Chapter 11: Kissimmee Basin

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SUMMARY

The Kissimmee Basin encompasses diverse wetland and aquatic ecosystems, including more than two dozen lakes, their tributary streams, associated marshes, and the Kissimmee River and its floodplain (**Figure 11-1**). The basin forms the headwaters of the Kissimmee-Okeechobee-Everglades system. In the 1960s, the Central and Southern Florida Flood Control (C&SF) Project modified these systems extensively to achieve flood control by construction of canals and water control structures in the Upper and Lower Kissimmee Basin. The 56-mile-long C-38 canal in the Lower Basin's Kissimmee Valley channelized the Kissimmee River, eliminating flow in the original river channel and preventing seasonal inundation of the floodplain, with profound ecological consequences. In the Upper Basin, modifications allowed lake stages to be regulated at reduced ranges of fluctuation, altering or eliminating much of the formerly extensive littoral zones around lakes. These and other environmental concerns led to the Kissimmee River Restoration Project (KRRP) and the Headwaters Revitalization Project (KRHRP) which involve land acquisition in the Upper and Lower Basins, backfilling over a third of C-38, reconnection of remnant river channels in the restored reach, increases in the water storage capacity of several Upper Basin lakes to provide continuous flows to the Kissimmee River, and development of a new lake stage regulation to support the restoration. The project is 50/50 cost-shared by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD).

The Kissimmee Watershed Program of South Florida Water Management District was originally formed in the 1990s to coordinate and evaluate the restoration and associated projects. More recently, the program has been directed to work to integrate Kissimmee watershed management strategies with the KRRP. The primary goals of the Kissimmee Watershed Program are to restore ecological integrity to the Kissimmee River and its floodplain ecosystem, develop a long-term management plan for resolving water and other management issues in the Kissimmee Chain of Lakes, and retain the existing level of flood control in the Kissimmee Basin. In addition to KRRP, major initiatives within the Kissimmee Basin designed to meet these objectives are the

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Kissimmee Basin Modeling and Operations Study (KBMOS) and the Kissimmee Chain of Lakes (KCOL) Long-Term Management Plan (LTMP) (**Figure 11-2**). The program is involved with a number of associated activities including restoration evaluation, several smaller restoration projects, water supply planning, water quality improvement, aquatic plant management, and land management, both within and beyond the boundaries of the Kissimmee Basin.

The Kissimmee Basin lies within the Lake Okeechobee Watershed, and is the single largest source of surface water to Lake Okeechobee. Water quality issues in the Lake Okeechobee Watershed are addressed by recent initiatives including the Lake Okeechobee Protection Plan (LOPP) and the Northern Everglades and Estuaries Protection Initiative (Chapters 10 and 7A of this volume, respectively).

Phase I of four major phases of the Kissimmee River Restoration Project was completed in February 2001. A second phase of backfilling, initiated in June 2006, is approximately 98 percent complete. The final phases of construction are projected to be completed in 2012.

In Water Year 2007 (WY2007) (May 1, 2006–April 30, 2007), Kissimmee Basin environmental conditions were dominated by drought conditions, with rainfall in the Upper Basin totaling 34.47 inches, which was 15.4 inches below the historical average; and the Lower Basin totaling 33.64 inches, which was 17.68 inches below the long-term average. The lack of rainfall resulted in the need to end releases to the Kissimmee River on November 8, 2006, resulting in lack of flow for the first time since completion of KRRP Phase I backfilling in 2001. Flow was restored in July 2007. Despite the drought and no-flow conditions in the Phase I reach, mean dissolved oxygen (DO) concentrations remained at suitable levels to support aquatic invertebrates and fishes through most of July. However, densities of long-legged wading birds on the restored floodplain, which had exceeded restoration expectations each year from 2002–2006, dropped this year, likely in response to limited foraging habitat on the floodplain.

Total phosphorus (TP) concentrations have increased since completion of Phase I, but the cause of this increase has not been determined. A recently completed vegetation map based on 2003 aerial photography, recorded dramatic increases in wetland vegetation within two years of completion of Phase I construction.

INTRODUCTION AND BACKGROUND

CHAPTER OVERVIEW

This year's Kissimmee Basin chapter is reduced in content from previous years: it is primarily intended to provide an update to previous Kissimmee Basin chapters based on events in WY2007. Although a comprehensive background section has been included, the bulk of the chapter is devoted to an overview of WY2007 Kissimmee Basin conditions and activities, with minimal exposition of previously-described material. To this end, the chapter is focused on presentations of data describing water year environmental conditions, newly available data from the Kissimmee River Restoration Evaluation Program (KRREP), descriptions of recent planning efforts, and abbreviated status updates on projects and other program activities. Readers are encouraged to refer to previous SFERs for additional information as needed.

The chapter is organized in four main sections. Following this *Introduction and Background* section, the second major section, *Cross-Watershed Activities*, includes new information on the role of the Kissimmee Watershed Program in addressing issues that span the boundaries between the Kissimmee Basin and downstream ecosystems in South Florida. The purpose of this section is to provide clarity on the District's approach to far-reaching interactions among watersheds and ecosystems in the headwaters of the Kissimmee-Okeechobee-Everglades system, specifically in the areas of water management and water quality, and to describe the distribution of responsibilities within and beyond the SFWMD to meet these challenges. A number of organizational entities and efforts administered by the SFWMD and other agencies are involved in the many construction, monitoring, modeling, and evaluation projects that are needed to address watershed-scale issues.

The third major section, *Basin Conditions*, summarizes environmental conditions in the Kissimmee Basin during WY2007. The section emphasizes basin hydrologic conditions and their relationship to water management decisions. It also reports on other indicators used to inform water management recommendations. The District has been experiencing drought conditions since the WY2006 dry season. This year's summary is focused on the extremely low rainfall conditions that dominated the District during WY2007 and their effects on several restoration evaluation studies.

The final major section of this chapter, *Project Updates*, is devoted to project-level data presentations and discussions of planning activities. This section will present newly available Phase I restoration response data from the Kissimmee River Restoration Evaluation Program (KRREP); plans for Phase II/III restoration evaluation studies; and status updates on the Kissimmee Chain of Lakes Long Term Management Plan (KCOL LTMP), the Kissimmee Basin Modeling and Operations Study (KBMOS), and several smaller restoration projects in progress within the basin.

In response to needs for increased integration and coordination at basin and watershed scales, the District has expanded the mission and geographic focus of the Kissimmee Program since the 1990s, when the program was formed primarily for coordination and evaluation of the Kissimmee River Restoration Project. Since that time, following management and Governing Board direction, the Kissimmee Watershed Program has embarked on major projects to address basin- and watershed-level issues, including development of a long-term plan to address management of the Kissimmee Chain of Lakes in the Upper Kissimmee Basin, and development of basin and regional modeling tools to enhance water management decisions both within and beyond the boundaries of the Kissimmee Basin.

Acronyms and other abbreviations used in this chapter are defined in the text the first time they are used. All are also included in the main SFER Glossary in this volume.

THE KISSIMMEE BASIN

The Kissimmee Basin in South-Central Florida forms the headwaters of the Kissimmee-Okeechobee-Everglades (KOE) ecosystem, encompassing an area of approximately 3,000 square miles, or mi^2 (7,800 square kilometers, or km^2) (SFWMD, 2002). The watershed includes the basins of the Kissimmee River and Lake Istokpoga in the Lower Kissimmee Basin, and the Kissimmee Chain of Lakes (KCOL) in the Upper Kissimmee Basin (**Figures 11-1A** and **11-1B**). The basin receives an average of approximately 50 inches of rainfall per year with most falling during a distinct wet season (June–October) (SFWMD, 2000). The Kissimmee Basin is the single-largest source of surface water to Lake Okeechobee, accounting for approximately 34 percent of inputs (SFWMD, 2002).

Prior to the 1960s, the KCOL and the Kissimmee River comprised an interconnected system of aquatic and wetland systems linked by broad, shallow marshes and creeks. The KCOL lakes drained to the river, which meandered 103 mi (166 km) to Lake Okeechobee through a 1–2 mi (1.5–3 km) wide floodplain (USACE, 1991). The lakes overflowed onto adjacent lands in the wet season, and provided water volumes that allowed year-round flow in the river and wet-season inundation of its floodplain (USFWS, 1959). A vast and diverse aquatic/wetland ecosystem was supported in the Kissimmee Basin under these hydrologic conditions.

Hurricanes in the 1940s caused disastrous flooding in KCOL communities, prompting the state of Florida to petition the federal government for a flood control plan for the region. The Central and Southern Florida (C&SF) Project for flood control and other purposes was authorized in 1948 by the U.S. Congress; and the Federal Rivers and Harbors Act of 1954, an addition to C&SF Project, authorized flood control projects in the Kissimmee Basin.

The C&SF Project was successful in meeting its goal of flood control. However, it dramatically altered hydrologic conditions in the Kissimmee Basin (Obeysekera and Loftin, 1990; Anderson and Chamberlain, 2005). In the Lower Basin, a major feature of the project was canal C-38, constructed between 1962 and 1971 through the valley of the Kissimmee River (**Figure 11-1A**). The canal intercepted flow from the native river channel and moved water that was formerly conveyed overland across the floodplain during wet seasons. The canal eliminated flow in river channels and prevented seasonal inundation of the floodplain. The main conduit of water between Lakes Kissimmee and Okeechobee became a 56 mi (90 km) long, 30 ft (9 m) deep canal that varied from 90 to 300 ft (27 and 91 m) in width. With five water control structures along the length of C-38 (USACE, 1991) (**Figure 11-1A**), in this “channelized” condition the system was a series of deep impoundments, regulated primarily for flood control and water supply, with ecological characteristics more similar to a series of reservoirs than a natural river/floodplain ecosystem.

The physical and hydrologic effects of channelization reduced the extent of floodplain wetlands and degraded fish and wildlife resources throughout the Lower Basin (USACE, 1991; Bousquin et al., 2005a; 2005b). Approximately 21,000 acres (ac) (8,500 hectares, or ha) of floodplain wetlands were drained, covered with spoil material, or converted into canal (USACE, 1991; Carnal and Bousquin, 2005). The previously wetland-dominated floodplain became a swath

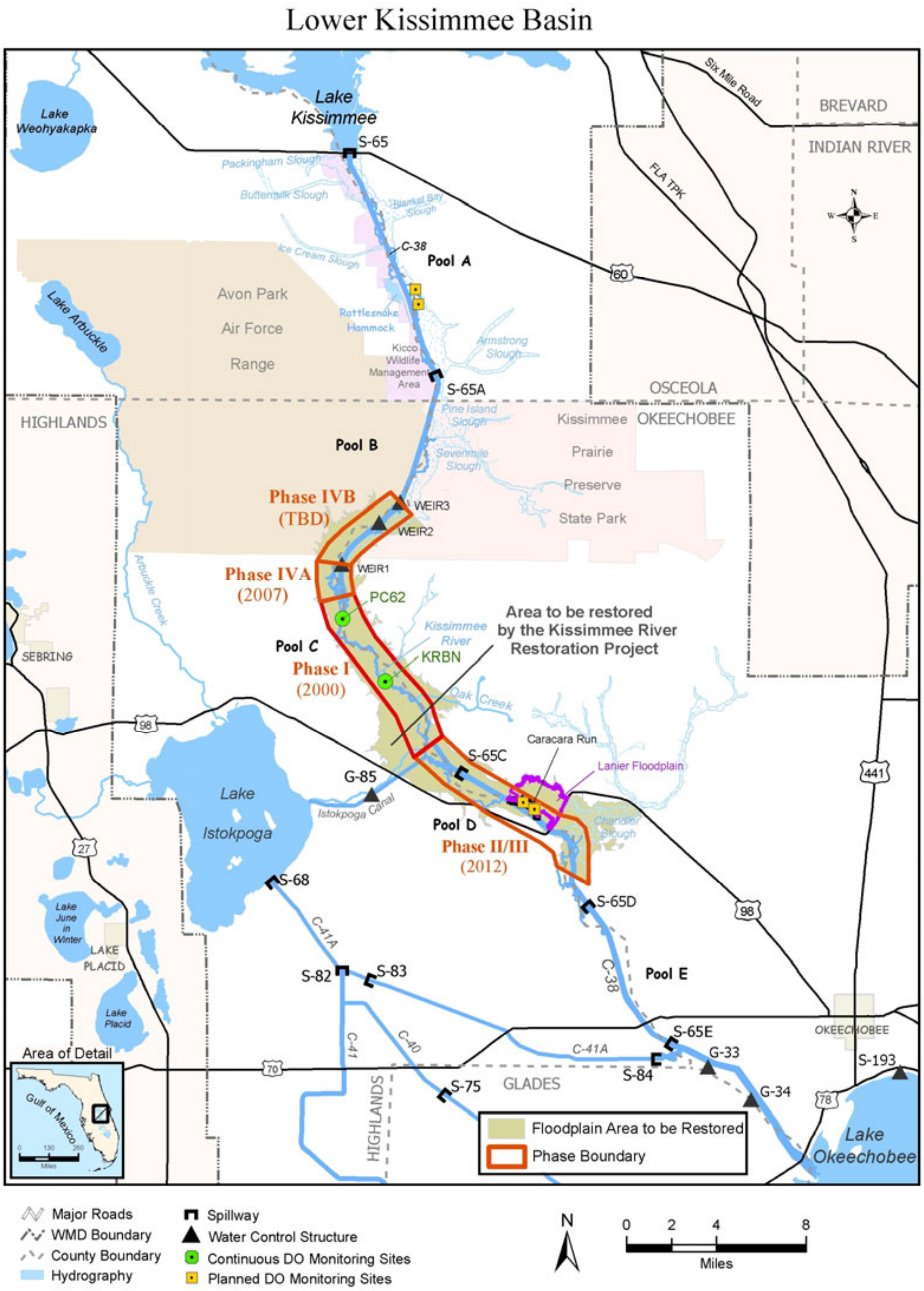

Figure 11-1A. Map of the Lower Kissimmee Basin and Lake Istokpoga Basin of the Kissimmee watershed.

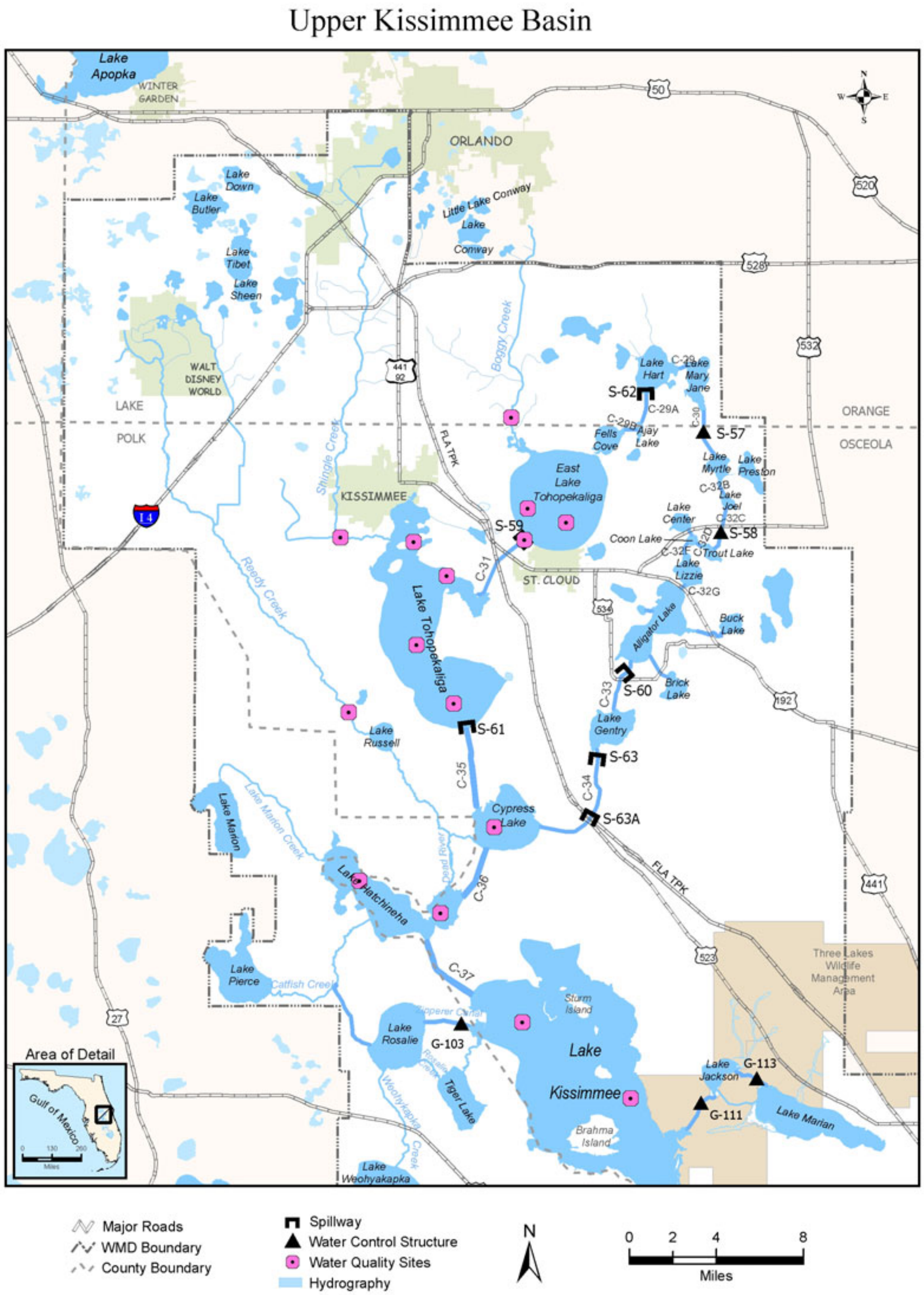

Figure 11-1B. Map of the Upper Kissimmee Basin of the Kissimmee watershed.

of upland plant communities within two years of completion of the canal (Carnal and Bousquin, 2005). Lack of flow in the disconnected (remnant) river channels encouraged growth of littoral (edge) vegetation, which affected water chemistry as senescence and death of vegetation covered the sand substrate with large amounts of organic matter, greatly increasing the biological oxygen demand of the system (Toth, 1990; Colangelo and Jones, 2005). Lack of flow also contributed to lower levels of dissolved oxygen (DO), which had negative impacts throughout the food web. Aquatic invertebrate communities in the channelized system became typical of those found in lakes and reservoirs, rather than riverine systems (Harris et al., 1995; Koebel et al., 2005). Stabilized water levels greatly reduced river-floodplain interactions, disrupting critical food web linkages that are dependent on seasonal flooding and prolonged rates of floodwater recession from the floodplain (Harris et al., 1995; Anderson and Chamberlain, 2005). With these losses of suitable habitat, waterfowl densities and species richness declined sharply (Williams and Melvin, 2005), and the diverse and abundant wading bird populations declined and were largely replaced by cattle egret (*Bubulcus ibis*), a species generally associated with terrestrial habitats (Perrin et al., 1982; Williams and Melvin, 2005). The river's valued largemouth bass (*Micropterus salmoides*) fishery was decimated as fish species tolerant of low DO and reduced water quality, such as Florida gar (*Lepisosteus platyrhincus*), replaced bass (Perrin et al., 1982; Glenn, 2005). More details on the effects of channelization on many components of the Kissimmee River ecosystem are available in Bousquin et al., 2005b.

