Chapter 11: Kissimmee River Restoration and Upper Basin Initiatives

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SUMMARY

The Kissimmee watershed forms the headwaters of the Kissimmee-Okeechobee-Everglades system (**Figure 11-1**). The watershed encompasses a diverse group of wetland and aquatic ecosystems, including more than two dozen lakes, their tributary streams, and the Kissimmee River. This chapter summarizes the mission-critical activities of the South Florida Water Management District (District or SFWMD) for flood control, water supply, water quality, and natural systems in the Upper and Lower basins of the Kissimmee watershed. Major projects in the watershed are the Kissimmee Basin Modeling and Operations Study; Kissimmee River Restoration Project (KRRP); Kissimmee River Headwaters Revitalization Project (KRHRP); and Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP) (**Figure 11-2**). A number of activities are associated with these projects including ecosystem restoration, restoration evaluation, aquatic plant management, land management, water quality improvement, and water supply planning.

Four hurricanes hit the state of Florida during 2004, including three (Charley, Frances, and Jeanne) that passed directly over the Kissimmee Basin. The Kissimmee Basin experienced high winds during each storm. Noted wind effects included seiches on Lake Kissimmee during all three storms. These large displacements of water, although of short duration, have the potential to move material within the lakes. A graphic example of this effect involved ripping the stems of the aquatic plant hydrilla (*Hydrilla verticillata*) and rolling these stems into large balls that were left on the shoreline. Total rainfall for August 2004 of 12.70 inches in the Upper Basin and 9.59 inches in the Lower Basin exceeded the 20-year and 10-year wet return-periods (Ali and Abtew, 1999), respectively. The September 2004 totals of 17.38 inches in the Upper Basin and 11.71 inches for the Lower Basin both exceeded the 100-year wet return-period (Ali and Abtew 1999). Almost a third of this rain was associated with the three hurricanes. Discharges from S-65 into the Kissimmee River during Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005) peaked near 10,000 cubic feet per second (cfs) and were among the highest on record.

The Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Study (KB Modeling and Operations Study) is an initiative that will develop a hydrologic/hydraulic model to be used to identify alternative structure operating criteria to meet operations objectives of the Kissimmee Basin and its associated water resource projects. This study, which is constrained to modifications of operating criteria of the existing water control infrastructure, will identify ways to achieve a more acceptable balance among flood control, water supply, aquatic plant management, and natural resource water management objectives, while also balancing

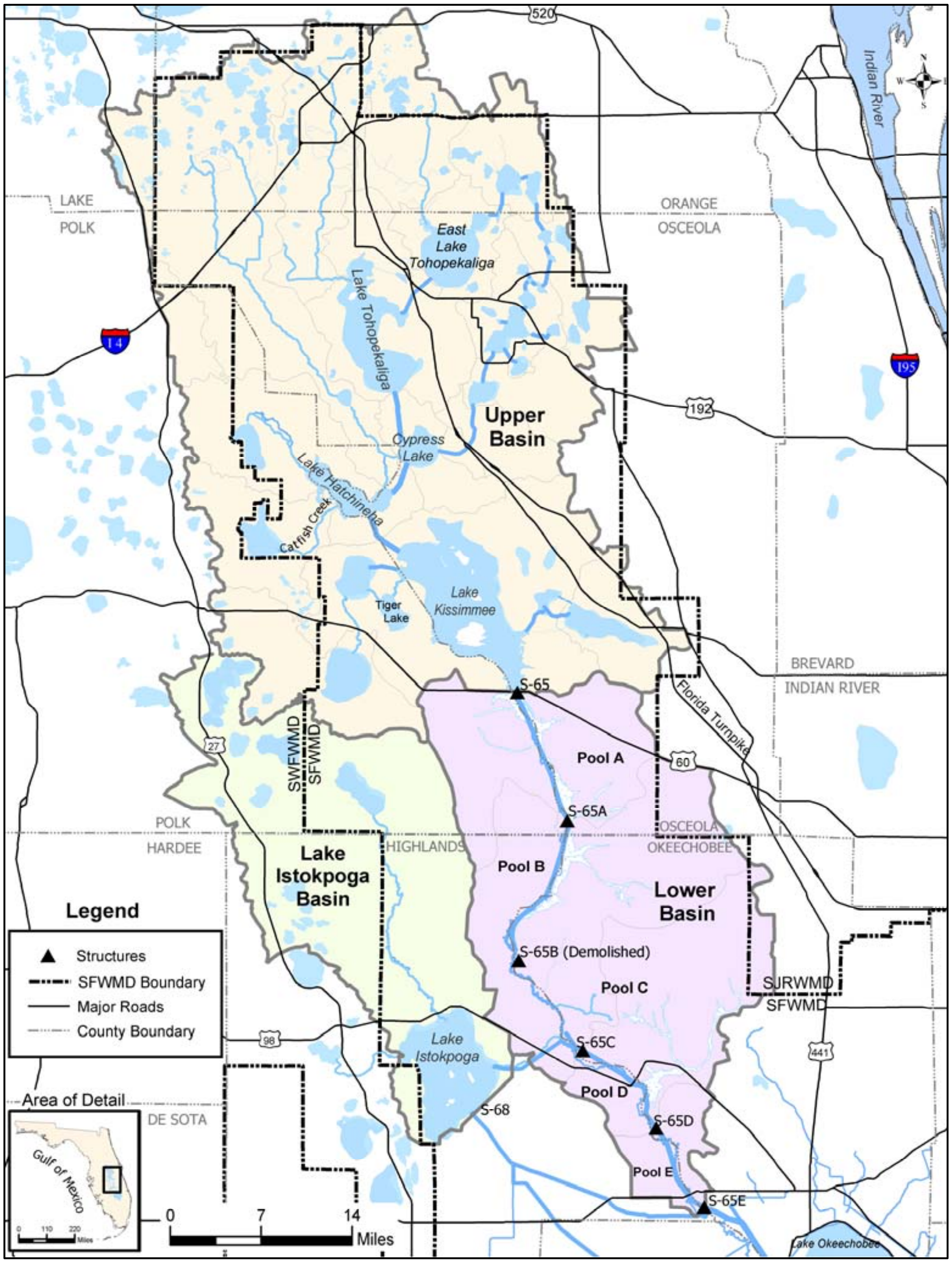

Figure 11-1. Geographic location of the Upper Basin, Lower Basin, and Lake Istokpoga Basin of the Kissimmee watershed.

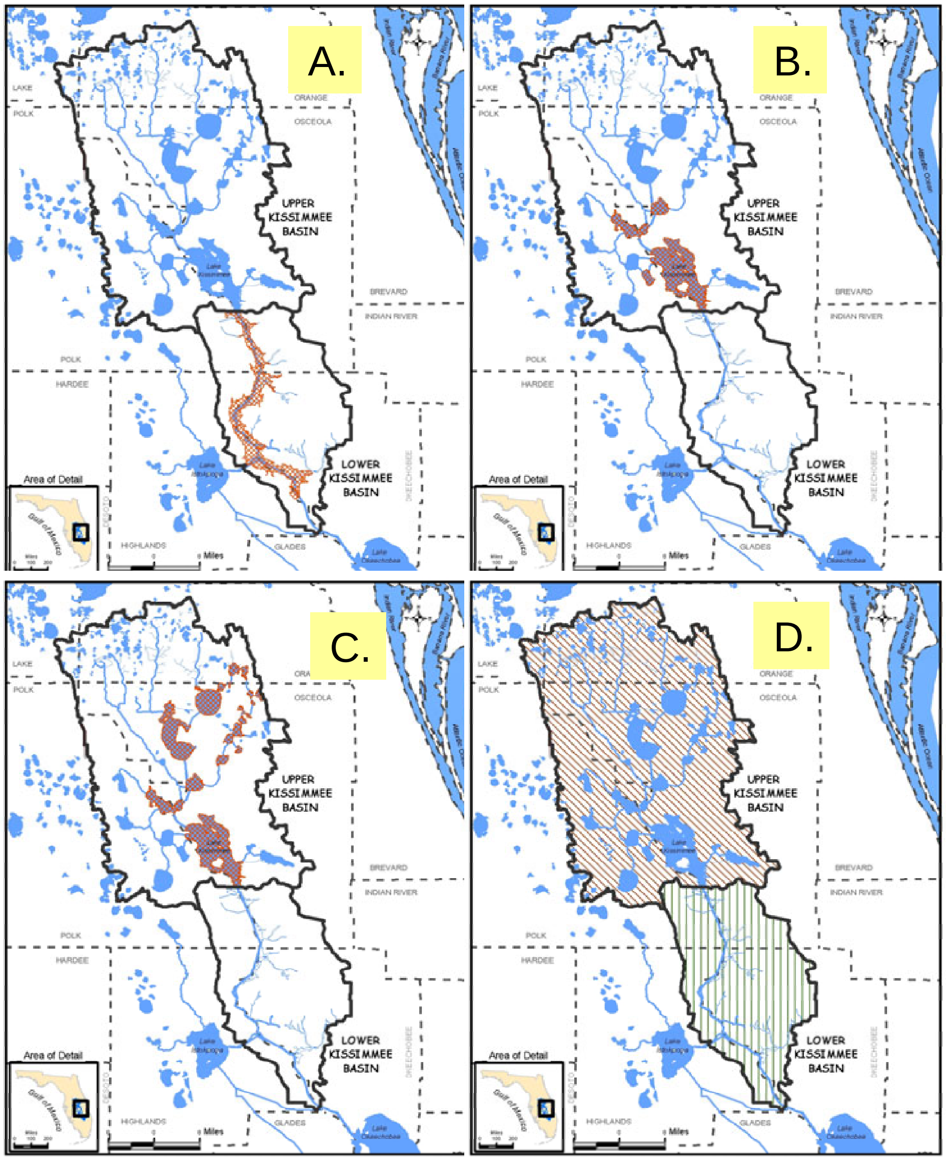

Figure 11-2. Geographic scopes (hatched areas on maps) of major initiatives in the Kissimmee Basin. The Kissimmee River Restoration Project involves two major elements: canal backfilling, water control structure removal, reconnection of remnant river channels and other construction features along the river in the Lower Basin (A); and the Headwaters Revitalization Project (B), which is designed to allow headwater inflows into the Kissimmee River to more closely approximate historical inputs via changes to regulation schedules and maximum stages of headwater lakes along with modifications to their interconnecting canals. The Kissimmee Chain of Lakes Long-Term Management Plan (C) has the purpose of improving and/or sustaining the ecosystem health of the KCOL regulated lakes while minimizing adverse impacts to downstream ecosystems. The Kissimmee Basin Modeling and Operations Study (D) includes the entire Upper and Lower Basins and seeks to optimize operations of water control structures to best meet flood control, water supply, aquatic plant management, and natural resource water management objectives while also balancing impacts across ecosystems including Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries.

impacts across ecosystems including Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries. Accomplishments during WY2005 include an evaluation of watershed delineations in the Upper Basin; identification of flood control, water supply, aquatic plant management, and natural resource operations objectives, including objectives related to the KRRP, the KCOL LTMP, and the Upper Basin restoration projects; preliminary analysis of rainfall and flow data within representative watersheds within the Kissimmee Basin; evaluation of the functionality, defensibility, and cost-effectiveness of candidate modeling tools, which resulted in selection of the MIKE SHE/MIKE 11 tool; and an evaluation of the adequacy of the existing Kissimmee Basin hydrologic monitoring network to meet established monitoring objectives.

The Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization projects were jointly authorized in the 1992 Water Resources Development Act. The two projects have an estimated combined cost of $578 million (Fiscal Year 2004) (FY2004). They will be completed in several phases, with the final phase of construction scheduled for completion in 2012 and the restoration evaluation to be completed in 2017.

The primary goal of the Kissimmee River Restoration Project is to reestablish the ecological integrity of the river-floodplain system, which is defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community having species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley, 1981). Restoration of ecological integrity requires reconstruction of the physical form of the river (i.e., canal backfilling, removal of water control structures, and elimination of secondary drainage ditches, levees, and roads) and reestablishment of historic (pre-channelization) hydrologic (i.e., discharge and stage) characteristics.

The primary purpose of the Kissimmee River Headwaters Revitalization Project is to provide the water storage and regulation schedule modifications needed to approximate the historical flow characteristics of the Kissimmee River system. A secondary project purpose is to increase the quantity and quality of lake littoral zone habitat in lakes Kissimmee, Hatchineha, Tiger, and Cypress for the benefit of fish and wildlife (USACE, 1996; Section 1.3.2).

A key element of the Kissimmee River Restoration Project is the comprehensive restoration evaluation program for tracking ecological responses to restoration. In addition to assessing restoration success, the evaluation program will provide scientific information for fine-tuning future project phases and for management of the water resources of the recovering and restored ecosystem. To address the goal of ecological integrity, the evaluation program has a broad scope encompassing hydrology, geomorphology, water quality, and major biological communities including plants, invertebrates, reptiles, amphibians, fish, and birds. All evaluation components were monitored prior to restoration to establish a baseline for evaluating future changes.

In June 2001, an interim operation schedule was implemented for water control structure S-65, which regulates discharge from Lake Kissimmee into the Kissimmee River. This interim schedule provides a strategy for meeting Kissimmee River Restoration Project needs for continuous flow by allocating water for discretionary releases. Although beneficial to the river, the interim schedule does not raise the high pool stage and thus does not fully allow for the expected natural river flows, nor does it provide benefits to littoral zone habitat in headwater lakes.

The Kissimmee River Headwaters Revitalization Project includes revisions to the interim regulation schedule along with structure and canal modifications to accommodate the increased capacity associated with the increased lake storage volumes needed to fully meet the requirements of the restoration. Presently, the SFWMD has acquired the majority of lands that will be inundated as a result of increased lake stages. Canal and structure modifications will be completed by 2010, at which point the revised regulation schedule will be implemented.

Phase I of the KRRP was completed in February 2001. This effort involved filling approximately 7.5 miles (12 kilometers) of the C-38 canal, recarving approximately 1.25 miles (2 kilometers) of river channel, and demolishing the S-65B structure to reconnect 15 miles (24 kilometers) of continuous river channel. Continuous flow and intermittent inundation of restored floodplain have been achieved although the revised regulation schedule has not yet been implemented.

A comprehensive description of the restoration evaluation program and initial responses (as of WY2004) to restoration activities in the Phase I area were reported in Chapter 11 of the *2005 South Florida Environmental Report – Volume I* (SFER) (Williams et al., 2005). A subset of evaluation projects were monitored during WY2005, and these results are reported in this chapter. WY2005 results include the following: (1) mean concentration of dissolved oxygen (DO) in the restored river channel continues to exceed baseline (pre-restoration) values; (2) turbidity and total suspended solids in the river channel water column remain low; (3) neither the loads nor concentrations of total phosphorus have declined at the water S-65C structure, which lies just downstream of the Phase I area; (4) colonization of mid-channel benthos by invertebrate species indicative of reestablished sand channel habitats; (5) dominance of woody snag invertebrate communities by passive filter-feeding insects, which require flowing water; (6) increased relative abundance of centrarchid fish species in river channel fish assemblages; (7) increased densities of long-legged wading birds on the floodplain; and (8) increased densities of waterfowl on the floodplain.

The Long-Term Management Plan for the Kissimmee Chain of Lakes was initiated in April 2003 through SFWMD Governing Board Resolution No. 2003-468. The project's purpose is to improve and sustain the ecosystem health of the KCOL regulated lakes while minimizing adverse impacts to downstream ecosystems. Several products have been produced over the last year. These include (1) an annotated bibliography of KCOL literature, (2) a stakeholder value survey of users of lakes in the KCOL, (3) life history requirements documents for candidate indicator species, and (4) conceptual lake ecosystem model publication. The annotated bibliography represents on ongoing effort to compile references to research and monitoring activities within the Kissimmee Chain of Lakes. Currently, there are approximately 650 references in the database, which is available online at http://www.sfwmd.gov/images/pdfs/kiss_procite_biblio_notes.pdf. Results of the stakeholder value survey indicated that picnicking, boating, hiking, and fishing by boat were the most common recreational activities on lakes within the KCOL. In addition, results showed that fish and wildlife habitat preservation was a higher priority than recreation and access to areas for recreation. The survey also revealed that activities associated with agency management responsibilities are not widely known, reinforcing the recognized need for continued public outreach. As a step in the development of the LTMP, a conceptual ecosystem model (CEM) was drafted for the KCOL. The draft CEM, which was reviewed by a peer review panel during July–August 2005, identifies key drivers and stressors within the KCOL and will be used, among other things, as a tool for development of performance measures.

INTRODUCTION

The Kissimmee watershed of South-Central Florida forms the headwaters of the Kissimmee-Okeechobee-Everglades (KOE) ecosystem, and encompasses an area of approximately 3,000 square miles, or mi^2 (7,800 square kilometers, or km^2) (SFWMD, 2003). The watershed includes the basins of the Kissimmee River (Lower Basin), the Kissimmee Upper Basin, and Lake Istokpoga (**Figure 11-1**). The Kissimmee Upper Basin/Kissimmee River system is the single largest source of surface water for Lake Okeechobee, accounting for approximately 34 percent of inputs (SFWMD, 2002). The major projects within the watershed are the Kissimmee River Restoration Project (KRRP), Kissimmee River Headwaters Revitalization Project (KRHRP), Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP), and Kissimmee Basin Modeling and Operations Study (KB Operations Model) (**Figure 11-2**). A number of other activities are carried out in association with these projects. These include aquatic plant management, land management, water quality improvement, and water supply planning.

Congress jointly authorized the KRRP and the KRHRP in the 1992 Water Resources Development Act (Public Law 102-580). The goal of the restoration project is to restore ecological integrity to the river-floodplain ecosystem. This goal is defined as the "reestablishment of a river-floodplain ecosystem that is capable of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region."

Successful restoration of the Kissimmee River is largely dependent on reestablishing hydrologic conditions that are similar to the pre-channelization period (Toth, 1990a). The KRHRP was designed to help meet this requirement and to maintain the existing level of flood control within the Kissimmee Basin (USACE, 1996). The project involves lakes Kissimmee, Hatchineha, Cypress, and Tiger (**Figure 11-2**) and includes land acquisition, adjustment of the S-65 regulation schedule, and modifications to structures and canals. Together, the KRRP and KRHRP will restore ecological integrity to approximately 40 mi^2 (104 km^2) of the river-floodplain system (USACE, 1991; 1996). Restoration success will be evaluated via a comprehensive ecological monitoring program.

In addition to the Kissimmee River Headwaters Revitalization Project, the Governing Board of the South Florida Water Management District (District or SFWMD) adopted a resolution (Resolution No. 2003-468) in April 2003, which directs the SFWMD to coordinate with the U.S. Army Corps of Engineers (USACE) and other stakeholders to develop the Kissimmee Chain of Lakes Long-Term Management Plan (**Figure 11-2**). This plan is currently under development and will address five goals: (1) hydrologic management, (2) habitat preservation and enhancement, (3) aquatic plant management, (4) water quality improvement, and (5) recreation and public use.

The KB Operations Model spans the entire Kissimmee Basin (**Figure 11-2**) in geographic scope and will use a hydrologic/hydraulic model to assess how existing basin operating criteria for the water control structures can be modified to achieve a more acceptable balance among flood control, water supply, aquatic plant management, and natural resource water management objectives, while also balancing impacts across ecosystems including Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries.

Successful completion of the KRRP, KRHRP, KCOL LTMP, and KB Operations Model has critical implications for other ecosystem restoration projects in South Florida. For example, the restoration project should increase phosphorus uptake from water flowing through the Kissimmee River system via restoration of floodplain wetlands, thus removing a portion of phosphorus loads that would otherwise reach Lake Okeechobee. Additionally, the KRRP is a prerequisite for successful completion of the Comprehensive Everglades Restoration Program (CERP).

According to the future-without-plan condition under CERP, it is assumed that the KRRP is in place and functioning (USACE and SFWMD, 1999).

The objective of this chapter is to provide an update of activities within the Kissimmee watershed during Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005); specifically, progress of the Kissimmee River Restoration Project, Kissimmee River Headwaters Revitalization Project, Kissimmee Chain of Lakes Long-Term Management Plan, and Kissimmee Basin Modeling and Operations Study, as well as an overview of watershed hydrology and effects of the 2004 hurricanes.

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KISSIMMEE WATERSHED BACKGROUND

HISTORICAL CONDITIONS

Historically, the Kissimmee Chain of Lakes and the Kissimmee River were one integrated system comprised of headwater lakes connected by broad shallow marshes and creeks that eventually drained into the Kissimmee River. Water levels within the KCOL fluctuated between 2 and 10 ft (0.6 and 3.0 m) annually (USACE, 1996). Lakes would rise in the wet season and overflow onto adjacent lands. The resulting marshes were highly productive, supported diverse fish and wildlife populations, and served as natural water retention reservoirs that provided storage in the wet season and continuous discharge to the Kissimmee River throughout the year (USFWS, 1959). Annual discharge typically peaked in October through November, and decreased through the dry season (Obeysekera and Loftin, 1990). During the dry season, lakes generally became isolated from one another, allowing for oxidation of bottom sediments and preventing accumulation of organic matter within littoral zones (USACE, 1996).

The historical Kissimmee River meandered 103 mi (166 km) within a 1 to 2 mi (1.5 to 3 km) wide floodplain (USACE, 1991). The low-gradient [0.3 ft/mi (0.07 m/km)] river gradually sloped from an elevation of 51 ft (15.5 m) at Lake Kissimmee to 15 ft (4.6 m) at Lake Okeechobee (USACE, 1991). Pre-channelization stage and discharge records (1942–1960) indicate that continuous flow and seasonal water level fluctuations were integral hydrologic characteristics of the unmodified system (Obeysekera and Loftin, 1990). Discharge exceeded 25 cfs (7 m^3/s) during 95 percent of the period of record, with overbank flow typically occurring when flows exceeded 1,400 cfs (40 m^3/s) in the upper reaches and 2,000 cfs (57 m^3/s) in the lower reaches (Toth, 1993). Stage duration data and floodplain elevations adjacent to gauging stations indicate that 94 percent of the floodplain was inundated over 50 percent of the time (Koebel, 1995). When inundated, water depths were generally 1 to 2.3 ft (0.3 to 0.7 m), with depth greater than 3 ft (1 m) occurring over 40 percent of the floodplain (Koebel, 1995).

The historical Kissimmee River was atypical of North American river systems because of its prolonged floodplain hydroperiod and protracted floodplain recession rate (Koebel, 1995). The predictable annual flood-pulse brought on by seasonal rains and the near-continuous connectivity of the river and floodplain is thought to have been critical to the trophic structure and biological productivity of the system. The Kissimmee River ecosystem consisted of a mosaic of wetland habitats that supported, among other things, a renowned sport fishery (USFWS, 1959), 16 species of wading birds (National Audubon Society, 1936–1959), at least 10 species of shorebirds (National Audubon Society, 1936–1959), and a large population of resident and over-wintering ducks (Perrin et al., 1982).

CENTRAL AND SOUTHERN FLORIDA PROJECT

Two major hurricanes in the late 1940s led to mass flooding and extensive property damage throughout the Upper Basin, prompting the state of Florida to petition the federal government to prepare a flood control plan for Central and South Florida. In 1948, the U.S. Congress authorized the USACE to initiate construction of the Central and Southern Florida (C&SF) Project for flood control and other purposes. The Kissimmee Basin flood control works were authorized by the Federal Rivers and Harbors Act of 1954 as an addition to the C&SF Project. The primary project purposes were to relieve flooding and minimize flood damages within the Kissimmee watershed and to improve navigational opportunities originally provided in the Congressional Act of 1902. Between 1962 and 1971, the meandering Kissimmee River was channelized and transformed into a 56 mi (90 km) long by 30 ft (9 m) deep canal that varied between 90 and 300 ft (27 and 91 m) in width, and was regulated by a series of five water control structures (USACE, 1991). The areas between water control structures, termed pools, function similarly to reservoirs and are named for the control structure at their southern terminus (e.g., Pool D lies between S56-C and S65-D; **Figure 11-1**). The Upper Basin project features were constructed between 1964 and 1970 and included dredging of canals between lakes and installation of water control structures to regulate lake levels and outflow (USACE, 1991).

Impacts of the Central and Southern Florida Project

Although the C&SF Project was extremely successful at achieving its flood control objective, it dramatically altered hydrologic conditions throughout the Kissimmee watershed (Obeysekera and Loftin, 1990). Water levels in the KCOL are now controlled by nine structures that regulate the amount and timing of discharges between lakes and to the Kissimmee River. Under regulation, the range of fluctuation has been reduced from 2 to 10 ft (0.6 to 3.0 m) to about 2 to 4 ft (0.6 to 1.2 m) annually (Obeysekera and Loftin, 1990). The historical, pre-regulated pattern of seasonal fluctuations provided periods of flooding and drying that played a critical role in maintaining the ecosystem's health and that supported biological communities adapted to and dependent upon these fluctuations (Perrin et al., 1982). Reducing the range of fluctuations has eliminated this natural cycle and promoted growth of dense vegetation that has resulted in the accumulation of organic material in littoral zones of these lakes (USACE, 1996). Smaller fluctuations also have allowed agricultural, residential, and commercial land uses to encroach upon historic flood zones surrounding the lakes, resulting in significant loss of wildlife habitat and higher nutrient inputs to the lakes (USACE, 1996).

In addition to habitat loss, habitat has been degraded by dense growth of problematic, native and exotic plant species (USACE, 1996) Dense concentrations of undesirable vegetation along littoral zones not only cause accumulation of organic sediment, but also negatively impact organisms dependent upon healthy littoral communities (USACE, 1996). The end result is loss of desirable native species, and reduction in overall plant and animal diversity and abundance. Hydrilla (*Hydrilla verticillata*) also has become a problem in the regulated system. Hydrilla was first noted in KCOL during the 1980s (USACE, 1996). The species spread rapidly within each lake; however, by the late 1980s an active hydrilla treatment program on lakes Kissimmee, Cypress, and Hatchineha was in place (USACE, 1996).

Within the Kissimmee River valley, the physical effects of channelization, including alteration of the system's hydrologic characteristics, drastically reduced the extent of floodplain wetlands and severely degraded fish and wildlife resources of the basin (USACE, 1991). Approximately 21,000 ac (8,500 ha) of floodplain wetlands were drained, covered with spoil material, or converted into canal (USACE, 1991). No-flow regimes in remnant channels encouraged extensive growth of floating vegetation, which impeded navigation (Toth, 1990b). Senescence and death of encroaching vegetation covered the shifting sand substrate with large amounts of organic matter, greatly increasing the biological oxygen demand of the system (Toth, 1990a). By the late 1970s, floodplain use by wintering waterfowl had decreased by greater than 90 percent compared to pre-channelization levels (Perrin et al., 1982). Diverse and abundant wading bird populations declined and were largely replaced by the cattle egret (*Bubulcus ibis*), a species generally associated with upland, terrestrial habitats (Perrin et al., 1982). The highly recognized largemouth bass (*Micropterus salmoides*) fishery was decimated, while fish species tolerant of low dissolved oxygen and reduced water quality, such as Florida gar (*Lepisosteus platyrhincus*), increased (Perrin et al., 1982). Aquatic invertebrate taxa of the channelized system were typical of those found in lakes and reservoirs rather than riverine systems (Harris et al., 1995). Stabilized water levels greatly reduced river-floodplain interactions, disrupting critical food web linkages dependent on seasonal flooding and protracted floodplain recession rates (Harris et al., 1995).

Environmental degradation of the Kissimmee River, specifically the loss of fish and wildlife resources, and growing concerns over the contributions of channelization to eutrophication of Lake Okeechobee, was the impetus for a river restoration initiative. As early as 1971, prior to completion of the channelization project, environmental conservation organizations called for restoration of the Kissimmee River. Over 20 years (1971–1991) of restoration-related efforts and consistent support from the state's governors, legislature, and congressional delegations culminated with the 1992 Water Resources Development Act (Public Law 102-580), which authorized "the ecosystem restoration of the Kissimmee River, Florida" and "to construct the Kissimmee River headwaters revitalization project."

KISSIMMEE WATERSHED ACTIVITIES

WATERSHED HYDROLOGY AND OPERATIONS

Hydrologic conditions within the Kissimmee watershed are a function of natural hydrologic processes (e.g., rainfall, evapotranspiration) and management decisions. The watershed receives an average of approximately 50 inches of rainfall per year with most falling during a distinct wet season (SFWMD, 2000). Much of the surface water runoff from the watershed is conveyed through a network of canals that interconnects the KCOL and terminates with Lake Kissimmee. The outflow from Lake Kissimmee enters channelized and reconstructed reaches of the Kissimmee River before continuing southward to Lake Okeechobee (**Figure 11-1**). 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 U.S. Army Corps of Engineers. 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 restoration project.

