Chapter 11: Kissimmee Basin

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SUMMARY

The Kissimmee Basin encompasses more than two dozen lakes in the Kissimmee Chain of Lakes (KCOL), their tributary streams and associated marshes, and the Kissimmee River and floodplain. The basin forms the headwaters of Lake Okeechobee and the Everglades; together they comprise the Kissimmee-Okeechobee-Everglades (KOE) system. In the 1960s, the Central and Southern Florida Flood Control (C&SF) Project modified the native KOE system extensively throughout South Florida, including construction of canals and water control structures to achieve flood control in the Upper and Lower Kissimmee basins.

Completed in 1971, the 56-mile-long C-38 canal in the Lower Kissimmee Basin channelized the Kissimmee River with profound ecological consequences, eliminating flow in the original river channel and preventing seasonal inundation of the floodplain. In the Upper Kissimmee Basin, C&SF Project modifications allowed lake stages to be regulated at reduced ranges of fluctuation, altering or eliminating much of the formerly extensive littoral zones around the lakes and the marshes between them.

These and other environmental losses led to legislation to authorize the federal/state Kissimmee River Restoration Project (KRRP), which includes the Kissimmee River Headwaters Revitalization Project. The project involves (1) land acquisition in the Upper and Lower Kissimmee basins; (2) backfilling over one-third of C-38 and reconnecting remnant river channels in the backfilled sections; (3) increases in the water storage capacity of several Upper Kissimmee Basin lakes to provide continuous flows to the reestablished reaches of the Kissimmee River; (4) the development of a new stage regulation schedule for the lakes to support the hydrologic needs of the restoration; and (5) a comprehensive ecological monitoring program to evaluate the success of the restoration project. The $620 million restoration project is 50/50 cost-shared by the U.S. Army Corps of Engineers (USACE) and the South Florida Water

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Management District (SFWMD or District). Construction began in 1999 and is scheduled to be completed in 2013.

The District's Kissimmee Watershed Program was originally formed in the 1990s to coordinate and evaluate the restoration and associated projects. More recently, the program has worked to integrate management strategies for the Kissimmee Basin with the KRRP. The primary goals of the Kissimmee Watershed Program are to restore ecological integrity (i.e., an ecosystem comparable to the natural habitat of the region) (SFWMD, 2005a) to the Kissimmee River and its floodplain; conduct ecological monitoring programs for restoration evaluation; develop a long-term management strategy for resolving water and other management issues in the KCOL; and retain the existing level of flood control in the Kissimmee Basin. In addition to the KRRP, major Kissimmee Basin initiatives designed to meet these program objectives are the Kissimmee Basin Modeling and Operations Study (KBMOS) and the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP). The program is now involved with many associated activities within and beyond the boundaries of the Kissimmee Basin, including water supply planning, water quality improvement, various restoration projects, aquatic plant management, and land management.

Phase I (of four major phases) of the KRRP was completed in February 2001. A second phase of backfilling was initiated in June 2006 and completed in September 2007. The final two phases of restoration construction are projected to be completed by late 2013.

Drainage from the Kissimmee Basin is the largest source of surface water to Lake Okeechobee. Water quality issues in the Lake Okeechobee Watershed have been addressed by several initiatives, including the 2007 amendment to the Lake Okeechobee Protection Act that established the Northern Everglades and Estuaries Protection Program (NEEPP). The NEEPP requires the SFWMD, in collaboration with coordinating agencies, to develop a Technical Plan for Phase II of the Lake Okeechobee Watershed Construction Project. Under the Technical Plan, the SFWMD has outlined several new initiatives to address water quality issues in both the Upper and Lower Kissimmee sub-watersheds, thus expanding upon earlier efforts established by the Lake Okeechobee Protection Plan (see Chapters 7A and 10 of this volume, respectively).

An analysis of 1987–2007 data on mercury (Hg) in Kissimmee Basin fish tissue suggested a decrease in Hg levels across the Kissimmee Basin during this period. The decline was likely due to regulations enacted in the early 1990s, which reduced mercury content of wastes and limited emissions from combustors and incinerators. Although this trend seems promising, as of 2007, Hg levels in largemouth bass and other large-bodied piscivorous fish remain at or above cautionary levels throughout the Kissimmee Basin.

Because of rapid population growth in the Kissimmee Basin, it is expected that the limit of sustainable water withdrawal from the Floridan aquifer will be reached in 2013. The SFWMD is working cooperatively with adjacent water management districts, counties, and Central Florida utilities to identify Alternative Water Supply projects. Modeling tools and evaluation performance measures are being used to evaluate proposed surface water withdrawal scenarios and to develop a Water Reservation for the Kissimmee River and lakes in the Upper Kissimmee Basin. At its June 2008 meeting, the District's Governing Board approved a resolution to begin rule development for the reservation and allocation of water necessary for the protection of fish and wildlife in the Kissimmee River, its floodplain, and the Kissimmee Chain of Lakes. Technical work to support the eight Water Reservations is in progress. The proposed rule is scheduled to be presented to the District's Governing Board in June 2009.

In Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008), Kissimmee Basin environmental conditions remained strongly influenced by regional drought conditions. While the drought severity lessened during WY2008, rainfall totals remained below average for the Upper and Lower Kissimmee basins — only 87 percent and 98 percent, respectively, of the long-term average. The wet season rainfall total approximated the long-term average, but only Lake Tohopekaliga refilled to high pool by the end of the wet season. Inflow from the Upper Kissimmee Basin to the Kissimmee River resumed in July 2007 after 252 days without inflow. Inflows from the Upper Kissimmee Basin were relatively small, measuring 200 to 500 cubic feet per second for most of the water year. At the end of WY2008, Upper Basin inflows increased sufficiently to inundate a portion of the floodplain for approximately six weeks, unlike WY2007 when inflows were not sufficient to inundate the floodplain. This short period of inundation created adequate foraging conditions that attracted many wading birds.

Continued encouraging responses to Phase I construction were observed in WY2008 restoration evaluation program monitoring data on river channel and floodplain hydrology, river channel dissolved oxygen concentrations, river channel littoral vegetation, geomorphology, aquatic invertebrates, fish, and wading birds and waterfowl. However, despite changes in operations under the current water regulation schedule, over the period since completion of Phase I construction, it has not been possible to maintain flow to the Phase I reach of the river during periods of extreme drought, although more natural seasonality of flow was achieved than in the channelized system, with maximum monthly flows occurring in the wet season instead of the mid-dry season. Other aspects of the hydrologic expectations have not been met under the interim regulation schedule, especially those related to floodplain inundation. In all water years since Phase I was completed, it was possible to inundate a portion of the floodplain for some period of time; however, the durations of floodplain inundation were too short and intermittent, the recession rates were too fast, and the criteria for broadleaf marsh hydroperiods were not achieved. Implementation of the Headwaters Revitalization water regulation schedule, projected for 2013, is expected to provide more operational flexibility to meet the hydrologic requirements of the river and floodplain.

The Kissimmee Program is initiating a number of new studies in Fiscal Year 2009 (FY2009) (October 1, 2008–September 30, 2009). Program restoration evaluation scientists are preparing for the next major phase of restoration reconstruction, Phase II/III, and are initiating new monitoring studies that will provide baseline and post-restoration data for evaluation of ecological responses to Phase II/III. A subset of metrics from these studies will be optimized for correlative analyses under the Phase II/III Integrated Studies project. Funds have been budgeted to install in the Phase II/III area 15 stage monitoring sites on the floodplain and two stage and flow monitoring sites in remnant river channels. The additional hydrologic monitoring will provide data for the evaluation of the hydrologic restoration expectations and will support other evaluation studies, especially those associated with the Phase II/III Integrated Studies. The network will also complement the Phase I network by extending hydrologic monitoring across the restoration project area. The Kissimmee Basin Phosphorus Project, for which development is scheduled to begin in FY2009, will evaluate the need for a comprehensive phosphorus dynamics program for the Kissimmee Basin, focusing on the effects of the KRRP on nutrient loading and on integrating this information with other District nutrient programs.

The KBMOS is a District initiative to identify alternative water control structure operating criteria for the Kissimmee Basin and its associated water resource projects. The final deliverable will be modified interim and long-term operating criteria for Kissimmee Basin water control structures. The KBMOS is projected to be completed in June 2009. The KCOL LTMP is a multiagency/stakeholder project that was initiated by the District's Governing Board Resolution 2003-468, which directs SFWMD staff to work with the USACE and other interested parties to improve the health and sustainability of regulated lakes in the Upper Kissimmee Basin. The SFWMD is the lead agency responsible for coordinating KCOL LTMP interagency activities and producing the plan. A draft of the KCOL LTMP is expected to be released in early 2009.

INTRODUCTION AND BACKGROUND

Responding to the need for increased integration and coordination at basin and watershed scales, the South Florida Water Management District (SFWMD or District) has expanded the mission and geographic focus of the Kissimmee Program since the 1990s, when the program was formed primarily for the coordination and evaluation of the Kissimmee River Restoration Project (KRRP). Since then, following management and Governing Board direction, the Kissimmee Watershed Program has embarked on and participated in major projects to address basin- and watershed-level issues including (1) initiatives to address water supply and water quality issues, (2) development of basin and regional modeling tools to enhance water management decisions, and (3) development of a long-term plan to address management of the Kissimmee Chain of Lakes (KCOL).

This chapter is an update to the *2008 South Florida Environmental Report* (SFER) – *Volume I, Chapter 11*, and highlights (1) water year environmental conditions and their effects on the system; (2) newly available data from the Kissimmee River Restoration Evaluation Program (KRREP) restoration evaluation studies; (3) descriptions of recent planning efforts; and (4) brief status updates on projects and other program activities during Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008). The watershed, which includes the basins of the Kissimmee River and Lake Istokpoga in the Lower Kissimmee Basin and the KCOL in the Upper Kissimmee Basin, is depicted in **Figures 11-1** and **11-2**.

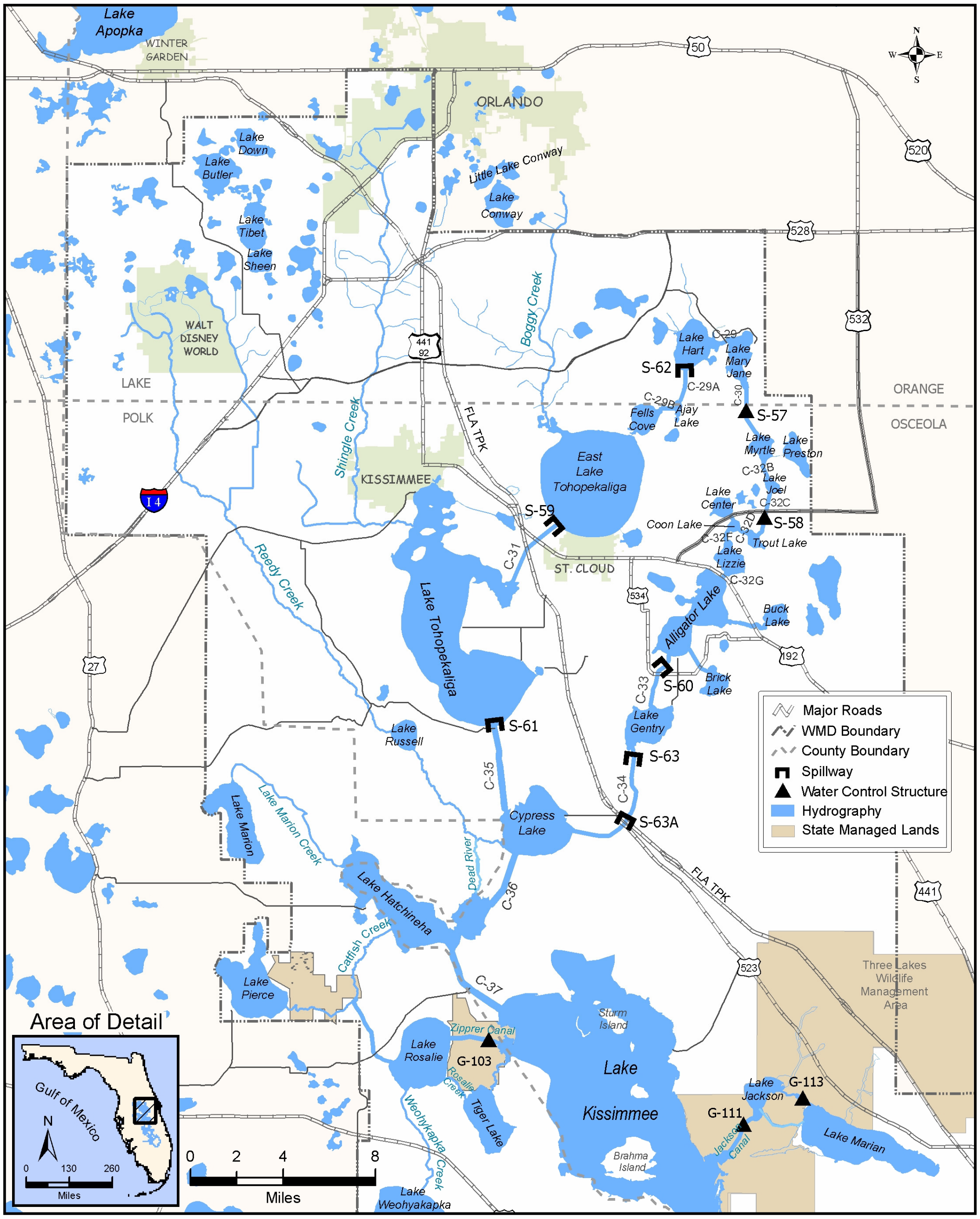

Figure 11-1. The Upper Kissimmee Basin.

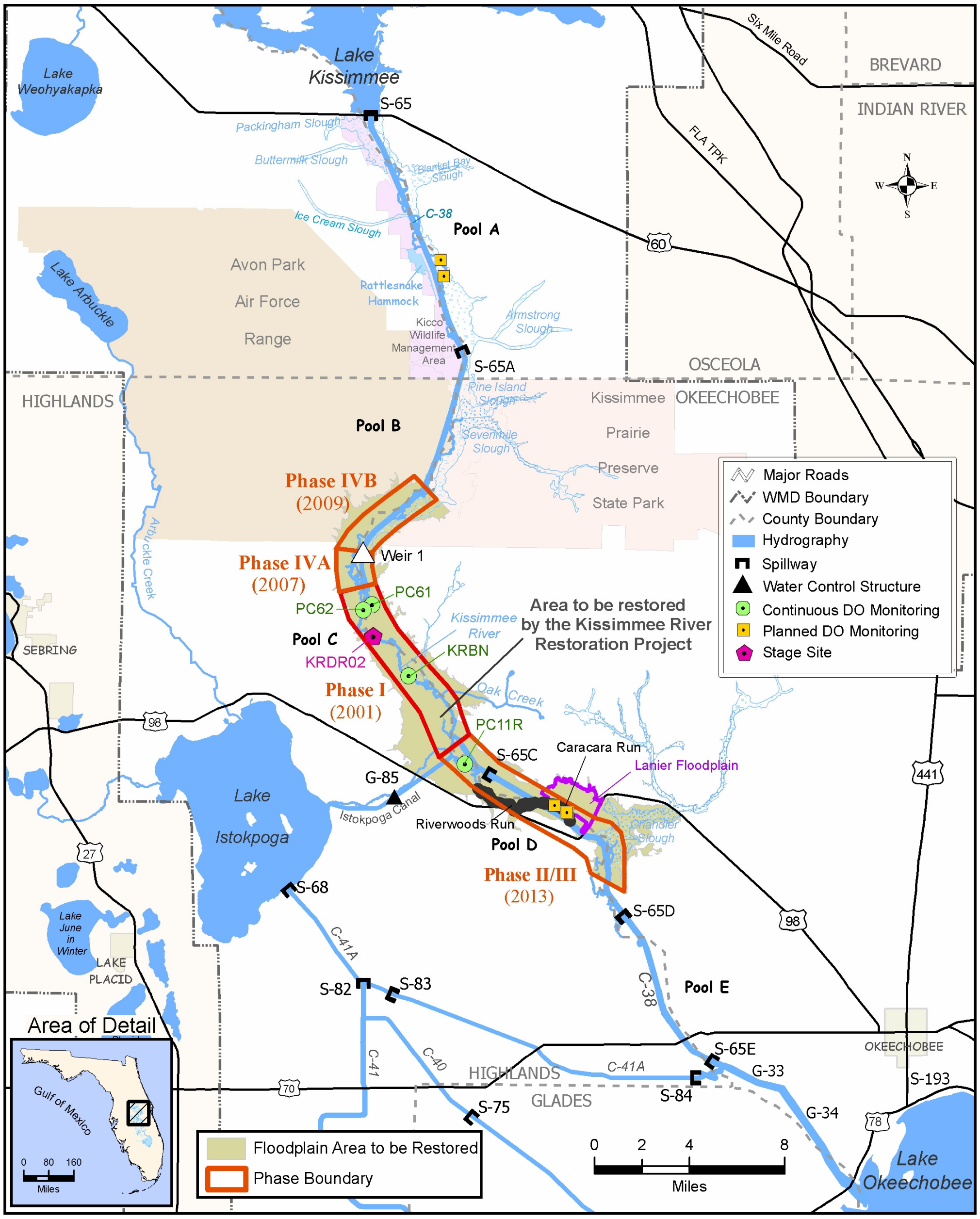

Figure 11-2. The Lower Kissimmee Basin.

This chapter is organized into four main sections:

1. The *Introduction and Background* section briefly summarizes the KRRP and other major projects taking place in the Kissimmee Basin. A description of the Kissimmee Basin and the history and background of the KRRP and KRREP are presented in the 2008 SFER – Volume I, Chapter 11 (SFWMD, 2008a).

2. The second major section, *Cross-Watershed Activities,* describes the role of the Kissimmee Watershed Program in addressing issues that span the boundaries between the Kissimmee Basin and downstream ecosystems. This section includes subsections on (1) water management and operations; (2) water quality topics, including a summary of phosphorus (P) loading to Lake Okeechobee and a new analysis of mercury bioaccumulation in Kissimmee Basin fish; and (3) water supply planning, including information on the planned Water Reservation for the Kissimmee Basin.

3. The third major section, *Basin Conditions*, summarizes environmental conditions in the Kissimmee Basin during WY2008. It emphasizes basin hydrologic conditions relative to water management decisions during the water year. The SFWMD has experienced drought conditions since the WY2006 (May 1, 2005–April 30, 2006) dry season. This year's summary continues to summarize the persistent low-rainfall conditions across the District during WY2008.

4. The final major section, *Project Updates*, is devoted to presentations of monitoring data, status reports on ongoing projects, and descriptions of planning activities for upcoming initiatives. This section includes (1) newly available Phase I restoration response data from the KRREP; (2) plans for Phase II/III restoration evaluation studies and pilot studies; and (3) status updates on the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP), the Kissimmee Basin Modeling and Operations Study (KBMOS), and several restoration projects in progress within the basin.

KISSIMMEE RIVER RESTORATION PROJECT AND ASSOCIATED INITIATIVES

Concerns about environmental degradation and habitat loss in the Kissimmee Valley, and the potential contribution of the channelized river to eutrophication in Lake Okeechobee, were the impetus for the Kissimmee River Restoration Project. Successful restoration of the Kissimmee River is largely dependent on reestablishing hydrologic conditions that are similar to the pre-channelization period (Toth, 1990). The Kissimmee River Headwaters Revitalization Project (KRHRP) is designed to provide sufficient storage in the headwaters lakes in the Upper Kissimmee Basin to allow water regulation to approximate historical flow and volume characteristics in the Kissimmee River. An additional expected benefit is the improvement of the quantity and quality of lake littoral zone habitat in the Upper Kissimmee Basin (USACE, 1996, Sections 1.3.2 and 5.1). Project modifications for the restoration are to take place without jeopardizing existing levels of flood control in the Kissimmee Basin.

Reconstruction of the river/floodplain's physical template is being implemented in four phases of construction currently projected for completion by 2013 (**Table 11-1**). Restoration components encompass (1) acquisition of needed lands in the Lower Kissimmee Basin; (2) backfilling a total of approximately 22 miles (mi) [(35 kilometers (km)] of C-38 canal (over one-third of the canal's length) from the lower end of Pool D north to the middle of Pool B; (3) reconnecting the original river channel across backfilled sections of the canal; (4) recarving sections of river channel destroyed during C-38 construction; and (5) removing the S-65B and S-65C water control structures and associated tieback levees. The material used for backfilling is the same material that was dredged during construction of canal C-38. Composed primarily of sand and coarse shell, it was deposited in large spoil mounds adjacent to the canal.

Table 11-1. Sequence of backfilling construction phases of the Kissimmee River Restoration Project with selected benefits.

Construction Sequence	Name of Construction Phase	Timeline	Miles of Backfilled Canal	Miles of River Channel Recarved	Miles of River Channel to Receive Reestablished Flow	Acres of Wetland Gained	Location
1	Phase I	June 1999 - February 2001 (complete)	8	1	14	5,792	Most of Pool C, small section of lower Pool B
2	Phase IVA	June 2006 - September 2007 (complete)	2	1	4	512	Upstream of Phase I in Pool B to Wier #1
3	Phase IVB	June 2008 - December 2009 (projected)	4	4	6	1,406	Upstream of Phase IVA in Pool B (upper limit approximately at location of Wier #3)
4	Phase II/III	October 2011 - September 2013 (projected)	9	4	16	4,688	Downstream of Phase I (lower Pool C and Pool D south to the CSX Railroad bridge)
		Restoration Project Totals	**22**	**10**	**40**	**12,398**	

A major component of the restoration project is evaluation of restoration success through the KRREP, a comprehensive ecological monitoring program (SFWMD, 2007a; SFWMD, 2005a; SFWMD, 2005b). Monitoring for ecological evaluation of restoration success will continue for at least five years after construction is completed or until responses stabilize.

The KRHRP (organizationally, a component of KRRP) will culminate with implementation of a new stage regulation schedule, called the Headwaters Revitalization Schedule, to operate the S-65 water control structure. The new schedule will allow water levels to rise 1.5 feet (ft) higher than the current schedule and will increase the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 acre-feet (ac-ft) [12,340 hectare-meters (ha-m)]. Lands that will be impacted by the higher water levels have been acquired, and projects to increase the conveyance capacity of canals and structures are in place to accommodate the larger storage volume. The Headwaters Revitalization Schedule is scheduled for implementation in 2013, when the Lower Kissimmee Basin backfilling and other restoration construction are expected to be completed.

Because of the time lag between completion of the earliest phases of the construction project and the implementation of the Headwaters Revitalization Schedule, the U.S. Army Corps of Engineers (USACE) authorized the District to make releases at S-65 when the lake stage was in Zone B of the existing regulation schedule. Zone B allows for releases for environmental purposes when flood control releases are not needed, and is used to maintain flow in the reach of the restored river channel continuously through the year and to allow seasonal variability. Environmental releases according to this interim schedule began in July 2001 after Phase I of construction for the KRRP had been completed and lake levels began to rise following the 2000–2001 drought. While the use of Zone B releases has been beneficial, it does not provide the full benefits of the Headwaters Revitalization Schedule (see the *Kissimmee River Restoration Evaluation Program: Updates from the Phase I Monitoring Studies* section of this chapter).

In the Lower Kissimmee Basin, the KRRP and KRHRP combined are expected to restore ecological integrity to approximately one-third of the river and floodplain, modifying a contiguous area of floodplain/river ecosystem of over 39 mi^2 (109 km^2). More than 20 mi^2 (51 km^2) of new wetlands will reestablish in areas that were drained by the canal, and 40 mi (70 km) of reconnected river channel will receive reestablished flow. In the Upper Kissimmee Basin, improved conditions are expected in over 7,000 acres of littoral marsh on the periphery of four regulated lakes (USACE, 1996). The KRRP (including KRHRP and the KBMOS, described below) is funded under a 50/50 cost-share agreement between the SFWMD and the USACE. Engineering and construction components of the project are the responsibility of USACE, while the District's purview is land acquisition and ecological evaluation of the restoration project.

Phase I construction of the KRRP was completed in February 2001. Approximately 7.5 mi (12 km) of flood control canal was backfilled in Pool C, and in the southern portion of Pool B, nearly 1.3 mi (2 km) of river channel that had been obliterated during canal construction was recarved, and water control structure S-65B was demolished. These efforts reestablished flow to 14 mi (23 km) of continuous river channel and allow for intermittent inundation of 5,792 acres (ac) [2,344 hectares (ha)] of floodplain. The second construction phase (Phase IVA) was completed in September 2007. This phase extends north into Pool B from the northern terminus of the Phase I project area (**Figure 11-2**). Phase IVA reconnected 4 miles of historical river channel by backfilling 2 miles of the C-38 canal, and is expected to recover 512 ac (1,265 ha) of floodplain wetlands.

Two additional phases of backfilling (Phases IVB and II/III) are scheduled for completion by 2013. While the restoration phases were originally named in the order of expected completion, this sequence has changed over the years for logistical reasons (i.e., budgetary considerations, coordination with land acquisition, or ease of access) (**Table 11-1**). Upper and Lower Kissimmee basin land acquisition for both the KRRP and KRHRP has been substantially completed.

Evaluating the success of the KRRP is a requirement of the District's cost-share agreement with the USACE, and is the task of the KRREP. The restoration is being tracked using 25 performance measures (SFWMD, 2005a; SFWMD, 2005b) to evaluate how well the restoration meets the project's ecological integrity goal (SFWMD, 2005b; SFWMD, 2005a). The ecological integrity goal is defined as reestablishment of a river-floodplain ecosystem that is "capable of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley, 1981). The performance measures, called expectations, are based on estimated pre-channelized system reference conditions and have undergone an external peer-review process. Ongoing restoration evaluation status is reported in several ways, including conference presentations, peer-reviewed and District publications, and chapters in the annual SFER. Monitoring will continue for at least five years past the completion of construction and implementation of the Headwaters Revitalization Schedule, or until monitoring has shown that ecological responses have stabilized. A final evaluation of project success will be based on these data. The most current evaluation program data are reported in the *Project Updates* section of this chapter.

Exotic, invasive vegetation is actively managed throughout the Kissimmee Basin area in an effort to meet management goals in addition to the restoration success goal. The SFWMD's Kissimmee Division works with the Vegetation Management Division and other agencies to coordinate vegetation management efforts with KRREP field sampling, to assure consistent efforts from year to year, and to develop guidelines to avoid inordinate impacts on native plant species. The goal of vegetation management in the Kissimmee River ecosystem is to achieve maintenance control, which is an efficient, cost-effective way to achieve tolerable, low levels of invasive species. More detailed information about exotic species management in the Kissimmee Basin is presented in the Kissimmee Basin Module of SFWMD, 2008b.

A BASIN PERSPECTIVE

The District's Kissimmee Program was created in the early 1990s, originally to provide scientific expertise for coordination and ecological evaluation of the KRRP, including both the restoration project and the headwaters lakes improvements included in the KRHRP. In recent years, the District has expanded the Kissimmee Program to encompass more of the Kissimmee Watershed, including 19 of the water bodies in the KCOL in the Upper Kissimmee Basin, in order to more explicitly address hydrologic and management linkages between the Upper and Lower Kissimmee basins. The key strategic priority of the Kissimmee Watershed Program is to integrate management strategies in the Kissimmee Watershed with restoration of the Kissimmee River (SFWMD, 2006). In line with this priority, the primary goals of the Kissimmee Watershed Program are restoration of ecological integrity to the Kissimmee River and its floodplain, and development of a long-term plan for addressing water and natural resource management issues in the KCOL, while retaining the existing level of flood control in the Kissimmee Basin.

In addition to the KRRP (**Figure 11-3**, panel A) and the KRHRP (**Figure 11-3**, panel B), coordinated initiatives designed to meet these program objectives include the interagency KCOL LTMP in the Upper Kissimmee Basin (**Figure 11-3**, panel C), which is creating a scientific and technical basis for assessing and managing environmental conditions relative to targeted conditions; and the KBMOS (**Figure 11-3**, panel D), a major modeling effort which will evaluate the basin-wide effects of alternative water operations schedules for the 13 structures controlling flow through the KCOL and Kissimmee River. Updates on the KCOL LTMP, the KBMOS, and small restoration projects are provided in the *Project Updates* section of this chapter. Activities associated with this suite of Kissimmee Program projects span ecosystem restoration, restoration evaluation, hydrologic management, modeling, aquatic plant management, land management, adaptive management of natural resources, water quality improvement, and water supply planning.

