Chapter 11: Kissimmee Basin

Bradley L. Jones, Stephen G. Bousquin, David H. Anderson, David J. Colangelo, Lawrence Spencer, Joseph W. Koebel Jr., Michael D. Cheek, José Valdés, Brent Anderson and Christine Carlson

Contributors: Bonnie Rose Ibsen, Kevin Carter, Steffany Gornak, Lynda Dirk[1], Maura Merkal and Lawrence Glenn III

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 system. In the 1960s, the Central and Southern Florida Flood Control (C&SF) Project modified the Kissimmee Basin's water resources extensively by constructing canals and installing water control structures to achieve flood control in the Upper and Lower Kissimmee basins. In the Lower Kissimmee Basin, construction of a 56-mile-long canal through the Kissimmee River resulted in profound ecological consequences caused by elimination of flow in the original river channel and prevention of seasonal floodplain inundation. 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 authorizing the federal/state Kissimmee River Restoration Project (KRRP).

The South Florida Water Management District (SFWMD or District) has been working since the 1990s to coordinate and evaluate the KRRP and associated projects. More recently, the District has worked to integrate the KRRP with various management strategies for the Kissimmee Basin and the Northern Everglades region. The primary goals of these efforts are to (1) restore ecological integrity to the Kissimmee River and its floodplain; (2) conduct ecological monitoring for restoration evaluation; (3) develop a long-term management strategy for resolving water and other management issues in the Kissimmee Chain of Lakes; and (4) retain the existing level of flood control in the Kissimmee Basin. In addition to the KRRP, major initiatives designed to meet these goals are the Kissimmee Basin Modeling and Operations Study, the Kissimmee Basin Water Reservations, and the Kissimmee Chain of Lakes Long-Term Management Plan.

Construction of the KRRP is on schedule with completion slated for late 2014. In Water Year 2010 (WY2010) (May 1, 2009–April 30, 2010), Phase IVB backfilling of the C-38 canal was completed. Phase IVB is the northernmost phase of backfilling and involved filling 4 miles of the

[1] Florida Atlantic University, Boca Raton, FL

canal in Pool B and recarving 4 miles of river channel, which reestablished flow to 6 miles of reconnected river channel. Other contract activities included the S-68 spillway addition (Lake Istokpoga outlet) and Istokpoga Canal improvements, the latter of which included replacing a water control structure and constructing a public boat ramp. In the Upper Kissimmee Basin, the U.S. Army Corps of Engineer's contract to widen the C-37 canal was put on a fast track through funding available from the federal American Recovery and Reinvestment Act. Widening of the canal will provide greater conveyance capacity between Lake Hatchineha and Lake Kissimmee.

Other activities included continuation of technical criteria development for Kissimmee Basin Water Reservations, continued ecological monitoring of KRRP Phase I responses, and collection of baseline data for Phase II/III of the KRRP. In addition, work resumed on evaluating modified structure operations and finalizing the management plan for the Kissimmee Chain of Lakes.

Because of rapid population growth in the Kissimmee Basin, the limit of sustainable water withdrawal from the Floridan aquifer is expected to be reached in 2013. At its June 2008 meeting, the District's Governing Board approved a resolution to begin rule development for the reservation of water necessary for the protection of fish and wildlife in the Kissimmee River, its floodplain, and the Kissimmee Chain of Lakes. In 2008–2009, the technical document to identify the water needed to protect fish and wildlife for all eight reservation water bodies in the Kissimmee Basin was drafted and peer-reviewed. These eight reservation water bodies are (1) the Kissimmee River and its floodplain, (2) Lakes Myrtle, Preston, and Joel, (3) Lakes Hart and Mary Jane, (4) East Lake Tohopekaliga, (5) Lake Tohopekaliga, (6) the Alligator Chain of Lakes, (7) Lake Gentry, and (8) Lakes Kissimmee, Cypress, and Hatchineha. The rule development process has included a series of public workshops to provide the public and stakeholders with information about the Water Reservation rulemaking process and technical results. Water Year 2010 activities in support of rule development included an investigation of water availability from East Lake Tohopekaliga.

During WY2010, Kissimmee Basin environmental conditions were strongly influenced by above-average rainfall, much of which fell during the dry-season months. The timing of rainfall did not allow the Kissimmee Chain of Lakes to refill until the dry season. Nevertheless, discharge from the Kissimmee Chain of Lakes was sufficient to inundate portions of the Kissimmee River floodplain for most of the wet season. As rainfall decreased at the end of the wet season, this discharge was reduced to about 300 cubic feet per second, and water levels in the Kissimmee River decreased until all flow was carried by the river channel. In mid-January, higher discharge from the lakes resulted in bank overflow and inundation of the floodplain for the remainder of the dry season.

Monitoring of ecological responses to Phase I restoration construction continued in WY2010. The *Kissimmee River Restoration Evaluation Program: Updates from Phase I Monitoring Studies* section of this chapter presents new data from several monitoring studies, including river channel and floodplain hydrology; river channel dissolved oxygen concentrations; phosphorus loads and concentrations; and responses of floodplain vegetation, freshwater bivalves, wading birds, and waterfowl. Continuous inflow from the Upper Kissimmee Basin, which has not always been possible since the completion of Phase I in 2001, was maintained in WY2010. The seasonality of flow continued to exhibit a more natural pattern. Analysis of water level fluctuations along the length of the river shows the influence of a backwater effect caused by the S-65C structure. Implementation of a new water regulation schedule (the Headwaters Revitalization Schedule) in 2015 and removal of S-65C in the next phase of restoration construction are expected to provide more operational flexibility to meet the hydrologic requirements of river and floodplain restoration.

Concentrations of dissolved oxygen (DO) in the river channel within the restoration area continued to show improvement. Two components of the DO performance measure met expected values in WY2010. The mean daytime, near-surface DO concentration during the dry season was within the expected range [5–7 milligrams per liter (mg/L)], and the mean daytime concentration within 1 meter of the channel bottom was greater than (>) 1 mg/L for 97 percent of the time, exceeding the restoration expectation of 50 percent. Concentrations with regard to the other two components (mean daytime, near-surface DO concentration in the wet season, and percent of mean daily DO concentrations > 2 mg/L) fell slightly short of their expected values. The final determination of restoration success with respect to DO will be made after the restoration project is completed.

Total phosphorus (TP) loads and flow-weighted concentrations in the C-38 canal have declined since WY2005 when water quality was affected by hurricanes. However, TP loads and concentrations are still higher than pre-Phase I values. In WY2010, the TP load at the S-65E structure, which is south of the restoration area and discharges into Lake Okeechobee, was 141 metric tons. This load was 29 percent of the lake's total load of 478 metric tons.

A vegetation map of the KRRP area, based on 2008 aerial imagery, was completed in WY2010 and compared to previous maps dating back to 1952. After restoration construction, wetland plant communities reestablished rapidly and continued to increase in areal coverage. Wetland vegetation increased from 2,700 acres in 1974 (25 percent of the Phase I and Phase IVA floodplain) to over 8,900 acres (83 percent) in 2008. Wet prairie and wetland shrub communities expanded greatly. However, the area of broadleaf marsh, which was the dominant vegetation type prior to river channelization, increased only slightly. Much of the area that was historically broadleaf marsh was covered with the two other vegetation types. Also, wetland shrub dominated by the invasive exotic primrose willow (*Ludwigia peruviana*) persisted near the S-65C structure due to relatively stable water levels. Removal of the S-65C structure and implementation of the Headwaters Revitalization Schedule is expected to drive further changes in the relative abundance of vegetation types, including increasing the extent of broadleaf marsh in lower elevations of the floodplain.

The abundance of the nonnative Asian clam (*Corbicula fluminea*) and the apparent lack of native bivalves in the Kissimmee River soon after completion of Phase I construction raised questions about possible interactions between *C. fluminea* and native bivalves. Results from an informal sampling in 2010 suggest that native bivalve populations can establish and co-occur with *C. fluminea* despite early colonization of the Phase I area by *C. fluminea*.

Seven wading bird nesting colonies were surveyed during 2010, three of which occurred near the Kissimmee River. The other colonies were observed in Lake Mary Jane (one), Lake Kissimmee (two), and Lake Istokpoga (one). Compared to the 2009 nesting effort, 2010 showed an increase due to a higher number of cattle egret (*Bubulcus ibis*) nests. However, as cattle pasture is restored to wetland habitat along the Kissimmee River, cattle egrets are expected to decline, and aquatic wading birds are expected to increase. The largest of the seven colonies, composed mostly of white ibis (*Eudocimus albus*), was observed on Rabbit Island in Lake Kissimmee. The continued small numbers of aquatic wading birds nesting within the Kissimmee River floodplain suggest that prey availability is not yet sufficient to support successful breeding. High water levels most likely hindered breeding in this area as well. During the WY2010 dry season, water levels within the floodplain were too deep for wading bird foraging during a time when most wading birds initiate breeding.

Wading bird and waterfowl abundance also was estimated in WY2010 through aerial surveys. Wading bird abundance in the restoration area exceeded the restoration expectation of 30.6 birds per square kilometer (km^2). Record numbers of wood storks (*Mycteria americana*) were observed in the restoration area during October–January. Waterfowl abundance also exceeded its restoration expectation of 3.9 ducks/km^2. Blue-winged teal (*Anas discors*) and mottled duck

(*Anas fulvigula*) remained the two most commonly observed species, accounting for more than 95 percent of the observations.

Restoration evaluation scientists continued to collect baseline data in preparation for the next major phase of restoration construction, Phase II/III. A subset of metrics from these studies will be optimized for correlative analyses under the Phase II/III Integrated Studies. Monitoring to track ecological responses to Phase II/III includes studies of hydrology, water quality (nutrients and dissolved oxygen), geomorphology, river channel and floodplain vegetation, and aquatic invertebrate, herpetofauna, fish, and bird communities. The Kissimmee River hydrologic monitoring network expanded into Pool D in WY2009, and monitoring continued in WY2010. The enhanced hydrologic monitoring network is providing additional data for the evaluation of hydrologic restoration expectations and will support other evaluation studies, especially those associated with the Phase II/III Integrated Studies. It is also being used for operational decision making in the Lower Kissimmee Basin. Other efforts in WY2010 included completion of a plan for assessing the effect of the KRRP on nutrient transport and retention, and a report on geomorphic studies.

In brief, the main accomplishments and findings of the Kissimmee Basin projects in WY2010 are as follows:

- Phase IVB of backfilling for the KRRP was completed, a new boat ramp was built on the Istokpoga Canal, and progress was made on construction of a new water control structure in the Istokpoga Canal and widening of the C-37 canal in the Upper Kissimmee Basin.
- Additional technical work was performed to identify water required for the protection of fish and wildlife in the East Lake Tohopekaliga Lake Management Area.
- Operations under the interim water regulation schedule succeeded in maintaining continuous inflow to the Kissimmee River in WY2010.
- Monitoring of the environmental response to KRRP Phase I construction continued. In WY2010, two components of the DO expectation exceeded expected values. Phosphorus loads and concentrations in the C-38 canal have continued to decline since WY2005, but are still above baseline levels. Coverage of wetland vegetation has increased, although the broadleaf marsh community is still under-represented. Wading bird nesting increased in WY2010, but spring water levels on the Kissimmee River floodplain were not optimal for breeding. Wading bird and waterfowl abundance in the Kissimmee River restoration area was greater than in WY2009 and exceeded restoration expectations.
- Collection of baseline data continued for evaluation of the next major phase of restoration construction (Phase II/III) in Pool D of the Kissimmee River. Data collections include monitoring of hydrology; water quality (nutrients and dissolved oxygen); geomorphology; river channel and floodplain vegetation; and aquatic invertebrate, herpetofauna, fish, and bird communities.

INTRODUCTION AND BACKGROUND

Responding to the need for increased integration and coordination of management activities at basin and watershed scales, the South Florida Water Management District (SFWMD or District) has expanded its mission and geographic focus in the Kissimmee Basin since the 1990s, when coordination and evaluation of the Kissimmee River Restoration Project (KRRP) was the main concern. Since then, following management and Governing Board direction, the SFWMD 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 regional modeling tools to enhance water management operations, and (3) development of a long-term plan to address management of the Kissimmee Chain of Lakes (KCOL).

This chapter is an update to Chapter 11 of the *2010 South Florida Environmental Report* (SFER) – *Volume I* (SFWMD, 2010), 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) studies, (3) descriptions of recent planning efforts, and (4) brief status updates on projects and other program activities during Water Year 2010 (WY2010) (May 1, 2009–April 30, 2010). The Kissimmee Basin is depicted in **Figures 11-1** and **11-2**.

The chapter is organized into four main sections:

- The *Introduction and Background* section briefly summarizes the KRRP and other 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 (SFWMD, 2008a, Chapter 11).
- The second major section, *Cross-Watershed Activities*, describes issues that span the boundaries between the Kissimmee Basin and downstream ecosystems. This section includes subsections on (1) water management and operations, (2) development of Water Reservations for the Kissimmee River and KCOL, and (3) water quality programs in the Kissimmee Basin related to Lake Okeechobee phosphorus management.
- The third major section, *Kissimmee Basin Hydrologic Conditions*, summarizes environmental conditions in the Kissimmee Basin during WY2010. It emphasizes basin hydrologic conditions relative to water management decisions during the water year. During WY2010, hydrologic conditions in the Kissimmee Basin were strongly influenced by above-average dry season rainfall resulting from El Niño.
- The final major section, *Project Updates*, is devoted to presentations of monitoring data, status reports on current projects, and descriptions of planning activities for new initiatives. This section includes (1) newly available Phase I restoration response data from the KRREP; (2) progress on Phase II/III restoration evaluation studies and pilot studies; and (3) status updates on KRRP construction, the Kissimmee Basin Modeling and Operations Study (KBMOS), and other projects within the basin.

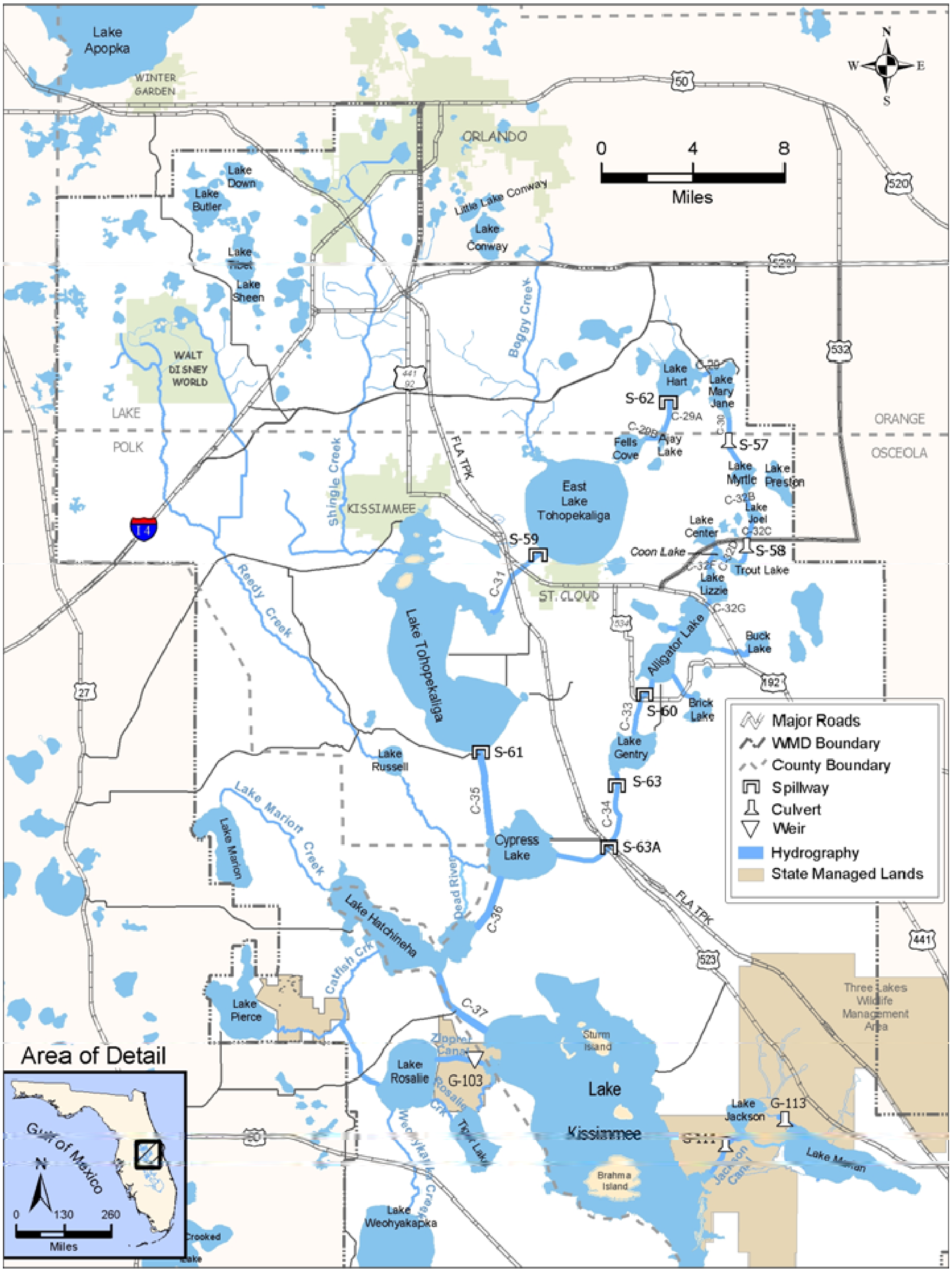


Figure 11-1. The Upper Kissimmee Basin.

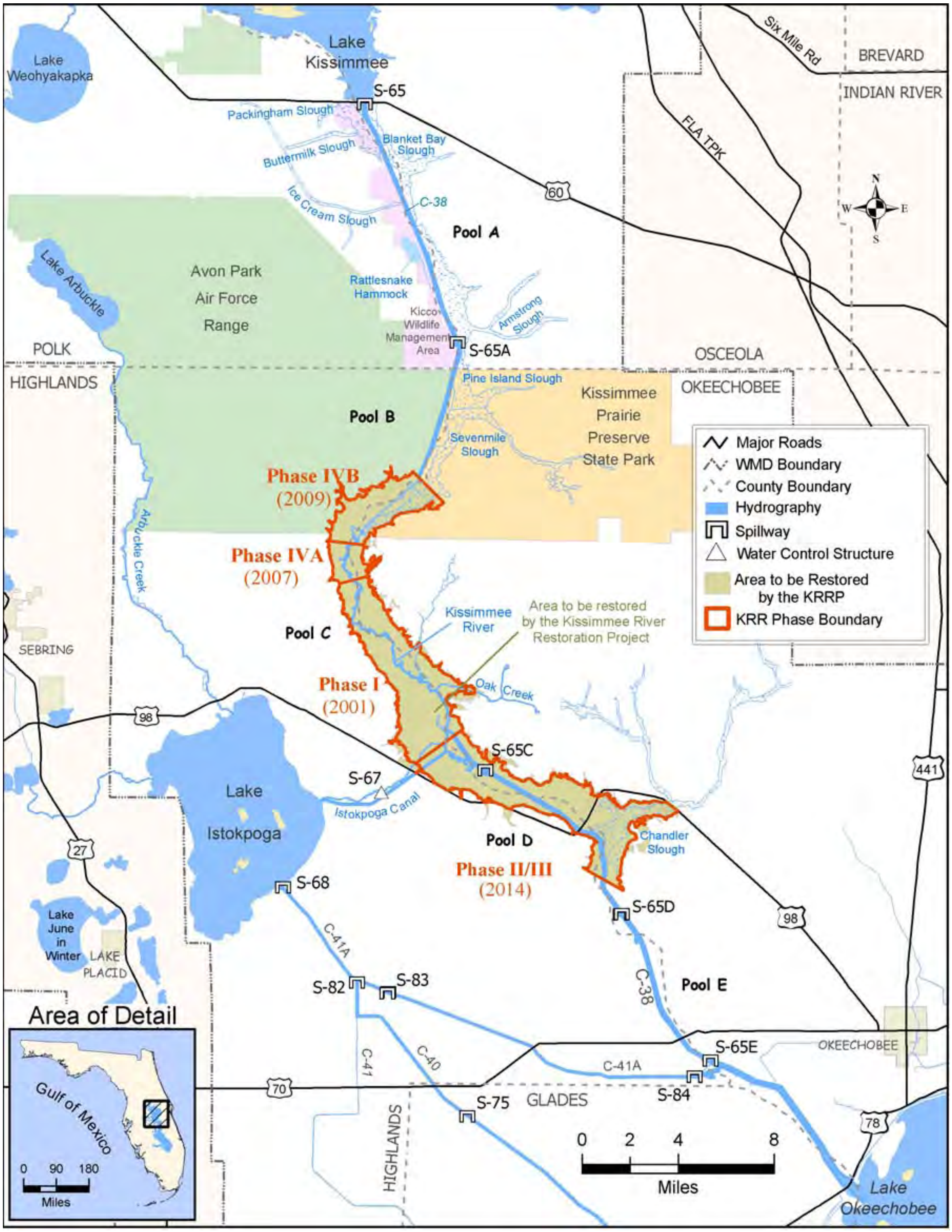


Figure 11-2. The Lower Kissimmee Basin.

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 KRRP. The goal of this project is to restore ecological integrity (i.e., a self-sustaining ecosystem comparable to the natural habitat of the region) (SFWMD, 2005a, Chapter 1) to the Kissimmee River and its floodplain. Successful restoration of the Kissimmee River is largely dependent on reestablishing hydrologic conditions that are similar to the pre-channelization period (Toth, 1990). A headwaters component of the project is designed to provide sufficient storage in headwater 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 Lakes Kissimmee, Hatchineha, Tiger, and Cypress (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.

In the Lower Kissimmee Basin, the KRRP is 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 square miles (mi^2) [101 square kilometers (km^2)]. More than 20 mi^2 (52 km^2) of new wetlands will reestablish in areas that were drained by the canal, and 40 miles (mi) [64 kilometers (km)] of reconnected river channel will receive reestablished flow. In the Upper Kissimmee Basin, over 7,000 acres (ac) [2,800 hectares (ha)] of littoral marsh are expected to develop on the periphery of the four lakes regulated by water control structure S-65 (USACE, 1996). The KRRP, which includes the KBMOS (described in the following section, *A Basin Perspective*), is funded under a 50/50 cost-share agreement between the SFWMD and the U.S. Army Corps of Engineers (USACE). Engineering and construction components of the project are the responsibility of the USACE, while the District's purview is land acquisition and ecological evaluation of the restoration project.

Restoration components include (1) acquiring 65,603 acres of land in the Lower Kissimmee Basin, of which approximately 98 percent have been acquired to date; (2) backfilling a total of approximately 22 mi (35 km) of the 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 the C-38 canal. Composed primarily of sand and coarse shell, this material was deposited in large spoil mounds adjacent to the canal.

Reconstruction of the river/floodplain's physical template is being implemented in four phases currently projected for completion by late 2014 (**Table 11-1**). Phase I construction of the KRRP was completed in February 2001. Approximately 7.5 mi (12 km) of flood control canal were backfilled in Pool C and the southern portion of Pool B, nearly 1.3 mi (2 km) of river channel that had been obliterated during canal construction were recarved, and water control structure S-65B was demolished. These efforts reestablished flow to 14 mi (23 km) of continuous river channel and allowed for intermittent inundation of 5,792 ac (2,344 ha) of floodplain.

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

Construction Sequence	Name of Construction Phase	Timeline	Backfilled Canal (miles)	River Channel Recarved (miles)	River Channel to Receive Reestablished Flow (miles)	Total Area (acres)	Wetland Gained (acres)	Location and Other Notes
1	Phase I Project Area	1999–2001 (complete)	8	1	14	9,506	5,792	Most of Pool C, small section of lower Pool B
2	Phase IVA Project Area	2006–2007 (complete)	2	1	4	1,352	512	Upstream of Phase I in Pool B to Weir #1
3	Phase IVB Project Area	2008–2009 (complete)	4	4	6	4,183	1,406	Upstream of Phase IVA in Pool B (upper limit near location of Weir #3)
4	Phase II/III Project Area	2012–2014 (projected)	9	4	16	9,921	4,688	Downstream of Phase I (lower Pool C and Pool D south to CSX Railroad bridge)
	Restoration Project Totals		**22**	**10**	**40**	**24,963**	**12,398**	

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 (207 ha) of floodplain wetlands. Phase IVB, upstream of Phase IVA, began in 2008 and was finished ahead of schedule in December 2009. Phase II/III, the last phase of construction, is scheduled to begin in 2012 and projected to be completed in late 2014. While the restoration phases were originally named in the order of expected completion, the sequence has changed over the years for logistical reasons (i.e., budgetary considerations, coordination with land acquisition, or ease of access).

The KRRP will culminate with the 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 lake 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). Approximately 97 percent of the 36,612 acres of land in the Upper Kissimmee Basin that will be impacted by the higher water levels have been acquired, and all projects to increase the conveyance capacity of canals and structures are in place to accommodate the larger storage volume, except the C-37 Canal Widening Project (see the *Kissimmee River Restoration Project Construction Activities* section of this chapter). The Headwaters Revitalization Schedule is scheduled for implementation in 2015 after the C-38 backfilling and other construction projects are 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 USACE authorized the District to make releases from 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 the KRRP Phase I construction 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).

A major component of the restoration project is the evaluation of restoration success through the KRREP, a comprehensive ecological monitoring program (SFWMD, 2005a; SFWMD, 2005b; SFWMD, 2007a). Evaluating the success of the KRRP is a requirement of the District's cost-share agreement with the USACE. Success is being tracked using 25 performance measures (SFWMD, 2005b) to evaluate how well the project meets its ecological integrity goal. Ecological integrity is defined as a reestablished 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 restoration expectations, are based on estimated conditions in pre-channelized river (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. 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. Monitoring for ecological evaluation of restoration success will continue for at least five years after construction is completed or until ecological responses have stabilized.

