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, 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, 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. Issues related to remaining land acquisition in the Lower Kissimmee Basin and cost crediting were resolved in WY2014, and the authorized Headwaters Revitalization Schedule (HRS) will be implemented upon completion of KRRP. Remaining restoration construction (backfilling of the C-38 canal) for Reach 3 (Phase III) and Reach 2 (Phase II) construction has been scheduled for 2015 and 2016, respectively. The new projected completion date for KRRP is 2019.

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The KRRP's success is being evaluated through the Kissimmee River Restoration Evaluation Program (KRREP). Evaluation of restoration success was recognized as a crucial component 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 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 prechannelized river or similar systems. A final evaluation of KRRP success will follow completion of all project components.

This year's update on KRREP evaluations includes analyses of newly available data from studies of hydrology, dissolved oxygen (DO), nutrients, wading birds, and waterfowl. This subset of restoration evaluation studies assesses the level of response of critical ecosystem components to physical restoration under interim (preproject completion) hydrologic conditions. Results from these studies provide information for sound water management decision making as the KRRP progresses and to guide water management after the project is complete. Key Water Year 2015 (WY2015) (May 1, 2014–April 30, 2015) highlights of this chapter include the following:

- **Hydrologic conditions.** The Kissimmee Basin received above-average rainfall in WY2015; the Upper and Lower Basins were above average by 9.0 inches and 12.7 inches, respectively. Above average rainfall in the dry season, especially from late November onward, significantly affected hydrologic conditions. Although efforts to bring lake levels to high pool by the end of the wet season were not successful in East Lake Tohopekaliga, Lake Tohopekaliga or Kissimmee-Cypress-Hatchineha (KCH), unusually high dry season rainfall resulted in prolonged periods of time at or within 0.5 feet (ft) of the maximum elevation of regulation schedule for 117 consecutive days in East Lake Tohopekaliga, 117 consecutive days in Lake Tohopekaliga, and 80 consecutive days in KCH between late November and February 1. Maintaining high stage or stage close to the regulation line in KCH contributed to a series of substantial stage reversals in the Kissimmee River floodplain over WY2015, i.e. significant increases in depth followed by rapid reductions in depth, resulting in relatively brief, intermittent periods of inundation of the Kissimmee River floodplain despite the high rainfall. The fish and wildlife (F&W) recession lines requested by the United States Fish and Wildlife Service (USFWS)/Florida Fish and Wildlife Conservation Commission (FWC) were implemented in the three lakes groups over the requested windows with minor departures from the lines due to variations in rainfall.
- **KRREP hydrology.** Expectation 3 incorporates hydroperiod requirements (1 ft of depth for 210 consecutive days) for broadleaf marsh (BLM), the dominant and most characteristic wetland plant community of the pre-channelization floodplain. The target for Expectation 3 has not been met in any year of the Interim Period and has not shown signs of improvement. Expectation 4 includes a metric for an upper limit on recession rates. The criteria for Expectation 4 (recession events) have not been met in the Interim Period. Recommendations were made for management of discharge to improve performance for these two expectations during the Interim Period.
- **Dissolved oxygen.** Concentrations of daytime DO in the river channel of the Phase I restoration area continued to be higher than pre-restoration levels in WY2015. Of the four metrics used to evaluate DO response, two were met in WY2015. Mean daytime DO concentrations fell just short of the dry season (November–May) target range but exceeded the wet season (June–October) target range in WY2015. The third metric, frequency of DO concentration > 1 milligram per liter (mg/L) within 1 meter (m) of the channel bottom, exceeded its 50 percent target. The fourth metric, frequency of

concentrations > 2.0 mg/L, fell 9 percent short of it 90 percent target, reflecting periods of hypoxic conditions in the river channel.

- **Phosphorus.** District scientists are in the process of reassessing the KRREP nutrient monitoring plan to better understand the potential of the Kissimmee River floodplain to retain phosphorus (P).
- **Wading bird nesting.** Twenty-three colonies were surveyed during the 2015 season, 15 of which were active. The peak number of aquatic wading bird nests documented throughout the basin was 2,521. All Kissimmee Basin colonies combined were dominated by nearly equal numbers of cattle egret (*Bubulcus ibis*; 1,198), white ibis (*Eudocimus albus*; 1,161), and great egret (*Ardea alba*; 1,132), followed by smaller numbers of great blue heron (*Ardea herodias*; 145) and wood stork (*Mycteria americana*; 83). The largest colony to form in the Kissimmee Basin this season was on Rabbit Island (1,523 nests), followed by Bumblebee Island (1,443 nests), and Lake Mary Jane (445 nests). The peak of nesting activity (April–May) for some colonies may not have been observed and so the seasonal total is likely a conservative estimate.
- **Wading bird abundance.** Mean monthly wading bird abundance within the restored portions of the river during the 2014–2015 season was 57.9 ± 31.7 birds per square kilometer (birds/km^2), bringing the three-year (2013–2015) running average to 37.1 ± 10.5; neither value being significantly greater than the restoration expectation of 30.6 birds/km^2. The mean annual three-year running average (2001–2015) is 41.7 ± 4.7 birds/km^2, which is significantly greater than the restoration expectation of 30.6 birds/km^2.
- **Waterfowl abundance.** Waterfowl abundance during the 2014–2015 survey was 7.3 ± 4.6, bringing the three-year (2013-2015) running average to 7.6 ± 1.0 birds/km^2; neither value being significantly greater than the restoration expectation of 3.9 ducks per square kilometer (ducks/km^2). The mean annual three-year running average (2001-2015) of waterfowl abundance is 10.5 ± 1.2 birds/km^2, significantly greater than the restoration expectation of 3.9 birds/km^2. The restoration target for waterfowl species richness has not yet been reached.

As part of the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project, a review of emerging issues, ongoing projects, monitoring and management activities, and ecological conditions are summarized in this chapter. Multiple agencies manage and monitor resources in the KCOL, including FWC, Osceola County, SFWMD, and USFWS. Summarizing those efforts provides an overview of the breadth of activities occurring in the region.

- **Emerging issue**. Avian vacuolar myelinopathy (AVM) is a neurological disease occasionally seen in birds that directly or indirectly consume neurotoxins produced by cyanobacteria that grow on the leaves of submersed plants. Recent studies have confirmed that at least some hydrilla (*Hydrilla verticillata*) populations on the KCOL have the cyanobacteria present, and that direct consumption of those submersed plants can cause AVM in herbivores or their predators. Studies on Lake Tohopekaliga have also verified that exotic apple snails (*Pomacea maculata*) can pass AVM onto their predators after grazing on the hydrilla/cyanobacteria, which may impact the endangered snail kite (*Rostrhamus sociabilis plumbeus*). However, no cases of AVM in waterfowl or their avian predators have been reported on the KCOL, despite the fact the cyanobacteria has been on the KCOL since at least 2009, when it was first discovered on Lake Tohopekaliga.
- **Osceola County**. New, high-resolution elevation data will soon be collected via a cost-share grant from the United States Geological Survey. The county received the grant to acquire one-foot contour light detection and radar (LiDAR) for the entire county footprint, which will allow emergency managers, county planners, natural resource managers, and

engineers to better plan for development impacts, emergency flood response, and many other important functions. The county also approved a Lakes Management Plan, which establishes a framework to improve coordination among agencies and stakeholders in the KCOL, identifies challenges in lake management in the county, reviews water quality issues related to the recent total maximum daily loads assigned to several county lakes by the Florida Department of Environmental Protection (FDEP), and outlines how staff in the county's Lakes section will work with the county's Stormwater Management Team to improve the lakes.

- **Vegetation monitoring**. FWC monitors littoral zone vegetation in the major waterbodies of the KCOL via aerial imagery collections every few years, and in 2015 began mapping Lake Kissimmee. SFWMD also established long-term vegetation monitoring plots in lakes East Tohopekaliga, Tohopekaliga, and Kissimmee in 2015 as well. The plots use a combination of quadrats and line transects to track shifts in plant cover up or down slope, which will help managers monitor effects of hydrological changes or management activities.
- **Fisheries**. FWC electrofishing data from the spring of 2014 for lakes East Tohopekaliga, Tohopekaliga, Cypress, and Kissimmee indicated they supported largemouth bass populations with high mean relative weights on Tohopekaliga and Kissimmee (99), and that East Tohopekaliga had fewer large bass [> 498 millimeters (mm)] than the other three lakes.
- **Alligators**. FWC monitors alligator populations using spot-light surveys at night, which showed good populations on Lakes Tohopekaliga, Kissimmee, and Hatchineha, with Kissimmee having roughly twice the population of any other lake in the KCOL. Lake Tohopekaliga showed a continuing recovery from a low in 2005, and Lakes Kissimmee and Hatchineha both showed increases from a low in 2010. Populations on East Lake Tohopekaliga and Lake Cypress were the smallest of the major lakes in the KCOL, but remained steady.
- **Snail kites**. The KCOL supported 25 percent of the statewide nesting activity in 2014, which continued a downward trend from 57 percent in 2012. This was not entirely due to increased nesting activity elsewhere; the total number of nests in the KCOL was also lower than in previous years, as was the total number of nests that fledged young (successful nests). 2014 was the first year since prior to 2007 that the KCOL did not have more total nests than any other region in the state, more successful nests, or more fledglings produced. This trend is primarily due to decreases in total nests and successful nests on East Tohopekaliga and Tohopekaliga, which are generally the two primary nesting lakes in the KCOL.
- **Water and nutrient budgets**. As part of the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project, water and nutrient budgets were developed for a combined KCH lake system. They indicated that unmeasured tributaries contributed a significant amount of flow and P load (38 and 43 percent, respectively) to the lakes. To evaluate these contributions, the Watershed Assessment Model (WAM) was used to estimate flow and loads from both major and minor tributaries as part of a land use-based nutrient budget study. WAM estimated the highest net contributor to P imports to the KCH subwatersheds were improved pasture, medium density residential, and citrus. The estimates generated by WAM were similar to estimates from water and nutrient budget analysis for total flow and total phosphorus (TP) loads.
- **Osceola County nutrient assessments**. Data from 15 water bodies in the county were collected from 2000 to 2012 and/or downloaded from Florida's Storage and Retrieval

Database (STORET). The data covered the years 2000 to 2012 with between 5 to 468 TP, 7 to 140 TN samples and 2 to 212 chlorophyll *a* samples per waterbody (**Table 9-15** later in this document). The median and mean values for TP and total nitrogen (TN) were very close to one another with a few exceptions. TP ranged from 0.018 mg/L at Trout Lake to 0.170 mg/L at Gator Bay. TN ranged from 0.39 mg/L at BB Slough to 1.94 mg/L at Center Lake. Chlorophyll *a* ranged from less than 1 mg/L at Boggy Creek to 32.8 mg/L at BB Slough. Based on the improved condition and analysis methodology, East Lake Tohopekaliga and Lake Hatchineha have improved and now fall below the nutrient thresholds.

