Chapter 9: Kissimmee River Restoration and Basin Initiatives

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SUMMARY

The South Florida Water Management District (SFWMD or District) continues to coordinate with the United States Army Corps of Engineers (USACE) on the Kissimmee River Restoration Project (KRRP). In addition, the SFWMD is integrating the KRRP with management activities throughout the Kissimmee Basin and the Northern Everglades region. The primary goals of these efforts are to (1) restore ecological integrity to the Kissimmee River and its floodplain, (2) collect ecological data to evaluate river restoration and support water management decision making, (3) enhance and sustain natural resource values in the Kissimmee Chain of Lakes (KCOL), and (4) retain the flood reduction benefits of the Central and Southern Florida Flood Control Project (C&SF Project) in the Kissimmee Basin. In addition to projects under the KRRP, the SFWMD also manages the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project.

The KRRP's goal of restoring ecological integrity to approximately one-third of the river and its floodplain depends largely on reestablishing the physical form of the river–floodplain system (i.e., the physical habitat template) and then applying hydrologic conditions similar to those that existed before the river was channelized in the 1960s. Achieving these conditions involves acquiring more than 102,000 acres of land in the river's floodplain and headwaters, backfilling 22 miles of the C-38 flood control canal, reconnecting remnant sections of the original river channel, removing two water control structures, and modifying portions of the river's headwaters to meet hydrologic criteria for river restoration. The first three construction phases of restoration, completed between 2001 and 2009, have reestablished flow to 24 miles of river channel and allowed intermittent inundation of 7,710 acres of floodplain. Construction activities continued in Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) in the headwaters and lower part of the river (Pool D). The last major phases of construction are scheduled to begin in 2017. The KRRP is currently scheduled for completion in 2019.

The KRRP's success is being evaluated through the Kissimmee River Restoration Evaluation Program (KRREP). Evaluation of restoration success was recognized as a crucial aspect of the project in the Final Integrated Feasibility Report and Environmental Impact Statement for the Restoration of the Kissimmee River, Florida (USACE, 1991) and was identified as a SFWMD responsibility in its cost-share agreement with the USACE (Department of the Army and SFWMD, 1994). Success is being tracked, in part, using 25 performance measures to evaluate how well the project meets its ecological integrity goal. Targets for these performance measures, called restoration expectations, are based on reference conditions derived from information on the pre-channelized river or similar systems. A final evaluation of KRRP success will follow completion of all project components. Many of the restoration expectations, particularly those

related to floodplain responses, depend on the removal of water control structure S-65C during upcoming phases of restoration construction and implementation of a new headwaters regulation schedule after construction is complete. This regulation schedule will allow additional storage capacity in the headwater lakes, thereby allowing more flexible operations that can more closely approximate the prechannelized river's flow regime, including discharges with more natural timing, magnitude, and rates of change, and is anticipated to drive the expected biological and physical changes in the system.

This year's update on restoration evaluation includes newly available data from studies on hydrology, water quality, wading birds, and waterfowl. This subset of restoration evaluation studies assesses the level of response of critical ecosystem components to physical restoration under the interim hydrologic conditions currently in place. Results from these studies provide information for sound water management decision making as the KRRP progresses and for guiding water management after the project is complete. Key WY2013 highlights of this chapter include the following:

- **Hydrologic conditions:** Although rainfall in the Kissimmee Basin was near average in WY2013, above average rainfall during June and August (related to Tropical Storm Isaac) resulted in rapid increases in discharge and water levels in the Phase I restoration area. Both of these events were accompanied by a hypoxic event where dissolved oxygen concentrations dropped below 2 mg/L. The first event lasted only ten days; the latter event lasted 51 days and was associated with a fish kill.
- **River channel hydrology:** Although flow was effectively continuous in the Phase I area throughout WY2013, discharge at S-65 was stopped for one day in December 2012 to conserve water in the upper basin. Discharge to the Kissimmee River continued through S-65A. Under the interim regulation schedule, continuous flow to the restoration area has been achieved in 9 of the last 12 years. The expected seasonal flow pattern was not achieved in WY2013 due to extended periods of low discharge.
- **Floodplain hydrology:** Floodplain stage met the fluctuation target, as it has every year since WY2002, in the upper part of the Phase I restoration area. The fluctuation target was also met at one site in the lower part of the restoration area, which has happened less frequently because the downstream structure, S-65C, can limit fluctuation there. The floodplain inundation target of at least 180 days was met at two of three floodplain sites in the upper floodplain and at both monitoring sites in the lower floodplain. At all five floodplain sites, a slow, prolonged decline in water levels met the target for floodplain recession (greater than 173 days duration and recession rate not exceeding 0.3 meters per 30 days).
- **Dissolved oxygen.** Concentrations of dissolved oxygen (DO) in the river channel of the Phase I restoration area continued to be higher than pre-restoration levels. Of the three metrics used to evaluate DO response in WY2013, two were met. Mean DO concentrations met or exceeded both wet season (June-October) and dry season (December-May) target ranges. The third metric, frequency of concentrations greater than 2.0 mg/L, fell only slightly short of its 90 percent target. The final determination of restoration success with respect to DO will be made after the restoration project is completed.
- **Nutrient loads and concentrations.** Nutrient loads at water control structures along the C-38 canal during WY2013 were not greatly different than historical averages. In the last 12 years, annual flow-weighted mean total phosphorus concentrations were generally higher than the 1974–1995 baseline period. Concentrations of both total phosphorus and total nitrogen in WY2013 were close to the recent 12-year averages.

- **Soil nutrients.** A survey of biogeochemical attributes of soils in the restoration area found that these attributes were generally similar throughout the floodplain, with the exception of phosphorus, which was higher in dredge material sampled on spoil mounds and the backfilled canal. However, the low solubility of phosphorus in this material suggests that significant downstream transport of dissolved phosphorus is unlikely. Most other areas of the floodplain have soils capable of retaining phosphorus when inundated. Higher carbon and nitrogen content in floodplain wetlands of the Phase I restoration area suggests that some of the former pasture land being restored to functional floodplain is beginning to accrete organic matter and nutrients. The survey was designed to produce baseline results that can be used to detect changes in soil nutrient content, organic matter, and phosphorus sorption/release potential when compared to a similar survey to be conducted after the restoration project is completed.
- **Wading bird nesting.** The number of nesting colonies of wading birds, as well as the total number of nests, increased from the previous year. Most nesting continued to occur on islands in the Kissimmee Chain of Lakes and Lake Istokpoga. The lack of significant colonies of aquatic wading birds near the Kissimmee River restoration area suggests that prey availability on the floodplain is not yet sufficient to support the completion of breeding. Hydrologic conditions more suitable for foraging and nesting are expected when the restoration project is finished.
- **Wading bird abundance.** Since 2001, the abundance of foraging wading birds within the restored portions of the river usually has met the expectation of 30.6 birds per square kilometer (km^2). Although mean monthly abundance during the 2012–2013 season was lower than the previous season, the average for the last three years remained above the restoration target. Wading bird numbers fluctuated as water levels on the floodplain rose and receded, and declined as the floodplain became dry in the spring except for a few remaining drying pools.
- **Waterfowl abundance.** The three-year running average of waterfowl abundance has consistently exceeded the restoration expectation of 3.9 ducks/km^2 since 2001. Waterfowl abundance during the 2012–2013 survey (9.4 ducks/km^2) was less than the previous year's mean of 13.6 ducks/km^2, but the three-year running average stayed well above the restoration target. Blue-winged teal dominated numerically, followed by mottled ducks, which were the only two species observed this year. The restoration target for waterfowl species richness (greater than or equal to 13 species) has not yet been reached.

As part of the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project, hydrologic and nutrient budgets were developed for Lake Tohopekaliga and East Lake Tohopekaliga for the period 1996-2011. These two lakes received average annual TP inputs of 39 metric tons (mt) and 7 mt, respectively. Outflows from the lakes were 30 mt and 3 mt. Lake Tohopekaliga retained an average of 21 percent of its TP inflow, while East Lake Tohopekaliga retained 53 percent. Discharge is monitored daily at major lake inflows and outflows, but many smaller tributaries are not monitored. Closer evaluation of these minor tributaries would improve nutrient budget estimates.

INTRODUCTION

The Kissimmee Basin includes more than two dozen lakes in the Kissimmee Chain of Lakes (KCOL), their tributary streams and associated marshes, and the Kissimmee River and floodplain (**Figures 9-1** and **9-2**). The basin forms the headwaters of Lake Okeechobee and the Everglades; together they comprise the Kissimmee–Okeechobee–Everglades system. In the 1960s, the Central and Southern Florida Flood Control Project (C&SF Project) modified the Kissimmee Basin's water resources extensively by constructing canals and installing water control structures to achieve flood control. In the Lower Kissimmee Basin, construction of a 56-mile-long canal through the Kissimmee River resulted in profound ecological consequences caused by elimination of flow in the original river channel and prevention of seasonal floodplain inundation. In the Upper Kissimmee Basin, C&SF Project modifications did not allow lake stages to rise as high or drop as low as they did when they were unregulated. The reduced ranges of fluctuation altered or eliminated much of the formerly extensive littoral zones around the lakes and the marshes between them. These and other environmental losses led to legislation authorizing the federal–state Kissimmee River Restoration Project (KRRP). The South Florida Water Management District (SFWMD or District) has been working since the 1990s to coordinate and evaluate the KRRP, which is being done through the Kissimmee River Restoration Evaluation Program (KRREP).

The KRRP is integrated with other management activities in the Kissimmee Basin and the Northern Everglades region. The primary goals of these efforts are to (1) restore ecological integrity to the Kissimmee River and its floodplain, (2) collect ecological data to evaluate river restoration and support management decision making, (3) enhance and sustain natural resource values in the KCOL, and (4) retain the C&SF Project's flood reduction benefits in the Kissimmee Basin. The geographic scope of projects under the KRRP, including the Kissimmee Basin Modeling and Operations Study (KBMOS), is shown in **Figure 9-3**. This figure also shows the area covered by another non-KRRP initiative, the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project. Other ongoing activities of regional importance, such as water reservation development, water management operations, nutrient control efforts, and invasive species management, have been discussed in detail in Chapter 11 of the *2010* and *2011 South Florida Environmental Reports* (SFER) – *Volume I.*

This chapter is an update to Chapter 9 of the 2013 SFER – Volume I (SFWMD, 2013). It focuses on progress of Kissimmee Basin projects during Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013). The chapter also summarizes hydrologic conditions during WY2013 and presents newly available data from the evaluation of the river restoration project and water and phosphorus budgets from certain lakes in the KCOL.

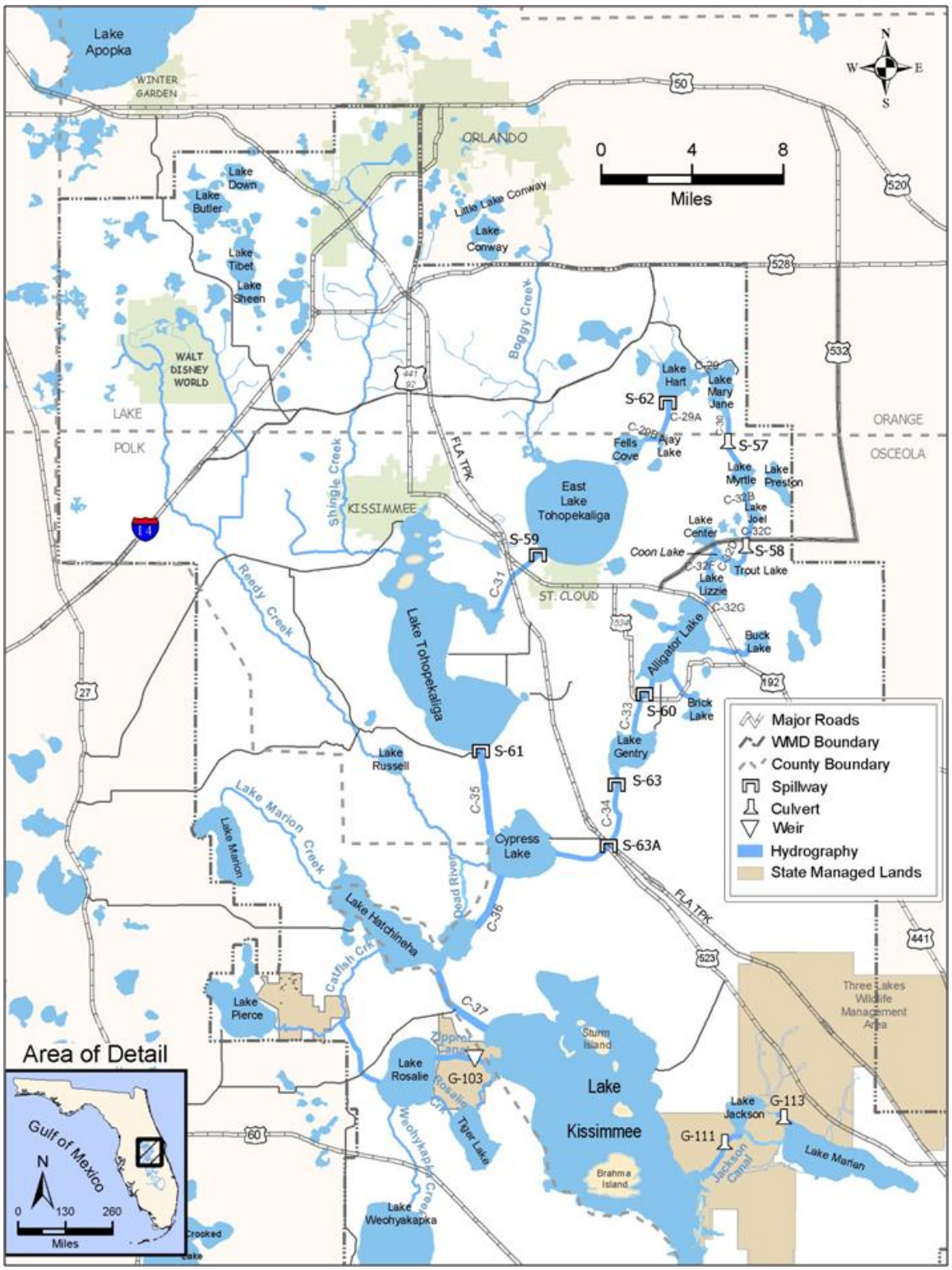

Figure 9-1. Upper Kissimmee Basin.

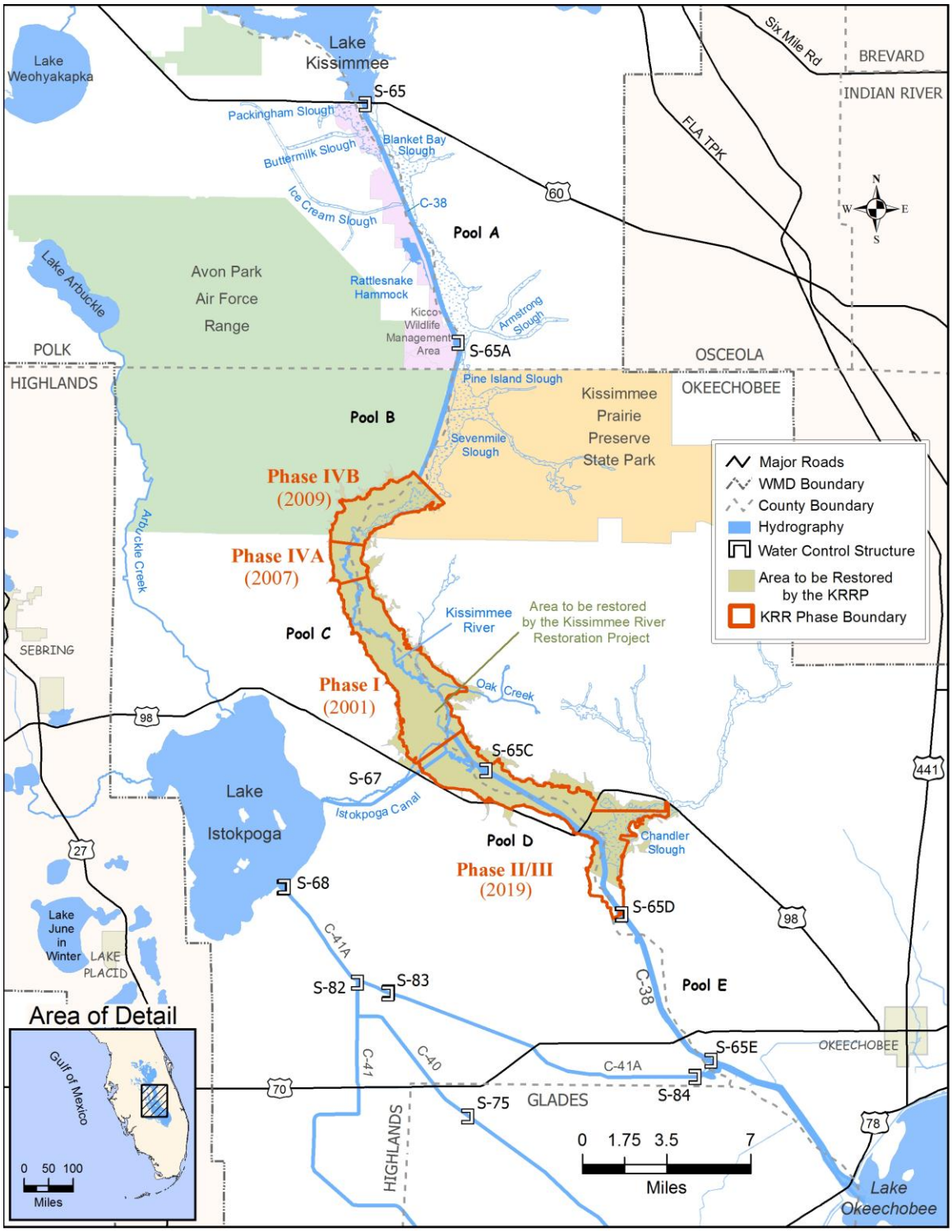

Figure 9-2. Lower Kissimmee Basin.