A BASIN PERSPECTIVE

After focusing on coordination and ecological evaluation of the KRRP in the 1990s, the District adopted a larger watershed perspective and expanded its focus to include more planning, modeling, and evaluation activities in the Kissimmee Basin. The key strategic priority that initiated this expanded effort was to integrate management strategies in the Kissimmee Basin with restoration of the Kissimmee River (SFWMD, 2006b). In line with this priority, the primary goals 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**, panels A and B), coordinated initiatives designed to meet these program objectives include the interagency Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP), which addresses fish and wildlife resources in the KCOL, including their natural resource dependencies and management issues and challenges (**Figure 11-3**, panel C); the KBMOS, which explicitly addresses hydrologic and management linkages between the Upper and Lower Kissimmee basins (**Figure 11-3**, panel D); and the Kissimmee Basin Water Reservations. Activities associated with these initiatives 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.

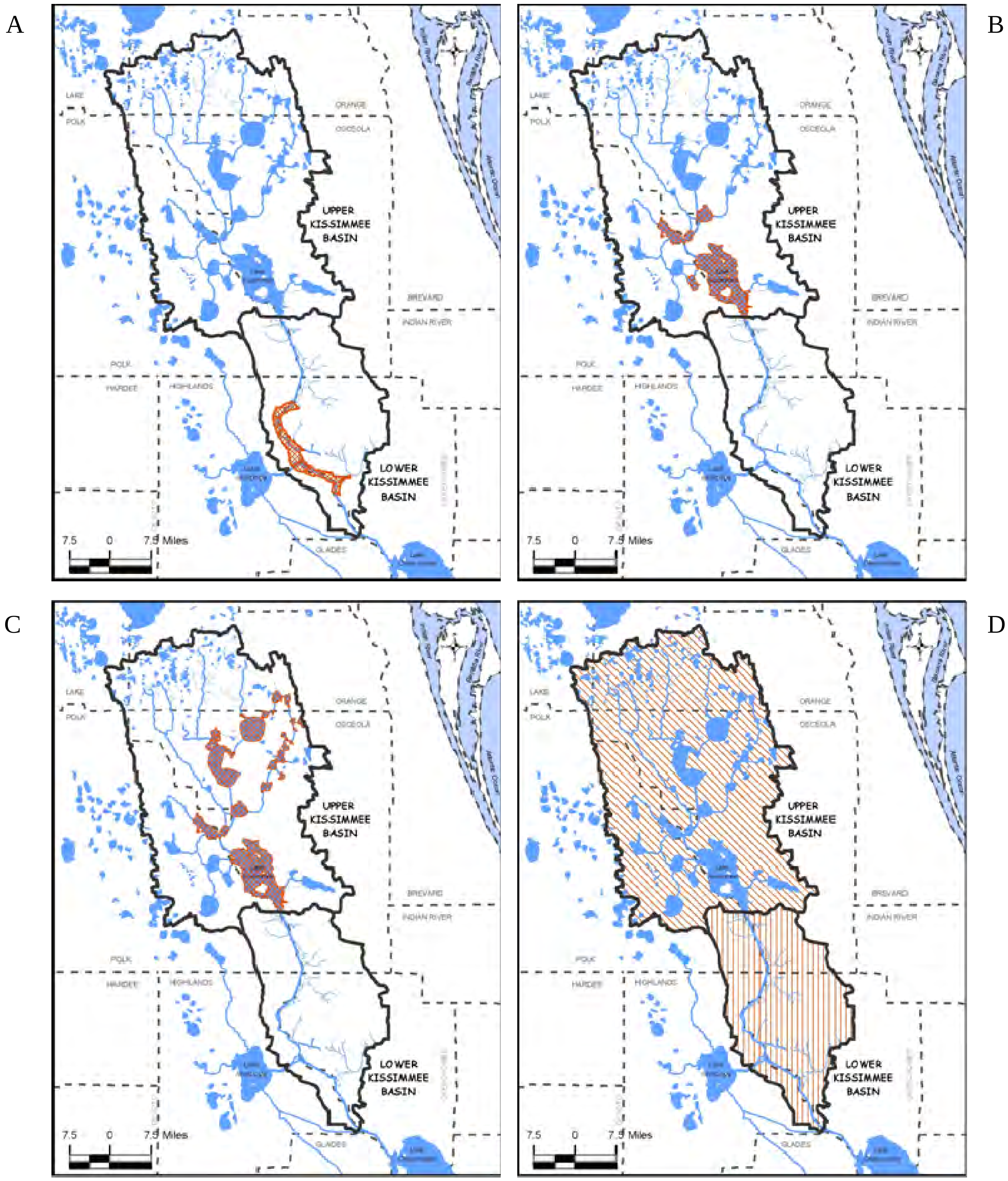


Figure 11-3. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) KRRP, (B) headwater lakes component of the KRRP, (C) Kissimmee Chain of Lakes Long-Term Management Plan, and (D) Kissimmee Basin Modeling and Operations Study and Kissimmee Basin Water Reservations.

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 SFWMD, which works to ensure close coordination among related projects. The SFWMD also works with other agencies to address watershed-scale water and natural system issues in regions that are hydrologically connected to the Kissimmee Basin. The SFWMD and these agencies are involved in many construction, planning, monitoring, evaluation, and modeling projects needed to address watershed-scale issues. This section focuses on these activities, specifically in the areas of water management, water quality, and water supply.

WATER MANAGEMENT, OPERATIONS AND COORDINATION

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 connects the KCOL (**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 (C&SF) Flood Control Project that provides flood control and water supply for 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 Kissimmee-Okeechobee-Everglades (KOE) system regulated by the C&SF Project. This coordination is achieved through weekly interagency meetings between the SFWMD staff and USACE to review recent rainfall data, the climatological outlook, water levels, and system operations in the various parts of the KOE system, and the overall condition of the entire system. Based on this information, environmental recommendations can be made to modify operations within existing operational flexibility. Second, 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, an 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. The District was involved in temporary deviation requests for the extreme drawdown of Lake Tohopekaliga for fisheries habitat improvement in 2004, in modifying 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 recent 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 *Project Updates* section of this chapter).

KISSIMMEE BASIN WATER RESERVATIONS

The Central Florida region is experiencing rapid population growth, especially in the region of 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) [432,000 cubic meters per day (m^3/day)] in 2000 to over 235 mgd (890,000 m^3/day) 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 (SJRWMD) and Southwest Florida Water Management District (SWFWMD) — have determined that the limit of sustainable withdrawal from the Floridan aquifer will be reached in 2013, prompting the current investigation of alternative supplies, including withdrawals from surface waters. Potential withdrawal from the KCOL is of particular concern due to potential ecological impacts on the lakes and on Kissimmee River restoration.

At its June 2008 meeting, the SFWMD's Governing Board approved a resolution to begin rule development for the reservation of water necessary for the protection of fish and wildlife in the Kissimmee River, the river's floodplain, and the KCOL (eight reservation water bodies in total; **Figure 11-4**). A Water Reservation is a tool provided by Section 373.223(4), Florida Statutes (F.S.), which allows the water necessary for the protection of fish and wildlife to be reserved from use by permit applicants through a formal rulemaking process. In 2008–2009, the technical work to identify the water needed to protect fish and wildlife for all eight reservation water bodies was drafted and peer-reviewed. The draft technical report and the peer-review panel comments are available on the District's website at www.sfwmd.gov/watersupply. This technical work was performed by District staff who relied heavily on previous work done through the KRRP, the KRREP, the KBMOS, and the KCOL LTMP. It also made use of data published by the Florida Fish and Wildlife Conservation Commission (FWC) and the U.S. Fish and Wildlife Service (USFWS).

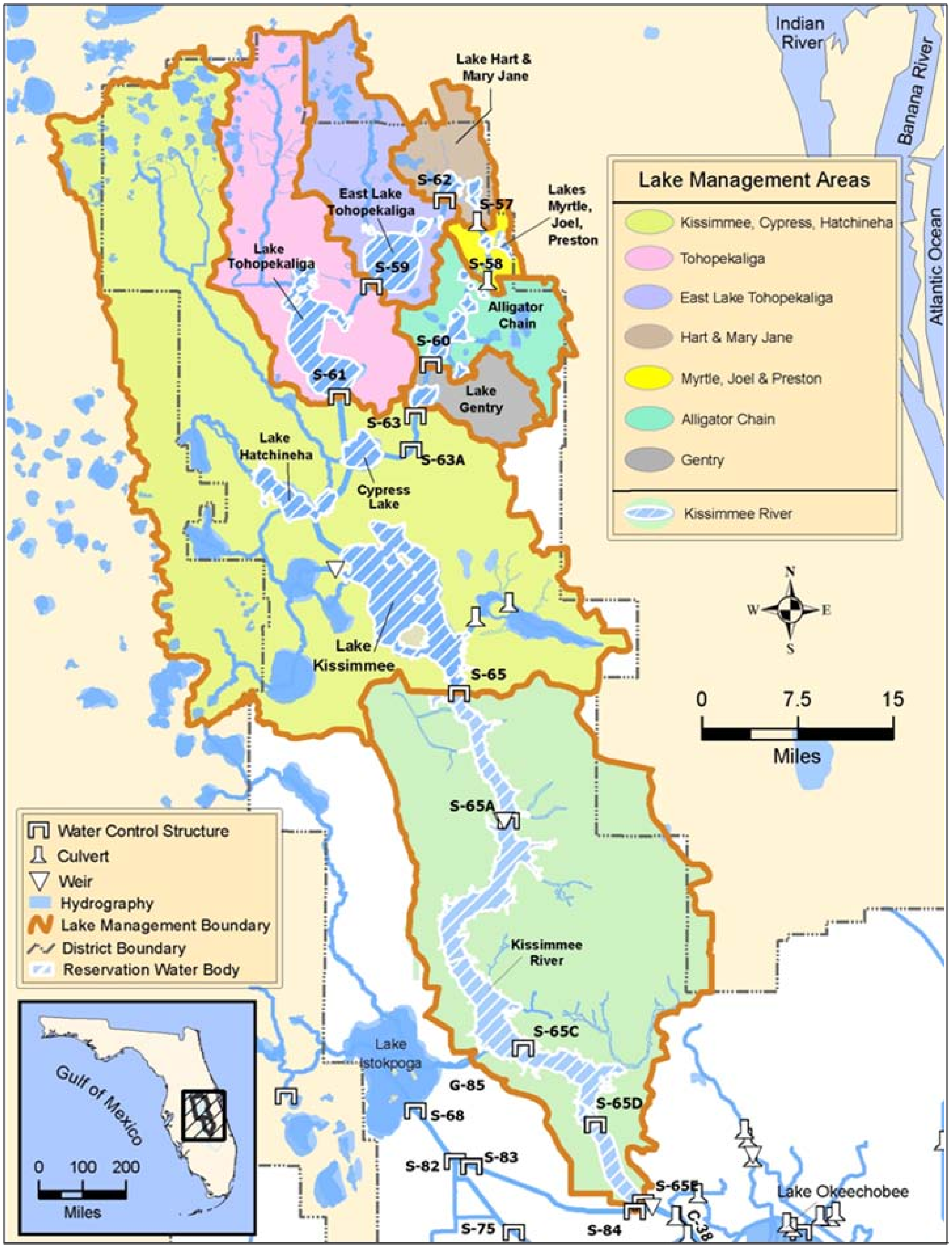


Figure 11-4. The eight Water Reservation water bodies in the Kissimmee Basin.

In 2009–2010, additional technical work was performed for East Lake Tohopekaliga. This work evaluated results from hypothetical withdrawal scenarios. A series of withdrawal scenarios were evaluated in a preliminary analysis to determine withdrawal and recovery criteria (AECOM, 2009). One set of these withdrawal and recovery criteria was used in the East Lake Tohopekaliga evaluation. Withdrawal quantities ranging from 5 to 30 mgd were tested.

A subset of performance measures derived from the KBMOS was used to identify potential natural system impacts (AECOM, 2010). These performance measures were used to evaluate how withdrawals changed the frequency and duration of extreme high, normal high, extreme low, and critically low stages and intra-annual variability in East Lake Tohopekaliga. The effect of withdrawals on downstream waters including the Kissimmee River was also evaluated.

Technical work in support of the rule development process is ongoing, and rule development is expected to continue into WY2011.

WATERSHED WATER QUALITY

Lake Okeechobee Watershed

The Kissimmee Basin lies entirely within the Lake Okeechobee Watershed as defined under the Northern Everglades and Estuaries Protection Program (NEEPP) (Section 373.4595, F.S.). The NEEPP requires that applicable water quality criteria be achieved and maintained in Lake Okeechobee and its tributary waters. The Lake Okeechobee Watershed Protection Plan (LOWPP), authorized under NEEPP (and its predecessor the Lake Okeechobee Protection Act) to address water quality issues, evaluates nutrient effects on the lake from the Kissimmee and other tributary basins. The LOWPP includes the S-65D and S-65E basins among its four priority basins in the Lake Okeechobee Watershed. These two basins include the lowermost pools and still-channelized sections of the Kissimmee River. The NEEPP requires that the LOWPP be reevaluated every three years to determine if further phosphorus load reductions are needed to achieve the Total Maximum Daily Load (TMDL). The next reevaluation report will be submitted to the Florida legislature in 2011.

The NEEPP encompasses the Caloosahatchee and St. Lucie rivers and estuaries in addition to the Lake Okeechobee Watershed. In accordance with this legislation, the coordinating agencies, consisting of the SFWMD, Florida Department of Environmental Protection (FDEP), and Florida Department of Agriculture and Consumer Services (FDACS), developed a technical plan for Phase II of the Lake Okeechobee Watershed Construction Project and river watershed protection plans for the Caloosahatchee and St. Lucie watersheds (SFWMD et al., 2008; SFWMD et al., 2009a, b). These plans are intended to augment and enhance restoration currently under way in the remnant Everglades south of the lake. The NEEPP provides a vehicle for meeting the Kissimmee Basin's portion of the TMDL for Lake Okeechobee.

Kissimmee Basin

Monitoring of nutrient loading from the Kissimmee Basin to Lake Okeechobee is reported in Chapter 10 of this volume. 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 WY2010, the entire Kissimmee Basin (both Upper and Lower sub-watersheds) contributed 141 metric tons (mt) of total phosphorus (TP) to Lake Okeechobee, or 29 percent of the total lake load of 478 mt (see Chapter 10 of this volume). This amount is slightly less than the Kissimmee Basin's average annual loading of 169 mt during the 1991–2005 LOWPP baseline period, which was 31 percent of the total lake load (549 mt) during that period (SFWMD et al., 2008).

Although the population of the Orlando-Kissimmee-St. Cloud region has grown rapidly, the Kissimmee Basin is still primarily rural. As of 2006 (SFWMD et al., 2008), only 5 percent of the Lower Kissimmee Sub-watershed was urban and the rest was predominantly agricultural (45 percent), natural (34 percent), and woodland/rangeland (15 percent). In the Upper Kissimmee Sub-watershed, urban areas comprised 20 percent of land use and most of the remaining area was agricultural (23 percent), natural (52 percent), and woodland/rangeland (4 percent). Most of the Upper Kissimmee Sub-watershed is in Osceola County, where residential and commercial development is taking place on large tracts of agricultural land, most of which was used to graze cattle. Nonpoint-source runoff of nutrients and other contaminants is the main water quality concern arising from this urban development because municipal wastewater treatment effluents have been diverted away from the surface water system to reclamation and irrigation facilities, rapid infiltration basins, and land spreading operations. However, it should be noted that the 2007 unit load estimate for TP from 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, loading from natural areas is 0.2 lbs/acre (SFWMD, 2007b).

Water Quality Management

Within the Kissimmee Basin, several agencies work to address water quality issues, including the FDEP, the FFDACS, the U.S. Environmental Protection Agency (USEPA), and the SFWMD. This section describes the current efforts of these agencies in the Kissimmee Basin.

As presented in more detail in Chapter 11 of the 2009 SFER (SFWMD, 2009), the FDEP identified elevated nutrient concentrations as a principal water quality issue in the Kissimmee Basin and verified 18 water bodies as impaired for nutrients (FDEP, 2006). The listing of verified impaired water bodies is the second of a five-phase TMDL process in the State of Florida (Chapter 403.067, F.S.; see www.dep.state.fl.us/water/tmdl/cycle.htm) and occurs after an initial basin assessment (the first phase). As part of a second cycle of evaluation, the FDEP issued a new verified list of impaired water bodies in November 2010 that identified additional nutrient impairments.

In 2011, the FDEP plans to develop draft TMDLs for some impaired water bodies, which is the third phase of the overall TMDL process. The main priority for TMDL development will be the status of a water body based on the schedule of a 1999 USEPA consent decree decision. For example, water bodies such as Lake Marian, Lake Jackson, Lake Kissimmee, and Lake Cypress may be a priority for TMDL development by the FDEP due to their initial listing on the 1998 303(d) list of verified waters. Because of the amount of impaired listings in the State of Florida (both the current FDEP lists and the USEPA's original 1998 list), it is probable that some future TMDLs in the Kissimmee Basin may not be developed until after 2011.

In general, the TMDL development involves determining the maximum amount of a given pollutant that a water body can assimilate and still meet its water quality standards. Water quality standards include a water body's designated use and the applicable numeric or narrative water quality criterion for pollutants. Water bodies in the Kissimmee Basin listed as impaired are designated as Class III water bodies and subject to the applicable state water quality criteria [see Chapter 62-302, Florida Administrative Code (F.A.C.)]. The methodology for determining whether a water body is impaired is described in the Impaired Waters Rule (Chapter 62-303, F.A.C.).

Because restoration of natural filtration, reaeration, and biological processes in the Kissimmee River is expected to improve water quality with respect to nutrients and dissolved oxygen (DO), the restored area of the river is exempt from TMDL development according to the state's Impaired Waters Rule. However, certain sections of the Lower Kissimmee Sub-watershed outside of the restoration project area have been identified as impaired for nutrients or DO, or both, and will have TMDLs developed. These sections include Blanket Bay Slough (Pool A drainage), the upper part of Oak Creek (Pool C drainage), an upland watershed in the Pool D drainage, and the S-154C sub-watershed below S-65E.

After a TMDL is developed and adopted into rule (Chapter 62-304, F.A.C.), the FDEP may develop and implement Basin Management Action Plans [(BMAPs), Phases 4 and 5 of the five-phase FDEP process] as a basis for reaching pollutant load reductions (Section 403.067, F.S.; see www.dep.state.fl.us/water/watersheds/bmap.htm). This process may include more detailed allocations among point and nonpoint sources of pollutant loading in the basin. In addition to any point and nonpoint sources of nutrients, allocations of nutrient loadings may 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, sites found to be contributing excessive nutrient inputs will likely be categorized as nonpoint sources of pollution. With extensive stakeholder input, BMAPs will be developed that contain final allocations, strategies for meeting the allocations, schedules for implementation, funding mechanisms, applicable local ordinances, and other elements.

The LOWPP and 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 Stormwater Treatment Areas (STAs). BMPs are mandatory unless an agricultural landowner monitors water quality and demonstrates that BMP implementation is not needed. In the Upper and Lower Kissimmee sub-watersheds, implementation of comprehensive source control measures is mandated by NEEPP 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 FDACS, FDEP, and SFWMD are expanding existing source control measures and developing new measures that include BMPs for agricultural and non-agricultural land uses, complementary to existing regulatory source control programs. Under the LOWPP, the SFWMD and FDACS initiated a coordinated effort to work with agricultural landowners within the Lower Kissimmee Sub-watershed to implement BMPs. The FDACS is also making progress in the Upper Kissimmee Sub-watershed. Landowners implementing conservation plans are being enrolled in the BMP program. In WY2010, the SFWMD continued to focus on rulemaking efforts that will expand the BMP rule to the Upper Kissimmee Sub-watershed. For additional details, see Chapter 4 of this volume.

Ambient Water Quality Monitoring

Since 1981, the SFWMD has maintained a long-term water quality sampling program in five major lakes of the KCOL (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, DO, and other constituents. One station is sampled at each tributary and up to three stations are sampled in each lake. Since 1973, the SFWMD has also sampled water quality in C-38 and/or lateral tributaries and remnant (non-flowing in the channelized system) and restored sections of river channel. In 2004, the SFWMD initiated additional sampling in the Kissimmee Basin under its Lake Okeechobee Watershed Assessment (LOWA) Program (see Chapters 4 and 10 of this volume). These stations are sampled for TP only. In the Upper Kissimmee Sub-watershed, 15 stations have been added at lake tributaries, connecting canals, and water control structures. In the Lower Kissimmee Sub-watershed, 43 stations are monitored within basins along the river.

Other sampling in the Kissimmee Basin has been conducted by the FWC, Florida Lakewatch, FDEP, USACE, U.S. Geological Survey (USGS), SWFWMD, Orange County, Polk County, Reedy Creek Improvement District, and City of Orlando. The FWC monitoring program 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. 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 *a*, and Secchi depth. The FDEP utilizes the Florida STORET database (http://storet.dep.state.fl.us/WrmSpa), which includes data from the FDEP and other sources, to prepare its water quality assessments for the TMDL program. Data were compiled from all available sources for its first assessment of the Kissimmee Basin in 2006. The SFWMD supplied over half of the data used in that assessment. The FDEP's second assessment was done in 2010.

Further information about water quality monitoring in the basin can be found in SFWMD (2005a, Chapters 4, 5, and 10), FDEP (2006), and SFWMD (2008b).

KISSIMMEE BASIN HYDROLOGIC CONDITIONS IN WATER YEAR 2010

RAINFALL

After three years of below-average rainfall in the Kissimmee Basin, WY2010 was a wetter year. Rainfall totaled 70.02 inches in the Upper Kissimmee Basin and 52.96 inches in the Lower Kissimmee Basin. These values are 141 percent and 103 percent of the long-term average (1971–2000) for the Upper Kissimmee and Lower Kissimmee basins, respectively. The wet season (June–October) experienced average rainfall, with the Upper Kissimmee Basin receiving 31.51 inches (105 percent of average) and the Lower Kissimmee Basin receiving 27.07 inches (95 percent of average). Much of the above-average rainfall occurred during the dry season, especially in the months of May and March (**Figure 11-5**). Rainfall was above average for the dry season, with the Upper Kissimmee Basin receiving of 38.51 inches (200 percent of average) and the Lower Kissimmee Basin receiving of 25.91 inches (114 percent of average). In the Upper Kissimmee Basin, rainfall during the dry season months of May and March accounted for 20 inches of total rainfall in WY2010 and about three-fourths of the increase above the annual average. The timing and quantity of rainfall were important factors in determining water levels and flows for the water bodies in the Kissimmee Basin.

TEMPORAL HYDROLOGIC PATTERNS

Temporal patterns of stage and discharge in the KCOL and the Kissimmee River reflect the seasonality of rainfall and seasonal changes in regulation schedules. During WY2010, the above-average rainfall during the dry season months was especially important. This section describes the temporal patterns for WY2010.

May 2009

In the Upper Kissimmee Basin, the spring recession began several months before the end of WY2009; therefore, lake levels were very close to the lowest stage of their respective regulation schedules at the beginning of WY2010. Rainfall in this region had been below average for the past six months of WY2009 (November–April), and relatively small discharges were needed to lower lake stages to meet the regulation schedule line (as illustrated for East Lake Tohopekaliga and Lake Tohopekaliga in **Figure 11-6**). However, above-average rainfall in May resulted in stage reversals in several lakes, such as East Lake Tohopekaliga, whose stage increased 1 foot (**Figure 11-6**, panel A), and Lake Tohopekaliga, whose stage increased approximately 2 ft (**Figure 11-6**, panel B).

Compared to East Lake Tohopekaliga and Lake Tohopekaliga, the stage reversal was much smaller in Lakes Kissimmee-Cypress-Hatchineha (**Figure 11-7**, panel B), whose stage was already below the regulation schedule line at the beginning of May, in part, because of discharges to meet the needs of the Kissimmee River. Later in the month, discharge at the S-65 structure increased to almost 5,000 cubic feet per second (cfs) when Lake Kissimmee's stage exceeded the regulation schedule line (**Figure 11-7**, panel C).

In the Lower Kissimmee Basin, the combination of increased rainfall and discharges at S-65 resulted in large stage reversals at site PC61 (5.75 ft) and site KRBN in the Kissimmee River (4.42 ft) (**Figure 11-8**). At the lower end of Pool C, site PC11 had a reversal of less than 1 foot. The stage at PC11 is regulated because the increase in stage was constrained by the regulated water levels at the S-65C structure.