- **Lake Tohopekaliga Nutrient Reduction Study**. Water samples have been collected monthly during periods of flow from 26 locations throughout the Lake Tohopekaliga and East Lake Tohopekaliga watershed by Osceola County. TP average concentrations ranged from 0.018 mg/L to 0.527 mg/L with a grand mean of 0.134 mg/L. Because of the short time period of collection (less than five years), statistical trend analyses found few significant changes in concentration over time.

INTRODUCTION

The Kissimmee Basin includes more than two dozen lakes in the 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 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 negative ecological consequences caused by elimination of flow in the original river channel, which prevented 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 KRRP. SFWMD has been working since the early 1990s to coordinate, operate, and evaluate the KRRP, which is being done through the KRREP.

The KRREP 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 scopes of projects in the Kissimmee Basin are shown in **Figure 9-3**. 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* (Jones et al. 2010, 2011).

This chapter is an update to Chapter 9 of the 2015 SFER – Volume I (Cheek et al. 2015). It focuses on progress of Kissimmee Basin projects during WY2015. The chapter also summarizes hydrologic conditions and water management during WY2015 and presents newly available data from evaluations of the KRRP and other monitoring and management activities from certain lakes in the KCOL.

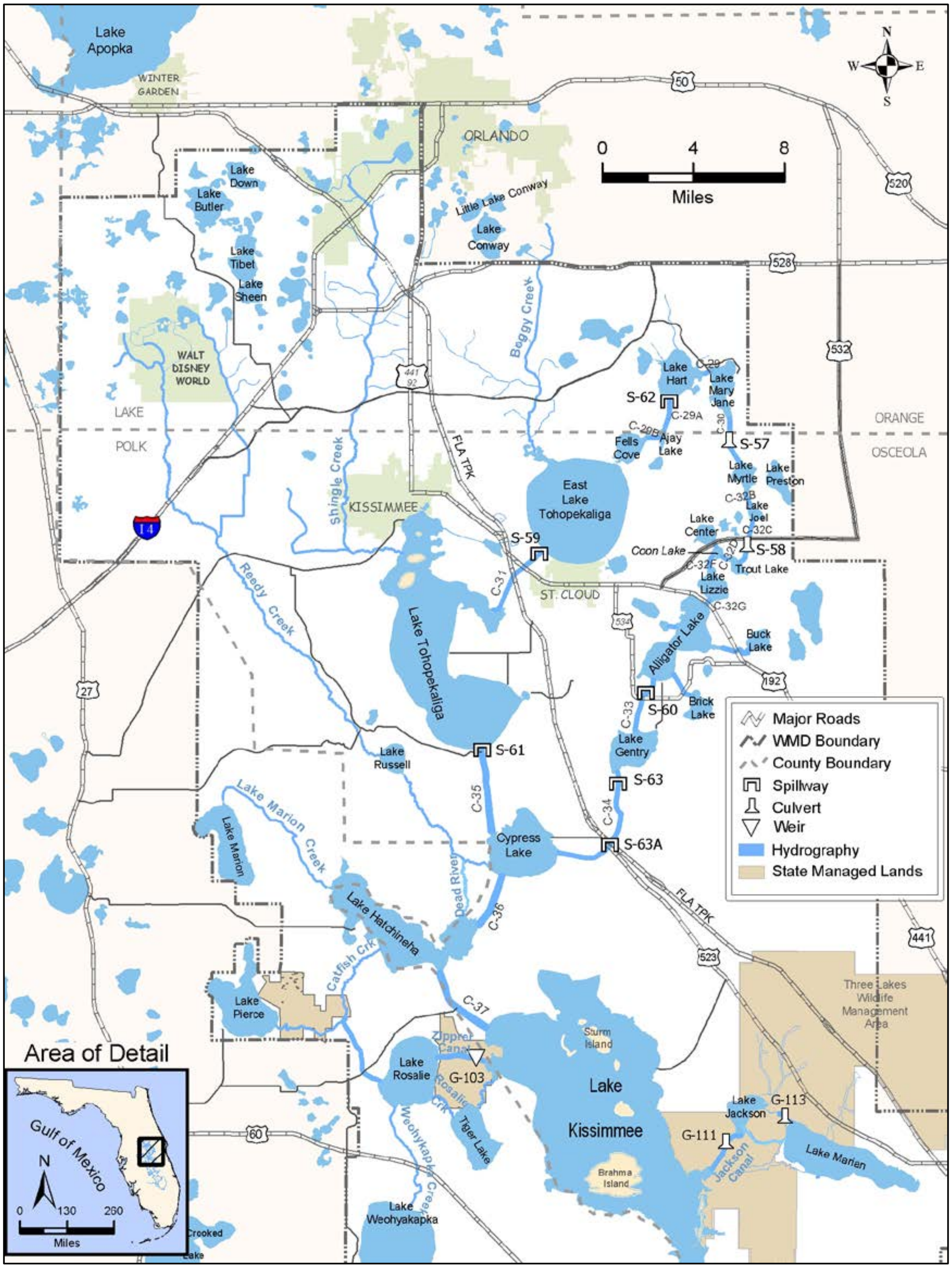


Figure 9-1. Upper Kissimmee Basin.
[Note: WMD – South Florida Water Management District.]

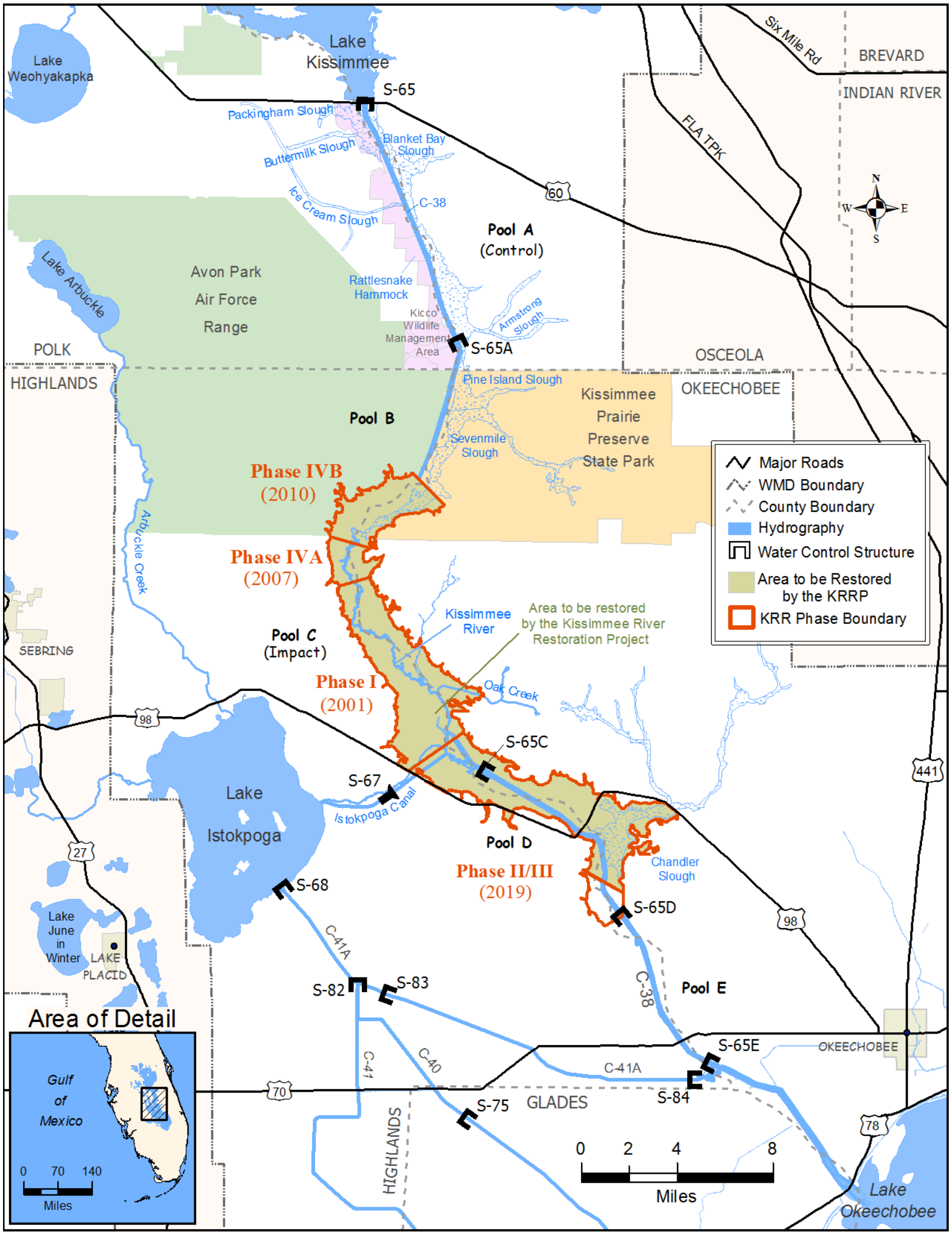


Figure 9-2. Lower Kissimmee Basin with actual and projected completion dates of construction phases. [Note: KRR – Kissimmee River Restoration.]