Operation of each structure is determined by a stage regulation schedule that specifies discharges that can be made through the structure depending on the headwater stage and time of year. The canals and structures are part of the C&SF Project that provides flood control and water supply to the region. The system also is operated to protect environmental values, especially ecological integrity in the Kissimmee River. Thus, hydrologic conditions in the Kissimmee watershed are a function of variable rainfall and management decisions that balance multiple needs.

The Kissimmee Basin is the largest tributary to Lake Okeechobee and thus serves as the headwaters to the rest of South Florida. The operation of water control structures in the Kissimmee Basin can influence the timing and volume of flows to downstream ecosystems. Consequently, operations in the Kissimmee Basin have to be coordinated with the rest of the South Florida system regulated by the C&SF Project. This coordination is achieved through a weekly interagency meeting to review the status of the entire system and by the formal consideration of Kissimmee River flows into the decision-making process for managing flows out of Lake Okeechobee. Also, efforts are being made to enhance the coordination of operations through the KCOL LTMP and the KB Modeling and Operations Study.

This section reviews hydrologic conditions in the Kissimmee Basin during WY2005 in relation to the operation of the C&SF Project. This section also summarizes analyses of the effects of 2004 hurricanes on dissolved oxygen and on changes in outflows from the Upper Basin over time.

Water Year 2005 – Temporal Patterns

During WY2005, hydrologic conditions in the Kissimmee Basin can be divided into three periods based on the predominant environmental and management drivers. These time periods are (1) the Lake Tohopekaliga extreme drawdown, (2) the hurricanes, and (3) the dry season recession.

LAKE TOHOPEKALIGA EXTREME DRAWDOWN

At the beginning of WY2005, most lakes in the Upper Basin were at regulation schedule, and lake stages were being lowered according to schedule to reach the low point of the schedule on June 1, 2004 to create storage for the coming wet season. Lake Tohopekaliga had already been lowered to approximately 49 feet according to a deviation to the regulation schedule requested by the Florida Fish and Wildlife Conservation Commission (FWC) for the Lake Tohopekaliga Extreme Drawdown and Habitat Enhancement Project. This project involved lowering water levels to dewater sediments so that organic sediments and nuisance vegetation, especially floating plant islands (tussocks), could be removed from the lake or stored within the lake as spoil islands. These activities are expected to benefit the lake by improving habitat for fisheries and for native aquatic plant life (USACE, 2002). A temporary deviation was approved for Lake Tohopekaliga to lower the lake to 48.5 feet National Geodetic Vertical Datum (ft NGVD) and to lower lakes Cypress, Hatchineha, and Kissimmee to 48.0 ft NGVD. The deviation for the latter group of lakes is required to lower Lake Tohopekaliga by gravity to 48.0 ft NGVD. The original plan was to begin lowering Lake Tohopekaliga on November 1, 2004 and to reach 49.0 ft NGVD by February 15, 2005. The lowering of stage in lakes Cypress, Hatchineha, and Kissimmee would begin November 15, 2004 and reach 49.0 ft NGVD by February 15, 2005 and then be allowed to go to 48.0 ft NGVD by June 1, 2005. Lake Tohopekaliga would be allowed to go to 48.5 ft NGVD between February 15, 2005 and June 1, 2005 to allow water to be passed through to S-65 and the Kissimmee River. This schedule was modified slightly because of concerns of lowered water levels on Everglade snail kite (*Rostrhamus sociabilis plumbeous*) nesting success.

A dry spring facilitated the drawdown of Lake Tohopekaliga. The drawdown project was concluded in June 2004 as wet season rainfall began. During this time period, very small releases were made through S-65 to supply water for the Kissimmee River Restoration Project. Discharges at S-65 were 280–300 cfs beginning in May 2004 and continuing into August 2004 (**Figure 11-3**). Discharges of this magnitude approximate the 10th percentile of discharges on those dates for the pre-channelization period of record.

As rainfall increased in June and July 2004, the lakes began to refill and lake stage increased. Lakes Tohopekaliga, Cypress, Hatchineha, and Kissimmee did not reach schedule until August 2004. Releases to the Kissimmee River were not increased until August 2004. Major increases in stage in Lake Kissimmee and releases to the Kissimmee River were associated with the rainfall that accompanied Hurricane Charley, the first of four hurricanes to make landfall in Florida during WY2005.

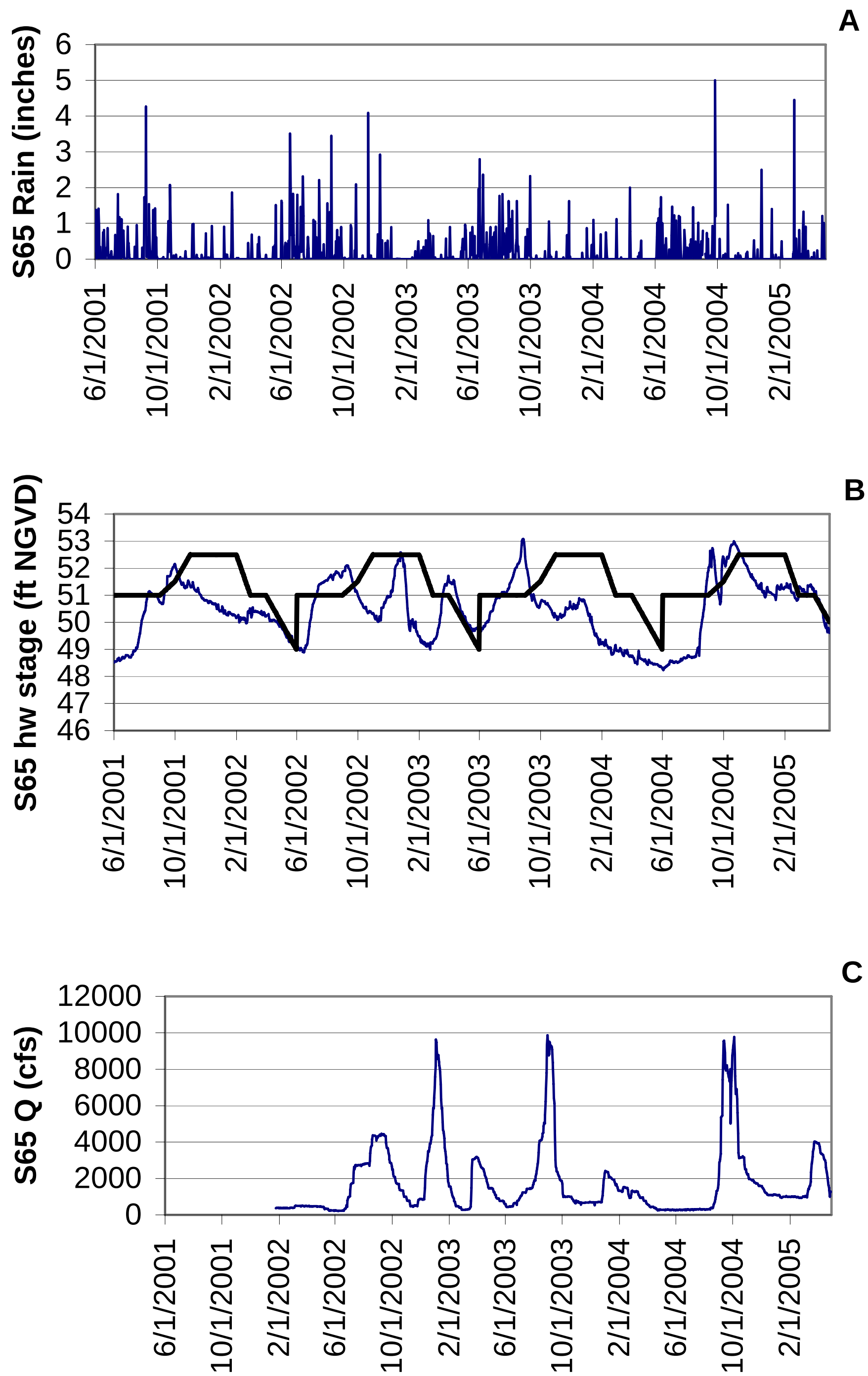


Figure 11-3. Rainfall (A), stage (B), and discharge (C) at S-65 from onset of continuous flow in the Kissimmee River following Phase I of construction for the restoration project. The bold line in Panel B is the stage regulation schedule for S-65 and does not depict modifications to the schedule for the Lake Tohopekaliga drawdown, which are described in the text.

THE 2004 HURRICANE SEASON

The 2004 hurricane season was unprecedented for Florida, with four hurricanes making landfall within the state. Three of these hurricanes (Charley, Frances, and Jeanne) passed over the Kissimmee Basin (**Figure 11-4**). The fourth (Ivan) made landfall in the panhandle region, was downgraded to a tropical storm as it moved across the southeast and into the Atlantic where it circled back across Florida and passed over the Kissimmee Watershed as a much weakened tropical depression, adding rain to an already saturated system. The paths of the hurricanes as they passed over the Kissimmee Basin are described below, based on a summary of the 2004 hurricane season from the National Hurricane Center in Miami on December 1, 2004.

Hurricane Charley made landfall on the southwest coast of Florida in the evening of August 13, 2004. When it came ashore, Hurricane Charley was a Category 4 hurricane with maximum sustained winds near 150 miles per hour (mph). As the hurricane moved north and east, the maximum wind speed decreased to 85 mph as it passed over the northwest corner of the Kissimmee Upper Basin early on August 14, 2004.

Hurricane Frances was a Category 2 hurricane when it made landfall on the east coast of Florida early on September 5, 2004. As Hurricane Frances moved inland in a west-northwest direction, it weakened to a tropical storm and passed over the Kissimmee Basin early on September 6, 2004. The track of the storm passed over the Kissimmee Prairie State Preserve and intersected the Kissimmee River at the S-65A structure before continuing through the Avon Park Air Force Range and passing over Lake Weohyakapka.

Hurricane Ivan made landfall in the panhandle region of Florida as a Category 3 hurricane on September 16, 2004. As it moved northwest across the southeastern United States, Ivan weakened to an extratropical low. A portion of this circulation passed over South Florida on September 21, 2004.

Hurricane Jeanne made landfall as a Category 3 hurricane on the east coast of Florida on September 26, 2004. Hurricane Jeanne came ashore at nearly the same location as Hurricane Frances three weeks earlier. This hurricane weakened to a tropical storm as it moved inland and passed over the Kissimmee basin later that day. Jeanne approached the Kissimmee Basin from the east and intersected the river at S-65C. The storm then turned northwest and followed the course of the river roughly through the area of Phase I of the restoration project. As the course of the river changed near the upstream limit of Phase I construction, the storm continued its northwest course over Avon Park Air Force Range and out of the basin.

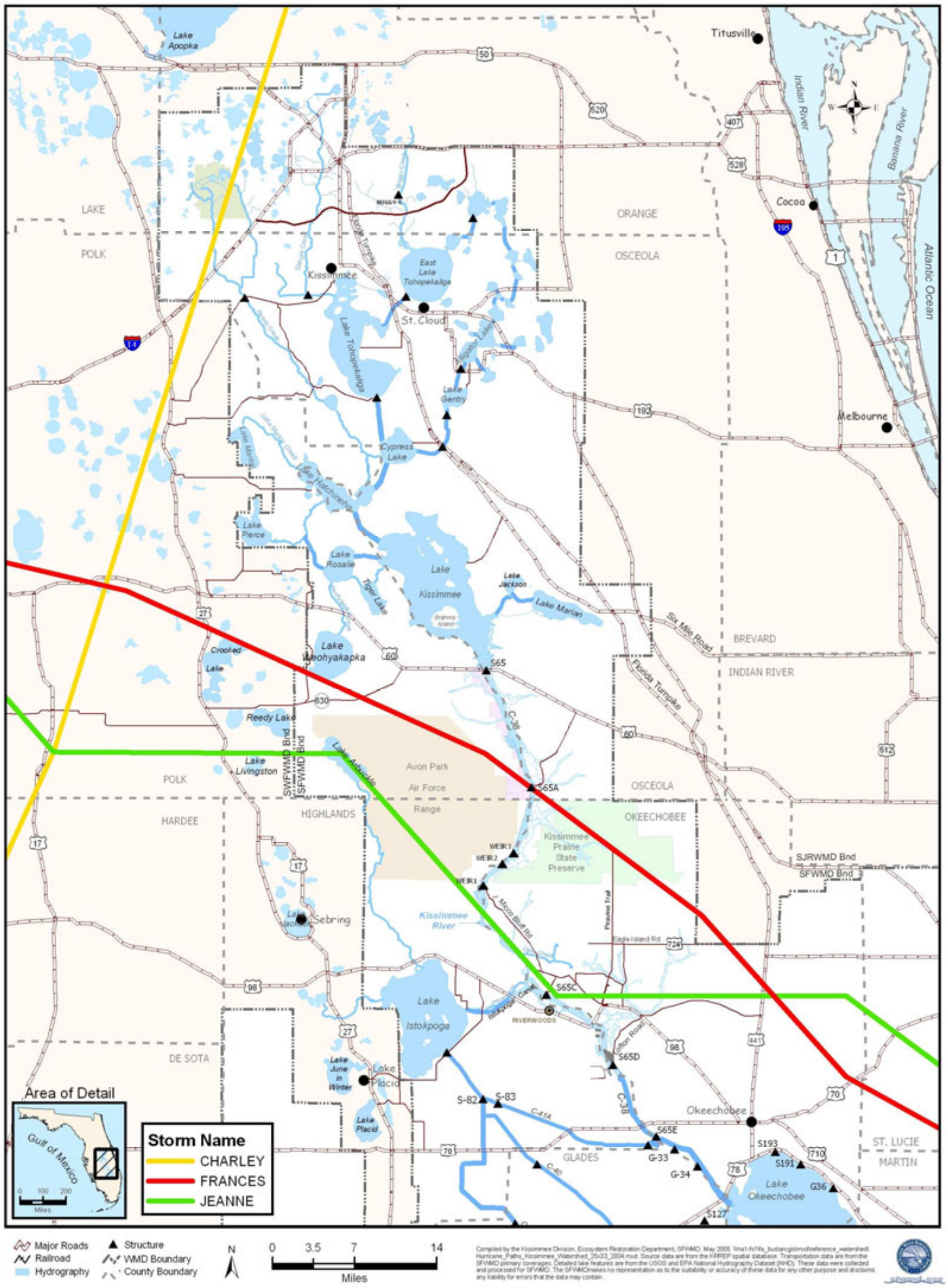


Figure 11-4. Paths for hurricanes Charley, Frances, and Jeanne as they passed over the Kissimmee Basin in Florida.

Hurricane Impacts

The effects of these hurricanes on the Kissimmee Basin are due to high wind speeds and rainfall as the storms passed over the basin. Maximum wind speed decreased as the hurricanes moved inland, and the wind speeds experienced by the Kissimmee Basin depended on the path of the hurricane (**Figure 11-5**). For Hurricane Charley, maximum wind speeds reached 30–40 mph over much of the Upper Basin while most of the Lower Basin experienced maximum wind speeds of only 25–30 mph. For Hurricane Frances, most of the Upper Basin experienced maximum wind speeds of 50–65 mph while the Lower Basin experienced higher wind speeds of 65–80 mph. For Hurricane Jeanne, the Upper Basin experienced 75–80 mph and the Lower Basin experienced 65–75 mph.

One indication of the effect of wind is that each of the storms passing over the Upper Basin caused a seiche (a standing wave that oscillates) to form in the lakes. Stage monitoring stations located at opposite ends of Lake Kissimmee provide data that illustrate the development of a surface seiche during each of the hurricanes (**Figure 11-6**). As Hurricane Charley was passing over the basin, there was a rapid decrease in stage at station LKISS5B near the southern end of Lake Kissimmee and a simultaneous increase in stage at LKISS9 near the northern end of the lake, which resulted in difference of six feet between the stations. This seiche gradually dampened until Hurricane Frances passed over the basin and created another displacement of water. The large displacements of water, although of short duration, have the potential to move material within the lakes. A graphic example of this effect involved ripping hydrilla stems and rolling them into large balls that were left on the shoreline (**Figure 11-7**).

Another example of wind effects involves the suspension of sediments. While quantitative data on turbidity in the lakes are limited, there were anecdotal observations of increased turbidity in the lakes following the hurricanes including photographs (e.g., **Figure 11-7**). In particular, there was a turbidity plume that originated in Lake Kissimmee and extended into the Pool A portion of C-38. This plume rapidly attenuated as it moved down the canal (D. Colangelo, SFWMD, personal observation).

In addition to the effect of wind, the hurricanes brought concentrated rainfall (**Figures 11-8** and **11-9**). From July 1–October 31, 2004, 30.99 inches of rain fell at S-65C, which is almost 10 inches greater than the 30-year average rainfall for Lower Basin. Almost a third of this rain was associated with the three hurricanes. Similar patterns were observed for other rain gauges in the Lower Basin.

Rainfall in August and September 2004 greatly exceeded the long-term averages in both the Upper and Lower basins (**Figure 11-10**). The total rainfall for August 2004 of 12.70 inches in the Upper Basin and 9.59 inches in the Lower Basin exceeded the 20-year and 10-year wet return-periods (Ali and Abtew, 1999), respectively. The total rainfall for September 2004 of 17.38 inches in the Upper Basin and 11.84 inches for the Lower Basin both exceeded the 100-year wet return-period (Ali and Abtew, 1999).

One result of the high rainfall during August and September 2004 was that stage for all lakes in the Upper Basin was above the high point of the stage regulation schedule. To lower lake stages back to the regulation schedule, maximum practicable releases were made throughout the system. Discharges in the Kissimmee River peaked near 10,000 cfs (note the discharge estimates at S-65 are being revised upward based on stream gaging made during this event) and were among the highest on record. As a safety precaution, boat ramps were closed for a period of time due to hazards associated with high-flow conditions. The high flow also resulted in some erosion problems at S-65A due to the asymmetry of flow because all of the gates could not be opened.

Because of the unusual and extreme conditions that existed in September 2004, the Water Control Operations Division, the Office of Modeling, the Kissimmee Division, and the Watershed

Management Department held weekly meetings to manage the reduction in discharge as stage began to drop. The management question involved balancing a gradual reduction in discharge to create a slow stage recession rate on the floodplain of the downstream river with the need to conserve water in the Upper Basin for lake health and for releases later in the dry season. One of the concerns in managing the area of Phase I of the Kissimmee River Restoration Project has been to create long, slow recession events that ideally do not exceed 1 ft per 30 days (USACE, 1991). These recession events are critical for the aquatic/semi-aquatic plants and animals using the floodplain. Also, a previous rapid recession event in the channelized river had been linked to low concentrations of dissolved oxygen and a fish kill (Toth, 1988). Since Phase I of the restoration project was completed in 2001, several previous high discharge events have occurred. During these events, it was demonstrated that high discharges could be reduced rapidly to 3,000 cfs without apparent harm to the system. During the rapid reduction in discharge, dissolved oxygen did not decrease to low levels and in some years actually recovered to higher concentrations. The rapid reduction in discharge also left more water in the Upper Basin to allow a more gradual reduction in discharge from 3,000 cfs to 1,000 cfs, which results in a gradual stage recession on the floodplain. Slower recession rates create floodplain hydroperiods favorable for wetland vegetation and for animals such as wading birds and fish. Model runs were updated weekly to determine the volume of water available in the Upper Basin for the floodplain recession. Weekly updates and adjustments to the system continued through mid-October, when discharges were approaching 3,000 cfs. One of the uncertainties identified was the difficulty of estimating inflows to the lakes in the Upper Basin, especially Lake Kissimmee.

Hurricanes are a recurring event in South Florida and have passed over the Kissimmee Basin with a frequency of about once every seven years on average for the last 129 years. The three hurricanes that passed over the Kissimmee Basin during the 2004 hurricane season had variable effects because of differences in their strengths, speeds of movement, and paths. This section emphasized physical measurements – wind speed, seiche formation, rainfall, lake stage, and discharge. One apparent biological response was the damage to the submerged aquatic plant community, primarily hydrilla, by wave action. Wave action also appears to have suspended sediments, which has the potential to limit light penetration and plant growth. It is unclear how long these impacts will persist in the lakes. Efforts to manage for hurricanes have to focus on management actions taken in anticipation of impacts rather than on the hurricane, per se. One action is in the design of operating criteria. For example, the schedules used to regulate water levels in the Upper Basin lakes lower water levels before the hurricane season to create more storage capacity.

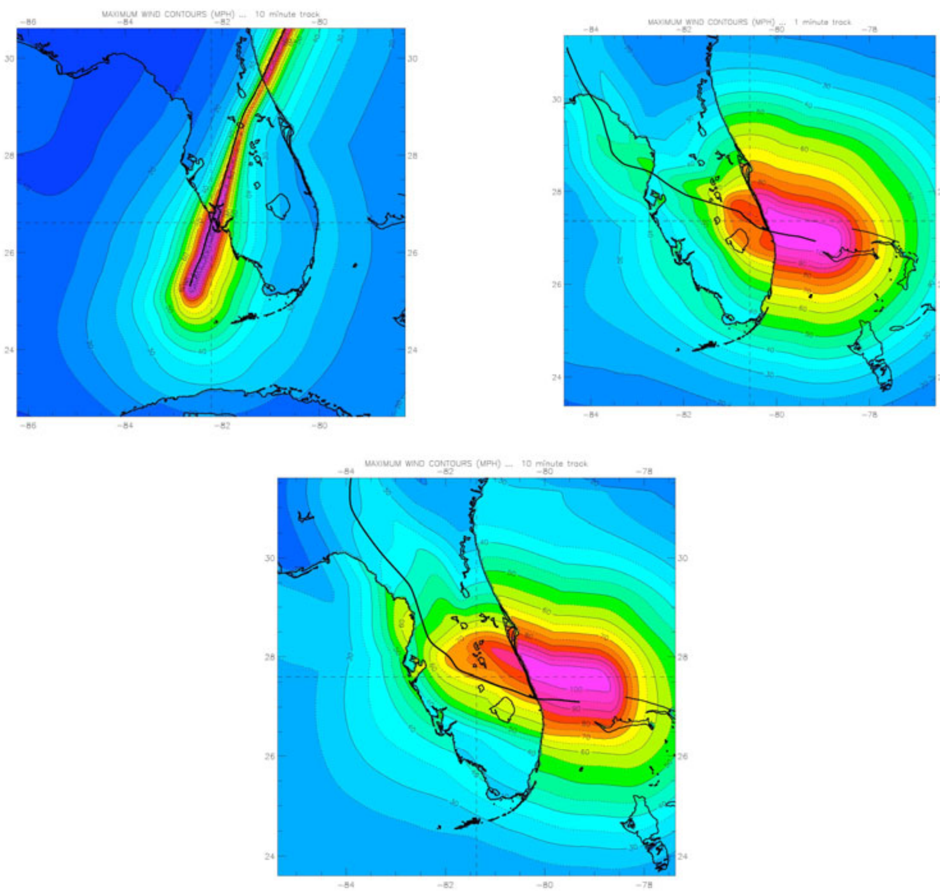


Figure 11-5. Maximum wind speed for hurricanes Charley, Frances, and Jeanne.

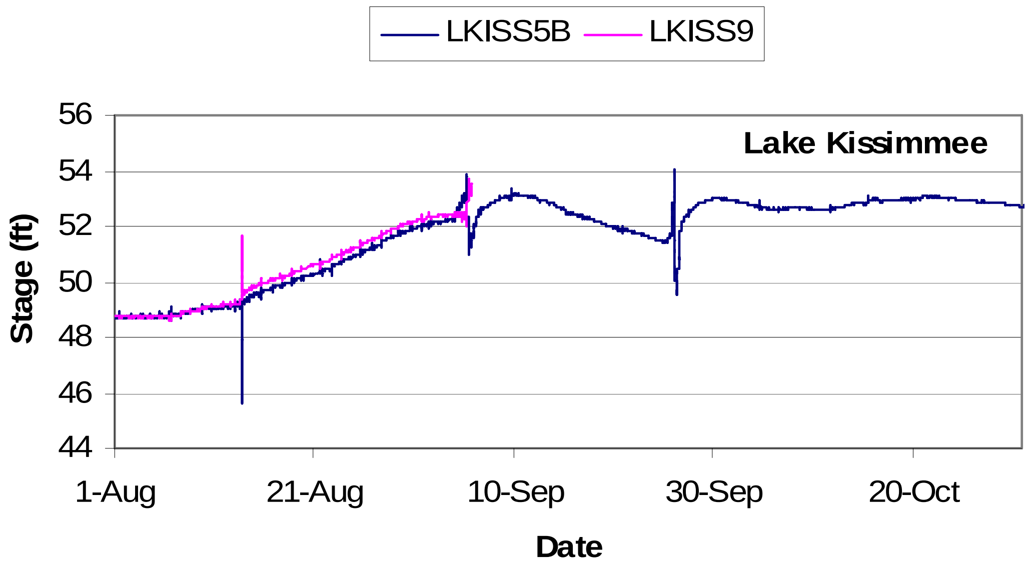
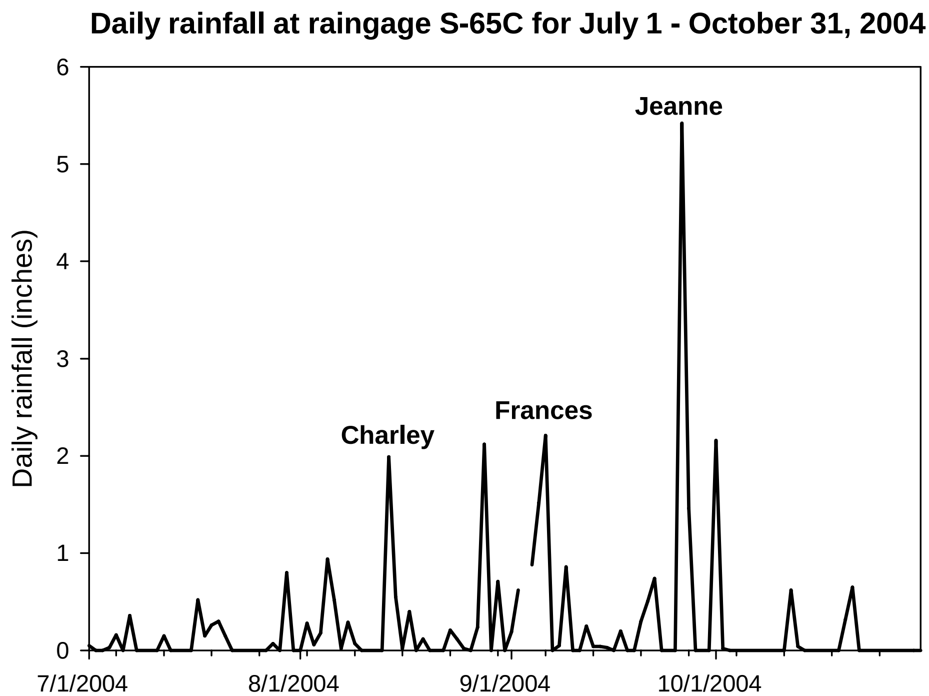


Figure 11-6. Stage at site LKISS5B near the southern end of Lake Kissimmee and site LKISS9 near the northern end that show surface seiches during the hurricanes.

Figure 11-7. Mounds of the aquatic plant hydrilla (*Hydrilla verticillata*) that were torn loose by wave action during Hurricane Charley and piled up near the shore of Lake Kissimmee (photo from Bob Howard, SFWMD).