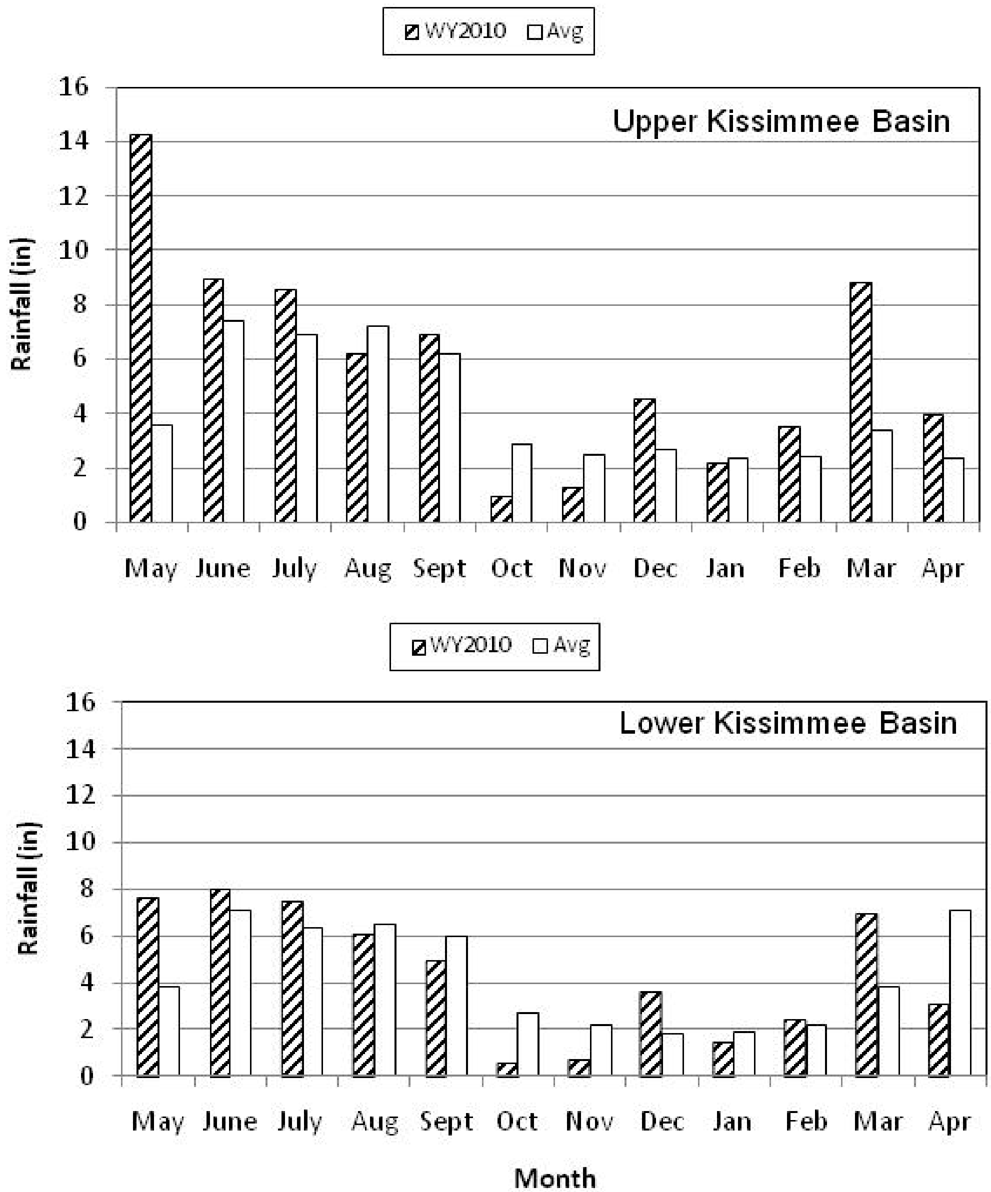
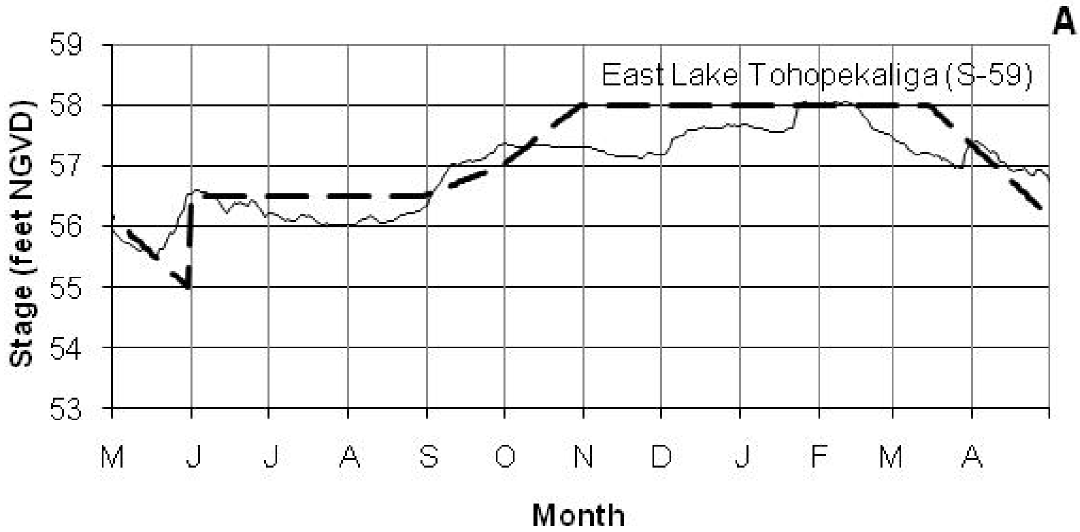


Figure 11-5. Monthly rainfall for WY2010 (May 1, 2009–April 30, 2010) and average rainfall (1971–2000) in the Upper Kissimmee Basin (top) and the Lower Kissimmee Basin (bottom).



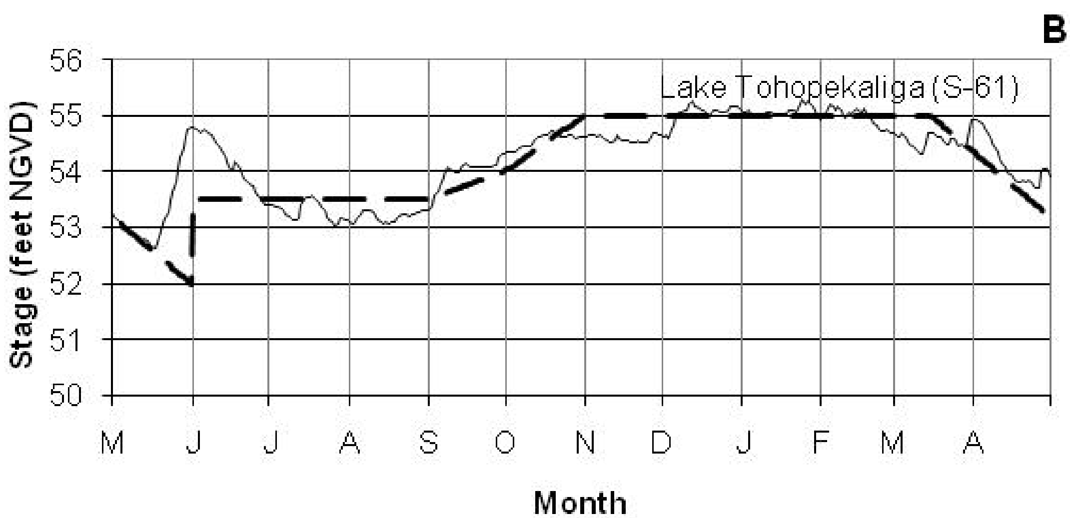


Figure 11-6. Regulation schedule (dashed line) and water level (solid line) for (A) East Lake Tohopekaliga and (B) Lake Tohopekaliga during WY2010.

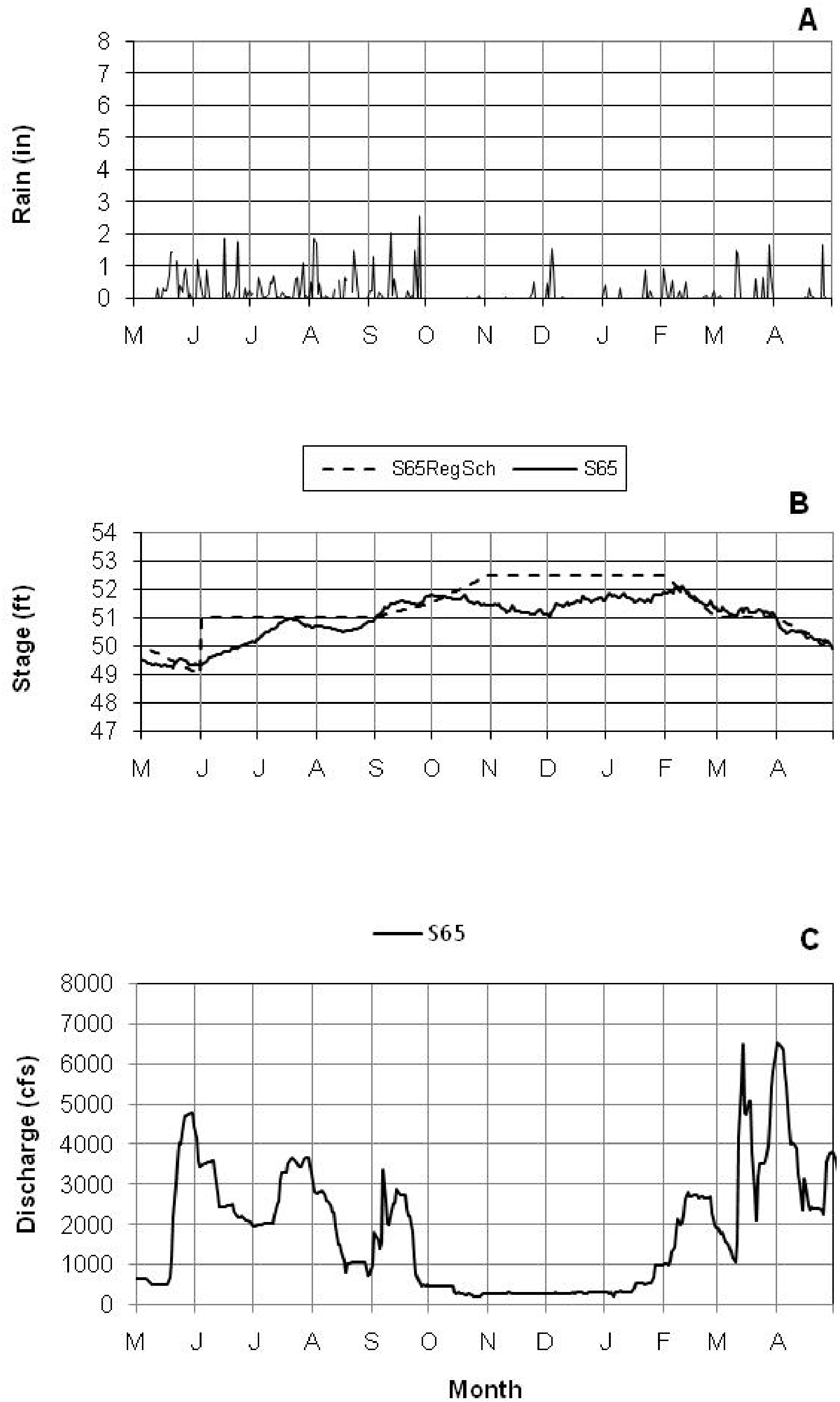


Figure 11-7. (A) Rainfall, (B) regulation schedule and water level, and (C) discharge at the outlet for Lake Kissimmee (S-65 structure) for WY2010.

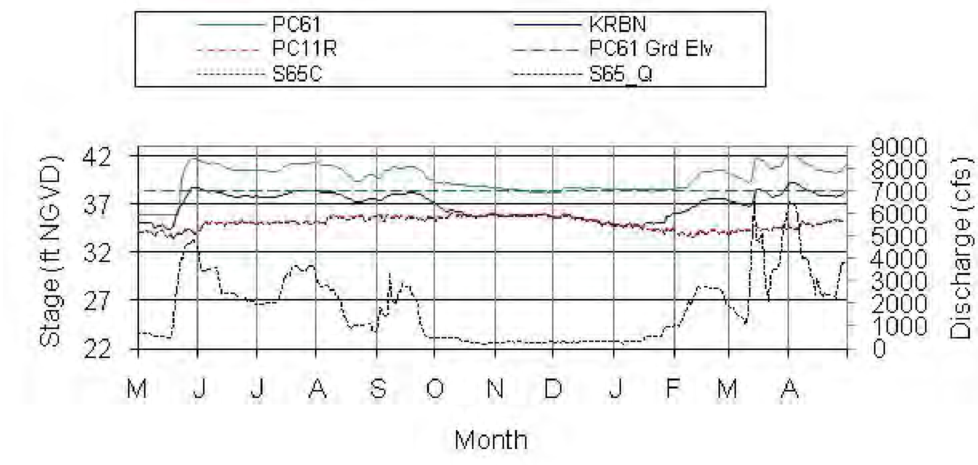


Figure 11-8. Mean daily stage at PC61, KRBN, PC11, and S-65C headwater in relation to mean daily discharge at S-65 during WY2010.

Wet Season

During the wet season, regulation schedules for the Upper Kissimmee Basin lakes rise from the low pool on May 31 to a summer plateau (summer pool) on June 1, where these schedules remain in effect until September or October (depending on Lake Kissimmee). In the fall, schedules begin to rise to the high pool (the highest stage in the regulation schedule) by the beginning of the dry season (November 1). During WY2010, the above-average rainfall in May raised the stage in East Lake Tohopekaliga to the summer pool on June 1 (**Figure 11-6,** panel A). Lake Tohopekaliga exceeded the summer pool on June 1 and had to be brought back to the regulation schedule line (**Figure 11-6,** panel B). The other Upper Kissimmee Basin lakes had stage reversals because of the rainfall in May. Because of stage reversal, Lakes Myrtle-Preston-Joel and Lakes Hart-Mary Jane reached the summer pool on June 1. The Alligator Chain of Lakes and Lake Gentry also experienced reversals but did not reach the summer pool until later in the summer. Lakes Kissimmee-Cypress-Hatchineha's stage rose to the summer pool in July and was managed below the regulation schedule line until September 1 (**Figure 11-7,** panel B). By September, the wet season rainfall had almost ended, and October had below-average rainfall (**Figure 11-5**). Consequently, none of the lakes reached the high pool by the end of the wet season.

Stages in the Kissimmee River also rose because of above-average rainfall in May and increased discharges at S-65 (**Figure 11-5**). At PC61, the stage increased from 35.96 ft on May 21, when the S-65 discharge was 500 cfs, to 41.71 ft, when the discharge was 4,800 cfs. This increase is a reversal of the 5.75 ft that resulted in water depth of 3.34 ft at this monitoring site. At monitoring site KRBN, the stage reversal was only 4.42 ft. The discharge at S-65 remained above 1,000 cfs for almost the entire wet season, exceeded 2,000 cfs until mid-August, and exceeded 2,000 cfs in early September (**Figure 11-7,** panel C). Under these flow conditions, the floodplain was inundated for the entire wet season at site PC61 (**Figure 11-8**). After the initial increase in discharge in May, discharge at S-65 was increased to more than 3,000 cfs in July and again in September, because the Lake Kissimmee stage exceeded the regulation schedule. These increases in discharge were accompanied by stage reversals in the Kissimmee River. In late July, a stage reversal of 1.01 ft occurred at PC61 and a reversal of 0.74 ft occurred at KRBN. In September, a reversal of 1.55 ft occurred at PC61 and a reversal of 0.98 ft occurred at KRBN. Because of decreasing rainfall, the discharge at S-65 was reduced to about 300 cfs.

Dry Season

During the dry season, above-average rainfall refilled most of the Upper Kissimmee Basin lakes to the high pool stage. Lake Tohopekaliga's stage reached the high pool in December, and East Lake Tohopekaliga's stage reached the high pool in February (**Figure 11-6**). Lake Gentry reached the high pool in December. The Alligator Chain of Lakes reached the high pool after the spring recession had begun. Lakes Myrtle-Preston-Joel, Lakes Hart-Mary Jane, and Lakes Kissimmee-Cypress-Hatchineha did not reach the high pool.

Temporary deviation regulation schedules went into effect for Lakes Myrtle-Preston-Joel, Lakes Hart-Mary Jane, and the Alligator Chain on January 1 and continued through August 31, 2010. The USACE, which had previously approved a deviation in the regulation schedules for KRRP construction purposes, kept the stage 0.5 ft below the regulation schedule.

During the spring, water levels in the Upper Kissimmee Basin lakes were lowered according to regulation schedules. For East Lake Tohopekaliga and Lake Tohopekaliga, recessions began in mid-February for snail kites, which was ahead of the regulation schedule. Above-average rainfall in March and April caused stage reversals in the Upper Kissimmee Basin, raising East Lake Tohopekaliga's and Lake Tohopekaliga's stages above the regulation schedule line (**Figure 11-6**). As a result, discharges were increased to lower the lakes to the regulation schedule line and continue the spring recession. The discharge at S-65 was increased to more than 6,000 cfs and above 2,000 cfs from mid-March until the end of April (**Figure 11-7**, panel C).

Early in the dry season, water levels in the Kissimmee River decreased because of declining rainfall and discharge at S-65 (**Figure 11-8**). Between October 1, 2009, and January 15, 2010, discharge at S-65 ranged from 195 cfs to 480 cfs and averaged 307 cfs. When the discharge at S-65 decreased to 300 cfs, the stage at site KRBN decreased until it became regulated by the stage at S-65C. This correspondence between KRDN and S-65C continued until discharge at S-65C was increased in mid-January (**Figure 11-8**). As discharge from the Upper Kissimmee Basin lakes began increasing in January, water levels began rising in the Kissimmee River. The stage at site PC61 rose above the ground elevation at this location. Three peaks of discharge at S-65 resulted in three stage reversals at PC61: 2 ft in February, 2.66 ft in mid-March, and 1.46 ft at the beginning of April (**Figure 11-8**).

PROJECT UPDATES

This section provides project and planning updates on the Kissimmee River Restoration Evaluation Program (KRREP); Kissimmee River Restoration Project (KRRP) construction activities in the Upper and Lower Kissimmee basins; the Kissimmee Basin Modeling and Operations Study (KBMOS); the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP); and other projects taking place in the Upper Kissimmee Basin.

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

With the completion of the KRRP Phase I construction in early 2001, restoration evaluation monitoring of the Phase I area entered its post-construction period. The first of four restoration construction stages, Phase I is being monitored by the SFWMD under the KRREP, as will selected successive phases of restoration (SFWMD, 2005a, Chapter 1). Many of the Phase I studies — which include assessments of hydrology, geomorphology, water quality, river channel and floodplain vegetation, aquatic invertebrates, herpetofauna, fish, and birds — already are indicating 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. The reference data used to make these predictions were data from the pre-channelized Kissimmee River, published data from relatively undisturbed but similar systems elsewhere, or experimental studies.

The monitoring results presented below provide the status of Phase I evaluation studies for which new data have been obtained since last year's report. A comprehensive update of the status of initial responses to Phase I reconstruction was published in the 2005 SFER – Volume I (SFWMD, 2005c, Chapter 11), with updates using newly available monitoring data published in the 2006-2010 SFERs – Volume I (SFWMD, 2006a, 2007a, 2008a, 2009, 2010). The combined results for a suite of interrelated river channel studies were presented in the 2006 SFER – Volume I, Chapter 11. **Table 11-2** provides a directory of KRREP monitoring study updates since 2005.

Table 11-2. Directory of Kissimmee River Restoration Evaluation Program Phase I restoration response monitoring study updates in the 2005–2011 *South Florida Environmental Reports* (SFERs) – *Volume I*, Chapter 11.

		Page Number in 2005–2011 SFERs — Volume I, Chapter 11						
KRREP Monitoring Study or Project	**Expectation #**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Kissimmee River Restoration Evaluation Program		11-8	11-37	11-22	11-28	11-36	11-26	11-25
Hydrology								
Stage-discharge relationships		11-20						
*Continuous river channel flow**	1	**[11-18]**				**[11-39]**	**[11-29]**	**[11-29]**
Variability of flow	2					**[11-40]**	**[11-31]**	**[11-32]**
Stage hydrograph	3	**[11-22]**				**[11-41]**	**[11-32]**	**[11-33]**
*Stage recession rate**	4	**[11-23]**	11-23	11-16	11-19	**[11-42]**	**[11-34]**	**[11-35]**
Flow velocity	5	**[11-25]**					**[11-35]**	**[11-37]**
Broadleaf marsh indicator	No expectation					11-43		
Geomorphology								
River bed deposits	6	**[11-26]**						**[11-70]**
Sandbar formation	7	**[11-26]**						**[11-70]**
Channel monitoring	No expectation					11-54		11-68
Sediment transport	No expectation							11-71
Floodplain processes	No expectation							11-72
Dissolved Oxygen*	8	**[11-28]**	**[11-44]**	**[11-25]**	**[11-28]**	**[11-45]**	**[11-36]**	**[11-38]**
River Channel Metabolism	No expectation				11-35			
Phosphorus	No expectation	11-33	11-52	11-30	11-32	11-51	11-43	11-43
Turbidity	9	**[11-30]**	**[11-48]**	**[11-27]**				
Periphyton	No expectation	11-46						
River Channel Vegetation								
Width of littoral vegetation beds	10	**[11-36]**				**[11-59]**		
River channel plant community structure	11	**[11-37]**				**[11-59]**		

Table 11-2. Continued.

KRREP Monitoring Study or Project	Expectation #	Page Number in 2005–2011 SFERs — Volume I, Chapter 11						
		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Floodplain Vegetation								
Areal coverage of floodplain wetlands	12	**[11-39]**			**[11-35]**			**[11-47]**
Areal coverage of broadleaf marsh	13	11-40			**[11-35]**			**[11-47]**
Areal coverage of wet prairie	14	11-40			**[11-35]**			**[11-47]**
Aquatic Invertebrates								
Macroinvertebrate drift composition	15	**[11-45]**	11-57					
Snag invertebrate community structure	16	**[11-46]**	11-55			11-62		
Aquatic invertebrate community structure in broadleaf marsh	17		11-57					
Benthic invertebrate community structure	18	**[11-45]**	11-58			11-62		
Native and Nonnative bivalves	No expectation							11-52
Herpetofauna		11-48						
Floodplain reptiles and amphibians	19		Response data will be collected after implementation of headwaters regulation schedule					
Floodplain amphibian reproduction and development	20		Response data will be collected after implementation of headwaters regulation schedule					
Fish Communities*								
Small fishes in floodplain marshes	21	11-50	Response data will be collected after implementation of headwaters regulation schedule					
River channel fish community structure	22	11-52	**[11-59]**			**[11-66]**		
Mercury in fish	No expectation					11-20		
Floodplain fish community composition	23	11-50	Response data will be collected after implementation of headwaters regulation schedule					

Table 11-2. Continued.

KRREP Monitoring Study or Project	Expectation #	Page Number in 2005–2011 SFERs – Volume I, Chapter 11 2005	2006	2007	2008	2009	2010	2011
Birds								
*Wading bird abundance**	24	**[11-58]**	**[11-71]**	**[11-32]**	**[11-44]**	**[11-72]**	**[11-50]**	**[11-60]**
Waterfowl	25		**[11-67]**	**[11-35]**		**[11-73]**	**[11-52]**	**[11-62]**
Shore birds	No expectation	11-57						
Wading bird nesting	No expectation		11-68		11-40	11-72	11-47	11-56
Threatened and Endangered Species	No expectation	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 of the restoration expectations, particularly those relating to floodplain responses, are dependent on full implementation of the revised Headwaters Revitalization Schedule that will be implemented upon KRRP completion. Currently projected to be implemented in 2015, the new schedule will provide the necessary storage volume in the KCOL to provide the volume and timing of water needed for the KRRP. The Headwaters Revitalization Schedule will more closely simulate historical hydrology than is possible under the current interim schedule.

New data from several monitoring projects from the Phase I area are available for WY2010. Where applicable, these reports also evaluate the current status of the associated Phase I restoration expectations. Subsequent sections in this section include updates on *Hydrology*, *Dissolved Oxygen*, *Total Phosphorus*, *Floodplain Vegetation*, *Freshwater Bivalves*, and *Birds* (wading bird nesting colonies, and wading bird and waterfowl abundance).

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. Hydrologic conditions are being evaluated with five expectations for the restored hydrology of the river channel and floodplain, which reflect criteria that have guided the restoration project since its inception (SFWMD, 2005b). The ability to meet these expectations depends on the implementation of the Headwaters Revitalization Schedule. Until this schedule is implemented (currently projected for 2015), an interim regulation schedule for S-65 is providing the restoration project with flow that varies seasonally and with water levels in Lake Kissimmee.

This update of the hydrologic conditions for Phase I extends the summary from WY2002 through WY2010 and evaluates progress toward meeting the hydrologic expectations under the interim flow conditions. Floodplain water level fluctuation (**Expectation 3**) and stage recession (**Expectation 4**) are evaluated using an upstream-downstream array of five monitoring sites (PC61, PC52, PC44, PC32, and PC21) on the floodplain (**Figure 11-9**). Monitoring at these locations will provide more insight into how conditions are changing along the length of the river. The section for Expectation 5, river channel velocity, was not updated.

Expectation 1

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

WY2010 was another year of continuous inflow (i.e., mean daily discharge exceeded 0 m^3/s every day) (**Figure 11-10**). Discharge exceeded 28.3 m^3/s for most of the wet season and decreased to 8.49 m^3/s for much of the dry season. With the inclusion of WY2010, the number of water years with continuous inflow from the Upper Kissimmee Basin increased to six of nine.

Inflow at S-65 from the Upper Kissimmee Basin has been continuous during WY2002–WY2010, except for portions of WY2002, WY2007, and WY2008 (**Figure 11-10**). In WY2002, there was no discharge at S-65 for the first 84 days of the water year because the basin was in a severe regional drought. A second time interval without inflow from the Upper Kissimmee Basin lasted 252 days between November 8, 2006, and July 18, 2007, because of another severe regional drought. This period of no inflow included portions of WY2007 (152 days) and WY2008 (79 days).