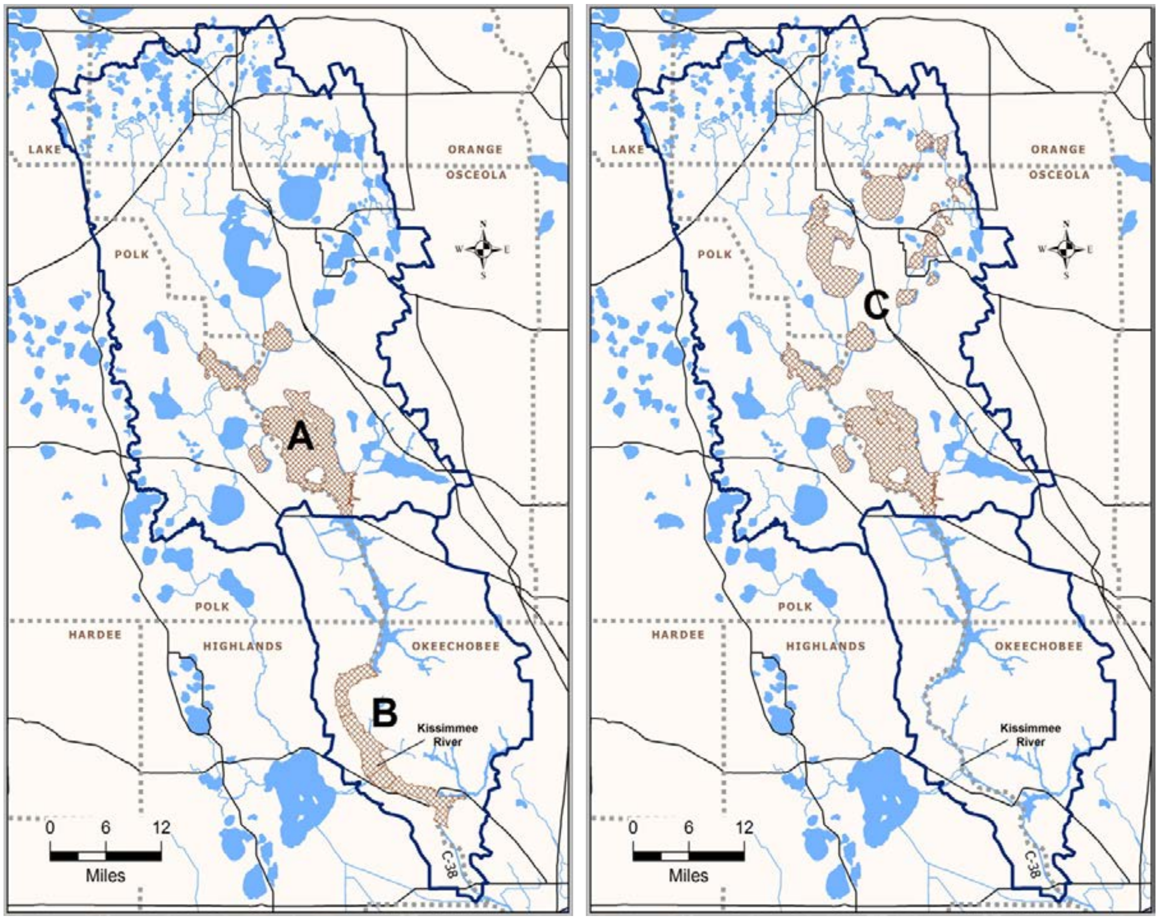


Figure 9-3. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) headwater lakes components of the KRRP, (B) KRRP, and (C) KCOL and Kissimmee Upper Basin Monitoring and Assessment Project.

KISSIMMEE RIVER RESTORATION PROJECT

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 the project is to restore ecological integrity to the Kissimmee River and its floodplain. Successful restoration depends largely on reestablishing hydrologic conditions similar to the pre-channelization period (Toth, 1990, USACE 1991, Koebel and Bousquin 2014). A headwaters component of the project is designed to allow additional storage capacity in the headwater lakes, providing discharge operations that can more closely approximate the pre-channelized river's flow regime, including discharges with more natural timing, magnitude, and rates of change. The increase in 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 original river channel and floodplain, modifying a contiguous area of floodplain-river ecosystem of over 39 square miles. More than 20 square miles of new wetlands will be reestablished in areas that were drained by the canal, and 40 miles of reconnected river channel will receive reestablished flow. In the Upper Kissimmee Basin, over 7,000 acres 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 SFWMD and USACE. Engineering and construction of the project are the responsibility of USACE, while SFWMD's purview is land acquisition, ecological evaluation, and hydrologic modeling for the restoration project.

RESTORATION CONSTRUCTION COMPONENTS

Restoration components include (1) acquiring 65,603 acres of land in the Lower Kissimmee Basin, (2) backfilling approximately 22 miles 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 the former Pool B, (3) reconnecting the original river channel across backfilled sections of the canal, (4) recarving sections of river channel destroyed during C-38 canal 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 allow the additional storage volume needed to meet the hydrologic criteria for river/floodplain 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 (Reach 1) construction was completed in February 2001. This phase was followed by Phase IVA/IVB (Reaches 2 and 3), which extends north from the Phase I project area and was completed in December 2010. Phases II and III (Reaches 2 and 3), the last major phases of construction, are currently scheduled to begin in 2015–2016. 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, and ease of access).

Table 9-1. Sequence of backfilling construction phases of the 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	2008–2010 (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	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 miles of flood control canal, recarved 6 miles of river channel that had been obliterated during canal dredging, and demolished a water control structure (S-65B). These efforts reestablished flow to 24 miles of continuous river channel and allowed intermittent inundation of 7,710 acres 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, the HRS, to operate the S-65 water control structure. The HRS will allow lake water levels to rise 1.5 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 acres 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 HRS, USACE authorized an interim regulation schedule that allows 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 the HRS is expected to provide.

CONSTRUCTION STATUS

In WY2015, construction activities consisted of beginning construction of the River Acres Supplemental Work contract and completion of the S-65EX1 spillway. **Table 9-2** provides brief descriptions of current activities along with a chronological list of the KRRP construction activities.

In recent years, the final backfilling contracts (Reach 2 and Reach 3) have been on hold due to real estate and cost crediting issues. All remaining real estate in the Lower Kissimmee Basin has been acquired. Additionally, cost credit issues, such as authorization of credit for large acquisitions in the Lower Kissimmee Basin have been resolved. As a result of these successes, USACE has accelerated the construction schedule. The new estimated completion date is 2019.

Table 9-2. Chronology of KRRP construction.
[Note: Bold text indicates C-38 canal 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
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 million
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 million

Table 9-2. Continued.

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
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 the C-36 canal was enlarged to maintain the existing level of flood protection.	Complete		July 2001	$2.6 million
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 million
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 million
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** million
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 canal portion of this contract was terminated before completion.	C-36 Complete C-37 Terminated		April 2003	$14.5 million
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 million
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 million
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 million
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 million
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 million
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**	**July 2006**	**October 2007**	**$29.8 million**
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	March 2007	June 2009	$13.5 million

Table 9-2. Continued.

Contract Number	Project Name and Description	Status	Start Date	End Date	Construction Cost
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	January 2007	March 2010	$14.3 million
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**	**July 2008**	**December 2010**	**$18 million**
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 million
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 million
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 million
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 million
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 million
18B	Pool D Boat Ramp – A new boat ramp and small parking area will be constructed.	Complete	September 2011	October 2012	$0.9 million
12A	S-69 Weir – The S-69 weir will serve as the terminus of the C-38 canal backfill.	Not yet awarded	November 2015	January 2017	Not yet available
18A	S-65E Spillway Addition – A gated spillway will be constructed in the S-65E west tie-back levee.	Under construction	August 2012	October 2014	Not yet available
15A	River Acres Supplemental Work – Repair of S-65DX3 structure and miscellaneous construction features	Awarded	July 2014	April 2015	Not yet available
10B	MacArthur Ditch will be backfilled.	Awarded February 2015	July 2015	February 2016	$4.65 million
12	**Reach 3 Backfilling – New channels will be dredged and 2.5 miles of the C-38 canal will be backfilled.**	**Not yet awarded**	**September 2015**	**September 2017**	**Not yet available**
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**	**June 2016**	**June 2019**	**Not yet available**

KISSIMMEE BASIN HYDROLOGIC CONDITIONS AND WATER MANAGEMENT IN WATER YEAR 2015

This section provides a description of hydrologic conditions in the Upper and Lower Kissimmee Basins and their relationship to water management activities during WY2015. The narrative focuses on the timing and quantity of rainfall in the Kissimmee Basin and the water management- and rainfall-driven temporal patterns of discharge and stage that resulted. In the Lower Kissimmee Basin, the District uses water control structures S-65, S-65A, and S-65C to manage flow to and water levels in the Kissimmee River and its floodplain, where USACE and SFWMD have completed three of five physical reconstruction phases of the KRRP since 2001. This work is designed to allow recovery of the river/floodplain ecosystem with appropriate water management per the authorized project objectives.

In the Upper Kissimmee Basin, SFWMD manages water levels in the KCOL, which is divided into seven groups of one or more lakes interconnected by canals. Each group of lakes is regulated by a single water control structure (**Figure 9-1**). Surface water from the northern Upper Kissimmee Basin flows to the KCH lake group (or the Headwaters Lakes) before being discharged through water control structures S-65 and S-65A to the C-38 canal, which flows to the reconstructed sections of the KRRP (**Figure 9-2)**. Because the Kissimmee River and its floodplain slope to the south, it is not possible to store significant volumes of water in the restoration project area; most of the water discharged fromS-65 leaves the Kissimmee Basin quickly at S-65E, where it enters Lake Okeechobee. Discharge from S-65 through S-65A is therefore the primary determinant of flow in the river channel, and the only way to generate the overbank flow needed to provide sufficient inundation of the floodplain for restoration is to provide prolonged, uninterrupted periods of discharge in excess of 1,200–1,400 cubic feet per second (cfs) through these structures.