In the Upper Basin, C&SF Project features were constructed between 1964 and 1970. These included dredging of canals between lakes and installation of nine water control structures regulating the amount and timing of discharges between lakes and from the lakes to the Kissimmee River (USACE, 1991). Regulation of the lakes reduced the range of lake level fluctuation from a pre-C&SF Project range of 2–10 ft (0.6–3.0 m) to approximately 2–4 ft (0.6–1.2 m) after regulation (Obeysekera and Loftin, 1990). The pre-regulation seasonal pattern of water level fluctuation had provided periods of flooding and drying at the edges of lakes, which played a critical role in the maintenance of littoral habitat, supporting plant and animal communities adapted to and dependent on these conditions (Perrin et al., 1982). Reduction of the range of fluctuation dampened this natural flooding and drying cycle, promoting development of excessively dense vegetation and accumulation of organic material in lake littoral zones (USACE, 1996). Reduced water level fluctuation also has allowed agricultural, residential, and commercial land uses to encroach on lake flood zones, resulting in additional loss of wildlife habitat and higher nutrient inputs to the lakes (USACE, 1996).

KISSIMMEE RIVER RESTORATION PROJECT AND ASSOCIATED INITIATIVES

Concerns about environmental degradation and habitat loss in the Kissimmee Valley, and the potential contribution of the channelized Kissimmee River to eutrophication in Lake Okeechobee, were the impetus for the Kissimmee River Restoration Project. As early as 1971 (prior to completion of C-38), conservationists were calling for restoration of the river. The 1992 Water Resources Development Act (Public Law 102-580) authorized ecosystem restoration of the Kissimmee River to restore ecological integrity to a portion of the former river-floodplain ecosystem (Bousquin et al., 2005a), and construction of the Kissimmee River Headwaters Revitalization Project (KRHRP) to support the restoration. The restoration goal of integrity for the river-floodplain ecosystem is defined as "capable of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley, 1981). Successful restoration of the Kissimmee River is largely dependent on reestablishing hydrologic conditions that are similar to the pre-channelization period (Toth, 1990). The purpose of the KRHRP is to provide sufficient storage in the headwaters lakes to allow water regulation to approximate historical flow and volume characteristics to the Kissimmee River. An additional expected benefit is improvement of the quantity and quality of lake littoral zone habitat for the benefit of fish and wildlife (USACE, 1996, Sections 1.3.2, 5.1). The project modifications and restoration are to take place without jeopardizing existing levels of flood control in the Kissimmee Basin.

The river restoration component involves land acquisition in the Lower Basin, backfilling approximately 22 mi (35 km) of C-38 (over one-third of the canal's length) from the lower end of Pool D north to the middle of Pool B, reconnection of remnant river channels by re-carving sections of river channel destroyed during C-38 construction; removal of the S-65B and S-65C water control structures and tieback levees in C-38; and evaluation of restoration success through a comprehensive ecological monitoring program, the Kissimmee River Restoration Evaluation Program (Williams et al., 2007; Bousquin et al., 2005a; Anderson et al., 2005b). Backfilling of C-38 and re-carving of river channels will be implemented in four phases of construction projected to be completed in 2012. Evaluation of restoration success will continue through at least 2017. The spoil material used for backfilling is the same material that was dredged during construction of canal C-38. This material was deposited in large spoil mounds adjacent to the canal. It is composed primarily of sand and course shell.

The KRHRP (organizationally, a component of KRRP) involves implementation of a new stage regulation schedule, called the Headwaters Revitalization schedule, to operate the S-65 water control structure. The new headwaters schedule will allow water levels to rise 1.5 feet higher than the current schedule and will increase the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 ac-ft (12,340 ha/m). Before the headwaters schedule is implemented, lands that will be impacted by higher water levels will be acquired and the conveyance capacity of the canals and structures will be increased to accommodate the larger storage volume. The KRHRP is scheduled for completion in 2012.

Because of the time lag between completion of the earliest phases of the construction project and implementation of the headwaters regulation schedule, the U.S. Army Corps of Engineers (USACE) authorized the District to make releases at S-65 when the lake stage was in Zone B of the existing regulation schedule. These releases were intended to maintain flow in the reach of restored river channel continuously through the year and that would vary seasonally. Environmental releases according to this schedule began in July 2001 after Phase I of construction for the KRRP had been completed and lakes levels began to rise after the 2000–2001 drought. While the use of Zone B releases has been beneficial (see the *Kissimmee River Restoration Evaluation Program: Phase I Response Updates* section), it does not substitute for the Headwaters Revitalization schedule.

In the Lower Basin, the KRRP and KRHRP combined are expected to restore ecological integrity to approximately one-third of the river and floodplain, including 20 mi^2 (51 km^2) of wetlands and 70 km (44 mi) of continuous river channel (USACE, 1991; 1996). In the Upper Basin, improved conditions are expected in over 7,000 acres of littoral marsh in four regulated lakes (USACE, 1996). The KRRP (including KRHRP and the KBMOS, described below) is funded under a 50/50 cost-share agreement between the SFWMD and the USACE. Engineering and construction components of the project are the responsibility of USACE, while the District's purview is land acquisition and ecological evaluation of the restoration project.

Phase I construction of the KRRP was completed in February 2001. Approximately 7.5 mi (12 km) of flood control canal was filled in Pool C and the southern portion of Pool B, nearly

1.3 mi (2 km) of river channel was re-carved, 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 6,000 ac (2,400 ha) of floodplain.

In June 2006, a second construction phase (Phase IVA) was initiated at the northern terminus of the Phase I project area. Phase IVA reconnects four miles of historic river channel by backfilling two miles of the C-38 canal and is expected to restore 155 ac (63 ha) of floodplain wetlands. Approximately 1.3 million cubic yards or 75,000 dump truck loads of spoil material will be pushed back into the canal in order to restore flow to the river channel. Other construction features include degrading a 4,000 ft section of a spoil mound on the floodplain, removal of three sheet pile weirs that were installed as part of the Kissimmee River restoration demonstration project and removal of a gated culvert in a section of remnant river channel. As of July 2007, this project was 98 percent complete.

At least two more phases of backfilling are scheduled between now and 2012. The restoration phases originally were named in the order of expected completion. The sequence has been changed over the years for logistical reasons (budgetary considerations, coordination with land acquisition, ease of access) (**Table 11-1**). Upper and Lower Basin land acquisition for both KRRP projects (KRRP and KRHRP) was substantially completed in 2006.

Table 11-1. Sequence of construction phases for the Kissimmee River Restoration Project.

Temporal Sequence	Name of Construction Phase	Timeline	Location of Backfilling
1	Phase I	1999-2001 (complete)	Most of Pool C, small section of lower Pool B
2	Phase IVA	2006-2007 (complete)	Upstream of Phase I in Pool B to Wier #1
3	Phase IVB	2008-2009	Upstream of Phase IVA in Pool B (upper limit approximately at location of Wier #3)
4	Phase II/III	2010-2012	Downstream of Phase I (lower Pool C and Pool D to the CSX Railroad bridge)

Evaluation of the success of the Kissimmee River Restoration Project is a requirement of the District's cost-share agreement with the USACE, and is the purview of the Kissimmee River Restoration Evaluation Program (KRREP). The project is being tracked using 25 restoration expectations (performance measures) to evaluate the success of the restoration in meeting the project's ecological integrity goal (Anderson et al. 2005b, Bousquin et al. 2005a). These performance measures have undergone an external peer-review process. Ongoing project status is reported in several ways, including conference presentations, peer-reviewed and District publications, and annual SFER chapters, although final evaluation of project success will not take place until project completion, implementation of KRHRP, and responses have stabilized (at least 5 years past project completion).

Exotic, invasive vegetation is actively managed throughout the KRR project area in an effort to meet management goals in addition to restoration success. Kissimmee Division and Vegetation Management Division staff coordinate vegetation management efforts with field sampling, work to assure consistent efforts from year to year, and follow guidelines to avoid inordinate impacts on native plant species and sampling efforts. This vegetation management program has been in place since 1988. The goal of vegetation management in the Kissimmee River ecosystem is to achieve "maintenance control", rather than complete elimination of exotics. Maintenance control is an effort to achieve tolerable, low levels of invasive species efficiently and cost-effectively. Additional information on exotic plants and animals throughout the Kissimmee basin, and their control, can be found in the Kissimmee Basin Module of Chapter 9 of this volume.

A BASIN PERSPECTIVE

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

In addition to the Kissimmee River Restoration Project (KRRP) (**Figure 11-2A)** and Kissimmee River Headwaters Revitalization Project (KRHRP) (**Figure 11-2B)**, coordinated initiatives designed to meet these objectives include the interagency Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP) in the Upper Kissimmee Basin (**Figure 11-2C**), which is creating a scientific and technical basis for assessing environmental conditions relative to targeted conditions, and collaborative strategies for identifying the need for management intervention or modification to achieve targets; and a major modeling effort, the Kissimmee Basin Modeling and Operations Study (KBMOS) (**Figure 11-2D**), which will evaluate the basin-wide effects of alternative operations schedules for the 13 structures controlling flow through the KCOL lakes and the Kissimmee River while considering impacts of the alternatives on discharges to Lake Okeechobee; as well as smaller restoration projects within the Kissimmee Basin. Activities associated with this suite of Kissimmee Basin projects span ecosystem restoration, restoration evaluation, hydrologic management, modeling, aquatic plant management, land management, adaptive management of natural resources, water quality improvement, and water supply planning. Updates on the LTMP, KBMOS, and restoration projects are provided in the *Project Updates* section of this chapter.

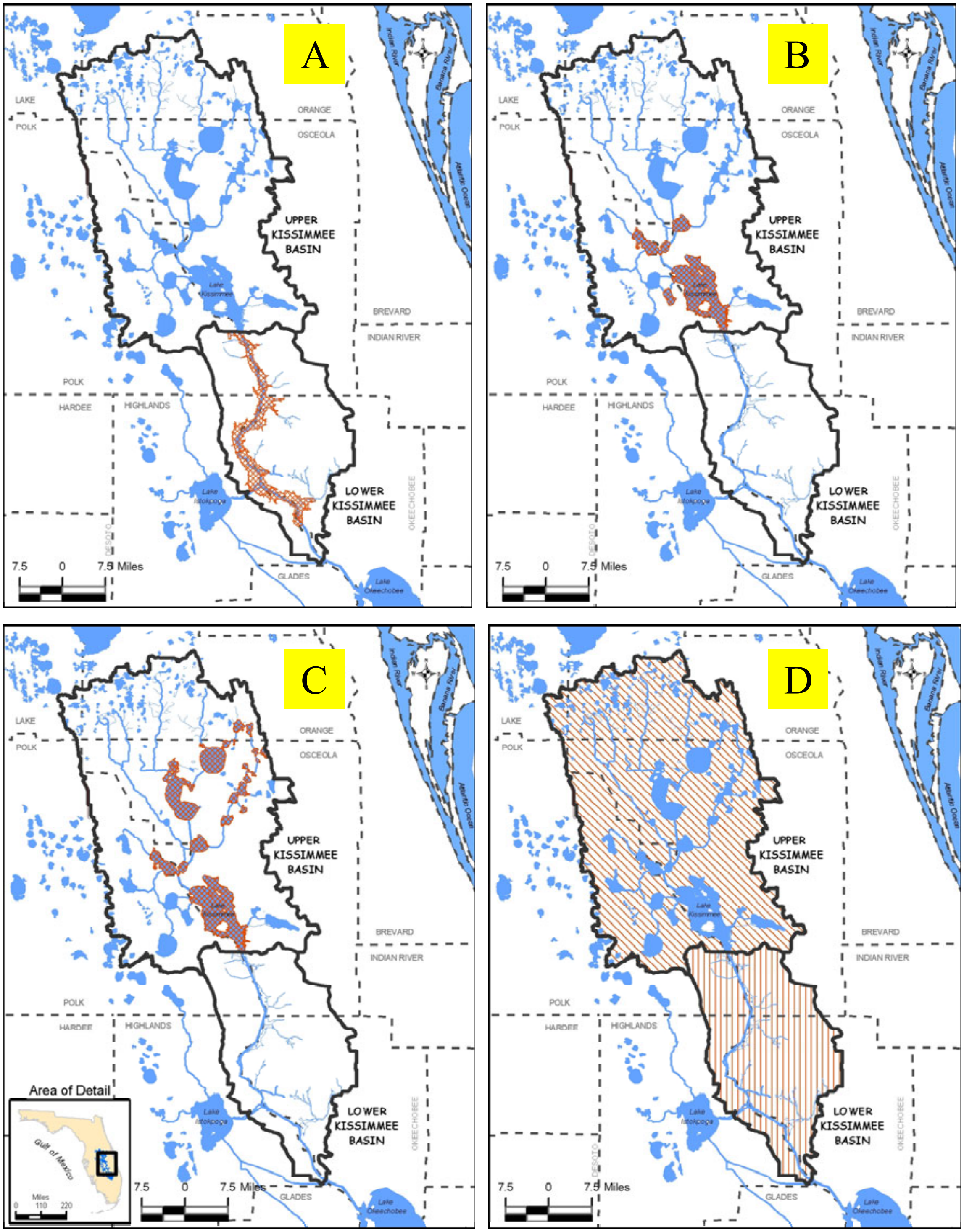

Figure 11-2. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin. Initiatives include the (A) Kissimmee River Restoration Project, (B) Kissimmee River Headwaters Revitalization Project, (C) Kissimmee Chain of Lakes Long-Term Management Plan, and (D) Kissimmee Basin Modeling and Operations Study.

CROSS-WATERSHED ACTIVITIES

Water-related issues with the potential for regional effects beyond the boundaries of individual basins and watersheds are a primary concern of the SFWMD, which works to ensure coordination among related projects. The Kissimmee Watershed Program works closely with other District groups and other agencies on watershed-level issues in regions that are hydrologically connected to the Kissimmee Basin, specifically to address watershed-scale flood control, water supply, water quality, and natural systems issues. The purpose of this section is to provide context for the District's approach to these far-reaching relationships across the Kissimmee Basin and other South Florida watersheds and ecosystems.

WATER MANAGEMENT AND OPERATIONS

Hydrologic conditions within the Kissimmee Basin are a function of natural hydrologic processes (e.g., rainfall, evapotranspiration) and management decisions that balance multiple needs. Much of the 50 inches of rainfall that falls annually over the basin is conveyed as surface water runoff through a network of canals that interconnects the KCOL and Lake Kissimmee (**Figure 11-1B**). Outflow from Lake Kissimmee enters channelized and reconstructed reaches of the Kissimmee River before continuing southward to Lake Okeechobee (**Figure 11-1A**).

The movement of water through this network is regulated by 13 water control structures managed by the SFWMD in accordance with regulations prescribed by the USACE. Nine structures and seven regulation schedules maintain lake and canal stages in the KCOL. Four structures manage stages along the Kissimmee River. (A fifth structure, S-65B, was demolished in 2000 as part of the KRRP). These canals and structures are part of the C&SF Project that provides flood control and water supply in the region. 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 at the structure and the time of year. The system also is operated to protect environmental values, especially ecological integrity in the Kissimmee River.

The operation of water control structures in the Kissimmee Basin can influence the timing and volume of flows to downstream ecosystems. Water management operations in the Kissimmee Basin must be coordinated with the rest of the South Florida system regulated by the C&SF Project. This coordination is achieved through several mechanisms. First, the District and USACE hold weekly conference calls that involve engineers and scientists. These interagency meetings review recent rainfall data, the climatological outlook, water levels and system operations, and the condition of the entire system. Based on this information, environmental recommendations can be made to modify operations within existing flexibility. Second, the flows in the Kissimmee River are formally considered by the inter-agency team in the decision-making process for managing flows out of Lake Okeechobee. Third, the emergency modeling team is used to guide operations during flood events to minimize impacts on natural systems. Fourth, periodic revisions of the stage regulation schedules used for the C&SF Project structures in the Kissimmee Basin consider the potential for impacts on downstream systems. The Kissimmee Basin Modeling and Operations Study (KBMOS) is an example of such a regulation schedule review.

WATERSHED WATER QUALITY

Lake Okeechobee Watershed

The Kissimmee Basin lies entirely within the Lake Okeechobee Watershed (Figure 10-3 in Chapter 10 of this volume) and is therefore within the geographic jurisdiction of the 2004 Lake Okeechobee Protection Act (LOPA), which requires that applicable water quality criteria be achieved and maintained in Lake Okeechobee and its tributary waters. The Lake Okeechobee Protection Plan (LOPP), authorized under the LOPA to address water quality issues, evaluates nutrient effects on the lake of the Kissimmee and other tributary basins. The LOPP includes among its four priority basins in the Lake Okeechobee Watershed the S-65D and S-65E sub-basins, which include the lowermost pools and still-channelized sections of the Kissimmee River. The LOPA requires that the LOPP be reevaluated every three years to determine if further phosphorus load reductions are needed to achieve the TMDL. The reevaluation report was completed in February 2007 and submitted to the legislature in March 2007. Monitoring and modeling of nutrient loading from the Kissimmee Basin to Lake Okeechobee are reported under LOPP (Lake Okeechobee Protection Plan) in Chapter 10 of this volume. Tables 10-2a, 10-2b, 10-3a, and 10-3b in Chapter 10 show discharge and nutrient loading for the Lower Kissimmee Regional Basin (between structures S-65 and S-65E) and the Upper Kissimmee Regional Basin (above structure S-65) for WY2007 and the LOPP's 1991-2005 baseline period. During WY2007, the entire Kissimmee Basin (both Upper and Lower regions) contributed 34 metric tons (mt) of phosphorus to Lake Okeechobee, or 17 percent of the lake's total incoming load. This amount is much less than the average annual loading of 169 mt during 1991–2005 (31 percent of the lake's total load) and was largely due to dry conditions in the Kissimmee Basin.

The Northern Everglades and Estuaries Protection Initiative was created in 2007 by the Florida legislature, which unanimously passed Senate Bill 392 (SB 392). This law expands the LOPP to encompass the Caloosahatchee and St. Lucie rivers and estuaries as well as the Lake Okeechobee watershed. The law requires the SFWMD, in coordination with collaborating agencies, to develop a technical plan for Phase II of the Lake Okeechobee Watershed Construction Project (LOWCP) by February 1, 2008, and River Watershed Protection Plans for the Caloosahatchee and St. Lucie watersheds by January 1, 2009. These plans will augment and enhance restoration currently under way in the remnant Everglades south of the lake.

The Northern Everglades Initiative provides a vehicle for meeting the Kissimmee Basin's portion of the TMDL for Lake Okeechobee. Kissimmee Watershed Program staff is participating in the planning effort for the Lake Okeechobee Phase II Technical Plan to help identify ongoing and additional projects within the Upper and Lower Kissimmee Basins that should be included in the plan. The Northern Everglades Initiative is described in greater detail in Chapter 7A of this volume.

Kissimmee Basin Water Quality

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

As shown in Table 10-1 (Chapter 10, this volume), the Kissimmee Basin is mostly rural. Land use in the Lower Kissimmee Basin is 60 percent agricultural and 5 percent urban, with most of the rest in natural areas. The Upper Kissimmee Basin is 27 percent agricultural and 20 percent urban (mainly the cities of Orlando, Kissimmee, St. Cloud and the Walt Disney World region). Most of the remaining area in the Upper Kissimmee Basin consists of lakes and land in a natural state. There are no municipal point sources of pollution in the Kissimmee Basin. Wastewater treatment effluents were diverted from the surface water system in the 1980s.

