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

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SUMMARY

Lake Okeechobee, the largest lake in the southeastern United States, is shallow, turbid, and eutrophic, and is a central component of the hydrology and environment of South Florida. The lake supplies water and flood control for nearby towns and surrounding areas, including agricultural land and downstream estuarine ecosystems. Lake Okeechobee is home to migratory water fowl, wading birds, and the federally endangered snail kite (*Rostrhamus sociabilis*). It is also a multimillion-dollar recreational and commercial fishery. This chapter provides the Water Year 2007 (WY2007) (May 1, 2006 through April 30, 2007) status of Lake Okeechobee and its surrounding watershed 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 Okeechobee and Estuary Recovery Program, and the Northern Everglades and Estuaries Protection Program. Significant programs related to the current drought that extend beyond WY2007 are included here because of their timeliness.

Lake Okeechobee has been subject to three long-term impacts: (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 (District or SFWMD), 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

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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.

Excessive phosphorus loads to the lake originate from agricultural and urban activities that dominate land use in the watershed. Total phosphorus (TP) loads were 630 metric tons per year (mt/yr) averaged over WY2003–WY2007, which is a decline from 715 mt/yr from the previous five-year period, WY2002–WY2006. The current five-year average load is more than four times higher than the Total Maximum Daily Load (TMDL) of 140 mt/yr (five-year average) considered necessary to achieve the in-lake TP target of 40 parts per billion (ppb). The TP load for WY2007 was 203 mt/yr due to the extremely dry conditions in the watershed. This is much less than the 795 mt/yr of the previous year, which included a wet summer and the passage of Hurricane Wilma.

The flow of water to Lake Okeechobee was 575,283 acre-feet (ac-ft) or 70,960 hectare meters (ha-m) in WY2007, approximately one-sixth of the 3,743,986 ac-ft or 461,814 ha-m recorded in WY2006, and approximately one-fifth the baseline average (1991-2005) of 2,535,572 ac-ft (312,758 ha-m). This reduced flow, due to drought conditions, led to a steadily declining lake stage from 13.46 ft (4.1 m) National Geodetic Vertical Datum (NGVD) on May 1, 2006, to 9.65 ft (2.94 m) NGVD on April 30, 2007. Water levels reached record lows of 8.82 ft (2.69 m) NGVD on July 3, 2007. The water-level decline in Lake Okeechobee contributed to the establishment of water restrictions throughout South Florida. These restrictions increased in severity from Phase I restrictions in November 2006, which reduced residential lawn watering to three days a week and agriculture watering by 15 percent, to Phase III restrictions implemented on May 16, 2007, which reduced lawn watering to one day a week and agriculture by 45 percent. To maintain water supply to the Everglades Agriculture Area (EAA), 14 temporary forward pumps were deployed in Lake Okeechobee.

Despite a long history of regulatory and voluntary incentive-based programs to control phosphorus inputs into Lake Okeechobee, no substantial reduction in loading occurred during the 1990s. Consequently, the lake continues to become more eutrophic with 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) [Section 373.4595, Florida Statutes, (F.S.)] available at http://www.flsenate.gov/statutes, 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 TP loading and exotic species expansion.

In January 2004, the SFWMD, FDEP, and FDACS submitted the Lake Okeechobee Protection Plan (LOPP) to the Florida legislature. The LOPA requires that the LOPP be reevaluated every three years to determine if further TP load reductions are needed to achieve the TMDL. The reevaluation report was completed in February 2007, and submitted to the legislature in March 2007. The LOPP contains a phased, watershed-based, comprehensive approach to reduce TP 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. These projects include phosphorus source control grant programs and the implementation of Best Management Practices (BMPs) 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 LOPA. 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 TP load reductions.

In addition to the LOPP, the SFWMD and USACE are implementing the Lake Okeechobee Watershed Project (LOWP), which is a part of the Comprehensive Everglades Restoration Plan (CERP). The LOWP will provide a regional Stormwater Treatment Area (STA) to reduce TP loads and provide alternative storage locations of water to help regulate water levels in Lake Okeechobee and produce greater environmental benefits while still serving water supply and other water resource functions. The LOWP is intended to reduce the TP load by approximately 60 mt/yr and store approximately 273,000 ac-ft (33,674 ha-m) of water. The load reduction will help to meet the restoration and TMDL goals for Lake Okeechobee. The offsite storage will help reduce high lake stage and reduce flood control discharges to the estuaries. A Tentatively Selected Plan has been presented at an Alternative Formulation Briefing. The draft Project Implementation Report (PIR) is scheduled to be completed by February 2008, and the final report by February 2009.

In October 2005, the state announced the Lake Okeechobee and Estuary Recovery (LOER) Plan to help restore the ecological health of Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. The plan consists of a combination of capital projects and numerous interagency initiatives designed to provide measurable and meaningful improvements to water quality and quantity in Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. Key state agencies charged with carrying out the plan include SFWMD, FDEP, FDACS, and Florida Department of Community Affairs.

In 2007, the Florida legislature substantially expanded the LOPA to include protection and restoration of the Lake Okeechobee watershed and the Caloosahatchee and St. Lucie estuaries. At the same time, the legislature also extended the Save Our Everglades Trust Fund for 10 years, providing a dedicated state funding source for the restoration through 2020. The revised legislation requires the SFWMD, in collaboration with coordinating agencies, to develop a Technical Plan for Phase II of the Lake Okeechobee Watershed Construction Project (LOWCP) by February 1, 2008, and River Watershed Protection Plans for the Caloosahatchee and St. Lucie River watersheds by January 1, 2009.

Conditions in Lake Okeechobee are reported as five-year averages for consistency with the TP TMDL and to reduce the variability that can be attributed to climate and hydrology. For WY2003–WY2007, the averages for TP, total nitrogen (TN), soluble reactive phosphorus (SRP), and dissolved inorganic nitrogen (DIN) were 173 ppb, 1.67 ppm, 54 ppb, and 303 ppb, respectively. The WY2007 averages for these nutrients were similar or lower than these five-year averages for TP (179 ppb), TN (1.46 ppm), and DIN (209 ppb). There has been a decline in the concentrations in this past year indicating some recovery after the passage of four hurricanes during 2004 and 2005. Only SRP was much higher (70 ppb) possibly a result of reduced algal and submerged aquatic vegetation growth.

The five-year average lake TP concentration is over four times higher than the goal of 40 ppb that was used to establish the TMDL. The five-year average ratio of total nitrogen-to-total phosphorus (TN:TP) at 11, and dissolved inorganic nitrogen to soluble reactive phosphorus (DIN:SRP) at 5.4, favor dominance of the blue-green algae that has accounted for most of the algal biomass in the lake. Surprisingly the current five-year average diatom to cyanobacteria ratio increased to 1.56 from values less than one in past years. The increase in diatoms may have been driven in part by the low light conditions or the higher DIN concentrations seen during the last three years in the lake.

The goal for water clarity in shoreline areas (100 percent light visibility to the lake bed from May through September) was attained approximately 9.9 percent of the time in the past five years, and the goal for algal bloom frequency (five percent of all samples exceeding 40 ppb of chlorophyll *a*) was exceeded in 8.2 percent of all samples taken in the past five years.

Submerged aquatic vegetation (SAV) coverage continued to decline from 10,872 acres (ac) (4,400 ha) in August 2005, to 2,965 ac (1,200 ha) in August 2006, primarily attributed to continued turbid water conditions that limited light. Monthly monitoring of transects showed that water level declines resulted in improved light conditions nearshore and musk grass (*Chara* spp.) began appearing at these sites. Continued decline of water levels shifted musk grass lakeward as the more nearshore stations dried out and the musk grass died. The biomass remained low (< 0.02 g. dry weight m^{-2}) until July 2007, when moderate to dense beds of SAV began developing in the southern and western areas of Lake Okeechobee.

A Geographic Information Systems map developed from aerial photography taken in 2003 shows a number of changes in the littoral landscape during WY2006: cattail coverage was 23,840 ac (9,648 ha), a four percent reduction from 25,000 ac (10,117 ha) in 1996; torpedograss (*Panicum repens*) coverage increased by 30 percent from 13,000 ac (5,261 ha) in 1996 to more than 17,000 ac (6,880 ha); fragrant water lily (*Nymphaea odorata*) increased by 38 percent from 8,000 ac (3,237 ha) to nearly 11,000 ac (4,452 ha) over the same period; and bulrush (*Scirpus californicus*) coverage declined by 13 percent from 194 ac (78 ha) in 1999 to 168 ac (68 ha).

One impact of hurricanes has been the redistribution of muck sediments from the central pelagic zone to more nearshore and littoral regions. The drought exposed a number of littoral and nearshore areas that have been covered with these muck sediments. The District, in cooperation with the state of Florida and the Florida Fish and Wildlife Conservation Commission (FWC) and Glades County, began a multi-million dollar effort to remove these muck materials and restore six locations in the lake. Over two million cubic yards of muck (1.6 million cubic meters) have been removed from an estimated 2,000 ac (809 ha) of exposed shoreline, potentially restoring SAV habitat. This project also removed an estimated 237 mt of phosphorus at an approximated cost of $11 million or $46.48 per kg.

During WY2007, coordinated efforts continued for revising the regulation schedule for Lake Okeechobee to improve system-wide benefits. In addition to the lake, other areas considered include the estuaries, the Water Conservation Areas, water supply for the Lake Okeechobee Service Area and Lower East Coast Service Area, snail kite habitat, integrity of the Herbert Hoover Dike that surrounds the lake, and navigation. In June 2006, the USACE identified a Tentatively Selected Plan that attempts to balance the performance measure criteria established for plan evaluation. However, final approval of the Plan has been delayed because of the potential increase in the number of low lake levels and Minimum Flows and Levels exceedances. This interim schedule is anticipated to be approved by the end of 2007, and would be in effect until either the risk of dike failure is reduced with the required improvements to Reaches 1, 2, and 3 of the Herbert Hoover Dike, or the 2010 CERP Band 1 schedule is implemented, whichever comes first.

Aerial and ground treatments of exotic and invasive emergent vegetation continued in WY2007. Approximately 7,000 ac (2,833 ha) of torpedograss was treated in the Moore Haven and Indian Prairie regions of the marsh. This brings the total acres treated in Lake Okeechobee since 2000 to nearly 32,000 ac (12,950 ha) of torpedograss.

Planting efforts for pond apple (*Annona glabra*) and cypress (*Taxodium* spp.) continued during WY2007 on the restored shoreline of Ritta Island located at the southern end of Lake Okeechobee. In addition, approximately 1,000 pond apple and cypress trees were planted in the vicinity of the S-310 locks and along two 4- to 8-ft spoil islands near Clewiston. Future plantings and maintenance of all the existing trees are planned for WY2008.

INTRODUCTION

Lake Okeechobee (located at 27^o N latitude and 81^o W longitude) is an important resource for the interconnected South Florida aquatic ecosystem and the U.S. Army Corps of Engineers (USACE) regional flood control project. The lake has a surface area of 445,559 ac [1,803 square kilometers (km^2)], and it is extremely shallow, with a mean depth of 8.9 feet (ft) [2.7 meters (m)] and maximal depth of 18 ft (5.5 m) (James et al., 1995a). Lake Okeechobee receives water from a 5,400-square-mile (mi^2) (14,000 km^2) watershed that includes the Upper Kissimmee Chain of Lakes, the Kissimmee River, Lake Istokpoga, Fisheating Creek, and other drainage basins (**Figure 10-1**). Lake waters flow south, east, and west to the Everglades Protection Area, the St. Lucie River (C-44 canal), and the Caloosahatchee River (C-43 canal), respectively.

Lake Okeechobee serves many roles, as it provides water supply to urban areas, agriculture, and downstream estuarine ecosystems; supports a multimillion-dollar sport fishery (Furse and Fox, 1994), a commercial fishery, and various recreational activities; and provides habitat for migratory waterfowl, wading birds, alligators, and the Everglade snail kite (Aumen, 1995). The lake also is used for flood control during the wet season. The lake faces three major environmental challenges: (1) excessive phosphorus (TP) loads, (2) unnaturally high and low water levels, and (3) rapid spread of exotic and nuisance plants.

This chapter updates the discussion of lake and watershed conditions presented in Chapter 10 of the *2007 South Florida Environmental Report – Volume I* (2007 SFER – Volume I), focusing on water quality, water levels, and aquatic vegetation. Results of recently completed research projects are presented, as well as status on ongoing watershed and in-lake management projects. Project timelines, information about Fiscal Year 2008 (FY2008) (October 1, 2007–September 30, 2008) funding sources, and other aspects of project planning are also included. Information regarding invasive plant control programs, and associated research projects to optimize those programs, are presented in Chapter 9 of this volume.

The extreme variability of weather in South Florida has been demonstrated in the past three years. Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005) began very dry but ended very wet, primarily because of four hurricanes (Charley, Frances, Ivan, and Jeanne; 2006 SFER – Volume I). WY2006 began as a very wet year, and included one hurricane (Wilma) in October 2005 (2007 SFER – Volume I). In spite of the passage of a tropical storm Ernesto in September 2006, WY2007 was very dry to a point where water supply restrictions were enacted (see the *Water Shortage Management* section in this chapter).

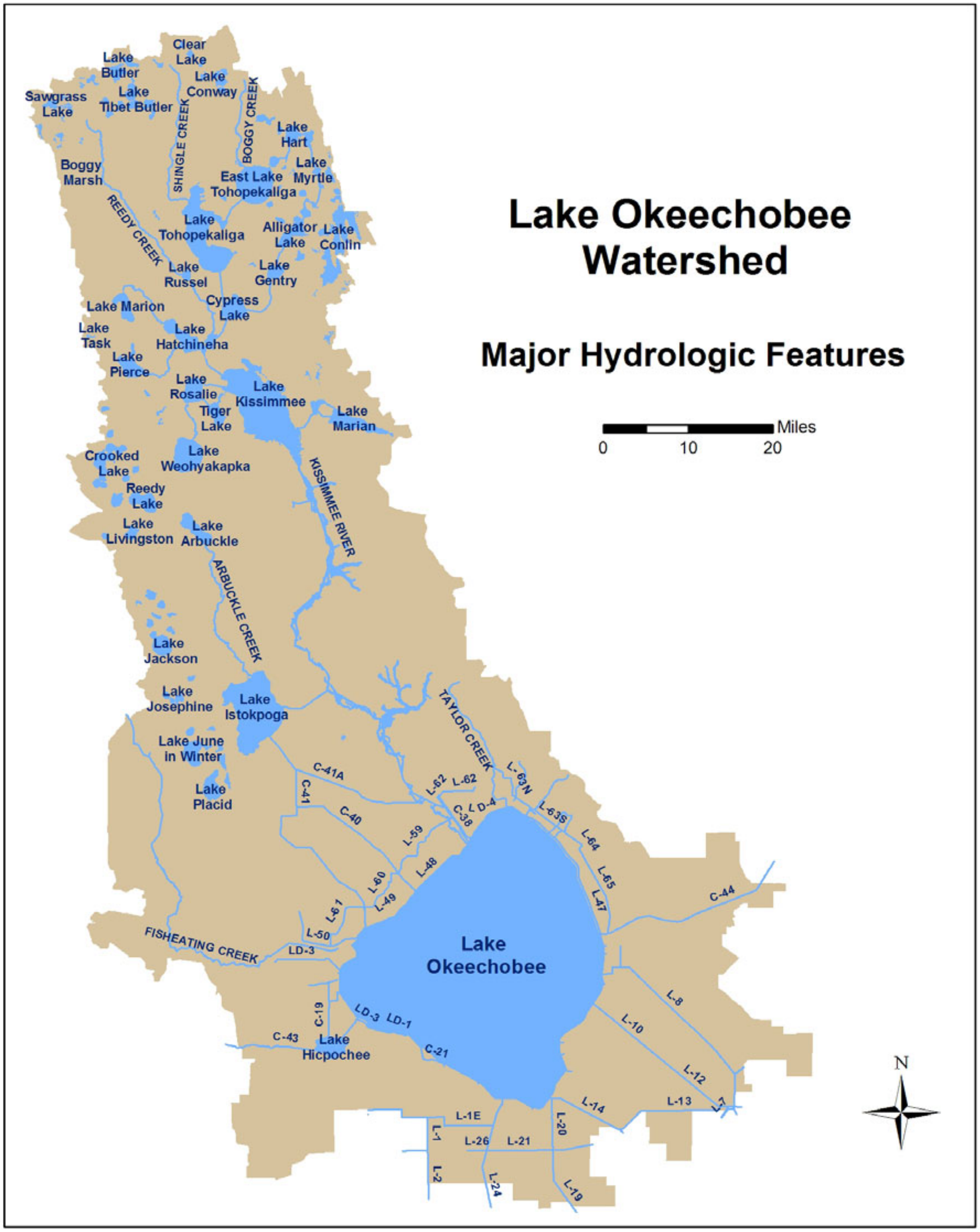

Figure 10-1. Major hydrologic features of the Lake Okeechobee watershed (L = levee, C = canal).

OVERVIEW OF LAKE OKEECHOBEE PROGRAMS

LAKE OKEECHOBEE PROTECTION PROGRAM

The Lake Okeechobee Protection Act (LOPA) [Section 373.4595, Florida Statutes (F.S.)] was passed by the 2000 Florida legislature to establish a restoration and protection program for the lake. This program 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 Lake Okeechobee Total Maximum Daily Load (TMDL) for total phosphorus (TP) developed by the Florida Department of Environmental Protection (FDEP, 2001). This TMDL is a long-term (five-year) rolling average of 140 metric tons (mt) of total phosphorus (TP) to be attained by 2015. The TMDL consists of 105 mt/yr of TP from the watershed and 35 mt/yr from atmospheric deposition. 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 the: (1) Lake Okeechobee Protection Plan (LOPP), (2) Lake Okeechobee Construction Project, (3) Watershed Phosphorus Control Program, (4) Research and Water Quality Monitoring Program, (5) Internal Phosphorus Management Program, (6) Exotic Species Control Plan, and (7) Annual Progress Report. The internal phosphorus management program can be found in the *In-lake Management* section of this chapter. The exotic species control program is documented in Chapter 9 of this volume.

LAKE OKEECHOBEE AND ESTUARY RECOVERY PROGRAM

In October 2005, Governor Bush announced the Lake Okeechobee and Estuary Recovery (LOER) Plan to improve the ecological health of Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries. Components of the LOER program include the Lake Okeechobee Fast Track (LOFT) projects, revisions to the Lake Okeechobee Regulation Schedule, establishment of TMDLs for Lake Okeechobee tributaries, implementation of mandatory fertilizer Best Management Practices (BMPs), revisions to Environmental Resource Permitting (ERP) criteria for new development, storage and/or disposal of excess surface water on public, private or tribal lands, implementation of growth management plans to encourage innovative land use planning, elimination of land application of residuals, and full implementation of the Lake Okeechobee Protection Plan (LOPP) and Lake Okeechobee Watershed Project (LOWP). All LOER components are underway and once implemented collectively will improve water quality, expand water storage, facilitate land acquisition, and enhance lake and estuary health.

Initial funding has been provided for five LOER construction projects north of Lake Okeechobee identified as LOFT projects. These LOFT projects are specifically designed to provide water quality improvements and include a 500-ac [202-hectare (ha)] expansion of the Nubbin Slough Stormwater Treatment Area (STA), a 30,000 acre-feet (ac-ft) [3,701 hectare meter (ha-m)] reservoir in association with the Taylor Creek STA, a 2,700-ac (1,093 ha) STA at Lakeside Ranch, and the re-routing of flows from the S-133 and S-154 basins to the Lakeside Ranch STA in the S-135 basin. The Nubbin Slough STA expansion and the flow re-routing projects were eliminated due to their very low cost-effectiveness in terms of TP load reductions. Two new projects were added: an 1,800 ac (728 ha) STA on Brady Ranch in the S-191 basin immediately east of the Lakeside Ranch site and a 150 ac (61 ha) STA on Lemkin Creek. The remaining two projects (Taylor Creek Reservoir and Lakeside Ranch STA) and the two new projects (Brady Ranch STA and Lemkin Creek STA) are in the planning/design phase.

NORTHERN EVERGLADES AND ESTUARIES PROTECTION PROGRAM

In 2007, the Florida legislature enacted the Northern Everglades Initiative (Senate Bill 392), which expands the Lake Okeechobee Protection Act to the entire Northern Everglades system, including the Lake Okeechobee watershed as well as the Caloosahatchee and St. Lucie rivers and estuaries (**Figure 10-2**). Over the next two years, the law calls for the development of far-reaching plans to protect and improve the quality, quantity, timing, and distribution of water north of Lake Okeechobee and in the Caloosahatchee and St. Lucie River watersheds. These plans will augment and enhance restoration currently under way in the Everglades south of the lake and builds upon ongoing restoration efforts north of Lake Okeechobee. The revised legislation requires the South Florida Water Management District (SFWMD or District), in collaboration with coordinating agencies, to develop a Technical Plan for Phase II of the Lake Okeechobee Watershed Construction Project (LOWCP) by February 1, 2008, and River Watershed Protection Plans for the Caloosahatchee and St. Lucie River watersheds by January 1, 2009. Phase I of the LOWCP was previously ratified by the Florida legislature and is currently being implemented. The LOWCP Phase II Technical Plan will identify additional water quality projects to achieve Lake Okeechobee Total Maximum Daily Loads. The Phase II plan also will identify the storage needs to reduce the harmful regulatory discharges to the St. Lucie and Caloosahatchee rivers, and to help manage Lake Okeechobee within a more ecologically desirable range. In addition, the legislation specifies that the Phase II Technical Plan include a Process Development and Engineering component (adaptive management) to finalize the detail and design of Phase II projects and to identify additional measures needed to increase the certainty that the overall objectives for improving water quality and quantity can be met. Each River Watershed Protection Program includes a watershed protection plan, a watershed construction project, a watershed pollutant control program, and a watershed research and water quality monitoring program. Additional information about the Northern Everglades Initiative can be found in Chapter 7A of this volume.

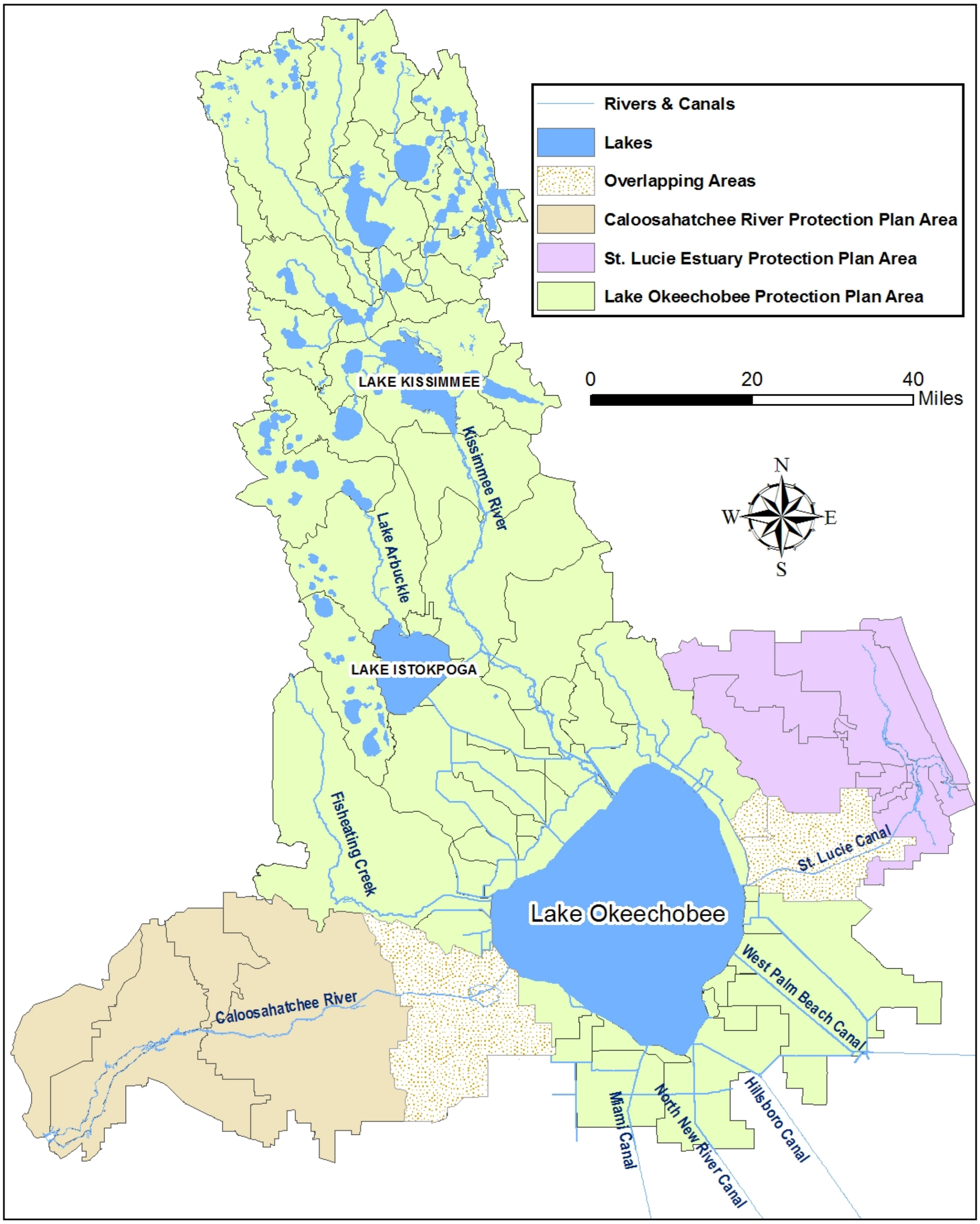

Figure 10-2. Northern Everglades Protection Plan areas.

WATERSHED STATUS AND MANAGEMENT

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 nine regional basins with a drainage area of 5,400 mi^2 (13,859 km^2) (**Figure 10-3**). The watershed was previously divided into six regions (Zhang et al., 2007). The Lower Kissimmee, Taylor Creek/Nubbin Slough, Indian Prairie, and Fisheating Creek regions were previously presented as one region, the North Lake Okeechobee Region. Water quality summaries and load-reduction management measures will be presented at the nine-region level as part of the Lake Okeechobee Phase II Technical Plan document that is due on February 1, 2008. Within the nine regional basins are 61 drainage basins (**Figure 10-3**).

The continuous urban and agricultural development in South Florida and consequent rapid land use changes in the watershed require periodic land-use updates to support District planning and management activities. The most recent land use data were updated in May 2006, as part of the LOPP reevaluation effort (**Table 10-1**, SFWMD et al., 2007). Nutrient levels in surface runoff are directly related to local land use and land management practices (Hiscock et al., 2003; Zhang et al., 2002). Besides natural areas, the major land uses in the Upper Kissimmee basins are urban and improved pasture, while the major land use in the Lower Kissimmee basins is improved pasture. The Taylor Creek/Nubbin Slough region mainly consists of improved pasture, natural area, and urban. Natural areas, citrus groves, and urban represent the majority of land use in the Lake Istokpoga and East Lake Okeechobee regions. The main land uses in the Indian Prairie region are improved pasture and natural area. The dominant land uses in the Fisheating Creek and West Lake Okeechobee regions are natural area and improved pasture. The major land use in the southern region is sugarcane farming.

Surface water flow, TP loads, and total nitrogen (TN) loads to the lake for WY2007 were calculated for the major drainage basins (**Tables 10-2a** and **10-3a**). This includes discharges from lakes Istokpoga and Kissimmee. These lakes are the outfalls of regional basins that collect water flow and nutrient loads from the smaller drainage basins that surround them (**Figure 10-3**). Data are based on continuous flow monitoring stations and TP and TN samples collected on a weekly basis (**Figure 10-4**). During WY2007, the largest surface-water inflow came from the Upper Kissimmee regional basin, followed by the Lake Istokpoga regional basin, L-59E, C-41, and Fisheating Creek. Discharge from the C-41 basin contributed the largest TP loads to Lake Okeechobee, followed by L-59E, Lower Kissimmee regional basin, and Fisheating Creek. The TP load to the lake in WY2007 from all tributary basins and atmospheric deposition was 203 mt. Discharge from the L-59E basin contributed the largest TN loads to Lake Okeechobee, followed by upper Kissimmee basins, and C-41 basin. The TN load to the lake in WY2007 from all tributary basins (including an estimated 1,233 mt from atmospheric deposition) was 2,671 mt.

These current year discharges are much smaller than the baseline period of record (calendar year 1991 to 2005, **Tables 10-2b** and **10-3b**). For the baseline period, the largest surface water inflow came from the Upper Kissimmee regional basin, followed by the Lower Kissimmee regional basin, Lake Istokpoga regional basin, Fisheating Creek, and Taylor Creek Nubbin Slough. The Upper Kissimmee regional basin contributed the largest TP loads to Lake Okeechobee, followed by Taylor Creek/Nubbin Slough, Lower Kissimmee regional basin, Fisheating Creek, and C-41. The average annual TP load to the lake for the baseline period from all tributary basins and atmospheric deposition was 546 mt. Discharge from the Upper Kissimmee regional basin contributed the largest TN loads to Lake Okeechobee, followed by the Lower Kissimmee regional basin, Lake Istokpoga regional basin, Fisheating Creek and C-41. The average annual TN load to the lake in the baseline period from all tributary basins and atmospheric deposition was 6,364 mt.