A B

C D

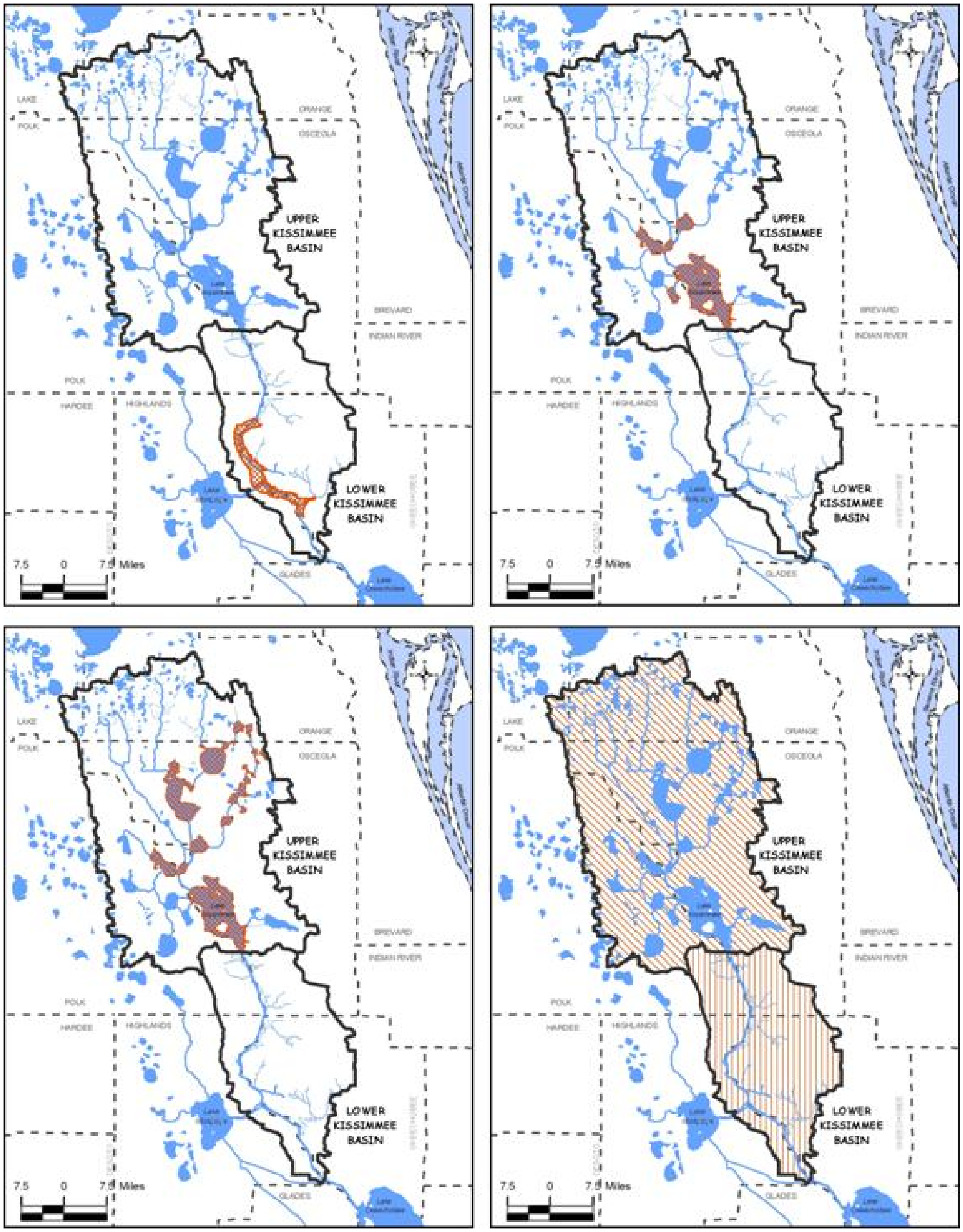

Figure 11-3. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (panel A) Kissimmee River Restoration Project, (panel B) Kissimmee River Headwaters Revitalization Project, (panel C) Kissimmee Chain of Lakes Long-Term Management Plan, and (panel D) Kissimmee Basin Modeling and Operations Study.

CROSS-WATERSHED ACTIVITIES

Water-related issues with the potential for regional effects beyond the boundaries of individual basins and watersheds are a primary concern of the District, which works to ensure close coordination among related projects. The Kissimmee Watershed Program works both within the District and with other agencies to address watershed-scale water and natural systems issues in regions that are hydrologically connected to the Kissimmee Basin. In addition to the SFWMD's efforts, several other agencies are involved in the many construction, planning, monitoring, evaluation, and modeling projects needed to address watershed-scale issues.

This section focuses on the Kissimmee Watershed Program's role and recent activities in addressing these far-reaching interactions, specifically in the areas of water management, water quality, and water supply.

WATER MANAGEMENT AND OPERATIONS

Hydrologic conditions in the Kissimmee Basin are a function of natural hydrologic processes (e.g., rainfall, evapotranspiration) and management decisions that consider multiple needs. Much of the basin's 50 inches of annual rainfall is conveyed as surface water runoff through a network of canals that interconnects the Kissimmee Chain of Lakes and Lake Kissimmee (**Figure 11-1**). Outflow from Lake Kissimmee enters the channelized and reconstructed reaches of the Kissimmee River before continuing southward to Lake Okeechobee (**Figure 11-2**).

The movement of water through this network is regulated by 13 water control structures managed by the SFWMD in accordance with regulations prescribed by the USACE. Nine structures and seven regulation schedules maintain lake and canal stages in the KCOL. Four structures manage stages along the Kissimmee River. A fifth structure, S-65B, was demolished in 2000 as part of the KRRP. These canals and structures are part of the Central and Southern Florida Flood Control (C&SF) Project that provides flood control and water supply in the region. Operation of each structure is determined by a stage regulation schedule specifying the discharges that can be made through the structure, depending on the headwater stage at the structure and the time of year. The system is also operated with the intent to protect environmental values, particularly ecological integrity in the Kissimmee River.

The operation of water control structures in the Kissimmee Basin can influence the timing and volume of flows to downstream ecosystems. Water management operations in the Kissimmee Basin must be coordinated with the rest of the South Florida system regulated by the C&SF Project. This coordination is achieved through several mechanisms. First, the District and USACE hold weekly Environmental Operations meetings that include engineers and scientists representing the Kissimmee, Okeechobee, Everglades, Stormwater Treatment Area (STA) Management, and Coastal Ecosystems divisions, and staff from the Operations and Control Department. These interagency meetings review recent rainfall data, the climatological outlook, water levels, and system operations in the various parts of the Kissimmee-Okeechobee-Everglades (KOE) system, and the overall condition of the entire KOE system. Based on this information, environmental recommendations can be made to modify operations within existing operational flexibility. Second, the flows in the Kissimmee River are formally considered by the interagency team in the decision making process for managing flows out of Lake Okeechobee. Third, the emergency modeling team is used to guide operations during flood events to minimize impacts on natural systems. Fourth, temporary deviations to the stage regulation schedules can be requested from the USACE to address specific issues. The development of a temporary deviation request involves support from an interdepartmental team as well as interagency review. Kissimmee Division staff was involved in temporary deviation requests for the extreme drawdown of Lake Tohopekaliga for fisheries habitat improvement in 2004, modified spring recessions in East Lake Tohopekaliga and Lake Tohopekaliga for snail kites (*Rostrhamus sociabilis*) in 2006, and in allowing water supply releases from Lake Istokpoga to downstream users during the drought if water levels fell below the low pool of the regulation schedule. Lastly, permanent revisions of the stage regulation schedules used for the C&SF Project structures in the Kissimmee Basin consider the potential for impacts on downstream systems. The KBMOS is an example of such a regulation schedule review (see the *Introduction and Background* and *Project Updates* sections in this chapter).

WATERSHED WATER QUALITY

Lake Okeechobee Watershed

The Kissimmee Basin lies entirely within the Lake Okeechobee Watershed (see Chapter 10 of this volume) and is therefore within the geographic jurisdiction of the 2004 Lake Okeechobee Protection Act (LOPA), which requires that applicable water quality criteria be achieved and maintained in Lake Okeechobee and its tributary waters. The Lake Okeechobee Protection Plan (LOPP), authorized under the LOPA to address water quality issues, evaluates nutrient effects on the lake from the Kissimmee and other tributary basins. The LOPP includes among its four priority basins in the Lake Okeechobee Watershed the S-65D and S-65E sub-basins, which include the lowermost pools and still-channelized sections of the Kissimmee River. The LOPA requires that the LOPP be reevaluated every three years to determine if further phosphorus load reductions are needed to achieve the Total Maximum Daily Load (TMDL). The reevaluation report was completed in February 2007 and submitted to the Florida legislature in March 2007.

Monitoring and modeling of nutrient loading from the Kissimmee Basin to Lake Okeechobee are reported under LOPP in Chapter 10 of this volume. Several tables in Chapter 10 show discharge and nutrient loading from this basin for WY2008 and the LOPP 1991–2005 baseline period. These discharges and loads are divided among those originating in the Lower Kissimmee sub-watershed (between S-65 and S-65E) and those originating in the Upper Kissimmee sub-watershed (above S-65). (The geographical areas of these two sub-watersheds are identical to the areas referred to as the Upper and Lower Kissimmee basins in other parts of this chapter.) During WY2008, the entire Kissimmee Basin (both Upper and Lower sub-watersheds) contributed 44 metric tons (mt) of total phosphorus (TP) to Lake Okeechobee, or 18 percent of the lake's total incoming load. This amount is much less than the average annual loading of 169 mt during 1991–2005 (31 percent of the lake's total load) and was largely due to dry conditions in the Kissimmee Basin.

The Northern Everglades and Estuaries Protection Program (NEEPP) was created in 2007 by the Florida legislature, which unanimously passed Senate Bill 392. This law expands the LOPP to encompass the Caloosahatchee and St. Lucie rivers and estuaries as well as the Lake Okeechobee watershed (see Chapter 7A of this volume). To augment and enhance restoration currently under way in the remnant Everglades south of the lake, the legislation requires the SFWMD, in collaboration with the coordinating agencies, to develop a technical plan for Phase II of the Lake Okeechobee Watershed Construction Project (LOWCP) by February 1, 2008, and River Watershed Protection Plans for the Caloosahatchee and St. Lucie watersheds by January 1, 2009 (see Chapters 10 and 12 of this volume, respectively). The NEEPP provides a vehicle for meeting the Kissimmee Basin's portion of the TMDL for Lake Okeechobee. Kissimmee Watershed Program staff participated in the planning effort for the Lake Okeechobee Phase II Technical Plan, completed in February 2008, to help identify ongoing and additional projects within the Upper and Lower Kissimmee basins that should be included in the plan.

Kissimmee Basin

Within the Kissimmee Basin, several agencies work to address water quality issues, including the Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), U.S. Environmental Protection Agency (USEPA), and the SFWMD. This section describes water quality efforts currently under way in the Kissimmee Basin and the responsible agencies.

As described in Chapter 10 of this volume, the Kissimmee Basin is primarily rural. In 2006, only 5 percent of the Lower Kissimmee sub-watershed was urban and the rest was predominantly agricultural (44 percent), wetland (24 percent), rangeland (15 percent), and upland forest (9 percent). In the Upper Kissimmee sub-watershed, urban areas comprised 21 percent of land use and most of the remaining area was agricultural (24 percent), wetland (24 percent), water (13 percent), upland forest (12 percent), and rangeland (4 percent). There are no municipal point sources of pollution in the Kissimmee Basin. Wastewater treatment effluents were diverted from the surface water system in the 1980s. Osceola County in the Upper Kissimmee sub-watershed is one of the fastest-growing counties in Florida; residential and commercial development is taking place on large tracts of agricultural land, most of which was used to graze cattle. This urban development has raised concerns regarding increasing runoff of nutrients and other contaminants to water bodies. However, for phosphorus, the 2007 unit load estimate for urban land uses [0.66 pounds (lbs) TP/acre)] is not much different than the unit load for most agricultural land uses. For example, unit loading from pastures and rangeland ranges from 0.27–0.72 lbs/acre and citrus is 1.62 lbs/acre. In comparison, natural areas are 0.2 lbs/acre (SFWMD, 2007b).

Kissimmee Basin Total Maximum Daily Load Water Bodies

The FDEP (2006), in its Water Quality Assessment Report, concluded that the major water quality problems in the Kissimmee Basin are high concentrations of nutrients, low dissolved oxygen, and mercury in fish tissue. In addition, iron, lead, copper, silver, and cadmium were detected at various locations, and concentrations of pesticides were found in the Reedy Creek drainage. However, most of these locations were not verified as impaired for these metals and pesticides. The FDEP stated that these elevated nutrients, along with elevated heavy metals and pesticides, can be attributed to urban and/or agricultural land uses, while mercury contamination is thought to result from atmospheric deposition.

The FDEP verified 34 water bodies in the Kissimmee Basin as impaired for one or two constituents. Of these water bodies, 18 were impaired for nutrients, 11 were impaired for mercury in fish tissue, eight were impaired for dissolved oxygen, two were impaired for fecal coliforms, one was impaired for lead, and one was impaired for copper (**Table 11-2**).

Table 11-2. Kissimmee Basin water bodies verified as impaired by the FDEP (2006).

Basin*	Water Body	Nutrients	Mercury in Fish Tissue	Dissolved Oxygen	Fecal Coliform	Lead	Copper
UKB	Horseshoe Creek				X		
UKB	Lake Hart		X				
UKB	East Lake Tohopekaliga		X				
UKB	City Ditch Canal			X			
UKB	Alligator Lake		X				
UKB	Lake Marian	X					
UKB	Lake Davenport			X			
UKB	Lake Hatchineha		X				
UKB	Lake Underhill	X					
UKB	Lake Holden	X					
UKB	Pineloch Lake	X					
UKB	Lake Copeland	X					
UKB	Lake Olive	X					
UKB	Clear Lake	X					
UKB	Lake Lorna Doone	X					
UKB	Lake Mann	X					
UKB	Cane Lake	X					
UKB	Lake Catherine	X		X			
UKB	Rock Lake	X					

Table 11-2. Continued.

Basin*	Water Body	Nutrients	Mercury in Fish Tissue	Dissolved Oxygen	Fecal Coliform	Lead	Copper
UKB	Lake Russell		X				
UKB	Reedy Cr. above L. Russell			X			
UKB	Davenport Creek				X		
UKB	Lake Butler	X	X				
UKB	Lake Mary Jane		X			X	
UKB	Red Lake						X
UKB	Lake Tohopekaliga		X				
UKB	Brick Lake		X				
UKB	Lake Cypress	X	X				
UKB	Lake Kissimmee	X	X				
UKB	Lake Jackson	X		X			
LKB – Pool A	Blanket Bay Slough	X		X			
LKB – Pool B&C	Oak Creek	X					
LKB – Pool D	Farm area			X			
LKB – below Pool E	S-154C			X			

*UKB – Upper Kissimmee Basin

*LKB – Lower Kissimmee Basin

Because water quality in the Kissimmee River within the restoration project area is expected to improve due to reestablishment of natural filtration, reaeration, and biological processes, the restored area of the river is exempt from TMDL development according to the state's Impaired Waters Rule (Chapter 62-303, Florida Administrative Code). However, certain sections of the Lower Kissimmee sub-watershed outside of the restoration project area have been identified as impaired and will have TMDLs developed. These sections include Blanket Bay Slough (Pool A drainage), Oak Creek (Pool C drainage), an upland watershed in the Pool D drainage, and the S-154C sub-watershed below S-65E.

With the FDEP as the lead agency, the timeline for developing TMDLs for these impaired waters is 2005–2011. TMDL development involves determining the maximum amount of a given pollutant that a water body can assimilate and still meet the applicable numeric or narrative water quality criterion for the pollutant. Water bodies in the Kissimmee Basin listed as impaired are subject to Florida Class III water quality standards.

After the TMDL is determined, initial and detailed allocations will be established among point sources and nonpoint sources of pollutant loading in the basin. In addition to any point source and nonpoint sources of nutrients, allocations of nutrient loadings also will be made to historical sources (e.g., the phosphorus-laden sediments within a water body) and upstream sources (e.g., those entering an impaired water body from upstream lakes). In the Kissimmee Basin, any sites that are found to be contributing excessive nutrient inputs will probably be categorized as nonpoint sources of pollution.

Following establishment of TMDLs, the FDEP will develop Basin Management Action Plans (BMAPs) as a basis for implementing nutrient loading reductions. Since late 2008, the SFWMD has been working in cooperation with the FDEP to develop the BMAP for the KCOL, which includes four nutrient-impaired lakes (Cypress, Kissimmee, Marian, and Jackson). The BMAPs will be developed with extensive stakeholder input and will contain final allocations, strategies for meeting the allocations, schedules for implementation, funding mechanisms, applicable local ordinances, and other elements.

Best Management Practices for the Kissimmee Basin

The LOPP and the subsequent 2007 amendment (NEEPP) identify areas for future legislative support to successfully implement the state's commitment to protect and restore Lake Okeechobee and to achieve its TMDL. Total phosphorus reductions and other water quality improvements are planned to be achieved through both the implementation of source controls, including Best Management Practices (BMPs), and regional projects such as STAs. In the Upper and Lower Kissimmee sub-watersheds, implementation of comprehensive source control measures is mandated by the LOPP and provides for a cost-effective way to reduce nutrients discharged from both agricultural and non-agricultural land uses that are nonpoint source contributors. As required by the legislation, the coordinating agencies (FDACS, FDEP and SFWMD) are expanding existing and developing new source control measures that include BMPs for agricultural and non-agricultural land uses, complementary to existing regulatory source control programs. Under the LOPP, the SFWMD and FDACS initiated a coordinated effort to work with agricultural landowners within the Lower Kissimmee sub-watershed to implement BMPs. The SFWMD and FDACS plan to expand BMP implementation efforts into the Upper Kissimmee sub-watershed in 2009. In addition, the FDEP and SFWMD will coordinate to implement BMPs and adopt technology-based standards for non-agricultural, nonpoint-source land uses in the Upper Kissimmee sub-watershed (for additional details, see Chapter 4 of this volume).

Mercury in the Kissimmee Basin

As mentioned above, the bioaccumulation of mercury (Hg) ranks as one of the major water quality issues in the Kissimmee Basin. Mercury bioaccumulation poses a health risk for humans and wildlife due to consumption of contaminated fish. Twenty water bodies in the Kissimmee Basin are under some level of public health advisory on the Limited Consumption Advisory list (FDOH, 2007). Also, the FDEP has verified 11 lakes in the Upper Kissimmee Basin as impaired for mercury in fish tissue (**Table 11-3**).

Because mercury contamination is thought to result from atmospheric deposition originating from external sources, such as fossil fuel power plants and municipal and medical waste incinerators, solutions to this problem are being addressed by the FDEP and the USEPA. For this reason, the SFWMD is not currently monitoring Hg in the Kissimmee Basin. However, the District uses data on total mercury (THg) concentrations in fish tissue data collected by the Florida Fish and Wildlife Conservation Commission (FWC). Mercury measured in fish tissue is preferable to sampling water, algae, or sediment because it provides a more precise measure of mercury in its most toxic form, methylmercury (MeHg). As an organic compound, MeHg is easily absorbed into the body, primarily via food sources, and it accounts for 99 percent of the mercury found in fish tissue (Grieb et al., 1990). Therefore, THg concentrations in fish tissue are considered a reasonable gauge of MeHg levels to which consumers of fish are exposed.

The SFWMD has examined THg data collected by the FWC in the Kissimmee Basin from 1987 to 2007. Fish were collected by electrofishing, and tissue data were collected in accordance with the FDEP Standard Operating Procedures (SOP) FS 6000 (General Biological Tissue Sampling) and FS 6200 (Finfish Tissue Sampling). This method of sub-sampling involves sectioning half-inch strips of fish muscle tissue taken from a fillet of dorsolateral muscle on the posterior portion of the body of the fish. The tissue is rinsed with analyte-free water and stored in a culture tube at -20º Celsius (C) until shipping for analysis. THg is measured using cold vapor atomic absorption spectroscopy according to USEPA Method 245.6.

Analysis of the FWC mercury data was problematic because sampling of fish was, in most cases, sporadic and inconsistent. In a given sampling year, the sample size for a species in a body of water ranged from 1 to 40. Since the FDEP uses data from fishes collected over the previous 7.5-year period, it is not necessary to collect samples every year from every body of water. However, a larger and more representative dataset would be needed for a definitive analysis of mercury levels in the Kissimmee Basin. It is also important to determine a baseline toxicity level in a changing aquatic ecosystem such as the Kissimmee Basin.

The species for which most data were obtained was largemouth bass (*Micropterus salmoides*), an abundant and popular sport and food fish. As such, the largemouth bass will serve as the sentinel species in this report. This species is also a logical focus for analysis of mercury contamination because of its relatively higher levels of mercury due to its size and its high trophic position. This analysis only uses data for bass that are legally harvestable under regulations for Northeastern and Central Florida (larger than 14 inches), since this size class is being consumed most regularly. The most extensive samples contained fish collected from Lake Tohopekaliga and East Lake Tohopekaliga. Therefore, the data for these lakes will be discussed in the greatest detail. However, data for the remaining lakes that were sampled are presented in **Table 11-3**.

For the available period of record, the range of annual mean THg levels in largemouth bass of East Lake Tohopekaliga was 0.52–1.34 micrograms per gram (µg/g) between 1989 and 2007. Summary statistics are presented in **Table 11-4**. Overall, the data indicated a decline of 53 percent between the peak in 1990 and the most recent collection in 2007 (**Figure 11-4)**. In Lake

Tohopekaliga, the range of annual mean THg for bass was 0.4–0.77 µg/g, and there was a decrease of 33.8 percent in mean THg from 1989 to 2007 (**Figure 11-5)**. Where data are available for multiple years, every water body in the basin indicates declining mercury levels in largemouth bass (**Table 11-3**).

Still, mercury in fish remains high throughout the basin. When the average mercury level in a species exceeds 0.2 µg/g, the Florida Department of Health (FDOH) issues a Limited Consumption Advisory for that species in the specified body of water, which the FDEP posts on its web site at: http://www.floridadep.org/labs/mercury/fhatoc.htm.

At this level, bass should be consumed no more than once a week, or once a month for children and women of childbearing age. In the most recent year of data, all bodies of water in the Kissimmee Basin tested above this level. The lakes in the KCOL that have the highest mean THg levels (Alligator, Brick, Gentry, Hart, and Mary Jane) ranged in concentrations from 1.06–1.46 µg/g, falling under a higher level of advisement in which bass should be eaten no more than once a month, and not at all for children and women of childbearing age.

A more robust dataset would be needed for thorough statistical analysis, including a more consistent sampling of other species. Despite these limitations, a decrease in Hg levels across the Kissimmee Basin is suggested by the 1987–2007 data. This decline was likely due to legislation and regulations enacted in the early 1990s which reduced mercury content of wastes and limited emissions from Florida municipal solid waste combustors and medical waste incinerators (Atkeson, 1999). Although this trend seems promising, as of 2007, Hg levels in largemouth bass and other large-bodied piscivorous fish remain at or above cautionary levels throughout the Kissimmee Basin.

Table 11-3. Overview of total mercury (THg) averages in largemouth bass during various periods of record (POR) in lakes of the Kissimmee Basin and the Kissimmee River. Trends in mercury levels are described as a percent change from the highest reported average. THg is reported in units of µg Hg/g wet wt tissue.

Location	Reported POR	No. of Collections During POR	Highest Average THg±SD (n)	[Year]	Most Recent Average THg±SD (n)	[Year]	% Change from Highest Average
Upper Basin							
Alligator Lake	1990–2004	2	1.42±0.57 (3)	[1990]	1.28±0.23 (12)	[2004]	-9.9
Brick Lake	1989–2004	3	1.37±0.11 (3)	[1989]	1.09±0.23 (10)	[2004]	-20.4
Lake Cypress	2004	1	0.52±0.18 (12)	[2004]	0.52±0.18 (12)	[2004]	-----
East Lake Tohopekaliga	1989–2007	19	1.34±0.51 (7)	[1990]	0.63±0.10 (7)	[2007]	-53.0
Lake Gentry	2002–2004	2	1.27±0.11 (2)	[2004]	0.87±0.23 (8)	[2005]	-31.5
Lake Hart	1991–2005	3	1.46±0.22 (5)	[2003]	1.03±0.33 (5)	[2005]	-29.5
Lake Hatchineha	1990–2004	3	1.18±0.26 (3)	[1990]	0.59±0.20 (10)	[2004]	-50.0
Lake Kissimmee	1989–2003	2	0.62±0.21 (16)	[1989]	0.58±0.17 (12)	[2003]	-6.5
Lake Mary Jane	2003	1	1.06±0.23 (12)	[2003]	1.06±0.23 (12)	[2003]	-----
Lake Marian	2002	1	0.36±0.12 (11)	[2002]	0.36±0.12 (11)	[2002]	-----
Lake Russell	2002	1	0.74±0.17 (11)	[2002]	0.74±0.17 (11)	[2002]	-----
Lake Tohopekaliga	1989–2007	18	0.77±0.18 (19)	[1989]	0.51±0.07 (9)	[2007]	-33.8
Tiger Lake	2003	1	0.39±0.11 (12)	[2003]	0.39±0.11 (12)	[2003]	-----
Lower Basin							
Kissimmee River	2004	1	0.61±0.23 (9)	[2004]	0.61±0.23 (9)	[2004]	-----

Table 11-4. Summary statistics for total mercury levels in largemouth bass muscle tissue collected in East Lake Tohopekaliga (panel A) and Lake Tohopekaliga (panel B) during the period of record 1989–2007**.**

East Lake Tohopekaliga					Lake Tohopekaliga				
(A)	Year	Mean	Std Dev	*n*	*(B)*	Year	Mean	Std Dev	*n*
	1989	1.31	0.36	13		1989	0.77	0.18	19
	1990	1.34	0.51	7		1990	0.62	0.13	9
	1991	1.08	0.12	9		1991	0.50	0.06	2
	1992	0.86	0.18	9		1992	0.66	0.09	2
	1993	0.94	0.26	4		1993	0.76	0.18	4
	1994	1.27	0.61	5		1994	0.40	0.11	3
	1995	0.62	0.16	7		1995	0.52	0.11	3
	1996	0.79	0.27	7		1996	0.40	0.11	14
	1997	0.52	0.16	3		1997	0.44	0.14	9
	1998	0.59	0.07	2		1998	0.40	0.10	2
	1999	0.87	0.22	6		1999	0.47	0.11	5
	2000	0.92	0.19	5		2000	0.51	0.16	6
	2001	0.81	0.16	6		2001	0.42	0.11	15
	2002	0.84	0.15	8		2002	0.52	0.23	7
	2003	0.71	0.23	9		2003	0.47	0.18	19
	2004	0.83	0.21	3		2005	---	---	--
	2005	0.67	0.08	9		2004	0.52	0.19	16
	2006	0.61	0.07	3		2006	0.56	0.12	13
	2007	0.63	0.10	7		2007	0.51	0.07	9

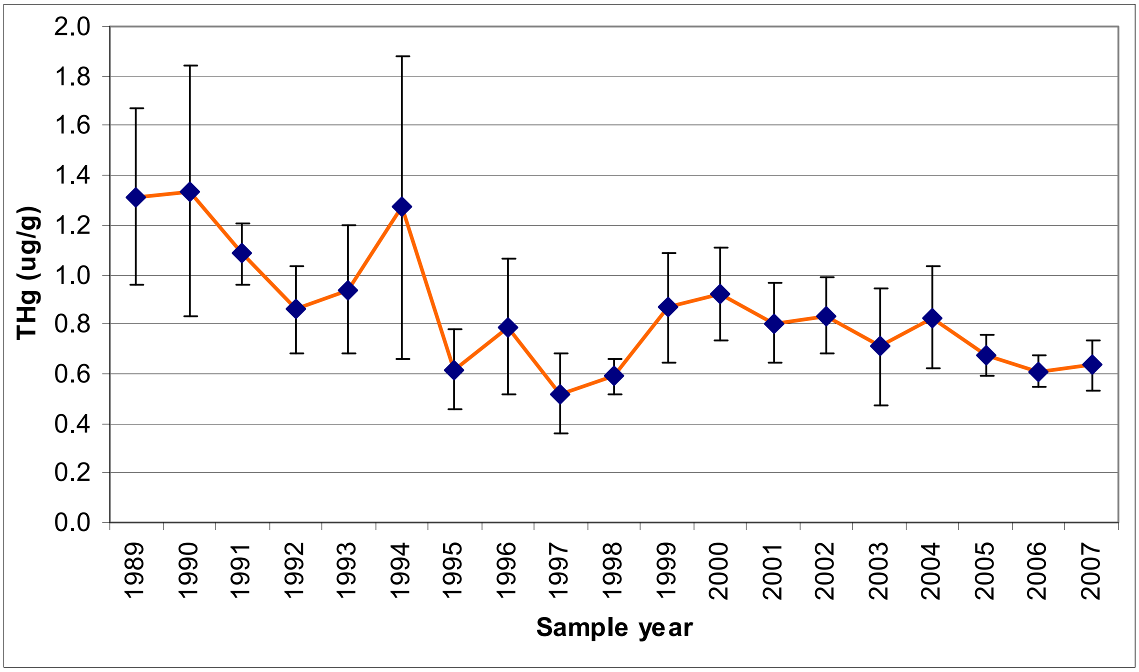

Figure 11-4. Average total mercury levels µg THg/g wet wt tissue ± one SD of largemouth bass in East Lake Tohopekaliga between 1989 and 2007. Individuals were of legally harvestable size (> 14 in.).