Osceola County is one of the fastest growing counties in Florida, so residential and commercial development is taking place on large tracts of agricultural land. Most of this land was used to graze cattle. However, the unit load for urban land uses (0.66 lbs P/acre) is not much different than the unit load for most agricultural land uses. For example, unit loading from pastures and rangeland ranges from 0.27 to 0.72 lbs/acre and citrus is 1.62 lbs/acre. Natural areas are 0.2 lbs/acre (SFWMD, FDEP, and FDACS, 2007).

Kissimmee Basin Total Maximum Daily Load Water Bodies

A Total Maximum Daily Load (TMDL) is a written, quantitative analysis and plan for attaining and maintaining water quality standards in all seasons for a specific water body and parameter. Thirty-four water bodies in the Kissimmee Basin are currently verified as impaired for one or more parameters including dissolved oxygen, nutrients, fecal coliforms, mercury (in fish tissue), lead, and copper (FDEP, 2006). The timeline for TMDL development is 2005–2011. The lead agency responsible for developing TMDLs for these impaired waters is the FDEP. Water bodies in the Kissimmee Basin that are listed as impaired are subject to Florida Class III water quality standards. Class III is a designated use for surface waters for recreation and propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

In the Lower Kissimmee Basin, sections of the Kissimmee River within the restoration project area are expected to experience improvement in water quality due to reestablishment of natural filtration, reaeration, and biological processes. Consequently, these areas of the Kissimmee Basin have been exempted from TMDL development according to rules established by the FDEP [Impaired Waters Rule, Chapter 62-303, Florida Administrative Code (F.A.C.)]. However, certain sections of the Lower Kissimmee Basin outside of the restoration project area have been identified as impaired and will have TMDLs developed for them. These areas include Blanket Bay Slough (Pool A sub-basin), Oak Creek (Pool C sub-basin), an upland watershed in the Pool D sub-basin, and the S-154C sub-basin below S-65E. TMDL development involves determining the maximum amount of a given pollutant that a water body can assimilate and still meet the applicable numeric or narrative water quality criterion for the pollutant. After the TMDL is determined, initial and detailed allocations will be established among point sources and nonpoint sources of nutrient loading in the basin. In addition to any point source and nonpoint sources, allocations of nutrient loadings also will be made to historical sources (e.g., the phosphorus-laden sediments within a water body) and upstream sources (e.g., those entering into an impaired water body from upstream lakes). In the Kissimmee Basin, any sites that are found to be contributing excessive nutrient inputs will probably be categorized as nonpoint sources of pollution. Implementation of nutrient loading allocations to nonpoint sources outside the authority of regulatory programs will require voluntary cooperation from dischargers to implement best management practices (BMPs).

Following establishment of TMDLs, the FDEP will develop Basin Management Action Plans (BMAPs) as a basis for implementing nutrient loading reductions. The BMAPs will be developed with extensive stakeholder input and will contain final allocations, strategies for meeting the allocations, schedules for implementation, funding mechanisms, applicable local ordinances, and other elements.

Best Management Practices for the Kissimmee Basin

The LOPP identifies areas for future legislative support to successfully implement the state's commitment to protect and restore Lake Okeechobee and to achieve its TMDL. Total phosphorus (TP) reductions and other water quality improvements are planned to be achieved through implementation of agricultural BMPs.

In the Upper Basin, the initially voluntary program is coordinated through the FDACS. The FDEP will coordinate implementation of nonagricultural, nonpoint source BMPs, such as septic systems and urban stormwater runoff. The BMPs are planned to be implemented beginning in 2009.

BMP implementation is currently on a voluntary basis in the Upper Basin, since it is outside the jurisdiction of the current Lake Okeechobee Works of the District Rule (Chapter 40E-61, F.A.C.) which limits the amount of phosphorus discharged from land parcels. However, based on recent changes to LOPA, the rule is being revised to include the Upper Kissimmee Basin. After this rule revision, landowners in the region will be required to implement BMPs. In the meantime, FDACS is working with agricultural landowners to voluntarily implement BMPs where water quality issues exist.

Mercury in the Kissimmee Basin

The bioaccumulation of mercury ranks as one of the major water quality issues in the Kissimmee Basin, along with nutrient transport, lake eutrophication, and deficiency of dissolved oxygen. The FDEP has verified 10 lakes in the Kissimmee Chain of Lakes as impaired for mercury in fish tissue (FDEP, 2006). In addition, the Florida Department of Health has issued fish consumption advisories for a variety of fish in the Kissimmee River and several lakes in the Kissimmee Chain of Lakes. Specific advisories, including fish species and eating guidelines, have been summarized for each water body (Florida Department of Health, 2006).

However, because mercury contamination is thought to result from atmospheric deposition originating from external sources such as fossil fuel power plants and municipal and medical waste incinerators, solutions to this problem are being addressed at state (FDEP) and national (USEPA) levels. The SFWMD is therefore not currently monitoring mercury in the Kissimmee Basin. Instead, the SFWMD is utilizing data obtained from the FWC. The FWC recently provided the SFWMD with data on total mercury concentrations in fish collected from 1987 to 2007. In the Kissimmee River, concentrations of total mercury in fish tissue of several species ranged from 0.046 to 1.10 μg/g (ppm) wet weight. Concentrations in fish caught from the Kissimmee Chain of Lakes ranged from zero to 2.31 μg/g. In WY2008, SFWMD staff will summarize these data by water body and fish species, and look for trends, to be reported in the 2009 SFER.

Ambient Water Quality Monitoring

Since 1981, the SFWMD has maintained a long-term water quality sampling program in five major lakes of the Kissimmee Chain (East Lake Tohopekaliga, Lake Tohopekaliga, Lake Cypress, Lake Hatchineha, and Lake Kissimmee) and three main tributaries to these lakes (Boggy Creek, Shingle Creek, and Reedy Creek). Sampling is conducted monthly for phosphorus, nitrogen, phytoplankton chlorophyll *a*, turbidity, water transparency, DO, and other constituents.

One station is sampled at each tributary and up to four stations are sampled in each lake. Since 1974, the SFWMD also has sampled water quality in C-38 and/or lateral tributaries and remnant and restored sections of river channel. Recently, the SFWMD has initiated additional sampling in the Kissimmee Basin under its Lake Okeechobee Watershed Assessment (LOWA) program. In the Upper Kissimmee Basin, 16 stations have been added at lake tributaries and water control structures (**Figure 11-1B**). In the Lower Kissimmee Basin, stations have been added at tributaries to the river.

BASIN ENVIRONMENTAL CONDITIONS – WATER YEAR 2007

This section focuses on environmental conditions in the Kissimmee Basin for Water Year 2007 (WY2007), including hydrologic conditions and operational actions taken to manage the Kissimmee Basin portion of the C&SF Project. Much of the information in this section is consistent with summaries provided at weekly interagency meetings to coordinate operational management of the entire C&SF Project.

Major events during WY2007 include the development of a severe drought over the basin and passage of a tropical storm. The organization of this section reflects the importance of rainfall as a driver of hydrologic conditions. The section includes discussions of temporal patterns in WY2007 (including onset of the drought, Tropical Storm Ernesto, the end of flow to the Kissimmee River (and the resumption of flow), and a summary of drought-related effects in the Kissimmee Basin. It should also be noted that due to the drought, WY2007 information is supplemented with more recent data on resumed flow conditions in the basin.

RAINFALL

During WY2007, hydrologic conditions and operations in the Kissimmee Basin were strongly influenced by below average rainfall that eventually resulted in drought conditions in the basin. In the Upper Basin, monthly rainfall was below the long-term average for every month except December and April (**Figure 11-3**). In the Lower Basin, August was the only month to exceed the long-term average in part because of rainfall associated with Tropical Storm Ernesto. In the Upper Basin, total rainfall for WY2007 was 34.48 inches, which is 69 percent of the long-term average (1971–2000) annual rainfall of 49.72 inches. The Lower Basin total for the water year was 33.64 inches, which was 66 percent of the long-term average of 51.32 inches. The wet season (June–October) totals were 21.9 inches for the Upper Basin and 24.93 inches for the Lower Basin. The dry season (November–May) totals were 12.58 inches for the Upper Basin and 8.91 inches in the Lower Basin. The wet season total for the Upper Basin and the dry season total for the Lower Basin both exceeded the 10-year dry return-period (Ali and Abtew, 1999).

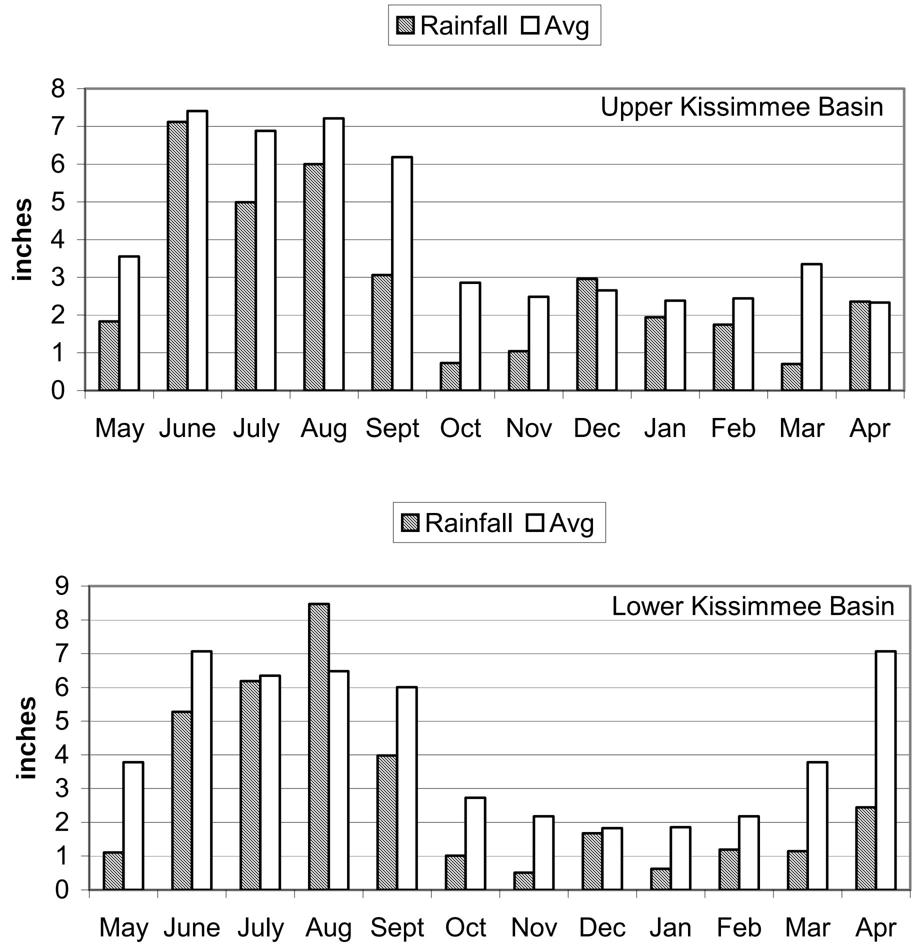

Figure 11-3. Monthly rainfall totals for WY2007 and average rainfall (1971–2000) in the Upper (top) and Lower (bottom) Kissimmee Basins (based on Chapter 2 of this volume).

WATER YEAR 2007 TEMPORAL PATTERNS

Aftermath of Wilma / Onset of Drought

By the end of the wet season in WY2006, rainfall, including that associated with Hurricane Wilma, filled the lakes in the Kissimmee Upper Basin to the high pool stage (highest stage allowed in the stage regulation schedule). The stage regulation schedules for the lakes in the upper Kissimmee basin attempt to mimic the natural seasonal fluctuation of water level although not the range of fluctuation, by making releases to lower water levels during the dry season (November–May) and allowing water levels to rise over wet season (June–October). By the beginning of WY2007, the spring recession of the stage regulation schedule was under way and all of the lakes were being lowered to the low pool stage (lowest point in the regulation schedule) by June 1. Water levels in Lake Tohopekaliga and East Lake Tohopekaliga were lowered according to the Zone B1 schedule (**Figure 11-4**). The Zone B1 line was developed to facilitate nesting by the endangered snail kite (*Rostrhamus sociabilis*). Snail kites typically nest over water, which provides a barrier to terrestrial predators. The Zone B1 schedule line begins the spring recession of water level earlier on these two lakes to provide the kites a cue that water levels would be changing and to allow for a more gradual recession rate so that nests would be less likely to be exposed to terrestrial predators before young kites could fledge. The development of the Zone B1/B2 schedule lines are described in more detail in last year's chapter (Williams et al., 2007) and were implemented as a onetime experiment in 2006. The District has continued to follow the Zone B1 line in 2007, which is consistent with the panel's recommendation that multiple years of data are necessary to evaluate the effectiveness of this management alternative. In Lake Kissimmee, water levels declined according to the schedule for releasing water to the Kissimmee River Restoration Project when lake stage was in Zone B of the regulation schedule (**Figure 11-5B**).

In the Lower Basin, the water levels in the Kissimmee River continued to decrease from a peak stage of 44.35 ft on November 2, 2005 that resulted from rainfall associated with Hurricane Wilma (**Figure 11-6**). Maintaining inflows at or above 1,000 cfs for much of the winter and early spring helped hold the water levels at Weir 1 near the bankfull stage. By the beginning of WY2007, releases from the Upper Basin had decreased to 400 to 500 cfs (**Figure 11-5C**). As inflow from the Upper Basin declined and water levels at Weir 1 fell below 37 ft, navigation issues were reported that were due to shallow water in the restored reach of the river.

On May 16, 2006, a recommendation was made to lower the headwater stage at S-65C to mimic seasonal fluctuation of water levels at the lower end of Pool C. Water level was lowered from 35.5 ft to 34 ft at a rate of 0.25 ft per week. The headwater stage had decreased to 34 ft in early June and remained there until it was allowed to increase because of rainfall in August.

In early August, discharge from the Upper Basin was reduced to minimal flows of 150 cfs. On August 8, water level in Lake Kissimmee fell below 48.5 ft and withdrawals of water from Lake Kissimmee were ended. Discharge of water to the Kissimmee River Restoration Project was maintained by passing water from Lake Tohopekaliga through Lakes Cypress, Hatchineha, and Kissimmee by matching the releases at S-65 to those at S-61 coming out of Lake Tohopekaliga. Discharge from the Upper Basin was reduced to minimal flows of approximately 150 cfs (**Figure 11-5C**).

The stage recession event that began with Hurricane Wilma ended on August 14, 2006, when the water levels at Weir 1 had dropped to 34.73 ft (**Figure 11-6**). For this event, water levels fell 9.62 ft at Weir 1 over 285 days, which is equivalent to a recession rate of 1.01 ft/30 days.

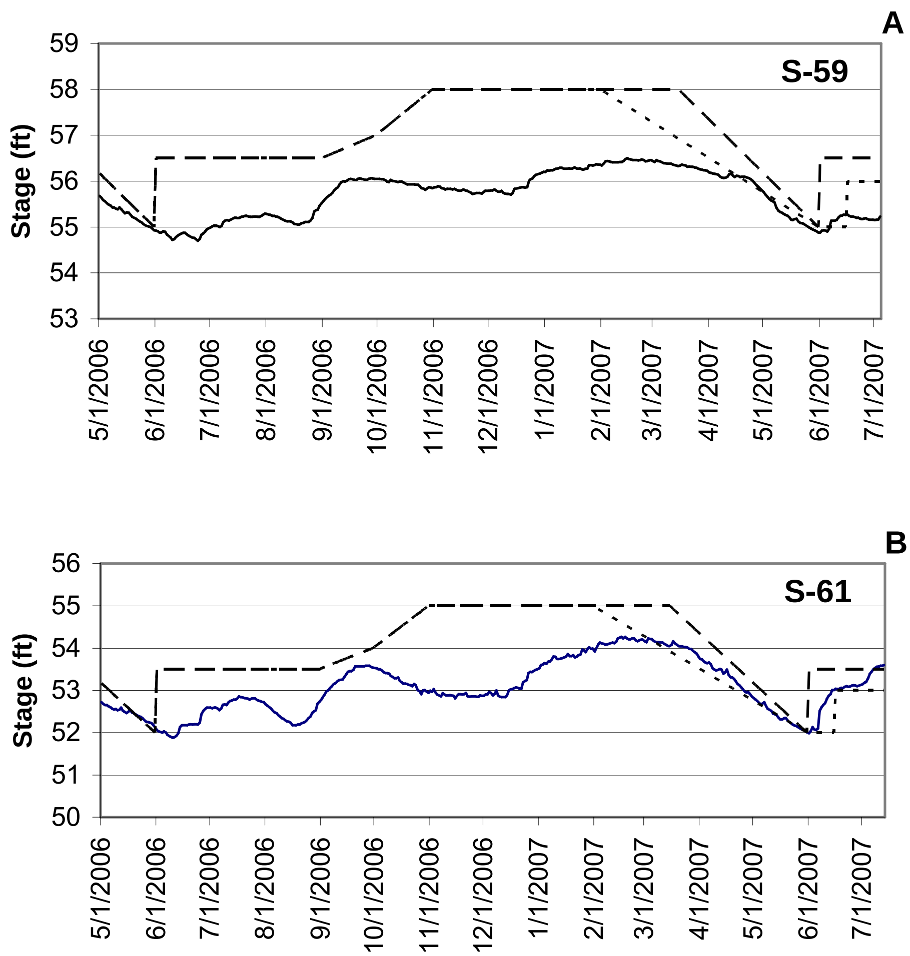

Figure 11-4. Stage (solid line), regulation schedule (dashed line), and Zone B1/B2 schedule (dotted line) for (A) S-59 on East Lake Tohopekaliga and (B) S-61 on Lake Tohopekaliga during WY2007.

