Chapter 8: Lake Okeechobee Watershed Protection Program Annual and Three-Year Update

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SUMMARY

Lake Okeechobee means "big water" in the Seminole Indian language, an appropriate name for a water body whose opposite shore cannot be seen from the water's edge. With a surface area of 730 square miles, it is the largest lake in the southeastern United States. Despite its impressive size, the lake is shallow, with an average depth of only 9 feet. Lake Okeechobee and its wetlands are at the center of a much larger watershed, the Greater Everglades, that stretches from the Kissimmee River through the Everglades and finally into Florida Bay. Lake Okeechobee is also a key component of South Florida's water supply and flood control systems.

Notably, Lake Okeechobee provides natural habitat for fish, wading birds, and other wildlife, and it supplies essential water for people, farms and the environment. The lake also provides flood protection and attracts boating and recreation enthusiasts from around the world. It is also home to sport and commercial fisheries.

Lake Okeechobee has been subject to three long-term impacts: (1) excessive total phosphorus (TP) loads, (2) extreme water level fluctuations, and (3) rapid spread of exotic and nuisance plants in the littoral zone. Despite these impacts, Lake Okeechobee continues to be a vital freshwater resource for South Florida, with irreplaceable natural and community values. The South Florida Water Management District (District or SFWMD), Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), United States Army Corps of Engineers (USACE) and other federal agencies, Florida Fish and Wildlife Conservation Commission (FWC), local governments, and other stakeholders

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are working cooperatively to address these interconnected issues in order to rehabilitate the lake and enhance the ecosystem services it provides, while maintaining other societal functions such as water supply and flood control.

For more than two decades, restoration efforts have been under way to improve the water quality and hydrology of the Lake Okeechobee Watershed through implementation of a suite of projects and programs. The reductions due to the dairy buyout, FDEP dairy technology-based rule and implementation of the 40E-61 rule, and other early initiatives leveled-off in the 1990s. As a result, in 2000, the Florida legislature passed the Lake Okeechobee Protection Act (LOPA), which requires the coordinating agencies—the District, FDACS, and FDEP—to work together to address TP loading and exotic species control. The LOPA was amended in 2007 to expand restoration efforts to include the St. Lucie and Caloosahatchee River Watersheds, and is now called the Northern Everglades and Estuaries Protection Program (NEEPP) [Section 373.4595, Florida Statutes (F.S.)]. The Lake Okeechobee Watershed Protection Plan (LOWPP) is required under the NEEPP, which promotes a comprehensive, interconnected watershed approach to protecting the lake and its downstream estuaries—Caloosahatchee and St. Lucie. It is a cooperative effort between the District, FDEP, and FDACS.

The NEEPP requires annual status reports and expanded three-year updates on the LOWPP. This chapter of the *2014 South Florida Environmental Report* (SFER) – *Volume I* provides the Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) status of the Lake Okeechobee Watershed Protection Program, and fulfills both the annual and three-year reporting requirements of the LOWPP. It includes updates on projects and programs being implemented to help address water quality and quantity issues affecting Lake Okeechobee, water quality conditions in the lake and its watershed, lake ecology, and the coordinating agencies' strategies for continued near-term restoration efforts. A cross-reference list for NEEPP reporting is provided in Appendix 8-1 of this volume, and more information on the Kissimmee Chain of Lakes and the Kissimmee River and exotic species status in South Florida is presented in Chapters 9 and 7 of this volume, respectively.

WATERSHED UPDATE

A summary of watershed activities and findings is presented below:

1. Numerous efforts have been conducted under the Lake Okeechobee Watershed Construction Project, including (1) completion of the Lakeside Ranch Stormwater Treatment Area (STA) Phase I construction, which is designed to remove phosphorus (P) from stormwater runoff in the Taylor Creek/Nubbin Slough Basin before it enters the lake; (2) two pilot-scale STAs in Taylor Creek and Nubbin Slough; (3) implementation of hybrid wetland treatment technology (HWTT), which represents a combination of chemical and wetland treatment technologies to remove TP at sub-basin and farm scales; (4) expansion of the Dispersed Water Management (DWM) Program to include five main program components and multiple projects; and (5) FDEP's initiation of the Lake Okeechobee Basin Management Action Plan (BMAP) development.
2. Research and assessment activities during WY2013 included (1) upgrading and calibrating the nutrient budget tool for the Upper Kissimmee Sub-watershed; (2) preliminarily evaluating the nutrient budget model for the Upper Kissimmee Sub-watershed; (3) conducting Florida apple snail (*Pomacea paludosa*) stocking study; (4) summarizing results of the alternative treatment investigations; (5) continuing to work on the Lake Okeechobee Pre-drainage Characterization Study; (6) continuing to evaluate the permeable reactive barrier technology; and (7) investigating potential analytical markers to identify different sources of nutrients to Florida's waters.

3. In WY2013, TP load to the lake from all drainage basins and atmospheric deposition was 569 metric tons (mt). The load was highest from the Taylor Creek/Nubbin Slough Sub-watershed which contributed 26 percent TP load and 10 percent discharge, with 6 percent drainage area; the Indian Prairie Sub-watershed contributed 20 percent of the TP load and 14 percent discharge, with 8 percent drainage area; and the Lower Kissimmee Sub-watershed contributed 18 percent of the TP load and 20 percent discharge, with 12 percent drainage area. The highest sub-watershed unit area load (UAL) of TP came from the Taylor Creek/Nubbin Slough Sub-watershed [1.53 pounds per acre (lb/ac)], followed by the Indian Prairie Sub-watershed (0.84 lb/ac) and the Lower Kissimmee Sub-watershed (0.50 lb/ac). In terms of flow-weighted mean (FWM) TP concentrations, the Taylor Creek/Nubbin Slough Sub-watershed had the highest value [533 micrograms per liter (µg/L, or parts per billion (ppb)], followed by the Indian Prairie Sub-watershed (286 ppb) and then the South Lake Okeechobee Sub-watershed (253 ppb) during WY2013.
4. The current five-year average (WY2009–WY2013) TP load from all drainage basins and atmospheric deposition was 451 mt, which is about 311 mt greater than the 140 metric tons per year (mt/yr) Total Maximum Daily Load (TMDL) for the lake.
5. As part of the three-year update, long-term average annual flows, loads, and concentrations from each sub-watershed were provided. For the most recent 12-year period (calendar years 2001–2012), the average annual TP load to the lake from all drainage basins and atmospheric deposition was 547 mt, and the average annual discharge to the lake was 2.36 million ac-ft. There continues to be disproportionally high TP loads compared to flows from Taylor Creek/Nubbin Slough, Indian Prairie, and Fisheating Creek sub-watersheds due to higher TP concentrations. The Upper Kissimmee and Lake Istokpoga sub-watersheds have displayed disproportionally low loads compared to flows due to lower TP concentrations.
6. In-lake TP concentrations declined from a high of 233 ppb in WY2005 to 93 ppb in WY2012. In WY2013, TP levels increased to 124 ppb, which is attributed to the increased loads and higher water levels as compared to WY2012. The current five-year (WY2009–WY2013) average TP concentration returned to pre hurricane (pre-2004) values.
7. Total nitrogen (TN) load to the lake from all drainage basins and atmospheric deposition was 6,397 mt in WY2013. The Indian Prairie, Lower Kissimmee, and Upper Kissimmee sub-watersheds contributed the largest TN loads to the lake. The Indian Prairie, Taylor Creek/Nubbin Slough, and Lower Kissimmee sub-watersheds displayed the highest UAL TN loads (in lb/ac). The South Lake Okeechobee, Indian Prairie, and Taylor Creek/Nubbin Slough sub-watersheds had the highest FWM TN concentrations.

The surface water flow to Lake Okeechobee was 2.152 million acre-feet (ac-ft), or about 2,656 million cubic meters (m^3) in WY2013, which is 91 percent of the most recent 12-year average (CY2001–2012) of 2.363 million ac-ft, or about 2,916 million m^3. Lake Okeechobee began the water year at an elevation of 11.68 feet (ft) [(3.56 meters (m)] National Geodetic Vertical Datum of 1929 (NGVD). Lower lake levels continued until August 25, 2012, when Tropical Storm Isaac delivered over 5 inches of rain on average District-wide. Inflow for the month of September was 34 percent of the entire water year. Lake stage increased to 15.17 ft (4.62 m) NGVD by September 19, 2012, as regulatory releases to the estuaries began. The stage continued to increase to 15.92 ft (4.85 m) NGVD on October 10, 2012. Regulatory releases were reduced on November 14, 2012, as water levels had declined to below 15.5 ft (4.72 m) NGVD. Base flow regulatory releases were initiated at that time interspersed with several pulse releases and regulatory releases to the Water Conservation Areas through the remainder of the water year. At the end of the water year on April 30, 2013, the lake water level was 13.41 ft (4.09 m) NGVD. Detailed information on regional hydrology during WY2013 is presented in Chapter 2 of this volume.

ECOLOGY UPDATE

Submerged aquatic vegetation (SAV) in Lake Okeechobee continued to increase this year, attaining a total coverage of 47,692 acres as compared to 36,325 acres the previous year. Coverage by the macroalga *Chara* spp. decreased, resulting in 62 percent of the total SAV acreage being comprised of the generally preferred vascular species. These changes appear to be a continuation of the trend noted in the previous two years related to generally lower lake stages resulting from both the implementation of the 2008 Lake Okeechobee Regulation Schedule (2008 LORS) and recent dry conditions. The trend of SAV being replaced by spike rush (*Eleocharis* spp.) and other emergent vegetation in previously open water nearshore areas, especially in the southern bays appears to be continuing. Cattail (*Typha* spp.) also appears to be expanding rapidly in the marsh. Several exotic invasive species (such as melaleuca, *Melaleuca quinquenervia*, and torpedograss, *Panicum repens*), also appear to be gaining ground. It is unclear what these shifts in the areal coverage of emergent vegetation, vascular SAV and non-vascular SAV are having on habitat values in the littoral and nearshore zones of Lake Okeechobee, although it is clear that conditions are substantially better than they were during the generally higher Lake stages that characterized the mid to late 1990s, or in the years immediately following the hurricanes of 2004 and 2005.

As in the previous year, algal bloom activity appeared to be quite low this past year, with only several instances of chlorophyll concentrations high enough to be indicative of bloom conditions, and only a single cyanobacterial toxin sample in excess of the detectable limit.

Overall, the Lake Okeechobee fishery appears to be in relatively good condition. Both nearshore and pelagic zone sport fish and forage fish populations continue to recover from the lingering effects of the hurricanes of 2004 and 2005. Overall, counts for most species were not as high as they were in 2010, when the fishery appeared to peak, but remain comparable to historical, pre-hurricane levels. The black crappie (*Pomoxis nigromaculatus*) population, whose recovery has lagged relative to other important lake species, appears to be continuing to improve, with the highest population values recorded since 2005 encountered this past year.

Wading bird utilization of the lake for foraging improved relative to the results recorded in 2012, returning to levels comparable to those encountered in 2010 and 2011. Prey densities were greater this year than in 2012, and preliminary results indicate that wading bird nesting on the lake was at historical levels.

No ecological monitoring was performed in Lake Istokpoga during the past water year although Lake Okeechobee field scientists did make several trips to the lake to clear weeds and otherwise maintain tree plantings done on several of the islands in the lake in previous years.

INTRODUCTION

Lake Okeechobee (located at 27° North latitude and 81° West longitude) has a surface area of 445,560 acres (ac) [1,800 square kilometers (km^2)], and is extremely shallow with a mean depth of 9 feet (ft) [2.7 meters (m)] and maximal depth of 12.1 ft (3.7 m) for the past 10 years. The lake is a central part of the interconnected South Florida aquatic ecosystem and the United States Army Corps of Engineers (USACE) regional flood control project. Lake Okeechobee provides numerous services to diverse users with tremendous economic interest in its health and fate. The lake is the primary water supply for the Okeechobee Utility Authority and the backup water supply for much of South Florida. It supports multimillion-dollar sport and commercial fisheries, and various recreational activities. It also provides habitat for migratory waterfowl, wading birds, alligators (*Alligator mississippiensis*), and the Everglade snail kite (*Rostrhamus sociabilis plumbeus*) (Aumen, 1995). The lake is also used for flood control during the wet season (June–October) and water supply during the dry season (November–May). The lake faces three major environmental challenges: (1) excessive TP loads, (2) extreme water level fluctuations, and (3) the rapid spread of exotic and nuisance plants.

As depicted on **Figure 8-1**, Lake Okeechobee receives water from a 3.45-million ac (1.4-million ha) watershed that includes four distinct tributary systems: Kissimmee River Valley, Lake Istokpoga–Indian Prairie/Harney Pond, Fisheating Creek, and Taylor Creek/Nubbin Slough. With the exception of Fisheating Creek, all major inflows to Lake Okeechobee are controlled by gravity-fed or pump-driven water control structures. These four major tributary systems are generally bound by the drainage divides of the major water bodies and are further divisible into 61 drainage basins and grouped by nine sub-watersheds based on hydrology and geography.

The nine sub-watersheds comprising the Lake Okeechobee Watershed (LOW) are the Upper Kissimmee (above structure S-65), Lower Kissimmee (between structures S-65E and S-65), Taylor Creek/Nubbin Slough (S-191, S-133, S-135, S-154, and S-154C basins), Lake Istokpoga (above structure S-68), Indian Prairie (C-40, C-41AN, C-41AS, C-41N, C41S, L-48, L-49, L-59E, L-59W, L-60E, L-60W, L-61E, and S-131 basins), Fisheating Creek (Fisheating Creek, L-61W, and Nicodemus Slough North basins), East Lake Okeechobee (Basin 8, C-44, S-153, and L-8 basins), West Lake Okeechobee (East Caloosahatchee, Hicpochee North, and Nicodemus Slough South), and South Lake Okeechobee, which includes the S-4 Basin, and most basins in the Everglades Agricultural Area (EAA) and Chapter 298 Districts (**Figure 8-1**).

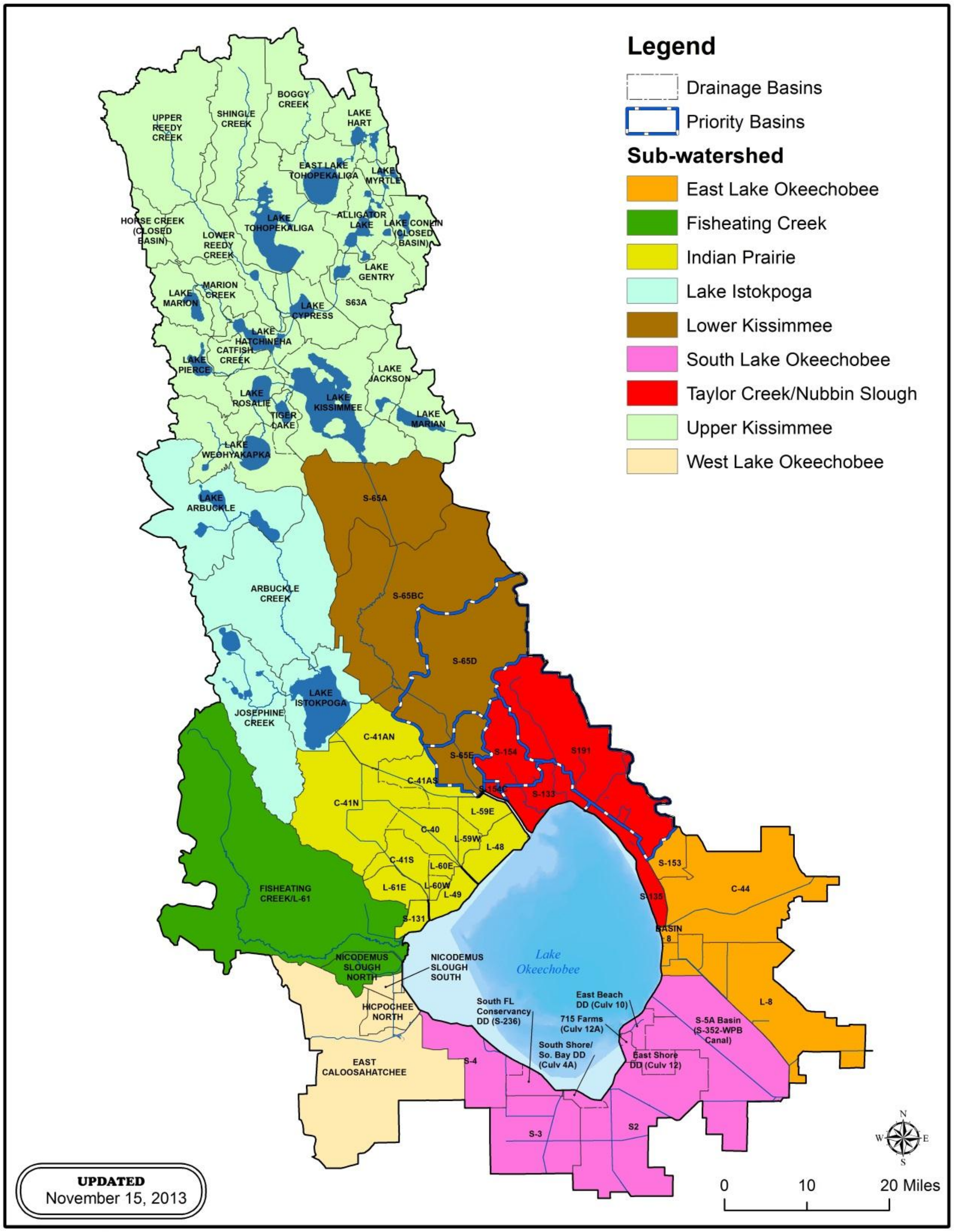

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Figure 8-1. Lake Okeechobee Watershed (LOW) detailing sub-watersheds, drainage basins, and major hydrology.

The Upper Kissimmee, Lower Kissimmee, Taylor Creek/Nubbin Slough, Lake Istokpoga, Indian Prairie, and Fisheating Creek sub-watersheds primarily drain into Lake Okeechobee by gravity. The S-133 Basin (part of the Taylor Creek/Nubbin Slough Sub-watershed) and other urban areas can also pump water into the lake from the north. When high lake stages make gravity flows impossible, urban areas north of the lake are drained via pumps. The Eastern and Western Lake Okeechobee sub-watersheds contribute flow by gravity, but only when Lake Okeechobee water levels are below 14.5 and 11.5 ft (4.4 and 3.5 m), respectively, in relation to the National Geodetic Vertical Datum of 1929 (NGVD).

This LOWPP Update includes an update to the LOW and sub-watershed boundaries. A detailed comparison between the 2011 LOWPP Update and the current boundaries at the sub-watershed level is presented in **Table 8-1**. As part of the boundary update, the overall LOW acreage was increased by only 8,615 acres (0.25 percent). Since 2011, three main internal sub-watershed changes consisted of (1) splitting the Nicodemus Slough Basin into a northern and southern portion, with the former remaining in the Fisheating Creek Sub-watershed and the latter allocated to the West Lake Okeechobee Sub-watershed; (2) reallocating the L-61W Basin from the Indian Prairie Sub-Watershed to the Fisheating Creek Sub-watershed; and (3) increasing the size of the S-4 Basin, which reduces the overall acreage of the West Lake Okeechobee Sub-watershed.

Table 8-1. Updated Lake Okeechobee Watershed (LOW) and sub-watershed areas.

Sub-watersheds	2011 LOWPP Area (ac)	2014 SFER Area (ac)
EAST LAKE OKEECHOBEE	238,790	239,013
FISHEATING CREEK	284,262	318,042
INDIAN PRAIRIE	290,208	276,577
LAKE ISTOKPOGA	390,023	394,203
LOWER KISSIMMEE	424,260	429,188
SOUTH LAKE OKEECHOBEE	364,052	363,141
TAYLOR CREEK/NUBBIN SLOUGH	197,872	197,795
UPPER KISSIMMEE	1,029,331	1,028,421
WEST LAKE OKEECHOBEE	223,062	204,094
Lake Okeechobee Watershed	**3,441,860**	**3,450,475**

Additionally, a new land use dataset, as developed in January 2013 as part of the Nutrient Budget Tool (PN-Budget) Upgrade and Calibration Project (JGH Engineering, 2013), was used (**Figure 8-2**). As some of the Lake Okeechobee Watershed area lies within the St. Johns River and Southwest Florida Water Management Districts (SJRWMD and SWFWMD, respectively), the land use dataset was created by merging the SWFWMD 2009, SJRWMD 2009, and SFWMD 2008/9 land use datasets and then clipping these to the study area.

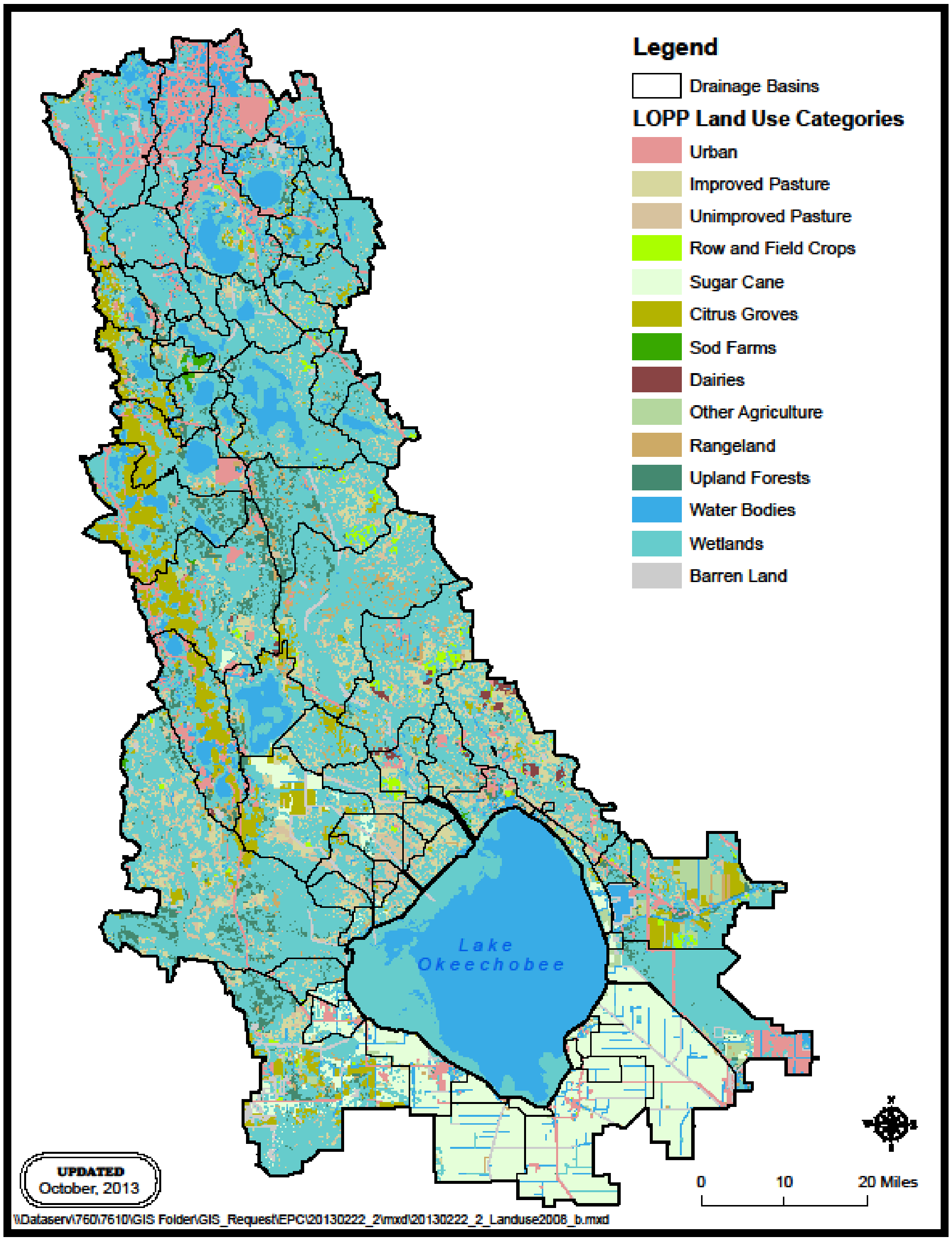


Figure 8-2. Land use distribution in the LOW.

The Lake Okeechobee Watershed is dominated by agricultural land uses that account for 51 percent of the total area [1.75 million ac, or 706,000 hectares (ha)]; followed by natural areas including wetlands, upland forests, and water bodies (31 percent); urban areas (11 percent); and rangeland (6 percent) (**Table 8-2**). Agricultural land uses can be further classified as (1) improved pasture (20 percent) and unimproved/woodland pasture (9 percent) for beef cattle grazing north of the lake; sugarcane production (12 percent) south of the lake within the EAA; (2) citrus groves (6 percent) located primarily within the East Lake Okeechobee and Lake Istokpoga sub-watersheds; and (3) sod farms, row crops, dairies, and other agriculture that make up the remaining (three percent) land uses within the watershed.

Table 8-2. 2009 land use summary for the LOW.

Land Use	Area (acres)	Percent
Urban	**392,617**	**11.4%**
Agriculture	**1,745,558**	**50.6%**
Improved Pasture	684,763	19.8%
Unimproved/Woodland Pasture	300,957	8.7%
Row and Field Crops	35,098	1.0%
Sugarcane	427,279	12.4%
Citrus Groves	199,543	5.8%
Sod Farms	6,355	0.2%
Dairies	19,927	0.6%
Other Agriculture	71,637	2.1%
Rangeland	**206,061**	**6.0%**
Upland Forests	**251,352**	**7.3%**
Water Bodies	**224,863**	**6.5%**
Wetlands	**608,353**	**17.6%**
Barren Land	**21,670**	**0.6%**
Watershed Total Acreage	**3,450,475**	**100%**

OVERVIEW OF THE LAKE OKEECHOBEE WATERSHED PROTECTION PROGRAM

Passed in 2000, the Lake Okeechobee Protection Act (LOPA) [Section 373.4595, Florida Statutes (F.S.)] established a restoration and protection program for the lake. In 2007, the Florida legislature amended the LOPA in Section 373.4595, F.S., which is now known as the Northern Everglades and Estuaries Protection Program (NEEPP). The NEEPP promotes a comprehensive, interconnected watershed approach to protect Lake Okeechobee and the Caloosahatchee and St. Lucie rivers (SFWMD et al., 2008). The NEEPP includes the Lake Okeechobee, Caloosahatchee River, and St. Lucie River watershed protection programs. The protection plans developed under the NEEPP for each of these three Northern Everglades watersheds identify actions (e.g. programs and projects) to help in achieving water quality and quantity objectives for the watersheds and to restore habitat. Water quality objectives are based on Total Maximum Daily Loads (TMDLs) established by the Florida Department of Environmental Protection (FDEP), which for Lake Okeechobee is 140 metric tons (mt) of total phosphorus (TP) per year, 105 mt of TP per year from the watershed tributaries, and 35 mt per year from atmospheric deposition. Storage targets are aimed at achieving appropriate water levels in Lake Okeechobee and more desirable salinities within the estuaries.

The District, in cooperation with the FDEP and Florida Department of Agriculture and Consumer Services (FDACS), collectively known as the coordinating agencies, developed the Lake Okeechobee Protection Plan, which is reevaluated every three years pursuant to the NEEPP. The Lake Okeechobee Protection Plan was originally submitted to the Florida legislature on January 1, 2004 (SFWMD et al., 2004). The Lake Okeechobee Phase II Technical Plan (LOP2TP) was submitted to the Florida legislature in February 2008 as required by the NEEPP (SFWMD et al., 2008). The LOP2TP identifies construction projects and on-site measures that prevent or reduce pollution at the source. The plan includes source controls such as Best Management Practices (BMPs) and several sub-regional and regional technologies such as the Stormwater Treatment Areas (STAs) and Alternative Treatment Technologies to improve the quality of water within the watershed and of that delivered to Lake Okeechobee. Several measures are also included in the plan to improve both water levels within the lake and the quantity and timing of discharges from Lake Okeechobee to the Northern Estuaries (St. Lucie and Caloosahatchee) to achieve more desirable salinity ranges. These measures include reservoirs, Dispersed Water Management (DWM) projects, Aquifer Storage and Recovery (ASR), and deep well injection. The coordinating agencies are tasked with implementing the NEEPP, each with specific areas of responsibility **(Figure 8-3)**. The SFWMD, in cooperation with the FDEP and FDACS, is the lead agency for annual status reports and three-year updates to the CRWPP; however, each agency is responsible for implementing its respective programs.

The LOWPP includes three main components: (1) the Lake Okeechobee Watershed Construction Project (LOWCP; which includes the Phase I and Phase II Technical Plans), (2) the Lake Okeechobee Watershed Phosphorus Control Program, and (3) the Lake Okeechobee Watershed Research and Water Quality Monitoring Program. In addition, the LOWPP includes the Lake Okeechobee Exotic Species Control Program and Lake Okeechobee Internal Phosphorus Management Program. A brief description of these elements is provided below, and a diagram illustrating the relationship among the respective protection programs, associated elements, and projects is presented in **Figure 8-4**.

The NEEPP requires that the District submit an annual progress report and three-year updates to the Florida legislature. This chapter constitutes the thirteenth annual report and 2014 three-year update to the legislature. It summarizes the hydrology, water quality, and aquatic habitat conditions of the lake and its watershed and load reductions necessary to meet the TMDL. It also provides source control program and related construction project updates and highlights the coordinating agencies' current and near-term efforts to achieve the TMDL and storage goals. More details on exotics within the District boundaries are presented in Chapter 7 of this volume. As supporting information to this chapter, a cross-reference list for NEEPP reporting is covered in Appendix 8-1, and the Northern Everglades Annual Work Plan for Fiscal Year (FY) 2014 is provided as Appendix 8-2 of this volume. A summary of completed and planned projects and activities to further the coordinating agencies' efforts to improve water in the LOW is provided in Appendix 8-3 of this volume.

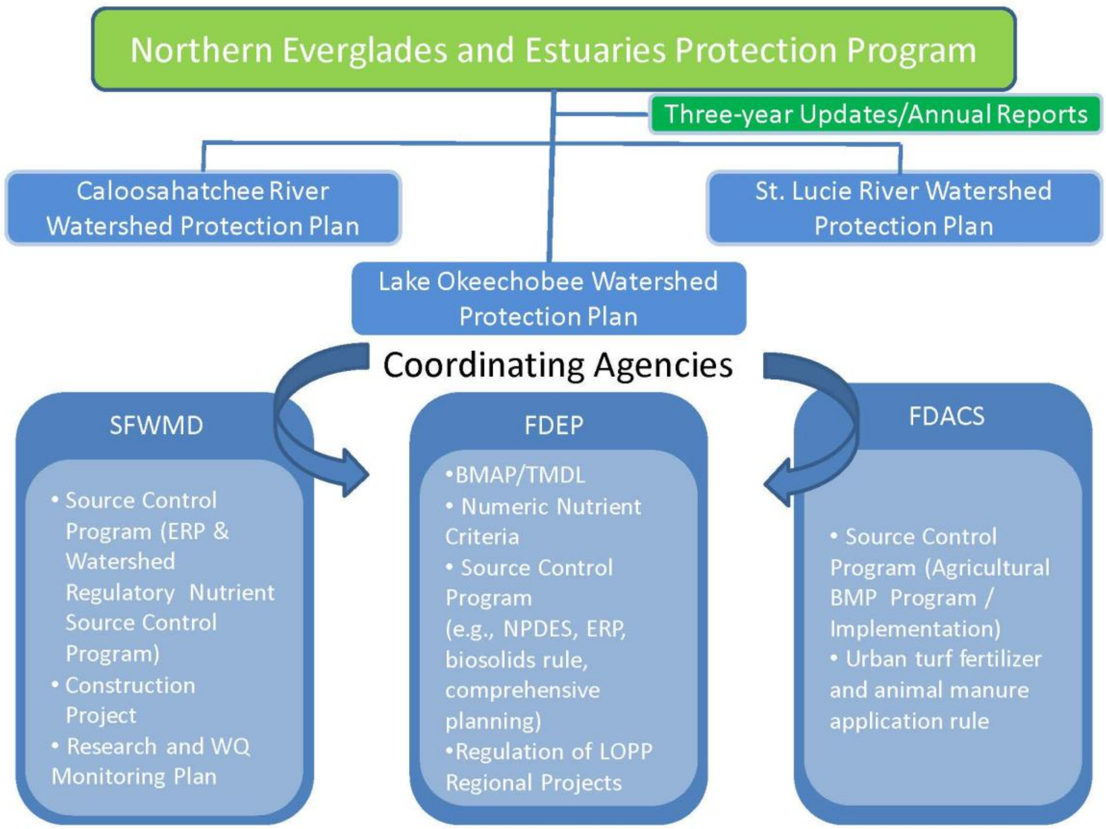


Figure 8-3. Coordinating agencies' areas of responsibility associated with the Northern Everglades and Estuaries Protection Program (NEEPP).

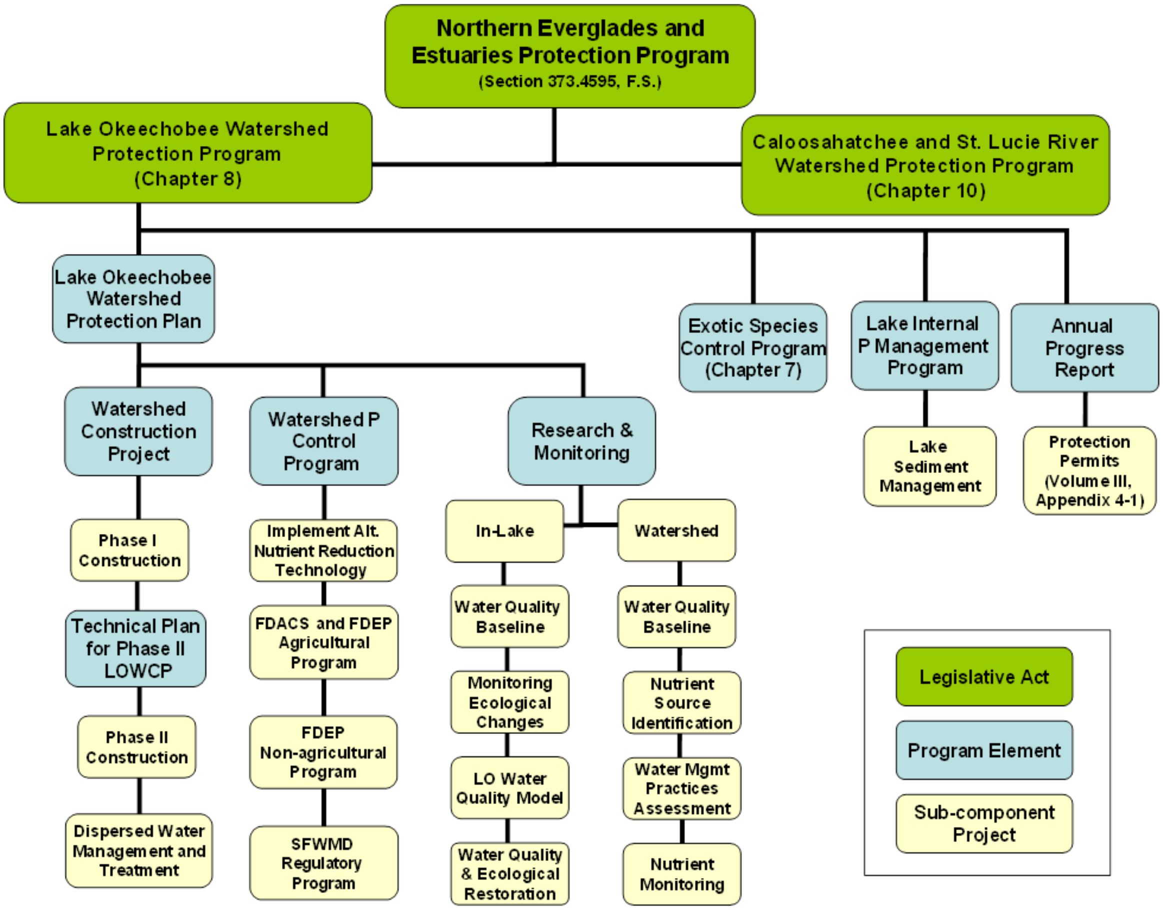


Figure 8-4. Northern Everglades and Estuaries Protection Program (NEEPP) structure, detailing the Lake Okeechobee Watershed Protection Program's (LOWPP) elements and projects. [Note: F.S. – Florida Statutes; LOWCP – Lake Okeechobee Watershed Construction Project; P – phosphorus; Alt. – Alternate; FDACS – Florida Department of Agricultural and Consumer Services; FDEP – Florida Department of Environmental Protection; SFWMD – South Florida Water Management District; and LO – Lake Okeechobee.]

WATERSHED CONSTRUCTION PROJECT UPDATE AND RELATED ACTIVITIES

This section provides updates to the LOWCP and related activities during WY2013. Project background information and details can be found in the 2011 Lake Okeechobee Protection Plan Update (SFWMD et al., 2011), available at www.sfwmd.gov/northerneverglades. Addressing the complex and varying problems in the Lake Okeechobee Watershed requires a multifaceted restoration approach. The coordinating agencies are committed to restoring Lake Okeechobee and its watershed, continuing existing efforts, and identifying new opportunities to improve the ecosystem. Over the past three years, the coordinating agencies have continued implementation of various efforts to improve conditions including: completion of Lakeside Ranch Stormwater Treatment Area (STA) Phase I, operation of two pilot-scale STAs in Taylor Creek and Nubbin Slough, implementation of Hybrid Wetland Treatment Technology to remove TP at sub-basin and farm scales, expansion of the Dispersed Water Management Program, and implementation of source control programs to retain nutrients at the source. The status of the C-44 Reservoir/STA Project is reported in the *St. Lucie Estuary Watershed Construction Project Update* section in Chapter 10 of this volume.

LAKESIDE RANCH STORMWATER TREATMENT AREA

The Lakeside Ranch STA is in the Taylor Creek/Nubbin Slough Sub-watershed, which is identified in the Lake Okeechobee Protection Plan as a priority sub-watershed. This project, expedited under the NEEPP, is a 2,700-ac (1,090 ha) STA in western Martin County on lands adjacent to Lake Okeechobee (**Figure 8-5**). This STA is also a feature of the Lake Okeechobee Watershed Project, a Comprehensive Everglades Restoration Plan (CERP) "project component," as defined in Section 373.1501, F.S. More information on CERP projects is available at www.evergladesplan.org/pm/projects/proj_01_lake_o_watershed.aspx.

Figure 8-5. Location and layout of Lakeside Ranch Stormwater Treatment Area (STA).

The Lakeside Ranch STA Project is designed in two phases, which combined, are expected to reduce TP loading to the lake by 19 mt annually. Phase I includes STA North, canal improvements, and the installation of the S-650 pump station. The pump station is able to pump water at a rate of 250 cubic feet per second (cfs), or 7 cubic meters per second (m^3/sec). Canal improvements have been made along the L-63 and L-64 levees. STA North consists of three treatment cells with an effective treatment area of 919 ac (372 ha). Phase I construction was completed in July 2012. Phase II will include the construction of a southern STA with an effective treatment area of 788 ac (319 ha), a new pump station at structure S-191, and a discharge canal. Phase II of the STA will also be able to recirculate water from the lake, which may provide potential for internal P removal. Final design of Phase II STA South was completed in December 2011. The final design for the S-191A pump station (Phase II) was completed in February 2012.

The total investment for the construction of Phase I STA was about $22.8 million. Pumping at the Lakeside Ranch STA commenced on August 2, 2012. The goal was to maintain water depths between 6 and 12 inches in the south end of the cells to allow establishment of wetland vegetation. On August 26, 2012, the STA became completely inundated following Tropical Storm Isaac. Start-up monitoring was initiated on August 29, 2012, and continued through December 11, 2012. The STA passed start-up monitoring requirements for phosphorus, mercury, and other toxicants with approval from the FDEP to begin flow-through operation on March 29, 2013. Pumping of water into Cells 1 and 2 began on July 3, 2013, but only Cell 2 was allowed to discharge. Flow-through operation in Cell 1 was initiated around the second week of July 2013, following confirmation that no protected black-necked stilt (*Himantopus mexicanus*) nests were present. Cells 1 and 2 are currently in flow-through mode. Flow-through in Cell 3, which sustained storm damage, is being delayed to allow stabilization of soils with wetland vegetation at the downstream end of the cell.

The Northern Everglades STAs, including Taylor Creek and Nubbin Slough discussed below, differ from the Everglades Agricultural Area STA basins with regard to upstream basin topography and a greater range of phosphorus concentrations flowing to the STAs. The design treatment goals are also different, so the experience gained in the Everglades Agricultural Area STAs is not always applicable to the Northern Everglades facilities. The District is gaining experience operating the Lakeside and Taylor Creek STAs and over the next several years this knowledge will be applied to future northern construction projects, operational strategies, vegetation management, and to the integration of future STAs with other project features such as reservoirs or hybrid wetland treatment systems. Before moving forward with Phase II of the Lakeside Ranch STA project, the District will evaluate the effectiveness of the first phase based on several years of performance. It will also be contingent on funding availability at that time.

TAYLOR CREEK AND NUBBIN SLOUGH STAS

The Taylor Creek STA (TC-STA) is one of two pilot-scale STAs being implemented north of Lake Okeechobee as part of the Lake Okeechobee Watershed Construction Project – Phase 1 (**Figure 8-6**). Constructed in April 2006, this two-celled STA has an effective treatment area of 118 acres (48 ha), which is fairly small compared to the Everglades STAs. The TC-STA was designed to remove approximately 2 mt/yr of TP from the Taylor Creek drainage basin.

Figure 8-6. Taylor Creek STA (photo by the SFWMD).

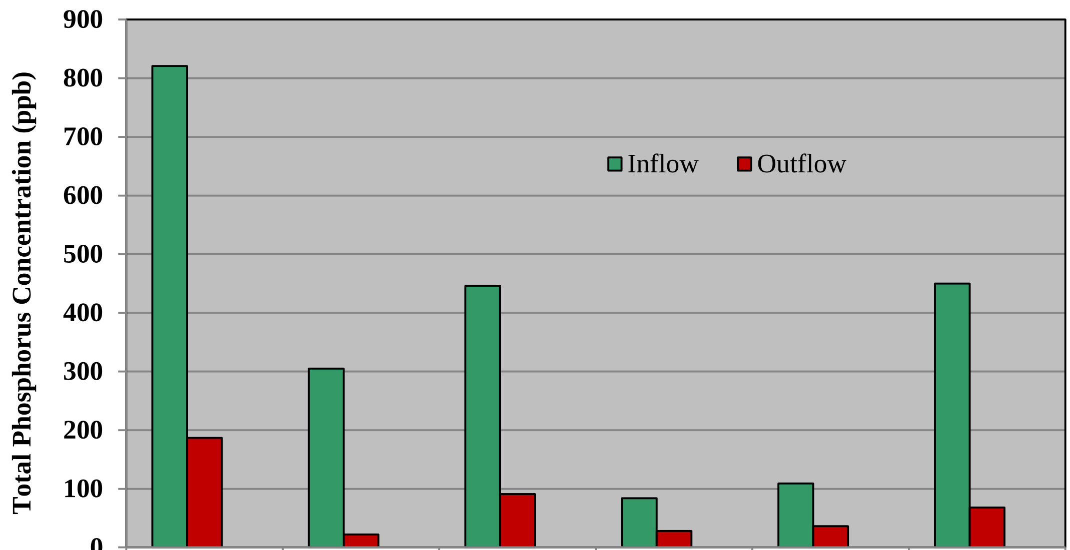
Flow-through operations at the TC-STA commenced on June 26, 2008. By the end of WY2013, the TC-STA had almost 37 months of flow-through; eight months in WY2009 (June 26, 2008–February 24, 2009), slightly less than eight months in WY2011 (September 8, 2010–April 30, 2011), a full twelve months in WY2012, and nine months in WY2013 (May 1, 2012–January 31, 2013), with TP load removals of 1.44, 0.91, 1.11, and 0.58 mt of TP respectively. TP load removal over the 37-month flow-through period was 4.04 mt. Flow-through operations were temporarily suspended on February 1, 2013, to address lack of system performance. Drawdown activities were conducted from April to June 2013 to help rejuvenate existing vegetation and allow for natural recruitment and additional plantings of cattail (*Typha* spp.) and giant bulrush (*Scirpus californicus*) in areas of the STA where there was little or no emergent vegetation. Currently, emergent vegetation covers about 75 percent of Cell 1 compared to only 20 percent prior to WY2013. This management strategy should help improve the P removal capability of the STA, which resumed flow-through operations in July 2013.

The Nubbin Slough STA is the larger of the two pilot STAs constructed north of the lake. It is also a two-celled enclosure with an effective treatment area of 773 ac (313 ha). The projected long-term average TP reduction within the STA is approximately 5.0 mt/yr, or about 85 percent of the TP load of Nubbin Slough at the project location (Stanley Consultants, Inc., 2003). The USACE completed construction of this facility in June 2006 but it remained inoperable until the construction modifications to the Nubbin Slough STA intake basin were completed in early June 2012. Pumping operations were initiated on June 12, 2012; however, a month later, a boil was observed in the Cell 2 distribution canal adjacent to the 30-acre lagoon. The boil was caused by water being piped under the storage pond levee by a remnant 6 inch (15 cm) transfer pipeline. Because the water boil showed no signs of soil movement or turbidity and did not present a threat to the stability of the storage pond levee, operations continued until August 24, 2012, when pumping was suspended in anticipation of Tropical Storm Isaac. The storm hit the region on August 27 and 28 and caused flooding in and around the STA. In the storm's aftermath, a significant boil was observed in the seepage ditch on the southeast side of Cell 1. A remnant 12-inch (30.5-cm) drainage pipe buried 3 ft (0.9 m) below ground by a previous owner was discharging water into the seepage ditch. The District's efforts to repair the buried pipeline were postponed until the dry season when groundwater levels were low enough to proceed with pipeline excavation and grouting, and then repairs to the damaged S-385 bypass weir and the two major pipes were completed. Field investigations identified additional remaining drainage pipes which will be located and repaired during the next dry season. The USACE and SFWMD have agreed to a one-year time extension (until September 9, 2014) for completing repairs, commissioning the pump station, and transferring the facility to the SFWMD.

HYBRID WETLAND TREATMENT TECHNOLOGY

The Hybrid Wetland Treatment Technology (HWTT) combines the strengths of both wetland and chemical treatments to maximize phosphorous (P) removal, minimize chemical use, and facilitate the removal of nitrogen (N). Chemical coagulants are added, either continuously or intermittently, to the front end of the treatment system, which contains one or more deep zones to capture the resulting floc material. A fundamental concept of the HWTT is that the floc resulting from coagulant addition generally remains active and has the capability of additional P sorption. Both passive and active reuse of floc material is practiced in the HWTT. Passive reuse refers to the settling of active flocs on plant roots and stems, where it can contact additional untreated parcels of water. Active reuse refers to the mechanical resuspension of previously settled floc. In addition to passive and active recycling/reuse of chemical flocs, optimization approaches include the sequencing and configuring of the wetland unit processes to provide desirable N and P species transformations.

There are currently six operational HWTT systems in the Northern Everglades. Three of four HWTT facilities constructed during WY2008 are still operational (Ideal 2 Grove, 1.3 cfs capacity; Nubbin Slough, 7.4 cfs capacity; and Mosquito Creek, 6 cfs capacity). Two additional HWTT facilities (Lemkin Creek, 5 cfs capacity; Wolff Ditch, 20 cfs capacity) initiated operations during WY2010. A seventh 10 cfs HWTT facility was completed at Grassy Island in the Taylor Creek basin at the beginning of WY2012, and expanded from 10 to 20 cfs during WY2012–WY2013. A third and final expansion to increase the flow treatment capacity of this facility to 30 cfs is expected to be completed by early WY2014. Effective performance of the HWTT technology is demonstrated by the reduction in TP concentrations between the inflow and outflow during the entire study period (Watershed Technologies, LLC, 2013). Flow-weighted (FWM) mean TP concentration reductions of the six active HWTT facilities during the entire study period ranged from 67 to 93 percent (**Figure 8-7**). Funding for a new HWTT facility has been identified and a specific location is currently being evaluated. During WY2013, in addition to alum, a polyaluminum chloride compound was used at two facilities as a supplemental coagulant. Water chemistry at Grassy and Mosquito Creek HWTT sites was different during parts of the rainy season when compared with the other HWTT sites. Alkalinity in the drainage waters from these two sites was low (<60 mg/L) and pH was close to neutral (>6.5). Under these circumstances of low alkalinity and circumneutral pH, the limerock beds at these facilities were not able to supply the needed alkalinity for a better floc formation with alum. Polyaluminum chloride is a supplemental coagulant that can be used in conjunction with alum during these periods to improve flocculation and reduce total P and total Al export from these HWTT facilities.



	Nubbin Slough	Ideal Grove	Mosquito Creek	Lemkin Creek	Wolff Ditch	Grassy Island
Inflow	821	305	446	84	109	450
Outflow	187	22	91	28	36	68
Reduction	77%	93%	80%	67%	67%	85%

Figure 8-7. Flow-weighted mean (FWM) total phosphorus (TP) concentrations in micrograms per liter [µg/L, or parts per billion (ppb)]. The period of record for TP concentrations is November 21, 2008–June 30, 2013 for Nubbin Slough, Ideal Grove and Mosquito Creek; March 9, 2010–June 30, 2013 for Lemkin Creek and Wolff Ditch; and July 11, 2011–June 30, 2013 for Grassy Island (off-line for construction during March 15, 2012–July 1, 2012 and May 2013).

DISPERSED WATER MANAGEMENT

An effort to drain the greater Everglades over the past century has changed the hydrology of the Everglades ecosystem to allow for rapid urban and agricultural development across South Florida. These development activities have altered the quality, quantity, timing, and distribution of water flows into Lake Okeechobee and the St. Lucie and Caloosahatchee Estuaries. The legislative intent of the NEEPP includes encouraging and supporting the development of creative partnerships to facilitate or further the restoration of surface water resources in the LOW and the St. Lucie and Caloosahatchee River watersheds. One way this is being accomplished is through the Dispersed Water Management (DWM) Program. The goals and objectives of the DWM Program are to provide shallow water storage, retention, and detention to enhance Lake Okeechobee and estuary health by reducing discharge volumes, reducing nutrient loading to downstream receiving waters, and by expanding ground water recharge opportunities.