Phosphorus loading rates into Lake Okeechobee have varied over time as a result of a combination of climatic conditions, land-use changes and changes in land and water management conditions (**Table 10-4**). From 1981 to 2007, the highest loading rate was 1,189 mt in WY1983, followed by 960 mt in WY2005 and 795 mt in WY2006. The highest five-year average load was 715 mt from WY2002 to WY2006. The most recent five-year average load from WY2003–WY2007 was 630 mt, which exceed the TMDL by 490 mt (**Table 10-4**). This five-year average included two of the wettest years on record (2005 and 2006) that included the impacts of four hurricanes. These extremes document the reason that the TMDL is based on a five-year average — to account for variations in water flow and loads.

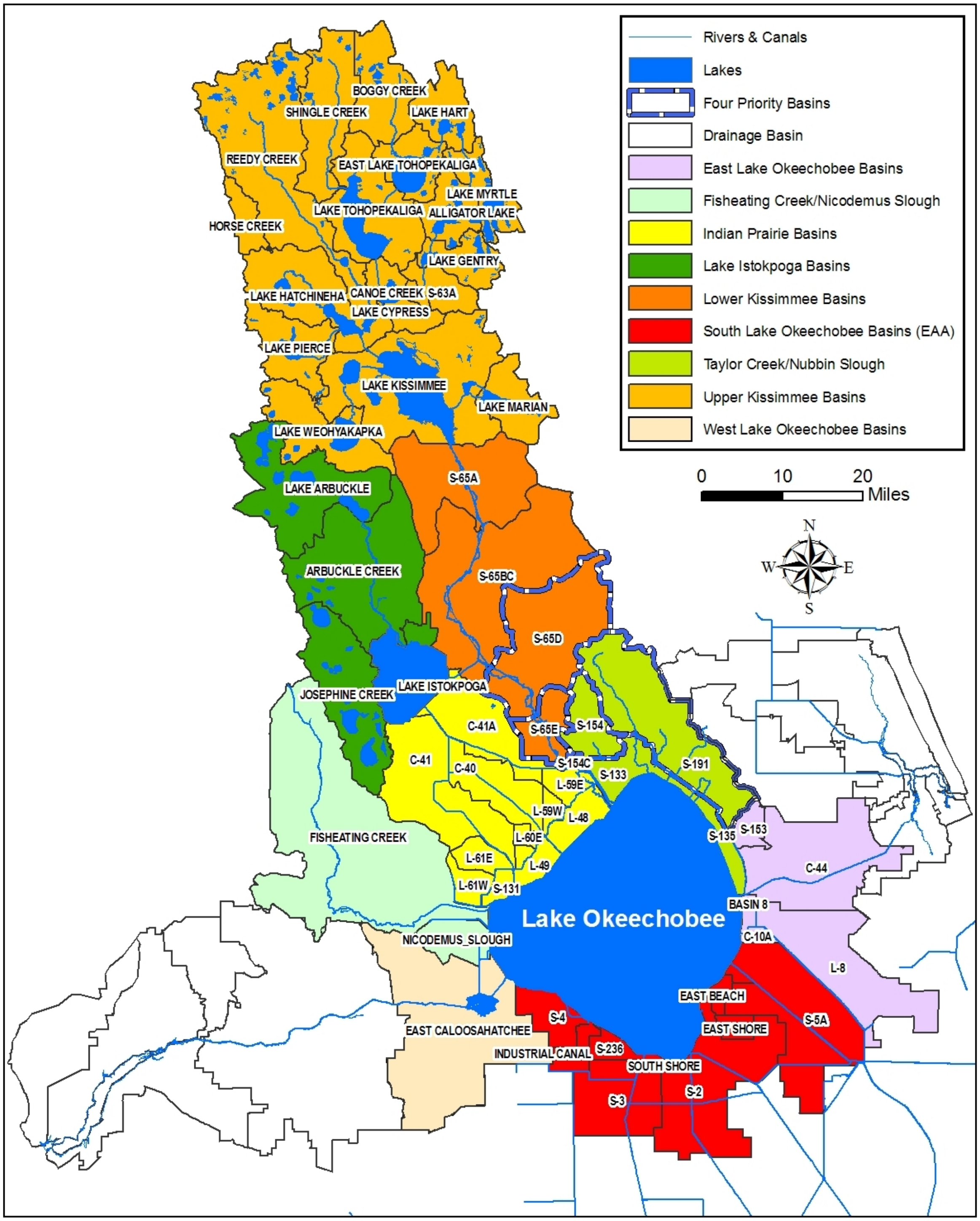

Figure 10-3. Lake Okeechobee watershed basins, regions, and priority basins.

Table 10-1. The 2006 land-use data grouped by regions in the Lake Okeechobee watershed.

Land Use	Entire Watershed		Upper Kissimmee	Lower Kissimmee (S65A-E)	Taylor Creek/Nubb in Slough (S191,S154, S133, S135)	Lake Istokpoga	Indian Prairie (12 basins)	Fisheating Creek and Nic. Slough	West LO Besins	South LO Basins (10 EAA Basins)	East LO Basins (C-44 and L-8)
	Acres	%	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Citrus	234,629	7%	57,478	11,666	3,572	55,918	30,331	12,542	23,741	95	39,287
Dairy	22,432	1%	0	5,950	11,085	3,031	177	26	2,164	-	-
Improved Pasture	674,356	20%	133,437	134,894	86,186	48,228	108,424	90,779	48,447	3,819	20,143
Natural Areas	1,282,267	37%	529,079	146,449	38,989	173,433	72,880	122,189	54,847	15,157	129,243
Ornamentals	4,687	0%	187	12	542	348	2,667	541	2	260	126
Other Areas	27,567	1%	8,396	2,358	1,517	3,626	1,707	4,583	1,971	1,105	2,303
Row Crops	23,157	1%	3,391	7,814	817	1,646	3,456	235	4,693	-	1,104
Sod Farms	39,081	1%	9,505	2,335	2,314	2,933	10,222	2,448	9	9,099	216
Sugarcane	399,711	12%	-	-	9,123	-	12,674	7,220	37,298	320,590	12,806
Tree Plantations	49,687	1%	3,743	8,358	-	12,710	58	17,919	6,899	-	-
Unimproved Pasture	140,249	4%	27,828	23,468	1,090	24,374	28,845	19,595	8,544	-	6,505
Woodland/Rangeland	184,381	5%	41,623	64,220	3,620	14,924	15,720	32,720	8,620	65	2,868
Urban	368,884	11%	207,006	21,758	39,444	50,976	6,987	4,209	3,757	11,517	23,230
Total	**3,451,087**	**100%**	**1,021,674**	**429,283**	**198,299**	**392,147**	**294,147**	**315,007**	**200,993**	**361,707**	**237,831**

Table 10-2a. WY2007 surface water inflows, total phosphorus (TP) concentrations and loading rates for the major tributary basins in the Lake Okeechobee watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Area (acre)	Average TP Concentration (ppb)	TP Load (mt)
715 Farms (Culv 12A)	1,991	245.6	3,302	172	0.42
C-40 basin (S-72) – S68	5,592	689.7	43,964	848	6.13
C-41 basin (S-71) – S68	45,381	5,597.6	94,654	673	38.80
S-84 basin (C-41A) – S68	22,790	2,811.1	58,487	125	2.30
S-308C (St. Lucie – C-44)	37,500	4,625.5	129,429	219	10.13
East Beach DD (Culv 10)	295	36.3	6,624	114	0.04
East Shore DD (Culv 12)	116	14.3	8,416	171	0.02
Fisheating Creek	41,474	5,115.7	289,366	347	17.75
Industrial Canal	13,910	1,715.7	13,024	143	2.45
L-48 basin	204	25.2	20,774	42	0.01
L-49 basin	2,974	366.9	12,093	78	0.29
L-59E	56,574	6,978.2	14,409	284	19.79
L-59W	1,504	185.5	6,440	104	0.19
L-60E	10,117	1,247.9	5,038	122	1.52
L-60W	3,534	435.9	3,271	205	0.89
L-61E	N/A	N/A	14,286	N/A	N/A
L-61W	N/A	N/A	13,567	N/A	N/A
Taylor Creek/Nubbin Slough (S-191)	17,850	2,201.8	120,754	616	13.56
S-131	17,406	2,147.0	7,164	79	1.69
S-133	0.00	0.00	25,660	0	0.00
S-135	0.28	0.03	18,088	117	0.00004
S-154	547	67.5	33,798	479	0.32
S-2	3,913	482.7	106,371	140	0.67
S-3	311	38.4	62,946	295	0.11
S-4	5,505	679.0	26,389	244	1.66
Lower Kissimmee Regional Basin	35,575	4,388.1	429,283	176	17.91
South FL Conservancy DD (S-236)	85	10.5	11,028	101	0.01
South Shore/South Bay DD (Culv 4A)	60	7.4	4,134	0	0.005
Nicodemus Slough (Culv 5)	N/A	N/A	25,641	N/A	N/A
Upper Kissimmee Regional Basin	121,053	14,931.7	1,021,674	107	16.03
Lake Istokpoga Regional Basin	64,371	7,940.1	392,147	69	5.24
S-5A Basin (S-352 WPB Canal)	0	0.0	119,475	0	0.00
East Caloosahatchee (S-77)	16,538	2,040.0	200,993	0	2.13
L-8 basin (Culv 10A)	27,291	3,366.3	108,402	83	2.79
Culvert 5A	20,823	2,568.5	N/A	187	4.79
Atmospheric Deposition					35
Totals	**575,283**	**70,960.0**	**3,451,091**	**236***	**203**

*Surface inflow concentration only
N/A – Not Available

Table 10-2b. Baseline (1991–2005) surface water inflows, TP concentrations, and loading rates for the major tributary basins in the Lake Okeechobee watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Average TP Concentration (ppb)	TP Load (mt)
715 Farms (Culv 12A)	8,555	1,055	112	1.18
C-40 basin (S-72) – S68	17,181	2,119	618	13.10
C-41 basin (S-71) – S68	58,682	7,238	540	39.08
S-84 basin (C-41A) – S68	60,456	7,457	77	5.72
S-308C (St. Lucie – C-44)	50,146	6,185	209	12.92
East Beach DD (Culv 10)	8,608	1,062	589	6.26
East Shore DD (Culv 12)	10,890	1,343	169	2.27
Fisheating Creek	221,012	27,261	201	54.70
Industrial canal	21,981	2,711	119	3.23
L-48 basin	20,047	2,473	231	5.70
L-49 basin	13,964	1,722	105	1.80
L-59E	28,335	3,495	173	6.03
L-59W	8,981	1,108	394	4.36
L-60E	2,231	275	207	0.57
L-60W	502	62	237	0.15
L-61E	1,190	147	159	0.23
L-61W	1,810	223	95	0.21
Taylor Creek/Nubbin Slough (S-191)	108,625	13,399	644	86.35
S-131	10,996	1,356	119	1.62
S-133	26,404	3,257	253	8.25
S-135	24,982	3,081	123	3.78
S-154	27,579	3,402	760	25.86
S-2	37,149	4,582	167	7.63
S-3	15,936	1,966	135	2.65
S-4	28,994	3,576	213	7.63
Lower Kissimmee Regional Basin	373,435	46,063	167	76.77
South FL Conservancy DD (S-236)	12,213	1,506	107	1.62
South Shore/South Bay DD (Culv 4A)	6,502	802	107	0.86
Nicodemus Slough (Culv 5)	634	78	51	0.04
Upper Kissimmee Regional Basin	959,653	118,371	78	91.92
Lake Istokpoga Regional Basin	301,389	37,176	80	29.64
S-5A basin (S-352 WPB Canal)	199	25	230	0.06
East Caloosahatchee (S-77)	5,835	720	139	1.00
L-8 basin (Culv 10A)	58,992	7,277	102	7.40
Culvert 5A	1,487	183	104	0.19
Atmospheric Deposition				35.0
Totals	**2,535,572**	**312,758**	**163***	**546**

*Surface inflow concentration only
N/A – Not Available

Table 10-3a. WY2007 surface water inflows, total nitrogen (TN) concentrations and loading rates for the major tributary basins in the Lake Okeechobee watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Average TN Concentration (ppm)	TN Load (mt)
715 Farms (Culv 12A)	1,991	246	5.08	12.5
C-40 basin (S-72) – S68	5,592	690	3.14	21.6
C-41 basin (S-71) – S68	45,381	5,598	3.67	205.2
S-84 basin (C-41A) – S68	22,790	2,811	0.66	18.6
S-308C (St. Lucie – C-44)	37,500	4,625	1.82	84.2
East Beach DD (Culv 10)	295	36	1.75	0.6
East Shore DD (Culv 12)	116	14	8.67	1.2
Fisheating Creek	41,474	5,116	2.05	104.6
Industrial Canal	13,910	1,716	2.28	39.1
L-48 basin	204	25	1.68	0.4
L-49 basin	2,974	367	1.39	5.1
L-59E	56,574	6,978	3.20	223.4
L-59W	1,504	186	1.18	2.2
L-60E	10,117	1,248	1.44	17.9
L-60W	3,534	436	1.51	6.6
L-61E	N/A	N/A	N/A	N/A
L-61W	N/A	N/A	N/A	N/A
Taylor Creek/Nubbin Slough (S-191)	17,850	2,202	2.26	49.9
S-131	17,406	2,147	1.48	31.7
S-133	0	0	N/A	0.0
S-135	0	0	1.87	0.0
S-154	547	67	1.74	1.2
S-2	3,913	483	5.20	25.1
S-3	311	38	3.71	1.4
S-4	5,505	679	3.00	20.3
Lower Kissimmee Regional Basin	35,575	4,388	2.40	105.4
South FL Conservancy DD (S-236)	85	10	2.42	0.3
South Shore/South Bay DD (Culv 4A)	60	7	2.86	0.2
Nicodemus Slough (Culv 5)	N/A	N/A	N/A	N/A
Upper Kissimmee Regional Basin	121,053	14,932	1.30	193.4
Lake Istokpoga Regional Basin	64,371	7,940	1.47	117.1
S-5A basin (S-352 WPB Canal)	0	0	N/A	0.0
East Caloosahatchee (S-77)	16,538	2,040	1.38	28.1
L-8 basin (Culv 10A)	27,291	3,366	1.98	66.8
Culvert 5A	20,823	2,568	2.07	53.1
Atmospheric Deposition*				1233.4
Totals	**575,283**	**70,960**	**2.03****	**2,671**

**Surface inflow concentration only
*from James et al., 2005
N/A - Not Available

Table 10-3b. Baseline (1991–2005) surface water inflows, TN concentrations, and loading rates for the major tributary basins in the Lake Okeechobee watershed.

SOURCE	Discharge (ac-ft)	Discharge (ha-m)	Average TN Concentration (ppm)	TN Load (mt)
715 Farms (Culv 12A)	8,555	1,055	4.73	49.9
C-40 basin (S-72) – S68	17,181	2,119	4.65	98.6
C-41 basin (S-71) – S68	58,682	7,238	4.82	348.6
S-84 basin (C-41A) – S68	60,456	7,457	1.45	108.5
S-308C (St. Lucie – C-44)	50,146	6,185	1.68	103.9
East Beach DD (Culv 10)	8,608	1,062	7.88	83.7
East Shore DD (Culv 12)	10,890	1,343	6.85	92.0
Fisheating Creek	221,012	27,261	1.52	414.5
Industrial Canal	21,981	2,711	2.89	78.5
L-48 basin	20,047	2,473	2.08	51.4
L-49 basin	13,964	1,722	1.60	27.6
L-59E	28,335	3,495	2.39	83.6
L-59W	8,981	1,108	2.24	24.8
L-60E	2,231	275	1.89	5.2
L-60W	502	62	1.98	1.2
L-61E	1,190	147	2.19	3.2
L-61W	1,810	223	1.48	3.3
Taylor Creek/Nubbin Slough (S-191)	108,625	13,399	2.00	267.9
S-131	10,996	1,356	1.49	20.2
S-133	26,404	3,257	1.73	56.2
S-135	24,982	3,081	1.62	49.9
S-154	27,579	3,402	2.03	69.2
S-2	37,149	4,582	5.28	242.2
S-3	15,936	1,966	4.61	90.6
S-4	28,994	3,576	3.18	113.6
Lower Kissimmee Regional Basin	373,435	46,063	0.99	454.6
South FL Conservancy DD (S-236)	12,213	1,506	4.46	67.2
South Shore/South Bay DD (Culv 4A)	6,502	802	4.65	37.3
Nicodemus Slough (Culv 5)	634	78	1.74	1.4
Upper Kissimmee Regional Basin	959,653	118,371	1.21	1436.4
Lake Istokpoga Regional Basin	301,389	37,176	1.21	449.7
S-5A Basin (S-352 WPB Canal)	199	25	6.76	1.7
East Caloosahatchee (S-77)	5,835	720	1.91	13.7
L-8 basin (Culv 10A)	58,992	7,277	2.45	178.0
Culvert 5A	1,487	183	1.36	2.5
Atmospheric Deposition*				1233.4
Totals	**2,535,572**	**312,758**	**1.64****	**6,364**

**Surface inflow concentration only
*from James et al., 2005
N/A – Not Available

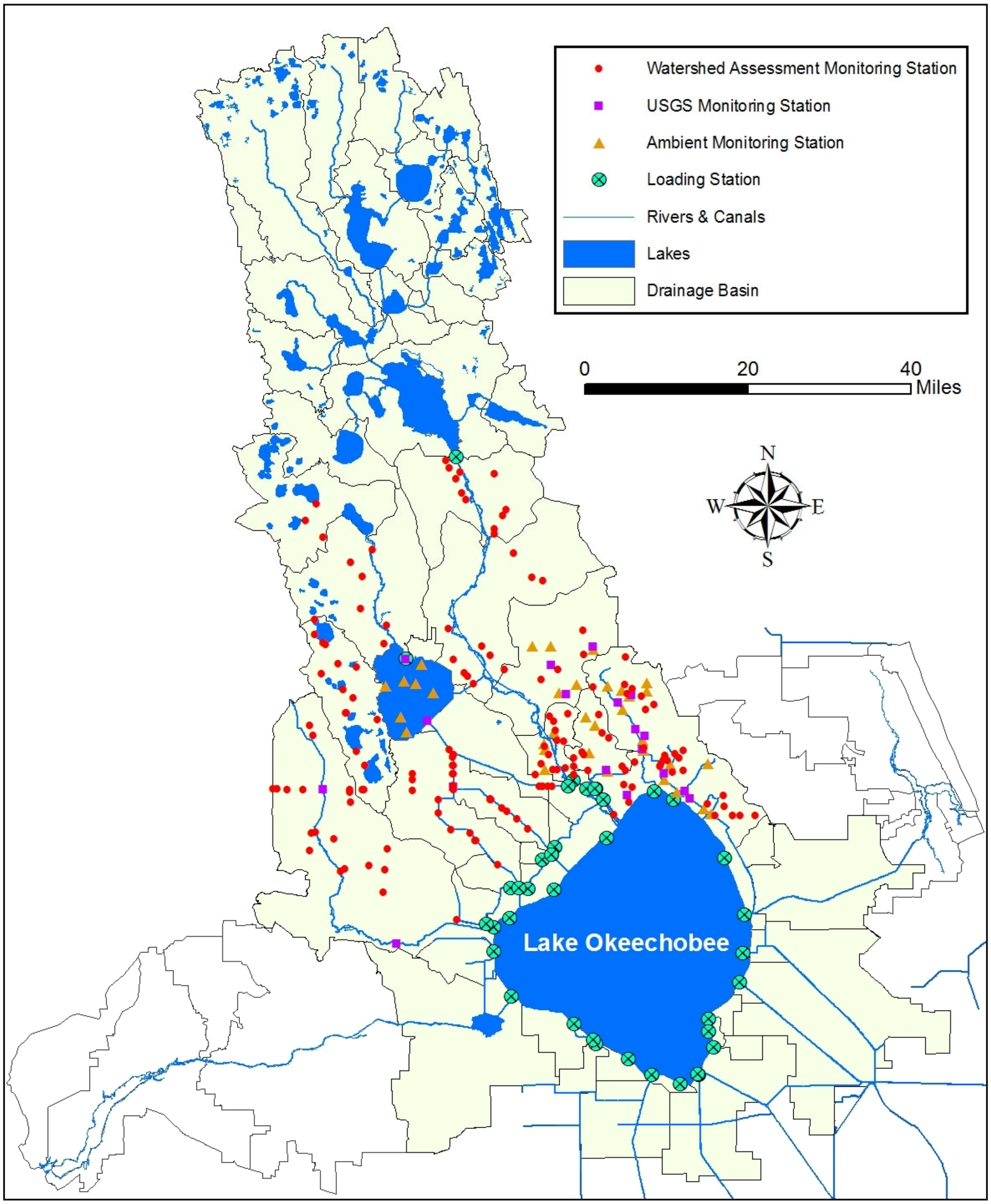

Figure 10-4. Locations of Water Year 2007 (WY2007) sampling stations where TP loads were determined from tributary basins that drain into Lake Okeechobee (green dots and purple squares). Other watershed water quality sampling stations also are shown.

Table 10-4. Water year TP loads to Lake Okeechobee (1981–2007).

Water Year May–April	Measured Load [a] (mt)	Long-term Load (five-year moving average) [a] (mt)	Long-term over-target Load (five-year moving average) [ab] (mt)
1981	151	N/A	N/A
1982	440	N/A	N/A
1983	1189	N/A	N/A
1984	369	N/A	N/A
1985	500	530	390
1986	421	584	444
1987	562	608	468
1988	488	468	328
1989	229	440	300
1990	365	413	273
1991	401	409	269
1992	408	378	238
1993	519	385	245
1994	180	375	235
1995	617	425	285
1996	644	474	334
1997	167	425	285
1998	913	504	364
1999	312	531	391
2000	685	544	404
2001	134	442	302
2002	624	533	393
2003	639	479	339
2004	553	527	387
2005	960	582	442
2006	795	715	575
2007	203	630	490

[a] Includes an atmospheric load of 35 mt/yr based on the Lake Okeechobee TMDL (FDEP, 2001).
[b] Target is the Lake Okeechobee TMDL of 140 mt compared to a five-year moving average.

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, Florida Department of Environmental Protection (FDEP), and Florida Department of Agriculture and Consumer Services (FDACS) entered into an interagency agreement to address how to implement the programs and coordinate with existing regulatory programs, including Lake Okeechobee Works of the District (LOWOD) Permitting Program [Chapter 40E-61 Florida Administrative Code (F.A.C.)], Dairy Rule, and Everglades Forever Act (EFA). Under the LOPA [Section 373.4595, Florida Statutes (F.S.)], the FDACS is charged with implementing a voluntary Best Management Practice (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 percent cost share, either through the FDACS or a combination of the FDACS and the Natural Resources Conservation Service (NRCS) funds. The FDEP is responsible for developing non-agricultural, non-point source BMPs. The District is responsible for the implementation of TP reduction projects and large-scale regional projects, research and monitoring, existing regulations, and exotic plant control.

FDACS Agricultural Programs

Since 2002, considerable effort has been expended on the implementation of agricultural BMPs and water quality improvement projects to immediately reduce the discharge of phosphorus from the watershed to the lake. Initially, the FDACS BMP program consisted of two phases: (1) the implementation of interim BMPs selected from existing cow/calf and citrus water quality BMP manuals via the manuals' assessment checklists; and (2) the development of more comprehensive, site-specific plans containing BMPs to address nutrient and stormwater management. Experience has shown that it is more efficient to proceed directly to the comprehensive planning stage; therefore, the interim assessment and BMP selection are no longer being conducted.

Agricultural Nutrient Management Plans (AgNMPs) were completed in 2002 for the 22 active dairies that cover more than 31,000 ac (12,545 ha) in the Lake Okeechobee watershed. Collectively, the completed AgNMPs indicated that it would cost a total of $140 million to achieve our water quality goals. The interagency team concluded that funds should first be expended on the stormwater component of the AgNMPs, aimed at lowering phosphorus concentrations at the edge-of-farm discharge point. Presently, all dairies have signed Notices of Intent to implement their AgNMPs. Detailed planning, engineering, and design for implementing the stormwater component of the AgNMPs at two of the dairies will be completed by June 2008. Implementation of all of the dairy AgNMPs is expected to be completed by FY2015.

Because the implementation of planned agricultural BMPs is expected to improve water quality substantially in the watershed, the FDACS and the NRCS have executed an interagency Memorandum of Agreement that commits available federal resources to expedite BMP-based planning for the remaining acres in the watershed. In support of this agreement, the FDACS contracted with the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), in conjunction with the NRCS, to provide training for private-sector third-party vendors that wish to assist in plan development.

To date, the FDACS and the NRCS have obtained $950,000 in federal appropriations, which have been used to identify, train, and contract with private-sector technical service providers to develop BMP-based plans for cow/calf, citrus, row crop, and other agricultural operations. This effort has significantly increased plan development and implementation, including the engineering and design of planned water-control structures.

A critical component in the success of the agricultural BMP program is the collection and analysis of data to determine whether the BMPs are working as anticipated. The interagency team is committed to continue funding on-farm BMP demonstration projects at representative sites that, over time, will provide both BMP effectiveness data and insight into what new or modified BMPs may be necessary to reach the phosphorus reduction goals required to achieve lake and tributary restoration. In cooperation with UF/IFAS, the FDACS is conducting BMP demonstration and evaluation projects at representative sites for all agricultural land uses in the watershed, including dairies, beef cattle, citrus, and vegetable production. This effort incorporates regional and sub-regional water quality monitoring in collaboration with the SFWMD and the United States Geological Survey (USGS), which can help identify where to focus plan development and implementation and BMP effectiveness studies.

The agricultural area in the Lake Okeechobee watershed covers about 1.7 million ac (688,000 ha), 50 percent of the total watershed area (**Table 10-1**). Completed nutrient management plans now cover approximately 474,200 ac (191,902 ha) in the watershed, and BMPs are in various stages of implementation. The majority of this acreage lies within the four priority basins (S-191, S-154, S-65D, and S-65E) (**Figure 10-3**). Plans are being developed for an additional approximately 600,000 ac (242,811 ha) of agricultural operations. Thus, more than half of the agricultural acreage in the entire watershed will soon be under voluntary FDACS programs to plan and implement practices to control offsite movement of phosphorus. At the current rate of participation, FDACS is on schedule to complete BMP-based plans for the remainder of the agricultural acreage in the watershed by July 2010 and to fully implement BMPs by 2015, as required by the Lake Okeechobee Protection Plan.

One of the challenges in implementing agricultural BMP programs in the watershed, and throughout the state, is attrition in producer participation due to development pressure and the sale of agricultural land for other uses. Considerable amounts of agricultural acreage are undergoing land-use changes, and this trend is expected to continue. In 2006, approximately 13,046 ac (5,280 ha) of land under BMP development or implementation in the watershed were sold and are no longer active under a BMP program.

This creates at least two complexities: (1) disappearance and fragmentation of large agricultural holdings, with concomitant increased expenditures of staff and financial resources to enroll a greater number of smaller parcels in BMP programs; (2) conversion of agricultural lands to other uses places additional responsibility on the SFWMD to ensure that associated stormwater discharges are at or below the levels prior to conversion.

The TP load reduction to Lake Okeechobee from typical BMPs implemented/planned through June 30, 2007, is 15 mt (**Table 10-5**). The dairy in the Josephine Creek was out of business and the property is under planned remediation practices. The potential load reductions by stormwater management system for the Larson dairies were not included due to the delay and uncertainty with the schedule. The total reduction of 15 mt reflects special BMP projects in the FDACS' typical cost-share BMP program and does not include the TP load reduction from either owner-implemented or typical cost-share BMPs implemented on cow/calf operations throughout the watershed. The FDACS has completed adoption of an amendment to administrative Rule 5M-3 that expands the effective area of the rule from the four priority basins to include the entire Lake Okeechobee watershed. The rule adopts BMP manuals for citrus producers and cow/calf operations, conservation plans for vegetable and row crop producers, and AgNMPs for dairy operations, and discusses the process for implementing these BMPs. The rule revisions mandate the implementation of a nutrient-management plan and require that cost-shared BMPs be completely implemented within 24 months of cost-share availability.

Through this rule, the implementation of appropriate BMPs — accompanied with the submission of a Notice of Intent to implement a BMP plan — provides the landowner with a presumption of compliance with Florida water quality criteria. Landowners that choose not to participate in the FDACS BMP program will be required to comply with the LOWOD (Chapter 40E-61, F.A.C.) permitting program and to demonstrate compliance with existing and future TP targets and requirements set forth in the Surface Water Improvement and Management (SWIM) Plan or an established tributary TMDL.

Table 10-5. TP load reduction projects implemented or planned by the Florida Department of Agriculture and Consumer Services under typical cost-share Best Management Practice program.