Completion of restoration construction in 2019, along with implementation of a revised regulation schedule for S-65 (HRS) are expected to provide additional upstream water storage for full restoration of the Kissimmee River. However, appropriate water management during the current Interim Period has the potential to realize substantial ecological benefits in the northern Phase I and Phase IV floodplain (**Figure 9-2**), including improvements in reestablishment of long-hydroperiod floodplain marshes and recovery of the fish and wildlife that depend on access to them and other wetlands. While it is not anticipated that the floodplain inundation targets can be fully met during the Interim Period, performance for these targets can be improved as discussed below in the *Hydrology* subsection, which is in the *Kissimmee River Restoration Evaluation Progra*m section. S-65 provides the dominant source of flow to reconstructed sections of the Kissimmee River and floodplain, but as water is released, stages in the Headwaters Lakes must decline unless rainfall balances discharge. For this reason, goals for the Headwaters Lakes may often conflict with the goals of KRRP, particularly when stages are targeted for the lakes that do not allow for discharge operations designed to address the hydrologic objectives of the KRRP given limited rainfall. Releases from Lakes Tohopekaliga and East Tohopekaliga to meet stage targets for those lakes also impact stage in KCH; therefore, in addition to indirectly affecting the KRRP, operations for these lakes may also inhibit meeting stage targets in KCH.

Stage regulation schedules authorized by USACE for each water control structure in the KCOL have a strong influence on temporal hydrologic patterns in the Kissimmee Basin (**Figure 9-4**). Each water control structure controls stage in one or more lakes within a defined lake group (**Figure 9-1**); each lake group in the KCOL has a regulation schedule associated with its water control structure (e.g., **Figures 9-7** and **9-8** later in this chapter). All of the KCOL regulation schedules have a similar shape, declining in the spring to their lowest elevations ("low pool") on May 31 to create storage for wet season rainfall, rising to a plateau ("summer pool") on June 1 to accommodate summer rainfall, and in the fall, rising further to their highest elevations ("high pool" or "winter pool") on November 1 (**Figure 9-4**) to provide additional storage for rainfall that typically peaks in late wet season. Starting in December for Lakes Myrtle-Preston-Joel, February for KCH, and mid-March for the other KCOL lakes, the schedules then recede again to their low pool stages on May 31 to provide capacity for the upcoming wet season. The regulation schedule lines specify seasonally varying maximum water elevations that, when exceeded (Zone A in **Figure 9-4**), trigger mandatory flood control releases to bring lake stage back to or below the regulation lines. When lake stage is at or below the regulation line (Zone B in **Figure 9-4**), water can be discharged for environmental purposes. For example, S-65 (controlling KCH) can be operated below its regulation line to release water to the KRRP to achieve restoration goals, or to allow lake stage recession or ascension objectives in KCH to be addressed. For purposes of this discussion, discharge operations that release water to meet environmental goals when stage is below the regulation line are called discretionary releases (as opposed to mandatory releases for flood control when a regulation line is exceeded). Thus, stage regulation schedules do not represent required or desirable lake stages; they specify only the maximum stage at which the lake or lake group may be operated.

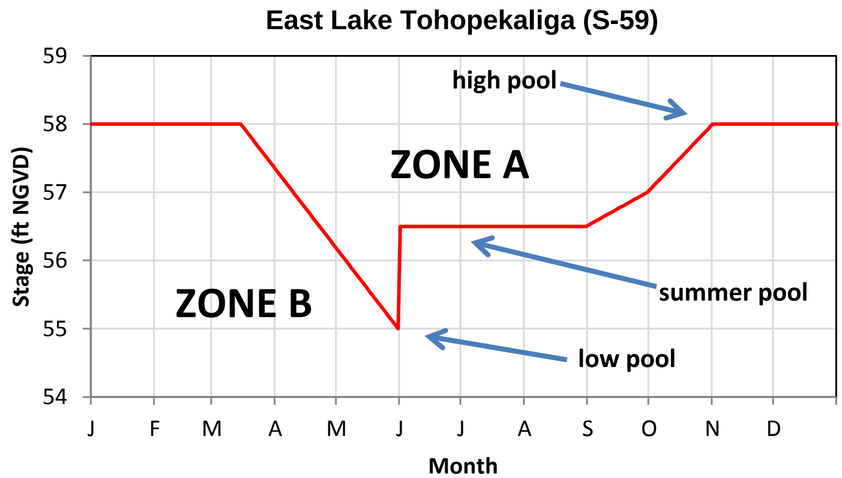


Figure 9-4. Example regulation schedule (East Lake Tohopekaliga) showing the regulation line (red) that separates Zone A (above the line) from Zone B (below the line). When lake stage is in Zone A, releases are mandatory for flood control; when stage is in Zone B, releases are discretionary for environmental purposes. All lakes in the KCOL have a similar schedule with a Zone A and Zone B.

The Kissimmee Basin is an ecosystem in which the progress and success of a federally-authorized, $1 billion ecosystem restoration project with mandated hydrologic and ecological goals (KRRP); nesting habitat for an endangered species (the snail kite in the KCOL lakes); demands from downstream ecosystems; and the sometimes divergent opinions of numerous stakeholders are factors in water management decisions. In addition to the hydrologic requirements of the KRRP, three of the Upper Basin lake groups—KCH, Lake Tohopekaliga, and East Lake Tohopekaliga—are the focus of much of the discretionary water management in the Kissimmee Basin as will be seen below. To address these divergent demands, SFWMD conducts seasonal interagency coordination meetings in which Kissimmee Basin stakeholders discuss and seek to arrive at consensus given sometimes conflicting management objectives. The meetings typically include staff from SFWMD, USFWS, FWC, USACE, FDEP, county governments, and non-governmental organizations such as Audubon of Florida. Requests from other stakeholders (e.g., representing downstream water bodies including Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries) are also considered in developing and implementing seasonal operational plans.

Planning meetings are conducted by a District team of scientists and hydrologists (Kissimmee Basin Operations) in coordination with KRREP staff, USFWS, and FWC, with support from the District's modeling and Water Control Operations groups. Planning meetings are held prior to the start of wet and dry seasons and may involve modeling or analysis requests, generally conducted by the District, to address specific questions. A smaller interagency technical team focuses on scientific issues, water management tradeoffs, and refinement of operational objectives. A common topic of discussion is the tradeoffs involved when flow to the KRRP through the S-65/S-65A structure is balanced against requests to manipulate flow to the river/floodplain to target the prolonged, stabilized periods of high stage often requested for KCH. Three of the lake groups in the KCOL—Lake Tohopekaliga, East Lake Tohopekaliga, and KCH—provide important snail kite nesting habitat, although nesting and production in the KCOL have been declining since 2011 (see the *Snail Kite Population Monitoring* section of this chapter). In the dry season, recession lines are typically requested for these lakes to moderate the rate at which lake stages are reduced to their seasonal low pools. During rainy periods, there can be concerns that discharge from S-65 (which enters Lake Okeechobee through S-65E) may cause increases in discharge from Lake Okeechobee to the estuaries. The objective of the planning meetings is to develop consensus among stakeholders on a seasonal standing recommendation document, which provides joint recommendations to SFWMD Water Control Operations for the upcoming season. The standing recommendations provide generalized but comprehensive operational guidance for a particular season for S-65C, S-65A, S-65, S-61, and S-59, and in some cases other lakes/structures in the KCOL. The standing recommendations include KRREP limits on rates of discharge increase/decrease at S-65/S-65A and guidelines for rates of increasing and decreasing headwater stage at S-65C to manage water levels in the southern Phase I floodplain of the Kissimmee River.

Hydrologic conditions in WY2015 were quantified with data collected by the SFWMD hydrologic monitoring program at water control structures throughout the Kissimmee Basin (**Figures 9-1** and **9-2**) and stage monitoring locations in the Kissimmee River channel and floodplain (**Figure 9-5**). This section follows the convention of District and USACE water managers by reporting hydrologic variables in English units—inches for rainfall, ft National Geodetic Vertical Datum of 1929 (NGVD29) for stage, and cfs for discharge.

Hydrology in the KRRP Phase I area floodplain is complex; its dynamics were characterized for WY2015 with two metrics—mean depth at floodplain BLM sites (here referred to as BLM depth) and mean depth on the Kissimmee River floodplain (here referred to as mean depth). BLM depth is calculated as the average depth at five stations in the northern floodplain at which BLM vegetation occurred prior to regulation (pre-1962, before construction of the C-38 canal) and where BLM is expected to reestablish after restoration construction is completed (see *Hydrology* subsection of the *Kissimmee River Restoration Evaluation Program* section of this chapter). The five stations were selected because they are located in the northern floodplain of the Phase I area and are thus outside the direct influence of the headwater stage of the downstream water control structure (S-65C), and for concurrence with Expectation 3, evaluated in the subsection mentioned in the previous sentence. BLM was the predominant wetland plant community on the floodplain prior to channelization and is expected to cover over 50 percent of the Kissimmee River floodplain after restoration construction is completed. BLM has very long hydroperiod requirements (see the *Expectation 3* subsection of the *Kissimmee River Restoration Evaluation Program* section). Mean depth is the average depth in the Phase I area floodplain, estimated using interpolations of mean daily stage measurements from a network of stage recorders covering most of the Phase I area. These interpolations are used to create a grid of water surface elevations, which are compared to ground elevations from a digital elevation model. Ground elevation is subtracted from the water surface elevation to obtain an estimated depth for each grid cell. Mean depth for the Phase I area is the average of depths of individual grid cells on a given date. Thus, mean depth provides an indication of conditions throughout the entire Phase I area, including the southern floodplain where depth is influenced by a backwater effect of S-65C (Anderson 2014a). BLM depth and mean depth exhibit similar trends, but BLM depth exhibits a greater range of fluctuation.