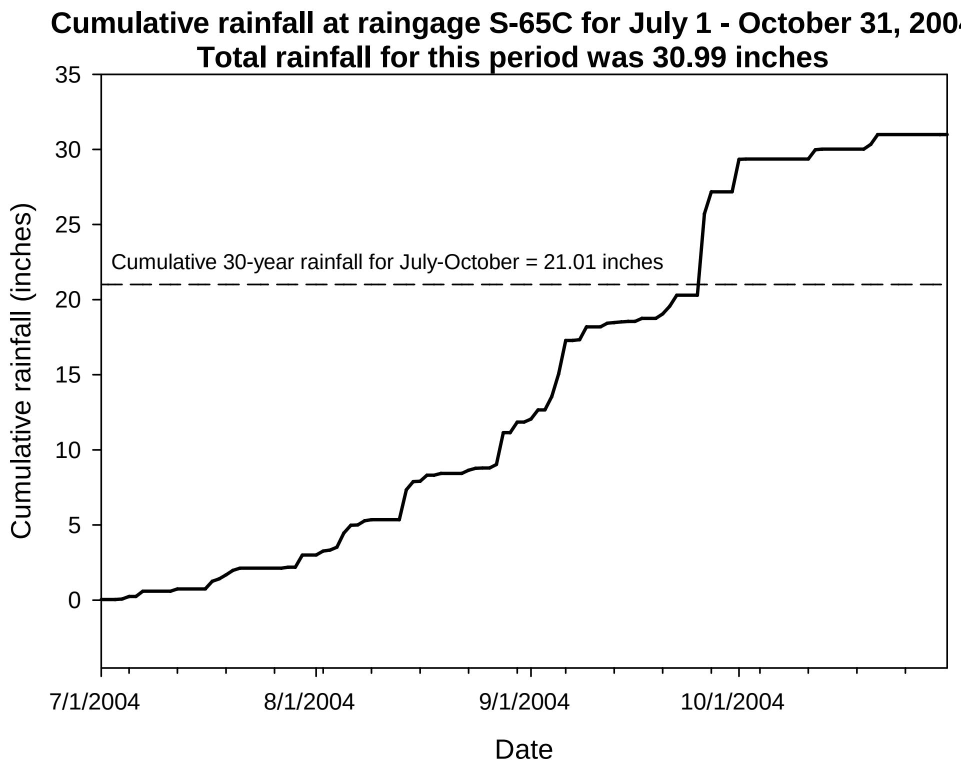
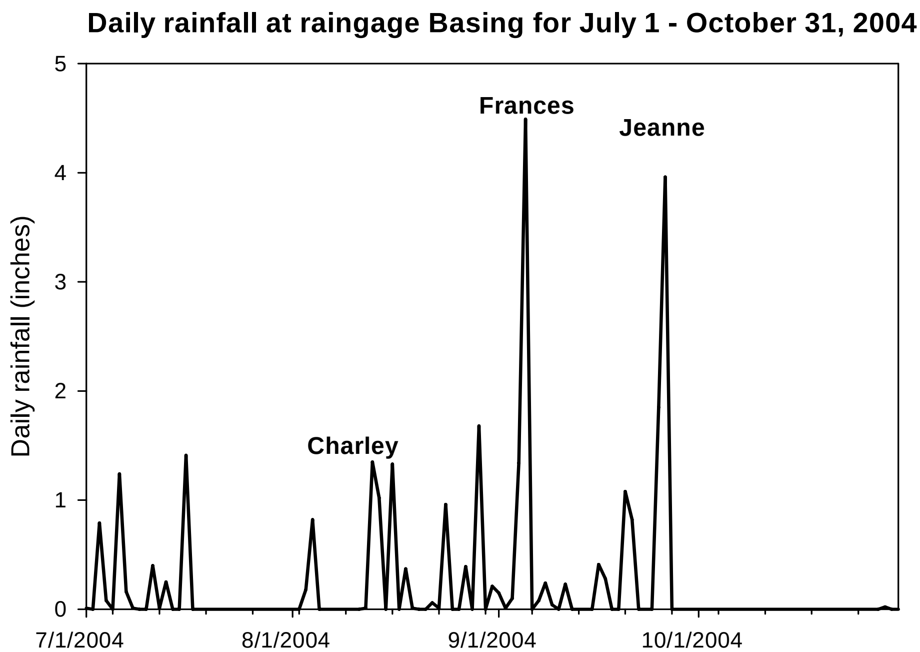


Figure 11-8. Rainfall at S-65C, July–October, 2004.



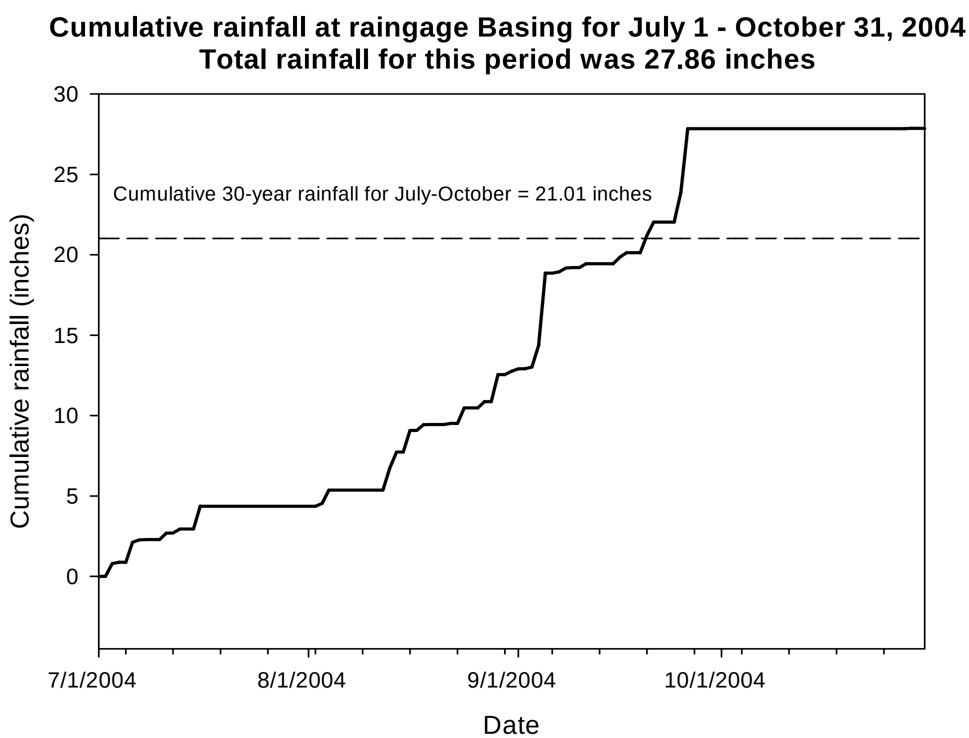


Figure 11-9. Rainfall at raingage Basing in the Lower Basin, July–October, 2004.

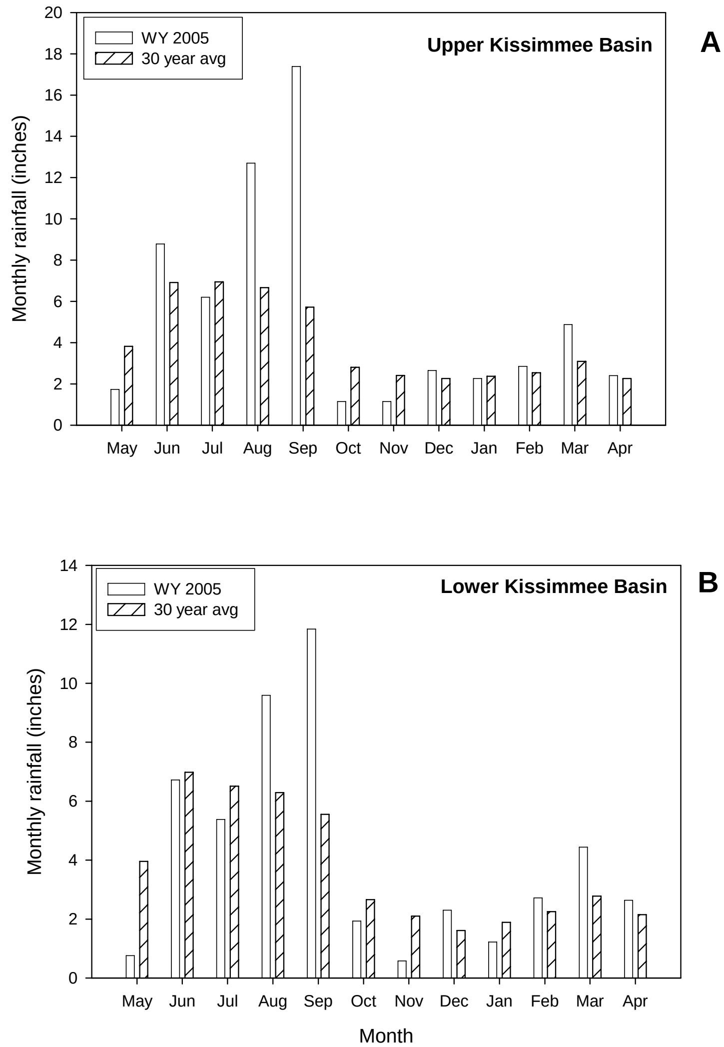


Figure 11-10. Monthly rainfall for WY2005 and for the 30-year-average (1971–2000) for the Upper Kissimmee Basin (A) and the Lower Kissimmee Basin (B).

Spring Recession

By the end of the hurricane season on November 30, 2004, the stage in almost all of the lakes had returned to regulation schedule. The recession event on the Kissimmee River that began on September 28, 2004 continued through February 26, 2005 (**Figure 11-11**). This recession event lasted 151 days during which stage decreased 7.39 feet, which is equivalent to a recession rate of 1.47 feet per 30 days.

During spring 2005, the stages for most lakes followed the regulation schedules. Also during the spring, the Everglade snail kite reemerged as a water management issue in the Upper Basin. In recent years, snail kite nesting on lakes Kissimmee and Tohopekaliga has represented a large percentage of the total number of snail kites fledged each year in Florida (Martin et al., 2003). Snail kites nest over water which reduces the vulnerability of the nest to terrestrial predators such as raccoons. In spring 2005, snail kites again nested on lakes Kissimmee and Tohopekaliga. In March 2005, a heavy rainfall event raised stage in Lake Tohopekaliga above the regulation schedule at a time when the regulation schedule was dropping. The process of lowering lake levels back to schedule resulted in a very rapid decrease in stage. Following this rapid decline in lake stage, a large number of the snail kite nests on Lake Tohopekaliga failed.

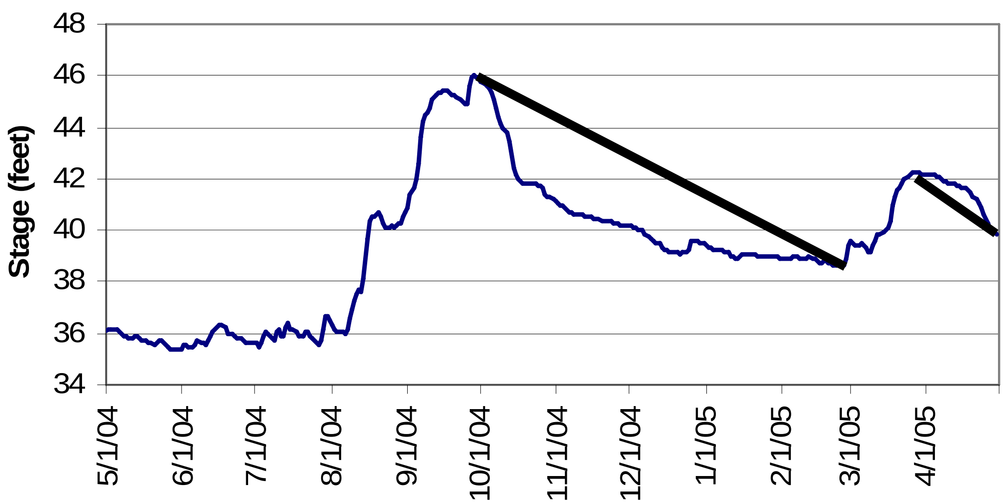


Figure 11-11. Stage at Weir 1. Heavy bars identify recession events that began in WY2005.

Hurricane Impacts on Dissolved Oxygen

Understanding the processes that drive changes in dissolved oxygen concentrations is important because low DO can affect habitat suitability for many aquatic organisms such as fish and invertebrates. DO concentrations in the river channel were monitored, along with discharge and stage, in an attempt to understand how water management decisions affect DO concentrations. Rapid stage recession events are thought to negatively affect DO dynamics. In 1988, before Phase I of the restoration project, extremely low DO concentrations in the C-38 canal and remnant river channel resulted in a relatively large-scale fish kill following a rapid floodplain recession event (Toth, 1988). One working hypothesis was that rapid inflows of DO deficient water (because of high biological oxygen demand from organic loading) from the floodplain contributed to the DO crash. Additionally, rapid inflow of water from the floodplain may have caused mixing of the large volume of DO deficient water near the bottom of the 10-m deep C-38 canal with the relatively low volume of oxygenated water at the surface, resulting in low DO concentrations throughout the water column. Although these scenarios may accurately describe processes leading to low DO concentrations in the channelized system, DO dynamics in the restored area of the Kissimmee River are likely very different.

Backfilling of the C-38 canal and restoration of flow through the river allowed for increased reaeration rates (D. Colangelo, unpublished data), flushed organic sediments from the river bottom (Williams et al., 2005), decreased the width of vegetation beds (Williams et al., 2005) and restored a more natural connection between the river channel and floodplain. A conceptual model of the processes that are thought to influence DO concentrations in the restored river channel was developed (**Figure 11-12**). Processes that contribute oxygen to the water column include photosynthesis by primary producers and reaeration through turbulent flow. Oxygen is consumed through respiration by aquatic organisms and chemical oxidation of organic compounds. Inflow of oxygen-deficient groundwater also may contribute to low DO concentrations. Discharge and stage are two factors that may influence these mechanisms and both can be managed through water control operations.

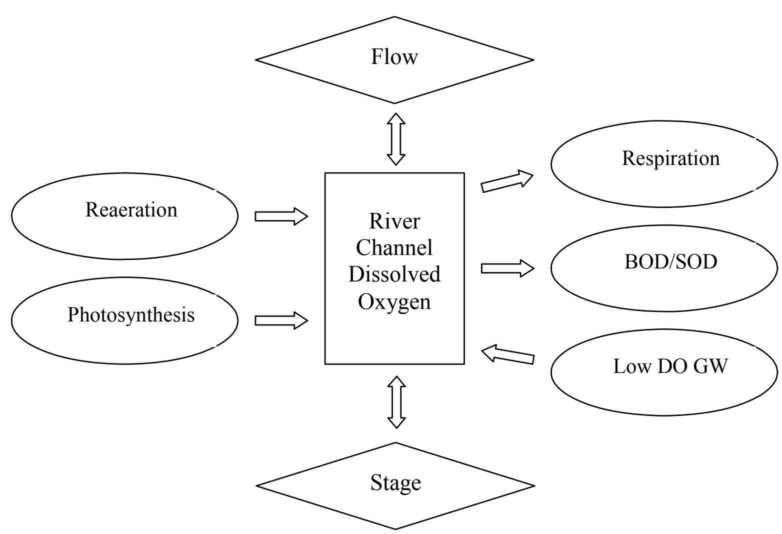


Figure 11-12. Conceptual model of factors that may affect dissolved oxygen concentrations in the river channel of the restored Kissimmee River. Ovals indicate processes that either contribute to or consume oxygen in the river channel (depending on arrow direction). Diamonds indicate factors that influence DO dynamics and can be managed.

River Channel Monitoring

In response to rainfall from Hurricane Charley and the approach of Hurricane Frances, discharge from Lake Kissimmee through S-65 increased from approximately 300 cfs on August 13, 2004 to > 9,000 cfs on September 12, 2004 (**Figure 11-13**). Dissolved oxygen concentrations in the river channel decreased from > 2 mg/L to < 1 mg/L during this period, with one exception. On August 28, 2004, DO concentrations began a rapid increase and peaked at 6.7 milligrams per liter (mg/L) on September 3, 2004 when Hurricane Frances passed over the Kissimmee River. Increased DO concentrations during this period were likely due to higher reaeration rates caused by turbulent mixing from high wind speeds and excessive rainfall (**Figure 11-13**). By September 8, 2004, DO concentrations had decreased to < 2 mg/L. A similar phenomenon occurred between September 24 and September 29, 2004 when Hurricane Jeanne passed over the area. As stage and discharge decreased, DO concentrations in the river channel gradually increased and remained above 2 mg/L for the remainder of the year (**Figure 11-13**).

Dissolved oxygen data from the 2004 hurricane season show that low DO concentrations coincided with rapid increases in discharge and stage except during the actual storm events when wind and rain induced reaeration caused rapid increases in DO concentrations. Mechanisms causing low DO concentrations during rapid stage and discharge increases may include the following:

1. When flow through structures S-65 and S-65A increased rapidly, oxygen deficient water from the C-38 canal to the north entered the river channel of the restored area.
2. High flow velocity in the river channel removed periphyton attached to submerged aquatic vegetation and bottom substrate, leading to decreased oxygen inputs from photosynthesis.
3. Rapid increases in stage resulted in less light penetration into the water column, reducing photosynthesis.
4. Phytoplankton suspended in the water column of the river channel was washed downstream by high flow velocity, reducing photosynthesis.
5. Large increases in flow and stage were the result of an intense rainfall event and runoff from the watershed increased, causing an increase in suspended organic solids/nutrients in the water column, which resulted in higher biochemical oxygen demand in the river channel.

Investigation of relationships between stage, discharge, and DO will continue through additional monitoring and data analysis. The goal of these studies is to develop DO performance measures for the restored area to help guide water control operations.

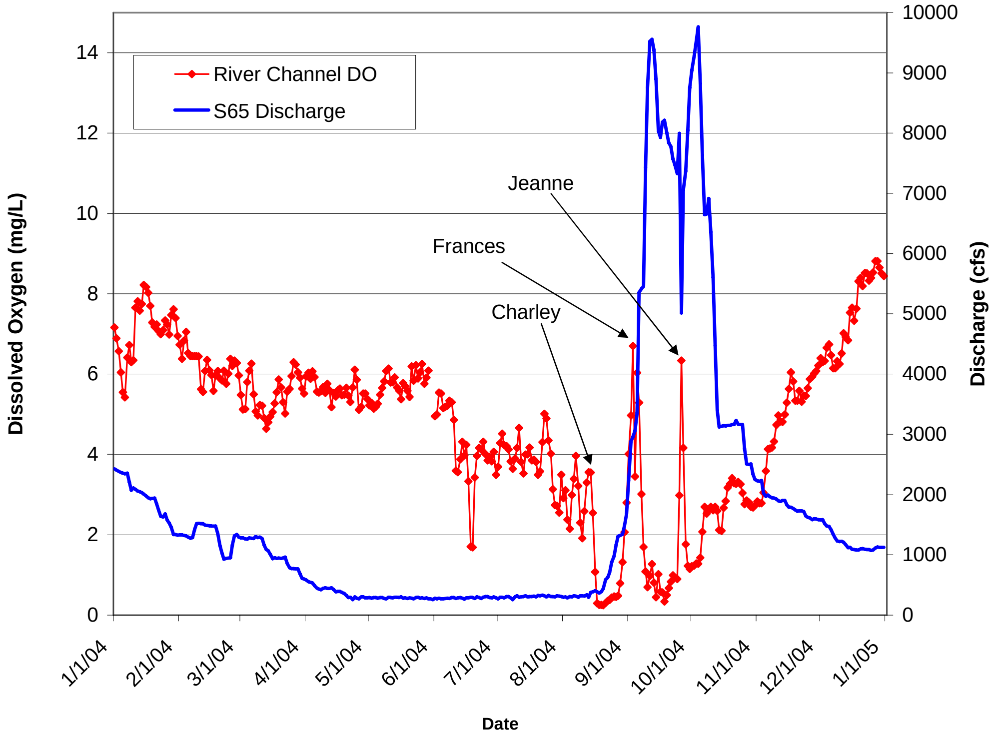


Figure 11-13. Mean daily dissolved oxygen, and discharge in the restored river channel during 2004.

Floodplain Recession Monitoring

In addition to river channel monitoring, DO and floodplain stage were monitored continuously at nine stations on the floodplain from October 14–November 10, 2004 as flood waters receded. Monitoring on the floodplain during stage recession was necessary because previous rapid recession events in the channelized system were thought to contribute to low DO in the river channel and C-38 canal. Water depth, presence or absence of flow, vegetation species, and percent cover also were recorded at each station on October 14, 19, and 28, 2004.

Additional, more extensive monitoring during floodplain recession events is needed to understand DO dynamics on the floodplain. However, initial results/preliminary analyses indicate that floodplain DO concentrations were highly variable. Changes in DO concentration did not seem to be related to stage or rate of change in stage. In general, DO concentrations were lower at stations with a high percentage of emergent vegetation than at stations in areas with open water and submerged aquatic vegetation and attached periphyton.

Future studies will focus on understanding the mechanisms that drive changes in DO on the floodplain. The goal of these studies is to develop performance measures that can be used to guide management decisions that may affect environmental conditions in the restored area.

Changes in Upper Basin Outflows

During meetings of the Water Resources Advisory Committee, the question was posed whether outflows from the Kissimmee Upper Basin had increased. Kissimmee Division staff was asked to investigate this question and specifically determine (1) if outflows were increasing, and (2) if outflows were increasing more than would be expected by rainfall.

This analysis was conducted for the whole Upper Basin and did not consider individual sub-basins. Outflow from the Upper Basin was determined as runoff volume (acre-feet, or ac-ft) for a water year was calculated from mean daily discharge (ft^3/s) at the current location of S-65. The discharge data were obtained from the SFWMD hydrologic database DBHYDRO (dbkey H0289). Prior to the construction of S-65, discharge at the outflow from Lake Kissimmee was measured by the U.S. Geological Survey (USGS) beginning in 1935. Daily runoff was summed for the water year (May 1–April 30) to calculate the total runoff for the water year. Average rainfall over the basin was determined by Thiessen polygons (G. Shaughnessy, SFWMD, unpublished data) and summed to provide estimates of rainfall by water years.

Runoff varied over the period of record between 16,000–2.2 million ac-ft per water year (**Figure 11-14**). Similarly, rainfall varied from 31–84 inches per water year. Runoff for several recent water years (WY1998, WY2003) was quite high and exceeded 1.6 million ac-ft, but these values were no higher than runoff for water years prior to regulation of the Upper Basin during the 1960s. Outflows did not exhibit an obvious trend over time and appeared to have a complex relationship to rainfall.

The relationship of runoff to rainfall was examined with a double-mass plot analysis (Searcy and Hardison, 1960). The double plot analysis was limited to WY1965–WY2004 because for the earlier years a different method was used to measure discharge at the outflow from Lake Kissimmee and because the network used to estimate rainfall contained fewer rain gauges. For this analysis, the cumulative runoff is plotted against the cumulative runoff predicted with a rainfall-runoff relationship from rainfall. If the individual points form a straight line, then it suggests that the relationship of rainfall to runoff has not changed. An inflection or bending of the line may indicate a change in the relationship, which may result form changes in the methodology used to collect the data or from changes in the watershed such as changes in land use.

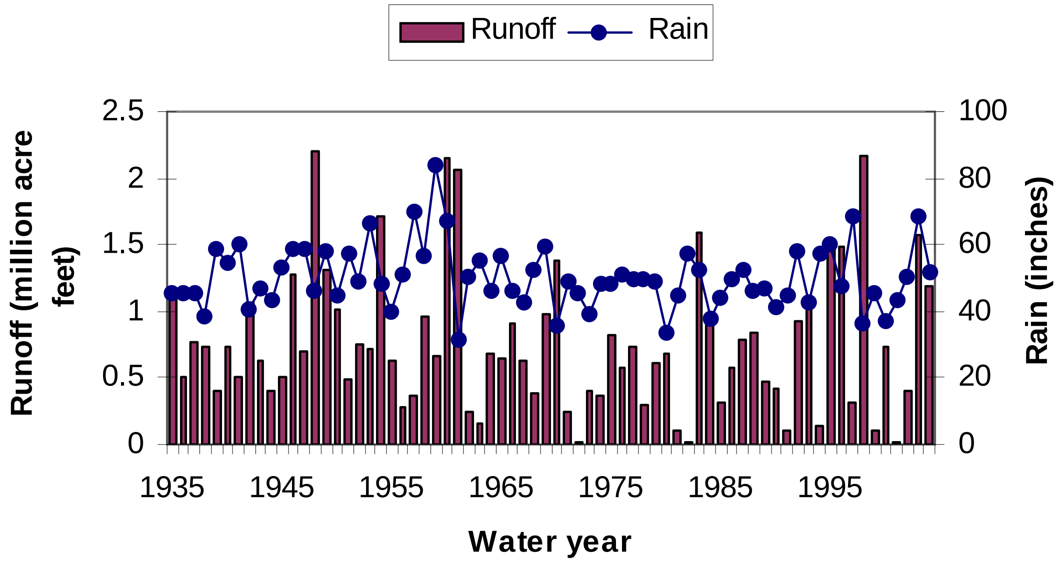


Figure 11-14. Runoff from the Upper Basin measured at S-65 and average rainfall over the basin totaled by water year.

For the double-plot analysis, a relationship of runoff to effective rainfall has to be developed. Following the procedure of Searcy and Hardison (1960), the rainfall that was effective in producing the runoff for a given water year (Water Year X) was conceptualized as a combination of the rainfall for that water year and preceding water years with the requirement that the sum of the coefficients, representing the proportional contribution from each year, be equal to one. Trial and error combinations of water year rainfall were used to obtain an effective rainfall that resulted in the maximum correlation of the ranking of water year runoff and effective rainfall. Effective rainfall for Water Year X was determined to be 0.9 of rainfall for Water Year X-1 and 0.1 of rainfall for Water Year X. Runoff was related to effective rainfall using a simple linear regression (**Figure 11-15**). This regression was significant and explained 69 percent of the variation in water year runoff. When this rainfall relationship was used to predict runoff, a plot of the cumulative observed runoff and cumulative predicted runoff formed a straight line (**Figure 11-16**). This analysis suggests that the relationship of rainfall over the Upper Basin and the runoff from the basin has not changed.

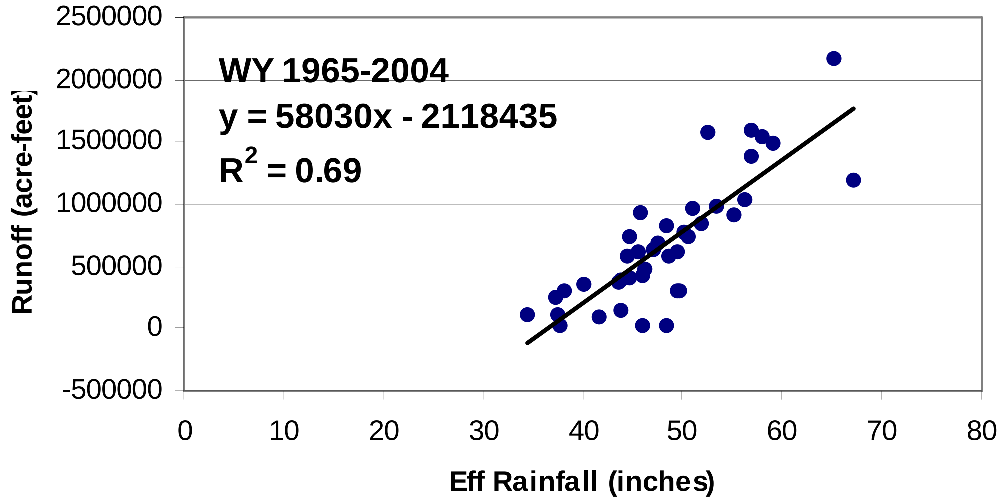


Figure 11-15. Relationship of water year runoff to effective water year rainfall.

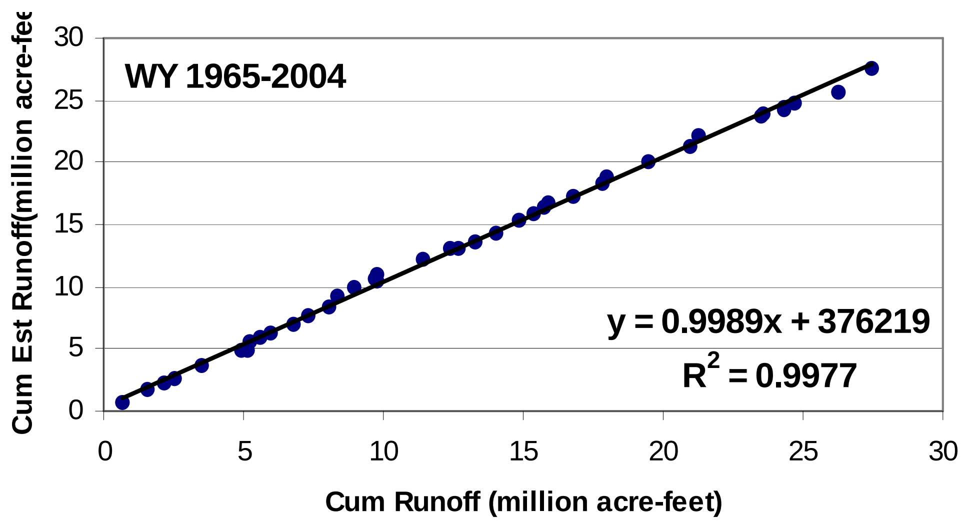


Figure 11-16. Double-mass plot of cumulative estimated runoff against observed runoff for WY1965–WY2004.