The DWM Program is a multifaceted approach to working cooperatively with public and private land owners to identify, plan, and implement mechanisms to retain or store water. The five main categories of projects under the District's DWM Program include storage and retention projects on private lands, storage and retention projects on public lands, Northern Everglades Payment for Environmental Services (NE-PES) projects, Florida Ranchlands and Environmental Services Projects (FRESP), and Water Farming Payment for Environmental Services (WF-PES) pilot projects (Note: Water farming is discussed further in Chapter 10 of this volume). The total storage, retention, and detention created by the DWM Program since 2005 is approximately 49,600 ac-ft. This includes contributions from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Wetland Reserve Program (WRP) and other programs, the FDACS BMP Program, agricultural landowners, agricultural organizations, non-governmental organizations (NGOs), and local governments.

The importance and potential of DWM is recognized and being implemented at both the state and federal levels. Examples of federal programs include two U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Programs. The Wetlands Reserve Program (WRP) offers technical and financial support to land owners who voluntarily agree to protect, restore, and enhance wetlands on their property by placing them in a long-term or permanent conservation easement. The Environmental Quality Incentive Program (EQIP) promotes environmental quality and agricultural production as compatible goals. This section focuses on the state's DWM efforts and highlights specific DWM projects, along with a map of the projects shown in **Figure 8-8**. **Table 8-3** provides a comprehensive list of the District's DWM projects in the Northern Everglades and their current status and estimated benefits. The District administers the DWM Program in consultation with the FDEP, FDACS, and USDA NRCS.

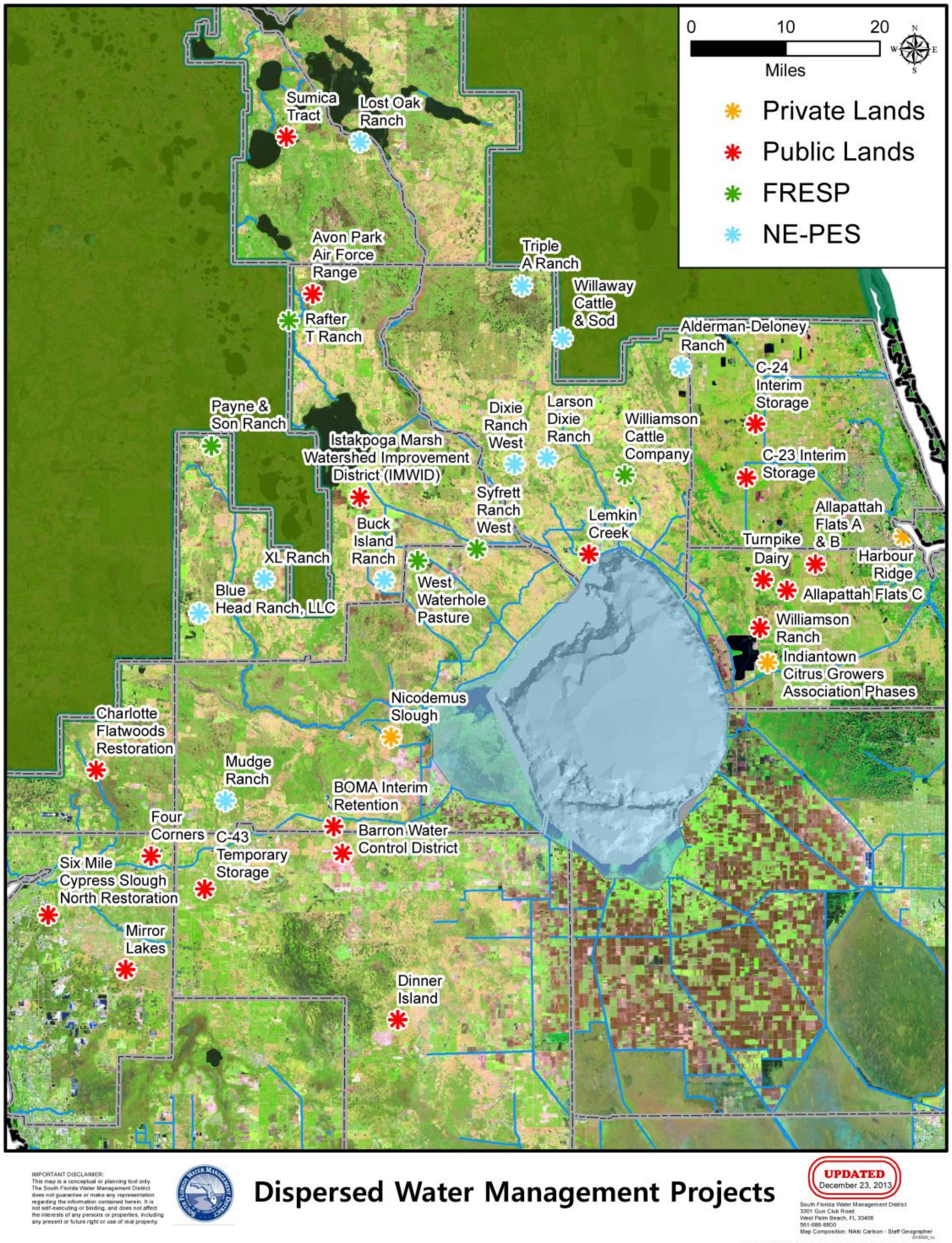


Figure 8-8. Dispersed Water Management (DWM) projects including storage and retention projects on private lands and public lands, Northern Everglades Payment for Environmental Services (NE-PES) projects, and Florida Ranchland Environmental Services Project (FRESP) in the Northern Everglades.

Table 8-3. Comprehensive list of the District's Dispersed Water Management (DWM) projects and their current status and estimated benefits.

Project Name	Category	Status	Estimated Benefits
Payne & Son Ranch	FRESP	Complete Operational	932 ac-ft/yr
Rafter T Ranch	FRESP	Complete Operational	1,145 ac-ft/yr
Syfrett Ranch West	FRESP	Non-operational	140 ac-ft/yr
West Waterhole Pasture	FRESP	Complete Operational	5,000 ac-ft/yr; 3.274 mt/yr TP
Williamson Cattle Company	FRESP	Complete Operational	150 ac-ft/yr
Alderman-Deloney Ranch	NE-PES	Complete Operational	147 ac-ft/yr
Buck Island Ranch	NE-PES	Complete Operational	1,573 ac-ft/yr
Dixie Ranch West	NE-PES	Complete Operational	315 ac-ft/yr
Larson Dixie Ranch	NE-PES	Complete Operational	856 ac-ft/yr
Lost Oak Ranch	NE-PES	Complete Operational	374 ac-ft/yr
Triple A Ranch	NE-PES	Construction	397 ac-ft/yr
Willaway Cattle & Sod	NE-PES	Complete Operational	229 ac-ft/yr
XL Ranch	NE-PES	Complete Operational	887 ac-ft/yr
Blue Head Ranch	NE-PES	Design Permitting	3,462 ac-ft/yr
Mudge Ranch	NE-PES	Design Permitting	396 ac-ft/yr
Harbour Ridge	Private Lands	Complete Operational	667 ac-ft/yr
Indiantown Citrus Growers Association - Phases I and II	Private Lands	Complete Operational	3,550 ac-ft/yr
Nicodemus Slough	Private Lands	Construction	34,000 ac-ft/yr
Six Mile Cypress Slough North Restoration	Public Lands	Construction	1,400 ac-ft/yr
Allapattah Flats A & B - Phase I	Public Lands	Complete Operational	3,500 ac-ft/yr
Allapattah Flats A & B - Phase II	Public Lands	Design	1,243 ac-ft/yr
Allapattah H Canal	Public Lands	Complete Operational	1,610 ac-ft/yr
Allapattah Flats C	Public Lands	Planning and Design	-
Avon Park Air Force Range	Public Lands	Complete Operational	10,000 ac-ft/yr
Barron Water Control District (BWCD)	Public Lands	Complete Operational	5,000 ac-ft/yr
BOMA Interim Retention	Public Lands	Complete Operational	836 ac-ft/yr
C-23 Interim Storage (Section D - PC55)	Public Lands	Complete Operational	110 ac-ft/yr
C-24 Interim Storage	Public Lands	Planning	-
C-43 Temporary Storage	Public Lands	Complete Operational	1,250 ac-ft/yr
Dinner Island	Public Lands	Construction	30 ac-ft/yr
Istokpoga Marsh Watershed Improvement District (IMWID)	Public Lands	Planning and Design	950 ac-ft/yr
Lemkin Creek	Public Lands	Planning	-
ECWCD Mirror Lakes Phase I	Public Lands	Complete Operational	1,000 ac-ft/yr
Adams Ranch Cattle and Citrus Operations (ARCCO)	Public Lands	Complete Operational	190 ac-ft/yr
Sumica Tract	Public Lands	Complete Operational	281 ac-ft/yr
Turnpike Dairy	Public Lands	Complete Operational	10 ac-ft/yr
Williamson Ranch	Public Lands	Complete Operational	537 ac-ft/yr
Charlotte Flatwoods Restoration	Public Lands	Planning	-

Storage and Retention Projects on Public Lands

Projects on public land enhance Lake Okeechobee and estuary health by reducing discharge volumes and nutrient loading to downstream receiving waters through modifications to existing water management structures and implementing operational strategies. In many cases, storage, retention, and detention is obtained by increasing the discharge control elevation of on-site drainage facilities or impounding water in shallow retention and detention areas. Examples of DWM projects on public lands in the Lake Okeechobee Watershed are provided below. More information on projects located in the river watersheds are discussed in Chapter 10 of this volume.

Istokpoga Marsh Watershed Improvement District, Water Quality Improvement Project. The Istokpoga Marsh Watershed Improvement District (IMWID), Water Quality Improvement Project is located in Lake Placid. This project is designed as a stormwater recycling system that will afford opportunities to capture and store excess stormwater during wet periods reducing flows and nutrient loads to Lake Okeechobee and then return the stored water to the canal system providing a supplemental source of surface water to augment farm irrigation during dry times. The project includes the phased design and construction of 1,200 acres of above-ground impoundments that will reduce IMWIDs average annual discharge volume of stormwater by approximately 60 percent and may remove as much as 70 percent of the TP currently discharged to the Harney Pond Canal and subsequently to Lake Okeechobee. The first phase, a 300-acre, above-ground impoundment, is in the final stages of permitting and design. Construction and funding agreements with the IMWID, FDACS, SFWMD, and FDEP are in place.

Lemkin Creek Project. The Lemkin Creek project site is located in Okeechobee County west of the Town of Okeechobee. The site has several isolated lakes resulting from previous sand mining activities. A large-scale conceptual design that identifies mechanisms to connect these lakes to adjacent county canals via culverts with risers is complete. These interconnections will improve the connectivity between the adjacent canals and on-site lakes, taking advantage of the storage available in the lakes. Flow and retention of stormwater through these lakes will reduce TP loads within Lemkin Creek and Lake Okeechobee. The DWM Program is reviewing the site to identify interim improvements that provide near-term storage and load reduction benefits until funding for the final design and construction of the conceptual project is identified.

Avon Park Air Force Range Project. The Avon Park Air Force Range (APAFR) is located in Highlands County. The purpose of the project is to retain stormwater on-site. The project provides approximately 10,000 ac-ft of retention by restoring and improving an external levee and replacing existing culverts with new culverts and risers. Currently, the project is complete and is operational.

Sumica Project. The Sumica project is located in Polk County. The Sumica Preserve site is jointly owned by the District and the county, and the county manages the property. The purpose of the project is to retain water within the central marsh of the Sumica Preserve site to restore the hydroperiod of the marsh. This is being accomplished by constructing a rock riprap berm in front of the outfall structure at S.R. 60. The estimated retention volume is 281 ac-ft. Currently, this project is complete and is operational.

Storage and Retention Projects on Private Lands

Projects on private land enhance Lake Okeechobee and estuary health by reducing discharge volumes and nutrient loading to downstream receiving waters through modifications to existing water management structures and implementing operational strategies. In many cases, storage, retention and detention is obtained though the execution of cooperative agreements that maximize the benefits the project can provide. An example of a DWM project on private lands in the Lake Okeechobee Watershed is provided below. More information on projects located in the river watersheds are discussed in Chapter 10 of this volume.

Nicodemus Slough Project. The Nicodemus Slough project is located in Glades County just south of the portion of the Herbert Hoover Dike along Fisheating Creek and west of County Road 78. The purpose of the project is to provide retention of excess water from Lake Okeechobee on the 15,906-acre site. In general, excess water in Lake Okeechobee will be pumped into the project area to rehydrate the naturally occurring slough system and lessen the undesirable effects of excess water in the lake. The estimated retention volume is 34,000 ac-ft. The Section 404 permit from the USACE was issued in July 2013. Construction began in November 2013.

Northern Everglades Payment for Environmental Services

The coordinating agencies have expanded opportunities for DWM in the Northern Everglades watersheds whereby private landowners manage water on parts of their property to provide two different water management services: water retention/storage or nutrient [total phosphorus (TP) or total nitrogen (TN)] load reduction through the District's NE-PES Program. Solicitations released through this program allow for an innovative approach by offering eligible cattle ranchers the opportunity to compete for contracts for water and nutrient retention. The goal of the NE-PES Program is to establish relationships via contracts with private landowners to obtain the water management services of water retention and nutrient retention to reduce flows and nutrient loads to Lake Okeechobee and the estuaries from the watersheds. The NE-PES is a working program that keeps ranchers working and reduces pressure to convert ranchlands to development or other more intense agricultural uses. The District is responsible for administering this program in coordination with the FDACS, FDEP, and USDA NRCS.

As the basis for the NE-PES Program, the Florida Ranchlands Environmental Services Project was a five-year pilot project to field-test and develop a PES program. FRESP partners included eight ranchers, World Wildlife Fund, Florida Cattlemen's Association, FDACS, FDEP, University of Florida Institute of Food and Agricultural Services (UF/IFAS), USDA NRCS, MacArthur Agro-ecology Research Center, and SFWMD. Further details of the FRESP Program are provided in Section 5 of the 2011 LOWPP Update.

An example of a very successful FRESP project that has continued operation through an extended agreement is the West Waterhole Pasture Project. It is a 2,370-acre marsh located in Glades County that drains into the C-40 (Indian Prairie) Basin. The project's goal is to remove phosphorus from on-site water and regional water from the C-40 Canal by pumping canal water into the marsh and allowing the nutrients to be filtered out before gravity discharging back to the C-40 Canal. In 2012, a total of 4.9 billion gallons of water were pumped into the marsh. Forty percent of the total inflow volume was retained in the marsh. Monitoring data indicates that 7.8 mt of TP (88 percent of the total inflow) was retained in the marsh. Also, 43.5 mt of TN (59 percent of the total inflow) was retained in the marsh.

NE-PES Solicitations. The first NE-PES solicitation was released in January 2011 offering eligible cattle ranchers the opportunity to compete for contracts for water and nutrient retention. Eight water retention contracts were awarded as a result of that solicitation. Of those, seven are operational and one is under construction. The total estimated retention is 4,778 ac-ft.

The second NE-PES solicitation was released in December 2012, once again offering eligible cattle ranchers the opportunity to compete for contracts for water and nutrient retention. Nineteen submittals were received. The proposals have been evaluated and ranked based upon defined evaluation criteria. The SFWMD Governing Board, at its July 11, 2013 meeting, authorized agency staff to begin negotiating with the respondents in ranked order. The first two ranked projects, Blue Head Ranch and Mudge Ranch, have entered into agreements with the District for a total estimated retention volume of 3,858 ac-ft. Upon identification of additional funding, negotiations with respondents will continue in ranked order.

KISSIMMEE RIVER RESTORATION

The SFWMD is continuing to coordinate with the USACE on the Kissimmee River Restoration Project (KRRP). The first three construction phases of restoration, completed between 2001 and 2009, have reestablished flow to 24 miles of river channel and allowed intermittent inundation of 7,710 acres of floodplain. Construction activities in WY2013 are listed in Chapter 9 (**Table 9-2**) of this volume. The KRRP's success is being assessed through a comprehensive monitoring program using 25 performance measures to evaluate how well the project meets its ecological integrity goal. Evaluations of the river's response since the first phase of construction was completed in 2001 have found that many of these performance measures are already being met. Results of these evaluations have been published annually in the SFER since 2005. The WY2013 update, presented in Chapter 9, presents results from studies on hydrology, water quality (nutrients and dissolved oxygen), wading birds, and waterfowl.

EVERGLADES HEADWATERS NATIONAL WILDLIFE REFUGE AND CONSERVATION AREA

The Everglades Headwaters National Wildlife Refuge and Conservation Area (NWR) is part of an initiative of the U.S. Fish and Wildlife Service (USFWS) to preserve the natural resources and rural way of life in the Kissimmee River Valley (**Figure 8-9**). This multi-partnered effort will promote habitat conservation through land acquisition, permanent conservation easements, and agreements with willing landowners. The refuge and conservation area was authorized to protect 150,000 acres in the threatened grassland, long-leaf pine savanna, sandhill, and scrub landscapes north of Lake Okeechobee, through fee title acquisition and permanent conservation easements on private lands allowing continued cattle and agricultural production while preventing future commercial, industrial, and residential development.

Conserving and restoring the headwaters region of the Everglades will complement the efforts undertaken in CERP by enhancing water quality and quantity throughout the Everglades and protecting the water supply for millions of people. In addition, the region provides important habitat for 88 federal and state listed threatened or endangered species as well as state Species of Greatest Conservation Need. This project will benefit the environment and economy of the region by conserving ecologically significant lands and natural resources. The initial planning for this project began with a proposal (http://www.fws.gov/southeast/evergladesheadwaters/pdf/GEPIProjectProposal.pdf) developed by the USFWS in August 2010. The main entities in the effort include the FWC, USDA NRCS, U.S. Department of Defense, The Nature Conservancy, and National Wildlife Refuge Association.

The USFWS web site (http://www.fws.gov/southeast/evergladesheadwaters/) details the long-term vision of the NWR: "If fully realized, the refuge and conservation area will span 150,000 acres north of Lake Okeechobee. Two-thirds of the acreage, or 100,000 acres, will be protected through conservation easements purchased from willing sellers. With easements, private landowners would retain ownership of their land, as well as the right to work the land to raise cattle or crops. The easements would ensure the land could not be developed."

The U.S. Department of Interior previously announced the public planning and outreach for this effort in January 2011, and the USFWS has been coordinating with local landowners and interested parties over the last two years. This interaction has included stakeholder public meetings as well as the release of two reports that detailed a Final Land Protection Plan (http://www.fws.gov/southeast/planning/PDFdocsLandAcquisition/EvergladesHeadwatersLPPandEAfinal/FinalLPPEvergladesHeadwatersSized.pdf) and Environmental Assessment (http://www.fws.gov/southeast/evergladesheadwaters/). The USFWS concluded their planning efforts and formally established the Everglades Headwaters National Wildlife Refuge and Conservation Area on January 18, 2012, making this the 556th unit of the National Wildlife Refuge System. Currently, the USFWS is evaluating priority properties for acquisition, conducting market value appraisals, and preparing for the initial purchases of conservation easement and fee title acquisitions. Two local grass-roots groups—the Sportsman's Trust Group, leaders of many of the local outdoor recreational groups; and the Northern Everglades Alliance, landowners representing ranching and agricultural interests in the area—developed during the planning of this effort have been instrumental in developing broad-based support.

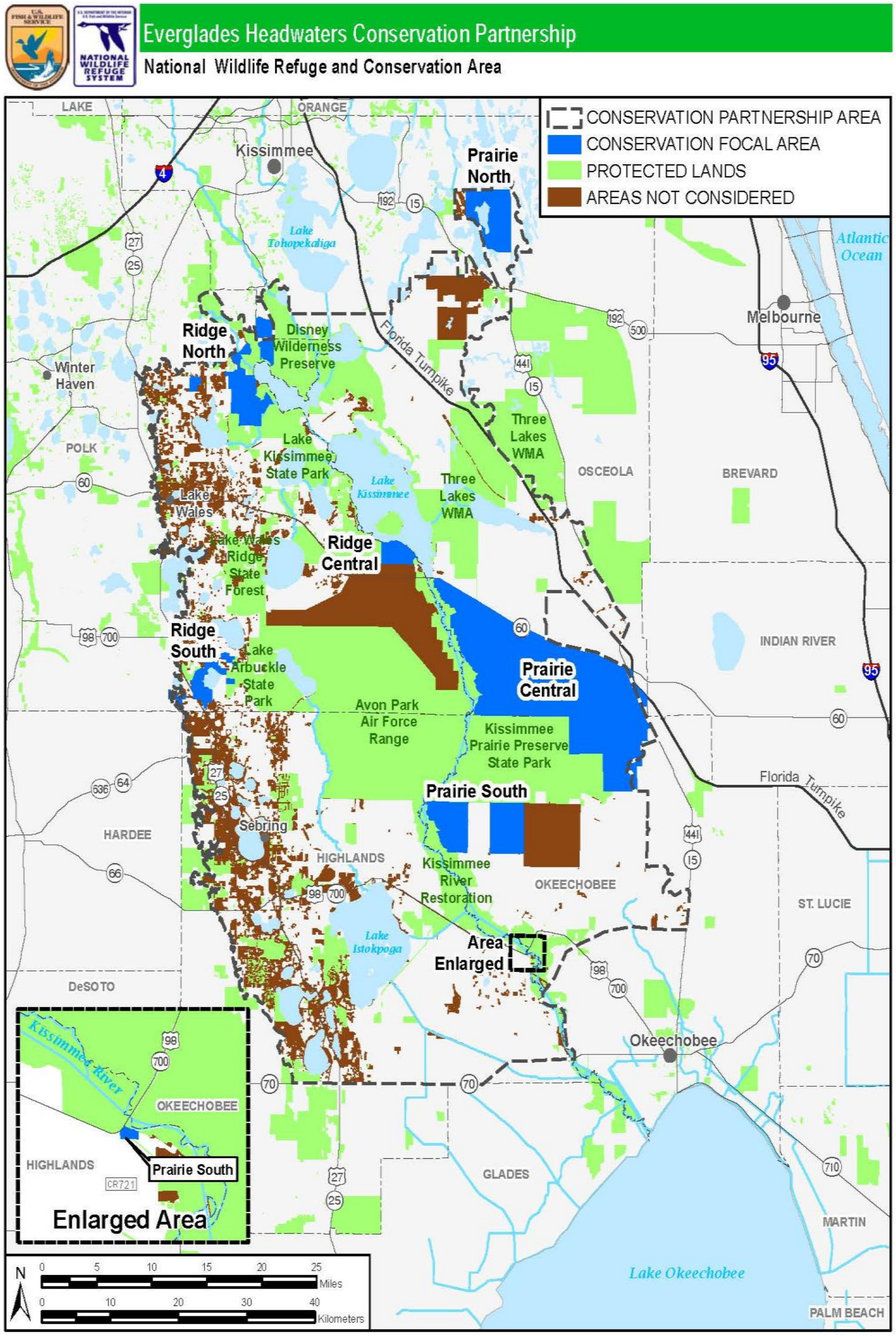


Figure 8-9. Everglades Headwaters Conservation Partnership, National Wildlife Refuge and Conservation Area.

PHOSPHORUS SOURCE CONTROL PROGRAM UPDATE SUMMARY

The Phosphorus Source Control Program is a multifaceted approach for improving the management of phosphorus sources within the watershed. Reducing phosphorus loads to reach the TMDL requirements necessitates actions at the source (on-site and sub-regional) and at local and regional scales. As source control is integral to the success of the Lake Okeechobee Watershed restoration program, the integrated management strategy of this plan is based on a foundation of phosphorus source control programs implemented by the coordinating agencies—the SFWMD, FDEP, and FDACS. Source control programs include BMPs, on-site treatment technologies, stormwater and wastewater infrastructure upgrades, and master planning through regulatory and cooperative programs focused on water quality and quantity. The loads remaining after the implementation of the source control programs will need to be addressed with local and regional downstream water quality improvement measures. Below is an update on recent source control activities and projects in the Lake Okeechobee Watershed to reduce TP loading to the lake since the 2011 LOWPP Update (SFWMD et al., 2011).

SFWMD PROGRAMS

According to the NEEPP, the multifaceted approach to reducing TP loads by improving the management of P sources within the watershed includes the implementation of regulations and BMPs and the development and implementation of existing BMPs. Chapters 40E-61 and 40E-63, Florida Administrative Code (F.A.C.), are long-standing regulations that establish criteria to ensure discharges from nonpoint agricultural and nonagricultural sources meet legislative objectives for water quality protection. The District continues to implement the mandated ERP and the Lake Okeechobee nutrient source control programs, which are described in further detail below. The District also collects water quality monitoring data at sites identified as key locations for tracking progress toward achieving water quality goals and identifying water quality concerns.

SFWMD Environmental Resource Permit Program

The District and FDEP are authorized to implement the ERP Program, which requires that new activities or modifications of existing activities provide reasonable assurances that they will not adversely affect the quality of receiving waters such that state water quality standards will be violated. In the Lake Okeechobee Watershed the existing ambient water quality does not meet standards, due to phosphorus impairment, In instances where an ERP applicant is unable to meet state water quality standards because existing ambient water quality does not meet standards and they system will contribute to this existing condition, the applicant must implement mitigation measures that are proposed by or acceptable to the applicant that will cause net improvement of the water quality in the receiving waters for those parameters that do not meet standards, pursuant to Rule 62-330.301(2), F.A.C. Additionally, an ERP applicant must demonstrate that the proposed activities will not cause "adverse water quantity impacts to receiving waters and adjacent lands and flooding to on-site or off-site properties, among other things (see Rule 62-330.301, F.A.C.). However, not all activities require ERP authorization. For example, certain agricultural activities may be exempt pursuant to Section 373.406, F.S. Additional ERP exemptions are set forth in Subsection 403.813(1), F.S., and Rule 62-330.051, F.A.C.

An annual update of the acres covered by District-issued permits by sub-watershed is provided in **Table 8-4** for the Lake Okeechobee Watershed. It should be noted that the projects are identified as Surface Water (SW) if they were issued before 1995 and ERP if issued after that time.

The Statewide ERP Rule (SWERP) became effective on October 1, 2013. The legislative mandate for this rulemaking provided that the individual water management districts maintain their existing water quality rules and their ability to promulgate future water quality rules. Therefore, only minor changes were made to the District's water quality rules. These rules are set forth in the ERP Applicant's Handbook, Volume II, for use within the geographical limits of the SFWMD. With regard to the future, proposed water quality rulemaking was included in the SFWMD Regulatory Plan filed in June 2013. It is anticipated that the rulemaking would be limited to an amendment to Part IV of the SFWMD'S ERP Applicant's Handbook, Volume II, to codify the existing guidance memorandum on water quality evaluations for discharges to outstanding Florida waters and water bodies that do not meet the state water quality standards.

Table 8-4. Acres of SFWMD-issued Environmental Resource Permit (ERP)/ Surface Water (SW) and Works of the District (WOD) permits by basin[1] in the Lake Okeechobee Watershed.

Basin	Total Acres with ERP/SW Permits	Percent of Total Acres	Total Acres with WOD Permits	Percent of Total Acres
Lake Okeechobee Watershed				
Upper Kissimmee	317,638	31%	0	0
Lower Kissimmee	191,383	45%	138,380	32%
Taylor Creek/Nubbin Slough (TCNS) S-133	10,373	40%	17,198	67%
TCNS S-135	9,925	56%	2,966	17%
TCNS S-154	11,467	36%	25,314	80%
TCNS S154C	0	0%	2,080	97%
TCNS S-191	27,107	23%	104,705	88%
Lake Istokpoga	36,877	9%	6,859	2%
Indian Prairie	187,398	68%	179,268	65%
Fisheating Creek	101,655	34%	244,587	82%
Nicodemus Slough	16,838	87%	17,866	92%
West Lake Okeechobee (WLO) S-4/Industrial Canal	12,199	29%	42,143	100%
WLO East Caloosahatchee	110,324	54%	32,961	16%
East Lake Okeechobee (ELO) C-44	88,934	67%	500	0%
ELO L-8	84,660	79%	4,566	4%
South Lake Okeechobee[2]	241,838	75%	310,839	97%
Total	**1,448,616**	**42%**	**1,130,231**	**33%**

[1] Overlapping ERP/SW records are not duplicated and the FDEP-issued permits are not included. Overlap may exist between ERP/SW and WOD permits. The ERP/SW permit GIS datasets are known to have missing applications between 1984 and 1994. The compilation of these missing applications is expected to be complete in WY2015. Until such time, acreage calculations may vary from year to year as data gaps are filled. 1 acre = 0.4047 hectares.

[2] Includes both 40E-61 and 40E-63, F.A.C, permits.

SFWMD Regulatory Phosphorus Source Control Programs

Lake Okeechobee Works of the District Rule

Chapter 40E-61, F.A.C., the Lake Okeechobee Works of the District (WOD) Rule, is the District's regulatory nutrient source control program for the lake. It was originally authorized by the Surface Water and Improvement Management Act (1987), which eventually became the NEEPP in 2007. The objective of the District's regulatory nutrient source control program is to ensure that the uses of Works of the District within the watershed are compatible with the District's ability to implement Chapter 373, F.S. The program is carried out through issuance of permits approving phosphorus control plans, performing inspections to verify compliance with permit conditions, monitoring water quality, prioritizing area of water quality concern, and providing incentives to users of WOD to implement additional water quality improvement activities. A breakdown of the acres covered by the District source control program in the Lake Okeechobee Watershed is provided in **Table 8-4** and maps are provided in Appendix 4-1 of this volume.

Because of supplemental requirements under the NEEPP, the rule must be amended. The focus of the SFWMD's initiatives during the three-year period covered by this update was on developing draft amendments to Chapter 40E-61, F.A.C., to meet the requirements of the NEEPP. Supporting documents and proposed draft rule amendments are under development by the coordinating agencies. In addition, sites are in place for the monitoring network to track progress towards achieving the water quality goals. More details on the District's regulatory nutrient source control program are provided in Chapter 4 of this volume.

Everglades Regulatory Source Control Program

A portion of the Southern Everglades Watershed overlaps the Lake Okeechobee Watershed boundary. As such, in addition to the Lake Okeechobee WOD Rule, the SFWMD also implements the Everglades Regulatory Source Control Program under Chapter 40E-63, F.A.C., which became effective in 1992 and was part of the Everglades Construction Project required under the Everglades Forever Act. The goal of this program is to reduce phosphorus in discharges from lands located in the Southern Everglades Watershed by mandating BMPs through permits and monitoring water quality to track progress towards meeting a quantitative performance measure. The Everglades Construction Project also required construction of projects (298 Diversion Projects) that diverted loads away from Lake Okeechobee. The majority of those loads are redirected south for treatment in Everglades Stormwater Treatment Areas prior to discharging to the Everglades Protection Area. These projects were completed and have resulted in substantially reduced TP loads to the lake from those areas.

Additionally, the success of source controls depends on routine verification of BMP implementation through on-site inspections, funding of research and demonstration projects to improve BMP effectiveness, and an education program that continuously provides feedback to permittees. Information exchange and sharing the latest phosphorus source control strategies, as they become available, will enable permittees to apply timely adaptive management to their BMPs. More details on this program are discussed in Chapter 4 of this volume and results of permitting and post-permit compliance activities for these areas are available to the public through e-permitting.

FDACS BEST MANAGEMENT PRACTICES PROGRAM

The NEEPP authorizes the FDACS to initiate rule development for BMPs, conservation plans, nutrient management plans, and other measures necessary for nutrient reduction in the Northern Everglades Watershed. In response, FDACS' Office of Agricultural Water Policy works with producers to develop, adopt, and implement agricultural BMPs specific to various agricultural commodities. Pursuant to the NEEPP, where FDACS has adopted agricultural nonpoint source BMPs or interim measures by rule, the owner or operator of an agricultural nonpoint source addressed by such rule shall either implement interim measures or BMPs, or demonstrate compliance with the District's WOD program under Chapter 40E-61, F.A.C., by conducting monitoring prescribed by the FDEP or the District.

Incentives for agricultural operations to enroll in FDACS BMP programs include a presumption of compliance with state water quality standards, pursuant to Chapter 403.067, F.S., and eligibility to participate in cost-share programs that provide assistance with the implementation of BMPs. The FDACS field staff and contractors also provide technical assistance with BMP implementation. Along with agricultural associations, the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Extension services, and others, FDACS holds BMP outreach events as needed or requested. UF/IFAS Extension independently holds frequent workshops on agricultural production and BMP-related topics.

A breakdown of the acres enrolled in the FDACS BMP program in the Lake Okeechobee Watershed is provided in **Table 8-5**. In the 2011 LOWPP Update, it was reported that approximately 1,317,133 acres of agricultural lands were enrolled in the FDACS program and, in this update, the enrollment is up to 1,595,033 acres, which is an increase of approximately 270,000 acres. It should be noted that due to differences in the GIS land use coverages, land use changes, and land uses categorized as agriculture, there is a difference in the agricultural acreage reported in this update and the 2011 update. More details on this program, including information on the FDACS Implementation Assurance Program, are discussed further in Chapter 4 of this volume.

The animal manure application rule became effective in February 2009. Provisions of this rule were modified slightly and incorporated into recent revisions of Chapter 5M-3, F.A.C.

Table 8-5. Acres and estimated percentage of agricultural land enrolled in BMP programs by sub-watershed in the Lake Okeechobee Watershed.

Basin	Agricultural Acres[1]	Total Acres Enrolled in FDACS BMP Program[2]	Percent NOI Enrollment
Lake Okeechobee Watershed			
Upper Kissimmee	316,637	102,788	32%
Lower Kissimmee	317,587	264,341	83%
Taylor Creek/Nubbin Slough (TCNS) S-133	14,896	10,548	71%
TCNS S-135	14,021	5,341	38%
TCNS S-154	27,427	23,981	87%
TCNS S-154C	2,100	2,075	99%
TCNS S-191	106,722	97,028	91%
Lake Istokpoga	193,093	142,405	74%
Indian Prairie	254,317	191,366	75%
Fisheating Creek	261,649	225,770	86%
Nicodemus Slough	18,424	17,910	97%
West Lake Okeechobee (WLO) S-4/Industrial Canal	34,649	27,359	79%
WLO East Caloosahatchee[3]	177,081	145,244	82%
East Lake Okeechobee (ELO) C-44	92,088	32,927	36%
ELO L-8	15,175	8,677	57%
South Lake Okeechobee	304,088	297,273	98%
Total	**2,149,954**	**1,595,033**	**74%**

[1] Agricultural acreages include Land Use Codes 2000-3210, 3300, and 4400-4430 and natural areas that are within NOI enrollment boundaries. Land use codes 2240 (Abandoned Groves), 3100 (Herbaceous Dry Prairie), 3200 (Upland Shrub and Brush land), and 3210 (Palmetto Prairies) are excluded where not covered by an NOI. Lake Istokpoga and Lower Kissimmee acreage includes Avon Park Air Force Range (code 1730) lands covered by NOI. Acreages calculated by the SFWMD.

[2] Notice of Intent (NOI) enrollment acreage data provided by the FDACS based upon the June 2013 enrollment database.

FDEP POLLUTANT SOURCE CONTROL PROGRAMS

The FDEP is responsible for point and nonpoint source control programs as outlined in the NEEPP and previous watershed protection plans (2012 SFER – Volume I, Chapter 4; 2011 LOWPP Update). These include programs such as the National Pollutant Discharge Elimination System (NPDES) permit program, regulation of biosolids and the ERP Program. Updated information on activities that have occurred since the 2011 LOWPP Update is provided below.

National Pollutant Discharge Elimination System Permit

The National Pollutant Discharge Elimination System (NPDES) is a federal program established by Section 402 of the Clean Water Act. The NPDES program requires point source dischargers to obtain permits that place limits on the type and quantity of pollutants that can be released into the nation's waters. The USEPA has delegated the authority to the FDEP to administer the NPDES permit program.

Municipal Separate Storm Sewer System Permit (MS4) Program

As the NPDES stormwater permitting authority, the FDEP is responsible for developing rules, issuing permits, managing and renewing permit applications, and performing compliance and enforcement activities for point source stormwater discharges to surface waters. NPDES permits issued by authorized states, including Florida, must be consistent with USEPA requirements.

Municipal Separate Storm Sewer Systems (MS4) are the most significant type of stormwater discharge regulated under the NPDES program, in terms of the area covered by each permit and the quantity of the stormwater discharge. An MS4 is a publicly owned conveyance or system of conveyances (ditches, curbs, catch basins, underground pipes, etc.) that is designed or used for collecting or conveying stormwater for discharge to surface waters of the state. MS4s can be operated by municipalities, counties, drainage districts and other special districts, colleges, military bases, or prisons. Coverage under NPDES permits, including MS4s, is issued for a maximum of five years and is renewable.

As implemented by Chapter 62-624, F.A.C., Phase I MS4 permits cover discharges of stormwater runoff from “medium” and "large" MS4s (i.e., those located in areas with populations of 100,000 or greater). Phase I MS4 permits require permittees and co-permittees to develop and implement a comprehensive stormwater management program to reduce pollutants in stormwater to the maximum extent practicable. Phase I MS4 permits also require permittees and co-permittees to identify, prioritize, and monitor certain representative major stormwater outfalls discharging to priority water bodies with either FDEP or USEPA TMDLs. These TMDL implementation requirements are established in the current permits for consistency with USEPA requirements. The ultimate object is, over time, to implement BMPs intended to meet an appropriate waste load allocation by reducing pollutant loading from the MS4 to the maximum extent practicable pursuant to adopted Phase I MS4 rules. Co-permittees are municipalities or other MS4 entities within the boundaries of a larger Phase I MS4 and are regulated under the same permit and have the same requirements as the larger Phase I MS4. Recently, Phase I permits have been reissued to Reedy Creek Improvement District in Orange County, the City of Orlando, and Polk County in the Lake Okeechobee Watershed.

Under Phase II, the NPDES program regulates discharges from certain MS4s not covered under Phase I that meet the criteria in Chapter 62-624, F.A.C. Like Phase I MS4s, regulated Phase II MS4s must develop and implement a comprehensive stormwater management program to reduce pollutants in stormwater discharge to the maximum extent practicable. Phase II MS4 permits cover smaller counties, municipalities, drainage districts and other special districts, colleges, military bases, or prisons. Since the 2011 Lake Okeechobee Protection Plan Update, Glades, Hendry, and Okeechobee Counties and the City of Clewiston now all have Phase II MS4 permit coverage.

Based on urbanized area data from the 2010 census, the USEPA identified small counties and municipalities nationwide as new Phase II MS4s. Highlands County, the City of Avon Park, and the City of Sebring have been designated new Phase II MS4s within the Lake Okeechobee Watershed. The FDEP has begun working with these and other newly designated small MS4s to help determine whether they will need to apply for Phase II MS4 permit coverage. If Phase II MS4 permit coverage is required, then the FDEP will continue to work with them to obtain coverage and implement a Stormwater Management Program under the permit.

Biosolids Rule

The Biosolids Rule, Chapter 62-640, F.A.C. was revised on August 29, 2010. The revision included requirements for site permitting, nutrient management plans, registration of Class AA biosolids distributed and marketed as fertilizer, and prohibition of land application of other types of biosolids (Class B) in the Northern Everglades watersheds unless a nutrient balance demonstration is completed by the applicant and approved by the FDEP. Since the rule has taken effect, none of the permits for the sites depicted in Chapter 4, Figure 4-7, of the 2012 SFER –

Volume I were renewed, and those sites are no longer active. In addition, no new permits have been issued within the Northern Everglades boundary since the rule revision.

FDEP Dairy Rule/Concentrated Animal Feeding Operations

Chapter 62-670, F.A.C., identifies feedlot and dairy wastewater treatment and management requirements. Agricultural operations regulated under Chapter 62-670, F.A.C., include concentrated animal feeding operations (CAFOs), dairy farms in the Lake Okeechobee Drainage Basin, and commercial egg production facilities. In 2003, the USEPA adopted the NPDES Permit Regulation and Effluent Limitation Guidelines and Standards for CAFOs. In December 2008, the USEPA revised the NPDES requirements for CAFOs and the FDEP has amended Rule 62-620.100, F.A.C., to incorporate by reference the current federal CAFO requirements. As part of the permitting requirements, each CAFO submits an annual report to the FDEP, which includes permitted herd size, average herd size, and nutrient balance summary (e.g., lists all nutrient imports and exports from the facility over the calendar year). All dairy CAFOs and one medium dairy AFO in the Lake Okeechobee Watershed are permitted under the NPDES program. However, the medium and small AFOs are not required to obtain NPDES permits under the CAFO rules.

The list of FDEP-permitted CAFOs was provided in 2011 LOWPP Update (Table A-4 in Appendix A). Since that time, no new CAFO permits were issued. All CAFOs listed in Table A-4 are current/renewed, except for Payson Park Thoroughbred Training Center, which is no longer required to have a CAFO permit due to reduction in animal counts. Therefore, the total number of CAFOs in the Lake Okeechobee Watershed as of this update is 22.

ENVIRONMENTAL RESOURCES PROGRAM

Statewide Environmental Resource Permitting

ERP applications within the Northern Everglades are processed either by the FDEP or District in accordance with an operating agreement between the agencies. The SWERP became effective on October 1, 2013. The legislative mandate for this rulemaking provided that the each water management district maintain their existing stormwater quality and quantity rules and their ability to promulgate future stormwater quality and quantity rules. Therefore, only minor changes were made to the District's stormwater quality and quantity rules. The SWERP rules are set forth in Chapter 62-330, F.A.C., the ERP Applicant's Handbook Volume I (General and Environmental), and the ERP Applicant's Handbook, Volume II, for use within the geographic limits of the SFWMD. The FDEP is not moving forward with the statewide stormwater ERP rule at this time.

OTHER PROGRAMS

Florida-Friendly Landscaping Program

The Florida-Friendly Landscaping Program is the overarching program that includes several sub-programs, including the Florida Yards and Neighborhoods Program, the Florida-Friendly BMPs for Protection of Water Resources by the Green Industries, and ordinance education. The 2011 LOWPP Update provides a list of the projects in the watershed in Table A-9 in Appendix A. To date, ordinances have been adopted in the Caloosahatchee River Watershed in Charlotte County, Cape Coral, Fort Myers, Lee County, Fort Myers Beach, and the City of Sanibel. In 2011, Charlotte County amended its ordinance to include a wet season blackout period as well as an annual nitrogen limit. In the St. Lucie River Watershed, local ordinances have been adopted for the City of Stuart, City of Port St. Lucie, Town of Sewall's Point, Martin County, and St.

Lucie County. In addition, the Florida Yards and Neighborhood Program has been expanded from the original homeowner approach to include a broader audience. Beginning January 1, 2014, a certification program will be required for any person applying commercial fertilizer to an urban landscape.

These water quality landscaping initiatives in urban environments would not be complete without a component to address golf courses. The Florida Golf Course Superintendents Association (FGCSA) has held four seminars over the past year and now has 60 superintendents certified in golf course BMPS. The FGCSA currently has four more seminars planned during July–September in St. Augustine, Wimauma, Orlando, and Naples. Seminars will also be held at the Florida Turf Grass Association Conference and Show in Orlando. Various organizations, such as the FDEP, University of Florida, and United States Golf Association present at these seminars.

Florida Department of Health

Subparagraph 373.4595(3)(c)7, F.S., requires all entities disposing of septage within the Lake Okeechobee Watershed to develop and submit to the Florida Department of Health (FDOH) an agricultural use plan that limits applications based upon phosphorus loading. An FDOH-regulated disposal site remained in the Lake Okeechobee Watershed as of April 2010, but has since been removed. As of this update, there remain no DOH-regulated land application sites in the Lake Okeechobee, St. Lucie River, or Caloosahatchee River watersheds.

WATERSHED ASSESSMENT, MONITORING AND RESEARCH

WATER QUALITY MONITORING

To achieve the NEEPP-required monitoring, the District monitors the water quality of inflows to and outflows from Lake Okeechobee at District-operated control structures and maintains a long-term water quality monitoring network within the Lake Okeechobee Watershed (**Figure 8-10**). This network is continuously reviewed for efficiency and to ensure all data objectives associated with legislatively mandated and permit required monitoring are being met. This enables stakeholders and the public to be kept informed about the progress of federally and state-funded restoration efforts. In addition, the District coordinates monitoring efforts with the FDACS, FDEP, and United States Geological Survey (USGS) to leverage monitoring sites and reduce duplication of efforts.

Figure 8-10. Locations of Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) water quality sampling stations under the ambient, tributary, and basin loading projects in the Lake Okeechobee Watershed.

The District's current monitoring network involves the collection of data from three hydrologic levels within the Lake Okeechobee Watershed: (1) sub-watershed and drainage basin level (basin loading stations), (2) sub-basin level (tributary and ambient stations), and (3) project/parcel/farm level (dairy stations). Load monitoring is conducted at stations at the sub-watershed and drainage basin level (basin loading stations). Basin loading stations are monitored for TP, TN, and flow. The Lake Okeechobee Operating Permit issued by the FDEP requires additional Class I/III water quality parameters be collected from 35 control structures with direct discharges into Lake Okeechobee. The sub-basin level concentration monitoring is conducted at ambient monitoring stations and tributary stations under three different projects: the ambient long-term trend projects, which are the Kissimmee River Eutrophication Abatement (KREA) and Taylor Creek Nubbins Slough (TCNS) projects and sites formerly part of the sub-basin loading project (OKUSGS). The collection and analysis of water quality from the OKUSGS sites is performed by the District and flow data are maintained at several of these sites by the USGS, under contract from FDACS. The Lake Okeechobee Watershed Assessment (LOWA) Project also monitors TP at the tributary level and is used to support the Works of the District BMP Program, Chapter 40E-61 F.A.C. (see Chapter 4 of this volume). The collection of data from project-specific, parcel- or farm-level monitoring (dairy monitoring stations) is the third tier of monitoring conducted under the umbrella of the watershed network. Data from all these monitoring efforts reside in the District's hydrometeorologic database (DBHYDRO) and are associated with the project names listed above in parentheses.

Total Phosphorus and Total Nitrogen Loads to Lake Okeechobee

TP loading rates into Lake Okeechobee have varied over time as a result of a combination of climatic conditions, land use changes, and changes in water management conditions. From WY1981–WY2013, the highest TP loading rate was 1,189 mt in WY1983, followed by 960 mt in WY2005, and 913 mt in WY1998 (**Table 8-6**). The highest five-year average load was 714 mt during the WY2002–WY2006 period of record (mainly due to the high discharges to the lake during the 2004 and 2005 hurricanes). The most recent five-year average load was 451 mt (WY2009–WY2013), which exceed the TMDL by 311 mt and was a 17 percent increase from 387 mt during the previous five-year period (WY2008–WY2012). This increase was a result of the increased load in WY2013. The five-year average from WY2007–WY2011 is the lowest average value since 1981 because it includes three of the driest years (WY2007, WY2008, and WY2011) since 1981.

The WY2013 TN load was estimated at 6,397 mt, an increase of 1,777 mt (38 percent) compared to the WY2012 load of 4,620 mt (**Table 8-7**). The WY2009–WY2013 TN load averaged 5,389 mt/yr, a 12 percent increase from the WY2008–WY2012 average of 4,788 mt/yr. As with TP load, this increase resulted from the increased load in WY2013. There is no in-lake goal for TN.

Table 8-6. Annual total phosphorus (TP) loads to Lake Okeechobee in metric tons (mt) from Water Years 1981–2013 (WY1981–WY2013) (May 1, 1980–April 30, 2013). [Note: NA – not available.]

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)[a,b] (mt)
1981	151	NA	NA
1982	440	NA	NA
1983	1,189	NA	NA
1984	369	NA	NA
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	384	244
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	534	394
2003	639	479	339
2004	553	527	387
2005	960	582	442
2006	795	714	574
2007	203	630	490
2008	246	551	411
2009	656	572	432
2010	478	476	336
2011	177	352	212
2012	377	387	247
2013	569	451	311

a. Includes an atmospheric load of 35 metric tons per year (mt/yr) based on the Lake Okeechobee Total Maximum Daily Load (TMDL) (FDEP, 2001).

b. Target is the Lake Okeechobee TMDL of 140 mt compared to a five-year moving average.

Table 8-7. Annual total nitrogen (TN) loads to Lake Okeechobee from WY2000–WY2012 (May 1, 1999–April 30, 2013). [Note: NA – not available.]

Water Year (May–April)	Measured TN Load (mt)	Long-Term TN Load (Five-Year Moving Average)[a] (mt)
2000	6,693	NA
2001	2,517	NA
2002	7,826	NA
2003	8,279	NA
2004	6,526	6,368
2005	8,775	6,785
2006	7,992	7,880
2007	2,965	6,907
2008	3,393	5,930
2009	6,689	5,963
2010	6,325	5,473
2011	2,913	4,457
2012	4,620	4,788
2013	6,397	5,389

a. Includes an atmospheric load of 1,233 mt/yr to account for atmospheric deposition

Total Phosphorus and Total Nitrogen Loading Data by Drainage Basin

Surface water flow and TP and TN loads to the lake for WY2013 were calculated for the major drainage basins using the basin loading stations. These calculations include discharges from Lakes Istokpoga and Kissimmee. These lakes are the outfalls of sub-watersheds that collect water flow and nutrient loads from smaller surrounding drainage basins (**Figure 8-10**). Data are based on monitoring stations where flow is continuously monitored and TP and TN samples are collected biweekly, based on flow, or monthly at a minimum. During WY2013, the TP load to the lake from all drainage basins and atmospheric deposition [estimated at 35 mt (FDEP, 2001)] was 569 mt (**Table 8-8**).