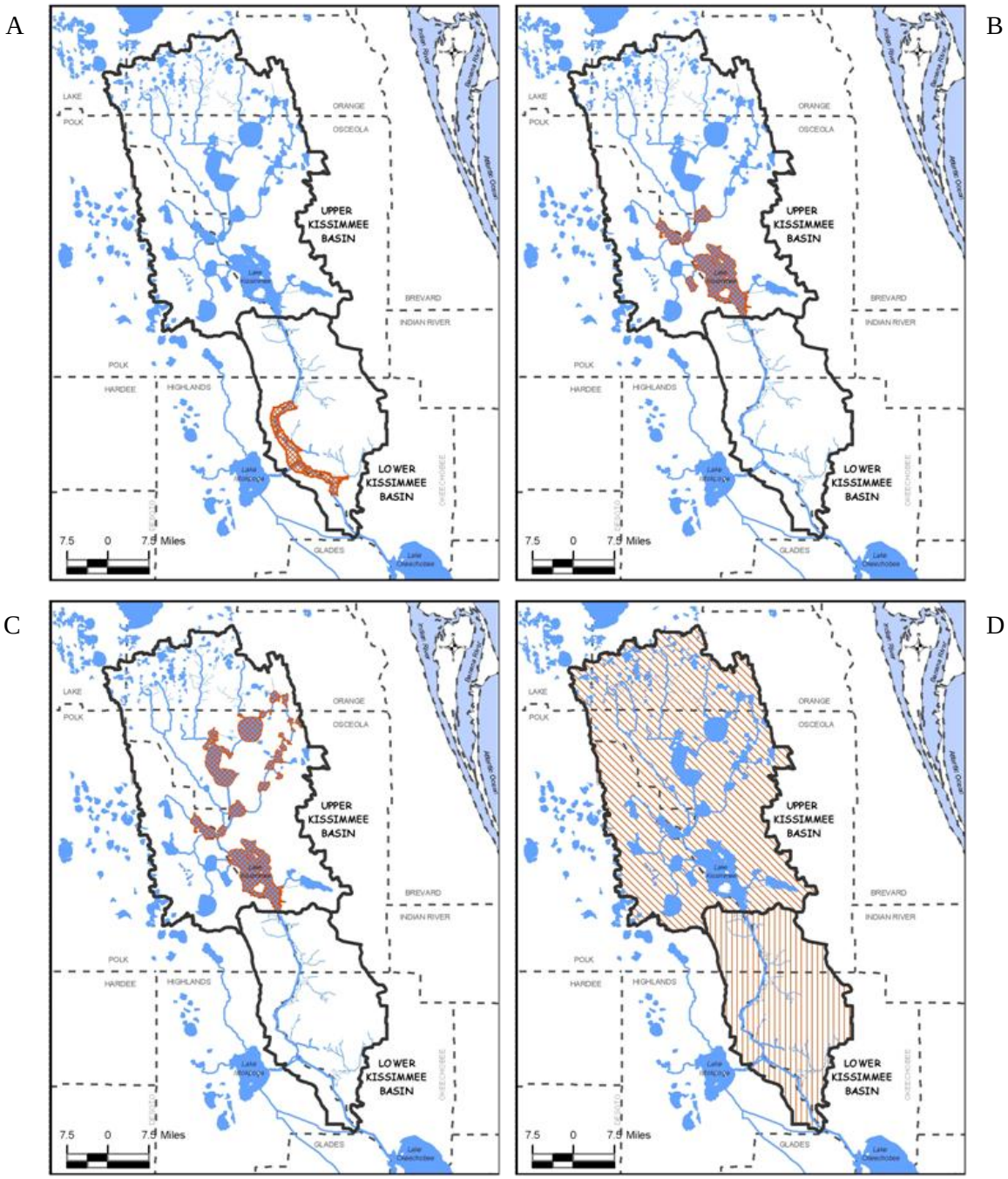

Figure 9-3. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) Kissimmee River Restoration Project (KRRP), (B) headwater lakes components of the KRRP, (C) Kissimmee Chain of Lakes (KCOL) and Kissimmee Upper Basin Monitoring and Assessment Project, and (D) Kissimmee Basin Modeling and Operations Study (KBMOS).

KISSIMMEE RIVER RESTORATION PROJECT

OVERVIEW

Concerns about environmental degradation and habitat loss in the Kissimmee River Valley and the potential contribution of the channelized river to eutrophication in Lake Okeechobee were the impetus for the KRRP. The goal of this project is to restore ecological integrity to the Kissimmee River and its floodplain. Successful restoration depends largely on reestablishing hydrologic conditions similar to the prechannelization period (Toth, 1990). A headwaters component of the project is designed to allow additional storage capacity in the headwater lakes, providing more flexible operations that can more closely approximate the prechannelized river's flow regime, including discharges with more natural timing, magnitude, and rates of change. Increasing storage in the headwater lakes by allowing higher stages for longer periods of time is expected to have the additional benefit of improving the quantity and quality of lake littoral zone habitat in Lakes Kissimmee, Hatchineha, Tiger, and Cypress (USACE, 1996). Restoration is to occur without jeopardizing existing flood reduction benefits provided by the C&SF Project in the Kissimmee Basin.

In the Lower Kissimmee Basin, the KRRP is expected to restore ecological integrity to approximately one-third of the river and floodplain, modifying a contiguous area of floodplain-river ecosystem of over 39 square miles (sq mi). More than 20 sq mi of new wetlands will be reestablished in areas that were drained by the canal, and 40 miles (mi) of reconnected river channel will receive reestablished flow. In the Upper Kissimmee Basin, over 7,000 acres (ac) of littoral marsh are expected to develop on the periphery of the four lakes regulated by water control structure S-65 (USACE, 1996). The KRRP is funded under a 50-50 cost-share agreement between the SFWMD and the United States Army Corps of Engineers (USACE). Engineering, construction, and water control manual modification components of the project are the responsibility of the USACE, while the SFWMD's purview is land acquisition, hydrologic modeling, and ecological evaluation of the restoration project.

RESTORATION CONSTRUCTION COMPONENTS

Restoration components include: (1) acquiring 65,603 ac of land in the Lower Kissimmee Basin, of which 99 percent has been acquired to date, (2) backfilling approximately 22 mi of the C-38 canal (over one-third of the canal's length) from the lower end of Pool D north to the middle of Pool B, (3) reconnecting the original river channel across backfilled sections of the canal, (4) recarving sections of river channel destroyed during C-38 construction, (5) removing the S-65B and S-65C water control structures and associated tieback levees, and (6) modifying portions of the river's headwaters to meet hydrologic criteria for river restoration. The material used for backfilling is the same that was dredged during construction of the C-38 canal. Composed primarily of sand and coarse shell, this material was deposited in large spoil mounds adjacent to the canal.

Reconstruction of the river–floodplain's physical template is being implemented in four phases (**Figure 9-2**), currently projected for completion in 2019 (**Table 9-1**). Phase I construction was completed in February 2001. This phase was followed by Phase IVA/IVB, which extends north from the Phase I project area and was completed in December 2009. Phases II and III, the last major phases of construction, are scheduled to begin in 2017. While the restoration phases were named in the order of expected completion, the sequence has changed over time for logistical reasons (i.e., budgetary considerations, coordination with land acquisition, ease of access).

Table 9-1. Sequence of backfilling construction phases of the Kissimmee River Restoration Project (KRRP) with selected benefits.

Construction Sequence	Name of Construction Phase	Timeline	Backfilled Canal (miles)	River Channel Recarved (miles)	River Channel to Receive Reestablished Flow (miles)	Total Area (acres)	Wetland Gained (acres)	Location and Other Notes
1	Phase I Project Area	1999–2001 (complete)	8	1	14	9,506	5,792	Most of Pool C, small section of lower Pool B
2	Phase IVA Project Area	2006–2007 (complete)	2	1	4	1,352	512	Upstream of Phase I in Pool B to Weir #1
3	Phase IVB Project Area	2008–2009 (complete)	4	4	6	4,183	1,406	Upstream of Phase IVA in Pool B (upper limit near location of Weir #3)
4	Phase II/III Project Area	2017–2019 (projected)	9	4	16	9,921	4,688	Downstream of Phase I (lower Pool C and Pool D south to CSX Railroad bridge)
Restoration Project Totals			**22**	**10**	**40**	**24,963**	**12,398**	

The construction phases completed so far have backfilled 14 mi of flood control canal, recarved 6 mi of river channel that had been obliterated during canal dredging, and demolished a water control structure (S-65B). These efforts reestablished flow to 24 mi of continuous river channel and allowed intermittent inundation of 7,710 ac of floodplain (**Table 9-1**).

The KRRP will culminate with modification of the Kissimmee Basin water control structure operations including the implementation of a new stage regulation schedule, called the Headwaters Revitalization Schedule, to operate the S-65 water control structure. The Headwaters Revitalization Schedule will allow lake water levels to rise 1.5 feet (ft) higher than the current S-65 schedule and will increase the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 acre-feet (ac-ft). Ninety-nine percent of the 36,612 ac of lands that will be affected by the higher water levels have been acquired, and all projects needed to increase the conveyance capacity of Upper Kissimmee Basin canals and structures are in place to accommodate the larger storage volume. The last of these upper basin projects, the C-37 Canal Widening Project, was completed in 2012.

Because of the time lag between completion of the earliest phases of the construction project and the implementation of the Headwaters Revitalization Schedule, the USACE authorized an interim regulation schedule that allows the SFWMD to make releases from S-65 when its headwater stage is within a certain range (termed “Zone B”) below the maximum regulated stage. Zone B allows releases from S-65 for environmental purposes when flood control releases are not needed. It is used to maintain flow in the reach of the restored river channel throughout the year and to allow seasonal variability. Environmental releases according to this interim schedule began in July 2001 after the Phase I construction was completed and lake levels began to rise following the 2000–2001 drought. Zone B releases have allowed continuous flow to the river since that time except for a 252-day dry period in 2006–2007. While the use of Zone B releases has been beneficial, it does not provide the full benefits that the Headwaters Revitalization Schedule is expected to provide.

CONSTRUCTION STATUS

In WY2013, construction activities consisted of the enlargement of the C-37 canal (between Lakes Hatchineha and Kissimmee) as well as projects in the Lower Kissimmee Basin such as Reach 2 and 3 Oxbow Excavation, S-65D Boat Ramp, CSX Railroad Bridge, River Acres Flood Reduction, and construction of the S-65EX1 spillway. These activities were completed in WY2013 or are scheduled for completion in WY2014. **Table 9-2** provides brief descriptions of current activities along with a chronological list of all the KRRP construction activities.

Table 9-2. Chronology of Kissimmee River Restoration Project construction. [Note: **Bold** text indicates C-38 backfilling contracts.]

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
1	Test Backfilling – A short section of the C-38 canal was backfilled as a test to evaluate engineering and design construction methods.	Complete		May 1994	$1.2 million (M)
14B	Pool A Spoil Mound Removal – A portion of a spoil mound in Pool A was degraded and two 48-inch culverts were installed under an access road.	Complete		October 2000	$0.62 M
3	S-65 Enlargement – The S-65 structure was enlarged from a three-bay to a five-bay spillway to maintain the existing level of flood protection for the headwater lakes.	Complete		May 2001	$4.8 M
2A	C-35 Dredging – Maintenance dredging was conducted in the C-35 canal to maintain the existing level of flood protection for the headwater lakes. A portion of C-36 was enlarged to maintain the existing level of flood protection.	Complete		July 2001	$2.6 M
4	Degradation of Local Levees in Pools A, B, and C – Local levees and associated borrow canals were restored to natural elevation.	Complete		2001	$1.5 M
5	S-65A Tieback Levee – The western tieback levee was degraded and box culverts installed in the eastern tieback levee. This allows additional discharge capacity adjacent to S-65A through the floodplain to avoid upstream impacts.	Complete		April 2001	$2.1 M
7	**Reach 1 Backfilling – Seven miles of the C-38 canal were backfilled, new river channels were constructed, and the S-65B structure was removed.**	**Complete**		**April 2001**	**$24.2 M**
2B	C-36 Enlargement – The C-36 and C-37 canals were enlarged to maintain the existing level of flood protection for the headwater lakes. Due to turbidity issues, the C-37 portion of this contract was terminated before completion.	C-36 Complete C-37 Terminated		April 2003	$14.5 M
8	U.S. Highway 98 Causeway – The causeway was elevated and resurfaced, a 100-foot flat-span bridge was built, and ten concrete culverts, each 2 meters by 3 meters by 30 meters, were installed under the highway for flood control and to improve hydrologic conditions in the Kissimmee River floodplain.	Complete		January 2004	$6.3 M
6A1A	8-83A/84A Spillways – When Kissimmee River floodplain water levels restrict Lake Istokpoga Basin discharges via the Istokpoga Canal, the C-41A spillway additions will offset the loss of discharge capacity by rerouting flows to the C-41A canal.	Complete		July 2007	$11.8 M
6B	Basinger Grove –Protection of the Basinger property from flooding due to elevated post-project Kissimmee River and Istokpoga Canal stages including construction of levees and pumping stations and a 22.5 acre detention area.	Complete		May 2008	$20 M

Table 9-2. Continued.

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
7B	Radio Tower – A radio tower at the S-65B structure was removed and a new one built approximately 11 miles to the west.	Complete		August 2007	$1.6 M
11	S-65D Grade Control Structure – Additional structures (S-65DX1 and S-65DX2) were built to increase the capacity of the S-65D structure.	Complete		October 2007	$7.5 M
13A	**Reach 4 Backfilling – 2.5 miles of the C-38 canal in Pool B were backfilled, a new river channel was excavated, and three existing navigable sheet pile weirs within the C-38 canal were removed.**	**Complete**		**October 2007**	**$29.8 M**
6A1B	S-68A Spillway – A new bypass channel was excavated, a gated spillway was constructed adjacent to the existing spillway, a portion of the existing levee was removed at the S-68 structure, and a temporary access road was constructed.	Complete		June 2009	$13.5 M
6A2	Istokpoga Canal Improvements – The G-85 weir was removed and replaced with the new S-67 control structure. Other features included construction of a tie-back levee, an access road, and a public boat ramp, and canal improvements.	Complete		March 2010	$14.3 M
13B	**Reach 4 Backfilling – 3.5 miles of the C-38 canal were backfilled along Reach 4 extending from the upstream limit of Contract 13A backfill northward to the upstream limit of the backfill.**	**Complete**		**December 2010**	**$18 M**
15	River Acres Flood Reduction – A seepage levee, flood protection tieback levee, and navigation canal were constructed for the River Acres community.	Complete	December 2009	July 2012	$2.97 M
2B1	C-37 Enlargement – The remainder of the C-37 canal, which was not completed under contract 2B, is being enlarged.	Complete	June 2010	September 2012	$15.6 M
9	CSX Railroad Bridge – An elevated single track railroad bridge is being constructed to allow navigation through the restored river channel.	Complete	November 2010	June 2013	$6.8 M
18	Pool D Oxbow Excavation and Embankment – A new oxbow connecting existing oxbows and an embankment along C-38 were constructed.	Complete	December 2010	November 2011	$2.8 M
10A	Oxbow Dredging – To accelerate completion of the KRRP, oxbow dredging to restore the historic river channel was removed from contract 10 and was completed in this separate contract.	Complete	September 2011	June 2012	$4.8 M
18B	Pool D Boat Ramp – A new boat ramp and small parking area will be constructed.	Complete	September 2011	October 2012	$0.9 M
12A	S-69 Weir – The S-69 weir will serve as the terminus of the C-38 canal backfill.	Awarded but under protest	August 2012	February 2014	NA
18A	S-65E Spillway Addition – A gated spillway will be constructed in the S-65E west tie-back levee.	Under construction	August 2012	April 2014	NA
10B	**MacArthur Ditch will be backfilled.**	**Not yet awarded**	**February 2015**	**October 2016**	**NA**
12	**Reach 3 Backfilling – New channels will be dredged and 2.5 miles of the C-38 canal will be backfilled.**	**Not yet awarded**	**February 2017**	**May 2018**	**NA**
10	**Reach 2 Backfilling – New channels will be dredged, 6.5 miles of the C-38 canal will be backfilled, and the S-65C structure will be removed.**	**Not yet awarded**	**February 2017**	**April 2019**	**NA**

Note: NA - not available

KISSIMMEE BASIN HYDROLOGIC CONDITIONS IN WATER YEAR 2013

This section discusses hydrologic conditions in WY2013 based on data collected by the SFWMD monitoring program at water control structures (**Figures 9-1** and **9-2**) and stage monitoring locations in the river channel and floodplain (**Figure 9-4**).

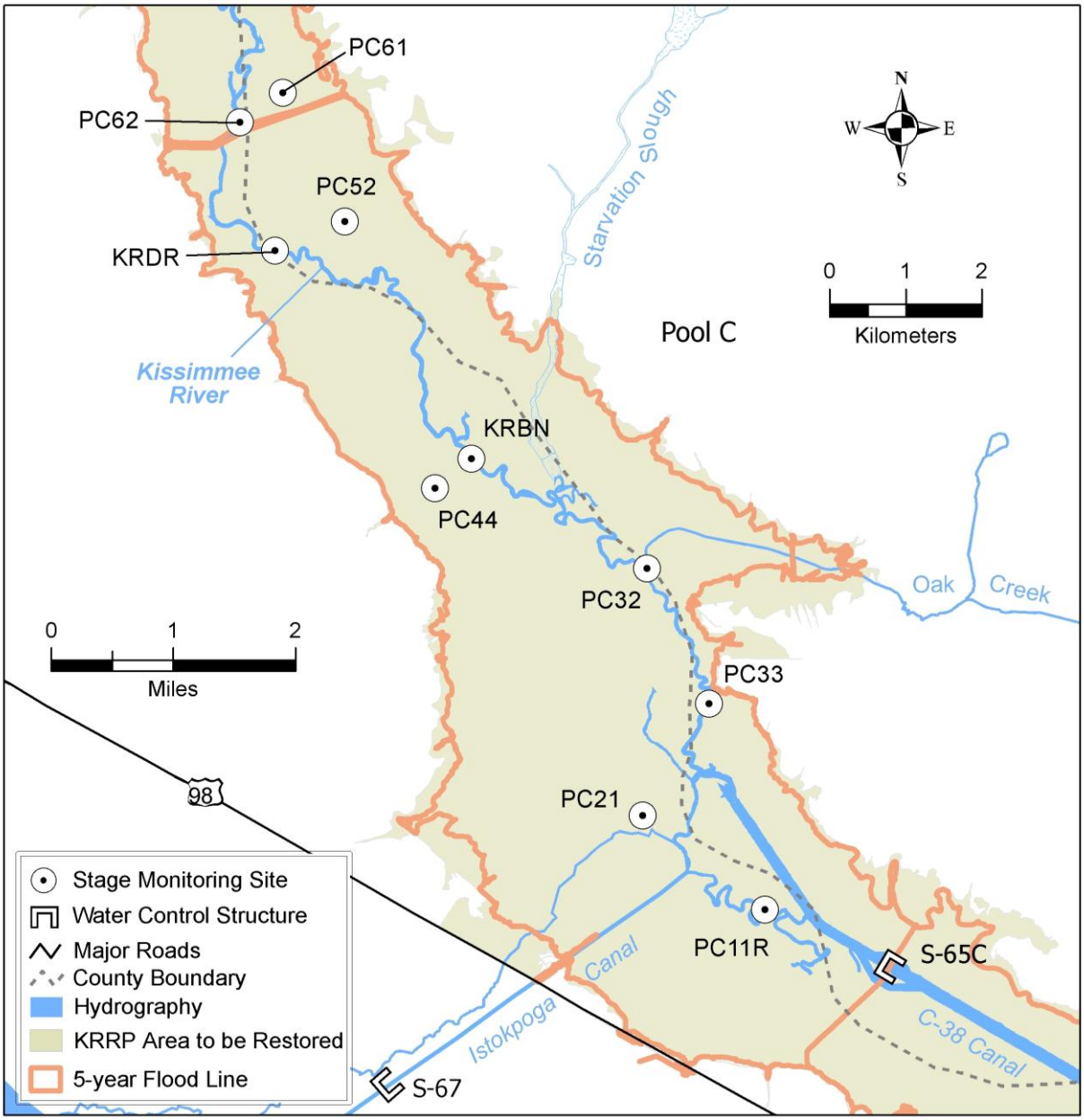

Figure 9-4. Locations of hydrologic monitoring sites in Pool C used to guide operations and to evaluate restoration expectations.

RAINFALL

During WY2013 annual rainfall was near average in both the upper and lower Kissimmee Basins. Rainfall was slightly higher in the wet season (June–October), especially June and August, and slightly below average during the dry season (November–May) (**Figure 9-5**). In the upper basin, total rainfall for the water year was 47.14 inches, which is 95 percent of the historical long-term average (1971–2000). The dry season total was 8 inches below average; the wet season was 5 inches above average. In the lower basin, total rainfall for the water year was 52.33 inches, which was 102 percent of the long-term average for the basin. Total rainfall for the wet season exceeded the long-term average by 11 inches; the dry season was 10 inches below average.