BASIN	PROJECT CATEGORY	PROJECT SITE	ESTIMATED ANNUAL PHOSPHORUS REDUCTION TO THE LAKE (mt)	COMPLETION DATE
S-154	Dairy Hurricane Upgrade	Milking R	0.63	7-31-06
S-191	Dairy Composting Project	McArthur 1 and 3	2.74	12-31-06
	Dairy Hurricane Upgrade	Larson 5	0.93	12-31-05
	Dairy Hurricane Upgrade	McArthur 1 and 3	0.40	12-31-05
	Dairy Stormwater Management System	Larson 5 and 6	1.58*	Waiting for Permit
	Dairy Stormwater Management System	Larson 7 and 8	1.84*	Waiting for Permit
	Florida Ranchlands Environmental Services Project	Williamson Cattle Company	0.09	10-01-06
S-65D and S-65E	Tailwater Recovery Project	Joe Hall	0.36	5-01-06
	Dairy Composting Project	Butler Oaks	1.91	5-01-06
	Dairy Hurricane Upgrade	Butler Oaks	0.28	2-28-06
	Dairy Stormwater Management System	B-4	3.08	6-30-08
	Dairy Stormwater Management System	Butler Oaks	4.45	6-30-08
C-41A	Citrus Variable Rate Fertilizer Technology	Lykes Brothers	0.20	12-30-05
Arbuckle Creek	Dairy Hurricane Upgrade project	Wabasso Dairy	To be determined	02-30-06
TOTAL			**15**	

* not included in the total reduction estimate

FDEP Non-Agricultural Programs

A phased approach is being used to reduce TP loads to Lake Okeechobee from non-agricultural areas in the Lake Okeechobee watershed. The largest contributors of TP loading from non-agricultural areas to Lake Okeechobee are sources within existing residential developments (fertilization, pet wastes, septic tanks) without stormwater treatment, golf courses, and failing wastewater systems (septic tanks and package plants). Efforts to address these sources since the inception of LOPA (Section 373.4595, F.S.) include implementation of BMPs, master planning for stormwater and wastewater, implementation of stormwater retrofits, the designing of larger urban stormwater projects, and public education.

During the past year, focus has continued on reducing the impacts of non-point source pollution from urban lands through public education programs and other non-structural BMPs. BMPs are practices determined by the coordinating agencies, based on research, field-testing, and expert review, to be the most economic and technologically effective and practicable on-location means for improving water quality in urban discharges. These nonstructural BMPs primarily target homeowners and businesses and rely on behavior changes rather than the construction of treatment tools or facilities. UF/IFAS extension agents are working with homeowners on better lawn management through the Florida Yards and Neighborhoods program. UF/IFAS staff has educated employees of landscape management companies about environmentally-sound landscaping through the Green Industry BMP Program. Additionally, the FDEP and UF/IFAS have continued their multi-year research partnership to determine minimum fertilizer and irrigation requirements to establish and maintain turf grasses.

Work on addressing pollutant loads from older, existing development that does not have stormwater treatment continues with the completion of stormwater master plans for the City of Okeechobee in Okeechobee County and the City of Moore Haven in Glades County. The SFWMD's Okeechobee Service Center is working cooperatively with Okeechobee County to expand the plans and begin implementing projects within them. Stormwater master plans are being developed for other urban areas within the Lake Okeechobee watershed. Because a majority of the urban areas were developed prior to the adoption of state stormwater regulations, the existing infrastructure is typically inadequate to properly deal with stormwater. Stormwater retrofits, such as detention/retention facilities and swales, are needed to improve the water quality of urban stormwater runoff.

Public education offers a means to promote measures for reducing phosphorus entering stormwater in the urbanized areas. The UF/IFAS provides weekly articles in the Okeechobee area 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-phosphorus fertilizers and the use of appropriate BMPs when applying such chemicals. This brochure is available at retail stores in the city of Okeechobee where fertilizers are sold. UF/IFAS monitors the number of people requesting assistance or information regarding this program.

Finally, under the LOER initiative announced by Governor Bush in 2005, agencies are working with the fertilizer industry to produce and distribute low- or no-phosphorus fertilizers state wide. The FDACS has published a proposed final rule reducing the amount of nitrogen by approximately 20 percent and phosphorus by 10 percent in urban turf fertilizer products. Additionally, the FDEP, in cooperation with all the water management districts, is working on a new state-wide stormwater rule that will increase the level of nutrient treatment for new stormwater discharges.

The U.S. Environmental Protection Agency (USEPA) and the FDEP are accelerating the development of TMDLs for tributaries in the Lake Okeechobee watershed. The USEPA Region 4 proposed TMDLs for the Lake Okeechobee tributaries in September 2006. The effort is currently under review and is expected to be completed in 2007.

SFWMD Phosphorus Control Programs

An extensive effort was expended in WY2006 on BMP implementation in the LOPP area to reduce TP loads to the lake. The SFWMD, in coordination with the FDACS and FDEP, has developed and implemented more that 30 TP reduction projects. These projects have been implemented under programs such as the Phosphorus Source Control Grants, Isolated Wetland Restoration, Dairy Best Available Technologies, Public/Private Partnerships, and Former Dairy Remediation (**Table 10-6**). TP load reduction from these TP reduction projects is estimated at 30 mt of the load reductions necessary to meet the lake's TMDL. All 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. The program consists of 13 projects with a total cost of $7.5 million. An interagency team evaluated the projects and ranked them using established evaluation criteria. The funded projects range in size and complexity, and grant recipients consist of landowners, public facilities, and private corporations.

Dairy Best Available Technologies

In October 2000, the District initiated the Dairy Best Available Technologies (BATs) projects to identify, select, and implement various technologies to significantly reduce TP discharge 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 stormwater prior to its release. 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. 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. This fourth site was completed in December 2005 and is in the performance monitoring phase. Annual TP load reductions have ranged from 25 to 100 percent. The performance evaluation period has been extended through 2007 due to the lack of chemical treatment needed during the extremely dry year.

Table 10-6. SFWMD TP load reduction projects implemented or planned under the Watershed Phosphorus Control Program.

Basin	Project Category	Project Site	Estimated Annual P Reduction to Lake (mt)	Construction Status
S-154	P Source Control Grant Program	Tampa Farms – Indiantown	1.11	Complete
		Milking "R" Chemical Treatment	0.00	Became part of Dairy BAT
	Dairy Best Available Technology (BAT)	Dry Lake 1	1.66	Complete
		Milking R	1.54	Complete
S-191	P Source Control Grant Program	QED – McArthur Farms 3	6.02	Complete
		Candler Ranch	0.00	Non-Operational
		Davie-Dairy Cooling Pond	0.39	Complete
		Evans Properties – Bassett Grove	0.13	Complete
		Tampa Farms – Indiantown	2.15	Complete
		Solid Waste Authority	1.16	In Design
		Taylor Creek ATS NRF	1.81	Compete
	Dairy BAT	Davie Dairy 1 and 2	0.50	Complete
	Isolated Wetland Restoration Project	Kirton Ranch	0.81	Complete
		Nubbin Slough Area A Restoration	To be determined	In Design
		Eckerd Youth Center	0.40	Feb-08
	Former Dairy Remediation	Mattson	0.54	Complete
		McArthur 5	0.30	Complete
		Candler	0.03	Complete
		Larson Dairy 7	0.29	Jul-08
		Pilgrim	0.29	Jul-08
	Public-Private Partnership	Davie Dairy 1 and 2 offsite stormwater treatment	0.40	Complete
S-133	P Source Control Grant Program	OUA-Ousley	0.22	Complete
	Isolated Wetland Restoration Project	Lemkin Creek	0.12	Complete
S-65D and S-65E	P Source Control Grant	Tampa Farms-Indiantown	3.26	Complete
		Smith Okeechobee Farms	0.59	Complete
		Lofton Ranch	0.04	Complete
		Solid Waste Authority	1.16	In Design
	Dairy BAT	Butler Oaks	2.36	Complete
	Former Dairy Remediation	Lamb Island Dairy – East	1.85	Complete
		Lamb Island Dairy – West	0.11	Complete
	Alternative Water Supply Project *	Haynes Williams	0.16	Complete
		David Williams	0.16	Complete
C-40	Florida Ranchlands Environmental Services Project	Lykes Brothers	0.20	Complete
C-41	Florida Ranchlands Environmental Services Project *	Buck Island Ranch	0.37	Complete
Fisheating Creek	P Source Control Grant Program	Lazy S Ranch Iron Humate	0.11	Complete
Total for Watershed P Control Programs			**30**	

* Cost-share with FDACS

Isolated Wetland Restoration

The Lake Okeechobee Isolated Wetland Restoration Program (LOIWRP) is designed to enhance and restore wetlands, reduce TP 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, as well as the value of the easement. The landowner is 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 multi-agency team that includes the FDACS, FDEP, NRCS, U.S. Fish and Wildlife Service (USFWS), and UF/IFAS. The four projects under the program are: (1) Kirton Ranch, completed in March 2004; (2) Lemkin Creek, a state-owned property in the design phase; (3) Eckerd Youth Center, a state-owned property approaching completion; and (4) Nubbin Slough Area A restoration, in design phase (**Table 10-6**).

Former Dairy Remediation

Five former dairy remediation projects are in various stages of implementation for the privately owned former dairies that are now cow/calf operations. Planned remediation practices include retaining runoff from old high intensity areas, rehydrating onsite wetlands, amending high-phosphorus soils, and reducing the flow of stormwater offsite. Design and construction were completed on three farms, and the construction for the remaining two will be completed by fall 2008. Water quality monitoring for TP concentration reductions during flow events will be conducted for a year and a half following construction completion.

Alternate Water Storage and Treatment

The 2005 Lake Okeechobee Estuary and Recovery (LOER) Action Plan was developed to help restore the ecological health of Lake Okeechobee and adjoining estuaries, through a series of fast-track water quality improvement projects and several other far-reaching and innovative components. Among these additional components is an initiative to identify options for storage and/or disposal of excess surface water to aid in reducing lake levels and high discharge volumes to the estuaries. Assessments of available public and tribal lands for storage of excess surface water have been completed for the watershed, with assessments continuously ongoing for private lands. Eight water storage/disposal projects have been completed including Lykes Basinger Grove, Phase II Indiantown Citrus Growers Association. Additional water storage projects are under way (Avon Park Air Force Range, Kissimmee Prairie Preserve State Park, etc.), with investigations and designs continuing for additional water storage projects with a goal of 450,000 ac-ft.

A related effort was also launched in October 2005. The Florida Ranchlands Environmental Services Project (FRESP) will design a program in which ranchers in the Northern Everglades sell environmental services of water retention, TP load reduction and wetland habitat expansion to agencies of the state and other willing buyers. These ranches can bring services on line quickly as compared to other options and will complement public investment in regional water storage and water treatment facilities. The sale of the services will provide additional income for ranchers that face low profit margins and will provide an incentive against selling land for more intensive agriculture and urban development — land uses that will further aggravate water flow, pollution, and habitat problems.

FRESP is being implemented through collaboration among World Wildlife Fund, eight participating ranchers, NRCS, and state agencies — FDACS, the District, and the FDEP. Technical support is being provided by scientists from the MacArthur Agro-Ecology Research Center and the University of Florida. Funding from federal, state, and private sources exceeds $5 million for Phase One (pilot project implementation and program design).

One key accomplishment of FRESP is the development of procedures to compare protocols for documenting environmental services from ranchlands. FRESP will field test different methods of using monitoring and modeling of hydrology, water and soil chemistry, and vegetation change to document the level of environmental services provided by ranch water management projects.

Four FRESP water management projects have been designed, permitted and constructed. Additional water management projects will be implemented by four additional ranchers. Projects include rehydrating drained wetlands, water table management, and pumping water from a nearby off-site canal through the existing ranch and then back into the canal. The eight water management projects occupy some 8,500 ac (not including drainage acres). A planning level estimate of the static water-retention capacity of the eight projects is 8,260 ac-ft (1,019 ha-m) of water for a single storm event with the average storage depth of 0.98 ft (0.3 m).

Other Regional Projects

Through a coordinated effort by the FDEP, City of Okeechobee, Okeechobee County, and the SFWMD, the Lemkin Creek Urban STA Project is designed to treat urban stormwater runoff from southwest Okeechobee County and reduce TP loading to the lake. Phase I of the project included water storage and wetland rehydration. Phase II consisted of the acquisition of approximately 135 ac (55 ha) of agricultural and abandoned mining lands. The project is currently in the design phase. 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 Brighton Seminole Reservation reservoir is another regional project. The main objective of the project is to design and construct a shallow reservoir for storing and treating excess water in the Indian Prairie Basin. In 2006, the project was in the planning and design phase. The topographic survey and geotechnical work has been completed and the modeling analysis is being finalized as the next step prior to moving into the 30 percent design phase of the project.

Regulatory

Ongoing activities include revising Chapter 40E-61, F.A.C., and permitting parcels for source controls using BMPs. The rule is being revised to reflect the requirements of the Lake Okeechobee Protection Act and to expand the rule boundary to include the Lake Okeechobee watershed as defined by the Lake Okeechobee Protection Plan. The SFWMD’s Governing Board authorized staff to initiate revising the rule in December 2006. Four rule development workshops were conducted in spring 2007, to solicit initial input from the public. The specific objectives are to amend the rule to:

1. Implement a phosphorus source control program utilizing BMPs for all lands within the Lake Okeechobee watershed;
2. Include a provision for agricultural land uses greater than 100 ac, with the option of participating in the FDACS Notice of Intent Program to meet the intent of the Works of the District (WOD) rule;

3. Define the monitoring network necessary to monitor the rule's effectiveness, to make compliance determinations and to enhance performance of downstream treatment facilities;
4. Account for land use changes that may affect phosphorus levels in discharges;
5. Establish a plan for optimizing the BMP program should the expected water quality criteria not be met;
6. Ensure that the rule is consistent with data presented in the LOPP; and
7. Include incentives for permittees to participate in phosphorus reduction demonstration projects that will provide valuable data for expanding, accelerating and optimizing the implemented BMPs to meet water quality objectives and for further refinement of the rule as necessary.

In addition, a new Environmental Resource Permit (ERP) basin rule, proposed as part of the LOER program, was initiated by the District's Governing Board in February 2006. The objective of the basin rule is to reduce phosphorus loads discharging from new development within the Lake Okeechobee, Caloosahatchee, and St. Lucie watersheds. Eight rule development workshops have been conducted to date.

The U.S. Environmental Protection Agency (USEPA) and the FDEP are accelerating the development of TMDLs for tributaries in the Lake Okeechobee watershed. The USEPA Region 4 proposed TMDLs for the Lake Okeechobee tributaries in September 2006. The effort is currently under review and is expected to be completed in 2007.

LAKE OKEECHOBEE CONSTRUCTION PROJECT

The Lake Okeechobee Construction Project is being implemented in two phases. Phase I projects in the four priority basins include two pilot STAs, 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, known as the Comprehensive Everglades Restoration Plan (CERP) LOWP, is to provide approximately 60 mt of TP load reduction needed to meet the TMDL target of 140 mt/yr.

Phase I of the Lake Okeechobee Construction Project

Phase I of the Lake Okeechobee Construction Project is intended to bring immediate TP 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).

Lake Okeechobee Critical Projects activity included completion of plans and specifications 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 were awarded for both STAs, and a combined groundbreaking ceremony was held on June 30, 2004. A ribbon-cutting ceremony was held for each facility on April 27, 2006. Both STAs are operational and in the performance monitoring stage.

Phase II of the Lake Okeechobee Construction Project

The objectives of the LOWP are to reduce TP 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) and constructing stormwater treatment facilities capable of removing approximately 54 mt of phosphorus from tributary flows prior to release to Lake Okeechobee. The project also will target about 3,500 ac (1,416 ha) of the watershed for wetland and habitat restoration. A Tentative Selected Plan (TSP) has been selected and presented at an Alternative Formulation Briefing. The draft Project Implementation Report (PIR) is scheduled to be completed in February of 2008, with a final PIR by February 2009. This project also is updated in Chapter 7A of this volume. More information also is available on the Comprehensive Everglades Recovery Plan web site at www.evergladesplan.org.

EVALUATION OF LAKE OKEECHOBEE PROTECTION PROGRAM

The 2004 LOPP projected an anticipated TP load reduction of 78 mt (based on reducing the 468 mt baseline load to 390 mt) by 2006 through implementation of the projects outlined in the Plan (SFWMD et al., 2004). However, actual TP loads to the lake were 634 mt per year, averaged over 2001 to 2006, which is 244 mt above the targeted load of 390 mt. While information indicates that improvements in water quality are occurring at the edge of farm or basin, these were masked by the hurricane events of 2004 and 2005, and by the presence of residual or legacy phosphorus in the watershed. For example, for the five years from 2001 through 2005 as compared to the baseline, flows for the four priority basins plus the lower Kissimmee River basins increased by 65 percent, while TP loads increased by 13 percent.

The 2007 LOPP report (SFWMD et al., 2007) evaluates the TP load reduction goals achievable for each activity so that the TP TMDL will be met by 2015. This plan evaluation also defines current and proposed TP reduction projects that require future funding, the lead agency responsible for implementing the activities, and the estimated percentage TP load reduction (**Table 10-7**). The estimated load reductions from future activities were estimated based on the best available information and data. These reductions were presented under the 10-year baseline condition from 1991 to 2000. The actual load reductions, as measured at the lake inflow structures, will 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.

Certain assumptions made in the reevaluation effort include hydrology, lake functions, TP-reduction estimates (project and BMP performance and implementation rates), the amount of residual phosphorus in the soils and associated phosphorus assimilative capacity, land-use changes, lag effects, and overall schedules and funding.

Rainfall affects flow in the system which, in turn, affects phosphorus transport. Flows can vary dramatically on an annual basis, as evidenced by the last two years of very wet conditions (**Table 10-3**) including the influence of five hurricanes. Therefore, the original baseline period was used for comparative purposes. This time period contains wet and dry years and, overall, represents average conditions.

Some uncertainties associated with the performance of BMPs include the impacts of different soils and hydrologic conditions, the quantity of water that can be held on a parcel without impacting an agricultural operation, residual phosphorus in the soils, and the rate of implementation of the BMPs. Long-term TP loading in the watershed has created legacy phosphorus in the soils. The increase in legacy phosphorus has reduced the assimilative capacity of soils and wetlands in the watershed, resulting in more phosphorus discharge to the lake. The BMP performance estimates were based on best professional judgment and take into account the uncertainties described above and information available from literature as well as actual performance data observed in the watershed.

Property values had significantly increased over the past five years, but recently have leveled off. Current land prices in the watershed continue to make 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 is to assure that these land-use changes will not increase TP loads to the lake.

Also, uncertainties exist regarding the assimilative capacity of Lakes Istokpoga and Kissimmee. Studies of these lake sediments have shown that they are currently assimilating TP but could eventually become over-loaded without intervention (White et al., 2003). As a result any TP load reduction upstream of these lakes could be masked by release of stored phosphorus for several years if not longer (Jeppesen et al., 2005). To meet the TP TMDL for Lake Okeechobee, reductions of TP loads north of these lakes must be considered.

Table 10-7. Ongoing and future phosphorus reduction activities in the Lake Okeechobee watershed, with lead agencies and estimated percent of total load reduction to meet the TP Total Maximum Daily Load (TMDL) of 140 metric tons (mt).

CATEGORY	LEAD AGENCY	ESTIMATED PERCENT TP LOAD REDUCTION
TP Load Reduction Activities Underway		
Owner[1] & Typical Cost Share[2] BMPs	Agriculture – FDACS Non agriculture – FDEP	19%
Watershed TP Reduction Projects (phosphorus source control projects as shown in **Table 10-4**)	SFWMD	9.5%
Regional Public Works Projects (EAA Reservoir and Flow Diversion Projects, Kissimmee River Restoration, Critical Projects)	SFWMD	15%
TP Load Reduction Activities Requiring Future Funding (2007-2015)		
Typical Cost Share BMPs and Additional Agricultural[3] BMPs that Require Funding	FDACS SFWMD	19%
Other Regional Projects (Lemkin Creek STA, Lake Okeechobee Fast Track Projects, Brighton Reservoir)	SFWMD	8%
CERP LOWP (2003–2015)	USACE and SFWMD	16.5%
LOPP Strategies (Aquifer Storage and Recovery, Public-Private Partnership Project, Chemical Treatment with Reservoir, Additional Regional Storage and Treatment, Managed Aquatic Plant System, Deep Well Injection)	SFWMD, FDEP, FDACS	13%

[1] Operational BMPs that can be implemented by landowners without cost-share.

[2] Typical BMPs (primarily cow-calf) implemented under cost share programs offered by FDACS and NRCS.

[3] The category describes advanced BMPs that require extensive cost-share including chemical treatment with retention/detention for citrus, dairy, row crop, ornamental, and sod.

WATERSHED RESEARCH, ASSESSMENT AND MONITORING

RESEARCH AND STUDIES

One of the elements under the LOPA program involves research and water quality monitoring activities. 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 Lake Okeechobee Interagency Team meetings and various project teams. The Interagency Team has been expanded to the Northern Everglades Interagency Team to include participants from local governments in the Northern Everglades Planning Area, including the Upper Kissimmee region and the Caloosahatchee and St. Lucie Estuaries watersheds.

A number of research and demonstration projects were started, continued, or completed in WY2007 (**Table 10-8)**. The LOPA required that on-farm and tributary water-management practices be assessed. The Watershed Assessment Model (WAM) (SWET, 2002) BMP selection, application and enhancement project (John Folks, personal communication) will provide FDACS with an assessment tool to better manage their programs (maximizing water quality improvements while minimizing the economic burden on farmers and Florida taxpayers). The WAM will be enhanced to include ArcGIS 9 based Graphical User Interface for use with the FDACS' Water Quality BMP Tracking Program/Notice of Intent Program. These enhancements focus on the needs of FDACS staff for developing optimized farm and regional level BMP implementation programs.

Technical assistance in review and analysis of existing data evaluating the Lake Okeechobee watershed legacy phosphorus issue was started in May 2007. The overall objective of this project is to identify and develop needed quantitative information on storage and dynamics of legacy phosphorus in the Lake Okeechobee watershed. Phase I of the project consists of a comprehensive search, review, and analysis of all phosphorus studies conducted in the northern Lake Okeechobee watershed, which will be conducted by a consultant. If the consultant's recommendation calls for additional data acquisition, then consultant shall design a strategic research approach to address the overall objective as part of Phase II of the study. The two most important questions the consultant shall address are: (1) How much phosphorus is currently stored in the watershed; and (2) How long it will take for legacy phosphorus to reach stable levels? The scheduled completion date for the project was December 2007.

ASSESSMENT OF BMP EFFECTIVENESS

In accordance with the LOPA, a two-phased approach was used to determine BMP effectiveness. The first phase required 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 to develop 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 without extensive data on their effectiveness. Implementation of BMPs from adopted and approved BMP manuals based on an FDACS farm assessment or a site-specific plan developed through the NRCS qualified for this phase. For the second phase, the SFWMD or the FDEP monitors 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 SFWMD through the LOWOD and the USGS Load Monitoring Programs. Additional monitoring at the parcel level is conducted by UF/IFAS research demonstration projects designed to verify the effectiveness of a typical suite of BMPs (**Table 10-8)**.

In July 2006, the SFWMD worked with a consultant to update the Phosphorus Reduction Performance and Implementation Costs for BMPs and technologies in the Lake Okeechobee Protection Plan area. The purpose of this re-evaluation was to update the values in the previous report, include one additional agricultural land-use category (ornamentals) in the assessment, and separate range/woodland pastures from unimproved pastures. To complete these tasks, a workshop was held in May 2006 with leading agricultural experts that had specific knowledge of BMP implementation practices and effectiveness. The workshop was invaluable in determining the latest research and management practices for the primary crops grown in the Lake Okeechobee basins. The appropriate values for existing and BMP practices for each agricultural land use were discussed in detail, with updated values developed by group consensus (Bottcher, 2006). It is anticipated that the implementation of owner and typical cost-share BMPs in the urban and agricultural sectors will provide approximately a 25 percent reduction in TP loads into the tributaries within the Lake Okeechobee watershed. Additional reductions could be achieved by a more aggressive BMP implementation program within the basin. The reductions shown are for a "typical" BMP implementation level under a moderately aggressive program that assumes a limited amount of cost-share support will be available for agricultural landowners.

Table 10-8. Status of Lake Okeechobee watershed research, demonstration, and assessment projects during WY2007.

PROJECT NAME (INVESTIGATOR)	MAJOR OBJECTIVES/CONCLUSIONS	STATUS
Taylor Creek Pilot STA Baseline Characterization (UF/IFAS)	The overall objective of the study was 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 was completed in May 2007.	Complete
Nubbin Slough Pilot STA Baseline Characterization (UF/IFAS)	The overall objective of the study was to document the existing soil and vegetative conditions in the Nubbin Slough 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 June 2006 and was completed in June 2007.	Complete
Taylor Creek Tributary Dredging (Okeechobee County)	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 water quality in Taylor Creek, which ultimately flows into Lake Okeechobee. The removal of this sediment will remove phosphorus from the system and improve flood protection and navigation in specific reaches. The soil analysis for dredged 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 nearby agricultural operations as a soil amendment. The project was completed in July 2007.	Complete
Lake Istokpoga Canal Maintenance Dredging and Sediment Removal Feasibility Study (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 FDEP'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. The project was begun in August 2005 and completed in August 2006.	Complete
Okeechobee County Comprehensive Stormwater Master Plan	The objective of this project is to enter into a cooperative agreement with the city and county of Okeechobee to develop a Comprehensive Stormwater Master Plan. The development and adoption of such a plan, coupled with the parallel development and implementation of a stormwater utility, will greatly enhance the County's current stormwater management system and will provide a means to better achieve Federal, state, and local water quality objectives.	Ongoing
Okeechobee County Stormwater Utility Feasibility Study	The objective of this project is to enter into a cooperative agreement with the city and county of Okeechobee for the development of a Stormwater Utility Feasibility Study. The study will provide recommendations regarding rate structures, proposed rates, and anticipated revenues including pros and cons generated by a potential stormwater utility, which could then be used as the funding vehicle to maintain and upgrade the existing stormwater-management programs for both the city and county.	Ongoing

Table 10-8. Continued.

PROJECT NAME (INVESTIGATOR)	MAJOR OBJECTIVES/CONCLUSIONS	STATUS
Water Quality Best Management Practice (BMP) for Beef Cattle Ranch Demonstration (Archbold Expeditions)	The study objectives are to: (1) develop an understanding of the relationship between beef cattle operational practices and water quality and (2) provide recommendations for the development of environmentally and economically sustainable cow/calf practices in the Lake Okeechobee watershed. Cattle stocking rates evaluated in this study 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 2008.	Ongoing
Taylor Creek Algal Turf Scrubber® Nutrient Recovery Facility (HydroMentia, Inc.)	This is a scaled-up demonstration of HydroMentia's proprietary water-treatment technology that employs algae to remove pollutants from impaired waters. The objectives of the project are to: (1) reduce total TP loads from stormwater runoff associated with the Taylor Creek drainage basin; (2) provide secondary enhancement of water quality through increased dissolved oxygen levels; and (3) recover and recycle captured nutrients through the harvesting and composting of harvested algae biomass. The facility is located on a 70-acre parcel owned by the District in the S-191 Basin in Okeechobee. The facility was designed to treat 15 MGD of water rerouted from Taylor Creek, a tributary to Lake Okeechobee. The facility is expected to remove 4,000 lbs of TP per year. The facility is fully constructed and operational. However, the system is presently not performing under design conditions because of the drought. The project started in January 2007 and will be completed in January 2008.	Ongoing
Technical Assistance in Review and Analysis of Existing Data for Evaluation of Legacy Phosphorus in the Lake Okeechobee Watershed (Soil & Water Engineering Technology, Inc.)	The objective of this project is to evaluate the legacy phosphorus in the Lake Okeechobee watershed based on existing information. This work is divided into two phases. For Phase I, the consultant shall conduct a comprehensive search, review and analysis of all phosphorus studies conducted in the northern Lake Okeechobee watershed. For Phase II, the consultant shall formulate recommendations based on results of Phase I. The consultant shall address the following three key questions: (1) how much phosphorus is currently stored in the watershed; (2) how long it will take to bring the quantity of stored phosphorus down to background levels (stable condition); and (3) knowing the length of time it would take to bring the quantity of stored phosphorus down to stable conditions, what management and predictive tools can be used for timely implementation of effective phosphorus control strategies? The final product will be a report that outlines an abatement plan to address the legacy phosphorus issue in the watershed. However, if the consultant's recommendations call for additional data acquisition, the consultant shall develop a work plan detailing the strategic research approach to be used to achieve the overall objective. The project was expected to be completed in December 2007.	Ongoing
Wetland BMP Research (UF/IFAS)	The study objectives are to: (1) demonstrate and determine the efficacy of isolated wetlands located in land areas used for dairy and cow/calf operations, on phosphorus assimilation and storage; (2) 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; (3) review current hydrologic and TP models for adaptation to the Okeechobee Basin wetland systems and to predict phosphorus assimilation capacity of the basin; (4) develop phosphorus assimilation coefficients/algorithms for use in water quality models to demonstrate the effectiveness of isolated and constructed wetlands to store phosphorus; and (5) 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. The project started in 2003 and is expected to be complete in June 2008.	Ongoing
Dairy Lagoon Seepage Characterization and Remediation Processes (UF/IFAS)	An extensive monitoring well network has been established to determine the movement of nutrients in groundwater resulting from lagoon leakage. Preliminary results indicate very little movement of phosphorus. Study to continue through a full dry/wet cycle to determine the effect on phosphorus movement. The modeling and monitoring will be completed in June 2008.	Ongoing

Table 10-8. Continued.