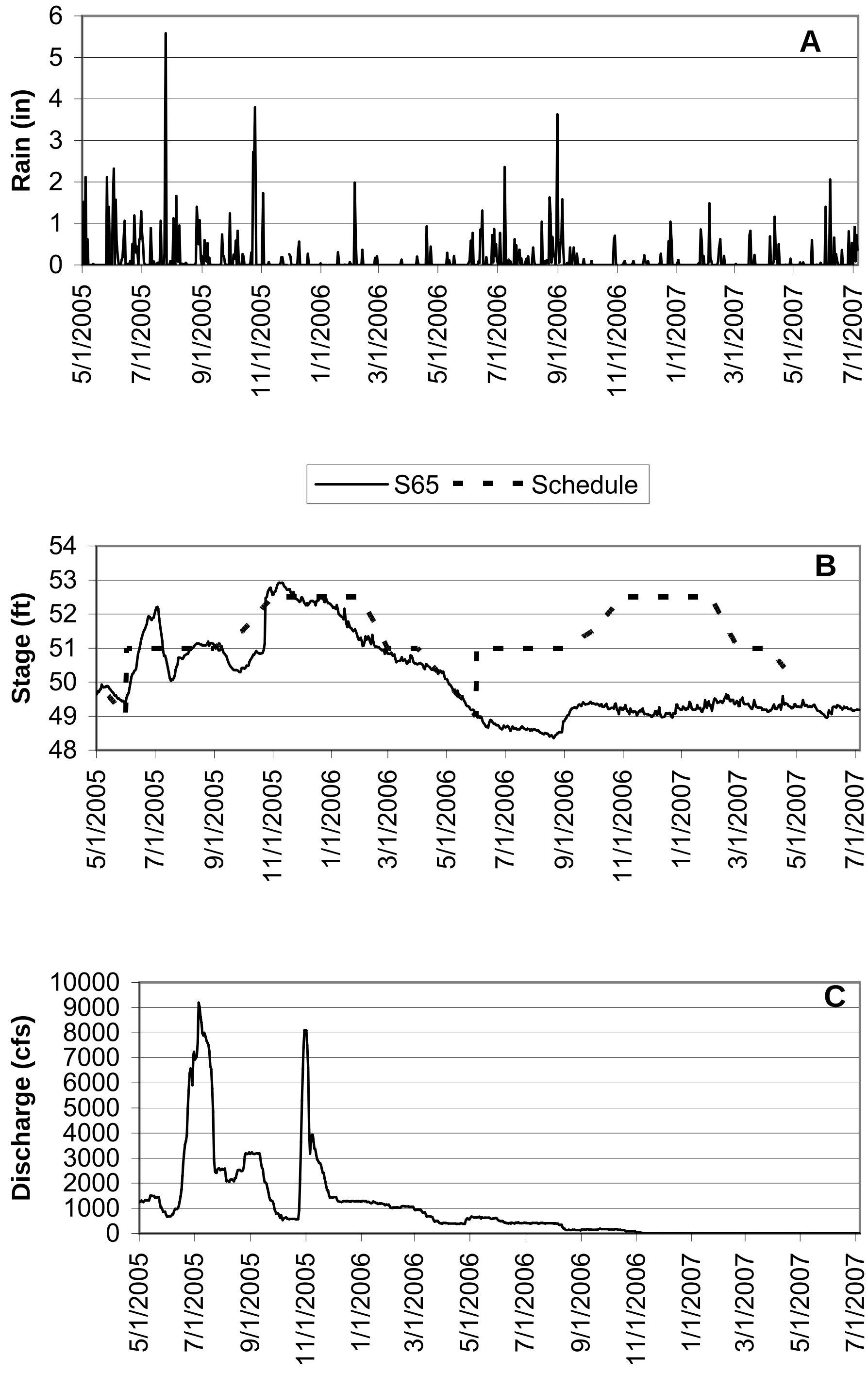

Figure 11-5. (A) Rainfall, (B) headwater stage, and (C) discharge at S-65 from onset of continuous flow in the Kissimmee River following Phase I of construction for the restoration project. The bold line in Panel B is the stage regulation schedule for S-65 and does not depict modifications to the schedule for the Lake Tohopekaliga drawdown, which are described in the text.

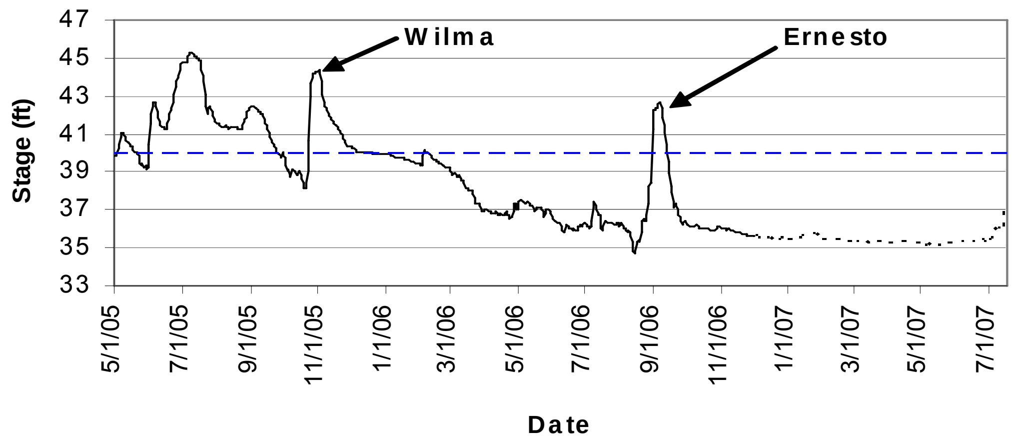

Figure 11-6. Water level at Weir 1 during WY2006 and WY2007. Dashed level indicates 40 ft NGVD, which approximates the bankfull stage at this location. The Weir 1 stage recorder was deactivated in December 2006, and missing values were replaced with data from a nearby river channel station RH4A24 (dotted line).

Tropical Storm Ernesto

Water levels began to rise slowly throughout the latter half of August. On August 30, 2006 Tropical Storm Ernesto passed over the basin. Rainfall associated with this storm helped raise water levels in the Upper Basin lakes (**Figures 11-4, 11-5B**). While inflow from Lake Kissimmee was not increased, the increased volume of water stored in the Upper Basin lakes helped extend the period of time that minimal releases to the Kissimmee River could be maintained.

At Weir 1, mean daily stage rose 2.80 ft between August 30 and August 31 due to rainfall and runoff associated with this storm (**Figure 11-6**). Water levels continued to rise at Weir 1 from local runoff. Water levels peaked at 42.64 ft on September 6, 2006, and then fell quickly. Water levels were only above approximate bankfull elevation for 14 days. The recession event that began on September 6 continued until water level had decreased to 35.11 ft on May 9, 2007. During this time period, water levels fell 7.53 ft over 245 days, which is equivalent to a recession rate of 0.92 ft/30 d.

One consequence of the rapid rise in water level was a decrease in the concentration of dissolved oxygen (**Figure 11-7C**). Mean daily values for DO began to fall from 3.35 mg/L on August 30, 2006, to < 1.0 mg/L on September 1, 2006 and to 0.1 mg/L on September 7, 2006. The DO concentration remained at low values for an extended period of time and did not exceed 1 mg/L until September 22, 2006, and 2 mg/L until October 3, 2006. Oxygen dynamics are described in more detail later in this chapter.

This rapid decline in the DO concentration contributed to a fish kill in Pool C. On September 5, several species of fish were observed showing overt signs of stress and breathing at the surface at several locations in the restored reach of the river. On September 6, a gross visual survey found approximately two thousand dead fish in both the restored reach of the Kissimmee River and in the downstream reach of the C-38 canal remaining in Pool C. On September 7, a more detailed survey noted that the fish kill included large numbers of largemouth bass (*Micropterus salmoides*) and sunfish species (*Lepomis* spp.), which have low tolerance to low concentrations of dissolved oxygen, as well as high numbers of relatively tolerant species, such as catfish (*Ameiurus* spp.) and blue tilapia (*Oreochromis aureus*). The greatest concentrations of dead fish were associated with areas that are highly influenced by floodplain runoff.

Standing crop estimates from baseline-period block net surveys indicated an average of 350 fish (of roughly the same species as represented in the kill) per 50 m x 50 m area of river channel. A rough estimate based on this channelized-period survey indicates densities of fish of 0.14 fish/m^2 prior to restoration, likely a conservative estimate for the restored-flow channel since it is for
non-flowing conditions. Extrapolated over the area of the Phase I restored river channel (~596,000 m^2), this gives an estimated total population size of 83,440 fish. By this estimate, the 2006 event killed approximately 2.4 percent of the population in the restored channel. It is unlikely that the kill initiated a trophic cascade because the fish that died belonged to different trophic levels.

For the Kissimmee River, a lower threshold for dissolved oxygen is being used as an indicator of stress than is used in other parts of the United States, based on evidence of geographic variation among populations of the same species (e.g., largemouth bass) to hypoxia tolerance (Doudoroff and Shumway, 1970; Smale and Rabeni, 1995). The threshold applied to the Kissimmee River is intended to track acute stress-related to rapid decreases in concentrations of dissolved oxygen below the normoxic condition (< 2mg/L) and not chronic, non-lethal problems that may occur at higher concentrations (Wendelaar Bonga, 1997). It is consistent with other studies in the region and in the Kissimmee River. Dissolved oxygen concentrations frequently fall below 5 mg/L in relatively pristine streams in the region, including streams in the Kissimmee Basin (Belanger et al., 1985; Colangelo and Jones, 2005). Because the low concentrations appear to be natural, Belanger et al. (1985) suggested that the 5 mg/L standard should be reviewed and possibly lowered. In other Florida studies, hypoxia has been defined as dissolved oxygen concentrations < 2 mg/L for a South Florida salt marsh (Timmerman and Chapman, 2004) and for the Kissimmee River (Furse et al., 1996). Additionally, many laboratory studies on fish response to hypoxia, including behavioral and physiological indicators, use 2.0 mg/L as the delineation between hypoxia and normoxia (Moss and Scott, 1961; Davis, 1975; Wendelaar Bonga, 1997). A radiotelemetry study of largemouth bass in the Kissimmee River found that in the summer and fall, bass occurred most often at locations where the concentration of DO was between 2 mg/L and 5 mg/L (Furse et al., 1996). A similar study of bluegill and black crappie in the Upper Mississippi River indicated the 2 mg/L threshold as the pivotal concentration of dissolved oxygen stimulating movement to areas of higher dissolved oxygen levels (Knights et al., 1995). Fontenot et al. (2001) found a strong positive relationship between dissolved oxygen levels and presence of larval sunfish and shad in backwaters of the Atchafalaya River basin, with larvae presence increasing immediately after local conditions shifted from hypoxic to normoxic (DO > 2.0 mg/L).

In Florida, fish kills can occur naturally during the wet season, when DO levels are at their seasonal low due to high water temperatures. They are especially likely when the concentration of oxygen decreases rapidly, which may occur when heavy and extended rain events follow a prolonged dry period. In the Kissimmee River, rainfall events may increase the movement of water with low DO concentrations from the channelized upstream reaches of the river (C-38 canal), from tributaries, and from runoff from the surrounding watershed. If decreases in DO concentration are slow enough, fish may physiologically acclimate. If water levels are high enough, fish may find refuge in portions of the floodplain with higher DO concentrations. The decrease in DO associated with Tropical Storm Ernesto happened quickly so that fish were not able to acclimate and when fish had limited access to the floodplain.

End of Flow

By September 2006, the Upper Basin had experienced several months of below-average rainfall (**Figure 11-3**), and most of the Upper Basin lakes were below regulation schedule. With the end of the wet season approaching, it was anticipated that lake stages would decrease to a level that would require ending releases from the Upper Basin to the Lower Basin. On September 12, a recommendation was made to raise the headwater stage at S-65C to hold more water in the area of the restoration project. This action was taken to hold water within the restored reach of the river because losses due to evapotranspiration would continue and because the water surface across the pool was expected to flatten in the absence of flow so that only portions of the river channel at elevations below the headwater stage at S-65C would be wet. Water levels were increased from 35.36 ft to 35.81 ft by September 18.

By the end of the wet season (October 31), none of the lakes had refilled to the high pool stage. Releases from Lake Tohopekaliga continued to be passed through Lake Kissimmee for the Kissimmee River Restoration Project until November 8, when the gates at S-61 on Lake Tohopekaliga and S-65 on Lake Kissimmee were closed. For the first time since inflow from the Upper Basin began in July 2001 following the completion of Phase I construction for the Kissimmee River Restoration Project, no water was released from the Upper Basin to the Kissimmee River (**Figure 11-5C**).

Releases from the Kissimmee River at S-65E to Lake Okeechobee ended earlier. Between October 16, 2006 and January 17, 2007 small releases were made at S-65E for short periods of time. After January 17, no releases were made at S-65E for the remainder of WY2007.

By the end of March 2007, snail kites were nesting on Lake Tohopekaliga. Eventually nests were also established on Lake Kissimmee. While snail kite activity was observed on East Lake Tohopekaliga, no nests were reported this year. Between 1992 and 2003, the number of snail kite nests in the Kissimmee Chain of Lakes (Kissimmee, Tohopekaliga, and East Lake Tohopekaliga) has varied between 0 and approximately 60 nests (Martin et al., 2003). Most nests have been on Tohopekaliga. In 2003, there were 17 nests on Lake Tohopekaliga, 12 nests on Lake Kissimmee, and one nest on East Lake Tohopekaliga. In WY2007, the highest concentration of snail kite nesting occurred in the upper Kissimmee Basin because of drought-related low water levels elsewhere in their range. At the beginning of the nesting season, the water levels in East Lake Tohopekaliga (**Figure 11-4A**), Lake Tohopekaliga (**Figure 11-4B**) and Lake Kissimmee (**Figure 11-5B**) were fluctuating slightly in response to changes in rainfall. Because lake levels were well below the schedule, releases from East Lake Tohopekaliga and Lake Tohopekaliga did not begin until later in the nesting season, when water levels intersected the Zone B1 line (**Figure 11-4**). The continued use of the Zone B1 regulation schedule line is consistent with one of the peer review panel's recommendations from last year.

Germination and growth of native submersed aquatic vegetation (SAV), such as eelgrass (*Valisneria*) and Illinois pondweed (*Potomegeton illinoensis*), has occurred in some areas of Lake Tohopekaliga and in Lakes Kissimmee, Hatchineha, and Cypress and may be in response to prolonged low water levels or to the discontinuation of treatments of a large area of some of these lakes at a high rate with the herbicide fluridone (Tim Coughlin, Florida Freshwater Fish and Wildlife Conservation Commission, personal communication). Fluridone is an herbicide that has been used to treat large areas of the exotic plant *Hydilla verticillata*. Its use has been suspended in these lakes because it appears that local populations of hydrilla have developed fluridone resistance. Fluridone has the potential to impact non-target plant species; a recent summit on hydrilla concluded that research is needed to quantify the impacts of hydrilla management on non-target plant species (Netherland et al., 2005). Hydrilla treatment is discussed in more detail in Chapter 9 of this volume. Because of staff limitations and other priorities, the District is not currently planning a study specifically to follow this SAV response in the lakes.

In the absence of inflow, the water in Pool C collected behind the S-65C structure to create a flat water surface across the pool. The area affected includes the Phase I area for the Kissimmee River Restoration Project. Difference in water levels between the tailwater stage at S-65A and the headwater at S-65C decreased to approximately 0.5 ft. These structures are over 20 miles apart (Abtew, 1992). When inflows ended on November 8, 2006 the headwater stage at S-65C was 35.69 ft. It decreased by 0.95 ft to 34.74 ft on May 1, 2007, before water levels began to rise again from rainfall. The decrease in water levels was due to evapotranspiration, seepage, and operation of the lock to allow boat traffic.

In the Lower Basin, minimal flows of at least 150 cfs were maintained through the end of October 2006, which marks the end of the period considered critical for low concentrations of dissolved oxygen because of warmer temperature. After inflow from the Upper Basin ended on November 8, 2006, dissolved oxygen concentrations remained fairly high because of cooler temperatures throughout the winter months (**Figure 11-7C)**. Dissolved oxygen concentrations began to fall in late spring and early summer as water temperature increased. At this time, additional DO sensors were deployed at both stations and maintained until DO concentrations were no longer critical. By July 11, 2007 a vertical gradient of oxygen concentration developed in the restored river channel. At PC62, the concentration of dissolved oxygen was 3 mg/L near the surface and 0.6 mg/L near the bottom of the channel (surface reading taken at 0.5 m and bottom reading taken within 0.5 m of the channel bottom at 1100 hrs on July 11, 2007).

The end of inflow from the Upper Basin was preceded by an extended period of low flow, which did not exceed bankfull stage at Weir 1 (**Figure 11-7**). Only a small portion of the floodplain was inundated. This inundated area was located in lower Pool C and was at ground elevations below the headwater stage at the S-65C structure. This greatly limited the amount of floodplain with appropriate water depths for wading bird foraging during the WY2007 dry season. Consequently, foraging wading birds occurred at low densities on the floodplain in WY2007 relative to the previous year (**Figure 11-7D**). Mean density for the dry season (December–May) for the floodplain in the area of Phase I was 11 ± 2 birds/km², which was similar to that observed before restoration (14.3 ± 3.4 birds/km²) (Williams et al., 2005). The dry season of WY2007 was the first since Phase I completion that the restoration expectation of 30.6 wading birds/km² was not met. The wading bird results are discussed more fully in the *Birds* section below.

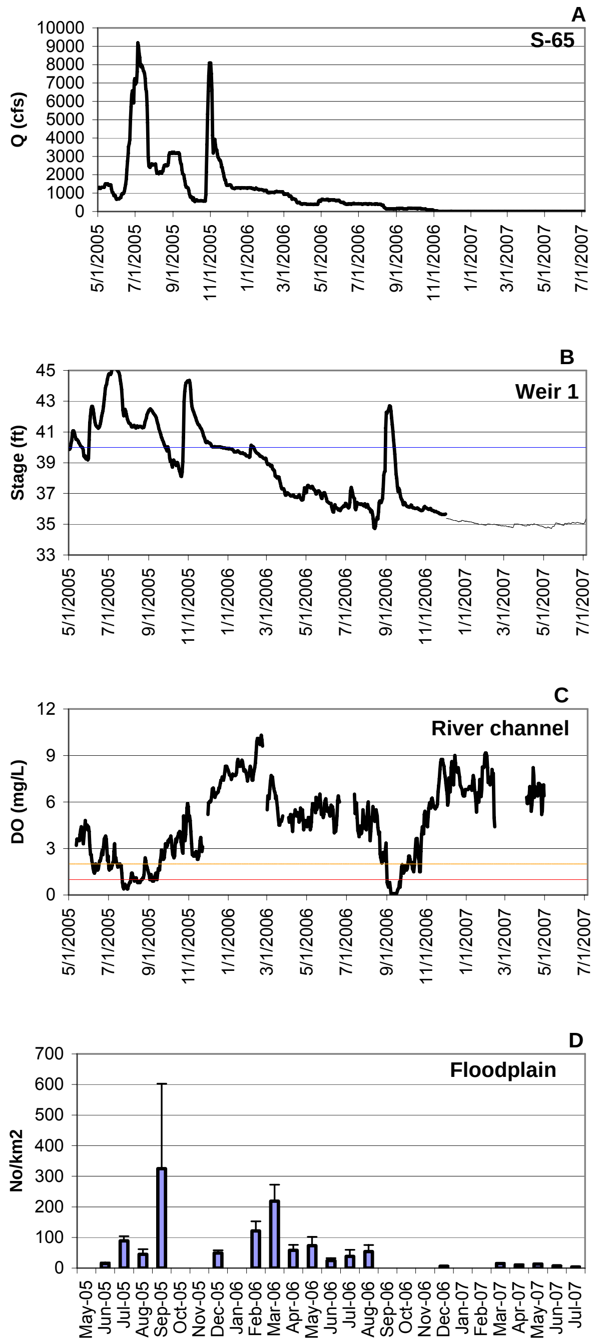

Figure 11-7. Effect of drought on (A) outflow from the upper basin, (B) water levels in the area of the restoration project, (C) dissolved oxygen in the reconnected river channel, and (D) density of long-legged wading birds (excluding cattle egrets) on the Phase I floodplain. Water levels in panel B are for Weir 1 through December 2, 2006, when this station was deactivated because of Phase IVA backfilling. The remainder of the trace is from a nearby station RH4A24. The dashed line in Panel B denotes bankfull stage. Dissolved oxygen measurements are mean daily values (n = 96 measurements/day at 15 minute intervals). Note that wading bird data was missing for May, October, and November 2005; January, September, October, and November 2006; and January and February 2007.