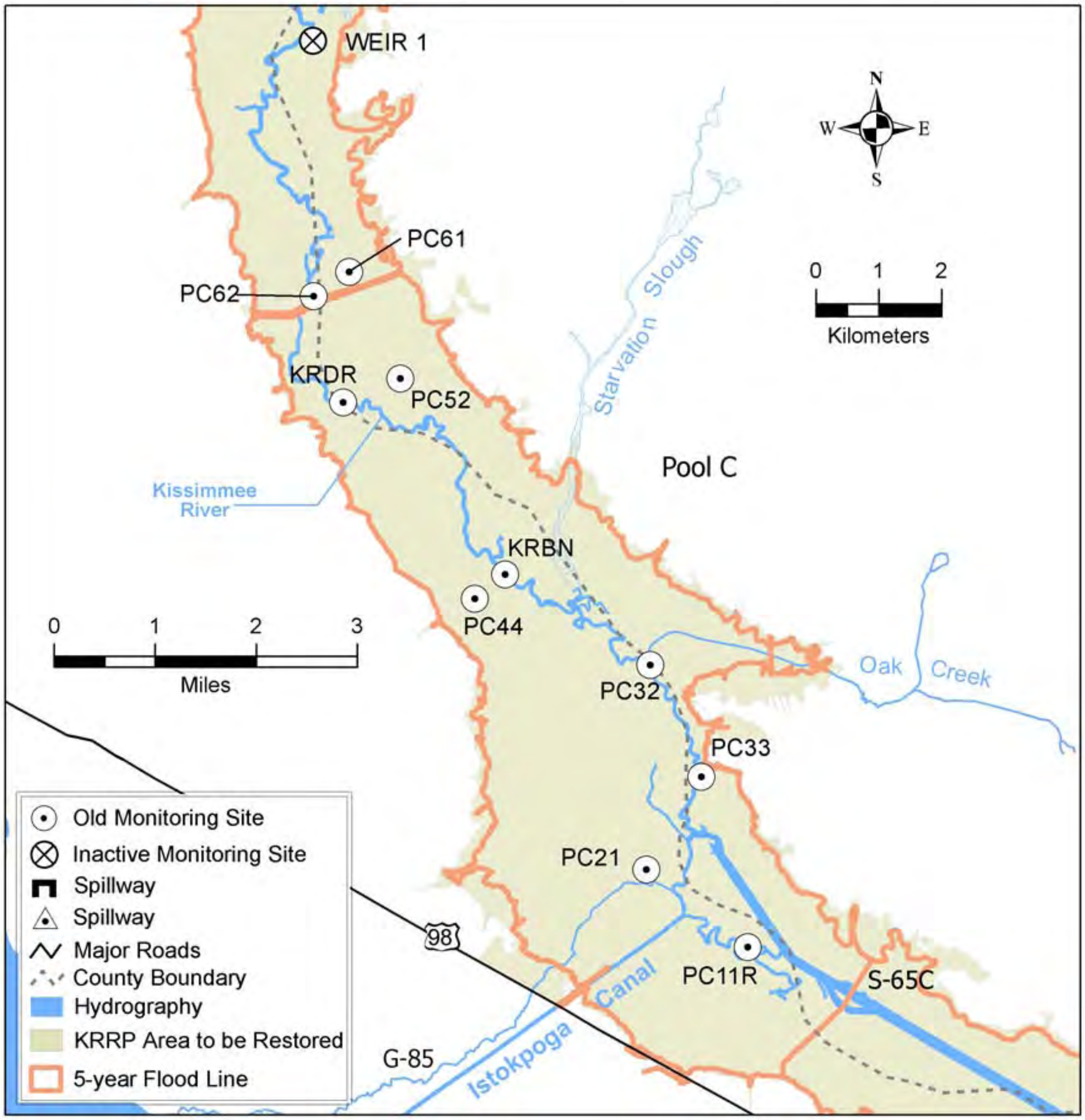


Figure 11-9. Hydrologic monitoring sites in Pool C used to guide operations and evaluate restoration expectations.

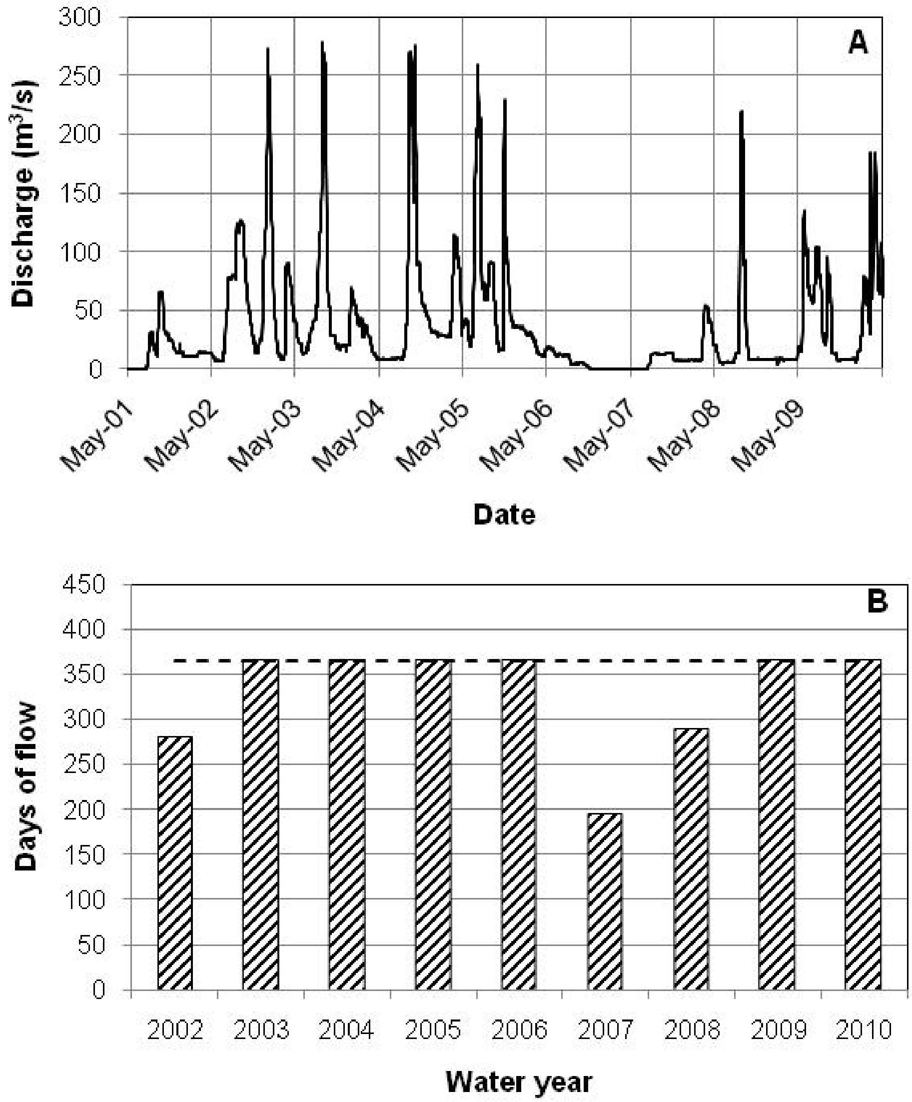


Figure 11-10. Mean daily flow [cubic meters per second (m^3/s)] at the S-65 structure, the outlet from the Upper Kissimmee Basin (top), and number of days with flow (bottom) for WY2002–WY2010.

Expectation 2

> Intra-annual mean monthly flows will reflect historical 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 lowest at the end of the dry season (**Figure 11-11**). In contrast, management of the channelized system resulted in peak flows 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. The addition of data from WY2010 had little effect on the seasonal distribution of flow during the interim period. For WY2002–WY2010, the coefficient of variation for mean monthly discharge ranged from 0.79 to 1.41 across months. For four months (February, March, August, and September), it was less than 1.

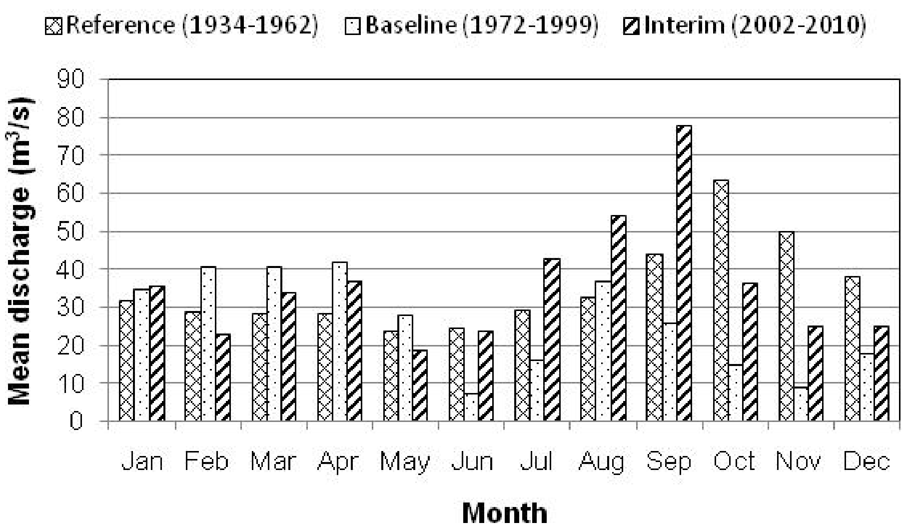


Figure 11-11. Seasonality of mean monthly discharge (m^3/s) at S-65 for the reference period (1934–1962), baseline period (1963–2000), and interim period (2001–2010). [Note: for 2001, zero values for the first six months were not included in the calculation of average discharge.]

Expectation 3

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

The change in stage for each water year (WY2002–WY2010) and the duration of water above ground level are quantified at five floodplain locations; from upstream to downstream, these sites are PC61, PC52, PC44, PC32, and PC21 (**Figure 11-9**). Upstream-downstream patterns in stage fluctuation and duration of inundation reflect the influence of the limited range (10–11 m) of managed water level fluctuation at S-65C, the downstream water control structure. The ground elevations at PC32 and PC21, the two most downstream sites, are near the lower end of the range of elevation at S-65C; therefore, water levels at these sites are regulated largely by S-65C. Because of the constrained water levels, the amplitude of stage fluctuation has exceeded the target of at least 1.14 m in six of nine years, including WY2010, at PC32, and two of nine years at PC21 (**Figure 11-12**). Because the ground elevations at PC32 and PC21 are near the lower end of managed water levels, these two sites are inundated nearly continuously and exceed the inundation duration target of at least 180 days in all years. At the three upstream sites (PC61, PC52, PC44), the ground elevation is at or above the upper limit of managed water elevations at S-65C. The target for amplitude of stage fluctuation has been met in all years including WY2010. The observed values tend to increase upstream. The duration of inundation target of 180 days has been exceeded only in some years at these sites. The number of years exceeding the target and the duration of inundation tend to increase upstream. In the 2010 SFER, Chapter 11 summary for this expectation, incorrect ground elevations were used for PC61 and PC44, which resulted in the underestimation of hydroperiod durations at PC61 and overestimation for PC44. Because of these errors, last year’s summary indicated that “the combination of the change in water level and inundation duration were best met at sites near the middle of the restoration project area.” It now appears that the inundation and stage fluctuation criteria are most likely to be met at the sites most upstream of the S-65C.

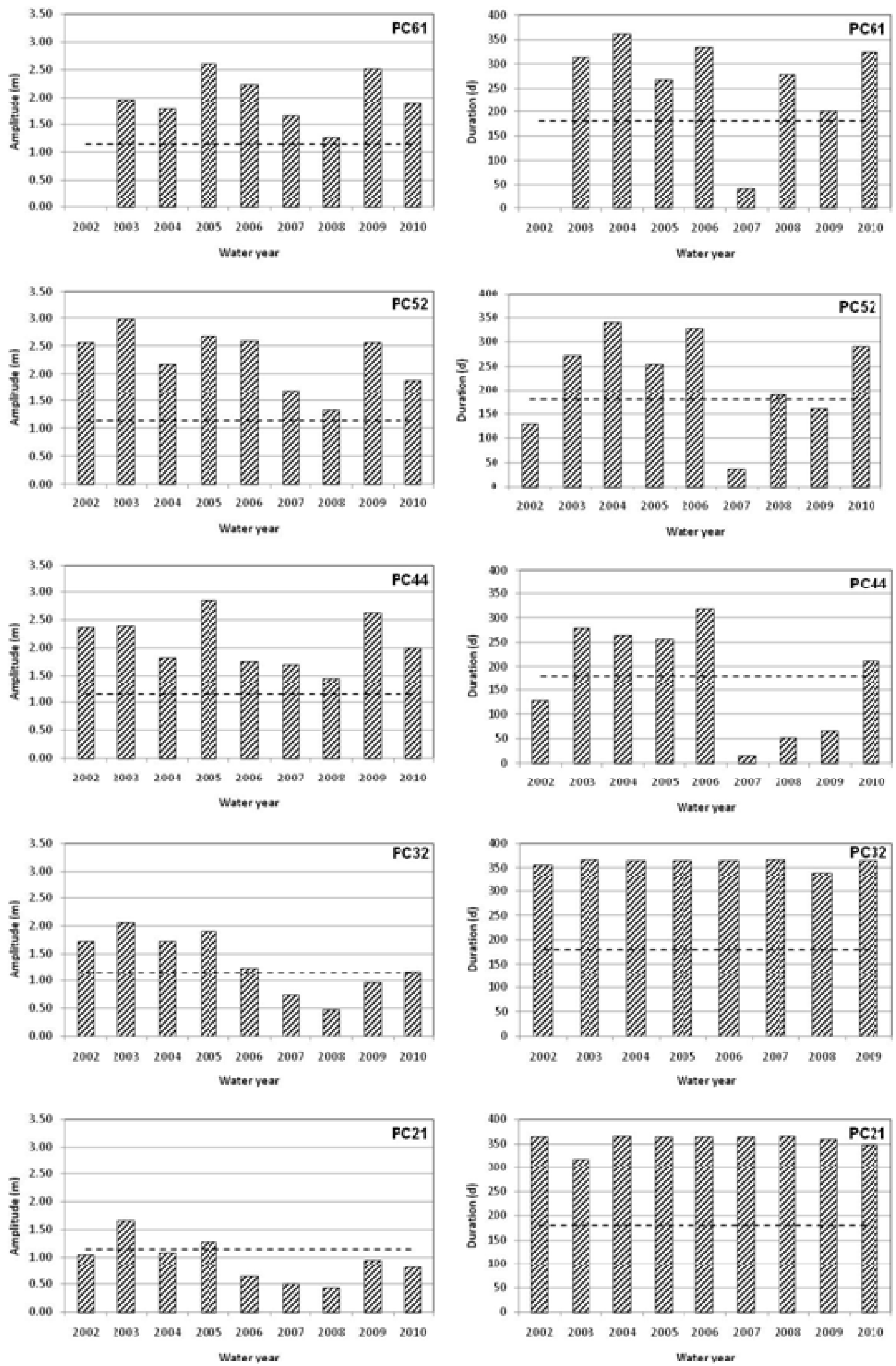


Figure 11-12. Amplitude of water level fluctuation (left) and duration of inundation (right) at five locations for WY2002–WY2010. The dashed horizontal lines represent minimum change in water level fluctuation of at least 1.14 meters (m) per year (right) and a minimum duration of 180 days per year for stage exceeding floodplain ground elevation (left).

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 0.3 m per 30 days (SFWMD, 2005b).

The stage reversal in late May 2009 initiated the first of several recession events during WY2010 (**Figure 11-13**). The characteristics of each event were quantified for five floodplain sites (**Table 11-3**). Four sites had three or four recession events instead of the single long recession event that characterized the pre-channelization period. Only PC21 had one event, which reflected the influence of the S-65C structure. Most events were shorter than the minimum duration of 173 days. Although durations were shorter than desired, several of the recession events had recession rates that did not exceed the 0.3 m/30 day threshold.

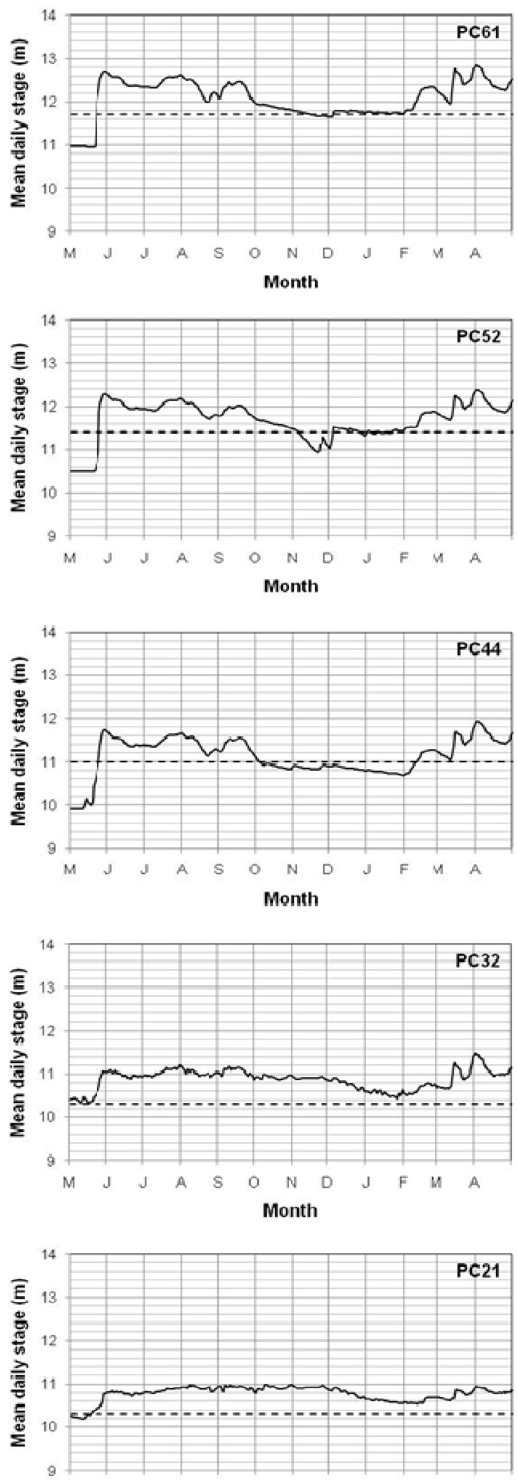


Figure 11-13. Water level (stage) in WY2010 at five floodplain locations. Dashed line is the ground elevation at the location.

Table 11-3. Calculation of recession rate for WY2010 events at five sites. Recession rate is calculated from the timing (T_{max}) and elevation (h_{max}) of the maximum stage for the event to the timing (T_{min}) and elevation (h_{min}) of the minimum stage. The recession rate (R) is calculated by dividing the change in water level elevation (Δh) by the change in time (Δt) and multiplying by 30 days.

Site	T_{max}	h_{max} (m)	T_{min}	h_{min} (m)	Δh (m)	Δt (d)	R (m/30d)
PC61	30-May-09	12.71	22-Aug-09	12.00	0.71	84	0.25
	18-Sep-09	12.47	2-Dec-09	11.64	0.83	75	0.33
	26-Feb-10	12.34	11-Mar-10	11.90	0.44	13	1.02
	2-Apr-10	12.84	1-Jul-10	11.80	1.04	90	0.35
PC52	30-May-09	12.29	21-Nov-09	10.93	1.36	175	0.23
	5-Dec-09	11.52	31-Dec-09	11.33	0.19	26	0.22
	2-Apr-10	12.39	11-Jul-10	11.60	0.79	100	0.24
PC44	29-May-09	11.74	31-Jan-10	10.68	1.06	247	0.13
	27-Feb-10	11.28	11-Mar-10	11.04	0.24	12	0.60
	16-Mar-10	11.69	23-Mar-10	11.40	0.29	7	1.24
	3-Apr-10	11.93	30-Jun-10	10.83	1.10	88	0.38
PC32	31-Jul-09	11.21	27-Jan-10	10.43	0.78	180	0.13
	16-Mar-10	11.26	23-Mar-10	10.86	0.40	7	1.71
	21-Apr-10	11.48	16-Jun-10	10.71	0.77	56	0.41
PC21	30-Oct-09	10.99	9-Feb-10	10.54	0.45	102	0.13

Expectation 5

> Mean velocities within the main river channel will range from 0.2 to 0.6 meters per second (m/s) during a minimum of 85 percent of the year (SFWMD, 2005b).

The expectation for mean channel velocity was evaluated using velocity estimates made during field flow measurements (i.e., stream gauging) at five locations in the river channel from upstream to downstream: PC62, KRDR, KRBN, PC33, and PC11R (**Figure 11-9**). This summary has not been updated for WY2010. Flow measurements were taken with an Acoustic Doppler Current Profiler, which was also used to measure the cross-sectional area of flow. Mean channel velocity was calculated by dividing the discharge by the cross-sectional area. Measurements were taken under a range of flow conditions beginning on November 28, 2001, at all sites except PC62, which was not established until later (**Table 11-4**). When measurements began at PC62, they were discontinued at PC11R.

The percentage of mean channel velocity estimates in the desired range of 0.2–0.6 m/s was less than the desired value of 85 percent at all cross-sections except at KRDR (**Table 11-4**). The smaller percentage estimates in the desired range reflect a larger number of estimates < 0.2 m/s, which is a consequence of the extended periods of time with low discharge (e.g., **Figure 11-10**, top panel). Less than 10 percent of the velocity measurements at any cross-section exceeded 0.6 m/s. Mean channel velocities > 0.6 m/s corresponded to discharge measurements greater than 50–60 m^3/s.

Table 11-4. Summary of mean channel velocity estimates from stream gauging. Number of observations (n), the beginning and ending dates for the time period during which measurements were made, minimum (Q_{min}) and maximum (Q_{max}) discharge (m^3/s) during which measurements were made, and the number (percentage) of mean channel velocity estimates for five river channel stations. Values in parentheses are the percent of the total number of observations made at a site.

						Mean Channel Velocity (m/s)		
Site	**n**	**Begin date**	**End date**	**Q_{min}**	**Q_{max}**	**<0.2**	**0.2-0.6**	**>0.6**
PC62	94	2/4/2004	6/4/2009	3.63	89.72	29(31)	61(65)	4(4)
KRDR	190	11/28/2001	6/4/2009	3.41	77.47	19(10)	167(88)	4(2)
KRBN	193	11/28/2001	6/4/2009	3.30	91.97	40(21)	144(75)	9(5)
PC33	198	11/28/2001	6/4/2009	3.42	129.39	85(43)	98(49)	15(8)
PC11R	94	11/28/2001	1/28/2004	6.37	403.93	70(74)	24(26)	0(0)

Dissolved Oxygen

Restoration has been expected to improve DO concentrations in the river channel. However, reference DO data from the pre-channelized, flowing river are not available to support quantitative performance measures. Therefore, reference conditions for the pre-channelized river were derived from data on other free-flowing, blackwater streams in South Florida. At least 11 samples were collected from each of the seven streams over a minimum of one year. Some streams were sampled for more than 10 years (**Figure 11-14**). The period of record for these reference data is 1973–1999. The mean daytime DO concentration in the reference streams was 4.2 milligrams per liter (mg/L) during the wet season and 6.1 mg/L during the dry season (**Figure 11-15**). 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.

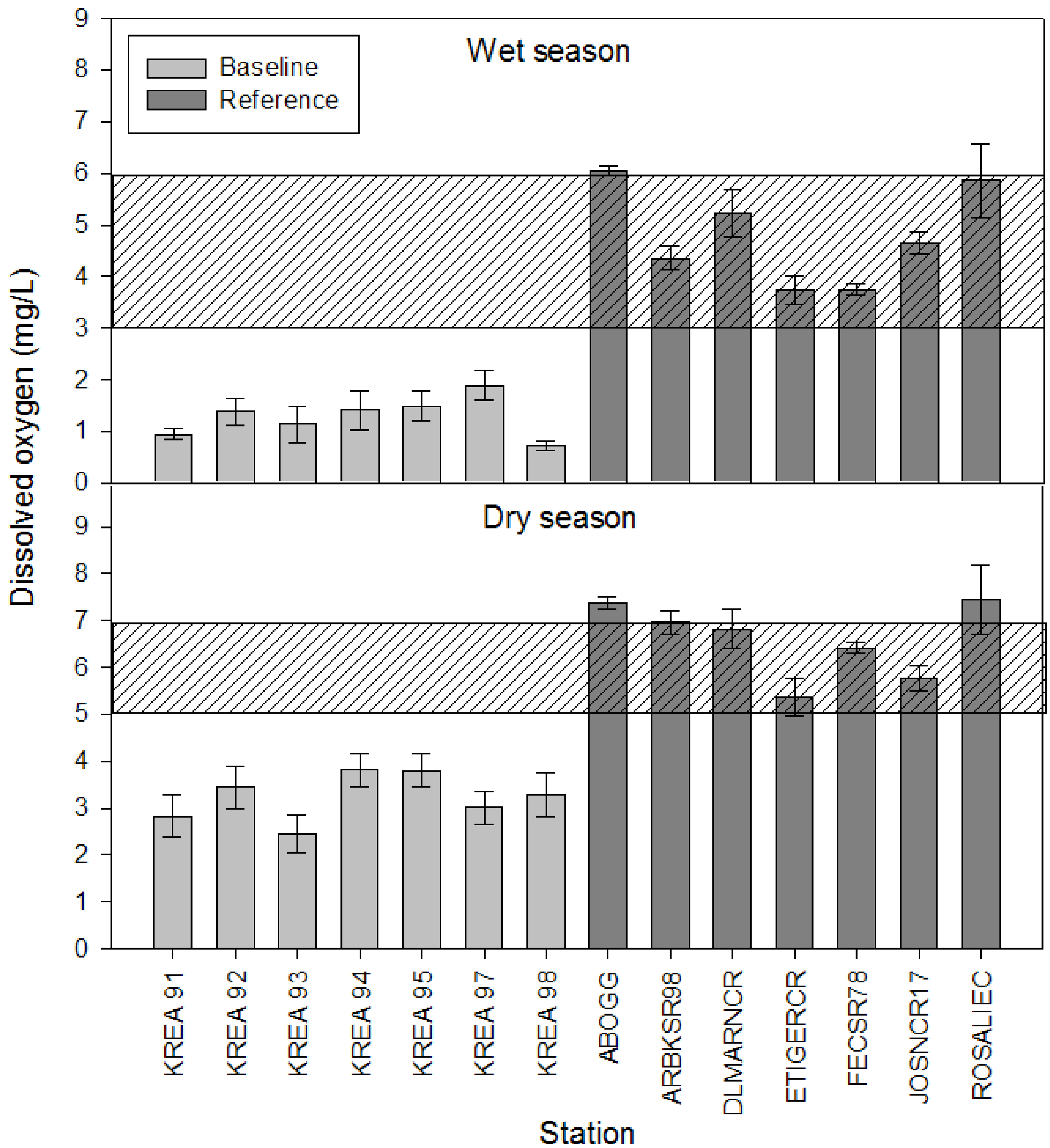


Figure 11-14. Mean [± standard error (S.E.) of the mean] dissolved oxygen (DO) concentrations in free-flowing, blackwater South Florida streams and remnant runs of the channelized Kissimmee River during the wet (June–November) and dry (December–May) seasons. Shaded area represents expected range of DO concentrations in the Kissimmee River after restoration. Station names are from the SFWMD's hydrometeorologic database, DBHYDRO.