PROJECT NAME (INVESTIGATOR)	MAJOR OBJECTIVES/CONCLUSIONS	STATUS
Cow/Calf Water Quality BMP Demonstration (UF/IFAS)	To evaluate the effectiveness of cow/calf production BMPs with regard to reducing TP loadings. Specific objectives include: (1) identify selected cow/calf BMPs and design hydrologic monitoring network for evaluating BMPs' effectiveness at watershed-scale for reducing TP discharges; (2) 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; (3) use the monitoring data to test and modify selected hydrologic simulation models for their effectiveness in simulating the effectiveness of BMPs; and (4) 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 June 2008.	Ongoing
Development of Cost-effective and Sustainable Forage Production and Fertilization Strategies for Remediation of Phosphorus-Loaded Soils (UF/IFAS)	Pastures are an integral part of the landscape in the Lake Okeechobee watershed. Previous work showed that improved forage production systems can facilitate TP exports from phosphorus-impacted soils. This project will extend existing on-farm demonstration studies monitoring the effects of soil phosphorus values on forage productivity, diagnostic tissue values and phosphorus mining capacity. The project will be completed in June 2008.	Ongoing
Rapid Soil and Tissue Analysis Techniques Using Near Infrared Reflectance Spectroscopy (UF/IFAS)	This project is evaluating remote-sensing techniques as a substitute for elaborate wet chemistry methods for soil, plant tissue and water analysis to provide improved, accurate, precise and rapid in-field diagnostics. Thus, providing the ability to interpret analytical results of soil, tissue and water tests for in the field recommendations for nutrient needs/applications and timing of crop harvesting to maximize production and environmental benefits. The project will be completed in June 2008.	Ongoing
Protocol Development to Evaluate the Effect of Water Table Management on Phosphorus Release to Drainage Water (UF/IFAS)	The thorough understanding of the potential phosphorus release from the soil profile is critical for the successful implementation of water table management. A body of literature is emerging that indicates raising water table in the uplands soils may release absorbed TP from the soil into the groundwater. This project will develop the protocol needed to determine the potential for these releases and recommend BMPs that can be used to prevent or manage these releases. The project will be completed in June 2008.	Ongoing
The Use of Composted Animal Waste (Cowpeat) as a Replacement for Canadian and Florida Peat in Potting Material (UF/IFAS)	These projects are phase two of the "cowpeat" dairy projects. A comparative study of the materials generated on the two cowpeat production projects to Canadian and Florida peat will be done on all of the major plant production areas found in Florida. Based on these comparison studies a standard will be developed to provide for consistent product for all commodities in the sate horticulture industry. The study will determine both environmental and production benefits from the use of cowpeat versus Florida and Canadian peat. The project will be completed in June 2008.	Ongoing
WAM BMP Assessment Tool and Model Upgrade (Soil and Water Engineering Technology, Inc.)	This project will provide FDACS and other agencies with an assessment tool that will enable BMP programs to maximize water quality improvements in Florida waters while minimizing the economic burden on farmers and Florida taxpayers. The project will be completed in June 2008.	Ongoing

WATER QUALITY MONITORING IN THE WATERSHED

Water quality monitoring is conducted through the LOWP (USGS stations) and other loading stations (flow and TP), the Lake Okeechobee Watershed Assessment (LOWA) micro-basin monitoring (TP only), and through the District's ambient water quality monitoring program (both TP and TN) (**Figure 10-4**). Through the LOWP, the USGS monitors 16 basin and 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 Comprehensive Everglades Recovery Plan web site at http://www.evergladesplan.org/.

In WY2004, the District restructured the LOWOD farm-level concentration monitoring network to the LOWA micro-basin level monitoring network, moving sampling sites 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. The site data collected under the program, along with 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 TP concentrations throughout the watershed. If changes are observed, then the District can perform more intensive monitoring within the basin and micro-basins to identify phosphorus sources. If high TP source areas are detected and TP discharges within a basin do not improve, then the coordinating agencies can require the implementation of additional BMPs or regional projects.

For the past four years, data have been collected at established LOWA micro-basin monitoring sites located in 14 drainage basins north of the lake (**Figure 10-4**; **Table 10-9**). During WY2007, all 14 basins had average TP concentrations above the specified target concentration (Surface Water Improvement and Management Plan target) (SFWMD, 1981). A detailed data analysis of each basin is provided to the coordinating agencies to help direct BMP implementation.

The District's long-term, ambient monitoring network consists of 27 sampling locations within the upper and lower tributaries in the basins immediately north of Lake Okeechobee (**Figure 10-4**). This monitoring network also includes an additional seven sampling sites within Lake Istokpoga (**Figure 10-4**). The sampling protocol calls for biweekly grab sampling for nutrients and physical parameters. Most of the sampling involves collections only when flow is occurring at these locations. Some of the sampling sites in this network have been maintained by the District since 1972. The five-year average TP and total nitrogen (TN) data from WY2003 through WY2007 are presented in **Table 10-10**. The District only calculates a TN value if both nitrate + nitrite (NOx) and total Kjeldahl nitrogen (TKN) are listed. Several very high concentrations of TN were detected, but since these were paired with elevated levels of TP during times of increased flow, the values were deemed to be reasonable for the drainage areas and therefore included in the calculations.

The Lake Istokpoga water quality monitoring program began in 1988. Nutrient loadings are calculated by combining nutrient concentrations with flow data obtained at the major inflow and outflow points to the lake. Data assessments at in-lake water quality stations also have helped to indicate trends in water quality and has allowed for better management of the system. Water quality indicators were critical in substantiating the need for the drought assisted drawdown and muck removal project that has resulted in environmental enhancement of the lake.

The monitoring networks are compatible in terms of techniques used over time by the District. The long-term ambient monitoring has been consistent in terms of its monitoring protocols (sampling and analytical methods, parameters, frequency, and site locations). The same type of consistency existed for the LOWOD farm level monitoring but site locations and length of monitoring depended on permit compliance. The newly designed LOWA network was also developed to ensure consistency among monitoring protocols. Data from any of these three projects could be comparable to each other since similar sampling and analytical methods were used. These three monitoring networks have comparable data when looking at the Lake Okeechobee watershed as a whole, but it is important to understand the specific data objectives for each of these networks when assessing water quality conditions and restoration/compliance effectiveness. Each of these programs target different hydrologic scales of contribution within the watershed. Data collected at the micro-basin or the parcel level provide different pieces of the watershed puzzle compared to what can be deduced from samples collected at the tributary level.

Table 10-9. WY2007 TP concentration data collected at sampling sites in the Lake Okeechobee watershed[a].

WATERSHED SAMPLING SITES						
BASIN	Mean (ppb)	Median (ppb)	Standard Deviation	Number of Samples	Number of Monitoring Sites	Basin SWIM Plan Concentration Target
Taylor Creek/Nubbin Slough (S-191)	711	382	1,757	256	34	180
S-133	126	84	124	32	3	180
S-154	632	303	963	96	12	180
S-65A	136	85	147	280	11	70
S-65B/C	165	80	183	116	14	95[b]
S-65D	542	135	1,007	62	12	180
S-65E	329	180	412	164	20	180
Slough Ditch S-84 (C-41A)	153	68	212	79	7	100
Harney Pond Canal S-71 (C-41)	298	126	394	331	20	180
Indian Prairie S-72 (C-40)	181	128	179	113	7	180
Josephine Creek	530	59	1,699	236	16	Not available
Fisheating Creek	412	314	349	333	21	180
Arbuckle Creek	316	91	561	221	10	Not available
Lake Arbuckle	143	43	274	66	4	Not available

[a] This table includes data from the LOWA, Ambient, and USGS monitoring sites. Only LOWA sites monitored for at least nine months of the water year were included in this table. Flagged data were excluded.

[b] S-65B and C basins had target TP concentrations of 60 and 130 ppb, respectively.

Table 10-10. WY2003–WY2007 TP and TN data collected from the long-term, ambient monitoring network in the Lake Okeechobee watershed.

	TOTAL PHOSPHORUS				TOTAL NITROGEN			
BASIN	Mean (ppb)	Median (ppb)	Std Dev	Number of Samples	Mean (ppb)	Median (ppb)	Std Dev	Number of Samples
Taylor Creek	480	388	344	679	1931	1749	1300	616
Nubbin Slough	575	500	345	379	2361	2175	1303	344
S-65D	193	126	211	343	1491	1407	475	291
S-154C and S-65E	579	459	458	344	2161	2001	815	266
Lake Istokpoga	91	78	59	129	1321	1276	251	108

LAKE STATUS

STATUS OF LAKE PERFORMANCE MEASURES IN WY2006

Measurements of TP, chlorophyll, phytoplankton, submerged aquatic vegetation (SAV), and water levels have been adopted as quantitative performance measures for the LOPA (SFWMD et al., 2004). These measures describe the status of the ecosystem and its responses to implemented restoration programs. Measures are five-year averages; this ensures consistency with TMDL reporting, reduces the effect of year-to-year variation attributed to climate and hydrology, and helps to reveal underlying trends. These values are compared to quantitative restoration goals (**Table 10-10**). The TP load is the only goal that is to be met by a set date, 2015, as specified in the phosphorus TMDL (FDEP, 2001). The Lake Okeechobee Protection Program Annual Report provides a technical foundation for these restoration goals. The WY2007 averaged observations are reported and document the water quality and lake level conditions of this year.

Of the 11 performance measures that can be compared to five-year (2002–2006) averages, one has reached its goal (**Table 10-10**). This was the diatom-to-cyanobacteria ratio, which may have increased over the last few years due to high turbidity resulting in a poor light climate that tends to favor some diatoms over cyanobacteria. An alternative explanation is that the higher DIN concentrations in the past three years have favored diatoms over cyanobacteria. The performance measures that were not met include TP loads, pelagic and nearshore TP, nutrient limitation, algal bloom frequency, water clarity, and SAV density. The closest attribute to reach its restoration goal is SAV density, which is attributed to two years (2002 and 2004) when lake conditions were conducive to a very large spatial distribution of plants. The WY2007 values for all performance measures are further from their respective targets with the exception of TP loads and algal blooms. The WY2007 conditions of the lake are explored further in this chapter's *Hurricane Recovery and Water Shortage* section. Of the three stage-related goals, one was achieved in this past water year: water levels did not exceed 15 ft because of water shortage conditions.

WATER SHORTAGE MANAGEMENT

During the past year, a region-wide drought (see Chapter 2 of this volume) has led to low flows to, reduced water levels in, and reduced discharges from Lake Okeechobee. Total flow to the lake was 575,283 ac-ft (70,960 ha-m) as compared to the 15-year annual average (1991 through 2005 calendar year) of 2,535,752 ac-ft (312,758 ha-m, see **Tables 10-2b** and **10-2b**). Because of the dry conditions, there was no release of water from Lake Kissimmee from December 1, 2006 through July 20, 2007. This resulted in a reduction of flow from the Kissimmee River to Lake Okeechobee, from a 15-year annual average of 1,333,088 ac-ft (164,434 ha-m) to 156,626 ac-ft (19,319 ha-m), which was 27 percent of the flow for WY2007. For the 15-year annual average, the Kissimmee River made up 53 percent of the surface flow to the lake, while in WY2007 this flow was only 27 percent of the surface flow to the lake.

As water levels continued to drop below the water supply-side management schedule, numerous actions were taken to reduce water consumption and maintain water supply (**Figure 10-5**). Water restrictions were increased over time beginning with Phase I, which reduced residential lawn watering to three days a week and golf course and agricultural irrigation by 15 percent, Phase II, which reduced lawn watering to two days a week and golf course and agricultural irrigation by 30 percent, and a modified Phase III, which reduced lawn watering to one day a week and golf course and agricultural irrigation by 45 percent. Fourteen temporary forward pumps were deployed at S-351, S-352, and S-354 on March 30, April 6, and April 13, 2007, respectively, to maintain water supply to the Everglades Agriculture Area (EAA).

These pumps allow water to move from the lake to the canals when lake water levels are below 10.2 feet (3.1 m) NGVD, at which point gravity flow to the canals in the EAA is extremely limited. Water levels continued to drop to their lowest point on record (8.82 ft on July 3, 2007).

Discharges from the lake to the estuaries and the agricultural region in WY2007 were 365,749 ac-ft (45,114 ha-m) which is less than half the 15-year annual average (834,076 ac-ft, or 102,882 ha-m). Over 50 percent of the discharge went south to the EAA, 19 percent to the Caloosahatchee Basin, and 9 percent to the St. Lucie Basin (**Figure 10-6**). Of the water discharged to the St. Lucie Basin (32,848 ac-ft, or 4,051 ha-m) only an estimated 453.5 ac-ft (59.9 ha-m) was discharged into the estuary.

Table 10-10. Summary of Lake Okeechobee rehabilitation performance measures, rehabilitation program goals, and lake conditions. Unless otherwise indicated, conditions for WY2007 are listed with five-year annual averages (WY2002–WY2006), as specified in the Restoration Assessment Plan of the Lake Okeechobee Protection Program.

PERFORMANCE MEASURE	GOAL	FIVE-YEAR AVERAGE	WY2007 AVERAGE
Total Phosphorus (TP) load	140 mt/yr (to be met by 2015)	629 mt/yr	203 mt/yr
Pelagic TP Pelagic TN Pelagic SRP Pelagic DIN	40 ppb N/A N/A N/A	173 ppb 1.67 ppm 54 ppb 303 ppb	179 ppb 1.46 ppm 70 ppb 209 ppb
Pelagic TN:TP Pelagic DIN:SRP	> 22:1 > 10:1	11:1 5.4:1	8.4:1 2.7:1
Plankton nutrient limitation	Phosphorus > Nitrogen	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus
Diatoms:cyanobacteria[a]	> 1.5	1.56	N/A
Algal bloom frequency	< 5% of pelagic chlorophyll *a* exceeding 40 μg/L	8.2%	1.04%
Water clarity	Secchi disk visible on Lake bottom at all nearshore SAV sampling locations from May–September	9.9%	7.3%
Nearshore TP	Below 40 ppb	108 ppb	135 ppb
Submerged aquatic vegetation (SAV)[b]	Total SAV > 40,000 ac	28,556 ac total	2,965 ac total
	Vascular SAV > 20,000 ac	16,111 ac vascular	495 ac vascular
Extremes in low lake stage (current water year)	Maintain stages above 10 ft	N/A	Goal not attained
Extremes in high lake stage (current water year)	Maintain stages below 17 ft; stage not exceeding 15 ft for more than four months	N/A	Goal attained
Spring recession (January to June 2006)	Stage recession from near 15.5 ft in January to near 12.5 ft in June	N/A	Goal not attained

a Mean (June 2002 to June 2006)
b Mean yearly acreages (from 2002–2006 maps)
N/A Not Applicable

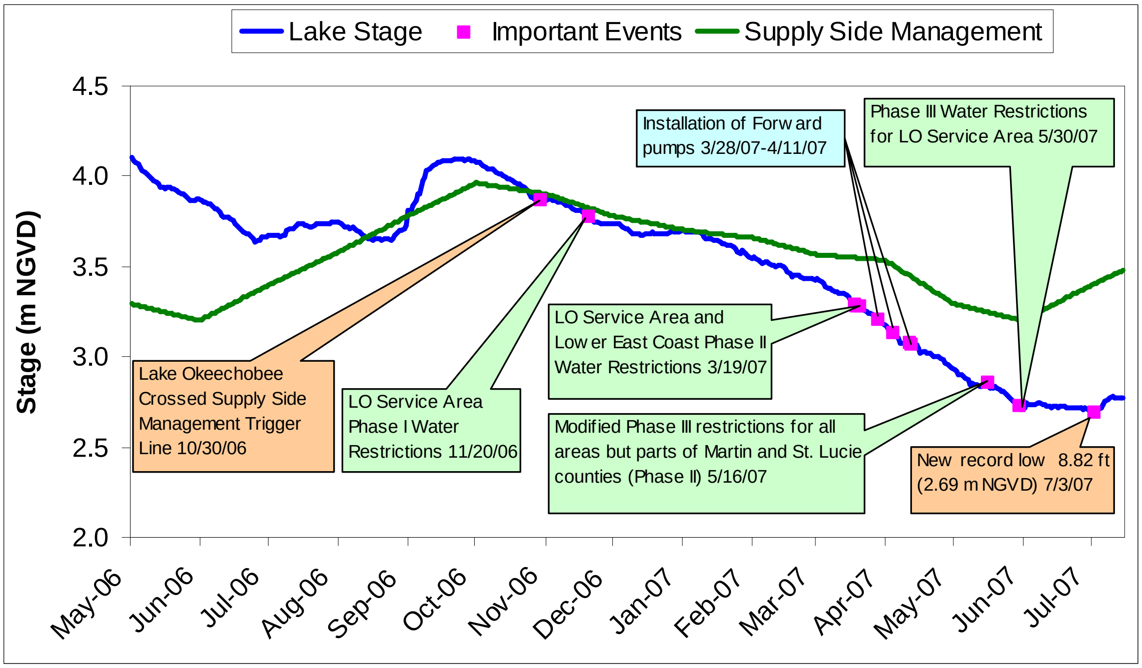

Figure 10-5. Lake Okeechobee stage, supply-side management trigger line and important water supply management events in the past year.

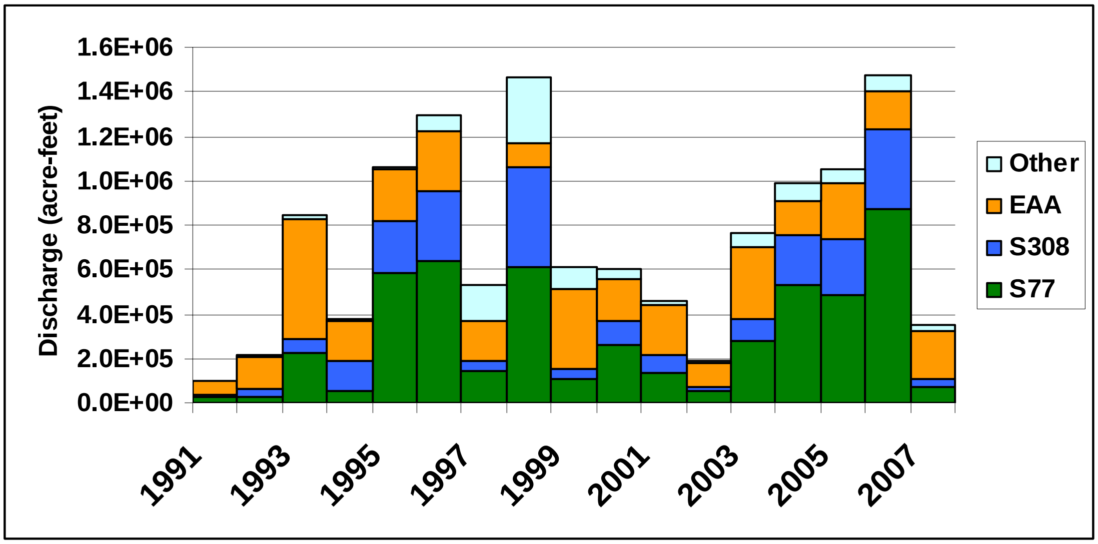

Figure 10-6. Discharges from Lake Okeechobee from WY1991 to 2007.

PHOSPHORUS BUDGET

The phosphorus budget for 2007 is quite different from previous years (see James et al., 1995a; Havens and James, 2005, for a description of budget computations). This difference is attributed primarily to drought conditions. Mean lake TP mass in WY2007 was half of the previous two years, due to lower water volume and to lower TP concentrations (**Table 10-11; Figure 10-7, Panels A** and **B)**. The lower TP concentration is the second year of a reduction of TP concentration in the lake. This may be due to the absence of storms and perhaps to reconsolidation of flocculent sediments (see the *Sediment* section in this chapter). The negative change in lake content also may be attributed to the same two factors.

Total TP loads to the lake from tributaries and atmospheric deposition (estimated as 35 mt/yr) (FDEP, 2001) in WY2007 totaled only 203 mt (**Table 10-11**; **Figure 10-7, Panel A**). This is approximately a quarter of the load from the previous year and nearly one-third of the average in the past 10 years. However, the average inflow-weighted concentration of TP increased from 167 ppb in WY2006 to 238 ppb in WY2007 (**Figure 10-7, Panel B).**

Table 10-11. Phosphorus budget (mt) for Lake Okeechobee in the most recent 10 water years.

May–April Water Year	Mean Lake TP Mass	Net Change in Lake Content[a]	LOAD (mt) In[b]	LOAD (mt) Out	NET (mt) Load[c]	Sediment Accumulation[d]	Net Sedimentation Coefficient (σ_y)
1998	610	510	913	594	319	-191	-0.31
1999	532	-543	312	241	70	613	1.15
2000	735	106	685	310	375	269	0.37
2001	383	-320	134	202	-68	252	0.66
2002	432	264	624	73	551	288	0.67
2003	594	143	639	310	330	187	0.31
2004	578	113	555	292	263	151	0.26
2005	1106	272	967	567	400	127	0.12
2006	1104	-195	808	780	28	223	0.20
2007	594	-311	203	181	22	333	0.56
Average	**667**	**4**	**584**	**355**	229	225	0.34

[a] Net change from beginning of water year (May 1) to beginning of next water year (May 1)

[b] Includes 35 mt/yr to account for atmospheric deposition

[c] Difference between load in and load out

[d] Difference between net change in lake content and net load (positive value is accumulation in sediments)

Despite the dramatic difference between the loads in WY2007 and WY2006, the net loads for each year are nearly the same (28 mt and 29 mt, **Table 10-11**). The dramatic changes in the lake content let to the increased sediment accumulation in WY2007 (340 mt) which resulted in an increase in the sedimentation coefficient (**Table 10-11; Figure 10-7, Panel C**). It is too early to tell if this increase in sedimentation is a sign of improved lake assimilative capacity or not.

The five-year moving average of inflow TP concentration (**Figure 10-7, Panel B**) shows an increasing inflow TP concentrations from the 1970s through the mid-1980s, followed by a decline through the 1990s. The decline in inflow TP coincides with declines of TP loads from tributaries that included the Lower Kissimmee River (S-65A through S-65E basins), Taylor Creek Nubbin Slough, and the Everglades Agricultural Area (**Figure 10-3**; Flaig and Havens, 1995). The five-year rolling average then increased from WY1998 to WY2002 and has declined since then due to low inflow concentrations in WY2003, WY2004, and WY2006. The increase in WY2007 to 238 ppb is a concern and may, in part, be attributed to higher contribution of flow and loads from smaller, more agriculturally intense basins other than the Kissimmee (such as L-59E and C-41).

Phosphorus concentrations of lake water (averaged from stations L001 through L008) have increased from approximately 40 ppb in the 1970s to over 200 in WY2005 and WY2006 (**Figure 10-7, Panel B**). The highest yearly average TP concentration occurred in WY2005 (233 ppb) followed by a slight decline in WY2006 (214 ppb). In WY2007, the concentration continued to decline (176 ppb). The five-year moving average reached above 150 ppb in WY2006 and was 172 ppb in WY2007.

The phosphorus budget can be used to quantify the effects of sediment–water interactions. The decline of the net sedimentation coefficient, σ_y (per year), which is the amount of TP that accumulates in the sediment per year divided by the average lake-water TP mass, is an indication of the increased importance of these sediment-water interactions (**Figure 10-7, Panel C**). A low net sedimentation coefficient indicates that the lake is unable to absorb excess TP loads from the watershed. For WY2007, the value increased to 0.56 per year, which is higher than the 10-year average of 0.34 per year (**Table 10-11**). The higher net sedimentation coefficient is a result, in part, of the smaller mass of TP in the water column that can be attributed to the small loads, the lower volume of water and less resuspension of TP from sediments in this past water year. The coefficient also is a result of the accumulation of TP in the sediments, which is the difference between settling and resuspension of TP to and from the sediment. Overall a declining trend has been observed for σ_y since the 1970s (**Figure 10-7, Panel C**; James et al., 1995a; Janus et al., 1990). WY2007 represents the first year since 2001 that there has been an increase in σ_y.

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, see the *Other Water Quality Concerns* section of this chapter), an element that plays a key role in sequestration of TP in sediments of Lake Okeechobee (Olila and Reddy, 1993; Moore and Reddy, 1994). Possible explanations for the reduction of calcium in the water column are a reduction of external calcium loads (James et al., 1995b) or reduced contact of the water column with the underlying limestone formation (Parker et al., 1955) as the mud sediment has increased in area (Havens and James, 1999). Another explanation is an increase in calcium absorption to the increased amounts of inorganic phosphorus that forms calcium phosphate. This form of phosphorus is insoluble and is found in mud sediments (Reddy et al., 1995).

Calcium typically precipitates phosphorus in a pH range that is only encountered in the lake in dense beds of SAV, or in the midst of phytoplankton bloom activity. Calcium is ineffective in precipitating phosphorus under conditions similar to those that prevail in the open-water region of the lake. Nevertheless, the District is currently investigating calcium as well as a number of other chemical compounds as potential methods for sequestering phosphorus.

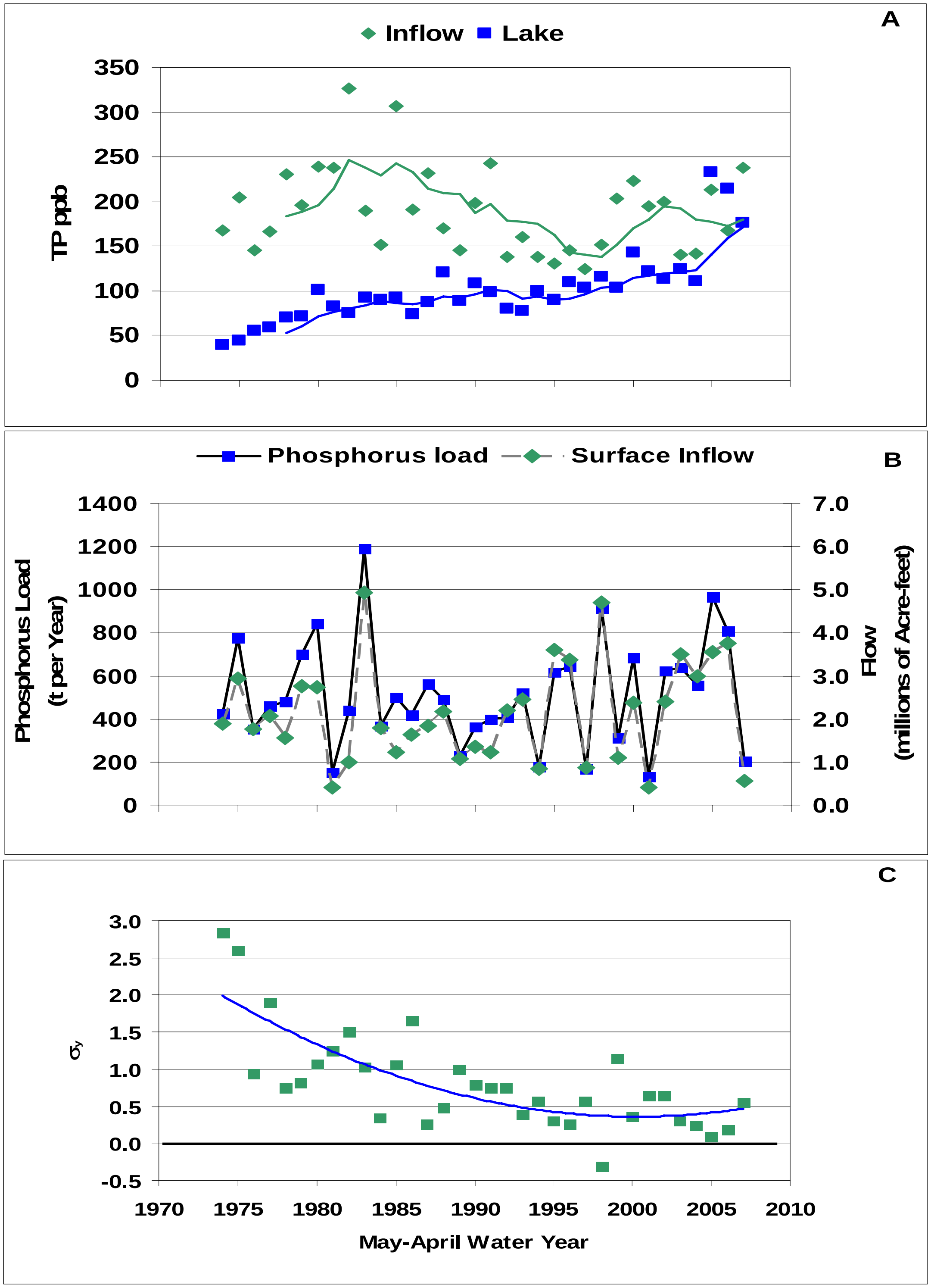

Figure 10-7. Panel A shows the timeline of inflow and lake average TP concentrations (five-year moving average trendlines); **Panel B** shows water year phosphorus load and inflow entering Lake Okeechobee from its tributaries; and **Panel C** charts the net sedimentation coefficient [σ_y] calculated from the WY2006 phosphorus budget of Lake Okeechobee.

ALGAL BIOMASS AND TOXINS

For the five year period of WY2003–WY2007, the ratio of total nitrogen-to-total phosphorus (TN:TP) and dissolved inorganic nitrogen-to-soluble reactive phosphorus (DIN:SRP) averaged 11:1 and 5.4:1, respectively (**Table 10-10**). These values favor dominance of blue-green algae, which presently account for most of the algal biomass in the lake and include some toxic species. Increased eutrophication of Lake Okeechobee and other water bodies in South Florida has led to an increased frequency of blue-green algal (cyanobacteria) blooms and their associated toxins. Biomass and taxonomic composition of bloom-forming cyanobacteria in Lake Okeechobee have been monitored since July 2003, on a monthly basis at 10 shoreline sites where blooms historically have been known to occur (**Figure 10-8**). Concurrently, water chlorophyll *a*, TN, and TP concentrations have also been monitored. Although there are no established state or federal standards for cyanobacterial toxins, their potential health risks are widely recognized. The World Health Organization has suggested that potable water contain no more than 1 ppb of microcystin, one of the cyanotoxins (WHO, 1998). Therefore, in May 2004, cyanobacterial toxin analysis was initiated as an additional component of this routine monitoring project. Water samples from five of the 10 shoreline stations are analyzed for the presence of cyanotoxins (microcystin, cylindrospermopsin, and anatoxin-a).