The largest surface water inflow came from the Upper Kissimmee Sub-watershed (above structure S-65), followed by the Lower Kissimmee and Indian Prairie sub-watersheds. The Upper Kissimmee Sub-watershed covers about 30 percent of the drainage area in the Lake Okeechobee Watershed, and contributed about 20 percent of total inflow during WY2013 (**Table 8-8**). The Lower Kissimmee Sub-watershed comprises 12 percent of the drainage area in the Lake Okeechobee Watershed and contributed about 20 percent of total inflow during WY2013. The Indian Prairie Sub-watershed covers eight percent of the drainage area in the Lake Okeechobee Watershed and discharged 14 percent of the total inflow in WY2013. The highest sub-watershed TP load came from the Taylor Creek/Nubbin Slough Sub-watershed (137 mt), followed by the Indian Prairie Sub-watershed (106 mt) and the Lower Kissimmee Sub-watershed (97 mt). The highest sub-watershed unit area load (UAL) of TP came from the Taylor Creek/Nubbin Slough Sub-watershed (1.53 lb/ac or 1.71 kg/ha), followed by the Indian Prairie Sub-watershed (0.84 lb/ac or 0.94 kg/ha) and the Lower Kissimmee Sub-watershed (0.50 lb/ac or 0.56 kg/ha) during WY 2013. In terms of FWM TP concentrations from sub-watersheds, the Taylor Creek/Nubbin Slough Sub-watershed had the highest value [533 micrograms per liter (µg/L), or parts per billion (ppb)], followed by the Indian Prairie Sub-watershed (286 ppb) and South Lake Okeechobee Sub-watershed (253 ppb) during WY2013.

Table 8-8. WY2013 surface water inflows (acre-feet, or ac-ft), TP loads (mt) and concentrations [micrograms per liter (µg/L, or parts per billion (ppb)], and unit area load (UAL) in pounds per acre (lb/ac) from the drainage basins to Lake Okeechobee.

Source	Area		Discharge		TP Load		Unit Load	Average TP Conc.
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppb)
East Lake Okeechobee Sub-watershed	**239,013**	**6.9**	**197,686**	**9.2**	**36.7**	**6.9**	**0.34**	**151**
C-44/S-153/Basin 8 (S-308 at St. Lucie Canal)	132,572	3.8	75,337	3.5	24.3	4.5	0.40	261
L-8 Basin (Culvert 10A)	106,440	3.1	122,350	5.7	12.5	2.3	0.26	83
Fisheating Creek Sub-watershed	**318,042**	**9.2**	**204,560**	**9.5**	**47.6**	**8.9**	**0.33**	**189**
Fisheating Creek at Lakeport/L-61W Basin	298,713	8.7	204,551	9.5	47.6	8.9	0.35	189
Nicodemus Slough North (Culvert 5)	19,329	0.6	9	0.0	0.0	0.0	0.00	383
Indian Prairie Sub-watershed	**276,577**	**8.0**	**299,311**	**13.9**	**105.8**	**19.8**	**0.84**	**286**
C-40 Basin [(S-72) – (S-68)]	24,076	0.7	33,224	1.5	17.0	3.2	1.55	414
C-41 Basin [(S-71) – (S-68)]	112,880	3.3	113,054	5.3	54.1	10.1	1.06	388
C-41A Basin [(S-84) – (S-68)]	57,748	1.7	62,654	2.9	11.3	2.1	0.43	146
L-48 Basin (S-127 total)	20,798	0.6	17,780	0.8	9.0	1.7	0.95	409
L-49 Basin (S-129 total)	11,966	0.3	7,903	0.4	0.7	0.1	0.13	71
L-59E Basin [(G-33)+(G-34)]	12,589	0.4	7,543	0.4	1.3	0.2	0.22	136
L-59W Basin (G-74)	6,596	0.2	25,660	1.2	7.4	1.4	2.46	232
L-60E Basin (G-75)	4,944	0.1	7,702	0.4	2.6	0.5	1.17	276
L-60W Basin (G-76)	3,453	0.1	4,515	0.2	0.9	0.2	0.58	164
L-61E Basin	14,407	0.4	14,796	0.7	1.3	0.2	0.20	71
S-131 Basin	7,122	0.2	4,480	0.2	0.3	0.1	0.09	52
Taylor Creek/Nubbin Slough Sub-watershed	**197,795**	**5.7**	**208,380**	**9.7**	**137.0**	**25.7**	**1.53**	**533**
S-133 Basin	25,626	0.7	23,227	1.1	9.7	1.8	0.83	338
S-135 Basin	17,756	0.5	16,317	0.8	1.9	0.4	0.23	94
S-154 Basin	31,815	0.9	52,305	2.4	42.6	8.0	2.95	660
S-154C Basin	2,134	0.1	2,820	0.1	3.7	0.7	3.82	1063
Taylor Creek/Nubbin Slough (S-191)	120,464	3.5	113,711	5.3	79.2	14.8	1.45	565
South Lake Okeechobee Sub-watershed	**363,141**	**10.5**	**93,047**	**4.3**	**29.0**	**5.4**	**0.18**	**253**
715 Farms (Culvert 12A)	3,353	0.1	0	-	0.0	0.0	0.00	no flow
East Beach Drainage District (Culvert 10)	6,657	0.2	2,000	0.1	1.2	0.2	0.39	475
East Shore Drainage District (Culvert 12)	8,409	0.2	3,920	0.2	1.0	0.2	0.25	201
Industrial Canal	13,024	0.4	15,148	0.7	3.0	0.6	0.51	160
S-2 Basin	106,274	3.1	38,636	1.8	15.5	2.9	0.32	325
S-3 Basin	63,134	1.8	5,180	0.2	1.0	0.2	0.04	162
S-4 Basin	29,121	0.8	26,631	1.2	6.8	1.3	0.52	208
South Florida Conservancy Drainage District (S-236)	9,931	0.3	421	0.0	0.1	0.0	0.01	101
South Shore/South Bay Drainage District (Culvert 4A)	4,036	0.1	441	0.0	0.1	0.0	0.05	152
S-5A Basin (S-352 West Palm Beach Canal)	119,202	3.5	670	0.0	0.4	0.1	0.01	452
West Lake Okeechobee Sub-watershed (S-77)	**204,094**	**5.9**	**5,070**	**0.2**	**0.4**	**0.1**	**0.00**	72
East Caloosahatchee Basin (S-77)	198,178	5.7	0	-	0.0	0.0	0.00	no flow
Nicodemus Slough South (Culvert 5A)	5,916	0.2	5,070	0.2	0.4	0.1	0.17	72
Lake Istokpoga Sub-watershed (S-68)	**394,203**	**11.4**	**280,540**	**13.0**	**31.8**	**6.0**	**0.18**	**92**
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	**429,188**	**12.4**	**423,814**	**19.7**	**96.5**	**18.1**	**0.50**	**185**
Upper Kissimmee Sub-watershed (S-65)	**1,028,421**	**29.8**	**439,646**	**20.4**	**48.7**	**9.1**	**0.10**	**90**
Totals from Lake Okeechobee Watershed	**3,450,475**	**100**	**2,152,054**	**100**	**534**	**100**	**0.34**	**201**
Atmospheric Deposition					35			
Total Loads to Lake Okeechobee					**569**			

Note: Values shown in this table only account for contributions from the basins to Lake Okeechobee. It does not capture contributions from these basins to other basins or other surface waters.

During WY2013, TN load to the lake from all drainage basins and atmospheric deposition (estimated as 1,233 mt) (James et al., 2005) was 6,397 mt (**Table 8-9**). The highest sub-watershed TN load came from the Indian Prairie Sub-watershed (999 mt), followed by the Lower Kissimmee and Upper Kissimmee sub-watersheds (826 and 659 mt respectively). The highest sub-watershed UAL came from the Indian Prairie Sub-watershed (7.96 lb/ac, or 8.92 kg/ha), followed by the Taylor Creek/Nubbin Slough Sub-watershed (5.84 lb/ac, or 6.54 kg/ha), and the Lower Kissimmee Sub-watershed (4.24 lb/ac, or 4.75 kg/ha). In terms of FWM TN concentrations from sub-watersheds, the South Lake Okeechobee Sub-watershed had the highest value [5.43 milligrams per liter (mg/L), or parts per million (ppm)], followed by the Indian Prairie Sub-watershed (2.71 ppm), and the Taylor Creek/Nubbin Slough Sub-watershed (2.04 ppm) during WY2013.

For the most recent 12-year period (calendar years 2001–2012), the average annual TP load to the lake from all drainage basins and atmospheric deposition was 547 mt (**Table 8-10**), and the average annual discharge to the lake was 2.36 million ac-ft. During this period, the largest surface water inflow came from the Upper Kissimmee Sub-watershed, followed by the Lower Kissimmee Sub-watershed and Lake Istokpoga Sub-watershed. The Indian Prairie Sub-watershed contributed the largest TP loads to the lake (103 mt), followed by the Taylor Creek/Nubbin Slough Sub-watershed (99 mt) and the Upper Kissimmee Sub-watershed (88 mt). The highest sub-watershed UAL TP load came from the Taylor Creek/Nubbin Slough Sub-watershed (1.10 lb/ac, or 1.23 kg/ha), followed by the Indian Prairie Sub-watershed (0.82 lb/ac, or 0.92 kg/ha) and Fisheating Creek Sub-watershed (0.49 lb/ac, or 0.55 kg/ha). In terms of FWM TP concentrations from sub-watersheds, the Taylor Creek/Nubbin Slough Sub-watershed had the highest value (558 ppb), followed by the Indian Prairie Sub-watershed (317 ppb) and Fisheating Creek Sub-watershed (234 ppb). There continues to be disproportionally high TP loads from Taylor/Nubbin, Indian Prairie, and Fisheating Creek sub-watersheds due to higher TP concentrations. The Upper Kissimmee and Lake Istokpoga sub-watersheds have displayed disproportionally low loads compared to flows due to lower TP concentrations.

The average annual TN load to the lake for the most recent 12-year period (calendar years 2001–2012) from all drainage basins and atmospheric deposition was 6,043 mt (**Table 8-11**). The Upper Kissimmee Sub-watershed contributed the largest sub-watershed TN loads to Lake Okeechobee, followed by the Indian Prairie and Fisheating Creek sub-watersheds. The highest sub-watershed UAL came from the Indian Prairie Sub-watershed (6.52 lb/ac, or 7.30 kg/ha), followed by the Taylor Creek/Nubbin Slough Sub-watershed (3.99 lb/ac, or 4.47 kg/ha) and Fisheating Creek Sub-watershed (3.46 lb/ac, or 3.88 kg/ha). In terms of FWM TN concentrations from sub-watersheds, the South Lake Okeechobee Sub-watershed had the highest value (3.93 ppm), followed by the Indian Prairie Sub-watershed (2.52 ppm) and the Taylor Creek/Nubbin Slough Sub-watershed (2.02 ppm).

Table 8-9. WY2013 surface water inflows (ac-ft), TN loads (mt) and concentrations [milligrams per liter (mg/L), or parts per million (ppm)], and UAL (lbs/ac) from the drainage basins to Lake Okeechobee.

Source	Area		Discharge		TN Load		Unit Load	Average TN Conc.
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppm)
East Lake Okeechobee Sub-watershed	**239,013**	6.9	**197,686**	**9.2**	**424.6**	**8.2**	**3.92**	**1.74**
C-44/S-153/Basin 8 (S-308 at St. Lucie Canal)	132,572	3.8	75,337	3.5	145.4	2.8	2.42	1.56
L-8 Basin (Culvert 10A)	106,440	3.1	122,350	5.7	279.2	5.4	5.78	1.85
Fisheating Creek Sub-watershed	**318,042**	9.2	**204,560**	**9.5**	**477.1**	**9.2**	**3.31**	**1.89**
Fisheating Creek at Lakeport/L-61W Basin	298,713	8.7	204,551	9.5	477.0	9.2	3.52	1.89
Nicodemus Slough North (Culvert 5)	19,329	0.6	9	0.0	0.0	0.0	0.00	3.81
Indian Prairie Sub-watershed	**276,577**	**8.0**	**299,311**	**13.9**	**998.8**	**19.3**	**7.96**	**2.71**
C-40 Basin [(S-72) – (S-68)]	24,076	0.7	33,224	1.5	141.8	2.7	12.98	3.46
C-41 Basin [(S-71) – (S-68)]	112,880	3.3	113,054	5.3	467.7	9.1	9.13	3.35
C-41A Basin [(S-84) – (S-68)]	57,748	1.7	62,654	2.9	171.9	3.3	6.56	2.22
L-48 Basin (S-127 total)	20,798	0.6	17,780	0.8	51.0	1.0	5.40	2.32
L-49 Basin (S-129 total)	11,966	0.3	7,903	0.4	16.7	0.3	3.08	1.71
L-59E Basin [(G-33)+(G-34)]	12,589	0.4	7,543	0.4	19.2	0.4	3.36	2.06
L-59W Basin (G-74)	6,596	0.2	25,660	1.2	62.9	1.2	21.01	1.99
L-60E Basin (G-75)	4,944	0.1	7,702	0.4	21.2	0.4	9.45	2.23
L-60W Basin (G-76)	3,453	0.1	4,515	0.2	10.4	0.2	6.63	1.86
L-61E Basin	14,407	0.4	14,796	0.7	28.2	0.5	4.31	1.54
S-131 Basin	7,122	0.2	4,480	0.2	7.9	0.2	2.45	1.43
Taylor Creek/Nubbin Slough Sub-watershed	**197,795**	**5.7**	**208,380**	**9.7**	**524.1**	**10.2**	**5.84**	**2.04**
S-133 Basin	25,626	0.7	23,227	1.1	50.1	1.0	4.31	1.75
S-135 Basin	17,756	0.5	16,317	0.8	34.8	0.7	4.33	1.73
S-154 Basin	31,815	0.9	52,305	2.4	143.3	2.8	9.93	2.22
S-154C Basin	2,134	0.1	2,820	0.1	9.3	0.2	9.63	2.68
Taylor Creek/Nubbin Slough (S-191)	120,464	3.5	113,711	5.3	286.6	5.6	5.24	2.04
South Lake Okeechobee Sub-watershed	**363,141**	**10.5**	**93,047**	**4.3**	**623.3**	**12.1**	**3.78**	**5.43**
715 Farms (Culvert 12A)	3,353	0.1	0	-	0.0	0.0	0.00	no flow
East Beach Drainage District (Culvert 10)	6,657	0.2	2,000	0.1	9.9	0.2	3.29	4.02
East Shore Drainage District (Culvert 12)	8,409	0.2	3,920	0.2	20.7	0.4	5.44	4.29
Industrial Canal	13,024	0.4	15,148	0.7	39.3	0.8	6.64	2.10
S-2 Basin	106,274	3.1	38,636	1.8	390.6	7.6	8.10	8.20
S-3 Basin	63,134	1.8	5,180	0.2	52.5	1.0	1.83	8.22
S-4 Basin	29,121	0.8	26,631	1.2	97.6	1.9	7.39	2.97
South Florida Conservancy Drainage District (S-236)	9,931	0.3	421	0.0	1.3	0.0	0.28	2.42
South Shore/South Bay Drainage District (Culvert 4A)	4,036	0.1	441	0.0	1.8	0.0	0.96	3.22
S-5A Basin (S-352 West Palm Beach Canal)	119,202	3.5	670	0.0	9.7	0.2	0.18	11.72
West Lake Okeechobee Sub-watershed	**204,094**	**5.9**	**5,070**	**0.2**	**8.5**	**0.2**	**0.09**	**1.36**
East Caloosahatchee Basin (S-77)	198,178	5.7	0	-	0.0	0.0	0.00	no flow
Nicodemus Slough South (Culvert 5A)	5,916	0.2	5,070	0.2	8.5	0.2	3.18	1.36
Lake Istokpoga Sub-watershed (S-68)	**394,203**	**11.4**	**280,540**	**13.0**	**622.7**	**12.1**	**3.48**	**1.80**
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	**429,188**	**12.4**	**423,814**	**19.7**	**825.6**	**16.0**	**4.24**	**1.58**
Upper Kissimmee Sub-watershed (S-65)	**1,028,421**	**29.8**	**439,646**	**20.4**	**658.9**	**12.8**	**1.41**	**1.21**
Totals from Lake Okeechobee Watershed	**3,450,475**	**100**	**2,152,054**	**100**	**5,164**	**100**	**3.30**	**1.95**
Atmospheric Deposition					1,233			
Total Loads to Lake Okeechobee					**6,397**			

Note: Values shown in this table only account for contributions from the basins to Lake Okeechobee. It does not capture contributions from these basins to other basins or other surface waters.

Table 8-10. Surface water inflows (ac-ft), TP loads (mt) and concentrations (ppb), and UAL (lb/ac) from the drainage basins to Lake Okeechobee for calendar years 2001–2012.

Source	Area		Discharge		TP Load		Unit Load	Average TP Conc.
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppb)
East Lake Okeechobee Sub-watershed	**239,013**	**6.9**	**124,121**	**5.3**	**26.5**	**5.2**	**0.24**	**173**
C-44/S-153/Basin 8 (S-308 at St. Lucie Canal)	132,572	3.8	55,687	2.4	19.0	3.7	0.32	277
L-8 Basin (Culvert 10A)	106,440	3.1	68,434	2.9	7.5	1.5	0.15	88
Fisheating Creek Sub-watershed	**318,042**	**9.2**	**243,180**	**10.3**	**70.3**	**13.7**	**0.49**	**234**
Fisheating Creek at Lakeport/L-61W Basin	298,713	8.7	239,932	10.2	69.8	13.6	0.52	236
Nicodemus Slough North (Culvert 5)	19,329	0.6	3,248	0.1	0.4	0.1	0.05	111
Indian Prairie Sub-watershed	**276,577**	**8.0**	**263,475**	**11.1**	**103.0**	**20.1**	**0.82**	**317**
C-40 Basin [(S-72) – (S-68)]	24,076	0.7	16,598	0.7	11.7	2.3	1.07	571
C-41 Basin [(S-71) – (S-68)]	112,880	3.3	65,047	2.8	42.6	8.3	0.83	531
C-41A Basin [(S-84) – (S-68)]	57,748	1.7	59,677	2.5	14.6	2.8	0.56	198
L-48 Basin (S-127 total)	20,798	0.6	10,794	0.5	4.0	0.8	0.43	303
L-49 Basin (S-129 total)	11,966	0.3	11,213	0.5	1.4	0.3	0.26	104
L-59E Basin [(G-33)+(G-34)]	12,589	0.4	38,220	1.6	8.1	1.6	1.42	172
L-59W Basin (G-74)	6,596	0.2	20,979	0.9	12.2	2.4	4.08	472
L-60E Basin (G-75)	4,944	0.1	7,181	0.3	1.9	0.4	0.85	215
L-60W Basin (G-76)	3,453	0.1	2,499	0.1	0.6	0.1	0.39	197
L-61E Basin	14,407	0.4	22,645	1.0	4.3	0.8	0.66	153
S-131 Basin	7,122	0.2	8,621	0.4	1.5	0.3	0.46	139
Taylor Creek/Nubbin Slough Sub-watershed	**197,795**	**5.7**	**143,780**	**6.1**	**98.9**	**19.3**	**1.10**	**558**
S-133 Basin	25,626	0.7	15,578	0.7	6.6	1.3	0.57	345
S-135 Basin	17,756	0.5	16,574	0.7	2.7	0.5	0.33	131
S-154 Basin	31,815	0.9	24,373	1.0	21.7	4.2	1.50	721
S-154C Basin	2,134	0.1	3,379	0.1	2.8	0.5	2.85	661
Taylor Creek/Nubbin Slough (S-191)	120,464	3.5	83,876	3.5	65.2	12.7	1.19	630
South Lake Okeechobee Sub-watershed	**363,141**	**10.5**	**96,297**	**4.1**	**19.7**	**3.8**	**0.12**	**166**
715 Farms (Culvert 12A)	3,353	0.1	821	0.0	0.1	0.0	0.06	no flow
East Beach Drainage District (Culvert 10)	6,657	0.2	1,229	0.1	0.7	0.1	0.24	470
East Shore Drainage District (Culvert 12)	8,409	0.2	2,750	0.1	0.6	0.1	0.15	174
Industrial Canal	13,024	0.4	19,861	0.8	4.2	0.8	0.71	171
S-2 Basin	106,274	3.1	27,854	1.2	5.1	1.0	0.11	148
S-3 Basin	63,134	1.8	13,736	0.6	1.7	0.3	0.06	99
S-4 Basin	29,121	0.8	21,656	0.9	6.2	1.2	0.47	234
South Florida Conservancy Drainage District (S-236)	9,931	0.3	6,879	0.3	0.9	0.2	0.19	103
South Shore/South Bay Drainage District (Culvert 4A)	4,036	0.1	1,455	0.1	0.2	0.0	0.12	118
S-5A Basin (S-352 West Palm Beach Canal)	119,202	3.5	56	0.0	0.0	0.0	0.00	452
West Lake Okeechobee Sub-watershed	**204,094**	**5.9**	**57,611**	**2.4**	**9.8**	**1.9**	**0.11**	**138**
East Caloosahatchee Basin (S-77)	198,178	5.7	34,086	1.4	6.2	1.2	0.07	no flow
Nicodemus Slough South (Culvert 5A)	5,916	0.2	23,525	1.0	3.6	0.7	1.34	124
Lake Istokpoga Sub-watershed (S-68)	**394,203**	**11.4**	**273,600**	**11.6**	**34.8**	**6.8**	**0.19**	**103**
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	**429,188**	**12.4**	**335,257**	**14.2**	**62.0**	**12.1**	**0.32**	**150**
Upper Kissimmee Sub-watershed (S-65)	**1,028,421**	**29.8**	**826,015**	**35.0**	**87.5**	**17.1**	**0.19**	**86**
Totals from Lake Okeechobee Watershed	**3,450,475**	**100**	**2,363,336**	**100**	**512**	**100**	**0.33**	**176**
Atmospheric Deposition					35			
Total Loads to Lake Okeechobee					**547**			

Table 8-11. Surface water inflows (ac-ft), TN loads (mt) and concentrations (ppm), and UAL (lb/ac) from the drainage basins to Lake Okeechobee for calendar years 2001–2012.

Source	Area		Discharge		TN Load		Unit Load	Average TN Conc.
	(acres)	(%)	(ac-ft)	(%)	(mt)	(%)	(lb/ac)	(ppm)
East Lake Okeechobee Sub-watershed	**239,013**	6.9	**124,121**	**5.3**	**298.3**	**6.2**	**2.75**	**1.95**
C-44/S-153/Basin 8 (S-308 at St. Lucie Canal)	132,572	3.8	55,687	2.4	125.6	2.6	2.09	1.83
L-8 Basin (Culvert 10A)	106,440	3.1	68,434	2.9	172.7	3.6	3.58	2.05
Fisheating Creek Sub-watershed	**318,042**	9.2	**243,180**	**10.3**	**498.7**	**10.4**	**3.46**	**1.66**
Fisheating Creek at Lakeport/L-61W Basin	298,713	8.7	239,932	10.2	495.8	10.3	3.66	1.68
Nicodemus Slough North (Culvert 5)	19,329	0.6	3,248	0.1	3.0	0.1	0.34	0.74
Indian Prairie Sub-watershed	**276,577**	**8.0**	**263,475**	**11.1**	**818.2**	**17.0**	**6.52**	**2.52**
C-40 Basin [(S-72) – (S-68)]	24,076	0.7	16,598	0.7	78.4	1.6	7.18	3.83
C-41 Basin [(S-71) – (S-68)]	112,880	3.3	65,047	2.8	308.1	6.4	6.02	3.84
C-41A Basin [(S-84) – (S-68)]	57,748	1.7	59,677	2.5	171.4	3.6	6.54	2.33
L-48 Basin (S-127 total)	20,798	0.6	10,794	0.5	27.8	0.6	2.94	2.08
L-49 Basin (S-129 total)	11,966	0.3	11,213	0.5	22.4	0.5	4.13	1.62
L-59E Basin [(G-33)+(G-34)]	12,589	0.4	38,220	1.6	102.0	2.1	17.87	2.16
L-59W Basin (G-74)	6,596	0.2	20,979	0.9	51.2	1.1	17.11	1.98
L-60E Basin (G-75)	4,944	0.1	7,181	0.3	13.7	0.3	6.13	1.55
L-60W Basin (G-76)	3,453	0.1	2,499	0.1	4.7	0.1	3.01	1.53
L-61E Basin	14,407	0.4	22,645	1.0	20.8	0.4	3.18	0.74
S-131 Basin	7,122	0.2	8,621	0.4	17.7	0.4	5.48	1.66
Taylor Creek/Nubbin Slough Sub-watershed	**197,795**	**5.7**	**143,780**	**6.1**	**358.1**	**7.4**	**3.99**	**2.02**
S-133 Basin	25,626	0.7	15,578	0.7	34.8	0.7	2.99	1.81
S-135 Basin	17,756	0.5	16,574	0.7	32.3	0.7	4.01	1.58
S-154 Basin	31,815	0.9	24,373	1.0	64.0	1.3	4.44	2.13
S-154C Basin	2,134	0.1	3,379	0.1	9.0	0.2	9.25	2.15
Taylor Creek/Nubbin Slough (S-191)	120,464	3.5	83,876	3.5	218.0	4.5	3.99	2.11
South Lake Okeechobee Sub-watershed	**363,141**	**10.5**	**96,297**	**4.1**	**467.0**	**9.7**	**2.83**	**3.93**
715 Farms (Culvert 12A)	3,353	0.1	821	0.0	4.4	0.0	2.90	no flow
East Beach Drainage District (Culvert 10)	6,657	0.2	1,229	0.1	6.8	0.1	2.24	4.47
East Shore Drainage District (Culvert 12)	8,409	0.2	2,750	0.1	18.5	0.4	4.85	5.46
Industrial Canal	13,024	0.4	19,861	0.8	67.6	1.4	11.44	2.76
S-2 Basin	106,274	3.1	27,854	1.2	171.8	3.6	3.56	5.00
S-3 Basin	63,134	1.8	13,736	0.6	69.9	1.5	2.44	4.12
S-4 Basin	29,121	0.8	21,656	0.9	84.0	1.7	6.36	3.15
South Florida Conservancy Drainage District (S-236)	9,931	0.3	6,879	0.3	36.2	0.8	8.03	4.26
South Shore/South Bay Drainage District (Culvert 4A)	4,036	0.1	1,455	0.1	7.0	0.1	3.84	3.91
S-5A Basin (S-352 West Palm Beach Canal)	119,202	3.5	56	0.0	0.8	0.0	0.01	11.72
West Lake Okeechobee Sub-watershed	**204,094**	**5.9**	**57,611**	**2.4**	**123.6**	**2.6**	**1.33**	**1.74**
East Caloosahatchee Basin (S-77)	198,178	5.7	34,086	1.4	71.2	1.5	0.79	no flow
Nicodemus Slough South (Culvert 5A)	5,916	0.2	23,525	1.0	52.4	1.1	19.51	1.80
Lake Istokpoga Sub-watershed (S-68)	**394,203**	**11.4**	**273,600**	**11.6**	**496.2**	**10.3**	**2.78**	**1.47**
Lower Kissimmee Sub-watershed [(S-65E) - (S-65)]	**429,188**	**12.4**	**335,257**	**14.2**	**490.7**	**10.2**	**2.52**	**1.19**
Upper Kissimmee Sub-watershed (S-65)	**1,028,421**	**29.8**	**826,015**	**35.0**	**1258.7**	**26.2**	**2.70**	**1.24**
Totals from Lake Okeechobee Watershed	**3,450,475**	**100**	**2,363,336**	**100**	**4,810**	**100**	**3.07**	**1.65**
Atmospheric Deposition					1,233			
Total Loads to Lake Okeechobee					**6,043**			

Ambient Water Quality Data Analysis

The long-term tributary or ambient water quality stations under projects KREA and TCNS consist of river and basin-level monitoring locations that are sampled on a biweekly flow-only basis. This analysis also considers concentration data from tributary level monitoring sites collected under project OKUSGS, which was initiated in 2005 (**Figure 8-10**). It is also important to note that the tributary concentration stations for C-41 and C-41A are located well upstream compared to the basin loading stations discussed earlier. TP and TN concentrations are collected at these 39 monitoring stations. The ambient water quality network has primarily focused on the assessment of those basins considered critical to the nutrient concentration issues in the Lake Okeechobee Watershed (**Figure 8-10**). Additional water quality assessment in the watershed is done under the LOWA monitoring network. These monitoring sites support the Works of the District BMP Program (Chapter 40E-61, F.A.C.) and the results of these efforts are discussed in Chapter 4 of this volume.

The statistical summaries shown in **Tables 8-12** and **8-13** also include concentration data from sites established for the Lake Okeechobee Tributary Loadings (OKUSGS) Project. This project was formally run by the USGS under contract from the District, FDACS, and USACE and consisted of 16 locations equipped with automatic samplers programmed to collect flow proportional samples. This project has been reduced over the years and now consists of two sites with automatic samplers collecting on a timed program and twelve of the original stations are sampled via grab collections. Flow data at 15 sites are being maintained by the USGS under contract from the FDACS. Future reporting will summarize loadings from these tributary sites once there is enough long-term data to establish statistical significance and the historical data are verified by the District.

The basic statistics for WY2013 TP concentration data by basin from the 39 ambient sites are presented in **Table 8-12**. For comparison purposes, data from seven-year averages for WY2006–WY2012 are also included. Due to its size and the number of monitoring stations, the S-191 Basin (Taylor Creek/Nubbin Slough) is further divided into two sub-basins: Taylor Creek (S-191TC) and Nubbin Slough (S-191NS). Most of the high concentrations for all tributary sites were observed in September, October, and November 2012. The first samples for this water year were collected after an average of 10 months of no observed flows at most sites. This indicates that the first few flushes after extended periods with no flow are still consistently exhibiting very high TP concentrations in many of the critical basins. Many of the higher concentration data points observed for WY2013 in the Lake Okeechobee Watershed were collected during the hydrologic time frame of Tropical Storm Isaac that delivered over 5 inches of rain on average District-wide.

TN values are calculated by adding nitrate + nitrite (NO_x) and total Kjeldahl nitrogen (TKN) concentrations. There is no FDEP-approved method for maintaining TN samples in an unrefrigerated environment over a seven-day period, so TN data collected via the automatic sampler should be viewed as experimental. The period of record for total nitrogen was lacking from several of the basins and this data may help to provide preliminary insight into additional sources of nitrogen in the watershed. The majority of TN in the Lake Okeechobee Watershed comes from the organic form of N (TKN). **Table 8-13** shows statistics of WY2013 TN data collected from the ambient network.

Table 8-12. Statistics of TP data collected from the ambient network in the Lake Okeechobee Watershed. WY2013 values are included to show annual changes.

BASIN	WY2006 to WY2012 (TP)					WY2013 (TP)				
	Mean (ppb)	Median (ppb)	Number of Samples	Max (ppb)	Min (ppb)	Mean (ppb)	Median (ppb)	Number of Samples	Max (ppb)	Min (ppb)
C-41	255	184	177	970	27	211	147	14	610	87
C-41A	57	54	111	121	16	80	77	82	158	26
Fisheating Creek	216	190	380	790	17	199	208	16	262	108
Lake Istokpoga	109	87	286	474	26	105	77	95	378	32
S-65A	75	67	330	271	23	67	57	47	195	25
S-65BC	83	71	324	273	22	72	59	48	181	44
S-65D	255	186	782	1,471	11	164	104	68	642	24
S-65E	379	226	200	2,859	23	639	277	43	3,330	38
S-154	575	454	246	2,330	14	865	839	25	1,412	343
S191TC (Taylor Creek)	413	332	1,304	2,049	14	484	422	108	1,623	113
S-191NS (Nubbin Slough)	394	379	565	2,390	10	417	320	69	1,216	104

Table 8-13. Statistics of TN data collected from the ambient network in the Lake Okeechobee Watershed. WY2013 values are included to show annual changes.

BASIN	WY2006 to 2012 (TN)					WY2013 (TN)				
	Mean (ppm)	Median (ppm)	Number of Samples	Max (ppm)	Min (ppm)	Mean (ppm)	Median (ppm)	Number of Samples	Max (ppm)	Min (ppm)
C-41	2.29	1.96	184	5.90	0.15	2.23	2.05	14	4.35	1.19
C-41A	1.47	1.45	86	2.27	0.88	1.73	1.66	36	2.63	1.20
Fisheating Creek	2.39	2.05	360	7.90	0.29	2.21	2.16	15	2.98	1.55
Lake Istokpoga	1.42	1.39	255	2.43	0.46	1.30	1.29	36	1.75	1.02
S-65A	1.34	1.25	327	2.87	0.77	1.37	1.34	48	3.23	0.77
S-65BC	1.29	1.19	324	2.38	0.58	1.26	1.17	48	1.95	0.98
S-65D	1.65	1.58	755	6.47	0.49	1.44	1.43	68	2.07	0.82
S-65E	2.12	1.93	203	4.76	0.45	2.68	1.96	42	12.65	0.50
S-154	2.26	2.20	241	4.75	0.06	2.55	2.52	25	3.88	1.74
S-191TC (Taylor Creek)	2.02	1.85	1,255	8.79	0.14	2.66	2.27	108	11.62	0.67
S-191NS (Nubbin Slough)	2.18	2.03	546	10.83	0.57	2.12	2.13	69	4.05	0.70

REEVALUATION OF WATER RETENTION/STORAGE NEEDS

The NEEPP recognizes the importance of managing the quantity, timing, and distribution of water from the three Northern Everglades watersheds to achieve the integrated and comprehensive environmental restoration of Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries. As a result, analysis has been conducted for each of the three protection plans to determine the amount of water that needs to be stored in each watershed to achieve these objectives. In the Lake Okeechobee Phase II Technical Plan (LOP2TP), an analysis was conducted to calculate the amount of water storage needed in the Lake Okeechobee watershed to better manage water levels in Lake Okeechobee and reduce excess damaging freshwater releases to the estuaries. This analysis included several critical assumptions including: no additional water can be sent south, water supply for existing users must be maintained, and additional storage will be needed in each of the estuary watersheds to address local basin runoff. Based on these assumptions, modeling analyses conducted using the Northern Everglades Regional Simulation Model (NE-RSM) indicated that approximately 900,000-1,300,000 ac-ft of storage was needed in the Lake Okeechobee watershed to help manage lake levels and reduce discharges to estuaries. The analysis indicated there was a breakpoint between 900,000 and 1,300,000 ac-ft of storage, above which additional increases in storage capacity would provide relatively small improvements in damaging releases to estuaries.

Since the time of the original LOP2TP storage analysis, several other regional planning efforts have been conducted that have also evaluated flow and storage needs north or south of Lake Okeechobee. For example, during the River of Grass Phase I planning effort, it was recognized that additional flows to the south, specifically to Everglades National Park and Florida Bay, were desirable. In recognition of this increased demand for flows south, screening level modeling analyses were conducted to evaluate varying volumes of storage north and south of Lake Okeechobee. The River of Grass modeling indicated that approximately 700,000-1,100,000 ac-ft of storage was needed in the Northern Everglades and EAA. The analysis also showed that there are certain combinations of storage north and south of the lake that perform better at environmental objectives, such as managing lake levels and reducing harmful discharges to the estuaries, and that approximately 450-575,000 ac-ft of storage is needed north of Lake Okeechobee. More recently, the Central Everglades Planning Project (CEPP) has evaluated sending an additional 200,000 average annual ac-ft of Lake Okeechobee water to the south through a series of new project features. The modeling conducted for CEPP indicated that the proposed project features and operations could significantly reduce damaging discharges to the estuaries.

It is clear from all of these modeling efforts that additional storage is needed in the Everglades system and most analyses seem to indicate that at least a million additional acre-ft of storage is needed throughout the system. The CRWPP and SLRWPP indicate that 400,000 and 200,000 ac-ft of storage are needed in each of these watersheds respectively in order to address local basin runoff, while the magnitude of storage needed in the Lake Okeechobee watershed varies depending on assumptions regarding delivery and storage volumes south of Lake Okeechobee. Regardless of the assumptions used, it is evident that the Lake Okeechobee watershed still needs significantly more storage, on the order of several hundred thousand ac-ft or more. This storage will need to be accomplished through a strategic combination of dispersed and regional storage distributed throughout the watershed. As new information becomes available, additional analyses will be conducted for the Lake Okeechobee watershed to refine storage volume targets and evaluate various combinations of dispersed and regional storage.

RESEARCH AND ASSESSMENT

The District, in cooperation with the FDACS, FDEP, UF/IFAS, and other agencies and interested parties, has implemented a comprehensive research and assessment program for the Lake Okeechobee Watershed. Nine research, demonstration, and assessment projects were under way or completed in WY2013 (**Table 8-14**). Two of these projects (one completed and one ongoing) are highlighted in detail in this section. More information on the other projects can be found on the District's website at www.sfwmd.gov/okeechobee.

Table 8-14. Status of Lake Okeechobee Watershed research, demonstration, and assessment projects during WY2013.

Project Name (Investigator)	Major Objectives and Results	Status
Nutrient Budget Tool Upgrade and Calibration (JGH Engineering)	The purpose of this project was to 1) make the nutrient budget tool compatible with ArcGIS 10.1; 2) evaluate and correct differences between Watershed Assessment Model (WAM) output and monitoring data in the Upper Kissimmee Sub-watershed; and 3) incorporate extended WAM model runs. The previous calibration of this Sub-watershed in 2009 only included flow and water quality data at the outfall, structure S-65. This updated calibration was much more detailed and was able to assess several factors that are more prevalent in this region including the high percentages of urban land uses and the presence of a large system of lakes. The high differences observed prior to this calibration were most likely due to assumptions regarding onsite urban retention/detention and the handling of wastewater treatment. As a result, TP from urban areas was too high and the lake attenuation in the system was over-compensating. The model was re-calibrated and the measured and observed annual averages matched reasonably well. The District will use the tool to analyze and evaluate nutrient management alternatives for this Sub-watershed.	Complete
Apple Snail Stocking	As an adjunct to ongoing experiments designed to identify a cost effective method for producing large numbers of native apple snails eggs and/or juveniles for stock enhancement efforts in Lake Okeechobee and other water bodies that constitute critical habitat for the federally endangered Everglade snail kite (Rostrhamus sociabilis plumbeus) apple snail stocking experiments in large scale enclosures open to natural predation have been initiated. Initial results indicate that it is possible to reliably establish populations of native apple snails from hatchery-produced animals stocked at relatively low densities. More details will be available once detailed analysis of the data is completed.	Ongoing
PN-Budget Tool Applications in the Upper Kissimmee Sub-watershed (SFWMD)	The overall goal of this project is to apply the PN-Budget tool to the Upper Kissimmee Sub-watershed to identify the hydrologic and loading data needed to develop a nutrient budget for the Upper Chain of Lakes. PN-Budget tool can be used to evaluate various P control programs to maximize water quality improvements from a drainage area. Specific objectives are to (1) select the area of interest (AOI) based on the reaches and monitoring locations that need to be studied, (2) compare the AOI results with the available monitoring data and adjust the model inputs if needed; and (3) obtain nutrient loading data needed for the lake nutrient budget analysis. The project is scheduled to be completed by September 2014.	Ongoing
New Treatment Technologies	Seven technologies were selected from 12 responses received to two Request-for-Proposal solicitations issued by the District. An eighth technology, Ferrate, was evaluated in conjunction with a demonstration conducted by Highlands County. A ninth technology, AquaLutions™, was tested under a separate contract with the District as was the mineral-based product WP-1™ at one location (Blue Heron Pond). Field tests were conducted for AquaLutions™, Ferrate and two applications of WP-1™. The following technologies were also evaluated in jar tests: Phoslock®, STI, ViroPhos™ and WP-1™, or at bench-top scale (Electrocoagulation). The assessment of treatment performance for each technology was based on a comparison of before-application versus after-application constituent levels, and all technologies were able to reduce total phosphorus and total nitrogen to varying degrees. The demonstrations were of short duration and limited scope and should be regarded as screening efforts to characterize the treatment potential of each technology. These limitations, coupled with the fact that the nutrient content of the waters tested varied considerably among demonstrations, that the field demonstrations had no control to compare against the application treatment and that results are from a mixture of field and laboratory studies precludes quantitative cross-comparisons among technologies such as contrasting the magnitude of constituent change, calculating meaningful removal rate constants (i.e., k values), determining the cost per pound of P removed or assessing long-term treatment efficacy.	Ongoing

Table 8-14. Continued.

Project Name (Investigator)	Major Objectives and Results	Status
Lake Okeechobee Pre-drainage Characterization	The Lake Okeechobee Pre-drainage Characterization Project uses the Watershed Assessment Model (WAM) to compare existing hydrological conditions with historical conditions that existed before significant human influences took place (i.e., pre-drainage 1850s). Pertinent literature describing pre-drainage conditions was reviewed and relevant data incorporated into WAM in preparation for the pre-drainage condition model runs. The coordinating agencies determined that before proceeding with comparing pre-drainage and existing hydrological conditions on all five sub-watersheds, the WAM Sensitivity and Uncertainty analysis should be completed. During the sensitivity and uncertainty analyses, WAM will be recalibrated resulting in increased confidence of the modeled pre-drainage and existing hydrological conditions.	Ongoing
The Fisheating Creek Feasibility Study	The Fisheating Creek Feasibility Study involves formulation, evaluation, and selection of the most appropriate mix of storage and water quality features to improve hydrology and water quality in the Fisheating Creek Sub-watershed. Planning targets for achieving surface water storage and quality improvements (TP load reduction) were also established through analyzing pre-drainage and existing conditions outputs from WAM simulations in close coordination with stakeholders and other agencies. The next step is to locate conceptual water quality and storage features. The Natural Resources Conservation Service is currently developing the Fisheating Creek Special Wetland Reserve Project (WRP), which involves large tracts of lands located north of State Road 70 that account for approximately 18 percent of the total sub-watershed area. It is important to account for all upcoming hydrological improvement projects in the Fisheating Creek Watershed in order to adequately characterize the additional features that will be needed to meet study goals. Postponing the study until WRP details are available and incorporating them into the FEC FS will allow this to occur. It is anticipated that the necessary data will be available in 2014, at which time the District may resume the project in FY2015 once this information is available and after WAM enhancements are completed under the Lake Okeechobee Pre-drainage Characterization project mentioned above.	Ongoing
Permeable Reactive Barrier (PRB) Technology [University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS)]	Permeable reactive barriers (PRBs) are a proven technique for groundwater remediation. The components of a PRB include a trench dug perpendicular to the groundwater flow direction and to a depth appropriate to the groundwater contamination problem of interest. The trench generally is filled with sorbents such as water treatment residuals (WTRs), aluminum and iron oxide compounds, and low cost materials available locally. Selected materials for PRB construction should have high affinity for P, long term stability, and appropriate hydraulic characteristics to enable adequate water flow. Sorbent materials may be combined with higher permeability materials (such as soils collected from on-site) as necessary and the combined materials tested to assess phosphorus stability. For this project aluminum-base water treatment residuals (Al-WTRs) were tested for the interception and long-term sequestration of soluble subsurface-P in the Lake Okeechobee Watershed. Al-WTRs from six different water treatment facilities across South Florida were tested, with the feasibility study completed in December 2009. PRB design and laboratory testing of the different WTRs was completed in September 2010. Due to material availability and P sorption capacity, an Al-WTR from Manatee County water treatment facility was selected to be tested in this study. In April 2011, two buried-wall PRBs were installed in the high intensive area of the former Rofra Dairy (presently Candler Ranch), which took part in the District buyout program in 1987. Monitoring results at the Candler Ranch experimental site in Okeechobee County were completed in January 2012, and the results showed that the PRB was functioning chemically as designed, but the site hydrology was not suitable for PRB implementation. A second PRB was installed in August 2012 at a more suitable location at Butler Oaks Ranch in Highlands County to better evaluate the effectiveness of this technology. However, due to some problems with the multi-level sampling wells during the 2012 rainy season, monitoring has been extended through September 30, 2013.	Ongoing

Table 8-14. Continued.

Project Name (Investigator)	Major Objectives and Results	Status
Development of Markers to Identify Nutrient Sources Impacting Florida's Surface Water Bodies	The main purpose of this study was to investigate and develop potential analytical marker(s) to use as tools in the identification of different sources of nutrients [primarily nitrogen (N) and phosphorus (P)] to Florida's waters. This study conducted a large assessment of N and P at water reuse plants to estimate potential nutrient mass loading from municipal waste reuse plants in Florida. A short-list of differentiation markers was developed to determine their ability to identify nutrient sources from municipal reclaimed water, stormwater, and septic tanks. The short-listed markers were then put through a series of both "bench-top" and field analyses and a "reconnaissance tool" was constructed to assess nutrient loading to water bodies. Sucralose was identified as a successful environmentally conservative marker specific to wastewater sources. The use of a gadolinium (Gd) anomaly/sucrose ratio showed the potential to differentiate between reuse effluent and septic tank sources; however, further research is needed to validate this technique. Overall, the study proposes a potentially useful assessment strategy for determining nutrient sources to Florida's waters. These promising tools and strategy, however, remain in a conceptual stage until additional studies build upon the initial findings. Ongoing investigations to build upon the initial report are under way and consist of field demonstration work in the Gordon River Watershed (Collier County) in Southwest Florida. This current effort is part of a FDEP nutrient source tracking study in the Everglades West Coast Basin and also includes some focused literature review as well as stakeholder outreach to work towards the continued development of robust markers to identify nutrient sources in Florida's waters.	Initial Report Complete, Follow-up Studies Ongoing
WAM Sensitivity and Uncertainty Analysis	This project involves implementing the two remaining recommendations for enhancing WAM that are included in the "*Peer Review of the Watershed Assessment Model (WAM)* (Graham et al., 2009). The two recommendations for enhancing WAM are the performance of a sensitivity analysis and an uncertainty analysis. All the other five recommendations by the peer review panel have been completed. As part of implementing the sensitivity and uncertainty analyses, WAM will be recalibrated resulting in increased confidence of the model's results, it will add a margin-of-safety value derived through a formal uncertainty analysis and the sensitivity analysis will allow us to identify the model's most sensitive parameters which can then be refined as appropriate,	Start in FY2014
Evaluation of Storage and Water Quality Alternatives at the Grassy Island and Brady Ranch Properties	The objective of this study is evaluate water quality and storage options for the District's Taylor Creek/Grassy Island and Brady Ranch properties located in the Taylor Creek/Nubbin Slough Sub-watershed. The District is planning to conduct hydrological modeling in 2014.	Ongoing

Nutrient Budget Tool Upgrade and Calibration

The nutrient budget tool, known as PN-Budget, is being applied to the Upper Kissimmee Sub-watershed to identify the hydrologic and loading data needed to develop a nutrient budget for the Upper Chain of Lakes. PN-Budget can also be used to evaluate various P control measures to estimate water quality improvement from a drainage area. In 2005, a geographic information system (GIS)-based Graphical User Interface (GUI) called P-Budget was developed for analyzing phosphorus load and import/export in the LOPP area (JGH Engineering, 2005). The area spans from just south of Orlando to areas bordering the lake on the south, east, and west and covers approximately 5,400 square miles. In 2010, the GUI was modified and renamed PN-Budget, to include nitrogen and updated to incorporate new nutrient budget coefficients and default land use parameters (The HDR Team, 2010). Since 2010, the District has upgraded ArcGIS to include several changes to their ArcObjects programming library. The PN-Budget tool includes a dynamic link to the Watershed Assessment Model (WAM) which is used to estimate annual nutrient loads in runoff and attenuated discharges in the hydrologic network. The tool includes the ability to compare monitoring data at specific hydrologic reaches. Some reaches within the Upper Kissimmee region have shown poor comparisons prompting the need to evaluate these areas in more detail and perform model recalibration. The overall objective of this project was to upgrade the software to work under the new ArcGIS platform and calibrate the model to match the monitoring data collected within the Upper Kissimmee Sub-watershed. The summary provided below was obtained from the final report by JGH Engineering (2013).

Model calibration was performed using measured data supplied by the District for TP monitoring sites located within the Upper Kissimmee Sub-watershed. These data were reviewed and average annual values were calculated using samples taken within the modeling period of record, which spans from January 2006–December 2010. The first step in the model calibration process, however, is to compare flow rates at flow monitoring sites which generally correspond to District control structures. Although this project only includes calibration of the Upper Kissimmee Sub-watershed, it was decided that the sites used in the original calibration would be used along with some additional Upper Kissimmee Sub-watershed sites. Flow information was obtained from the District's DBHYDRO database for sites that can be attributed to a single upstream drainage area. Some sites can reflect alternate drainage areas depending on upstream controls on systems such as the C-41A Canal, which can be diverted to the C-40 and C-41 Canals. PN-Budget is an average annual model that does not reflect the daily operation of control structures. Also, some structures could not be used because of other inflows or outflow in or out of the basin that are not monitored. For example under certain conditions, water is allowed to overflow the lock near the S-133 pump station, but the flow at the lock is not monitored. Therefore, the overall discharge is not completely known.

Because the model output is in cubic meters per year (m^3/yr), the monitored flow data were converted from cfs/day to m^3/yr and averaged for the five-year modeling period. There were several sites in the Upper Kissimmee Sub-watershed that could not be used because of significant gaps in the data, including S-59, S-60, S-61, and S-63A. S-62 was used, but it should be noted that 34 days of the modeling period were missing. The sites chosen for flow (Q) are shown in **Figure 8-11**. There are generally two factors that can be adjusted in the model to calibrate flow rates. Evapotranspiration (ET) and off-site groundwater exchanges (recharge and seepage). ET is a straightforward global parameter that was adjusted slightly after reviewing basins such as S-191, which is not significantly influenced by the other calibration factor, i.e., groundwater exchanges.

Previous modeling efforts by Soil and Water Engineering Technology, Inc. (SWET) found that groundwater along a ridge on the western side of the Upper Kissimmee and Lake Istokpoga Sub-watersheds flows to the west outside of the study area. Similarly, some groundwater along the northern and northeastern boundary of the Upper Kissimmee Sub-watershed also flows out of the basin. A dataset was provided by SWET showing the locations of these zones, which in the full version of WAM is used as a groundwater zone assignment to reaches for which these zones were assigned to offsite reaches. In PN-Budget, the same effect is achieved by setting the model output grid called perc to zero in these areas. Normally, groundwater volumes in the perc grid reemerge in the same hydrologic reach as the surface water. The dataset was adjusted slightly until a reasonable fit was achieved in matching the monitoring data.

Seepage from Lake Okeechobee is another factor that must be considered, since the lake levels are normally staged higher than the surrounding near-shore basins. A buffer of approximately 2,000 feet was created around the lake and the corresponding values in the perc grid were raised by a calibrated factor until matching results were achieved with the surrounding flow stations. It should be noted that basins adjacent to the lake also have culvert connection, which allow gravity flow primarily for irrigation into the basins. The S-127 and S-135 pump flow data were adjusted to account for the culvert connections so that the model results could be compared to the net flow monitored out of the those basins. **Figure 8-11** shows the areas of offsite groundwater recharge and lake seepage used for the model.