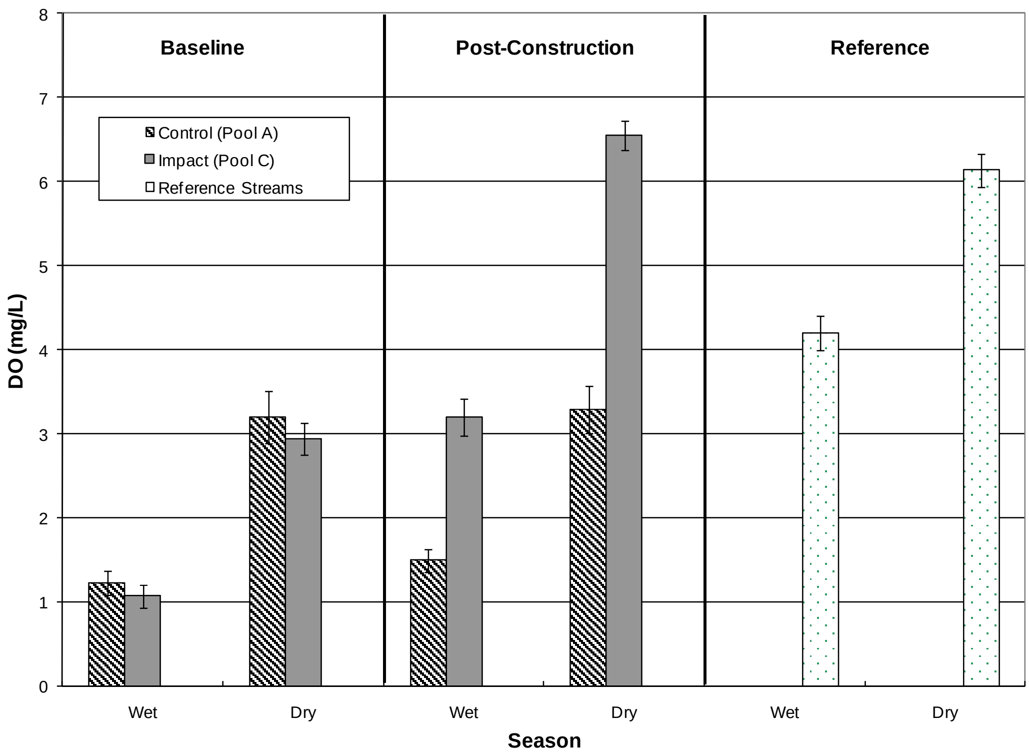


Figure 11-15. Mean (± S.E.) DO concentrations (mg/L) in reference streams (period of record =1973–1999) and control and impact areas during the wet and dry season, during the baseline (1997–1999) and post-restoration (2001–present) periods.

To establish baseline conditions in the stagnant river runs, DO was monitored daily over 24 hours at a depth of approximately 1 m in two remnant river channel stations in Pool C. Sampled river channels were approximately 20–30 m wide and 2–3 m deep. DO also was sampled monthly, during the day, within seven remnant river runs in Pools A and C. This monitoring has continued beyond the 1997–1999 baseline period and provides comparisons of conditions before and after the Phase I restoration construction.

Within the remnant river runs during the baseline period, 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 common during the warmer months of the year. DO concentrations near the surface could reach 4–5 mg/L, but concentrations near the bottom were lower than the detection limit (< 0.2 mg/L). During 1997–1999, mean DO concentrations in remnant river runs in Pool A and C were 1.2 mg/L and 1.1 mg/L, respectively, during the wet season, and 3.2 mg/L and 3.0 mg/L, respectively, during the dry season (**Figure 11-15**). DO concentrations exceeded 2 mg/L for only 22 percent of the baseline period, and 5 mg/L for only 6 percent of this period.

The reference and baseline data were used to develop four components of Expectation 8 (SFWMD, 2005b) to evaluate changes in DO as restoration proceeds (**Table 11-5**).

Table 11-5. DO restoration expectation metrics and WY2010 values.

Expectation Metric	WY2010 Value (mg/L)	Metric Achieved in WY2010?
Mean daytime DO concentration 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).	2.5 ± 0.4 mg/L	No
Mean daytime DO concentration 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).	6.2 ± 0.5 mg/L	Yes
Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90 percent of the time (annually).	84%	No
DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50 percent of the time annually.	97%	Yes

Following completion of the first phase of construction, DO concentrations within the restoration area (Pool C) averaged 3.2 mg/L during the wet season and 6.5 mg/L during the dry season (**Figure 11-15**). In comparison, post-construction DO concentrations in the control area (Pool A) averaged 1.5 and 3.3 mg/L during the wet and dry seasons, respectively (**Figure 11-15**). Annual mean DO concentrations in the restoration area increased from < 3.0 mg/L before construction to 4.1 mg/L in WY2010 (**Figure 11-16**). Also in WY2010, mean daily water column DO concentrations were > 2.0 mg/L for 84 percent of the time, and minimum daily concentrations were > 2.0 mg/L for 65 percent of the time. Concentrations within 1 m of the channel bottom were > 1 mg/L for 97 percent of the time and > 2 mg/L for 70 percent of the time (**Table 11-5**). In summary, two of the four metrics used to evaluate DO response were met under the interim regulation schedule during WY2010. The final determination of restoration success with respect to DO in the river channel will be made after implementation of the Headwaters Revitalization Schedule.

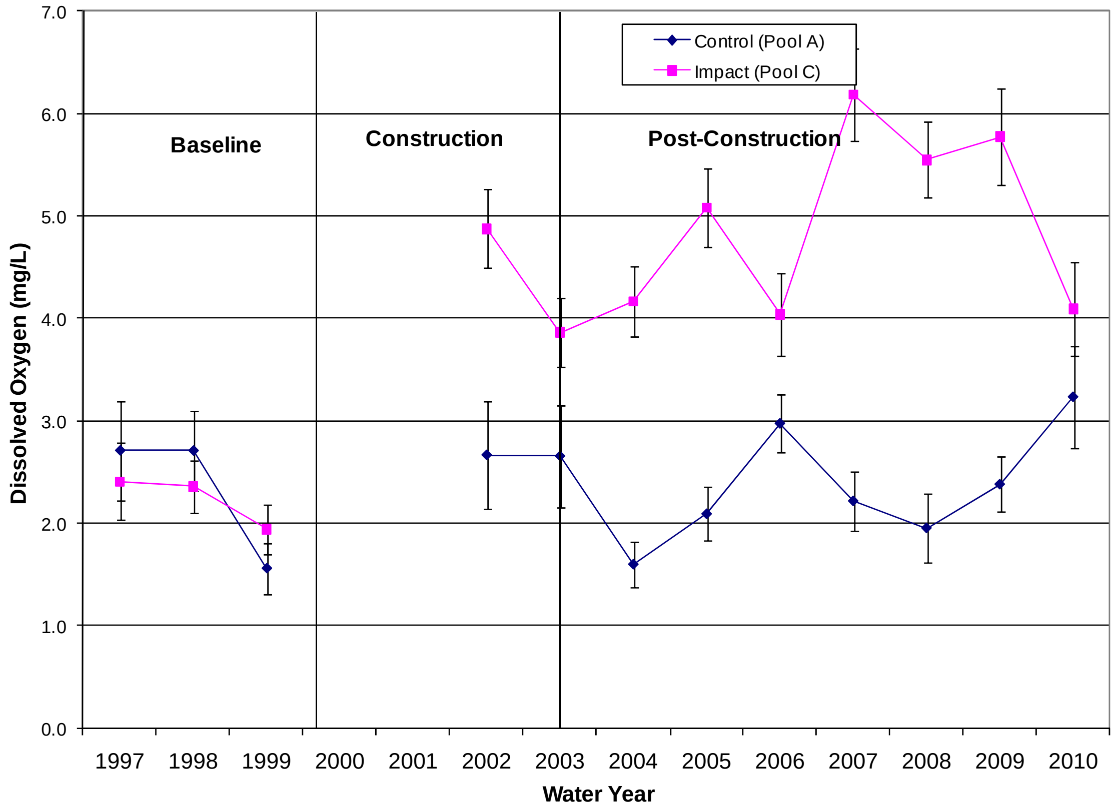


Figure 11-16. Mean DO concentrations (mg/L) in the Kissimmee River for each water year during the baseline and post-construction periods.

Total Phosphorus

As Lake Okeechobee’s largest tributary, the Kissimmee River is a major contributor of phosphorus to the lake (see Chapter 10 of this volume). Construction of the C-38 canal and lateral drainage ditches has presumably contributed to phosphorus loading from the Kissimmee Basin 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 activity, 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 lead to reduced loading from these pools and 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 or is assimilated by wetland vegetation. The filling of ditches and removal of cattle from the floodplain also may help to lower TP loads from lateral sources.

To estimate phosphorus loading at each C-38 water control structure, baseline and post-construction TP concentrations have been monitored routinely at each structure along with daily estimates of discharge. TP concentrations were measured from grab samples collected every two weeks (although sampling has ranged from weekly to monthly during portions of the period of record) and composite samples collected by auto-samplers. The auto-sampler gathered samples 10 times per day, which were 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 discharges and then summed annually. Because TP loads can vary greatly between wet years and dry years, annual TP loads were divided by annual discharges to obtain flow-weighted mean (FWM) TP concentrations at each structure. These annual 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 per year (mt/yr) at S-65C and 83 mt/yr at S-65D (**Figure 11-17**). These amounts comprised 43 and 71 percent of the average load at S-65E, respectively. Annual FWM TP concentrations averaged 53 parts per billion (ppb) at S-65C (range of 33–87 ppb), and 78 ppb at S-65D (range of 47–141 ppb) (**Figure 11-18**). 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/yr (**Figure 11-17**), and the FWM TP concentration was 43 ppb (**Figure 11-18**).

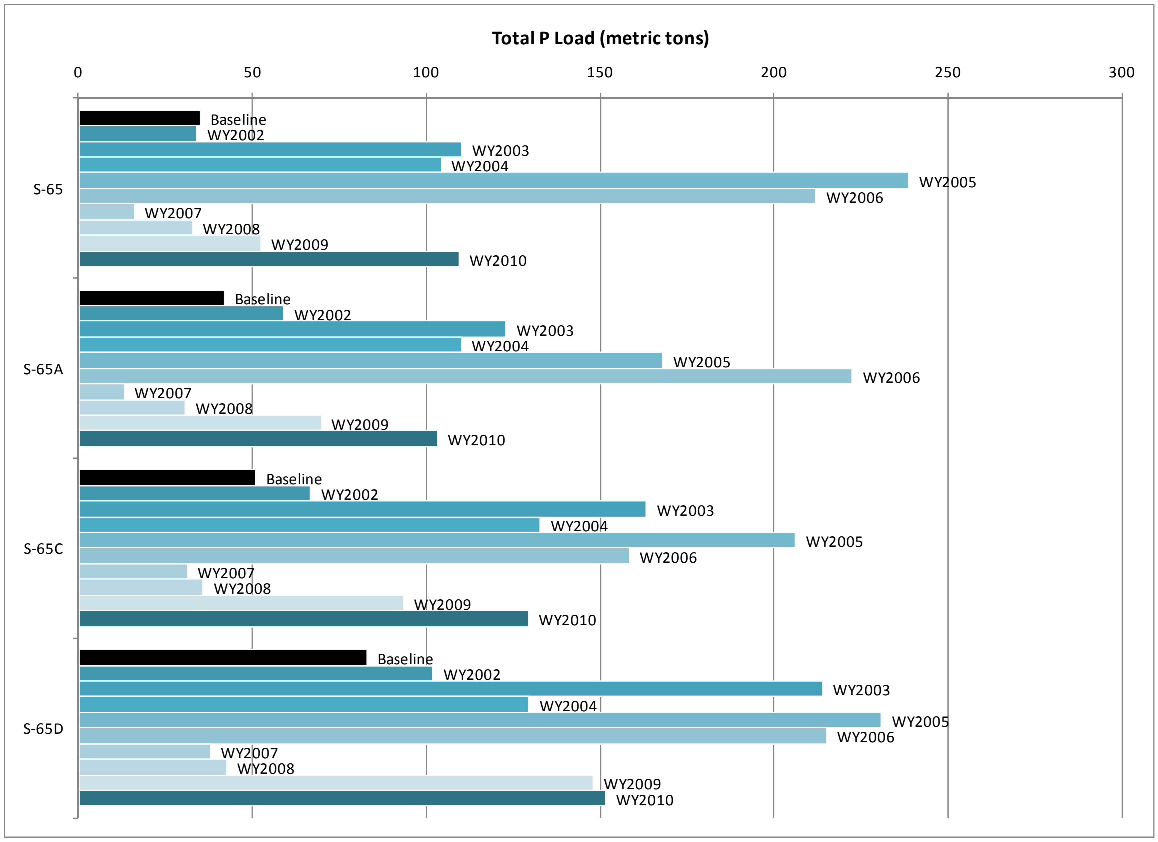


Figure 11-17. Annual total phosphorus (TP) loads (metric tons) from C-38 structures in comparison to baseline loads from 1974–1995. WY2002, WY2007, and WY2008 were drought years, and WY2005 was wet due to hurricanes.

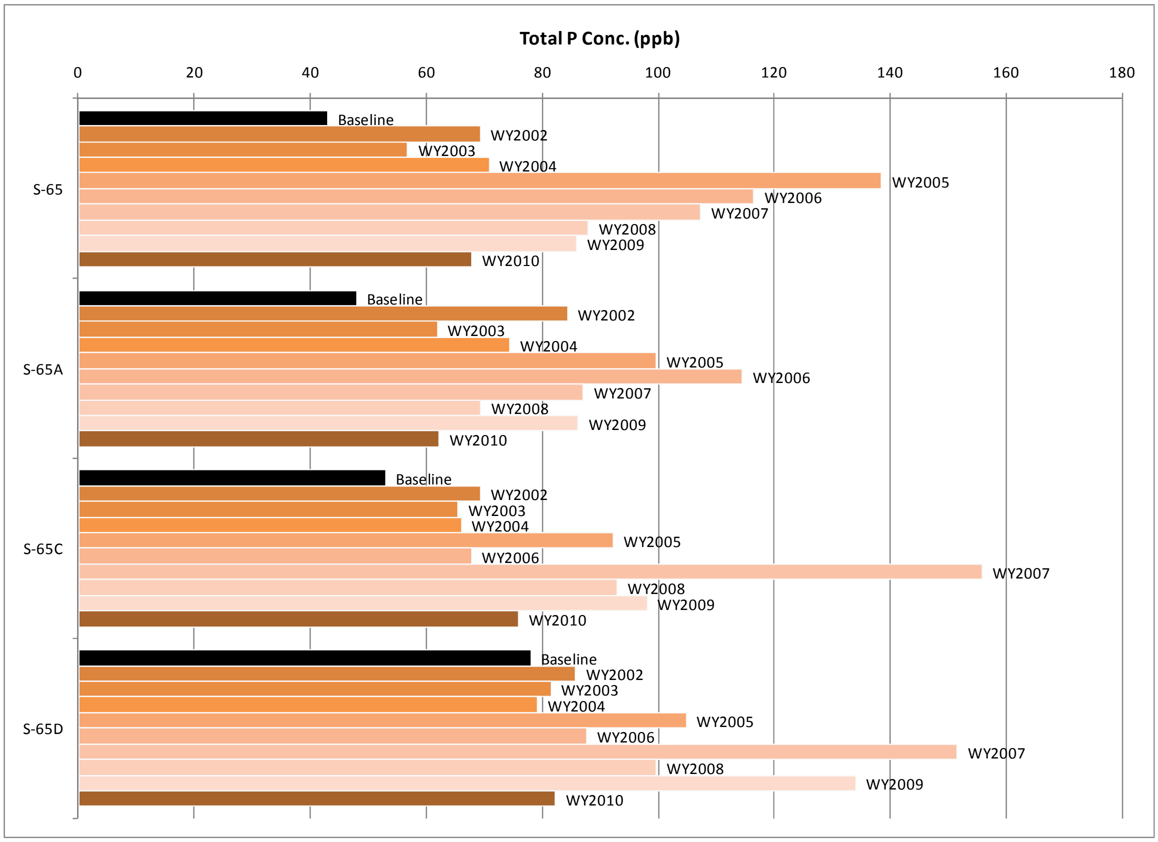


Figure 11-18. Annual flow-weighted mean TP concentrations in parts per billion (ppb) at C-38 structures in comparison to baseline concentrations (1974–1995).

Reference, pre-channelization conditions for TP loads and concentrations in the Kissimmee River cannot be determined with much 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 (SFWMD, 2005a, Chapter 5). Although quantitative performance measures have not been established for TP, restoration should 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 (currently projected for 2015). In the meantime, TP concentrations may increase periodically as the nutrient runs off from former pastures and the floodplain transitions from terrestrial to wetland vegetation.

Under the current interim regulation schedule, the floodplain in the restoration area was inundated intermittently, but periodic dry conditions, especially in WY2007 and WY2008, resulted in little hydrologic interaction between the river channel and floodplain. Under these hydrologic conditions, wetland vegetation became reestablished to a large extent, but the composition of wetland community types still has not attained the proportions that are expected once the KRRP is entirely completed (see following section on *Floodplain Vegetation*). Therefore, in the transitional years since 2001, the floodplain is unlikely to have assimilated phosphorus at its highest potential efficiency.

Evaluation of TP loading trends from year to year is difficult because loading is highly dependent on the amount of discharge through the system. During WY2002–WY2006, discharge and loads at the C-38 structures were generally greater than the 1974–1995 baseline averages, but were much lower in the drought years of WY2007 and WY2008 (**Figure 11-17**). Annual discharges during WY2009–WY2010 were higher than in the previous two years. Total phosphorus loads in WY2010 were affected by above-average discharges toward the end of the period (**Figure 11-17**). The WY2010 loads were more than twice the baseline averages.

FWM TP concentrations have been higher at all structures since the baseline period (**Figure 11-18**) and remained relatively high in WY2010. However, FWM TP concentrations continued to decline since the WY2005 highs, during which three hurricanes crossed the Kissimmee Basin. The WY2010 concentrations are near the same levels as FWM concentrations for WY2002–WY2004. Despite its recent decline, the FWM TP concentration at S-65 is still higher than it was in the mid-1990s. The higher concentrations in the headwater inflow have a strong effect on concentrations downstream in the canal. These higher concentrations are at least partially due to higher concentrations in Lake Kissimmee, possibly from hydrilla (*Hydrilla verticillata*) treatments that allow more exposure of lake sediment to wind resuspension and more growth of phytoplankton, and from the impact of hurricanes. The increase also may be due to greater inflows of phosphorus to the headwater lakes, possibly including local runoff near S-65. However, it should be noted that the headwater discharge is still one of the most dilute sources of TP in the Lake Okeechobee Watershed.

Monitoring of phosphorus at the C-38 water control structures provides important trend information, but as restoration proceeds there is considerable interest in determining how restoration of floodplain wetlands will influence the retention of phosphorus. The KRRP is causing changes in the movement of water through the river-floodplain system that may increase the retention of phosphorus and reduce phosphorus loading to Lake Okeechobee. As the flow path shifts from the relatively large C-38 canal to the shallower and narrower river channel, which will overflow and inundate its broad floodplain for extended periods, there may be more uptake, deposition, and storage of phosphorus in plants, algae, and soils. However, distinguishing the KRRP's effects from other factors such as variations in annual discharge and changes in land use and runoff is difficult. A primary reason for this difficulty is the nature of the project and the system that is being restored. The KRRP was not designed as a nutrient removal project. It is intended to restore the river's natural habitat and will increase natural variability. Consequently, the character of the restoration area is very different from a constructed wetland such as a Stormwater Treatment Area, which has well-defined boundaries, highly regulated flows, and measured inputs and outputs that can be monitored conveniently.

With regard to the Lake Okeechobee TMDL, better estimates of the KRRP's effect on phosphorus retention would be very useful for predicting potential reductions in TP loading from the Kissimmee Basin. To better understand and predict phosphorus movement through the restored river, a study of phosphorus dynamics began in WY2009. In the first year of this study, a report was prepared that included evaluation of existing data, model assessment, and development of a framework for further investigation of the KRRP's effect on phosphorus transport and retention. In this report's conclusions, information on the phosphorus content of river channel sediments and floodplain soils, and the interaction of sediment and soil phosphorus with the overlying water, were identified as priority needs for determining how restoration will affect phosphorus movement through the river/floodplain system. In WY2010, the District initiated the design of a survey to address the first of these priorities, which includes the collection of sediment and soil samples from the river channel and floodplain, an analysis of phosphorus and related constituents, and a comparison of TP in the floodplain soils to other soils in the Lake Okeechobee Watershed. Work on the survey is anticipated to begin in WY2011.

Floodplain Vegetation

Expectations predicting coverage of wetland vegetation communities on the restored Kissimmee River floodplain (Carnal, 2005a, b, c) were based on historical areal coverage using data from the 1952 pre-channelization vegetation map (**Figure 11-19**, map a). The expectations for overall wetland area and the two dominant vegetation types, broadleaf marsh and wet prairie, are: (1) wetland vegetation will cover at least 80 percent of the full restoration area (Phases I, II/III, and IV) (Carnal, 2005a), (2) broadleaf marsh vegetation will cover at least 50 percent of the full restoration area (Carnal, 2005b), and (3) wet prairie vegetation will cover at least 17 percent of the restoration area (Carnal, 2005c). These expectations refer to the entire restored floodplain area and predict full response only after the Headwaters Revitalization Schedule is implemented.

A vegetation map based on 2008 aerial imagery of the Kissimmee River floodplain was completed in 2009 covering the restoration phases completed at that time (Phases I and IVA). This map was compared with previous maps (**Figure 11-19,** maps a–d) of floodplain vegetation from 1952, 1974 (three years following completion of channelization), and 2003 (two years following completion of Phase I) to evaluate interim responses of floodplain vegetation.

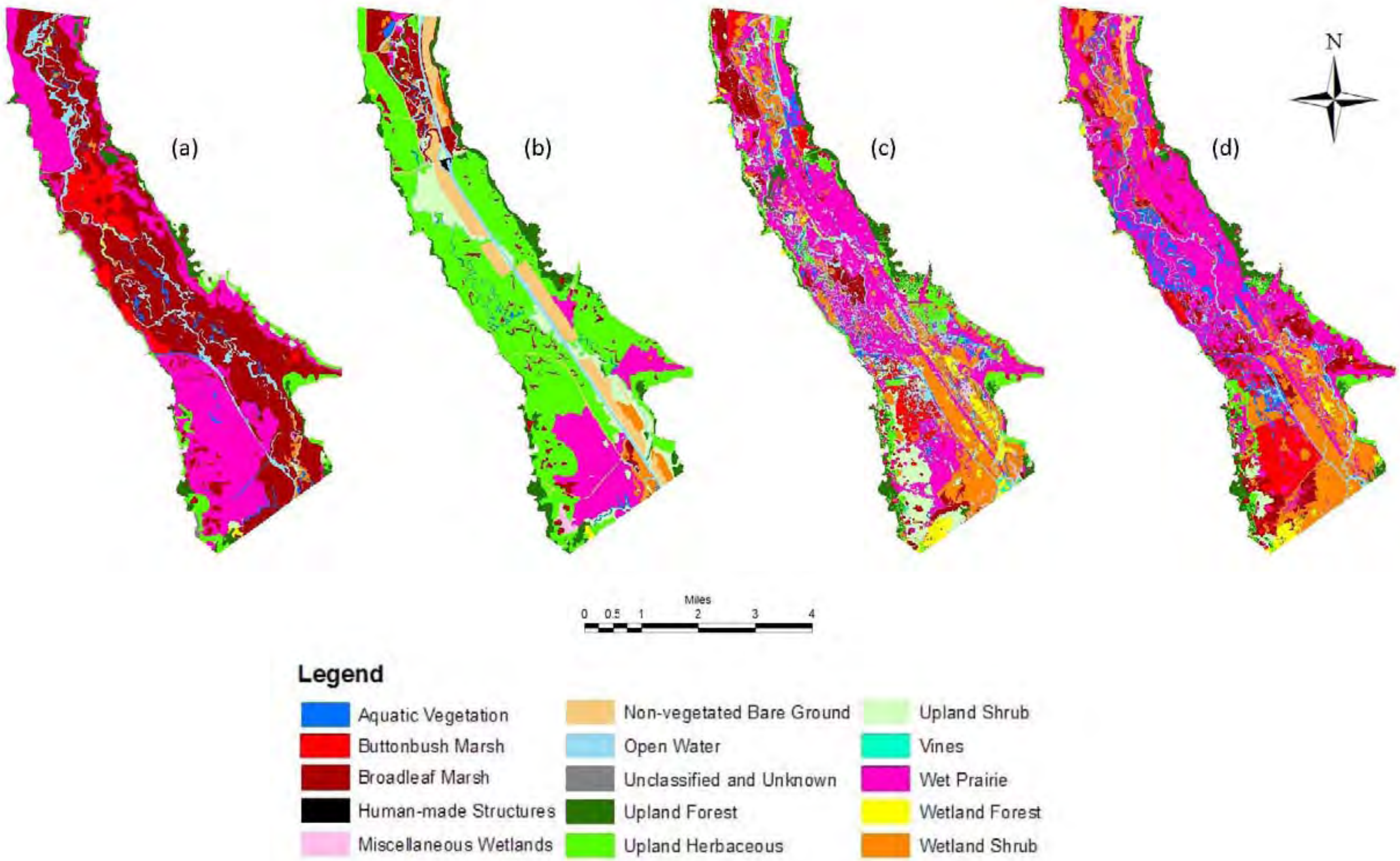


Figure 11-19. Vegetation maps of the Phase I and Phase IVA construction areas from four time periods in the history of the Kissimmee River: (a) 1952–1954, (b) 1974, (c) 2003, and (d) 2008.