Resumption of Flow

As rainfall continued through the dry season and began to increase during the wet season, the basin began to generate runoff to the tributaries that drain into the Upper Basin lakes. Increased flow in Shingle Creek raised water levels in Lake Tohopekaliga, which resulted in releases to Lakes Cypress, Hatchineha, and Kissimmee. On July 18, discharges from Lake Kissimmee at S-65 were resumed. This action ended a 252-day period of no inflow from the Upper Basin. Minimal flows were made according to the regulation schedule for Lake Kissimmee stage.

Water levels at S-65C had fallen to 34.74 ft by May 12 before starting to rise in response to rainfall. This represented a decrease of 0.95 ft in water levels from the stage of 35.69 ft on November 8, when flow ended.

On July 21, releases were resumed from S-65E to Lake Okeechobee. For the 273-day period between October 17, 2006 and July 16, 2007, there were 244 days without flow at S-65E and 29 days of low flow averaging 49 cfs.

There was a 180-day period without flow, from January 18 to July 16, 2007.

SUMMARY OF DROUGHT EFFECTS

Droughts occur periodically in South Florida. These extended periods of below-average rainfall can directly influence water levels and flow. Drought conditions during WY2007 had both positive and negative effects on the environment including the following:

1. Lakes in the Upper Basin did not refill by the end of the wet season but did not go outside the range of water levels allowed in stage regulation schedules.
2. Low water levels did cause navigation issues, particularly for the two fish camps along the C-37 canal, when Lake Kissimmee was at low pool and at the upper reach of the Kissimmee River Restoration Project under low flow conditions.
3. Prolonged low water levels may have allowed germination and growth of native submersed aquatic vegetation, such as eelgrass (*Valisneria* sp.) and Illinois pondweed (*Potomegeton illinoensis*), in Lake Tohopekaliga and in Lakes Kissimmee, Hatchineha, and Cypress.
4. The Kissimmee River was without inflow from the Upper Basin for 252 days.
5. After flow ceased, the concentration of dissolved oxygen in the river channel remained relatively high until it fell below thresholds of concern in July 2007 because of the lack of flow.
6. Minimal flows and lack of water level fluctuation resulted in much of the floodplain being dry.
7. Inappropriate water depths for foraging resulted in the lowest densities of wading birds using the floodplain since completion of Phase I.

PROJECT UPDATES

This section provides project and planning updates on the Kissimmee River Restoration Evaluation Program, the Kissimmee Basin Modeling and Operations Study, the Kissimmee Chain of Lakes Long-Term Management Plan, and several restoration projects within the Kissimmee Basin.

KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM: PHASE I RESPONSE UPDATES

With completion of KRRP Phase I construction in early 2001, restoration evaluation monitoring of the Phase I area entered the post-construction period. The first of four restoration construction stages, Phase I is being monitored by Kissimmee Watershed Program scientists under the KRREP, as will selected successive phases of restoration (Williams et al., 2007; Bousquin et al., 2005a). Many of the Phase I studies (which include studies of hydrology, geomorphology, water quality, river channel and floodplain vegetation, benthic and other aquatic invertebrates, herpetofauna, fish, and birds) are already indicating significant changes consistent with those predicted by the expectations (performance measures) developed for the KRREP (Anderson et al., 2005b), and, as new data became available, results have been reported in previous SFER chapters. These studies collected data prior to restoration construction for comparison with data from the restored system, in order to evaluate the success of the project. This year, aspects of three of the restoration evaluation studies (hydrology, dissolved oxygen, and wading birds) are being reported in the drought impacts discussion in the *Basin Environmental Conditions* section. Data for these studies are collected monthly or more frequently; they are therefore well placed to show the effects of this extreme event.

This year, several projects are reporting newly available data from the Phase I area: two water quality studies (dissolved oxygen and phosphorus monitoring), will report results for WY2007. Data are also available on floodplain vegetation responses from recently completed mapping of 2003 aerial photography; wading bird nesting and foraging use of the floodplain are also reported.

Many of the restoration expectations are dependent on full implementation of a revised water regulation schedule under the Headwaters Revitalization Project (USACE, 1996), which will more closely simulate historic hydrology than is currently possible under the present regulation schedule. The Headwaters Revitalization Project, which will provide the necessary storage volume in the KCOL to provide the water needed for the Kissimmee River Restoration, is scheduled to be implemented in 2012.

A comprehensive update of the status of initial responses of the river to Phase I restoration was published in the 2005 SFER – Volume I, Chapter 11, with further updates published in 2006 and 2007. Combined results for a suite of interrelated river channel studies were presented in the 2006 SFER. The sections presented below provide the current status of Phase I evaluation studies that have been updated since the 2007 SFER.

Dissolved Oxygen

DO was monitored continuously at a depth of approximately 1 m in two restored river channel stations in Pool C (KRBN and PC62, **Figure 11-1A**). Sampled river channels were approximately 20–30 m wide and 2–3 m deep. DO also was sampled monthly within seven remnant river runs in Pools A and C. DO data were not collected prior to channelization; therefore, the reference condition was derived from data on seven free-flowing, blackwater streams in South Florida. Each stream had at least 11 samples collected over a minimum of one year and some streams were sampled for more than 10 years. The mean daytime 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 11-8**). Since continuous data were not available for the reference streams, a metric for minimum daily DO concentration was not developed. 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 (< 0.2 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 11-8**). DO concentrations exceeded 2 mg/L for 22 percent of the baseline period, and 5 mg/L for 6 percent of this period.

These reference and baseline data were used to develop the following expectations (performance measures) to evaluate changes in DO as restoration proceeds:

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

Following completion of the first phase of construction, DO concentrations within the restoration area averaged 3.1 mg/L during the wet season and 6.2 mg/L during the dry season (**Figure 11-8**). Post-construction DO concentrations in the control area (Pool A) averaged 1.5 and 3.2 mg/L during the wet and dry seasons, respectively (**Figure 11-8**). Mean annual DO concentrations in the restoration area (Pool C) increased from < 3.0 mg/L before construction to > 6 mg/L in WY2007 (**Figure 11-9)**. Mean daily water column DO concentrations were > 2.0 mg/L for 87 percent of the time in WY2007. From May 1, 2006 until August 30, 2006, DO concentrations were greater than 2 mg/L and usually greater than 3.5 mg/L (**Figure 11-10**). On August 31, 2006, DO concentrations plummeted with the passage of Tropical Storm Ernesto over Central Florida (see the *Basin Environmental Conditions* section for more detail on the environmental effects of Tropical Storm Ernesto). Low DO concentrations during this time period are believed to be a result of a combination of factors including inflow of DO-depleted water from the channelized upstream reach of the river (Pool A), increased organic matter-laden runoff from tributaries and the floodplain (causing increased biochemical oxygen demand), and sloughing of oxygen-producing periphyton and phytoplankton under high river channel flow velocities. DO concentrations remained below 1 mg/L until September 22, 2006, when concentrations began to rebound. By the beginning of November, 2006, DO concentrations had increased to > 3 mg/L and remained so through the end of WY2007.

On November 8, 2006 the water control gates at S-65 (the outlet of Lake Kissimmee) were closed due to low lake levels in the Kissimmee Chain of Lakes, cutting off flow to the Kissimmee River. Although DO concentrations in the Kissimmee River are affected by re-aeration through turbulent flow, DO concentrations remained well above 5 mg/L throughout most of the dry season (**Figure 11-10**).

The restoration expectations for DO concentrations in the restored river channel are to be evaluated after implementation of the Kissimmee River Headwaters Revitalization Project regulation schedule. However, at least two of the four metrics used to evaluate DO response were met under the interim regulation schedule during WY2007.

In FY2008, four additional DO monitoring stations will be installed as part of the Phase II/III Integrated Study (**Figure 11-1A**). These stations will collect DO data at 15-minute intervals at 0.5 – 1.0 m depth and within 0.5 m of the channel bottom. Data from these stations will provide crucial information on water column and bottom water diel DO concentrations.

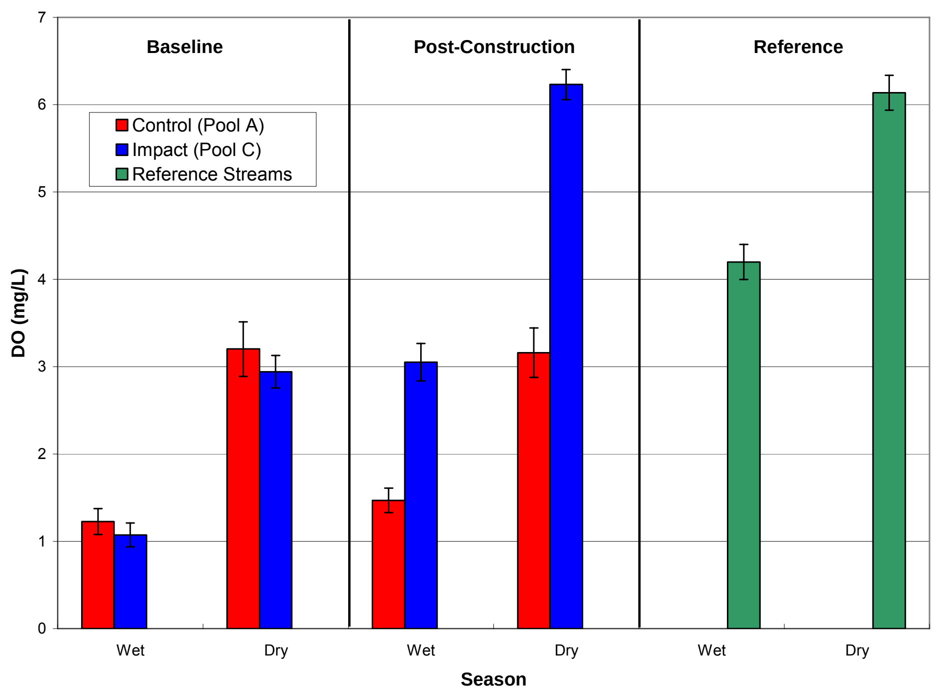

Figure 11-8. Mean (± S.E.) dissolved oxygen (DO) concentrations (mg/L) in reference streams and control and impact areas during the wet and dry season, before and after Phase I construction.

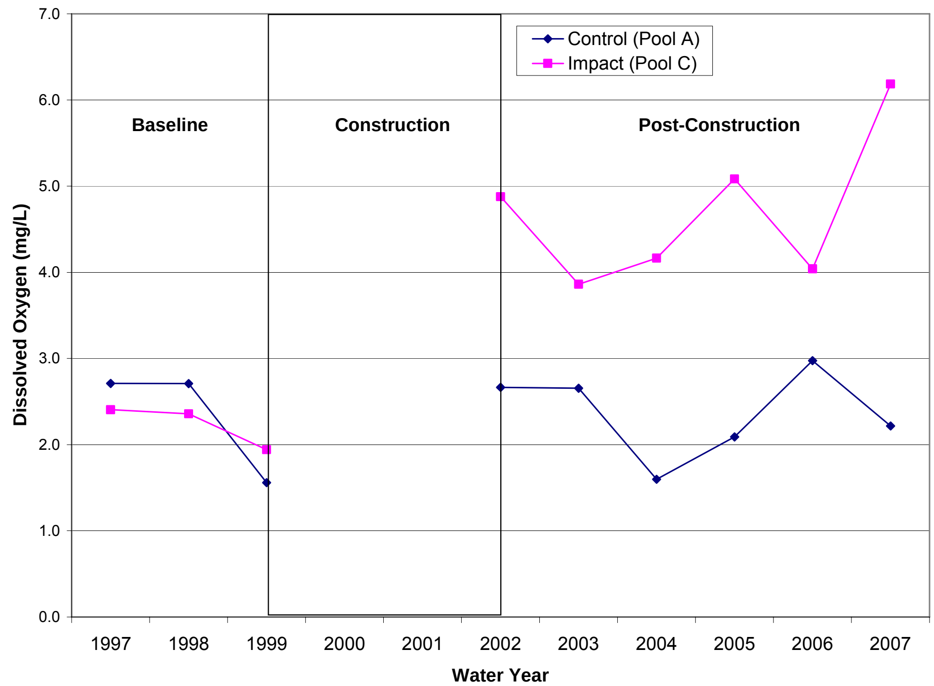

Figure 11-9. Mean DO concentrations (mg/L) in the Kissimmee River for each water year during the baseline and post-construction period.

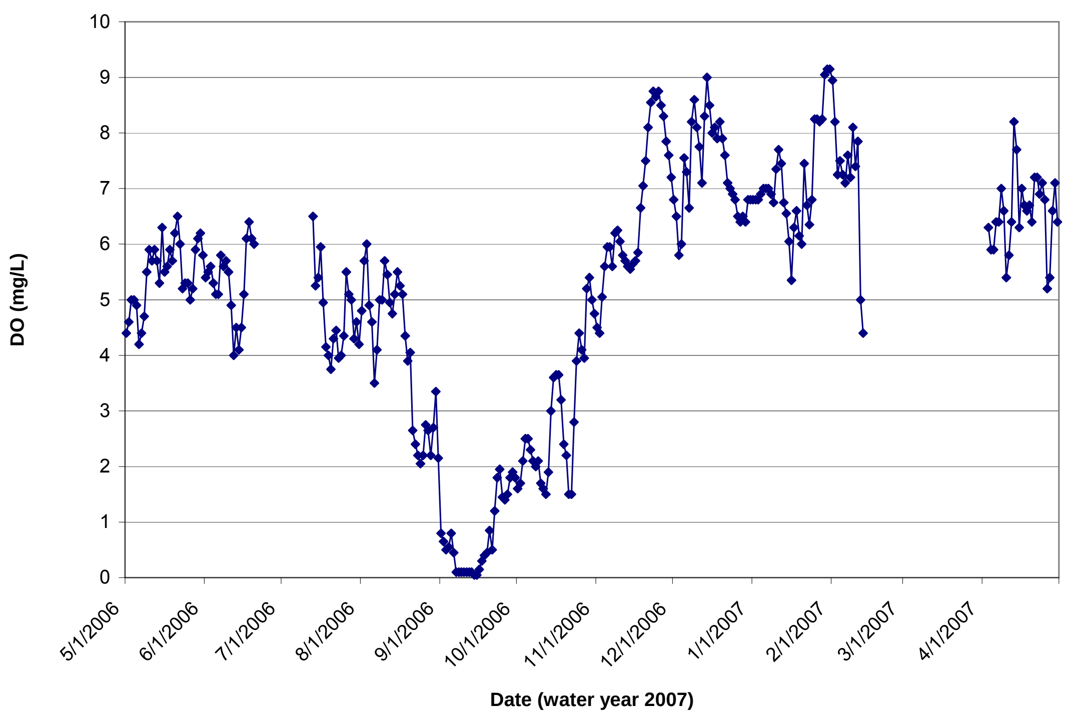

Figure 11-10. Mean daily DO concentrations in the restored river channel during WY2007.

Phosphorus

The Kissimmee River is Lake Okeechobee's largest tributary and contributes 31 percent of the lake's phosphorus input (Table 10-2b in Chapter 10). 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 opportunities for detention and assimilation in floodplain wetlands. While Pools A, B, and C (**Figure 11-1A**) are not major exporters of phosphorus, restoration of the river and floodplain may eventually promote lower inputs from these pools and reduced loading from the headwater lakes in the Upper Kissimmee Basin. 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 ditches and removal of cattle from the floodplain also may help to lower TP loads from lateral sources.

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

Calendar years 1974 through 1995, during which the C-38 canal was intact, were chosen as the baseline period of record. During those 22 years, TP loading averaged 51 metric tons per year (mt y^{-1}) at S-65C and 83 mt y^{-1} at S-65D (**Figure 11-12**). These amounts comprised 43 and 71 percent of the average load at S-65E, respectively. Annual FWM TP concentrations averaged 53 parts per billion (ppb) at S-65C (ranged from 33–87 ppb), and 78 ppb at S-65D (ranged from 47–141 ppb) (**Figure 11-12**). Concentrations were greater during years of lowest flow (1981 and 1985). At S-65, upstream of the restoration project area, the mean loading rate was 35 mt y^{-1} (**Figure 11-11**) and the FWM TP concentration was 43 ppb (**Figure 11-12**).

Reference, pre-channelization conditions for TP loads and concentrations in the Kissimmee River cannot be determined with any certainty because phosphorus was not routinely monitored before channelization. Nevertheless, knowledge of former characteristics of the river, 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 when a more natural river-floodplain hydroperiod and stable wetland ecosystem become established. These conditions will be achieved after the Headwaters Revitalization Project regulation schedule is implemented in 2012. In the meantime, TP concentrations may increase periodically as the nutrient is released from former pastures and the floodplain transitions from terrestrial to wetland vegetation.

Under the interim regulation schedule, the floodplain in the Phase I restoration area has been inundated intermittently. Observational data and 2003 aerial photography indicate that wetland vegetation re-colonized the Phase I area to some extent following restoration (see "Floodplain Vegetation Responses" later in this chapter). However, the current (interim) regulation schedule has not allowed for the seasonal pattern of floodplain inundation that is expected when the Headwaters Revitalization Project regulation schedule is implemented. Thus, in the transitional years since Phase I was completed, the floodplain is unlikely to have assimilated phosphorus at its highest efficiency. This was especially true in WY2007, when there was very little hydrologic interaction between the river channel and floodplain due to drought conditions. The river overflowed its banks only once for a two-week period in September 2006 in response to Tropical Storm Ernesto. During the rest of the water year, most of the floodplain was dry.

Evaluation of phosphorus loading trends on a year-to-year basis is difficult because so much depends on the amount of discharge through the system. Until WY2007, discharge and loads at the C-38 structures were generally greater than during the 1974–1995 baseline period. Loads were much lower in the drought year of WY2007 (**Figure 11-11**). Most of the loading occurred during May–September. Beginning in November 2006, S-65 was closed and discharge through the upper pools declined to virtually zero. Low levels of discharge at S-65D and S-65E continued through the winter.

In contrast, FWM TP concentrations remained relatively high in WY2007. Concentrations at all structures have been higher since the baseline period, but were especially high at S-65C and S-65D during WY2007 (**Figure 11-12**). The highest concentrations were observed in September 2006 and coincide with the pulse of discharge associated with Tropical Storm Ernesto. These high concentrations are consistent with observations during previous drought years, and possibly reflect pulses of runoff following dry periods and a greater influence of upland runoff from lateral tributaries (and less influence from headwater discharge), especially in the lower pools. At the juncture between the Upper and Lower Basins, near the outlet of Lake Kissimmee to the Kissimmee River, an attempt was made in WY2007 to monitor a possible source of high-nutrient runoff. However opportunities to collect runoff were limited during the drought; access to private property was also an issue. Consequently, no water quality samples were collected from this site in WY2007. Expansion of the jurisdictional area of the SFWMD Works of the District program in FY2009 will allow access to sampling on this property.