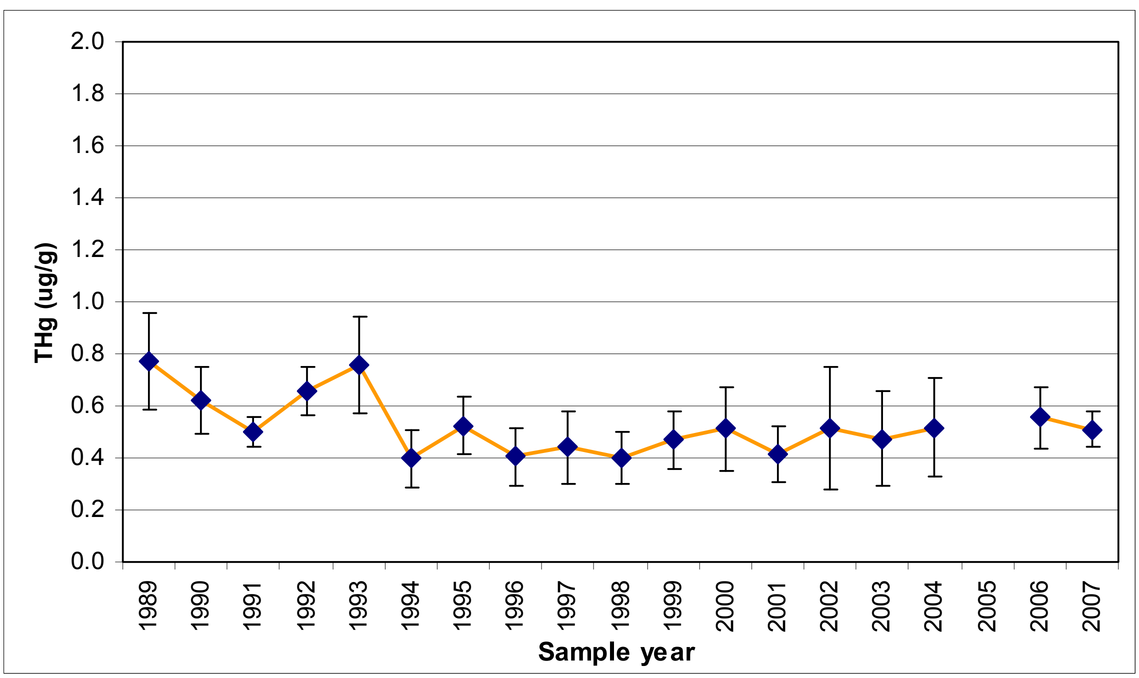

Figure 11-5. Average total mercury levels ((µg THg/g wet wt tissue) ± one SD of largemouth bass in Lake Tohopekaliga between 1989 and 2007. Individuals were of legally harvestable size (> 14 in.).

Ambient Water Quality Monitoring

Since 1981, the SFWMD has maintained a long-term water quality sampling program in five major lakes of the Kissimmee Chain (East Lake Tohopekaliga, Lake Tohopekaliga, Cypress Lake, Lake Hatchineha, and Lake Kissimmee) and three main tributaries to these lakes (Boggy Creek, Shingle Creek, and Reedy Creek). Sampling is conducted monthly for TP, total nitrogen (TN), phytoplankton chlorophyll *a*, turbidity, water transparency, dissolved oxygen (DO), and other constituents. One station is sampled at each tributary and up to three stations are sampled in each lake. Since 1974, the SFWMD also has sampled water quality in C-38 and/or lateral tributaries and remnant (nonflowing in the channelized system) and restored sections of river channel. Recently, the SFWMD initiated additional sampling in the Kissimmee Basin under its Lake Okeechobee Watershed Assessment (LOWA) Program (see Chapter 10 of this volume). These stations are sampled for TP only. In the Upper Kissimmee sub-watershed, 12 stations have been added at lake tributaries, connecting canals, and water control structures. In the Lower Kissimmee sub-watershed, stations have been added at tributaries to the river.

The FWC also conducts a monitoring program, which includes the lakes sampled by the SFWMD plus Alligator Lake, Lake Gentry, Lake Jackson, and Lake Marian. Water quality is sampled for parameters similar to the SFWMD parameter list, but sampling is done quarterly instead of monthly. The FWC program is being reevaluated, and the SFWMD and FWC are discussing how the two monitoring programs can be optimized.

Florida Lakewatch samples 12 of the 19 lakes — Alligator Lake, Brick Lake, Lake Lizzie, Coon Lake, Lake Center, Ajay Lake, Fells Cove, Lake Gentry, East Lake Tohopekaliga, Lake Tohopekaliga, Cypress Lake, and Lake Kissimmee. Monitoring is conducted monthly for TP, TN, chlorophyll, and Secchi depth.

The FDEP also samples the Kissimmee Basin periodically. The FDEP utilizes the Florida STORET database (http://storet.dep.state.fl.us/), which includes data from the FDEP and other sources, to prepare its water quality assessment every five years.

Further information about water quality monitoring in the basin can be found in SFWMD (2005a), FDEP (2006), and the draft KCOL LTMP (SFWMD, 2008d).

WATER SUPPLY

The Central Florida region is experiencing rapid population growth, especially in urban areas such as Orlando, Kissimmee, and St. Cloud. The population in the Kissimmee Basin Planning Area is projected to increase by approximately 150 percent from 2000–2025, growing from approximately 500,000 to more than 1.1 million residents (SFWMD, 2007b). One key factor that will control growth is availability of water to service the increasing population. The demand for public water supply is expected to double from almost 114 million gallons per day (mgd) in 2000 to over 235 mgd by 2025 (SFWMD, 2007b). In the Upper Kissimmee Basin, where 90 percent of the projected growth will occur, water supply for consumptive uses is withdrawn almost exclusively from the Floridan aquifer. The SFWMD, along with the two water management districts that abut this region — the St. Johns River Water Management District and Southwest Florida Water Management District — have determined that the limit of sustainable withdrawal from the Floridan aquifer will be reached in 2013, prompting the current investigation of alternative supplies.

The SFWMD is working cooperatively with adjacent water management districts, counties, and Central Florida utilities to identify Alternative Water Supply projects. The use of surface water from the KCOL is of particular concern due to potential impacts to the KRRP. Modeling tools and evaluation performance measures developed for the KBMOS are being used to evaluate proposed surface water withdrawal scenarios and to develop a Water Reservation for the Kissimmee River. Kissimmee Division staff has provided technical support for several related efforts, including the Okeechobee Watershed Construction Project Phase II Technical Plan and the Central Florida Water Feasibility Study.

Water Reservation for the Kissimmee River Restoration Project

Section 373.223(4), Florida Statutes, allows the water necessary for the protection of fish and wildlife to be reserved from permitted withdrawal through a formal rulemaking process. At its June 2008 meeting, the District's Governing Board approved a resolution to begin rule development for the reservation and allocation of water necessary for the protection of fish and wildlife in the Kissimmee River, the river's floodplain, and the KCOL. The Water Reservation is being developed for the Kissimmee River and its floodplain because the hydrology of the river channel and floodplain are closely coupled. For the KCOL, a separate Water Reservation is planned for each of the seven Lake Management Areas (Myrtle, Preston, and Joel; Hart and Mary Jane; East Tohopekaliga; Tohopekaliga; Alligator Chain; Gentry; and Kissimmee, Cypress, and Hatchineha) because fish and wildlife resources vary among each Lake Management Area. The lakes within each Lake Management Area are managed using the same regulation schedule (i.e., they have the same water levels) and, therefore, experience the same change in water level from a withdrawal.

For each water body Water Reservation, the technical work will involve identifying fish and wildlife resources for protection, their hydrologic requirements, and a target time series of flow, stage, or volume that represents these requirements. The Kissimmee Division is the lead for the technical work and will draw on its considerable efforts to date, including the KRRP, the KRREP, the KBMOS, and the KCOL LTMP. The Kissimmee Division will be working collaboratively with staff from other agency departments, including Water Supply and Hydrologic Environmental Systems Modeling, to complete the technical support and rulemaking process. The proposed rule is expected to be presented to the District's Governing Board in June 2009.

KISSIMMEE BASIN ENVIRONMENTAL CONDITIONS IN WATER YEAR 2008

During WY2008, hydrologic conditions in the Kissimmee Basin were strongly influenced by a regional drought that has continued since WY2007. While the severity of the drought declined in WY2008, lake water levels tended to be well below the regulation schedule. Flow was reestablished to the Kissimmee River in July 2007 but was maintained at low levels for most of the remainder of WY2008. Hydrologic conditions were also influenced by operational actions that were undertaken to facilitate vegetation management actions (Lake Gentry and Lake Cypress) or for environmental benefits, including a temporary deviation for the endangered snail kite (*Rostrhamus sociabilis*) in Lake Tohopekaliga.

RAINFALL

In WY2008, rainfall followed a seasonal pattern with most months having below average rainfall in the Upper and Lower Kissimmee basins (**Figure 11-6**). The Upper Kissimmee Basin totaled 43.5 inches, which is 87 percent of the long-term average for a water year. The Lower Kissimmee Basin totaled 43.6 inches for the water year, which is 98 percent of the long-term average. The Upper Kissimmee wet season (June–October) total was 30.6 inches, which approximated the long-term average. The dry season total was below average. While WY2008 was drier than average, it was not as dry as WY2007, which had only 69 percent of average rainfall for the Upper Kissimmee Basin and 76 percent for the Lower Kissimmee Basin.

At the beginning of WY2008, the U.S. Drought Monitor (http://drought.unl.edu/dm/) indicated that the most northern portion of the basin was experiencing moderate drought, the more central portion of the basin was experiencing severe drought, and the lowermost portion of the basin was experiencing extreme drought. With the increased rainfall in WY2008, the severity of the drought declined. By the end of WY2008, none of the basin experienced extreme or severe drought and only a small portion experienced abnormally dry to moderate drought conditions.

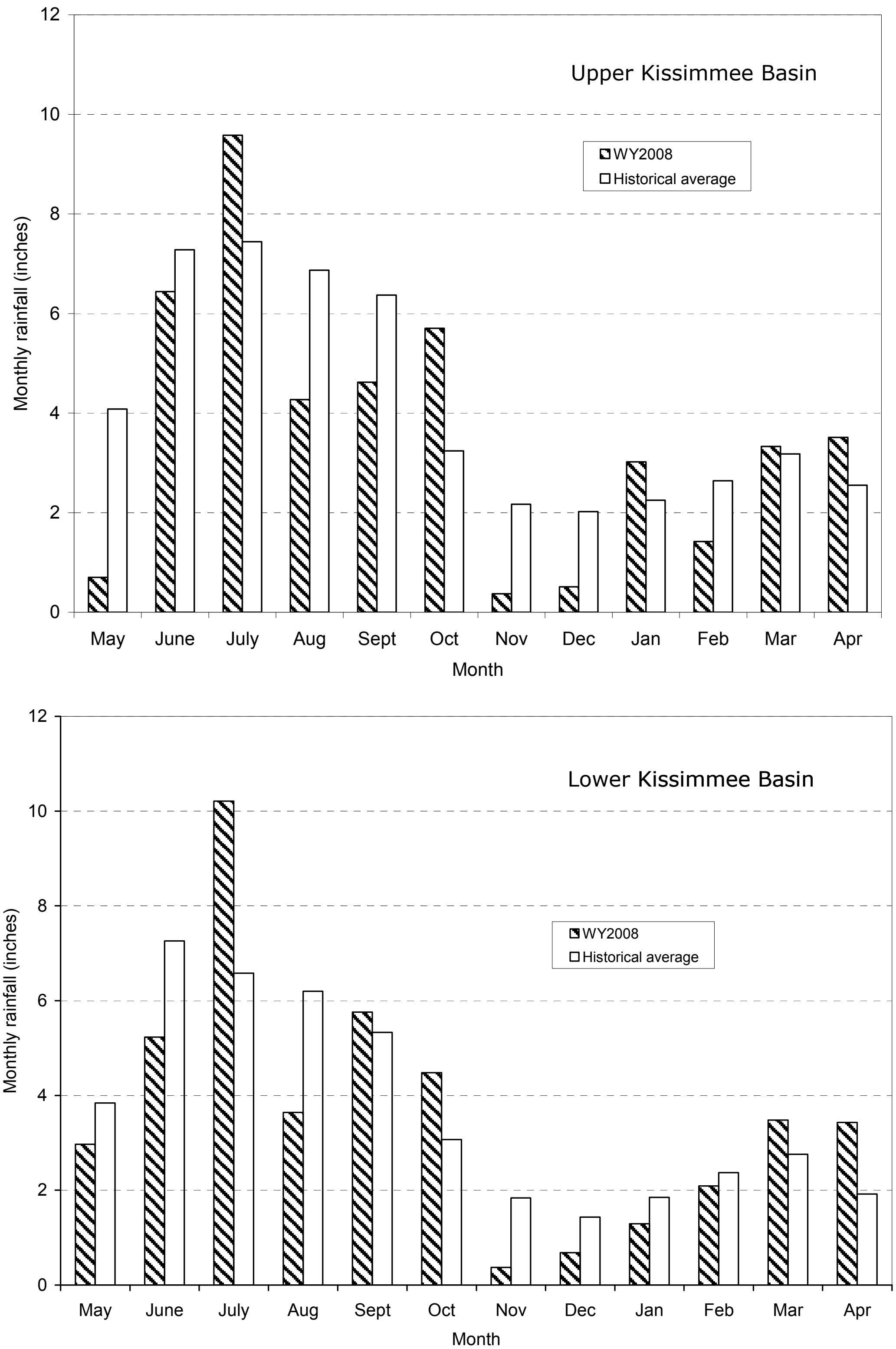

Figure 11-6. Monthly rainfall totals for Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008) and the average rainfall (1971–2000) in the Upper (top) and Lower (bottom) Kissimmee basins (based on Chapter 2 of this volume).

TEMPORAL PATTERNS

Temporal patterns in hydrologic conditions reflect both the seasonality of rainfall described above and changes in the operation of water control structures. Of particular importance are the seasonal rising and falling of the schedule line in the stage regulation schedules for each of the Upper Kissimmee Basin lakes. Because the regulation schedules have similar shapes, the description of the temporal patterns is organized around the spring recession, summer pool, and high pool of the schedule lines.

Spring 2007 Recession

The regulation schedule lines for all the lakes begin dropping from the high pool (highest elevation of the schedule) in December through March, depending on the lake. The spring recession ended for all lakes on May 31, 2007, when the water level reached the low pool (lowest elevation in the schedule line). The spring 2007 recession spanned the end of WY2007 and the beginning of WY2008 on May 1, 2007. In WY2007, none of the lakes reached the high pool stage (highest elevation of a stage regulation schedule) by the end of the wet season (October 31, 2006). Flow to the Kissimmee River ended on November 8, 2006. In the absence of inflow, the headwater (upstream) stage at S-65C was raised to 36 ft to hold as much water in the pool as possible.

By the beginning of WY2008, water levels in all the lakes in the KCOL were lowered because the stage regulation schedule line decreases in the spring, as shown for East Lake Tohopekaliga and Lake Tohopekaliga in **Figure 11-7**. Because Lake Kissimmee was already at low pool (**Figure 11-8**), the water discharged from upstream lakes was held in Lake Kissimmee to maintain water levels rather than resuming discharges to the Kissimmee River. In the absence of flow, water levels in the river were almost the same as the most upstream monitoring stations (KRDR02, KRBN) as the headwater (upstream) at S-65C, which indicates that the water surface profile was essentially flat across the length of the reconnected river channel (**Figure 11-9**). By the end of the spring recession, the headwater stage at S-65C fell to 35 ft, largely due to evapotranspiration and seepage losses.

Snail kite nesting was well under way on Lake Tohopekaliga and Lake Kissimmee by mid-March 2007. Nests were also present on East Lake Tohopekaliga later in the season. Snail kites stopped nesting for the season in October 2007. The snail kite is of particular interest because of its status as an endangered species and its dependence on water to provide nesting habitat and food. Snail kites nest in woody vegetation primarily over water, which serves as a barrier to terrestrial predators. Its primary food item is the Florida apple snail (*Pomacea paludosa*). Snail kites have been nesting on Lake Kissimmee, Lake Tohopekaliga, and East Lake Tohopekaliga. In recent years, especially during the recent drought, much of the snail kite nesting in Florida has occurred on these three lakes. Because of its endangered status and continued population declines, a strategy was developed through informal consultation with the FWC and the U.S. Fish and Wildlife Service (USFWS) to begin lowering the water levels in East Lake Tohopekliga and Lake Tohopekaliga before the regulation schedule would require it. The rationale for beginning the spring recession earlier in these lakes is to provide snail kites with a cue that water levels will be falling in these lakes before many nests are established and to slow the overall recession rate. This strategy was used in 2006 and 2007.

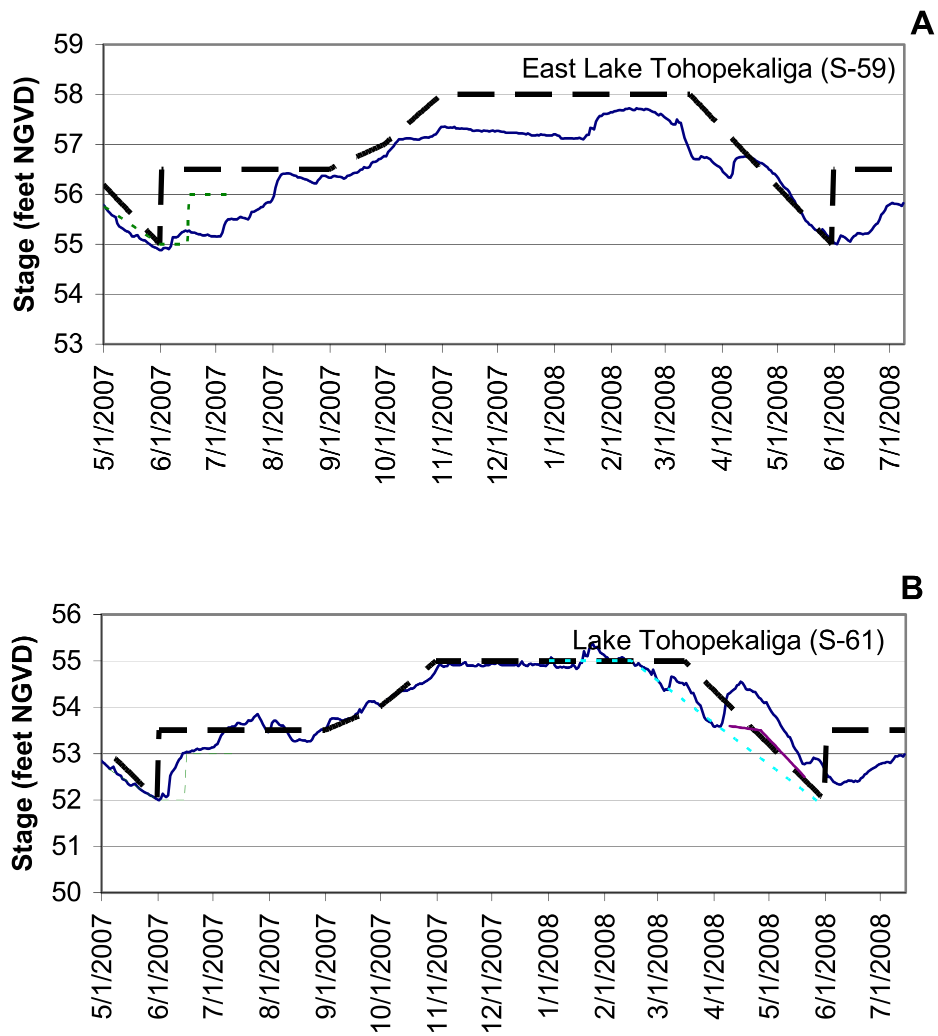

Figure 11-7. Stage (solid line), regulation schedule (dashed line), and modifications to the regulation schedule (dotted lines) in East Lake Tohopekaliga (panel A) and Lake Tohopekaliga (panel B) during WY2008. Panel B includes early recession line for snail kites (dashed green) and the temporary deviation schedule line (maroon).

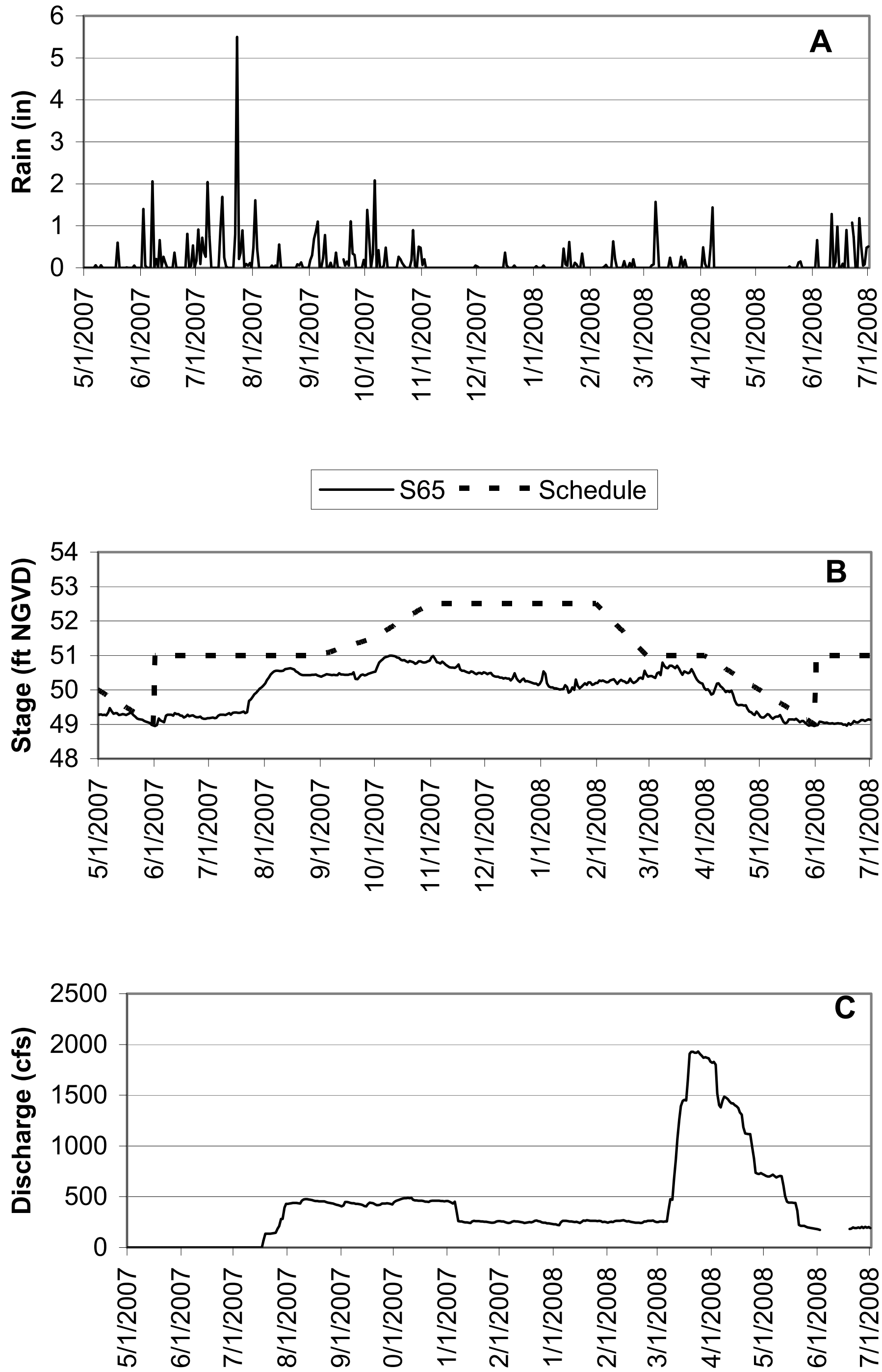

Figure 11-8. Rainfall (panel A), headwater stage and stage regulation schedule (panel B), and discharge (panel C) at S-65 outlet from Lake Kissimmee to the Kissimmee River during WY2008.

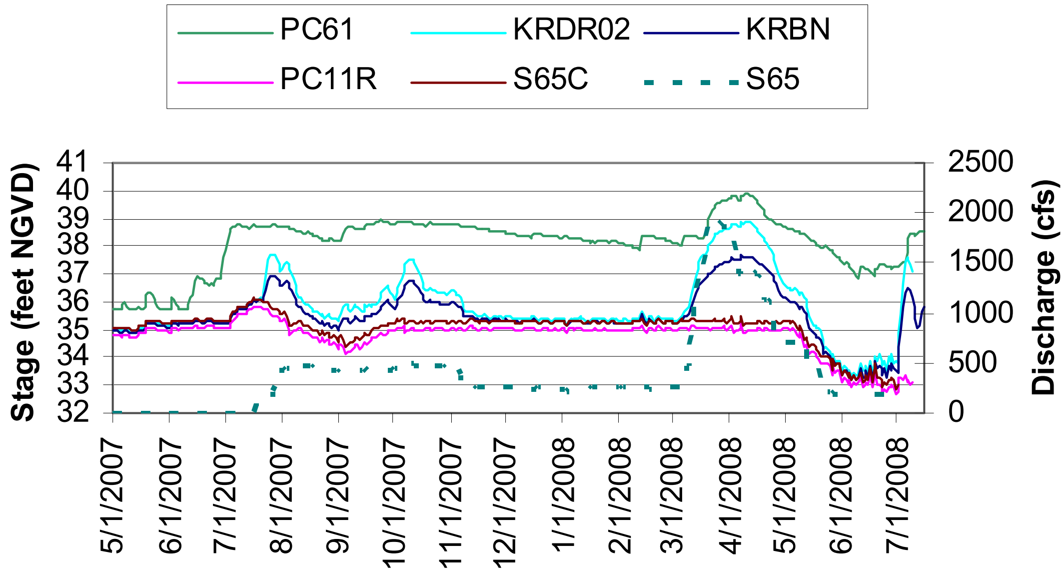

Figure 11-9. Stage at select locations along the river and discharge (cubic feet per second, or cfs) at S-65 for WY2008.

Water Year 2008 Summer Pool

On June 1, 2007, the regulation schedule line increases from the low pool to the summer pool for all of the lakes (**Figure 11-7** and **Figure 11-8**, panel B). The summer pool is a plateau in the schedule line that is one-third to two-thirds of the distance between the low and high pools. The low pool allows the lakes to rise from this pool's stage to the summer pool when rainfall occurs early in the wet season.

Water levels in all the lakes began rising in July 2007 as rainfall increased. Most lakes reached the summer pool elevation by September, except for the Lakes Myrtle-Preston-Joel Group and the Alligator Chain. By July 18, 2007, water levels in Lake Kissimmee (S-65) began to rise above the low pool stage of 49 ft, and releases to the Kissimmee River resumed (**Figure 11-8**, panel B). This ended a 252-day period during which releases from the Upper Kissimmee Basin were not made to the Lower Kissimmee Basin. When discharge from the Upper Kissimmee Basin resumed on July 18, 2007, it was maintained at approximately 500 cubic feet per second (cfs). Water levels at monitoring locations along the length of the reconnected reach of river channel (KRDR02, KRBN) and on the floodplain near the upstream limit of Phase I (PC61) began to rise in response to rainfall (**Figure 11-9**).

Also in July 2007, because inflow from the Upper Kissimmee Basin had resumed, the headwater (upstream) stage at S-65C was lowered from 35 to 34 ft (**Figure 11-9**), as fluctuating water levels are important for wetland health. Water backing up at the structure inundates a portion of the floodplain. If the headwater (upstream) at S-65C is held constant, then the stabilized water levels on the floodplain may form floating vegetation mats and interfere with seed germination of native wetland plants.

Water Year 2008 High Pool

The high pool is the highest elevation in the regulation schedule line. Depending on the lake, the regulation schedule line typically begins rising from the summer pool to the high pool stage on September 1 or October 1, and reaches the high pool at the end of the wet season (October 31). If there is sufficient rainfall, then the lake can refill to the high pool by the end of the wet season. Rainfall was below average in August and September 2007 but above average in October (**Figure 11-6**). The October rainfall helped raise the water levels in all the lakes. Only Lake Tohopekaliga reached the high pool of the regulation schedule by the end of the wet season.

In September, the water level in Lake Hatchineha rose high enough to allow a small tussock removal project to move forward. The purpose of the project was to remove approximately 5 acres of floating tussock islands so the islands would not interfere with navigation in the downstream canal (C-37) or block the outflow at the downstream structure (S-65). Removal of the tussock material also enhances conditions for fish in the lake.

In September, the headwater (upstream) stage at S-65C was raised back to 35 ft after having been lowered to 34 ft in July (**Figure 11-9**). In early November, the discharge from Lake Kissimmee was reduced from 500 to 250 cfs. This reduction was necessary to conserve water in order to continue releases to the Kissimmee River without continuing to lower Lake Kissimmee.

Water Year 2008 Spring Recession

In mid-February 2008, releases from East Lake Tohopekaliga and Lake Tohopekaliga were initiated to begin the spring recession in these lakes a little early for snail kites. This action was undertaken after consulting informally with the FWC and USFWS. The rationale for beginning the spring recession earlier in these lakes is to provide snail kites with a cue that water levels will be falling in these lakes before many nests are established and to slow the overall recession rate. This strategy was also used in 2006 and 2007.