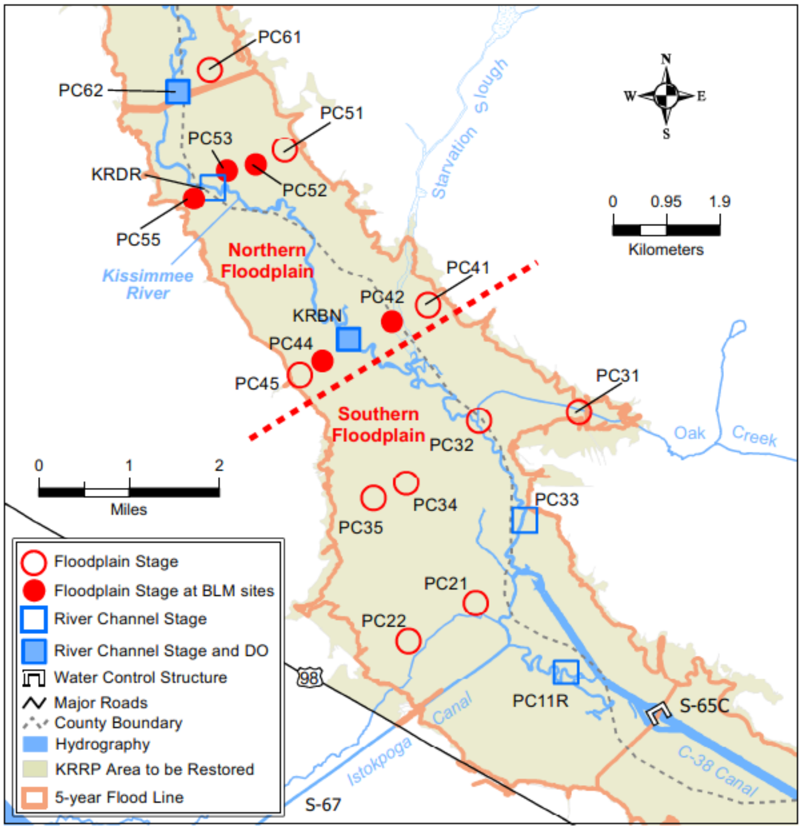


Figure 9-5. Locations of hydrologic monitoring sites in Pool C used to guide operations and evaluate restoration expectations.

RAINFALL

During WY2015, annual rainfall was above average for the second consecutive year in the Upper Kissimmee Basin (UKB) and the third consecutive year in the Lower Kissimmee Basin (LKB). The UKB total of 56.8 inches was 9.0 inches above the long-term average (1971–2000); the LKB total of 57.4 inches was 12.7 inches above average. Most rainfall fell in the June–October wet season, but above average rainfall in the dry season (November 1, 2014–May 31, 2015) made an important contribution to the annual total, especially in the UKB in the months of November, February, and April (**Figure 9-6**), which raised and held lake stages to the regulation schedules and consequently resulted in substantial flood control discharge to the LKB. Wet season rainfall totaled 31.7 inches (8.8 percent above average) in the UKB and 35.6 inches (27.2 percent above average) in the LKB. Dry season rainfall in the UKB rainfall totaled 25.2 inches (34 percent above average) and in the LKB 21.9 inches (30.5 percent above average).

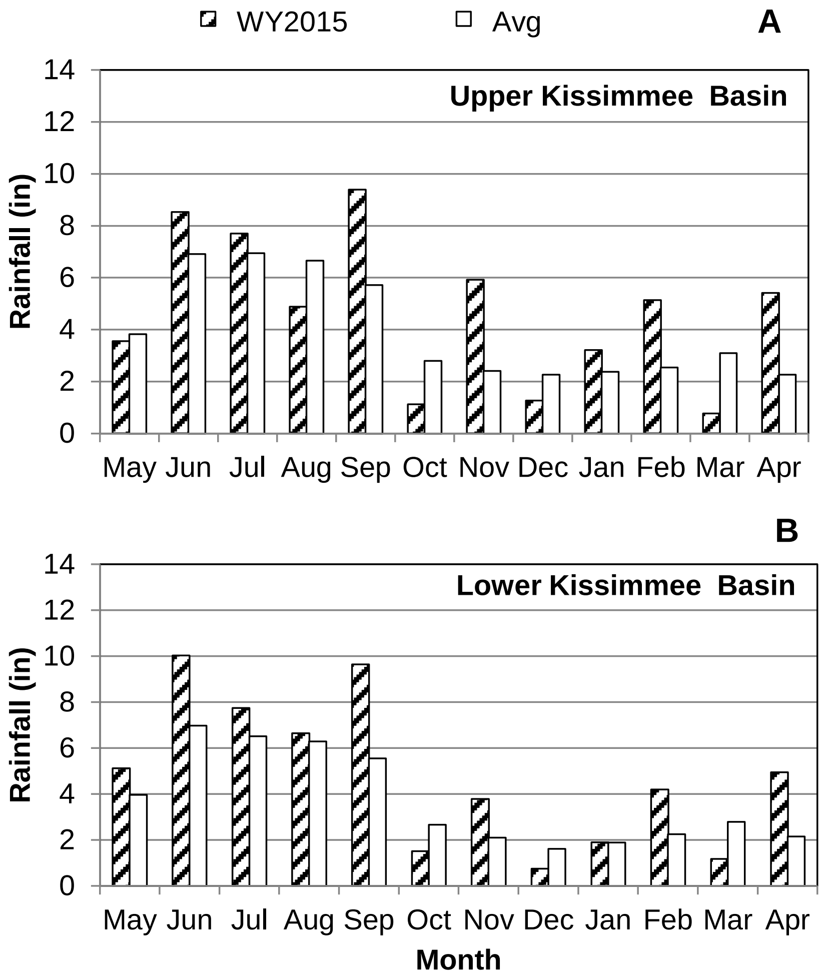


Figure 9-6. Monthly rainfall [in inches (in)] for WY2015 and average rainfall (1971–2000) in (A) the UKB and (B) the LKB.

TEMPORAL HYDROLOGIC PATTERNS

WY2015 began in May 2014 (the last month of the 2013–2014 dry season) with the lakes in the KCOL being lowered to their regulation low pools (lowest regulatory stages) per their respective regulation schedules. Stages in the groups of smaller, northern KCOL lakes (Lakes Myrtle, Preston, and Joel; Hart and Mary Jane; the Alligator Chain; and Gentry) approximately followed their respective flood regulation schedule lines to their low pools in May. Operations for East Lake Tohopekaliga (**Figure 9-7**, panel A), Lake Tohopekaliga (**Figure 9-7**, panel B), and KCH (**Figure 9-8**, panel B) over the 2013–2014 dry season used Zone B flexibility to specify F&W lines to moderate the rate of stage decline over the winter snail kite nesting season while reaching the regulation schedule lows on May 31 (**Figure 9-4**). Lowering the northern lakes and East Lake Tohopekaliga to low pool required varying amounts of discharge; this water flowed to Lake Tohopekaliga, which, in combination with the above average rainfall in April, resulted in substantial discharge (~1,700 cfs) from the S-61 structure to maintain the Tohopekaliga F&W recession line. These releases to KCH, in combination with rainfall, ultimately had negative effects on the Kissimmee River when KCH discharge was increased from approximately 400 cfs in late April to almost 2,000 cfs, and was soon reduced to approximately 300 cfs (**Figure 9-8**, panel B) to maintain its own F&W recession line. These changes in discharge resulted in rapid inundation of Kissimmee River floodplain BLM sites, which went from dry to approximately 0.5 ft depth and back to dry (see Event 1 in **Figure 9-9**, panel A and **Table 9-3**). This was the first of six significant stage reversals to impact the Kissimmee River floodplain in WY2015 (**Table 9-3**), all but one of which ended with BLM depth less than 0.3 ft, which is used as a criterion for a dry floodplain because it represents poor habitat conditions for larger fish, which can experience increased mortality (Chick et al. 2004) under such conditions. During the dry season, reversals and ensuing reductions in floodplain depth on the Kissimmee River floodplain are disruptive of fish reproduction and recruitment in the river channel and wading bird foraging on the floodplain. During both the wet and dry seasons they cause periods of intermittent inundation separated by rapid drydowns of the floodplain, a basic reason for near annual failures since 2001 to improve performance for the KRREP hydroperiod performance measure, even in wet years, as described in the *Kissimmee River Restoration Evaluation Program section's Hydrology* subsection below.

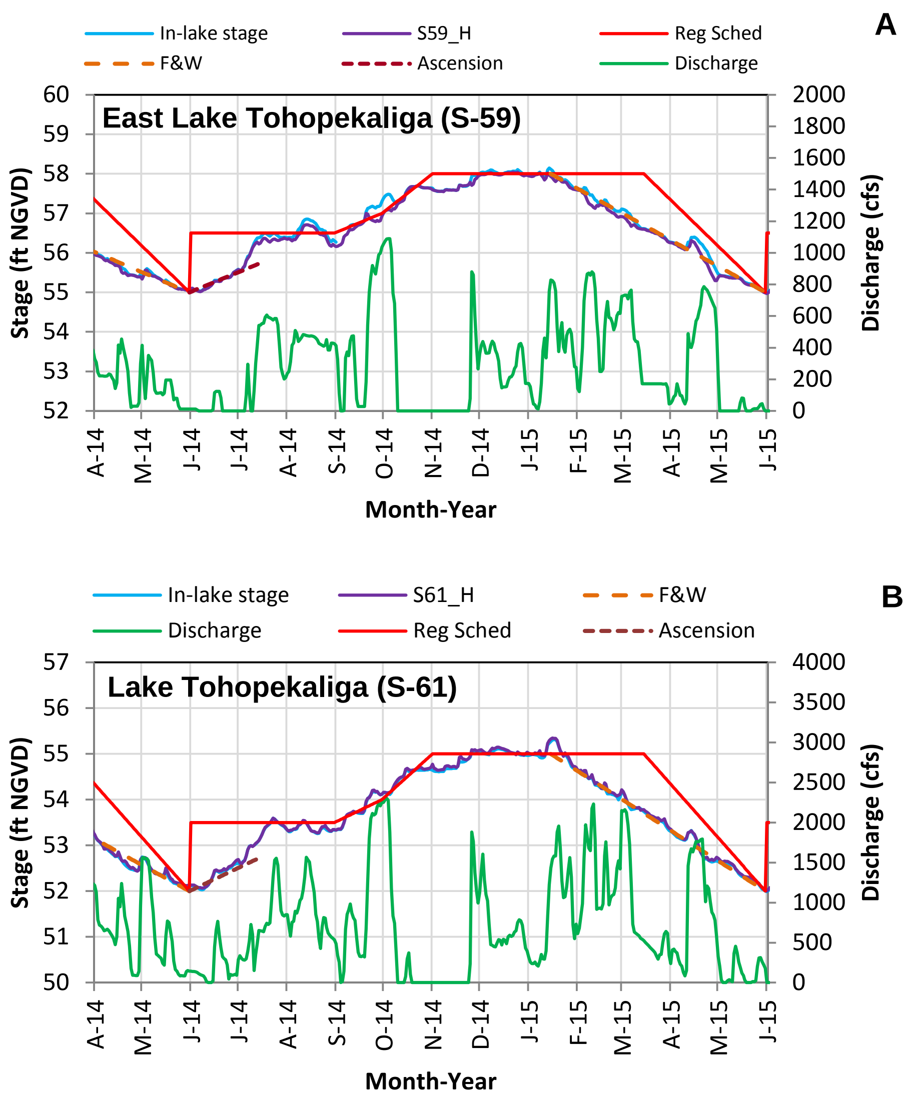


Figure 9-7. Regulation schedule (dashed line), water level (solid line) for (A) East Lake Tohopekaliga and (B) Lake Tohopekaliga during WY2015 and April of WY2014 and May of WY2016. Orange dashed lines are desired water level recession targets for snail kites.