KISSIMMEE BASIN HYDROLOGIC ASSESSMENT, MODELING, AND OPERATIONS STUDY

The Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Study (KB Modeling and Operations Study) is an SFWMD initiative to identify alternative structure operating criteria to meet the flood control, water supply, aquatic plant management, and natural resource operations objectives of the Kissimmee Basin and its associated water resource projects. This study will assess how existing Kissimmee Basin operating criteria for the water control structures can be modified to achieve a more acceptable balance among flood control, water supply, aquatic plant management, and natural resource water management objectives while also balancing impacts across ecosystems including Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries. Operating criteria will be developed to effectively meet these various objectives with complete reliance on the existing water management infrastructure and the land interests of the state of Florida and the SFWMD. This effort will develop and apply a hydrologic and hydraulic model for the Kissimmee Basin. Model development will focus on capabilities required to evaluate alternative structure operations.

This study is independent of but closely related to the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP) that is discussed in greater detail later in this chapter. The KCOL LTMP will develop assessment performance measures to define and track key aspects of lake ecosystem health for the KCOL. The hydrologic conditions necessary to achieve these assessment performance measures will be translated into hydrologic performance measures for use in the evaluation of alternative structure operations.

The content of the remainder of the KB Modeling and Operations Study section is extracted and summarized from the Kissimmee Basin Assessment Report (Earth Tech, 2005). Phase I of this study will be completed in June 2005, and includes nine tasks:

1. Phase I Work Plan: Development of detailed task descriptions, roles, responsibilities, and schedules.
2. Watershed Delineation Verification: Evaluation/comparison of SFWMD watershed delineations in the Upper Basin (Guardo, 1992) with other watershed delineations developed by local governments and other stakeholders. Boundaries will be updated, as necessary, based on hydrographic and topographic data and local area knowledge. These watersheds are the basic units for model development and are important in defining water control units and water budgets.
3. Problem Identification: Identification of flood control, water supply, aquatic plant management, and natural resource operations objectives including objectives related to the KRRP, the KCOL LTMP, and the Upper Basin Restoration projects. Subtasks include extensive interviews, literature reviews, meetings, and data analysis to identify location, magnitude, and significance of each objective relative to operation of the C&SF Project.
4. Preliminary Data Analysis: Includes an analysis of 29 years of daily rainfall and flow data for five selected watersheds within the Kissimmee Basin. The objective is to evaluate existing data and identify possible trends associated with documented changes in land use, water management, water use, and population. Understanding of data characteristics, rainfall/runoff relationships, and cause and effects of physical changes in the basin will provide guidance for model conceptualization and identification of appropriate modeling tools.
5. Model Evaluation: Evaluation of the functionality, defensibility, and implementation costs for models capable of simulating surface water/groundwater interactions. Detailed evaluation criteria will be developed and applied to a short list of models for use in a workshop forum. Experts for each of the candidate models will be given an opportunity to address how their model best met the project needs as defined during problem identification (Task 3).

Consultant, SFWMD, USACE, and USFWS staff will participate in the evaluation and selection process that will consider how well each model can simulate water resources problems and rainfall/runoff relationships within the data constraints identified in tasks 3, 4, and 6.

6. Evaluation of Existing Monitoring Network: Evaluation of the existing flow, stage, and surficial aquifer monitoring network will be conducted to support model development and calibration, water management operations, and ongoing SFWMD watershed investigations. Additional monitoring sites will be recommended with a goal of use for eventual model refinement.
7. Model Development Plan/Strategy: Develops a proposed plan/strategy to develop, calibrate, verify, and apply a modeling approach to simulate basin hydrology and C&SF water control structure operations, and to formulate and evaluate operations alternatives to meet the flood control, water supply, aquatic plant management, and natural resource operational objectives defined in Task 3. This approach will be based on the insights gained in tasks 2–6.
8. Kissimmee Basin Assessment Report: Preparation of a report and executive summary to provide a comprehensive description of the Kissimmee Basin and also compile the task 2–7 reports.
9. Work Plan for Subsequent Phases: Develops a detailed description of tasks, methods, materials, and costs proposed for hydrologic/hydraulic model development, calibration, and verification, and development of operating criteria for interim and long-term plans.

As of the end of April 2005, draft deliverables for tasks 1 through 6 have been completed. Significant findings from these are summarized below. Final versions of these deliverables along with products from tasks 7 through 9 will be delivered by the end of June 2005.

Watershed Delineation Verification

Federal, state, county, and other agencies sub-basin delineations in the Upper Basin were examined. Discrepancies were identified in 33 locations. All but five of these discrepancies were resolved using the available data; the unresolved areas will require field investigation.

Problem Identification

Problem Identification was accomplished through a literature review, interviews, workshops, and the review and analysis of data. Characterization of the water resource issues was accomplished through analyses of historical flood events, evaluation of Kissimmee Basin landscape characteristics, investigation of surface water permitting requirements, and review of original design criteria and data for the Kissimmee Basin portion of the C&SF Project. The purpose of the task was to identify water resource management issues within the Kissimmee Basin and assess how well Kissimmee Basin water resource management requirements are being met by current operating criteria. Water resource management requirements include the combined project goals and objectives of the Kissimmee Basin portion of the C&SF Project, the Kissimmee River Restoration Project, the Kissimmee River Headwaters Revitalization Project, and the KCOL Long-Term Management Plan, as well as goals related to navigation, recreation, and public use. Four categories of operations objectives were defined: flood control, water supply, aquatic plant management, and natural resources.

Flood Control

The C&SF Project infrastructure of the Kissimmee Basin regional water management system was designed in the late 1950s and early 1960s for land use conditions that were never envisioned to reach current levels of development intensity. The basis for design of this system was an estimate of the 10-year storm event. As a result of the increased stormwater flows caused by these unanticipated land use changes, the current flood control capacity of the system may be less than stated in the original design.

In addition to being constrained by the regional water management infrastructure, the C&SF Project is constrained by the land interests owned by the state of Florida and the SFWMD. In the Upper Basin, land interests are tied to either the ordinary high water or the safe upland lines defined by the state of Florida. The exception to this is the lands purchased by SFWMD around lakes Kissimmee, Hatchineha, Cypress, and Tiger as part of the Kissimmee River Headwaters Revitalization Project. On these lakes, the SFWMD is in the process of acquiring flowage easements to allow lake levels to be managed up to 54 ft NGVD. In the Lower Basin, water levels within the Kissimmee River floodplain are constrained relative to the modeled extent of a 5-year and 100-year flood events. Water levels on Lake Okeechobee are the downstream constraint.

Flooding remains an issue in the Kissimmee Basin. Since construction of the C&SF Project, parts of the region have experienced significant urbanization which has dramatically changed the landscape. Surface water permitting requirements along with the conversion of lands from agricultural to urban uses have increased stormwater runoff timing and volumes. Increases of this type have the potential to cause exceedance of lake storage capacities, downstream flooding, diminished flood control capability, and KCOL discharges greater than those that would have occurred under natural conditions. Continued rapid growth and development in the Upper Basin will further compound this situation and potentially overwhelm the already taxed regional water management system.

Localized flooding caused by storm events occurs in many areas of the Kissimmee Basin along tributaries and near lakes. Flooding occurs at roads, subdivisions, business and agricultural interests. Areas most affected include the city of St. Cloud, the city of Kissimmee, and numerous subdivisions throughout Osceola, Orange, and Polk counties. Less developed areas of Okeechobee and Highlands counties also experience flooding, but fewer persons are affected. Streams/watersheds experiencing flooding include Shingle Creek, Boggy Creek, Reedy Creek, Mill Slough, Fish Slough, Chandler Slough, and several other streams and tributaries in both the Upper and Lower basins. Lakes in the Kissimmee Basin also experience unusually high stages during large rain events, which can lead to flooding of shoreline properties. While many of the lake and tributary flooding issues are local in nature, some are regional and potentially can be addressed through operations pursuant to the flood control objective of this project.

In addition to the regional flood control issues, numerous local flooding problems were reported within the watersheds and tributary system due to closed basins, undersized local drainage structures, lack of a drainage system, or lack of maintenance (siltation or debris). The topography in the northern part of the Kissimmee Basin is dominated by karst features, including closed drainage basins and sinkholes. Lake levels in these areas fluctuate in response to local rainfall conditions. Many of the lakes are hydraulically connected to the Floridan aquifer system (FAS). When a series of wet years occurs in these basins, and long-term precipitation inputs exceed basin losses such as evapotranspiration and downward leakance to the FAS, water levels in the lakes and the surficial aquifer system (SAS) tend to rise. This can result in flooding of some properties adjacent to lakes and can reduce the capacity of drainage systems due to groundwater infiltration and standing water. Modifications to C&SF project operations will not address these issues.

Water Supply

Water supply problems encompass both human and ecosystem water supply needs. The water utilities serving the growing population within the Upper Basin recognize that groundwater supplies are limited and are considering the option of using surface water. Water supply is also critical for environmental management and restoration. One unresolved issue in water supply planning in the Kissimmee Basin is the amount of water needed to maintain healthy lake ecosystems and restore ecological integrity to the Kissimmee River floodplain. Until this quantity is determined, there is uncertainty in the amount of surface water available to meet domestic, industrial, and agricultural water supply needs within the basin.

A second issue relates to the way lake levels are managed to support water supply needs. Current operating criteria hold Upper Basin lake levels at higher levels during the winter and spring to assure adequate water supplies. During the late spring and summer, they are held at lower levels to provide storage for flood control. On an annual basis, lake levels are not allowed to fluctuate more than a few feet, which is contrary to the seasonal pattern of natural water level fluctuations. Under natural conditions, the lake would tend to be lowest in the spring at the end of the dry season and highest at the end of the wet season (November) and would experience extreme lows during droughts. Current operating criteria and the resulting stabilized water levels have contributed to accumulations of organic material to build up in lake littoral zones, and the loss of lacustrine, littoral, and wetland habitats.

The third issue relates to restoration of the Kissimmee River. The Kissimmee River Headwaters Revitalization Project increases the amount of storage on lakes Kissimmee, Hatchineha, Cypress, and Tiger. This additional quantity of water was authorized to meet the hydrologic criteria of the Kissimmee River Restoration Project. Those criteria are designed to mimic pre-C&SF discharges from Lake Kissimmee to the Kissimmee River. The KRHRP allows for the purchase of land up to the 54 ft NGVD elevation on the specified lakes, but it provides no guarantees that water will be provided from the lakes farther north in the KCOL. Use of surface water to meet increasing urban and agricultural demands in the northern portion of the basin has the potential to impact the KRRP by reducing the total amount of water available for meeting KRRP hydrologic criteria.

Aquatic Plant Management

Hydrilla is a significant problem in lakes Kissimmee, Hatchineha, Cypress, and Tohopekaliga. Hydrilla was not present at nuisance levels when the regulation schedules of these lakes were initially adopted in December 1981. The result has been routine requests to deviate from the regulation schedules to meet the conditions needed for chemical treatment of hydrilla. These treatments require lake levels to be lowered during the spring and gates to be closed to provide required chemical residence times. Over the past decade, these requests have become an almost yearly occurrence and have increased conflicts with other operations objectives. Desired treatment conditions have also been difficult to achieve due to uncertain weather conditions during the spring treatment period.

The annual treatment requirement for hydrilla management is the key conflict because it requires annual deviations to a fixed set of conditions. This type of water level management is contrary to the needs of the natural system, which exhibited a high degree of interannual variability. For this reason, a treatment threshold needs to be developed. The threshold would represent the maximum level of hydrilla infestation that can be tolerated before treatment. This would potentially reduce the frequency of treatments. Operating criteria that allow the flexibility to accommodate threshold or opportunity triggers are desirable because they have the potential to reduce the inherent conflict among aquatic plant management operations objectives and flood control, water supply, and natural resource operations objectives. They would make it unnecessary for some temporary deviations from approved operating criteria to be coordinated in processes that can be lengthy and have unforeseen delays.

Natural Resources

The original C&SF Project, the KRRP, the KRHRP, and the KCOL LTMP all have natural resource management objectives. These objectives include hydrologic management, habitat preservation and enhancement, fish and wildlife, and water quality requirements. Collectively, these requirements are intended to provide quality habitat for the fish and wildlife resources. Specifically, they are intended to provide for the preservation, enhancement and/or restoration of creeks, rivers, floodplains, and lakes, as well as littoral, lacustrine, and other basin wetland habitats. Natural resource operations criteria must provide flows, stages, and volumes compatible with the natural system while also considering impacts of those operations to upstream and downstream ecosystems. Successful implementation of such operating criteria will protect native wildlife and their food sources and increase the potential for recovery of threatened and endangered species. Specific natural resource concerns include lake level management for those lakes not included in the KRHRP, failure to achieve hydrologic criteria of the KRRP, and downstream impacts to Lake Okeechobee and the estuaries.

Although the Kissimmee River Headwaters Revitalization Project was designed to provide the necessary stages, flows, and storage volumes to meet natural resource operations objectives for the restored river and lakes Kissimmee, Hatchineha, Cypress, and Tiger, it does not address hydrologic requirements for the lakes north of Lake Cypress (**Figure 11-1**). Under current operating criteria, the lakes north of Lake Cypress will continue to experience stabilized water levels with the consequence of continued degradation of lake habitat quality and fish and wildlife resources. To avoid these consequences, lake operating criteria need to restore more natural timing and magnitude of water level fluctuations and incorporate multiyear strategies that allow extreme drawdowns and prolonged durations of higher-than-normal lake levels. These operating criteria should also be applied to lakes Kissimmee, Hatchineha, Cypress, and Tiger.

Meeting hydrologic criteria of the Kissimmee River Restoration Project is a balancing act between the Upper and Lower basins and is essential to the success of the project. Flood control, water supply, and aquatic plant management operations objectives all have potentially conflicting requirements that put the operating criteria for the KRRP at risk. In March 2001, following completion of the first phase of this project, interim operating criteria were adopted for the S-65 structure at the outlet of Lake Kissimmee into the Kissimmee River. The purpose of these operating criteria was to provide continuous flow to the Phase I restoration area. Since adoption of the operating criteria, there have been annual requests to deviate from them for lake habitat preservation and enhancement and aquatic plant management projects. In addition to these deviations, above-average rainfall basinwide has produced flood conditions that have also resulted in operations incompatible with KRRP requirements. If the SFWMD and USACE are to be successful implementing the KRRP, then operating criteria must be adopted that appropriately balance the needs of the Kissimmee Basin with the needs of the KRRP.

The Kissimmee Basin is the largest watershed discharging to Lake Okeechobee and flows from the basin have the potential to negatively impact lake water levels during flood and drought conditions. This interdependent relationship has the potential to impact the St. Lucie and Caloosahatchee estuaries, as well as the Everglades. Development of operating criteria for the Kissimmee Basin need to allow for the evaluation of watershed conditions so that impacts can be balanced among ecosystems.

Conflicts Among Operations Objectives

Under current operating criteria, conflicts often arise among the requirements for flood control, water supply, aquatic plant management, and natural resource operations objectives. Rather than seeking approaches that balance or use a fixed set of decision rules to deviate from those operations, the current process pits one objective against another and often results in politically and/or environmentally unpopular consequences. This study is intended to provide a balanced approach to formulating and evaluating modifications to Kissimmee Basin structure operating criteria. The approach will take into account the various requirements of the flood control, water supply, aquatic plant management, and natural resource operations objectives, and will seek an alternative that maximizes benefits while minimizing potential adverse impacts.

Preliminary Data Analysis

A preliminary, qualitative evaluation of daily rainfall and daily flow data was conducted for five watersheds or groups of watersheds (basins) selected to represent the hydrologic variability within the Kissimmee Basin. The primary focus of the evaluation was to compare rainfall and flow data on a watershed scale to (1) identify watershed response characteristics and data constraints in support of formulation of the basinwide hydrologic/hydraulic model, and (2) to provide information regarding data availability and consistency in support of the anticipated modeling and the monitoring plan evaluation. Data analysis was qualitative and did not quantify the rainfall-runoff relations. A quantitative hydrologic analysis is required to separate the hydrologic factors from the regulation schedule impact on flows/discharges for the watersheds. The need to evaluate rainfall records for the rain gauge stations prior to their use in modeling was identified. Numerous records were missing from the rainfall data and others were thought to contain errors.

Model Evaluation

An inventory of computational modeling tools that could be used to simulate hydrologic/hydraulic systems in which there is significant interaction between the surface and subsurface components of water flow was compiled. A total of 19 modeling tools were identified and screened by model experts, including software developers and experienced model users from academia, government, and private consulting. Six of these models were selected for further evaluation, including the WASH123SD, FTLOADDS, MODFLOW, XP-SWMM, MOD-HMS, and MIKE SHE/MIKE 11. Three categories of criteria were used in the evaluation of the candidate modeling tools:

1. Functionality. Whether the modeling tool has the computational ability to quantify hydrologic and hydraulic variables significant to determining the influence a given operational scenario may have on the Kissimmee Chain of Lakes, Kissimmee River, and Lake Okeechobee, as well as the lands hydrologically connected to the Kissimmee Chain of Lakes and Kissimmee River.
2. Defensibility. This evaluation category included such criteria as the availability of documentation of model tests, whether the modeling tools had been applied to problems of similar normalized scales, with feasible run times, and the extent of use of the modeling tools in the published literature.
3. Cost-effectiveness. Items considered in evaluation of cost-effectiveness included implementation costs associated with software, development time, software maintenance, computational time, training, technical support, and ancillary tools.

A Model Evaluation Workshop was conducted to further screen the short-listed models. The final recommendation was to adopt the MIKE SHE/MIKE 11 modeling tool.

Evaluation of Existing Monitoring Network

Prior to evaluation of the existing Kissimmee Basin hydrologic monitoring network, objectives for the network were identified. Information regarding the existing and planned monitoring networks in the Kissimmee Basin operated by the SFWMD and other entities was compiled to assess the spatial and temporal extent of available flow and stage data. The network was assessed relative to its ability to meet established monitoring objectives. Proposed new monitoring sites were sited utilizing detailed GIS data for hydrography, topography, wetlands, and other natural features and constraints.

Recommendations for additional monitoring throughout the Kissimmee Basin were presented to the SFWMD Monitoring Steering Committee in April 2005. Six monitoring projects were identified:

1. Upper Basin Water Budget/Operations: Improve Kissimmee Upper Basin water budgets and provide near real-time access for operations and event monitoring/modeling.
2. Upper Basin-Operations: Provide real-time access to USGS data for operations and event monitoring/modeling
3. Reach 4A Monitoring: Monitor floodplain inundation prior to and following the backfill of an additional reach of the C-38 canal
4. Lower Basin Water Budget: Improve Kissimmee Lower Basin Water Budgets specifically related to tributary inflows
5. East Pool C: Establish surface water and SAS monitoring in the East Pool C vicinity for the evaluation of groundwater/surface water interactions.
6. Lower Basin SAS Well Network: The Lower Basin SAS Well Network was initiated in 2004 to characterize the SAS in the Lower Basin. This initiative will enhance understanding of the behavior and mechanics of the regional hydrologic system and support development of an integrated groundwater-surface water model for the Kissimmee watershed. There is a general lack of information regarding the hydrogeologic properties of the SAS in the Lower Basin and the degree of groundwater/surface water interactions. This work is being undertaken on a collaborative basis with the USACE as part of the Kissimmee River Restoration Project. The USACE is performing the drilling and testing of the new wells, while the SFWMD is responsible for instrumenting, fencing, and maintaining them. As of May 1, 2005, 18 wells had been installed along the periphery of the floodplain, and 11 wells had been instrumented and fenced. Additional wells are planned for both the floodplain area and throughout the contributing watershed. Completion of the monitoring well network is expected by the end of FY2007.

Twenty-one stage, eleven flow, and five SAS monitoring stations were identified and approved by the Monitoring Committee. Site reconnaissance and installation, where feasible, are scheduled for completion by September 30, 2005.

Phase II of the KB Modeling and Operations Study will be initiated in July 2005. This study will include the development and application of modeling tools to formulation, evaluate, and select a suite of alternative operating criteria for Kissimmee Basin structures.

Draft Environmental Impact Statement for Modification of Kissimmee Basin Structure Operating Criteria

The draft Environmental Impact Statement (EIS) required for modification of structure operating criteria within the Kissimmee Basin is a USACE project that will be conducted in parallel with the KB Modeling and Operations Study. The study area includes the Kissimmee River, the Kissimmee Chain of Lakes, and the associated tributaries and drainage areas. The lakes include lakes Kissimmee, Hatchineha and Cypress; Lake Tohopekaliga; East Lake Tohopekaliga, Fell's Cove, and Lake Ajay; lakes Hart and Mary Jane; lakes Joel, Myrtle, and Preston; the Alligator Chain of Lakes (Alligator, Brick, Lizzie, Coon, Center, and Trout); and Lake Gentry (Appelbaum, 2005).

The draft EIS includes participation of the USACE staff in the KB Modeling and Operation Study and completion of National Environmental Policy Act investigations associated with a proposal to modify a federal project. The proposed action that will be evaluated is modification of Kissimmee Basin structure operating criteria to better meet the competing demands of flood control, water supply, aquatic plant management, and natural resource needs. The USACE will seek a balanced approach to formulating and evaluating modifications to structure operating criteria that will take into account the various requirements of the flood control, water supply, aquatic plant management, and natural resource operations objectives and seek an alternative that maximizes benefits while minimizing potential adverse impacts (Appelbaum, 2005).

The draft Environmental Impact Statement will consider the effects of the proposed operating criteria modifications on wetlands, aesthetics, water quality, water supply, endangered and threatened species, fish and wildlife habitats and values, historical or archaeological resources, flood control, navigation, public use, and recreation. Other resources and issues may be identified during this public consultation process. The draft EIS is expected to be completed by the end of 2007 (Appelbaum, 2005).

KISSIMMEE RIVER RESTORATION PROJECT

Restoration Project Implementation

The Kissimmee River, Florida Project is comprised of the Kissimmee River Restoration and the Kissimmee River Headwaters Revitalization projects. Currently, there are 31 project-related features. Fourteen of these have been completed, seven are in the planning stage, six are in the design phase, and four are under construction.

The purpose of the Kissimmee River Headwaters Revitalization Project is to provide the necessary water storage and regulations needed to approximate the historical flow characteristics for the Kissimmee River system, and to increase the quantity and quality of lake littoral zone habitat for the benefit of fish and wildlife (USACE, 1996; Section 1.3.2). These purposes will be accomplished by increasing the water storage capacity of lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 ac-ft (12,340 ha-m) and by increasing the conveyance capacity of the canals and structures to accommodate these increased storage volumes. Meeting these objectives involves (1) acquisition of approximately 20,800 ac (8,400 ha) of land bordering these lakes, (2) widening the C-36 canal between lakes Cypress and Hatchineha and the C-37 canal between lakes Hatchineha and Kissimmee, (3) adding two gates to the S-65 water control structure to increase the outlet capacity from Lake Kissimmee, and (4) modifying the stage regulation schedule for the S-65 structure.

The headwaters revitalization regulation schedule is zoned to provide varying discharges based on season and water level (**Figure 11-17**). Specifically, these modifications allow for a wider range of lake stage fluctuations, with maximum lake stages increasing from 52.5 ft (15.9 m) to 54.0 ft (16.4 m) NGVD. The new regulation schedule with increased maximum stage both provides for the reestablishment of pre-channelization seasonal outflow characteristics from Lake Kissimmee to the Lower Basin and benefits the lakes by expanding littoral zones and peripheral wetlands by approximately 14,000 ac (5,700 ha) (USACE, 1996). Additionally, the increase in the range of lake stage fluctuation is expected to improve the overall quality and productivity of littoral and wetland habitats.

To date, the C-36 and S-65 modifications are complete. The majority of lands that will be inundated as a result of increased stage on lakes Kissimmee, Hatchineha, Cypress, and Tiger have been acquired. The widening of C-37 is expected to be completed in 2006. The headwaters revitalization operation schedule will be implemented upon completion of the C-37 modifications and removal of the S65-C structure. In June 2001, an interim operation schedule was implemented for S-65. This interim schedule provides a strategy for meeting the river restoration project needs for continuous flow by allocating water for discretionary releases. The interim schedule will remain in place until the new schedule is implemented. Although beneficial to the river, this schedule does not raise the high pool stage and thus does not allow the expected natural river flows. Also, the interim schedule does not provide the benefits to littoral zone habitats in headwater lakes that will be realized with the headwaters revitalization schedule.

The river restoration component requires the acquisition of approximately 68,300 ac (27,640 ha) of land in the Lower Basin and involves a plan to (1) backfill an approximately 22 mi (35 km) section of C-38 from the lower end of Pool D to the middle of Pool B, (2) reconnect remnant river channels by recarving sections of river channel destroyed during C-38 construction, (3) remove the S-65B and S-65C water control structures and tieback levees, and (4) evaluate restoration success through a comprehensive ecological monitoring program. Backfilling of C-38 and recarving of river channels will be implemented in a series of construction phases to be completed in 2012; evaluation of restoration success will continue through 2017 (**Figure 11-18**). Ultimately, the project will result in restoration of approximately 104 km^2 of river-floodplain ecosystem, including 70 km of continuous river channel.

Phase I construction of the KRRP was completed in February 2001. Approximately 7.5 mi (12 km) of flood control canal was filled in Pool C and the southern portion of Pool B. Nearly 1.3 mi (2 km) of river channel was recarved and water control structure S-65B was demolished. These efforts reconnected 15 mi (24 km) of continuous river channel and allow for intermittent inundation of approximately 12,000 ac (4,900 ha) ha of floodplain. The next phase of construction (Phase IVa) is scheduled to begin in late 2005/early 2006 and will involve backfilling approximately 1.9 mi (3 km) of C-38 canal, beginning at the northern terminus of the Phase I area. Phase IVa represents a portion of a construction phase (Phase IV) that was originally scheduled for the end of the restoration project. The Phase IV project has now been divided into Phase IVa and Phase IVb, with construction of Phase IVb to be completed at the end of the restoration project.

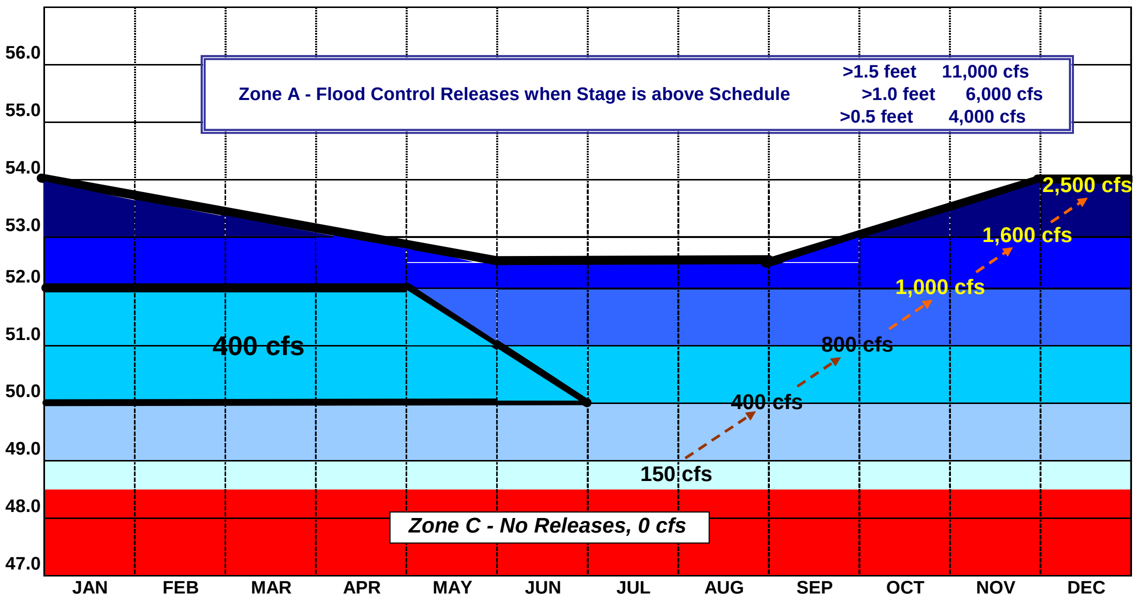


Figure 11-17. Revised regulation and operational schedule for the Upper Kissimmee Basin (UKB) Chain of Lakes including lakes Kissimmee, Hatchineha, Cypress, and Tiger, controlled by S-65.