One concern throughout the spring recession was the impact of flow, especially greater than 2,000 cfs, on the construction of a weir across the C-38 downstream of S-65E. This tailwater weir was constructed to maintain a tailwater elevation at the weir to protect the structure. Without the weir, the tailwater at S-65E is determined by water levels in Lake Okeechobee, which fell to a record low last summer. If the lake water level were to continue falling, then a head difference might develop between the tailwater (downstream) and headwater (upstream) sufficient to destabilize the structure and cause failure. The loss of the S-65E might cause the sequential failure of upstream structures as each structure would lose its tailwater. The construction of the tailwater weir began in the spring and was substantially completed on August 2, allowing normal operations of S-65E to resume. Additionally, it should be noted that the lock at S-65E was closed on February 4, 2008, because of safety issues related to the low lake levels in Lake Okeechobee. The S-65E lock had been previously closed from May 31–October 5, 2007, because of safety concerns due to low water levels.

In March 2008, the USFWS identified an additional concern for snail kites nesting in Lake Tohopekaliga — snail kite nesting success declines when water level falls below 53.5 ft. On March 13, the USFWS requested a temporary deviation from the USACE to allow the water level to remain 0.5 ft above the regulation schedule line until June 1, when the schedule line increased to 53.5 ft. This request reduced the amount of time the schedule line was below 53.5 ft. The USACE issued a Finding of No Significant Impact on April 8, 2008, and the District implemented the proposed deviation (**Figure 11-7**, panel B).

During March 2008, the FWC began removing 20 acres of nuisance vegetation (e.g., tussocks, cattail, and Cuban bulrush) from the littoral zone of Lake Gentry with a harvester. The purpose of this project was to clear unwanted vegetation to allow the establishment of a more natural plant community and improve conditions for fish and wildlife. For this lake, the spring recession typically begins in mid-March and reaches 61 ft in early April. Because the harvester begins to lose access to the littoral zone when the water level drops below 61 ft, the FWC had requested the water level be held at or above that height until project completion on April 21, 2008. The USACE approved this request, and the District maintained such water levels until the project was successfully completed.

In Lake Cypress, hydrilla had grown to the surface and began forming a mat over much of the lake, which creates poor habitat for fish and wildlife. The FDEP Bureau of Invasive Plant Management (recently transferred to the FWC), which attempts to manage this exotic plant to the lowest level possible, treated most of the lake with a new systemic herbicide, called penoxsulam. This treatment requires maintaining a lake-wide target concentration range of 8-12 parts per billion (ppb), ideally for 120 days. The herbicide treatment began on April 7. High inflows effectively ended the treatment by July 21, when the highest penoxsulam concentration found in the lake was 3 ppb. Goal concentrations were therefore maintained for about 110 days. Hydrilla biovolume and biocover were found to have decreased by 70 percent during the treatment, although hydrilla has now recovered and is expanding. This was the largest treatment to date using this newly available product, and its best-use methods are still being developed. The new herbicide was used to in response to evolved resistance in Upper Kissimmee Basin populations to the formerly preferred herbicide fluridone. In the future, treatments will not likely be made during peak hydrilla growth seasons in an effort to extend the period of hydrilla control. Because Lake Cypress receives inflow from Lake Tohopekaliga (S-61) and Lake Gentry (S-63), a coordinated adjustment of the discharge from these lakes is required periodically in order to maintain target herbicide concentrations. To maintain goal concentrations, herbicide was pumped from a metered tank located at the closest upstream water control structure (S-61). Herbicide concentrations are monitored to ensure concentrations stay within the target range. To address concerns that penoxsulam treatments may impact native species (e.g., Netherland et al., 2005), inspections are being conducted for one year by the FWC to determine impacts on native species. To date, in Lake Cypress, pickerelweed (*Pontederia cordata*) and floating species have shown adverse impacts. In other lakes, soft-stem bulrush (*Scirpus validus)* has been adversely impacted by penoxsulam treatments.

In early March 2008, the discharge at S-65 was increased from 250 cfs to almost 2,000 cfs over a two-week interval. Discharge remained at 2,000 cfs for about two weeks. The increased discharge was necessary to lower the water surface elevation to the regulation schedule line, which decreases during the spring (**Figure 11-8**). At this discharge, a large portion of the floodplain is inundated. Subsequent water levels exceeded 1,000 cfs for about six weeks. Discharge gradually decreased to 200 cfs by late May 2008, and was maintained at this level until July 2008.

PROJECT UPDATES

This section provides project and planning updates on the Kissimmee River Restoration Evaluation Program (KRREP) monitoring studies, the Kissimmee Basin Modeling and Operations Study (KBMOS), the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP), and several smaller restoration projects within the Kissimmee Basin.

KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM: UPDATES FROM THE PHASE I MONITORING STUDIES

With the completion of the Kissimmee River Restoration Project Phase I construction in early 2001, restoration evaluation monitoring of the Phase I area entered the post-construction period. The first of four restoration construction stages, Phase I is being monitored by Kissimmee Watershed Program staff under the KRREP, as will selected successive phases of restoration (SFWMD, 2005a). Many of the Phase I studies — which include studies of hydrology, geomorphology, water quality, river channel and floodplain vegetation, benthic and other aquatic invertebrates, herpetofauna, fish, and birds — already indicate significant changes consistent with those predicted by the expectations (performance measures) developed for the KRREP (SFWMD, 2005b). As new data become available, results are reported in the SFER. The Phase I studies all used reference data to develop expectations; reference data were collected prior to restoration construction for comparison with data collected in the reconstructed system for project success evaluation.

A comprehensive update of the status of initial responses to Phase I reconstruction was published in the 2005 SFER – Volume I, Chapter 11, with additional updates from individual monitoring studies published in 2006, 2007, and 2008. The combined results for a suite of interrelated river channel studies were presented in the 2006 SFER – Volume I, Chapter 11. **Table 11-5** provides a directory of KRREP monitoring study updates since 2005. The monitoring results presented below provide the status of Phase I evaluation studies that have been updated since last year’s report.

Table 11-5. Directory of Kissimmee River Restoration Evaluation Program Phase I restoration response monitoring study updates in the 2005–2008 SFERs – Volume I, Chapter 11.

		Page Number in SFER Volume I, Chapter 11				
KRREP Monitoring Study or Project	**Expectation #**	**2005**	**2006**	**2007**	**2008**	**2009**
Kissimmee River Restoration Evaluation Program		11-8	11-37	11-22	11-28	YES
Hydrology						
Stage-discharge relationships		11-20				
*Continuous river channel flow**	1	**[11-18]**				**[YES]**
Variability of flow	2					**[YES]**
Stage hydrograph	3	**[11-22]**				**[YES]**
*Stage recession rate**	4	**[11-23]**	11-23	11-16	11-19	**[YES]**
Flow velocity	5	**[11-25]**				
Broadleaf marsh indicator						**[YES]**
Geomorphology						YES
River bed deposits	6	**[11-26]**				YES
Sandbar formation	7	**[11-26]**				YES
Channnel monitoring						YES
Dissolved oxygen*	8	**[11-28]**	**[11-44]**	**[11-25]**	**[11-28]**	**[YES]**
River channel metabolism					11-35	
Phosphorus		11-33	11-52	11-30	11-32	YES
Turbidity	9	**[11-30]**	**[11-48]**	**[11-27]**		
Periphyton		11-46				
River channel vegetation						
Width of littoral vegetation beds	10	**[11-36]**				**[YES]**
River channel plant community structure	11	**[11-37]**				**[YES]**
Floodplain vegetation					11-35	
Areal coverage of floodplain wetlands	12	**[11-39]**			**[11-35]**	
Areal coverage of broadleaf marsh	13	11-40			**[11-35]**	
Areal coverage of wet prairie	14	11-40			**[11-35]**	
Aquatic invertebrates		11-45	11-55			
Macroinvertebrate drift composition	15	**[11-45]**	**[11-57]**			
Snag invertebrate community structure	16	**[11-46]**	**[11-55]**			YES
Aquatic invertebrate community structure in broadleaf marsh	17		11-57			
Benthic invertebrate community structure	18	**[11-45]**	**[11-58]**			YES
Herpetofauna		11-48				
Floodplain reptiles and amphibians	19		After implementation of headwaters regulation schedule			
Floodplain amphibian reproduction and development	20		After implementation of headwaters regulation schedule			
Fish communities*						
Small fishes in floodplain marshes	21	11-50	After implementation of headwaters regulation schedule			
River channel fish community structure	22	11-52	**[11-59]**			**[YES]**
Floodplain fish community composition	23	11-50	After implementation of headwaters regulation schedule			
Birds		11-55	11-67	11-32	11-40	
*Wading Bird Density**	24	**[11-58]**	**[11-71]**	**[11-32]**	**[11-44]**	**[YES]**
Waterfowl	25		**[11-67]**	**[11-35]**		**[YES]**
Shore birds		11-57				
Wading Bird Nesting			11-68		**[11-40]**	YES
Threatened and endangered species		11-60				

[xxx] bolded brackets indicate a major update in reference to the status of a restoration expectation (performance measure)
* = measures that are being used as Strategic Plan success indicators

Many restoration expectations are dependent on full implementation of a revised water regulation schedule that will result from the Kissimmee River Headwaters Revitalization Project (KRHRP) (USACE, 1996). The KRHRP, which will provide the necessary storage volume in the KCOL to provide the volume and timing of water needed for the KRRP, is scheduled to be implemented in 2013. The resulting Headwaters Revitalization Schedule will more closely simulate historical hydrology than is possible under the current interim schedule.

For WY2008, several monitoring projects are reporting newly available data from the Phase I area. Where applicable, these reports also evaluate the current status of the associated Phase I restoration expectations. This year's chapter includes updates on hydrology, two water quality studies (dissolved oxygen and phosphorus), geomorphology, river channel vegetation, aquatic invertebrates, fish, wading bird nesting, and wading bird and waterfowl use of the floodplain.

Hydrology

The reestablishment of hydrologic conditions (water surface elevations and flow) comparable to those of the natural system is the driver for restoring ecological integrity to the Kissimmee River and its floodplain. After construction is completed, the Kissimmee River will continue to be a highly managed system with water flow regulated by water control structures upstream (S-65, S-65A) and downstream (S-65D) of the restoration project. A critical component for managing water for the restored river is the Headwaters Revitalization stage regulation schedule, which is targeted for implementation in 2013. Beginning with the 2005 SFER – Volume I, Chapter 11, hydrologic conditions have been summarized relative to operations in the basin. That chapter also contained a summary of hydrologic conditions relative to criteria for evaluation of the restoration project. This section provides an update on that report by summarizing hydrologic data from WY2001 (when Phase I of construction for the restoration project was completed) through WY2008. During this time period, an interim stage regulation schedule was used for S-65, which is intended to provide more continuous flow than occurred in the channelized system.

The first five of the 25 restoration expectations developed to aid the evaluation of the KRRP (SFWMD, 2005b) are hydrologic. These hydrologic expectations reflect criteria that have guided the restoration project since its inception (SFWMD, 2005b). This update focuses on the first four of the hydrologic expectations. An additional candidate hydrologic performance measure is reported that describes the hydroperiod requirements for broadleaf marsh. This candidate performance measure has not yet undergone the same documentation and review process as the formal restoration expectations. However, it is expected to be reviewed and added to the formal set of restoration expectations in the near future.

Expectation 1

The number of days that discharge is equal to 0 m^3/s in a water year will be zero for restored river channels of the Kissimmee River (SFWMD, 2005b).

For WY2002–WY2008, the discharge at S-65 was greater than (>) 0 cubic meters per second (m^3/s) for 88 percent of the days (**Figure 11-10**). An 85-day period of no flow occurred at the beginning of WY2002, when the basin was recovering from a severe regional drought. Phase I of the KRRP was completed in February 2001. Once discharge at S-65 resumed on July 24, flow was continuous through November 8, 2006, when the discharge ended because of another severe regional drought. The river was without inflow from the Upper Kissimmee Basin for 252 days, which spanned 42 percent of WY2007 (152 days) and 22 percent of WY2008 (79 days). This period of no flow ended on July 18, 2007. Since then, there has been continuous inflow from the Upper Kissimmee Basin.

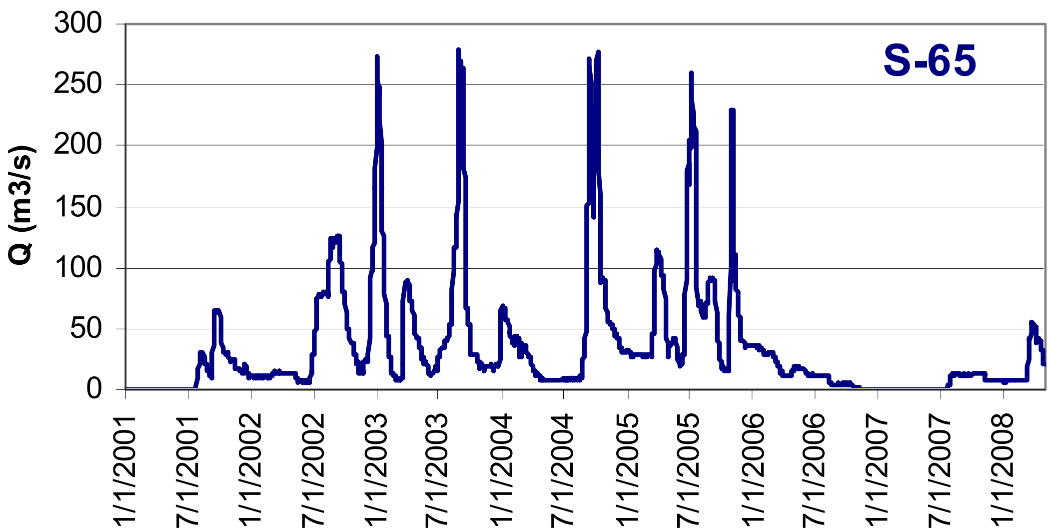

Figure 11-10. Mean daily flow (m^3/s) at S-65, the outlet from the Upper Kissimmee Basin.

Expectation 2

Intra-annual mean monthly flows will reflect historic seasonal patterns and have intra-annual variability (coefficient of variation) < 1.0 (SFWMD, 2005b).

Before channelization, the Kissimmee River exhibited a distinct seasonality of flow with mean monthly discharge being highest at the end of the wet season and the beginning of the dry season and being lowest at the end of the dry season (**Figure 11-11**). The channelized system was operated so that peak flows occurred in the dry season. Since the completion of Phase I, peak flows have occurred in the wet season but a month earlier than in the reference period. This shift in the maximum may reflect the relatively short period of record since 2001. Coefficient of variation for mean monthly discharge ranged from 0.71–1.48. Four months (February, March, May, and December) had a coefficient of variation (CV) of less than (<) 1.

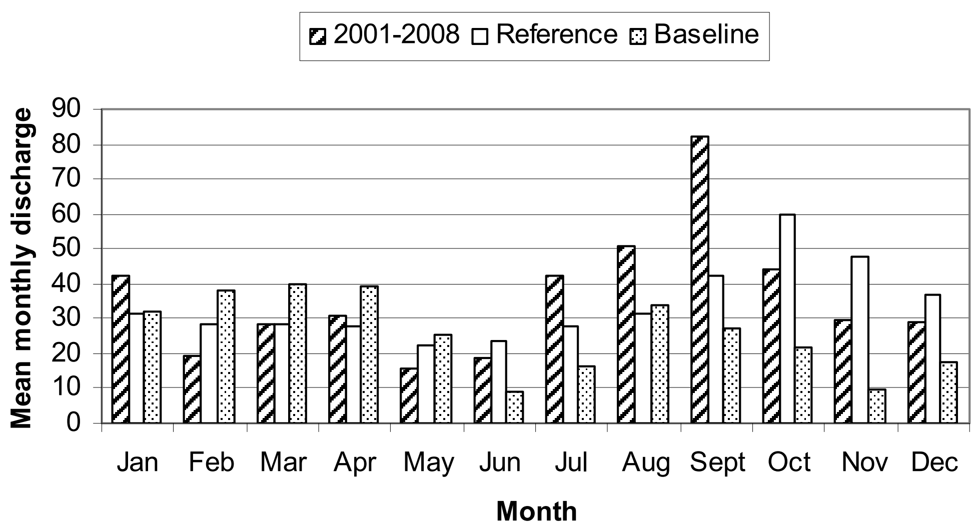

Figure 11-11. Seasonality of mean monthly discharge (m^3/s) at S-65 for the interim period (2001–2008), the reference period (1934–1962), and the baseline period (1963–2000). Note that for 2001, 0 values for the first six months were not included in the calculation of average discharge.

Expectation 3

River channel stage will exceed the average ground elevation for 180 d per water year and stages will fluctuate by at least 1.14 m (SFWMD, 2005b).

For WY2001–WY2008, the range of water level fluctuation at weir 1, located near the upstream end of Phase I backfilling, ranged from 1.62 meters (m) in WY2008 to 3.62 m in WY2005 (**Figure 11-12**). In all water years, the range of fluctuation exceeded the target of 1.14 m. The duration of water levels greater than floodplain ground elevation varied from 14 days in WY2007 to 243 days in WY2006. Only WY2003 and WY2006 exceeded the duration of 200 days with water levels exceeding the floodplain ground elevation.

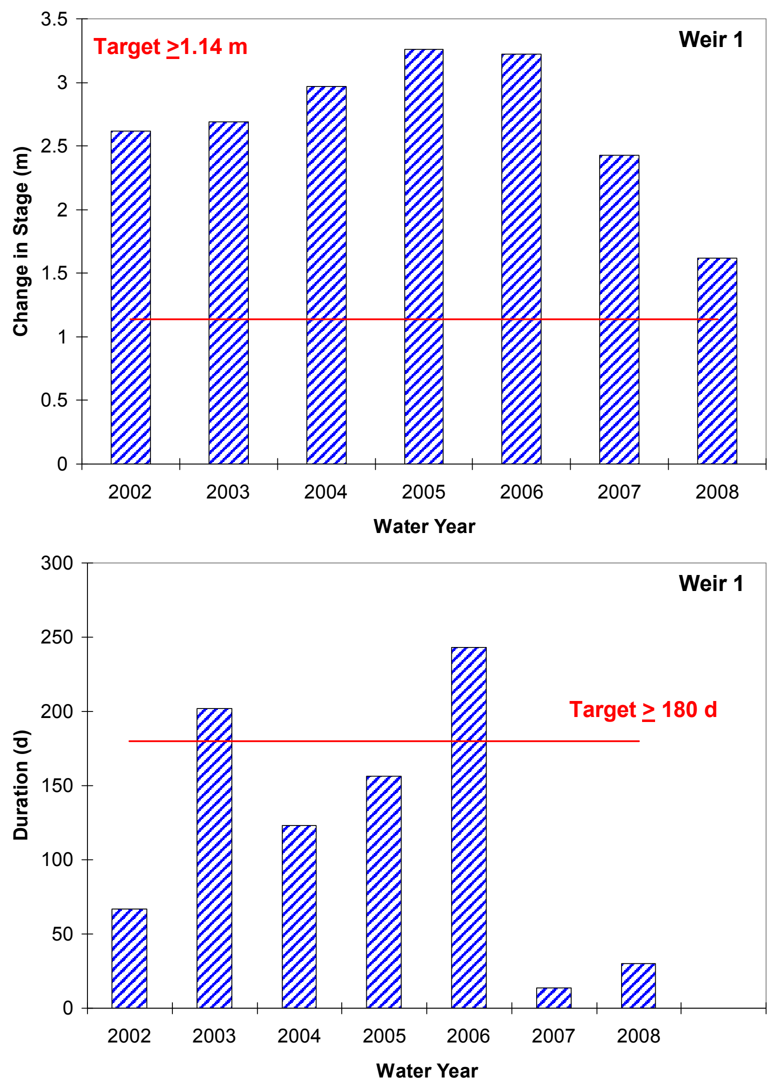

Figure 11-12. Water level fluctuation (top panel) and duration of inundation (bottom panel) at weir 1. The red horizontal lines represent target change in water level fluctuation of at least 1.14 meters (m) per year (top) and target duration of stages exceeding floodplain ground elevation of 180 days per year (bottom).

Expectation 4

An annual prolonged recession event will be reestablished with an average duration of > 173 days and with peak stages in the wet season receding to low stage in the dry season at a rate that will not exceed 1.0 ft (30 cm) per 30 days SFWMD, 2005b).

Since 2001, 15 recession events have been identified (**Figure 11-13**). This number is almost two events per year rather than a long single event each year. These events tend to be faster, with 12 events having faster-than-desirable recession rates. Faster recession rates are also consistent with the shorter-than-desirable durations of floodplain inundation in **Figure 11-12** (bottom panel).

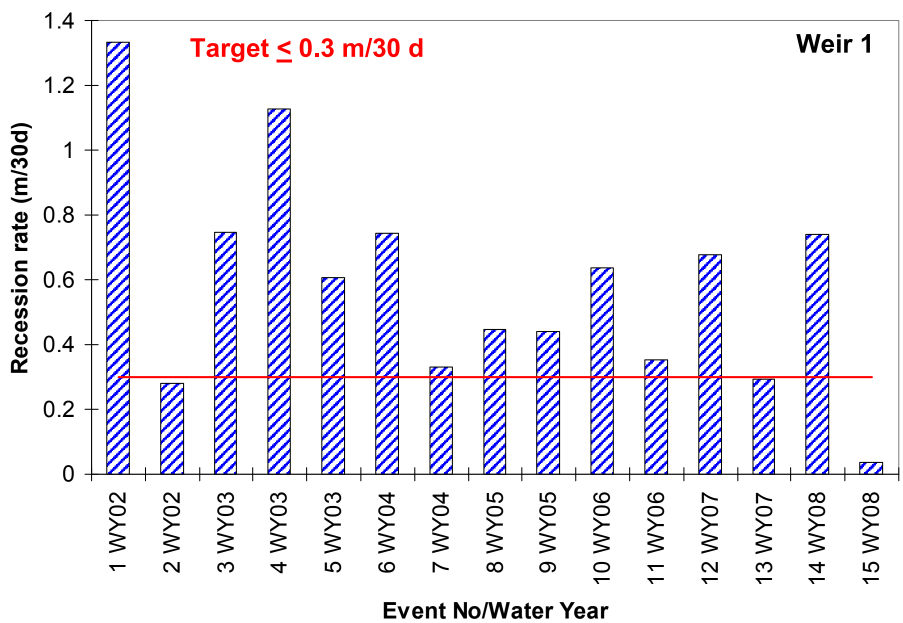

Figure 11-13. Recession rates for 15 events at weir 1 and the water year in which each occurred. The red horizontal line represents the threshold of < 0.03 m/30 days.

Broadleaf Marsh Hydroperiods

Broadleaf marsh was one of the dominant plant communities on the floodplain prior to channelization and is expected to be one of the dominants in the restored system. It is considered a deep hydroperiod marsh requiring depths between 0.30 and 1.1 m for 200 days or more. None of the water years from WY2002–2008 have met this criterion (**Figure 11-14**). Only WY2003 and WY2006 exceeded 150 days with water depths greater than 0.3 m.

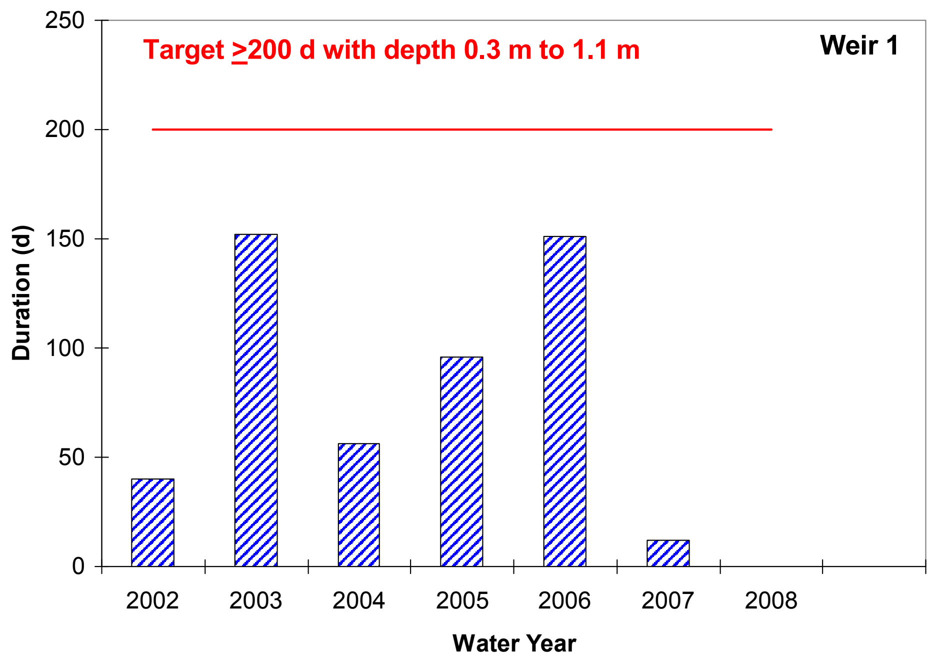

Figure 11-14. Broadleaf marsh indicator evaluated at the upstream end of the restoration project at weir 1. The red horizontal line represents the target of inundation to a depth for 0.3 m to 1.1 m for at least 200 days.

Conclusions

The evaluation of four of the restoration expectations for hydrology and the broadleaf marsh indicator suggests that some improvements have occurred in hydrologic conditions since the completion of Phase I backfilling and under the interim stage regulation. Changes in operations under the interim schedule have maintained continuous inflow from the Upper Kissimmee Basin except during periods of extreme drought. During the pre-regulation period, flow did not end even during droughts. Changes in operations also have resulted in more natural seasonality of flow with the maximum monthly flows occurring in the wet season instead of the mid-dry season.

Not all aspects of the expectations have been met under interim regulation schedule, especially those related to floodplain inundation. All water years have had a good range of water level fluctuation, which inundated a portion of the floodplain for some period of time. However, the duration of floodplain inundation was too short and intermittent, the recession rates were too fast, and the criteria for broadleaf marsh hydroperiods were not achieved.

This section summary has focused on data from a single location (weir 1) located near the upstream end of the Phase I backfilling. The presence of upstream and downstream structures can affect hydrologic conditions to a variable degree along the length of the river channel. For example, the presence of the S-65C structure creates a backwater effect that extends upstream. Monitoring sites located closer to the structure tend to experience a smaller range of water level fluctuation but can have a longer hydroperiod. In the 2005 SFER – Volume I, Chapter 11 contained a discussion of the differences in the slope of stage-discharge relationships at three locations near the upper, middle, and lower reach of the river channel reconnected by Phase I of the project. This initial analysis showed that the slope of the stage-discharge relationship decreased from the most upstream site to the most downstream site. This pattern was interpreted to be due in part to a backwater effect at the downstream structure (S-65C). It is anticipated that these location effects will be examined in more detail in future SFERs.

The implementation of the Headwaters Revitalization Schedule should help achieve the hydrologic expectations. This schedule allows the water levels in Lake Kissimmee to go higher, creating an opportunity to store an additional 123 million m^3 (100,000 ac-ft) of water. The increased storage would allow releases from Lake Kissimmee to be moderated to sustain longer and continuous periods of floodplain inundation with slower recession rates than is possible under the current interim schedule. The increased storage might also maintain flow during droughts.

WATER QUALITY

Dissolved Oxygen

Dissolved oxygen (DO) was monitored continuously at a depth of approximately 1 m in two restored river channel stations in Pool C (KRBN and PC62, **Figure 11-1**). Sampled river channels were approximately 20–30 m wide and 2–3 m deep. DO also was sampled monthly within seven remnant (nonflowing under channelized conditions) river runs in Pools A and C. DO data were not collected prior to channelization; therefore, the reference condition was derived from data on seven free-flowing, blackwater streams in South Florida. Each stream had at least 11 samples collected over a minimum of one year, and some streams were sampled for more than 10 years (**Figure 11-15**). The period of record for these reference data is 1973–1999. The mean daytime DO concentration in the reference streams was 4.8 milligrams per liter (mg/L) during the wet season and 6.6 mg/L during the dry season (**Figure 11-16**). In five of the seven streams, DO was > 5 mg/L in more than 50 percent of the samples. In seven of the eight streams, more than 90 percent of the samples had concentrations > 2 mg/L.