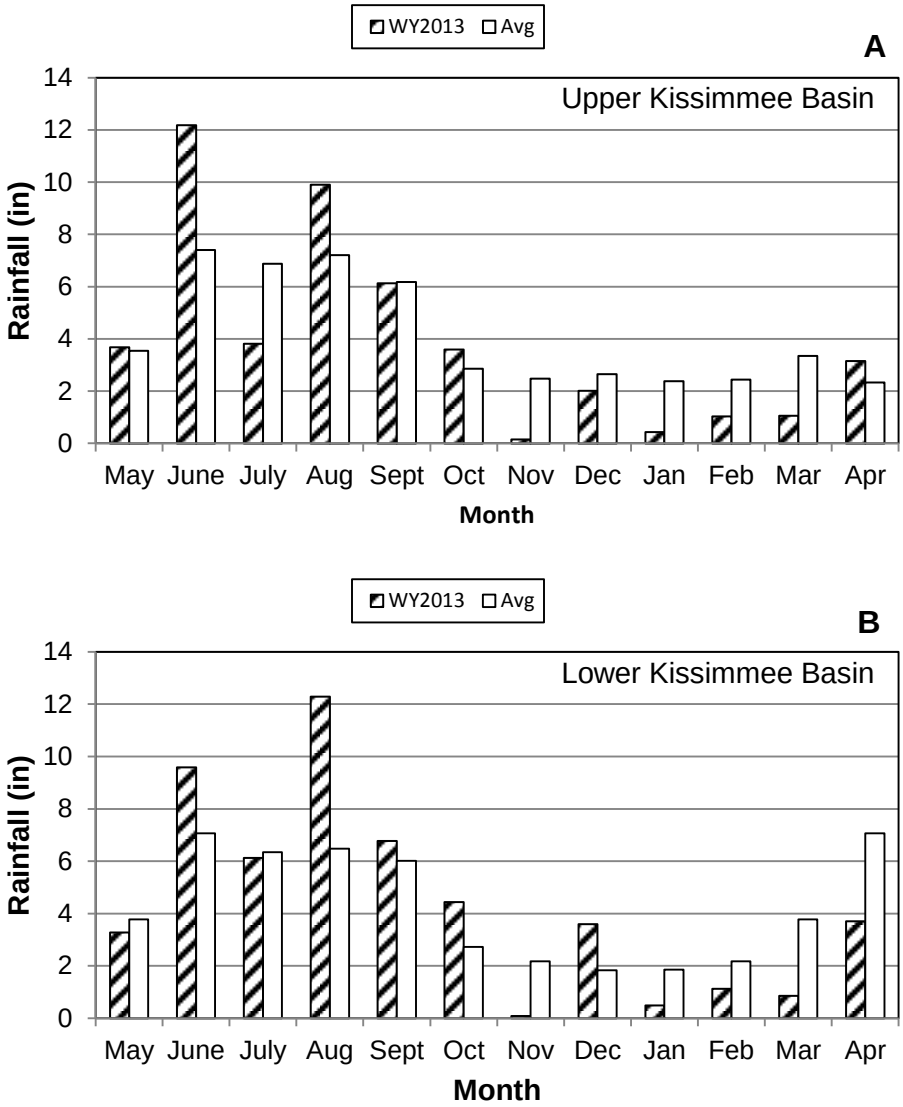

Figure 9-5. Monthly rainfall [in inches (in)] for Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) and average rainfall (1971–2000) in (A) the Upper Kissimmee Basin and (B) the Lower Kissimmee Basin.

TEMPORAL HYDROLOGIC PATTERNS

At the beginning of WY2013, all of the lakes were lowered to the lowest point of their individual regulation schedules by June 1 (see **Figure 9-6A** for East Lake Tohopekaliga, **Figure 9-6B** for Lake Tohopekaliga, and **Figure 9-7B** for Lakes Kissimmee, Cypress, and Hatchineha). During May, mean daily discharge at S-65 ranged between 150 and 1,500 cubic feet per second (cfs) (**Figure 9-7C**). The increase in discharge from 150 to 1500 cfs was accompanied by a slight increase in stage in the river channel as shown for site KRBN, but it was not sufficient to inundate the floodplain, as shown for PC61 (**Figure 9-8A**).

During the wet season, above average rainfall in June raised water levels in almost all of the lakes to the summer high of their respective regulation schedules by late June or early July (see **Figure 9-6A** for East Lake Tohopekaliga and **Figure 9-6B)** for Lake Tohopekaliga); Kissimmee-Hatchineha-Cypress did not reach the summer pool until later in the summer (**Figure 9-7B**) and only after above average rainfall in August and increased inflow from Lake Tohopekaliga.

In the lower basin, above average rainfall during June resulted in runoff and rising water levels in the Phase I area of the restoration project as shown for station PC61 (**Figure 9-8A**). Runoff in the lower basin also increased discharge at S-65C without an increase in discharge at S-65. As discharge increased, a hypoxic event developed when the mean daily concentration of dissolved oxygen (DO) decreased below 2 mg/L (**Figure 9-8B**). Mean daily DO values dropped to almost 0 mg/L at KRBN and briefly dipped below 1 mg/L at PC62. Dissolved oxygen was less than 2 mg/L at both river channel measurement sites for ten days (June 29-July 8). As discharge decreased, DO increased to over 3 mg/L by mid-July. Discharge continued at low levels (250-300 cfs) until late August.

In late August, Tropical Storm Isaac passed west of Florida and contributed significantly to the above average rainfall during August in the upper and lower Kissimmee Basins (**Figure 9-**5). The seven-day total ending on August 31 was 4.62 inches for the upper basin and 6.51 for the lower basin. Because the upper basin lakes were at or close to their regulation schedule lines, discharge was increased greatly from all of the lakes, as shown for Kissimmee-Cypress-Hatchineha in **Figure 9-7C**. Because of the combination of runoff from the lower basin and increased headwater discharge, discharge from the Phase I area through S-65C was also increased from 1,506 cfs on August 26 to 8,663 cfs on August 31 – an increase of more than 7,000 cfs in six days (**Figure 9-8A**). Over the same time period, water levels in the northern floodplain increased by about 4 feet as shown for PC61 in **Figure 9-8A**. Water levels in the southern floodplain of the Phase I area did not rise as much because of the effect of the S-65C structure.

The rapid changes in discharge and water levels in the Phase I area were associated with the development of a second hypoxic event. Mean daily DO dropped below 2 mg/L on August 28 at KRBN and on August 30 at PC62 (**Figure 9-8B**). By September 2, both stations had dropped to 0 mg/L. By September 5, 2012, a fish kill had occurred in the Phase I area. An observational or informal survey of a portion of the Phase I area found 3,805 dead fish; most (>80 percent) were sunfish including largemouth bass. As discharge and water levels decreased, DO recovered slowly. Mean daily DO did not exceed 2 mg/L until October 20, so hypoxic conditions persisted for 51 days.

Such decreases in DO have been observed previously in the Kissimmee River when high rainfall occurs after periods of low discharge (2006, 2008, 2009, and 2010 SFER – Volume I, Chapter 11). Rapid increases in discharge from upstream appear to exacerbate the effect of direct rainfall. Severely low concentrations may result in a fish kill. For centrarchids (largemouth bass and other sunfish) in the Kissimmee River, DO concentrations of 1–2 mg/L are stressful and concentrations less than 1 mg/L can cause death (see details in the 2008 SFER – Volume I, Chapter 11).

District scientists are continuing to study the problem of storm events that lead to hypoxia in the river. As stated in Chapter 9 of the 2013 SFER – Volume I, the mechanisms involved likely include some combination of the following: (1) influx of organic material from the floodplain and tributaries causing a rapid increase in biochemical oxygen demand (BOD), (2) dilution of oxygenated river channel water with anoxic water from runoff and upstream discharge (e.g., C-38 in Pool A), (3) inhibition of photosynthesis caused by flushing of photosynthetic aquatic organisms and greater attenuation of light with increased water depth and turbidity, and (4) seepage of anoxic groundwater from the surficial aquifer.

By the beginning of the dry season on November 1, the water levels in only a few of the upper basin lakes (Myrtle-Preston-Joel and Gentry) had risen to their winter high pools of their regulation schedules. Lakes Hart and Mary Jane reached their winter pool a little later in the dry season, but only after inflow from Myrtle-Preston-Joel had increased.

During the dry season, water levels in the KCOL declined due to evapotranspiration and managed releases. At S-61 and S-59, releases began in March and April, respectively, when lake levels intersected recession lines for the federally endangered snail kite (*Rostrhamus sociabilis plumbeus*) (**Figure 9-6**). Environmental releases continued to be made at S-65 for the Kissimmee River (**Figure 9-7C**). These stopped for one day in December (12/12/12) to slow the rise in water levels and discharge in the Phase I area because of a more than 2 inch rainfall event in a single day. This event resulted in a slight increase in water levels in the Kissimmee River and floodplain, which then declined over the dry season (**Figure 9-8A**).

Photos illustrating hydrological conditions in the Phase I restoration area throughout WY2013 are available on the District's website at http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/kissimriverarea_wateryr_2013.pdf (compiled by B. Anderson, SFWMD). Of particular interest is the hydrologic response to Tropical Isaac demonstrated by photos taken before and after this late August storm. Subsequent photos show the floodplain as water levels decline and leave drying pools that are attractive foraging sites for aquatic birds.

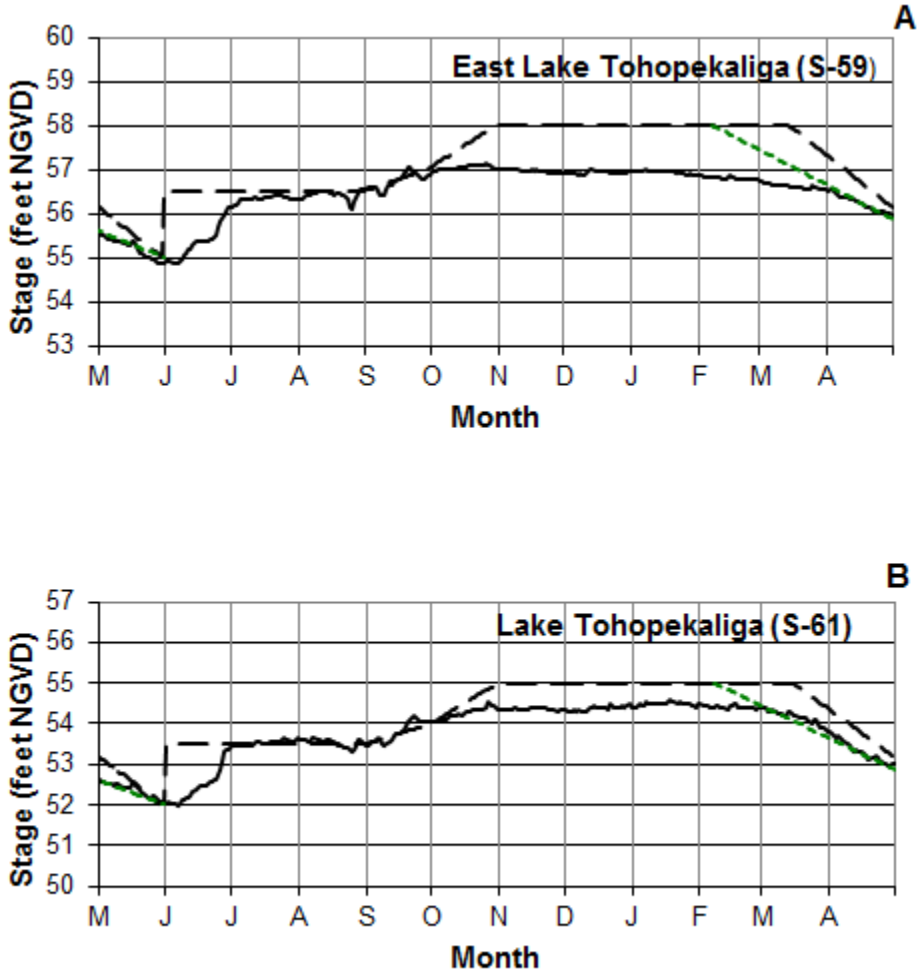

Figure 9-6. Regulation schedule (dashed line) and water level (solid line) in feet relative to the National Geodetic Vertical Datum of 1929 (NGVD) for (A) East Lake Tohopekaliga and (B) Lake Tohopekaliga during WY2013. Green dotted lines are desired water level recession for snail kites.

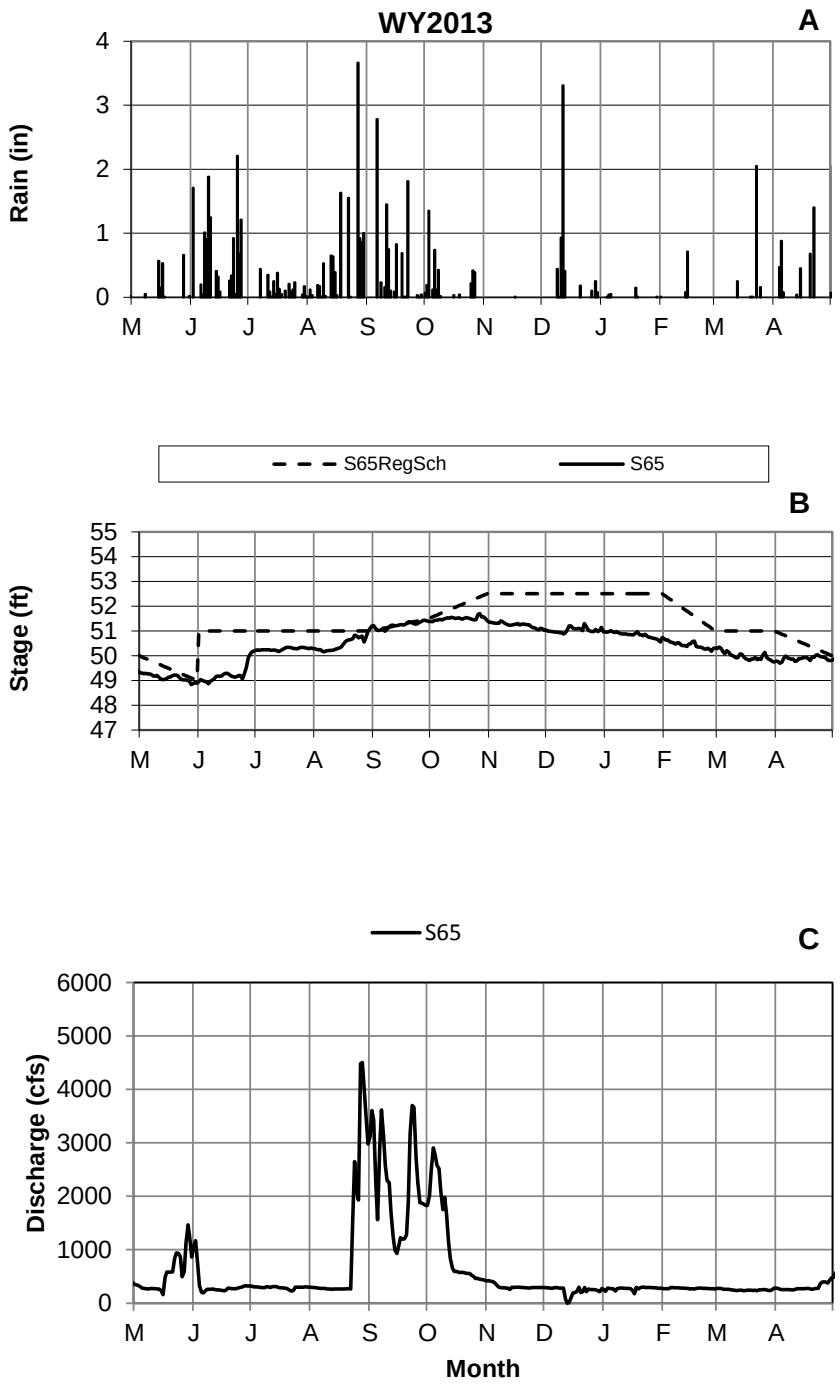

Figure 9-7. (A) Rainfall, (B) regulation schedule and water level in feet (ft), and (C) discharge in cubic feet per second (cfs) at the outlet of Lake Kissimmee (S-65 structure) for WY2013. Environmental releases are made when the S-65 stage is between the regulation schedule line in panel B and 48.5 feet.

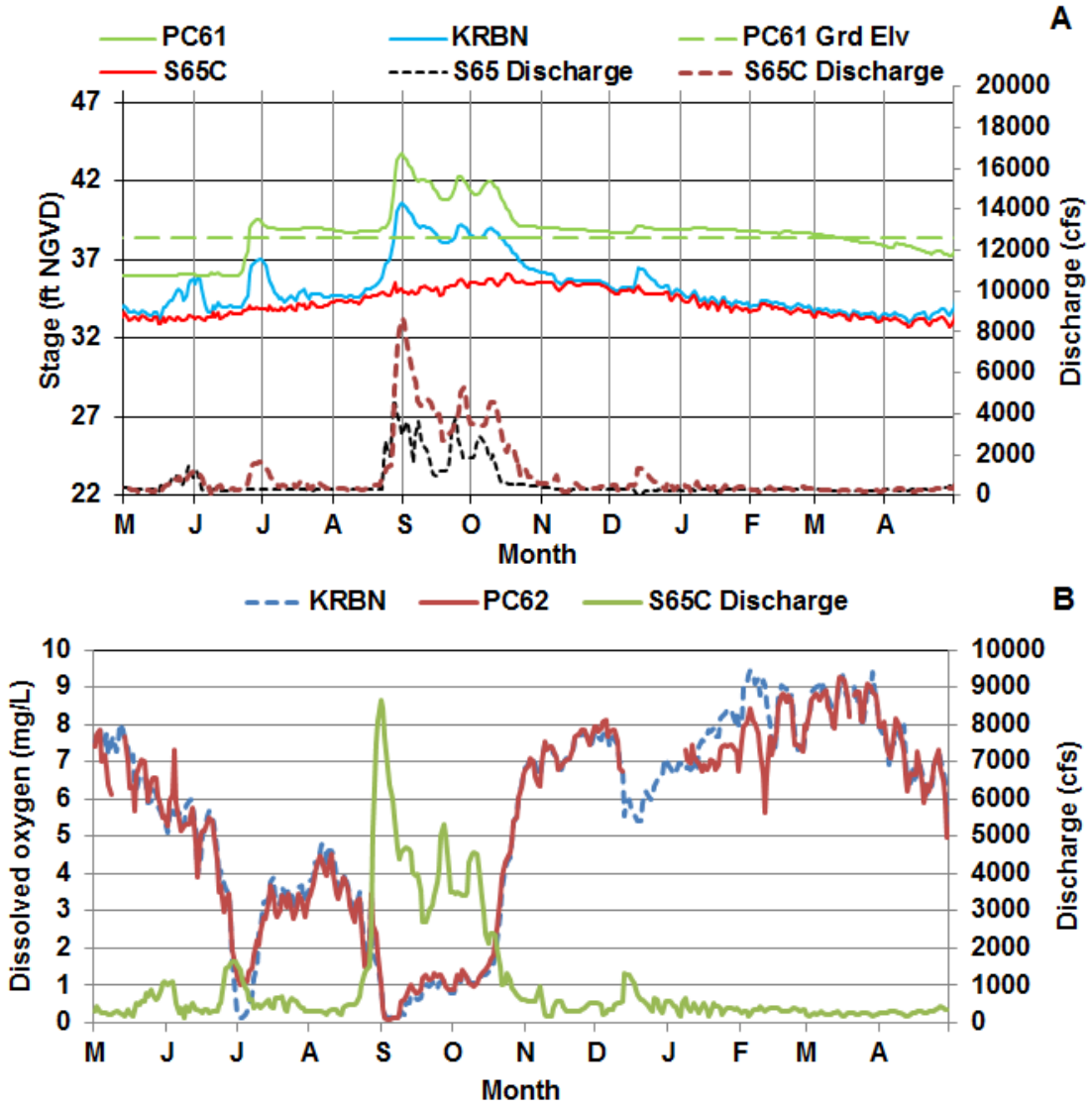

Figure 9-8. (A) Mean daily stage on the floodplain at PC61, in the river channel at KRBN, and in the C-38 canal on the upstream side of S-65C in relation to mean daily discharge at S-65 and S-65C during WY2013, and (B) mean daily dissolved oxygen (calculated from 15-minute measurements) in the river channel at KRBN and PC62, and discharge at S-65C. See **Figure 9-4** for locations of hydrological monitoring sites.

KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM

A major component of the KRRP is the assessment of restoration success through the Kissimmee River Restoration Evaluation Program (KRREP), a comprehensive ecological monitoring program (SFWMD, 2005a; SFWMD, 2005b; 2007 SFER – Volume I, Chapter 11). Evaluating the success of the KRRP was identified as a SFWMD responsibility in its cost-share agreement with the USACE (Department of the Army and SFWMD, 1994). Success is being tracked, in part, using 25 performance measures (SFWMD, 2005b) to evaluate how well the project meets its ecological integrity goal. Ecological integrity is defined as a reestablished river–floodplain ecosystem that is "capable of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley, 1981). Targets for these performance measures, called restoration expectations, are based on estimated conditions in the prechannelized system (reference conditions) and have undergone an external peer-review process. Trends and results from restoration evaluations are reported in several ways, including conference presentations, peer-reviewed and SFWMD technical publications, and annual SFER chapters. Many of the restoration expectations, particularly those related to floodplain responses, depend on removal of the S-65C structure during upcoming phases of construction, and implementation of the Headwaters Revitalization Schedule. Therefore, a final evaluation of project success must wait until all restoration components are in place. However, ecological responses being documented prior to project completion are used to evaluate the ongoing status of ecosystem recovery and adaptive management of the system. Monitoring for ecological evaluation of restoration success will continue for at least five years after construction is complete or until ecological responses have stabilized.

Limited post-construction monitoring continued in WY2013 in the Phase I restoration area. Many of the Phase I studies, which include collection of data on hydrology, geomorphology, water quality, river channel and floodplain vegetation, aquatic invertebrates, herpetofauna, fish, and birds, have already indicated changes consistent with those predicted by the expectations developed for the KRREP. A comprehensive update of initial responses to Phase I reconstruction was published in Chapter 11 of the 2005 SFER – Volume I, with updates using newly available monitoring data published in subsequent SFERs. The combined results for a group of interrelated river channel studies were presented in Chapter 11 of the 2006 SFER – Volume I. **Table 9-3** provides a directory of KRREP monitoring study updates since 2005.

To contain costs, most KRREP studies do not collect data continuously. Most studies are active for two to five years during the baseline (pre-restoration), interim, and/or post-restoration response periods. The "interim period" for KRREP evaluations of the Phase I area is defined as the years between completion of Phase I construction (2001) and completion of all remaining construction phases and implementation of the Headwaters Revitalization Schedule. During the interim period, the river's physical and hydrologic characteristics are only partially restored.

Only studies that collected new data in WY2013 are updated in this section. These new results from studies on hydrology, dissolved oxygen, nutrients, wading birds, and waterfowl document the current interim status of these ecosystem components. Where applicable, the results are evaluated in relation to associated restoration expectations.

Table 9-3. Directory of Kissimmee River Restoration Evaluation Program (KRREP) Phase I restoration response monitoring study updates in the *2005–2014 South Florida Environmental Reports* (SFERs).

KRREP Monitoring Study or Project	Expectation Number	Page Number in 2005–2014 SFERs — Volume I									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Kissimmee River Restoration Evaluation Program		11-8	11-37	11-22	11-28	11-36	11-26	11-25	9-16	9-19	9-19
Hydrology											
Stage-discharge relationships	None	11-20									
Continuous river channel flow	1	**[11-18]**				**[11-39]**	**[11-29]**	**[11-29]**	**[9-20]**	**[9-23]**	**[9-22]**
Variability of flow	2					**[11-40]**	**[11-31]**	**[11-32]**	**[9-20]**	**[9-23]**	**[9-23]**
Stage hydrograph	3	**[11-22]**				**[11-41]**	**[11-32]**	**[11-33]**	**[9-21]**	**[9-24]**	**[9-24]**
Stage recession rate	4	**[11-23]**	11-23	11-16	11-19	**[11-42]**	**[11-34]**	**[11-35]**	**[9-24]**	**[9-27]**	**[9-28]**
Flow velocity	5	**[11-25]**					**[11-35]**	**[11-37]**	**[9-24]**		
Broadleaf marsh indicator	None					11-43					
Geomorphology											
River bed deposits	6	**[11-26]**						**[11-70]**			
Sandbar formation	7	**[11-26]**						**[11-70]**			
Channel monitoring	None					11-54		11-68			
Sediment transport	None							11-71			
Floodplain processes	None							11-72			
Dissolved Oxygen	8	**[11-28]**	**[11-44]**	**[11-25]**	**[11-28]**	**[11-45]**	**[11-36]**	**[11-38]**		**[9-27]**	**[9-28]**
River Channel Metabolism	None				11-35						
Phosphorus	None	11-33	11-52	11-30	11-32	11-51	11-43	11-43	9-25	9-31	9-32
Turbidity	9	**[11-30]**	**[11-48]**	**[11-27]**							
Periphyton	None	11-46									
River Channel Vegetation											
Width of littoral vegetation beds	10	**[11-36]**				**[11-59]**					
River channel plant community structure	11	**[11-37]**				**[11-59]**					
Floodplain Vegetation											
Areal coverage of floodplain wetlands	12	**[11-39]**			**[11-35]**			**[11-47]**			
Areal coverage of broadleaf marsh	13	11-40			**[11-35]**			**[11-47]**			
Areal coverage of wet prairie	14	11-40			**[11-35]**			**[11-47]**			

Table 9-3. Continued.

KRREP Monitoring Study or Project	Expectation Number	Page Number in 2005—2014 SFERs — Volume I									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Invertebrates											
Macroinvertebrate drift composition	15	**[11-45]**	11-57								
Snag invertebrate community structure	16	**[11-46]**	11-55			11-62					
Aquatic invertebrate community structure in broadleaf marsh	17		11-57								
Benthic invertebrate community structure	18	**[11-45]**	11-58			11-62					
Native and nonnative bivalves	None							11-52			
Herpetofauna		11-48									
Floodplain reptiles and amphibians	19		Response data will be collected after implementation of the Headwaters Regulation Schedule.								
Floodplain amphibian reproduction and development	20		Response data will be collected after implementation of the Headwaters Regulation Schedule.								
Fish Communities											
Small fishes in floodplain marshes	21	11-50	Response data will be collected after implementation of the Headwaters Regulation Schedule.								
River channel fish community structure	22	11-52	**[11-59]**			**[11-66]**			**[9-29]**		
Mercury in fish	None					11-20					
Floodplain fish community composition	23	11-50	Response data will be collected after implementation of the Headwaters Regulation Schedule.								
Birds											
Wading bird abundance	24	**[11-58]**	**[11-71]**	**[11-32]**	**[11-44]**	**[11-72]**	**[11-50]**		**[9-36]**	**[9-41]**	**[9-46]**
Waterfowl	25		**[11-67]**	**[11-35]**		**[11-73]**	**[11-52]**		**[9-37]**	**[9-42]**	**[9-48]**
Shore birds	None	11-57									
Wading bird nesting	None		11-68		11-40	11-72	11-47		9-33	9-38	9-40
Threatened and Endangered Species	None	11-60									

[xxx] bolded brackets indicate a major update in reference to the status of a restoration expectation (performance measure)

HYDROLOGY

The reestablishment of hydrologic conditions (water surface elevations and flow) comparable to those of the natural system is the primary driver for restoring ecological integrity to the Kissimmee River and its floodplain. Hydrologic conditions are being evaluated with respect to five expectations for the restored hydrology of the river channel and floodplain. These expectations reflect criteria that have guided the restoration project since its inception (SFWMD, 2005b). The ability to meet these expectations depends on the implementation of the Headwaters Revitalization Schedule. Until this schedule is implemented, an interim regulation schedule for S-65 is providing discharge to the river that varies seasonally and with water levels in Lake Kissimmee. However, this interim schedule is not expected to fully deliver the seasonal pattern of discharge needed for river restoration.

The addition of WY2013 data extends the evaluation of the Phase I interim period to twelve years (WY2002–WY2013). This evaluation quantifies the status of the hydrologic expectations under the interim flow conditions. This year's update focuses on four hydrologic expectations for discharge and stage. A fifth expectation for water velocity was evaluated in Chapter 11 of the 2012 SFER – Volume I. Chapter 11 of the 2011 SFER – Volume I includes more detail on methods. For purposes of scientific evaluation of restoration, hydrologic responses are presented in SI units instead of English units, which are the convention for water management and are used elsewhere in this chapter.

Expectation 1

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

In WY2013, mean daily discharge at S-65 ranged from 0 m^3/s to 128 m^3/s and averaged 17 m^3/s (**Figure 9-9a**). As described in the *Temporal Hydrologic Patterns* section, discharge at S-65 was stopped for one day in December 2012 (as it was for a five-day period in July 2011) to conserve water while runoff from the S-65A sub-basin maintained discharge to the Kissimmee River. Consequently, even though discharge at S-65 was not continuous during WY2013 (or WY2012), discharge to the Phase I area was continuous. So, the expectation has been met for 9 of 12 years, including WY2013 (**Figure 9-9b**).

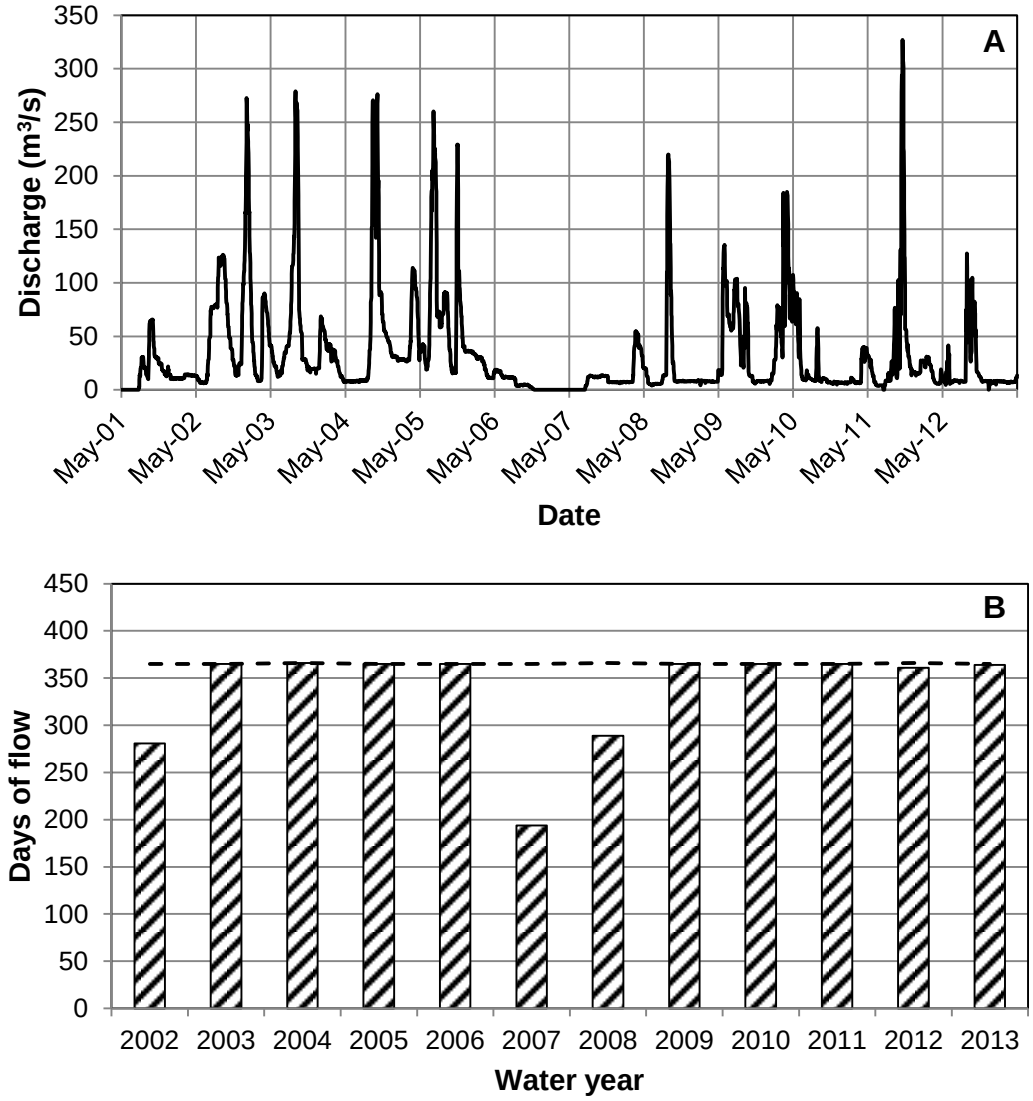

Figure 9-9. (A) Mean daily discharge [cubic meters per second (m^3/s)] at the S-65 structure, the outlet from the Upper Kissimmee Basin, and (B) number of days with flow at S-65 for WY2002–WY2013.

Expectation 2

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

During WY2013, monthly mean discharge at S-65 reached a maximum of 63 m^3/s in September and decreased to a minimum of 7 m^3/s in December and remained at 7-8 m^3/s for the remainder of the water year (**Figure 9-10**). This seasonal pattern reflected the above-average rainfall in the upper basin during August and the below-average rainfall for most of the dry season (**Figure 9-5**). The addition of WY2013 to the interim period resulted in a coefficient of variation for monthly mean discharge that ranged from 0.84 to 1.49. Only four months (May,

August, September, and February) during the WY2002-WY2013 period had a coefficient of variation less than 1.0, so the expectation was not met.

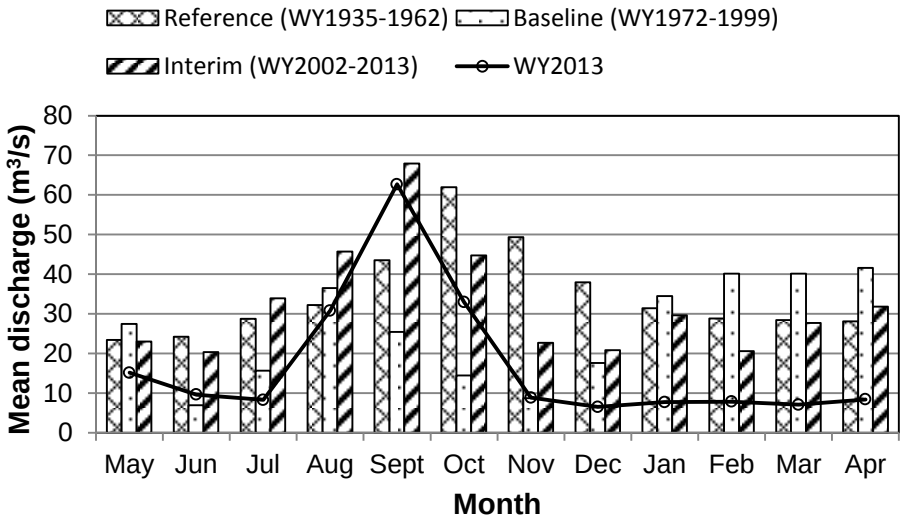

Figure 9-10. Seasonality of monthly mean discharge at S-65 for WY2013 and for average values for reference (WY1935–WY1962), baseline (WY1972–1999), and interim periods (WY2002–2013).

Expectation 3

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

The amplitude of stage fluctuation and duration of water above ground level were quantified at five floodplain locations. These locations were selected to be representative of the same position within a floodplain cross-section as the pre-channelization reference data that were used to develop the expectation. From upstream to downstream, these sites are PC61, PC52, PC44, PC32, and PC21 (**Figure 9-4**). The three most upstream sites (PC61, PC52, PC44) are referred to here as the northern floodplain sites; the two most downstream sites (PC32, PC21) are referred to as the southern floodplain sites. Water level fluctuation in the southern floodplain is constrained by the downstream water control structure, S-65C, which is managed to keep water levels at an elevation between 10 and 11 m in relation to the National Geodetic Vertical Datum of 1929 (NGVD29). The ground elevations at PC32 and PC21 are near the lower end of the range of elevation at S-65C; therefore, water levels at these sites are regulated largely by S-65C, which will be removed in the last phase of restoration construction.

At the beginning of WY2013, the stage at all five floodplain sites was below ground level (**Figure 9-11**). Stage at the three northern floodplain sites (PC61, PC52, and PC44) increased sharply in late June in response to above-average rainfall and higher discharge and then began to decrease. Stage at the northern floodplain sites increased sharply in late August with above-average rainfall and even larger discharges than in June. Stage then varied with discharge, but generally decreased over the remainder of WY2013. At the southern floodplain sites (PC32, PC21) stage also increased in late June and August, but by smaller amounts than at the northern

sites. Aside from increases in late June and August, stage at the southern floodplain sites varied with the headwater stage at S-65C (**Figure 9-11**).

In WY2013, all stations except PC21 met the target for amplitude of stage fluctuation of at least 1.14 m (**Figure 9-12**). The three most upstream sites (PC61, PC52, and PC44) also met the target in each of the preceding eleven years of the interim period; the two downstream sites met the target less frequently – PC32 in eight years and PC21 in only three years. The target for inundation duration of at least 180 days was met at all sites except PC44. The duration of inundation at PC32 and PC21 was shorter than in previous years because the water level at S-65C was lowered for part of the year. In conclusion, the expectation for river channel stage fluctuation and inundation duration was not met at all monitoring locations in WY2013.

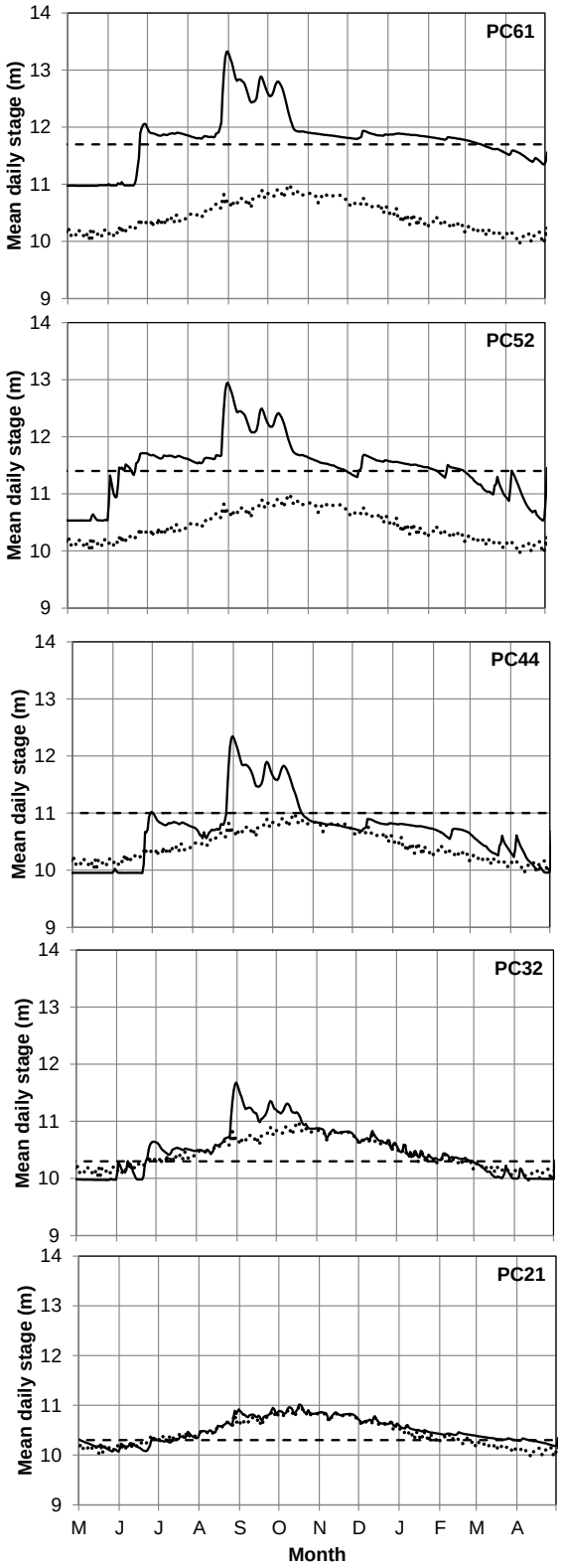

Figure 9-11. Water level (stage) in meters (m) during WY2013 at five floodplain locations. Dashed line is the ground elevation at the location. Dotted line is the headwater stage at S-65C.