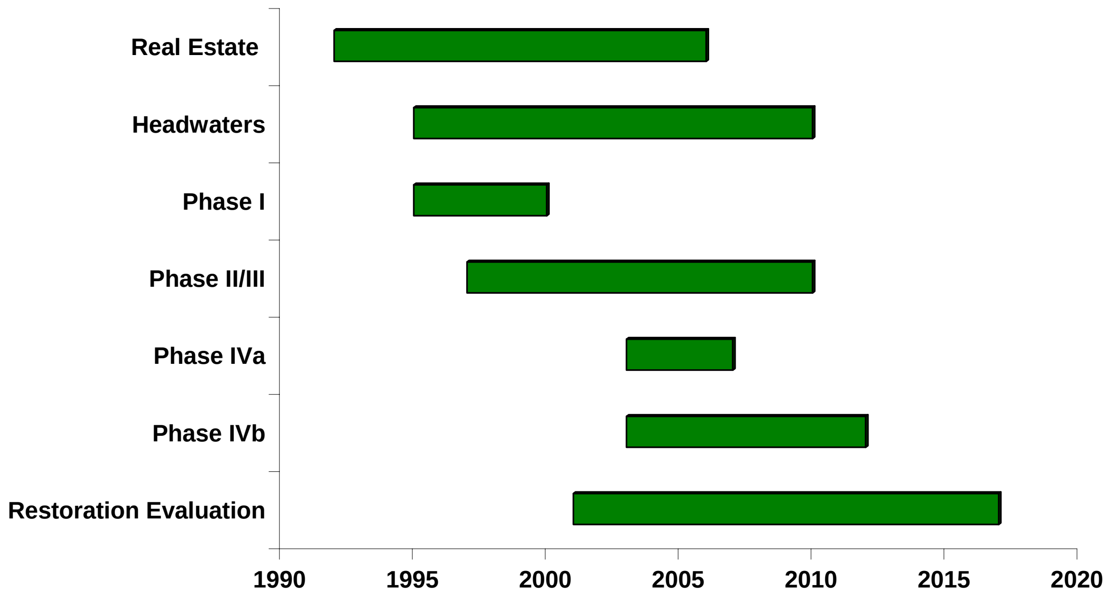


Figure 11-18. Implementation schedule for the Kissimmee River Restoration Project. During WY2005, adjustments were made to the implementation date for the Headwaters Revitalization Project (2006–2010) and Phase IV backfilling project (project was divided into two components, Phases IVa and IVb).

Restoration Evaluation Program Overview

A key element of the Kissimmee River Restoration Project is a comprehensive ecological evaluation program to (1) assess achievement of the ecological integrity goal, (2) establish causality between the restoration project and observed changes, and (3) support adaptive management in the later phases of the project. The major elements of this program are outlined in the authorized feasibility plan for Kissimmee River restoration (USACE, 1991). Restoration evaluation, as outlined in the feasibility study, is also part of the 1994 50-50 Cost-Sharing Project Cooperative Agreement between the SFWMD and USACE. Also, restoration evaluation relates directly to the District's mission, "to manage and protect water resources of the region by balancing and improving water quality, flood control, naturals systems, and water supply." Finally, restoration evaluation has already demonstrated its value for this project in the assessment of multiple restoration options during the Pool B Demonstration Project (Toth, 1993), and in the assessment of the feasibility of backfilling C-38 and potential impacts on water quality (Koebel et al., 1999).

The KRRP is unusual among restoration projects for having a comprehensive monitoring program to evaluate project success. The success of many projects has not been determined (Bash and Ryan, 2002; DellaSala et al., 2003), in part because of the lack of a widely accepted, standardized approach for restoration evaluation (Anderson and Dugger, 1998). Restoration evaluation poses a number of challenges. First, it is difficult to make inferences about changes and causality for ecosystem restoration projects, such as the Kissimmee River, because, like other whole ecosystem manipulations, they lack treatment replication, randomization, and controls (e.g., Carpenter, 1998). Second, project goals have to be expressed as meaningful and measurable criteria that specify acceptable conditions. Third, success criteria should be based on reference conditions that represent the unimpacted or pristine system. Pre-impact data is frequently lacking, as are reference sites, because ecosystems selected for restoration tend to be rare or have unique functions on the landscape (NRC, 1992). These issues are addressed in the strategy for restoration evaluation described below for the KRRP.

To evaluate the goal of ecological integrity, the evaluation program is broad in scope and includes major abiotic components of the ecosystem (hydrology, geomorphology, and water quality) and major biological communities (e.g., plants, invertebrates, fish, and birds). The strategy for evaluating the KRRP's success centers around two key activities: (1) monitoring to assess changes in important metrics that represent the condition of the river-floodplain ecosystem, and (2) development of restoration expectations (**Figure 11-19**). Information about observed changes in the system will be compared to anticipated changes described by individual restoration expectations (performance measures) to evaluate whether the expectation has been achieved. The results from evaluating all expectations will be integrated to determine success of the project. If an expectation is not achieved, then there will be an opportunity during the integration process to consider if adaptive management strategies should be implemented.

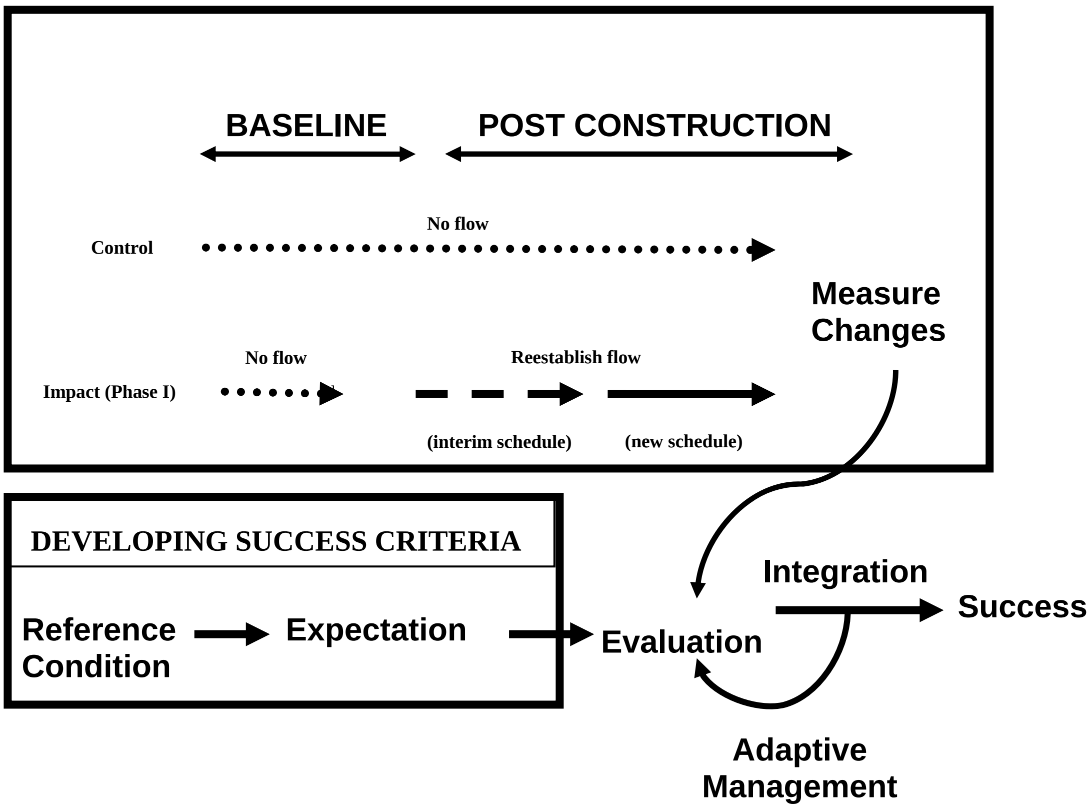


Figure 11-19. Strategy for evaluating the Kissimmee River Restoration Project.

Monitoring System Change

To detect system change, data were collected prior to the Phase I construction to establish a baseline for evaluating future responses. Baseline studies were conducted in Pool C, which included most of the area impacted by Phase I construction. Most studies also monitored a control site in order to utilize the Before-After/Control-Impact (BACI) design (Stewart-Oaten et al., 1986). The BACI design can be used to detect changes at an impact site (Pool C for Phase I) relative to changes at a control site, but in a strict sense it does not allow inferences about the causes of change. Causality will have to be established through a weight of argument, as used in epidemiological and ecotoxicology studies (e.g., Stewart-Oaten et al., 1986; Anderson and Dugger, 1998). The BACI design does not require that the control and impact sites be identical, but they should be similar and should respond in a similar manner to environmental drivers such as climate. For most studies, the control site was Pool A, which is located upstream of the restoration project area and not scheduled for restoration. Baseline data will be compared to data collected after construction and restoration of pre-channelization hydrologic conditions.

A restoration expectation describes an aspect of ecological integrity for the Kissimmee River. It incorporates one or more metrics, is based on the best available reference condition data, and, if necessary, has been adjusted for constraints external to the restoration project. For this project, reference conditions were based on data from the pre-channelized river, where possible; however, such data were not available for all expectations. Reference conditions also were based on existing data from other rivers or wetland systems that were identified as appropriate reference sites for that expectation.

The District's Kissimmee Division will publish two volumes of Kissimmee River restoration evaluation studies in 2005. The goal of these documents is to disseminate relevant and timely information regarding research and restoration evaluation efforts to the public and the scientific community. The first volume, Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River, is a compendium of reports on baseline studies conducted for the restoration evaluation program. The reports present detailed background, data, and analyses related to baseline and reference conditions; selection of reference sites; responses to channelization as inferred from comparisons between baseline and estimated reference conditions; and development of the restoration expectations and ongoing monitoring programs. The second volume, Defining Success: Expectations for Restoration of the Kissimmee River, is a compendium of background information and documentation for the expectations and monitoring programs that will be used to evaluate the restoration project's success. The expectations will be short summaries that describe project methods, baseline conditions, reference conditions, and the logic that guided expectation development. Together, these District publications will supplement journal publications by documenting and archiving development of the restoration expectations and monitoring programs, as well as pre-restoration evaluation studies.

Restoration Evaluation Program: Status and Results

The first phase of river reconstruction was completed in February 2001. An interim headwater regulation schedule was implemented in June 2001, and has provided continuous flow through the reconnected river channel. Evaluation efforts to date include the (1) assessment of baseline conditions, (2) identification of reference conditions that represent the pre-channelization condition of the river, (3) monitoring for construction impacts during Phase I, and (4) monitoring initial responses to Phase I backfilling and implementation of the interim stage regulation schedule. Ongoing restoration evaluation efforts focus on the river channel affected by Phase I construction, with limited efforts to assess early recovery by select floodplain components (e.g., stage/hydroperiod, wetland vegetation, and wading birds/waterfowl). A comprehensive description of the restoration evaluation program and initial responses in the Phase I area was provided in the Chapter 11 of the 2005 SFER – Volume I (Williams et al., 2005). The purpose of this section is to update results of selected evaluation projects for which data were collected during WY2005.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is one of the most frequently used indicators of water quality because it is easy to understand and relatively simple to measure (Belanger et al., 1985). DO is essential to the metabolism of most aquatic organisms and can influence growth, distribution, and structural organization of aquatic communities (Wetzel, 2001). Oxygen distribution also affects the solubility and availability of many nutrients and can impact the productivity of aquatic ecosystems (Wetzel, 2001). For these reasons, DO has been identified as a key indicator of ecological integrity and an essential component of the Kissimmee River Restoration Evaluation Program. Mean DO concentration in the Kissimmee River channel is expected to increase significantly after flow is restored. Restoration of continuous flow should increase reaeration rates and decrease sediment oxygen demand by flushing organic deposition from the underlying sandy river bottom. Continuous flow also should restrict mid-channel growth of aquatic macrophytes, and increase light availability (and therefore oxygen production) in the water column. Concentrations should be within the range of values reported for reference streams and show similar seasonal patterns. Four metrics were chosen to evaluate changes in DO as restoration proceeds: (1) mean wet season daytime concentration of dissolved oxygen at 0.5 m, (2) mean dry season daytime concentration of dissolved oxygen at 0.5 m, (3) annual percentage of samples with dissolved oxygen concentrations > 2 mg/L, (4) percent of time DO concentrations within 1 m of the channel bottom are > 1 mg/L.

DO was monitored continuously at a depth of approximately 1 m in three remnant river run stations each in Pools A and C. Sampled river channels were approximately 20–30 m wide and 2–3 m deep. DO was also sampled monthly within seven remnant river runs and two canal stations in Pools A and C. For several months before and after phase I of the restoration, weekly DO depth profiles (DO sampled at 0.5 m and each meter thereafter to 0.5 m above bottom sediment) were taken at four stations within remnant river channels. Monitoring sites were selected to cover a large geographic area. Canal stations near water control structures S-65A and S-65C monitored DO concentrations of water flowing into and leaving the restoration project area. DO data were not collected prior to channelization; therefore, the reference condition was derived from data on seven free-flowing, blackwater streams in South Florida. Each stream had at least 11 samples collected over a minimum of one year and some streams were sampled for more than 10 years. The mean DO concentration in the reference streams was 4.8 mg/L during the wet season and 6.6 mg/L during the dry season (**Figure 11-20**). In five of the eight 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.

Within the channelized river, DO concentrations were frequently below 1 mg/L throughout the water column at all times of day. A gradient in DO concentration (DO decreasing with depth) was observed during May–June 1999. DO concentrations near the surface could be as high as 4–5 mg/L while concentrations near the bottom were lower than the detection limit (< .2 mg/L). During 1996–1999, mean DO concentrations in remnant river runs in Pool A and C were 1.4 and 1.2 mg/L, respectively, during the wet season, and 3.1 and 3.3 mg/L, respectively, during the dry season (**Figure 11-20**). DO concentrations exceeded 2 mg/L for 22 percent of the baseline period, and 5 mg/L for 6 percent of this period.

Following completion of construction for Phase I of the restoration, mean daytime DO concentrations within the restored area averaged 3.0 mg/L during the wet season and 6.0 mg/L during the dry season (**Figure 11-20**). Post-construction DO concentrations in the control area

(Pool A) averaged 1.1 and 4.5 mg/L during the wet and dry seasons, respectively (**Figure 11-20**). Mean annual DO concentrations in the restoration area (Pool C) increased from < 3.0 mg/L before construction to > 5.0 mg/L in 2004 (**Figure 11-21)**. Mean daily water column DO concentrations were > 2.0 mg/L for 80 percent of the time. Dissolved oxygen concentrations within one meter of the channel substrate were > 1.0 mg/L over 50 percent of the time. After restoration of flow, the previously observed DO gradient vanished. DO concentrations were similar throughout the water column.

It is important to note that post-construction DO concentrations of < 1 mg/L have been recorded in the river channel during the wet season and, in some cases, low DO concentrations have persisted for as long as several months. Although the restoration expectation for DO concentrations in the restored river channel is to be evaluated after implementation of the Kissimmee River Headwaters Revitalization Project regulation schedule, three of the four metrics used to evaluate DO response are being met under the interim regulation schedule.

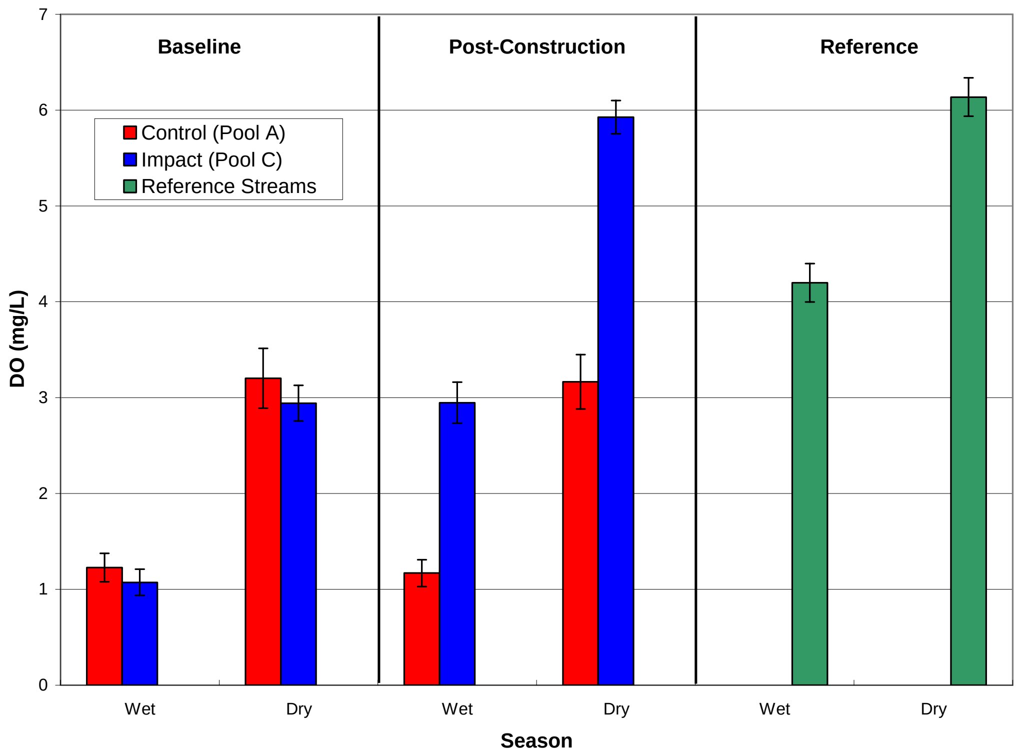


Figure 11-20. Mean (± standard error of the mean) dissolved oxygen (DO) concentrations (mg/L) in reference streams and the control and impact areas during the wet and dry season, before and after Phase I construction.

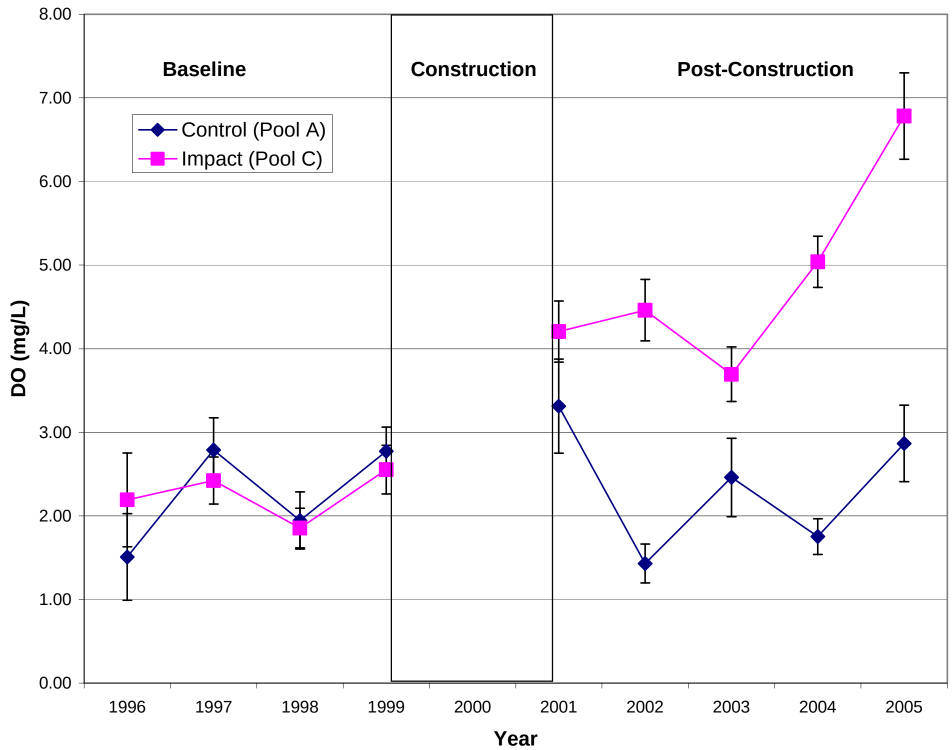


Figure 11-21. Mean annual DO concentrations in the Kissimmee River (± standard error of the mean).

TURBIDITY

The Kissimmee River is a slow-flowing system in a basin with nearly flat terrain. Consequently, turbidity and total suspended solids (TSS) concentrations have been very low and are expected to remain low after restoration. Baseline turbidity and TSS were sampled monthly during 1996–1999 in seven remnant river runs of Pools A and C (**Table 11-1**). Mean turbidity at these locations was very low, ranging from 1.3 to 3.5 nephelometric turbidity units (NTU). TSS concentrations were ≤ 25 mg/L, and were usually lower than the detection limit (i.e., < 3 mg/L). Slightly higher turbidity values were measured in summer and appear to reflect greater densities of phytoplankton, as indicated by chlorophyll *a* concentrations.

No turbidity or TSS data were collected from the Kissimmee River before it was channelized, so the reference condition was derived from general knowledge of pre-channelized conditions and data on other South Florida streams. Turbidity in the former river is assumed to have been very low due to (1) the river's location in a watershed with nearly flat topography, sandy soils, and low-intensity land use; (2) headwater inflow from Lake Kissimmee, which supplied 58 percent of total river discharge (Bogart and Ferguson, 1955); (3) groundwater seepage from aquifers underlying upland areas (Parker, 1955); (4) low channel velocities; and (5) filtering effects of marsh and littoral vegetation. Floods in the Kissimmee Basin were characterized by slow changes in stage, low flow velocities, and long periods of recession. Floodwaters were relatively clear and little silt was left after floods passed (Bogart and Ferguson, 1955). This suggests that suspended material associated with surface runoff did not significantly influence water quality, and any turbidity in the river would have been primarily due to plankton, suspended detritus, or erosion of channel sediment during extreme flows. In a flowing, blackwater river surrounded by dense vegetation, phytoplankton blooms would have been rare, so turbidity and TSS would have remained low (turbidity < 5 NTU and TSS < 3 mg/L) under both low and high discharge conditions. In summary, reference conditions for turbidity and TSS probably did not differ significantly from baseline measurements, except that maximum values may have been lower due to a reduced likelihood of algal blooms.

Due to the lack of reference data from the pre-channelized river, eight free-flowing, blackwater streams in South Florida were selected as reference sites. These streams and their watersheds share some features of the former Kissimmee River (e.g., low topographic relief, sandy substrate, presence of swamps or marshes, low velocity), although other characteristics may differ (e.g., watershed size, discharge, watershed development, and artificial drainage). Turbidity and TSS values in these streams are low (mean turbidity = 2.0–6.5 NTU) and are probably typical of the former Kissimmee River (**Table 11-2**). Values have ranged up to two orders of magnitude higher in these streams, but such events are rare and were sometimes caused by surface runoff and local disturbances. The pre-channelized Kissimmee River probably did not exhibit these extremes due to the characteristics of the river and its watershed.

Although Pool C river runs were expected to be temporarily affected by mobilization of accumulated vegetation and organic deposits as the restoration project reestablished flow in reconnected remnant river channels, turbidity and TSS were expected to return to reference levels after one full year of moderate flow (20–40 m^3 per second) through the restored river channel. This expectation has been met for turbidity.

Following Phase I construction, turbidity remained low in the restored reach of the river during WY2002–WY2005. Turbidity averaged 3.1 to 6.1 NTU at the four stations in the restored reach (**Table 11-3**). The overall average was 5.0 NTU. Maximum values at these stations ranged up to 14.3 NTU. Turbidity levels were consistent between the four years. These data are not statistically different from the reference stream data.

TSS concentrations have been slightly higher than expected. Median TSS concentrations at the four stations within the restored reach ranged from 3.0–9.0 mg/L (**Table 11-3**). Nevertheless, the difference between these concentrations and concentrations in the reference streams is probably not ecologically significant. Neither TSS nor turbidity was affected by the three hurricanes that passed through Central Florida in August and September 2004.

Table 11-1. Turbidity and total suspended solids (TSS) in remnant river runs of Pools A and C from March 19, 1996 to June 8, 1999 (Jones, in press).

Water Body and SFWMD Station ID	Turbidity (NTU)				TSS (mg/L)[1]		
	N	Median	Mean ± Std. Error	Max.	N	Median	Max.
Ice Cream Slough Run--Pool A (KREA 97)[2]	31	2.5	2.5 ± 0.2	6.5	31	< 3.0	11.0
Rattlesnake Ham. Run--Pool A (KREA 91)	331	2.2	2.3 ± 0.2	4.5	31	< 3.0	7.0
Schoolhouse Run--Pool A (KREA 92)	335	2.4	3.5 ± 0.5	17.3	35	< 3.0	25.0
Montsdeoca Run--Pool C (KREA 98)[3]	117	1.2	1.3 ± 0.2	3.6	18	< 3.0	3.0
Oxbow 13--Pool C (KREA 93)	332	1.9	2.1 ± 0.1	3.7	33	< 3.0	13.0
Micco Bluff Run--Pool C (KREA 94)	331	1.6	1.9 ± 0.2	5.5	32	< 3.0	18.0
MacArthur Run--Pool C (KREA 95)	334	1.6	1.8 ± 0.2	6.3	35	< 3.0	5.0

[1] Most total suspended solids values were below detection limit (usually < 3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

[2] Ice Cream Slough Run data begins in November 1996.

[3] Montsdeoca Run data begins in December 1997.

Table 11-2. Turbidity and TSS data for Florida stream reference sites (Jones, in press).

	Turbidity (NTU)				TSS (mg/L)[1]		
Water Body	N	Median	Mean ± Std. Error	Max.	N	Median	Max.
Fisheating Creek	393	1.6	3.8 ± 0.9	290.0	365	< 3.0	986.7
Arbuckle Creek	85	2.9	3.4 ± 0.2	14.4	39	< 3.0	24.0
Lake Marian Creek	37	2.0	4.5 ± 1.9	70.0	13	4.0	15.0
Reedy Creek	150	1.3	2.0 ± 0.2	18.9	99	< 3.0	58.0
Tiger Creek	33	3.9	3.9 ± 0.3	8.7	12	3.0	8.0
Josephine Creek	85	2.2	2.4 ± 0.2	10.5	39	< 3.0	14.0
Boggy Creek	204	2.0	6.5 ± 2.8	570.0	116	< 3.0	416.0
Catfish Creek, S. Branch	11	3.8	4.8 ± 0.8	11.1	4	4.5	11.0

[1] Most total suspended solids values were below detection limit (usually < 3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

Table 11-3. Turbidity and total suspended solids in river runs of Pools A and C after Phase I construction (May 1, 2001 to April 30, 2005).

	Turbidity (NTU)				TSS (mg/L)[1]		
Water Body and SFWMD Station ID	N	Median	Mean ± Std. Error	Max.	N	Median	Max.
Ice Cream Slough Run--Pool A (KREA 97)[2]	21	3.0	3.1 ± 0.2	4.6	21	5.0	10.0
Rattlesnake Ham. Run--Pool A (KREA 91)[2]	33	2.5	2.7 ± 0.2	5.9	33	3.2	18.8
Schoolhouse Run--Pool A (KREA 92)	44	1.9	2.2 ± 0.1	5.0	46	< 3.0	9.8
Montsdeoca Run--Pool C (KREA 98)	44	4.8	5.1 ± 0.3	13.7	44	7.0	13.2
Oxbow 13--Pool C (KREA 93)	45	5.6	5.8 ± 0.3	14.3	45	8.0	17.2
Micco Bluff Run--Pool C (KREA 94)	45	5.7	6.1 ± 0.4	13.2	46	9.0	19.1
MacArthur Run--Pool C (KREA 95)	44	2.5	3.1 ± 0.4	10.7	45	< 3.0	16.8

[1] Many total suspended solids values were below detection limit (usually < 3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

[2] Ice Cream Slough Run and Rattlesnake Hammock Run were not sampled during certain periods due to inaccessibility. Most data from Ice Cream Slough Run are from WY2004 and WY2005.