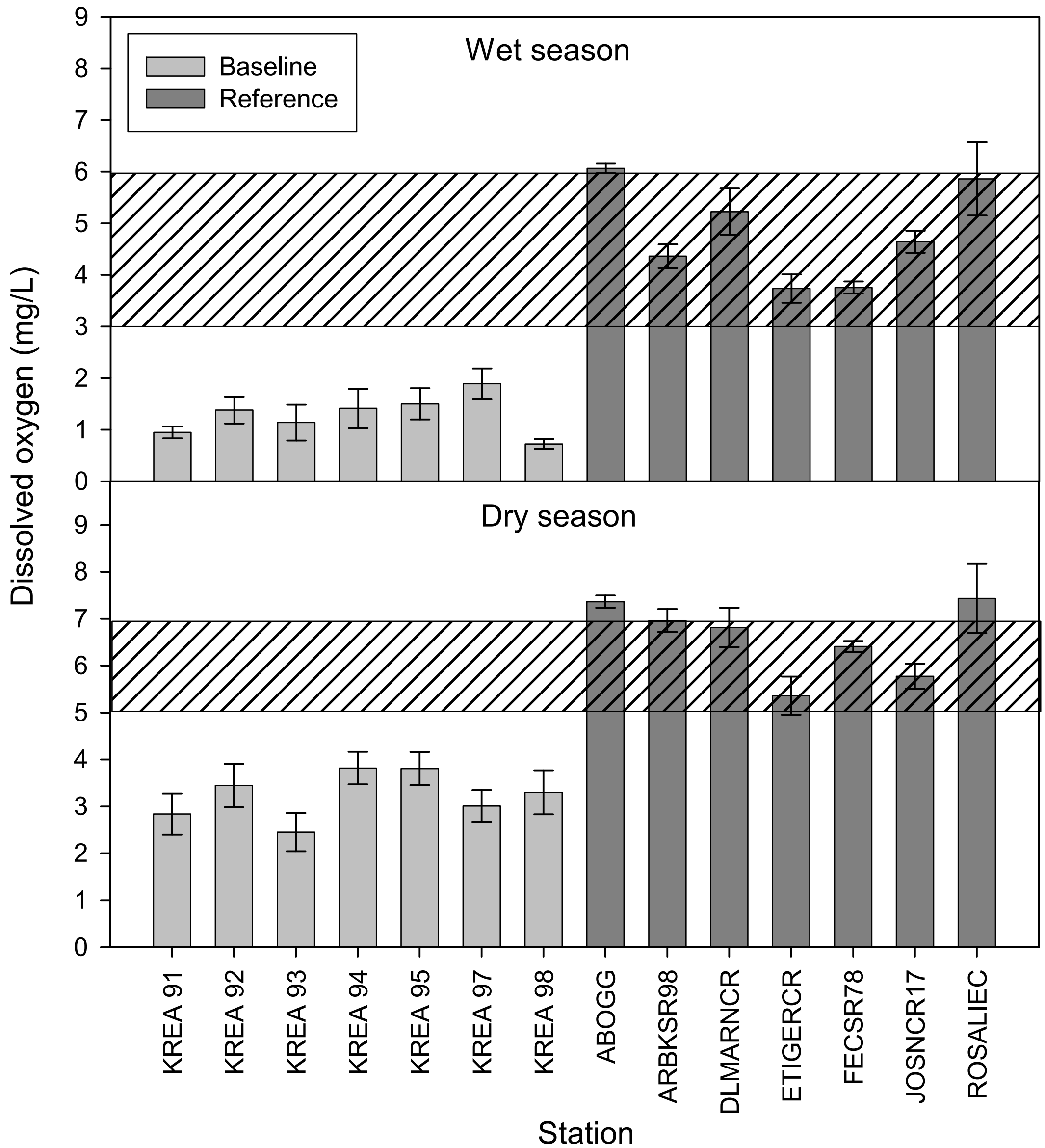

Figure 11-15. Mean [± standard error (S.E.) of the mean] dissolved oxygen (DO) concentrations in free-flowing, blackwater, South Florida streams and remnant runs of the channelized Kissimmee River during the wet (June–November) and dry (December–May) season. Shaded area represents expected range of DO concentrations in the Kissimmee River after restoration. Station names are from the District's DBHYDRO database.

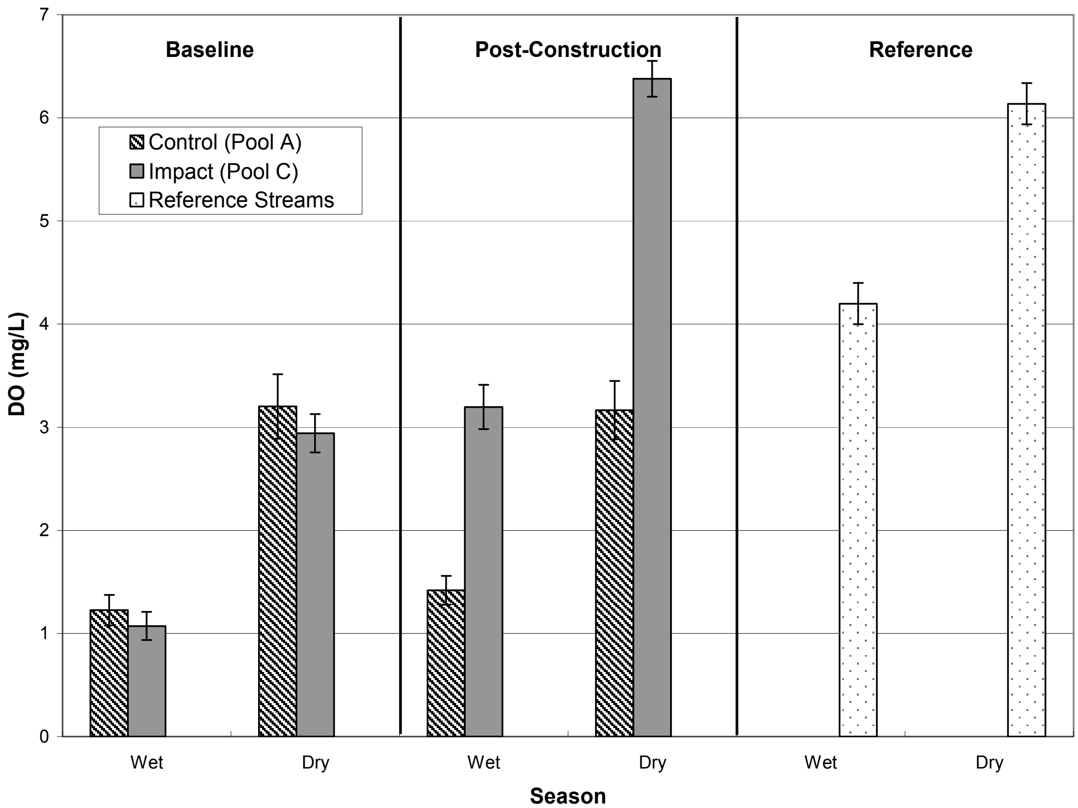

Figure 11-16. Mean (± S.E.) DO concentrations (mg/L) in reference streams (Period of record =1973-1999) and control and impact areas during the wet and dry season, during the baseline (1997–1999) and post-restoration (2001–present) periods.

Within the channelized river, DO concentrations were frequently below 1 mg/L throughout the water column at all times of day. A gradient in DO concentration, decreasing with depth, was observed during May–June 1999. DO concentrations near the surface could be as high as 4 to 5 mg/L, while concentrations near the bottom were lower than the detection limit (< 0.2 mg/L). During 1996–1999, mean DO concentrations in remnant river runs in Pools A and C were 1.4 and 1.2 mg/L during the wet season, and 3.1 and 3.3 mg/L during the dry season, respectively (**Figure 11-16**). DO concentrations exceeded 2 mg/L for 22 percent of the baseline period, and 5 mg/L for 6 percent of this period. These reference and baseline data were used to develop the following four components of Expectation 8 (SFWMD, 2005b) to evaluate changes in DO as restoration proceeds:

- Mean daytime concentration of DO in the river channel at 0.5–1.0 m depth will increase from < 2 mg/L to 3–6 mg/L during the wet season (June–October).
- Mean daytime concentration of DO in the river channel at 0.5–1.0 m depth will increase from 2-4 mg/L to 5-7 mg/L during the dry season (December–May).
- Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90 percent of the time (annually).
- DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50 percent of the time annually.

Since continuous data (showing diel dissolved oxygen curves) were not available for the reference streams, a metric for minimum daily DO concentration was not developed. However, minimum and maximum daily DO concentrations were measured at the two previously mentioned stations within the restored channel from approximately 1997 to date. These data are used to help make weekly operational decisions as well as evaluate DO regimes in the restored portion of the river over the long term. Following completion of the first two phases of construction, DO concentrations within the restoration area averaged 3.2 mg/L during the wet season and 6.4 mg/L during the dry season (**Figure 11-16**). Post-construction DO concentrations in the control area (Pool A) averaged 1.4 and 3.2 mg/L during the wet and dry seasons, respectively (**Figure 11-16**).

Mean annual DO concentrations in the restoration area (Pool C) increased from < 3.0 mg/L before construction to 5.6 mg/L in WY2008 (**Figure 11-17**). Mean daily water column DO concentrations were > 2.0 mg/L for 81 percent of the time in WY2008, and minimum daily concentrations were > 2.0 mg/L for 71 percent of the time. From May 1, 2007–July 4, 2007, DO concentrations were > 2.0 mg/L, and usually > 4.0 mg/L (**Figure 11-18**). On July 5, 2007, DO concentrations decreased to below 2.0 mg/L and remained low for approximately two weeks. On July 18, 2007, water control gates at S-65 (the outlet of Lake Kissimmee) were reopened after being closed for 252 days due to drought conditions.

Oxygen concentrations increased for about one week to approximately 2-4 mg/L before decreasing again on July 24, 2007. Both oxygen sag events followed relatively intense rainfall events of approximately 2 inches in 24 hours. Low DO concentrations during these time periods are believed to be a result of a combination of factors, including inflow of DO-depleted water from the channelized upstream reach of the river (Pool A), increased organic matter-laden runoff from tributaries and the floodplain (causing increased biochemical oxygen demand), and sloughing of oxygen-producing periphyton and phytoplankton under high river channel flow velocities.

Dissolved oxygen concentrations increased by August 17, 2007, and remained > 2.0 mg/L until September 30, 2007, when another oxygen sag occurred. However, by mid-October 2007, DO concentrations increased > 2.0 mg/L and remained so through the end of WY2008.

The restoration expectations for DO concentrations in the restored river channel are to be evaluated after implementation of the Kissimmee River Headwaters Revitalization Project regulation schedule. However, two of the four metrics used to evaluate DO response were met under the interim regulation schedule during WY2008.

In April–May 2008, two additional DO monitoring stations were installed (one in Persimmon Mound Run in the Pool A control area, and one in Caracara Run in Pool D,) as part of the Phase II/III Integrated Study (**Figure 11-2**). These stations collect DO data at 15-minute intervals at 0.5–1.0 m depth and within 0.5 m of the channel bottom. Data from these stations will be reported in the 2010 SFER and should provide crucial baseline information about water column and bottom water diel DO concentrations. These data also will be used to calculate baseline community metabolism estimates for the channelized section of the Kissimmee River.

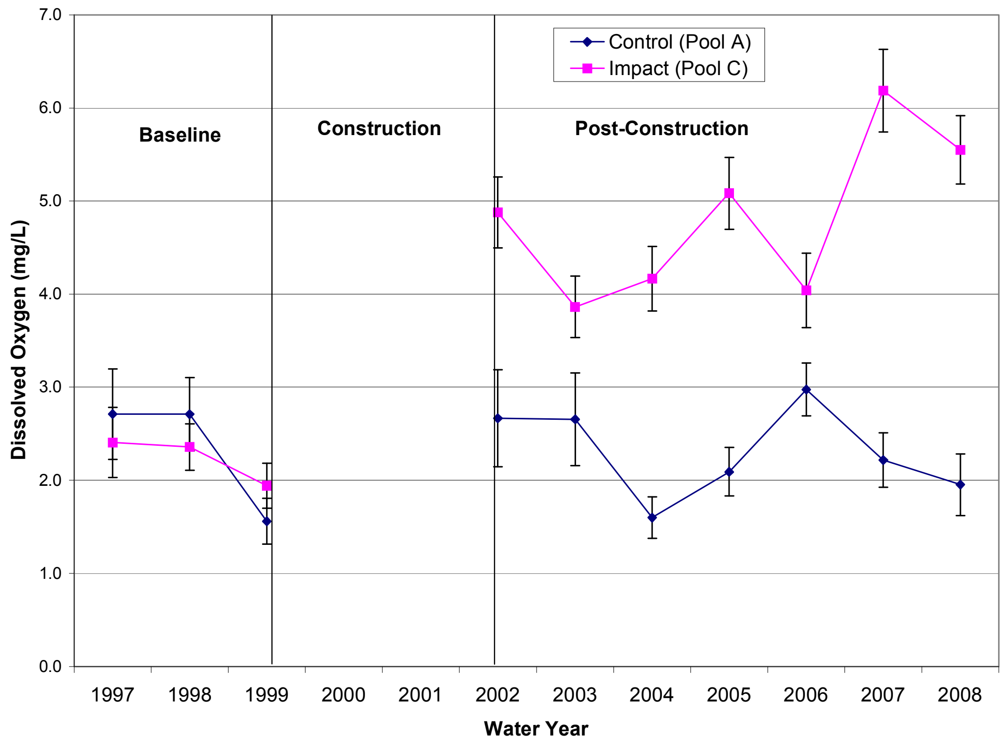

Figure 11-17. Mean DO concentrations milligrams per liter (mg/L) in the Kissimmee River for each water year during the baseline and post-construction period.

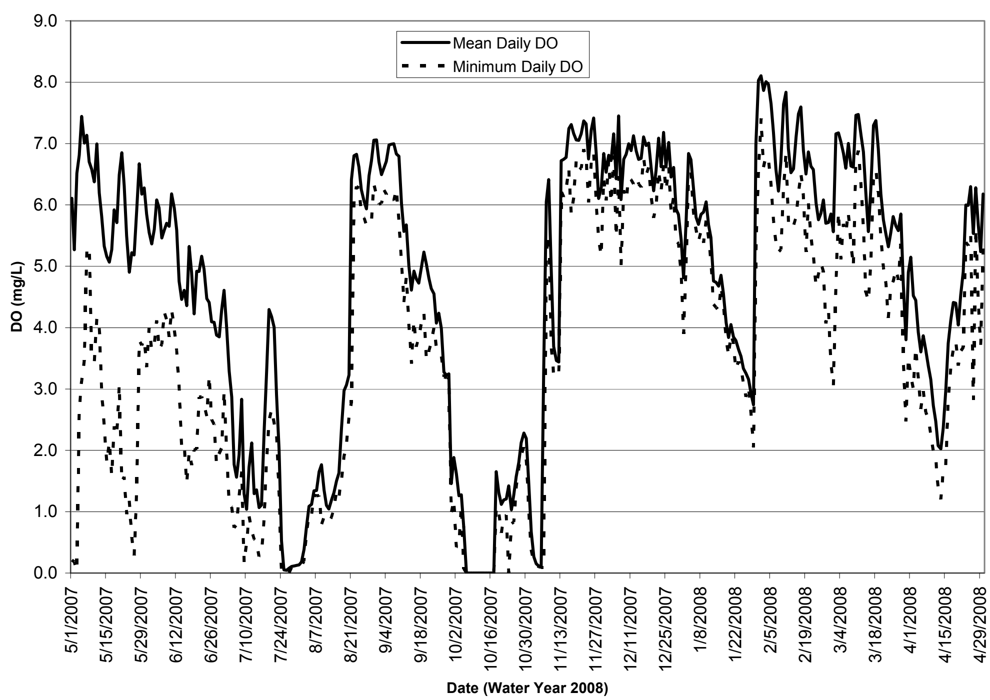

Figure 11-18. Mean (192 values per day) and minimum (lowest single value of 192 data points) daily DO concentrations (mg/L) at 1.0 m depth in the restored river channel during WY2008.

Total Phosphorus

The Kissimmee River is Lake Okeechobee's largest tributary and contributes an average of 31 percent of the lake's total phosphorus input (see Chapter 10 of this volume). Construction of C-38 and lateral drainage ditches has presumably contributed to Lake Okeechobee's excessive TP load by facilitating downstream transport of phosphorus runoff and limiting opportunities for detention and assimilation in floodplain wetlands. Compared to the local drainages of Pools D and E, which have more intensive agricultural development, the drainages of Pools A, B, and C (**Figure 11-2**) are not major exporters of phosphorus. Nevertheless, restoration of the river and floodplain may eventually promote lower inputs from these pools in addition to reducing loading from the headwater lakes in the Upper Kissimmee sub-watershed. Restoration of sloughs and marshes along the river may increase the retention of phosphorus from tributary watersheds and headwater lakes as flow velocities decrease and phosphorus settles out of the water column or is assimilated by wetland periphyton and macrophytes. The filling of ditches and removal of cattle from the floodplain also may help to lower TP loads from lateral sources.

Baseline and post-construction TP data are obtained from routine monitoring at each C-38 water control structure. TP concentrations are determined from weekly to monthly grab samples and composite samples collected by auto-samplers at each structure. The auto-sampler gathers samples 10 times per day, which are combined into a single bottle collected on a weekly basis. Estimates of daily TP loads were computed from measured or interpolated TP concentrations and daily discharge data and then summed annually. Annual TP loads were divided by annual discharges to obtain flow-weighted mean (FWM) TP concentrations at each structure. Because TP loads can vary greatly between wet years and dry years, FWM concentrations provide a more useful metric for evaluating trends.

Calendar years 1974–1995, during which the C-38 canal was intact, were chosen as the baseline period of record. During those 22 years, TP loading averaged 51 mt y^{-1} at S-65C and 83 mt y^{-1} at S-65D (**Figure 11-19**). These amounts comprised 43 and 71 percent of the average load at S-65E, respectively. Annual FWM TP concentrations averaged 53 ppb at S-65C (ranged from 33–87 ppb), and 78 ppb at S-65D (ranged from 47–141 ppb) (**Figure 11-20**). Concentrations were greater during years of lowest flow (1981 and 1985). At S-65, upstream of the restoration project area, the mean loading rate was 35 mt y^{-1} (**Figure 11-19**), and the FWM TP concentration was 43 ppb (**Figure 11-20**).

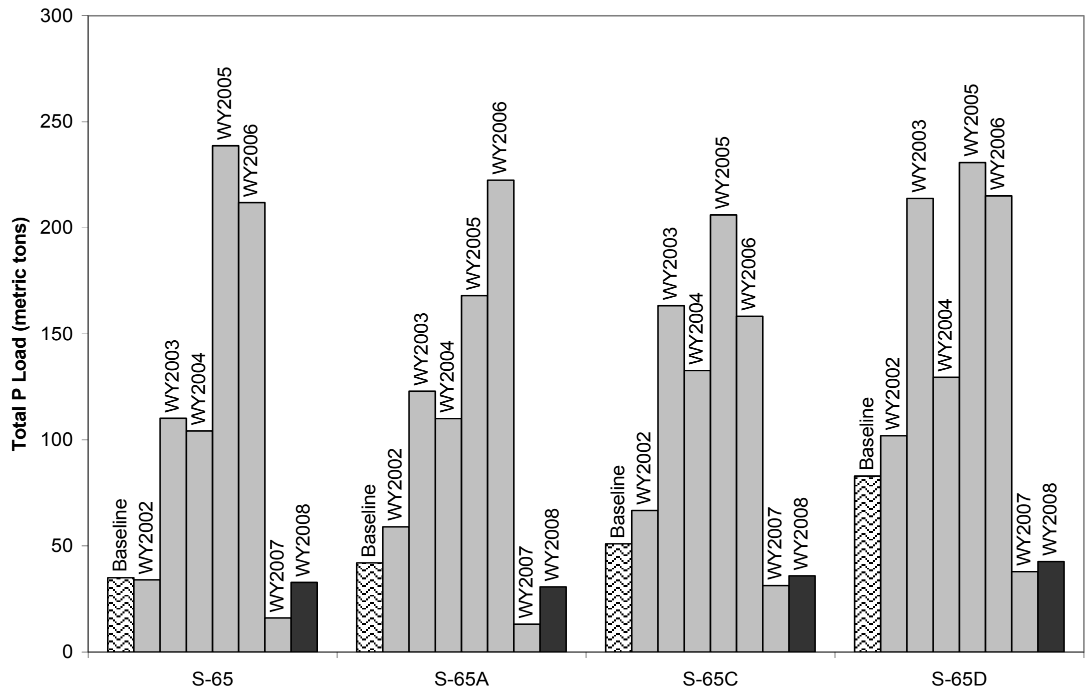

Figure 11-19. Annual total phosphorus (TP) loads (metric tons, or mt) from C-38 structures in comparison to baseline loads from 1974-1995. Water Years 2002, 2007, and 2008 were drought years, and WY2005 was wet due to hurricanes.

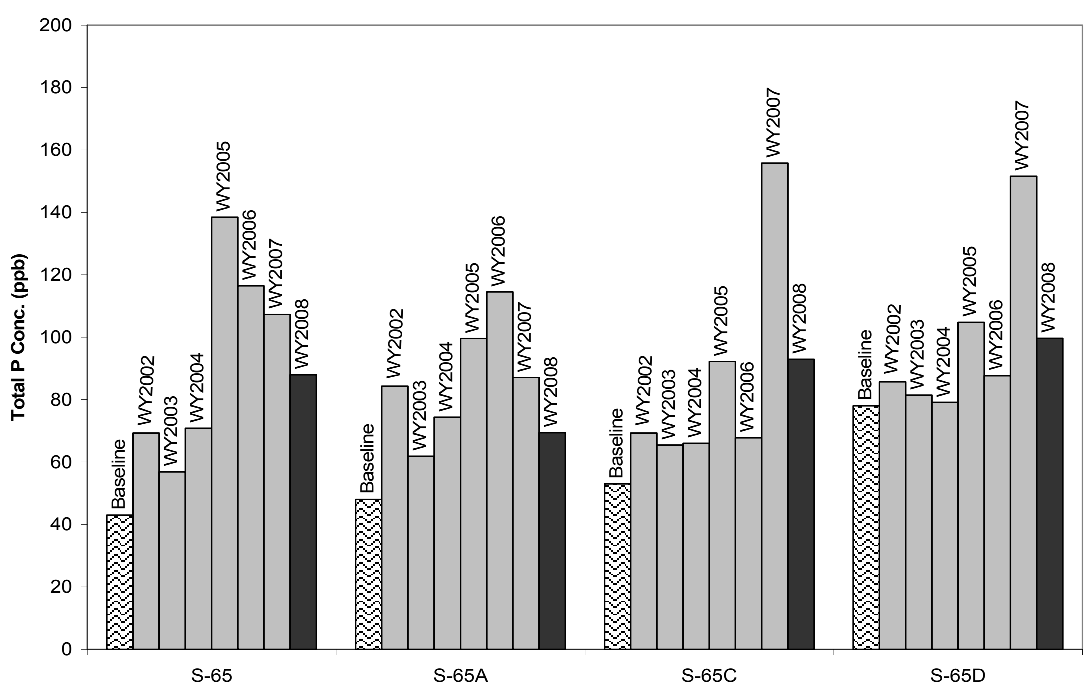

Figure 11-20. Annual flow-weighted mean (FWM) TP concentrations in parts per billion (ppb) at C-38 structures in comparison to baseline concentrations (1974–1995).

Reference, pre-channelization conditions for TP loads and concentrations in the Kissimmee River cannot be determined with any certainty because phosphorus was not routinely monitored before channelization. Nevertheless, knowledge of former characteristics of the river and its floodplain and watershed make it reasonable to assume that concentrations were lower in the pre-channelized river. Restoration should tend to favor a return to lower concentrations when a more natural river-floodplain hydroperiod and stable wetland ecosystem become established. These conditions are expected to be achieved after the Headwaters Revitalization Schedule is implemented in 2013. In the meantime, TP concentrations may increase periodically as the nutrient is released from former pastures and the floodplain transitions from terrestrial to wetland vegetation.

Under the interim regulation schedule, the floodplain in the Phase I restoration area has been inundated intermittently. Observational data and 2003 aerial photography indicate that wetland vegetation re-colonized the Phase I area to some extent following restoration (SFWMD, 2008a). However, the current (interim) regulation schedule has not allowed for the seasonal pattern of floodplain inundation that is expected when the KRHRP regulation schedule is implemented. Therefore, in the transitional years since Phase I was completed, the floodplain is unlikely to have assimilated phosphorus at its highest efficiency. This was especially true in WY2007 and WY2008, when there was little hydrologic interaction between the river channel and floodplain due to drought conditions. The river overflowed its banks only once for a two-week period in September 2006 in response to Tropical Storm Ernesto.

Evaluation of TP loading trends on a year-to-year basis is difficult because so much depends on the amount of discharge through the system. Until WY2007, discharge and loads at the C-38 structures were generally greater than during the 1974–1995 baseline period. Loads were much lower in the drought years of WY2007 and WY2008 (**Figure 11-19**). Reduced discharges from the headwater lakes accounted for much of this change. Beginning in November 2006, S-65 was closed and discharge through the upper pools declined to virtually zero. This structure was not opened again until July 18, 2007, and only minimal flows were released to C-38 during the rest of WY2008. TP loads at the C-38 structures were only slightly higher in WY2008 compared to WY2007 (**Figure 11-19**). In contrast, FWM TP concentrations remained relatively high in WY2008, even though they were lower than they had been for the previous year. Concentrations at all structures have been higher since the baseline period (**Figure 11-20**).

While the KRRP was not designed as a TP-removal project, there is considerable interest in how restoration of floodplain wetlands will influence the retention of phosphorus within the Kissimmee Basin. In FY 2009 (October 1, 2008–September 20, 2009), SFWMD staff is working to identify models, existing information to support these models, and additional data needs for assessing the restoration project's effect on phosphorus movement and retention, and developing more reliable and defendable estimates of future TP loading. A plan describing selected approaches for modeling and monitoring is planned to be developed in WY2009.

One question that has been asked with regard to TP loading concerns low DO (hypoxia) in the bottom sediment of the river channel and C-38 and its effect on phosphorus biogeochemistry. Hypoxia can result in the release of phosphorus bound in sediment, which can then enter the water stream. As previously discussed in the *Dissolved Oxygen* section, the river channel and C-38 commonly exhibited low DO concentrations (< 2 mg/L) before the first phase of restoration, and still have experienced some periods of low DO since that time. However, the SFWMD has not examined the effect of these oxygen sags on phosphorus release from channel sediment.

Compared to the amount of phosphorus transported downstream from sources throughout the basin, the amount of phosphorus released from river channel sediment is expected to be relatively minor, if not insignificant. However, this supposition may be examined further in the upcoming evaluation of Phase II/III of the restoration project. District staff is currently considering a proposed study of phosphorus assimilation and release as wetlands are restored in the Pool D floodplain and flow is diverted to historic channels, and phosphorus release from channel sediment is being reviewed for inclusion in that study.

The Phase II/III evaluation will also monitor TP concentrations during backfilling in Pool D to determine if restoration construction is causing more transport of phosphorus downstream to Lake Okeechobee. An elevation of phosphorus transport is not expected. Although two brief spikes in TP were observed during the early part of Phase I restoration construction (Colangelo and Jones, 2005), adjustments were soon made in Pool C water levels that reduced channel erosion, and the construction contractor modified the backfilling method to isolate the activity from the flow of the river. Since then, construction has had no observed significant effect on TP concentrations.

Geomorphology

A three-year geomorphic monitoring pilot study was initiated in September 2006 with the University of Florida and the U.S. Geological Survey with the goal of establishing a long-term program to addresses stability and sedimentation monitoring requirements stipulated in the Integrated Feasibility Report/Environmental Impact Statement (USACE, 1991). The overall objectives of such monitoring are to (1) to assess post-restoration channel stability and floodplain sedimentation, and (2) assess the extent of in situ burial versus erosion (downstream transport) of organic deposits accumulated in remnant Pool D river channels during the channelized period.

Specific ongoing components of the current pilot study include (1) channel cross-section (Phases I and II/III) and planform (imagery interpretation) analysis (Phase I); (2) coring and characterization of organic riverbed sediments in Pool D (Phase II/III); (3) measurement of in-channel sediment (suspended and bedload) transport; and (4) measurement of sediment deposition on the floodplain (Phases I and II/III). Analysis of preliminary results on channel cross-sectional variability in the Phase I section of the river is presented below. Final results on this and other ongoing work are planned to be presented at the end of the three-year pilot study.

Phase I Channel Monitoring: Cross-Sectional Transects

Channel monitoring was conducted to assess the variability and stability of different types of cross-sections in restored portions of the river. Cross-sections in unrestored portions of the river were used as control stations for comparative purposes. The three major types of river reaches that occur in the restored portion of the river are (1) remnant channels, which are formerly flowing channels that were essentially left intact during channelization but lack flow in the channelized system; (2) recarved channels, which are former channels that were buried by spoil during channelization and have been reconstructed to the approximate geometry of the former channel; and (3) connector channels, which are short segments of channel that were cut across backfilled portions of C-38 and are in approximately the same position as former channels. The latter appear wider than either the remnant or recarved channels, intended to minimize potential impacts to the backfilled areas, which have slightly lower elevations and a greater portion of ponding than the surrounding floodplain wetlands.