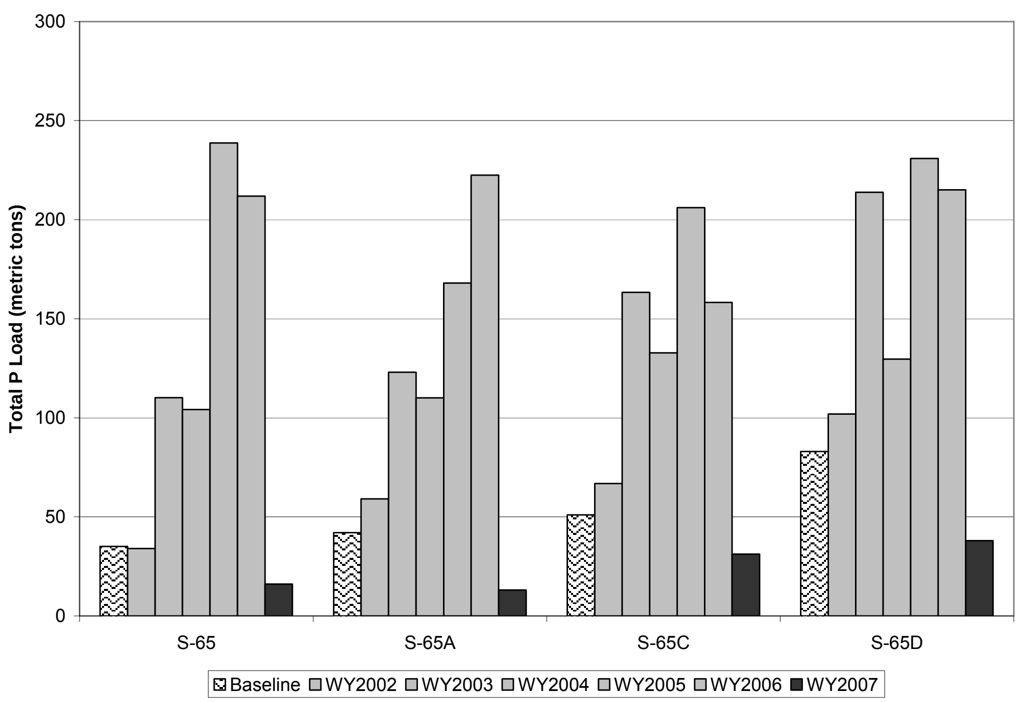

Figure 11-11. Annual total phosphorus (TP) loads (metric tons or mt) from C-38 structures in comparison to baseline (1974-1995) loads.

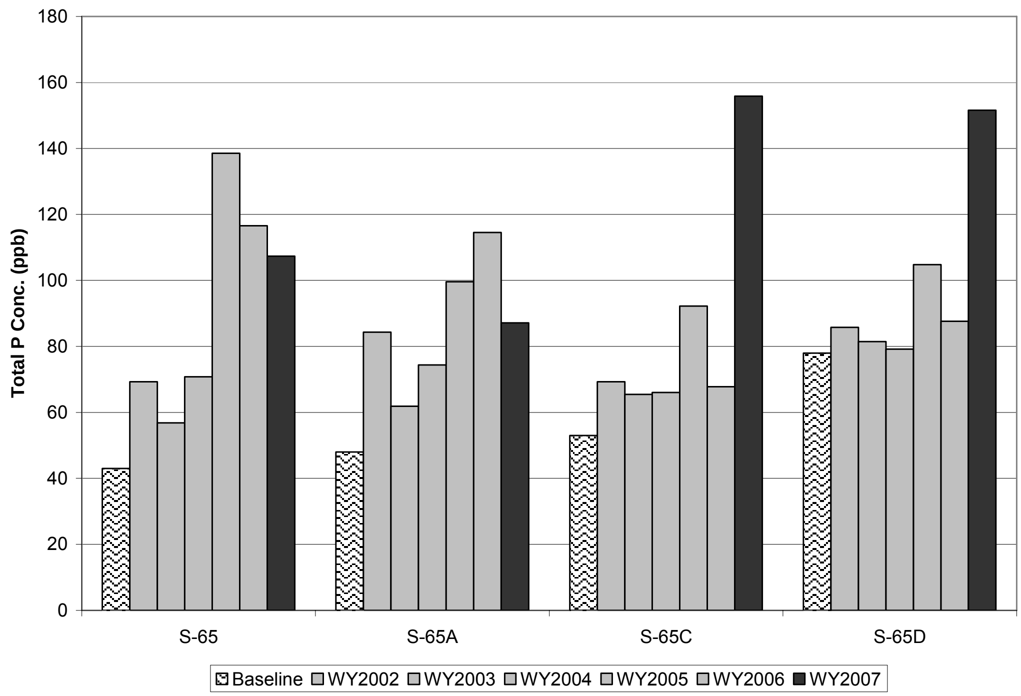

Figure 11-12. Annual flow-weighted mean (FWM) TP concentrations (parts per billion, or ppb) at C-38 structures in comparison to baseline (1974–1995) concentrations.

While the Kissimmee River Restoration Project was not designed as a phosphorus-removal project, there is considerable interest in how restoration of floodplain wetlands will influence the retention of phosphorus within the Kissimmee Basin. In the current fiscal year, SFWMD staff is working to identify models, existing information to support these models, and additional data needs for assessing the restoration project's effect on phosphorus movement and retention and developing more reliable and defendable estimates of future phosphorus loading. A plan that describes selected approaches for modeling and monitoring will be developed in WY2008.

One question that has been asked with regard to phosphorus loading concerns low DO (hypoxia) in the bottom sediment of the river channel and C-38 and its effect on phosphorus biogeochemistry. Hypoxia can result in the release of phosphorus bound in sediment, which can then enter the water stream. As discussed in the previous section on dissolved oxygen, the river channel and C-38 commonly exhibited low DO concentrations before the first phase of restoration, and still has experienced some periods of low DO after that. However, the SFWMD has not examined the effect of these oxygen sags on phosphorus release from channel sediment. Compared to the amount of phosphorus transported downstream from sources throughout the basin, the amount of phosphorus released from river channel sediment should be relatively minor, if not insignificant. However, this supposition may be examined further in the upcoming evaluation of Phase II/III of the restoration project. Staff is discussing a proposed study of phosphorus assimilation and release as wetlands are restored in the Pool D floodplain and flow is diverted to remnant channels. Release of P from channel sediment will be considered for inclusion in that study.

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

River Metabolism

Gross primary productivity (GPP), community respiration (CR) and net daily metabolism (GPP-CR) on the Kissimmee River were estimated before and after the first phase of restoration. Dissolved oxygen measurements taken within the river channel were used to estimate metabolism. Metabolism estimates were used to evaluate ecosystem level changes in the system after flow was restored. Gross primary productivity was higher and more variable after flow was restored to the river, indicating a change toward a more dynamic, productive, river system (**Figure 11-13**). The main factor contributing to an increase in GPP was reduction in shading of the water column by floating and mat-forming aquatic macrophytes, which allowed for increased algal production. Community respiration rates also increased. Post-construction net daily metabolism values suggested that the connection between the river and its floodplain has been at least partially restored. After flow was restored to the river channel, metabolism estimates were generally similar to those measured on the Ogeechee River, a relatively pristine, low-gradient, blackwater river (similar to the Kissimmee River) in Georgia. For additional information see Colangelo, 2007.

Floodplain Vegetation Responses: 2003 Vegetation Mapping Results

A vegetation map based on 2003 aerial imagery of the Kissimmee River floodplain (two years following completion of Phase I restoration construction) was completed in 2006. The Phase I area of this map was compared with previous maps of floodplain vegetation from 1952 (pre-channelization) and 1974 (three years following completion of channelization) to evaluate initial floodplain vegetation responses to Phase I restoration (**Figure 11-13**).

The results indicate that reestablishment of wetland plant communities occurred rapidly in the Phase I area. Wetland vegetation overall increased from less than 900 hectares in 1974 (23 percent of the Phase I floodplain) to over 2,500 hectares in 2003 (66 percent) (**Tables 11-2** and **11-3**). Wet prairie vegetation more than doubled in area between 1974 and 2003, and wetland shrub communities expanded sevenfold (**Tables 11-2** and **11-3, Figure 11-14**). Area of broadleaf marsh, the dominant wetland vegetation type prior to channelization, decreased slightly from its pre-restoration coverage (**Tables 11-1** and **11-2; Figures 11-14** and **11-15**).

Historically, broadleaf marshes occurred in relatively deep, central portions of the floodplain where hydroperiods were prolonged, while wet prairie occurred on the periphery of the floodplain where inundation was shorter and shallower (Carnal and Bousquin, 2005). Although continuous flow was maintained in river channels and intermittent inundation of the floodplain occurred during the two years that elapsed between completion of Phase I and the 2003 imagery, historic hydroperiods will be much more closely approximated when the Headwaters Revitalization water regulation schedule for the headwaters lakes is implemented in 2012. The changes in hydrology that will follow implementation of the headwaters schedule are expected to drive further changes

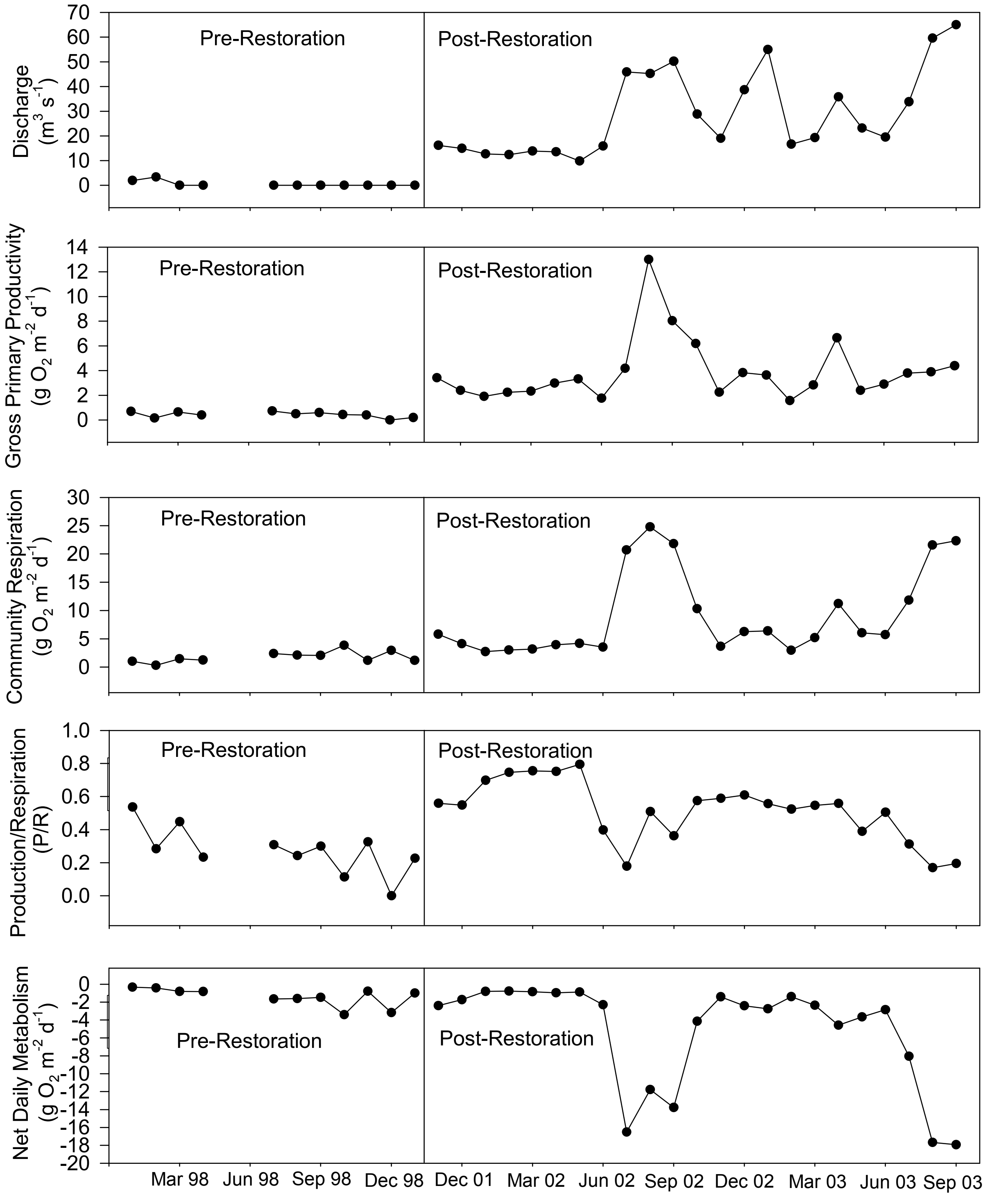

Figure 11-13. Mean monthly discharge, gross primary productivity, community respiration, production to respiration ratio, and net daily metabolism (GPP–CR) in the Kissimmee River during the study period.

Table 11-2. Sum of area in hectares for vegetation types within the Phase I restoration area over three time periods.

	1952	1974	2003
Broadleaf Marsh	1673	175	167
Wet Prairie	1186	525	1270
Wetland Shrub	276	104	774
Other Wetlands	82	68	341
Total Wetlands	3216	872	2552
Other Veg. Types	631	2975	1295

Table 11-3. Percent area for vegetation types within the Phase I restoration area over three time periods.

	1952	1974	2003
Broadleaf Marsh	43.5%	4.6%	4.4%
Wet Prairie	30.8%	13.6%	33.0%
Wetland Shrub	7.2%	2.7%	20.1%
Other Wetlands	2.1%	1.8%	8.9%
Total Wetlands	83.6%	22.7%	66.4%
Other Veg. Types	16.4%	77.3%	33.7%

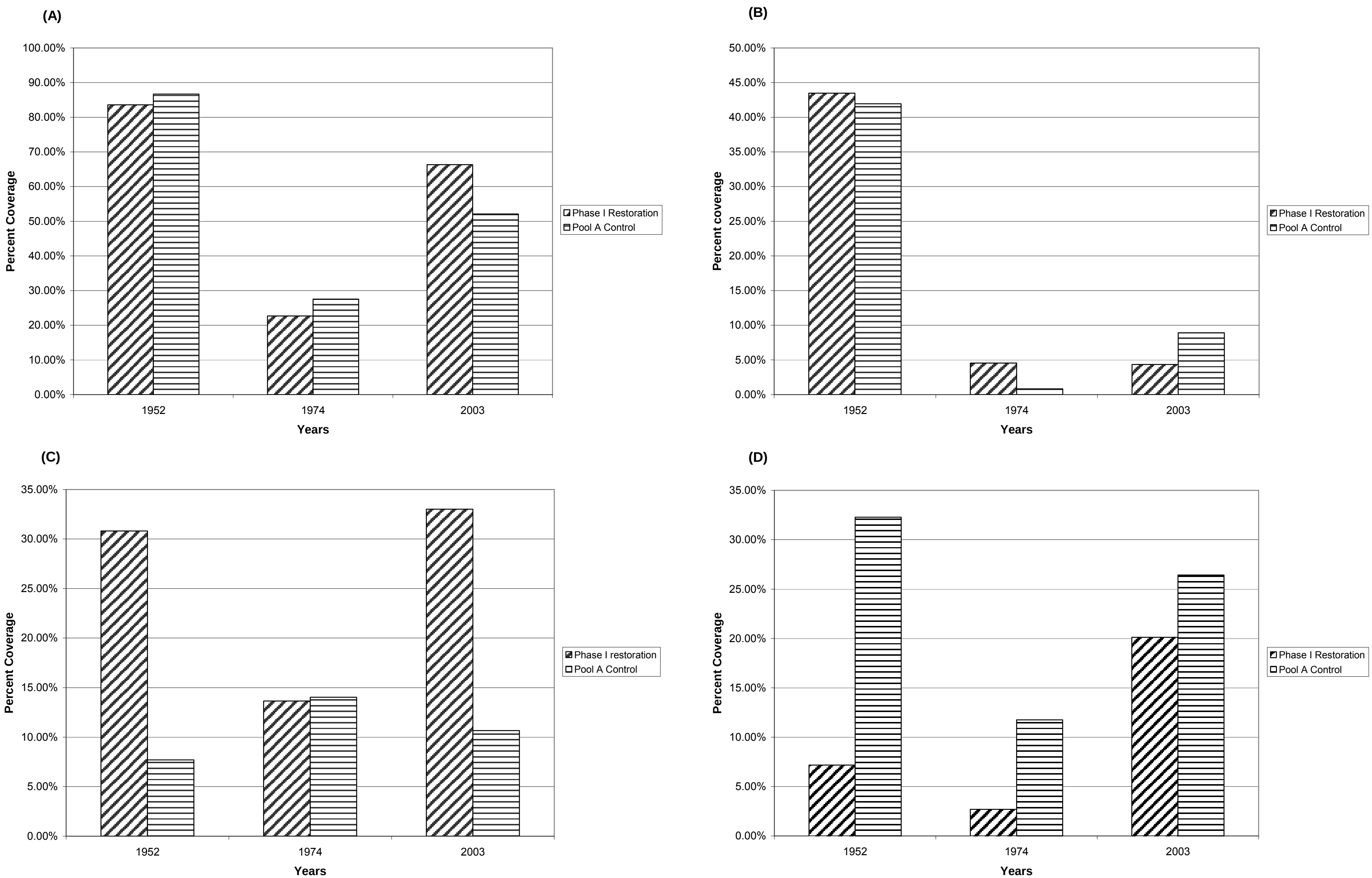

Figure 11-14. Comparisons over 1952, 1974, and 2003 vegetation maps of percent coverage of (A) total wetland habitat, (B) broadleaf marsh vegetation, (C) wet prairie vegetation and (D) wetland shrub vegetation in restored and unrestored (control) areas.

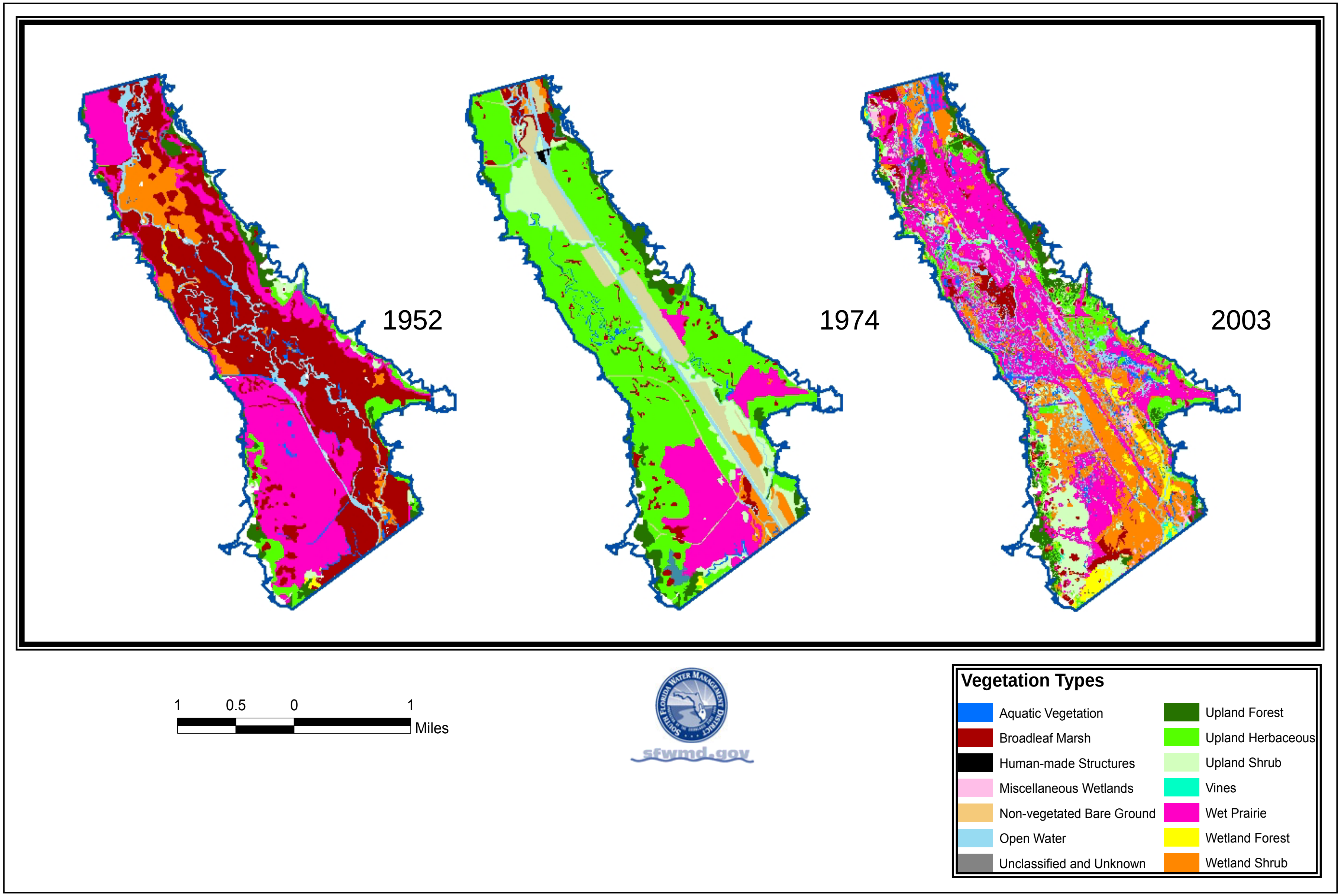

Figure 11-15. Vegetation maps of Phase I restored area from pre-channelization (1952), post-channelization (1974), and post-restoration (2003).

in the relative abundance of vegetation types. These conditions should favor broadleaf marsh vegetation in lower elevations of the floodplain.