This comparison indicates that wetland plant communities reestablished rapidly in the restoration area, and these communities have continued to increase in areal coverage over the interim period (**Table 11-6**). Wetland vegetation overall increased from 1,100 hectares (2,700 acres) in 1974 (25 percent of the Phase I and Phase IVA floodplain) to over 3,600 hectares (8,900 acres or 83 percent) in 2008 (**Table 11-6**; **Figure 11-20**, map a). Wet prairie vegetation, which is now dominant throughout the restoration area, has more than tripled between 1974 and 2008 (**Table 11-6**; **Figure 11-20**, map c). Wetland shrub communities occupy more than six times the area in 2008 than in 1974 (**Table 11-6**). However, the area of broadleaf marsh, the dominant wetland vegetation type prior to channelization, had only increased slightly by 2008 from its pre-restoration coverage and was well below its historical coverage (**Table 11-6**; **Figure 11-20**, map b). Buttonbush marsh, a close associate of broadleaf marsh, also increased after nearly disappearing from this area in the channelized system (**Table 11-6**).

Table 11-6. Sum of area in hectares (and percent area) of vegetation types within the Phase I restoration area over four time periods.

	1952	**1974**	**2003**	**2008**
Buttonbush Marsh	240 (5.5%)	0 (0.0%)	160 (3.6%)	310 (7.1%)
Broadleaf Marsh	1,928 (43.9%)	365 (8.3%)	282 (6.4%)	404 (9.2%)
Wet Prairie	1,364 (31.1%)	542 (12.3%)	1,413 (32.2%)	1,741 (39.6%)
Wetland Shrub	38 (0.9%)	123 (2.8%)	728 (16.6%)	830 (18.9%)
Other Wetland	92 (2.1%)	82 (1.9%)	365 (8.3%)	355 (8.1%)
Total Wetlands	**3,662 (83.4%)**	**1,111 (25.3%)**	**2,947 (67.1%)**	**3,641 (82.9%)**
Other Vegetation	731 (16.6%)	3,282 (74.7%)	1,446 (32.9%)	753 (17.1%)
Total Area	**4,394**	**4,394**	**4,394**	**4,394**

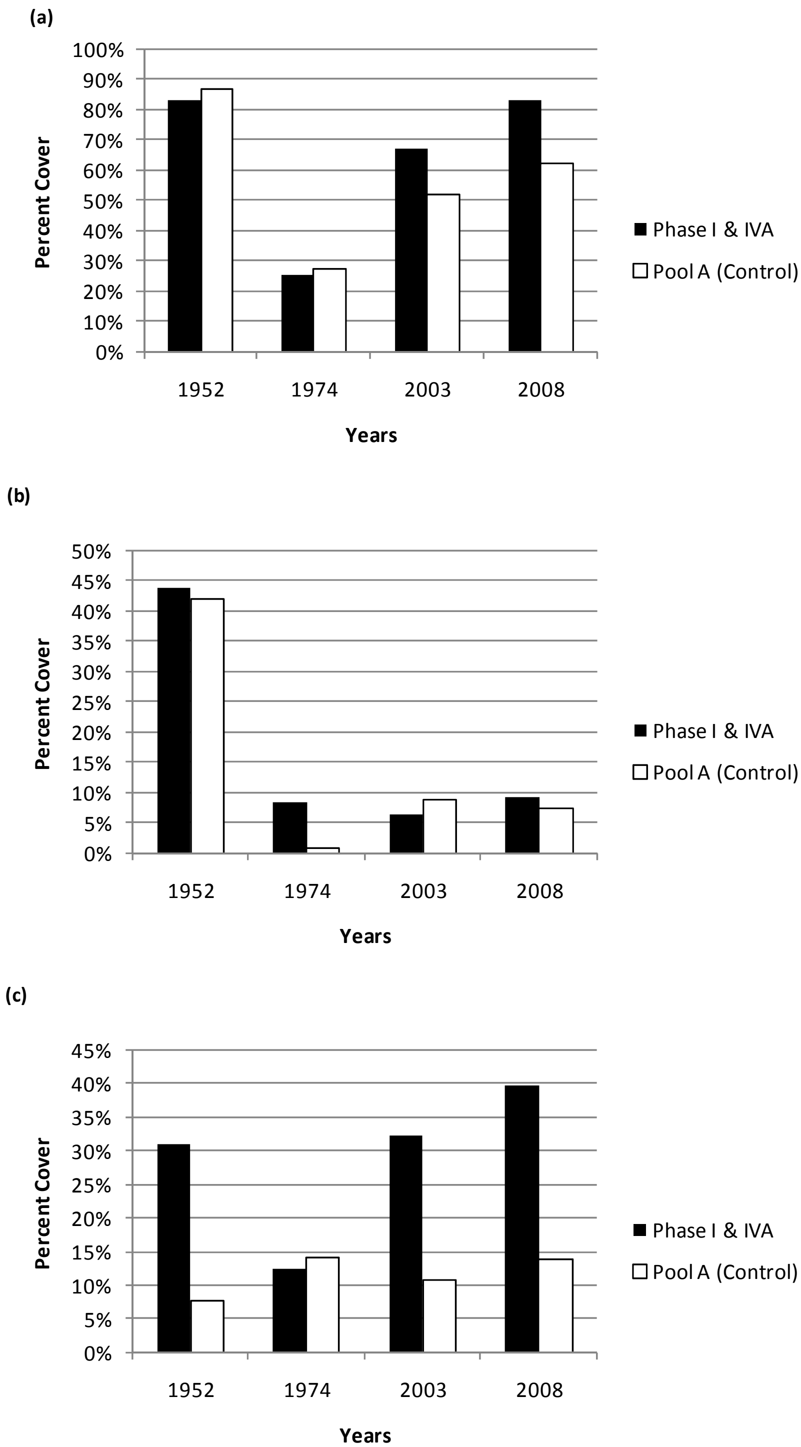


Figure 11-20. Comparisons of percent cover from 1952, 1974, 2003, and 2008 vegetation maps for (a) total wetland habitat, (b) broadleaf marsh vegetation, and (c) wet prairie vegetation in restored and unrestored (control) areas.

Historically, broadleaf marshes occurred in relatively deep, central portions of the floodplain where hydroperiods were prolonged, and wet prairie occurred on the periphery of the floodplain where inundation was shorter and shallower (Carnal and Bousquin, 2005). However, much of the area that was historically broadleaf marsh was covered with wet prairie and wetland shrub vegetation in 2008 (**Figure 11-19**). There are indications that the central portion of the floodplain in the central to northern portion of the current restoration area is composed mostly of wet prairie dominated by maidencane (*Panicum hemitomon*). Because maidencane has hydroperiod characteristics closer to broadleaf marsh than other wet prairie types, this suggests that a small increase in hydroperiod in this area could increase coverage of broadleaf marsh (Spencer and Bousquin, in prep.).

Wetland shrub vegetation, predominantly consisting of invasive primrose willow (*Ludwigia peruviana*), dominates the central portion of the floodplain nearest the S-65C water control structure. *Ludwigia* seems to have benefitted from relatively stable water levels associated with the structure and has been able to out-compete native species in this area. When this structure is removed and the Headwaters Revitalization Schedule is implemented, conditions will not be as favorable for *Ludwigia*, and native vegetation may return to this area (Spencer and Bousquin, in prep).

Although near-continuous flow was maintained in the river channel and the floodplain was inundated intermittently during the seven years that elapsed between completion of Phase I and the 2008 imagery, historical hydroperiods will be much more closely approximated when the Headwaters Revitalization Schedule is implemented. The changes in hydrology that will follow implementation of the Headwaters Revitalization Schedule are expected to drive further changes in the relative abundance of vegetation types. These conditions should favor broadleaf marsh vegetation in lower elevations of the floodplain.

Freshwater Bivalves

This section discusses preliminary data collected in 2010 on native and nonnative bivalves. Little is known about the composition, abundance, and distribution of mollusks in the Kissimmee River prior to channelization. Johnson (1972) identified seven species as occurring in the Kissimmee–Okeechobee–Everglades drainage basin, with one species, Florida shiny spike (*Elliptio buckleyi*), occurring in the Kissimmee River. Shortly after channelization, Vannote (1971) collected two native bivalves [Florida shiny spike and barrel floater (*Anodonta couperiana*)] and the nonnative Asian clam (*Corbicula fluminea*). Between 1995 and 1997, during pre-Phase I construction monitoring, quantitative benthic sampling did not produce any bivalves although qualitative collection of bivalve shells indicated the presence of *E. buckleyi*, *A. Couperiana*, and possibly a third native, the paper pondshell (*A. imbecilis*), and *C. fluminea*. From 2002–2004, during post-Phase I monitoring, quantitative benthic samples did not produce any native bivalves. However, *C. fluminea* was abundant, accounting for greater than 70 percent of benthic macroinvertebrate mean annual density (1,586 individuals/m^2) and 71 percent of mean annual biomass (1,201 mg/m^2).

Several studies indicate that some nonnative taxa [e.g., Zebra mussel (*Dreissena polymorpha*)] can have strong negative impacts on native freshwater mollusks in natural systems (Strayer et al., 1999; Ricciardi et al., 1996; Haag et al., 1993); however, the impacts of other nonnatives, like *C. fluminea*, are less clear (Kraemer, 1979; McMahon, 1991). The abundance of *C. fluminea* and the apparent lack of native bivalves in the Kissimmee River following Phase I have raised several questions about the possible interactions between *C. fluminea* and native bivalves. For this reason, a simple, preliminary survey of bivalves using an informal sampling technique (timed search) was conducted in the Phase I area to address the following questions:

- What native bivalve taxa occur in the Phase I project area?
- Do native bivalves co-occur with *C. fluminea*?
- Is the distribution of bivalves related to environmental factors (e.g., substrate particle size, substrate organic matter content, current velocity, and DO)?

In June 2010, 21 marginal channel sand areas in the river channel were selected for sampling at the lower end of the Phase I project area (**Figure 11-21**). Sites were visually located, and based on known habitat preferences of native unionids (also known as freshwater mussels), selected because of the probability that such sites would support mussel populations. Sampling at each location was conducted by three member teams for 10 minutes. Each team member was responsible for searching a specific depth zone ranging from approximately 1–25 centimeters (cm), 26–75 cm, and 76–100 cm. Sampling was done manually by slowly crawling along the sand bar while systematically searching the sand to a depth of approximately (~) 10 cm. All native and nonnative bivalves were identified (when possible), photographed, measured to the nearest 1 millimeter (mm), and returned to the water.

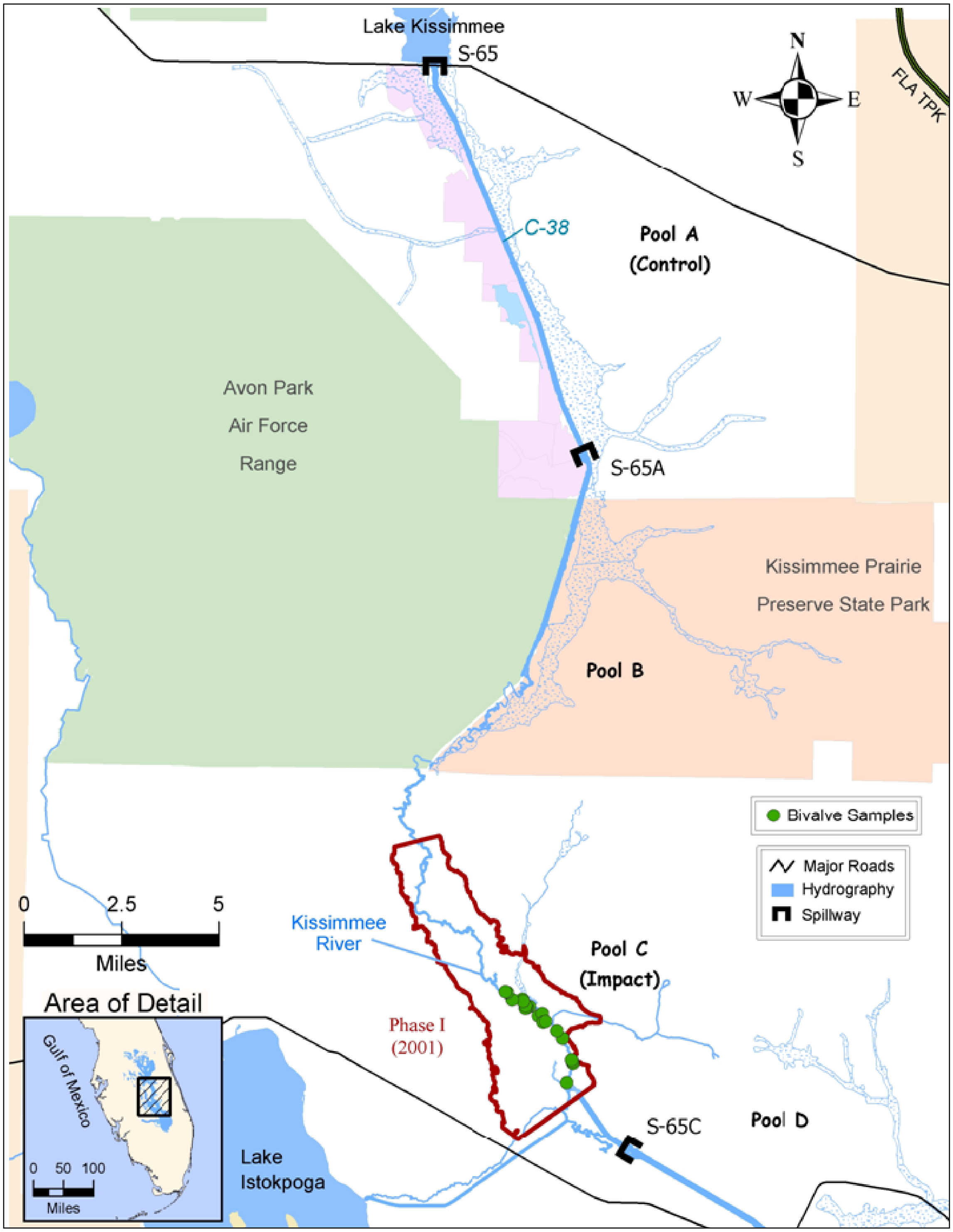


Figure 11-21. Sampling sites for native and nonnative bivalves at the lower end of the Phase I Project area of the KRRP in June 2010.

Prior to sampling, five benthic cores were collected from randomly determined locations on each sandbar within the area to be sampled. Cores were taken to a depth of ~ 15 cm. Organic matter was separated from sand by elutriation. Coarse particulate organic matter (CPOM) was retained on a 1 mm mesh sieve with fine particulate organic matter (FPOM) retained on a 75 micrometer (µm) mesh sieve. Organic matter was dried to a constant mass at 60° Celsius (C) for a minimum of 24 hours. Organic matter was ashed at 400°C for four hours to determine ash-free dry mass. Remaining sand was dried and separated into size fractions using a stack of sieves (1 mm, 500 µm, 250 µm, 125 µm, and 75 µm). Current velocity and DO were measured using a Marsh-McBirney series 2000 current meter and a YSI® Multi-Probe water quality instrument, respectively, at three locations at each site corresponding to the depth zones where bivalves were collected.

A total of 688 native bivalves, primarily *E. buckleyi*, and 1,191 nonnative *C. fluminea* were collected from all locations. At least two currently unidentified taxa were also collected at several sites, but were far less abundant. At most sites, both *E. buckleyi* and *C. fluminea* were collected from each depth zone. *E. buckleyi* ranged in size from 10–64 mm with a median size of 38 mm (**Figure 11-22**). *C. fluminea* ranged in size from 3–22 mm with a median size of 8 mm (**Figure 11-22**). Based on the presence of small individuals for both taxa, *E. buckleyi* and *C. fluminea* appear to be reproducing within the sampled area. Analyses of environmental data are in progress.

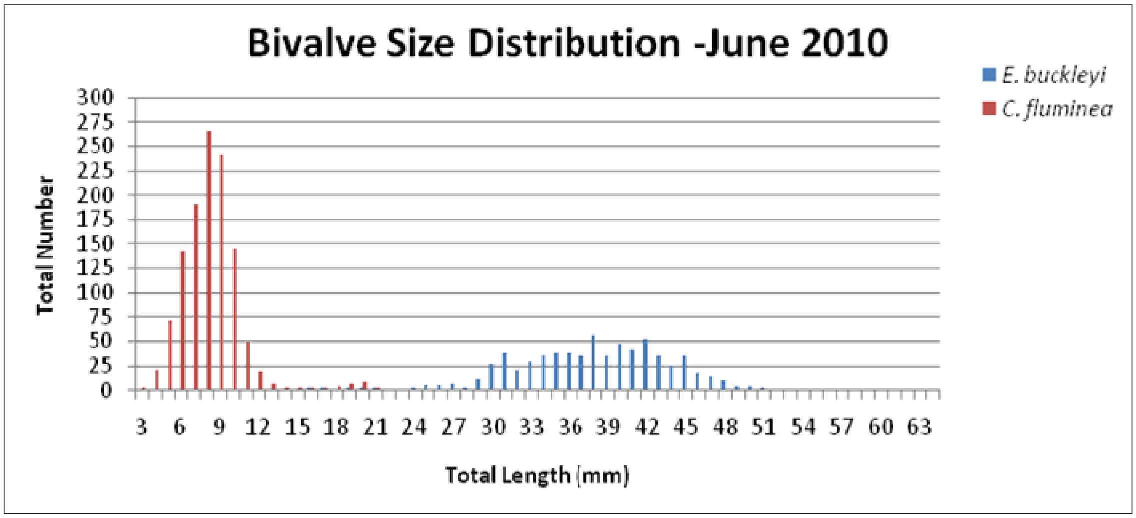


Figure 11-22. Size distribution of Florida shiny spike (*Elliptio buckleyi*) and Asian clam (*Corbicula fluminea*) in marginal sand habitats in the Phase I Project area. Other native bivalves were rare and not indicated on this chart.

Based on this informal sampling method and relatively small sample size, preliminary results indicate that *E. buckleyi* and at least two additional native unionids co-occur with *C. fluminea* in marginal river channel sand habitats. Although informal sampling should be avoided when attempting to estimate relative abundances, it appears that *E. buckleyi* can be present in large numbers when *C. fluminea* is present. The results further suggest that native populations can establish and persist despite early colonization of the Phase I area by *C. fluminea*. Additional sampling in mid-channel habitats will help to identify the distribution of all bivalves within the channel. This information will be used to develop a more rigorous, quantitative sampling program that can be implemented throughout the restoration project area.

Birds

Birds are integral to the Kissimmee River/floodplain ecosystem and highly valued by their 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 can be found in the 2005 SFER (SFWMD, 2005c, Chapter 11). This section highlights portions of the avian program for which data were collected during the winter and spring of 2009–2010.

Wading Bird Nesting Colonies

As part of the KRREP, the SFWMD performed systematic aerial surveys on February 16, March 22, April 23, and May 18 to search for wading bird nesting colonies within the Kissimmee River floodplain and surrounding wetland/upland complex approximately 2 miles (3 km) east and west of the 100-year flood line. Nesting colonies were also monitored, when encountered, during separate aerial surveys of foraging wading birds on January 11, February 12, March 9, April 13, and May 11. Known colonies in Lakes Mary Jane, Kissimmee (Rabbit Island), and Istokpoga were surveyed at least once. The number of nests reported represents the maximum number of nests for each species observed. It is likely that the nests for a relatively small number of dark-colored birds, such as little blue heron (*Egretta caerulea*), glossy ibis (*Plegadis falcinellus*), tricolored heron (*Egretta tricolor*), and black-crowned night heron (*Nycticorax nycticorax*), were undercounted during the aerial surveys because of their lower visibility from above (Frederick et al., 1996). Thus, the colony total presented in **Table 11-7** is considered conservative. Nest fate and nesting success were not monitored, but one ground survey was conducted at the Pool C boat ramp colony (April 23) to obtain a more accurate nest count and determine the presence of less visible dark-colored species (e.g., little blue heron and tricolored heron). A total of seven colonies were surveyed during 2010, only three of which occurred within the Kissimmee River survey area (**Table 11-7**, **Figure 11-23**). The other four colonies were observed in Lake Mary Jane (one), Lake Kissimmee (two), and Lake Istokpoga (one).

The largest colony, composed of 1,156 white ibis (*Eudocimus albus*), 249 great egret (*Ardea alba*), 200 cattle egret (*Bubulcus ibis*), and 47 great blue heron (*Ardea herodias*) nests, was first observed on February 16 on Rabbit Island in Lake Kissimmee. Rabbit Island has supported the largest colony in both the Upper and Lower Kissimmee basins in recent years (**Table 11-7**, SFWMD 2008a, 2009). However, a significant proportion (> 50 percent) of the white ibis nesting on Rabbit Island appeared to have abandoned nesting sometime between April 23 and May 18. No subsequent survey was conducted to determine if the number of nesting ibis was further reduced, but anecdotal evidence suggests that nesting effort for white ibis was further reduced before the end of the breeding period. One possible factor contributing to the partial colony abandonment was the above-normal rainfall during the previous five months and the 4.68 inches of rainfall over Lake Kissimmee during the period between April 23 and May 18. This rainfall may have caused water level reversals in surrounding isolated wetlands where a portion of these birds were likely foraging outside of Lake Kissimmee. Reversal of water levels during the dry season is thought to decrease prey availability for wading birds by redistributing prey over a larger surface area and decreasing prey density, thereby leading to nest abandonment when sufficient food cannot be captured to feed young.

The largest colony to form along the Kissimmee River was first observed on May 18 in the southern reach of MacArthur Run near the Pool C boat ramp. This colony was composed of 842 cattle egret, 22 little blue heron, and 15 tricolored heron nests. The other two colonies along the Kissimmee River formed outside of the restored portions of the river; one in the northern third of Pool A near the River Ranch Resort on an island in the C-38 canal and the other southwest of the Pool D floodplain on private property (Lykes Brothers, Inc.) (**Table 11-7**, **Figure 11-23**).

Table 11-7. Peak numbers of wading bird nests inside or within 2 miles of the Kissimmee River 100-year flood line (between the S-65 and S-65D structures) and within Lakes Mary Jane, Kissimmee, and Istokpoga. Surveys were conducted March–June 2004, March–June 2005, February–June 2006, May–July 2007, January–May 2008, February–April 2009, and February–May 2010.