Within each of these types of reaches are also variations. Both remnant channels (nonflowing in the channelized system) and recarved channels (sections of the river that were obliterated during construction of C-38 and reconstructed prior to reestablishment of flow) may show differences between bendways and straight reaches. Generally, bendways show an asymmetric form, and straight reaches are typically more symmetric. The connector reaches are straight, and it is unknown how much variation occurs in this group. The two major questions are (1) how do the cross-sections differ in geometry among the three groups (remnant, recarved, or connector), and (2) how do the cross-sections differ within the three groups (straight, bendway, or other). Cross-sections were established for annual surveying in each of these three types of river reaches to examine how they differ in form and how they might change in form over time (**Table 11-6** and **Figure 11-21**).

Table 11-6. Location of geomorphology survey transects. S indicates a straight reach, and B is a bendway on a meander.

Run Name	Pool	Transect Type	Number
Persimmon Mound	A	Remnant (control)	4 (2S, 2B)
Montesdeoca	C	Remnant	4 (2S, 2B)
Montesdeoca South	C	Connector	2
Fulford	C	Recarved	4 (2S, 2B)
Fulford South	C	Connector	2
Caracara	D	Remnant (pasture)	2 (1S, 1B)
Chandler	D	Remnant (forest)	2 (1S, 1B)
TOTAL			**20**

Four transects were placed in a run in Pool A for comparative purposes, allowing for eventual assessments in the before-after-control-impact (BACI) design (Stewart-Oaten et al., 1986; Smith, 2002). Of the runs in Pool A, Persimmon Mound Run was chosen because of its length (portions were distant from C-38) and width, which allowed access to the general vicinity by motorboat (actual channel bottom elevation measurements along the transects were made from a motorless inflatable boat). In Pool C, Montesdeoca Run is a former remnant run that is now receiving flow.

Four transects were selected for sampling, two on bendways and two on straight reaches. Montsdeoca South is a straight connector run in Pool C that crosses backfilled C-38, just south of Montsdeoca Run. Two transects were selected for sampling in this short reach. Fulford Run is a recarved run in Pool C. Four transects were selected for sampling, two on bendways and two on straight reaches. Fulford South is a straight connector run in Pool C that crosses backfilled C-38, just south of Fulford Run. Two transects were selected for sampling in this short reach. In addition, transects were also surveyed in two runs in Pool D, Caracara Run and Chandler Run. The land uses in each were very different, with Caracara Run largely used for cattle ranching and Chandler Run densely forested. Two transects in each were surveyed where sediment cores were also taken, one in a straight reach and the other in a bendway.

From a geomorphic perspective, there is not an appreciable difference between the channel geometry of transects taken in different reaches, except for the connector channels. None of the other 16 transects surveyed showed a bar in the middle of the channel (**Figure 11-22**). All four transects surveyed across the connector channels showed the development of either an island or submerged bar (**Figure 11-23**). In comparison to other types of cross-sections, connectors were also far wider than the remnant and recarved reaches. Connectors were built wider than the other types of channels, with the intent of protecting backfilled C-38, by having greater channel capacity which in turn would mean less velocity and erosion along the vulnerable sides. However, likely due to the lower velocities, some sediment had deposited in the middle of both connectors, forming bars which may eventually become vegetated islands. Bendways and straight reaches were not notably different in their width-depth ratios in the initial year of monitoring.

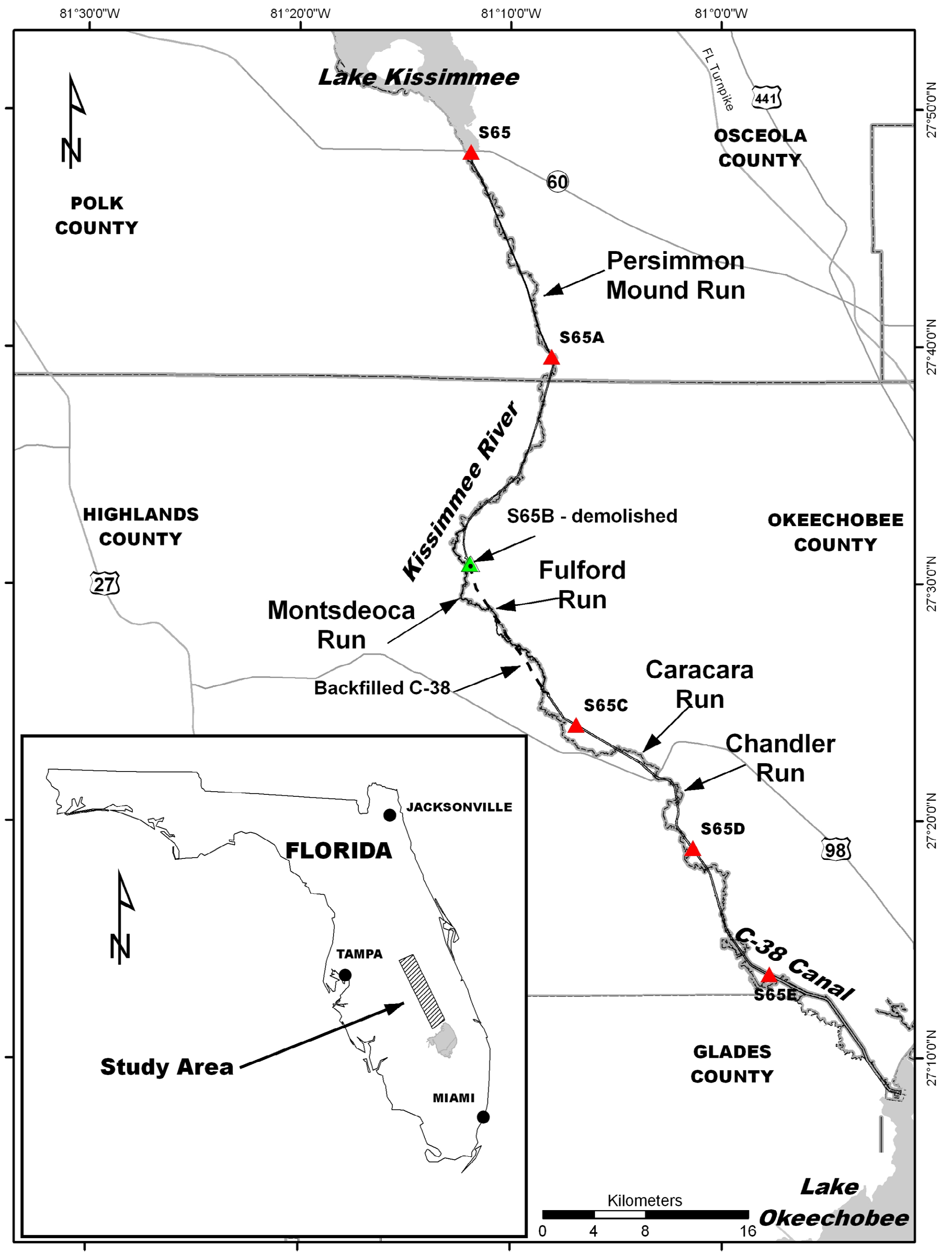

Figure 11-21. Location of the Lower Kissimmee River and general location of geomorphology transects sampled. The area currently restored is in Pool C (downstream of former S-65B and upstream of S-65C).

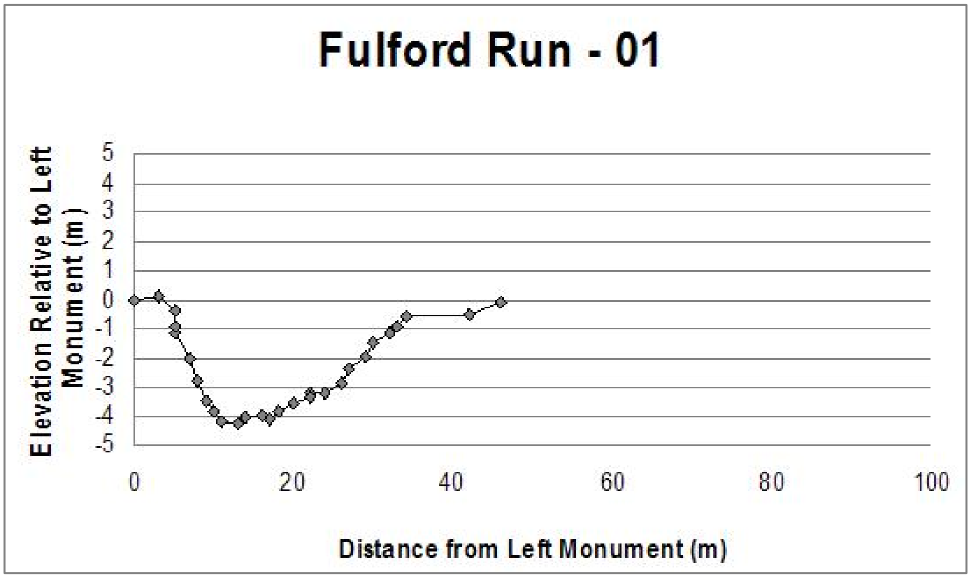

Figure 11-22. One example of a geomorphology transect at Fulford Run. Like most other cross-sections, the channel was about 30 m wide and did not have a mid-channel bar. "Left monument" refers to a fixed metal stake driven into the floodplain on the left bank of the river (looking downstream).

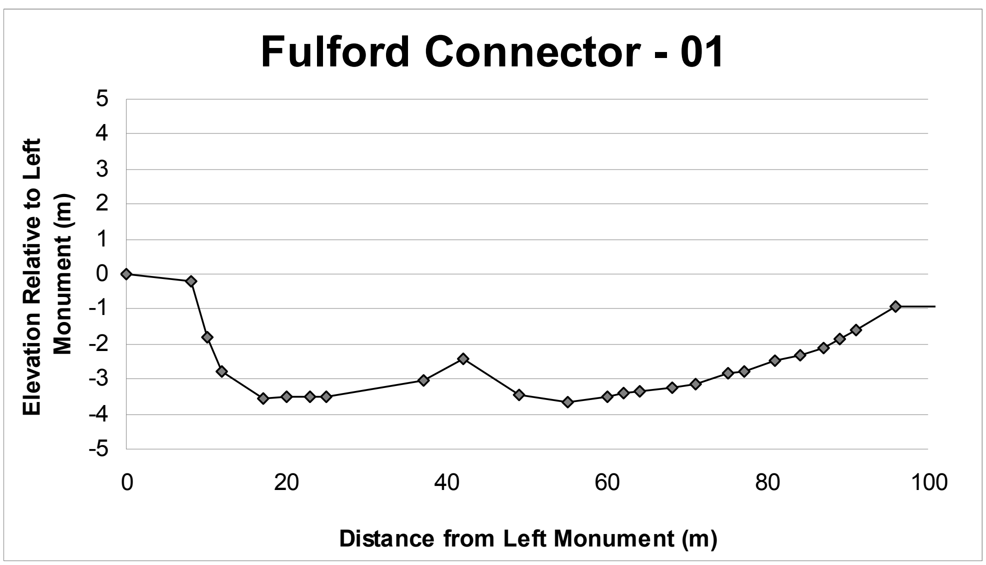

Figure 11-23. One example of a geomorphology transect at a connector south of Fulford Run, showing a connector channel over 80 m wide that has developed a mid-channel bar or island. "Left monument" refers to a fixed metal stake driven into the floodplain on the left bank of the river (looking downstream).

River Channel Littoral Vegetation

The elimination of flow in the Kissimmee River substantially modified the habitat of river channel plant communities, leading to changes in species composition and increases in the extent of vegetation cover in river channels (SFWMD, 2005a). Plant growth is constrained in flowing rivers by channel depth and flow, and plants are typically limited to channel edges (Dawson, 1988). These bands of plants, which usually begin at the shallow base of channel banks and extend toward the center of the channel, are known as littoral vegetation, vegetation mats, or vegetation beds. They are composed of mixed communities of emergent, submergent, and floating species, as well as assemblages rooted on semi-floating, bog-like substrates composed of dead and living plant material. Because of its sensitivity to flow and channel characteristics, littoral vegetation was selected early in KRREP planning as an indicator of ecological response to reestablished flow in river channels, and has been monitored in the Phase I area since 1998.

Based on reference data, metrics selected to monitor restoration-related changes in littoral vegetation beds include the width of vegetation beds, the overall coverage of plants in channels, and the species composition of these plant communities. Expectations (performance measures) were developed for vegetation bed width (SFWMD, 2005b) and the relative cover of the two dominant plant growth forms in these communities — emergent and floating/mat-forming species (SFWMD, 2005b). Following reestablishment of flow, it is expected that vegetation bed widths will decline substantially on inner channel bends and straight reaches and that the community structure of these beds will change from communities that are co-dominated by floating/mat-forming species and emergent species to communities heavily dominated by emergent species. These predictions are detailed in SFWMD, 2005b, and were based on quantitative reference data obtained from a partially restored remnant channel in Pool B in 1998. The run had received intermittent flows and stage fluctuations since 1985 and continuous, moderate-to-high flow for six to nine months prior to data collection. Weirs placed across the C-38 canal as part of the Pool B demonstration project (Toth, 1991) temporarily diverted flow through the remnant channel.

Baseline and post-construction monitoring data were collected at permanent transects located in Phase I area remnant channels in Pools B and C (impact area) and in several control channels in Pool A, which will not be restored. To date, sampling was conducted twice annually (dry and wet seasons) from 1998–2003 and in summer 2007 and winter 2008. The 1 m-wide belt transects were located at bends and straight reaches of remnant river channels. From 1998–2003, more than 100 transect sections were measured per sample period in Pools B and C; approximately 40 transect sections were measured per sample period in Pool A. Sampling was temporarily suspended from 2004–2006 to free staff and resources for other evaluation work. Sample size was randomly reduced in 2007–2008; this reduction was based on power analyses of previous years' data to determine the number of transects needed to achieve acceptable standard errors with less field effort. Sampling will continue intermittently until implementation of the Headwaters Revitalization Schedule, with more frequent sampling to resume for at least five years after implementation of the new schedule or until responses stabilize.

Cover classes (Daubenmire, 1959) of all species present in contiguous 2 m x 1 m quadrats along each transect were recorded. Estimates were derived for both sides of the channel at each transect (two "transect sections" per transect). Relative cover of each species and growth-form (e.g., emergent, floating/mat-forming, submergent) in each bed was calculated as the sum of quadrat cover class midpoints for each species or growth-form, divided by the sum of midpoints of all species in the bed. Midpoints of cover class ranges are used to enable calculation of means from cover classes (Daubenmire, 1959). Relative cover was averaged over all vegetated transect sections sampled for each species or growth-form for each of the sample periods. Grandmeans for the baseline period are the averages of the four 1998–1999 sample period means for each species or growth form (n = 4); grandmeans for the post-construction period are the averages of the eight 2001–2003 and 2007–2008 sample period means (n = 8). Data were also collected during Phase I construction in 2000 under intermittent flow conditions, and show consistent but less pronounced responses.

Vegetation bed widths were measured to the nearest 1 m along the transects from the bank to the waterward edge of the bed. Submergent species were recorded when visible from the surface, but did not affect calculations of bed width. Beds were measured on both sides of the channel at each transect. Transect sections were classified by channel pattern (inner bend, outer bend, or straight reach). Widths were averaged for each sampling period over all sampled transect sections in each pattern category. Grand means of widths for the baseline period are the averages of the four baseline sample period means (n = 4) for each pattern category; grandmeans for the post-construction period are the averages of the eight post-construction sample period means (n = 8) for each pattern category.

Mean widths of vegetation beds on inside and straight channel reaches in the impact area declined substantially to below the expected values following construction (**Figure 11-24**). Mean relative cover of floating and mat-forming species in the impact area decreased from 48 percent before to 16 percent after reestablishment of flow, approaching but not meeting the expectation, while emergent cover increased from 48 to 83 percent, exceeding the expectation for emergent cover (**Figure 11-25**). Relative cover percentages shown in **Figure 11-25** do not total 100 percent because the remaining 1 to 5 percent of cover, comprising submergent, terrestrial, and unclassifiable species, is not graphed. Overall, vegetation cover declined in river channels from a baseline mean of approximately 60 percent of the channel to 16 percent following Phase I construction, although no formal expectation exists for this metric.

The observed changes are all proceeding in the directions predicted by the expectations, and three of the four have exceeded expectations despite a severe drought that resulted in an extended period of no flow in 2006–2007 (SFWMD, 2008a). Although the headwaters revitalization stage regulation schedule has not yet been implemented, the interim results indicate that the trajectories of monitored river channel vegetation metrics have followed predicted trends.

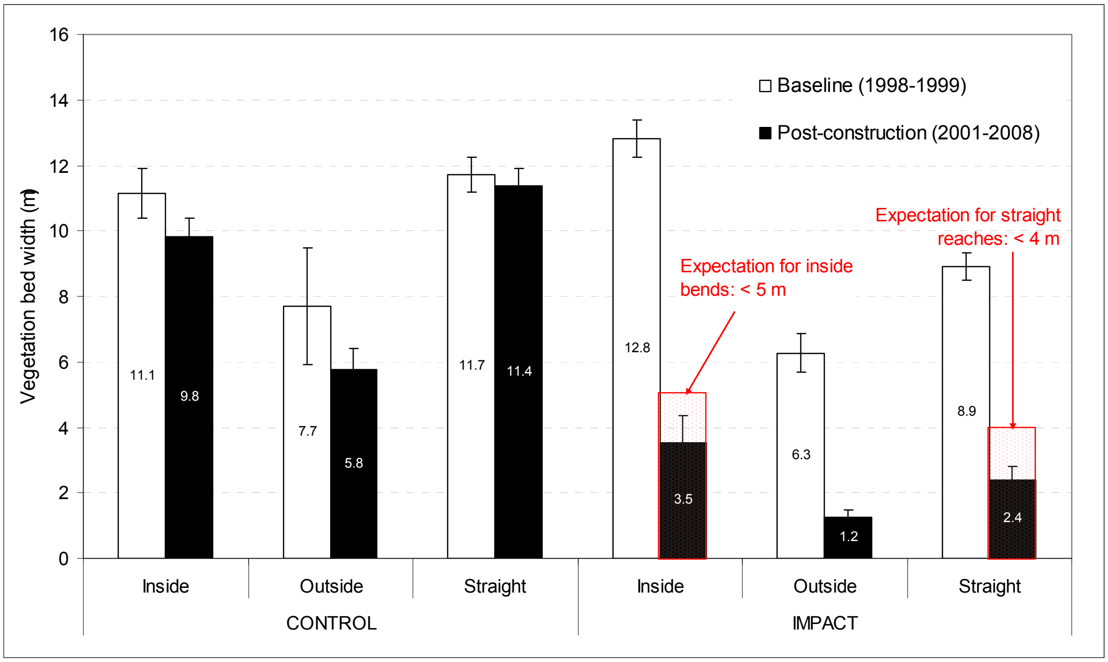

Figure 11-24. Vegetation bed widths averaged (± 1 S.E.) over the baseline and post-Phase I construction periods of the Kissimmee River Restoration Project.

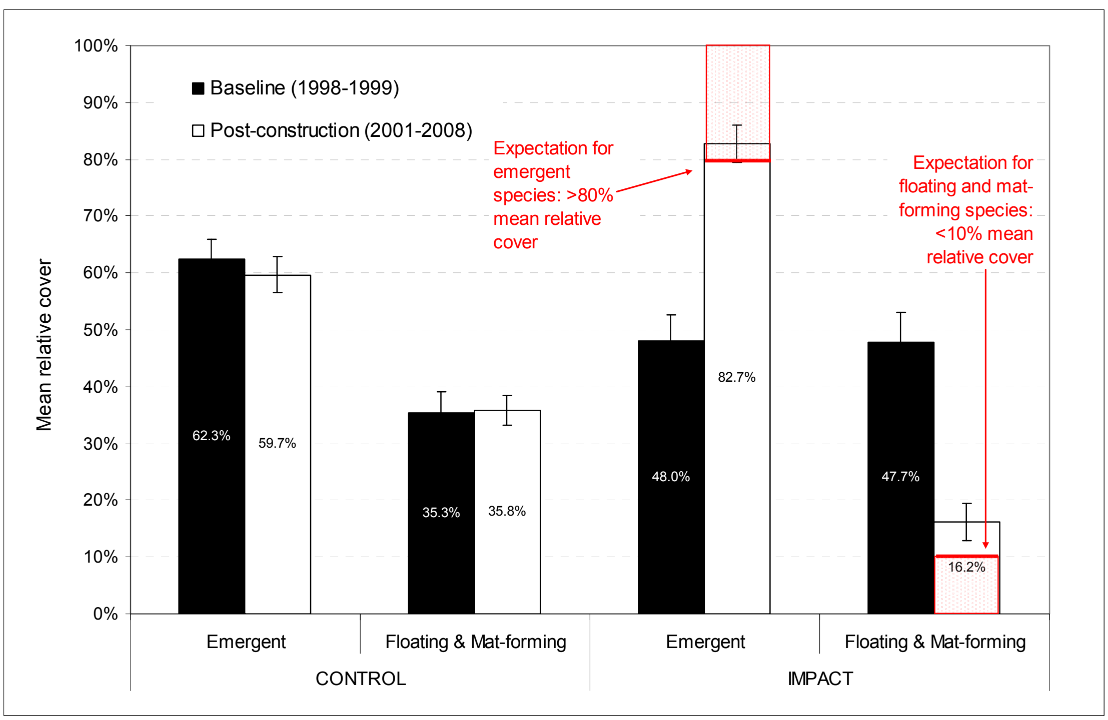

Figure 11-25. Mean (± 1 S.E.) relative cover of emergent species and floating/mat-forming species during the baseline and post-Phase I construction periods of the Kissimmee River Restoration Project.

Aquatic Invertebrates

Aquatic invertebrates were identified as a critical biological component for assessing restoration of ecological integrity within the Kissimmee River ecosystem (Karr et al., 1991; Harris et al., 1995). Aquatic invertebrates can play an integral role in river ecosystem processes and have a long history of use in biomonitoring (Plafkin et al., 1989; Rosenberg and Resh, 1993) and can serve as indicators of biotic integrity and ecological health (Karr et al., 1991).

Restoration of the Kissimmee River is expected to reestablish critical habitat characteristics including continuous flow, increased levels of dissolved oxygen, more natural substrate composition, and more natural floodplain hydroperiods. These changes in habitat characteristics are likely to significantly alter aquatic invertebrate community structure within river channel and floodplain habitats. A conceptual model for invertebrate community structure in the restored system predicts an increase in the density, diversity, and relative abundance of specific indicator taxa and functional feeding groups (Harris et al., 1995). Structural and functional shifts in aquatic invertebrate community characteristics along this predicted trajectory will ultimately be used as an indicator of restoration success. The objectives of this study were to evaluate interim responses by snag-dwelling and mid-channel benthic macroinvertebrates to restored flow and habitat structure in the Kissimmee River. Interim response data are compared to baseline data collected between 1995 and 1998 in order to document responses associated with restoration of biological integrity and recovery of the food base.

Baseline (pre-restoration) conditions for mid-channel benthic and snag-dwelling aquatic invertebrate communities were documented between August 1995 and May 1997 in Pool A (control) and Pool C (impact area) of the channelized Kissimmee River. Samples were analyzed for density, species richness, species diversity, functional feeding group composition, and functional habitat association. Within the river channel, baseline macroinvertebrate species richness, and diversity were low in benthic habitats and on woody debris. Functional feeding and functional habitat associations were dominated by taxa characteristic of lentic (nonflowing) or depositional habitats including Amphipoda (*Hyallela azteca*), Ephemeroptera: Caenidae (*Caenis* spp.), Diptera: Chironomidae (*Glyptotendipes* spp. and *Chironomus* spp.), and Diptera: Chaoboridae (*Chaoborus* spp.).

Reference conditions for species composition of aquatic invertebrates in restored mid-channel benthic habitats are primarily based on the presence of taxa within mid-channel benthic habitats of the Ogeechee and Satilla rivers, two southeastern Coastal Plain (Georgia) blackwater rivers (Benke et al., 1984; Stites, 1986). Reference conditions for density and biomass of passive filtering-collectors on river channel woody debris are derived from published data on functional feeding group composition, density, and biomass of snag-dwelling invertebrates in the Satilla River and Cedar Creek (South Carolina), a second-order blackwater stream (Benke et al., 1984; Smock et al., 1985).

Based on these reference conditions, habitat-based expectations for restoration have been developed. Specifically, the macroinvertebrate fauna of mid-channel benthic habitats will primarily consist of taxa that are common and characteristic of sandy substrates (SFWMD, 2005b). Additionally, the passive filtering-collector guild will account for the greatest proportion of mean annual density, mean annual biomass, and mean annual snag-dwelling macroinvertebrate production (SFWMD, 2005b).

Initial responses to restored flow and habitat structure under the interim regulation schedule have been positive for mid-channel benthic invertebrate communities. Taxa characteristic of lentic habitats have been replaced by several taxa common and characteristic of sandy benthos in free-flowing rivers of the southeastern United States. Within three years of restoring continuous flow (June 2001–June 2004), common (those accounting for greater than 5 percent of total density in any year) benthic macroinvertebrate taxa include characteristic sand-dwelling chironomids such as *Cryptochironomus* spp., *Polypedilum* spp. and Tanytarsini group, and the nonnative bivalve *Corbicula fluminea*. Other characteristic sand-dwelling macroinvertebrates also were present, but generally occurred in low numbers (**Table 11-7**). Although more characteristic taxa are likely to colonize sandy substrates within the Kissimmee River, and the expectation for restoration has not yet been achieved, the presence of most of these sand-dwelling macroinvertebrates is a positive indicator that restoration of flow and benthic habitat structure will lead to restoration of benthic macroinvertebrate community structure. The commonality of *Corbicula*, while of some concern, should not overshadow the fact that numerous native taxa not present under channelized conditions have returned to the system. *Corbicula* was introduced into Florida in 1964 (Heard, 1964) and was present in the Kissimmee River as early as 1971 (Vannote, 1971), although its relative abundance at that time is unknown. *Corbicula* will continue to be monitored over the course of the evaluation program to track population trends and identify and document any potential negative interactions with native invertebrates (i.e., displacement of native bivalves).

Aquatic invertebrate community structure and functional group associations on large woody debris also have shifted since reestablishing flow. Taxa characteristic of enriched lentic habitats and tolerant of low levels of dissolved oxygen have been replaced by taxa more characteristic of snag habitats in free-flowing blackwater rivers of the southeastern United States. Initial response data indicate that passive filtering-collectors, including Trichopetra: Hydropsychidae (*Cheumatopsyche* spp.), Trichoptera: Polycentropodidae (*Cyrnellus* spp.), and Chironomidae (*Rheotanytarsus* spp.), account for the greatest proportion of mean annual macroinvertebrate density and biomass on large woody debris within the restored system (**Figure 11-26**). Therefore, although the proportion of filtering-collectors on snags in the Kissimmee River is less than that of the reference site (Satilla River, Georgia), the expectation for response of this community has been achieved under the interim regulation schedule. Shifts in benthic and snag-dwelling macroinvertebrate community structures are consistent with restoration of biological integrity and recovery of the food base. Future studies will attempt to address the mechanisms responsible for these changes by integrating changes in aquatic invertebrate community structure with changes in hydrology, geomorphology, and DO concentrations.

Table 11-7. Sand-dwelling taxa in reference sites and the channelized Kissimmee River, and taxa that have, or are likely to, colonize the river's sand habitats.