Considering the completeness of the flow monitoring data at the chosen sites, a goal was set to match the model flow output to within 10 percent of the monitoring data. As the model relies on rainfall data points that have been spatially distributed using the Thiessen method, exact matches cannot be expected. After achieving reasonable fit with the ET and groundwater adjustments, there were areas that did not meet the goal, which required examining the physical data represented in the model. Flows in urban areas were generally too high. As a result, model parameters for onsite retention/detention were adjusted to assume that more urban land uses had such systems. This was an appropriate assumption considering that most of the development in these areas was constructed within the last 30 years, after water management rules for retention/detention were implemented.

After some additional revisions to the extent of the off-site groundwater recharge, the goal of matching the flow to within 10 percent was achieved at all monitoring locations except at S-62 (too high) and S-63 (too low). This indicated a potential problem with the routing within the model. High definition aerials were reviewed and it was found that some of the area draining to S-62 is most likely draining to S-63 (see cross-hatched area in **Figure 8-12**). There are lakes and sloughs in that area that were not represented in the reach network. The reach network was revised, requiring that all the preprocessed distance grids had to be re-created using WAM's setup routines. After this change, flows matched within 10 percent of measured data (**Table 8-15**).

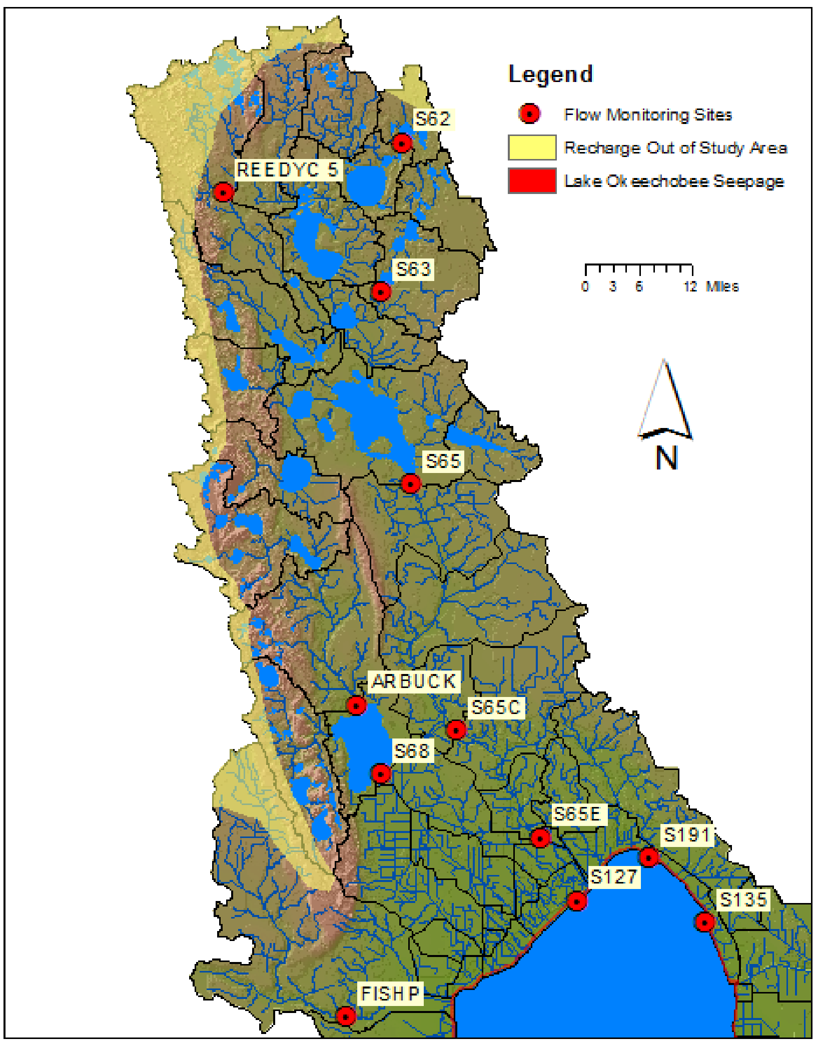


Figure 8-11. Flow monitoring stations, off-site recharge and lake seepage zones.

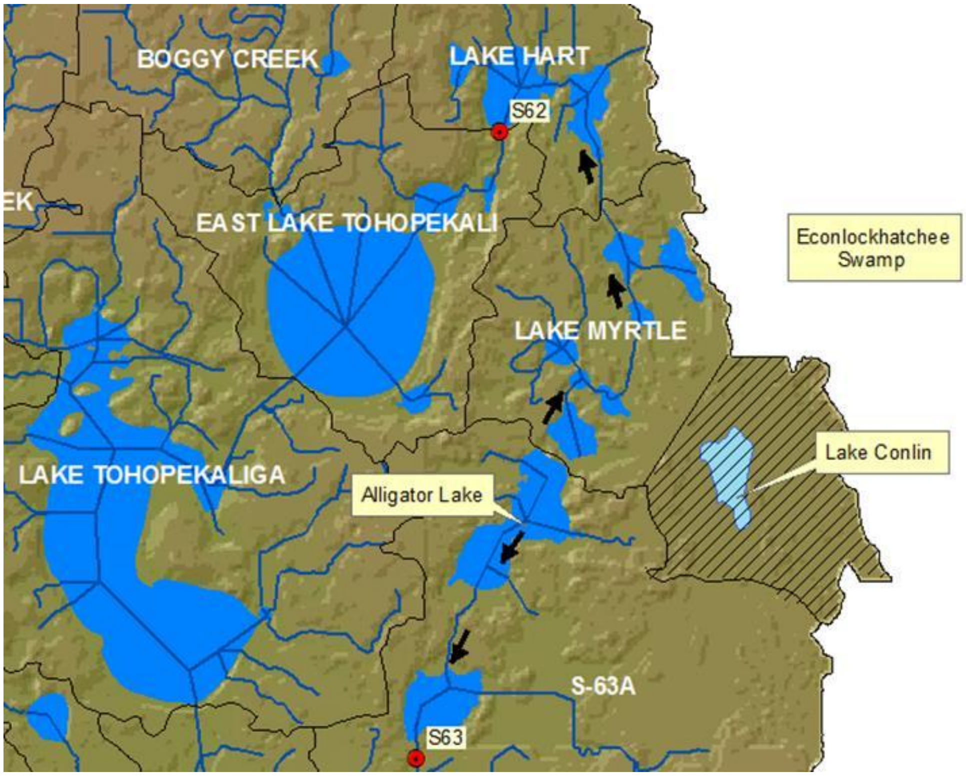


Figure 8-12. Reach network and drainage area revision.

Table 8-15. Summary of flow calibration results in annual volume from 2006–2010.

WAM Reach	Structure	Average Annual Flow (m^3x10^3) Modeled	Measured	Difference
153	S65E	904,762	832,875	8.6%
272	S65C	824,025	801,245	2.8%
409	S191	58,242	57,794	0.8%
498	S135	8,486	8,675	-2.2%
582	S127	9,534	9,604	-0.7%
764	FISHP	141,493	129,947	8.9%
2002	S68	180,166	183,028	-1.6%
2069	ARBUCK	143,778	136,959	5.0%
3002	S65	638,720	681,897	-6.3%
3085	S63	40,288	43,485	-7.4%
3135	S62	31,588	29,111	8.5%
3376	REEDYC 5	38,090	38,068	0.1%

An initial review of the model results found that drainage areas dominated by urban land uses exhibited high TP concentrations compared to the observed monitoring data for those locations. High concentrations at the sources (pre-attenuation) were observed for residential land uses compared to other land uses. To correct this, model parameters associated with wastewater treatment assumptions were adjusted to include more residential land uses under full treatment as opposed to secondary treatment which returned treated flow back into the hydrologic network. This is more consistent with the research and assumptions of past P budget studies and effectively reduced the concentrations at those sources. It also reduced flow from those areas and required minor readjustments to the extent of the offsite groundwater recharge.

Despite the changes to the urban areas, a wide disparity still existed when comparing the modeled TP concentrations to the monitoring data across the watershed. Several steps were taken to reduce the differences. It should be noted, however, that it is much more difficult to match TP data than it is to match the flow volumes. The PN-Budget model is limited to an average annual analysis as opposed to the full version of WAM which includes dynamic daily routing. Most of the District control structures in the Upper Kissimmee Sub-watershed are seasonally operated which cannot be simulated in PN-Budget. The model also has to rely on globally set assumptions for land uses. Actual land use practices, such as fertilization, will vary across the Sub-watershed. The sites used in the calibration for TP are shown in **Figure 8-13**. The monitoring frequency should be considered. Of the 1826 days in the model run period, an average of only 48 samples were taken because they are typically only sampled when flow is present. The temporal distribution of the TP data was analyzed and some sites were found to only include data in one or two years of the five-year period. These low data sites were not used in the calibration. Another site, CL06283121, was also not used because of observed turbidity in the area during the period of record cause by nearby construction. Measured TP at the site was four to five times higher than other upstream and downstream monitoring sites. Another limitation of the monitoring data is that the calculated annual average concentration is not flow-weighted at most locations, where only six of the 19 sites coincided with flow monitoring sites. Annual average concentrations were recalculated using the flow data available. BS-59 only included two data points that corresponded to recorded flow and, therefore, the FWM value was not used.

To provide greater flexibility in calibrating the attenuation process, the attenuation algorithm in PN-Budget was modified. Previously, attenuation was applied in two sequential processes—overland flow and stream/lake/slough flow. To account for the influences of the three reach types (stream, lake, or slough), weighted coefficients are used to reflect the relative influence of the reach types based on the length of each reach type. Riparian wetlands were handled by adding those flow lengths to the sloughs in the reach attenuation.

To better represent the attenuation, it was decided to expand the attenuation from two processes (overland and stream/slough/lake reaches) to four processes (overland/wetland, slough reaches, stream reaches, and lake reaches). A sensitivity analysis found that the effects of the riparian wetlands were reduced by being combined with the slough reaches. Therefore, it was combined with the overland flow process. Subdividing the three different reach types also provided the ability to set different background concentrations for each reach type.

These changes improved the results. However, despite several efforts to adjust the attenuation coefficients, some disparity in the results when compared to the monitoring data was still found. Review of the monitoring data showed that the lakes in the Upper Kissimmee Sub-watershed appear to have widely varying background concentrations of TP that range from 20 ppb in the upstream lakes to 60 ppb in Lake Kissimmee at the downstream portion of the sub-watershed. Background concentrations are very important because they form a limit on how far a concentration can be attenuated downward or upwards if the concentration entering the system is lower than the system's background concentration. The attenuation algorithm was subsequently revised to include individual background concentrations for certain lakes within the hydrologic network. After several trial runs using adjusted attenuation coefficients, the results are obtained and comparisons are shown in **Table 8-16**.

For reasons previously stated, closer matches to the measured data cannot be expected. The previous calibration of this Sub-watershed in 2005 only included flow and water quality data at the sub-watershed's outfall structure, S-65. This updated calibration was much more detailed and was able to assess several factors that are more prevalent in this region including the high percentages of urban land uses and the presence of a large system of lakes. The high differences observed prior to this calibration were most likely due to assumptions regarding onsite urban retention/detention and the handling of wastewater treatment. As a result, TP from urban areas was still too high and the lake attenuation in the system was over-compensating. The separation of the attenuation processes has simplified the process of determining and adjusting the related coefficients during calibration.

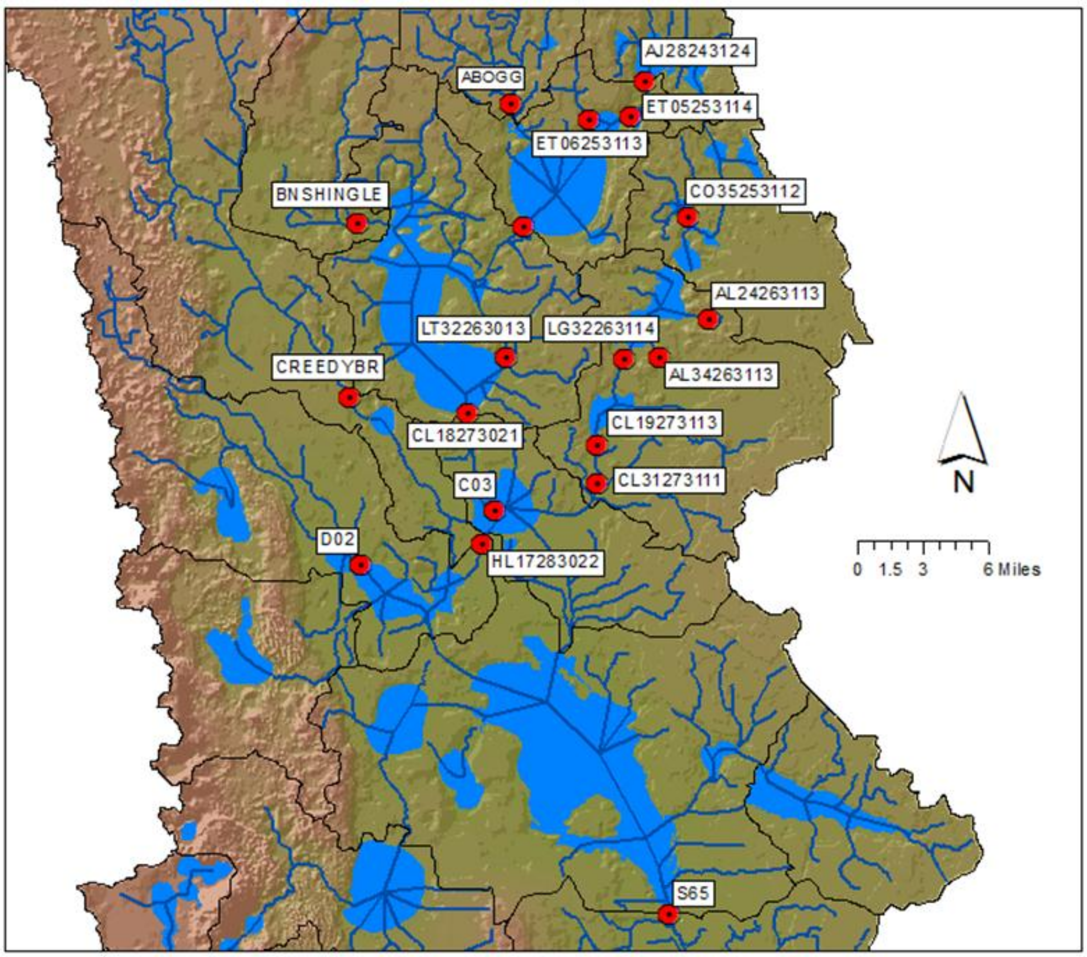


Figure 8-13. TP sampling sites used for model calibration.

Table 8-16. TP calibration results in average annual concentration.

WAM Reach	Station	No of Samples	Drainage Area (ha)	Average Annual Conc. (ppb)	
				Modeled	Measured
3002	S65	89	416,556	49	57
3065	D02	58	300,447	48	54
3066	HL17283022	64	173,620	51	72
3067	C03	58	172,723	51	73
3082	CL31273111	24	31,262	58	87
3084	CL19273113*	27	30,754	41	35
3091	LG32263114*	22	19,006	35	30
3093	AL34363113	67	3,726	64	32
3094	AL24263113	55	10,056	59	30
3104	CL18273021*	49	125,732	52	56
3112	LT32263013	54	2,053	107	164
3127	BS-59	24	59,211	27	21
3132	ET05253114	43	24,853	36	41
3135	AJ28243124*	21	23,433	29	31
3151	CO35253112	56	3,862	61	61
3167	ET06253113	79	1,435	86	79
3175	ABOGG	38	20,260	76	36
3247	BNSHINGLE	45	33,123	74	65
3317	CREEDYBR	35	62,763	37	130

*Sampling taken on downstream side of structure.

Evaluation of New Alternative Treatment Technologies

The coordinating agencies have been evaluating alternative water quality treatment technologies in both the STAs and the Northern Everglades for almost two decades, and are often approached by individuals and firms with proposals for improving regional water quality, prompting the need for a structured process to learn about and evaluate these technologies. In an effort to evaluate unsolicited proposals, the District provided opportunities for the individuals and firms to demonstrate their potential technologies for reducing TP or TN loading in both surface waters and sediments, and focused on any source that would be subject to agency interest/regulation—estuaries, canals, Lake Okeechobee discharges, and soil inactivation. All the products and processes were initially vetted with a pre-determined set of evaluation criteria by a team of District staff, and the test sites were either District-owned, or cooperating landowner properties. No dedicated funding was provided, although the District has provided support by contributing staff time and the analysis of water quality samples by the District's Chemistry Laboratory. The vendor bore all other costs associated with conducting demonstrations. This effort evolved into a product screening process and was not intended to be a research and development process for the vendors. A technical publication on this effort is currently being developed (Chimney et al., 2013).

A total of seven technologies were selected for evaluation from a pool of 12 responses received in response to solicitations issued by the District. Two of the technologies, Ferrate and AquaLutions™, were evaluated under separate agreements with Highlands County and the District, respectively. The selected technologies were generally categorized as flow- through processes (Ferrate, AquaLutions, and Electrocoagulation) or mineral-based product applications

(Phoslock™, WP1™, STI, and ViroPhos™). Field tests were conducted for AquaLutions™, Ferrate, and WP-1™. Two of the applications are discussed in further detail below.

AquaLutions™ Technology. The state-funded AquaFiber Technologies Corporation (AquaFiber) of Winter Park, FL to conduct a pilot study to assess the treatment efficacy of their patented technology (AquaLutions™) to remove TP and TN from surface waters at two sites along the Caloosahatchee River. AquaFiber deployed their AquaKnight™, a mobile treatment unit that housed the AquaLutions™ treatment technology for a period of five days at each test site: November 26–30, 2012 at the first test site, and December 3–7, 2012 at the second test site. Water was pumped at rates between 4,700 and 9,900 gal/day from near-shore locations directly into the AquaKnight™ for treatment over three consecutive days (deployment days 2, 3, and 4) at each test site. AquaFiber staff adjusted the AquaLutions™ process during this time to optimize nutrient removal efficiency. AquaLutions™ was very effective at removing all forms of P, including TP, where 89 and 96 percent of inflow TP concentrations were removed at test sites 1 and 2, respectively. AquaLutions™ was moderately effective at removing TN, TKN, TDKN, TON, and DON, where 36 and 55 percent of inflow TN concentrations were removed at test sites 1 and 2, respectively. AquaLutions™ was not very effective at reducing concentrations of NO_X or NH_4 at either test site. Outflow SO4 concentrations more than doubled at both test sites compared to their respective inflow concentrations. AquaLutions™ removed virtually all the chlorophyll *a* and much of the chlorophyll *b* and pheophytin *a* at both test sites. Correspondingly, turbidity was substantially reduced at both test sites. AquaLutions™ caused a slight increase in specific conductivity and a slight decrease in pH at both test sites. [Note that the operating principals behind the AquaLutions™ treatment technology are not publically available due to a confidentiality agreement between the District and AquaFiber concerning the technology.]

Ferrate Demonstration at Canal B - IMWID Lake Placid. Ferrate (FeO_4^{2-}) is a supercharged iron molecule in which iron (Fe) is in the $^{+}6$ oxidation state, or iron (VI). Ferrate is unstable at neutral pH, which makes it difficult to store and ship to treatment facilities and, therefore, it was synthesized at the test site in a patented device called a Ferrator® from caustic, sodium or calcium hypochlorite, and ferric chloride.

The SFWMD in collaboration with Highlands County Parks and Natural Resources and Ferrate Treatment Technologies (FTT), LLC, conducted a field demonstration of the product "Ferrate" using water from Canal B, Istokpoga Marsh, Water Improvement District (IMWID), Lake Placid, FL. This field demonstration was conducted to evaluate the effectiveness of the Ferrate technology to reduce phosphorus concentrations in surface waters. Water from Canal B of the IMWID was used in this field demonstration that was conducted from September 17–26, 2012. Canal B is one of the main drainage canals from the rich organic caladium fields in the IMWID with high and variable P loadings, making it an ideal site to test this new technology. A ferrate dose of 5 mg/L was consistently used during the entire field demonstration. The following observations were made based on comparing untreated inflow and Ferrate-treated outflow water samples.

1. Initial TPO_4 concentrations of inflow waters from this canal were high, averaging 1.327 mg/L, with about 95 and 93 percent present as $TDPO_4$ and OPO_4, respectively.
2. Ferrate was very efficient in reducing $TDPO_4$ and OPO_4 concentrations, with outflow water samples at method detection levels (0.002 mg/L) on all sampling events. Similarly, ferrate was able to reduce inflow TPO_4 concentrations by 97 percent, which is a reflection of the high total dissolved P fraction (95 percent) in the inflow canal waters.
3. TN and TKN concentrations were also effectively reduced, with outflow samples showing an average of 48 and 56 percent reduction, respectively. In contrast, NO_X outflow concentrations increased by an average of 19 percent.

4. Alkalinity levels were reduced (83 percent) as expected by the Fe levels added to the inflow samples to adjust pH. Water pH was reduced from an average inflow value of 6.5 to an average outflow value of 5.6, representing a 14 percent reduction. SO_4 levels in outflow samples also showed an average reduction of 13 percent.
5. Turbidity levels in the outflow samples decreased substantially (70 percent reduction) as the ferric phosphate flocs dropped from the water column. In contrast, outflow specific conductivity levels showed a considerable increase (415 percent) due to the ferrate treatment.
6. Total Fe concentrations in outflow samples showed a considerable increase due to the ferrate treatment and the ferric chloride added for pH adjustment and coagulation. However, for a full-scale system, the pH of outflow samples is generally adjusted to 7, which would allow the excess iron to precipitate before treated water is discharged from the treatment facility.

The products and processes reviewed demonstrate considerable potential for phosphorus treatment capacity. Nitrogen removal capacity was also demonstrated by several of the products and processes. Likely, there are many more technologies which are potentially available and applicable for stormwater quality improvement in the South Florida environment. As such, the challenge is not the existence or availability of technologies to treat and improve stormwater quality, but to learn how to efficiently and effectively deploy the broad range of products and processes across the numerous land uses and drainage environments.

Two of the processes observed through NATA demonstrated how they could be used to pull stormwater from a flowing stream or canal and return treated water back to the same stream. This physical arrangement is almost certain to be one of the most commonly encountered in our highly developed drainage system. If these processes can be scaled up to larger flows (which is highly probable), then they may be among the easiest to implement at the field scale. Available data from testing and literature searches indicate that granular or liquid products may provide good treatment to the water into which they are placed. Confidence in the treatment contribution declines as the liquid disperses or granular product settles to the bottom of a water body or as new water is introduced to a stormwater pond or as water flows downstream in a canal. A process needs to be developed in which the granular or liquid nutrient binding agents could be utilized to treat stormwater in an off-line manner. This may be as simple as traditional alum treatment or it may take an entirely different form.

Another opportunity may be to broadcast a nutrient binding agent over a large area of land to prevent nutrient run-off from entering the stormwater stream. Of course, the binding agent must not block nutrient utilization by the vegetation for which it was applied. If food crops, animal or vegetable, are grown, most, if not all, agricultural operators will reject the application of any chemicals on their property not fully vetted by governing bodies or agencies. Substantial testing would be required before such a use could be endorsed.

The data and information gained from evaluating these technologies will provide a basis for future site specific efforts and studies.

IN-LAKE STATUS

PERFORMANCE MEASURES

Measurements of TP, chlorophyll *a* (Chl*a*), phytoplankton, submerged aquatic vegetation (SAV), and water levels are used as quantitative performance measures for the NEEPP. These measures describe the status of the ecosystem and its responses to implemented restoration programs. Measures are five-year averages to ensure consistency with TMDL reporting, reduce year-to-year variation due to climate and hydrology, and improve understanding of underlying trends. These values are compared to quantitative restoration goals. The LOPP provides a technical foundation for these restoration goals (SFWMD et al., 2004). The WY2013 averaged observations document current water quality and lake-level conditions. A summary of the Lake Okeechobee performance measure monitoring results is provided in **Table 8-17**, and the in-lake sampling locations used for calculating water clarity measurement are depicted in **Figure 8-14**.

HYDROLOGY

Lake Okeechobee water level began WY2013 at an elevation of 11.68 ft (3.56 m) NGVD, which placed it in the beneficial use band (**Figure 8-15**). Environmental releases were made based on the SFWMD adaptive protocols; primarily to the Caloosahatchee River to prevent algal blooms and high chloride levels from entering the Olga drinking water plant. Lower lake levels continued until August 25, 2012, when Tropical Storm Isaac delivered over 5 inches of rain on average District-wide (see Volume III Appendix 4-1). Inflow for the month of September was 34 percent of the entire water year. Lake stage increased to 15.17 ft (4.62 m) (NGVD by September 19, 2012, when regulatory releases to the estuaries started. The stage continued to increase, reaching 15.92 feet (4.85 m) on October 10, 2012. Regulatory releases were reduced on November 14, 2012, as water levels had declined to below 15.5 ft (4.72 m) NGVD. Base flow regulatory releases were initiated at that time interspersed with a number of pulse releases and regulatory releases to the Water Conservation Areas through the remainder of the water year. At the end of the water year on April 30, 2013, the lake water level was 13.41 ft (4.09 m) NGVD.

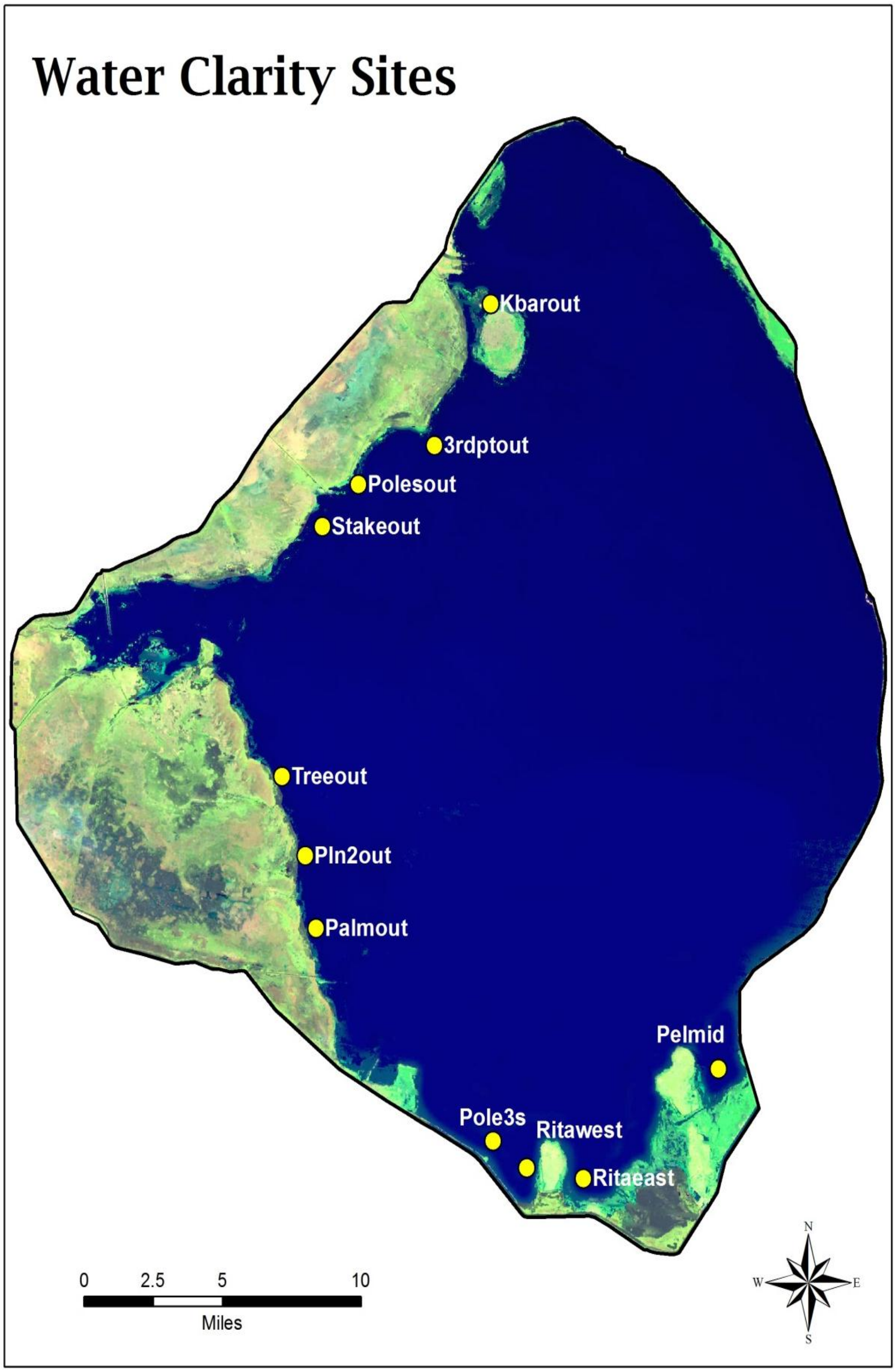


Figure 8-14. Sampling locations used for calculating water clarity measurements in the 2014 SFER.

Table 8-17 Summary of Lake Okeechobee rehabilitation performance measures, rehabilitation program goals, and lake conditions for the (WY2009–WY2013), as specified in the Restoration Assessment Plan of the Lake Okeechobee Protection Program. WY2012 and WY2013 values are included to show annual changes.

Performance Measure	Goal	Five-Year Average	WY2013 [a]	WY2012
Total Phosphorus (TP) load	140mt/yr	451 mt/yr	569 mt/yr	377 mt/yr
Nitrogen Load	N/A	5,389 mt/yr	6,397 mt/yr	4,620 mt/yr
Pelagic TP	40 ppb	122 ppb	124 ppb	92 ppb
Pelagic TN	N/A	1.50 ppm	1.44 ppm	1.33 ppm
Pelagic SRP	N/A	39 ppb	42 ppb	24 ppb
Pelagic DIN	N/A	199 ppb	208 ppb	121 ppb
Pelagic TN:TP	> 22:1	12.3:1	11.6:1	14.5:1
Pelagic DIN:SRP	> 10:1	5.1:1	5.0:1	5.0:1
Plankton nutrient limitation	Phosphorus >Nitrogen	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus	Nitrogen >>> Phosphorus
Algal bloom frequency	< 5% of pelagic chlorophyll *a* exceeding 40 µg/L	7.4%	1.2%	1.1%
Water clarity	Secchi disk visible on Lake bottom at all nearshore SAV sampling locations from May–Sep	30.0%	58% [c, d]	74%
Nearshore TP	Below 40 ppb	76 ppb	77 ppb	41 ppb
Submerged aquatic vegetation (SAV)[b]	Total SAV > 40,000 acres	38,731 acres total	47,692 acres total	36,325 acres total
	Vascular SAV > 20,000 acres	30,008 acres vascular	27,388 acres vascular	16,556 acres vascular
Extremes in low lake stage (current water year)	Maintain stages above 10 ft	N/A	Goal attained	Goal attained
Extremes in high lake stage (current water year)	Maintain stages below 17 ft; stage not exceeding 15 ft for more than 4 months	N/A	Goal attained	Goal attained
Spring recession (January to June 2013)	Stage recession from near 15.5 ft in January to near 12.5 ft in June	N/A	Goal partially attained (within 0.5 feet from January to May reversal occurred in June)	Goal not attained

[a] The diatom:cyanobacteria ratio performance measure could not be updated for WY2013.
[b] Mean yearly acreages (from August 2007–2012 maps)
[c] SAV transparency readings taken only in June 2010
[d] The water clarity measurement was modified due to changes in monitoring. Values were obtained from nearshore stations (**Figure 8-14**). Secchi and depth were compared and, if the ratio of Secchi to depth was above 0.9, then the Secchi was considered visible on the bottom of the lake.

N/A - Not available

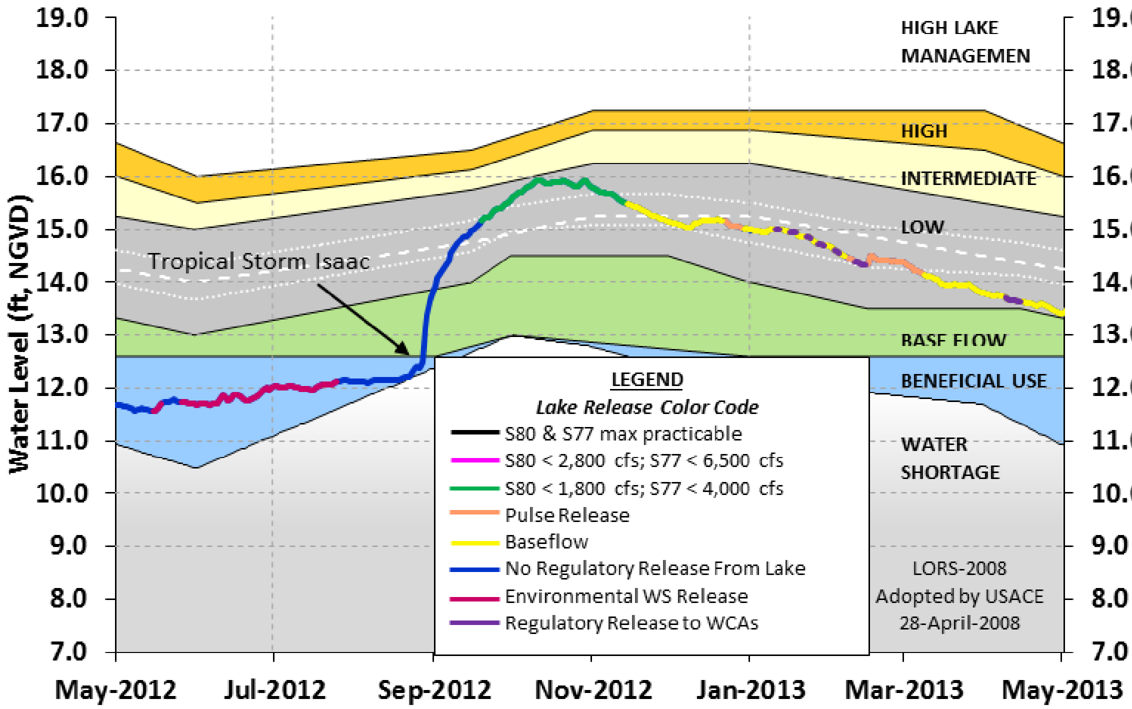


Figure 8-15. Annotated Lake Okeechobee stage [in feet National Geodetic Vertical Datum, or ft NGVD) hydrograph.

NUTRIENT BUDGETS

TP loads to the lake from tributaries and atmospheric deposition (estimated as 35 mt/yr; FDEP, 2001) totaled 569 mt in WY2013 (**Table 8-18**). This represents a slightly greater than 50 percent increase in loads compared to WY2012 due in part to an increase overall flow (10 percent) and much higher loads from northern and eastern basins (see Volume III, Appendix 4.1). Mean lake TP mass in WY2013 was higher than the previous water year due to higher water volume and higher in-lake concentrations (**Table 8-18** and **Figure 8-16**). Loads out of the lake in WY2013 were higher than WY2012 as discharge was higher. The net load (inputs minus outputs) in WY2013 was 443 mt. Sediment accumulation was less than the previous year, resulting in a net sedimentation coefficient (sediment accumulation/mean lake TP mass) of 0.38 (**Table 8-18** and **Figure 8-17**).

TP concentrations in the lake's water column declined from a high of 233 ppb in WY2005 to 93 ppb in WY2012 (**Figure 8-18**). In WY2013, TP levels increased to 124 ppb, which is attributed to the increased loads and higher water levels as compared to WY2012. The current five-year (WY2009–WY2013) average TP concentration returned to pre hurricane (pre-2004) values. Increased water levels may reduce light levels, affecting plant and periphyton growth, and consequently nutrient uptake from the water column. Higher water levels may also promote more resuspension of phosphorus laden sediments as a result of larger exposed areas of open water.

Table 8-18. TP budget (mt) for Lake Okeechobee for the most recent 10 water years (WY2004–WY2013).

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)
2004	578	113	553	302	251	138	0.24
2005	1108	270	960	582	378	108	0.10
2006	1104	-194	795	798	-3	191	0.17
2007	593	-269	203	176	27	296	0.50
2008	462	132	246	26	220	88	0.19
2009	602	-276	656	242	414	690	1.15
2010	490	291	478	77	401	110	0.22
2011	428	-338	177	208	-31	307	0.72
2012	307	10	373	88	285	275	0.90
2013	530	241	569	126	443	202	0.38
Average	**620**	**-2**	**501**	**263**	**239**	**241**	**0.46**

[a] Net change from the start (May 1) through the end (April 30) of each Water Year

[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)

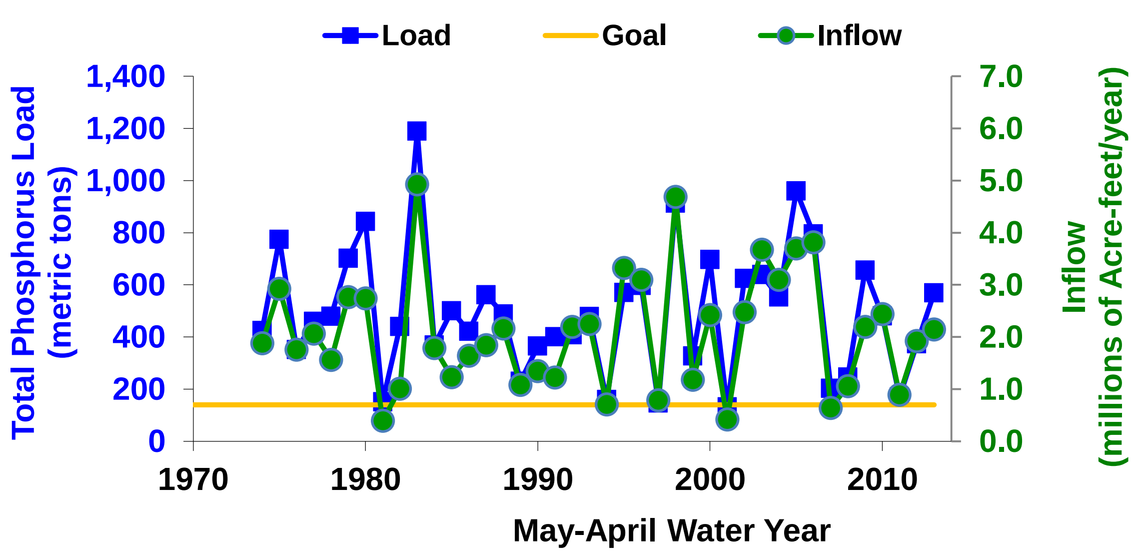


Figure 8-16. Water year TP load and inflow entering Lake Okeechobee from its tributaries calculated from the lake TP budget.

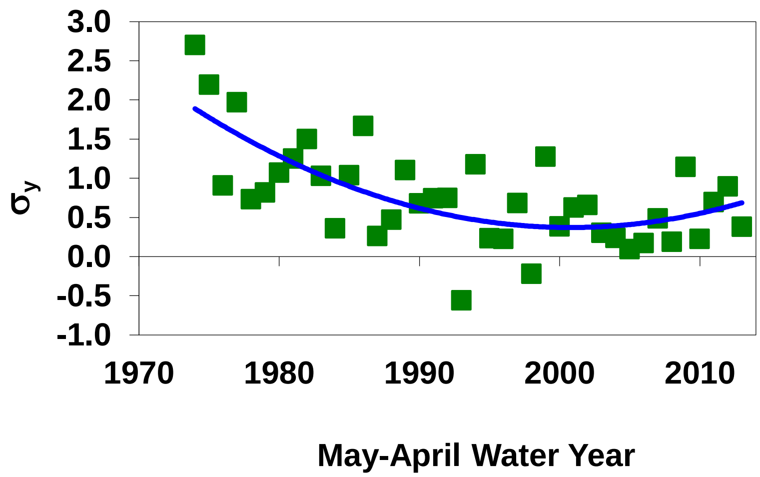


Figure 8-17. Timeline of the net sedimentation coefficient (σ_y) calculated from the WY2009 TP budget of Lake Okeechobee. [Note: Trend line is a second-order polynomial.].

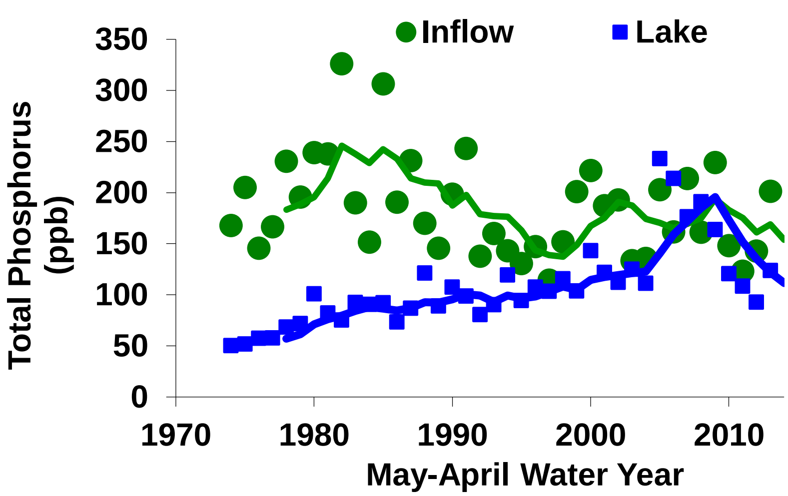


Figure 8-18. Inflow and lake average annual TP concentrations and five-year moving average trend lines.

The net sedimentation coefficient, σ_y (per year), of the phosphorus budget is the amount of TP that accumulates in the sediment per year divided by the average lake water TP mass (**Table 8-18** and **Figure 8-17**). A low σ_y indicates that the lake absorbs less excess TP loads from the watershed. For WY2013, the σ_y value was 0.38 per year (**Table 8-18**), which is below the 10-year average value of 0.46 per year. The WY2013 value is much less than the previous year value primarily because of the larger average mass stored within the water column in WY2013. Over the past four decades, σ_y declined from around 2.5 in the 1970s to below 1 in the 1990s (**Figure 8-17**; James et al., 1995; Janus et al., 1990; Havens and James, 2005).

TN loads to the lake are approximately tenfold greater than TP, which generally reflects the typical ratio of N to P in living systems (**Table 8-19**). Annual loads also are closely related to the hydrology of the lake, fluctuating between 2,500 and 14,000 mt/year (**Figure 8-19**). Discharge loads from the lake are approximately half of the inflow loads (**Table 8-19**). Inflow TN concentrations tend to be higher than either in-lake or outflow concentrations while outflow concentrations tend to be slightly higher than in-lake concentrations (**Figure 8-20**). This is probably a result of the intra-annual variability of nitrogen in the lake, with higher nitrogen levels in winter than in summer (Maceina and Soballe, 1990), and increased discharge of water in the late winter and spring.

Despite this difference between loads into and out of the lake, TN concentrations in the lake have been relatively stable since the 1980s (**Figure 8-20**). This stability is likely due to biological processes in the lake that remove nitrogen through the denitrification process (James et al., 2011). Evidence of this uptake is observed in the lake adsorption rate, which averages more than 50 percent of the load into the lake (**Table 8-19**).

Table 8-19. Total nitrogen (TN) budget (mt) for Lake Okeechobee for the most recent 10 water years (WY2004–WY2013).

Water Year	Mean Lake TN Mass	Net Change in Lake Content[a]	Load In[b] (mt)	Load Out (mt)	Net Load[c] (mt)	Lake Adsorption[d]	Net Adsorption Coefficient (σ_y)
2004	6,924	-208	6,526	4,642	1,884	2,092	0.30
2005	10,023	2,588	8,775	6,609	2,166	-422	-0.04
2006	9,389	-2,692	7,992	8,048	-56	2,636	0.28
2007	4,873	-3,460	2,965	2,023	942	4,402	0.90
2008	3,772	2,128	3,393	392	3,001	873	0.23
2009	6,566	-1,075	6,689	2841	3,848	4,923	0.75
2010	6,659	2,735	6,325	1,106	5,219	2,484	0.37
2011	5,762	-3,402	2,913	3,018	-105	3,297	0.57
2012	4,427	487	4,620	1,460	3,160	2,673	0.60
2013	6,178	1,705	6,397	1879	4,517	2,812	0.46
Average	**6,457**	**-119**	**5,659**	**3,202**	**2,458**	**2,577**	**0.44**

[a] Net change from the start (May 1) through the end (April 30) of each Water Year

[b] Includes 1233 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)

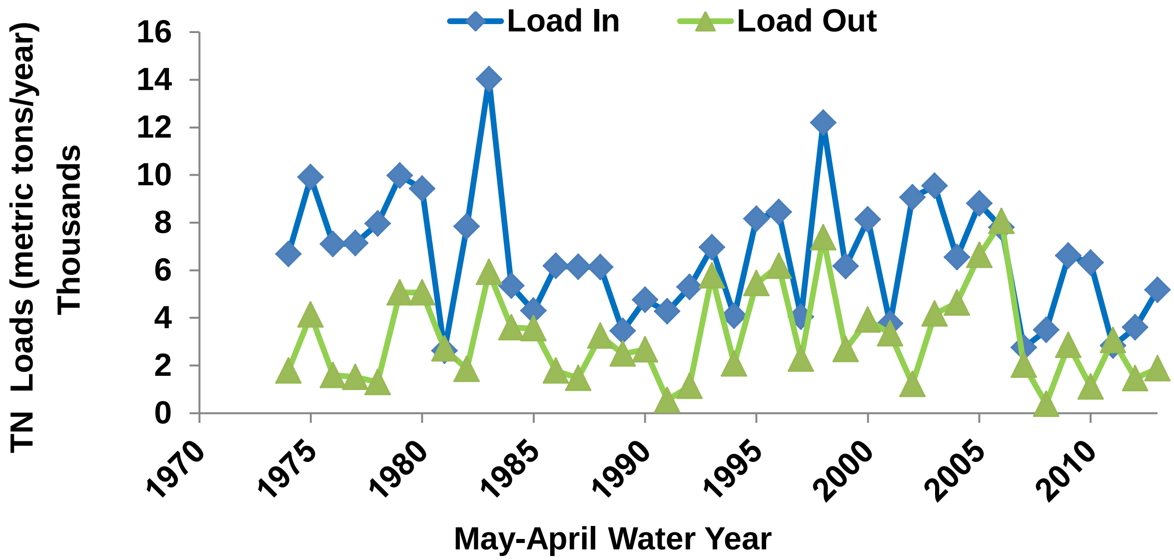


Figure 8-19. Timeline of water year inflow and outflow nitrogen load to and from Lake Okeechobee calculated from the nitrogen budget of the lake.

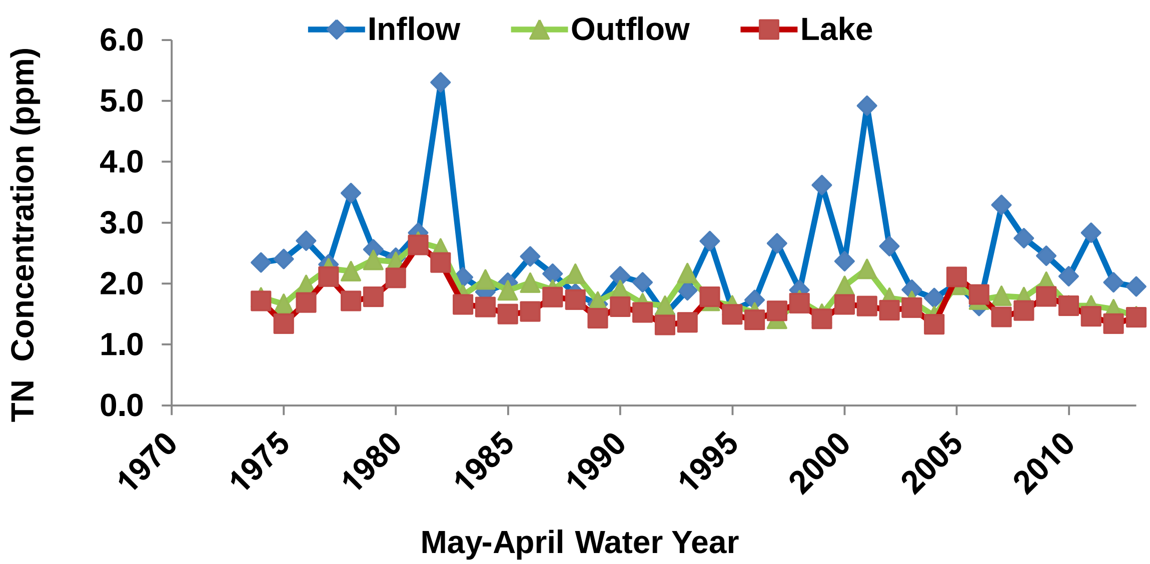


Figure 8-20. Timelines of inflow, outflow, and lake average TN concentrations calculated from the nitrogen budget of Lake Okeechobee.

IN-LAKE MONITORING

SUBMERGED AQUATIC VEGETATION

Submerged aquatic vegetation (SAV) abundance, a key indicator of the lake's overall ecological health, has been monitored in Lake Okeechobee since WY2000. Over the 14-year period, few changes have been made to either the annual mapping or transect mapping program. However, in WY2011 and WY2012 modifications were made to both programs in an effort to (1) provide more accurate and precise reporting of areal coverage data, (2) make the transect monitoring data more comparable to the annual mapping data thereby providing more informative data to the stakeholders, and (3) streamline the sampling process for more cost-effectiveness and added efficiencies. Further details of these modifications are presented in the 2012 and 2013 SFERs – Volume I, Chapter 8.

Results

Areal coverage of nearshore SAV, as measured in August of each year, has varied between approximately 28,000 and 51,000 ac (11,330 and 20,640 ha, respectively) since WY2008 and appears to have recovered from the low of 3,000 ac (1,210 ha) reported in WY2007 after two years of hurricanes (**Figure 8-21**). SAV areal coverage over the past three years has slowly increased reaching 47,692 ac (19,300 ha) in WY2013. In WY2013, the acreages for all the vascular species (*Vallisneria americana*, *Hydrilla verticillata*, *Potamogeton* spp., *Ceratophyllum* spp., and *Najas guadalupensis*) increased compared to WY2012, accounting for 62 percent of the total SAV acres (**Figure 8-22**). *H. verticillata* was the dominant SAV species (14,579 ac, 5,900 ha) followed by *V. americana* (11,120 ac, 4,500 ha), *Ceratophyllum* spp. (6,178 ac, 2,500 ha), *N. guadalupensis* (3,707 ac, 1,500 ha), and *Potamogeton* spp. (3,459 ac, 1,399 ha). Areal coverage of the non-vascular *Chara* spp., decreased by almost 4,000 ac (1,618 ha) in WY2013 and accounted for 38 percent of the total SAV acres (**Figure 8-22**). Although SAV mapping in the marsh began in WY2011 and there were over 11,000 ac (4,450 ha) of SAV present, lake levels were so low in WY2012 and WY2013 that the marsh was dry and inaccessible.