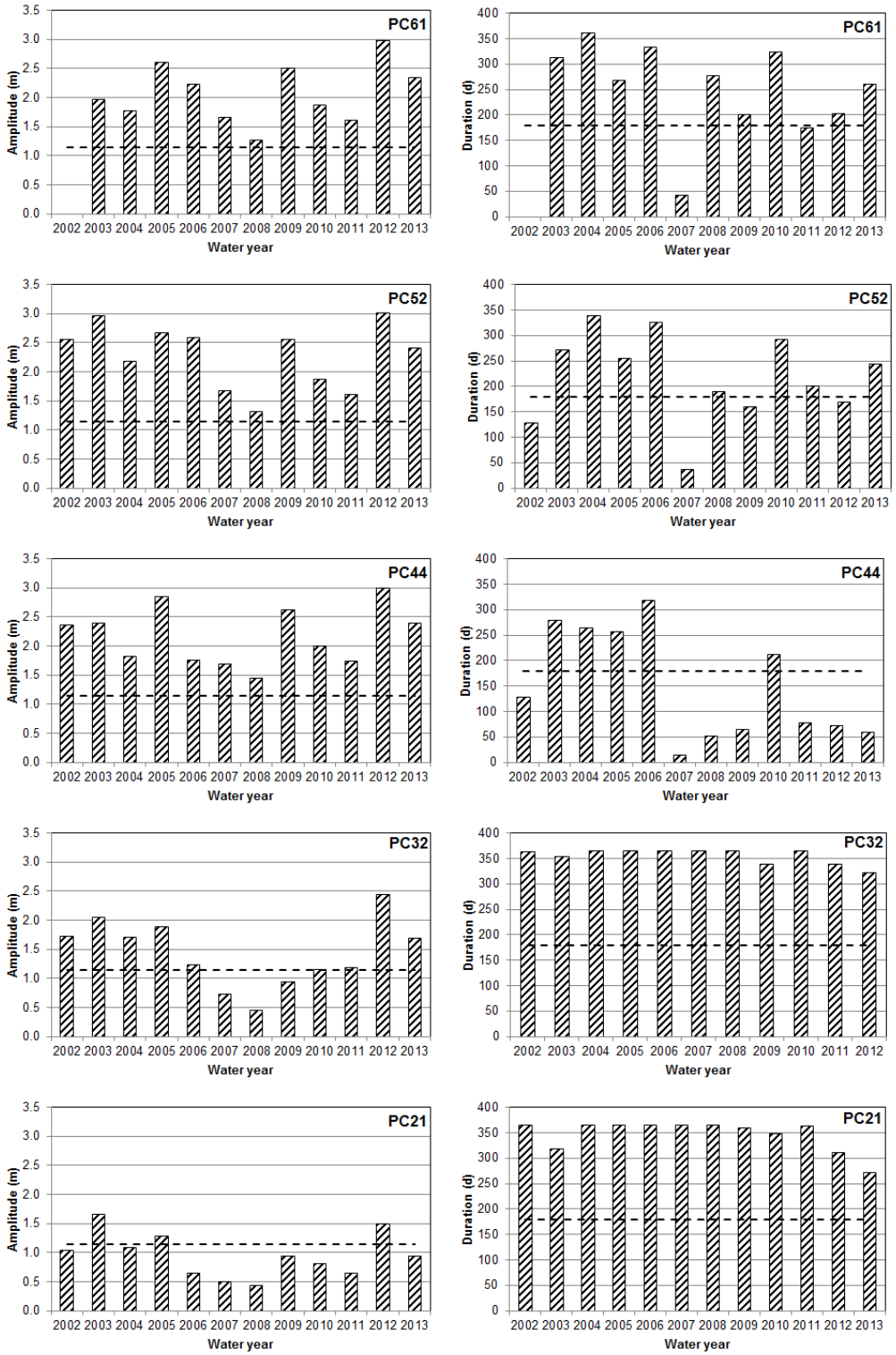

Figure 9-12. Amplitude of water level fluctuation (left) and duration of inundation (right) at five locations for WY2002–WY2013. The dashed horizontal lines represent minimum change in water level fluctuation of at least 1.14 m per year (left) and a minimum duration of 180 days per year for stage exceeding floodplain ground elevation (right).

Expectation 4

An annual prolonged recession event will be reestablished with a duration of > 173 days and with peak stages in the wet season receding to low stage in the dry season at a rate that will not exceed 0.3 m per 30 days (SFWMD, 2005b).

During WY2013, a single recession event, identified by a stage reversal larger than 0.45 m, occurred at the five floodplain stage monitoring sites (PC61, PC52, PC44, PC32, and PC21) (**Table 9-4**). At all of these locations, this event met the combination of a duration longer than 173 days and an event recession rate that did not exceed 0.3 m per 30 days. Thus, the expectation for a single, prolonged recession event was met in WY2013.

Table 9-4. Calculation of recession rates for WY2013 events at five sites. Recession rate is calculated from the timing (T_{max}) and elevation (h_{max}) of the maximum stage for the event to the timing (T_{min}) and elevation (h_{min}) of the minimum stage. The recession rate (R) is calculated by dividing the change in water level elevation (Δh) by the change in time (ΔT) and multiplying by 30 days.

Site	T_{max}	h_{max} (m)	T_{min}	h_{min} (m)	Δh (m)	ΔT (d)	R (m/30 days)
PC61	31-Aug-12	13.32	28-May-13	11.30	2.02	270	0.22
PC52	31-Aug-12	12.95	29-Apr-13	10.53	2.42	241	0.30
PC44	31-Aug-12	12.35	27-Apr-13	9.96	2.39	239	0.30
PC32	31-Aug-12	11.68	11-Apr-13	9.99	1.69	223	0.23
PC21	17-Oct-12	11.01	29-Apr-13	10.18	0.83	194	0.13

DISSOLVED OXYGEN

Expectation 8

Mean daytime concentration of dissolved oxygen in the Kissimmee River channel at 0.5-1.0 m depth will increase from < 1-2 mg/L to 3-6 mg/L during the wet season (June-November) and from 2-4 mg/L to 5-7 mg/L during the dry season (December-May). Mean daily concentrations will be greater than 2 mg/L more than 90% of the time. Dissolved oxygen concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50% of the time (SFWMD, 2005b).

Restoration has been expected to improve DO concentrations in the river channel. However, reference DO data from the prechannelized, flowing river are not available to support quantitative performance measures. Therefore, reference conditions for the prechannelized river were derived from data from other free-flowing, blackwater streams in South Florida. At least 11 samples were collected from each of the seven streams over a minimum of one year. Some streams were sampled for more than 10 years (**Figure 9-13**). The period of record for these reference data is 1973–1999. The mean daytime DO concentration in the reference streams was 4.2 milligrams per liter (mg/L) during the wet season and 6.1 mg/L during the dry season (**Figure 9-14**). In five of

the seven streams, DO was greater than 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 greater than 2 mg/L.

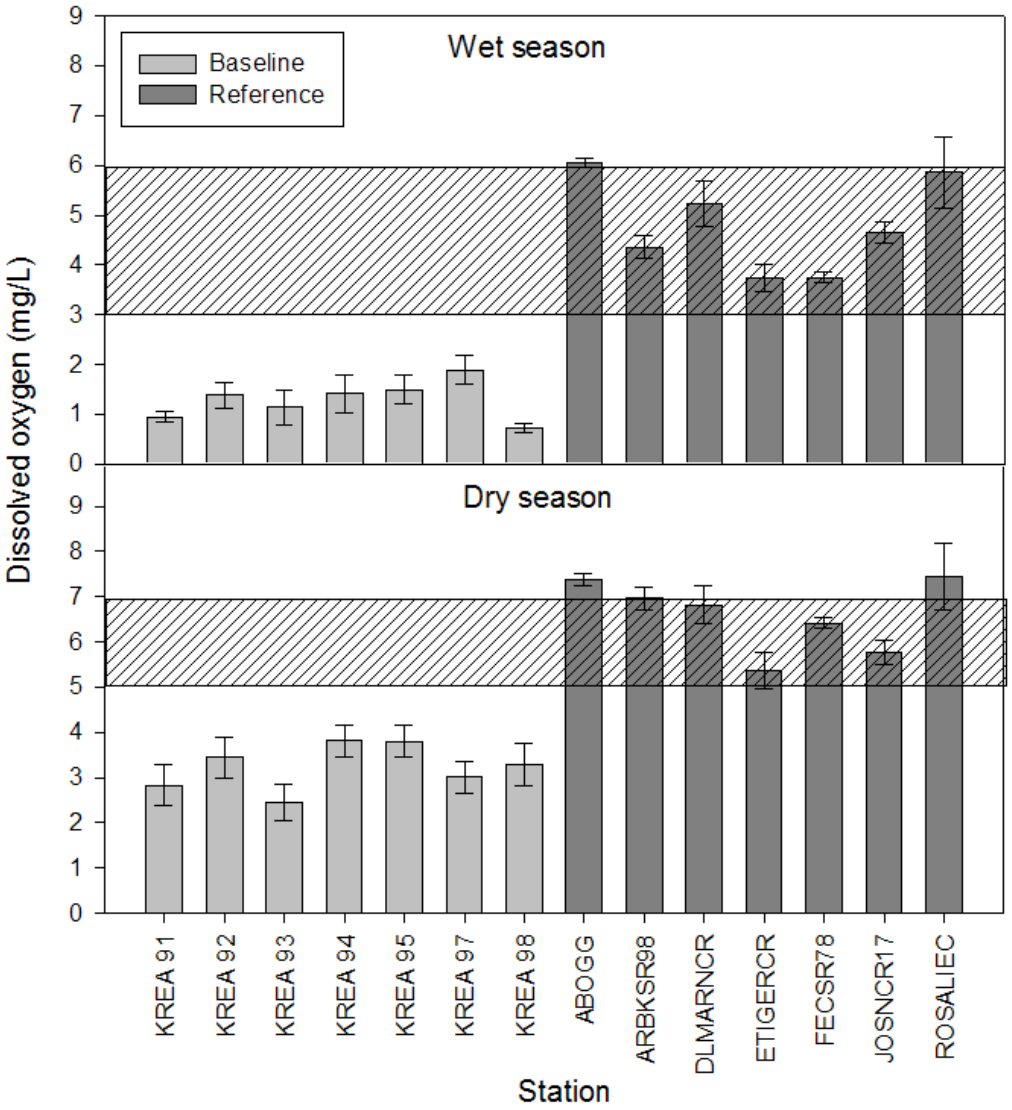

Figure 9-13. Mean [± standard error (S.E.) of the mean] dissolved oxygen (DO) concentrations in milligrams per liter (mg/L) in free-flowing, blackwater South Florida streams (dark-shaded) and remnant runs (light-shaded) of the channelized Kissimmee River during the wet (June–November) and dry (December–May) seasons. Hatched areas represent expected range of DO concentrations in the Kissimmee River after restoration. Station names shown are South Florida Water Management District (SFWMD) monitoring sites.

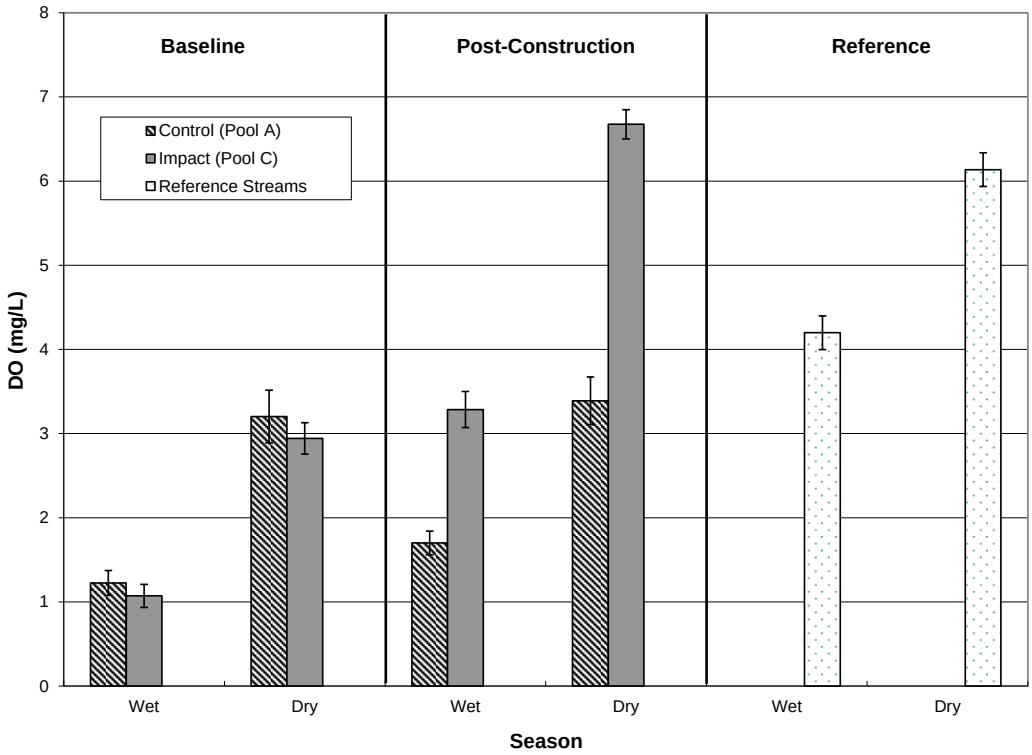

Figure 9-14. Mean (± S.E.) DO concentrations (mg/L) in reference streams (period of record = 1973–1999) and control and impact areas during the wet and dry seasons, during the baseline (1997–1999) and post-restoration (2001–present) periods.

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

Within the remnant river runs during the baseline period, DO concentrations were frequently below 1 mg/L throughout the water column at all times of day. A gradient in DO concentration, decreasing with depth, was common during the warmer months of the year. DO concentrations near the surface could reach 4–5 mg/L, but concentrations near the bottom were lower than the detection limit (< 0.2 mg/L). During 1997–1999, mean DO concentrations in remnant river runs in Pool A and C were 1.2 mg/L and 1.1 mg/L, respectively, during the wet season, and 3.2 mg/L and 3.0 mg/L, respectively, during the dry season (**Figure 9-14**). DO concentrations exceeded 2 mg/L for only 22 percent of the baseline period, and 5 mg/L for only 6 percent of this period.

The reference and baseline data were used to develop four components of Expectation 8 (SFWMD, 2005b) to evaluate changes in DO as restoration proceeds (**Table 9-5**).

Following completion of the first phase of construction, DO concentrations within the restoration area (Pool C) averaged 3.3 mg/L during the wet season and 6.7 mg/L during the dry season (average of all post-construction data) (**Figure 9-14**). In comparison, post-construction DO concentrations in the control area (Pool A) averaged 1.7 and 3.4 mg/L during the wet and dry

seasons, respectively (**Figure 9-14**). Mean DO concentrations in the restoration area increased from less than 3.0 mg/L before construction to 7.3 mg/L in WY2013 (**Figure 9-15**). Also in WY2013, mean daily water column DO concentrations were greater than 2.0 mg/L for 82 percent of the time. In summary, two of the three metrics measured in WY2013 to evaluate DO response were met under the interim regulation schedule (**Table 9.5**). Despite this general improvement in DO concentrations within the river channel, short-term declines coinciding with storm events continue to be an issue during the wet season. We are working to determine the causes of these DO sags and are developing techniques to ameliorate them through adjustments to water control operations. The final determination of restoration success with respect to DO in the river channel will be made after implementation of the Headwaters Revitalization Schedule.

Table 9-5. DO restoration expectation metrics and WY2013 values.

Expectation Metric	WY2013 Value	Metric Achieved in WY2013?
Mean daytime DO concentration in the river channel at 0.5–1.0 m depth will increase from < 2 mg/L to 3–6 mg/L during the wet season (June–October).	3.7 ± 0.6 mg/L	Yes
Mean daytime DO concentration in the river channel at 0.5–1.0 m depth will increase from 2–4 mg/L to 5–7 mg/L during the dry season (December–May).	7.3 ± 0.3 mg/L	Yes
Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90 percent of the time (annually).	82%	No
DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50 percent of the time annually.	--	Data not collected in WY2013

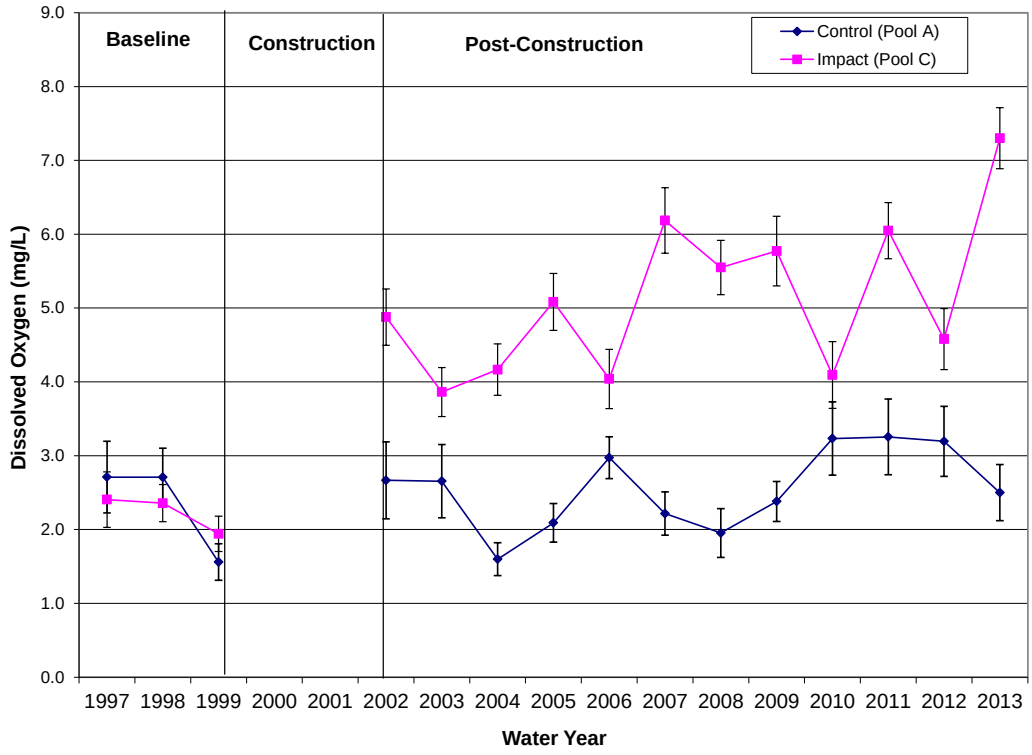

Figure 9-15. Mean DO concentrations (mg/L) in the Kissimmee River for each water year during the baseline and post-construction periods.

PHOSPHORUS AND NITROGEN

Expectation

No expectation has been established for phosphorus and nitrogen.

As Lake Okeechobee's largest tributary, the Kissimmee River conveys a major portion of phosphorus to the lake (see Chapter 8 of this volume). Construction of the C-38 canal and lateral drainage ditches has presumably contributed to phosphorus loading from the Kissimmee Basin by facilitating downstream transport of phosphorus runoff and limiting opportunities for detention and assimilation in floodplain wetlands. Because nutrients were not monitored before channelization, the amount of increase, if any, resulting from the C&SF Project cannot be estimated from historical data. However, knowledge of the river's former characteristics and its floodplain and watershed (SFWMD, 2005a; HDR Engineering, Inc., 2012) make it reasonable to assume that concentrations were lower prior to channelization and watershed development.

Although the lack of pre-channelization data has precluded development of a quantitative expectation for nutrient loading reduction, the restored river is anticipated to attenuate loading from lateral tributaries and the headwater lakes once a more natural hydroperiod and a stable wetland ecosystem become established. In the meantime, phosphorus concentrations may increase periodically as the nutrient runs off former pastures and the floodplain transitions from terrestrial to wetland vegetation.