Taxon	Satilla River[1]	Ogeechee River[2]	Channelized Kissimmee-Pool A	Channelized Kissimmee-Pool C	Restored Kissimmee	Reference
Diptera						
Corynoneura spp.	X***	X			X*	Merritt et al. 1996
Cladotanytarsus spp.	X**	X				
Cryptochironomus spp.	X**	X			X***	Merritt et al. 1996
Lopescalidius spp.		X				Epler 1992
Parakiefferiella spp.	X***	X				Epler 1992
Paracladoplelma spp.					X*	Epler 1992
Polypedilum spp.	X**	X	X*	X*	X***	Merritt et al. 1996
Rheosmittia spp.		X				Epler 1992
Robackia spp.	X***	X				Epler 1992
Tanytarsus spp.	X**				X**	Merritt et al. 1996
Tanytarsini group			X*	X*	X**	Merritt et al. 1996
Thienemaniella spp.	X**				X*	Epler 1992
Orthocladinae		X	X*	X*	X*	Epler 1992
Ceratopogonidae	X***	X		X*	X*	Merritt et al. 1996
Ephemeroptera						
Stenonema spp.						Berner&Pescador 1988
Cercobrachys spp.						Berner&Pescador 1988
Mollusca						
Sphaeriidae					X*	Toth 1991
Corbicula fluminea		X			X***	Toth 1991
Trichoptera						
Nectopsyche spp.						Pescador et al. 1995
Oecetis spp.						Merritt et al. 1996
Setodes spp.						Merritt et al. 1996

* = rare
** = frequent
*** = abundant
[1] = Benke et al. 1984, [2] = Stites 1986

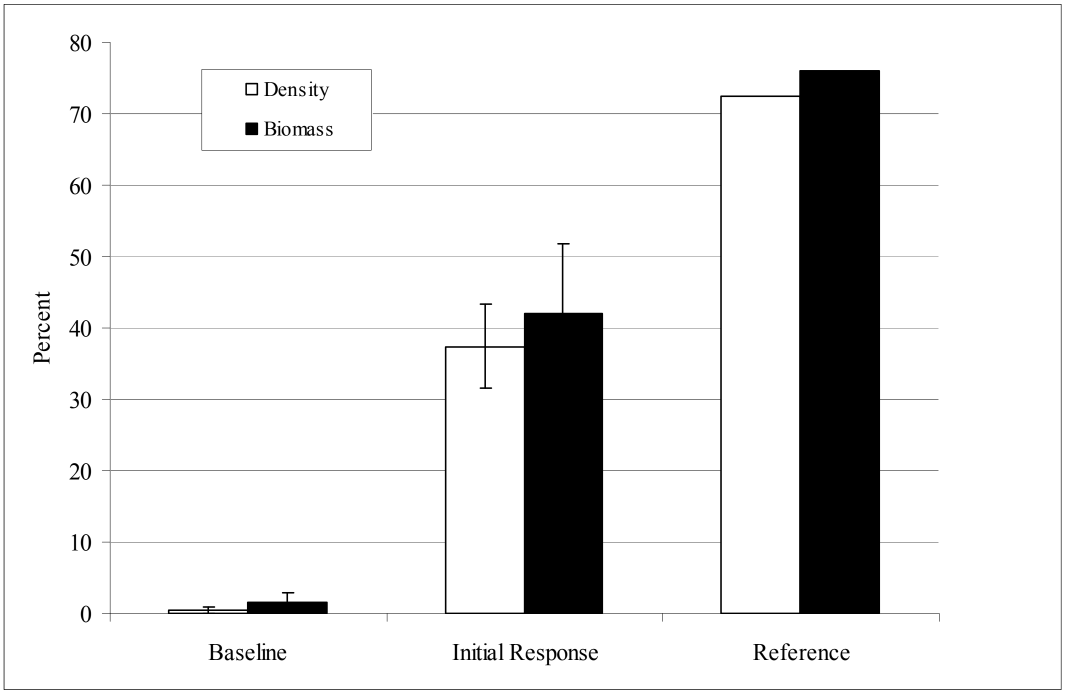

Figure 11-26. Mean (± 1 S.E.) annual density and biomass of passive filtering-collector invertebrates on snags during baseline and post-Phase I sample periods.

Fish

River Channel Fish Assemblage Structure

Monitoring fish assemblage response to restoration is an important component of the comprehensive Kissimmee River Restoration Evaluation Program due to the ecological significance of fish in large river-floodplain ecosystems (Welcomme, 1979). Fish species representing a range of trophic levels (herbivore, piscivore, omnivore, invertevore, planktivore, detritivore) consume foods from aquatic and terrestrial environments (Karr et al., 1986) and serve as a critical link in the energy pathway between primary producers and higher trophic level consumers, including amphibians, reptiles, birds, and mammals (Karr et al., 1991; Gerking, 1994). Because freshwater fishes are relatively long-lived (Carlander, 1977; Lee et al., 1980) and can travel considerable distances within their watershed (Fish and Savitz, 1983; Gent et al., 1995; Furse et al., 1996), they integrate aspects of aquatic ecosystems across broad temporal and spatial scales (Karr et al., 1986). Fishes are therefore excellent indicators of aquatic ecosystem health or integrity (Oberdorff and Hughes, 1992; Gammon and Simon, 2000).

Restoration targets for fish assemblages inhabiting restored reaches of the Kissimmee River were developed from data collected in three reference rivers in peninsular Florida because of the lack of available data from the Kissimmee River prior to channelization. Electrofishing data from the St. Johns, Withlacoochee, and Oklawaha rivers, collected annually during the autumn low water period from 1983–1990, serves as reference condition data for the Kissimmee River. All three rivers are located entirely within or having headwaters originating in peninsular Florida below the Suwannee and St. Johns drainages, the demarcation between peninsular and northern fish assemblages (Swift et al., 1986; Gilbert, 1987). All rivers have undergone varying degrees of anthropogenic alteration including channelization, impoundment, and point sources of pollution (Bass, 1991; Estevez et al., 1991; Livingston, 1991; Livingston and Fernald, 1991) and, therefore, are not pristine reference sites for the historic Kissimmee River. However, this information about the composition of riverine fish assemblages within peninsular Florida is provided as best available data.

Relative abundance measures of three species and one family showed strong differences between data collected in the Kissimmee River between 1992–1994 prior to Phase I construction (baseline period) and from the reference sites. Therefore, these taxa were selected for development of restoration targets. These targets are based on each species' or family's dependence on functional, physiochemical, or biological characteristics expected to be restored to the river-floodplain ecosystem. These measures include relative abundance of bowfin (*Amia calva*), Florida gar (*Lepisosteus platyrhinchus*), redbreast sunfish (*Lepomis auritus*), and centrarchids (sunfishes and basses). Based on the reference data, post-restoration fish assemblages in restored river reaches are expected to be composed of ≤ 1 percent bowfin, ≤ 3 percent Florida gar, ≥ 16 percent redbreast sunfish, and ≥ 58 percent centrarchids (**Figure 11-27**).

Phase I of Kissimmee River restoration was completed in February 2001. The physically restored reach has received continuous flow since July 2001, except for a 252-day period from November 9, 2006–July 18, 2007, when flow was eliminated as a result of drought conditions in the basin. River channel fish assemblages were sampled in August 2004, approximately three years after completion of Phase I, to determine if changes in assemblage structure had occurred that would indicate an initial fish assemblage response to restoration efforts. These results indicated a positive response for the centrarchid component of the fish assemblage (see the 2006 SFER – Volume I, Chapter 11).

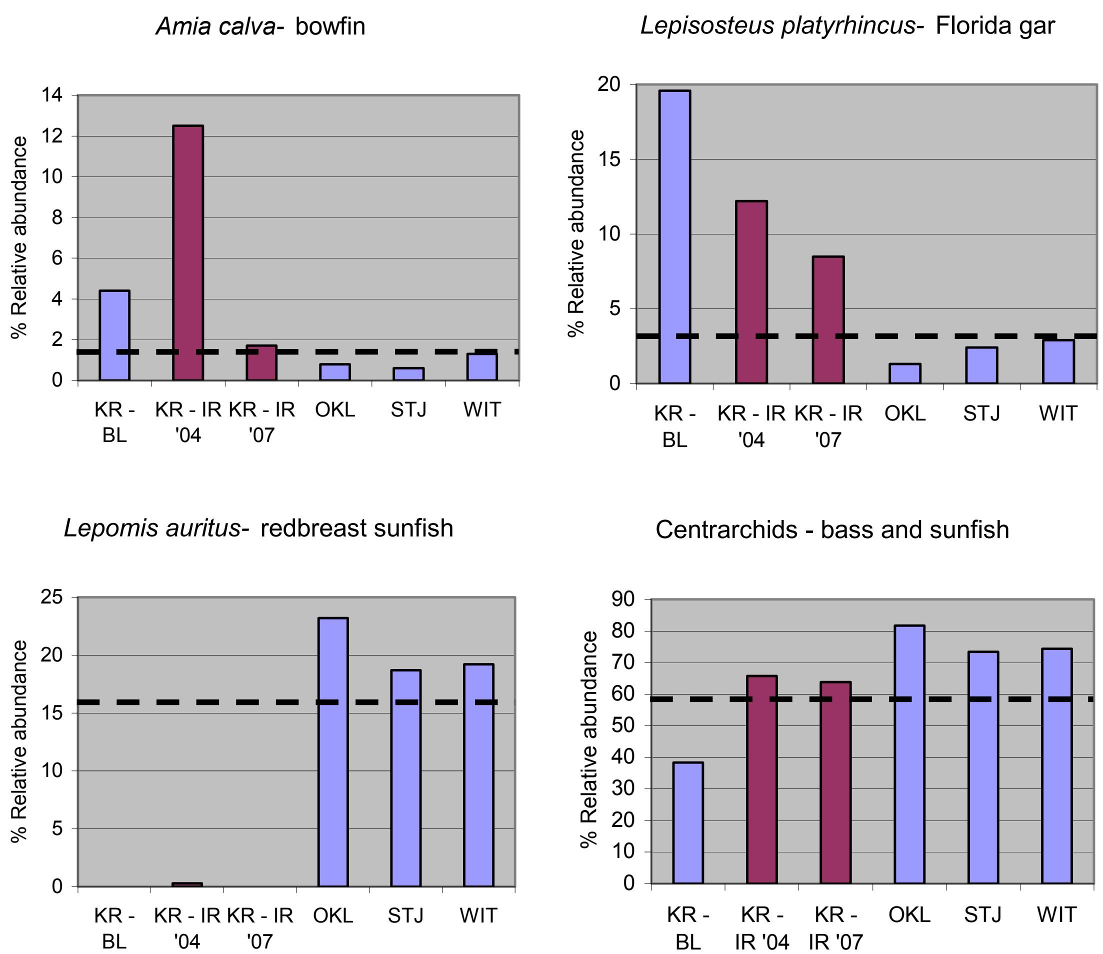

Figure 11-27. Baseline mean annual relative abundance of fish taxa or family (blue bars) that will be used to evaluate restoration success in reestablishing river channel fish assemblage structure. Red bars indicate relative abundance of fish taxa or family from initial response data collected in the physically restored reach of the Kissimmee River in 2004 and 2007. Dashed line indicates expected value for each taxa or family following restoration. (KR - BL = Kissimmee River baseline condition, KR - IR = Kissimmee River initial response, OKL = Oklawaha River, STJ = St. Johns River, WIT = Withlacoochee River)

As shown in **Table 11-8**, fishes were sampled again in summer 2007 as a follow-up to the 2004 fish assemblage investigation. Sixteen taxa were collected at control sites in Pool A. Dominant taxa (> 5 percent relative abundance) included bowfin (8.8 percent); mosquitofish (*Gambusia holbrooki*) (30.4 percent); least killifish (*Heterandria formos*a) (7.9 percent); Florida gar (25.1 percent); and bluegill (*Lepomis macrochirus*) (11.8 percent). Eighteen taxa were collected at physically restored sites in Pool C. Dominant taxa included mosquitofish (11 percent); Florida gar (8.5 percent); bluegill (37.9 percent); redear sunfish (*Lepomis microlophus*) (7.9 percent); largemouth bass (*Micropterus salmoides*) (6.4 percent); and sailfin catfish (*Pterygoplichthys disjunctivus*) (8.1 percent). Centrarchids accounted for 24.7 and 63.8 percent of the fish assemblages in Pools A and C, respectively (**Table 11-9**). The most notable changes in the fish assemblage structure in physically restored reaches since 2004 are (1) shifts within the centrarchid community, (2) decrease in bowfin relative abundance, and (3) increased relative abundance of the exotic vermiculated sailfin catfish. Centrarchid response to reestablishment of flow continues to be positive and exceeds the target value of 58 percent or greater. Bluegill abundance increased by 94 percent, while abundance of largemouth bass and spotted sunfish decreased by 46 and 74 percent, respectively.

Dissolved oxygen levels in the physically restored area have remained elevated compared to pre-restoration levels and likely will continue to facilitate conditions suitable for centrarchids. For example, mean seasonal DO levels in Pool C have increased from 1.4 to 3.2 mg/L in the wet season (June–November) and from 3.2 to 6.4 mg/L during the dry season (December–May). Some centrarchid taxa become stressed when DO levels fall below 2 mg/L (Moss and Scott, 1961). Stress can include any stimulus that threatens homeostasis such that survival is compromised (Brett, 1958). Seasonal hypoxia exhibited under baseline conditions is an example of a stress stimulus that could have negatively impacted physiological functions in centrarchids, including decreased disease resistance, growth rate, and fecundity (Wendelaar Bonga, 1997). Higher DO levels present in the physically restored area likely have alleviated the stressed condition, thereby allowing energy expenditures to be redirected to growth and reproduction, both of which enhance survival. Increased DO levels in the wet season is especially important for survivorship of young-of-the-year fishes, as they often are more susceptible to hypoxic conditions (Wendelaar Bonga, 1997).

Reestablishment of the historic river channel-floodplain connectivity also may be partly responsible for the sustained increase in centrarchid relative abundance. Inundated floodplain provides crucial habitat for centrarchids during various life history stages, especially as breeding and nursery areas. Centrarchids require areas with limited flow for nesting (Carlander, 1977; Lee et al., 1980), while it is believed that young-of-the-year and juveniles are afforded protection from predation within shallow, densely vegetated habitats (Savino and Stein, 1982) that occur throughout the floodplain landscape. Floodplain habitats have been periodically inundated and available annually to river channel fishes since the reestablishment of flow in the restored area.

Table 11-8. Annual relative abundance of fishes collected by electrofishing in 2004 and 2007 in physically restored (Pool C) and channelized (Pool A) sections of the Kissimmee River. Values for dominant taxa (> 5 percent) are listed in bold print.

Taxa	Taxa	2004 Pool A	2004 Pool C	2007 Pool A	2007 Pool C
Ameiurus natalis	yellow bullhead	--	0.5	--	--
Ameiurus nebulosus	brown bullhead	--	3.6	--	--
Amia calva	bowfin	0.8	**12.5**	**8.8**	1.7
Dorosoma petenense	threadfin shad	--	0.3	--	--
Elassoma evergladei	Everglades pygmy sunfish	--	0.3	0.2	--
Enneacanthus gloriosus	bluespotted sunfish	--	--	--	0.3
Erimyzon sucetta	lake chubsucker	--	0.5	--	0.6
Etheostoma fusiforme	swamp darter	--	--	--	0.3
Fundulus chrysotus	golden topminnow	--	--	--	0.3
Gambusia holbrooki	mosquitofish	**76.3**	1.0	**30.4**	**11**
Heterandria formosa	least killifish	**5.2**	--	**7.9**	0.4
Hoplosternum littorale	brown hoplo	--	--	0.5	--
Labidesthes sicculus	brook silverside	--	0.3	--	1.3
Lepisosteus osseus	longnose gar	--	--	--	0.6
Lepisosteus platyrhincus	Florida gar	**5.2**	**12.2**	**25.1**	**8.5**
Lepomis auritus	redbreast sunfish	--	0.3	--	--
Lepomis gulosus	warmouth	--	**5.4**	1.1	4.4
Lepomis macrochirus	bluegill	**6.0**	**19.5**	**11.8**	**37.9**
Lepomis microlophus	redear sunfish	1.6	**7.7**	2.7	**7.9**
Lepomis punctatus	spotted sunfish	0.6	**19.2**	3.2	4.9
Lucania goodei	bluefin killifish	--	--	0.1	--
Menidia beryllina	inland silverside	--	0.3	--	--
Micropterus salmoides	largemouth bass	2.0	**11.9**	2.7	**6.4**
Notemigonus crysoleucas	golden shiner	--	0.3	--	3.4
Notropis petersoni	coastal shiner	--	--	0.5	--
Opsopoeodus emilidae	pugnose minnow	1.6	--	--	--
Oreochromis aureus	blue tilapia	--	0.3	--	--
Poecilia latipinna	sailfin molly	--	--	0.6	--
Pomoxis nigromaculatus	black crappie	0.4	1.8	3.2	2.0
Pterygoplichthys disjunctivus	Vermiculated sailfin catfish	0.3	2.1	1.2	**8.1**

Table 11-9. Percent contribution by centrarchids collected via electrofishing within three peninsular Florida rivers between 1983 and 1990 and in Pool C of the Kissimmee River during the baseline period between 1992 and 1994 (KIS – BL) and for initial response in 2004 and 2007 (KIS – IR).

Species	KIS – BL	KIS – IR 2004	KIS – IR 2007	STJ	OKL	WIT
Centrarchus macropterus	--	--	--	0.01 ± 0.01	--	--
Enneacanthus gloriosus	0.5 ± 0.2	--	0.3	0.03 ± 0.02	0.02 ± 0.01	0.5 ± 0.2
Lepomis auritus	--	0.3	--	18.7 ± 1.2	23.2 ± 1.6	19.2 ± 2.9
Lepomis gulosus	4.8 ± 1.6	5.4	4.4	1.3 ± 0.2	4.9 ± 0.5	6.1 ± 0.4
Lepomis macrochirus	16.5 ± 4.0	19.5	37.9	35.0 ± 1.1	27.7 ± 2.4	14.8 ± 2.8
Lepomis marginatus	0.3 ± 0.1	--	--	0.03 ± 0.03	0.1 ± 0.04	2.5 ± 0.7
Lepomis microlophus	4.4 ± 0.9	7.7	7.9	8.1 ± 1.1	9.3 ± 0.6	6.7 ± 1.8
Lepomis punctatus	1.5 ± 0.7	19.2	4.9	3.4 ± 0.3	10.7 ± 1.5	18.5 ± 2.1
Micropterus salmoides	9.4 ± 0.7	11.9	6.4	4.8 ± 0.2	5.3 ± 0.4	5.8 ± 2.3
Pomoxis nigromaculatus	0.9 ± 0.02	1.8	2.0	2.1 ± 0.3	0.5 ± 0.1	0.3 ± 0.2
TOTAL	**38.3**	**65.8**	**63.8**	**73.4**	**81.7**	**74.4**

St. Johns River – STJ
Oklawaha River – OKL
Withlacoochee River – WIT

At 1.7 percent, relative abundance of bowfin in physically restored reaches approached the restoration target of ≤ 1 percent and indicates a reduction by 86 percent since 2004. Bowfin prefer heavily vegetated habitats with little to no flow and may be using off-channel habitats, including secondary channels and inundated floodplain, to a greater degree. Conversely, relative abundance of bowfin and Florida gar increased by 90 and 328 percent, respectively, in remnant river reaches in the control area in Pool A. Both bowfin and Florida gar are able to thrive in degraded aquatic habitats, especially in waters exhibiting hypoxic conditions, because both species have the ability to "gulp" atmospheric oxygen. The marked increase in the relative abundance of these fishes suggests the continued decline in river channel habitat quality in remnant river reaches in Pool A.

The vermiculated sailfin catfish is a relative recent introduction to the Kissimmee River and was first collected during baseline studies in 1998. It is indigenous to the Amazon Basin in South America. Although it has been collected from a variety of water body types in Florida, including canals, lakes, ponds, streams, and rivers (Fuller et al., 1999), little is known about its specific habitat preferences. However, it constructs nesting burrows in shallow, sandy shorelines, a condition that has increased dramatically in physically restored river reaches. Increased availability of preferred nesting habitat coupled with access to inundated floodplain habitats that are known to serve as nursery grounds for numerous fish species may be facilitating the increased relative abundance of this species.

While the centrarchid metric of the restoration target appears to have been achieved, the remaining three metrics (percent bowfin, percent Florida gar, and percent redbreast sunfish) have not. However, two of these metrics are on a trajectory toward the expectation value. Relative abundance of Florida gar decreased from 12.2 to 8.5 percent, and the bowfin relative abundance of 1.7 percent approaches the target value of ≤ 1 percent (**Figure 11-27**). The predicted decrease in relative abundance of bowfin and Florida gar is expected to take longer than the six years that have transpired since completion of Phase I construction.

Because these two taxa are among the longest lived in the system (bowfin has an approximate 10-year lifespan; Florida gar has an approximate 12- to 18-year lifespan), a greater length of time is required before detectable shifts in their population dynamics are manifested in the structure of the fish assemblage as a whole. The expected increase in redbreast sunfish also will require a greater length of time due to the geographic limits of the source population in the watershed. Reestablishment of redbreast sunfish in Pool C requires downstream dispersal of individuals from the remnant population occurring in Pool B, which was not expected to be immediate. These preliminary data also must be interpreted with care, as the data represent a single year, and fish assemblages exhibit high annual variability in assemblage structure (Oberdorff et al., 2001).

In an effort to increase the integrity of fish assemblage response data and to better characterize variability, collections will be conducted annually through the remainder of the project. This collection frequency will generate a more robust dataset for analyzing population trends in fish assemblages over time, especially recruitment, which will be a useful metric for gaining insight into potential factors influencing observed shifts in fish assemblage structure in the Kissimmee River.

Birds

Birds are both integral to the Kissimmee River/floodplain ecosystem and highly valued by its human users. While quantitative pre-channelization data are sparse, available data and anecdotal accounts indicate that the system supported an abundant and diverse bird assemblage (National Audubon Society, 1936–1959; FGFWFC, 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Further, since many bird groups (e.g., wading birds, waterfowl) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller, 1995). Detailed information regarding the breadth of the avian evaluation program and the initial response of avian communities to Phase I restoration is presented in the 2005 SFER – Volume I, Chapter 11. This section highlights portions of the avian program for which data were collected during WY2008.

Wading Bird Nesting Colonies

As part of the KRRP's evaluation program, the District performed systematic aerial surveys (January 29, March 27, and May 27, 2008) to search for wading bird nesting colonies within the floodplain and surrounding wetland/upland complex of the Kissimmee River. Nesting colonies were also monitored, when encountered, during separate aerial surveys of foraging wading birds (January 10, February 7, March 6, April 10, May 5, and June 3, 2008). The number of nests reported represents the maximum number for each species. Nesting success was not monitored, but one ground survey on February 20 was conducted at the S-65D cypress colony to obtain more accurate nest counts and determine the presence of less visible dark-colored species [i.e., little blue heron (*Egretta caerulea*) and tricolored heron (*E. tricolor*)].

One small colony containing two great egret (*Ardea alba*) and four great blue heron (*A. herodias*) nests was observed near the S-65D boat ramp in mature cypress during the 2008 season. As in 2007, long-legged wading bird species may have lacked sufficient aquatic prey to initiate breeding due to drought conditions and insufficient inundation of the floodplain for effective foraging. Additionally, the timing and magnitude of floodplain inundation and recession is not yet optimal for rookery formation due to operational constraints. Implementation of the regulation schedule for the Headwaters Revitalization Project in 2013 is expected to allow water managers to more closely mimic the historical stage and discharge characteristics of the river, presumably leading to suitable hydrologic conditions for wading bird nesting colonies.

Wading Bird Densities

Monthly aerial surveys were used to measure the densities of foraging wading birds. Prior to Phase I construction (baseline period), mean annual dry season densities of long-legged wading birds in the Phase I area averaged (± S.E.) 3.6 (± 0.9) birds/km² in 1997 and 14.3 (± 3.4) birds/km² in 1998. Since completion of Phases I and IVa, densities of long-legged wading birds have exceeded the restoration expectation of 30.6 birds/km² each year except in 2007, averaging 37.8 (± 15.4), 61.7 (± 14.5), 59.6 (± 24.4), 103.0 (± 31.5), 11.0 (± 2.1), and 34.7 (± 6.4) birds/km² in the dry seasons of 2002, 2004, 2005, 2006, 2007, and 2008, respectively (**Figure 11-28**). Data were not collected in 2003 (SFWMD, 2008a). The lower limit of the 95 percent confidence interval has exceeded the expectation in three of six years.

Wading bird numbers this year rebounded significantly from last year's post-Phase I restoration six-year low, when most floodplain foraging habitat was completely dry and the river had no flow for nearly nine months (SFWMD, 2008a). Foraging conditions on the floodplain gradually improved after summer rains reestablished flow to the river on July 18, 2007. Glossy (*Plegadis falcinellus*) and white ibis (*Eudocimus albus*) dominated numerically, followed in order of abundance by cattle egret (*Bubulcus ibis*), great egret, small white heron (snowy egret [*Egretta thula*] and juvenile little blue heron), great blue heron, and small dark heron (tricolored heron and adult little blue heron). Federally endangered wood storks (*Mycteria americana*) were observed during surveys in December, February, and March.

Waterfowl Densities

Four duck species, blue-winged teal (*Anas discors*), green-winged teal (*A. crecca*), mottled duck (*A. fulvigula*), and hooded merganser (*Lophodytes cullulatus*), were detected during baseline aerial surveys. During the same time period, casual observations of wood duck (*Aix sponsa*) were made during ground surveys for other projects (SFWMD, 2005a). Mean annual density (± S.E.) was 0.4 ± 0.1 ducks/km² in the Phase I area, well below the restoration expectation of 3.9 ducks/km². Following completion of Phases I and IVa, average annual duck densities have exceeded the restoration expectation each year except in 2007, and the lower limit of the 95 percent confidence interval has exceeded the expectation in five of seven years (**Figure 11-29**). Absence of water across much of the floodplain during the 2006–2007 drought prevented wintering waterfowl from foraging along most of the Kissimmee River and resulted in the post-Phase I low of 1.3 (± 1.3) ducks/km². Densities returned to almost two times the restoration target by November 2007 (7.6 [± 1.9] ducks/km²) with seasonal rains and the reestablishment of flow to the river (see *Wading Bird Densities* section of this chapter).

The American wigeon (*A. americana*), northern pintail (*A. acuta*), northern shoveler (*A. clypeata*), ring-necked duck (*Aythya collaris*), and black-bellied whistling duck (*Dendrocygna autumnalis*) were not detected during baseline surveys, but have been present following restoration. However, these species are not regularly observed, and the restoration target for waterfowl species richness (≥ 13 species) has yet to be reached on an annual basis. Blue-winged teal and mottled duck remain the two most commonly observed species, accounting for over 95 percent of observations.

Restoration of the physical characteristics of the Kissimmee River and floodplain, along with the hydrologic characteristics of headwater inputs, is expected to produce hydropatterns and hydroperiods that will lead to the development of extensive areas of wet prairie and broadleaf marsh, two preferred waterfowl habitats (Chamberlain, 1960; Bellrose, 1980). Changes in the species richness and density of waterfowl within the restoration area are likely to be directly linked to the rate of development of floodplain plant communities and the faunal elements these plant communities support. Extrinsic factors, such as annual reproductive output on summer breeding grounds and local and regional weather patterns, may also play a role in the speed of recovery of the waterfowl community.

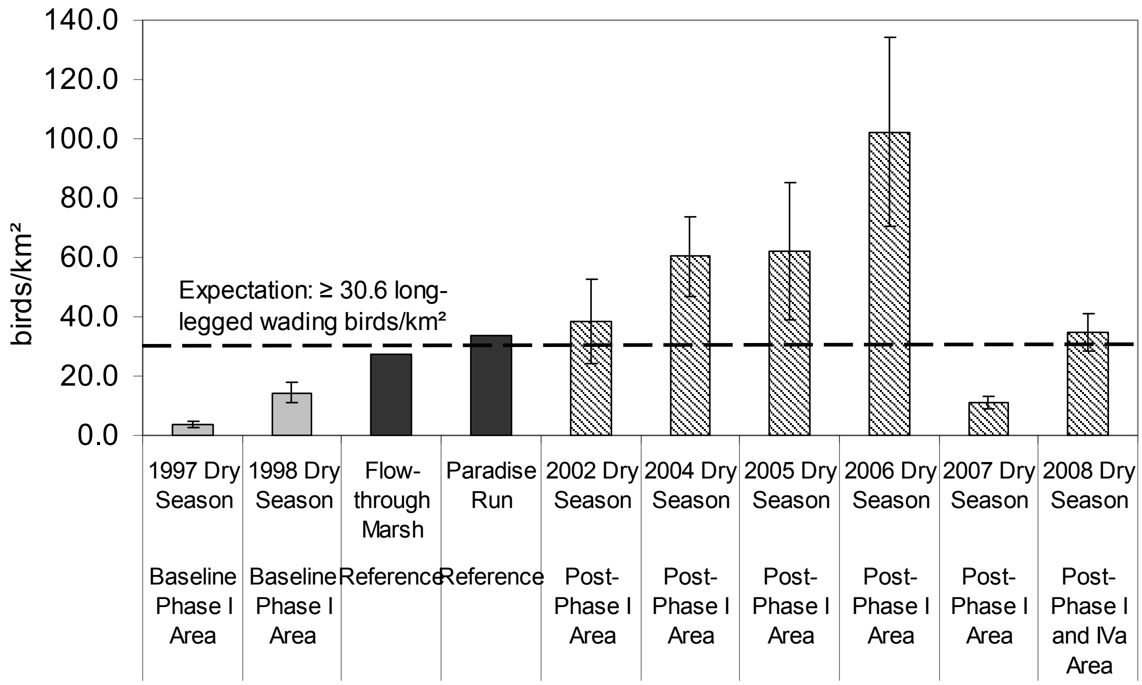

Figure 11-28. Baseline, reference, and post-Phases I and IVa densities (± S.E.) of long-legged wading birds (excluding cattle egrets) during the dry season (December–May) within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately 10 months following completion of Phase I.