Kissimmee River

Year	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	GLIB	BCNH	Total
2004	-	-	-	-	-	-	-	-	-	-
2005	400	81	-	-	5	-	-	-	-	486
2006	500	133	-	-	4	-	-	-	-	637
2007	226	-	-	-	-	-	1	-	-	227
2008	-	2	-	-	4	-	-	-	-	6
2009	240	126	-	-	27	11	3	-	-	407
2010	891	35	-	-	31	22	15	-	-	994
Total	**2,257**	**377**			**71**	**33**	**19**			**2,757**

Lake Mary Jane

Year	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	WOST	BCNH	Total
2010	-	250	-	-	-			100	1	**351**
Total	-	**250**	-	-	-	-	-	**100**	**1**	**351**

Lake Kissimmee

Year	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	GLIB	BCNH	Total
2009	740	150	75	10	50	42	87	10	3	**1,167**
2010	200	249	1,156	-	59	-	-	-	-	**1,664**
Total	**940**	**399**	**1,231**	**10**	**109**	**42**	**87**	**10**	**3**	**2,831**

Lake Istokpoga

Year	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	WOST	BCNH	Total
2010	103	325	110	-	75	-	-	-	-	**613**
Total	**103**	**325**	**110**	**-**	**75**	**-**	**-**	**-**	**-**	**613**

CAEG = cattle egret (*Bubulcus ibis*)
GREG = great egret (*Ardea alba*)
WHIB = white ibis (*Eudocimus albus*)
SNEG = snowy egret (*Egretta thula*)
GBHE = great blue heron (*Ardea herodias*)
LBHE = little blue heron (*Egretta caerulea*)
TRHE = tricolored heron (*Egretta tricolor*)
GLIB = glossy ibis (*Plegadis falcinellus*)
WOST = wood stork (*Mycteria americana*)
BCNH = black-crowned night heron (*Nycticorax nycticorax*)

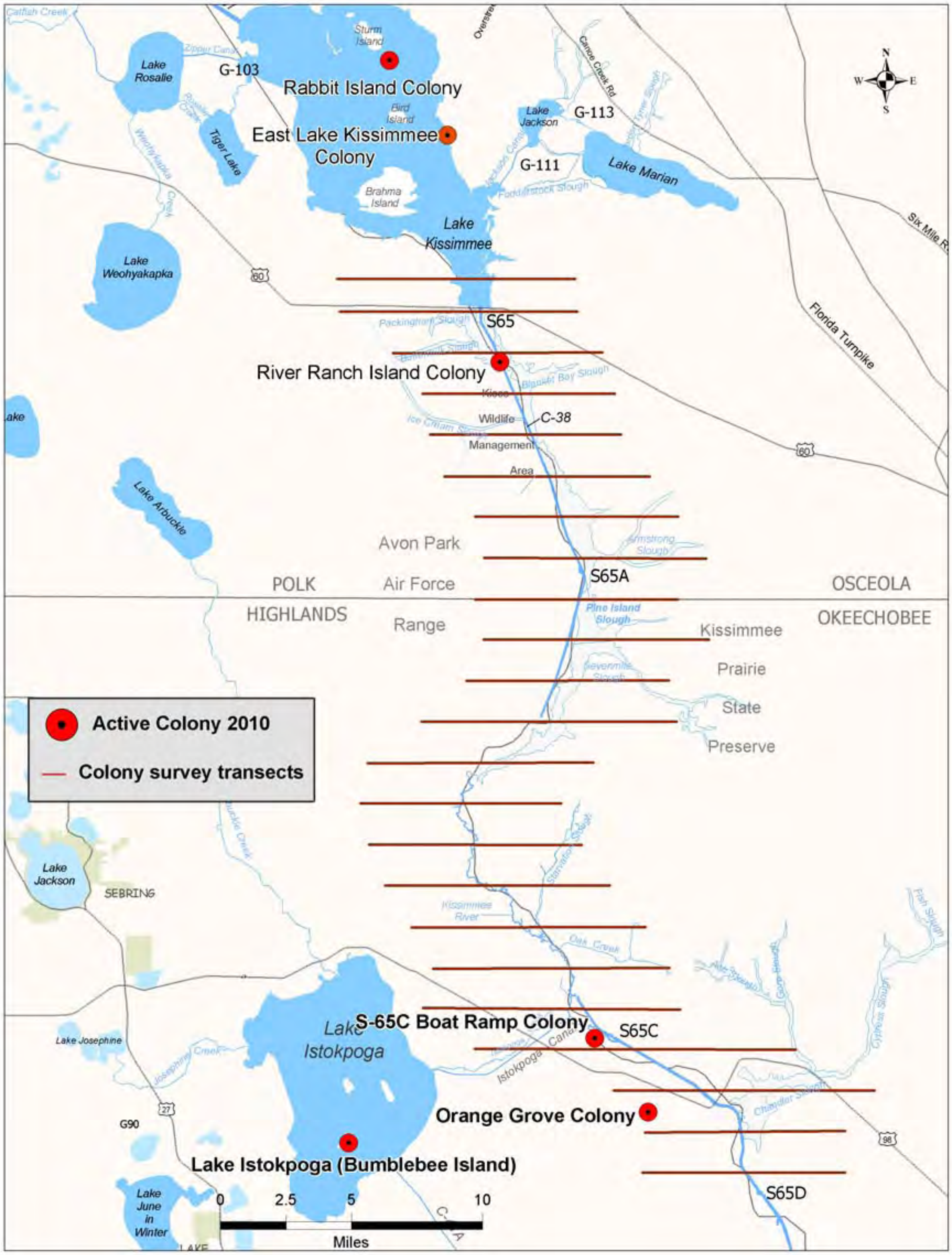


Figure 11-23. Aerial survey transect routes and nesting colony sites within the Kissimmee River floodplain and surrounding wetland/upland complex during 2010. The Lake Mary Jane colony (not shown) is approximately 30 miles to the north-northeast of Lake Kissimmee and 16 miles southeast of Orlando.

Although this year's total nesting effort was more than last year, the increase was due entirely to a higher number of cattle egret nests. The cattle egret, a terrestrial wading bird indicative of conversion of wetland habitat to cattle pasture along the Kissimmee River, is expected to decrease in abundance as a result of river restoration. The area of pasture available for foraging by cattle egrets is expected to continue to decrease once Phase II/III of the KRRP is completed, when over 4,688 acres of pasture will revert to native wetland habitats. Then, aquatic wading birds are expected to return in greater abundance within the restored sections of the river (see following section on *Wading Bird Abundance*).

The continued small numbers of aquatic wading birds nesting within the restoration area suggest that prey availability on the floodplain is not yet sufficient to support successful breeding. This is likely due to water management operational constraints that limit the range and seasonality of floodplain inundation, thereby limiting the concentration effect of dry season recessions on wading bird prey items (e.g., small fish and aquatic invertebrates). Additionally, aquatic prey populations within the river may need more time to recover to sufficient size to support wading bird breeding after the drought years of 2006–2007, when much of the floodplain was completely dry. During the WY2010 dry season, water levels within the restoration area were well above average, and much of the floodplain was too deep for wading bird foraging during a time when most wading birds initiate breeding and energetic demands are greatest. Implementation of the Headwaters Revitalization Schedule will 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 Abundance

Monthly aerial surveys were used to measure the abundance of foraging wading birds. Prior to Phase I construction (baseline period), dry season abundance of long-legged wading birds in the Phase I area averaged [± standard error (S.E.)] 3.6 (± 0.9) birds/km² in 1997 and 14.3 (± 3.4) birds/km² in 1998. Since completion of Phase I, abundance has exceeded the restoration expectation of 30.6 birds/km² each year except in 2007 and 2009, averaging 37.8 (± 15.4), 61.7 (± 14.5), 59.6 (± 24.4), 103.0 (± 31.5), 11.0 (± 2.1), 34.7 (± 6.4), 18.6 (± 6.4), and 48.5 (± 8.8) birds/km² in the dry seasons of 2002–2010, excluding 2003 when data were not collected (**Figure 11-24**) (SFWMD, 2008a). Furthermore, the lower limit of the 95 percent confidence interval (C.I.) has exceeded the expectation in four of seven years. The three-year running average, upon which the restoration evaluation is based, was 33.9 birds/km² for 2008–2010, just over the expectation of 30.6 birds/km².

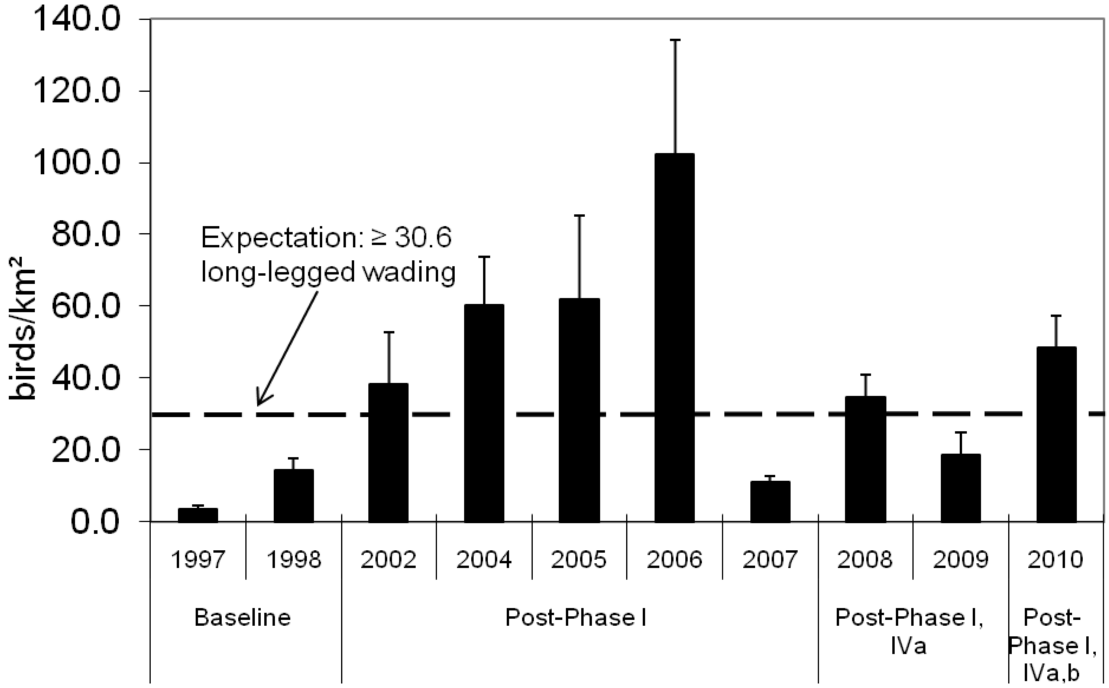


Figure 11-24. Baseline and post-Phases I, IVA, and IVB abundance (± S.E.) of long-legged wading birds [excluding cattle egrets (*Bubulcus ibis*)] during the dry season (December–May) within the 100-year flood line of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately 10 months following completion of Phase I.

Wading bird numbers within the restored portions of the river were more than double last year's mean of 18.6 birds/km². However, last year's lower numbers were attributed to birds being attracted to the active Phase IVB construction area (included in the 2010 survey for the first time), where water levels were more suitable for foraging than within the previously restored areas (SFWMD, 2010). Despite above-average rainfall and water depths within the restored areas, the dry season (especially in March and April) mean abundance for the season was still held relatively high by the above-average estimates during December–February, when monthly abundance was 71.2, 61.2, and 58.8 birds/km², respectively. Record numbers of adult and juvenile wood storks (*Mycteria americana*) were observed this fall/winter during October–January, with a peak number seen during October, including one flock of over 350 individuals. This is largely attributed to migratory birds arriving from outside of the basin in the fall after a banner nesting season during 2009 (Cook and Kobza, 2009).

White ibis and great egrets dominated numerically, followed in order of abundance by glossy ibis, wood storks, small white herons [snowy egrets (*Egretta thula*) and juvenile little blue herons], great blue herons, cattle egrets, black-crowned night herons, small dark herons (tricolored herons and adult little blue herons), roseate spoonbills (*Platalea ajaja)*, and yellow-crowned night herons (*Nyctanassa violacea)*.

Waterfowl Abundance

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, Chapter 14). Mean annual abundance (± 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 Phase I, annual average duck abundance has exceeded the restoration expectation each year except in 2007 and 2009, and the lower limit of the 95 percent C.I. has exceeded the expectation in six of eight years (**Figure 11-25**). Waterfowl abundance this season (8.0 ± 2.4 birds/km²) was more than double last year's mean of 3.2 ± 1.5 birds/km². The three-year running average, on which the restoration evaluation is based, was 6.3 birds/km² in 2008–2010, significantly over the expectation of 3.9 birds/km². As usual, blue-winged teal and mottled ducks dominated numerically, while only four individuals each of hooded mergansers and wood ducks were observed within transects.

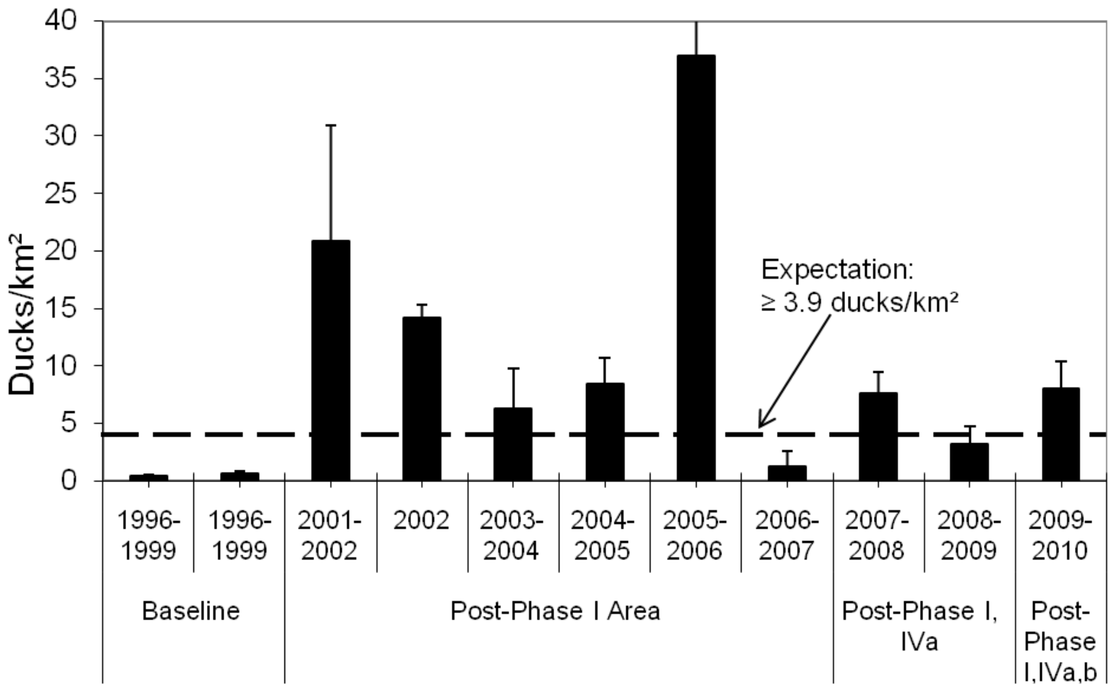


Figure 11-25. Baseline and post-Phases I, IVA, and IVB abundance (± S.E.) of waterfowl during winter (November–March) within the 100-year flood line of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately nine months following completion of Phase I.

The American wigeon (*Anas 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 abundance 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 they support. Extrinsic factors, such as annual reproductive output on summer breeding grounds and local and regional weather patterns, also may play a role in the speed of recovery of the waterfowl community.

PHASE II/III RESTORATION EVALUATION AND HEADWATERS LAKES MONITORING

Phase II/III Integrated Studies and Monitoring

Several monitoring studies were started in WY2009 to evaluate ecological responses to Phase II/III of the KRRP. Currently, these studies are collecting data to establish baseline conditions prior to the beginning of Phase II/III restoration construction in 2012. Monitoring includes water quality (phosphorus and DO); 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 the Phase II/III Integrated Studies is to better identify relationships among individual components of the ecosystem. This goal is one of the mandates of the KRREP. A better understanding of the relationships among monitoring studies will aid in adaptive management of the ecosystem during recovery. The Integrated Studies are using comparable designs that will be implemented using coordinated spatial and temporal sampling to enhance correlative analyses 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 before-after-control-impact (BACI) design (SFWMD, 2005a, Chapter 1), with sampling conducted in control and impact areas before and after reconstruction of the project area.

Phase II/III Hydrology Network

During WY2009, the hydrologic monitoring network in Pool D of the Kissimmee River was expanded to establish a baseline in Pool D for Phase II/III. The network was expanded from six sites to 22 sites (**Figure 11-26**). The six previously existing sites are arranged from upstream to downstream (**Figure 11-26**) and include C38BAS, which was established in 1997, and five sites that were established in 2003 (PD01F, PD02R, PD03F, PD04F, and PD05F). The expansion included placing stage recorders at 16 new sites (**Figure 11-26**), of which 13 are in floodplain locations and three are in river channel locations. Two of the river channel sites have index velocity meters to provide information about discharge carried by the river channel. Chapter 11 in the 2009 SFER provides more details about the requirements for the monitoring network and the basis for site selection. Baseline stage data were collected at most sites for an entire year. This chapter update focuses on a preliminary summary of the stage data for WY2010 and discusses potential controls on stage fluctuation.

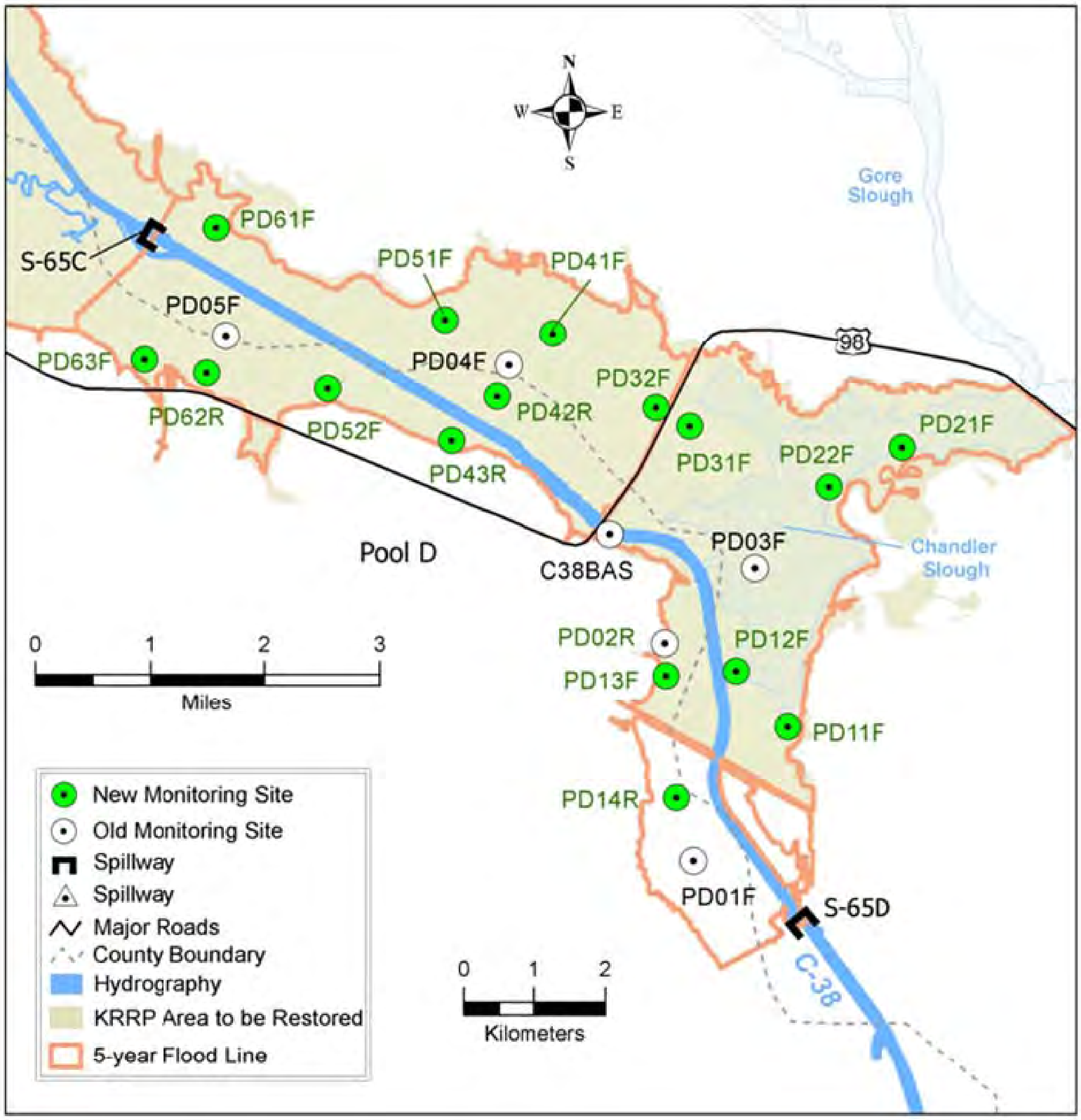


Figure 11-26. New hydrologic monitoring sites (established in 2009) relative to old sites (established prior to 2009) in Pool D of the Kissimmee River that will be used to evaluate responses to Phase II/III of the Kissimmee River Restoration Project.

Rainfall in Pool D was estimated by averaging the daily rainfall at S-65C and at S-65D (**Figure 11-27**, panel A). Rainfall totaled 59.78 inches, which was greater than the Lower Kissimmee Basin-wide average of 52.96 inches. The 6.82-inch difference may reflect the basin-wide estimate methodology, which factored in the larger area, additional stations, and the area represented by each gauge. The estimate for Pool D does not capture the major seasonality of rainfall including the above-average rainfall events in the dry season months of May, December, and March. By the end of October (May 2009 and the wet season), 39.78 inches had fallen (**Figure 11-27**, panel A).

During WY2010, discharge at S-65D ranged from 1 cfs to 8,259 cfs (**Figure 11-27**, panel B) and averaged 8,259 cfs. During WY2010, the water surface of Pool D was fairly flat in the C-38 canal because of the canal design. Mean daily stage at the upstream end of C-38 (S-65C tailwater) and at the downstream end (S-65D headwater) differed by no more than 0.24 ft and was no more than 0.15 ft for 98 percent of the year (**Figure 11-27**, panel B). The S-65D structure is operated to maintain an optimum stage of 26.8 ft. Mean daily stage fluctuated by 1.2 ft at both locations (**Table 11-8**).

The stage at 10 sites appeared to be controlled by the stage in the C-38 canal (**Table 11-8**). At these sites, the amplitude of stage fluctuation was small, 1.2–1.3 ft, and approximated that of the C-38 canal. The minimum and maximum stages were also about the same as those for S-65D headwater (**Table 11-8**). When the time series for these 10 sites was plotted with the one for the S-65D headwater, the time series almost completely overlap. An example of this overlap is shown for C38BAS (**Figure 11-27**, panel C). Five of these sites (C38BAS, PD02R, PD42R, PD62R, and PD14R) were located in remnant river channels with direct connections to the C-38. One site (PD14R) had a smaller amplitude of 0.75 ft, which was likely the result of data collection not beginning until September 27, 2009, after the occurrence of peak stages in the C-38. The other five sites were located on the floodplain at the southern end of Pool D where water levels are controlled by the S-65D structure. PD03F is designated as a floodplain site, but is located in a channelized portion of Chandler Slough with a direct connection to the C-38.

The stage at 12 sites appeared to be controlled by rainfall. The amplitude of stage fluctuation for these sites in WY2010 ranged from 2.27 ft to 5.69 ft (**Table 11-8**). Increases in stage at these sites (**Figure 11-27**, panel D) tend to correspond to periods of higher rainfall (**Figure 11-27**, panel A). The amplitude of stage fluctuation was less than 3 ft for only two sites (PD21F and PD22F). Data collection at PD21F and PD22F, which are also located in Chandler Slough, did not begin until September 16 and October 28, 2009, respectively. These sites showed a much greater range of stage fluctuation than the sites controlled by C-38 (**Table 11-8**).

In conclusion, stage data were collected for at least 185 days of WY2010, and an entire year of data were collected at 13 of 22 stage monitoring sites in Pool D. This preliminary analysis of stage data for WY2010 suggests that stage monitoring sites in Pool D can be placed in two groups. In one group, the amplitude of stage fluctuation was relatively small, approximately 1.2 ft, and was controlled by water levels in the C-38 canal. In the second group, stage amplitude was much larger, > 3 ft for most sites, and was controlled by rainfall.

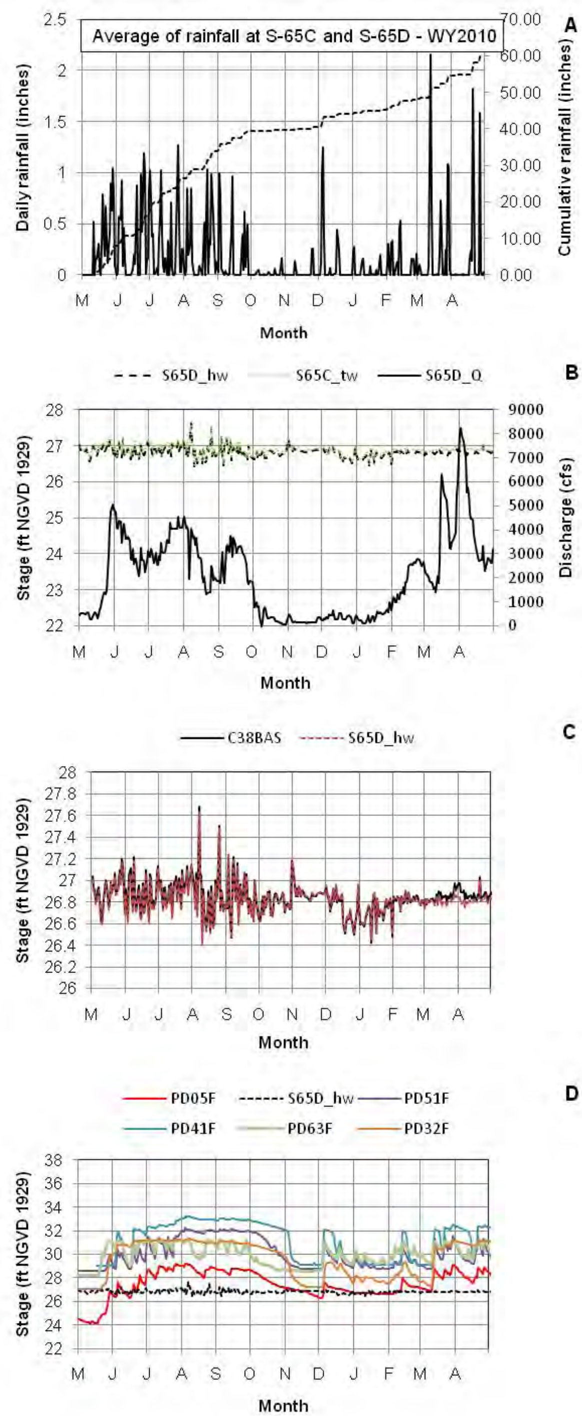


Figure 11-27. (A) Rainfall, (B) stage and discharge in the C-38, (C) stages at selected C-38 controlled sites, and (D) stage at selected rainfall controlled sites.

Table 11-8. Number of measurements (n) in WY2010, minimum stage, maximum stage, amplitude (maximum stage–minimum stage) for WY2010 in Pool D, Kissimmee River. Control identified whether amplitude of stage fluctuation was determined by water levels in the C-38 canal or by rainfall.