Nutrient Loads and Concentrations

This section presents nutrient loads and concentrations monitored at the five C-38 water control structures. Data collected since completion of Phase I restoration construction (WY2002-WY2013) are compared to baseline data (1974-1995) obtained prior to construction.

To estimate phosphorus and nitrogen loading along the C-38 canal, baseline and post-construction total phosphorus (TP) and total nitrogen (TN) concentrations were monitored routinely at each of the canal's water control structures along with daily estimates of discharge. Total P and TN concentrations were measured from grab samples collected every two weeks. Total P concentrations were also monitored with auto-samplers. Sub-samples collected multiple times per day were combined into a single sample that was taken from the autosampler weekly. Estimates of daily nutrient loads were computed from measured or interpolated concentrations and daily discharges. These daily loads were then summed annually.

Nutrient loads are highly dependent on discharge and vary widely from year to year. At S-65, for example, annual discharges during the post-Phase I period, ranged from approximately 121,000 ac-ft to over 1,500,000 ac-ft (**Figure 9-16**), while annual TP loads ranged from 16 mt to 239 mt (**Figure 9-17**). Relative to other years since Phase I construction, WY2013 discharges and nutrient loads were moderate.

Since the 1974-1995 baseline period, more of the Kissimmee Basin's TP load has originated from the Upper Kissimmee Basin. During WY2002-WY2013, the average TP load at S-65 was 88 metric tons per year (mt/yr), which was more than 150 percent of the average baseline load of 35 mt/yr. In contrast, the average TP load at S-65E increased by only 28 percent (117 mt/yr to 150 mt/yr), and this difference was mostly accounted for by the difference in discharge (21 percent) between the two periods. As a percentage of the S-65E load, the TP load at S-65 was 30 percent during 1974-1995 and 59 percent during WY2002-WY2013.

The flow-weighted mean (FWM) nutrient concentration is a metric useful for monitoring trends at each structure. The annual FWM TP concentrations in **Figure 9-18** were calculated by dividing annual nutrient load by annual discharge. These concentrations reached a peak in WY2005–WY2007 following disturbance caused by three hurricanes passing over the headwater lakes in WY2005. Declines in these concentrations over the next few years can be partially attributed to improving water quality in the headwater lakes. However, the declining trend has reversed since WY2011 due to the influence of the "No-Name Storm" of October 2011 and Tropical Storm Isaac in August 2012. The impact of the No-Name Storm was discussed in Chapter 9 of the 2013 SFER – Volume I.

As expected from the discharge and TP load results, the average of annual FWM TP concentrations at S-65E was nearly the same during 1974-1995 (111 micrograms per liter or µg/L) and WY2002-WY2013 (113 µg/L). However, the average annual concentration at S-65 nearly doubled (43 µg/L to 85 µg/L). Influences on TP concentrations at S-65 have been discussed in previous SFERs. Essentially, the higher concentrations appear to be due more to local influences near the structure than to a general increase in concentrations in Lake Kissimmee and the upstream lakes. Several reasons have been proposed for the higher concentrations found in the southern extremity of the lake, including local watershed runoff, in-lake disturbances from vegetation control and wind events, construction activity at S-65, and changes in data collection methods. The SFWMD has obtained a few water quality samples, prior to WY2013, indicating that local runoff can strongly influence TP in the south end of Lake Kissimmee.

From **Figures 9-17** and **9-18**, it is apparent that phosphorus measured at S-65C, downstream of the restoration area, is highly dependent on the phosphorus discharged from S-65. In particular, annual FWM TP concentrations at S-65C have been usually similar to concentrations at S-65. Also, comparing the post-Phase I period to the baseline period, average annual loads and

concentrations at S-65C have followed the increase at S-65. Annual TP loads during WY2002-WY2013 averaged 97 mt at S-65C, compared to 51 mt during the baseline period, while average annual FWM TP concentrations increased from 53 µg/L to 83 µg/L. Thus, higher TP loading from S-65 is an important factor in considering why the TP load and concentration at S-65C have not yet declined, overall, since the baseline period.

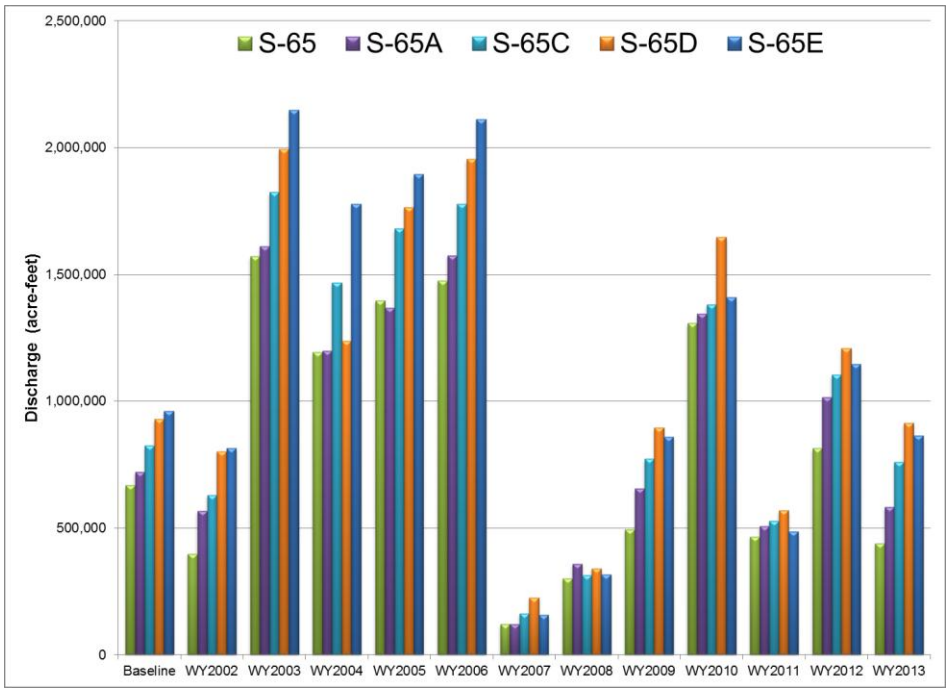

Figure 9-16. Annual discharges from C-38 structures for WY2002–WY2013 in comparison to average annual discharges during the baseline (calendar years 1974–1995). WY2002, WY2007, WY2008, and WY2011 were drought years, and WY2005 was wet due to hurricanes.

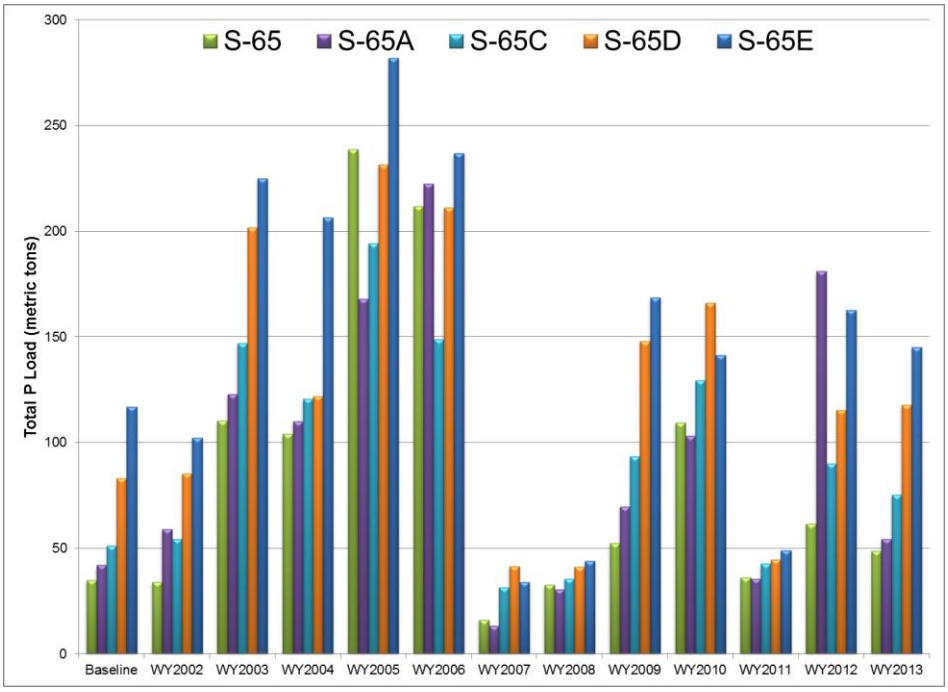

Figure 9-17. Annual total phosphorus (TP) loads from C-38 structures for WY2002–WY2013 in comparison to average annual baseline loads during calendar years 1974–1995. WY2002, WY2007, WY2008, and WY2011 were drought years and WY2005 was wet due to hurricanes.

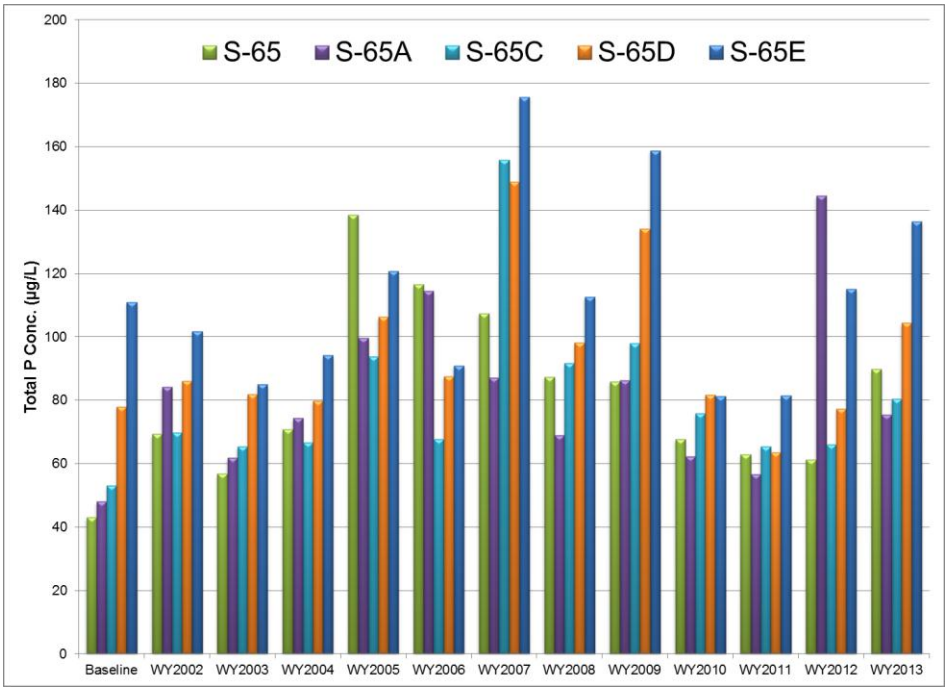

Figure 9-18. Annual flow-weighted mean (FWM) TP concentrations in micrograms per liter (µg/L) at C-38 structures for WY2002–WY2013 in comparison to average annual baseline concentrations during calendar years 1974–1995.

The graph of annual loads of total nitrogen (**Figure 9-19**) looks very similar to the graph of annual discharges (**Figure 9-16**), indicating that TN loads are highly dependent on discharge. Annual FWM TN concentrations have ranged from 0.96 to 1.55 mg/L since WY2002 (**Figure 9-20**). These concentrations were usually similar among the C-38 structures and varied less from year to year than TP. In WY2013, FWM TN concentrations at the five structures fell within a narrow range of 1.19 to 1.39 mg/L.

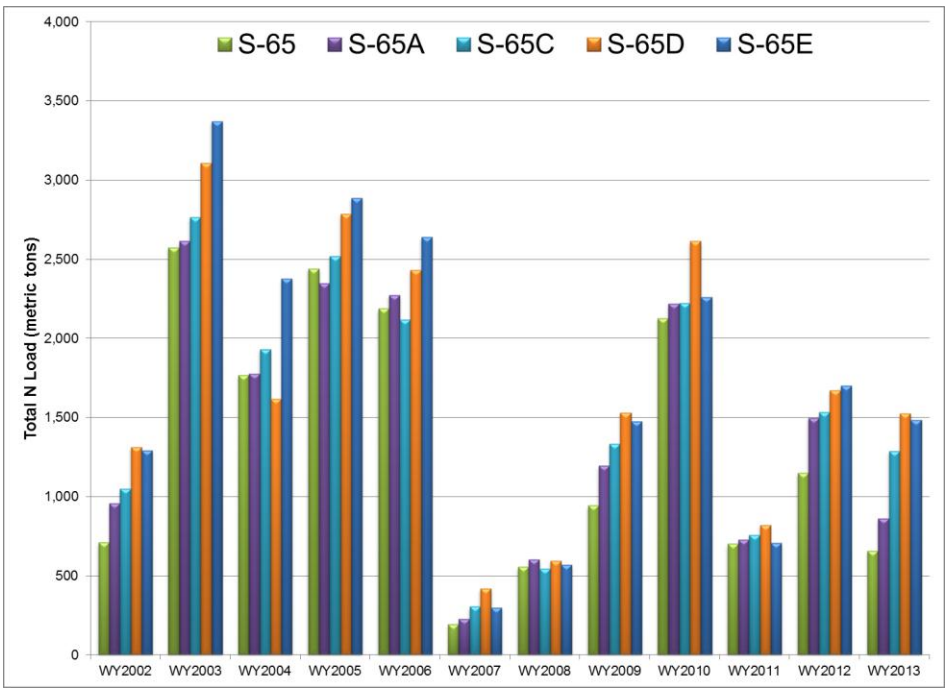

Figure 9-19. Annual total nitrogen (TN) loads from C-38 structures for WY2002–WY2013. WY2002, WY2007, WY2008, and WY2011 were drought years and WY2005 was wet due to hurricanes.

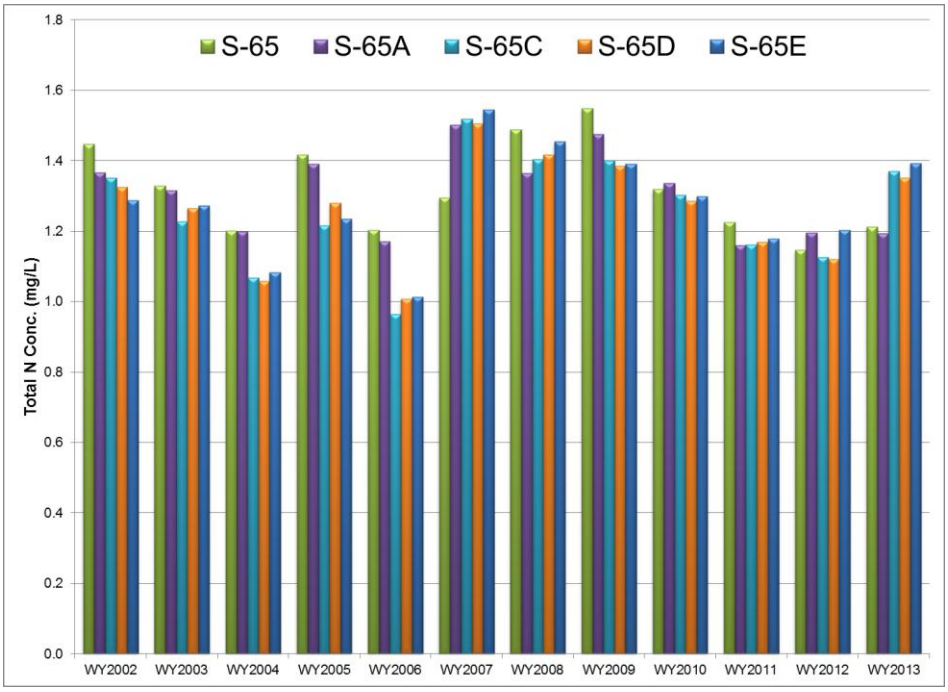

Figure 9-20. Annual flow-weighted mean (FWM) TN concentrations in milligrams per liter (mg/L) at C-38 structures for WY2002–WY2013.

Soil Nutrient Survey

Because the Kissimmee Basin is the largest contributor of phosphorus to Lake Okeechobee, the Kissimmee River floodplain's potential to retain phosphorus is significant for Lake Okeechobee phosphorus control efforts. Since WY2002, the interim regulation schedule has allowed intermittent inundation of the restoration area, but periodic dry conditions have sometimes limited hydrologic interaction between the river channel and floodplain. Consequently, the river–floodplain system probably has not sequestered nutrients at its highest potential efficiency.

Data presented in the 2013 SFER – Volume I, Chapter 9, indicated that the restored floodplain will be capable of retaining a large amount of phosphorus during flood events. However, reliable estimates of the amount of retention that can be expected typically after restoration require further investigation. To better understand the process of phosphorus movement and assimilation, and improve predictive reliability, the SFWMD developed a plan to gather more information on river-floodplain biogeochemistry and hydrodynamics, which will change as the system is restored. The goals of this Kissimmee River Nutrient Dynamics Study are to describe the processes by which the restored river-floodplain system might sequester nutrients and to estimate the potential of restoration to slow nutrient movement and increase nutrient retention.

As part of this study, a survey was initiated to gather data on the biogeochemical characteristics of soils in the restoration area, and use these data to assess the retention and accumulation of organic matter and associated nutrients within the restored river-floodplain system. The survey was designed to allow detection of changes in soil attributes occurring over several years. The baseline data gathered for this assessment are intended to be compared with future data to be collected after the restoration project is completed.

In this survey, investigators collected sediment and soil samples from the river channel and floodplain; measured the content of phosphorus, nitrogen, and other soil constituents; examined the spatial distribution of these soil constituents and their association with various landscape types and vegetation communities; and estimated the potential for soils to retain or release phosphorus. Sampling of 230 sites in the floodplain and river channel was performed according to a random sampling design stratified primarily by landscape units (sub-regions that incorporate certain soil types and vegetation communities) and secondarily by vegetation classifications. The final report (Osborne et al., 2012) included these findings:

- Landscape units were similar with respect to soil biogeochemical attributes, with the noted exception of phosphorus, which was higher in dredge material sampled on spoil mounds and the backfilled canal. At this stage in the restoration project, hydrology has more influence on vegetation growth patterns than soil attributes. Over time, as wetland plant communities become more established, they will gain influence on soil organic matter and nutrient accretion, and soil nutrient content will become more strongly linked to certain landscape units and vegetation communities.

- The dredge material found in spoil mounds and the backfilled canal consists of Miocene-era marine deposits rich in phosphatic minerals. However, this phosphorus appears to be associated with calcium-rich minerals that have low solubility. Therefore, although the dredge material has the potential to release phosphorus slowly over time through leaching and flooding, the low solubility of phosphorus in this material suggests that significant downstream loading of dissolved phosphorus is unlikely. Nevertheless, care should be taken, as it has in previous phases of restoration construction, to minimize the potential for particulate suspension and downstream transport during manipulation and relocation of these materials.

- Soil phosphorus storage capacity (SPSC) is a calculated metric derived from soils data that indicates whether soils are likely to retain or leach phosphorus when inundated. The SPSC is also an indicator of the amount of additional phosphorus that can be added to a soil with a positive capacity before that soil begins to release it. Values of SPSC were mapped to indicate areas of potential P accretion and release. Soils in most areas of the floodplain had positive SPSC values, suggesting that these soils are likely to retain phosphorus. However, samples from spoil mounds and backfilled canal areas had negative SPSC values, indicating the potential for phosphorus release.

- Analysis of river channel sediments confirms previous geomorphic studies (2005 SFER – Volume I, Chapter 11) indicating that restored flow to certain channel reaches has removed the undesirable organic detritus that had accumulated in disconnected sections of river channel.

- Higher carbon and nitrogen content in floodplain wetlands of the Phase I restoration area suggests that some of the former pasture land being restored to functional floodplain is beginning to accrete organic matter and nutrients. Field observations of recent organic matter deposition and restoration of vegetation communities suggest that this accretion process will continue and become more measureable with time.