During summer 2005, many of the water bodies located within the SFWMD basin experienced prolific blue-green algal blooms. In Lake Okeechobee, chlorophyll *a* and microcystin toxin concentrations were elevated from August through October 2005 with the highest concentrations observed in the Harney Pond/Fisheating Bay area (**Figure 10-9**). Hurricane Wilma struck in October 2005 and a significant decrease in both parameters was immediately observed, probably as a result of water column instability caused by wind and seiche activities. Chlorophyll *a* levels have remained below 25 mg m^{-3} and microcystin levels have been below the analytical limit of detection (0.2 ppb) since Hurricane Wilma. The high suspended solids and resulting low light levels that persisted contributed to the lack of algal bloom formations and low toxin levels.

However, lake levels declined slowly throughout WY2007 and by January 2007 had gone below 12 ft (3.66 m) NGVD (**Figure 10-5**). Since then, South Florida has experienced drought conditions: lake levels reached a record low of 8.82 ft NGVD on July 3, 2007. As a result of the drought, light conditions have recently improved in the nearshore area and although no algal blooms were reported through July 2007, bloom occurrences were expected to increase as light and nutrient inputs increased during late summer.

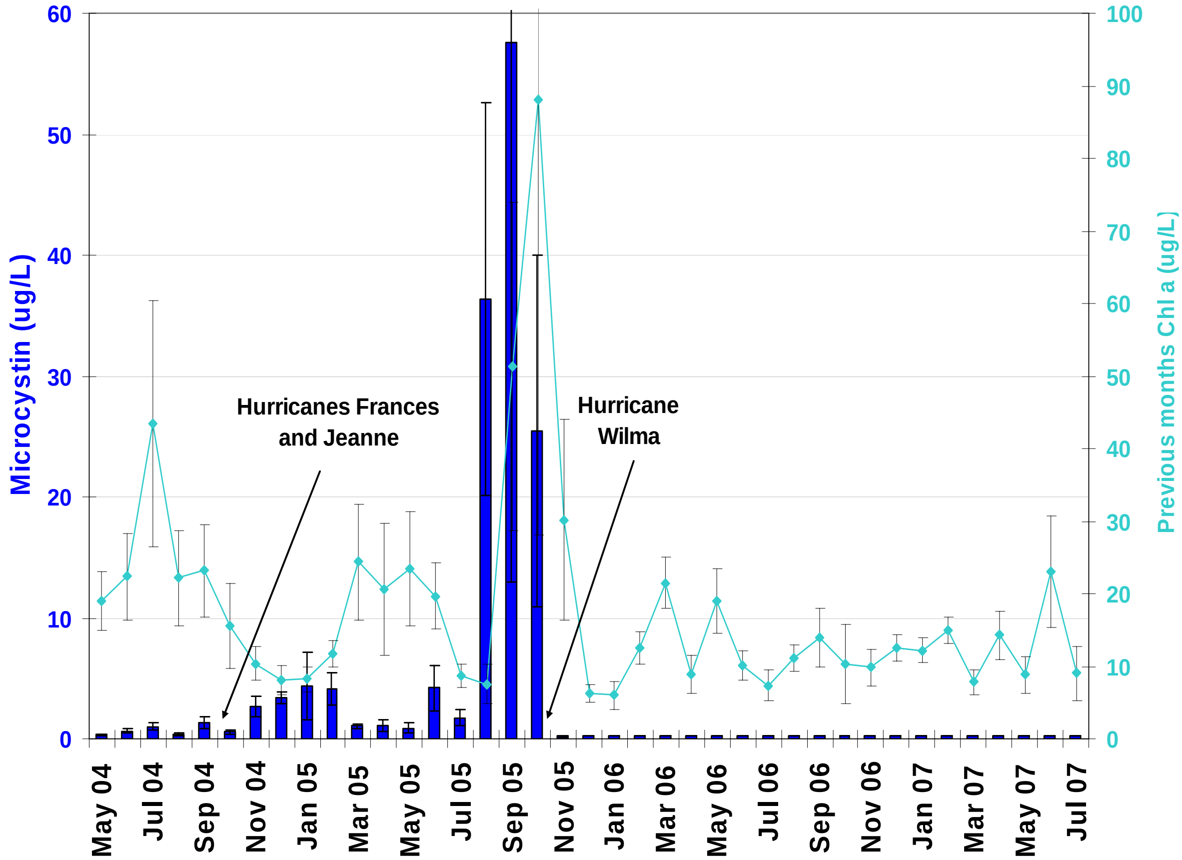

Figure 10-9. Average microcystin and previous month's chlorophyll *a* concentrations in Lake Okeechobee from May 4, 2007 through June 30, 2007.

OTHER WATER QUALITY CONCERNS

The District maintains a pesticide monitoring program that measures selected pesticides in sediments and water samples on a semiannually and quarterly basis, respectively at locations throughout South Florida. Additional information on the program can be found on the District's web site at www.sfwmd.gov under the *What We Do, Environmental Monitoring*, *Reports* section, and the *Pesticide* tab. For Lake Okeechobee, pesticides are monitored at S-65E, S-191, Fisheating Creek (FECSR78), S-2, S-3, and S-4. In the latest report (November 2006), where water was flowing into the lake (Fisheating Creek), only atrazine and hexazinone were found above the detection limit (**Table 10-12**). These two pesticides are non-selective herbicides that are easily leached from soil, relatively non-toxic to mammals and fish, and do not bioconcentrate significantly (Pfeuffer, 2006). The concentrations of these pesticides also are well below the chronic toxicity levels for water flea (*Daphnia magna*) (**Table 10-12**).

Herbicides are the only form of pesticides used by the SFWMD on Lake Okeechobee. These herbicides are used to control exotic and invasive species. The District has conducted a number of studies that tested herbicide levels shortly after treatment. (Pfeuffer, 1988a, 1998b, 1990). Often the herbicide was at or near the detection limit of the analysis. The SFWMD also has studied some effects of herbicides on lake fauna. Some negative effects have been observed on buttonbush when treating torpedograss in mixed stands; however, this problem has been largely resolved by treating these stands in winter, during the period of buttonbush dormancy. The District also is investigating the potential negative impacts on bulrush from the spraying of water hyacinth in bulrush stands (see the *Emergent Aquatic Vegetation* section in this chapter). Overall, however, exotic vegetation control activities tend to result in improvements in littoral zone plant community structure, which has important indirect benefits to Lake Okeechobee wildlife (see the *Vegetation Management* section of this chapter and Chapter 9 of this volume).

James et al., (1995b) noted a declining trend of calcium in Lake Okeechobee and hypothesized that this could be attributed to reduced loading credited to reduced back pumping into the lake from the Everglades Agricultural Area. Although this hypothesis has not been confirmed, the trend is consistent with a decline of all ion and ionic related measurements of Lake Okeechobee's water column including calcium, sulfate, and conductivity (**Figure 10-10**). In WY2007 all of these parameters had increased over the previous year due to reductions of lake volume from evapotranspiration.

Sulfate is known to contribute to eutrophication (Lamers et al., 2002) and is recognized to impact mercury cycling in the Everglades (Marvin-Dipasquale and Oremland, 1998). However, as with other ions in the lake, sulfate has declined from over 60 ppm in the early 1970s to under 30 ppm in recent years. No sulfate research has been conducted on Lake Okeechobee to date. Although mercury is a concern in Florida waters, especially for fish consumption, measurements of mercury in Lake Okeechobee fish have found 0.285 ± 0.126 ppm (N=22) in largemouth bass (*Micropterus salmoides*) and 0.093 ± 0.045 ppm (N=29) in bluegill (*Lepomis macrochirus*). The Florida Department of Environmental Protection Fish Consumption Health Advisories (http://www.dep.state.fl.us/labs/mercury/docs/fhapre.htm) states that, "Fish ...containing less than 0.5 parts per million [mercury] are considered safe for unlimited consumption." Thus there are no restrictions on fish consumption from Lake Okeechobee.

Table 10-12. Pesticide residues (µg/L) above the method detection limit found in surface water samples collected by SFWMD at Okeechobee sampling sites in October/November 2006 (from Pfeuffer, 2006) and chronic toxicity values for water flea (*Daphnia magna*).

Site	Flow	Atrazine	Atrazine desethyl	Bromacil	Hexazinone	Simazine	Number of compounds detected at site
S191	N	0.016 I	BDL	0.11 I	BDL	BDL	2
S65E	N	BDL	BDL	0.087 I	BDL	BDL	1
S2	N	0.14 *	0.029 I *	BDL	BDL	0.010 I *	3
S3	N	0.14	0.026 I	BDL	0.028 I	BDL	3
S4	N	0.097	0.016 I	BDL	BDL	BDL	2
FECSR78	Y	0.011 I	BDL	BDL	0.19	BDL	2
# Chronic toxicity of *Daphnia magna*		345 (1)	N/A	N/A	7,580 (1)	55 (1)	

I value reported is less than the practical quantitation limit, and greater than or equal to the method detection limit

BDL - Below Method Detection Limit

* average of replicate values

Florida Administrative Code (FAC) 62-302.200, for compounds not specifically listed, acute and chronic toxicity standards are calculated as one-third and one-twentieth, respectively, of the amount lethal to 50 percent of the test organisms in 96 hours, where the 96 hour LC50 is the lowest value which has been determined for a species significant to the indigenous aquatic community.

1 - USEPA (1991)

N/A- not available

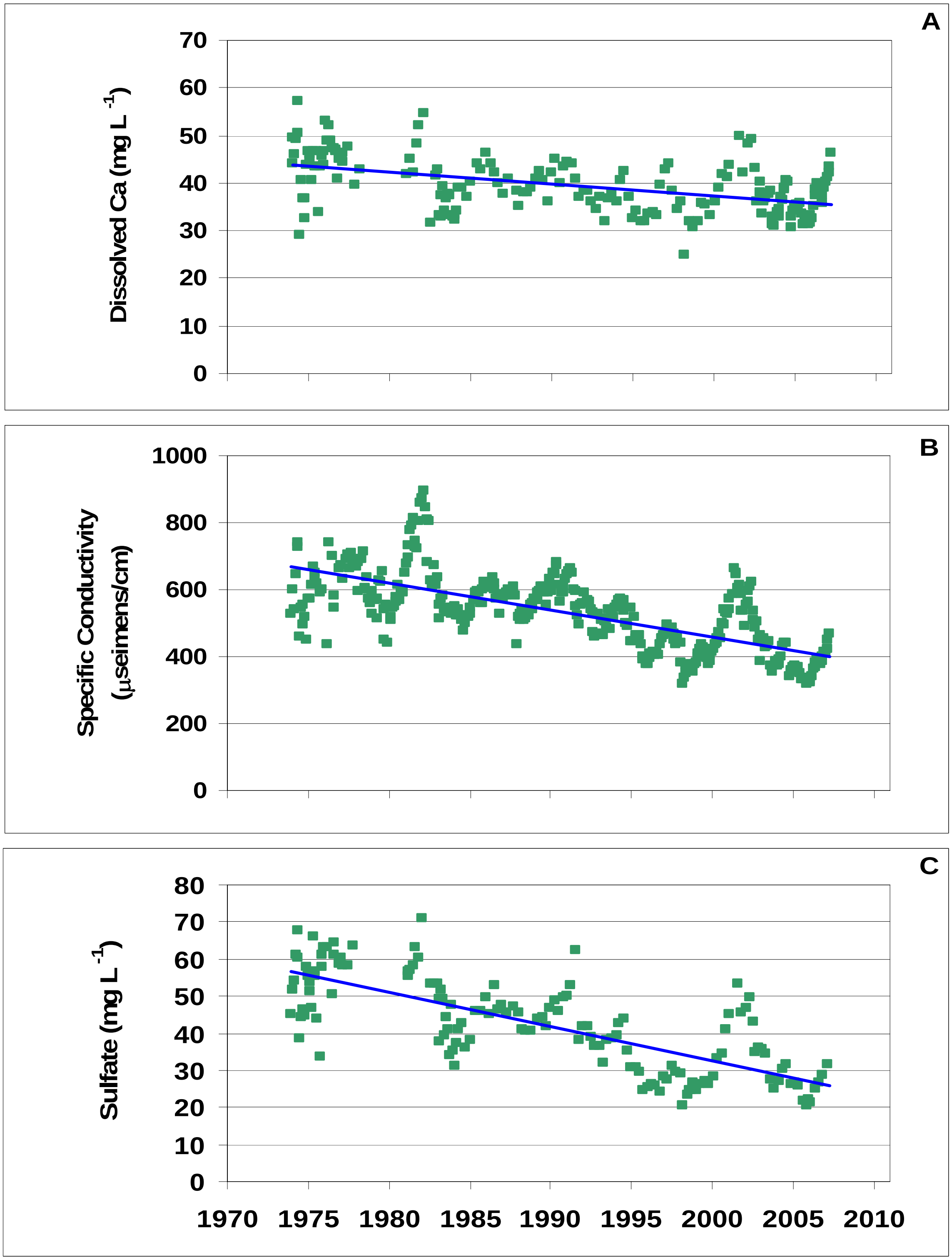

Figure 10-10. Monthly average values of (**Panel A**) calcium [r^2=0.25], (**Panel B**) specific conductivity [r^2=0.47], and (**Panel C**) sulfate [r^2=0.58] at the eight long-term monitoring stations (L001–L008). The blue line is a linear regression of the average values over time.

Hurricane Recovery and Low Lake Levels

Continued monitoring of water quality in the three regions of the lake (**Figure 10-11** and *2006 SFER – Volume I, Chapter 10*) indicate that the lake water quality has not completely recovered from the effects of hurricanes in 2004 and 2005 (**Figure 10-12**). The pre-hurricane period (September 1, 2003–September 1, 2004) was compared to the post-hurricane years (October 1, 2004–October 1, 2005, November 1, 2005–November 1, 2006, December 1, 2006–April 30, 2007) using a least square mean comparison of a Mixed model Analysis of Variance (Littell et al., 1996). The results show that all TP and SRP concentrations in post-hurricane years were significantly higher than pre-hurricane conditions (**Figure 10-12, Panels A and B**). All DIN and TN concentrations were significantly higher in post-hurricane years with the following exceptions in the littoral region: TN from October 2005–2006, and TN and DIN December 2006–April 2007 (**Figure 10-12, Panels C and D**). Because of low lake levels, sampling in the littoral region of the lake was discontinued in January 2007.

The persistence of TP, SRP, total suspended solids (TSS), and reduced Secchi Disk depth have been attributed to an increased susceptibility of sediments to resuspension. This susceptibility was discussed in *2007 SFER – Volume I*, *Chapter 10*, and was hypothesized to be due to an increased layer of unconsolidated sediments. Additional evidence of this increased layer is presented in comparisons of profiles for eight offshore sediment cores (**Figure 10-13**). Higher water content, and thus more unconsolidated sediments, are observed in the upper sediment column in 2005 than in 1988 at five sites. The profiles of water content at three other locations were similar before and after 2004.

Consistent with the hypothesis of an increased layer of unconsolidated sediments is a dramatic change in the relationship between antecedent wind conditions and TSS in the offshore region (**Figure 10-14, Panel A**). The slope of the post-hurricane wind speed-TSS regression [7.94 mg TSS $(km\ h^{-1})^{-1}$] was substantially higher than the pre-hurricane slope [1.74 mg TSS $(km\ h^{-1})^{-1}$), Analysis of Covariance $p < 0.05$]. These data indicate that for a given average wind velocity, much more sediment was resuspended, consistent with increase in unconsolidated sediments. In addition, prior to the hurricanes, the strongest relationship was found between the average wind speed one day prior to sample collection. In the 24-month post-hurricane period, the strongest relationship was between TSS and wind speed averaged over the three days prior to sample collection. This result indicates that once suspended the sediment particles remained in the water column for a longer time in the post-hurricane period compared to the pre-hurricane period, and that the resuspended sediment particles were smaller after the hurricanes.

After the 2004 hurricanes, the slower settling of suspended solids most likely resulted in the redistribution of this material throughout the lake, as indicated by the increase of TSS in the littoral region (**Figure 10-14, Panel B**). This increase was statistically significant in the second and third post-hurricane years (November 1, 2005–November 30, 2006, December 1, 2006–April 30, 2007, using the Mixed model analysis described above). To determine if changes in the sediment distribution had occurred a study was conducted in 2006 to compare sediment cores taken at 170 locations to a depth of at least 10 cm throughout Lake Okeechobee in 1998 (**Figure 10-15**).

Four sediment types have been identified in the lake: peat, mud, sand and rock (**Figure 10-16**). From 1998 to 2006, the area of mud sediments increased slightly, more peat was exposed and sand and rock were covered primarily with mud sediments (**Figure 10-16, Panels A** and **B; Table 10-13**).

Maximum mud thickness declined from 71 cm in 1998 to 51 cm in 2006 (**Figure 10-17, Panels A and B**). Mud depths declined by up to 41 cm in the central lake area and increased by up to 20 cm in surrounding areas, with mud being deposited primarily in northern littoral and northeastern nearshore regions throughout the rest of the lake (**Figure 10-17, Panel C**). The reduction of mud sediments is likely due to resuspension and redistribution by waves and currents produced by Hurricanes Frances and Jeanne in 2004 and Wilma in 2005.

In addition, sediment TP and TN concentrations were compared to determine any changes from 1998 to 2006. Average TP concentrations declined from 651 to 593 mg/kg with the greatest declines in the lake's western and southeastern regions (**Figure 10-18, Panels A** and **B**). The largest increase occurred along the northern and western edges (**Figure 10-18, Panel C**). Concentrations of TN were more homogenous in 1998 than in 2006 and declined from an average of 9,550 mg/kg to 9,056 mg/kg, with the greatest declines in the central and western regions (**Figure 10-19, Panels A** and **B**). The biggest increases occurred in the northern and southern regions (**Figure 10-19, Panel C**). On a lake-wide basis, the average changes in concentration of TP and TN were not significantly different; however, the remixing and redistribution of sediments throughout the lake could be attributed to the effects of the 2004–2005 hurricanes.

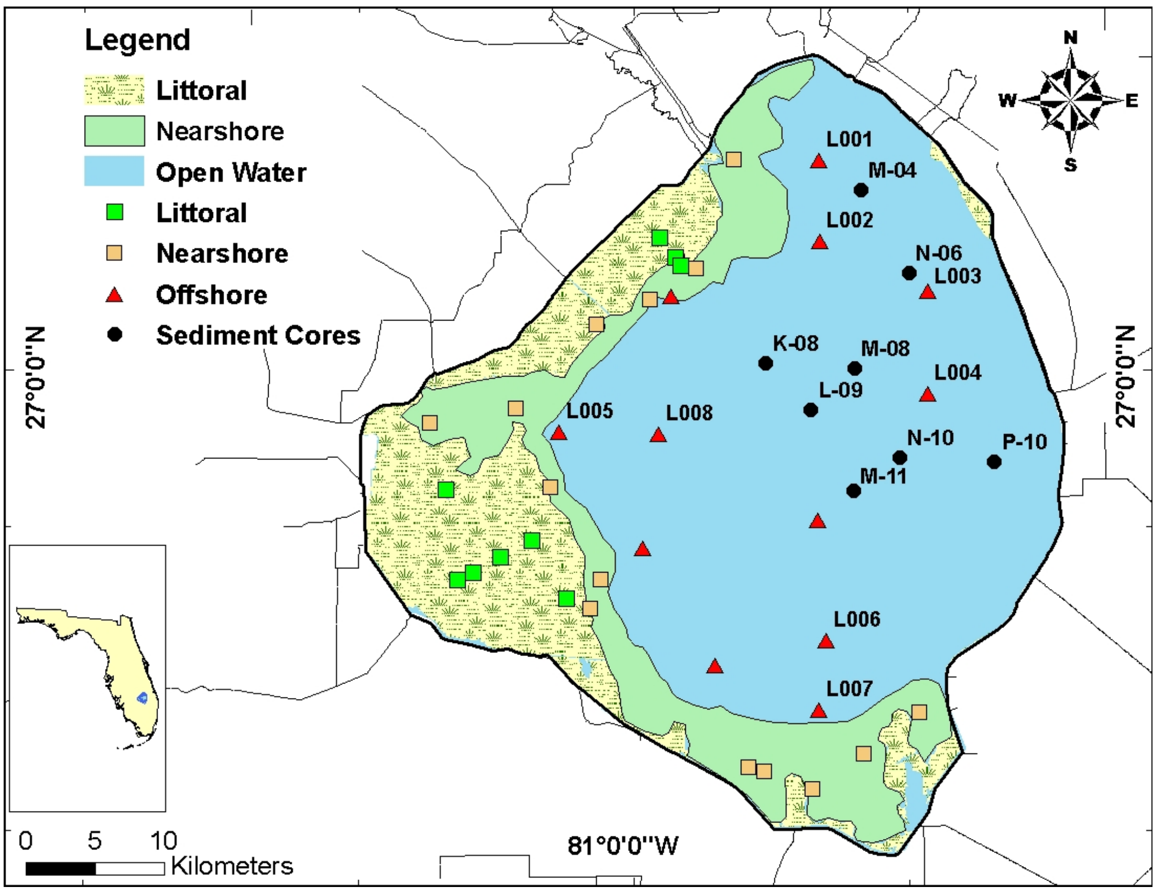

Figure 10-11. Locations of sampling stations in the Lake Okeechobee network and map of littoral, nearshore and offshore regions. The long-term monitoring network stations, L001 through L008, are identified. The sediment sampling stations shown are reported in **Figure 10-13**.

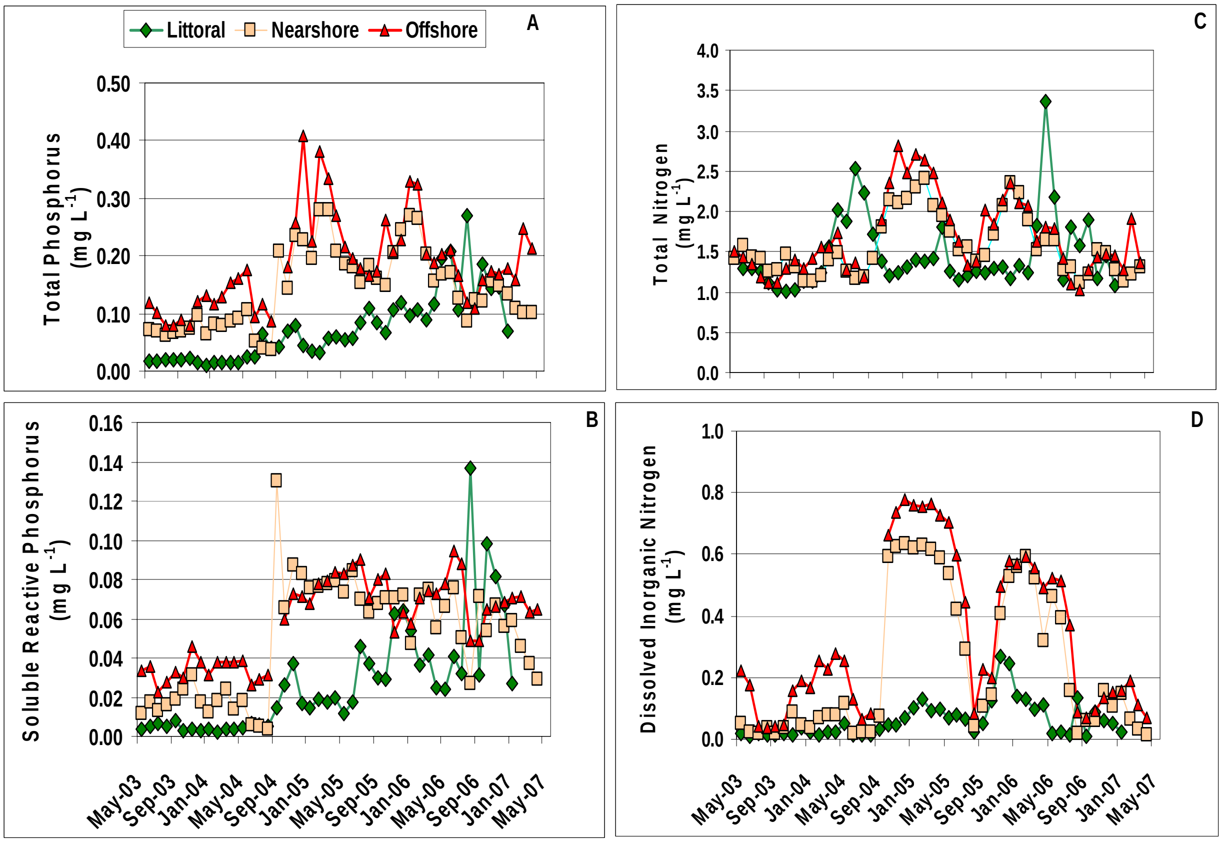

Figure 10-12. Monthly averaged water quality data for the three regions of the lake from May 2003 through April 2007.
Panel A: total phosphorus; **Panel B:** soluble reactive phosphorus;
Panel C: total nitrogen; and **Panel D:** dissolved inorganic nitrogen.

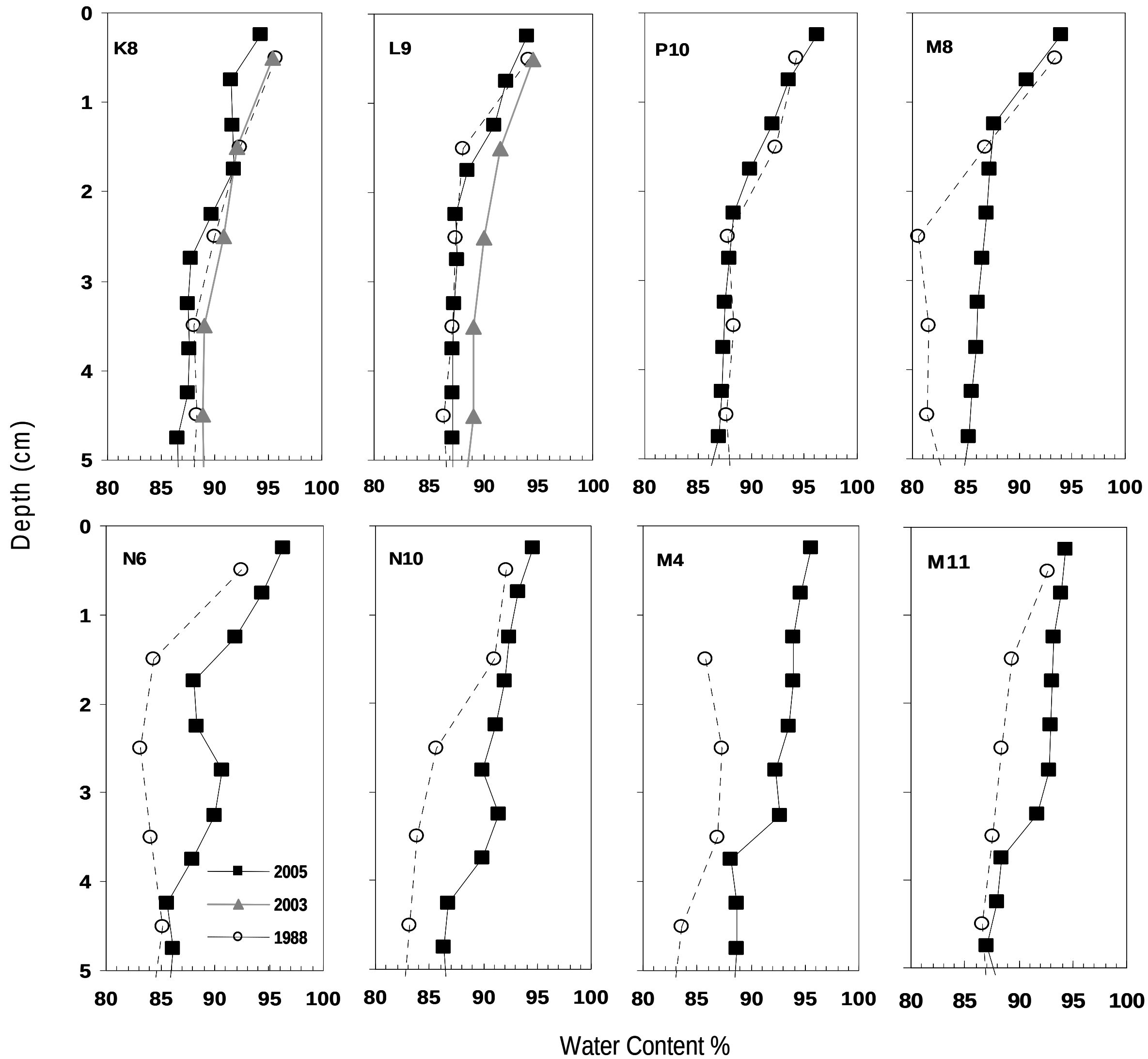

Figure 10-13. Water content profiles of sediment cores taken from Lake Okeechobee in 1988, 2003, and 2006.