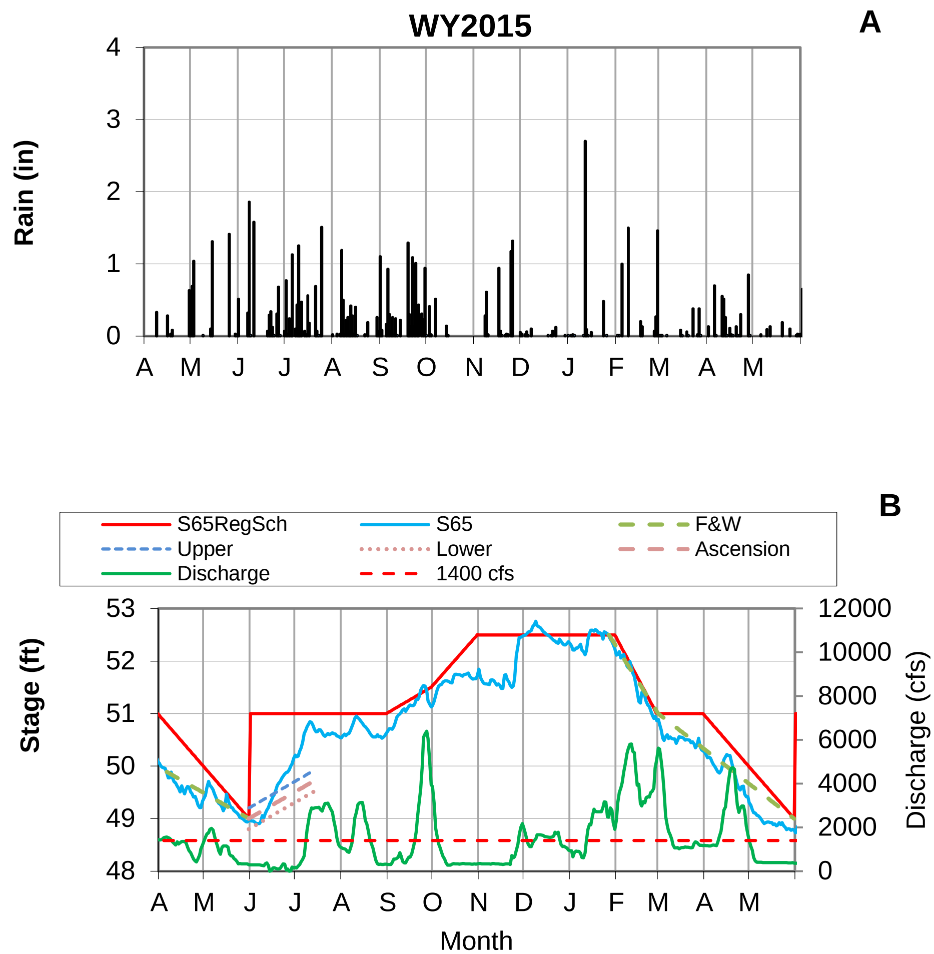
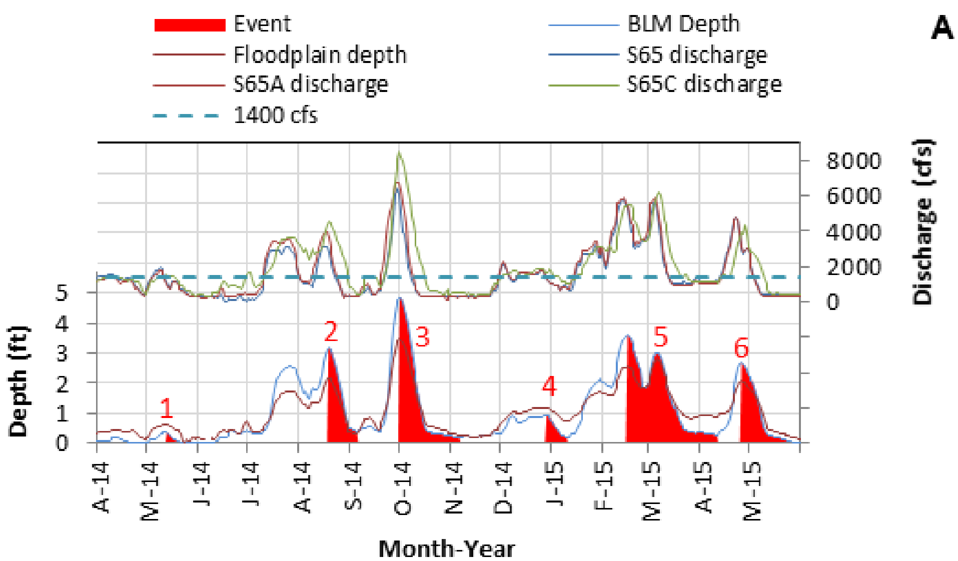


Figure 9-8. (A) Rainfall in inches (in) and (B) regulation schedule and water level in feet (ft) in KCH, discharge in cfs at the outlet of Lake Kissimmee (S-65 structure) for WY2015 and April of WY2014 and May of WY2016. Panel B includes stage recession targets for F&W, the stage ascension target line, and upper and lower boundary lines for ascension limits.



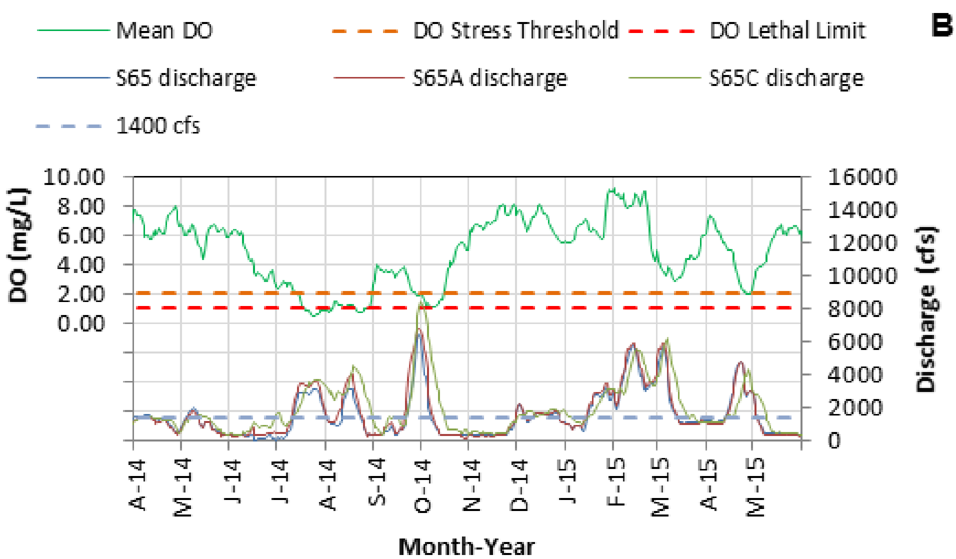


Figure 9-9. (A) Floodplain depth and BLM depth water depth at five stations (PC52, PC55, PC53, PC44, and PC42) in the northern floodplain where BLM occurred pre-channelization and is expected to reestablish after restoration is completed in relation to mean daily discharge at S-65, S-65A, and S-65C during WY2015 and April of WY2014 and May of WY2016, and (B) mean daily DO (calculated from 15-minute measurements) in the river channel at KRBN and PC62, and discharge at S-65, S-65A, and S-65C. Red numbers in panel A identify six events where the floodplain was inundated and rapidly drained as described in **Table 9-3**. See **Figure 9-5** for locations of hydrologic monitoring sites and the subsection on *Hydrology* in the *Kissimmee River Restoration Evaluation Program* section for more information.

Table 9-3. Characteristics of six events where changes in discharge caused increases and then decreases in BLM depth to very low levels for six events shown in **Figure 9-9**. For each event, the BLM depth is given at the start, the peak, and the end of the event.

Event	BLM depth (ft)			Duration of Depth Decrease (days)	Interval between Events (days)
	Event Start	Event Peak	Event End		
1	0.00	0.37	0.00	11	86
2	1.74	3.16	0.40	17	25
3	0.40	4.85	0.20	36	52
4	0.22	0.94	0.21	12	36
5	0.21	3.59	0.25	54	14
6	0.26	2.70	0.00	32	----

OPERATIONAL REQUESTS AND OUTCOMES

The planning process described above was used to develop recommendations for water management operations in WY2015, which began on May 1, 2014, and ended on April 30, 2015. The recommendations were made by KRREP scientists and staff from other agencies prior to the start of the wet and dry seasons. The following section summarizes the recommendations for the river (from KRREP) and requests for the lakes (from USFWS/FWC) for the 2014 wet season and the 2014–2015 dry season, followed by narratives of the outcomes of water management actions designed to address these goals.

Wet Season 2014

KRREP Recommendations for Wet Season 2014

- Avoid discharge > 1,500 cfs at S-65 from June-mid-October to reduce the likelihood of hypoxic events and fish kills and to raise lake stage.
- Attempt to maximize lake stage at the end of the wet season in anticipation of managing a discharge pulse in mid-October for floodplain inundation, followed by a slow reduction in discharge.
- Implement a pulse of discharge approximating pre-channelization seasonality (September–October): (a) initiate a pulse on October 15 of 3,000 cfs for 3 days, then ramp down to 1,200 cfs for 45 days if KCH stage is stable or rising and greater than 51 ft, or (b) a pulse of 2,100 cfs for 7 days, then a discharge ramp down to 1,200 cfs for 45 days if KCH stage was stable or rising and at least 50.5 ft but less than 51 ft. In either case, the pulse was to be terminated as KCH stage declined to 50.5 ft. This proposal was included in the standing recommendation dated May 30, 2014, with a note for Window C (October 15–December 31) that pulse details were still under discussion and would be finalized by September. A July 7 technical subteam meeting was used to consider output from a spreadsheet model simulating the effect of different discharge pulse designs based on pre-channelization flow data; however, no consensus was reached on a final pulse design.