PHOSPHORUS

The Kissimmee River is Lake Okeechobee's largest tributary and contributes 34 percent of the lake's surface water input of phosphorus (SFWMD, 2002). Construction of C-38 and lateral drainage ditches has presumably contributed to Lake Okeechobee's excessive total phosphorus (TP) load by facilitating downstream transport of phosphorus runoff and limiting opportunity for detention and assimilation in floodplain wetlands. While Pools A, B, and C (**Figure 11-1**) are not major exporters of phosphorus, Phase I restoration of the river and floodplain may promote lower inputs from these pools and reduced loading from the headwater lakes. Restoration of sloughs and marshes along the river may increase retention of phosphorus from tributary watersheds and headwater lakes as flow velocities decrease and phosphorus settles out of the water column or is assimilated by wetland periphyton and macrophytes. Filling of lateral ditches and removal of cattle from the floodplain also may help to lower phosphorus loads from tributaries.

Baseline and post-construction total phosphorus data have been obtained from routine monitoring at each C-38 water control structure. TP concentrations were determined from weekly to monthly grab samples and composite samples collected by auto-samplers. Estimates of daily TP loads were computed from measured or interpolated TP concentrations and daily discharge data and then summed annually. Annual TP loads were divided by annual discharges to obtain flow-weighted mean TP concentrations at each structure. Because TP loads can vary greatly between wet years and dry years, flow-weighted mean concentrations provide a more useful metric for evaluating trends.

The calendar years 1974 through 1995 were chosen as the baseline period of record. During those 22 years, TP loading averaged 51 metric tons per year (mt y^{-1}) at S-65C and 83 mt y^{-1} at S-65D (**Figure 11-22**). These amounts comprised 43 and 71 percent of the average load at S-65E, respectively. Annual flow-weighted mean concentrations averaged 53 parts per billion (ppb) at S-65C (ranged from 33–87 ppb), and 78 ppb at S-65D (ranged from 47–141 ppb) (**Figure 11-23**). Concentrations were greater during years of lowest flow (1981 and 1985). At S-65, upstream of the restoration project area, mean loading rate was 35 mt/y (**Figure 11-22**) and the flow-weighted mean concentration was 43 ppb (**Figure 11-23**).

Reference conditions for TP loads and concentrations of the Kissimmee River cannot be determined with any certainty because phosphorus was not routinely monitored before channelization. Nevertheless, knowledge of former characteristics of the river, its floodplain, and its watershed make it reasonable to assume that concentrations were lower in the pre-channelized river. Restoration should tend to favor a return to lower concentrations, but not until a natural river-floodplain hydroperiod and stable wetland ecosystem become established. These conditions will not be achieved until the Headwaters Revitalization Project regulation schedule is implemented in 2010.

Under the interim regulation schedule, floodplain in the Phase I restoration area has undergone a number of wet/dry cycles. Observational data suggest that much of the terrestrial vegetation has disappeared from the floodplain and that wetland plant species have begun recolonizing the restored area. However, the interim regulation schedule has not allowed for the pattern of floodplain inundation that is expected once the Headwaters Revitalization Project regulation schedule is implemented. Thus, in the transitional years since Phase I was completed, the developing broadleaf marsh is not likely to have been assimilating incoming phosphorus at its highest efficiency.

To date, neither loads nor concentrations of total phosphorus have declined at S-65C and S-65D since the baseline period. In fact, they have been higher (**Figures 11-22** and **11-23**). Loads were especially high in WY2005 due to the 2004 hurricanes. During this year, loads were higher at S-65 than at downstream structures, possibly due to floodwaters going around the lower structures during peak flows in late summer. Annual flow-weighted mean TP concentrations also were higher in WY2005 due to concentrations in September 2004 that ranged as high as 311 ppb at S-65.

Not enough data are currently available to determine the causes of these high TP concentrations following the hurricanes. However, above-average concentrations have been measured at S-65 in prior years since the late 1990s. These elevated concentrations could not be attributed to increases in Lake Kissimmee or other lakes in the Kissimmee Chain. Concentrations at S-65 were not always representative of concentrations in the middle of Lake Kissimmee, which averaged 37 ppb in WY2002, and 43 ppb in WY2003. Therefore, recent evidence points to sources at the southern end of Lake Kissimmee that are increasing concentrations at the lake's outlet. If sources of phosphorus at the lake's southern end can be identified and controlled, then phosphorus inputs into the Kissimmee River and, ultimately, Lake Okeechobee could decrease.

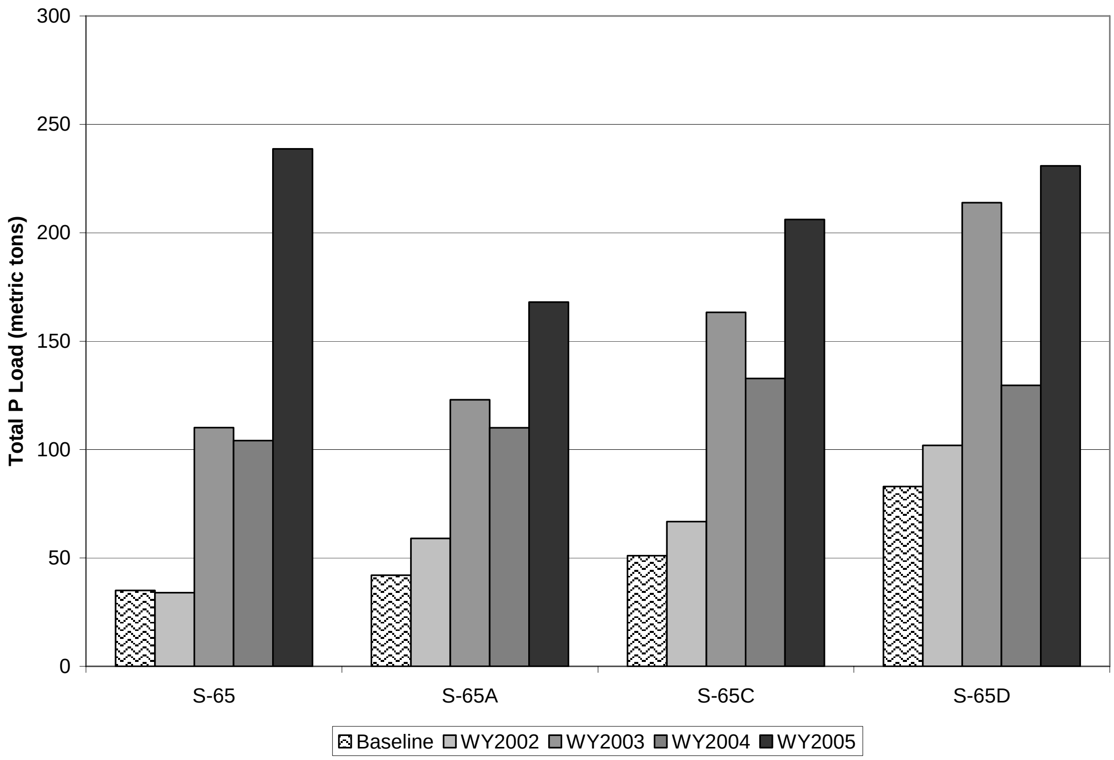


Figure 11-22. Annual total phosphorus (TP) loads (metric tons, or mt) from C-38 structures in comparison to baseline (1974-1995) loads.

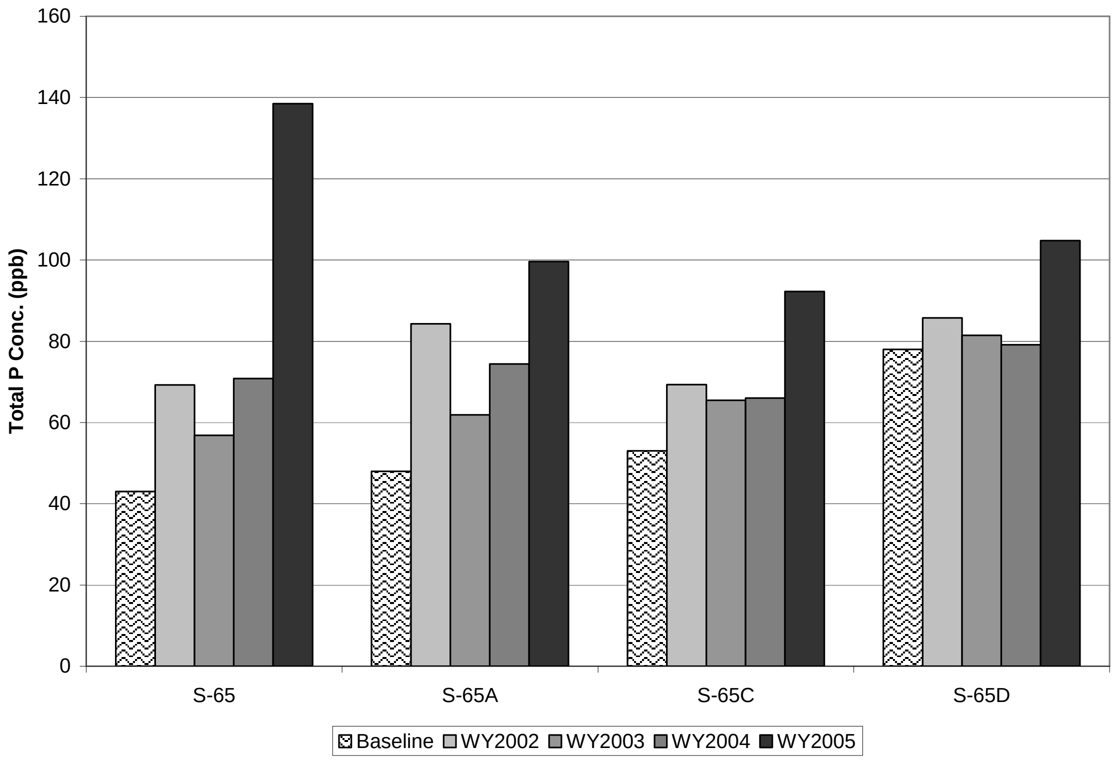


Figure 11-23. Annual flow-weighted mean TP concentrations (parts per billion, or ppb) at C-38 structures in comparison to baseline (1974–1995) concentrations.

AQUATIC INVERTEBRATES

Aquatic invertebrates were identified as a critical biological component for assessing restoration of ecological integrity within the Kissimmee River ecosystem (Karr et al., 1991; Harris et al., 1995). Aquatic invertebrates can play an integral role in river ecosystem processes including nutrient cycling (Merritt et al., 1984), decomposition of detritus (Wallace and Webster, 1996), and energy flow to higher trophic levels (e.g., amphibians, reptiles, fishes, wading birds, and waterfowl) (Weller, 1995; Benke et al., 2001). Aquatic invertebrates also have a long history of use in biomonitoring (Plafkin et al., 1989; Rosenberg and Resh, 1993) and can serve as indicators of biotic integrity and ecological health (Karr, 1991).

In order to establish a baseline for comparisons with post-restoration aquatic invertebrate communities, multiple techniques were used to sample mid-channel benthic habitats, mid-channel water column (drift), and large woody debris in remnant river channels and broadleaf marsh. Replicate (three) snag and benthic core samples were collected quarterly between August 1995 and May 1997 from randomly selected locations in three remnant river channels in Pools A (control area) and C (restoration area) (**Figure 11-1**). Replicate (three) "stovepipe" samples also were collected quarterly between August 1995 and May 1997 from randomly selected locations in remnant broadleaf marsh in Pools A and C. Broadleaf marsh habitat in Pool A was dry during most of this time period, and was sampled only once during the two-year study. Broadleaf marsh habitat in Pool C was sampled three times over the same time period. Samples were washed, separated into coarse and fine particulate fractions, and hand-picked under a dissecting microscope with magnification up to 50X. Samples were analyzed for invertebrate taxonomic composition, density, biomass, species richness, species diversity, functional feeding group composition, and functional habitat association. Mean quarterly density and biomass were calculated from replicate samples on each date. Mean annual values were calculated from four quarterly samples in 1995–1996 and two quarterly samples in 1996–1997. Mean annual values were averaged to determine overall mean density and biomass. Secondary production of aquatic invertebrates also was calculated for each habitat type. Aquatic invertebrate drift samples were collected quarterly, for one year, from remnant channels in Pool A and C beginning in January 1998. Two drift nets (0.1 m^2 equipped with 125 µm mesh netting) were placed 15 cm below the water surface and 0.5 m above the substrate at three locations within each of three remnant river channels in Pool A and C. Samples were collected at 8-hour intervals (± 1 hour) over a 24-hour period. Current velocity at each surface and bottom net opening, wind direction, and wind velocity were measured whenever a net was set or removed.

Within the river channel, baseline species richness and diversity were low in mid-channel benthic and snag habitats. Functional feeding and functional habitat associations indicate a community dominated by taxa characteristic of lentic (non-flowing) water. Mean density (± SE) and mean biomass (± SE) of snag-dwelling filtering collectors in Pool C was 53.1 ± 33.4 and 5.9 ± 3.8, respectively (n = 17). Overall, passive filtering-collectors accounted for 0.5 (± 0.4) percent of total numbers and 1.9 (± 1.4) percent of total biomass in Pool C (**Figure 11-24**). Total annual production of aquatic invertebrates on snags was similar to other southeastern Coastal Plain rivers; however, the distribution of production among functional feeding groups on snags within the Kissimmee River was highly skewed toward collector-gatherers and scrapers.

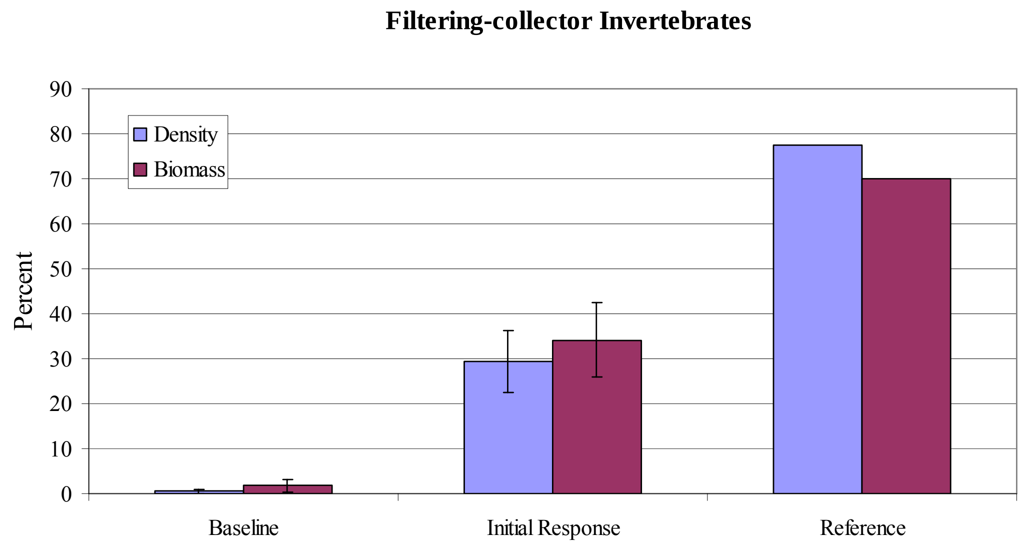


Figure 11-24. Mean percent of filtering-collectors on Pool C snags during baseline (1995–1996; n = 17) and initial response (2001; n = 36) sample periods. Reference data are from Benke et al. (1984), and represents the mean density and biomass percentages for two sites on the Ogeechee River, GA.

Baseline aquatic invertebrate species richness and diversity within remnant broadleaf marsh were low compared to natural wetland systems of Central Florida (Rader, 1994; Evans et al., 1999). Total annual production of aquatic invertebrates within remnant marsh and on floodplain woody debris was low. More than 76 percent total aquatic invertebrate production in Pool A was attributable to one taxon, while more than 36 percent of total production in Pool C was attributable to three taxa. More than 78 percent of total floodplain snag production in Pool C was attributable to five taxa.

No flow regimes within remnant channels of the channelized Kissimmee River apparently greatly altered aquatic macroinvertebrate community structure and drift composition. Downstream transport of aquatic invertebrates in the channelized system occurs via swimming or rafting, primarily on floating mats of water lettuce (*Pistia stratiotes*). Macroinvertebrate taxa, including Coleoptera, Diptera, Ephemeroptera, and Odonata comprise < 1 percent of total drift density and 23–29 percent of total drift biomass in Pools A and C. Macro- and microcrustaceans accounted for approximately 97–99 percent of total drift density and 54–56 percent of total drift biomass in Pools A and C. Miscellaneous taxa, including Hemiptera, Trichoptera, Lepidoptera, Collembola, Gastropoda, Nematoda, and Oligochaeta) comprised < 1 and 3 percent of remaining drift numbers in Pool A and C, respectively. Miscellaneous taxa accounted for approximately 16 and 22 percent of total drift biomass in Pool A and C, respectively. This is very different from free-flowing southeastern Coastal Plain blackwater rivers, where larval Coleoptera, Diptera, Ephemeroptera, and Trichoptera are the major contributors to drift numbers and biomass (Benke et al., 1986; 1991; **Table 11-4**).

Table 11-4. Major invertebrate groups found in the drift of the Satilla and Ogeechee rivers, GA (Benke et al. 1986; 1991) and Pool C of the channelized Kissimmee River. There was no significant difference between invertebrate drift numbers or biomass between Pools A and C; therefore, only Pool C data is presented. Numbers indicate frequency of occurrence.

	Satilla River		Ogeechee River		Kissimmee River (Pool C)	
Taxonomic Group	Density	Biomass	Density	Biomass	Density	Biomass
Diptera	52.9	53.8	27.3	10.6	< 1	11.2
Coleoptera	11.3	21.5	6.2	27.4	< 1	2.5
Ephemeroptera	5.8	6.2	15.4	34.6	< 1	7.4
Trichoptera	18.6	13.8	11.5	20.2	--	--
Odonata	1.4	4.6	1	5.3	<1	2.4
Crustacea*	10	< 1	31.9	1.9	96.8	54.6
Miscellaneous	--	--	6.7	--	2.7**	21.9**

* Includes macro- and microcrustaceans.

** Includes Hemiptera, Trichoptera, Megaloptera, Lepidoptera, Collembola, Gastropoda, Oligochaeta, and Nematoda

Restoration of pre-channelization hydrology, including continuous flow and long-term floodplain inundation frequencies, is expected to reestablish the historic habitat template within the river channel (i.e., shifting sand substrate and increased deposition of large woody debris) and floodplain (i.e., historic wetland vegetation communities). Increases in DO coupled with restored habitat is the impetus for colonization, persistence, and productivity of an aquatic invertebrate community typical of benthic and snag habitats in undisturbed blackwater rivers of the southeast Coastal Plain. Continuous flow, coupled with a seasonal flood-pulse and protracted floodplain recession rate, will reestablish characteristic aquatic invertebrate drift composition, density, and biomass. Reestablished floodplain hydroperiods and associated vegetation communities are expected to lead to increased aquatic macroinvertebrate species richness and diversity in broadleaf marsh habitats.

The expectation for a shift in aquatic invertebrate species composition in restored sand habitats (i.e., mid-channel benthic) is based on the presence of dominant indicator taxa within sandy benthic habitats of the Ogeechee and Satilla rivers, two sixth-order southeastern Coastal Plain blackwater rivers of Georgia (Benke et al., 1984; Stites, 1986). Reference conditions for density, biomass, and production of aquatic invertebrates on river channel woody debris is derived from published data on functional feeding group composition, density, biomass, and annual production of snag-dwelling invertebrates in the Satilla River, a blackwater river with similar physical, chemical, and hydrologic patterns as the historic Kissimmee River (Benke et al., 1984). Reference conditions for macroinvertebrate drift density and biomass are based on invertebrate drift data from the Ogeechee and Satilla rivers, Georgia (Benke et al., 1986; 1991).

Historic data on aquatic invertebrate community structure of broadleaf marsh habitats within the Kissimmee River are not available, and documented studies on aquatic invertebrate community structure of subtropical wetland systems are limited (Rader, 1994; 1999; Evans et al., 1999), and have focused on systems that are structurally different from pre-channelization broadleaf marshes of the Kissimmee River (i.e., Water Conservation Areas of the Everglades and marshes of pine flatwoods). Although these studies provide insight into the potential for high species richness and diversity within restored or natural marshes of Florida, the primary source of information on aquatic invertebrate species richness and diversity within pre-channelization broadleaf marsh is derived from existing baseline data from remnant marsh in Pool C.

Initial responses to restored flow and habitat structure under the interim regulation schedule have been noted for mid-channel benthic and snag-dwelling invertebrate communities. Within six months, dominant benthic invertebrate taxa included native clams (*Musculium*/*Pisidium*/*Sphaerium* complex), the exotic clam, *Corbicula fluminea*, sand-dwelling chironomids including *Cryptochironomus* spp., *Tanytarsus* spp. and *Polypedilum* spp. and several microcrustaceans. Aquatic invertebrate community structure and functional group associations on large woody debris also have undergone significant change since reestablishing flow. Taxa characteristic of "enriched" lentic habitats and tolerant of low levels of dissolved oxygen have been replaced by taxa characteristic of free-flowing blackwater streams of the southeastern United States. Preliminary analyses indicate dominance by passive filtering-collectors including *Cheumatopsyche* spp. (Trichopetra: Hydropsychidae), *Cyrnellus* spp. (Trichoptera: Polycentropodidae) and *Rheotanytarsus* spp. (Chironomidae). Mean density (± SE) and mean biomass (± SE) of snag-dwelling filtering-collectors in Pool C was 9724.3 ± 4467.5 and 746.4 ± 411.6, respectively (n = 36). Overall, passive filtering-collectors accounted for 29.4 percent of total numbers and 34.1 percent of total biomass in Pool C (**Figure 11-24**). Recolonization by hydropsychid caddisflies and other passive filtering-collector taxa indicate a shift toward restoration of biological integrity and recovery of the invertebrate food base. Passive filtering-collectors are expected to dominate density and biomass on large woody debris within the restored system and should account for the greatest proportion of secondary production in this habitat.

Expectations for macroinvertebrate drift densities and biomass are dependant on implementation of the Headwaters Revitalization Project regulation schedule that will reestablish historic inflow patterns, floodplain hydroperiods, and seasonal stage recession rates. It is expected that larval Coleoptera, Diptera, Ephemeroptera, and Trichoptera will account for the greatest proportion of aquatic invertebrate drift density and biomass in the restored Kissimmee River. Invertebrate drift will be sampled monthly beginning two years after implementation of the revised headwaters regulation schedule. A modified baseline sampling procedure will be used for post-construction restoration evaluation. Three samples will be collected for four hours beginning at dusk using 31 cm x 31 cm drift nets equipped with 125 µm netting facing into the direction of flow, at depths 15 cm below the water surface and 0.5 m above the channel substrate. Because of potential differences in current velocity at the surface and bottom of the water column, nets at each of these locations will provide a better estimate of total water column drift rates. Surface and bottom nets will be placed at three randomly selected locations within reconnected river channels in Pool C, and one randomly selected location in each of three remnant channels in Pool A. Current velocity (m/s) will be measured at each net opening when nets are deployed and retrieved to determine mean current velocity and volume of water sampled. Samples will be analyzed for invertebrate taxonomic composition. Macroinvertebrate drift will be measured for at least two consecutive years. Macroinvertebrate drift composition will be compared to the baseline condition and stated expectation.

Response of floodplain aquatic invertebrate community structure also will be evaluated after restoration of pre-channelization floodplain hydrologic conditions and reestablishment of historic vegetation communities. Sampling of remnant broadleaf marsh and restored broadleaf marsh will commence two years after initiating the revised Upper Basin headwaters schedule, and coincide with sampling of fishes, amphibians, reptiles, and wading birds within floodplain habitats. Methods will include monthly, replicate (five) throwtrap (area = 0.25 m^2) samples from randomly selected locations within Pool A and C Broadleaf Marsh and Pasture habitats undergoing transition to Broadleaf Marsh. Sampling will continue for three consecutive years. Although no specific expectation for aquatic invertebrate production has been developed for broadleaf marsh habitats, estimates of community production will be calculated in order to estimate the potential amount of prey biomass available to higher trophic levels.

RIVER CHANNEL FISH ASSEMBLAGE STRUCTURE

Fishes are ecologically important components of large river-floodplain ecosystems (Welcomme, 1979) and were identified as an essential component of the Kissimmee River restoration evaluation plan. Fish species representing a range of trophic levels (herbivore, piscivore, omnivore, invertevore, planktivore, detritivore) consume foods from aquatic and terrestrial environments (Karr et al., 1986) and serve as a critical link in the energy pathway between primary producers and higher trophic level consumers, including amphibians, reptiles, and birds (Karr et al., 1991; Gerking, 1994). Because freshwater fishes are relatively long-lived (Carlander, 1977; Lee et al., 1980) and can travel considerable distances within their watershed (Fish and Savitz, 1983; Gent et al., 1995; Furse et al., 1996), they integrate aspects of aquatic ecosystems across broad temporal and spatial scales (Karr et al., 1986). Fishes also are often used as bioassays for contaminants within aquatic environments (Sprague, 1973; USEPA, 1977). Fishes are therefore excellent indicators of aquatic ecosystem health or integrity (Karr et al., 1986; Ohio EPA, 1987; Oberdorf and Hughes, 1992; Gammon and Simon, 2000).

Channelization of the Kissimmee River dramatically altered the hydrology of the system and resulted in drainage or obliteration of approximately 8,000 ha of floodplain wetlands, elimination of instream and overbank flow, and isolation of the river from its floodplain (Koebel, 1995). These hydrologic alterations propagated changes in physical, chemical, functional, and biological aspects of the ecosystem that influence fish assemblages. Principle ecosystem processes and functions altered by channelization and potentially affecting fish assemblages include depressed levels of dissolved oxygen, restructuring of the food web, and habitat loss or degradation (Welcomme, 1979; Junk et al., 1989; Gladden and Smock, 1990).

Fish assemblages were sampled in remnant river channels under channelized conditions to determine the impact of channelization on attributes of fish community structure and to provide a baseline for comparisons with post-restoration fish assemblages. Annual electrofishing was conducted by the Florida Game and Freshwater Fish Commission (FGFWFC) (currently known as the Florida Fish and Wildlife Conservation Commission, or FWC) in June from 1992–1994 (FGFWFC, 1994). Dominant species (greater than 5 percent of mean annual relative abundance) at control sites in Pool A included Florida gar (*Lepisosteus platyrhincus*) (36.8 percent), bluegill (*Lepomis macrochirus*) (19.9 percent), bowfin (*Amia calva*) (8.4 percent), and largemouth bass (*Micropterus salmoides*) (7.9 percent) (**Table 11-5**). Community composition at Impact sites (Pool C) was similarly dominated by Florida gar (19.6 percent), bluegill (16.5 percent), and largemouth bass (9.5 percent), but also included mosquitofish (*Gambusia holbrooki*) (16.9 percent) and golden shiner (*Notemigonus crysoleucas*) (11.7 percent) (**Table 11-5**). Centrarchids accounted for only 31.8 and 38.3 percent of the fish communities in Pools A and C, respectively (**Table 11-6**).

Table 11-5. Relative abundance of dominant (> 5%) fish taxa of the Kissimmee River and reference rivers. All data were collected by electrofishing. Reference rivers were sampled by the Florida Game and Fresh Water Fish Commission between 1983 and 1990 and include the St. Johns (STJ), Oklawaha (OKL), and Withlacoochee (WIT) rivers. Baseline (pre-restoration) data were collected in Control (Pool A; will not be restored) and Impact (Pool C; will be restored) areas from 1992–1994. Continuous flow was restored to river channels in Pool C following completion of Phase I backfilling in 2001. Initial response data were collected in both the Control and Impact areas during 2004. Relative abundance is reported as mean ± SE for reference and baseline data; no standard errors are reported for initial response data because they represent a single sample year, not a mean of multiple years. Mean annual relative abundance values that indicate dominance of a given taxa are listed in bold print.