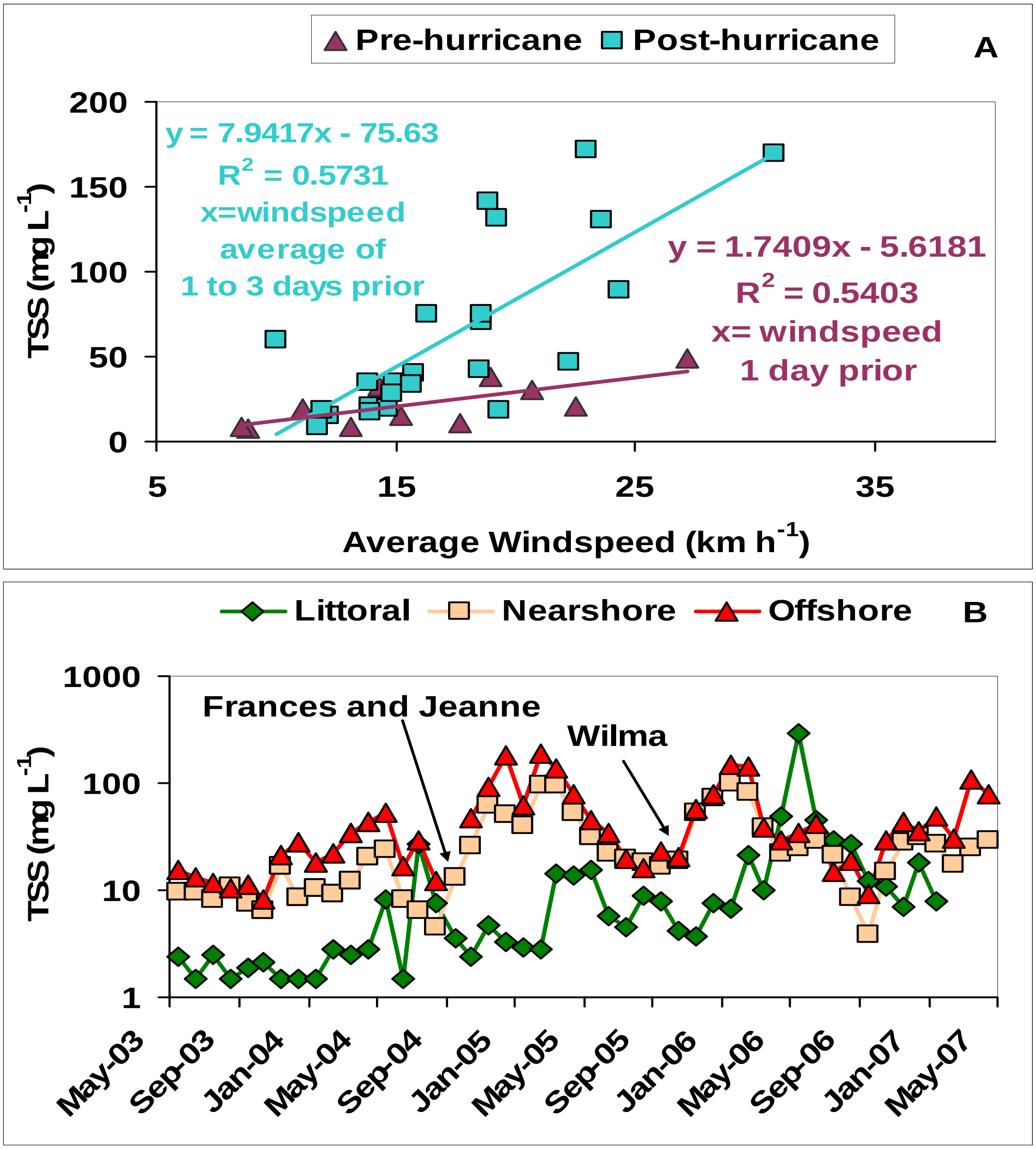

Figure 10-14. (**Panel A**) Average antecedent wind speed one day and one to three days prior, respectively, versus total suspended solids in the 12 months prior and 24 months after the September, 2004, hurricanes that hit Lake Okeechobee; and (**Panel B**) monthly averaged values of total suspended solids (TSS) concentration in the littoral, nearshore and offshore regions of Lake Okeechobee.

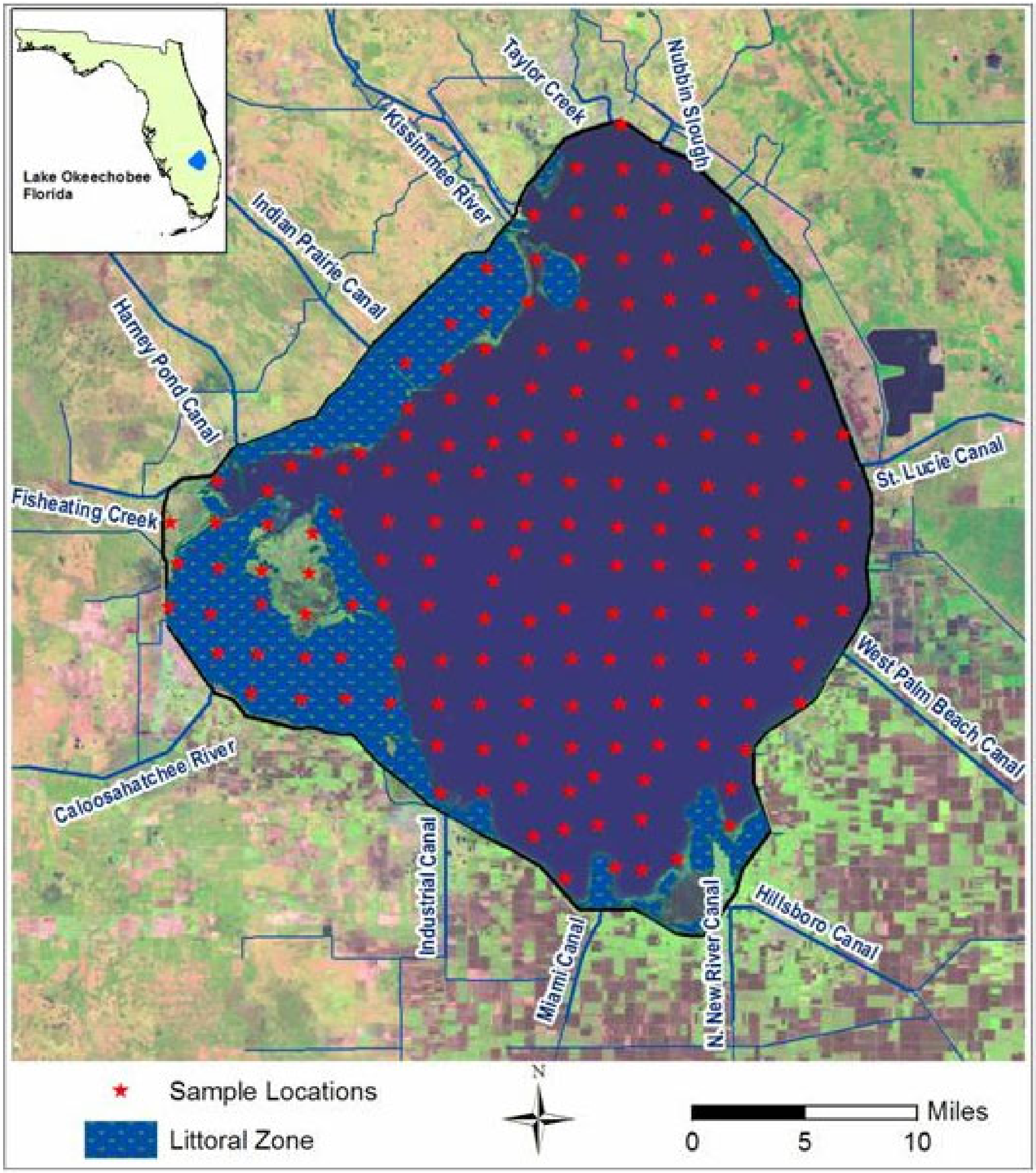

Figure 10-15. Sediment sampling sites in Lake Okeechobee. Samples collected between May 2006 and October 2006 with a 3 inch (7.62 cm) internal diameter polycarbonate core tube.

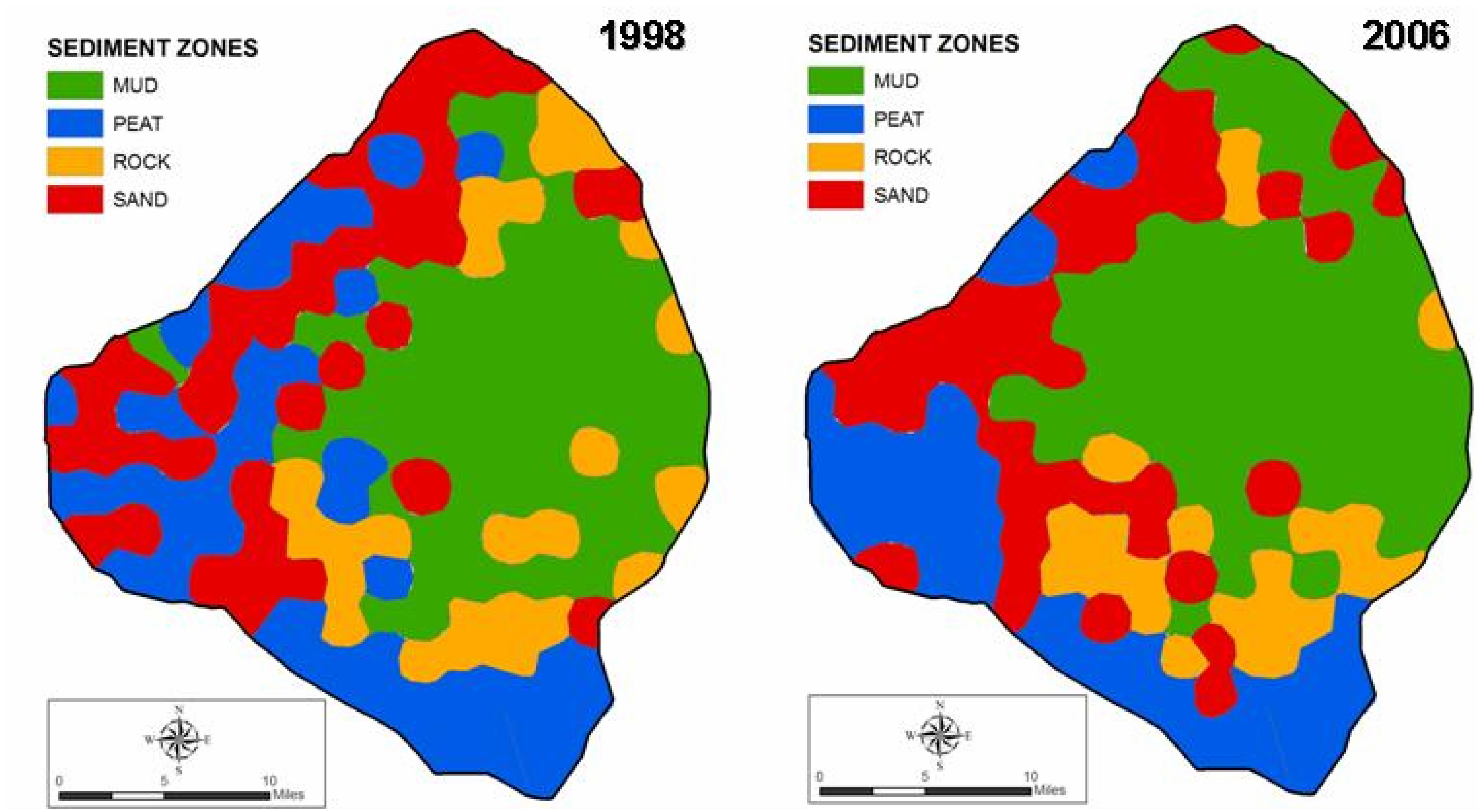

Figure 10-16. Comparison of surface sediment types in Lake Okeechobee for 1998 and 2006.

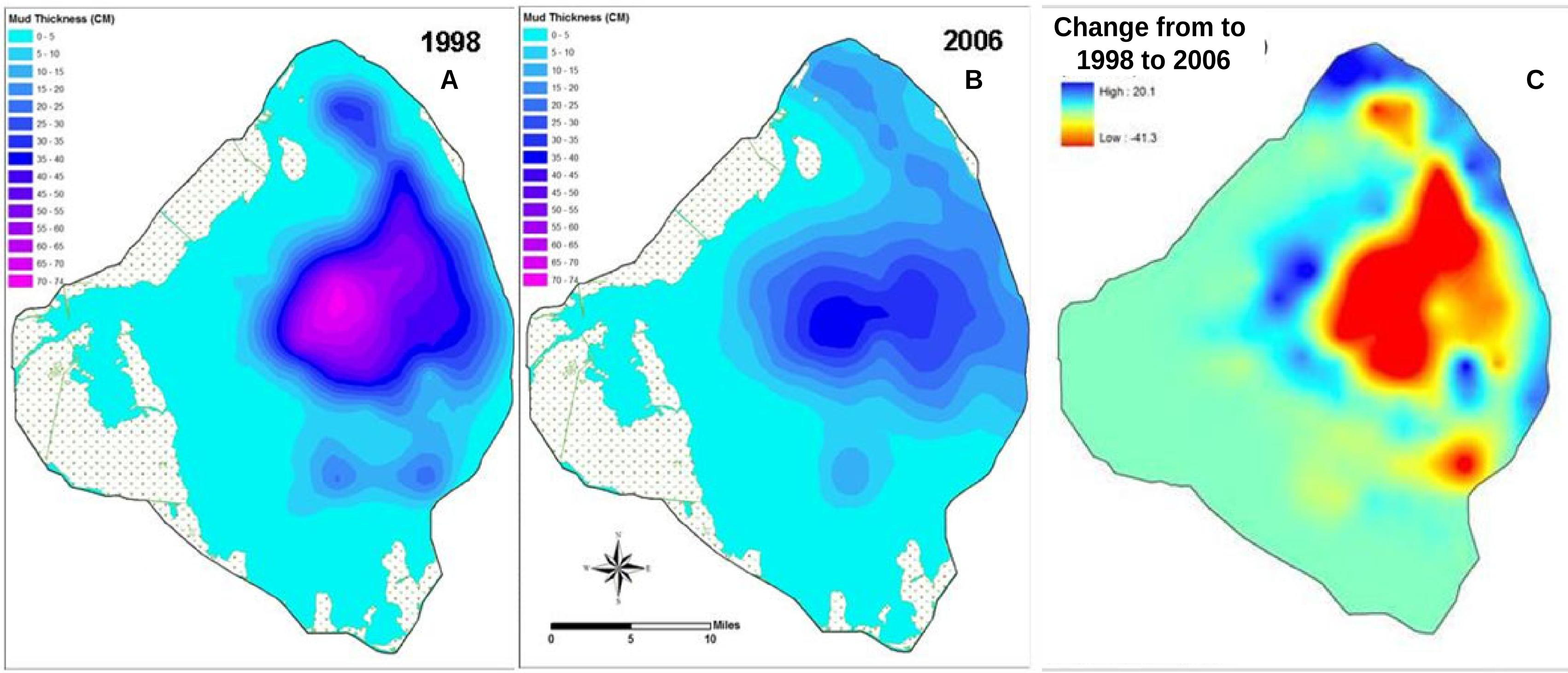

Figure 10-17. Mud thickness estimates in Lake Okeechobee based on sediment samples taken in (**Panel A**) 1998, (**Panel B**) 2006, and (**Panel C**) the change between 1998 and 2006.

Table 10-12. Estimated area of the four sediment zones in 1998 and 2006 and the percent change between the two periods.

	ZONE	ACRES	HECTARES	PERCENT OF LAKE AREA
	Total	**445,559**	**180,311**	**100.0%**
1988	**Mud**	191,672	77,567	43.0%
	Peat	95,350	38,587	21.4%
	Rock	54,778	22,168	12.3%
	Sand	103,759	41,990	23.3%
2006	**Mud**	199,633	80,788	44.8%
	Peat	98,145	39,718	22.0%
	Rock	48,560	19,652	10.9%
	Sand	99,221	40,153	22.3%
2006–1998 Change in Area	**Mud**	7,960	3,221	1.8%
	Peat	2,795	1,131	0.6%
	Rock	-6,218	-2,516	-1.4%
	Sand	-4,538	-1,836	-1.0%

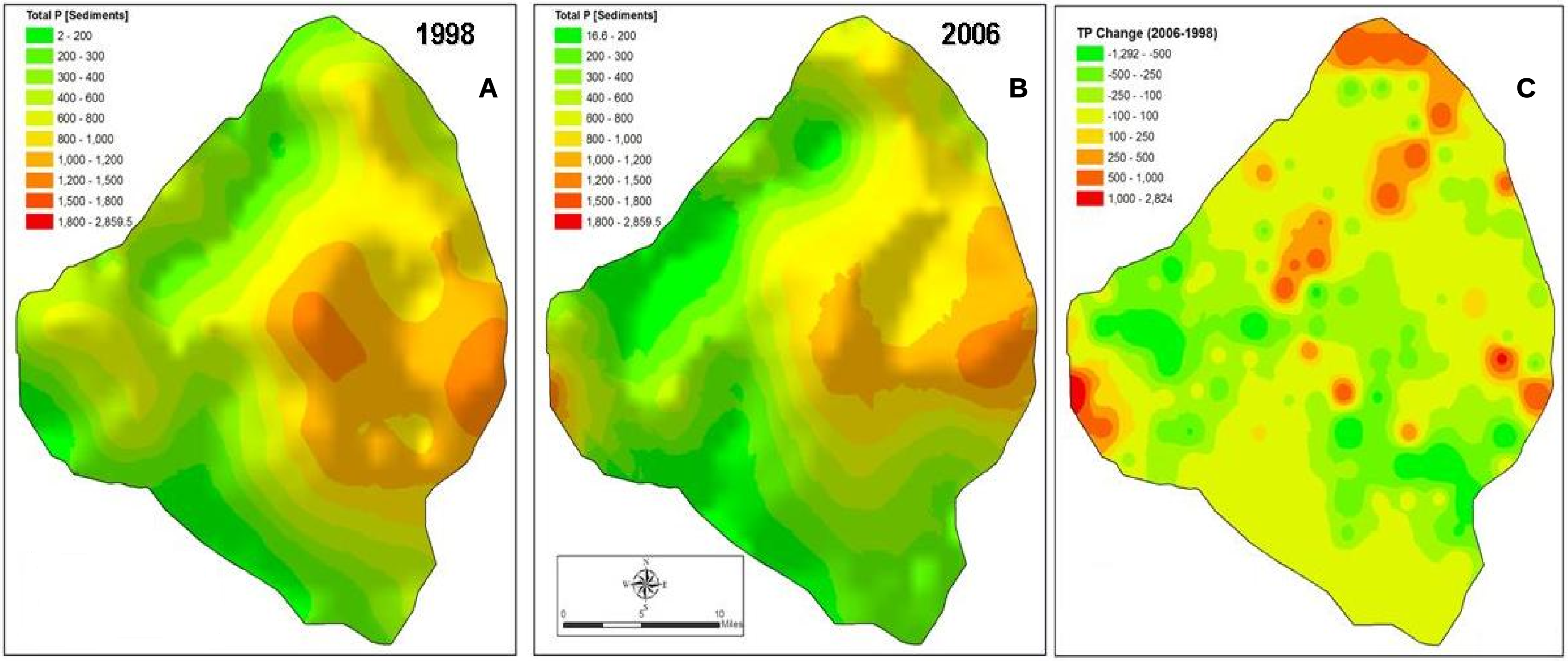

Figure 10-18. Estimated sediment TP concentration in Lake Okeechobee based on samples taken in (**Panel A**) 1998, (**Panel B**) 2006, and (**Panel C**) the change between 1998 and 2006.

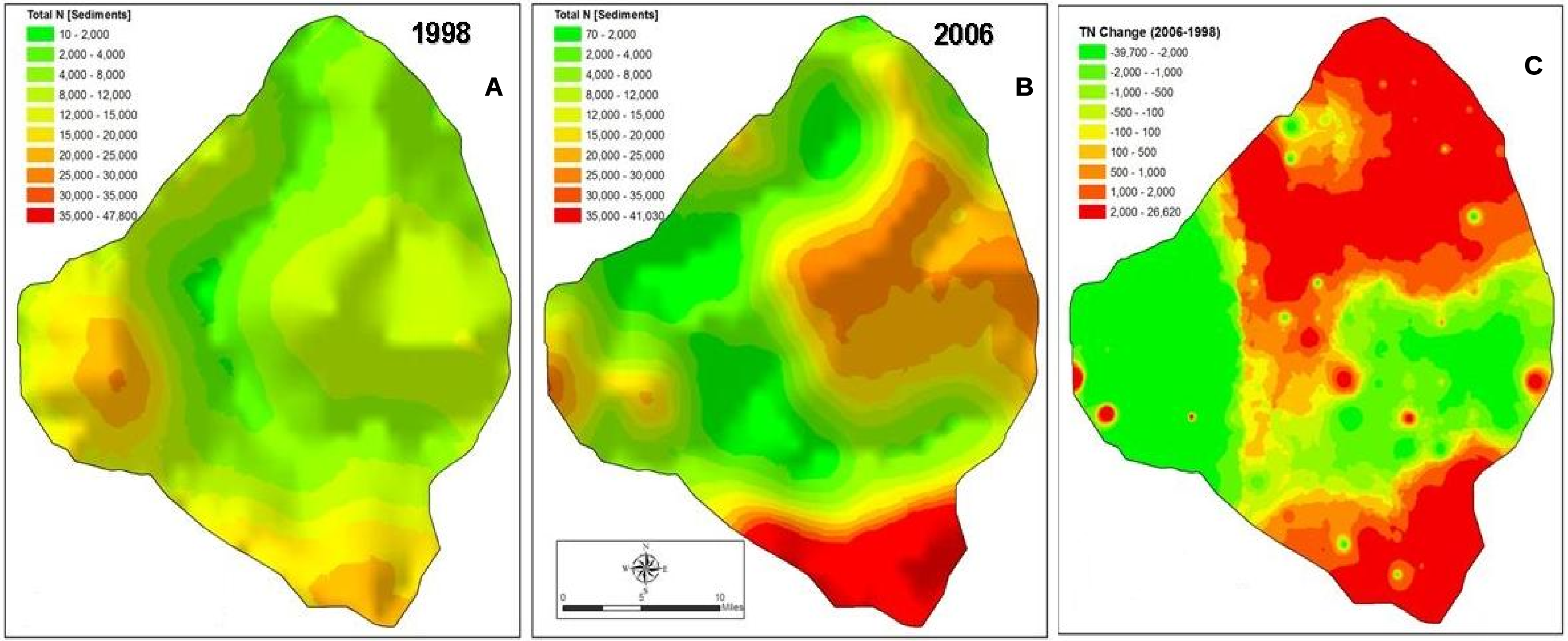

Figure 10-19. Estimated sediment total nitrogen concentration in Lake Okeechobee based on samples taken in (**Panel A**) 1998, (**Panel B**) 2006, and (**Panel C**) the change between 1998 and 2006.

Submerged Aquatic Vegetation

The biomass of submerged aquatic vegetation (SAV) has declined substantially since the hurricanes of 2004 and 2005 (**Figure 10-20**). Average SAV biomass obtained during routine monthly transect samplings declined from 32.32 g. dry wt. m^{-2} in the month before the 2004 hurricanes (July 2004) to 4.65 g. dry wt. m^{-2} after the 2004 hurricanes (October 2004). No post-hurricane recovery was observed as biomass continued to decline throughout 2005 in response to poor light conditions. Hurricane Wilma passed over the lake in October 2005 and perpetuated the high lake levels, high suspended solids, and low light levels that led to additional losses of SAV.

The spatial extent of the hurricane damage to the SAV is evident from the results of the 2004 to 2006 (pre-hurricanes to post-hurricanes period) annual mapping surveys (**Figure 10-21**). SAV coverage was reduced from 54,875 ac in late summer 2004 (before hurricanes Frances and Jeanne) to 10,872 ac in late summer 2005 (after hurricanes Frances and Jeanne). A further reduction in coverage occurred post-Hurricane Wilma with SAV occupying less than 3,000 ac in late summer 2006. Additionally, the SAV assemblage switched from a mixed community of vascular plants before the hurricanes to a musk grass (*Chara* spp.)-dominated, non-vascular plant community after the hurricanes.

The recent drought caused many of the nearshore transect sites to dry out. The number of dry nearshore sites increased from three to 45 by July 2007. However, the shallow water levels resulted in significantly improved light conditions at the more lakeward transect sites and *Chara* began appearing at these sites as the *Chara* at the more nearshore sites dried out and died. Although the spatial distribution shifted, the biomass remained low (< 0.02 g. dry wt. m^{-2}) until July when moderate to dense beds of *Chara* began developing in the southern and western areas (**Figure 10-20**).

It is expected that the recovery sequence of SAV from the current drought conditions should be similar to that observed after the 2000–2001 drought. Once re-flooding occurs, *Chara* should rapidly expand across the nearshore areas in the southern region and then spread around to the western and northern regions. Assuming that light conditions remain favorable and the sedimentary seed bank is still viable, *Chara* should decline and vascular plants should become dominant. Research to evaluate the nearshore seed bank status will be conducted as sites become re-inundated.

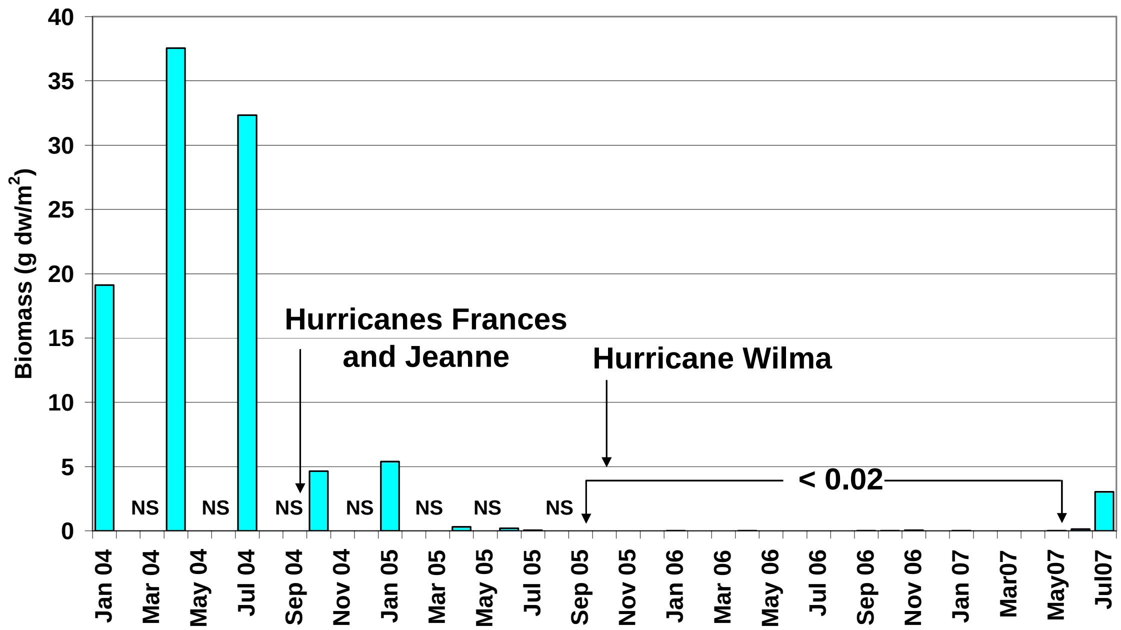

Figure 10-20. Results of monthly submerged aquatic vegetation (SAV) transect sampling (January 2004 through June 2007).

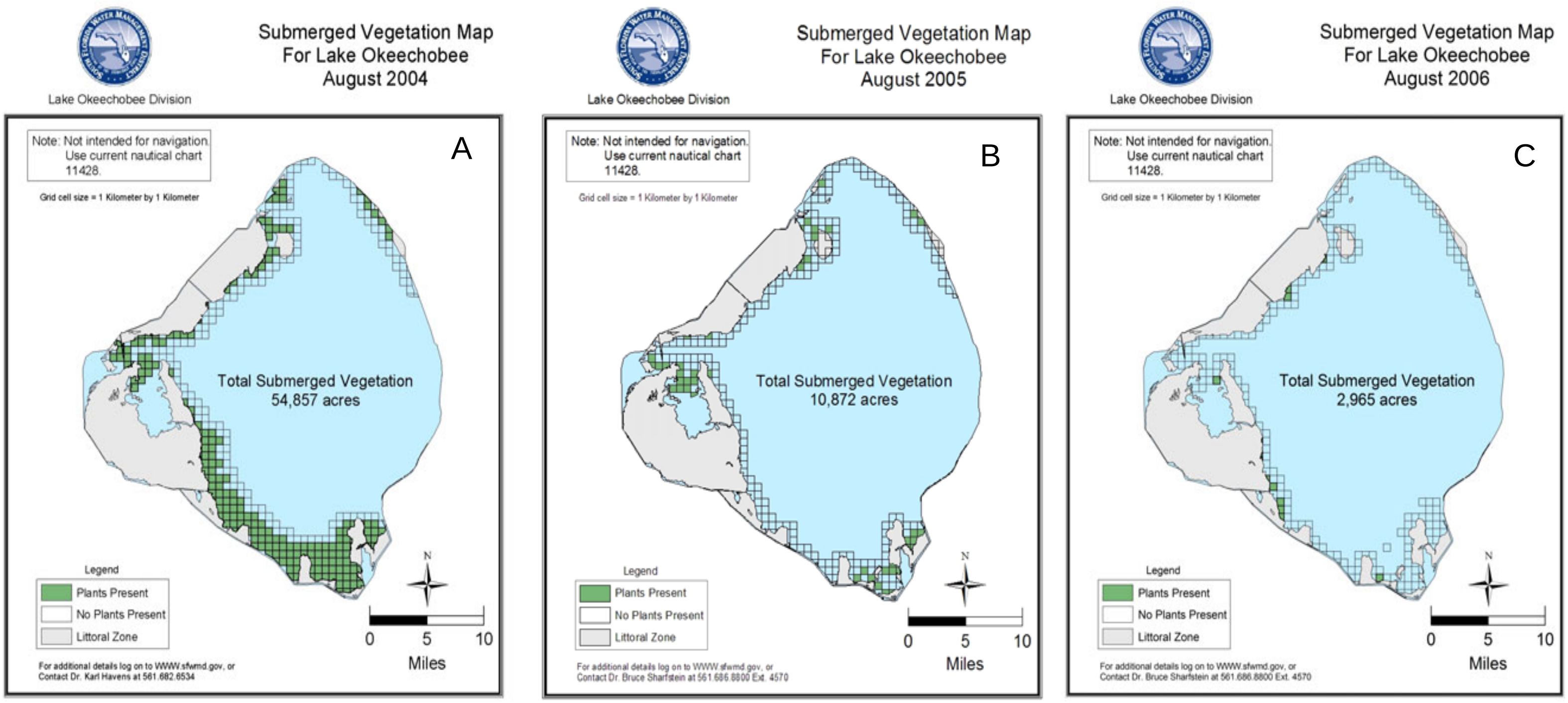

Figure 10-21. Annual (August) SAV mapping results for (**Panel A**) 2004 before hurricanes Frances and Jeanne, (**Panel B**) 2005 before Hurricane Wilma, and (**Panel C**) after Hurricane Wilma 2006.