Site	dbkey	n	Min	Max	Amplitude	Control
C38BAS	GT994	365	26.42	27.69	1.26	C-38 canal
PD02R	PA209	365	26.39	27.64	1.24	C-38 canal
PD01F	PA211	365	26.40	27.60	1.20	C-38 canal
PD03F	PA213	365	26.41	27.63	1.22	C-38 canal
PD11F*	WF805	365				C-38 canal
PD12F*	WF807	365				C-38 canal
PD13F	WN201	360	26.41	27.67	1.25	C-38 canal
PD42R	WN303	311	26.44	27.71	1.27	C-38 canal
PD62R	WN306	312	26.41	27.71	1.31	C-38 canal
PD14R	WN326	216	26.41	27.15	0.75	C-38 canal
PD04F*	PC138	365				Rain
PD05F	PC140	365	24.11	29.20	5.09	Rain
PD41F	WN099	349	28.99	33.20	4.21	Rain
PD43F	WN101	282	28.78	31.83	3.05	Rain
PD51F	WN103	365	28.61	32.23	3.62	Rain
PD52F	WN105	365	25.86	29.02	3.17	Rain
PD31F	WN128	365	26.64	30.88	4.24	Rain
PD32F	WN130	365	27.08	31.29	4.21	Rain
PD61F	WN132	290	27.72	31.75	4.03	Rain
PD63F	WN134	365	28.18	31.18	3.00	Rain
PD21F	WN309	185	29.57	31.84	2.27	Rain
PD22F	WN311	227	27.66	30.54	2.89	Rain
S65D_hw	06960	365	26.42	27.64	1.22	
S65C_tw	06958	365	26.47	27.67	1.20	

*Reference elevations under revision.

Phase II/III Nutrient Monitoring

The Phase II/III evaluation will include monitoring of TP and TN concentrations during construction in Pool D to determine if increased transport of nutrients downstream to Lake Okeechobee occurs during construction. Monitoring was initiated in WY2010 to gather baseline data in advance of Phase II/III construction. Data collection also includes turbidity, phytoplankton chlorophyll, DO, and other water quality parameters. An increase in nutrient transport during construction work is not expected as the backfilling method is designed to isolate activity from the flow of the river (Colangelo and Jones, 2005).

Phase II/III Baseline Herpetofaunal Community Structure Study

The Phase II/III Integrated Studies incorporate a new herpetological study that is closely integrated with hydrology, vegetation community structure, and food web dynamics. Beginning in WY2009, visual encounter surveys were conducted in forested upland habitat adjacent to the floodplain, and 300 m of linear drift fences were installed on the outer fringe of the forested edge of the unrestored floodplain to investigate seasonal patterns of breeding and foraging movements to and from the floodplain. The wet season of WY2009 also marked the initiation of vocalization surveys to document baseline conditions for the Anuran (frogs and toads) breeding population in the floodplain of the channelized system. These surveys continued in WY2010. Once river restoration is complete, this baseline study will be used in assessing the success of restoration with regard to the herpetological component of ecological integrity. This herpetological study will continue until Phase II/III construction begins in 2012, and will resume following the completion of construction slated for late 2014.

Geomorphology

The SFWMD conducted a geomorphic monitoring pilot study from 2006–2009 in cooperation with the University of Florida and the USGS with the goal of establishing a long-term program to address stability and sedimentation monitoring requirements stipulated in the Integrated Feasibility Report/Environmental Impact Statement (IFR/EIS) (USACE, 1991). The overall long-term objectives of the monitoring are to: (1) 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 channelization period. The study area includes both the Phase I and Phase II/III restoration areas. Specific components of the pilot study included: channel cross-section and planform (imagery interpretation) analysis, coring and characterization of organic riverbed sediments in Pool D, measurement of in-channel sediment (suspended and bed load) transport, and measurement of sediment deposition on the floodplain. The approaches and results of this study are summarized in the following sections. The full report, *Geomorphic Monitoring of the Kissimmee River Restoration: 2006–2009*, is available on the District's website at www.sfwmd.gov (see *Library and Multimedia* tab).

Channel Cross-sectional Monitoring

Three types of river reaches occur in the Kissimmee River restoration area: (1) remnant channels left intact during channelization, (2) recarved channels excavated to the approximate geometry of former channels buried by spoil during channelization, and (3) connector channels excavated across backfilled portions of C-38. The latter were constructed wider than remnant or recarved channels to mitigate possible erosion of the backfill material. To monitor channel change in the current restoration area (Pool B/C) of the Kissimmee River, 21 cross-sections distributed among these reach types were benchmarked in selected river runs. In addition, four cross-sections were benchmarked in each of the unrestored Pools A and D for comparative purposes (**Figure 11-28**). Cross-sections were initially surveyed in February 2007 and resurveyed in January 2008 and 2009. An additional transect was added in Pool D in 2009.

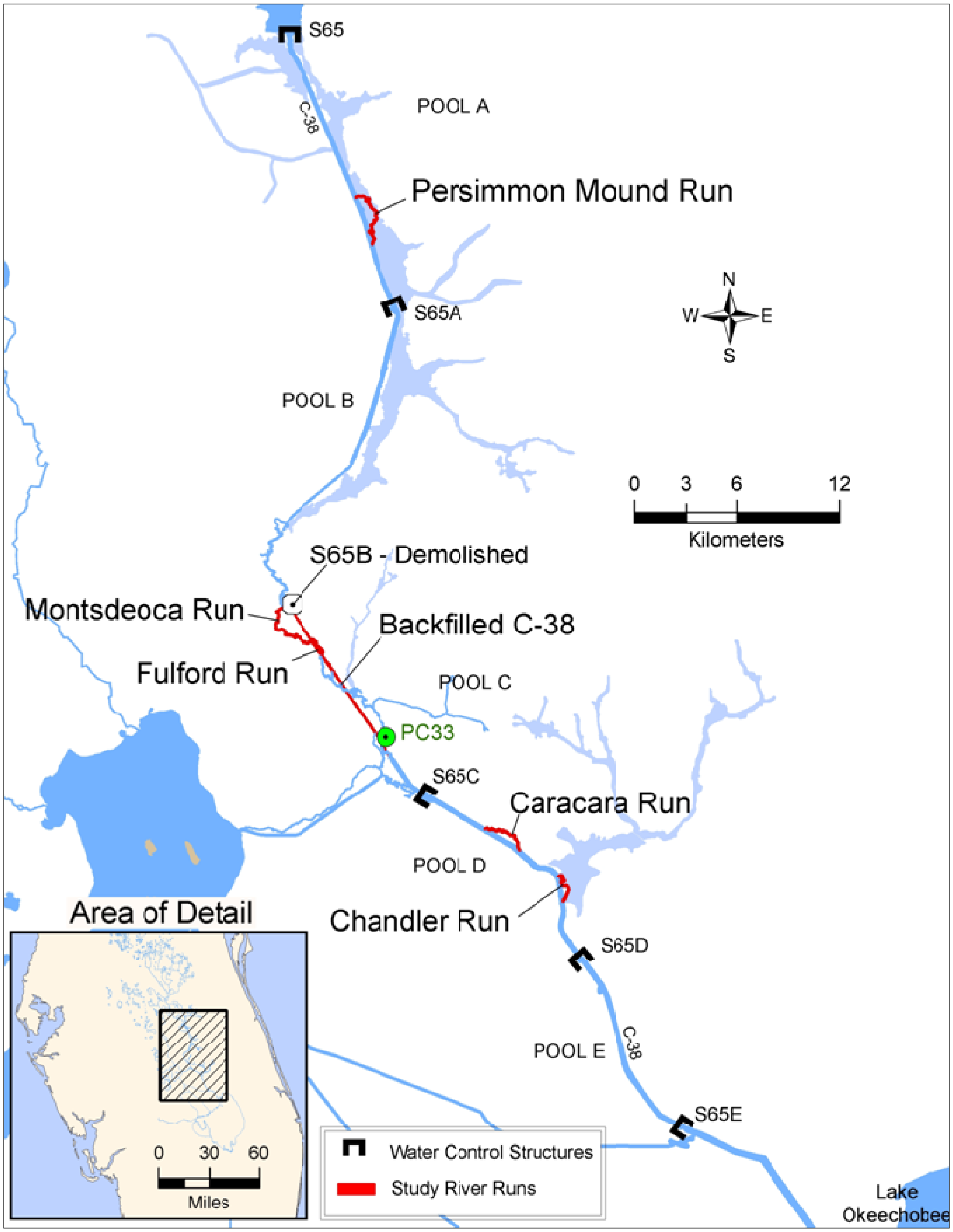


Figure 11-28. The Kissimmee River run sites and sediment load monitoring station (PC33) in the geomorphic pilot study.

Connector channels, which averaged 100 m wide, were shallower than the remnant and recarved channels, which averaged 30 m wide. In addition, an island or a submerged bar was common in the connector reaches. The reduction in velocity associated with the wider channels apparently leads to sediment deposition and bar and island formation. It seems that the connector reaches have not acquired an equilibrated morphology because of their larger size. The connector channels will likely continue to experience more deposition and bar growth over time until these channels reach an equilibrium form. Continued monitoring of these connectors will confirm how quickly they will change over time.

Geospatial Analysis of Channel Planform Changes

One important component of monitoring the KRRP is better documentation and understanding of the planimetric channel form, rates of change, and comparisons to pre-channelization morphometry. Geospatial analysis of channel planform change was conducted in the Lower Kissimmee Basin to understand channel changes (sinuosity and lateral migration) over large areas since restoration construction. An additional focus was to document and monitor the number and size of sandbars. Imagery from 1944, 1954, 1958, 1994, and 2005–2006 was used to create planimetric channel maps for three time periods: 1940s, 1950s, and 2006.

In Pool A, no major changes, except small avulsions, were evident between the 1940s and 1950s in the pre-channelized channel. In Pool B (now the upper portion of Pool B/C), channel planform changes occurred from the 1940s to 1950s, including minor cutoffs, avulsions, and local migration. In Pool D, some lateral migration occurred between the 1940s and 1950s. Pool E, which will not be restored, shows the largest degree of avulsion (up to 60 m) and some lateral migration from the 1940s to the 1950s. From the 1950s to 2006, the major planform change in all sections of the Kissimmee River was creation of the C-38 canal.

Prior to channelization, the Kissimmee River contained multiple sandbars, a characteristic of a migrating sand riverbed. Sandbars were very abundant in Pool A and Pool E in 1944. Other portions of the pre-channelized river had smaller sandbars. After the river was channelized during 1962–1971, all sand bars had disappeared by 1994. By 2004, the post-restoration channel shows an increase in sandbars, and in many reaches more sandbar areas are evident than had been in 1944. By 2005–2006, the middle portions of Pool B/C show more sandbar area than in 1944 or 2004. One key question that remains is the source of this sand, which may be related to bank erosion and river restoration construction. More study will be needed to determine the rates of bank erosion and to create a sediment budget for the Kissimmee River.

Bottom Sediment Observations

Fifty-two cores were collected in 2009 at various points along the channel centerline in Pool D to gain insight into the characteristics, amount, and spatial trends of deposited riverbed material. Most cores were over 50 cm deep, with some cores extending over 1 m below the riverbed surface. Of the 52 cores collected, the original sand bottom was apparently reached in 47 cores. Cores were characterized into three basic categories: (1) sand, (2) fines (silt and clay), and (3) organics. The mean thickness of fine and organic sedimentation across the 52 cores was 38 cm. A general correlation ($r^2 = 0.54$) was observed between the depth of the inferred original channel bottom and fine and organic sedimentation. Deeper areas appear to be areas of greater sedimentation.

Sediment Transport

In July 2007, a streamflow-gauging station was established on the Kissimmee River at PC33 near Basinger, FL (USGS streamflow station ID 022691600; drainage area 5,270 km^2) (**Figure 11-28**). Sediment transport characteristics monitored at the station include suspended sediment, bed load, and bed material. The organic content of the suspended sediment and bed load was also monitored.

The Kissimmee River is a fine- to medium-grained, sand-bed river. Suspended sediment ranged from 2 to 78 percent sand at low and high flows, respectively. The organic content of the suspended sediment increased with flow, ranging from 3 mg/L at low flows to 21 mg/L at high flows. Organic percentage of the suspended sediment load ranged from 31 percent during low flow months to 2 percent during high flow months, indicating that inorganic suspended sediment loads increase faster with rising discharge than organic suspended sediment loads.

The Kissimmee River transports most of its suspended sediment and bed load during periods of high flow. The 10 highest daily suspended sediment loads were transported during Tropical Storm Fay, during August 21–31, 2008, and totaled 44,600 mt, which is 56 percent of the total suspended sediment load for the period of study. The highest daily bed load transport occurred on August 23, 2008, during Tropical Storm Fay when 749 mt of sediment was transported at a mean daily discharge of 157 m^3/s. This bed load was 20 percent of the total bed load discharge for the period of study. The initiation of bed load transport occurred at 28.3 m^3/s. The median grain size of bed load was similar for all flows, ranging from 0.36 to 0.41 mm. The largest particle sizes transported as bed load were 1.0 to 2.0 mm at flows of 140 to 152 m^3/s. Organic percentage of the bed load ranged from 85 percent during low flow months to less than 1 percent at high flows.

Effective discharge computations indicate that the majority of bed load sediment was transported at 47 m^3/s and 239 m^3/s. The 47 m^3/s effective discharge value is close to the bankfull discharge of 50 m^3/s and may be the channel-forming flow. The channel-forming flow is that discharge which is most effective in transporting sediment and forming the channel. The higher effective discharge at 239 m^3/s may be related to the frequent large flows that occurred in association with Tropical Storm Fay. These flows may be important in floodplain processes, but more research is needed to confirm this. Large amounts of bank erosion were observed on the Kissimmee River in connection with the tropical storm, and in some reaches, the river scoured its bed. Both bank erosion and the channel bed could be sources for suspended sediment and bed load. Future studies directed at constructing a sediment budget for the Kissimmee River may be able to determine the significant sediment sources.

Comparison of suspended sediment concentration data from the Kissimmee River at the PC33 monitoring station (2007 through 2008) to data from the S-65E structure closer to Lake Okeechobee (1973 through 1998) indicates that suspended-sediment concentrations are higher at PC33 for the same normalized discharge than at S-65E. It is unclear whether the higher suspended sediment concentrations at PC33 are due to restoration project construction or to other factors. Suspended sediment data are not available for the Kissimmee River near the restoration area of Pool C prior to channelization, during the channelized period, or directly after restoration. Therefore, the suspended sediment data (concentrations and loads) presented in this chapter serve as reference values to determine if concentrations and loads increase, decrease, or remain steady over time.

Floodplain Processes

Sixteen floodplain sediment monitoring transects were established on the Kissimmee River in the winter/spring of 2007 (**Figure 11-28**). These sites were re-measured in May 2008 and again in December 2008. Thirteen of the transects were in river runs within the Pool B/C restoration area and contained 86 clay feldspar pads. Three transects were in river runs in the Pool D channelized reach and contained 14 clay feldspar pads. Transects were aligned perpendicular to the channel and extended from the river edge to 50 to 575 m across the floodplain. Periodic measurements of the clay pads were made for: (1) deposition rate, (2) texture, (3) bulk density, and (4) composition (carbon and phosphorus concentrations).

From January to May 2007, low flow conditions prevailed on the Kissimmee River, and water levels at upstream sections of the restored channel were lower than usual with dry conditions on the floodplain. During this low flow period, areas of the restored channel near the S-65C structure experienced high water conditions due to water ponding behind the structure. Floodplain depressions and sloughs were inundated, and most areas of the floodplain were moist to very wet. The wetter period in March and April 2008 led to one overbank flow in Pool C. Sediment deposition measured on 81 pads in Pool B/C in May 2008 averaged 6.7 mm/yr, ranging from 0 mm/yr to 29.8 mm/yr (near a slough). Higher flows associated with Tropical Storm Fay in August 2008 led to overbank flooding over an extended period. Floodplain sediment deposition measured on 82 pads in Pool B/C in December 2008 indicated a mean sedimentation rate of 15.0 mm/yr, ranging from -7.9 mm/yr (erosional) to 110 mm/yr (part of a levee building event from Tropical Storm Fay).

Sediment deposition rates measured on eight pads in the unrestored Pool D showed average deposition of 1.6 mm/yr in May 2008 and 1.3 mm/yr in December 2008, attributable to autochthonous organic dry deposition, intra-floodplain sediment transport, and aeolian (wind) processes. Both means are an order of magnitude lower than in the restored reach.

About 25 percent of all sediment trapped on the Kissimmee River floodplain is organic. Percent organic content on the floodplain increased significantly ($p < 0.002$, Student's t-test) after overbank flooding attributed to Tropical Storm Fay.

Classifying the restored Kissimmee River floodplain into four landscape types (backfilled C-38 canal, borrow areas to backfill the canal, original floodplain, and elevated spoil regions adjacent to connector segments of the channel) showed that sediment deposition, organic content, and bulk density varied greatly between landscape type.

Floodplains may act as an effective sink for several pollutants; one of the best studied is phosphorus. Sediment concentrations of TP in the Kissimmee River floodplain indicate that the system has some of the highest phosphorus concentrations of studied floodplains in the southeastern United States. (G. Noe, USGS, personal communication, 2009). Phosphorus concentrations increased linearly with organic content, with sloughs and depressions representing the greatest sinks for phosphorus.

HEADWATERS LAKES VEGETATION MONITORING

Monitoring of littoral zone vegetation in four headwater lakes of the Kissimmee River (Lakes Kissimmee, Cypress, Hatchineha, and Tiger) was completed in WY2010. Data from this study will provide a baseline to evaluate plant community changes in peripheral areas where new littoral habitat is expected to form as a result of increases in lake stages made possible by the Headwaters Revitalization Schedule.

In addition, the SFWMD and FWC entered into a partnership to map littoral vegetation in the four headwater lakes. Acquisition of digital aerial imagery was completed in WY2010. The mapping phase of the project was completed in August 2010, with final map data distributed to both agencies at that time. The collaborative nature of this project, which resulted in a single classification system and mapping requirements for the project, can serve as a model for future partnerships between the agencies.

KISSIMMEE RIVER RESTORATION PROJECT CONSTRUCTION ACTIVITIES

C-38 Backfilling and River Channel Restoration

Hydrologic restoration continues on the $634 million KRRP, which is cost-shared equally by the USACE and the SFWMD. Since 1992, the SFWMD has invested approximately $341 million to acquire nearly all 102,061 acres needed for this restoration effort. Another phase of canal backfilling and river channel restoration was completed in December 2009, more than a year ahead of schedule. Phase IVB is the northernmost section of C-38 backfilling. It is located between the Avon Park Bombing Range to the west and Kissimmee Prairie State Park to the east. Phase IVB involved backfilling 4 miles of C-38 and recarving 4 miles of river channel, resulting in reestablished flow to 6 miles of reconnected river channel. Along with construction of Phase I and Phase IVA to the south, which were completed in 2001 and 2007, respectively, 14 of 22 miles of canal have been backfilled to date, and near-continuous water flow has been reestablished in the project area. The last phase of backfilling (Phase II/III) is scheduled to begin in 2012 and slated for completion in late 2014.

S-68 Spillway and S-83/S-84 Spillway Additions

Completed in FY2010, the S-68 spillway addition was built adjacent to and northeast of the existing S-68 structure to increase conveyance capacity when Kissimmee River floodplain water levels restrict Lake Istokpoga Basin discharges via the Istokpoga Canal. The spillway addition offsets the loss of discharge capacity by re-routing flows down the C-41A canal.

Completed in FY2008, the S-83/S-84 spillway additions (located along the C-41A canal between Lake Istokpoga and Pool E of the Kissimmee River) increased the conveyance capacity of the C-41A canal located between Lake Istokpoga and the C-38 canal.

Istokpoga Canal Improvements

Construction activity along the Istokpoga Canal reached a milestone in WY2010 with the opening of a new public boat ramp and parking facility near the U.S. 98 Bridge. Upon completion, ownership of this facility was transferred from the USACE to the SFWMD. In addition, the former G-85 structure midway along the canal was replaced with a new water control structure (S-67), which has a 400 cfs capacity with culverts and riser gates. Work on this new structure is still ongoing. Earlier work involved dredging the Istokpoga Canal to a 30-foot bottom width and removing a spoil mound along the canal. These canal improvements extend from S-67 to the confluence of the Istokpoga Canal and the Kissimmee River. Other construction activity included a tieback levee at S-67 and an access road from County Road 621 to S-68.

C-37 Canal Widening

The USACE's contract to widen the C-37 canal between Lake Hatchineha and Lake Kissimmee was put on a fast track in response to its selection for funding under the federal American Recovery and Reinvestment Act of 2009.This project will widen and deepen the C-37 canal by removing 780,000–1,000,000 cubic yards of bottom material. The project will provide greater conveyance capacity of water between the two lakes to maintain the same level of flood control once the KRRP is in place. Completion of this work is expected in June 2012.

River Acres Flood Reduction

This USACE contract, which was awarded in December 2009, includes dredging, widening, and lengthening of the River Acres navigation canal, and construction of a water control structure to allow some flow through the canal. Also, a new bridge will be built over the canal to maintain access for River Acres residents.

CSX Bridge Replacement

This USACE contract will consist of modifying existing CSX railroad tracks by providing an elevated single track railroad bridge and removal of the embankment and culverts. This will allow restoration of the historical Kissimmee River channel near the boundary between Highlands and Okeechobee counties. The historical riverbed will be reestablished by dredging a channel through the existing railroad embankment. Construction began in FY2010.

Pool D Oxbow Excavation and Embankment

Several oxbows in Pool D are being dredged and reconnected to form a continuous river channel. An embankment will be built along the C-38 canal in this area to help with headwater elevations at S-65DX1, a small structure on the S-65D tieback levee that will discharge water from the restored river channel once the KRRP has been completed. Work began in FY2010.

Rolling Meadows/Catfish Creek Wetland Restoration

Located in Polk County along the southern shore of Lake Hatchineha, the Rolling Meadows property was acquired by the SFWMD and the FDEP as part of the KRRP. The total property of about 5,800 acres includes about 1,900 acres of low-lying, drained sod farm and about 3,900 acres that provide a connection between the Allen David Broussard Catfish Creek State Park and the Kissimmee State Park.

The primary restoration goal is to return approximately 1,600 acres of agricultural fields to littoral wetland habitat by reconnecting them with Lake Hatchineha, probably by breaching the levee along the south edge of the lake. This will be the first phase of restoration. The second phase will be to restore the diverted and channelized Catfish Creek to its historical remnant stream bed and floodplain flow pattern. Design is expected to begin in FY2011, with phased construction planned for FY2011 and FY2012.

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 greater 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. Comprehensive study information including description of the operating objectives, performance measures and indicators, the planning process, and the alternative evaluation system are in the Alternative Plan Selection Document (Earth Tech, 2008). An update of this document is scheduled for release in mid-2011.

The KBMOS was initiated in September 2004. Since the previous reporting period, alternative plans promoted to formulation have been refined to optimize their environmental performance. An alternative plan describes proposed modifications to water control structure operating criteria. To verify refined alternative plan compliance with study flood control constraints, the SFWMD and the USACE have initiated a detailed flood analysis. This analysis requires recalibration of the study modeling tools to smaller than hourly time steps. The 2004 and 2008 wet seasons were chosen for this recalibration period because they represent recent flood events with the majority of the KRRP features in place and include multiple hurricanes and tropical storms. Recalibration was initiated in December 2009 and is expected to be completed by mid-2011. After the modeling tools are calibrated, the top performing alternative plans will be evaluated and refined, if necessary, to meet flood control constraints. Once the flood analysis is complete, the top four plans will proceed to full evaluation and ultimately to selection of a preferred alternative.

The estimated completion date for KBMOS has been extended to accommodate the flood analyses. The new estimated completion date is March 2012, with a December 2012 anticipated completion date for the associated USACE Environmental Impact Statement. 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 www.sfwmd.gov/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 the SFWMD 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. Lake ecosystem health, as defined for the KCOL LTMP, is a sustainable system capable of maintaining its structure and function over time (Haskell et al., 1992). For the KCOL, "sustainable" implies a sustainable managed system, because the plan partners recognize that these lakes cannot be returned to their pre-regulation condition. The plan goals, management objectives, plan principles, and plan proposal are intended to accomplish the plan purpose through a coordinated multiagency, multidisciplinary management framework.

The KCOL LTMP defines management objectives and assessment targets for the lakes, and identifies the existing suite of watershed and lake management tools that can be applied to address existing and emerging issues and concerns within the lakes. The plan proposes implementation of a monitoring and assessment program to support an adaptive management process. The monitoring and assessment program is intended to provide a systematic approach for collecting and assessing ecosystem information relative to management objectives, management actions, and ecosystem and management uncertainty. The adaptive management process is designed to enhance management decision making by providing a structured, scientific process to address the many uncertainties that occur in project planning, implementation, and assessment. Together, the monitoring and assessment program and the adaptive management process are intended to provide management oversight by assessing effectiveness, incorporating robustness into project design, and providing information critical to evaluating whether management actions are producing desired results. The proposed agency action includes four parts: (1) becoming a plan partner, (2) filling management gaps, (3) increasing interagency coordination, and (4) developing an integrated watershed management plan. The intent of this plan is to increase awareness of the complicated management challenges facing the KCOL and justify the allocation of more resources to the region.

The draft version of the KCOL LTMP was completed in October 2008, but was placed on hold to allow agency management and resource priorities to be reevaluated relative to the District's fiscal constraints. Meanwhile, the SFWMD has initiated the proposed monitoring and assessment program, and interagency activities related to this program are expected to begin in late 2010.

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 11-29**). The WMA encompasses 61,580 acres and supports one of the highest densities of bald eagles (*Haliaeetus leucocephalus*) 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 (completed in 2008).
- **Phase III – Project Design and Permitting:** Prepare design documents (plans and specifications) for the permitting and implementation of the

preferred alternative (initiation has been delayed and activities are being restructured to allow a phased implementation of restoration project features).

- **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 III of the project was initiated in December 2009. The scope of this phase was reduced to include only the design and permitting work associated with replacing the G-113 structure due to the FWC's budget constraints. The re-scoped Phase III is expected to be completed by April 2011, with construction of the G-113 replacement structure scheduled for completion by December 2012.

Figure 11-29. Boundaries of the Three Lakes Wildlife Management Area.

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