- Analyses demonstrated that cumulative distribution functions (CDFs) and geostatistical modeling using Kriging procedures can provide scientifically defendable mechanisms for assessing the response of soil nutrients after restoration. The CDFs and maps of Krigged

data can be compared to similar products created from post-restoration data to detect changes in soil nutrient content and sorption/release potential.

- To illustrate spatial patterns with better resolution than could be obtained from ordinary Kriging, a Residual Kriging method was employed. Maps created with this method depicted higher total carbon, total nitrogen, and organic matter content in broadleaf marsh areas surrounding the Istokpoga Canal and in other floodplain wetlands and depressional areas. Spoil mounds and backfill areas had lower values. Residual Kriging clearly indicates higher TP concentrations in the spoil mounds and backfilled areas (**Figure 9-21**). Although re-grading of surface materials in the backfilled areas has increased the spatial extent of elevated soil phosphorus, this should not be a great concern because the spoil materials are recalcitrant to phosphorus release.

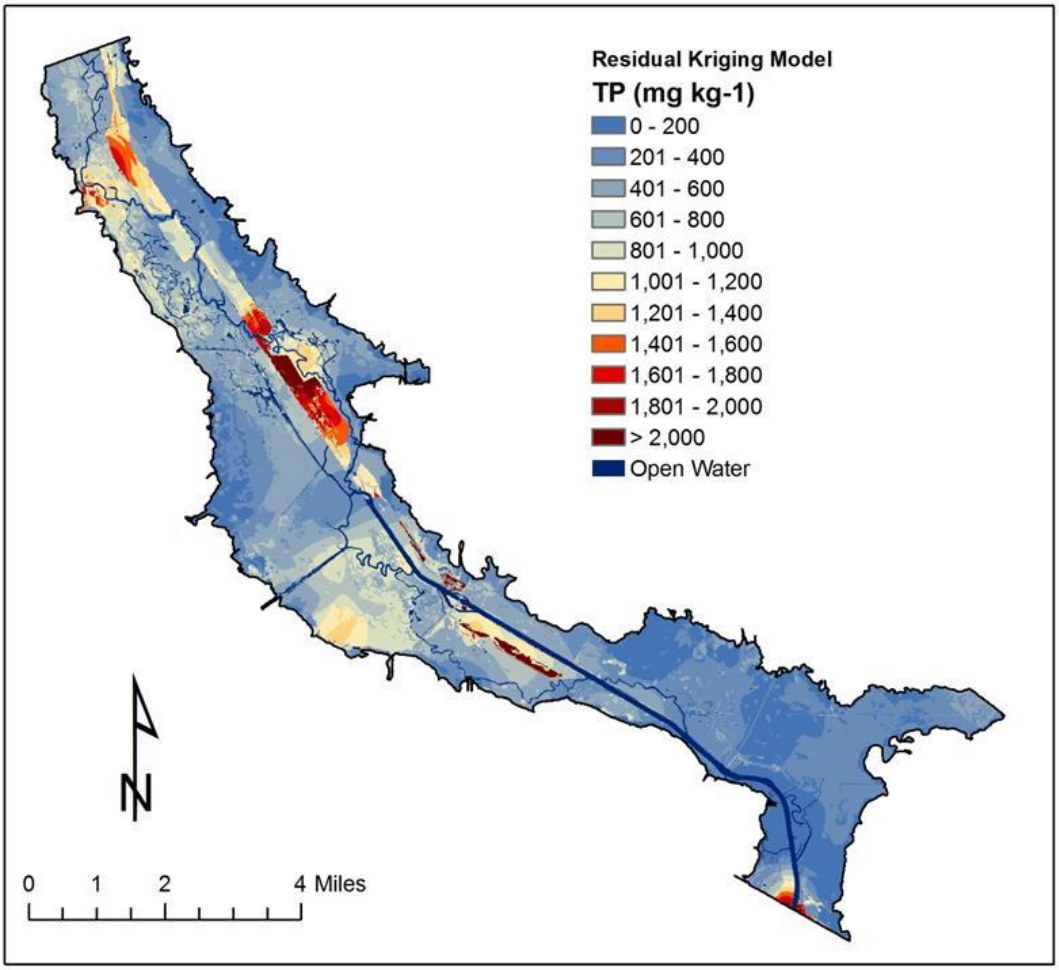

Figure 9-21: Spatial distribution of soil TP concentrations (0-10 cm depth) in the Phase I and Phase II/III restoration areas of the Kissimmee River created with a Residual Kriging procedure (from Osborne et al., 2012). Note the presence of spoil, backfill, and re-graded areas clearly in the data interpolation.

WADING BIRDS AND WATERFOWL

Birds are integral to the Kissimmee River-floodplain ecosystem and highly valued by the public. 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; Florida Game and Fresh Water Fish Commission, 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. 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 Chapter 11 of the 2005 SFER – Volume I. The objective of this section is to highlight portions of the avian program for which data were collected during the winter and spring of 2012–2013, and compare recent data to restoration expectations.

Wading Bird Nesting Colonies

Expectation

No expectation has been established for wading bird nesting colonies.

As part of the KRREP, the SFWMD performed four aerial surveys (March 1, April 23, May 15, and May 23, 2013) to visit known wading bird nesting colonies and search for others in the Kissimmee Basin and Lake Istokpoga. Nesting colonies were also monitored, when encountered, during separate aerial surveys of foraging wading birds on Nov. 15 and Dec. 11, 2012, and Jan. 15, Feb. 12, Mar. 12, Apr. 16, and May 7, 2013. Known colonies in Lakes Mary Jane, Kissimmee (Rabbit Island), and Istokpoga were surveyed at least once. The numbers of nests reported here represent the maximum number of nests for each species observed. It is likely the nests for a relatively small number of dark-colored birds, such as little blue heron (*Egretta caerulea*), glossy ibis (*Plegadis falcinellus*), tricolored heron (*Egretta tricolor*), yellow-crowned night heron (*Nyctanassa violacea*) and black-crowned night heron (*Nycticorax nycticorax*), were undercounted during the aerial surveys because of their lower visibility from above (Frederick et al., 1996). Thus, the colony totals presented in **Table 9-6** are considered conservative. Nest fate and nesting success were not monitored, but one ground survey was conducted at the Rabbit Island colony (May 15) and the Lake Mary Jane colony (May 23) to obtain a more accurate nest count and determine the presence of less visible dark-colored species. Eleven colonies were surveyed during 2013, six of which occurred within 3 km of the Kissimmee River restoration project area (**Table 9-6**; **Figures 9-22** and **9-23**). The other five colonies were observed on Lakes Mary Jane, Conlin, Kissimmee, Istokpoga, and within Kissimmee Prairie Preserve State Park (Seven Mile Slough).

Four small colonies were active within the Kissimmee River 100-year floodline (**Table 9-6**; **Figure 9-22**): the S-65C Boat Ramp and Structure colonies, River Ranch, and Chandler Slough. The largest, the S-65C Boat Ramp colony, was dominated by the terrestrial cattle egret (*Bubulcus ibis*) (599 nests under construction), while nesting by aquatic wading bird species totaled only 43 nests at all four colonies within the floodplain (**Table 9-6**). The cattle egret nests at the S-65C boat ramp colony were just being constructed, but all 599 were abandoned sometime between the Apr 23 and May 15 survey flights. Although the exact cause of abandonment is uncertain, one likely reason is the fragile condition of the nesting substrate that was observed during a ground survey approximately 2 weeks after the abandonment, when several unidentified nests with dead chicks were also observed. Prior to abandonment, many of the nests were being built in dead and dying shrubs, mostly wax myrtle (*Myrica cerifera*), with some red bay (*Persea borbonia*) and red maple (*Acer rubrum*), that were decomposing and collapsing as the result of an aerial herbicide

treatment of invasive exotic vegetation sometime during 2011. So as the nests were being built, the substrate may have been collapsing and the birds abandoned the site. Even one small wind event, such as a downdraft from a thunderstorm, could have caused the collapse of most, if not all, of the nests under construction. One small colony (Chandler Slough) was observed this year for the first time since 2006, although it contained only 7 great blue heron nests and 16 great egret nests.

Two other small colonies (Melaleuca Island and Orange Grove) formed in the vicinity of the Kissimmee River, but outside of the 100-year floodline. Together these colonies had 22 great blue heron (*Ardea herodias*) and three great egret nests. Although the colony locations are considered to be just outside the restoration project area, birds feeding young at the colony are within foraging flight distance from the project area.

A previously unknown colony on the northeastern shore of Lake Conlin was surveyed this season during one overflight when 40 wood stork (*Mycteria Americana*) nests and one great blue heron nest were observed in large cypress trees. As was the case in the prior nesting season, the colonies on Lakes Mary Jane and Istokpoga were dominated by aquatic species, while nesters on Lake Kissimmee were mostly cattle egrets. The largest colony to form this year was the rookery island in Lake Mary Jane (1,224 nests), which was dominated by white ibis (*Eudocimus albus*) and great egrets (*Ardea alba*) (**Table 9-6**). The number of aquatic species nesting on Lake Mary Jane was up by 607 nests (113 percent), largely due to an increase in white ibis and great egrets. Cattle egret nesting on Mary Jane was down by 135 nests (-57 percent). Aquatic species nesting on Rabbit Island in Lake Kissimmee were down by approximately 214 nests (-40 percent), due to a decrease in the number of great egrets, great blue herons, white ibis, and snowy egrets. Cattle egret nests on Rabbit Island were up by approximately 30 nests (4 percent). Bumblebee Island in Lake Istokpoga had an increase in both cattle egret (175; 233 percent) and great egret (168; 96 percent) nests, while great blue heron nests declined by 20 nests (-26 percent) (**Table 9-6**). No white ibis nests were observed on Bumblebee Island as in previous years.

Compared to 2012, the number of aquatic bird nests in all observed colonies was up by 634 nests (46 percent), while the number of cattle egret nests was up by 521 (30 percent) (**Table 9-6**). Most nesting of both aquatic wading bird species and cattle egrets continues to occur outside of the Kissimmee River Restoration area on islands in the Kissimmee Chain of Lakes and Lake Istokpoga. To date, no significant colonies of aquatic species have formed near the restoration project area. The continued small numbers of aquatic species nesting along the restored portion of the river suggests that prey availability on the floodplain is not yet sufficient to support the completion of breeding for these wetland-dependent birds. While conditions on the floodplain can become optimal for foraging wading birds during certain times of the year (see Wading Bird Abundance section) on the floodplain, the timing and magnitude of floodplain inundation and recession is not yet optimal for rookery formation due to constraints on water control operations. Implementation of the Headwaters Revitalization Schedule in 2016 will allow water managers to more closely mimic the historical stage and discharge characteristics of the river, presumably leading to suitable hydrologic conditions for wading bird nesting colonies.

Table 9-6. Peak numbers of wading bird nests inside or within two miles of the Kissimmee River 100-year floodline (between the S-65 and S-65D structures) and within Lakes Mary Jane, Conlin, Kissimmee, and Istokpoga.

Kissimmee River

Year*	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	SMDH	BCNH	Total
2004	-	-	-	-	-	-	-	-	-	-
2005	400	81	-	-	5	-	-	-	-	486
2006	500	133	-	-	4	-	-	-	-	637
2007	226	-	-	-	-	-	1	-	-	227
2008	-	2	-	-	4	-	-	-	-	6
2009	240	126	-	-	27	11	3	-	-	407
2010	891	35	-	-	31	22	15	-	-	994
2011	751	14	-	8	35	26	9	-	-	843
2012	1,202	2	-	18	32	-	-	108	-	1,362
2013	599	38			30					667
Total	**4,809**	**431**	**-**	**26**	**168**	**59**	**28**	**108**	**-**	**5,629**

Lake Conlin

Year*	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	WOST	BCNH	Total
2013	-	-	-	-	1	-	-	40	-	41
Total	-	-	-	-	1	-	-	**40**	-	**41**

Bird Island (Lake Mary Jane)

Year*	CAEG	GREG	WHIB	SNEG	SMDH	LBHE	TRHE	WOST	BCNH	Total
2010	-	250	-	-	-	-	-	100	1	351
2011	-	200	-	-	-	-	-	200	-	400
2012	235	176	119	25	-	-	-	172	-	727
2013	100	376	566	-	50	-	-	132		1,224
Total	**335**	**1002**	**685**	**25**	**50**	**-**	**-**	**604**	**1**	**2,702**

Rabbit Island (Lake Kissimmee)

Year*	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	GLIB	BCNH	Total
2009	740	150	75	-	50	42	87	10	3	1,157
2010	200	249	1,156	-	59	-	-	-	-	1,664
2011	350	250	540	75	75	-	-	-	-	1,290
2012	645	250	156	39	87	-	-	-	-	1,177
2013	675	135	95	7	35	11	25	5	5	993
Total	**2,610**	**1034**	**2,022**	**121**	**306**	**53**	**112**	**15**	**8**	**6,281**

Bumblebee Island (Lake Istokpoga)

Year*	CAEG	GREG	WHIB	SNEG	GBHE	LBHE	TRHE	WOST	BCNH	Total
2010	103	325	110	-	75	-	-	-	-	613
2011	381	200	50	-	45	-	-	-	-	676
2012	75	175	-	-	75	-	-	-	-	325
2013	250	343	-	-	55	-	-	-	-	648
Total	**809**	**1043**	**160**	**-**	**250**	**-**	**-**	**-**	**-**	**2,262**

CAEG = cattle egret (*Bubulcus ibis*)
GREG = great egret (*Ardea alba*)
WHIB = white ibis (*Eudocimus albus*)
SNEG = snowy egret (*Egretta thula*)
GBHE = great blue heron (*Ardea herodias*)
BCNH = black-crowned night heron (*Nycticorax nycticorax*)
LBHE = little blue heron (*Egretta caerulea*)
TRHE = tricolored heron (*Egretta tricolor*)
GLIB = glossy ibis (*Plegadis falcinellus*)
WOST = wood stork (*Mycteria americana*)
SMWH = small white heron (snowy egret and juvenile little blue heron combined)
SMDH = small dark heron (little blue heron and tricolored heron combined)
*Surveys were conducted approximately monthly Jan-Jun.

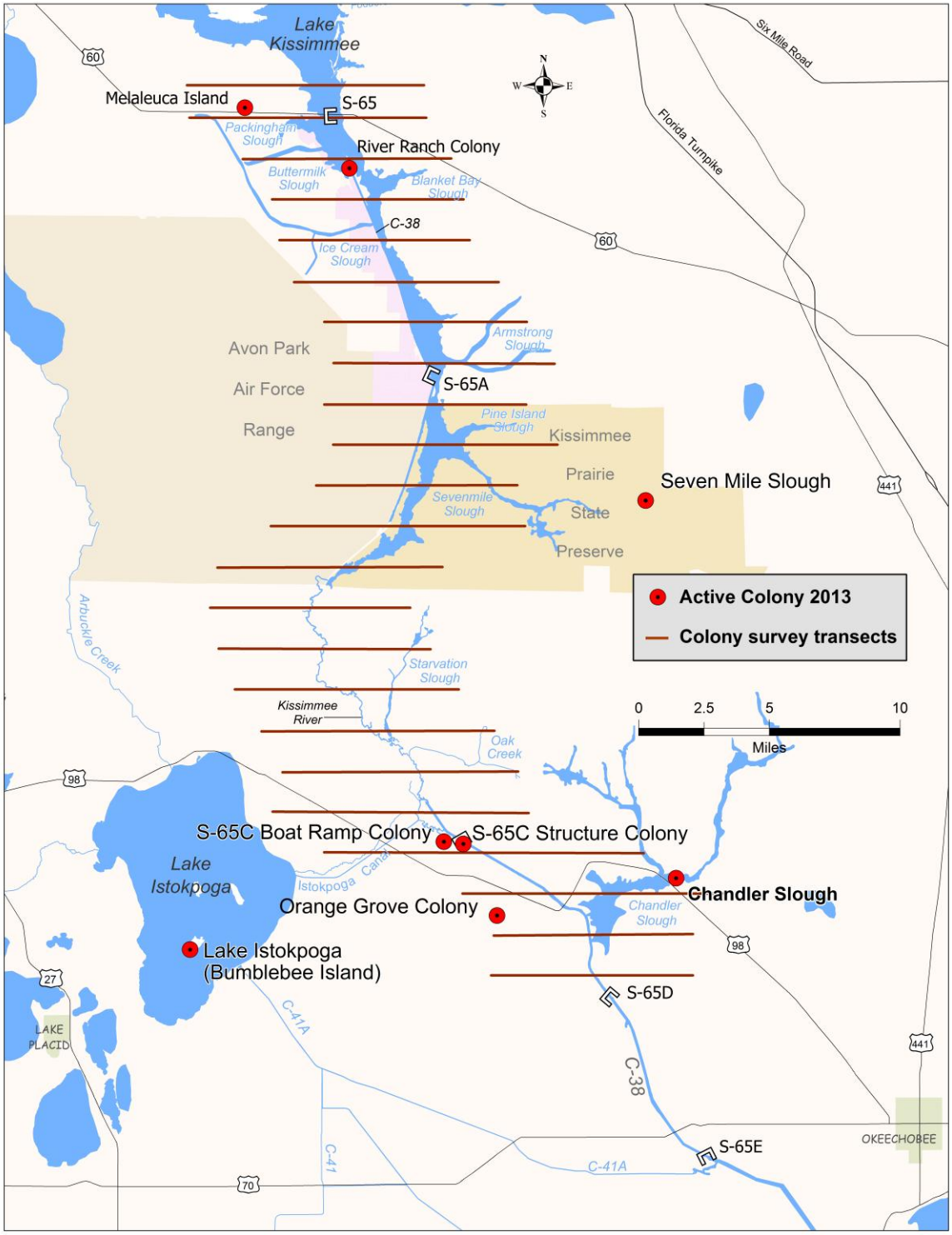

Figure 9-22. Aerial survey transect routes and nesting colony sites within the Kissimmee River floodplain and surrounding wetland-upland complex during 2013.

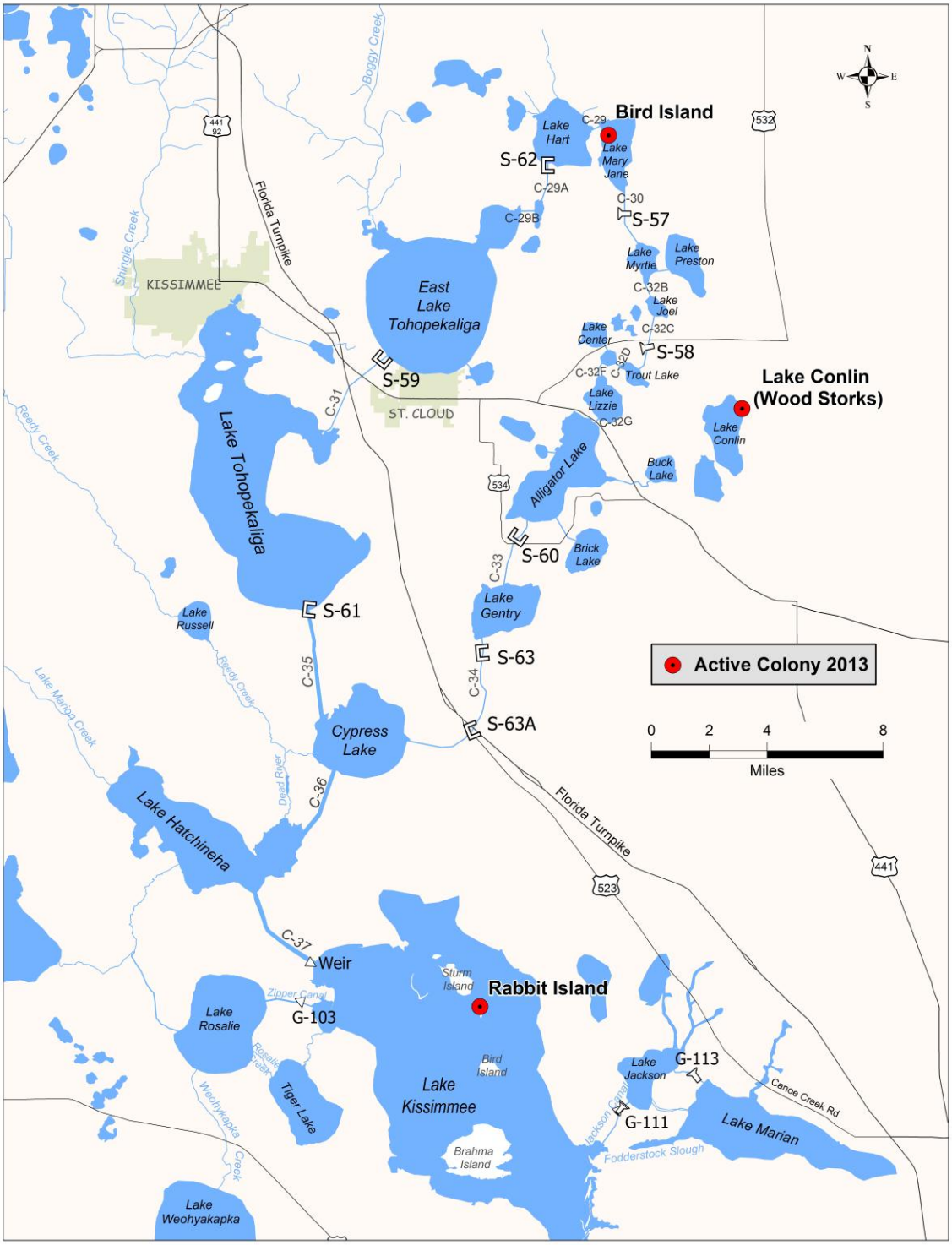

Figure 9-23. Observed nesting colony sites within the Kissimmee Chain of Lakes during 2013.