- Due to lack of consensus for the pulse recommendation, a proposal was made by Kissimmee Basin Operations to temporarily (for two years) alternate a year of attempting to meet lake requests with a year of trying to meet river objectives; also, without consensus from lake stakeholders.

USFWS/FWC Requests for Wet Season 2014

- Raise KCH stage to 52.5 ft and hold that stage for 60 consecutive days ending January 1, 2015, because, "Lake Kissimmee in particular has not reached full pool very frequently in recent years, or for very long" and "to maximize the KCOL ecology."
- Attempt to reach full pool in KCH on October 17, 2014. [This request was not possible within the constraints of the authorized federal regulation schedule for KCH/S-65 (**Figure 9-8**), which allows 52.5 ft to be reached on November 1 at the earliest.]
- Limit KCOL lakes ascension rate to 6 inches per month to decrease the risk of drowning apple eggs, snail kite nests, and alligator nests. *[This request was accompanied by a request to prioritize the high pool request over ascension rates if limiting ascension in summer months would affect reaching high pool; however, the District could not accurately predict whether winter pool would be reached, as it is dependent on concentrated rainfall later in the season. Clarification was received from USFWS/FWC in July that the ascension requests were intended to apply only to KCH, Lake Tohopekaliga, and East Lake Tohopekaliga]*.

Wet Season 2014 Water Management Outcomes

Variable releases were made from East Lake Tohopekaliga, and near continuous releases were made from Lake Tohopekaliga to limit their rates of stage increase, but by early July the District's operational ability to control the rate of stage rise in these two lakes was overwhelmed by rainfall (**Figure 9-6**), even with the only slightly above normal rainfall that occurred in June and July. The District's ability to limit stage ascension in KCH was constrained starting as early as mid-June by the combination of rainfall, releases from S-61 (**Figure 9-7**, panel B) to control ascension in Lake Tohopekaliga, and limitations on rates of discharge increase at S-65 to protect the Kissimmee River (see the *Hydrology* subsection in the *Kissimmee River Restoration Project Evaluation Program* section). Variable discharge was made from KCH (**Figure 9-8,** panel B), while limiting discharge at S-65A to approximately 300 cfs ± 50 cfs through June due to declining DO in the Kissimmee River in June and July. On July 10, USFWS/FWC requested to discontinue the stage ascension limits in KCH, East Lake Tohopekaliga, and Lake Tohopekaliga, believing they would reduce lake stages later in the year. With continued steady rainfall, East Lake Tohopekaliga (**Figure 9-7**, panel A) and Tohopekaliga (**Figure 9-7**, panel B) reached their summer pools in mid-July 2014 after rising rapidly with the somewhat above average June and July rainfall in the UKB (**Figure 9-6**), which had also been a factor in the District's inability to limit ascension rates. Once lake stages approached their regulation lines, discharge was adjusted to hold lake stages at or near the regulation lines until September, when stages were allowed to start rising along the regulation lines toward winter pool.

In KCH, stage also reached the summer flood regulation line in mid-July 2014. Attempts to maintain stage high in KCH over the summer resulted in a series of rapid increases in discharge for flood control at S-65 over the summer months due to the proximity of lake stage to the flood regulation line. In mid-July, discharge was increased for flood control to approximately 3,500 cfs at S-65A (**Figure 9-8**, panel A); as a result of this increase in discharge, water depth increased in the Phase I area (BLM depth increased to approximately 2.5 ft); the rapid increase in discharge and depth was accompanied by a deep sag in DO in the Kissimmee River, with DO concentration averaging close to or well below 1 mg/L until early September. Stage in KCH then began to decline due to reduced rainfall, resulting in a discharge reduction to less than 1,400 cfs for ~7 days, reducing BLM depth to approximately 1.5 ft. As lake stage rose again to the regulation line in mid-August, discharge was increased again for flood control to almost 4,000 cfs at S-65A, resulting in a BLM depth on the Kissimmee River floodplain of approximately 3 ft. In late August, discharge at S-65 was reduced again in an effort to prevent lake stage from declining, from approximately 4,000 cfs on August 16 to 300 cfs (minimum discharge) on August 28 (12 days). As a result, BLM depth declined in the second event of the water year to drain the floodplain (**Table 9-3** and **Figure 9-8**). This reduction in discharge was accompanied by an increase in DO and recovery from the first of two hypoxic events of the wet season (see below). Another rain event caused an increase in lake stage above the regulation schedule line in late September (**Figure 9-8**, panel B), which necessitated another rapid increase in discharge to approximately 6,000 cfs, followed by another rapid reduction from 6,400 cfs on September 30 to 300 cfs on October 14. The rapid reduction in discharge resulted in BLM depth decreasing by 4.5 ft in 18 days (0.25 ft per day). These two wet season events, along with the one in May, made three events during the wet season that the floodplain was inundated to significant water depth and then drained rapidly. Although such drawdown events may initiate DO recoveries, they disrupt prolonged, natural, annual cycles of floodplain inundation with repeated, short duration wet/dry events. The rapid drydowns and reversals of stage on the Kissimmee River floodplain were noted and criticized by observers and Kissimmee River stakeholders, including Audubon of Florida.

In early October, a decision was made to forego the October 15 pulse in the KRREP recommendation above. In making this decision, consideration was given to several factors including (a) concerns expressed by estuary stakeholders about the potential for increased discharge to cause increased releases from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries, (b) the lack of consensus by the interagency team on implementation of a pulse, (c) a declining rate of stage increase in KCH that peaked at approximately 51.5 ft (**Figure 9-8**, panel B), (d) the occurrence of a large discharge event in late September, and (e) an hypoxic event in the Kissimmee River that accompanied the September discharge event. The KRREP recommendation was revised to specify very slow recessions from further flood control events to connect floodplain inundation events by reducing the probability of lowering floodplain stage very far before the next rain event (see Event 3 in **Table 9-3** and **Figure 9-8**). October rainfall was below average and as a result most lake stages stopped rising in mid-to-late October in all of the lakes except Myrtle-Preston-Joel, which was the only lake group to reach its high winter pool before the end of the wet season. Stage in KCH did not rise above ~51.5 ft during wet season and therefore ended wet season 1 ft below its high pool. The original USFWS/FWC request to reach high pool on October 17, two weeks early in KCH, was not possible within the constraints of the authorized federal regulation schedule for KCH/S-65 (**Figure 9-**8, panel B), which allows 52.5 ft to be reached on November 1 at the earliest.

Hypoxia in the Kissimmee River occurs when the concentration of oxygen dissolved in water (DO) decreases to less than 2 mg/L. In the Kissimmee River, DO concentrations less than 2 mg/L are stressful to centrarchids (largemouth bass [*Micropterus salmoides*] and other sunfish); concentrations below 1 mg/L may be lethal (Furse et al. 1996). Hypoxic conditions can also affect other organisms, such as many aquatic invertebrates, that depend on DO. A section summarizing current knowledge of the relationship of hypoxia to water management in the Kissimmee River was included in the 2015 SFER – Volume I, Chapter 9 (see *Hypoxia in the Kissimmee River: Consequences, Causes and Water Management* section in Cheek et al. 2015). The Kissimmee River experienced two hypoxic events over the wet season, defined for the Kissimmee River as mean daily DO concentration less than 2 mg/L. Previous work in the Kissimmee River has found that DO concentrations of 1 to 2 mg/L are stressful for centrarchids (largemouth bass and other sunfish) and that concentrations less than 1 mg/L can cause death [see Furse et al. (1996) and additional details in Bousquin et al. (2008) and the associated *Response to Comments* documentation in Appendix 1A-5 of the 2008 SFER– Volume I (SFWMD 2008)]. The first hypoxic event began when DO declined below 2 mg/L on July 16. It continued for 46 days until August 30. During this event, DO declined below the anoxic (potentially lethal) threshold of 1 mg/L for 16 consecutive days (July 19–August 30, 2014). The second event began on September 28 and for lasted 18 days, ending on October 15. During the second event DO did not decline below the 1 mg/L threshold, likely due to a combination of a fortuitous pattern of rainfall/discharge and KRREP limitations on rates of increase in discharge for S-65/S-65A. The duration and severity of hypoxic and anoxic conditions were likely ameliorated by the judicious discharge ramp up guidelines that were in place (Cheek et al. 2015).

Dry Season 2014–2015

USFWS/FWC Requests for Dry Season 2014–2015

- An unusual rain event in late November 2014 brought KCH close to high winter pool three weeks into the dry season (the UKB received 5.9 inches of rain in November 2014, or 264 percent of normal). Following inconclusive discussions about requested KCH stages and durations in a December 11, 2014, planning meeting, the District responded by email on December 19 that they would manage discharge from KCH to target 52 ft as possible but would use a 0.5 ft buffer below the regulation line for the purpose of moderating floodplain reversals in the Kissimmee River, which are often caused by sudden increases in discharge for flood control when lake stage is operated too close to the regulation line, but that they would allow stage to rise higher during forecast dry conditions when flood control releases were less likely to be needed. On December 23, USFWS/FWC revised their prior request for KCH (originally made as part of the wet season requests, see above) to attempt to follow the declining regulation line (without a buffer) from February 1 to March 1, then to follow a straight line to 49 ft on May 31. USFWS/FWC's request for Lake Tohopekaliga and East Lake Tohopekaliga was to remain at high pool through January 15 (55 and 58 ft, respectively), then to begin recessions along a straight line drawn to their regulation lows on May 31. Assuming the recessions started at the regulation lines, the requests for Lake Tohopekaliga and East Lake Tohopekaliga projected recession rates of ~0.7 ft per 30 days for both lakes.
- A later revision of the request for KCH made on January 11, 2015, requested 52 ft or as high as possible through January, following the descending portion of the regulation schedule to substitute for a recession target line until March 1, then following a line drawn from the regulation line on March 1 to the KCH regulation low (49 ft) on May 31, resulting in projected recession rates of 1.6 ft per 30 days through March 1 and ~0.7 ft per 30 days from March 1 to May 31.
- With lake stages above schedule in late January, the USFWS/FWC requests were modified again to assign higher priority to Lake Tohopekaliga than East Lake Tohopekaliga with respect to the rates of recession that would be used to return their stages below their regulation lines. The KCH recessions were assigned lowest priority.
- Kissimmee Basin Operations recommended to allow a buffer below the regulation line after March 1 in all three lake groups, which ultimately was not implemented due to downstream concerns about discharge to Lake Okeechobee causing releases to the Caloosahatchee and St. Lucie estuaries.