Similarly, areas of wetland shrub communities are expected to approximate pre-channelization extents following full restoration. In 1952, approximately 7 percent of the floodplain was wetland shrub. This had decreased to about 3 percent in 1974, two years after channelization. By 2003 (two years following Phase I construction), wetland shrub communities occupied about 20 percent of the Phase I floodplain (**Table 11-3**). Most of this shrub coverage is due to willow, buttonbush, and primrosewillow communities. No effort is being made currently to discourage wetland shrub communities, although upcoming monitoring of planned controlled burning in the Phase IVA floodplain and a restored marsh in Pool A is expected to provide data that will be useful in adaptive management of floodplain succession of vegetation if needed. Acquisition of aerial imagery for the next full floodplain vegetation map is planned for 2008.

Expectations (performance measures) predicting restored areas of the Kissimmee River floodplain (Carnal, 2005a; 2005b; 2005c) were developed prior to restoration based on historic areal coverage using the same 1952 pre-channelization vegetation map. The expectations for overall wetland area and the two dominant vegetation types (broadleaf marsh and wet prairie) are (1) that wetland vegetation will cover at least 80 percent of the full restoration area (Phases I, II/III, and IV) (Carnal, 2005a); (2) that broadleaf marsh vegetation will cover at least 50 percent of the full restoration area (Carnal, 2005b); and (3) that wet prairie vegetation will cover at least 17 percent of the restoration area (Carnal, 2005c). These expectations refer to the entire restored floodplain area and predict full response only after the headwaters schedule is implemented.

Wetland vegetation reestablished rapidly in the first two years following Phase I restoration. Although these wetlands were disproportionately dominated by wet prairie vegetation compared to pre-channelized conditions, full restoration of the historic mosaic of vegetation types, including extended areas of broadleaf marsh, will require the prolonged hydroperiods that are anticipated to result from the revised Headwaters Revitalization schedule, which will be implemented in 2012.

Birds

Birds are both integral to the Kissimmee River/floodplain ecosystem and highly valued by its human users. While quantitative pre-channelization data are sparse, available data and anecdotal accounts indicate that the system supported an abundant and diverse bird assemblage (National Audubon Society, 1936–1959; FGFWFC, 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Further, since many bird groups (e.g., wading birds, waterfowl) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller, 1995). Detailed information regarding the breadth of the avian evaluation program and the initial response of avian communities to Phase I restoration can be found in the 2005 SFER – Volume I, Chapter 11. This section highlights portions of the avian program for which data were collected during WY2007.

Wading Bird Nesting Colonies

As part of the Kissimmee River Restoration Project evaluation program, the SFWMD performed systematic aerial surveys (May 17, June 11, July 16) to search for wading bird nesting colonies within the floodplain and surrounding wetland/upland complex of the Kissimmee River. Flights dedicated specifically for colony surveys were not conducted from January through April, due to a position vacancy. In addition to dedicated flights for colony surveys, nesting colonies also were monitored, when encountered, during separate aerial surveys of foraging wading birds (March 26, April 23, May 21, June 18, July 23). The number of nests reported for each colony represents the maximum number of nests for each species. Nesting success was not monitored, but two ground surveys (May 8, Jun 29) were conducted at the C-38 colony to obtain more accurate nest counts and determine the presence of less visible dark-colored herons.

One colony containing an estimated 227 nests was observed during the 2007 season, including 226 cattle egret (CAEG) nests and one tricolored heron (TRHE) nest (**Table 11-4**). The colony was first encountered by boat on May 8, when birds were either building nests or incubating eggs. The colony was subsequently abandoned sometime between discovery and the May 17 survey flight. Four of five 2006 colonies were absent from this year's surveys, but it should be noted that dedicated flights were not conducted this year during the typical peak of nesting activity (February–April) (**Figure 11-16**). However, it is unlikely that any colonies formed and successfully fledged young prior to our May 17 flight given the below-average nesting activity and unfavorable foraging conditions throughout the region (see *Wading Bird Densities* section) and lack of observations during the Mar 26 survey for foraging wading birds. As in 2006, nearly all nests occurred in a single CAEG colony. The abandonment of this colony in mid-May may have been due in part to the absence of nesting stimuli from native wading bird species that likely lacked sufficient aquatic prey to initiate breeding (Belzer and Lombardi, 1989).

Table 11-4. Peak numbers of wading bird nests in colonies in or within 3 km of the Kissimmee River 100-year flood line between the S65 and S65-D structures. Surveys were conducted Mar-Jun, 2004; Mar-Jun, 2005; Feb-Jun, 2006; and May-Jul 2007. (ANHI=Anhinga, CAEG=Cattle egret, GBHE=Great Blue Heron, GREG=Green egret, TRHE=Tricolored heron).

Lat.	Long.	Colony Name (Location)	Year	ANHI	CAEG	GBHE	GREG	TRHE	Colony Total (nests)
81 13.219	27 42.946	42W (4.5 km west of Pool A floodplain)	2004	-	-	-	-	-	**-**
			2005	-	-	-	-	-	**-**
			2006	-	-	-	8	-	**8**
			2007	-	-	-	-	-	**-**
81 04.466	27 22.853	C38 Caracara Run (east bank of C-38 canal in Pool D)	2004	-	-	-	-	-	**-**
			2005	-	-	-	-	-	**-**
			2006	-	500	-	-	-	**500**
			2007	-	226	-	-	1	**227**
81 16.527	27 32.088	Cypress West (5.2 km west of Pool B floodplain)	2004	-	-	-	-	-	**-**
			2005	-	-	-	21	-	**21**
			2006	-	-	-	25		**25**
			2007	-	-	-	-	-	**-**
81 00.380	27 22.620	New Chandler Slough (Chandler Slough near U.S. 98, Pool D floodplain)	2004	-	-	-	-	-	**-**
			2005	-	-	-	-	-	**-**
			2006	-	-	-	40	-	**40**
			2007	-	-	-	-	-	**-**
81 04.649	27 21.076	Orange Grove (1.9 km SW of Pool D floodplain)	2004	-	-	-	-	-	**-**
			2005	30	-	5	60	-	**95**
			2006	20	-	4	60		**84**
			2007	-	-	-	-	-	**-**
81 06.442	27 37.791	Pine Island Slough (1.6 km east of Pool B floodplain)	2004	-	-	-	-	-	**-**
			2005	-	400	-	-	-	**400**
			2006	-	-	-	-	-	-
			2007	-	-	-	-	-	**-**
Total Nests			**2004**	**0**	**0**	**0**	**0**	**0**	**0**
			2005	**30**	**400**	**5**	**81**	**0**	**516**
			2006	**20**	**500**	**4**	**133**	**0**	**657**
			2007	**-**	**226**	**-**	**-**	**1**	**227**

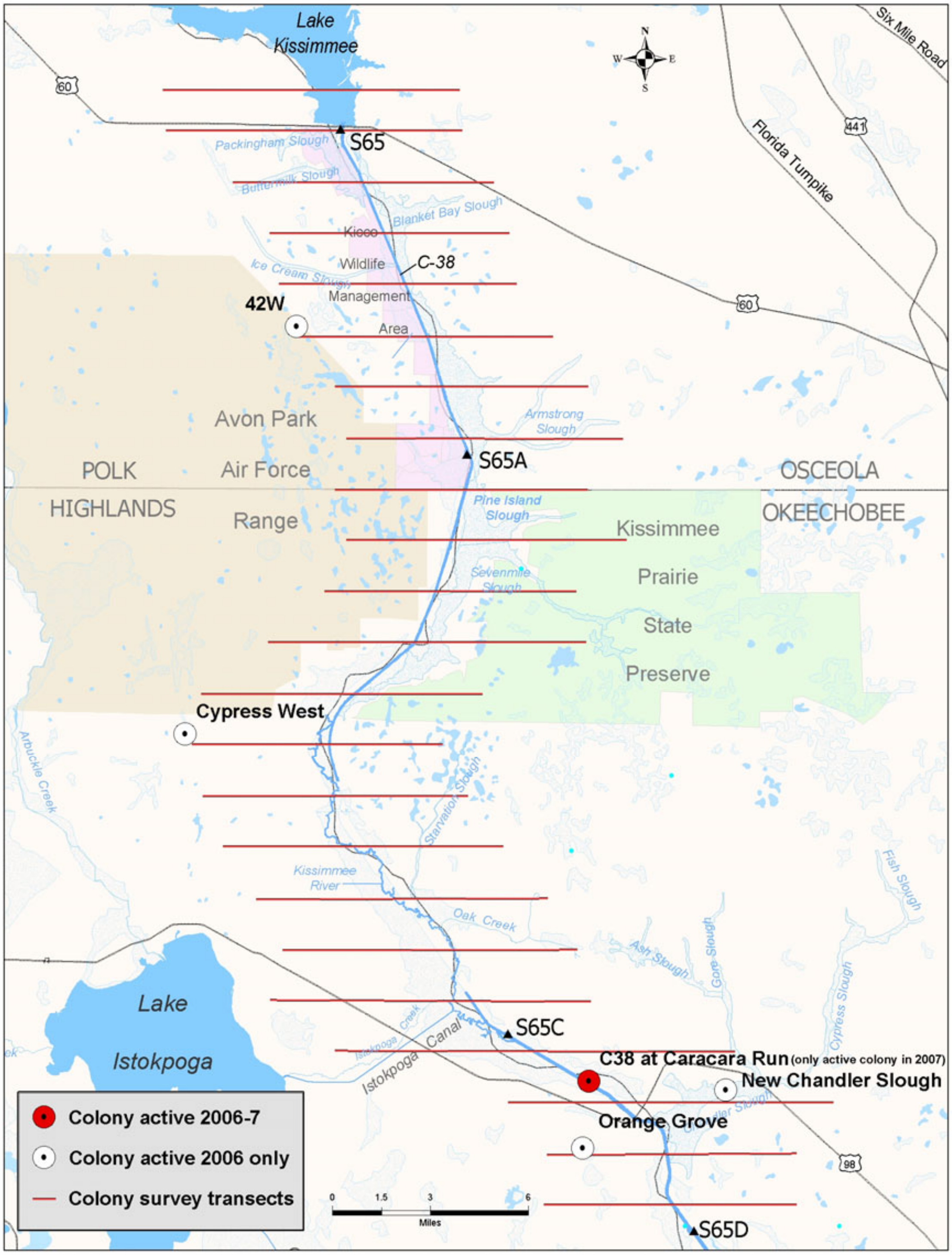

Figure 11-16. Transect layout and locations of nesting colonies within the Kissimmee River floodplain and surrounding wetland/upland complex during 2006 and 2007.

Wading Bird Densities

Approximately monthly aerial surveys were used to measure the densities of foraging wading birds. Prior to Phase I construction (baseline period), mean annual dry season densities of long-legged wading birds (excluding cattle egrets) in the Phase I area averaged (± SE) 3.6 ± 0.9 birds/km² in 1997 and 14.3 ± 3.4 birds/km² in 1998. Since completion of Phase I, wading bird densities have exceeded the restoration expectation of 30.6 birds/km² each year except 2007, averaging 37.8 ± 15.4 birds/km², 61.7 ± 14.5 birds/km², 59.6 ± 24.4 birds/km², 103.0 ± 31.5 birds/km², and 11.0 ± 2.1 birds/km² in the dry seasons of 2002, 2004, 2005, 2006, and 2007, respectively (2003 data were not collected; **Figure 11-17**). Furthermore, the lower limit of the 95 percent confidence interval (95 percent C.I.) has exceeded the expectation in three of five years. However, this dry season was the first since Phase I completion that the restoration expectation was not met, and densities were similar to those observed during the 1998 baseline surveys. This is likely to be an effect of the extreme drought conditions experienced during the 2007 dry season rather than effects of Phase I restoration per se. Most floodplain foraging habitat was completely dry this year and was inundated only during a brief period (September 4-16, Tropical Storm Ernesto) in the wet season prior to an earlier than average fall recession. These conditions may have prevented significant prey base production within abandoned river channels and isolated wetlands and limited prey availability during the winter/spring breeding season (see the Wading Bird Nesting Colonies section above). Water levels have not returned to appropriate foraging depths throughout most of the floodplain as of mid-July 2007. Wading bird density remains low, with the exception of cattle egrets that continue to occur in significant numbers throughout the floodplain. In areas where water levels are currently returning to appropriate foraging depths with the onset of summer rains, it is likely that prey items are widely dispersed at low densities in newly inundated areas, which precludes efficient foraging by wading birds. Anecdotal evidence from June and July survey flights indicates that birds were utilizing adjacent isolated wetlands in greater numbers outside of the floodplain, where prey availability may have been greater. Excluding cattle egrets, white ibis was the most common species in all 2007 dry season surveys, with great egret, glossy ibis, small white heron (snowy egret and immature little blue), great blue heron, and little blue heron also commonly encountered. Wood storks were observed only during the December survey.

Phase II/III Evaluation Planning

Preliminary planning for evaluation of Phase II/III of the Kissimmee River Restoration Project took place in early 2007. A set of ecological studies to monitor response to Phase II/III restoration was identified, including studies of dissolved oxygen, phosphorus, geomorphology, river channel and floodplain vegetation, invertebrates, herpetofauna, fish, and birds. The goal of Phase II/III evaluation is to better identify the relationships among individual components of ecosystem response to restoration through increased integration of a subset of studies. Improved understanding of these relationships will aid adaptive management of the ecosystem. Most of the studies are planned to take place in Caracara Run or the Lanier Floodplain area of Pool D (**Figure 11-1A**). The projects are using comparable designs that will be implemented using coordinated spatial and temporal sampling to enhance correlative and time-series analyses between and among studies. As in the Phase I evaluation studies, most of the Phase II/III studies use a BACI (before-after/control-impact) design (Bousquin et al., 2005a), with sampling to be conducted in control and impact areas before and after restoration of the Phase II/III project area. Pilot studies and initial sampling for the Phase II/III studies, as well as pilot vegetation sampling for monitoring to detect littoral zone changes expected to result from KRHRP in four headwaters lakes, are taking place in summer–fall of 2007. Aerial photography for baseline vegetation maps to evaluate Phase II/III and KRHRP is planned for spring 2008.

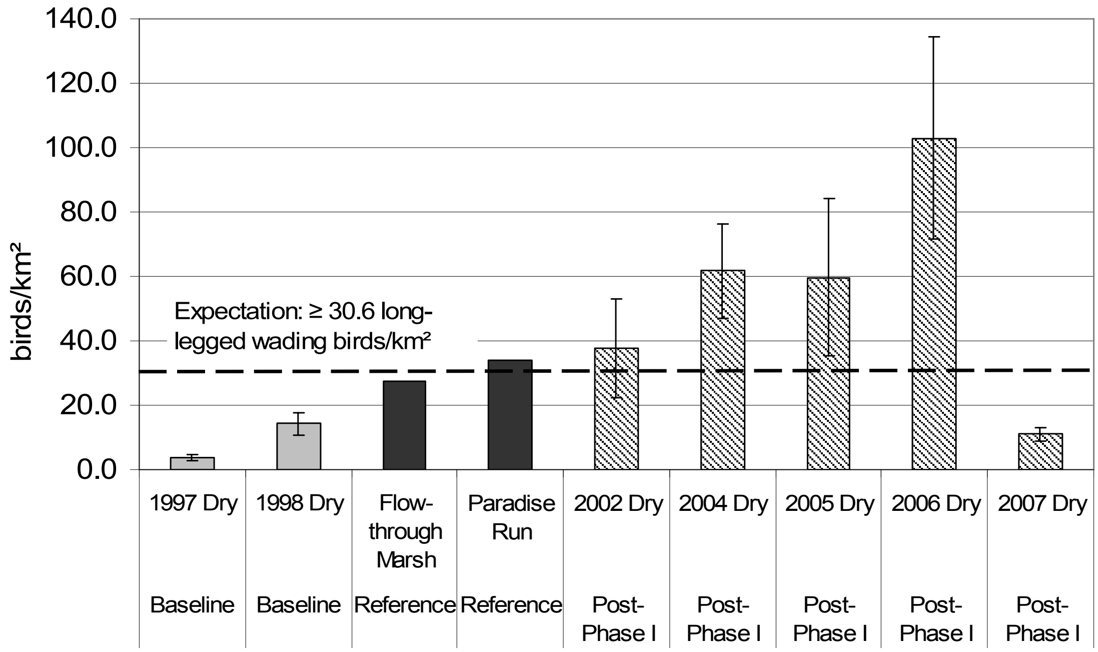

Figure 11-17. Baseline, reference, and post-Phase I densities (± SE) of long-legged wading birds (excluding cattle egrets) during the dry season (December-May) within the 100-year flood line of the Kissimmee River. Baseline densities were measured in the Phase I area prior to restoration. Post-restoration densities were measured beginning approximately 10 months following completion of Phase I.

Kissimmee Basin Modeling and Operations Study

The Kissimmee Basin Modeling and Operations Study (KBMOS) is an SFWMD initiative to identify alternative water control structure operating criteria for the Kissimmee Basin and its associated water resource projects. The KBMOS component of the KRRP will define the required water control structure operations needed to meet the hydrologic requirements of the river restoration project while also achieving a more acceptable balance between water resource management objectives associated with flood control, water supply, aquatic plant management, and the natural resource requirements of the Kissimmee Chain of Lakes. In addition, the KBMOS will ensure that modified operations will not cause impacts greater than those currently experienced on Lake Okeechobee from Kissimmee Basin inflows. The selected water control structure operating criteria are not intended to meet the desired inflow envelop described for Lake Okeechobee. This is being addressed by the Northern Everglades Project. 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. The KBMOS is independent of, but closely related to, the KCOL Long-Term Management Plan (KCOL LTMP) that is discussed in greater detail later in this chapter.