Wading Bird Abundance

Expectation 24

Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be ≥ 30.6 birds per square kilometer (birds/km^2) (SFWMD, 2005b).

Monthly aerial surveys were used to estimate foraging wading bird abundance. Prior to the restoration project, dry season abundance of long-legged wading birds in the Phase I restoration area averaged [(± standard error (S.E.)] 3.6 ± 0.9 birds/km^2 in 1997 and 14.3 ± 3.4 birds/km^2 in 1998. Since completion of Phases I, IVA, and IVB of restoration construction in 2001, 2007, and 2009, respectively, abundance has exceeded the restoration expectation of 30.6 birds/km^2 (evaluated as a three-year running average), except during 2007–2009 and 2009–2011 (**Table 9-7**; **Figure 9-24**).

Mean monthly wading bird abundance within the restored portions of the river during the 2012–2013 season (28.8 ± 6.6 birds/km^2) was just over half of last year's estimate of 44.4 birds/km^2, although the three-year running average (31.0 ± 7.2) remains just above the restoration target of 30.6 birds/km^2. Wading bird numbers were below average in December, likely due to the approximate 0.22 ft reversal of water levels on the floodplain following a rain event just prior to the survey flight. Numbers increased in January to slightly above the monthly mean before dropping again in February to slightly below the monthly mean. The decrease in February also occurred sometime after a water level reversal of approximately 0.8 ft on the floodplain. Abundance estimates came back up in March to slightly below the monthly mean and subsequently declined to below average each month through May as water levels receded and the floodplain became completely dry except for a few remaining drying pools.

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

Table 9-7. Post-restoration abundance as three-year running averages (± S.E.) of long-legged wading birds excluding cattle egrets during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

Period	Three-year Running Average ± S.E.
2002–2004	65.4 ± 5.1
2003–2005	74.3 ± 3.5
2004–2006	76.4 ± 4.8
2005–2007	58.9 ± 8.8
2006–2008	49.3 ± 27.4
2007–2009	21.4 ± 7.0
2008–2010	33.9 ± 8.6
2009–2011	29.0 ± 9.8
2010–2012	37.6 ± 9.0
2011–2013	31.0 ± 7.2

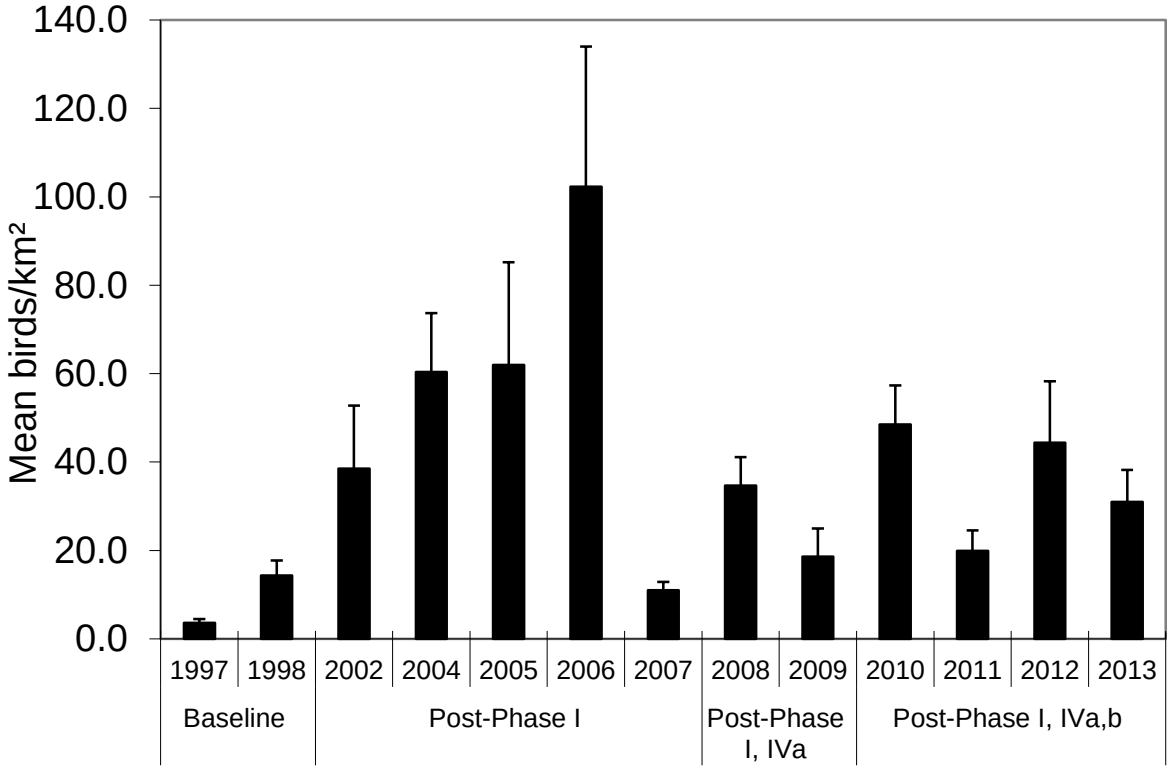

Figure 9-24. Baseline and post-Phases I, IVA, and IVB mean abundance ± S.E. of long-legged wading birds (excluding cattle egrets) per square kilometer (birds/km^2) during the dry season (December–May) within the 100-year floodline of the Kissimmee River.

Waterfowl Abundance

Expectation 25

Winter densities of waterfowl within the restored area of the floodplain will be ≥ 3.9 ducks per square kilometer (ducks/km^2). Species richness will be ≥ 13 (SFWMD, 2005b).

Four duck species, blue-winged teal (*Anas discors*), green-winged teal (*A. crecca*), mottled duck (*A. fulvigula*), and hooded merganser (*Lophodytes cullulatus*), were detected during baseline aerial surveys. During the same period, casual observations of wood ducks (*Aix sponsa*) were made during ground surveys for other projects (SFWMD, 2005a). Mean annual abundance ± S.E. was 0.4 ± 0.1 ducks/km² in the Phase I area before restoration construction, well below the restoration expectation of 3.9 ducks/km². The three-year running average of waterfowl abundance has consistently exceeded this expectation since Phase I restoration construction was completed in 2001 (**Table 9-8**; **Figure 9-25**). Waterfowl abundance during the 2012–2013 survey (9.4 ± 1.1 ducks/km^2) was less than the previous year's mean of 13.6 ducks/km^2, but it brought the three-year running average up slightly from last year and kept it well above the restoration target. Blue-winged teal dominated numerically, followed by mottled ducks, which were the only two species observed this year.

Table 9-8. Post-restoration abundance as three-year running averages ± S.E. of waterfowl during the winter (November–March) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

Period	Three-year Running Average ± S.E.
2002–2004	14.1 ± 4.0
2003–2005	9.9 ± 2.2
2004–2006	17.5 ± 9.8
2005–2007	15.2 ± 11.2
2006–2008	15.7 ± 11.1
2007–2009	4.0 ± 1.5
2008–2010	6.3 ± 1.5
2009–2011	6.6 ± 1.7
2010–2012	10.0 ± 1.8
2011–2013	10.5 ± 1.6

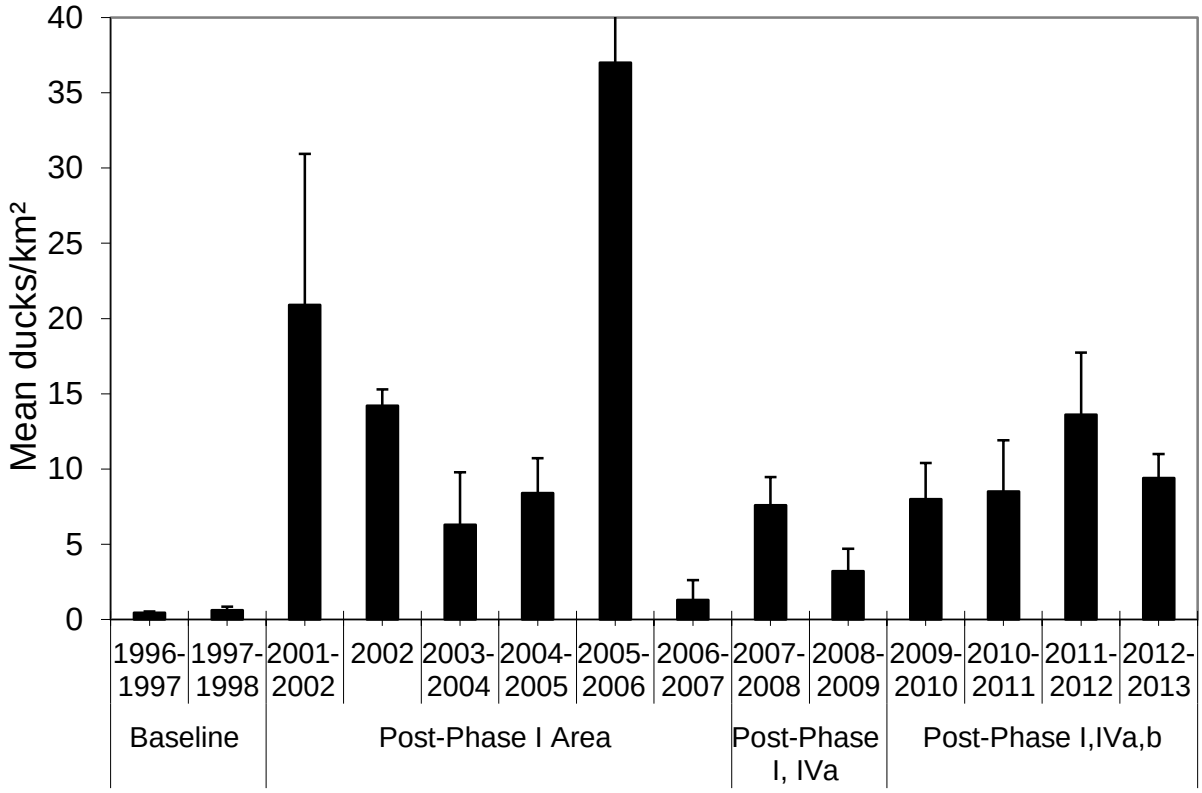

Figure 9-25. Baseline and post-Phases I, IVA, and IVB mean abundance ± S.E. of waterfowl [ducks per square kilometer (ducks/km^2)] during winter (November–March) within the 100-year floodline of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately nine months following completion of Phase I.

The American wigeon (*Anas americana*), northern pintail (*A. acuta*), northern shoveler (*A. clypeata*), ring-necked duck (*Aythya collaris*), and black-bellied whistling duck (*Dendrocygna autumnalis*) were not detected during baseline surveys, but have been present following restoration. These species are not regularly observed, and the restoration target for waterfowl species richness (≥ 13 species) has yet to be reached on an annual basis. Blue-winged teal and mottled duck remain the two most commonly observed species, accounting for over 95 percent of observations since 2001.

Restoration of the physical characteristics of the Kissimmee River and floodplain, along with the hydrologic characteristics of headwater inputs, is expected to produce hydropatterns and hydroperiods that will lead to the development of extensive areas of wet prairie and broadleaf marsh, two preferred waterfowl habitats (Chamberlain, 1960; Bellrose, 1980). Changes in the species richness and abundance of waterfowl within the restoration area are likely to be directly linked to the development of floodplain plant communities and the faunal elements they support, particularly populations of aquatic invertebrates (Harris et al., 1995). Extrinsic factors, such as annual reproductive output on summer breeding grounds and local and regional weather patterns, also may play a role in the speed of recovery of the waterfowl community.

KISSIMMEE BASIN MODELING AND OPERATIONS STUDY

The Kissimmee Basin Modeling and Operations Study (KBMOS) is the first comprehensive review of water management operations for the Kissimmee Basin in more than 30 years. Its goal is to evaluate alternative operations for C&SF Project water control structures throughout the Kissimmee Basin to align upstream and downstream operations with KRRP headwater discharges at S-65 and enhance/sustain habitat conditions for fish and wildlife throughout the KCOL. The study, which was initiated in 2004, has produced the following products:

- Three versions of Kissimmee Basin planning and flood event modeling and evaluation tools
- Lake and river evaluation performance measures
- Evaluation of over 100 alternative plans for modification of Kissimmee Basin structure operating criteria
- Project documentation for the alternative plan selection process including performance metrics, the alternative evaluation system, and description of the alternative plans evaluated during screening and formulation including performance, scoring, and ranking
- Development of a managed extreme low water level drawdown decision tree defining local and regional considerations that must be resolved before a KCOL lake drawdown is implemented
- Extensive public outreach and involvement at the federal, state, local, and individual stakeholder level

The study is currently on hold due to greater Kissimmee River Restoration Project cost-crediting issues. Further information about the KBMOS is available at www.sfwmd.gov/kissimmee.

UPPER KISSIMMEE BASIN PROJECTS

KISSIMMEE CHAIN OF LAKES AND KISSIMMEE UPPER BASIN MONITORING AND ASSESSMENT PROJECT

The KCOL and Kissimmee Upper Basin Monitoring and Assessment Project, initiated in October 2010, addresses deficiencies in ecological data identified over the past 10 years that are needed to support (1) management decision making; (2) consumptive use permitting, compliance, and rulemaking; (3) the Northern Everglades and Estuaries Protection Plan; and (4) pre- and post-project implementation for KBMOS. The project scope has been reduced due to fiscal constraints, but still includes numerous important deliverables for KCOL and C&SF Project water bodies: (1) updated bathymetric maps and stage-area-volume tables, (2) littoral vegetation maps, (3) a hydroperiod tool that uses topographic survey data to measure and analyze depth and duration of inundation in lake littoral zones, and (4) nutrient budgets for each lake basin and sub-basin. To date, littoral vegetation mapping has been completed for all 19 C&SF water bodies and bathymetric mapping is complete for 18 of them. Hydroperiod tool implementation is ongoing.

To support the nutrient reduction plan developed for Lake Tohopekaliga (Camp Dresser & McKee, Inc., 2011), hydrologic, chloride, phosphorus and nitrogen budgets for the period 1996-2011 were developed for both Lake Tohopekaliga and East Lake Tohopekaliga (James, 2012,

2013). An earlier version of the Lake Tohopekaliga budgets was presented in the Chapter 9 of the 2013 SFER – Volume I.

Lake Tohopekaliga has two major inflows – Shingle Creek and the St. Cloud (C-31) Canal – where discharge is monitored. The Lake Tohopekaliga budgets were revised to reflect the availability of more accurate flow data from water control structure S-59, which releases water from East Lake Tohopekaliga to the St. Cloud Canal. In addition to the two main inflows, many other minor tributaries flow into Lake Tohopekaliga, but their discharges are not monitored. Instead, their combined input was estimated from the difference between measured inflows, outflow, and change in lake storage. Using the revised data set summarized in **Table 9-9**, the percentage of water input from the two major inflows increased from 36 to 53 percent, and the contribution from unmeasured inflows declined from 47 to 31 percent. Precipitation falling directly on the lake accounted for the remaining 16 percent. Two-thirds of the water lost from the lake left via the outlet structure S-61, while seepage and evaporation made up 16 percent and 18 percent, respectively.

Shingle Creek and C-31 contributed the most phosphorus (18.7 mt/yr) to Lake Tohopekaliga. Using a median TP value of 88 µg/L from water samples collected from the minor tributaries, the minor inflows were estimated to contribute nearly the same amount (18.0 mt/yr). This revised estimate for the minor inflows is lower than the 28 mt/yr reported in the 2013 SFER.

Seventy-six percent of the phosphorus entering the lake flowed out through S-61. Twenty-one percent was retained in the lake as the TP settled to the sediment.

Table 9-9. Water and total phosphorus budgets for Lake Tohopekaliga (calendar years 1996-2011).

Source/Sink	Water (ac-ft/yr)	Water (%)	Total P (mt/yr)	Total P (%)
Inputs				
Major inflows (Shingle Cr. & C-31)	277,390	53%	18.7	49%
Minor inflows/runoff	163,383	31%	18.0	47%
Rainfall and deposition	86,957	16%	1.6	4%
Losses				
Surface discharge through S-61	347,582	66%	27.9	76%
Seepage into groundwater	82,001	16%	1.2	3%
Evaporation	97,296	18%	-----	-----
Retention of TP in sediment	-----	-----	7.8	21%

East Lake Tohopekaliga also has two main inflows, Boggy Creek and the C-29 Canal, the latter of which receives flow from Lake Hart at S-62. Discharges for these two inflows are monitored, but discharges for most of the other minor tributaries are not. The two main inflows contributed 61 percent of the lake's water input, while the minor tributaries contributed 12 percent. Two-thirds of the incoming water left the lake through S-59, and evaporation and other outflow, assumed to be seepage to groundwater, made up 30 percent and 3 percent of losses from the lake, respectively (**Table 9-10**).

Together, Boggy Creek and C-29 contributed 63 percent of the lake's TP input. The TP load from unmeasured inflows, determined by multiplying the estimate of unmeasured flow in the hydrologic budget by the median TP concentration (68 µg/L) of water samples taken from the minor lake tributaries (James, 2013), was 24 percent of the total. Outflow from the lake through S-59 accounted for 47 percent of TP output. Over half (53 percent) of the lake's TP input was retained in the lake (**Table 9-10**).

Table 9-10. Water and total phosphorus budgets for East Lake Tohopekaliga (calendar years 1996—2011).

Source/Sink	Water (ac-ft/yr)	Water (%)	Total P (mt/yr)	Total P (%)
Inputs				
Major inflows (Boggy Cr. & C-29)	108,360	61%	4.5	63%
Minor inflows/runoff	20,577	12%	1.7	24%
Rainfall and deposition	47,756	27%	0.9	13%
Losses				
Surface discharge through S-59	117,866	67%	3.4	47%
Seepage into groundwater	5,456	3%	< 0.1	< 1%
Evaporation	52,714	30%	-----	-----
Retention of TP in sediment	-----	-----	3.8	53%

Based on the estimated amount of unmeasured TP flowing into these two lakes, the minor tributaries should be evaluated more closely to improve the nutrient budget estimates. Improved loading estimates could be attained through direct measurement of flow in certain tributaries or application of the District's PN Budget Tool, which utilizes the WAM watershed model.

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