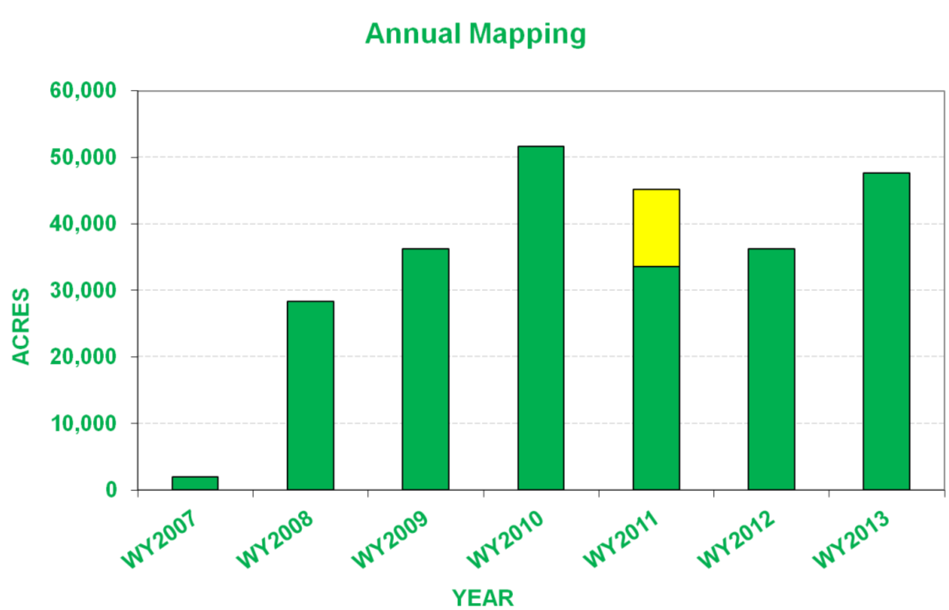


Figure 8-21. Annual SAV mapping results from WY2007–WY2013.

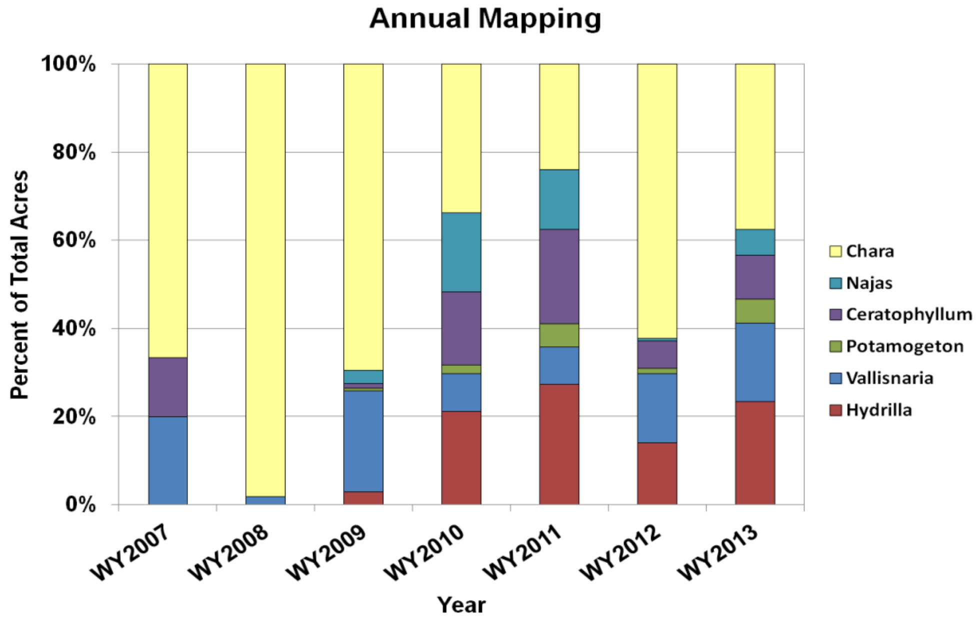


Figure 8-22. Percent of total acres for each SAV species from WY2007–WY2013. Vascular species include *Vallisneria americana*, *Hydrilla verticillata*, *Potamogeton* spp., *Ceratophyllum* spp. and *Najas guadalupensis. Chara* spp. is the only non-vascular species. Sampling was conducted in August of each year.

The current SAV coverage of 47,692 ac (19,300 ha) with 62 percent being vascular species meets the rehabilitation performance measure of greater than 40,000 ac (16,181 ha) of total SAV with at least half comprised of vascular species. This is the second time in the past five water years that Lake Okeechobee achieved this restoration goal. However, reevaluation of this metric may need to be considered given the change in operating schedule and resultant lower lake levels. These low lake levels have resulted in previously SAV-dominated areas in the nearshore becoming dominated by emergent and terrestrial plants. For example, approximately 7,000 ac that was open-water SAV habitat in the south end of the lake (South Bay) prior to WY2008 has shifted to emergent marsh habitat. If lake stages continue to remain near the lower end of the desired stage envelope or lower, this enlarged marsh habitat likely will continue to occupy formerly open-water SAV habitat forcing the SAV to colonize areas farther offshore. However, vascular species appear not to be able to colonize this area as readily as the non-vascular Chara species so expansion by the vascular species may be slow and/or limited.

In WY2012, the transect sampling methodology was changed to match the August annual mapping sampling methodology such that the new transect sites are now a subset of the annual mapping sites. This allows for comparison of results from grid cells sampled during the quarterly transect mapping with the results from the same grid cells sampled in past annual mappings. Additionally, the results from the August annual sampling can be used for the August quarterly sampling event so only one sampling trip is needed.

Results from the quarterly transect grid cells also show that SAV in Lake Okeechobee continues to recover from the WY2005 and WY2006 hurricanes, the extremely low lake levels of WY2008 and WY2009, and a tropical storm in WY2009 (**Figure 8-23**). WY2010 had the highest number of sites with plants (39 of the 54) since WY2007 and only one site was inaccessible. Lake levels during the WY2010 growing season (six months prior to the August sampling) averaged 12.4 ft and the Secchi depth to total depth ratio (SD:TD) averaged 0.77 suggesting favorable depth and light conditions for plant germination and growth (a SD:TD > 0.5 indicates light penetration is to the sediment surface). The average lake level six months prior to the WY2011 sampling event were almost 2 ft higher than the levels during the WY2010 growing season, the SD:TD decreased to 0.65 and plants were lost at 7 offshore sites. Drought conditions prevailed during WY2012 with water levels declining to 10.26 ft during the August sampling and almost half (25) of the sites were dry and inaccessible.

SAV slowly recovered over the next year with plants beginning to establish at more of the offshore sites but by the August WY2013 sampling water levels were low enough and the marsh vegetation was dense enough that more of the inshore sites were inaccessible, especially in the newly developed southern marsh. So although more offshore sites had plants, fewer of the inshore sites had plants resulting in a net gain of only 4 additional sites with plants over the year. Between the August WY2013 and November WY2013 sampling events, Tropical Storm Isaac hit South Florida increasing lake levels by about 3.5 ft over a two month period. Lake stage reached 15.93 ft in October WY2013, turbidity increased, light levels decreased and plants were again lost at some of the offshore sites. Over the winter of WY2013, plants were gained at some of the sites in the southern marsh as that area was again inundated but by the spring of WY2013 a decline in lake levels dried the southern marsh sites once again. Since WY2012, the dynamic lake levels have resulted in the shifting in the colonizable area for SAV from inshore to offshore and back to inshore. This is reflected in the small fluctuation in the number of sites with plants (from 22 to 27) over the past year. As plants are lost inshore, especially in the newly developed southern marsh, they are gained offshore and vice versa.

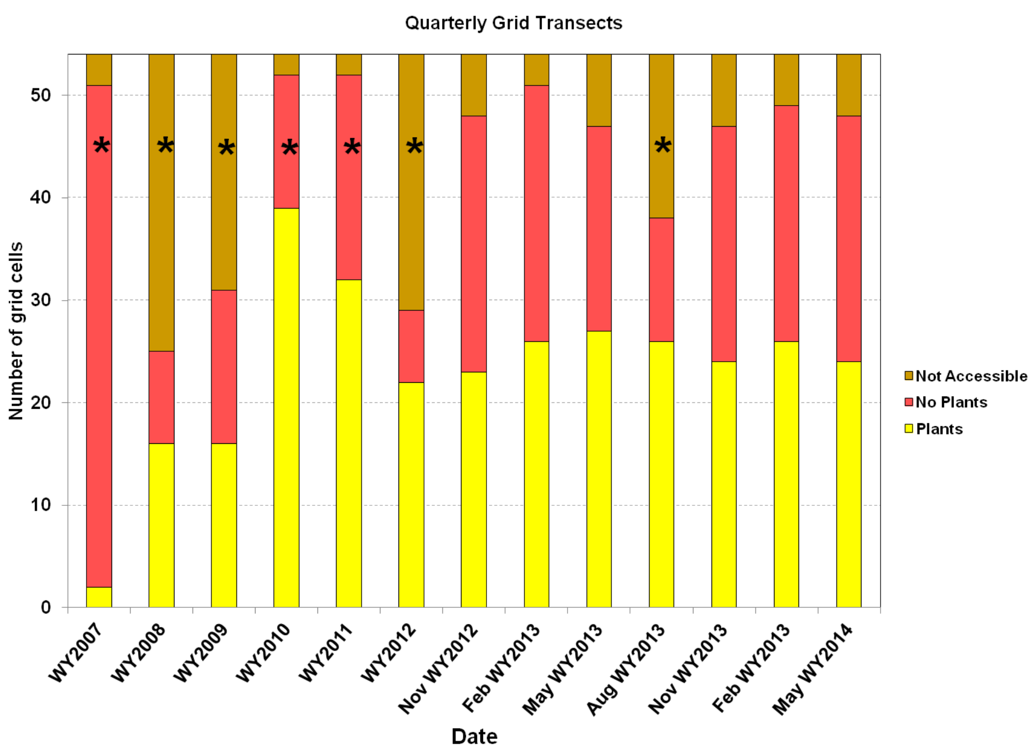


Figure 8-23. Number of grid cells with plants, without plants and that were not accessible (dry, terrestrial, emergent) for the 54 sites along the 7 transects on an annual basis from WY2007 to WY2012 (*****data pulled from the August annual mapping grid cells) and on a quarterly basis from November WY2012–May WY2014.

PHYTOPLANKTON

Routine Monitoring

Routine plankton monitoring (RPM), conducted primarily on a quarterly basis since 1994, has been an important component of Lake Okeechobee pelagic and nearshore monitoring since the late 1980s (Phlips et al., 1993). Phytoplankton monitoring is important because phytoplankton are the base of the lake's food web and because algal blooms (Chl*a* concentrations $\geq$ 40 ppb) which have been periodically documented can have wide ranging negative effects, from triggering fish kills, to impacting human health and safety. While quarterly phytoplankton monitoring was conducted during the past water year, budgetary constraints and resulting delays in processing samples, prevent the authors from reporting any new data for 2012 and 2013. However, this lack of new result also presented an opportunity to do a thorough statistical analysis of the currently available data (from 1994-2011), which is described below.

A long-term drought commenced in 2007 and generally lower (e.g., <13 ft msl) lake stages since then have resulted in improved water column light penetration; often down to bottom sediments in the nearshore region of the lake. While annual nutrient loading to the lake has been reduced over the past five years, due primarily to reduced inflows, water column nutrient concentrations are still classified as eutrophic creating conditions in the nearshore region favorable to widespread and frequent cyanobacteria-dominated blooms. However, despite these conditions, no blooms of any magnitude have been observed since August 2005.

Phytoplankton restoration goals for Lake Okeechobee are to (1) reduce cyanobacteria bloom frequency, (2) decrease the cyanobacteria percent composition of blooms to less than 50 percent and (3) promote conditions wherein diatoms are consistently dominant and the diatom:cyanobacteria ratio is greater that 1.5:1.

Algal Abundance Data

When comparing the annual mean total algal abundance (as cell biovolumes) across three temporal periods (pre-hurricane, 1994–2004; hurricane, 2005–2006; and post-hurricane, 2007–2011), the pelagic and nearshore regions both had significantly ($p<0.05$) lower abundances during the hurricane period. The hurricane period includes impacts from Hurricanes Frances, Jeanne, and Wilma; the primary impacts being a large and sustained increase in total suspended solids (TSS) concentrations and the loss of most of the SAV and periphyton communities, which can indirectly limit phytoplankton blooms by nutrient competition (Phlips et al., 1993). While the annual means for the post-hurricane period were higher for both regions and for the algal bloom monitoring (Bloom Mon) nearshore region abundance data, the increase was not statistically significant (**Figure 8-24**).

When comparing the Bloom Mon annual mean total abundances to the equivalent RPM nearshore abundances, the Bloom Mon annual mean abundances were significantly higher, while the RPM nearshore and pelagic annual mean total abundances were not significantly different. The Bloom Mon data used in this analysis were the same quarterly sampling data that were collected during the RPM monitoring project and the abundances were normalized to account for differences in the number of sampling locations among both monitoring projects. The temporal comparisons were conducted with a two-way analysis of variance (ANOVA) using ranked data, followed by the Tukey HSD (honest significant difference) test, using ranked means. The among regions abundance comparison was conducted with the Kruskal-Wallis nonparametric ANOVA, followed by another Tukey HSD test, also using ranked mean values. As RPM and Bloom Mon projects sample phytoplankton in different ways (integrated water column versus surface water samples, respectively), samples collected via both methods at site L005 during the same months were compared. A Mann-Whitney U test indicated that there was no significant difference ($p<0.25$) among biovolume abundances among samples from both projects collected at this site.

The higher algal abundance noted in the Bloom Mon data may reflect the location of these stations, which were intentionally placed more inshore, in areas of the lake where human contact through the location of back-up drinking water supply intakes and recreational activities are more likely to occur.

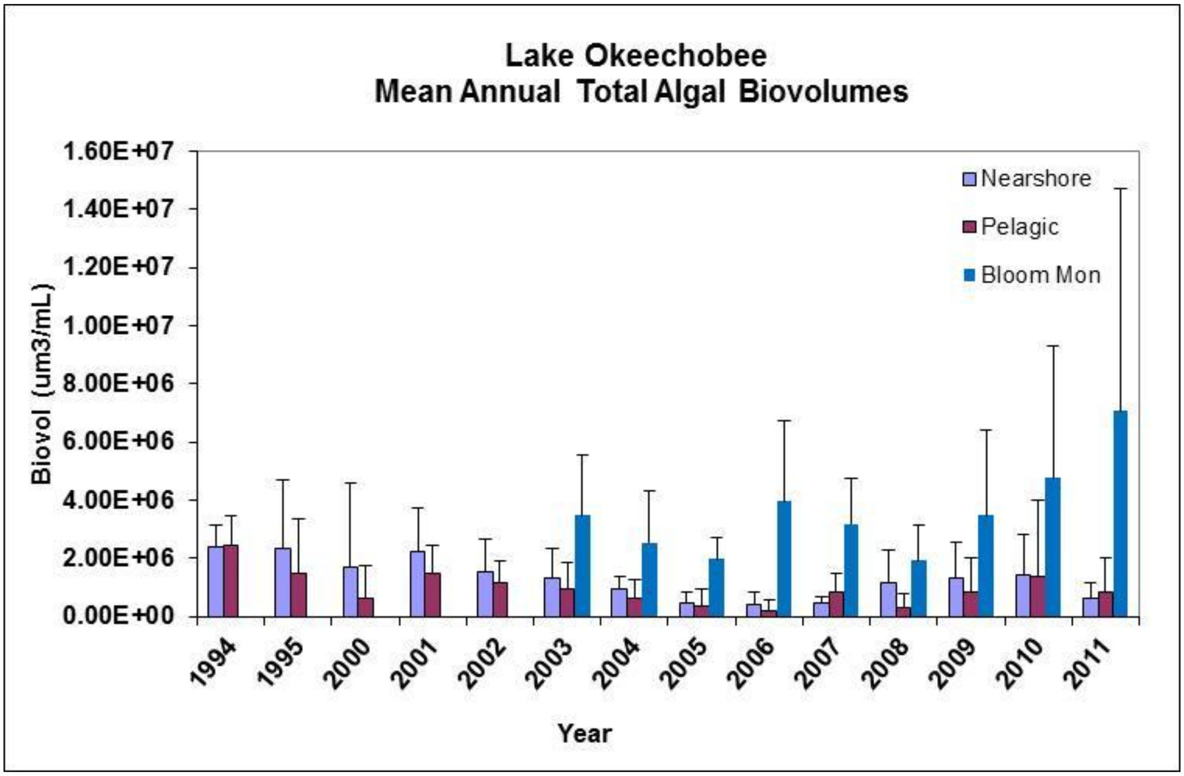


Figure 8-24. Lake Okeechobee mean total algal biovolumes from 1994–2011.

Community Composition

Non-metric multi-dimensional scaling (NMDS) ordination analysis for 2000–2011 (1994 and 1995 did not have data for all four quarters) suggests that region ($R=0.81$, $p<0.01$) and then season ($R=0.57$, $p<0.01$) were the two most influential factors in the phytoplankton community biovolumes and taxonomic structure (**Figure 8-25**) The largest differences in phytoplankton communities between the two regions were observed among the years, whereas during nine of these years, the amount of within-year separation was negligible to marginal ($R<0.5$). There were two years (2002 and 2007) where phytoplankton communities among the two regions were moderately different although the highest amount of separation ($R=0.54$; $p<0.01$) during 2007 was at the low end of the moderate range. The phytoplankton communities were most different between fall and winter ($R=0.8$, $p<0.01$) but only marginally different between winter and spring ($R=0.30$, $p<0.01$).

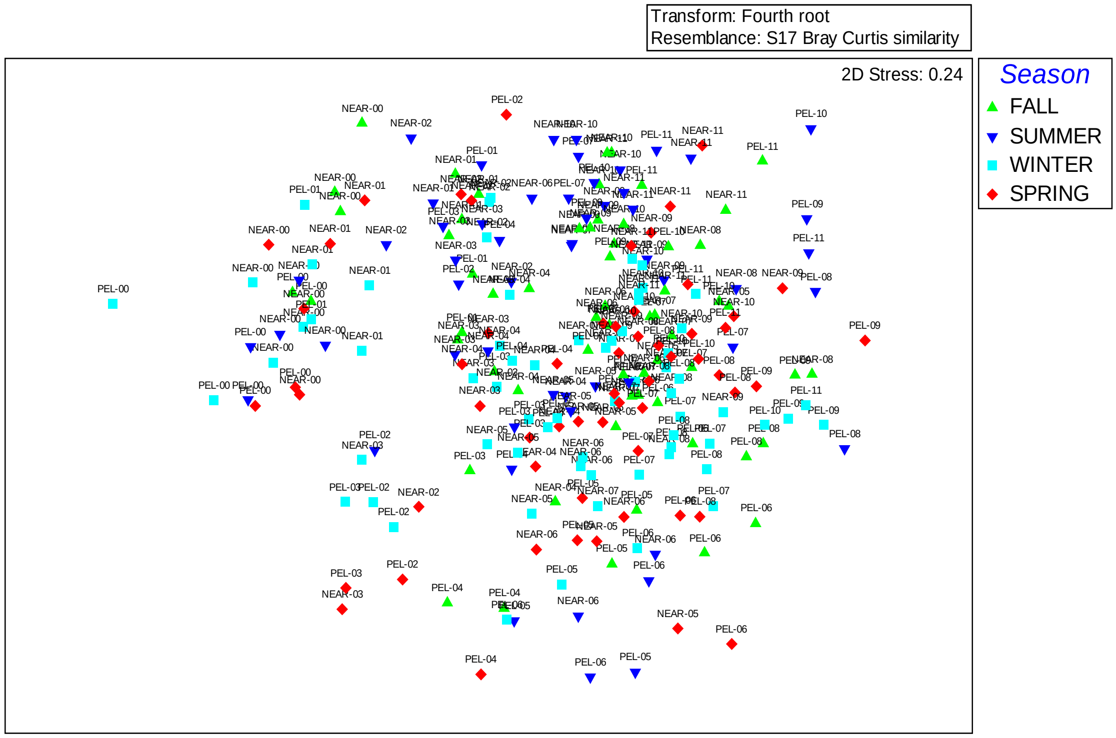


Figure 8-25. Phytoplankton community ordination plot by region and season.

There was a lot of variability in both the pelagic and nearshore phytoplankton communities, as expressed by similar values of 20 and 23 percent, respectively. The greatest taxonomic abundance differences among the regions were comprised primarily of higher diatom biovolumes in the nearshore region. Within each season, variability and similarity values also were low (17–23 percent). Among seasons, the amount of phytoplankton dissimilarity was little changed (78–83 percent dissimilarity values) and differences in primarily diatom taxa (*Cyclotella*, *Fragilaria*, *Aulacoseira*) biovolumes, with a few cyanobacteria taxa (*Cylindrospermopsis*, *Lyngbya*, *Planktolyngbya*) and *Cryptomonas* spp. generally accounting for the majority of this variability.

Among the years when the communities were the most dissimilar (>90% mean dissimilarity values), differences were generally between cyanobacteria and diatom abundances, with cyanobacteria dominating the earlier years (2000–2003) and a larger concentration of diatoms more recently (2004–2011). These results suggest that the phytoplankton assemblage experienced an increase in diatom importance and variability since 2004, while cyanobacteria became less important. Diatoms also were the dominant algal division from 2004 to 2011, while most of the cyanobacteria taxa contributed a very small proportion of the community similarity and among-communities dissimilarity values. Since 2009, *Cylindrospermopsis*, *Planktolyngbia*, and *Cryptomonas* spp. have become more abundant and may be indicating a shift back to increased cyanobacteria abundance. However, because of the size of the data set and distortion that results from displaying the results in two dimensions the authors caution against the use of this analysis for anything beyond the examination of general trends (Clarke and Warwick 2001). The stress value associated with the two-dimensional among-regions and seasons plot was sufficiently high to caution against their use for anything beyond the examination of general trends, or may simply reflect the large size of the dataset (Clarke and Warwick, 2001).

Phytoplankton communities among years ($R=0.73$, $p<0.01$) also were well-separated and the differences in the phytoplankton communities became more pronounced as the interval between years increased. There were a few adjacent years (2009-11) where the phytoplankton communities were only marginally different ($R<0.24$, $p<0.01$) and these years corresponded to generally low to very low lake stages.

When using the 1994–2011 dataset, a relatively small difference was observed in the phytoplankton communities among lake stages, when classified as "high" (>15.5 ft msl), "medium" (12.5 to 15.5 ft msl), or "low" (<12.5 ft msl) ($R=0.09$), although marginal differences were observed ($R=0.27$, $p<0.01$) among these stage classifications when examined with region as the second factor. The greatest difference among the phytoplankton communities was observed between high and low lake stages ($R=0.43$, $p<0.01$). Similarly, little difference was observed in the phytoplankton communities among sites ($R=0.12$, $p=0.001$), whether examined on an all-years or all-seasons basis. The largest difference was between the phytoplankton communities at 3POLE (near the northwestern tip of Ritta Island in the southern nearshore region), FEB (near the mouth of Fisheating Bay), and LZ40 (in the center of the lake), but the largest difference ($R=0.37$, $p=0.001$) among these site comparisons suggests that the communities were only marginally different. These comparisons suggest that temporal factors were more important in influencing the phytoplankton community structure relative to variability in either lake stage or site location. Since various measurements of phytoplankton photosynthetic-characteristics (e.g., light-limited photosynthetic rate) were shown to be homogenous among sites during higher lake stages and heterogeneous under lower lake stages (Maki et al., 2004), it is perhaps surprising that larger differences in the phytoplankton community abundances were not observed under different lake stages. The marginal differences in the phytoplankton community abundances under varying lake stages may reflect less variability in phytoplankton abundance, relative to variation in the examined photosynthetic characteristics. Another possible contributing factor to the phytoplankton community differences only being marginal among the regions and sites may be the decreased representation of the two nearshore sites during periods of very low lake stage as sampling was not conducted because these sites were inaccessible.

Stepwise addition of water quality variables suggested a positive but weak relationship (Spearman $\rho=0.21$, $P=0.01$) between a combination of 16 transformed water quality variables (depth, Secchi:total depth ratio, water column temperature, pH, specific conductance, Chl*a*, NH_4 (ammonium), NOx (nitrate+nitrite), TP, SRP, TP:TN and DIN:SRP ratios, mean daily lake stage, and wind speed) and the phytoplankton community composition. Similarly, weak positive correlations between combinations of subsets of these variables also were observed. No autocorrelation was found among the measured water quality variables.

Diatom to Cyanobacteria Ratio

Diatom to cyanobacteria ratios were less than 1:1 between 1994 and 2002. Since 2004, the ratios have exceeded 1.5:1 every year except for 2010, when the nearshore ratio declined to 1.35:1 (**Figure 8-26**). The Bloom Mon data shows the same trend observed for the RPM nearshore sites, with the exception that cyanobacteria became proportionately more important during 2009-11 and the diatom to cyanobacteria ratios were ≤1.0:1 during that period.

Since 2004, the diatom genera *Fragilaria*, *Aulacoseria*, *Cyclotella*, and *Stephanodiscus* have become increasingly important in both biovolumes and frequency of detection. With relatively low lake stages, light penetration often to the sediments in the nearshore region, an excess of nutrients and a lack of large-scale disturbances since 2008, it is somewhat surprising that cyanobacteria have not regained their dominance in the nearshore phytoplankton community during the 2009-11 monitoring period. Perhaps prolonged N-limitation, increased grazing by fish and macroinvertebrates, or some other unmeasured factor may be responsible for the lack of cyanobacteria dominance that was characteristic of Lake Okeechobee prior to the hurricanes. Alternatively, meroplankton, often comprised of pelagic diatom taxa (Phlips et al., 1997), has been found in the water column during low lake levels and this easily resuspended component of the nearshore phytoplankton community may constitute the dominant component of the phytoplankton community during periods of lower lake stages. Overall, meeting or exceeding the diatom to cyanobacteria restoration target prior to Lake Okeechobee meeting its restoration goals, suggests that this performance measure may not be a meaningful measure and should be modified accordingly. Indications are that the diatom:cyano ratio is most closely tied to lake stage rather than to lake nutrient status, which was originally thought to be the driver of this relationship.

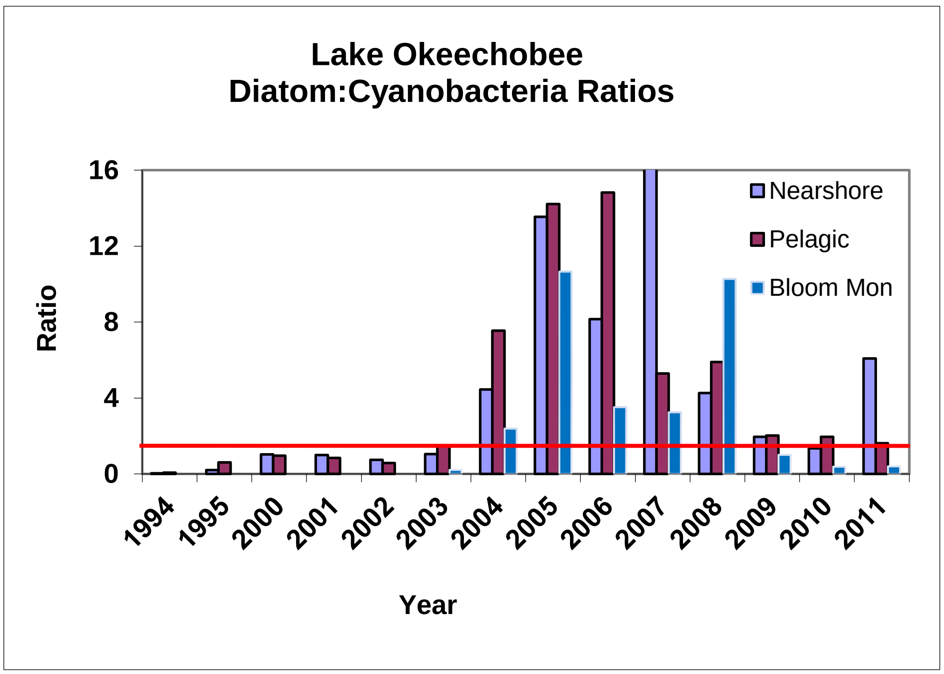


Figure 8-26. Lake Okeechobee diatom cyanobacterial ratios from 1994–2011.

Algal Bloom Monitoring

Chl*a* concentrations, indicative of phytoplankton densities, and the toxins associated with cyanobacterial blooms have been monitored on a monthly basis at nine nearshore sites since May 2004. In May 2011, this sampling effort was combined with the long-term water quality monitoring sampling effort and six of the nine algal bloom monitoring sites were relocated to nearby water quality monitoring sites (**Figure 8-27**). Three sites were dropped because there were no corresponding water quality sites nearby. Combining these two projects into one project resulted in more consistent data collection and reporting since the algal bloom and toxin data are now a subset of the water quality data instead of a separate sampling effort. An additional benefit to this sampling optimization is that it provided a substantial cost savings in both labor and operating expenses with minimal impact to algal bloom and toxin assessment capabilities. It should be noted that this is at best a sentinel sampling program involving a very limited number of sites sampled relatively infrequently. Algal blooms tend to be transient and ephemeral therefore the algal bloom monitoring program is in no way meant to be a comprehensive assessment of bloom or cyanotoxin events on Lake Okeechobee. However, over the years, it has demonstrated its ability to identify general trends in bloom and toxin occurrence. The following data for WY2013 needs to be interpreted with these limitations in mind.

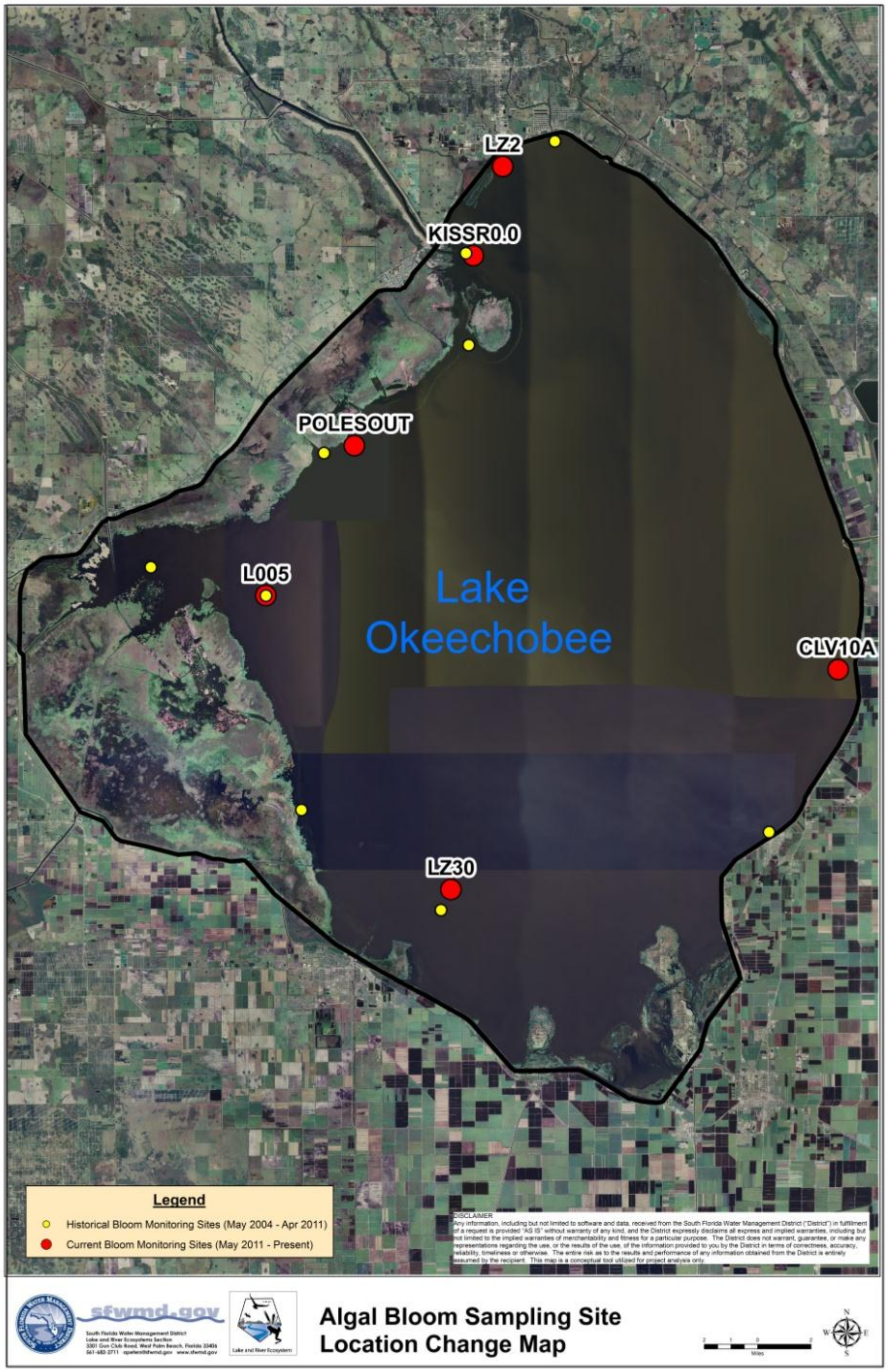


Figure 8-27. Map of algal bloom and microcystin sampling locations in Lake Okeechobee from May 2004–April 2011 (yellow dots) and from May 2011–April 2013 (red dots). Current monitoring locations are a subset of the long-term water quality monitoring network.

During WY2013, average Chl*a* concentrations did not exceed 40 µg/L, the threshold that defines algal bloom conditions (**Figure 8-28**). However, in September 2012 the Chl*a* concentration at POLESOUT along the western shore was 43 µg/L, indicating a light bloom. There were also four instances where Chl*a* concentrations were above 30 µg/L indicating the potential for a bloom to occur. All four instances occurred at the two sites along the western shore (L005 and POLESOUT). In June 2012, the Chl*a* concentration was 35 µg/L at L005 and in July it was 34 µg/L at POLESOUT. In October 2012, Chl*a* concentrations were 35 µg/L at both L005 and POLESOUT. Algal toxin concentrations during WY2013 exceed the analytical limit of detection (0.2 µg/L) only once in May 2012, when toxin levels reached 1.1 µg/L at the southern site of LZ30 suggesting that a bloom may have occurred at this site somewhat prior to the May sampling (**Figure 8-28**). Over the past 3 to 4 years, light conditions in the lake have been favorable for surface bloom formation but only minor isolated surface blooms have been detected since the prolific blue-green algal blooms that occurred in summer 2005.

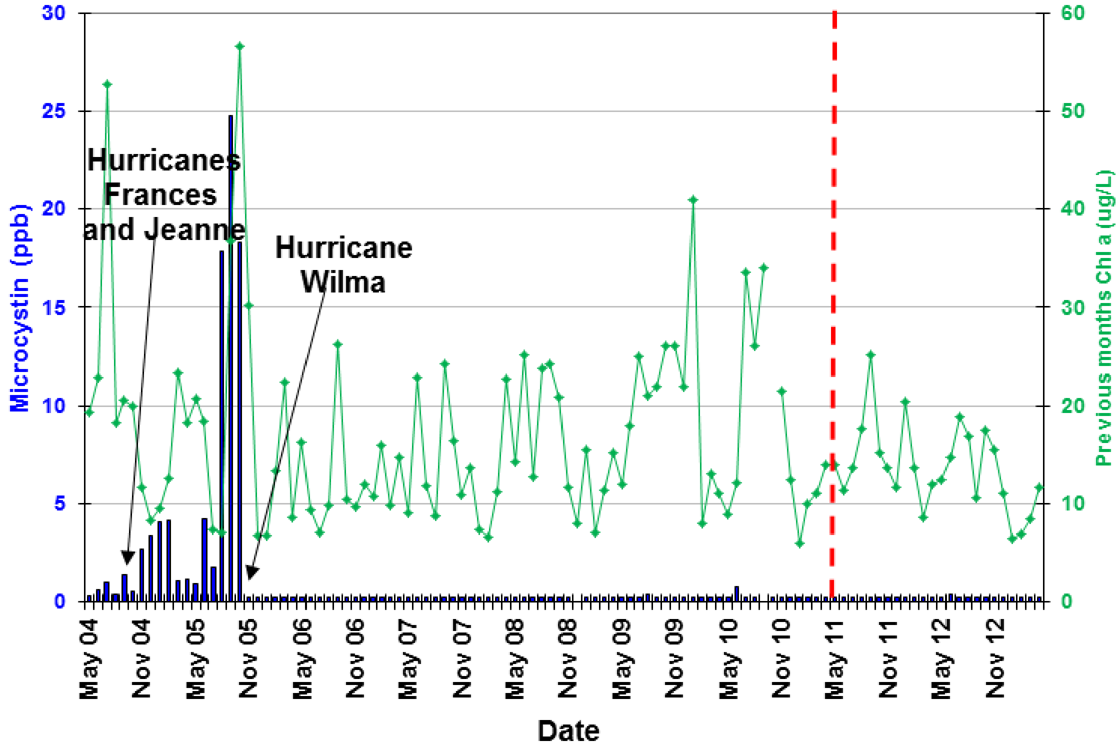


Figure 8-28. Average chlorophyll *a* (Chl*a*) and microcystin concentrations in Lake Okeechobee from May 2004–April 2011 (9 sites) and from May 2011–April 2013 (6 sites). Dashed red line indicates when sampling locations changed. A Chl*a* concentration of >40 µg/L indicates bloom conditions.

Periphyton

Periphyton is an important food source for herbivorous macroinvertebrates and fish in Lake Okeechobee (Havens et al., 1996b; Steinman et al., 1997, Carrick and Steinman, 2001). In the nearshore region of the lake, periphyton also may compete with phytoplankton for nutrients when periphyton biomass is high, indirectly limiting phytoplankton growth (Phlips et al., 1997; Havens et al., 1996b; Rodusky et al., 2001).

The most recent periphyton monitoring on Lake Okeechobee started in August 2002 and continued until November 2012. Monitoring was suspended from spring 2006 to fall 2007 because of the loss of most submerged aquatic vegetation (SAV) and emergent plants (EAV) in the nearshore region following the passage of Hurricanes Frances, Jeanne, and Wilma during 2004 –2005. Monitoring resumed in October 2007 and continued until September 2010, at which time it was suspended because of budgetary constraints. Epiphytic (algae that grows on plant stems and leaves) monitoring recommenced in October 2011 and continued through spring (March/April) and fall (September) 2012. Sampling and laboratory methods and site locations for 2002–2006 were reported in McCormick et al. (2010) and Rodusky (2010), while the most recent sites are shown in **Figure 8-29**.

With the lake being primarily within or below what is considered to be the ecologically beneficial stage envelope (12-15 ft msl) during most of the 2007-2012 period, one novel aspect of data analyses not previously performed was examining whether generally lower lake stages resulted in increased nearshore periphyton community abundances and nutrient storage. While nutrient loading to the lake between 2007 and 2012 does not necessarily reflect target post restoration conditions, nutrient inputs to the lake have generally been lower during the past five water years, relative to those recorded during WY2003–WY2006. The objective of this update is to compare spring and fall periphyton abundance (as biovolumes) and nutrient storage data collected during WY2003–WY2006 to that collected from WY2008 to present. The hypothesis being that with lower lake stages, periphyton will increase in abundance and cellular carbon and store more nitrogen (N) and phosphorus (P). Further information on periphyton biomass (as dry weight) and community structure can be found in the 2012 SFER – Volume I, Chapter 10.

With frequent and sometimes large fluctuations in lake stage and additional wind and wave driven impacts from hurricanes during the study period, both the EAV and SAV have experienced large changes in areal coverage. For example, after Hurricane Frances, Jeanne, and Wilma passed very near or over the lake, SAV was dramatically reduced. Conversely, with the extended period of mostly very low to generally ecologically beneficial lake stages during 2007–2012, EAV expanded its range offshore and several taxa which prior to the hurricanes were very sparse (e.g., *Typha*) greatly increased in areal coverage. Consequently, epiphytic community comparisons on the same host taxa over the entire study period had to be limited to *Chara*, *Schoenoplectus*, and *Vallisneria*—species which maintained relatively stable coverage throughout the study period.

All the epiphytic and epipelic abundance (as biovolumes) data were compared by non-metric multidimensional ordination scale (NMDS) analysis in PRIMER, v6. Among the two study periods, the epipelon had the clearest separation ($R=0.97$, $p<0.01$), indicating that lower lake stages coincided with increased epipelic abundance, as illustrated in **Figure 8-30**. Conversely, there was marginal to little separation and therefore difference in the epiphytic abundances on *Schoenoplectus, Vallisneria*, and *Chara* ($R\leq0.30$, $p\leq0.30$) between the two study periods, as illustrated in **Figures 8-31** and **8-32** . There were no epiphyte data for *Chara* in fall 2004 or for *Schoenoplectus* in fall 2008 (north and west), fall 2011, and spring 2012 (north) and in 2008–2010 (south) because of seasonal senescence of host plants, replacement of one taxon with another (e.g., *Typha* spp. replacing *Schoenoplectus* sp. near King's Bar), or delays in the recovery of host plants after the 2004–2005 hurricanes. Also, there was not any data for west region

Chara, north region *Hydrilla*, and *Typha* spp. during the first study period, and for *Potamogeton* during the second study period.

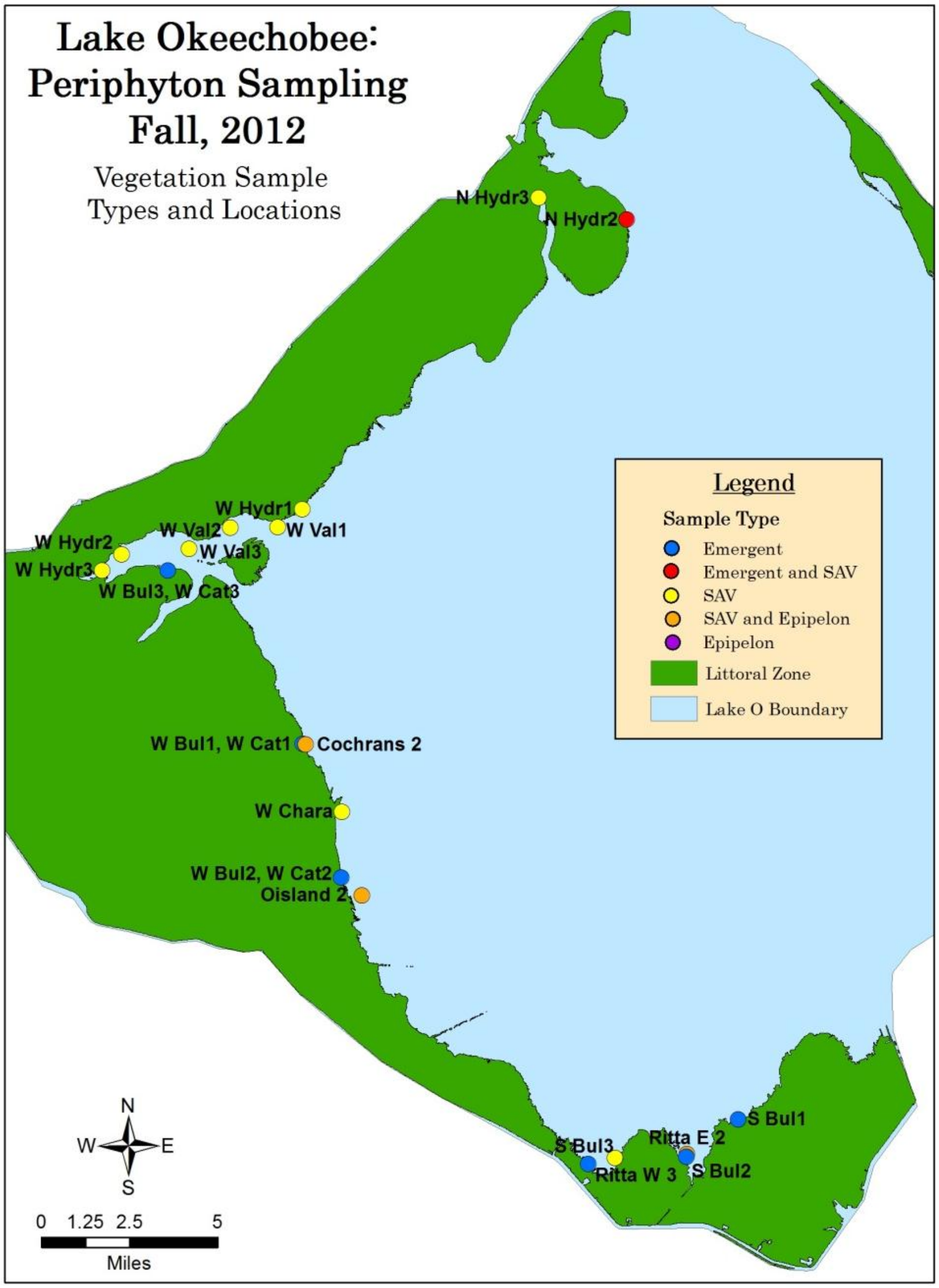


Figure 8-29. Nearshore epiphytic sites for the fall 2012 monitoring period. Littoral zone sites in the south which were previously dominated by SAV beds continue to be dominated by emergent plants.

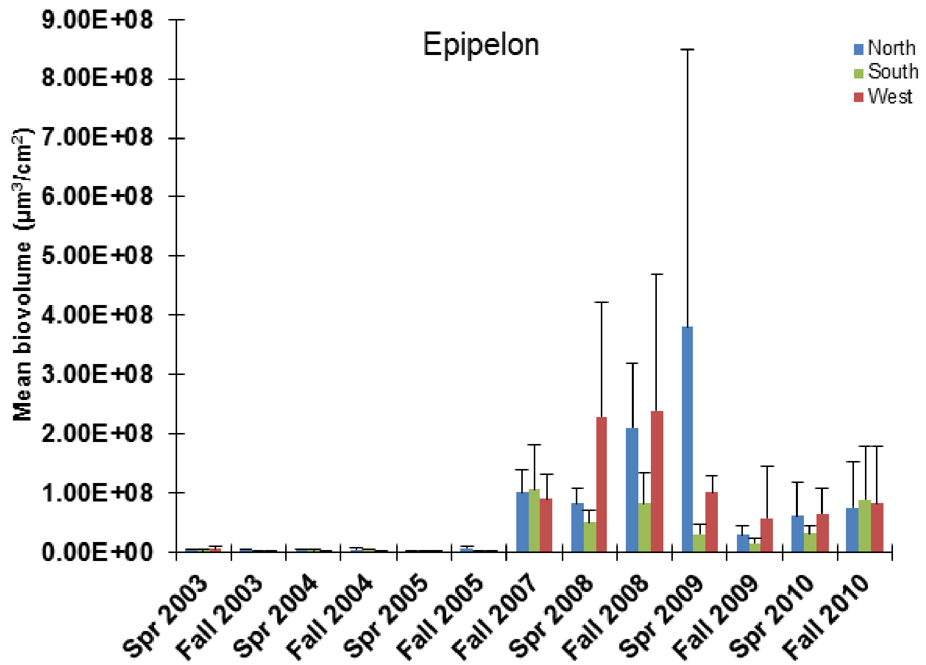


Figure 8-30. Nearshore epipelic mean regional abundances (+1 std deviation) in Lake Okeechobee as cubic micrometers per square centimeter ($\mu m^3/cm^2$).

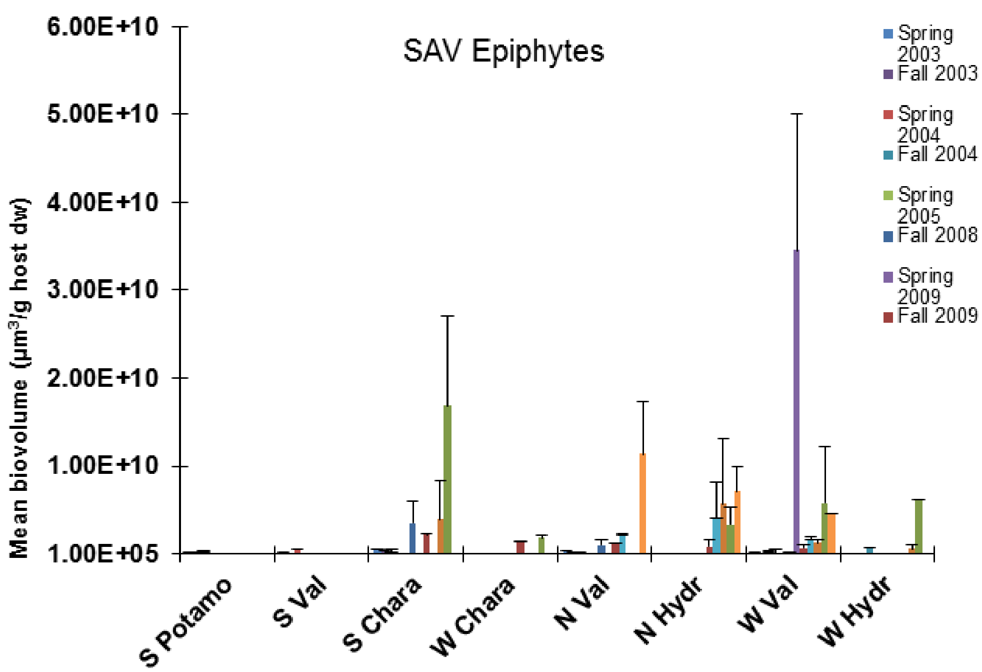


Figure 8-31. Nearshore *Chara****,*** *Hydrilla****,*** *Potamogeton* and *Vallisneria* epiphytic mean abundances (+1 std deviation) in Lake Okeechobee as cubic micrometers per gram ($\mu m^3/g$) host dry weight. Means are presented by geographic region (N=north, S=south, W=west)

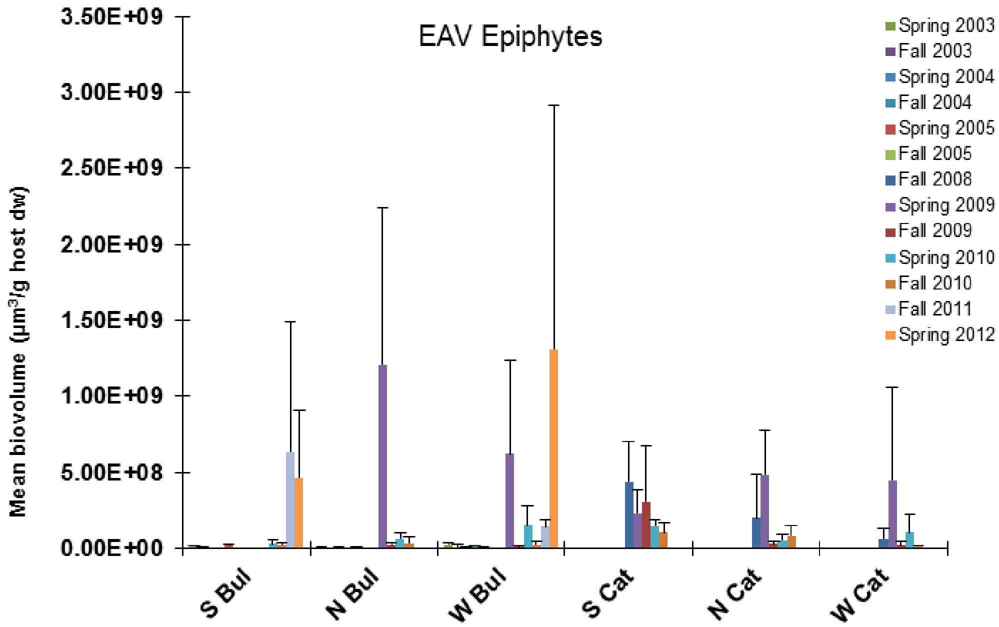


Figure 8-32. Nearshore *Schoenoplectus* (Bul) and *Typha* (Cat) epiphytic mean biovolumes (+1 std deviation) in Lake Okeechobee as cubic micrometers per gram ($\mu m^3/g$) host dry weight.