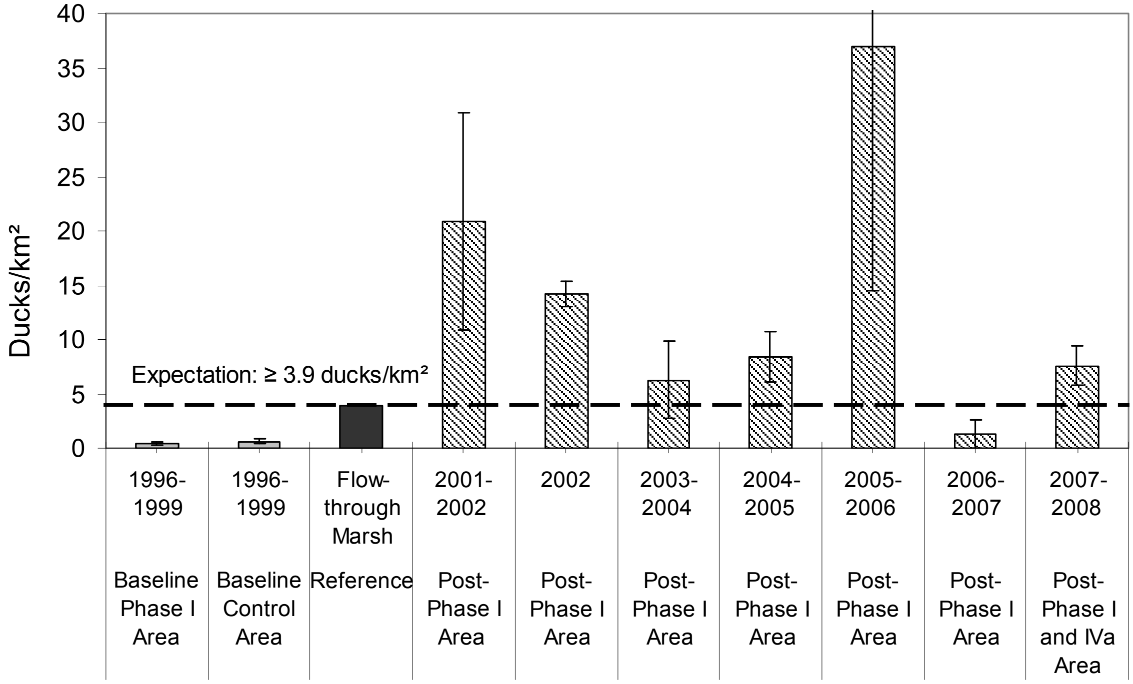

Figure 11-29. Baseline, reference, and post-Phases I and IVa densities (± S.E.) of waterfowl during winter (November–March) within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately nine months following completion of Phase I.

PHASE II/III RESTORATION EVALUATION PLANNING

Phase II/III Integrated Studies and Monitoring

Planning for evaluation of Phase II/III of the KRRP took place in 2007, with continued refinement and implementation of several pilot studies in 2007–2008. Monitoring to track responses to Phase II/III restoration construction will include studies of water quality (phosphorus and dissolved oxygen), geomorphology, river channel and floodplain vegetation, and aquatic invertebrate, herpetofauna, fish, and bird communities. Metrics collected by many of these studies are planned for coordinated analyses under the Phase II/III Integrated Studies. The goal of Phase II/III Integrated Studies is to better identify the relationships among individual components of the ecosystem through enhanced coordination of a subset of Integrated Studies. A better understanding of the relationships among monitoring studies will aid in adaptive management of the ecosystem during recovery. Most of the studies are planned to take place in Caracara Run, Riverwoods Run, or the Lanier Floodplain area of Pool D (**Figure 11-2**), because these areas are expected to encompass the dominant river channel and floodplain habitats that will be restored.

The Integrated Studies are using comparable designs that will be implemented using coordinated spatial and temporal sampling to enhance correlative analysis among studies, such as regressions, time-series analysis, and other methods. As in the Phase I evaluation studies, most of the Phase II/III studies will use a BACI design (SFWMD, 2005a), with sampling conducted in control and impact areas before and after reconstruction of the project area. Pilot studies and pilot work for the Phase II/III studies are being conducted in summer/fall 2008. Pilot vegetation sampling to detect littoral zone changes expected to result from KRHRP in four headwaters lakes is also under way in 2008. Aerial photography for baseline vegetation maps to evaluate Phase II/III was flown in spring 2008, with mapping scheduled for completion in summer 2009. Mapping for the KRHRP is planned for 2009.

Hydrology Network

The hydrologic monitoring network in Pool D is being expanded to support the evaluation of Phase II/III of the KRRP. The additional monitoring will aid the evaluation of five restoration expectations for hydrology and will support other evaluation studies, especially those associated with the Phase II/III Integrated Studies. In addition, the Phase II/III network will complement the Phase I network, so that a hydrologic monitoring network will extend across the project. This network will also be used to create maps of water surface elevations, which can be used with a Geographic Information Systems tool to evaluate hydroperiods for specific areas within the restoration project.

Funds have been budgeted for Fiscal Year 2009 (FY2009) (October 1, 2008–September 30, 2009) to install 15 stage monitoring sites on the floodplain, and two stage and flow monitoring sites in remnant river channels (Caracara Run and Riverwoods Run) that will be reconnected during Phase II/III construction. Final site selection will be completed in early FY2009 so that installation can begin as soon as possible.

The additional hydrologic monitoring proposed for Phase II/III of the restoration project will be part of the District's monitoring network. Before installation begins, the proposed expansion of the network will be reviewed by the Environmental Monitoring Coordination Team to ensure there is no duplication of monitoring efforts. To ensure data collected at these monitoring sites is consistent with the rest of the monitoring network, the installation of the new monitoring sites will be overseen by the District's SCADA and Hydro Data Management Department, which also maintains the sites, provides quality assurance/quality control of the data, and stores the data in the District's DBHYDRO database.

Kissimmee Basin Phosphorus Project

While the present-day Kissimmee River has low concentrations of TP relative to some other tributaries to Lake Okeechobee, it contributes a significant fraction of the total phosphorus load to the lake because of its large volume of water (SFWMD, 2008c). Although the KRRP was not designed as a nutrient removal project, it is causing several changes in the movement of water through the system that may increase the potential for retention and reduction of the total phosphorus load to Lake Okeechobee. These changes include virtually continuous, variable flow through the system due to changes to the regulation schedule at structure S-65 (Lake Kissimmee) and movement of water through the river channel and re-inundated floodplain in the area where C-38 has been backfilled. Flow through the much shallower river channel and over the 1- to 3-mile-wide floodplain is thought to create more opportunity for uptake and storage of P when compared to flow through the C-38 canal due to deposition and increased contact between the water flowing through the system and the river channel/floodplain vegetation and sediment/soil.

The goal of this project, which is scheduled to begin in FY2009, is to develop a comprehensive phosphorus dynamics program for the Kissimmee Basin, focusing on the effects of the KRRP and on integrating this information with other SFWMD nutrient programs. Tasks include (1) developing a framework for a phosphorus program for the KRRP; (2) performing exploratory data analysis and summarizing existing data; (3) evaluating and further developing the Watershed Assessment Model (see Chapter 10 of this volume) for the Kissimmee Basin; (4) creating a reporting format on the effects of the restoration project on phosphorus dynamics/loading; (5) preparing status and annual reports on the phosphorus program; (6) enhancing the integration of phosphorus studies and coordination with other agency programs; and (7) recommending and implementing new studies to fill data gaps, as appropriate.

KISSIMMEE BASIN MODELING AND OPERATIONS STUDY

The KBMOS is a District initiative to identify alternative water control structure operating criteria for the Kissimmee Basin and its associated water resource projects. The KBMOS is independent of, but closely related to, the KCOL LTMP, discussed below. The KBMOS will define the required water control structure operations needed to meet the hydrologic requirements of the river restoration project, while also achieving a more acceptable balance between water resource management objectives associated with flood control, water supply, aquatic plant management, and the natural resource requirements of the KCOL. In addition, the KBMOS will ensure that modified operations will not cause impacts greater than current impacts on Lake Okeechobee from Kissimmee Basin inflows. These impacts will be evaluated relative to the desired stage envelope defined for Lake Okeechobee. The Northern Everglades and Estuaries Protection Program will address additional measures needed to meet the desired stage envelope because the KBMOS is intended only to refine operating criteria to effectively meet the above-stated objectives with complete reliance on the existing water management infrastructure and the land interests of the state of Florida and the SFWMD.

The KBMOS was initiated in September 2004. Since the previous reporting period, current and future base condition model runs and the model peer review have been completed, and alternative plan screening has been initiated. Four Computer-Aided Participation (CAP)

Workshops have been held to develop and modify alternative plans. CAP Workshops allow stakeholder participants the opportunity to modify regulations schedules and operating criteria to see how changes positively or negatively influence upstream and downstream conditions. These workshops also provide opportunities for participants from multiple backgrounds to interact and share knowledge and experience, and provide hands-on working experience with the modeling tools and performance measures.

CAP Workshops have been successful in bringing a wide range of stakeholders to the table, identifying roadblock issues, and increasing communication and dialog between stakeholders groups that seldom interact. While the KBMOS was originally scheduled to be completed by June 2008, the completion date has been rescheduled to June 2009 to accommodate additional stakeholder involvement and conflict resolution. The final deliverable will be modified interim and long-term operating criteria for Kissimmee Basin water control structures. Further information about the KBMOS is available at https://projects.earthtech.com/sfwmd-kissimmee/.

UPPER KISSIMMEE BASIN AND TRIBUTARY PROJECTS

Kissimmee Chain of Lakes Long-Term Management Plan

The KCOL LTMP is a multiagency/stakeholder project that was initiated by the passage of the District's Governing Board Resolution 2003-468. This resolution directs SFWMD staff to work with the USACE and other interested parties to improve the health and sustainability of the KCOL by developing a long-term management plan for regulated lakes in the Upper Kissimmee Basin (**Figure 11-1** and **Figure 11-3**, panel C). The SFWMD is the lead agency responsible for coordinating the KCOL LTMP interagency activities and producing the plan. The other agencies/stakeholders include the FWC, FDEP, FDACS, USACE, USFWS, USEPA, local governments, community leaders, Lake Mary Jane Alliance, Audubon of Florida, Nature Conservancy, Alligator Chain of Lakes Home Owners Association, Alligator Chain Heritage Association, and other stakeholders. The purpose of the KCOL LTMP is to enhance and/or sustain lake ecosystem health by (1) providing the scientific and technical basis for assessing current and future environmental conditions relative to agreed-upon targets, and (2) developing collaborative strategies for identifying needs for management intervention or modification to achieve these targets. The KCOL LTMP is conceived as the collaborative framework upon which the partner agencies can manage the KCOL and adjacent/connected lands.

A draft version of the KCOL LTMP is expected to be released in late 2008. Plan content has been significantly revised to address peer-review panel recommendations. Since the peer review, the plan document has been reorganized around the management theme. Additional outreach has been initiated to make contact with stakeholders associated with each of the Lake Management Areas (LMAs). **Figure 11-30** shows the lakes included in each of the seven LMAs in the KCOL. This additional outreach has resulted in significant discoveries that have enhanced the interagency team's understanding and familiarity with the resources.

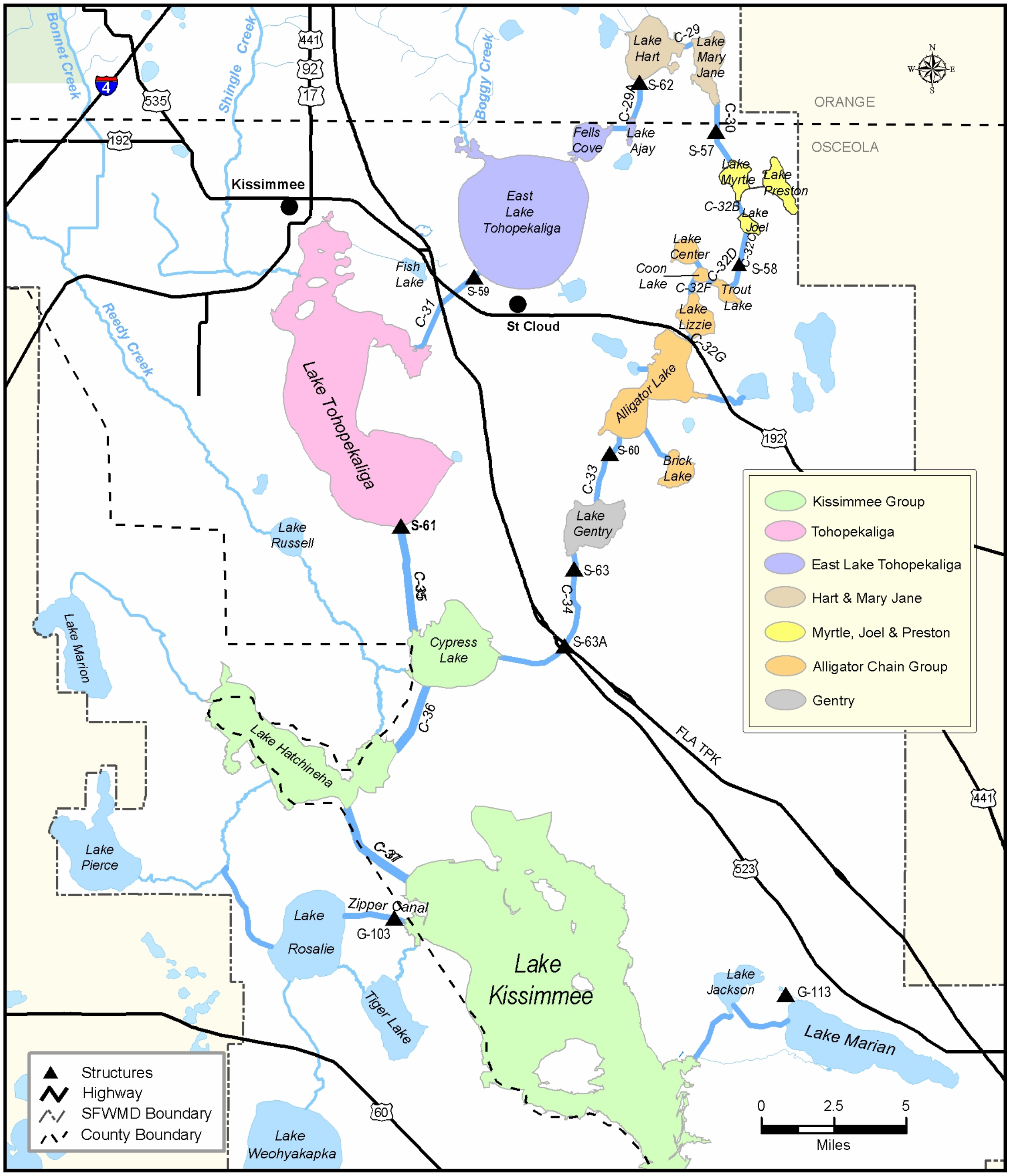

Figure 11-30. Lake Management Areas used in the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP).

In addition, management goals and objectives have been linked to performance measure targets, and missing/needed performance targets have been identified. A goal of either sustaining or enhancing has been identified for each of the LMAs. Although the panel suggested targets be specified for each LMA, it was determined that there presently is not enough information to do so. Instead, issues and concerns specific to each LMA have been identified and used to rank the LMAs with the respect to the level of difficulty for future management. This ranking takes into consideration the fish and wildlife value of the resources as well as the current challenges being faced relative to the goals for sustaining or enhancing the resource.

The KCOL LTMP Data Collection and Monitoring and System Assessment described in the 2007 technical basis for the KCOL LTMP (SFWMD, 2007b) has been further developed into a monitoring and assessment program (SFWMD, 2008d), which includes three types of monitoring that link to areas of reporting required for effective management decision making. The three types of monitoring include (1) long-term monitoring to assess whether management objectives are being met, (2) monitoring to assess the effectiveness of management actions, and (3) monitoring to improve our understanding of ecosystem functions and processes. Long-term monitoring is conducted routinely to assess the current condition of the lakes and to examine trends. Although such monitoring may be used to assess management effectiveness, additional monitoring may be needed for specific purposes. This typically begins before the management action is implemented to establish a baseline condition. The duration of data collection depends on the expected time of response following the action taken. Monitoring to assess management effectiveness may take the form of a quasi-experimental design if some lakes (or areas within a lake) are subjected to treatment while others are left alone. The third type of monitoring is intended to improve understanding of ecosystem processes and functions. This is intended to fill information gaps concerning key attributes of the lakes and their watersheds. Data collected can be used to recommend improvements to existing targets for these attributes or to support establishment of new targets.

Results and recommendations from these three types of monitoring activities will be assembled into an annual system assessment report that will help resource managers make appropriate adjustments to management and monitoring programs. System assessments will be performed annually and will compare ecosystem conditions with performance measure targets. The system assessment report will provide information in a form suitable for decision making, adaptive management, and determination of management success. The report will be presented annually to the interagency team. Key recommendations and concerns will be highlighted to notify the interagency team to management actions or corrections that need to be made.

The proposed adaptive management process for the KCOL is shown in **Figure 11-31**. The adaptive management process relies on the monitoring and assessment program to collect data and assess conditions and response to management actions. Once issues are identified by stakeholders or through the monitoring and assessment program, the interagency team will be called to a “special session” to assess the problem and determine whether management actions are required. If management action is required, the interagency team will promote its concerns and the technical basis for the proposed management action to the appropriate decision makers to gain authorization to allocate resources toward implementation of the proposed management action.

The science team will then evaluate the uncertainties associated with both the issue and the management action, and develop an appropriate set of monitoring criteria to support the assessment for effectiveness of the management action. Ecosystem response will be monitored and evaluated to determine whether a given management action is producing the desired response and/or outcome. If the desired response/outcome does not occur, then the data collected and the uncertainties identified will be evaluated to determine whether and/or how the management action might be adjusted. If this does not produce the desired response/outcome, then the process begins again with an assessment of why the desired response, outcome, or objective is not being achieved.

The final component of the revised KCOL LTMP is an agency action plan describing how the partner agencies will integrate current programs and activities, align them with KCOL LTMP management goals and objectives, and propose new management measures for consideration. The KCOL LMTP will be updated in five-year cycles. Implementation success will depend on the partner agencies agreeing to make resource commitments to the monitoring and assessment program as well as the adaptive management framework.

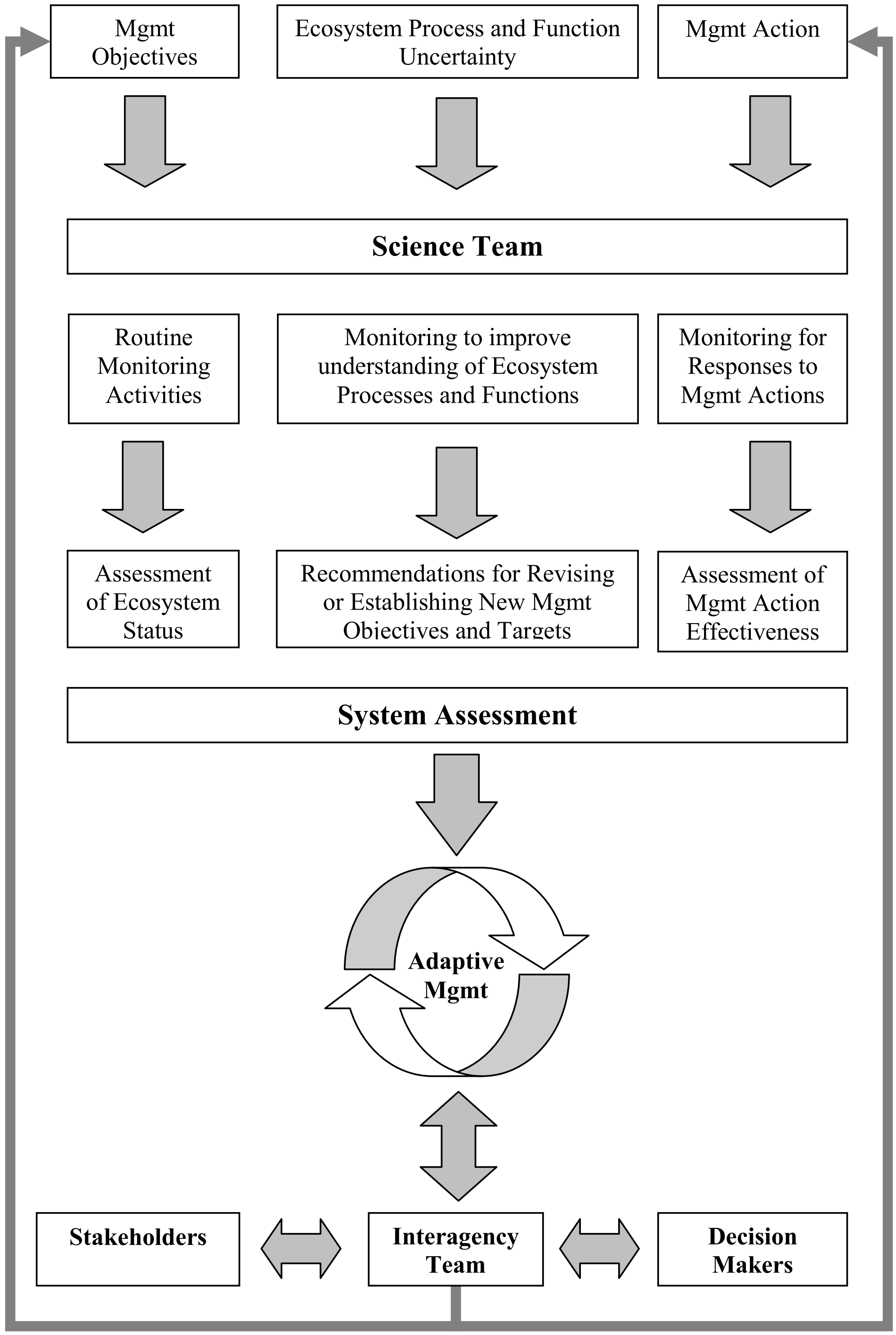

Figure 11-31. The proposed adaptive management process for the KCOL LTMP. The adaptive management process relies on the monitoring and assessment program to collect data and assess conditions and responses to management actions.

Three Lakes Wildlife Management Area Restoration

The FWC proposed the Hydrologic Restoration Project of the Three Lakes Wildlife Management Area (WMA) within the framework of the KBMOS. The project, which is being executed by the SFWMD in cooperation with the FWC, has the goal of restoring more natural hydrology and wetland function in the Three Lakes WMA, located near Lake Marian in the Upper Kissimmee Basin (**Figure 11-32**). The WMA encompasses 61,580 acres and supports one of the highest densities of bald eagles in the lower 48 states. The project includes four phases:

- **Phase I – Hydrologic Assessment**: Compile data and prepare recommended modeling approach for the Three Lakes WMA (completed in February 2007).
- **Phase II – Modeling Work Plan Implementation**: Develop the modeling tool to formulate, evaluate, and rank alternatives; develop and evaluate alternative plans; and select the preferred alternative.
- **Phase III – Project Design and Permitting**: Prepare design documents (plans and specifications) for the permitting and implementation of the preferred alternative.
- **Phase IV – Construction and Construction Support Services**: Implement the preferred alternative.

The contributing sub-watersheds within the Three Lakes WMA are hydraulically connected to Lake Kissimmee through the G-111 structure and the Jackson Canal. The major hydrologic components included in the study are Lake Marian, Lake Jackson, Fodderstack Slough, Parker Slough, Jackson Canal, and isolated wetlands connected to the system through the water table.

Phase II was initiated in May 2007 and is scheduled for completion by the end of 2008. To date, three public meetings have been held to inform area residents about the project and to solicit input for performance measures and alternative plans. Development and calibration of the modeling tools and performance measures have been completed. Eight alternative plans have been developed and are currently being evaluated and ranked.

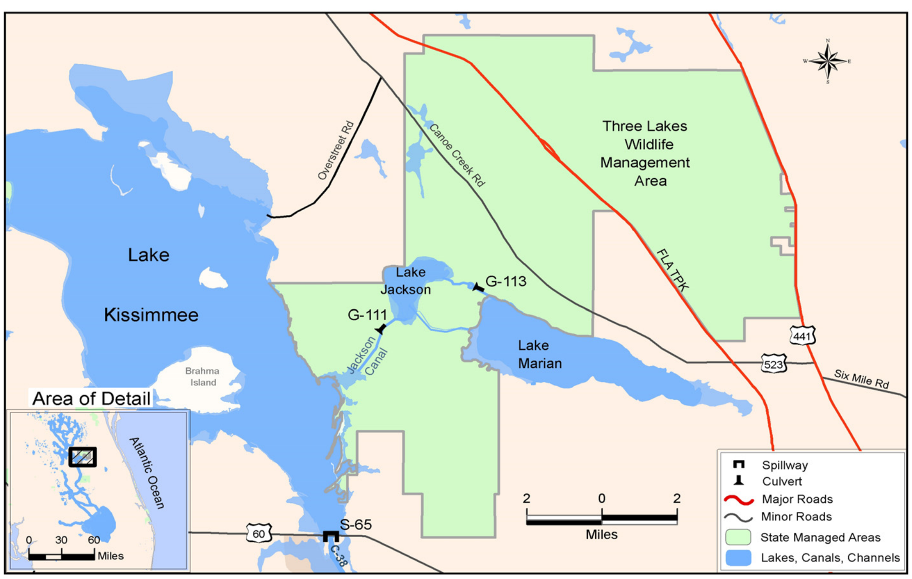

Figure 11-32. Boundaries for the Three Lakes Wildlife Management Area.

Rolling Meadows/Catfish Creek Wetland Restoration

Rolling Meadows Ranch lies along the south shore of Lake Hatchineha. The property was purchased by the SFWMD and FDEP as part of the Kissimmee River Restoration Project. The restoration plan identifies the restoration of approximately 2,300 acres of wetlands, possibly fed by water from Lake Hatchineha, when lake stage exceeds a certain elevation and from Catfish Creek, which flows through the property. The impounded wetland will be managed to mimic the natural hydroperiod of the lake and will provide enhanced wetland habitat for wildlife. The upland area outside the impounded wetland may be incorporated into the Lake Kissimmee State Park, which is operated by the FDEP.

To assess how water will be delivered to the impoundment, hydrologic modeling of Catfish Creek was completed, as documented in the Catfish Creek Wetland Restoration Study Hydrologic and Hydraulic Modeling Report in March 2004 (SFWMD, 2004). This report provided several water delivery alternatives. A subsequent contract included additional modeling as well as gathering of historical data, geotechnical work, a water budget, site characterization, and a list of alternative restoration plans for the Rolling Meadows/Catfish Creek property. This report was completed in September 2007 (HNTB Corp. et al., 2007). The preferred alternative includes several diversion structures, adjustable weirs, and restoration of a remnant stream bed which is likely part of the historical Catfish Creek flow-way (**Figure 11-33**). The statement of work for the final design is currently in development. This contract will include all remaining modeling and engineering needed for construction of the project. The final design contract is anticipated to be initiated in late FY2008 or early FY2009.

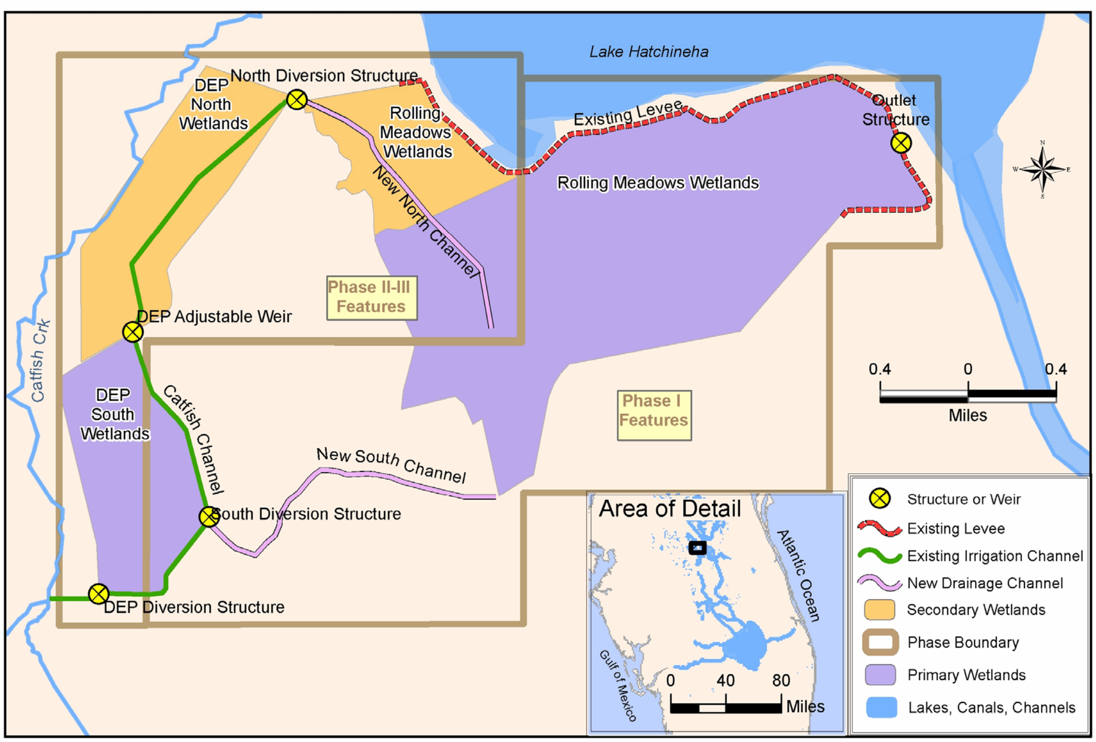

Figure 11-33. Diagram of the preferred alternative for Rolling Meadows/Catfish Creek restoration.

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