LAKE RESEARCH AND BIOMONITORING

PREDICTIVE MODELING

The Lake Okeechobee Water Quality Model (LOWQM) was developed to forecast responses of the lake to long-term management scenarios, such as sediment management and phosphorus load reduction (see James et al, 2005, for a description of the model). This model assumes a whole lake average for all water quality terms. It does not consider the unique regions of the lake and excludes submerged or emergent plants.

The Lake Okeechobee Environmental Model (LOEM) has been developed to meet the need for a more complex spatially explicit model to address questions regarding the influence of water level on nutrient and sediment transport into the littoral zone and how water transparency and biomass of submerged plants in the near-shore zone will be influenced both by changes in water level and reduced phosphorus loads. The LOEM is an integrated hydrodynamic, sediment transport, and water quality model (Jin et al., 2007; Jin and Ji, 2005; Ji and Jin, 2006). The current model has been calibrated and verified for 3-D hydrodynamic, sediment, water quality, and SAV modeling. The real-time module is currently under development and it is anticipated that the LOEM will be ready for real-time application in May 2008.

Future work in support of the LOEM will include research on SAV to improve our understanding of nutrient uptake and release, growth, competition, and influence on sediment resuspension and water currents. Improvements in the capability of the model to predict SAV occurrence will assist management of the lake for invertebrates, amphibians, reptiles, fish and birds.

Another future work in support of the LOEM is the sediment particle-tracing module development. This module will enhance the LOEM to assess different large-scale sediment relocation options (dredging, artificial islands, multi-zones management, etc.) under different hydrological scenarios (hurricanes, high-low lake state). The LOEM can provide the most adequate locations for sediment management and environmental impact and recovery period for each option.

SUBMERGED AQUATIC VEGETATION

The lake research/modeling program continues to focus on: (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 to provide 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 the control of torpedograss and other exotic and nuisance plants. Chapter 9 of this volume provides further information on exotic species and on biomonitoring of invertebrates, fish, and emergent aquatic vegetation.

Light Influence on the Growth and Germination of Submerged Aquatic Vegetation

Current investigations continue to evaluate the effects of light intensity on growth and germination of the four major species of SAV in Lake Okeechobee: eelgrass (*Vallisneria Americana*), musk grass (*Chara zeylanica*), hydrilla (*Hydrilla verticillata*), and peppergrass (*Potamogeton illinoensis*). (Of these dominant SAV species, only *Chara* is a macro-algae and not a true vascular plant.) This work is being done to aid the development of an evaluation tool to predict the effect of alternative lake management strategies on environmental conditions in Lake Okeechobee.

Results to date indicate that eelgrass has the highest light requirement for plant growth (Grimshaw et al., 2002), while *Chara* (Grimshaw et al., 2005), and hydrilla (Grimshaw and Sharfstein, in review) have lower photosynthetically active radiation (PAR) growth requirements in that order. Moreover, of the SAV examined, hydrilla was found to have the most rapid growth rate (Grimshaw et al., in review), followed by eelgrass (Grimshaw et al., 2002), and musk grass (Grimshaw et al., 2005).

These studies also indicate that light is required for seed germination in eelgrass (Grimshaw, in prep.). Experiments to determine the light requirements for germination of peppergrass and for sporulation of musk grass are currently underway. Further studies involving other factors such as nutrients are being considered for future research.

Competition Among Common Submerged Aquatic Macrophytes

With the cooperation of the USACE and DB Environmental Industries the Lake Okeechobee "tank farm" has been constructed at the Port Mayaca lock facility (**Figure 10-21a**). The farm consists of three tanks with constant inflow from the lake for research on SAV. The initial study will look at competition among the prevalent SAV species under different light regimes. This work is intended to support the Lake Okeechobee module of the Monitoring and Assessment Plan (MAP), designed to establish a baseline and framework for measuring system responses to CERP, which has listed SAV biomass as a key performance measure to evaluate changes in lake conditions. In addition, this experiment will contribute to our understanding of SAV dynamics in the lake, the development of which is a key goal of the LOPP. The primary goal of this study is to better understand the complex dynamics of this SAV system by helping to determine why one species may out-compete another in this lake under characteristic lake conditions, as well as to observe possible successional functions.

Four species of aquatic vegetation common to Lake Okeechobee will be investigated in this study: *Vallisneria americana, Hydrilla verticillata, Chara zeylanica,* and *Potamogeton illinoensis*. Experimental design will follow a reciprocal replacement series, involving planting species in pure culture and in mixtures at various proportions. Plantlets of each will be transplanted into landscaping pots, with each pot containing an allotment of six plants either in monoculture or paired with another species. Each tank will provide a light treatment using neutral density screens to allow different levels of ambient light to reach the sediment surface. Tanks will be monitored on a weekly basis for visual assessment of growth. This experiment is expected to cover a span of several years of study to observe seasonal, long-term, and successional trends.

Figure 10-21a. Lake Okeechobee tank farm to study competition among SAV species.

EMERGENT AQUATIC VEGETATION

Bulrush

Stands of giant bulrush located along the lakeward edge of the marsh provide important fish and wildlife habitat. They also dampen wave energy and stabilize bottom sediments, thus reducing turbidity and protecting desirable submerged vegetation located behind the bulrush barrier. The areal coverage and distribution of bulrush along the edge of the northwest marsh has been monitored since 1999. Since 1999, the areal coverage of bulrush has varied from 194 ac (78 ha) in 1999, 266 ac (108 ha) in 2001, 193 ac (78 ha) in 2002, 167 ac (68 ha) in 2003, and 285 ac (116 ha) in 2005 (**Figure 10-22**).

Excessive inundation of bulrush stands due to prolonged high stage levels might cause the distribution of bulrush to decline. Loss of the protective bulrush stands might cause a cascade of events leading to loss of other native vegetation and degradation of water quality and wildlife habitat. Several studies designed to evaluate the influence of water depth on bulrush establishment and growth are ongoing or have recently been completed. In Tin House Cove, bulrush stem count data was collected monthly from October 2001 to May 2005 by the Florida Fish and Wildlife Conservation Commission (FWC). Maximum bulrush stem density occurred when flooding depth was less than 3.5 feet (1.1 m). Stem density declined following an increase in inundation depth and then increased in conjunction with a decline in flooding depth (**Figure 10-23**).

SFWMD scientists counted bulrush stem densities in Fisheating Bay and observed a decline during a period when the inundation depth exceeded 3 ft (1.0 m, summer 2005 through spring 2006) and stem densities tended to increase in summer and fall 2006, following a decline water depth (**Figure 10-24**).

Bulrush also may sustain non-target damage from herbicide spraying. Lake Okeechobee's vegetation management program targets the floating exotic plants water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*), which can cause extensive environmental damage because of their extremely aggressive and rapid rate of growth and expansion. These species and the plants are commonly treated with the contact herbicide diquat. Spray crews sometimes treat water hyacinth and water lettuce after they have become lodged in emergent vegetation such as bulrush. The extent of damage and affect this spraying has on the distribution of bulrush along the lakeward edge of the marsh likely varies annually and is influenced by lake levels.

The time required for a bulrush stand to recover to its pre-treatment stem density was monitored following a summer 2005 diquat treatment in Fisheating Bay. Stem density decreased rapidly (within two weeks) and required nearly 18 months to return to pre-treatment densities. At the time of treatment, bulrush was in greater than 4 ft of turbid water. Thus, unfavorable environmental conditions likely prolonged the time required for recovery (**Figure 10-25**).

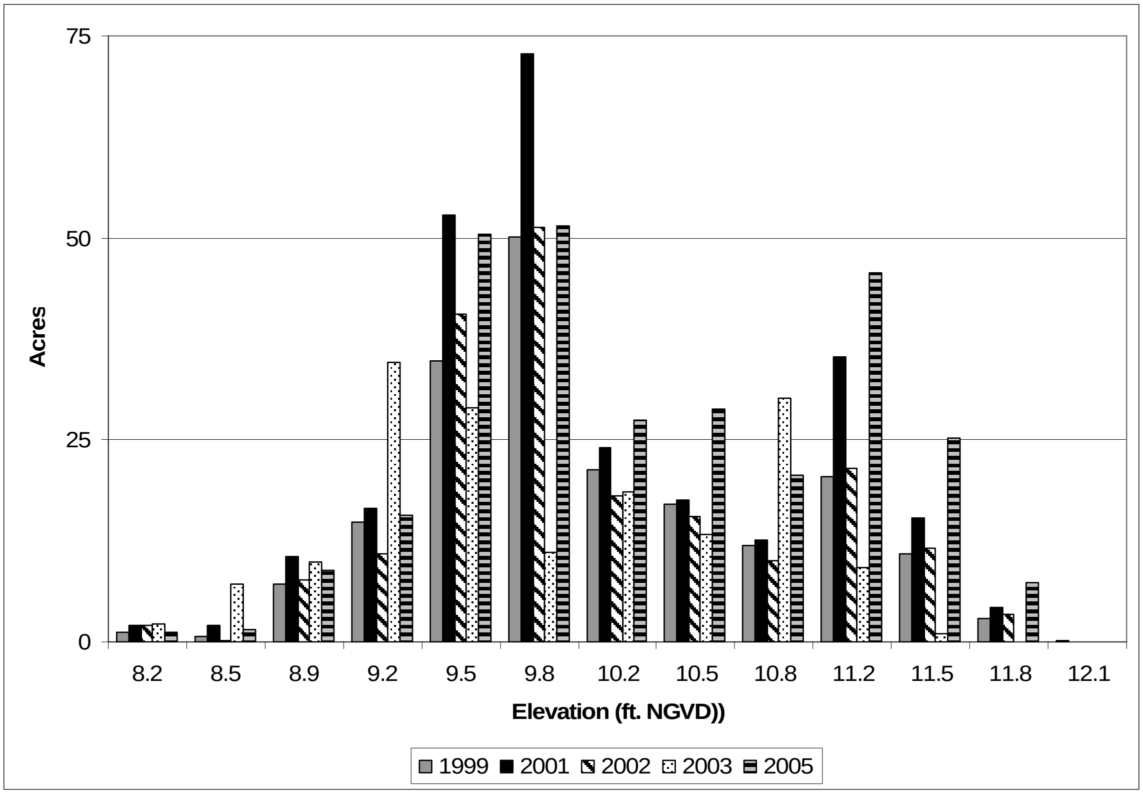

Figure 10-22. Aerial coverage (hectares) and distribution of bulrush by calendar year (1999–2005) and elevation along the lakeward edge of Lake Okeechobee's northwest marsh.

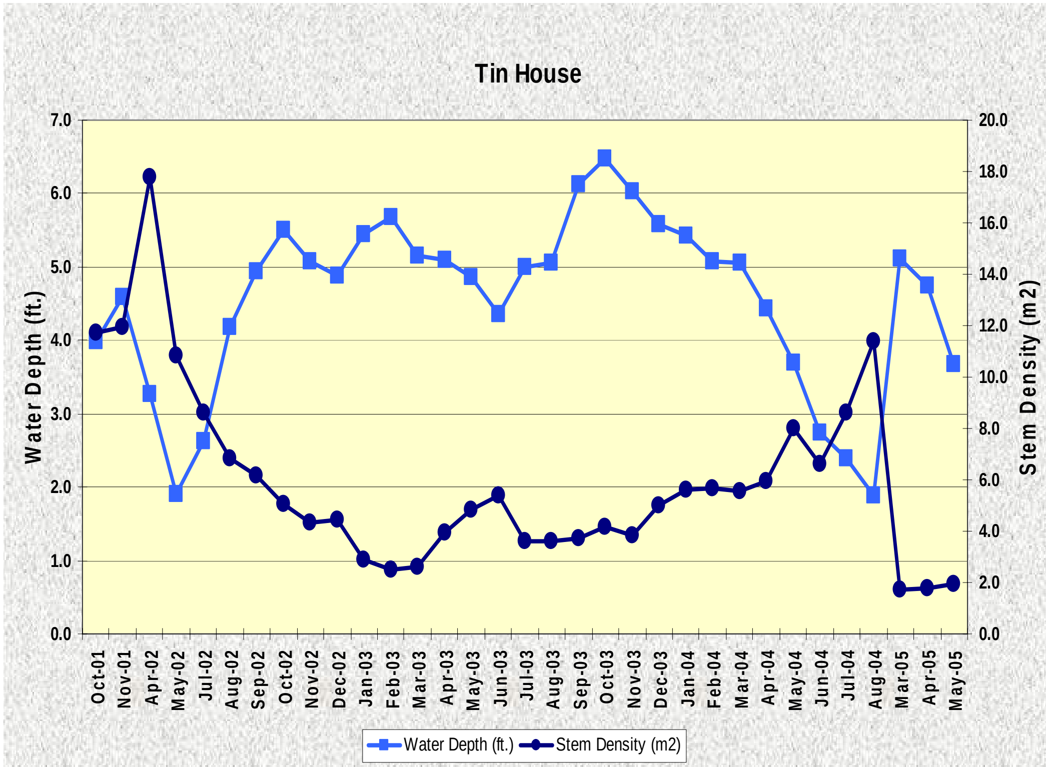

Figure 10-23. Bulrush stem density and water depth at Tin House Cove October 2001–May 2005. Data provided by the Florida Game and Freshwater Fish Commission.

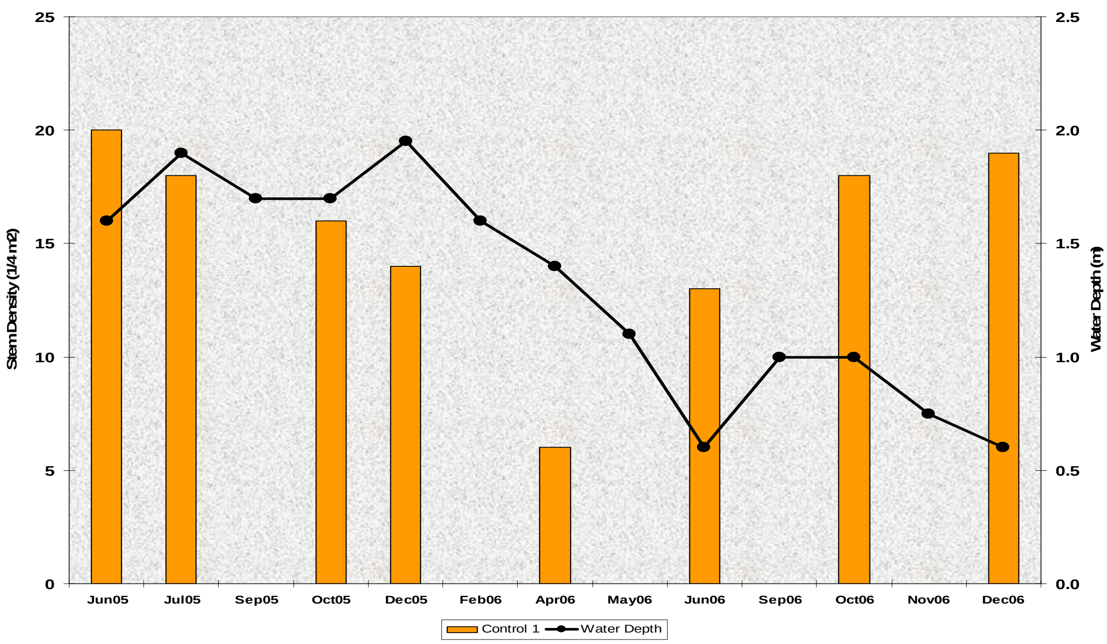

Figure 10-24. Bulrush stem density and water depth in Fisheating Bay from June 2005–December 2006.

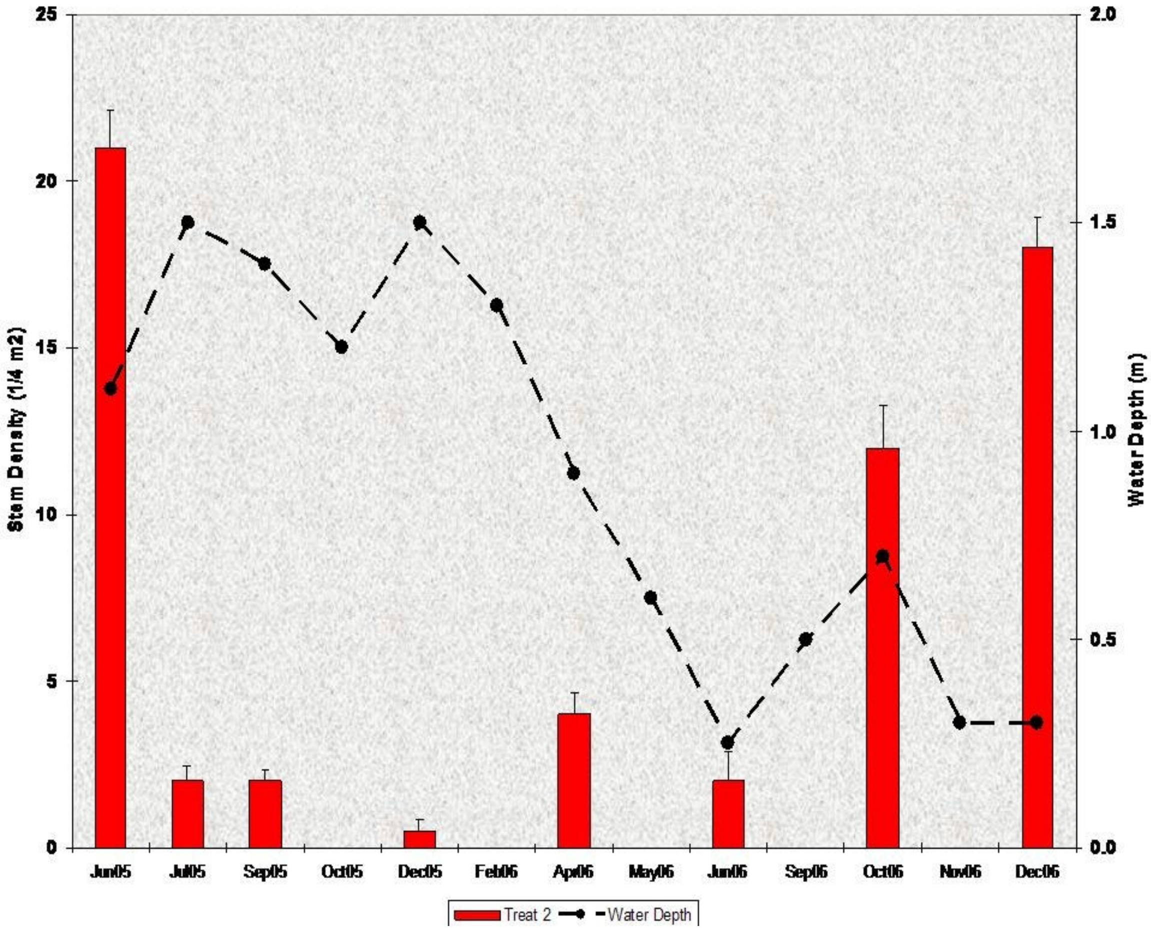

Figure 10-25. Bulrush stem density and water depth following a diquat treatment in Fisheating Bay from June 2005–December 2006.

Vegetation Maps

A baseline vegetation map describing the distribution and areal coverage of vegetation in Lake Okeechobee's marsh was developed in the early 1970s (Pesnell and Brown, 1977). A second and more detailed vegetation map was developed in 1996. The most recent Geographic Information Systems (GIS) map was developed using color infrared aerial photography collected in 2003 (**Figure 10-26**). Analysis of these maps indicates that there have been a number of changes in the littoral landscape.

In the 1970s, cattail was located primarily along the lakeward edge of the marsh and covered less than 20,000 ac (8,094 ha). The dominant emergent vegetation in the interior marsh included beakrush (*Rhynchospora baldwinii*), spikerush (*Eleocharis cellulosa*), mixed grasses, and cord grass (*Spartina bakeri*). By 1996, cattail coverage increased to nearly 25,000 ac (10,117 ha) and was established in some areas of Moonshine Bay. In the upper elevation regions of the interior marsh (shorter hydroperiod region), the exotic species torpedograss (*Panicum repens*) displaced more than 13,000 ac (5,261 ha) of beakrush and spikerush. In regions with longer hydroperiods (e.g. Moonshine Bay), the coverage of fragrant water lily (*Nymphaea odorota*) increased from approximately 2,000 ac (809 ha) prior to the 2001 drought to greater than 8,000 ac (3,237 ha) in 2003.

Prior to the current (2007) drought there was a concern that thousands of acres of spikerush in Moonshine Bay were displaced by *Nymphaea*. One reason for this concern is that *Nymphaea* tends to produce more organic material that eventually falls to the marsh floor creating a flocculent/turbid substrate. Spikerush also is considered better habitat for apple snails. The current drought has reduced the areal coverage of *Nymphaea*. No management actions have been taken at the time of this report.

In 2003, cattail coverage decreased to 23,840 ac (9,648 ha). The reduction in cattail coverage was attributed to large-scale fires that burned much of the emergent marsh and a record drought in 2001–2002. Although the total acreage of cattails decreased in 2003, the distribution of cattail expanded in Moonshine Bay. At elevations generally greater than 13.5 ft (4.1 m) NGVD, torpedograss coverage increased to greater than 17,000 ac (6,880 ha) despite the treatment of 10,000 ac (4,047 ha) of torpedograss in 2000 to 2002. The distribution of fragrant water lily increased to nearly 11,000 ac (4,452 ha). Although fragrant water lily is a native, excessive growth of this plant may not be desirable because large amounts of flocculent detrital material can accumulate in dense lily beds.

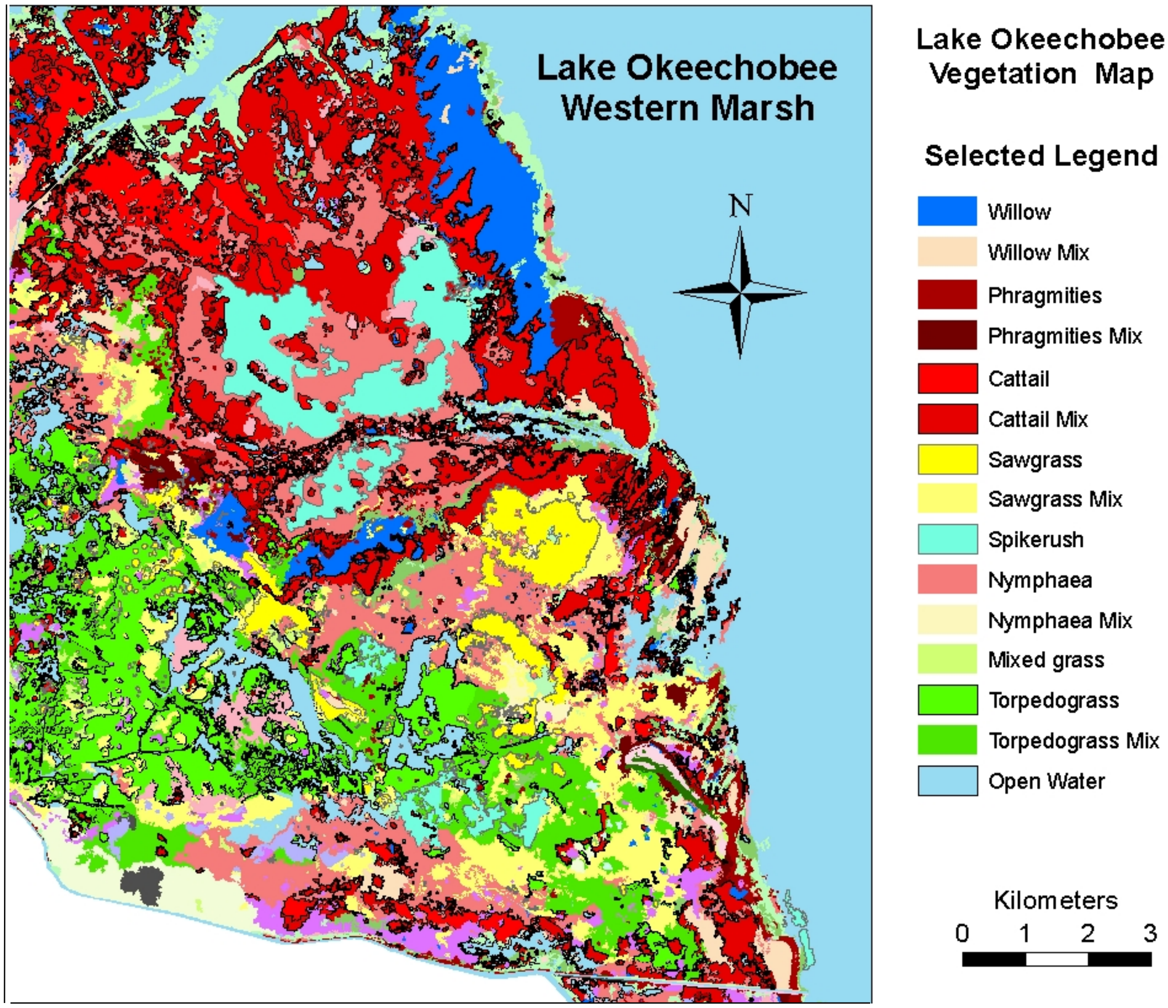

Figure 10-26. Vegetation map (2003) showing the distribution of the primary emergent plant communities located in Lake Okeechobee's central marsh east of the City of Moore Haven.

A regional drought through 2006–2007 created dry conditions that exposed the lake's 100,000-acre (40,469 ha) marsh. In February and May 2007, more than 80 percent of the emergent vegetation in the western marsh (Clewiston to Buckhead Ridge) burned due to wildfires and permitted prescribed burns (**Figure 10-27**). The fires removed many dense monospecific stands of cattail in the lower elevations regions of the marsh. The re-growth and expansion of cattail is currently limited by the dry conditions in the marsh. The fires also eliminated most of the above-ground torpedograss biomass in the western marsh. However, torpedograss is rapidly becoming re-established from underground rhizomes that were insulated from the damaging effects of fire (**Figure 10-28**). Previous torpedograss vegetation management work in Lake Okeechobee indicates that treatment efficacy is often greatest when small but actively growing torpedograss is treated when the marsh is dry (**Figure 10-29**). To take advantage of the favorable treatment conditions, more than 5,000 ac (2,023 ha) of torpedograss had been treated through spring 2007, and additional treatments were planned for the summer (**Figure 10-30**). Treatment efficacy and successional changes in the marsh landscape will be monitored and documented with future mapping projects.

Figure 10-27. Prescribed cattail burn near Cochran's pass in February 2007.

Figure 10-28. Post-burn resurgence of torpedograss (green) south of Indian Prairie canal.

Figure 10-29 The torpedograss shown above was treated during summer 2006 under dry marsh conditions. Treatment efficacy was nearly 100 percent. The picture was taken in July 2007.

Figure 10-30. Torpedograss treatment west of Moore Haven Canal (June 2007).

EXOTIC SPECIES

The District's Vegetation Management Division has tracked and managed the most invasive and detrimental exotic plants in Lake Okeechobee. Exotic plant tracking is currently limited to torpedograss and melaleuca. Melaleuca is now totally controlled on the lake; annual treatments are now aimed primarily at seedling control. The torpedograss population on the lake currently covers approximately 16,000 ac. Five-thousand acres were treated in both 2004 and 2005. Torpedograss control is keeping up with, and may be eclipsing, its rate of spread (see the *Vegetation Management* section in this chapter). The 2004 and 2005 hurricanes appear to have had minimal impact on melaleuca and torpedograss.

Although a list of non-indigenous animals in south Florida has been developed (Chapter 9, Table 9-2, of this volume), the distribution and effect of these exotic and potentially invasive animals within the Lake Okeechobee Ecosystem is unknown. To handle this concern, an integrative approach is needed. A proposed first step is a meeting of District scientists from the various Divisions that may be concerned about exotic animals to discuss preliminary actions that could be taken. Because this problem is one of state and national interest, these preliminary actions will be relayed to the Florida Invasive Animal Task Team (FIATT). The expectation is that a multi-agency plan to assess and manage non-indigenous species posing the greatest environmental threat to the ecosystems of South Florida will be developed.