Mean periphyton abundance was higher during the second study period. Data for epipelon, *Chara*, *Schoenoplectus*, and *Vallisneria* and fall 2011 or spring 2012 epiphytic samples generally had the highest mean overall epiphytic abundances. The epipelic abundances were consistently one to two orders of magnitudes higher during the second study period. However, as epiphytic abundances increased with lower lake stages, the amount of associated variability among the sample abundances likewise increased, as illustrated in the size of the standard deviation bars in **Figures 8-31** and **8-32**). This variability likely accounts for the small differences in separation among the first and second period epiphytic abundances for these host plants. Also, epiphytic abundances for the last sampling period (fall 2012) have not yet been determined from the taxonomic samples. Epiphytic biovolumes on *Schoenoplectus* have been approximately an order of magnitude lower relative to that on the SAV host taxa. Epiphytic biovolumes on *Typha* were determined only between 2008 and 2010 and the general pattern was that the epiphytes on *Typha* were similar to half an order of magnitude higher than those on *Schoenoplectus*. In general, epiphytes on both emergent host taxa have generally been lower than on the SAV host taxa; the same pattern observed for epiphytic biomass during 1989-1991 (Zimba, 1995). Since 2002, both the epiphytic and epipelic communities on all host taxa have been dominated (>80 percent) by diatoms. One-way ANOVA and Tukey HSD tests conducted in SAS v9.3 indicated that periphyton nitrogen (N), phosphorus (P), and carbon (C) mean storage concentrations were similar among the two study periods for most of the comparable host epiphytes and for the epipelon (**Figure 8-33**).

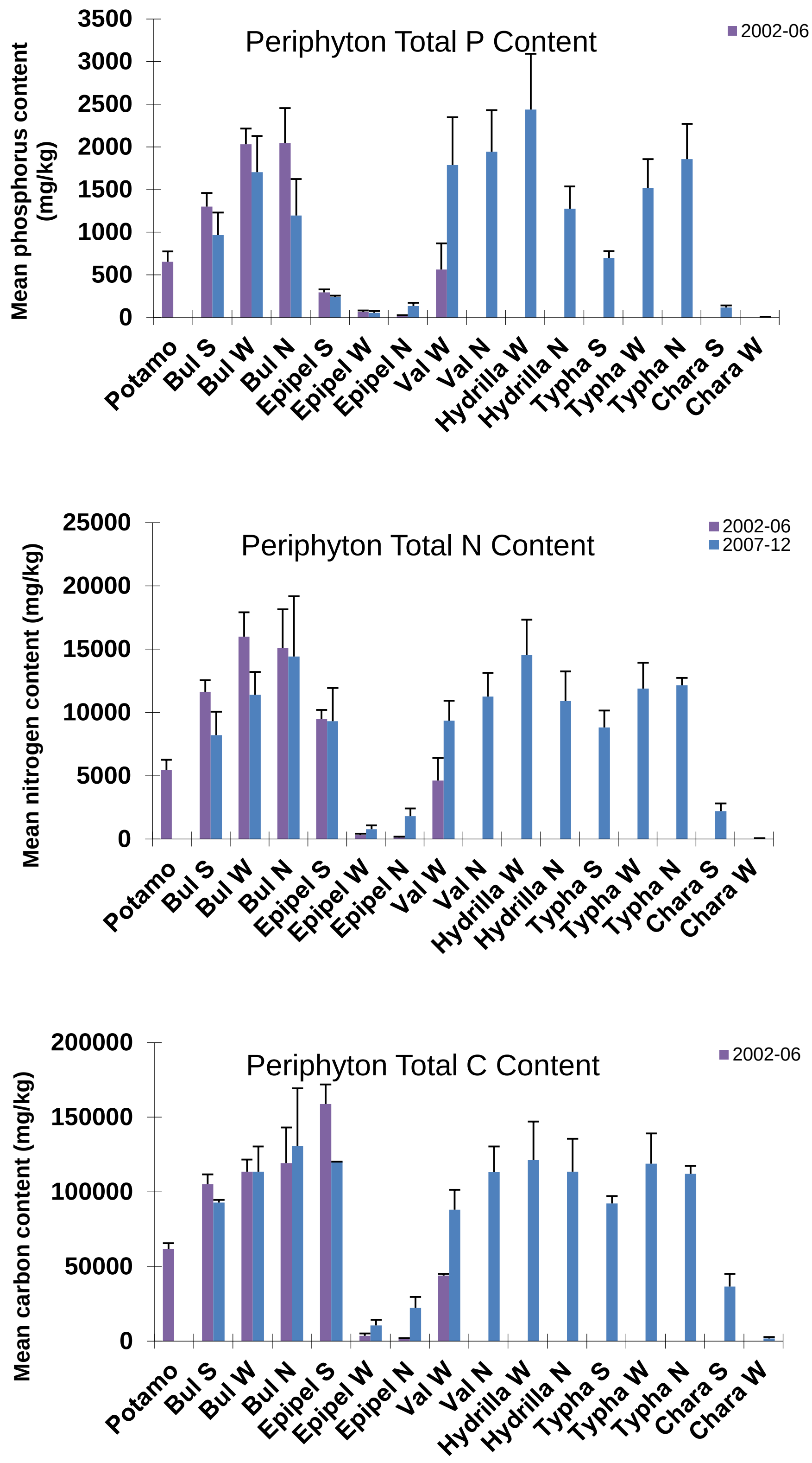


Figure 8-33. Nearshore study period (+1 SE) regional mean epiphytic and epipelic total P, N and C cellular content in milligrams per kilogram of material (mg/kg).

The exceptions were for the west region *Vallisneria*, where total N and C content were statistically significantly higher ($p<0.05$) in the second study period, while the first study period total P content also was significantly higher ($p<0.05$) in *Schoenoplectus*. Also, there were no statistically significant differences in the amount of nutrients or carbon content among the different host-associated epiphytic communities, except for *Chara*-associated epiphytes, which had significantly less nutrient and carbon content relative to the other epiphytic communities during the second study period. Likewise, epipelon had significantly less nutrient and carbon content relative to the epiphytic communities during both study periods. There were no first study period nutrient or carbon content data for *Chara* and *Hydrilla*.

Mean total N:P ratios were very similar between the two study periods and during this reporting period, were little changed from those previously reported (see 2011 SFER – Volume I, Chapter 10) and continued to suggest strong N-limitation (8:1-10:1) for all epiphytic and epipelic communities, with two exceptions. *Chara* and epipelon in the southern region of the lake had mean N:P ratios of 18:1 and 38:1, respectively. These data suggest that P-limitation or conditions approaching P-limitation can occur among some of the periphyton communities in the southern region of the lake. These results are not surprising given the distance of these sites from major inflows, their well-developed plant communities, and their tendency to be partially hydrologically uncoupled from the pelagic zone under low to moderate lake stages.

While variability in host substrate areal coverage and differences in number of sites (one per host type in each region during the first study period versus three during the second study period) made temporal comparisons during the two study periods somewhat problematic, the results generally suggest that lower lake stages resulted in increased periphyton abundance, especially in the epipelic communities. There were indications that nutrient and carbon storage were higher in a few of the second study period epiphytic communities; but the overall theme seems to be that there aren't substantial differences among the EAV or SAV epiphytic communities, with the exception of *Chara*.

However, when differences in periphyton abundance are considered, vascular SAV-associated epiphytes likely store more nutrients and produce more carbon at the community level, relative to the epiphytic communities on EAV hosts and the sediment-associated epipelic communities. Therefore, in addition to other positive ecological benefits provided by vascular SAV habitat (e.g., providing fish habitat), open-water vascular SAV habitat appears to provide the conditions that maximize periphyton abundance and nutrient storage. Maximizing periphyton, a primary producer in freshwater aquatic food webs, likewise maximizes the amount of food available to higher trophic level organisms such as macroinvertebrates and herbivorous or omnivorous fish and may have contributed to the lack of large-scale phytoplankton blooms in the lake since 2006. Maximizing SAV areal coverage and periphyton abundance in the nearshore region may be very important in preventing a possible switch from SAV to phytoplankton dominance, given water column P concentrations (Liboriussen and Jeppesen, 2006; Bécares et al., 2008; Yang et al., 2008; Rodusky, 2010). Therefore, lower water levels along with continued reductions in watershed nutrient loading may be very important components in preventing the nearshore region of the lake from switching to a persistent phytoplankton dominated condition.

LAKE OKEECHOBEE VEGETATION MAPPING

The composition, distribution, and areal coverage of Lake Okeechobee's emergent marsh community is strongly influenced by hydrologic conditions, vegetation management activities and competition between species, especially when native habitats are impacted by invasive exotic plants. Color infrared aerial photography collected in 2012 was used to evaluate and map most of the plant communities in the lake's central western marsh. The marsh was equally divided into a series of 100 m X 100 m (1 ha) grids. The dominant and secondary plant communities within each grid were identified and recorded. Nearly 19,000 ha of marsh vegetation were mapped (**Figure 8-34**) in 2012. The woody shrub species willow (*Salix caroliniana*), buttonbush (*Cephalanthus occidentalis*), and saltbush (*Atriplex pentandra*) were the dominant plants in 27 percent of the marsh (5,115 grids). Cattail was the second most common plant community (1,885 grids), followed by graminoid marsh species (1,649 grids) and spikerush (*Eleocharis cellulosa*) (1,493 grids).

The marsh landscape changed significantly during the period 2010–2012 in response to changing hydrologic conditions. One example of the change was obvious in Moonshine Bay, a region in the central marsh. Lily (*Nymphaea* sp.) was the most dominant plant community in the area during 2010. A regional drought in 2011 caused the lily communities in Moonshine Bay to become exposed on dry sediments. The dry conditions were not favorable for lily and its distribution in this region of the marsh decreased significantly. Cattail was apparently better able to adapt to the drier conditions and when Moonshine Bay re-flooded in 2012, cattail had replaced lily as the dominant community in the area (**Figure 8-35**). The woody shrubs communities also increased in extent in Moonshine Bay and throughout much of the marsh during the period from 2010–2012 in response to drier conditions and lower lake levels.

Further expansion of the cattail community was evident in a 1 km^2 section of Moonshine Bay that was mapped in 2013 (**Figure 8-36**). Cattail was dominant in 12 of the 100, one hectare grids mapped in 2010. That number increased to 32 grids in 2012 and 55 grids in 2013. During the same period, the lily community was reduced from 68 grids to 32 grids.

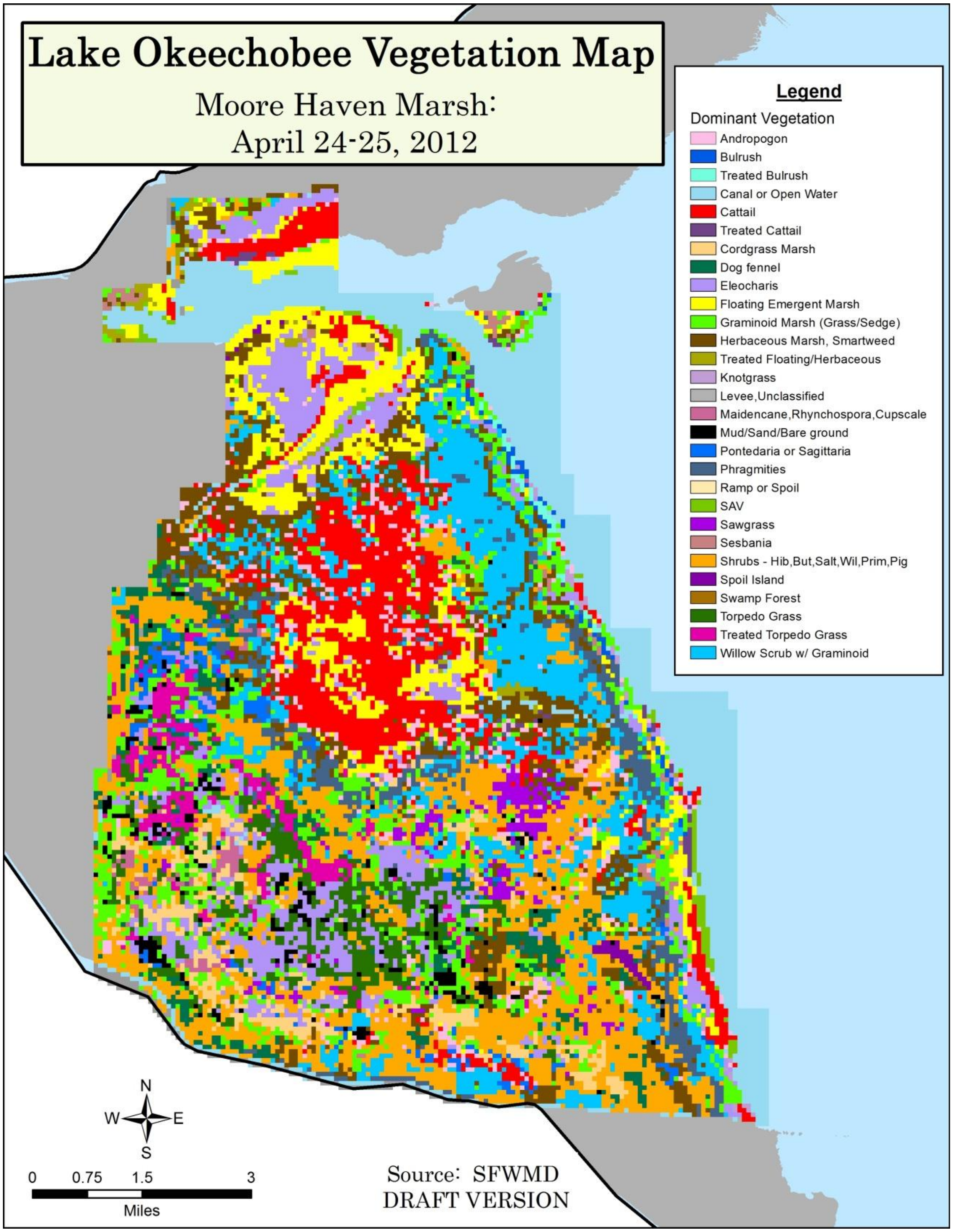


Figure 8-34. 2012 vegetation map of Lake Okeechobee's western marsh (Moore Haven Marsh) showing the dominant vegetation in each 1 ha grid.

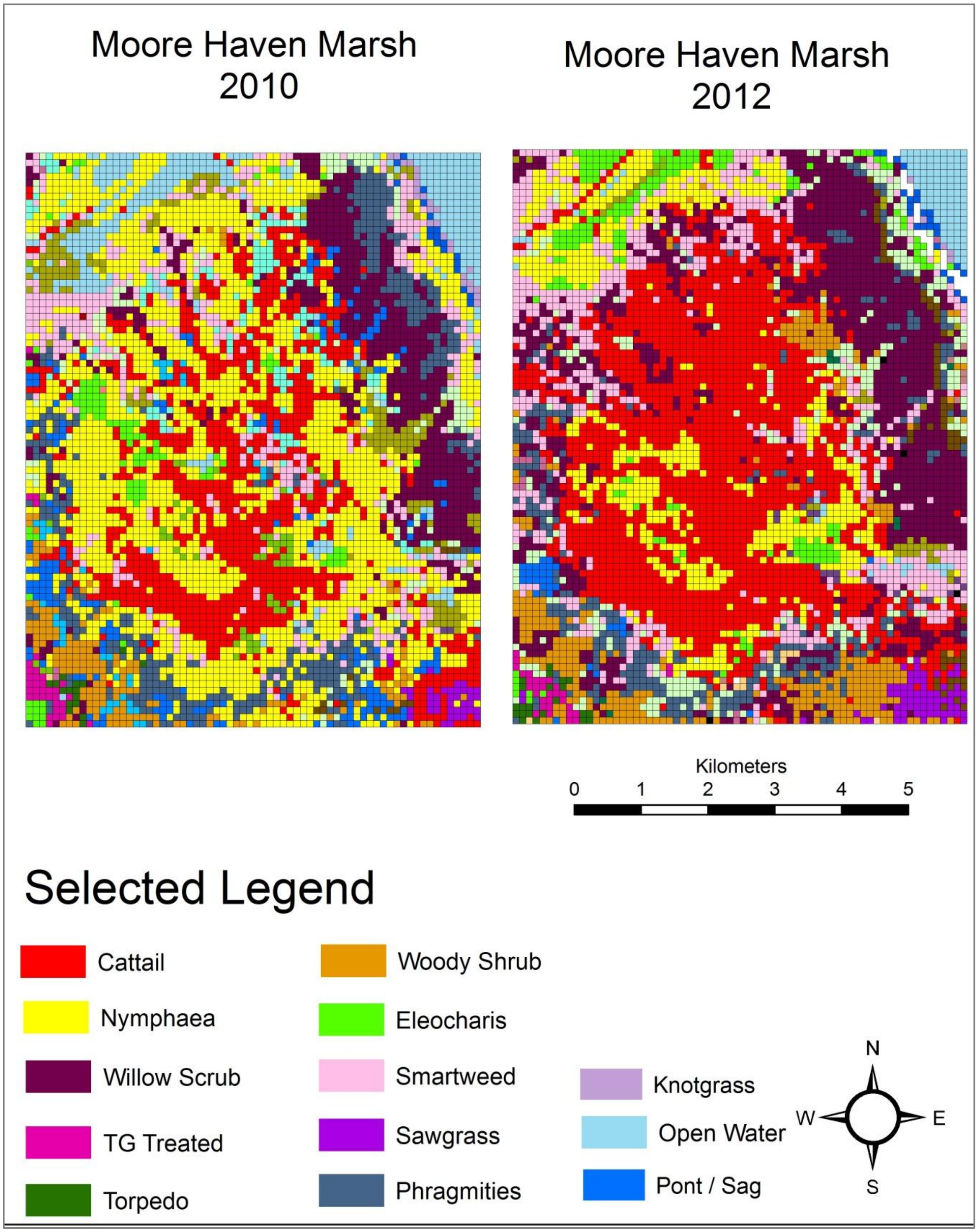
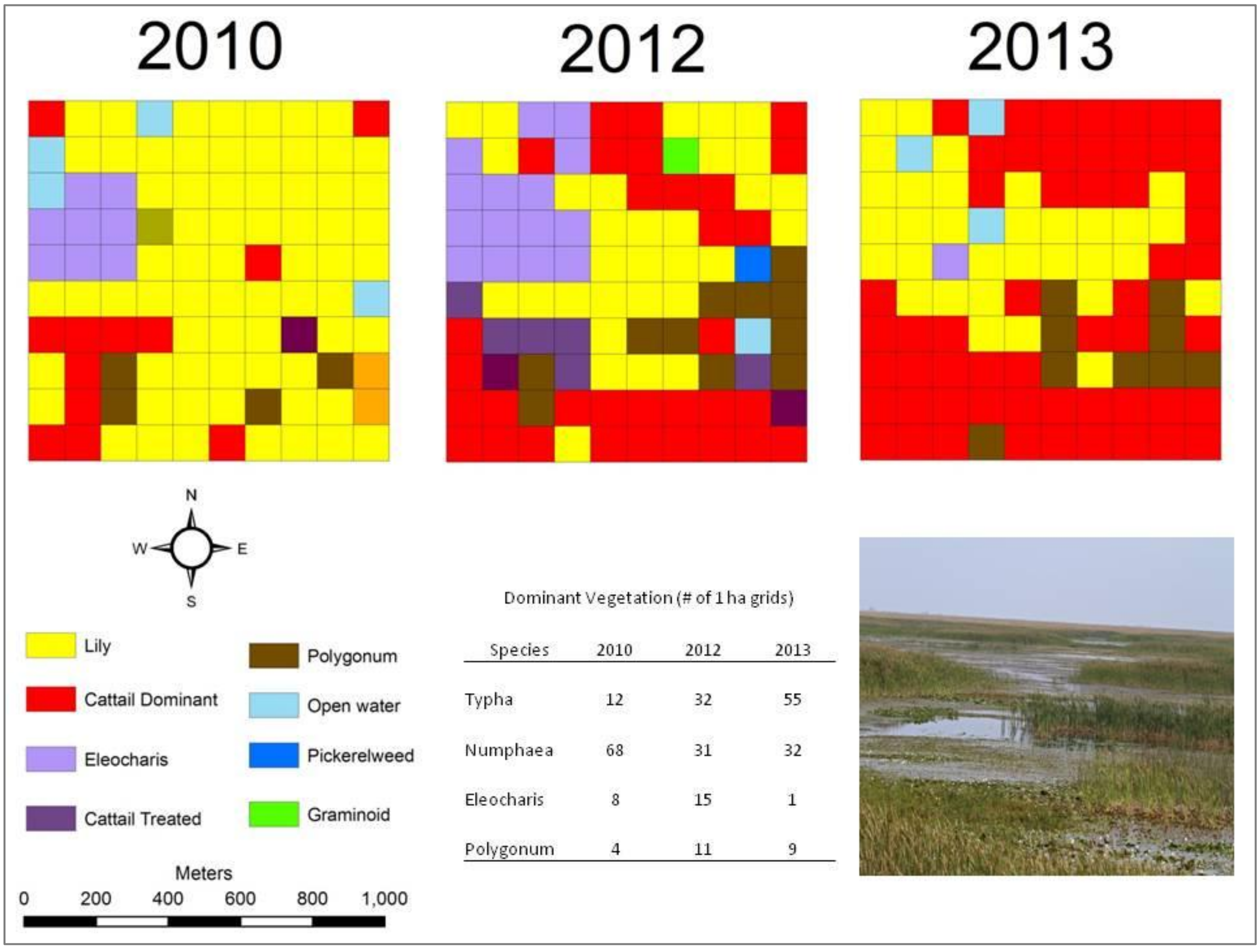


Figure 8-35. Moonshine Bay region of the Moore Haven marsh in Lake Okeechobee. The dominant vegetation in each 1 ha grid is shown by year.



Species	2010	2012	2013
Typha	12	32	55
Numphaea	68	31	32
Eleocharis	8	15	1
Polygonum	4	11	9

Figure 8-36. Vegetation maps of a 1 km^2 area of Moonshine Bay. Temporal changes in the dominant vegetation were primarily caused by changes in hydrologic conditions and quantified in the inserted table.

EXOTIC SPECIES CONTROL PROGRAM

The purpose of the Exotic Species Control Program is to identify the exotic species that threaten native flora and fauna within the Lake Okeechobee Watershed and develop and implement measures to protect native species. The exotic plants and animals identified as threatening native species require management, or in the case of animal species, monitoring of possible future problems. Supporting information on nonindigenous species is also presented in Chapter7 of this volume.

Torpedograss (*Panicum repens*) is the most common emergent exotic plant in the lake's marsh and extensive efforts to reduce its coverage are ongoing. An evaluation of treatment efficacy indicated that many of the treatments provided excellent torpedograss control (90– 100 percent), some for many years following a single treatment. Of the 21 treatment sites evaluated, control (efficacy) was rated as 90 percent or greater at 11 locations (**Figure 8-37**). Torpedograss treatments reduce the occurrence of dense monocultures of torpedograss that provide limited habitat for wading birds and harvestable sport fish. When torpedograss is removed native plants commonly recolonize treated sites. Removing torpedograss and reestablishing shallow open water sites that include a mixture of native vegetation can provide productive foraging habitat for wading birds. This was observed in a number of previously treated sites throughout the marsh during the 2013 wading bird survey **(Figure 8-38**).

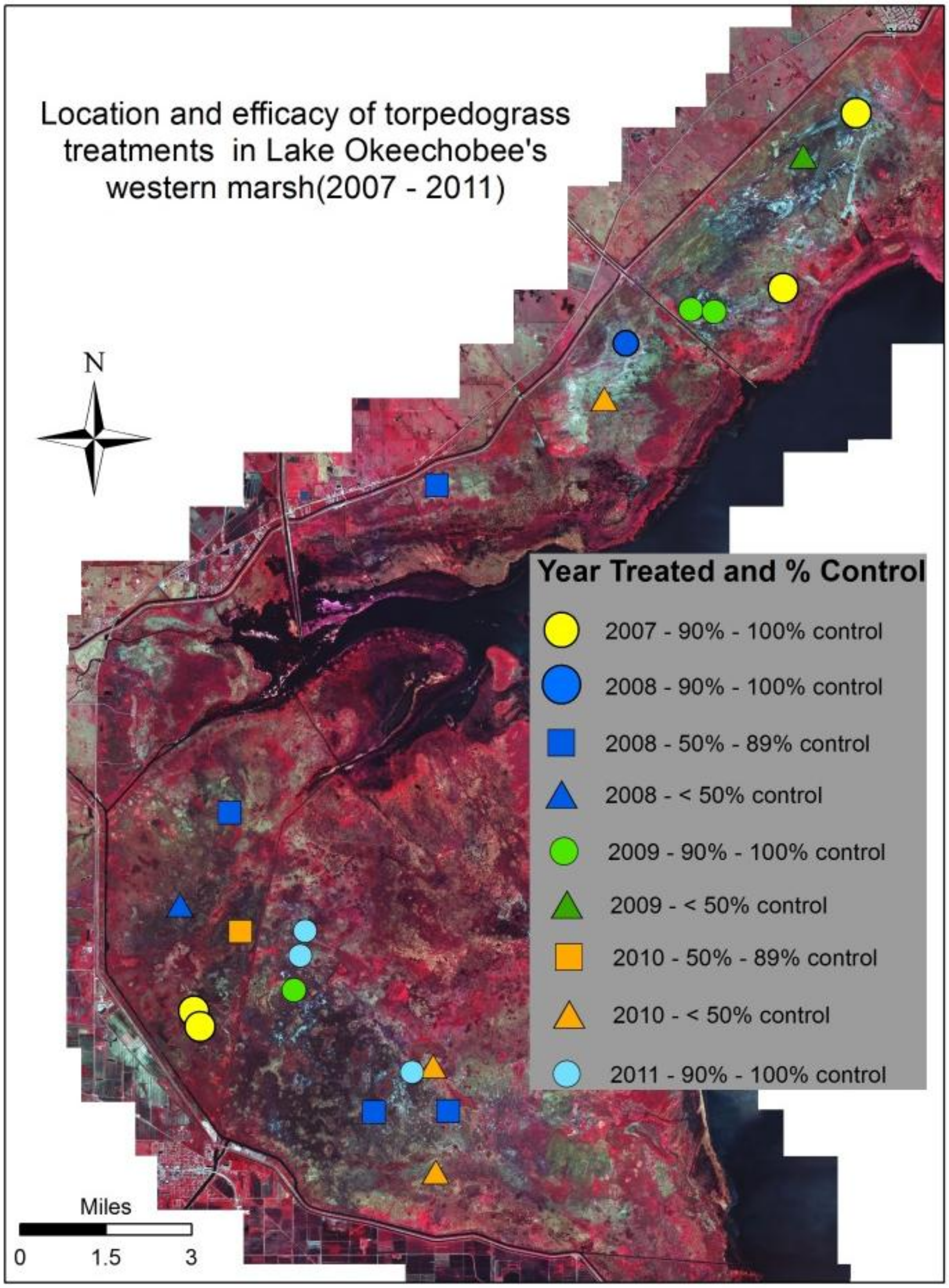


Figure 8-37. Location and efficacy of torpedograss treatments in Lake Okeechobee's western marsh. Colors indicate the year of treatments and the symbol indicates treatment efficacy evaluated as percent control.

Figure 8-38. Wading birds observed foraging in a shallow open water site with mixed native vegetation two years after a successful torpedograss treatment. The site in the Indian Prairie marsh previously had provided poor foraging habitat due to dense coverage of torpedograss (photo by the SFWMD, December 2013).

During the period from July 201–June 2013, 2,185 acres of torpedograss were treated in the western marsh. There was a need to treat thousands of additional acres but funding was not available. New infestations of torpedograss have established near the outer edge of the marsh. This is a concern because important and productive fish habitat is being lost in an area heavily utilized by anglers. In addition to torpedograss, more than 350 acres of melaleuca (*Melaleuca quinquenervia*) and 210 acres of exotic watergrass (*Luziola subintegra*) were treated. Melaleuca resurfaced as a concern this past water year due to the dry conditions in the southwestern marsh over the last several years which provided good conditions for seed germination. In total, more than 4,900 fewer acres of emergent exotic and nuisance vegetation was treated in 2013 as compared to 2012 (**Figure 8-39**).

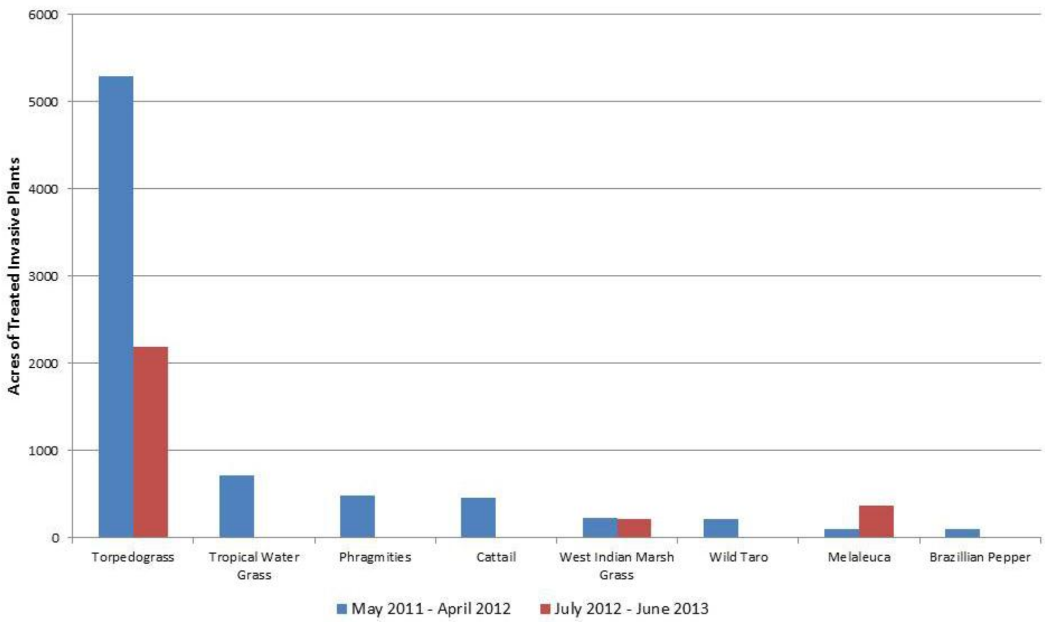


Figure 8-39. Number of acres of the most commonly treated exotic or invasive plants in Lake Okeechobee's western marsh during the past two years.

MACROINVERTEBRATES

Since 2008, with some exceptions as noted below, biannual macroinvertebrate sampling has been conducted by the FWC in February and August. During these sampling trips, triplicate samples have been collected at each of 18 long-term nearshore and pelagic sites (Warren et al., 2008), for a total of 54 samples. During May of both 2009 and 2010 only partial sampling was conducted at half of these sites. Incomplete sampling also occurred in 2011 and no samples were collected from 2012 to 2013 due to budgetary constraints. All the samples collected during this period have been processed, with the exception of 22 samples collected during 2011. The processed samples still need to undergo a quality assurance/quality control step prior to reporting the data (G. Warren, FWC, personal communication). The remaining 22 preserved samples have been archived prior to sample processing and taxonomic identification steps. These samples are anticipated to be processed and validated by September 30, 2013. Therefore, it is anticipated that updated macroinvertebrate data will be available for reporting in the 2015 SFER – Volume I.

FISH

Lake Okeechobee's fishery is monitored annually by the FWC. They use a standardized lake-wide electrofishing protocol to monitor the near shore fishery and a lake-wide trawling protocol to monitor pelagic species.

Electrofishing

Lake-wide electrofishing conducted at 22 sites during October 2012 resulted in the capture of 4,345 fish, with a combined biomass of 701,247 g. Fish abundance and biomass spiked in 2010, but 2011 and 2012 numbers were greater than those observed in the years between 2005 and 2009. Fish biomass and abundance have generally increased since the all-time low for this data set recorded in 2006 (**Figure 8-40**). Thirty-four fish species were represented in the 2012 catch. Six dominant species (more than 5 percent of the sample) collectively comprised 78 percent of the catch by number and were, in order of abundance: threadfin shad (*Dorosoma petenense*), largemouth bass (LMB; *Micropterus salmoides*), bluegill (*Lepomis macrochirus*), gizzard shad (*D. cepedianum*), eastern mosquitofish (*Gambusia holbrooki*), and sailfin molly (*Poecilia latipinna*). Five dominant species (more than 5 percent of the sample) collectively comprised 82 percent of the catch by weight and were, in order of biomass: LMB, striped mullet (*Mugil cephalus*), Florida gar (*Lepisosteus platyrhincus*), bluegill, and gizzard shad.

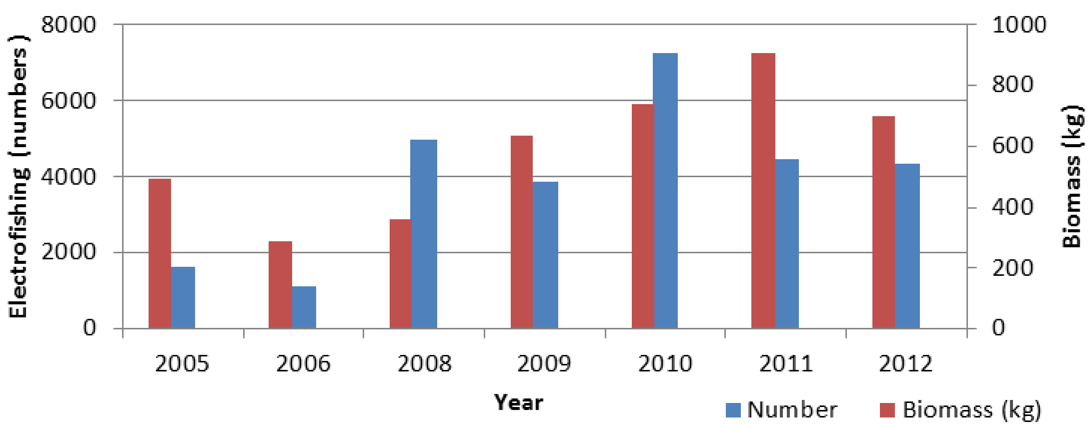


Figure 8-40. Lake-wide electrofishing data indicating total biomass (kg) (red) and the total number of fish (blue) collected during October 2005–2012.

Comparison of lake-wide electrofishing data indicated changes in the community through changes in proportions of select predator and prey species (**Figure 8-41**). Shad species comprised the highest proportion of the catch in 2008, while the proportion of piscivorous fish was generally low. As the proportion of several forage species generally declined from 2009–2012, the proportion of the population consisting of LMB, bluegill, and redear sunfish (*Lepomis microlophus*) increased.

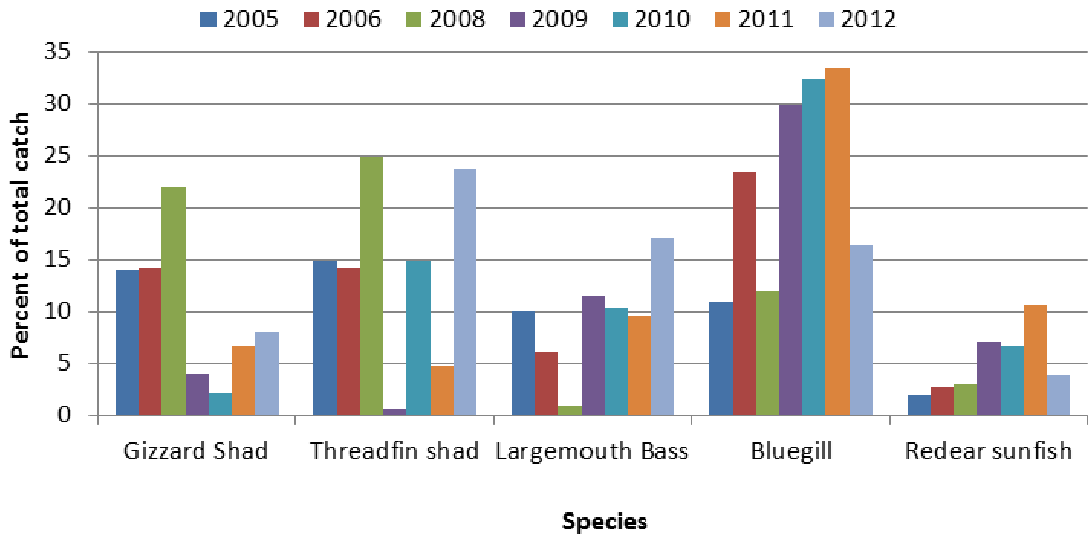


Figure 8-41. Percent of total catch of selected prey and piscivorous species collected by electrofishing during October 2005–2012. [Note: In 2007, no data were collected due to drought conditions that prevented access to inshore sampling sites.]

In addition to fish abundance, the size and composition of the fish community can be evaluated using catch per unit effort (CPUE) data. All time low catch rates for many species were found in 2006 following the passage of several hurricanes over or near the lake in 2004 and 2005. These hurricanes negatively impacted the lake by causing rapid changes in water level, resuspending the internal sediment pool, and uprooting much of the emergent and submerged vegetation community. However, since 2008, there has been a generally increasing trend in catch rate (with a spike in 2010 for some species) in the number of several dominant species including bluegill and largemouth bass (**Figure 8-42**).

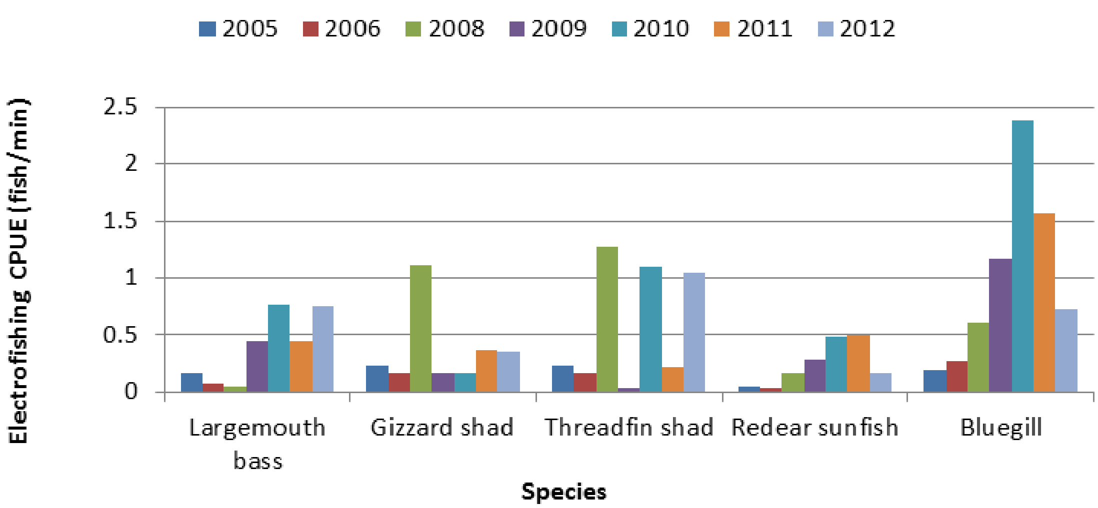


Figure 8-42. Electrofishing catch per unit effort (CPUE) values for October 2005–2012. [Note: In 2007, no data were collected due to drought conditions that prevented access to inshore sampling sites.]

Trawling

Lake-wide trawl sampling at 27 sites resulted in the capture of 4,650 fish with a combined biomass of 381,299 grams (**Figure 8-43**). Twenty fish species were represented in the catch. Four dominant species (more than 5 percent of the sample) collectively comprised 90 percent of the catch by number and were, in order of abundance: threadfin shad, black crappie (*Pomoxis nigromaculatus*), bluegill, and white catfish (*Ameiurus catus*). Five dominant species (more than 5 percent of the sample) collectively comprised 83 percent of the catch by weight and were, in order of biomass: white catfish, black crappie, Florida gar, bluegill, and channel catfish (*Ictalurus punctatus)*.

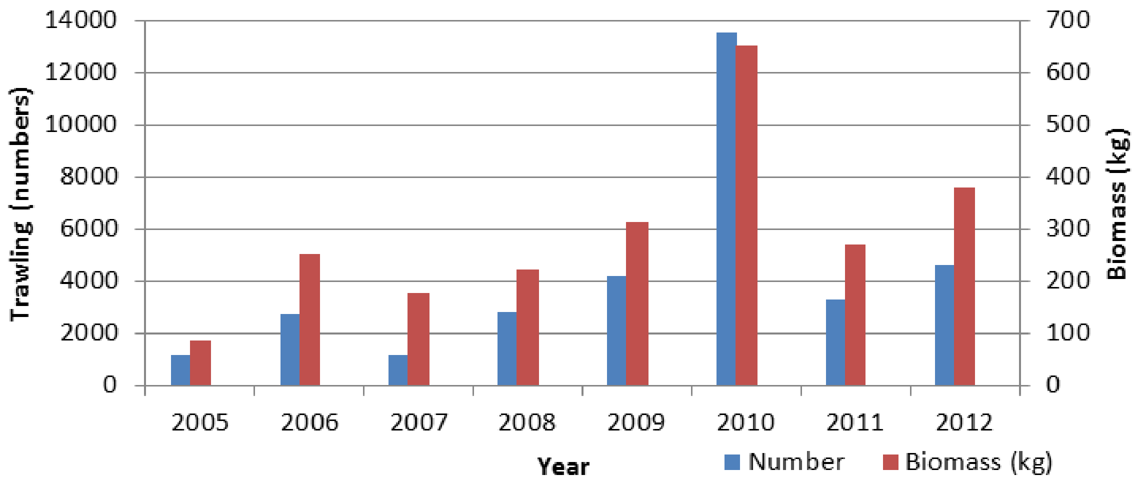


Figure 8-43. Comparison of lake-wide trawling data indicating the total number of fish (blue) and total biomass (kg) (red) collected during December 2005–2012.

Fish abundance and biomass have generally shown an increasing trend from a low in 2005 to present (**Figure 8-44**). Like the electrofishing data, abundance and biomass spiked in 2010. This was largely attributed to large spikes in threadfin and gizzard shad populations that year. When compared to 2005, the total catch and biomass in 2012 has increased by 306 and 345 percent, respectively, indicating a large increase in the pelagic fish population.

Black crappie comprised more than 40 percent of the total catch in 2005 and declined to less than 5 percent of the catch in 2008–2010 (**Figure 8-44**), but have since increased to 29 percent of the catch in 2012. The number of threadfin shad (a dominant prey item) has slowly declined since 2008, when they accounted for 41 percent of the total catch. Currently, threadfin shad account for 31 percent of the catch. The decrease in threadfin shad abundance represents a switch from a primarily prey based community to a more predator dominated community.

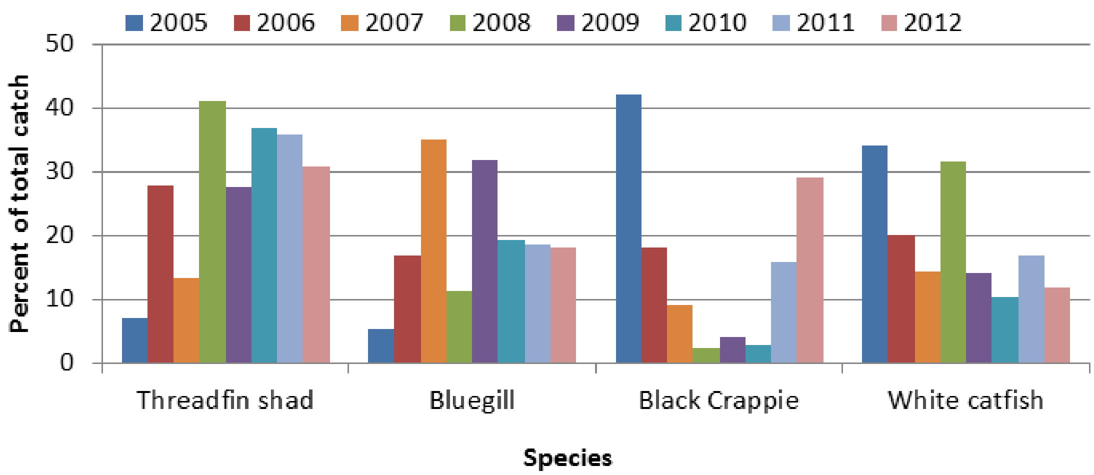


Figure 8-44. Percent of total catch of selected prey and piscivorous species collected by trawling in the pelagic region of the lake during December 2005–2012.

Threadfin shad, bluegill, and white catfish reached their highest catch rates (CPUE) in 2010 but declined to more historic average catch rates in 2011 and 2012 (**Figure 8-45**). The catch rate of black crappie declined sharply for several years after 2006 with an all-time low of 0.12 fish/minute in 2008 (n=64 fish). However, the catch rate of black crappie has increased since 2009 and is now the highest it has been since this study began in 2005 (CPUE=2.51 fish/minute) suggesting a recovery of the lake's crappie population.

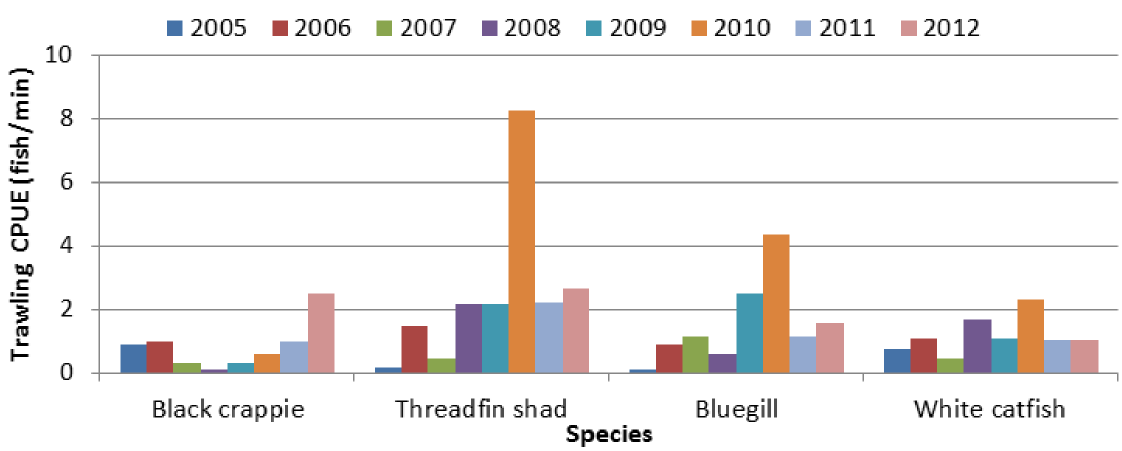


Figure 8-45. Trawling CPUE (fish per minute) values for December 2005–2012.

Sport Fish Recovery

Largemouth bass are seeing some of the highest catch rates since this study began in 2005. The past few years have shown increases in number and sizes of bass in the population. Peaks in abundance are occurring at two length groups with the first peak at 10 -18 cm and the second peak at 28-34 cm (**Figure 8-46**). By contrast, in 2005 when the population was beginning to crash, there were almost no small fish. The increases of the past few years will ensure good spawn rates for some time into the future. The bass population is definitely recovering.

In 2012, there were 1,353 black crappie collected in the lake-wide trawl (highest number collected since 2005. A majority of these fish were young-of-the-year in the 10 cm-14 cm range (**Figure 8-47**). Having such a high number of smaller black crappie is a positive indicator for the population. Catch rates are not quite at levels that were seen during the 1980s but the catch rates have been increasing and the black crappie population is recovering.