		Reference Rivers			Kissimmee River			
Taxa	Common Name	STJ	OKL	WIT	Pool A Baseline	Pool C Baseline	Pool A Init. Resp.	Pool C Init. Resp.
Amia calva	bowfin	0.6 ± 0.2	0.8 ± 0.1	1.3 ± 0.4	**8.4** ± 2.5	4.4 ± 0.7	--	**12.5**
Fundulus seminolis	seminole killifish	**6.0** ± 1.8	0.1 ± 0.07	0.1 ± 0.04	--	--	--	--
Gambusia holbrooki	mosquitofish	0.3 ± 0.2	0.5 ± 0.1	**6.4** ± 2.3	4.5 ± 2.4	**16.9** ± 9.0	**76.3**	1.0
Heterandria formosa	least killifish	0.03 ± 0.03	--	0.1 ± 0.04	0.2 ± 0.2	0.7 ± 0.6	**5.2**	--
Lepisosteus platyrhincus	Florida gar	2.4 ± 0.4	1.3 ± 0.2	2.9 ± 0.9	**36.8** ± 2.9	**19.6** ± 3.0	**5.2**	**12.2**
Lepomis auritus	redbreast sunfish	**18.7** ± 1.2	**23.2** ± 1.6	**19.2** ± 2.9	--	--	--	0.3
Lepomis gulosus	warmouth	1.3 ± 0.2	4.9 ± 0.5	**6.1** ± 0.4	1.6 ± 0.4	4.8 ± 1.6	--	**5.5**
Lepomis macrochirus	bluegill	**35.0** ± 1.1	**27.7** ± 2.4	**14.8** ± 2.8	**19.9** ± 4.8	**16.5** ± 4.0	**6.0**	**19.5**
Lepomis microlophus	redear sunfish	**8.1** ± 1.1	**9.3** ± 0.6	**6.7** ± 1.8	2.6 ± 1.0	4.4 ± 0.9	--	**7.8**
Lepomis punctatus	spotted sunfish	3.4 ± 0.3	**10.7** ± 1.5	**18.5** ± 2.1	0.1 ± 0.1	1.5 ± 0.7	--	**19.2**
Micropterus salmoides	largemouth bass	4.8 ± 0.2	**5.3** ± 0.4	**5.8** ± 2.3	**7.9** ± 3.5	**9.5** ± 0.7	--	**11.9**
Notemigonus crysoleucas	golden shiner	**6.3** ± 0.8	1.7 ± 0.3	0.5 ± 0.1	**14.4** ± 5.5	**11.7** ± 4.3	--	0.3
Notropis pertersoni	coastal shiner	0.01 ± 0.01	2.0 ± 0.6	**5.6** ± 2.3	--	--	--	--

Table 11-6. Percent contribution by centrarchids collected via electrofishing within three peninsular Florida rivers between 1983 and 1990 and in Pool C of the Kissimmee River during baseline (KIS-BL; 1992 and 1994) and initial response (KIS-IR; 2004) periods. (St. Johns River – STJ; Oklawaha River – OKL; Withlacoochee River – WIT).

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

Data on the pre-channelization condition of river channel fish assemblages in the Kissimmee River are limited to a single sample collected in 1956 by the FGFWFC. In this survey, a 0.4-ha section of river channel was delimited by block nets to which rotenone was applied. Due to lack of sample replication and because dissimilar sampling methods were employed, reference conditions were derived from rivers similar to the Kissimmee occurring in peninsular Florida. Electrofishing data from the St. Johns, Withlacoochee, and Oklawaha rivers, collected annually during the autumn low water period from 1983–1990, serves as reference condition data for the Kissimmee River. All three rivers are located entirely within or having headwaters originating in peninsular Florida below the Suwannee and St. Johns drainages, the demarcation between peninsular and northern fish assemblages (Swift et al., 1986; Gilbert, 1987). All rivers have undergone varying degrees of anthropogenic alteration that include channelization, impoundment, and point sources of pollution (Bass, 1991; Estevez et al., 1991; Livingston, 1991; Livingston and Fernald, 1991) and therefore are not pristine reference sites for the historic Kissimmee. However, information on the composition of riverine fish assemblages within peninsular Florida is provided as best available data.

Redbreast sunfish (*L. auritus)* and bluegill were dominant in each peninsular river with mean annual relative abundance exceeding 18 percent (range: 18.7–23.2 percent) and 14 percent (range: 14.8–35.0 percent), respectively (**Table 11-5**). Other centrarchids contributing greater than 5 percent mean annual relative abundance included spotted sunfish (*L. punctatus*), redear sunfish (*L. microlophus*), warmouth (*L. gulosus*), and largemouth bass. Mosquitofish and coastal shiner (*Notropis petersoni*) were the remaining dominant species in the Withlacoochee River, while golden shiner and Seminole killifish (*Fundulus seminolis*) contributed greater than 5 percent in the St. Johns River (**Table 11-5**). Centrarchids collectively comprised ≥ 70 percent of the river channel fish community in all three peninsular Florida rivers (**Table 11-6**).

Four relative abundance metrics show strong differences between baseline and reference conditions and were used to develop performance measures (restoration expectations) for river channel fish assemblages. These metrics include relative abundance of bowfin, Florida gar, redbreast sunfish, and centrarchids (sunfishes and basses). Relative abundances of Florida gar and bowfin are typically higher in river systems with degraded water quality (Champeau, 1990; Bass, 1991). Relative abundance of redbreast sunfish is positively correlated with increased flow (Aho and Terrell, 1986). Florida gar and bowfin both prefer little to no flow and abundant aquatic vegetation. (Lee et al., 1980; Mettee et al., 1996). Reestablishment of historic sand substrate and sandbars following restoration will increase spawning habitat for centrarchids (Carlander, 1977; Struber et al., 1982; Aho and Terrell, 1986), with increased recruitment resulting from reestablishment of river channel-floodplain linkage that historically provided floodplain habitat as refugia for juveniles (FGFWFC, 1957). Post-restoration fish assemblages in river channels are expected to be comprised of bowfin (< 1 percent), Florida gar (< 3 percent), redbreast sunfish (> 16 percent), and centrarchids (> 58 percent) (**Figure 11-25**).

Phase I of Kissimmee River restoration was completed in February 2001 and the physically restored reach has received continuous flow since July 2001. River channel fish assemblages were sampled in August 2004, approximately three years after completion of Phase I, to determine if changes in community structure have occurred that would indicate an initial fish assemblage response to restoration efforts. Eleven taxa were collected at control sites in Pool A (**Table 11-7**). Dominant taxa included mosquitofish (76.3 percent), least killifish (*Heterandria formosa*) (5.2 percent), Florida gar (5.2 percent), and bluegill (6.0 percent) (**Table 11-7**). Twenty taxa were collected at physically restored sites in Pool C (**Table 3**). Dominant taxa included bowfin (12.5 percent), Florida gar (12.2 percent), warmouth (5.4 percent), bluegill (19.5 percent), redear sunfish (7.7 percent), spotted sunfish (19.2 percent), and largemouth bass (11.9 percent (**Table 11-5**). Centrarchids accounted for 10.4 and 65.8 percent of the fish communities in Pools A and C, respectively (**Table 11-6**).

Table 11-7. Annual relative abundance of fishes collected via electrofishing by South Florida Water Management District in 2004 in physically restored (Pool C) and channelized (Pool A) sections of the Kissimmee River.

Taxa	Common name	Pool A	Pool C
Ameiurus natalis	yellow bullhead	--	0.5
Ameiurus nebulosus	brown bullhead	--	3.6
Amia calva	bowfin	0.8	12.5
Dorosoma petense	threadfin shad	--	0.3
Elassoma evergladei	Everglades pygmy sunfish	--	0.3
Erimyzon sucetta	lake chubsucker	--	0.5
Gambusia holbrooki	mosquitofish	76.3	1.0
Heterandria formosa	least killifish	5.2	--
Labidesthes sicculus	brook silverside	--	0.3
Lepisosteus platyrhinchus	Florida gar	5.2	12.2
Lepomis auritus	redbreast sunfish	--	0.3
Lepomis gulosus	warmouth	--	5.4
Lepomis macrochirus	bluegill	6.0	19.5
Lepomis microlophus	redear sunfish	1.6	7.7
Lepomis punctatus	spotted sunfish	0.6	19.2
Menidia beryllina	inland silverside	--	0.3
Micropterus salmoides	largemouth bass	2.0	11.9
Notemigonus crysoleucas	golden shiner	--	0.3
Opsopoedus emilidae	pugnose minnow	1.6	--
Oreochromis aureus	blue tilapia	--	0.3
Pomoxis nigromaculatus	black crappie	0.4	1.8
Pterygoplichthys disjunctivus	sailfin catfish	0.3	2.1

The most notable positive change in restoration expectation metrics in restored areas is the increased percent composition of centrarchid taxa. Initial response data indicate that centrarchids collectively comprise 65.8 percent of the community, an increase of 71.8 percent from the baseline value (38.3 percent), thus achieving the restoration expectation for that metric (**Figure 11-25**). Two centrarchid taxa, redear sunfish and spotted sunfish have increased substantially in percent composition in the restored area. Collectively, percent composition of these two taxa increased from 5.9 to 27.0 percent. Both taxa are dominant in the three reference rivers.

Several ecosystem level changes have occurred in the physically restored area between June 2001 and August 2004 that may have influenced the increase in centrarchid relative abundance. For example, mean seasonal DO levels in Pool C have increased from 1.2 to 3.0 mg/L in the wet season (June–November) and from 3.3 to 6.0 mg/L during the dry season (December–May) (Williams et al., 2005). Some centrarchid taxa become stressed when DO levels fall below 2 mg/L (Moss and Scott, 1961). Stress can include any stimulus that threatens homeostasis such that survival is compromised (Brett, 1958). Seasonal hypoxia exhibited under baseline conditions is an example of a stress stimulus that could have negatively impacted physiological functions in centrarchids including decreased disease resistance, growth rate, and fecundity (Wendelaar Bonga, 1997). Higher DO levels present in the resorted likely has alleviated the stressed condition, thereby allowing energy expenditures to be redirected to growth and reproduction, both of which enhance survival. Increased DO levels in the wet season is especially important for survivorship of young-of-the-year fishes, as they often are more susceptible to hypoxic conditions (Wendelaar Bonga, 1997).

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

While the centrarchid metric of the restoration expectation appears to have been achieved, the remaining three metrics (percent bowfin, percent Florida gar, and percent redbreast sunfish) have not. Relative abundance of bowfin is on an opposite trajectory, having increased from 4.4 to 12.5 percent (**Figure 11-25**). However, two metrics are on a trajectory toward the expectation value. Relative abundance of redbreast sunfish increased from 0 to 0.3 percent and Florida gar relative abundance decreased from 19.6 to 12.2 percent (**Figure 11-25**). The predicted decrease in relative abundance of bowfin and Florida gar is expected to take longer than the three years that have transpired since completion of Phase I construction. Because these two taxa are among the longest lived in the system (bowfin has an approximate 10-year lifespan; Florida gar has an approximate 12- to 18-year lifespan), a greater length of time is required before for shifts in their population dynamics are manifested in the structure of the fish assemblage as a whole. The expected increase in redbreast sunfish also will require a greater length of time due to the geographic limits of the source population in the watershed. Reestablishment of redbreast sunfish in Pool C requires downstream dispersal of individuals from the remnant population occurring in Pool B, which was not expected to be immediate. These preliminary data also must be interpreted with care, as they represent only a single year and fish assemblages exhibit high annual variability in assemblage structure (Oberdorf et al., 2001).

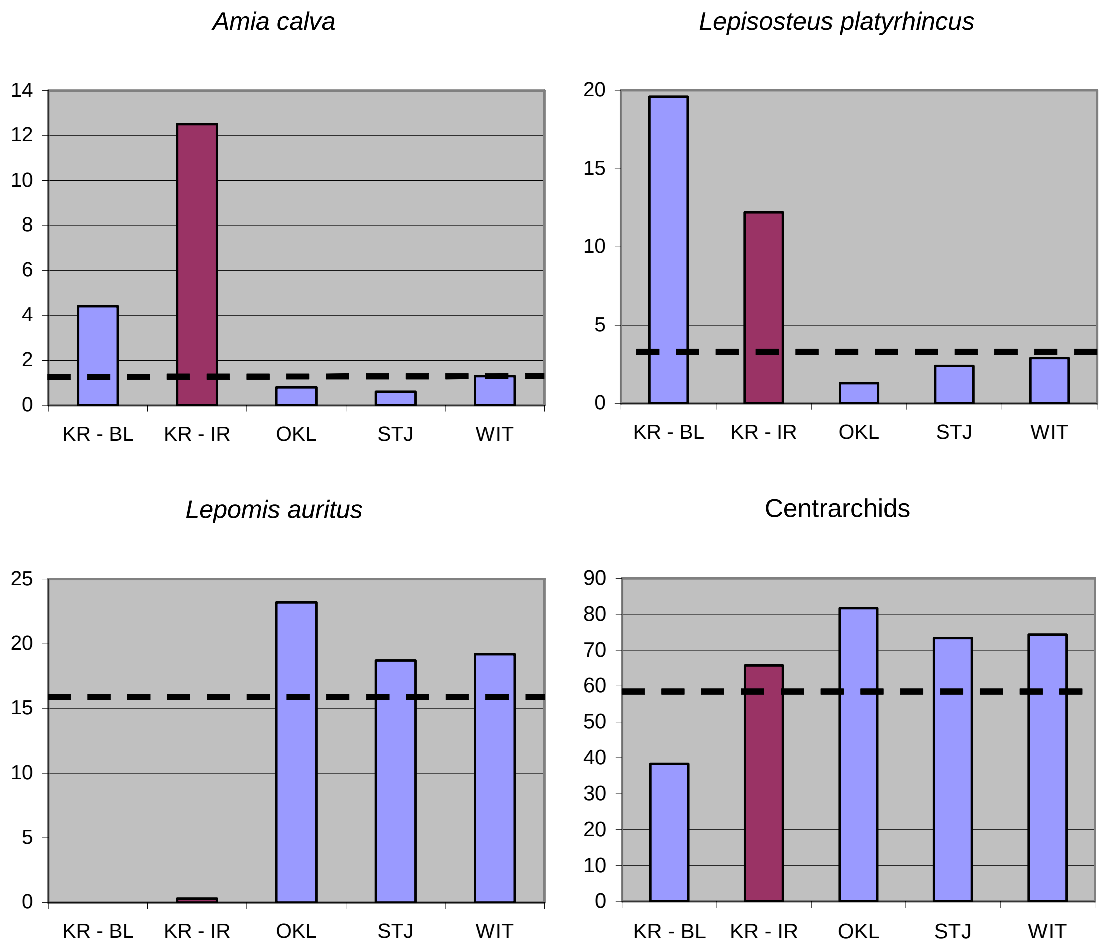


Figure 11-25. Baseline mean annual relative abundance of fish taxa or family (blue bars) that will be used to evaluate restoration success in reestablishing river channel fish assemblage structure. Red bars indicate relative abundance of fish taxa or family from initial response data collected in the physically restored reach of the Kissimmee River in 2004. Dashed line indicates expected value for each taxa or family following restoration. (KR-BL = Kissimmee River baseline condition; KR-IR = Kissimmee River initial response; OKL = Oklawaha River; STJ = St. Johns River; WIT = Withlacoochee River).

Observed changes in metrics not included in performance measure development indicate that environmental conditions may have deteriorated further in the unrestored (channelized) portion of the system since baseline collections were made. Species richness declined in both study areas since 1994, with the most dramatic decline occurring in Pool A (**Table 11-7**). The recent survey indicates only 11 taxa are currently utilizing remnant river runs, compared to 21 taxa collected in the 1992–1994 survey. Review of species composition and dominance provides insight for potential reasons for observed shifts. Mosquitofish, least killifish, and Florida gar comprise 76.3, 5.2, and 5.2 percent of the assemblage, respectively. Mosquitofish and least killifish are especially tolerant of low levels of dissolved oxygen and can exist in highly degraded habitats (Meffee and Snelson, 1989). These taxa often remain dominant under degraded conditions due to high reproduction rates associated with their reproductive mode (live bearer) (Meffee and Snelson, 1989). Meanwhile, centrarchid abundance has declined from 31.8 to 10.4 percent. Persistence of degraded environmental conditions including seasonal hypoxia, increased organic deposits on the riverbed (resulting in diminished quality and quantity of preferred nesting sites), and continued disconnection of the historic river channel-floodplain linkage are all believed to have contributed to the further decline in the centrarchid population. Expected recovery times for river channel fish assemblages may be underestimated due to additional exposure to diminished environmental conditions associated with channelization.

Expectations for river channel fish assemblage metrics are dependent not only on reestablishment of the river's physical form, but also on reintroduction of historic hydrologic conditions which are contingent on implementation of the Headwaters Revitalization Project regulation schedule. Comprehensive monitoring to evaluate success of fish assemblage metrics will begin after pre-channelization hydrologic conditions have been restored. Successful achievement of the restoration expectation for river channel fish assemblage structure requires that all metrics be met for a three-year period.

AVIAN COMMUNITY

Birds are both integral to the Kissimmee River/floodplain ecosystem and highly valued by its human users. While quantitative pre-channelization data are sparse, available data and anecdotal accounts indicate that the system supported an abundant and diverse bird assemblage (National Audubon Society, 1936–1959; FGFWFC, 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Further, since many bird groups (e.g., wading birds, waterfowl) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller, 1995). Detailed information regarding the breadth of the avian evaluation program can be found in Chapter 11 of the 2005 SFER – Volume I. This section highlights portions of the avian program for which data were collected during WY2005.

Aerial surveys were used to measure the densities of wading birds and waterfowl within the 100-year flood line, as well as to search for rookeries of nesting wading birds on or near the floodplain. Surveys were conducted approximately monthly during the baseline period (pre-restoration; 1996–1998) and have continued after Phase I of the restoration project was completed. Restoration is expected to bring increased use of the floodplain by both long-legged wading birds and waterfowl. Furthermore, mixed species wading bird rookeries are anticipated to regularly form on and near the floodplain and tributary sloughs once abundant food resources and appropriate hydrology have been reestablished.

To investigate densities of wading birds and waterfowl on the floodplain, east-west aerial transects (n = 218) were established at 200 m intervals beginning at the S-65 structure and ending at the S-65D structure (see **Figure 11-1** for structure locations). Each month, transects were randomly selected for counts until a minimum of 15 percent of the 100-year floodplain was surveyed in both the Phase I and unrestored portion of the river/floodplain. Surveys were conducted via helicopter flying at an altitude of 30.5 m and a speed of 130 km/hr. A single observer counted all wading birds and waterfowl within 200 m of one side of the transect line. Because it is not always possible to distinguish tricolored herons (*Egretta tricolor*) from adult little blue herons (*E. caerulea*) during aerial surveys (Bancroft et al., 1990), the two are lumped into the category, small dark herons. Likewise, snowy egrets (*E. thula*) and immature little blue herons were classified as small white herons (Bancroft et al,. 1990). Densities of wading birds and waterfowl were calculated separately for restored and unrestored areas using the ratio method of Jolly (1969). In addition to surveys of wading bird densities, systematic aerial searches for wading bird colonies are flown monthly during the nesting season. Each colony survey flight spans Pools A–D and covers the entire 100-year floodplain plus an additional 3 km to the east and west of its border (**Figure 11-26**). Once a colony is located, the numbers and species of nesting wading birds are counted from the air and, when possible, verified through ground surveys.

Because no quantitative data are available for densities or relative abundances of long-legged wading birds or waterfowl of the pre-channelized Kissimmee River, restoration expectations for responses by these groups to the KRRP are based on reference data from aerial surveys of a flow-through marsh in Pool B (wading birds and waterfowl) that was built as part of the Kissimmee River Demonstration Project and for floodplain areas along Paradise Run (wading birds), a portion of the Kissimmee River near Lake Okeechobee that still retains some channel flow and periodic floodplain inundation (Toland, 1990; Perrin et al., 1982). The 3.5 km^2 flow-through marsh was constructed just south of the S65-A tieback levee during 1984–1985 and was manipulated to simulate inundation and overland flow that were typical of the pre-channelized Kissimmee River floodplain (Toth, 1991). Based on these reference data, it is expected that annual dry season (December–May) densities of long-legged wading bird (excluding cattle egrets) will be $\geq$ 30.6 birds/km^2 and winter (November–March) waterfowl densities will be $\geq$ 3.9 ducks/ km^2 . No quantitative data are available for the numbers, locations, and species composition of wading bird nesting colonies within the pre-channelized Kissimmee River/floodplain system and no appropriate reference data were identified. Therefore, a restoration expectation was not developed for reproductive effort by colonially nesting wading birds. However, this key aspect of ecological integrity of the restored Kissimmee system will be monitored throughout the restoration evaluation program.

During baseline surveys, mean annual dry season densities of aquatic wading birds in the Impact area averaged ($\pm$ SE) 3.6 $\pm$ 0.9 birds/ km^2 in 1997 and 14.3 $\pm$ 3.4 birds/ km^2 in 1998. Since completion of Phase I, wading bird densities have exceeded the restoration expectation of 30.6 birds/km^2 each year, averaging 37.8 $\pm$ 15.4 birds/ km^2, 61.7 $\pm$ 14.5 birds/ km^2, and 59.6 $\pm$ 24.4 birds/ km^2 in 2002, 2004, and 2005, respectively (2003 data were not collected; **Figure 11-27**). Furthermore, the lower limit of the 95 percent confidence interval (95% C.I.) has exceeded the expectation in two of three years. White ibis, great egret, and small white heron (snowy egret and immature little blue heron) were the most commonly detected species during both the baseline and post-Phase I surveys.

While there has been a strong numerical response by foraging wading birds to the first phase of restoration, reproductive effort has not followed suit. Baseline aerial surveys indicated no active breeding colonies on the floodplain in 1996, one colony of cattle egrets and little blue herons in Pool B in 1997, and one colony of great egrets and anhingas (*Anhinga anhinga*) in Chandler Slough in Pool D in 1998. Both colonies were small, with less than 100 pairs.

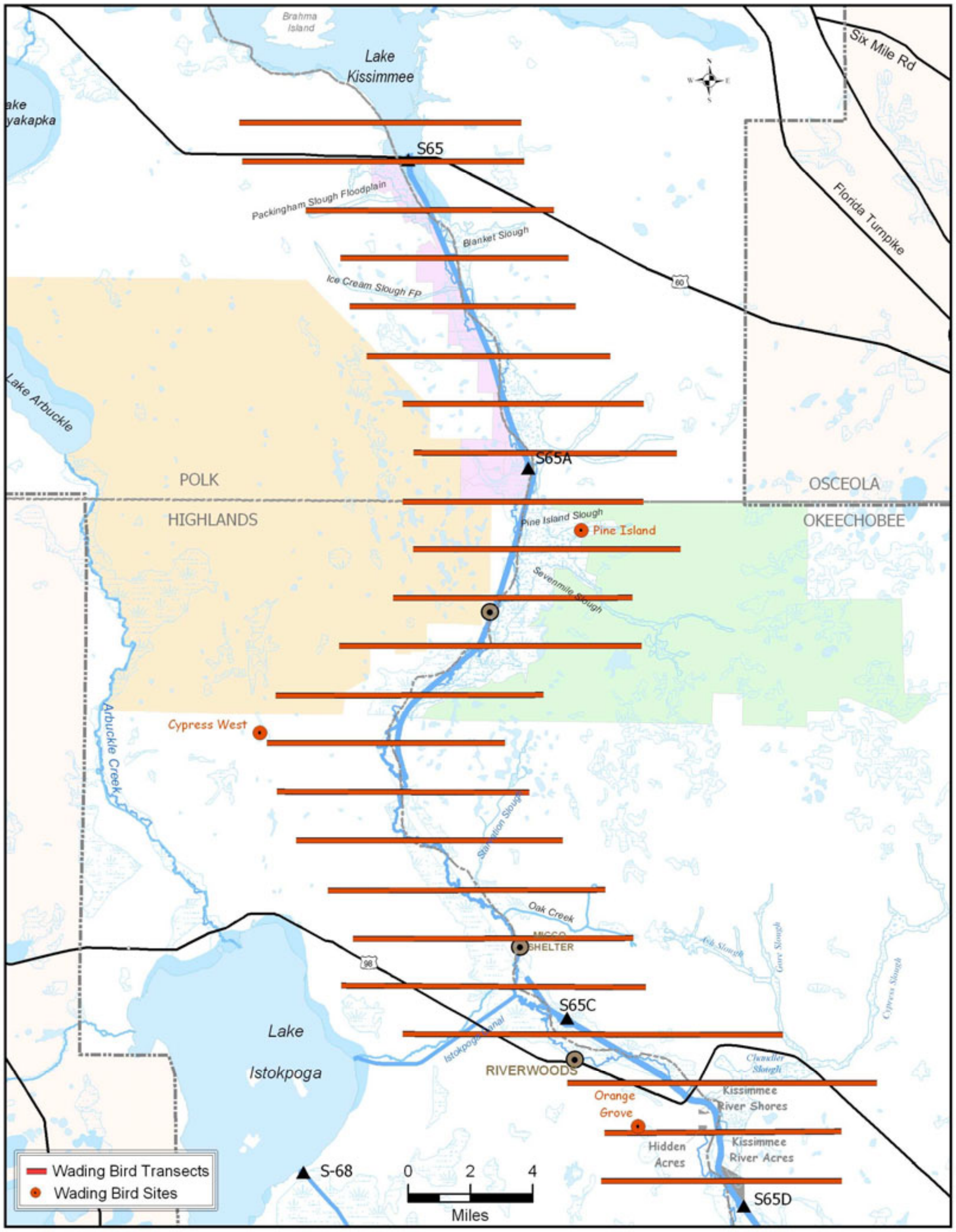


Figure 11-26. Transect layout and locations of 2005 nesting colonies within the Kissimmee River floodplain and surrounding wetland/upland complex. No nesting colonies were found during 2004.

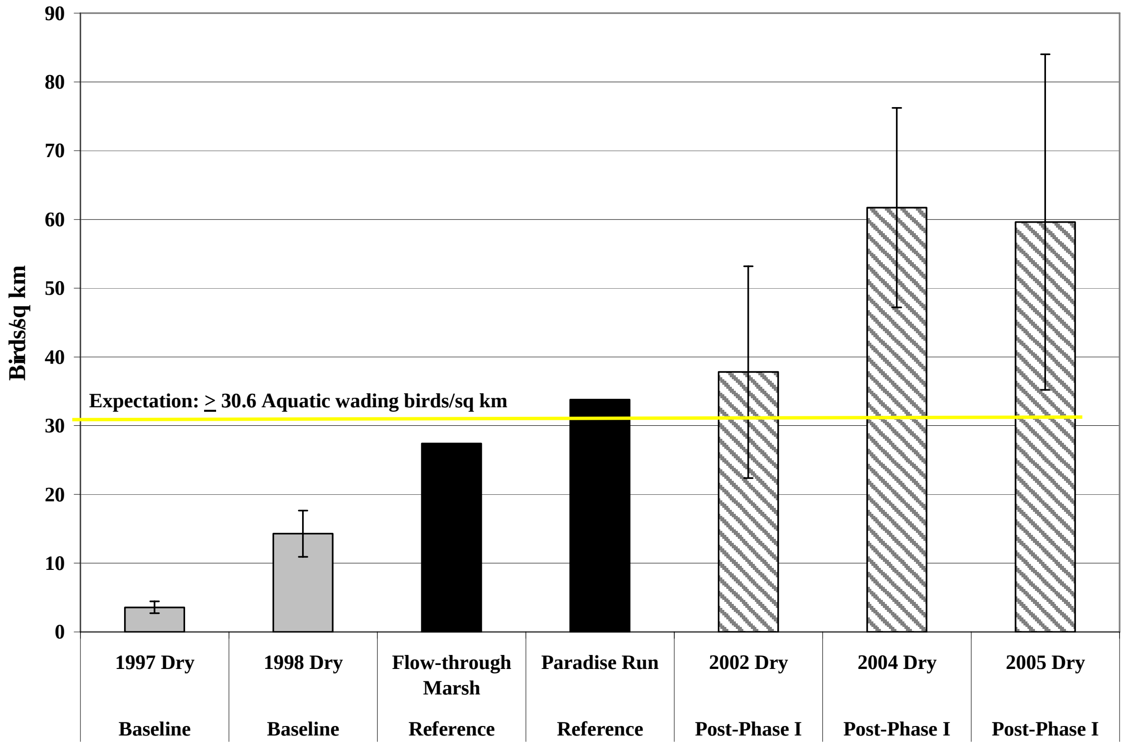


Figure 11-27. Baseline, reference, and post-Phase I densities (± SE) of long-legged wading birds (excluding cattle egrets) within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately 10 months following completion of Phase I.

Post-Phase I breeding colony surveys were conducted during 2004 and 2005. During 2004, no colonies were found. During 2005, three colonies containing an estimated 516 total nests were observed (**Figure 11-26**). Of this number, 400 were cattle egrets and 30 were anhingas; long-legged wading birds (great egret, great blue heron) constituted the remainder (n = 86) of nests. A number of factors may account for the lack of nesting effort following Phase I backfilling. First, it may take a number of years following backfilling for populations of prey items to reach levels capable of supporting breeding colonies. Also, the timing of floodplain inundation and recession may not yet be appropriate for rookery formation. Implementation of the regulation schedule for the Headwaters Revitalization Project in 2010 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. Responses by long-legged wading birds (foraging density and reproductive effort) to the restoration project will be measured across the entire restoration area (Phases I–IV). Monitoring will continue until five years after completion of the last phase of the restoration project.