LAKE MACROINVERTEBRATE STATUS — IMPLEMENTATION OF A THREE-YEAR BASELINE MONITORING STUDY

The first two years of a three-year baseline assessment of the lake's sublittoral macroinvertebrate community have been completed. These data are being compared to historical data collected between 1987 and 1996 to assess temporal changes. Triplicate samples were collected in August 2005 and 2006 and February 2006 and 2007, from the same 18 pelagic sites sampled by Warren et al. (1995). Six sites each were located in the three dominant sediment types (mud, peat and sand); and within-sediment site locations were determined by water depth. A total of 116 *taxa* have been collected to date. The values for all of the community quality descriptors except for mean evenness increased significantly (t-test; $p < 0.05$) from year one to year two of the study (**Table 10-14**). All of the values for the current study except for mean evenness were significantly less than the values for the 1987–1996 historical study period (ANOVA; $p < 0.05$).

Segmented worms (*Oligochaetes*) dominated the community assemblage, accounting for 64 percent of the total number of organisms in year one and 35 percent in year two. *Pelecypods* (clams and mussels) accounted for 9 percent of the total number of organisms in year one and were as the second-most abundant taxa in year two (26 percent). Additionally, the only species of *Pelecypods* found in year two was the exotic Asian clam, *Corbicula fluminea*. The peat sediment in the southern region had the most densely populated, species-rich, and diverse community followed by the sand and mud zones, respectively (**Figure 10-31**). Although total number of organisms, diversity, and species richness increased from year one to year two of the study, these descriptors of community quality declined from the historic study period of 1987–1996. During the historic study period, the *Oligochaetes* dominated (49 percent), the midge fly larvae (*Chironomids*) were the second-most abundant at 27 percent, and the *Pelecypods* only accounted for 2 percent of the community. Overall, the assemblage continued to reflect poor water quality conditions, but improvements in the descriptors of community quality in year two of the study were observed.

Table 10-13. Descriptors of community quality of Lake Okeechobee sublittoral zone benthic invertebrate communities.

DESCRIPTOR	2006–2007	2005–2006	1987–1996
Total *Taxa*	68	48	99
Mean Species Richness	8.9	5.7	12.3
Mean Diversity	1.88	1.54	2.10
Mean Evenness	0.66	0.69	0.62
Mean Total Organisms m^{-2}	7,591	3,338	19,185

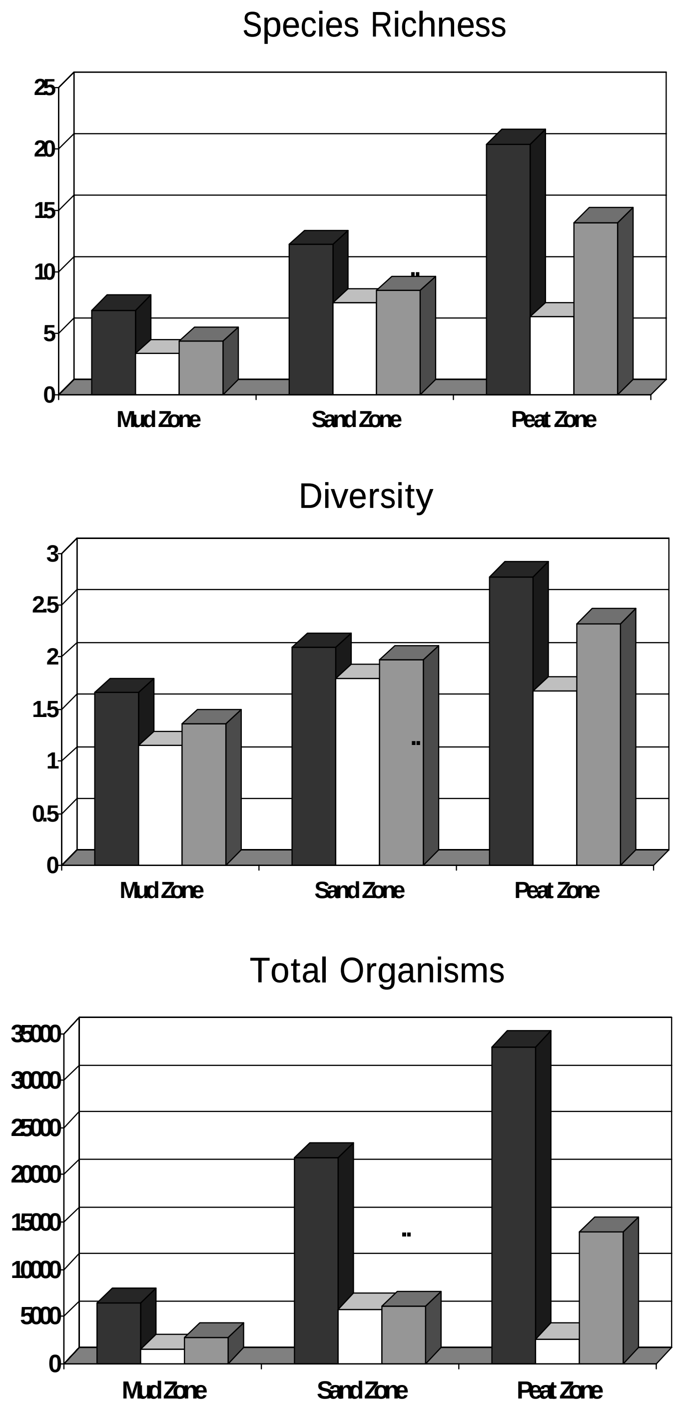

Figure 10-31. Means of invertebrate community species richness, diversity, and total organisms in different sediment habitats of the Lake Okeechobee sublittoral zone. Black bars are 1987 to 1996, white are 2005 to 2006, and gray are 2006 to 2007.

FISH

Population Structure

The District's Lake Okeechobee Division, through the Restoration Coordination and Verification (RECOVER) program, is supporting a three-year study being conducted by the FWC to evaluate the status of the Lake Okeechobee fishery. This work is a continuation and expansion of the study, for which results were presented in the *2006 SFER – Volume I, Chapter 10*.

Electrofishing

Lake-wide electrofishing was conducted in late September 2005 and early October 2005 and 2006. Twenty-two predetermined sites located in the interior marsh and along the lakeward edge of the western marsh were sampled. At each site, three 15-minute periods of electrofishing were conducted for a total of 990 minutes. Twenty-five fish species were represented in the catch. A total of 1,123 fish were collected in 2006 compared to 1,629 fish collected in 2005. Total fish biomass also was reduced by 202,576 grams (59 percent) in 2006.

The 10 most numerically abundant species, which comprised 90 percent of the 2006 catch, were bluegill (*Lepomis macrochirus*), threadfin shad (*Dorosoma petenense*), gizzard shad (*Dorosoma cepedianum*), Florida gar (*Lepisosteus platyrhincus*), white catfish (*Ameiurus catus*), Orinoco sailfin catfish (*Pterygoplichthys multiradiatus*), largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), readear sunfish (*Lepomis macrochirus*) and bowfin (*Amia calva*). In 2006, channel catfish and bowfin replaced black crappie (*Pomoxis nigromaculatus*) and lake chubsucker (*Erimyzon sucetta*) on the most abundant species list (**Table 10-15**).

Table 10-15. Top 10 species by abundance collected by electrofishing annually.

	2005		2006	
SPECIES	**Count**	**Percent**	**Count**	**Percent**
BLCR	40	2	*	*
BLUE	187	11	263	23
BOW	*	*	25	3
CHCA	*	*	32	3
FGAR	246	15	108	10
GISH	233	14	159	14
LACH	35	2	*	*
LIMU	45	3	71	6
LMB	156	10	69	6
RESU	42	3	30	3
THSH	241	15	159	14
WHCA	571	35	94	8

** Not in top 10 by abundance*

LEGEND

BLCR Black crappie
BLUE Bluegill
BOW Bowfin
CHCA Channel catfish
FGAR Florida gar
GISH Gizzard shad
LACH Lake chubsucker
LIMU Orinoco sailfin catfish
LMB Largemouth bass
RESU Redear sunfish
THSH Threadfin shad
WHCA White catfish

The largemouth bass population in Lake Okeechobee has been monitored with the standardized lake-wide electrofishing protocol since fall 1992. Largemouth bass recruitment was poor from 1999 to 2001, improving somewhat in 2002 and 2003 in conjunction with the resurgence of the SAV community following a drought in 2000 and 2001. Extremely high lake stages commencing in 2003 began to impact fishery habitat and hurricanes Frances and Jeanne in 2004 further reduced the areal coverage of aquatic plant communities. The large scale loss of habitat in Lake Okeechobee is one factor that may have a negative influence on the recruitment of young-of-the-year bass into harvestable size classes. In 2005 and 2006, 97 and 72 percent of the largemouth bass collected by electrofishing were greater than 254 mm (harvestable size), respectively (**Figure 10-32)**. During this period, the catch rate, calculated as catch-per-unit-effort (CPUE) reached the lowest rate ever observed. The CPUE was 0.16 fish/minute in 2005 and dropped to 0.07 fish/minute in 2006. Without substantial recruitment of juvenile fish, the sustained viability of a quality largemouth bass fishery in Lake Okeechobee is in question.

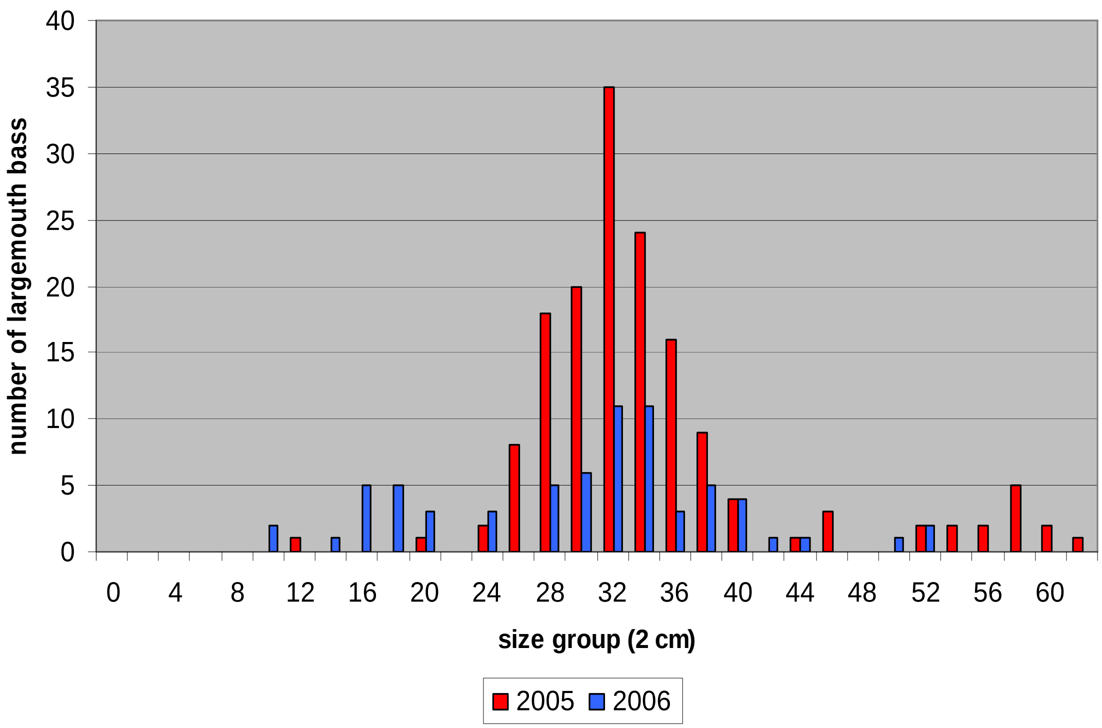

Figure 10-32. Length (x-axis) and frequency (y-axis) plot of largemouth bass collected through electrofishing from Lake Okeechobee. Annual sampling effort was 990 minutes (three 15-minute repetitions at each of 22 sites).

Trawl

Lake-wide trawl sampling was conducted in mid-December 2006. Sampling occurred at 27 pre-determined sites (1987–1991 lake-wide trawl sampling sites) located in the nearshore and open water areas of Lake Okeechobee. Two 10-minute replicate trawls were conducted at each site for a total of 540 minutes of trawling. Lake-wide trawl sampling resulted in the capture of 1,145 fish for a combined biomass of 85,644 grams. Nineteen fish species were represented in the catch, an increase of five species compared to 2005. Threadfin shad, white catfish, black crappie, bluegill sunfish, and channel catfish collectively comprised 88 percent of the catch by abundance (**Table 10-16**). The two species that collectively comprised 58 percent of the catch by weight and in order of biomass were white catfish and Florida gar. Sport fish including black crappie, bluegill sunfish, and redear sunfish accounted for 8, 6, and 3 percent of the total catch by weight, respectively.

Comparison of lake-wide trawl sampling data from 2005, 2006, and data averaged for the historical 1987–1991 period indicated notable variations. The 2005 catch rate of 2.1 fish/minute and the 2006 catch rate of 5.1 fish/minute were 75 and 39 percent lower, respectively, compared to an annual average catch rate of 8.4 fish/minute (7,340 fish) during the 1987–1991 period.

Black crappie accounted for 34 percent of the total catch historically and the annual average catch of adult (> 200 mm in size) black crappie totaled 2,037 fish. Only five adult black crappie were collected in 2005 and 32 adult black crappie were collected in 2006. The recent decrease in black crappie corresponded with a large decrease in threadfin shad abundance. In 2005 and 2006, threadfin shad accounted for 7 percent (80 fish) and 28 percent (768 fish) of the total catch compared to 50 percent (> 3,600 fish) of the average annual total catch during the 1987–1991 period. Historical food habit analysis indicate young-of-year threadfin shad and gizzard shad are almost the exclusive forage of adult black crappie in Lake Okeechobee, which may help to explain the low adult population numbers encountered in 2005 and 2006.

Table 10-15. Top six species by abundance collected by trawl during each sampling period. (Legend for species consistent with **Table 10-12**.)

	1987–1991* (Five-Year Total)		2005		2006	
SPECIES	**COUNT**	**PERCENT**	**COUNT**	**PERCENT**	**COUNT**	**PERCENT**
BLCR	12394	34	483	42	500	18
BLUE	3129	9	61	5	466	17
CHCA	*	*	39	3	143	5
GISH	652	2	*	*	*	*
THSH	18256	50	80	7	768	28
WHCA	784	2	389	34	559	20

** Not in top six by abundance*

IN-LAKE MANAGEMENT

REVISION OF THE LAKE OKEECHOBEE OPERATING SCHEDULE

The revision of Lake Okeechobee's operating schedule will optimize it within existing structural constraints to meet the diverse requirements of the lake, its receiving waters, and its users. This project is being led by the USACE with Project Delivery Team support from the SFWMD as the local sponsor, and input from the USFWS, the FWC the City of Sanibel, and Martin and Lee counties.

The project was expedited in 2005, with the expected approval and implementation of a revised regulation schedule in early 2007. Substantial comments were received at the public meetings held throughout South Florida to present the initial Tentatively Selected Plan (TSP) and the Supplemental Environmental Impact Statement (SEIS). As a result, the initial implementation date of January 2007 has been extended until the end of 2007 to allow sufficient time for the USACE to address concerns with the TSP and better balance the performance measures of the physiographic areas evaluated. New alternatives were evaluated, and a revised SEIS and Water Control Plan were developed accordingly for public review.

The TSP was evaluated based on overall system-wide performance measure benefits including estuaries, Lake Okeechobee, Water Quality Everglades/Water Conservation Areas, and Water Supply Lake Okeechobee Service Area, Lower East Coast Service Area, snail kite habitat, Herbert Hoover Dike integrity, and navigation impacts. Temporary forward pumps are a component of the TSP in the event of extreme low lake stages [< 10 ft (< 3.1 m) NGVD], similar to conditions that arose during the 2000–2001 drought and the current drought. The successful deployment of these temporary pumps during the 2007 drought indicates that this component of the TSP is useful.

The USACE's proposed Lake Okeechobee Regulation Schedule (LORS) is an interim or temporary schedule which focuses on public health, safety, and general welfare considerations associated with safety of the Herbert Hoover Dike ("HHD"). The LORS is destined for implementation over a short-term period currently estimated to be three years. The temporary LORS is projected to result in lake levels that may potentially result in an exceedance and / or violation of the District's Lake Okeechobee Minimum Flows and Level (MFL), depending upon actual rainfall received during the implementation timeframe of this regulation schedule.

In an effort to mitigate the severity and frequency of low lake levels caused by the USACE's Preferred Alternative on water supply and lake ecology related to the MFL, the District developed a revised water shortage management plan. The revised plan has been discussed extensively with various stakeholders and generally describes the water shortage operations conducted during the current drought situation (2006–2007). No major improvements in the Lake Okeechobee MFL performance were achieved following extensive modeling efforts. Once the public health issues associated with the HHD are addressed, immediate implementation of an alternative schedule is necessary to address prolonged low lake levels and the associated impacts on the Lake's ecology and water supply.

WATERWAY MAINTENANCE DREDGING

As a result of the 2007 drought, the SFWMD provided financial assistance to the cities of Pahokee and Belle Glade, to re-dredge their respective waterways to their original design elevation. In conjunction with rebuilding the Pahokee Harbor and campground amenities from extensive storm-related damages, the City of Pahokee initiated dredging efforts to remove accumulated sediment in the harbor. The District provided cost-share funding to the city to dredge an additional two feet lower to accommodate the lower lake stages anticipated with the new Lake Okeechobee Regulation Schedule Study and to allow larger boats to enter the harbor.

The District has also provided funding to the City of Belle Glade to conduct mechanical maintenance dredging of the finger canals of the Belle Glade Marina, in conjunction with boat ramp and campground restoration efforts that are under way with grant funds from Palm Beach County.

The sediment removal projects may improve in-lake water quality through the removal of phosphorus from the lake in the dredged material, since both waterways are inside the Herbert Hoover Dike. Navigation is expected to be negatively impacted by the lower lake levels and this effort will moderate anticipated future impacts to the harbor and marina’s access. These efforts will also enhance recreational activities in the lake for both cities.

VEGETATION MANAGEMENT

Aerial and ground treatments of exotic and invasive emergent vegetation continued in 2006–2007. Approximately 5,000 ac (2,023 ha) of torpedograss and 3,000 ac (1,214 ha) of cattail were treated in the Moore Haven and Indian Prairie regions of the marsh. This brings the total acreage treated in Lake Okeechobee since 2000 to nearly 25,000 ac (10,117 ha) of torpedograss and 7,400 ac (2,995 ha) of cattail. While torpedograss treatment efficacy has varied, a generally high level of control has been achieved. In some areas of the Moore Haven marsh, torpedograss has been controlled for more than four years following a single treatment. Native vegetation including spikerush and fragrant water lily has become established in many of the treatment sites. Treatment efficacy of cattail also has been high. Cattail treatments have been confined to interior marsh locations to preserve the remaining cattail wall that helps prevent nutrient-rich pelagic water from entering the interior marsh. Many cattail treatment sites are now open and recent wild fires in some of the treated areas have helped reduce cattail wrack. Recently opened areas are being utilized by anglers and wading birds. Changes in the marsh community continue to be monitored and quantified through the use of GIS-based vegetation maps.

HABITAT RESTORATION

Planting efforts for pond apple (*Annona glabra*) and cypress (*Taxodium* spp.) trees continued during WY2007 on both the restored shoreline of Ritta Island and at the southern end of Lake Okeechobee. In addition, approximately 1,000 pond apple and cypress trees were planted in the vicinity of the S-310 locks and along two nearby spoil islands near Clewiston. Future plantings as well as maintenance of all the existing trees are both planned for WY2008.

SEDIMENT MANAGEMENT

Low water levels on Lake Okeechobee provided a management opportunity for the District to cost effectively remove muck sediments from nearshore regions of the lake. Once these muck sediments are removed and water levels return to normal, the anticipated environmental benefits include improved water clarity, return of submerged plants and increased critical habitat for fish and wildlife. Six areas were selected for this project: (1) Northwest Marsh, (2) Eagle Bay Marsh, (3) Eagle Bay Island, (4) Horse Island, (5) Harney Pond Recreation Area, and (6) Fisheating Bay (**Figure 10-33**). Total project costs of $11 million were funded through state appropriations, the FWC, and the SFWMD for FY2007 (**Table 10-17**). An estimated 2,000 ac (809 ha) were scraped, which removed over 2 million cubic yards of muck (1.6 million cubic meters). This project removed an estimated 237 mt of phosphorus at an approximate cost of $46.48 per kg of phosphorus.

A seed bank study conducted in November of 2005 showed viable seeds in areas near scraped sites (see *2006 SFER – Volume I, Chapter 10*). Scraping was conducted to remove the overlying muck while minimizing the disturbance of underlying sediment and seedbed. The scraped areas will be monitored for regrowth.

An example of the mud scraping project is Eagle Bay Island. The water levels prior to scraping were so low that the Okeechobee municipal pier was out of water and the muck sediments were dry and cracked (**Figure 10-34, Panel A**). Track hoes, off-road loaders and excavators were used to scrape and remove these sediments (**Figure 10-34, Panel B**). After removal, the remaining sand sediments should allow for submerged plant growth and improved fish and wildlife habitat (**Figure 10-34, Panel C**).

Permanent disposal of these muck sediments is currently ongoing. The sediments have to be analyzed for toxins prior to this disposal. One permanent disposal site is a berm inside the levee on the C-41 canal (**Figure 10-34, Panel D**). Other locations are currently being considered.

Table 10-17. Sediment scraping project's estimated area of scraped materials removed and costs for FY2007.

PROJECT AREA	Estimated Area (ac)	Estimated Cubic Yards of Wet Muck Removed	Estimated Cubic Meters of Wet Muck Removed	Estimated Metric Tons of TP removed	Total Cost (Dollars)	Cost per kg TP removed (Dollars)	Cost per Cubic Yard Scraped (Dollars)
North West Marsh Area	400	850,000	649,872	53	2,000,000	37.60	2.35
Eagle Bay outside the lake	100	130,000	99,392	8	500,000	61.46	3.85
Eagle Bay inside the lake	50	350,000	267,594	80	2,000,000	24.96	5.71
Harney Pond Canal area	400	400,000	305,822	36	4,000,000	110.30	10.00
Fish Eating Bay area	900	180,000	137,620	16	500,000	30.64	2.78
Horse Island	150	186,068	142,259	43	2,000,000	46.95	10.75
TOTAL	**2,000**	**2,096,068**	**1,602,559**	**237**	**11,000,000**	**46.48**	**5.25**

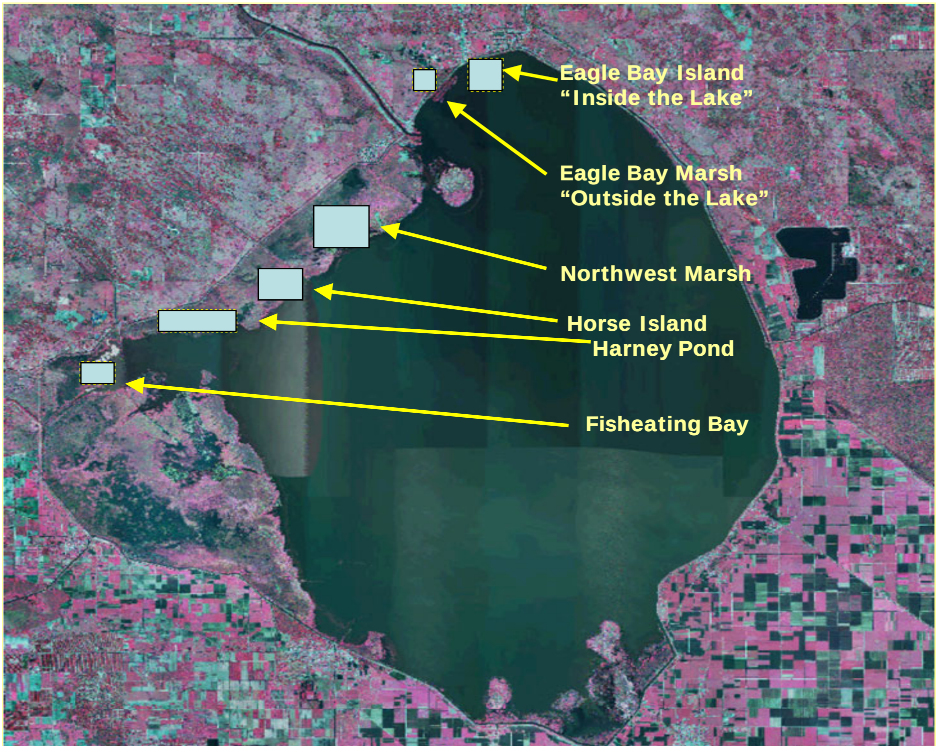

Figure 10-33. Sediment scraping sites in Lake Okeechobee (not to scale). Muck sediments were removed from the locations for disposal elsewhere.

Figure 10-34. Sediment scraping project: (**Panel A**) Eagle Bay Island before sediment removal, (**Panel B**) during removal, and (**Panel C**) after removal. **Panel D**, disposal of material from Fisheating Bay to the C-41 canal berm.

CONCLUSIONS

A comprehensive array of state and federal projects has been undertaken within the watershed and in Lake Okeechobee 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 associated with the lake, 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 TP 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 as it is an integral part of the Kissimmee-Okeechobee-Everglades ecosystem and an important component of the flood-control and water-supply network of South Florida.

The current drought has provided some challenges and opportunities for habitat improvement in the lake. Water supply was maintained with the installation of temporary forward pumps. Low lake levels allowed large portions of the littoral region to be burned to remove torpedo grass. This was followed by chemical treatment to control the re-emergence of this exotic invasive plant. Lower lake levels improved the nearshore light climate allowing SAV re-growth after two years of high and turbid waters. Low lake levels also allowed the restoration of 2,000 ac (809 ha), of nearshore lake bed, removing 2 million cubic yards (1.6 million cubic meters) of phosphorus-laden muck sediments. These changes should provide noticeable improvements in the health of the Lake Okeechobee system in the coming years.

APPROPRIATIONS/EXPENDITURES

The FY2001–FY2007 summary of state of Florida funding appropriations and expenditures for the Lake Okeechobee Protection Program is presented in **Table 10-18**. FY2007 values reflect preliminary financial information as of September 30, 2007. Final values are expected to be received in early 2008. There were no appropriations from the state in FY2004, and the FDACS received no state appropriations during FY2006.

Table 10-18. State funding appropriations and expenditures for the Lake Okeechobee Protection Program (FY2001–FY2007).

Note: FY2007 financial data is preliminary as of September 30, 2007.

Agency	Appropriation	Expended to date	Available
FY01 SFWMD11 (1519G)	8,500,000	8,500,000	0
FY01 SFWMD12 (1591G)	15,000,000	14,999,999	1
FY01 SFWMD Total	**$23,500,000**	**$23,499,999**	**$1**
FY02 SFSWP1 (1748)	10,000,000	10,000,000	0
FY02 SFWMD Total	**$10,000,000**	**$10,000,000**	**$0**
FY03 DEP TMDL Implementation Funds	850,000	811,860	38,140
FY03 SFWMD31 (1769)	7,500,000	6,023,400	1,476,600
FY03 SFWMD Total	**$8,350,000**	**$6,835,260**	**$1,514,740**
FY05 SFWMD51 - Nubbin Slough	4,300,000	1,045,122	3,254,878
FY05 SFWMD61	5,000,000	0	5,000,000
FY05 - DEP Nubbin Slough	3,300,000	0	3,300,000
FY05 - Hydromentia	1,800,000	1,800,000	0
FY05 SFWMD Total	**$14,400,000**	**$2,845,122**	**$11,554,878**
Fast Track Projects - Reimbursable Expenditures	25,000,000	6,885,773	18,114,227
FY06 SFWMD Total	**$25,000,000**	**$6,885,773**	**$18,114,227**
FY07 Hydromentia - Algae Turf Scrubber - FDEP	750,000	750,000	0
FY07 Hydromentia - Algae Turf Scrubber- FDACS	221,610	101,610	120,000
Fast Track Projects - Reimbursable Expenditures	25,000,000	0	25,000,000
Community Budget Issue Requests(CBIR) - Taylor Creek PL566 & Alternative Storage/Disposal of Excess Water	6,200,000	529,934	5,670,066
FY07 Sub Basin Monitoring Network	225,000	225,000	0
FY07 Cody's Cove & Eagle Bay Grant	2,500,000	2,479,828	20,172
Indiantown Citrus Growers Association	287,808	0	287,808
Raulerson & Sons Ranch Stormwater Reuse AWS	330,000	330,000	0
FY07 SFWMD Total	**$35,514,418**	**$4,416,372**	**$31,098,046**
FY08 Northern Everglades $49M			
FY08 LOFT	34,720,106	0	34,720,106
FY08 NE Water Storage Disposal Projects	4,200,000	0	4,200,000
FY08 LOFT Construction Contract	8,379,894	0	8,379,894
FY08 Technical Plan	1,700,000	0	1,700,000
FY08 SFWMD Total	**$49,000,000**	**$0**	**$49,000,000**
Grand Total - SFWMD State Appropriation	**$165,764,418**	**$54,482,526**	**$111,281,892**
FY01 FDACS Appropriation	15,000,000	15,000,000	0
FY05 FDACS Appropriation	5,000,000	5,000,000	0
FY05 FDEP Pahokee WWTP	700,000	700,000	0
FY07 FDACS Appropriation	24,628,051	24,628,051	0
Total Outside Agency State Appropriation	**$45,328,051**	**$45,328,051**	**$0**
Total State Appropriation for Lake Okeechobee Projects	**$211,092,469**	**$99,810,577**	**$111,281,892**

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