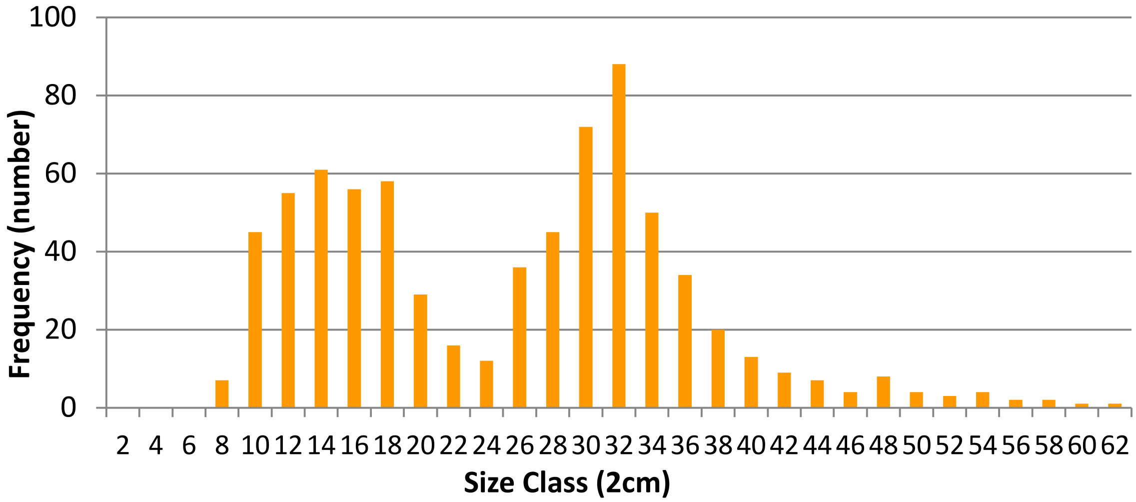


Figure 8-46. Length distribution per 2-cm size class for largemouth bass, n=742 collected in October 2012 lake-wide electrofishing samples.

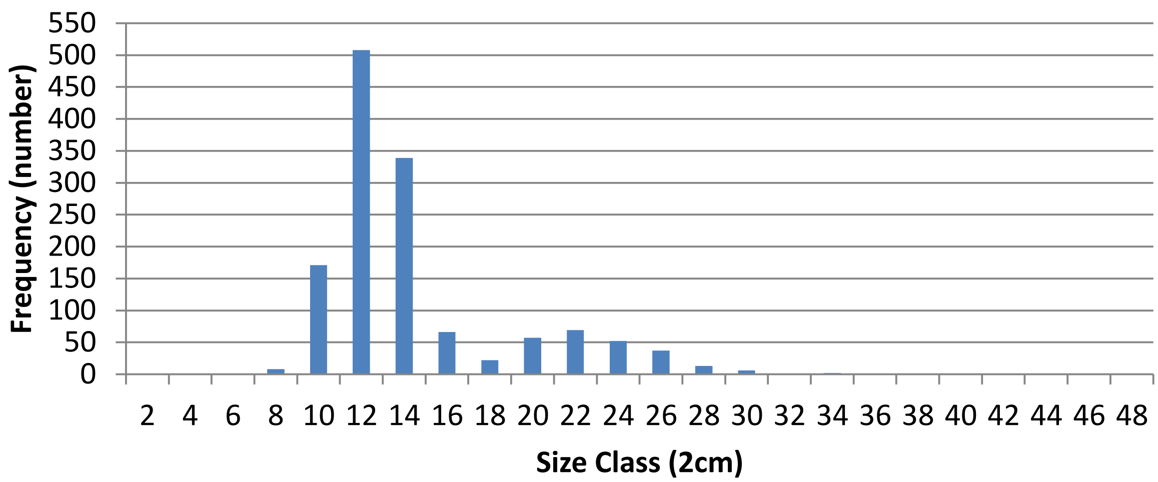


Figure 8-47. Length distribution per 2-cm size class black crappie, n=1353 collected in December 2012 lake-wide trawling samples.

WADING BIRD SURVEYS

Wading bird foraging has been monitored in Lake Okeechobee since 2010. These data can be used as indicators of habitat quality and provide an important tool for examining the effects of hydrology, restoration efforts, and changes in the trophic levels that constitute the prey base. This monitoring can provide insight into habitat suitability and utilization based on climatology and water management decisions and allows for a general overall assessment of ecological conditions within the lake. It also provides important supporting data for the annual Lake Okeechobee wading bird nesting surveys carried out by Florida Atlantic University for the RECOVER program.

Methods

Wading bird surveys were conducted from December 2012 through June 2013 along east-west transects established at 2 kilometer (km) intervals throughout the entire littoral zone of Lake Okeechobee. Survey frequency was increased to twice monthly starting in March 2013. Further details regarding survey methods are described in the 2012 SFER – Volume I, Chapter 8.

Results and Discussion

This year's flights began in December 2012 with the lake at a stage of 15.3 ft (4.7 m) NGVD with approximately 99 percent of the marsh inundated (**Figure 8-48**). Throughout the season, stage exhibited a strong and steady recession with averages of 0.08ft weekly and 0.31ft monthly creating conditions that were favorable to wading bird foraging and nesting.

The number of foraging birds returned to levels seen in 2010 and 2011 after a noticeable overall decrease in 2012. Mean wading bird flock size throughout the season ranged from 276 to 379 birds. In general, the sizes of the foraging flocks were larger than in 2012 and similar to what they had been in previous years. The data indicated that 48 percent of the foraging flocks consisted of 100 to 400 birds in 2013 compared to 44 percent in 2012. There was a noticeable shift in flocks of 50-100 birds from 44 percent in 2012 to 23 percent in 2013, and large flocks of 500+ birds from 12 percent in 2012 to 29 percent in 2013. The total number of birds foraging in the lake peaked in March which predated the peak of nesting activity.

The increase in foraging wading birds in 2013 was likely the result of a continued rebound in prey densities after the driest period on record in 2011 left the Lake Okeechobee marsh completely dry for more than six months. Recolonization of the prey base can be a slow process and studies have shown that it can take up to three years in the Everglades (DeAngelis et al., 1997) although in this instance it appeared to occur more rapidly in the Lake Okeechobee marsh. A depressed prey base is a common occurrence in the Everglades following drought where there is typically a time lag between when water becomes available and fish begin to spawn (DeAngelis et al., 1997). Since stage levels in the lake were favorable for increases in wading bird prey prior to the 2013 dry season, foraging numbers and nesting effort were noticeably higher. Prey sampling conducted on the lake during the 2012 breeding season indicated that the prey densities were half of what they were in the 2011 breeding season (**Figure 8-49**). In 2013 prey densities were higher than in 2012 but still considerably lower than 2011 [J. Chastant, Florida Atlantic University (FAU), personal communication].

Nesting effort followed a similar trend as prey density over the past three years. A noticeable difference was this year's increase to almost historic levels in nesting in the lake (6919 nests; J. Chastant, FAU, unpublished provisional data). Nesting effort in 2013 not only surpassed 2012 but will likely be the highest recorded effort since 2006. It is likely that numerous variables accounted for this increase including higher lake stage at the onset of the dry season, proper recession rates, increased prey densities, and no less than 50 percent of the littoral zone being inundated throughout the dry season with greater than 75 percent being inundated through March.

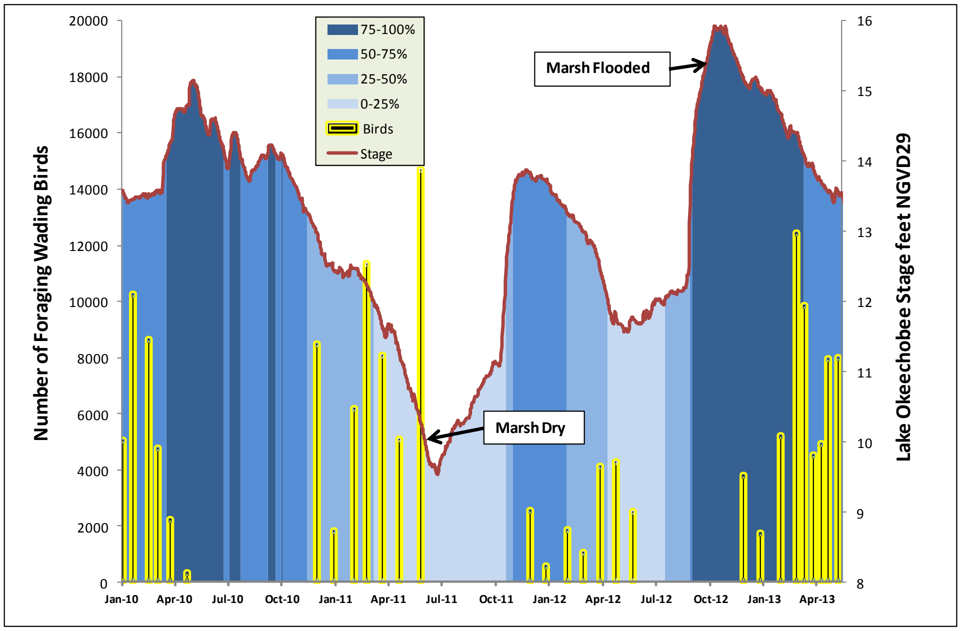


Figure 8-48. A comparison of the total number of foraging birds surveyed each month from 2010 until 2013 in relation to lake stage and percent of the marsh flooded.

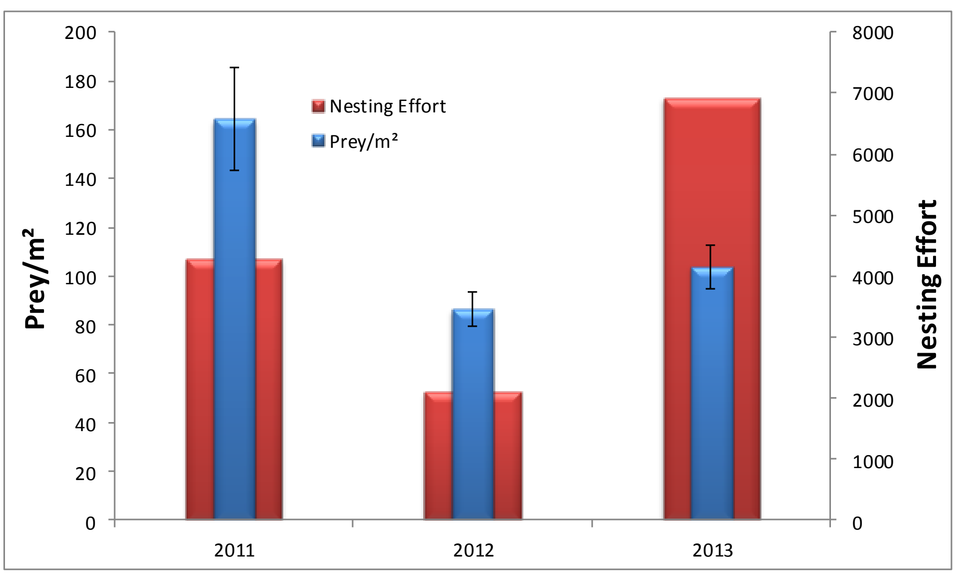


Figure 8-49. A comparison of prey/m² and nesting effort from 2011–2013 [J. Chastant, Florida Atlantic University (FAU), unpublished provisional data].

Twelve colony sites were active on the lake with Liberty Point 2 and Moore Haven East 4 containing 50 and 35 percent of the nests respectively. Peak nesting on the lake occurred in April (6,870 active nests **Table 8-20**) which coincided with the initiation and peak of nesting by white ibis. Great egrets (*Ardea alba*) and snowy egrets (*Egretta thula*) peaked in March and continued with high nesting effort through April. Snowy egrets were the most common breeder on the lake followed by white ibis (*Eudocimus albus*) and great egrets (cattle egret, *Bubulcus ibis*, excluded). Roseate spoonbills (*Platalea ajaja*) foraging flocks were frequently observed during the breeding season as well as numerous birds roosting at colony sites. Two nests were found at Moore Haven East 4 but both failed. Wood storks (*Mycteria americana*) were also observed foraging and roosting near colony sites but no nests were located in 2013.

Table 8-20. Species specific peak nest efforts in detected colonies during the 2013 breeding season (J. Chastant, FAU, unpublished provisional data).

Month	GREG	GBHE	WHIB	SNEG	LBHE	TRHE	WOST	GLIB	ROSP	CAEG	ANHI	Peak nest effort[1]
January	---	4	---	---	---	---	---	---	---	---	---	4
February	650	16	---	---	---	---	---	---	---	---	15	666
March	1592	13	---	2911	100	500	---	---	---[2]	---	58	5116
April	920	10	2400	2000	401	739	---[2]	400	---[2]	---	45	6870
May	350	---	1550	750	200	320	---	250	**2**	1000	10	3422
June	70	---	300	250	70	100	---	---	---	1850	---	790

[1]Does not include CAEG or ANHI
[2]Species detected during monthly survey effort but never seen nesting

GREG- great egret
WHIB – white ibis
LBHE – little blue heron
WOST – wood stork
RSOP – roseate spoonbill
ANHI – anhinga
GBHE – great blue heron
SNEG – snowy egret
TRHE – tricolored heron
GLIB – glossy ibis
CAEG – cattle egret

Utilization of the littoral zone for foraging may be driven by lake stage at the onset of the dry season. Over the last four years of surveys foraging flocks were encountered at lake stages ranging from 15.14 to 9.73 ft (4.61 to 2.97 m) NGVD. The location of these foraging flocks usually followed a predictable pattern, tracking the receding water across the littoral zone (**Figure 8-50**). In 2010 and 2013, wading birds appeared to use much of the littoral zone throughout the season as lake stages remained higher (**Figure 8-51**). Different observations were found in 2011 and 2012, where accessibility was limited by low lake stages from the beginning of the season with less than 25 percent of the littoral zone available throughout most of the dry season. Under these conditions, birds were primarily found foraging in and around cuts and tributaries flowing into the lake and to a smaller degree, in small drying pockets within the littoral zone.

Although foraging conditions on Lake Okeechobee may not always be ideal, the lake appears to act as a last refuge when foraging conditions outside of the lake are poor. A benefit of the large size of the lake is that it acts as a buffer against all but very large localized and regional rain events. This emphasizes the importance of the lake as a refuge during seasons with poor hydrological conditions and is likely a contributing factor to the overall success of wading birds in other parts of the system.

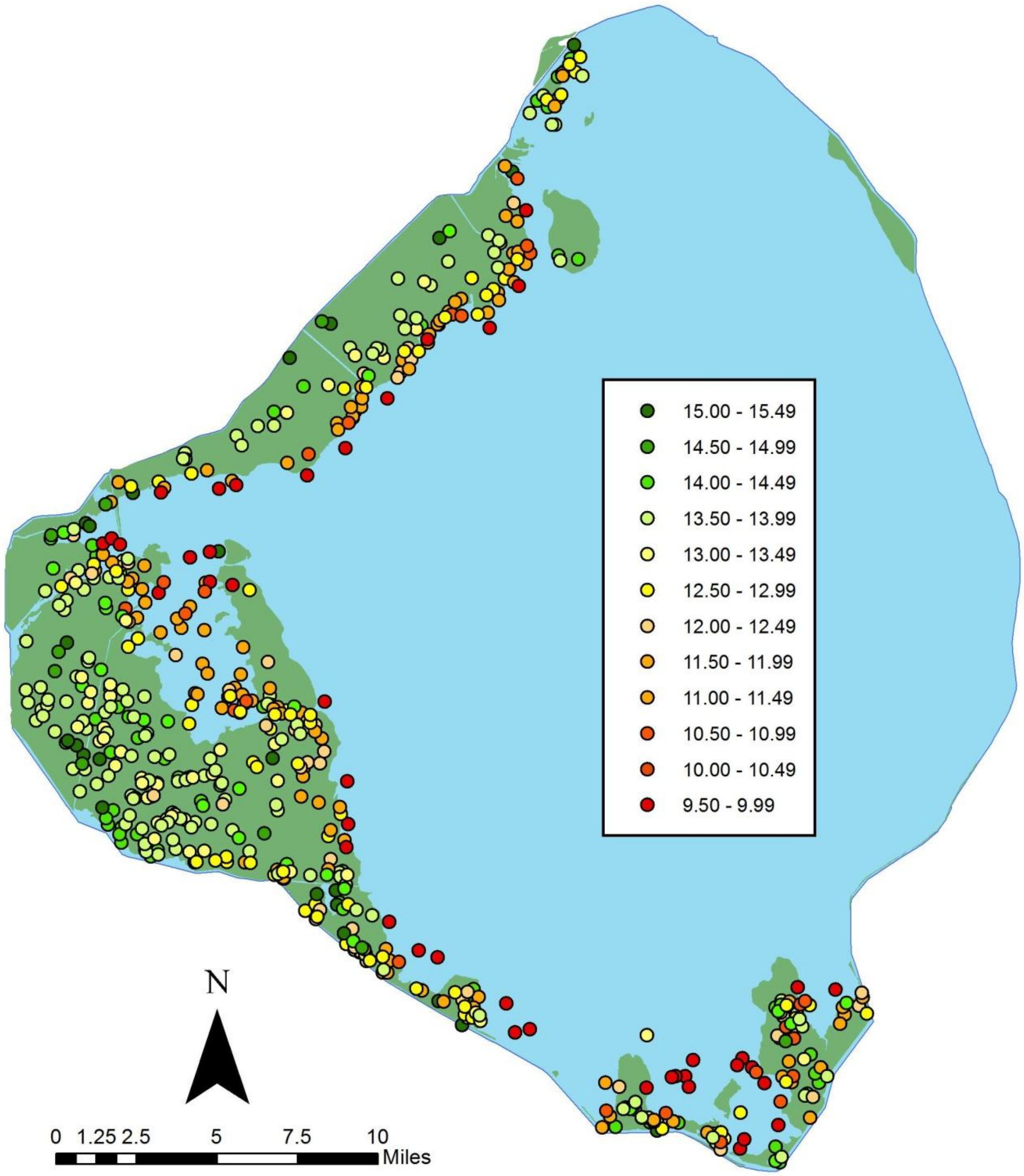


Figure 8-50. A spatial comparison of wading bird foraging flock locations in relation to lake stage from 2010–2013.

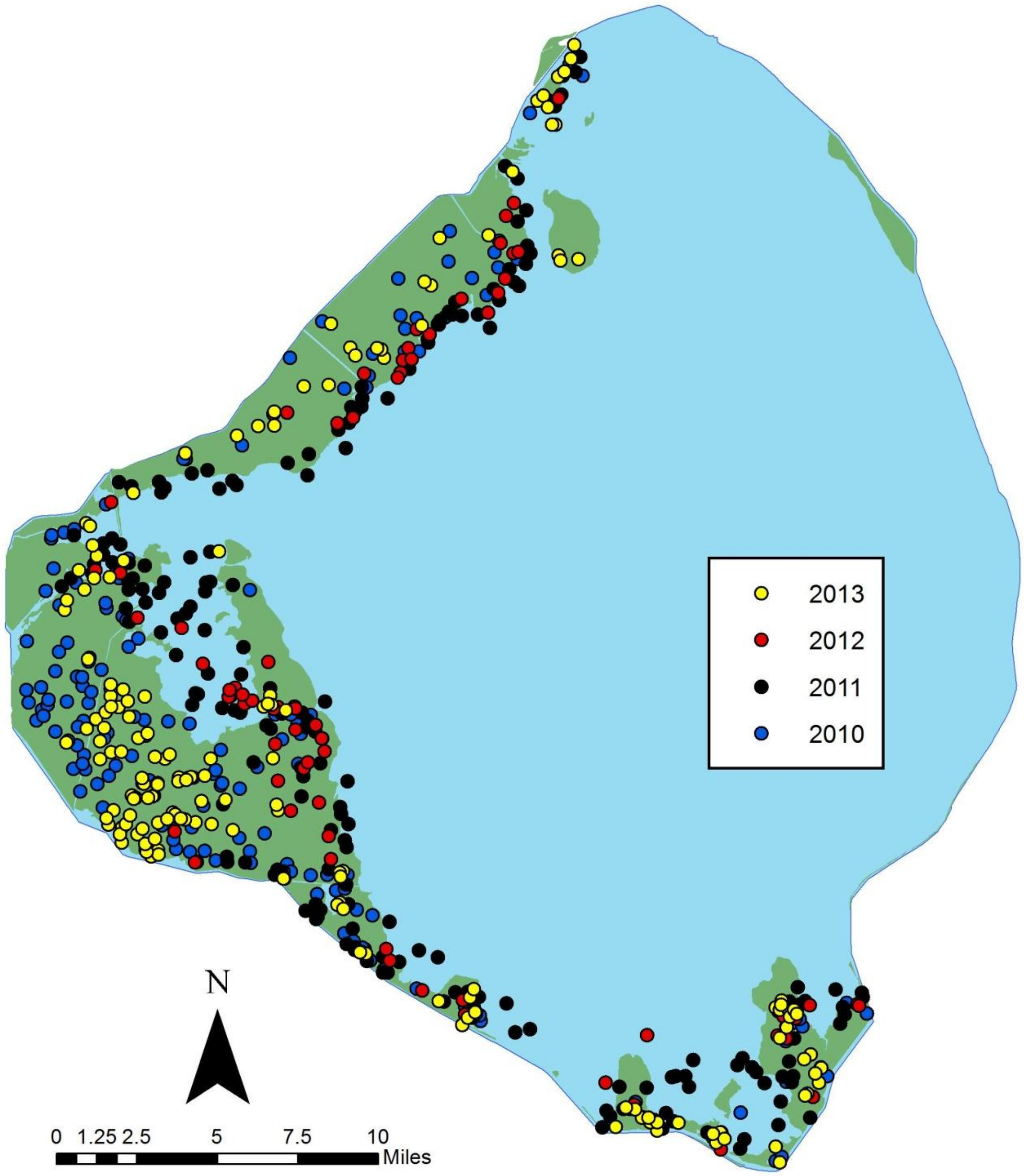


Figure 8-51. A spatial comparison of wading bird foraging locations based on dry seasons from 2010–2013.

APPLE SNAILS

A large portion of the Lake Okeechobee marsh is designated as critical habitat for the endangered snail kite (*Rostrhamus sociabilis plumbeus*) whose primary food source is the Florida apple snail (*Pomacea paludosa*). Recent water management actions, climatic conditions, and perhaps other unknown factors have resulted in a reduction of the native apple snail population accompanied by an expansion of the population of the exotic apple snail (*P. maculata,* formerly *insularum*) in Lake Okeechobee. As it is unclear what the long-term effects of this change in apple snail species dominance will be on snail kites, on the native snail population, and on the nearshore and littoral zone habitats of Lake Okeechobee, investigations into the potential for hatchery rearing and stock enhancement of native apple snails have been undertaken.

Hatchery Study

While working in partnership with Harbor Branch Oceanographic Institute, culture protocols were established for raising animals under laboratory conditions. However, production under these culture methods is limited by space and is labor intensive, making the program potentially cost prohibitive. Therefore, in 2011, a study was initiated within the Lemkin Creek isolated wetland in an effort to (1) determine if a more extensive and potentially less labor intensive in-situ hatchery program could be an efficient and less costly means of producing a large number of animals for restocking purposes and (2) test various stock enhancement scenarios to identify the most effective stocking strategies for achieving optimal survival and population reestablishment.

To meet these objectives, nine small (27 m^2) hatchery enclosures were constructed and stocked with apple snails (see 2013 SFER – Volume 1, Chapter 8 for details). In the hatchery enclosures, District staff monitored total clutch production, analyzed egg clutch characteristics for comparison to wild clutches, and estimated the average survival from hatchling to adult within each enclosure.

Methods

In April 2011, nine enclosures constructed within the Lemkin Creek wetland were stocked with sexually mature Florida apple snails at densities of 0.5, 2, and 4 snails per m^2 (low, medium, and high). Post stocking, the enclosures were visited every two weeks throughout the remainder of the apple snail breeding season (May–October) in 2011. District staff continued to monitor enclosures throughout the 2012 breeding season as well (March–October). All egg clutches within the enclosures were enumerated. Egg clutches laid on artificial substrates or on natural substrates within arm's reach of the enclosure walls were collected and transported to an outdoor mesocosm facility located on District property where the eggs were hatched and reared. These egg clutches were analyzed to determine the number of eggs per clutch and the hatch rate of each clutch. Egg clutches laid on the walls of the enclosure or on substrate toward the center of the enclosure beyond arms reach were counted but not collected. These clutches provided the source for the 2012 adult population ensuring the continuation of reproduction during the next breeding season.

To determine the population density of each enclosure during the second breeding season, a capture-mark-recapture study was undertaken at the beginning of the 2012 breeding season. By estimating the population of each enclosure in 2012, it was possible to calculate the average survival of hatchlings from the 2011 season that successfully grew to adulthood to breed in 2012.

The Lemkin Creek marsh was chosen for this study primarily based on its anticipated hydrologic stability. However, 2011 was the driest dry season on record since the 1930s and the marsh completely dried out by the beginning of June 2011 and remained this way for two months. During the dry period, adult apple snails were found buried in the sediments within the enclosures and were still alive. However, research has indicated that there is a direct correlation between time since drydown and mortality, with smaller animals being more susceptible to death (Darby 1997). As the marsh dried out one month following stocking, it is likely that snails hatched into the enclosures during that first month did not have sufficient time to grow large enough to survive such dry conditions. Therefore, for this analysis, juveniles hatched into the enclosures before June 2011 were not taken into account. If any juveniles did survive from this time period, then it was most likely a low number and should minimally bias any of the population analyses in this report (see the 2013 SFER – Volume I, Chapter 8 for detailed methods and site description).

By the beginning of the 2013 breeding season, all the enclosures were full of very dense emergent vegetation which precluded efficient harvesting of eggs so collections were discontinued. This presents an unanticipated management issue for this type of extensive hatchery system, and one that will need to be dealt with to make this otherwise attractive approach sustainable for the long term.

As a consequence of the dense emergent vegetation in the enclosures, no eggs were harvested during the 2013 breeding season. The 2013 SFER – Volume I, Chapter 8 reported the results from the 2011 breeding season and the first half of the 2012 breeding season. The following results encompass the 2011 breeding season (as previously reported) as well as the entire updated 2012 breeding season.

Results and Discussion

Habitat suitability within the Lemkin Creek enclosures appeared to be adequate to sustain long term apple snail growth and reproduction (**Figures 8-52** and **8-53**). Snails stocked into the enclosures began reproducing immediately, albeit slowly, in 2011 and gradually increased production until the drydown in June and July (**Figure 8-52**). The slow start to the season was likely related to the small initial size of the stocked snails. After the drydown, egg production began about where it left off and peaked in September shortly after the marsh was re-inundated with water.

Despite the marsh being completely dry for two months, the stocked adult snails seemed to have had high enough survival throughout this period to provide an adequate breeding population once the marsh was re-flooded. Typically, peak reproduction for apple snails occurs in April and May given adequate hydrologic conditions (Darby et al., 1997). This trend was not seen in 2011 due to the time of stocking (the end of April), the small initial size of the stocked animals, and the poor hydrologic conditions immediately following stocking. The timing of peak reproduction in 2011 illustrates that the reproductive season has the potential to be prolonged if hydrology is restored or remains at a level conducive to breeding. This flexibility could greatly benefit apple snail populations by allowing significant production to occur even if conditions are poor early in the season.

At the end of the 2011 breeding season, the snails had visibly grown indicating that sexual maturity had been reached and that food resources within the enclosure were sufficient to maintain growth. This was evident at the beginning of the 2012 breeding season when the snails again began reproducing in early March (**Figure 8-53**) indicating that juvenile snails hatched into the enclosures in 2011 had grown to become reproductive adults the following year. Clutch production in 2012 was high and steady from the end of March through April, peaked in mid-May and tapered off by early August. This is more representative of the typical reproductive season.

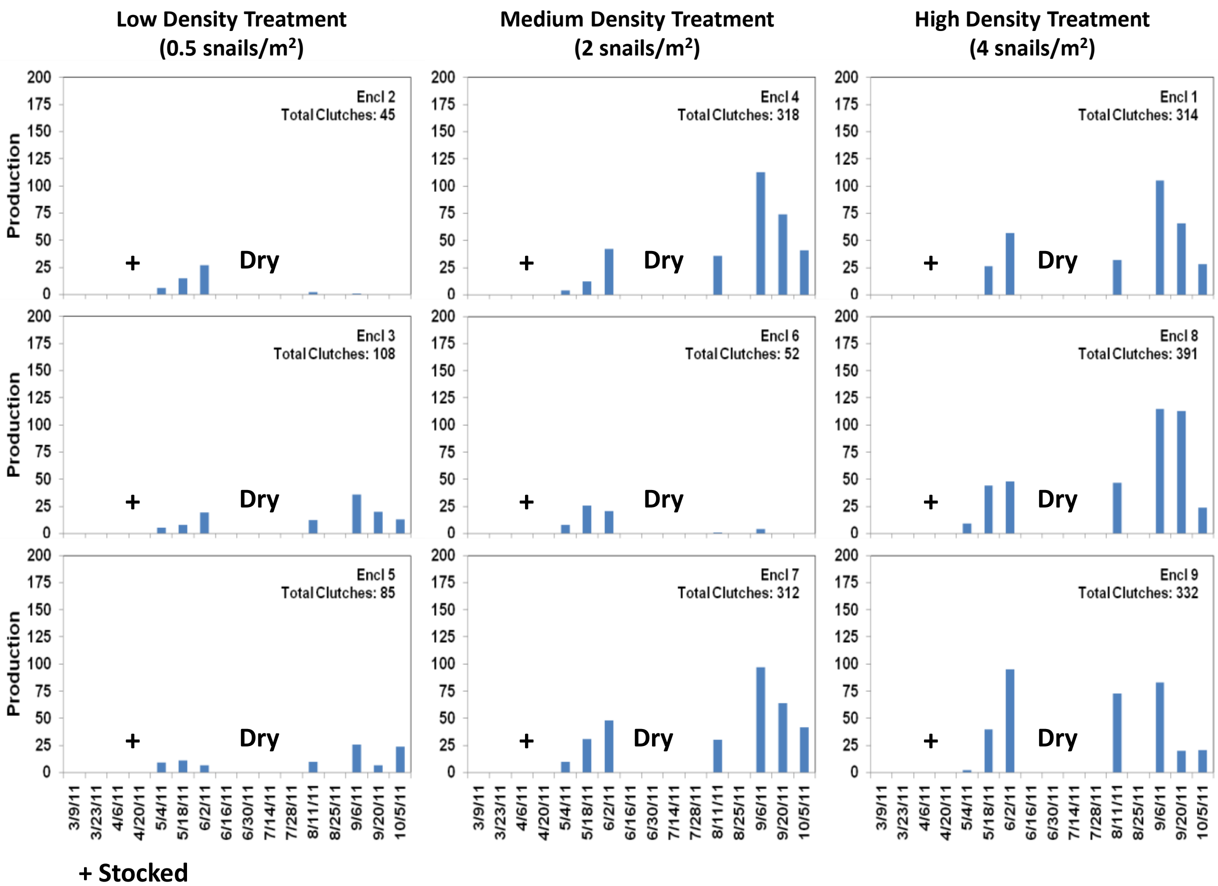


Figure 8-52. Total number of Florida apple snail (*Pomacea paludosa*) egg clutches produced over time in each of the nine Lemkin Creek enclosures in 2011. The marsh was completely dry from the beginning of June until the end of the July during which time there was no production in any of the enclosures.

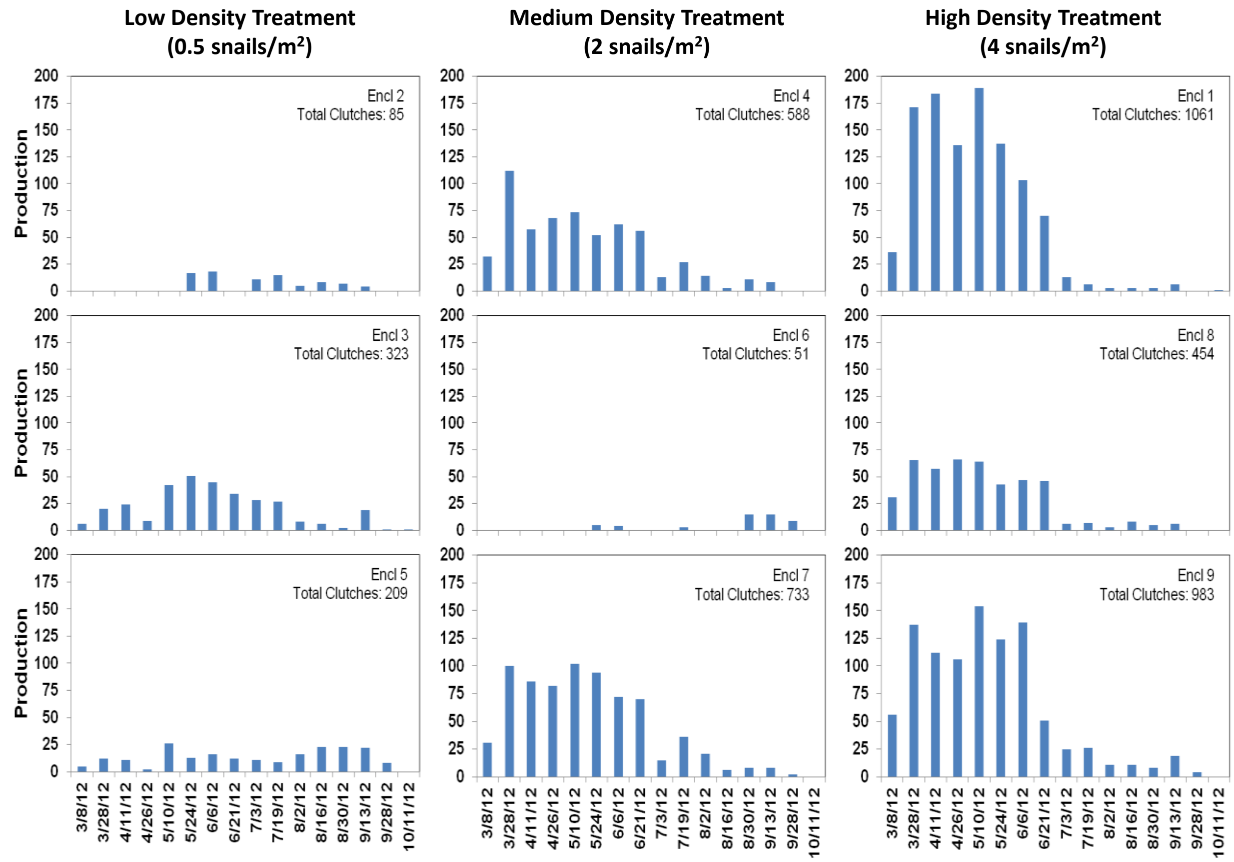


Figure 8-53. Total number of apple snail egg clutches produced over time in each of the nine Lemkin Creek enclosures in 2012.

In 2011, a total of 1,957 egg clutches were produced in all of the enclosures combined (**Figure 8-52**). The average clutch size was 25 eggs (range: 18 to 35). This equates to approximately 50,000 eggs produced over a 14 week time period during the first production season. There was no significant difference in production among the enclosures in either the low or high density treatments (p = 0.1385 and p = 0.7970, respectively) but there was a significant difference among the medium density treatments (p = 0.0080). The average production in medium density enclosures 4 and 7 was 46.0 clutches while average production in enclosure 6 was only 8.6 clutches. Four to six weeks post-stocking it was noted that the submerged aquatic vegetation in enclosures 6 and 2 was still very sparse and had not developed as well as it had in all the other enclosures. This could have resulted in a reduced food supply and possibly in a reduced survival rate which may be one possible explanation why these two enclosures had the lowest production rates. There was also a significant difference (p = 0.0005) when considering production between the three density treatments (low, medium and high). Average production in the low density treatment was 12.3 clutches which was significantly lower than in the medium (average = 33.5 clutches) and high (average = 49.9 clutches) density treatments. The medium and high treatments were not significantly different from each other.

The capture-mark-recapture study that was initiated within the enclosures at the beginning of the 2012 breeding season indicated that juvenile survival to adulthood within the enclosures (1.5 to 4 percent) was just high enough to provide replacement brood stock with the exception of 2 of the low density enclosures (2 and 5) and one of the medium density enclosures (6) where survival over the winter was less than 1 percent. This was confirmed by the fact that seven out of nine enclosures had reproduction the following year suggesting that apple snails can establish self-sustaining populations upon stocking, at least in the absence of high predation pressure. Production during the 2012 (**Figure 8-53**) season far exceed the 2011 season. A total of 4487 egg clutches were produced with an average clutch size of 33 eggs (range: 19 to 46). This equates to roughly 148,000 eggs which is almost three times more eggs than were produced in 2011. Similar to 2011, average production among the medium density enclosures was once again significantly different (p = 0.0001) in enclosure 6. Additionally, among the low density enclosures, average production in enclosure 2 was significantly lower than the other two enclosures (p = 0.0021).

Overall average production in the high density treatment was 52.0 clutches per enclosure which was significantly (p = 0.0072) higher than the average production in the low (average = 12.8 clutches) but similar to the production in the medium (average = 28.6 clutches) treatment.

Under laboratory conditions hatch rates are usually much lower than they are in the wild. Given that the stocked snails were cultured animals and were also stocked into the enclosures at high densities relative to natural conditions, it was anticipated that hatch rates in the enclosures would be similar to those encountered with laboratory reared snails. However, contrary to this expectation, hatch rates among all density treatments were comparable to the hatch rates of wild egg clutches. The average percent hatch rate across all treatments was 69 percent in 2011 (range: 68 to 73 percent) and 79 percent in 2012 (range: 66 to 92 percent). Egg clutches collected from various lakes since 2007 have had an average hatch rate of 82 percent (range: 61 to 89 percent). So neither stocking density, nor habitat quality within the enclosures seems to have affected hatch rate making the clutches produced by animals in the enclosures comparable to wild egg clutches.

For most collection dates throughout the 2011 breeding season, clutch production per female was lower than the expected one clutch per week, the exception being during the reproduction peak in September (**Figure 8-54**). Across all density treatments, before and after September, 81percent of the females produced less than 0.75 egg clutches per week (the average being 0.52 clutches per week), whereas during peak reproduction only 27 percent of the females produced less than 0.75 egg clutches per week (the average being 0.97 clutches per week).

It was more difficult to calculate clutch production per female for the 2012 breeding season because the total number of females within each enclosure was unknown. Population size was estimated in each enclosure in 2012 using the Lincoln-Peterson capture-mark-recapture method and the number of reproductive females was based on an assumed 1:1 sex ratio. Using these population results, production per female was greater than 0.75 clutches per week from the end of March to the end of June (**Figure 8-55**). Moreover, during that same time period, production exceeded one clutch per female per week in all but the last collection. The disparity in clutch production per female between 2011 and 2012 may be related to the difference in the density of egg laying substrate. When the enclosures were built in 2011 they were free of any emergent vegetation. Instead, 100 bamboo stakes were placed in each enclosure to provide egg laying substrate that could conveniently be removed and collected. Conversely, in 2012, the enclosures were full of emergent vegetation which the snails used almost exclusively as laying substrate. Therefore, it is possible that production during the 2011 breeding season was limited by available egg laying substrate. This also illustrates that apple snails may lay much more than one egg clutch per week which has been the accepted average in the literature until now.

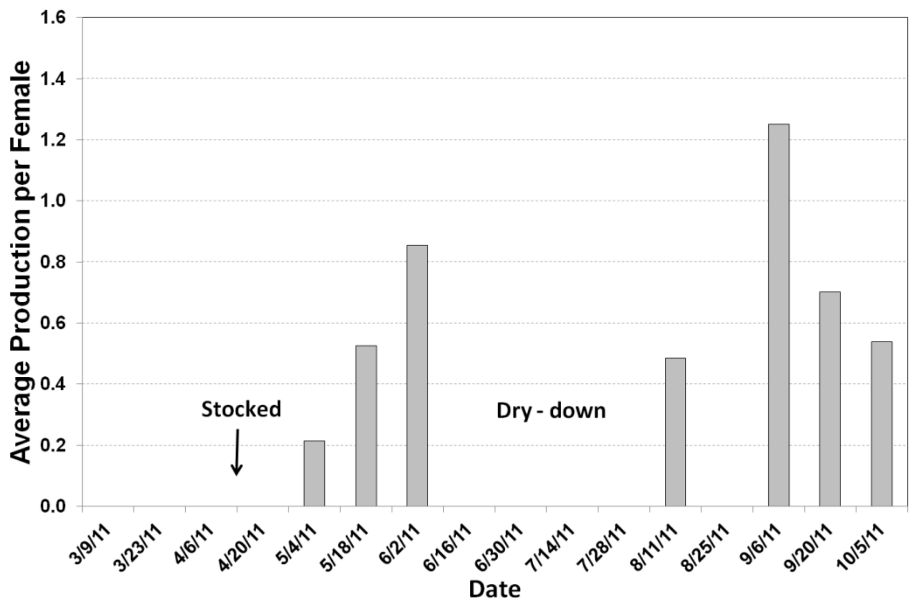


Figure 8-54. Number of apple snail egg clutches produced per female averaged across all nine enclosures for each egg clutch collection date during the 2011 breeding season. The marsh was completely dry from the beginning of June until the end of the July during which time there was no production in any of the enclosures.

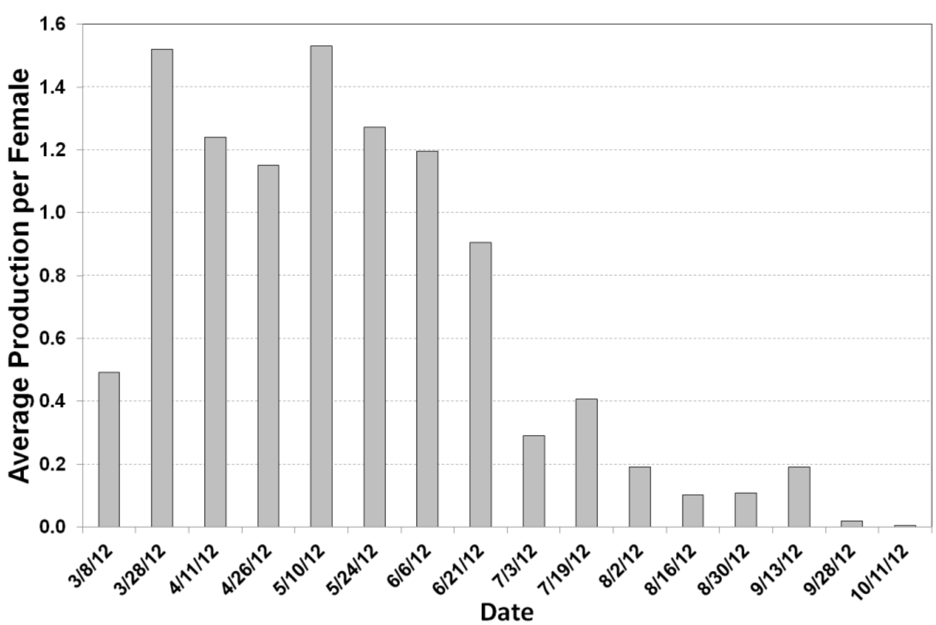


Figure 8-55. Number of apple snail egg clutches produced per female averaged across all nine enclosures for each egg clutch collection date during the 2012 breeding season.

Stocking Experiment

Methods

Twelve snail enclosures measuring 225 m^2 each were constructed in the Lemkin Creek marsh using contractor's grade silt fencing reinforced with polyvinyl chloride (PVC) poles and weighted at the bottom with bricks. The enclosures were built in areas where there was suitable emergent vegetation for use as egg laying substrate. No bird netting was placed over the tops of the enclosures and no attempt was made to remove aquatic predators at the time that the fencing was installed. It was anticipated that this approach would represent a more realistic picture of what would happen under a typical stocking protocol, as it retained the potential for natural predation to act as a forcing factor on population density and reproductive capacity.

On March 28, 2012, nine of the enclosures were randomly assigned a stocking density of low, medium or high and stocked at 0.4, 0.9, or 1.8 snails per m^2 (three replicates each). Three enclosures were not stocked and were used as controls. The snails that were used for stocking were collected as egg clutches from the in-situ hatchery enclosures during the 2011 breeding season and hatched and reared over the winter at the Districts outdoor mesocosm facility The chosen stocking densities were based on the number of animals that could be obtained from the grow-out facility but loosely bracketed the range of snail densities normally encountered in the wild.

Prior to stocking, 2,094 snails were tagged with multiple colored bee tags to allow differentiation between stocked animals and newly produced snails during density estimation sampling (throw trapping). It was however soon realized that neither the hatchery enclosures nor the stocking enclosures themselves were completely sealed and that we had effectively established a population of snails throughout the Lemkin wetland. Under these circumstances, tagging could only distinguish wild (immigrants or new production) from stocked snails, but would provide information related to immigration and emigration between the stocking enclosures.

To estimate egg production in each enclosure, a 1 m x 1 m PVC quadrat was flipped end over end the full length of the enclosure (15 times) along 4 transects. Transects were sampled on either an east to west direction or a north to south direction. The direction was switched for each event so the same area wasn't sampled each time. Egg clutches were tallied and clutch density per m^2 was calculated and converted to total clutches per enclosure (clutch density per m^2 x 225). Sampling began two weeks after stocking and continued every three weeks thereafter during the remaining 2012 breeding season (April–October). This schedule ensured that clutches were not counted twice as clutches laid 3 weeks prior would have already hatched. Egg clutch sampling resumed in March 2013 and will continue on the three week schedule to the end of the 2013 breeding season (October).

Because the enclosures were stocked with different densities of animals, it was necessary to standardize production data within each enclosure to reflect the number of clutches produced per female. This allowed for a direct comparison between treatments to determine whether stocking density affects overall reproductive capacity. Apple snails are generally thought to exist at a 1:1 sex ratio and that was assumed to be true for the purposes of this analysis. However, these numbers may be slightly biased since animals were not sexed before they were stocked into enclosures. The control enclosures were not stocked (their population coming from immigration from escapees from the hatchery enclosures that gradually populated the Lemkin marsh) so production per female could not be determined for the control treatment.

Throw trap sampling was conducted in June and October 2012 to obtain population estimates and survival rates. The June sampling event provided information on the population size and survival rates of the tagged animals that were stocked into the enclosures in March while the October event was intended to determine the population size and survival rate of the juvenile snails that were hatched and grown within the enclosure over the breeding season. To estimate the survival of stocked animals, the total number of tagged snails estimated to be in each enclosure from the June throw trapping event was divided by the number of tagged snails stocked into each enclosure. To estimate juvenile survival, the total number of snails estimated to be in each enclosure in October was divided by the number of juveniles estimated to have hatched into each enclosure over the breeding season. To get an estimate of the total number of animals hatched into each enclosure, total egg production for each enclosure was calculated as stated above and multiplied by the average clutch size and the average hatch rate derived from the 2012 hatchery data.

Sampling was accomplished using a 1 m x 1 m x 0.6 m PVC box frame which enclosed a 1 m^2 area. The frame lacked a top and bottom and after being thrown in a haphazard manner in the enclosure, was immediately pushed into the bottom substrate to prevent animals from escaping under the trap. Two people stood on opposite sides of the trap and did simultaneous 8 minute hand searches within their half of the trap. All snails captured were documented. During the June sampling it was determined that no snails were captured after the first 2 to 3 minutes of sampling so in October the search time was cut to 4 minutes. Seven 1 m^2 throw traps were sampled per enclosure which equates to 3 percent of the total enclosure area being sampled.

To test the accuracy of this sampling method, a capture probability was determined according to the blind protocol of Darby et al. (1999). At random intervals prior to the hand search, a known number of marked snails (0, 1, or 2) were placed in the trap by a third person while the two samplers were not watching. The proportion of marked snails recovered during the search was then estimated.

Results and Discussion

Snail stocked into the enclosures came from a number of different age cohorts. Therefore, some of the snails stocked into the experimental enclosures in March had not yet reached sexual maturity, which is evident in the low overall production rates seen over the first month (**Figure 8-56**). According to Darby et al. (1997), reproduction typically begins in March and peaks in April and May given adequate hydrological conditions. This pattern was seen in the hatchery enclosures during 2012 (**Figure 8-57**) but peak production in the stocking enclosures was delayed by more than two months. Production in the stocking enclosures plunged in the two weeks prior to the July peak giving the impression of a dual or cyclical pattern. This same pattern was seen in the hatchery enclosures although the decrease, which occurred in March, was not as dramatic.

A total of 4,376 egg clutches were produced across all treatments (control = 898, low = 959, medium = 872, high = 1647). This equates to approximately 144,169 eggs produced over the 2012 breeding season. Approximately 21 percent of the egg clutches produced were from within the control enclosures. Average production per sampling event in the control treatment was 30 egg clutches while production in the low, medium, and high treatments was 32, 29, and 55 egg clutches, respectively. However, there were no significant differences between the control treatment and the stocking density treatments ($p > 0.0988$). Additionally, production in the medium density treatment was actually lower than production in the control treatment. Over the sampling period, average production in the control treatment was greater than in the medium treatment on seven of the ten sampling events, and it was greater than the low density treatment on four of the ten events (**Figure 8-57**). During the August sampling event, production in the controls accounted for 47 percent of the overall production. Although no egg clutches were seen in the stocking enclosures immediately after they were built or just prior to stocking, it is evident from the control treatment that reproductive adult snails were present. It is not known, however, whether they were snails that were present in the marsh that happened to get trapped inside the enclosures during construction or whether they were snails that emigrated from nearby enclosures after stocking occurred.

The production per female could not be calculated for the control treatment because the initial population density was not known. When production per female was compared between the low, medium and high treatments, there was a significant difference ($p < 0.0001$, **Figure 8-57**). The average production per female in the low density treatments (0.35 clutches/female/wk) was two to three times as much as it was in the high (0.13 clutches per female per week) and medium (0.14 clutches per female per week) density treatments. As was the case in the hatchery study, the stocking densities used were low when compared to laboratory standards (50 to 100 snails per m^2), but high compared to what is typically found in natural habitats (0.5 to 1 snails per m^2). These stocking results are similar to the hatchery results in that they both suggest that to maximize production on a per female basis, it is best to stock at densities closer to what is typically found under natural conditions. However, if the goal is to maximize total production per enclosure, then stocking at 1.5 to 2 snails per m^2 is the best strategy.