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 (Williams and Melvin, in press). Mean annual density (± SE) was 0.4 ± 0.1 ducks/ km^2 in the Phase I area, well below the restoration expectation of 3.9 ducks/ km^2 . Following completion of Phase I, average annual duck densities have exceeded the restoration during all four years and the lower limit of the 95% C.I. have exceeded the expectation in three of four years (**Figure 11-28**). The American wigeon (*A. americana*), northern pintail (*A. acuta*), northern shoveler (*A. clypeata*), ring-necked duck (*Aythya collaris*), and black-bellied whistling duck (*Dendrocygna autumnalis*) were not detected during baseline surveys, but have been present following restoration. Blue-winged teal and mottled duck have been the two most commonly observed species during both baseline and post-Phase I surveys. 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 on the floodplain that will lead to the development of extensive areas of wet prairie and broadleaf marsh, two preferred waterfowl habitats (Chamberlain, 1960; Bellrose, 1980). Changes in the species richness and density of waterfowl within the restoration area are likely to be directly linked to the rate of development of floodplain plant communities and the faunal elements they support. Extrinsic factors such as annual reproductive output on summer breeding grounds and local and regional weather patterns may also play a role in the speed of recovery of the waterfowl community. Responses by waterfowl to the restoration project will be measured across the entire restoration area (Phases I–IV). Waterfowl monitoring will continue until five years after completion of the last phase of the restoration project.

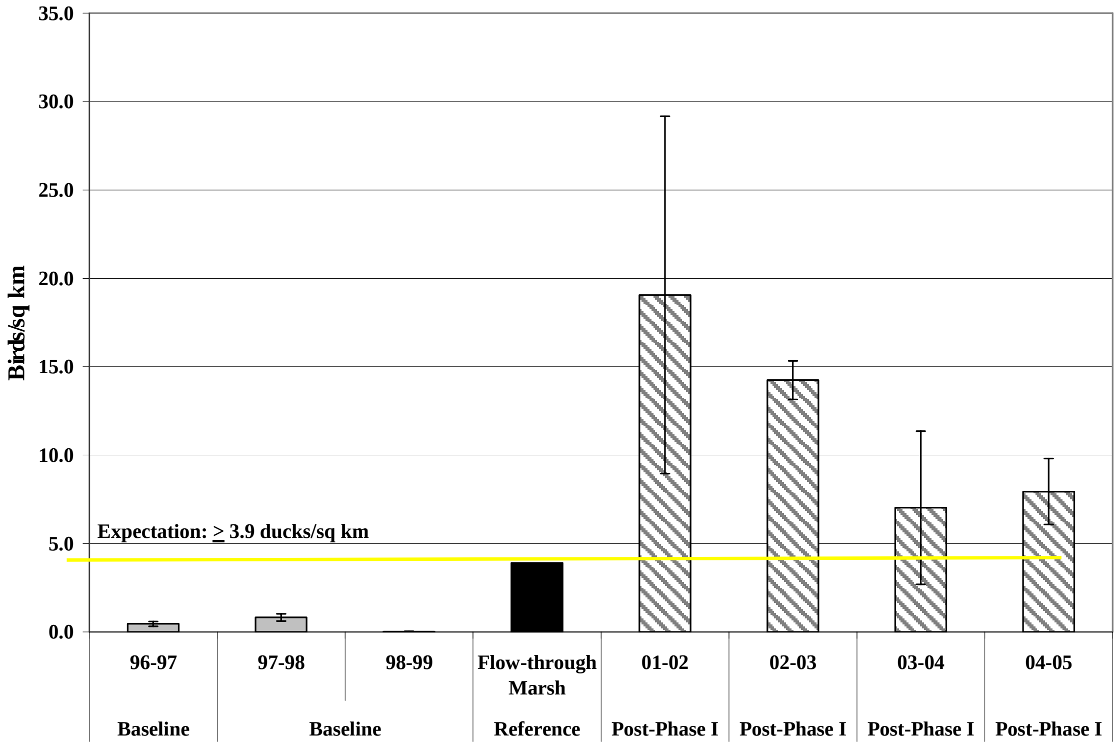


Figure 11-28. Baseline, reference, and post-Phase I densities (± SE) of waterfowl within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately 9 months following completion of Phase I.

Relationships Among Phase I Responses to River Channel Restoration

Phase I of the Kissimmee River Restoration Project recarved/reconnected approximately 15 mi (24 km) of continuous river channel. This section of river channel has received continuous flow for approximately four years since completion of Phase I construction and implementation of the interim regulation schedule for the S-65 structure. Reestablishment of pre-channelization flow patterns has long been hypothesized to be the primary driver of restoration-related changes to the physical, chemical, and biotic characteristics of river channels (USACE, 1991; 1996). **Figure 11-29** presents a summary of responses of selected river channel restoration evaluation projects (see Williams et al., 2005 for methods of individual projects) and a conceptual framework for relationships among physical, chemical, and biotic components. Reestablishment of flow has been associated with physical (decreased thickness of river bed organic layer, formation of sandbars), chemical (increased levels of dissolved oxygen), and biological [decreased width of vegetation mats, increases in filterer collector invertebrates, increases in relative abundance of centrarchid fishes, increases in swimming fish-eating birds (anhinga, double-crested cormorant)] responses in river channels. While these data are correlative and do not represent tests of cause and effect, they are consistent with the hypothesis that restored flow will drive ecosystem change.

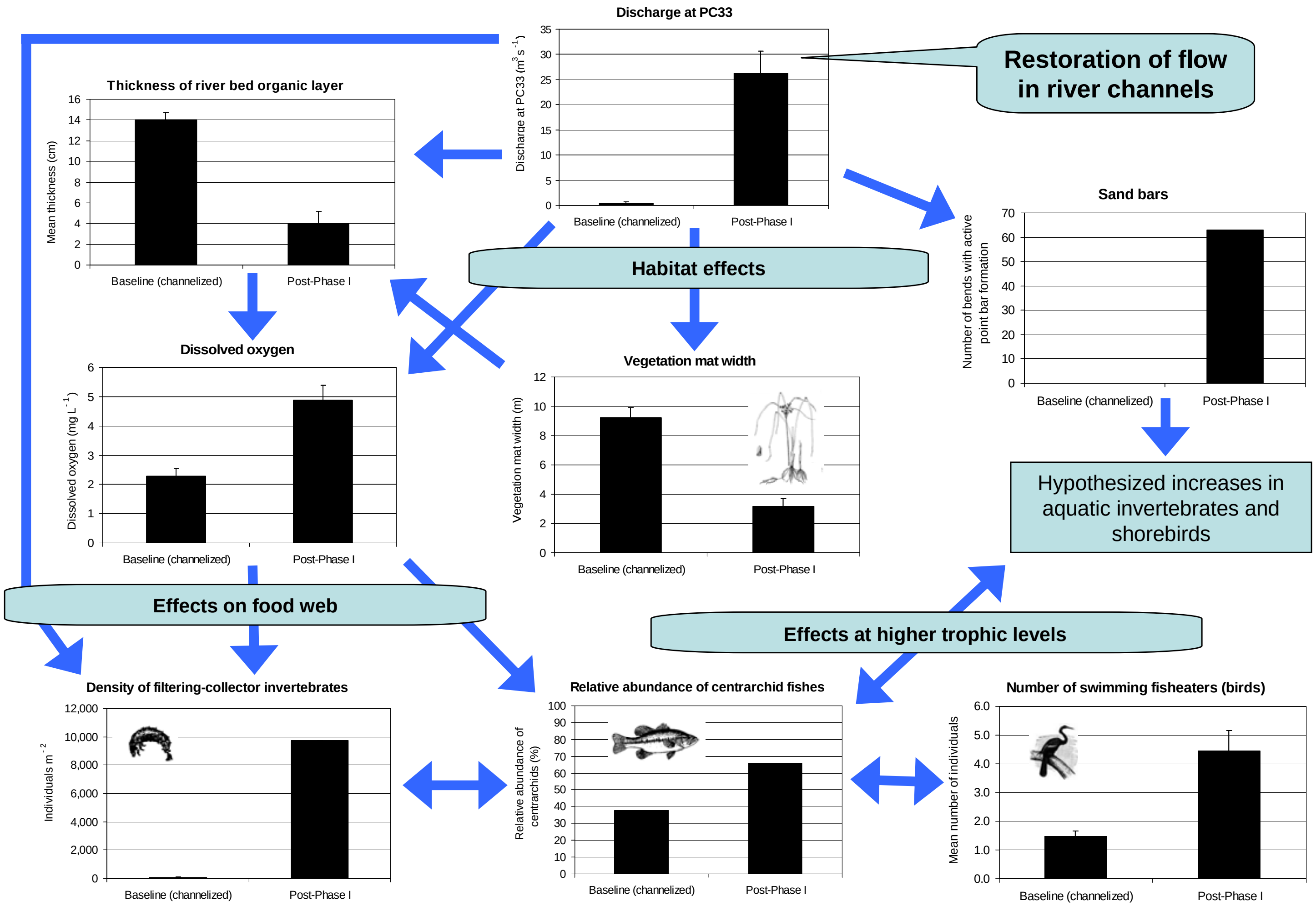


Figure 11-29. Monitoring results for seven river channel metrics before (1971–June 1999) and after (post-February 2001) flow was restored by Phase I backfilling of the Kissimmee River Restoration Project. Blue arrows show hypothesized relationships among ecosystem components and drivers. Graphs with error bars are means of multiple years of sampling (± one standard error); those without error bars are for a discrete sampling event used to represent the baseline or post-construction period. All responses are in the directions predicted by the associated expectations. Sand bars provide habitat for aquatic invertebrates and shorebirds, although monitoring results are not yet available for these taxa.

KISSIMMEE CHAIN OF LAKES LONG-TERM MANAGEMENT PLAN

The KCOL LTMP is a multiagency/stakeholder project whose purpose is to improve, enhance and/or sustain ecosystem health for regulated lakes in the Upper Basin while balancing impacts between upstream and downstream ecosystems (**Figure 11-2**). The KCOL LTMP was initiated in April 2003 (Resolution No. 2003-468). The SFWMD is the lead agency responsible for coordinating KCOL LTMP interagency activities and producing the plan. Other cooperating agencies include the FWC, the Florida Department of Environmental Protection (FDEP), Florida Department of Agriculture and Consumer Services (FDACS), USACE, USFWS, U.S. Environmental Protection Agency (USEPA), local governments and community leaders, and other stakeholders.

After identifying existing water resource issues and conflicts within the KCOL, partner agencies decided the plan should focus on hydrologic management, habitat preservation and enhancement, aquatic plant management, water quality, and public use and recreation. It was agreed that plan partner agencies should seek consensus among stakeholders on the resources that need to be protected and preserved through interagency management practices and mandates. The plan is intended to complement existing local government and watershed projects such as the Kissimmee Basin Water Supply Plan, Total Maximum Daily Loads, Lake Okeechobee Protection Plan, and SFWMD land management activities.

Scheduled for public release in March 20007, the plan will include those measures of ecosystem health and quality agreed upon by stakeholders. The plan will also contain a summary of scientific and management practices/tools developed to assist in management decision-making within the KCOL, including the following:

- conceptual ecosystem model
- stakeholder value survey
- assessment of current lake ecosystem health
- suite of lake evaluation and assessment performance measures
- data collection and monitoring plan
- partner agency action plans

Several products have been produced over the last year. These include (1) an annotated bibliography of KCOL literature, (2) a stakeholder value survey, (3) life history requirements documents, and (4) conceptual lake ecosystem model publication.

Annotated Bibliography

A review was conducted by the SFWMD to determine the extent of literature available on specific aspects of the KCOL ecosystem. A bibliographic database was established to house complete citations and associated abstracts. Approximately 650 references are currently available. This bibliography can be accessed on the District's web site at http://www.sfwmd.gov/images/pdfs/kiss_procite_biblio_notes.pdf. This document is updated regularly when new references are added.

Stakeholder Value Survey

A survey was conducted to assess the values residents and visitors in Osceola, Polk, Highlands, and Okeechobee counties associate with the Kissimmee Chain of Lakes (Tolley, 2005). The outreach sub-committee identified seven stakeholder groups to survey within the four counties (Osceola, Polk, Highlands, and Okeechobee) encompassing the Kissimmee Chain of Lakes. The target population in these four counties is 844,860 people, requiring

387 completed surveys to achieve a 95 percent confidence level with a ± 5 percent confidence interval. The survey results are based on 394 completed surveys.

Surveys were taken on a voluntary basis by 228 individuals attending nine community events from October 2004–February 2005. In addition, 166 surveys were returned out of 743 surveys mailed. The mailing list was generated using the SFWMD's various stakeholder mailing lists. Because the sample was not random, the findings cannot be translated into conclusive generalizations.

The first section of the survey assessed what respondents knew or thought about natural resource management practices. The second section of the survey asked the respondents to categorize themselves into one of the seven stakeholder groups, and further identify themselves within the stakeholder group. The respondent was able to identify with multiple stakeholder groups. The third section of the survey asked the respondents to choose from a list of lakes they have visited and the types of activities they have participated in. Within this section, the respondents were asked to rate water quality, aquatic plant/weed management, public access, recreation, habitat preservation, and fish and wildlife in terms of high, medium, or low priority. These aspects were rated individually, and were not ranked against each other. The fourth section of the survey asked respondents about their involvement in environmental issues, their media preference, and if they would like to be contacted in the future about the Kissimmee Chain of Lakes Long-Term Management Plan.

Results showed that a significant number of people use the lakes and associated uplands for leisure activities and that protecting water quality is a high priority relative to their continued enjoyment of these activities. This information, coupled with the high number of nonconsumptive recreational uses in the top five lake uses, suggests that most people care a great deal about places where they can readily experience and enjoy nature. The top five recreational uses were:

1. Picnicking
2. Boating
3. Hiking and freshwater fishing from a boat (tie)
4. Sunning, swimming, playing on the beach
5. Bird watching

Seventy-six percent of respondents said that water supply should be the focus of agency management. There may be two interpretations for this number. First, there have been consistent media reports over time that water supply in Central Florida has become a critical growth and development issue, and this may be reflected in the responses. Secondly, the response may reflect a perception that our water supply comes from surface water rather than groundwater, thus revealing another opportunity for public education regarding water supply.

In addition, results showed that fish and wildlife habitat preservation was a higher priority than recreation and access to areas for recreation, suggesting that respondents of the survey place an intrinsic value, rather than a utilitarian value, on the environment. The survey revealed that activities associated with agency management responsibilities are not widely known, which reinforces the need for continued public outreach. The survey revealed no clear indication of media preference for receiving environmental information, but this does not suggest a lack of interest. Slightly over half of the respondents wanted more information about the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP) and provided contact information.

The results of this survey and analysis will be used to better align project goals and performance measures with stakeholder values. It will also guide further outreach activities including the development of two brochures for the KCOL LTMP. One brochure will be a double-sided sheet which can be updated periodically with the latest developments that come as a result of the progress of the KCOL LTMP.

The other will be a brochure with a longer shelf life. In addition to information about the KCOL LTMP, perhaps this brochure can give an overview of management practices and list the agencies responsible for those practices. Given the high number of responses to questions about water quality and nonconsumptive recreational uses, it is suggested that people may respond favorably to a brochure that depicts nature, natural areas, and passive recreational activities.

Life History Requirements Documents

Florida Fish and Wildlife Conservation Commission biologists are identifying critical habitat requirements for selected candidate indicator species. These habitat requirements will be used to define the hydrologic requirements needed to support the life histories of the selected candidate species. Indicator species will be chosen in part based on their sensitivity to changes in preferred habitats.

Conceptual Ecosystem Model

As a step in the process toward performance measure development, KCOL LTMP partner agencies and stakeholders drafted a conceptual ecosystem model (CEM) for the KCOL. This model indicates, using a simple box-and-arrow diagram, how various cultural stressors affect attributes of the ecosystem that are of value to nature and society. The model is based on the Lake Okeechobee/CERP template and is comprised of a top-to-bottom hierarchy of drivers, stressors, ecosystem effects, priority attributes of the ecosystem, and performance measures. Stressors identified in the model include wetland drainage, altered hydrology, exotic flora and fauna (specifically hydrilla), and phosphorus and other water quality pollutants.

The CEM will be used to generate ecosystem attributes to be considered for development into performance measures. The District will expand on the initial CEM effort by developing a draft document that describes the CEM, attributes of the model to be considered for performance measure development, and available attribute data. The FWC has embarked on a separate effort to identify critical life history requirements for selected candidate indicator species (see previous section). These life history requirements will be used in association with the CEM to develop the hydrologic performance measures for the KCOL.

A draft document describing the Ecosystem Conceptual Model was completed by the SFWMD in June 2005. This document will then be provided to a scientific peer review panel for review to determine if included metrics are suitable for development into hydrologic performance measures for the hydrologic/hydraulic model being developed for the Kissimmee Basin Modeling and Operations Study.

Future Efforts – Performance Measure Development

Evaluation and assessment performance measures will be developed for the KCOL. Evaluation performance measures will define the hydrologic requirements of key components of the ecosystem. Assessment performance measures will define desirable ecological characteristics that can serve as indicators of ecosystem health. Performance measures will be produced using best available data and best professional judgment. Performance measures will define targets, ranges, and variability of metrics.

It is recognized that there will be conflicting requirements among various components of the system; this is expected based on the historic range and variability of water levels. Producing ideal habitat conditions on an annual basis for all species residing within the system is unrealistic. Therefore, evaluation performance measures will need to define how often within a given time frame, a target needs to be met. Additionally, performance measures will have to address inherent differences among lakes, such as morphology, water quality, etc.

Identification of Baseline and Reference Conditions: Scientists in the Kissimmee Division of the SFWMD are leading this task, which involves examining available documents and databases for biological and water quality data from the KCOL. A draft report summarizing baseline and reference conditions is scheduled to be completed by April 2006.

Assessment of Current Lake Ecosystem Health: Best available data will be used to assess the current state of lake ecosystem health within the KCOL.

Data Collection and Monitoring Plan: A data collection and monitoring plan will be developed for the KCOL in support of collecting data for assessment performance measures.

Partner Agency Action Plans: Partnering agencies will be asked to develop action plans once lake ecosystem health has been assessed. The intent of these plans is to identify ways in which agency mandates and resources can be applied to improve lake ecosystem health.

TRIBUTARY RESTORATION PROJECTS

Restoration of Packingham and Buttermilk Sloughs

The KICCO Wildlife Management Area (WMA) is an approximate 7,400-ac (3000-ha) property in Polk County. The property is managed by the District's Land Stewardship Division and was purchased under the Save Our Rivers Program in 1985 as part of the KRRP. The area is located on the west side of the C-38 canal in Pool A of the Kissimmee River (**Figure 11-1)**. The north border is State Highway 60, and the south border lies south of the S-65A water control structure.

The C-38 canal will not be backfilled north of S-65A. Therefore, flow will not be restored to the remnant Kissimmee River in Pool A. Although restoration of the river will not take place in Pool A, there are smaller projects within the pool that will serve to increase water storage capacity, improve water quality, mitigate flooding, and restore the wetland community in portions of the floodplain associated with the river's tributaries. The purpose of the project is to restore historic (pre-C&SF Project) floodplain hydroperiods to Packingham and Buttermilk sloughs. Benefits will include increased wetland habitat for wildlife and creation of a "wetland corridor" between Lake Kissimmee and the restored portion of the Kissimmee River.

The main features of the restoration plan are the creation of two containment levees, backfilling of drainage ditches, and installation of gated water control structures. Water depth in each impoundment will be managed to mimic the historic surface water levels in the basin according to a predictive model developed from historic data at nearby Fort Kissimmee.

Hydraulic and hydrologic modeling was completed in March 2005. Model results showed that water levels within the impoundments will be adequate for restoration of the historic floodplain hydroperiod without impacting property outside of the 100-year flood line. Detailed design is under way and is scheduled for completion this fiscal year.

Rolling Meadows Wetland Restoration

Rolling Meadows Ranch lies on the south shore of Lake Hatchineha (**Figure 11-1**). The 2,260-acre property was purchased by the SFWMD and the FDEP as part of the Kissimmee River Restoration Project. Currently, this property is leased back to the previous owner and operated as a sod farm.

The restoration plan identifies the construction of a 1,670-acre impounded wetland, possibly fed by water from Lake Hatchineha when lake stage exceeds a certain elevation, and from Catfish Creek, which historically entered Lake Hatchineha 2,000 feet north of the property. The impounded wetland will be managed to mimic the natural hydroperiod of the lake and will provide enhanced wetland habitat for wildlife. The upland area outside the impounded wetland may be incorporated into the Lake Kissimmee State Park, which is operated by the FDEP.

The property also will be used for temporary storage of spoil dredged from C-37 by the USACE as part of the Kissimmee River Restoration Project. The spoil will be used for backfilling farm ditches, strengthening levees, and creating a scenic road around the property. The USACE has agreed to build the wetland impoundment in exchange for the temporary storage of the spoil material.

To assess how water will be delivered to the impoundment, hydrologic modeling of Catfish Creek was needed. The Catfish Creek Wetland Restoration Study Hydrologic and Hydraulic Modeling Report was completed in March 2004. According to this report, there are three options for providing water to the impoundment: (1) Catfish Creek would be allowed to discharge directly into Lake Hatchineha, and Rolling Meadows impoundment would receive water directly from Lake Hatchineha through a water control structure; (2) Catfish Creek would be diverted to discharge directly into the impoundment, the impoundment would discharge into Lake Hatchineha through a weir and when lake stage is high, water from the lake would enter the impoundment; and (3) discharge from Catfish Creek would be split between Lake Hatchineha and the impoundment, the impoundment would discharge into Lake Hatchineha through a weir and when lake stage is high, water from the lake would enter the impoundment.

Currently, a statement of work to develop a conceptual restoration plan for the property is under review. The scope of work for this contract includes creating a conceptual restoration plan for the Rolling Meadows/Catfish Creek property using information provided by the SFWMD, FDEP, and other stakeholders. The contract will include the necessary survey and modeling effort to adequately support the analysis of different alternatives and the recommended plan. Previously completed modeling will be used to guide additional work. Results of the existing Phase I and Phase II environmental assessment will be used to guide additional soil and water testing. Historical (pre-C&SF Project) data such as aerial photography, vegetation and soil maps, and stage data, shall be used to delineate natural communities and the historical route of Catfish Creek.

WATERSHED WATER QUALITY

Ambient Water Quality Monitoring

The SFWMD maintains a water quality sampling program in five major lakes of the Kissimmee Chain (East Lake Tohopekaliga, Lake Tohopekaliga, Lake Cypress, Lake Hatchineha, and Lake Kissimmee) and three main tributaries to these lakes (Boggy Creek, Shingle Creek, and Reedy Creek). Monitoring is conducted for phosphorus, nitrogen, phytoplankton chlorophyll *a*, turbidity, water transparency, DO, and other constituents. Despite continuing development around the lakes, annual mean TP concentrations have remained stable.

Kissimmee Basin TMDL Water Bodies

A Total Maximum Daily Load (TMDL) is a written, quantitative plan and analysis for attaining and maintaining water quality standards in all seasons for a specific water body and parameter. Approximately 23 water bodies in the Kissimmee Basin are currently listed for TMDL development for several parameters including dissolved oxygen, nutrients, ionized ammonia, turbidity, mercury, cadmium, and others. The timeline for the TMDL development is 2005–2011. As the lead agency responsible for TMDL development, the FDEP is approaching water quality improvement in the Kissimmee Basin from a watershed perspective.

Water bodies in the Kissimmee Basin that are listed for TMDL development are subject to Florida Class III water quality standards. Class III is a designated use for waters, which means surface waters for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

In general, sections of the Kissimmee River within the restoration project area that are currently listed for TMDL development are expected to experience improvement in water quality due to reestablishment of natural filtration, reaeration, and biological processes.

Lake Okeechobee Protection Plan

The Kissimmee Basin falls within the geographic jurisdiction of the Lake Okeechobee Protection Act (LOPA). The LOPA requires that applicable water quality criteria be achieved and maintained in Lake Okeechobee and its tributary waters. This act sets forth a series of activities and deliverables for the coordinating agencies, which include the SFWMD, FDEP, and FDACS.

On January 1, 2004, the three coordinating agencies completed the Lake Okeechobee Protection Plan (LOPP), which was authorized under the LOPA. The LOPP identifies areas for future legislative support to successfully implement the state's commitment to protect and restore this resource and to achieve the TMDL for Lake Okeechobee. These agencies are currently seeking funding to implement the LOPP. One aspect of this plan addresses the need to fund cost-share best management practices (BMPs) on agricultural lands. The funding needed in the upper Kissimmee Basin is approximately $5 million. These BMPs are planned to be implemented beginning in 2009. Additional information on the LOPP can be found in Chapter 10 of this volume.

The LOPP presents an innovative protection program that is both comprehensive and phased in its implementation. In the Upper Basin, initial TP reductions and other water quality improvements will be achieved through implementation of agricultural BMPs using a voluntary program coordinated through the FDACS. The FDEP will coordinate implementation of non-agricultural, non-point source BMPs, such as septic systems and urban stormwater runoff.

The KCOL LTMP will contribute significantly to development of a watershed plan for the region by providing a scientifically based water quality management strategy for the Kissimmee Chain of Lakes. It will be important for addressing specific water quality needs that are not included in the LOPP or TMDL programs.

KISSIMMEE UPPER BASIN LOCAL GOVERNMENT PARTNERSHIPS

Much of the water flowing to the KCOL and Kissimmee River originates in four headwaters basins north of the KCOL. This area is one of the most rapidly urbanizing areas in Florida. The quality and quantity of water flowing through these basins influence the health of all downstream systems. The SFWMD works with local governments throughout the Upper Basin to fund water resource projects to improve water quality, water supply, natural resources, and flood control levels of service.

CONCLUSIONS

Four hurricanes hit the state of Florida during 2004, including three (Charley, Frances, and Jeanne) that passed directly over the Kissimmee Basin. The Kissimmee Basin experienced high winds during each storm. Noted wind effects included seiches and associated uprooting of aquatic vegetation in lakes, especially hydrilla. Rainfall in September 2004 exceeded the 100-year wet return-period. Discharges from S-65C into the Kissimmee River approached record levels, peaking at approximately 10,000 cfs, a number that may be revised upward following new rating curve information.

The Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Study (KB Modeling and Operations Study) is an initiative that will develop a hydrologic/hydraulic model to be used to identify alternative structure operating criteria to meet operations objectives of the Kissimmee Basin and its associated water resource projects. Achievements during WY2005 include an evaluation of watershed delineations in the Upper Basin; identification of flood control, water supply, aquatic plant management, and natural resource operations objectives, including objectives related to the KRRP, the KCOL LTMP, and the Upper Basin restoration projects; preliminary analysis of rainfall and flow data of selected watersheds within the Kissimmee Basin; evaluation of the functionality, defensibility, and cost-effectiveness of candidate modeling tools, which resulted in selection of the MIKE SHE/MIKE 11 tool; and an evaluation of the adequacy of the existing Kissimmee Basin hydrologic monitoring network to meet established monitoring objectives.

Phase I of the KRRP was completed in February 2001, and involved filling approximately 7.5 miles (12 km) of the C-38 canal and demolishing the S-65B structure to reconnect 15 miles (24 km) of continuous river channel. Although the Headwaters Revitalization Project stage regulation schedule has not yet been implemented, the changes in channel form and extent of floodplain inundation associated with construction and the implementation of an interim stage regulation schedule have significantly altered the physical habitat template to which other components of the ecosystem are beginning to respond. During WY2005, a number of responses to restoration have been measured, including continued increases in river channel DO over baseline levels; continued low levels of turbidity and total suspended solids in the river channel; colonization of mid-channel benthos by invertebrate species indicative of reestablished sand channel habitats and dominance of woody snag invertebrate communities by passive filter-feeding insects, which require flowing water; increased relative abundance of centrarchid fishes in river channel fish assemblages; and increased densities of wading birds and waterfowl.

The KCOL LTMP resulted from a District Governing Board resolution and has the purpose of improving and sustaining lake ecosystem health in the KCOL. Major accomplishments during the last year include development of a KCOL annotated bibliography; completion of a stakeholder survey; development of documents detailing habitat requirements of candidate indicator species; and a draft conceptual ecosystem model for the KCOL.

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