The KBMOS was initiated in September 2004. Since the 2007 report, significant progress has been made in both the development of the evaluation performance measures and the modeling tools. Peer review is complete on the evaluation performance measures. Remaining activities include performance measure testing to ensure specified metrics can be appropriately simulated by the modeling tools and that specified targets, target ranges, and assigned utility indices are appropriate relative to model output. Model development, training, calibration, and verification are complete and model peer review activities have initiated. Current and future base condition model runs are in progress and are expected to be complete by September 2007. Once complete, alternative plan screening and evaluation will begin.

A public outreach component is incorporated into the KBMOS to encourage stakeholder participation in the performance measure and alternative plan development. Communication and information gathering is facilitated through email, interagency workshops, and public meetings. The public outreach component for the KBMOS consists primarily of public workshops intended to educate the public on the study and how to get involved and to solicit input on desirable water level conditions. The primary public input period will initiate with the development of alternative plans. A glossy brochure entitled "Guide to the Computer-Aided Participation Process" was produced to define key terminology and to introduce the template that will be used to collect stakeholder preferred criteria for evaluation. A performance indicator type has been developed to capture stakeholder requirements not addressed under the flood control, natural resource, water supply, and aquatic plant management measures and indicators developed by the partner agencies. These stakeholder performance indicators will be used to report how well a given alternative plan performed relative to the stakeholder defined criteria.

The public outreach component of the KBMOS is part of a larger public outreach program associated with the Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP). Under the KCOL LTMP local stakeholder groups including Homeowner Associations, the local chapter of the Audubon Society and the Osceola County Lakes Management Advisory Board are being consulted to define management objectives and priorities for the water bodies within the KCOL.

Due to delays during calibration and verification, the project end date has been pushed back from December 2007 to June 2008. The final deliverable will be modified interim and long-term operating criteria for Kissimmee Basin water control structures. Information and documents related to the study can be found at https://projects.earthtech.com/sfwmd-kissimmee/.

UPPER BASIN AND TRIBUTARY PROJECTS

Kissimmee Chain of Lakes Long-Term Management Plan

The Kissimmee Chain of Lakes Long-Term Management Plan (KCOL LTMP) is a multiagency/stakeholder project that was initiated by the passage of SFWMD Governing Board Resolution 2003-468. This resolution directed SFWMD staff to work with the USACE and other interested parties to improve the health and sustainability of the Kissimmee Chain of Lakes by developing a long-term management plan for regulated lakes in the Upper Basin (**Figure 11-1B**, **Figure 11-2**). The SFWMD is the lead agency responsible for coordinating KCOL LTMP interagency activities and producing the plan. Other cooperating agencies include the Florida Fish and Wildlife Conservation Commission (FWC), FDEP, FDACS, USACE, U.S. Fish and Wildlife Service (USFWS), USEPA, local governments and community leaders, and other stakeholders. The purpose of the KCOL LTMP is to improve, enhance and/or sustain lake ecosystem health by (1) providing the scientific and technical basis for assessing current and future environmental conditions relative to agreed-upon targets, and (2) developing collaborative strategies for identifying needs for management intervention or modification to achieve these targets. The KCOL LTMP is conceived as the collaborative framework upon which the partner agencies can manage the KCOL and adjacent/connected lands.

Scheduled for public release in 2008, 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.

In the past year, plan development moved forward from the conceptual ecological model described in the 2007 SFER to the development and refinement of assessment performance measures and indicator measures. These performance measures and indicator measures represent attributes that are responsive to management and indicative of lake health. The difference between the two types of measures is that performance measures have numerical targets, while indicator measures do not. In a number of instances, important ecological attributes of the KCOL were identified for which little or no reference information exists (e.g., number of wading bird colonies/nests). While it was impossible to develop meaningful numerical targets in these situations, KCOL LTMP cooperators have agreed that they are still important to assess.

A draft document containing the assessment measures, conceptual model, and an ecological assessment plan was submitted for peer review in June 2007. The next phase of the plan's development is the formulation of action plans by the partnering agencies. The intent of these plans is to identify ways in which mandates and resources of each agency can collectively be applied to perform routine assessments of lake ecosystem health, and identify management activities needed to improve, enhance, and/or sustain lake ecosystem health.

Three Lakes Wildlife Management Area Restoration

The Florida Fish and Wildlife Conservation Commission (FWC) proposed the execution of the Hydrologic Restoration Project of the Three Lakes Wildlife Management Area (WMA) within the framework of the Kissimmee Basin Operations and Modeling Study. The project, which is being executed by the SFWMD in cooperation with the FWC, has the goal of restoring more natural hydrology and wetland function in the Three Lakes WMA near Lake Marian in the Upper Kissimmee Basin (**Figure 11-1B**). The area supports one of the highest densities of bald eagles in the lower 48 states.

The project includes four phases:

- Phase I – Hydrologic Assessment: Compilation of data and preparation of recommended modeling approach for the Three Lakes Wildlife Management Area. This Phase has been completed.
- Phase II – Modeling Work Plan Implementation: Development of the modeling tool to formulate, evaluate, and rank alternatives to identify the preferred alternative.
- Phase III – Project Design and Permitting: Preparation of design documents (plans and specifications) for the permitting and implementation of the preferred alternative.
- Phase IV – Construction and Construction Support Services: Implementation of the preferred alternative.

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

Restoration of Packingham and Buttermilk Sloughs

The purpose of this project was to restore historic (Pre-C&SF Project) floodplain hydroperiods to Packingham and Buttermilk Sloughs located in Pool A of the Kissimmee River (**Figure 11-1A**). Benefits would 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 were the creation of two containment levees, backfilling of drainage ditches, and installation of gated water control structures. Water depth in each impoundment would be managed to mimic the historic surface water levels in the basin according to a predictive model developed from historic data.

In May 2007, the project was terminated due to guidance adopted from The Federal Aviation Administration Advisory Circular (AC 150/5200-33A) on hazardous wildlife attractants on or near airports. The FAA advisory states that hazardous wildlife attractants (such as wetlands) should be at least 5,000 feet away from an airport's air operations area. Unfortunately, the Packingham/Buttermilk slough restoration project is within the air operations area of the Westgate River Ranch air strip and therefore cannot be constructed as planned.

Rolling Meadows/Catfish Creek Wetland Restoration

Rolling Meadows Ranch lies on the south shore of Lake Hatchineha in the Upper Kissimmee Basin (**Figure 11-1B**). The 2,260-acre property was purchased by the SFWMD and the FDEP as part of the Kissimmee River Restoration Project. 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 Lake Kissimmee State Park, which is operated by the FDEP.

To assess how water will be delivered to the impoundment, hydrologic modeling of Catfish Creek was needed. The Catfish Creek Wetland Restoration Study Hydrologic and Hydraulic Modeling Report was completed in March 2004. This report provided several water delivery alternatives. A subsequent contract includes additional modeling as well as gathering of historical data, geotechnical work, a water budget, site characterization, and a list of alternative restoration plans for the Rolling Meadows/Catfish Creek property. This report will be complete in August 2007.

CONCLUSIONS

Work on the Kissimmee River Restoration Project continued in WY2007. Following the success of Phase I restoration construction, in which 15 miles of former river channel were reconnected in 2001 by the U.S. Army Corps of Engineers in partnership with the District, Phase IVA construction was completed in September 2007. Phase IVA (which is the second of three phases of construction) will backfill an additional 1.9 miles (3.0 km) of canal upstream from the northern end of Phase I. Phase IVA reestablished flow in four additional miles (6.4 km) of river channel and will allow inundatation of 155 additional acres (63 ha) of floodplain wetlands. The final phase of construction, Phase II/III, is scheduled to begin in 2010.

The Kissimmee Basin experienced below-average rainfall in Water Year 2007. After six years of continuous reestablished flow in the Phase I restoration area, Phase I area responses were interrupted in Water Year 2007 by the drought, which necessitated discontinuation of flow in the restored reach of river channel for 252 days before flow again became possible in July.

Data collection for studies within the Phase I area continued in Water Year 2007. Restoration evaluation studies for which new data became available in Water Year 2007 included hydrology, water quality, dissolved oxygen, areal coverage of floodplain vegetation, and density of wading birds. Despite the drought and no-flow conditions in the Phase I reach, mean dissolved oxygen concentrations remained at levels appropriate for supporting river invertebrates and fish through most of July. However, densities of long-legged wading birds on the Phase I area floodplain, which had exceeded restoration expectations each year from 2002−2006, dropped this year in response to limited foraging habitat on the floodplain. A recently completed floodplain vegetation map based on 2003 aerial photography indicated dramatic increases in wetland vegetation within two years of completion of Phase I construction.

Work on the Kissimmee Chain of Lakes Long-Term Management Plan continued in Water Year 2007. This plan will help sustain, enhance, and/or improve the ecosystem health of lakes in the Upper Kissimmee Basin.

Also in Water Year 2007, the Kissimmee River Restoration Evaluation Program completed preliminary planning for evaluation studies of Phase II/III restoration and the Kissimmee River Headwaters Revitalization Project. Phase II/III construction is currently scheduled to begin in late 2010; baseline (pre-restoration) pilot studies are in progress in summer 2007. A primary goal of Phase II/III studies is to better integrate monitoring of individual components of ecosystem response to restoration.

LITERATURE CITED

Abtew, W. 1992. An Atlas of the Lower Kissimmee River and Lake Istokpoga Surface Water Management Basins. Technical Memorandum. DRE 313. South Florida Water Management District, West Palm Beach, FL.

Ali, A. and W. Abtew. 1999. Regional Rainfall Frequency Analysis for Central and Southern Florida. Technical Publication WRE #380. South Florida Water Management District, West Palm Beach, FL.

Anderson, D.H., and J.R. Chamberlain. 2005a. Impacts of Channelization on the Hydrology of the Kissimmee River, Florida. Chapter 2 *in:* S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Anderson, D.H., S.G. Bousquin, G.E. Williams and D.J. Colangelo, eds. 2005b. Defining Success: Expectations for Restoration of the Kissimmee River. South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #433.

Belanger, T.V., F.E. Dierberg and J. Roberts. 1985. Dissolved Oxygen Concentrations in Florida's Humic-Colored Waters and Water Quality Standard Implications. *Florida Scientist*, 48: 107-119.

Belzer, W. and J. Lombardi. 1989. Cattle egret symbiosis and horonry abandonment. *Colonial Waterbirds*, 12: 115-117.

Bousquin, S.G., D.H. Anderson, G.E. Williams, and D.J. Colangelo, eds. 2005a. Introduction to Baseline Studies of the Channelized Kissimmee River. Chapter 1 *in: Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River.* South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Bousquin, S.G., D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. 2005b. *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River.* South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Carnal, L.L. and S.G. Bousquin. 2005. Areal Coverage of the Floodplain Plant Communities in Pool C of the Channelized Kissimmee River. Chapter 10 *in:* S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Carnal, L.L. 2005a. Areal Coverage of Floodplain Wetlands. Expectation 12 *in:* D.H. Anderson, S.G. Bousquin, G.E. Williams and D.J. Colangelo, eds. 2005. *Defining Success: Expectations for Restoration of the Kissimmee River*. South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #433.

Carnal, L.L. 2005b. Areal Coverage of Broadleaf Marsh. Expectation 13 *in:* D.H. Anderson, S.G. Bousquin, G.E. Williams and D.J. Colangelo, eds. 2005. *Defining Success: Expectations for Restoration of the Kissimmee River*. South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #433.

Carnal, L.L. 2005c. Areal Coverage of Wet Prairie. Expectation 14 *in:* D.H. Anderson, S.G. Bousquin, G.E. Williams and D.J. Colangelo, eds. 2005. *Defining Success: Expectations for Restoration of the Kissimmee River*. South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #433.

Colangelo, D.J. 2007. Response of River Metabolism to Restoration of Flow in the Kissimmee River. *Freshwater Biology*, 52: 459-470..

Colangelo, D.J. and B.L. Jones. 2005. Dissolved Oxygen in the Channelized Kissimmee River and Seven Reference Streams. Chapter 4 *in:* S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Colangelo, D.J., and B.L. Jones. 2005. Phase I of the Kissimmee River restoration project, Florida, USA: impacts of construction on water quality. Environmental Monitoring and Assessment 102:139-158.

Davis, J.C. 1975. Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review. *J. Fish. Res. Board. Can.*, 32(12): 2295-2332.

Doudoroff, P. and D.L. Shumway. 1970. Dissolved Oxygen Requirements of Freshwater Fishes. *Food Agric. Organ.* U. N., FAO Tech. Pap. 86: 291 pp.

FDEP. 2006. Water Quality Assessment Report: Kissimmee River and Fisheating Creek. Florida Department of Environmental Protection, Tallahassee, Florida.

FGFWFC. 1957. Recommended Program for Kissimmee River Basin. Florida Game and Fresh Water Fish Commission, Tallahasee, FL.

Florida Department of Health. 2006. Your Guide to Eating Fish in Florida. Florida Department of Health, Tallahassee, Florida. 24 pp. Available at: http://www.doh.state.fl.us/environment/community/fishconsumptionadvisories/Fish_consumption_guide.pdf

Fontenot, Q.C., D.A. Rutherford and W.E. Kelso. 2001. Effects of Environmental Hypoxia with the Annual Flood Pulse on the Distribution of Larval Sunfish and Shad in the Atchafalaya River Basin, Louisiana. *Transactions of the American Fisheries Society,* 130: 107-116.

Furse, J.B., L.J. Davis and L.A. Bull. 1996. Habitat Use and Movements of Largemouth Bass Associated with Changes in Dissolved Oxygen and Hydrology in Kissimmee River, Florida. Proc Annu. Conf. Southeast. Assoc. Fish and Wild. Agencies, 50: 12-25.

Glenn III, J.L. 2005. Status of Fish Assemblages of the Kissimmee River Prior to Restoration: Baseline Conditions and Expectations for Restoration. Chapter 13 *in:* S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee Rive*r, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Harris, S.C., T.H. Martin and K.W. Cummins. 1995. A Model for Aquatic Invertebrate Response to the Kissimmee River Restoration. *Restoration Ecology*, 3: 181-194.

Karr, J.R. and D.R. Dudley. 1981. Ecological Perspectives on Water Quality Goals. *Environmental Management*, 5: 55-68.

Knights, B.C., B.L. Johnson and M.B. Sandheinrich. 1995. Responses of Bluegills and Black Crappies to Dissolved Oxygen, Temperature, and Current in Backwater Lakes of the Upper Mississippi River during Winter. *North American Journal of Fisheries Management,* 15: 390-399.

Koebel, J.W., Anderson, D.H. and L.M. Rojas. 2005. Aquatic Invertebrate Community Structure and Functional Characteristics in the Kissimmee River-Floodplain Ecosystem: Baseline and Reference Conditions and Expectations for Restoration. Chapter 11 *in:* S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. *Establishing a Baseline: Pre-restoration Studies of the Channelized Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Martin, J., W. Kitchens, and M. Speirs. 2003. Snail kite demography annual report 2003. U.S. Fish and Wildlife Service, Vero Beach, FL.

Moss, D.D. and D.C. Scott. 1961. Dissolved Oxygen Requirements of Three Species of Fish. Transactions of the American Fisheries Society, 90: 377-393.

National Audubon Society. 1936–1959. Audubon Warden Field Reports. National Audubon Society, Tavernier, FL.

Netherland, M.D., M.V. Hoyer, M.S. Allen and D. Canfield. 2005. A Summary of Future Management Recommendations from the December 2004 Hydrilla Summit in Florida. *Aquatics*, 27: 4,6,8-10.

Obeysekera, J.T. and M.K. Loftin. 1990. Hydrology of the Kissimmee River Basin – Influence of Man-Made and Natural Changes, , pp. 211-222 *in:* M.K. Loftin, L.A Toth and J.T Obeysekera, eds. *Proceedings of the Kissimmee River Restoration Symposium.* South Florida Water Management District, West Palm Beach, FL.

Perrin, L.S., M.J. Allen, L.A. Rowse, F. Montalbano III, K.J Foote and M.W. Olinde. 1982. A Report on Fish and Wildlife Studies in the Kissimmee River Basin and Recommendations for Restoration. Florida Game and Freshwater Fish Commission, Okeechobee, FL.

SFWMD. 2000. Kissimmee Basin Water Supply Plan. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2002. Surface Water Improvement and Management (SWIM) Plan: Update for Lake Okeechobee. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2006. Strategic Plan 2006–2016. South Florida Water Management District, West Palm Beach, FL.

SFWMD, Florida Department of Environemental Protection, and Florida Department of Agriculture and Consumer Services. 2007. Lake Okeechobee Protection Plan Evaluation Report, February 23, 2007. South Florida Water Management District, West Palm Beach, FL.

SFWMD, FDEP and FDACS. 2007. Lake Okeechobee Protection Program, Lake Okeechobee Protection Plan Evaluation Report. South Florida Water Management District, West Palm Beach, FL

Smale, M.A. and C.F. Rabeni. 1995. Hypoxia and Hypothermia Tolerances of Headwater Stream Fishes. Transactions of the American Fisheries Society, 124: 698-710.

Timmerman, C.M. and L.J. Chapman. 2004. Behavioral and Physiological Compensation for Chronic Hypoxia in the Sailfin Molly (*Poecilia latipinna*). *Physiological and Biochemical Zoology*, 77: 601-610.

Toth, L.A. 1990. An Ecosystem Approach to Kissimmee River Restoration. pp. 125-133 *in:* M.K. Loftin, L.A. Toth and J.T. Obeysekera, eds. *Proceedings of the Kissimmee River Restoration Symposium*, South Florida Water Management District, West Palm Beach, FL.

USACE. 1991. Final Integrated Feasibility Report and Environmental Impact Statement, Environmental Restoration, Kissimmee River, Florida. U.S. Army Corps of Engineers, Jacksonville, FL.

USACE. 1996. Central and Southern Florida Project, Kissimmee River Headwaters Revitalization Project: Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement. U.S. Army Corps of Engineers, Jacksonville, FL.

USFWS. 1959. Appendix A: A Detailed Report of the Fish and Wildlife Resources in Relation to the Corps of Engineers' Plan of Development, Kissimmee River Basin, Florida *in: Central and Southern Florida Project for Flood Control and Other Purposes: Part II, Supplement 5 – General Design Memorandum*, Kissimmee River Basin. U.S. Army Engineers, Office of the District Engineer, Jacksonville, FL.

Weller, M.W. 1995. Use of Two Waterbird Guilds as Evaluation Tools for the Kissimmee River Restoration. *Restoration Ecology*, 3: 211-224.

Wendelaar Bonga, S.E. 1997. The Stress Response in Fish. *Physiological Reviews,* 77(3): 591-625.

Williams, G.E. and S.L. Melvin. 2005. Studies of Bird Assemblages and Federally Listed Bird Species of the Channelized Kissimmee River, Florida. Chapter 14 *in:* S.G. Bousquin, D.H. Anderson, G.E. Williams and D.J. Colangelo, eds. *Establishing a Baseline: Pre-Restoration Studies of the Kissimmee River*, South Florida Water Management District, West Palm Beach, FL. Technical Publication ERA #432.

Williams, G.E., D.H. Anderson, S.G. Bousquin, C. Carlson, D.J. Colangelo, J.L. Glenn, B.L. Jones, J.W. Koebel Jr. and J. Jorge. 2007. Kissimmee River Restoration and Upper Basin Initiatives. Chapter 11. South Florida Environmental Report – Volume I: The South Florida Environment., South Florida Water Management District, West Palm Beach, FL.