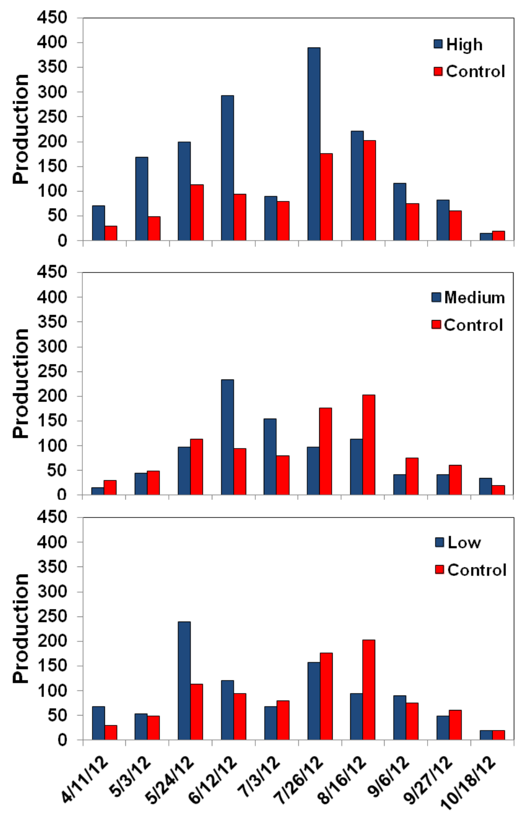


Figure 8-56. Comparison of the average number of apple snail egg clutches in the control treatments to those in the high, medium, and low density treatments over time (control = 0 snails per m^2, low = 0.4 snails per m^2, medium = 0.9 snails per m^2, and high =1.8 snails per m^2).

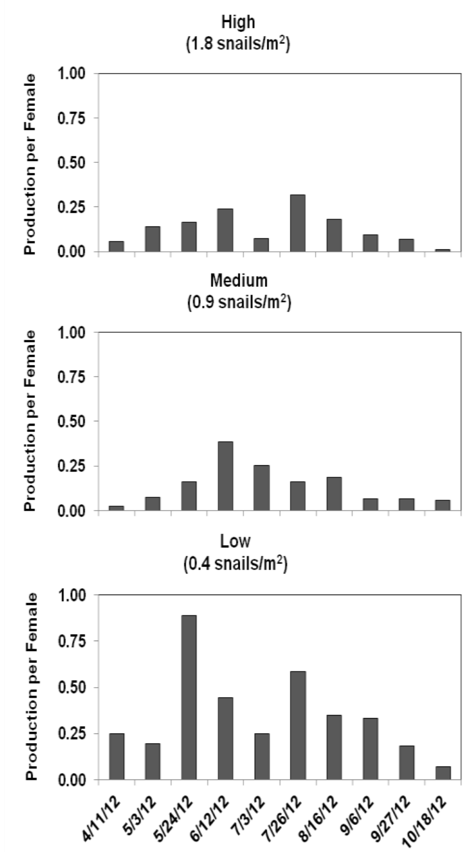


Figure 8-57. Average production per apple snail female per week for each treatment during the 2012 breeding season.

During the June population estimate sampling, eight of the twelve enclosures were sampled (2 replicates for each treatment) for a total of 56 throw traps. A total of nine tagged snails were caught (control = 1, low = 3, medium = 2 and high = 3) and density estimates ranged from 0 to 0.29 snails per m^2. In determining the capture probability (or recovery probability), a total of 34 marked snails were placed in the traps and 23 were recovered. The capture probability for each enclosure ranged from 60 to 80 percent indicating that only 60 to 80 percent of the snail population was being caught so the population density estimates were adjusted to reflect this sampling bias. After adjusting, the average population estimates were 67 snails per enclosure in the low treatment, 45 snails in the medium treatment, and 67 snails in the high treatment. These populations equate to 74, 22, and 11 percent of the initial stocking densities in the low, medium and high treatments, respectively. It is not known whether these decreases in snail populations were a result of mortality (predation, resource, or density pressures) or the net result of immigration and emigration into and out of the enclosures. During the 2012 snail breeding season, snail kites were very active in the wetland and it was not uncommon for there to be six to eight snail kites foraging overhead while sampling was being conducted. On numerous occasions, snail kites were spotted capturing apple snails from the area around or in the enclosures. It was also noted that egg clutch density increased substantially in the area surrounding the enclosures after stocking indicating possible emigration of snails out of the enclosures. The population in the control enclosures also increased to 22 snails (assuming all enclosures were snail free prior to the stocking event) indicating possible immigration of snails. Additionally, during the June throw trapping, three untagged snails were captured (two in high treatment enclosures and one in a low treatment enclosure). These untagged snails may be juveniles that were hatched from eggs deposited in the enclosure in April or they may be snails that had emigrated from another enclosure or from the wetland surrounding the enclosure. If the latter, then this is another indication that snails may be moving freely within the wetland and enclosures.

All twelve enclosures were sampled during the October population estimate sampling for a total of 84 throw traps. Ten untagged and zero tagged snails were captured and density estimates per m^2 were the same as in June. The adjusted average population estimates were all lower than the June sampling with 30 snails in the low treatment, 0 snails in the medium treatment, and 45 snails in the high treatment. Conversely, the control treatment population increased to 60 snails. Using the egg clutch results to determine the number of snails that were hatched into each enclosure, it was determined that the percent survival of the juveniles over the breeding season was 0.59, 0, 0.36, and 0.75 in the low, medium, high, and control treatments, respectively. These numbers are extremely low and may not truly reflect the actual populations. For throw trap sampling to provide reliable estimates of snail density, a large number of traps are needed. It has been suggested that enough throw traps should be done in order to obtain a coefficient of variation (CV) of between 20 and 30 percent. The CV in the sampling was almost 75 percent. It is also recommended that the vegetation within the throw traps be uprooted, rinsed, and examined for snails. This protocol was not followed in the sampling as clearing 3 to 6 percent of the vegetation in this relatively small area could have had an effect on snail behavior.

Although the October throw trapping population estimates seemed low, it became evident at the beginning of the 2013 breeding season that juvenile snails hatched into the enclosures in 2012 had grown to become reproductive adults the following year (**Figure 8-58**). Snails again began reproducing in early March 2013 and by the end of May the enclosures had almost 1,000 more egg clutches than in the same time period the year before. Additionally, the wetland surrounding the enclosures was becoming populated with numerous egg clutches. In June 2013, the egg clutches in the surrounding wetland will be enumerated in the same manner as the enclosures to get an estimate of production outside of the enclosures.

Bearing in mind that the Lemkin wetland was re-hydrated less than a year before the snail experiments began, and that all the snails in the wetland came originally from the hatchery enclosures, these stocking results suggest that it is feasible to stock juvenile apples snails at relatively low densities to improve native populations. Apple snails can establish a self-sustaining population through time even when exposed to normal rates of predation. This information is critical to understanding the potential efficacy of any large-scale apple snail stock enhancement program that may be implemented in the future.

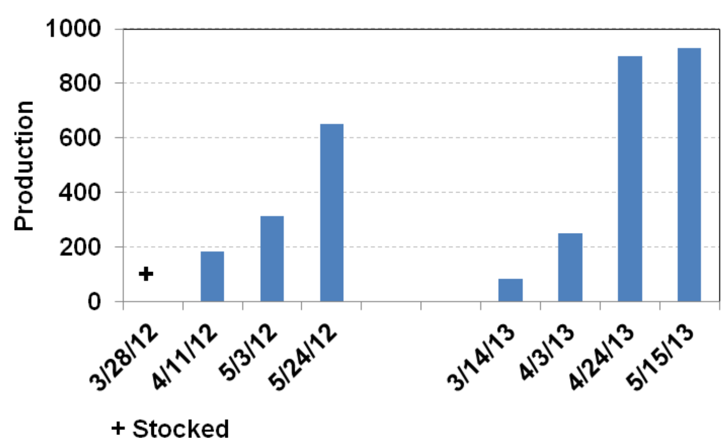


Figure 8-58. Total number of apple snail egg clutches produced in the stocking enclosures from March–May 2012 and 2013.

STRATEGIES FOR MOVING FORWARD

For more than two decades, the coordinating agencies—including the SFWMD, FDEP, and FDACS—have been working to improve the water quality and hydrology of the Lake Okeechobee Watershed through implementation of a suite of projects and programs. Since 2000, approximately $2.27 billion of state and federal contributions have been invested in the Northern Everglades watersheds to implement nutrient removal, water storage/retention, and restoration activities. A comprehensive list of completed and planned projects and activities to further the coordinating agencies' efforts to improve the quantity, quality, timing, and distribution of water in the Lake Okeechobee Watershed is provided in Appendix 8-3 of this volume, and a map of completed efforts In the Northern Everglades is included in **Figure 8-59**. Some highlights of completed efforts in the Lake Okeechobee Watershed include:

- Development and implementation of nutrient source control programs such as the FDACS Agricultural BMP and the District's Regulatory Nutrient Control programs in Chapter 40E-61, F.A.C. These are complimentary programs that focus on minimizing nutrients in surface water runoff through applying BMPs.
    - The FDACS program focuses on agricultural BMPs, which are practical, cost-effective actions that agricultural businesses can use to reduce pesticides, fertilizers, animal waste, and other pollutants entering our water resources. Land owners have enrolled approximately 1.6 million acres (74 percent of agricultural land in the LOW) in the FDACS-adopted agricultural BMP program.
    - The District's Regulatory Nutrient Source Control Program consists of the ERP Program and Works of the District Permit Program under Chapter 40E-61, F.A.C. The ERP Program requires applicants to demonstrate that new activities or modifications made to existing activities will not be harmful to water resources and will not violate state water quality standards. The District's WOD Program objective is to ensure that the uses of Works of the District within the watershed are compatible with the District's ability to implement Chapter 373, F.S. The existing rule includes criteria for users of WOD to obtain a permit to implement source control activities, including BMPs, for new and existing agricultural and nonagricultural lands within a portion of the LOW. The WOD Program also prescribes monitoring requirements and a performance methodology for measuring effectiveness in achieving water quality goals. Compliance with permit conditions is verified through onsite inspections and records review.
- Development and implementation of a program which provides shallow water storage, retention, and detention to enhance Lake Okeechobee and estuary health by reducing discharge volumes, reducing nutrient loading to downstream receiving waters, and expanding groundwater recharge opportunities. The District's Dispersed Water Management Program is a multifaceted approach to creating creative cooperative partnerships with public and private land owners focused on retaining or storing water. The five main categories of projects under the District's DWM Program include storage and retention projects on private lands, storage and retention projects on public lands, Florida Ranchlands Environmental Services Projects, Northern Everglades Payment for Environmental Services Projects, and Water Farming Payment for Environmental Services Pilot Projects.

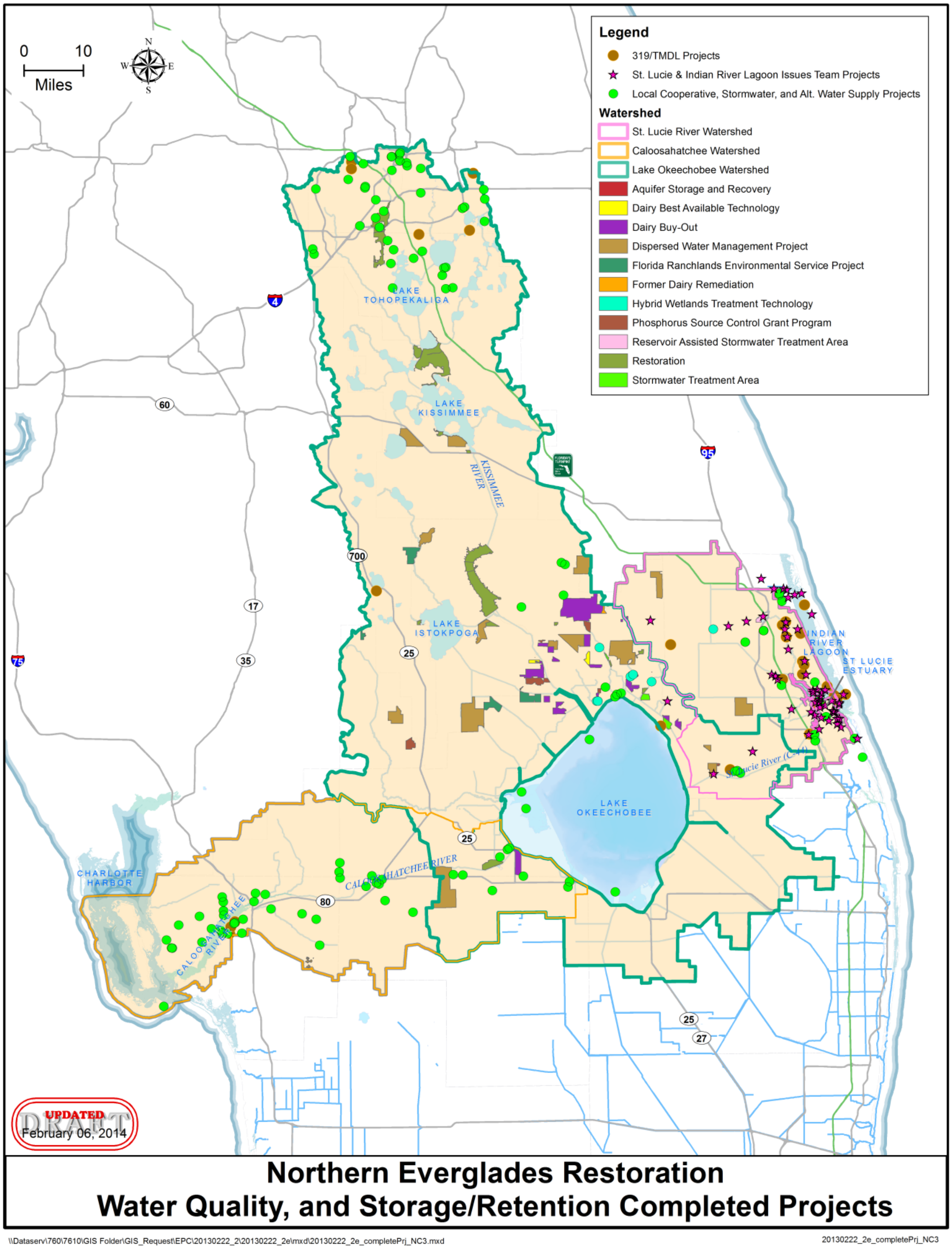


Figure 8-59. Summary of completed projects in the Northern Everglades. [Note: Provisional data subject to change; completed Wetland Reserve Projects not included.]

- Construction of three regional STAs designed to reduce TP loading to Lake Okeechobee, and which are also expected to remove TN from the system.
- Constructed more than 30 phosphorus-reduction projects including isolated wetland restorations, Dairy Best Available Technology projects, former dairy remediation projects, and evaluation of new technologies and public-private partnership projects.
- Completed three phases of the Kissimmee River Restoration Project. Once restoration construction is completed, 40 square miles of Kissimmee River and floodplain ecosystem will be affected including almost 25,000 acres of wetlands and 40 miles of historic river channel. Ultimately, these restoration efforts will result in hydrologic, water quality (phosphorus reduction), and ecological benefits.
- Completed rule amendments such as the FDEP adopted amendments to Chapter 62-640, F.A.C., to improve statewide application site accountability and management of Class B biosolids. The rule changes included requirements for site permitting, nutrient management plans, and biosolids provisions in Section 373.4595, F.S., which have resulted in a shift away from biosolids land application in the Lake Okeechobee Watershed. Since 2007, the number of active biosolids sites has decreased from 22 to 0. Currently, there are no permitted biosolids sites in the Northern Everglades.
- Investigations of innovative treatment technologies and demonstration projects. Once such technology that is proving to be successful is HWTT, which combines the strength of both wetland and chemical treatments to maximize nutrient removal while minimizing chemical use. There are currently six operational HWTT sites in the Northern Everglades and an additional location in the Indian Prairie Sub-watershed is proposed. Based on monitoring results of the six operational HWTT projects in the Northern Everglades, this effort is proving to be a promising technology. During the entire study period of the operational sites, results showed FWM TP concentrations reductions of 63 to 96 percent and total nitrogen reductions of 20 to 58 percent.
- Removed approximately 1.9 million cubic yards of muck from Lake Okeechobee, in conjunction with the Florida Fish and Wildlife Conservation Commission, exposing thousands of acres of natural lake bottom sand and promoting the return of native plant species.

Despite these continued and ongoing efforts, with the most recent five-year rolling average load to the lake of 451 mt, it is recognized that more work still needs to be done. Meeting the water quality and quantity goals still remains a considerable challenge for several reasons. High levels of watershed phosphorus loading and a lack of stormwater storage in the watershed are the primary watershed issues, while internal lake loading and exotic species remain challenging in the lake itself. Another challenge is funding. These issues are described in detail in the 2011 LOWPP Update (SFWMD et al., 2011).

As presented in the 2011 LOWPP Update, legacy phosphorus is any phosphorus in the watershed that is present as the result of anthropogenic activities and has transport potential to Lake Okeechobee. The accumulation of legacy phosphorus within the LOW as the result of anthropogenic activities poses the biggest challenge to implementing an effective watershed-scale nutrient management program. Based on recent work, it is estimated that approximately 65 percent of TP in soils is reactive and may be available for release at different time scales. Assuming 10 to 25 percent of the reactive phosphorus is available for release (Reddy et al., 2011), the current amount of legacy phosphorus in the system could support the current phosphorus loading (e.g., approximately 500 mt of TP per year) to Lake Okeechobee for the next 20 to 50 years. The reduction of new sources of phosphorus and its mobility to the lake through abatement practices is expected to be the only means of addressing this large-scale problem and must include upland, wetland, and stream sources (SWET, 2008). The abatement plan (SWET, 2008), which outlines specific phosphorus control practices and strategies at different spatial scales, anticipated phosphorus reduction performances, and implementation costs, is described in detail in Chapter 4 of the 2011 LOWPP Update.

Fixing the complex and varying problems in the Lake Okeechobee Watershed requires a multifaceted restoration approach. In other words there is not a "silver bullet" fix for LOW restoration and both water quality and water storage/retention projects are needed at the local, sub-regional, and regional levels. For example, source controls are generally the most cost effective measure for reducing nutrients; however, like any other technology-based solution, they have a maximum achievable water quality benefit. There is typically a gap between the nutrient levels that source controls can achieve and downstream water quality goals (e.g., TMDL). In most cases, it is necessary to invest in downstream sub-regional and regional projects to further reduce nutrients and lessen this gap. Another example is retaining water across the landscape as with DWM projects; while this does reduce the amount of water entering the regional system, it is not in itself able to capture the sheer volume of water entering Lake Okeechobee (2.4 million ac-ft/yr long-term average). Additional sub-regional and regional water storage capacity is needed to improve the timing and volumes of downstream water deliveries. Therefore, the coordinating agencies focus on projects, plans, and programs that implement measures at various spatial scales.

KEY ACTIVITIES MOVING FORWARD

The coordinating agencies are committed to the restoration of Lake Okeechobee and its watershed, continuation of existing efforts, and identifying new opportunities to improve the ecosystem. This section highlights key activities moving forward that the coordinating agencies will undertake to improve the quality, quantity, timing, and distribution of water in the LOW. It provides the framework for the continued restoration efforts over the next three years, which is a mix of new initiatives and continued implementation of existing programs.

Lake Okeechobee Basin Management Action Plan

A BMAP is the "blueprint" for restoring impaired waters by reducing pollutant loadings to meet a Total Maximum Daily Load (TMDL). A TMDL is the maximum amount of a pollutant that a water body or segment can assimilate from all sources without exceeding water quality standards. A BMAP represents a comprehensive set of strategies—permit limits on wastewater facilities, urban and agricultural BMPs, conservation programs, financial assistance and revenue generating activities, etc.—designed to implement the pollutant reductions established by the TMDL. A description of the BMAP development process is available at www.dep.state.fl.us/water/watersheds/bmap.htm. As described in Subsection 403.067(7), F.S., BMAPs address some or all of the watershed and basins tributary to the water body and equitably allocate pollutant reductions to individual basins, as a whole to all basins, or to each identified point source or category of nonpoint sources, as appropriate. BMAPs provide an iterative approach to achieving the TMDL through an implementation plan that is adopted by FDEP secretarial order pursuant to Chapter 120, F.S., and therefore are enforceable.

The legislative intent of the NEEPP states that the implementation of the LOWPP, the river watershed protection plans, and the related BMAP will work in conjunction to "…provide a reasonable means of achieving the total maximum daily load requirements and achieving and maintaining compliance with state water quality standards" [Subparagraph 373.4595(1)(h), F.S.]. The NEEPP also provides that the Lake Okeechobee Phase II Technical Plan and the River Watershed Protection Plans shall provide the basis for Northern Everglades BMAPs, pursuant to Subsection 373.4595(5)(b), F.S. In early 2013, the FDEP initiated development of a BMAP for the LOW. The LOW BMAP will build upon the decade plus work already done under the

LOWPP. The BMAP is being developed collaboratively with existing and new stakeholders and will work in combination with the regulatory programs and provide for an enforceable framework necessary to achieve restoration. These actions, coupled with the LOWPP, make for a comprehensive suite of actions developed by the coordinating agencies to address Lake Okeechobee restoration.

To date, the FDEP has held several public stakeholder workshops for the development of the Lake Okeechobee BMAP as shown in **Table 8-21**. Through development of the BMAP, FDEP, working in partnership with the coordinating agencies, will inventory existing planned projects and calculate load reductions for projects to estimate the achievements anticipated with each BMAP iteration. Another important benefit of BMAPs is that they increase grant and funding opportunities for projects in watersheds with developing and adopted BMAPs. For example, FDEP TMDL Restoration Grants applications consider "included in a BMAP" in the scoring system.

Table 8-21. Summary of progress to date for the Lake Okeechobee Basin Management Action Plan (BMAP) development.

Date	Location	Main Topics Covered
02/20/2013	SFWMD Okeechobee Service Center; Okeechobee, FL	Kick-off meeting and general Introduction to local stakeholders on the FDEP's Basin Management Action Plan process; review of Lake Okeechobee watershed history and restoration activities; announcement of the Istokpoga Marsh water quality improvement partnership project with the Istokpoga Marsh Watershed Improvement District
04/16/2013	SFWMD Okeechobee Service Center; Okeechobee, FL	1st BMAP Technical Meeting; overview of Lake Okeechobee watershed boundary and stakeholders; FDEP's initial water quality and water quantity review for Indian Prairie, Taylor Creek and Nubbins Slough sub-watersheds.
06/11/2013	Kissimmee Civic Center, Kissimmee, FL	2nd BMAP Technical Meeting; FDEP's initial water quality and water quantity review of Upper and Lower Kissimmee sub-watersheds; overview of ongoing and planned water quality restoration efforts.
08/06/2013	SFWMD Okeechobee Service Center; Okeechobee, FL	3rd BMAP Technical Meeting; additional watershed local stakeholders identification; Initial discussion on total phosphorus (TP) reductions for the first BMAP phase; description of project information needed by FDEP for inventory process.
11/15/2013	Osceola County Board of County Commissioners Chambers, Kissimmee, FL	4th BMAP Technical Meeting; project collection and stakeholder outreach; update on model development; initial discussions on the Lake Okeechobee BMAP Monitoring Plan; Lake Okeechobee BMAP and the Lake Okeechobee Protection Plan.

The FDEP and SFWMD have been tasked by the Florida legislature and governor to maximize resources across the agencies. The SFWMD and FDEP staff work together closely to streamline efforts between the LOWPP and the BMAP to minimize duplicative work and maximize available resources. Two streamlining efforts that are under way include:

1. **Projects:** The 2011 LOWPP Update outlined improvements to the lake and its watershed with a focus on near-term projects, estimates of project specific load reductions and implementation timelines. A similar process is currently under way in the BMAP development. Working in partnership with the SFWMD and FDACS, the FDEP is building upon the projects in the LOWPP and working to identify and develop additional new projects, estimate project specific load reductions, and develop implementation schedules for incorporation into the BMAP. Once the BMAP is adopted, this information will be included in the 2017 LOWPP Update.
2. **Leveraging Existing Technical Work:** As mentioned previously, restoration efforts in the LOW have been ongoing for almost two decades which includes extensive technical evaluation of water quality data. The FDEP will leverage this existing technical work in the BMAP, as appropriate.

Continued Implementation of the Pollutant Source Control Programs

The Pollutant Source Control Program is a multifaceted approach, including the coordinated implementation of regulations and BMPs and development and implementation of improved BMPs by agencies and stakeholders. The SFWMD, FDEP, and FDACS are defined as the coordinating agencies for implementing the Pollutant Source Control Program in the Northern Everglades watersheds, as defined by the NEEPP. To ensure a coordinated and complementary effort, the roles are detailed in the watershed protection plans (which are updated every three years) and a Memorandum of Understanding among the agencies. Source control programs by agency are as follows:

- **SFWMD:** Regulatory programs for water quality and quantity protection for agricultural and nonagricultural activities under Environmental Resource and Works of the District permits (ERP and WOD, respectively).
- **FDEP:** Statewide point source controls (NPDES, MS4 permitting programs), urban BMPs, ERP Program, Biosolids Rule, and Comprehensive Planning.
- **FDACS:** BMPs for incentive-based agricultural non-point sources that are either owner implemented (Notice of Intent to Implement, or NOI), or cooperative cost-share BMPs.

Key activities include continued implementation of these programs and the specific rule amendments discussed below. Details of these programs and updates to recent activities are provided earlier in this chapter. Some additional information on the FDACS agricultural BMP program is provided below.

In recent years, the FDACS has requested $5 million annually of Everglades Forever Act funding in their legislative budget request to continue implementing their agricultural BMP program which includes both owner implemented and cost-share BMPs, of which $3 million annually has been appropriated by the Florida legislature. A majority of these funds are focused on resources needed to implement cost-share BMPs. Applicable practices under the “owner-implemented” category are non-structural in nature, which include nutrient and irrigation management, maintenance of vegetative buffers to protect water features from sediment runoff, and location of livestock feeding/mineral stations away from water features. Approximately 74 percent of the agricultural lands in the LOW are enrolled in the FDACS BMP program for these types of practices.

"Cost-shared" BMPs provide an additional level of BMPs above and beyond the "owner-implemented" BMPs. This category of BMPs are structural in nature and typically include surface water control structures, detention/retention structures, alternative watering facilities for livestock, and tail-water recovery ponds. Generally, these practices require significant investment by the landowner and require long-term planning and cost-share assistance for installation and maintenance. The FDACS estimates that approximately $70 million is needed to complete implementation of cost-share BMPs in the LOW. The FDACS will be seeking additional funding to expedite the implementation of cost-shared BMPs in the LOW.

Proposed Rule Amendments

Districts Regulatory Source Control Program. Chapter 40E-61, F.A.C., the Lake Okeechobee Works of the District Rule, is the District's regulatory nutrient source control program for the lake. It was originally authorized by the Surface Water and Improvement Management Act (1987), which eventually became the Northern Estuaries and Everglades Protection Program in 2007. The objective of the District's Regulatory Nutrient Source Control Program is to ensure that the uses of Works of the District within the watershed are compatible with the District's ability to implement Chapter 373, F.S. In order to address mandated requirements added by the NEEPP, the rule must be amended. The proposed amendments to Chapter 40E-61, F.A.C., were included in the SFWMD Regulatory Plan filed in June 2013. Further details on the District's Regulatory Nutrient Source Control Program are presented in Chapter 4 of this volume.

Environmental Resource Program (ERP). The SWERP became effective on October 1, 2013. The legislative mandate for this rulemaking provided that the individual water management districts maintain their existing water quality rules and their ability to promulgate future water quality rules. Therefore, only minor changes were made to the District's water quality rules. These rules will now be set forth in the SFWMD's ERP Applicant's Handbook, Volume II. With regard to the future, proposed water quality rulemaking was included in the SFWMD Regulatory Plan filed in June 2013. It is anticipated that the rulemaking would be limited to an amendment to Part IV of the ERP Applicant's Handbook, Volume II, to codify the existing guidance memorandum on water quality evaluations for discharges to outstanding Florida waters and water bodies that do not meet the state water quality standards.

Dispersed Water Management Program

The goals and objectives of the DWM Program are to provide shallow water storage, retention and detention to enhance Lake Okeechobee and estuary health by reducing discharge volumes, reducing nutrient loading to downstream receiving waters and expanding ground water recharge opportunities. Under this program the SFWMD, FDACS, FDEP, NRCS, agricultural landowners and stakeholders, NGOs, local governments, and other water resource related organizations have collaborated and coordinated to develop several DWM initiatives.

These initiatives include the planning, implementation, operations, and monitoring of storage and retention projects on private and public lands, and include expanding the amount of dispersed storage provided by the NE-PES Program on ranchlands and initiating a set of new WF-PES projects on fallow citrus lands. In addition to holding water at locations where DWM projects are in place, further actions have been taken to increase temporary water storage throughout the region due to recent high Lake Okeechobee water levels from months of above-average rainfall.

The total storage, retention, and detention created by the DWM Program since inception is 49,600 ac-ft. Based on the success of this program and current funding constraints, the SFWMD is seeking additional funding opportunities to maintain and expand the number and types of projects that retain and store water. Since 2006, the District has dedicated over $17.6 million in funds (ad valorem, Save Our Everglades Trust Fund, Lake Okeechobee Trust Fund, and Water Management Lands Trust Fund) for purposes of the DWM Program. Also, the program will be receiving 319(h) Grant funds ($1,506,410) for the Water Farming Pilot Projects. The total funding currently available for the DWM Program is approximately $28.8 million, which is estimated to fund existing obligations through FY2018. Existing obligations continue through FY2024, and the total funding required to meet existing obligations between FY2019 and FY2024 is approximately $18 million.

Evaluation of Lakeside Ranch STA Phase I Performance and Operation of Northern Everglades STAs

This project, expedited under the NEEPP, is a 2,700-ac (1,090 ha) STA in western Martin County on lands adjacent to Lake Okeechobee (**Figure 8-5**). This STA is anticipated to be one component of the Tentatively Selected Plan chosen for the Lake Okeechobee Watershed CERP project. As discussed in the Construction Project section at the beginning of this chapter, the Lakeside Ranch STA Project is designed in two phases. Construction of the Phase I was completed in August 2012 and two of the three cells are currently flow through operational. Final design of Phase II STA South was completed in December 2011. The final design for the S-191A pump station (Phase II) was completed in February 2012. The District will continue to operate, maintain and monitor the performance of this STA. Before moving forward with Phase II, the District will evaluate the effectiveness of the first phase based on several years of water quality data. It will also be contingent on funding availability at that time.

The Northern Everglades STAs, including Taylor Creek and Nubbin Slough, differ from the Everglades Agricultural Area STA basins with regard to upstream basin topography and the range of phosphorus concentrations flowing into the STAs. The design treatment goals are also different, so the experience gained in the Everglades Agricultural Area STAs is not always applicable to the Northern Everglades facilities. As noted above, the District will gain experience operating the Lakeside and Taylor Creek STAs over the next several years. This knowledge will be applied to future northern construction projects, operational strategies, vegetation management, and the integration of future STAs with other project features such as reservoirs or hybrid wetland treatment systems.

In addition to Lakeside Ranch STA, there are two other pilot-scale STAs in the LOW that were built as Critical Projects to reduce TP concentrations in the Taylor Creek/Nubbin Slough priority basin. These include (1) the Taylor Creek STA, a 142-acre STA located at the District-owned Grassy Island Ranch Site which receives flows from and discharges to Taylor Creek; and (2) Nubbin Slough, an 809-acre STA located at the New Palm Dairy Site on District-owned lands which receives flows from and discharges to Nubbin Slough. The Taylor Creek Critical STA has removed 4 mt TP over 37 months of flow through operations. The District has implemented management strategies, such as rejuvenating existing vegetation, to help improve the phosphorus removal capability of the STA, and will continue with operate, maintain and monitor the STA. The USACE is undertaking repairs to the Nubbin Slough Critical STA and the USACE and SFWMD have agreed to a one-year time extension, until September 9, 2014, for completion of repairs, commissioning of the pump station, and transfer of the facility to the SFWMD.

Innovative Treatment Technologies

The NEEPP supports the investigation and implementation of innovative treatment technologies and specifically states “Use of cost-effective biologically based, hybrid wetland/chemical and other innovative nutrient control technologies shall be incorporated in the plan where appropriate.” The coordinating agencies have been evaluating alternative water quality treatment technologies in both the STAs and the Northern Everglades for almost two decades, and are often approached by individuals and firms with proposals for improving regional water quality, prompting the need for a structured process to learn about and evaluate these technologies.

District's Alternative Treatment Requests for Proposals (RFPs). In an effort to evaluate unsolicited proposals, the District provided opportunities for the individuals and firms to demonstrate their potential technologies for reducing phosphorus (P) or nitrogen (N) loading in both waters and sediments discharged from the Everglades watershed, and focused on any source that would be subject to agency interest/regulation: estuaries, canals, Lake Okeechobee discharges, and soil inactivation. All the products and processes were initially vetted with a pre-determined set of evaluation criteria by a team of District scientists as well as other agency staff, and the test sites were either District-owned or cooperating landowner properties. No dedicated funding was provided, although the District has provided support by contributing staff time and the analysis of water quality samples by the District's Chemistry Laboratory. All other costs associated with conducting demonstrations were borne by the vendor. This effort evolved into a product screening process and was not intended to be a research and development process for the vendors.

A total of seven technologies were selected for evaluation from a pool of 12 responses received in response to solicitations issued by the District. Two of the technologies, Ferrate and AquaLutions™, were evaluated under separate agreements with Highlands County and the District, respectively. The selected technologies were generally categorized as flow- through processes (Ferrate, AquaLutions and Electrocoagulation) or mineral-based product applications (Phoslock™, WP1™, STI and ViroPhos™). Field tests were conducted for AquaLutions™, Ferrate and WP-1™. Results of these pilot tests are described in the *Research and Assessment* section of this chapter. A technical publication on this effort is currently being developed (Chimney et al., 2013).

Hybrid Wetland Treatment Technology (HWTT). HWTT combines the strengths of both wetland and chemical treatments to maximize phosphorous removal minimize chemical use and facilitate the removal of nitrogen. There are currently six operational HWTT systems in the Northern Everglades. Effective performance of the HWTT technology is demonstrated by the reduction in TP concentrations of ranging from 67 to 93 percent during the entire study period of these six systems (Watershed Technologies, LLC, 2013). Although P removal is the primary function of this technology, HWTT systems also provide environmental benefits through wetland and wildlife habitat restoration and creation, such as is the case for the Lemkin Creek and Wolff Ditch systems. The coordinating agencies have found this to be an effective technology for removing TP and continue to identify new locations for implementation as funding allows.

Funding for a new HWTT facility has been identified and a specific location is currently being evaluated. Site selection is a key component of maximizing productivity and efficiency. In choosing new locations, conditions such as flow availability, inflow P availability for treatment, and inflow water quality parameters should be considered as they have proven to be vital in maximizing the cost/benefit of specific projects.

LOCAL PROJECTS

The SFWMD and FDEP have worked with numerous local governments throughout the Lake Okeechobee Watershed to improve water quality, enhance flood protection and enhance wastewater infrastructure to meet the needs of future generations. To date, the FDEP has provided grant funding (319 and TMDL) toward over 30 non-point source projects in the St. Lucie, Caloosahatchee, and Okeechobee watersheds. The total costs (inclusive of match by the local governments) of these projects were in excess of $38 million.

Building on successes such as the state of Florida's Water Projects funding and TMDL Grant funding, the SFWMD contributed nearly $15 million toward 36 stormwater and wastewater infrastructure partnership projects with local governments throughout the Lake Okeechobee Watershed. In addition, the District coupled with state and local governments in the investment of Alternative Water Supply (AWS) infrastructure by contributing almost $5 million toward 30 AWS projects in this region. Overall, almost $20 million of District ad valorem dollars were invested back into the local communities for the enhanced management and protection of water resources within this watershed since 2000. These partnership projects between the District and FDEP with local governments include stormwater and wastewater improvement projects, alternative water supply projects, and flood improvement projects. Benefits include water quality improvements, water retention, and water recycling. These projects provide benefits on a local and sub-regional scale and collectively provide water quality and quantity benefits on a regional scale. The coordinating agencies will continue to identify local project and funding sources. One mechanism for doing this is through the FDEP's BMAP, as discussed in detail above.

Some District partnership projects in the LOW funded in FY2014 include the Orange County and Windermere stormwater projects. The purpose of these projects is to reduce the nutrient loadings to the Butler Chain of Lakes coming from adjacent sub-basins. There are several components including stormwater catch basin retrofits and sub-basin stormwater pond evaluation and upgrades. The amounts approved for FY2014 for Orange County is $165,000 and for Town of Windermere is $116,000.

WORKING COLLABORATIVELY TO IDENTIFY FUNDING OPPORTUNITIES

One of the biggest challenges to implementing large, watershed-scale restoration efforts is identifying funding for projects that will improve the quality, quantity, timing, and delivery of water. To date the state's ongoing commitment to restoring Lake Okeechobee is evidenced in the number of projects and programs implemented. Combined, the state and federal government has contributed over $2.27 billion in funding for Northern Everglades. While these figures are impressive, it is recognized that additional projects and funding are needed. The coordinating agencies are committed to continuing to work with the state, federal government, and local entities to secure funding for projects and programs in the Northern Everglades to further restoration efforts. Below are three examples of three recently funded sub-regional projects that will be constructed in the near term. The coordinating agencies will continue to investigate funding opportunities for other such projects that provide substantial load reduction and water storage/reuse in the LOW.

Istokpoga Marsh Watershed Improvement District - Water Quality Improvement Project. A recent success in identifying funding for Lake Okeechobee Projects is the Istokpoga Marsh Watershed Improvement District. This project is located in the Indian Prairie Sub-watershed which, based on a long term average (2001–2012), has the highest TP loading (103 mt, or 20 percent) of the nine sub-watersheds in the LOW and the second highest TP concentration (317 ppb). It is designed as a stormwater recycling system that will afford opportunities to capture and store excess stormwater during wet periods, reducing flows and nutrient loads to Lake Okeechobee, and then return the stored water to the canal system providing a supplemental source of surface water to augment farm irrigation during dry times. The project includes the phased design and construction of 1,200 acres of above-ground impoundments that will reduce IMWIDs average annual discharge volume of stormwater by approximately 60 percent and may remove as much as 70 percent of the TP currently discharged to the Harney Pond Canal which could otherwise enter Lake Okeechobee at a downstream point. The state provided approximately $6 million to acquire the land for the project, and recently identified an additional $6 million to implement Phase I, an approximate 300-acre above ground impoundment. Agreements between the FDEP, FDACS, the District and Highlands County are in place for this corporative project.

Nicodemus Slough Dispersed Water Management Project. The Nicodemus Slough project is located in Glades County just south of the portion of the Herbert Hoover Dike along Fisheating Creek and west of County Road 78. The purpose of the project is to provide retention of excess water from Lake Okeechobee on the 15,906 acre site. In general, excess water in Lake Okeechobee will be pumped into the project area which will serve to re-hydrate the naturally occurring slough system and to lessen the undesirable effects of excess water in Lake Okeechobee. The estimated retention volume is 34,000 ac-ft. The Section 404 permit from the USACE was issued in July 2013. Construction began in November 2013.

Lake Hicpochee North Hydrologic Enhancement Project. Historically, Lake Hicpochee was one of three lakes that were considered the headwaters of the Caloosahatchee River. The channelization of the Caloosahatchee River in the 1800's created an unnatural connection between Lake Hicpochee and Lake Okeechobee. This unnatural connection has bisected Lake Hicpochee into north and south portions resulting in detrimental impacts to hydrology and ecology in the C-43 Basin. The objective of the Lake Hicpochee Hydrologic Enhancement project is to provide shallow water storage within the north half of the lake bed to promote habitat restoration and water quality treatment benefits. The next step is acquisition of approximately 640 acres of land for a shallow storage feature north of the lake bed that are part of the planned Duda land acquisition. Approximately $1.3 million of SOETF funds and $700K of District funds have been identified for the land acquisition. Captured excess flows will either be from the C-19 Canal or the Caloosahatchee River depending on the operational plan that is developed for the project.

NEAR-TERM IMPLEMENTATION AND COST ESTIMATES

Near-term projects and activities are those anticipated to be initiated and/or completed in the next three years. Their current and projected status from FY2014 to FY2016 is summarized below in **Table 8-22**. Cost estimates for these "near-term" activities by program are provided in **Table 8-23**. The coordinating agencies will continue to pursue alternative funding sources including federal matching funds, other non-state funding, and public-private partnerships wherever possible to expedite implementation of this plan.

Table 8-22. Current and projected status of near-term projects and activities within the next three years (FY2014–FY2016).

		Initiated/ Under Way	Completed	Ongoing
Source Control Program	Implementation of Agricultural and Urban BMPs			✓
	Proposed revision to the SFWMD's existing Regulatory Nutrient Source Control Program (Chapter 40E-61, F.A.C.) for the Lake Okeechobee Watershed	✓	✓	
	SFWMD to codify existing guidance memorandum into rule	✓	✓	
Construction Project	Lake Okeechobee Basin Management Action Plan Development			✓
	Dispersed Water Management Projects			✓
	Istokpoga Marsh Watershed Improvement District – Water Quality Improvement Project Phase I	✓	✓	
	Nicodemus Slough	✓	✓	
	Lake Hicpochee North Hydrologic Enhancement Project	✓	✓	
	Other State and Private Lands Projects			✓
	NE-PES			✓
	HWTT Facilities			✓
	Implementation of new HWTT Facility	✓	✓	
	O&M of Existing Facilities			✓
	CERP Aquifer Storage & Recovery Regional Study	✓	✓	
	CERP C-44 Reservoir and STA	✓		
	Evaluation and Operation of Northern Everglades STAs			✓
	Rolling Meadows Restoration Phase I	✓	✓	
	Kissimmee River Restoration	✓		
	Local Stormwater Projects			✓
	Taylor Creek/Brady Ranch Site Feasibility Study	✓	✓	
Research and Water Quality Monitoring Program	Alternative Nutrient Reduction Technologies – Screening, Research and Development			✓
	Lake Okeechobee Research and Studies			✓
	Continue Watershed and In-Lake Monitoring			✓
	BMP Demonstration and Optimization in District Lands and Private Partnerships	✓	✓	
Exotic Species Control Program	Exotic Vegetation Management			✓

Table 8-23. LOWPP near-term expenditures FY2014–FY2016.

Category of Cost	Cost Estimate
Source Control Program	
Agricultural BMPs	$ 13.4 M
Regulatory Nutrient Control Program	$ 2.3 M
Construction Project	
O&M of Completed Projects	$ 13.6 M
Near-term Projects	$ 171.2 M
Research and Water Quality Monitoring	$ 12.5 M
Exotic Species Control	$ 0.6 M
Total Cost	**$ 213.6 M**

Cost estimates are based on the following assumptions:

- Costs do not include dollars that have already been expended.
- Costs were obtained from FY2014 budget or projected/estimated values.
- Costs based on FY2013 dollars and adjusted using a 2.5 percent inflation rate for FY2015 and FY2016. The expenditure for FY2014 was not adjusted for inflation since it was based on the actual budget.
- Programmatic costs (staff and contractual) costs were included when available.
- The O&M costs for completed projects include costs for evaluation and operation of three Northern Everglades STAs (Taylor Creek, Nubbin Slough, and Lakeside Ranch), FRESP/DWM projects, and the existing HWTT.
- The near-term construction project costs include the NE-PES Program (both current and planned), Istokpoga Marsh Watershed Improvement District – Water Quality Project Phase I, Nicodemus Slough Project, a new HWTT facility, Kissimmee River Restoration, Taylor Creek/Brady Ranch Site Feasibility Study, two local stormwater projects, Rolling Meadow Wetland Restoration, and CERP C-44 Reservoir and STA.
- The research and monitoring estimates include costs for research and monitoring for water quality as well as vegetation and biological sampling.
- The exotic species control includes only the District's cost. Additional funds provided by USACE and FWC are not included in the estimates.

APPROPRIATIONS AND EXPENDITURES

The FY2001–FY2014 summary of NEEPP State of Florida funding appropriations and expenditures for the LOWPP is presented in **Table 8-24**.

Table 8-24. NEEPP state funding appropriations and expenditures for the LOWPP for Fiscal Years 2001–2014 (FY2001–FY2014) (October 1, 2000–September 30, 2014).

Appropriation Year	SFWMD Appropriation	Expended to Date	Available
FY2001 SFW11 (SA1519G) [a]	8,500,000	8,478,572	0
FY2001 SFW12 (SA1591G)	15,000,000	15,000,000	0
FY2001 SFWMD Total	**$23,500,000**	**$23,478,572**	**$0**
FY2002 SFSWP1 (SA1748)	10,000,000	10,000,000	0
FY2002 SFWMD Total	**$10,000,000**	**$10,000,000**	**$0**
FY2003 FDEP TMDL Implementation Funds	850,000	850,000	0
FY2003 SFW31 G42 (SA1769)	7,500,000	7,465,050	34,950
FY2003 SFWMD Total	**$8,350,000**	**$8,315,050**	**$34,950**
FY2005 SFW51 Nubbin Slough G44 (DEP - SA2064A)	4,300,000	3,376,937	923,063
FY2005 - Nubbin Slough/Lk Okeechobee Fast Track G3 (SA1680)	3,300,000	3,167,289	132,711
FY2005 - Hydromentia	1,800,000	1,800,000	0
FY2005 SFWMD Total	**$9,400,000**	**$8,344,226**	**$1,055,774**
FY2006 SFW61 G46 (1717A)	5,000,000	2,733,243	2,266,757
FY2006 DEP Fast Track Projects - Reimbursable Expenditures G4 (SB 444)	25,000,000	25,000,000	0
101 Ranch 17.2 Acre Reservoir	42,000	42,000	0
C&B Farms Trail Water Recovery	93,600	93,600	0
101 Ranch 44 Acre Reservoir	30,864	30,864	0
Stormwater Irrigation	51,920	51,920	0
FY2006 Sub Basin Monitoring Network	225,000	225,000	0
FY2006 SFWMD Total	**30,443,384**	**28,176,627**	**0**
FY2007 Hydromentia - Algae Turf Scrubber - FDEP G41 (SA1821)	750,000	750,000	0
FY2007 Hydromentia - Algae Turf Scrubber- FDACS G39	221,610	221,610	0
FY2007 Fast Track Projects - Reimbursable Expenditures G66 (SA1825)	24,925,000	24,925,000	0
FY2007 Taylor Creek PL566 & Alternative Storage/Disposal of Excess Water G47 (SA1821)	6,200,000	4,758,101	1,441,899
FY2007 Cody's Cove & Eagle Bay - G52	2,478,548	2,478,548	0
Indiantown Citrus Growers Association FDACS G54 [b]	287,808	267,853	0
Raulerson & Sons Ranch Stormwater Reuse AWS FDACS G56	330,000	330,000	0
FY2007 SFWMD Total	**$35,192,966**	**$33,731,112**	**$1,441,899**
FY2008 Sub Basin Monitoring Network	225,000	225,000	0
FY2008 SFWMD Total	**$225,000**	**$225,000**	**$0**
Grand Total - SFWMD State Appropriation - Fund 221000/421000	**$117,111,350**	**$112,270,587**	**$2,532,623**
FY2012 Lake O Pre-drainage Characterization G98	175,000	106,800	68,200
FY2012 Lake O Pre-drainage Characterization G98 (interest)	716	0	716
FY2012 SFWMD Total	**$175,716**	**$106,800**	**$68,916**
FY2013 Lake O Pre-drainage Characterization G100	15,000	15,000	0
FY2013 SFWMD Total	**$15,000**	**$15,000**	**$0**
FY2013 Dispersed Water Management Wetland Reserve Program			
Allapattah Ranch (NRCS WRP Grant 103)	3,000,000	80,932	2,919,068
Williamson and Turnpike Dairy (NRCS WRP Grant 104)	700,035	402,420	297,615
FY2013 SFWMD Total	**$3,700,035**	**$483,351**	**$3,216,684**
FY2014 Dispersed Water Management Water Farming Pilot Project (319 Grant)	1,506,401	0	1,506,401
FY2014 SFWMD Total	**$1,506,401**	**$0**	**$1,506,401**
Grand Total - SFWMD Grant Agreements - Fund 214000	**$5,397,152**	**$605,151**	**$4,792,001**

Table 8-24. Continued.

Appropriation Year	SFWMD Appropriation	Expended to Date	Available
Save Our Everglades Trust Fund			
FY2008 NE - CAL-STL-LO - Grant 58 (SA1741)	2,623,146	2,623,146	0
FY2008 NE - LOPP - Grant 59 (SA1741)	31,045,000		113,343
LOFT - Lakeside Ranch STA		24,142,924	
NE Dispersed Water Management		6,241,844	
Technical Plan		546,890	
FY2008 Bio Wetland & Chem/Hybrid Technologies - Grant 62 (SA1741)	5,000,000	5,000,000	0
FY2009 NE - BMPs - Grant 96 (SA1662)	3,009,120	3,009,120	0
FY2010 NE - BMPs - Grant 94 (SA1620)	1,500,000	1,500,000	0
FY2011 NE - BMPs - Grant 94 (SA1693 and Section 107)	1,500,000	1,500,000	0
FY2012 NE - LOPP - Grant 99 (SA1580B) [c]	7,088,802		7,029,180
Nicodemus Slough		59,623	
Total - Save Our Everglades Trust Fund - 222000/412000 [d]	**$51,766,068**	**$44,623,546**	**$7,142,522**
FY2005 FDEP Pahokee WWTP (SA2064A)	700,000	700,000	0
Total - Appropriations to FDEP	**$700,000**	**$700,000**	**$0**
FY2001 FDACS Appropriation (SA1591G)	15,000,000	15,000,000	0
FY2005 FDACS Appropriation (SA2064A)	5,000,000	5,000,000	0
FY2007 FDACS Appropriation	3,900,000	3,900,000	0
FY2008 FDACS Appropriation (SA 1741)	6,000,000	6,000,000	0
FY2009 FDACS Appropriation (SA1662)	3,000,000	3,000,000	0
FY2010 FDACS Appropriation (SA1620)	3,000,000	3,000,000	0
FY2011 FDACS Appropriation (SA1693 and Section 107)	3,000,000	3,000,000	0
FY2012 FDACS Appropriation (SA1580B)	3,000,000	3,000,000	0
FY2013 FDACS Appropriation (SA1641)	3,000,000	3,000,000	0
FY2014 FDACS Appropriation (SA1600)	3,000,000	750,000	2,250,000
Total - Appropriations to FDACS	**$47,900,000**	**$45,650,000**	**$2,250,000**
Total Outside Agency State Appropriation	**$48,600,000**	**$46,350,000**	**$2,250,000**
Total - Lake Okeechobee	**$222,874,570**	**$203,849,284**	**$16,717,146**

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