KRREP Recommendations for Dry Season 2014–2015

- Because of reduced temperatures during most of winter dry season resulting in less concern for discharge-related DO sags, the District relaxed dry season discharge ramp up/ramp down guidelines for S-65 for the 2014–2015 dry season by doubling them through April 2015 to facilitate control of lake stage reversals and negative departures while attempting to follow stage recession target lines.
- The District recommended for USFWS to add guidelines for variability around the F&W lines, to avoid potentially unnecessarily abrupt increases and decreases in discharge to the Kissimmee River with rain events.
- In a January 15, 2015, meeting, SFWMD and USFWS/FWC agreed to prioritize attempting to meet the requested operations for KCH through the remainder of the 2014–2015 dry season, then to alternate to a “river year” from the 2015 wet season into the first months of the 2015–2016 dry season.

Dry Season 2014–2015 Water Management Outcomes

The 2014–2015 dry season began with all of the lake groups below regulation schedule except Myrtle-Preston-Joel. Several weeks in to the dry season near the end of November, an unusually large rainfall event raised all of the lakes to approximately the high pools of their respective regulation schedules, shown for East Lake Tohopekaliga and Lake Tohopekaliga in **Figure 9-7** and for KCH in **Figure 9-8**. The event and resulting proximity to the regulation lines necessitated dramatic increases in discharge for flood control. As stage in KCH was rising, discharge was increased to 2,000 cfs, which increased mean water depth on the floodplain to almost 1 ft (**Figure 9-9**, panel A). To keep lake stage from declining following the event, discharge was reduced from 1,700 cfs on December 27 to 655 cfs on January 6, 2015. The reduction in discharge caused BLM depth on the Kissimmee River floodplain to decrease, resulting in the fourth event in WY2015 in which floodplain depth was reduced substantially after an abrupt reversal (see Event 4 in **Table 9-3** and **Figure 9-9**). In February, discharge from S-65 that varied from 3,000 to 6,000 cfs was used to lower KCH stage along the regulation line as had been requested by USFWS, resulting in a BLM depth of 2.5 to 3.0 ft in the floodplain until mid-March, when discharge was reduced because of the change in slope of the recession line after March 1; discharge was reduced from over 5,000 cfs on March 6, 2015, to approximately 1,100 cfs on March 15. This reduction in discharge resulted in the fifth event in WY2015 in which the floodplain was inundated to significant depth and then rapidly drained (see Event 5 in **Table 9-3** and **Figure 9-9**). The F&W recession line requested by FWC for KCH began to converge with the regulation schedule in late April as lake stage declined. To control a reversal in lake stage in late April, discharge was increased to 4,700 cfs on April 23 and then decreased to 400 cfs on May 9. This discharge reduction resulted in the sixth event in the water year in which the floodplain was inundated to a significant depth and rapidly drained (see Event 6 in **Table 9-3** and **Figure 9-9**).

Unusually high dry season rainfall resulted in prolonged periods of time at or within 0.5 ft of high pool in East Lake Tohopekaliga, Lake Tohopekaliga, and KCH between late November and February 1: in East Lake Tohopekaliga, 117 consecutive days within 0.5 ft of high pool and 57 days at or above high pool (57.9 ft or above); in Lake Tohopekaliga, 117 consecutive days within 0.5 ft of high pool and 62 days at or above high pool (54.9 ft or above); and in KCH 80 days within 0.5 ft of high pool and two periods of 28 days (November 29–December 26, 2014) and 17 days (January 13–29, 2015) at or above high pool (52.4 ft or above). The F&W recession lines requested by USFWS/FWC were implemented in the three lakes groups for which requests were received, with minor departures from the lines over most of the requested windows through May 31. Control of stage in KCH to follow the line required abrupt changes in discharge at S-65, resulting in multiple stage reversals for the Kissimmee River floodplain.

Although the Kissimmee River experienced several unexpected declines in DO in the WY2015 dry season (**Figure 9-8**, panel B), DO did not decline below 2 mg/L (hypoxic) for a significant duration of time. Reversal criteria used were the same as those used during dry season 2013–2014, although criteria were not proposed by USFWS/FWC to provide operational flexibility below the target lines (negative departures).

WY2015 Water Management Summary and Conclusions

Wet season rainfall was insufficient to raise stage to winter high pool in KCH in the 2014 wet season despite efforts to manage discharge to favor stage rise, and despite reaching KCH summer pool in mid-July. Discharge operations from KCH (S-65) over the wet season greatly affected water depth in the Kissimmee River floodplain, which is almost fully dependent on discharge (Anderson 2014a) for inundation, and which responds dramatically to changes in discharge intended to control stages in KCH. Discharge operations over the wet season are illustrative of problems that result for the Kissimmee River when attempts are made to hold stable high lake stages rather than following a stage-discharge relationship in which discharge increases and decreases with lake stage.

In unregulated headwater/river ecosystems including the Kissimmee Basin prior to regulation, discharge increases with lake stage, which in turn declines with discharge unless rainfall compensates. The resulting variability in within- and among- year stage and discharge provided the variable periods of inundation of the Kissimmee River needed to sustain its vast floodplain, and likely sustained littoral zones in the Headwaters Lakes characterized by a diverse range of zonal plant communities. Periods of stabilized, high lake stage were relatively rare, occurring only when rainfall/inflow exactly compensated for stage-driven discharge, and were never accompanied by low discharge (**Figure 9-10**). Periods of high stage in the lakes occur naturally at some interannual frequency without the need for reductions in discharge, occurring when rainfall is sufficient to balance discharge, as was to some extent possible in the 2014–2015 dry season. Operations such as those used over summer 2014 (and previous years) do not, without adequate rainfall, produce the desired result for the Headwaters Lakes of reaching and maintaining high pool, while causing severe problems for moving toward reestablishment of Kissimmee River floodplain hydrology. Stage in the months in which the regulation schedule permits maximum high pool to be reached is dependent on concentrated rainfall during this window of time, and prolonged periods of stabilized lake stages require sustained, steady rainfall to maintain lake stage while compensating for discharge. Ecological problems in WY2015 associated with rapid drawdowns and reversals, and their effects on project goals for the KRRP, are detailed in the *Hydrology* subsection in the *Kissimmee River Restoration Evaluation Program* section below. Other problems for the Kissimmee River were related to attempts to follow regulation lines (or winter/spring recession lines) too closely, which tends to set off sudden increases and decreases in discharge in response to rain events.

Unusually high dry season rainfall resulted in prolonged periods of time at or within 0.5 ft of high pool in East Lake Tohopekaliga, Lake Tohopekaliga, and KCH between late November and February 1: in East Lake Tohopekaliga, 117 consecutive days within 0.5 ft of high pool and 57 days at or above high pool (57.9 ft or above); in Lake Tohopekaliga, 117 consecutive days within 0.5 ft of high pool and 62 days at or above high pool (54.9 ft or above); and in KCH 80 days within 0.5 ft of high pool and two periods of 28 days (November 29, 2014–December 26, 2014) and 17 days (January 13, 2015–January 29, 2015) at or above high pool (52.4 ft or above). The F&W recession lines requested by USFWS/FWC were implemented in the three lakes groups for which requests were received, with minor departures from the lines over most of the requested windows through May 31. However, control of stage in KCH to follow its line required abrupt changes in discharge at S-65, resulting in multiple stage reversals for the Kissimmee River floodplain.

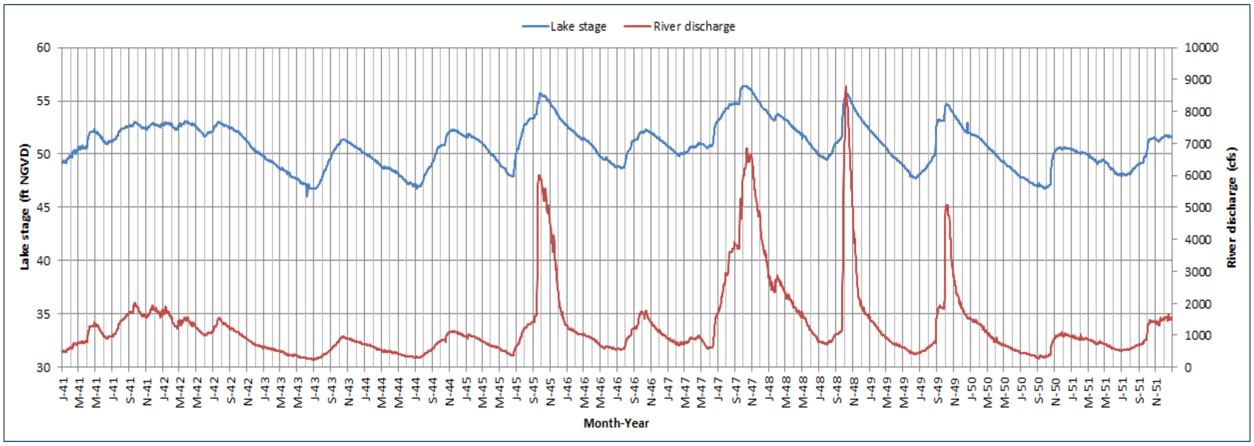


Figure 9-10. Hydrograph showing the relationship between stage in KCH and discharge to the Kissimmee River over a selected 10-year period (1941–1951) prior to regulatory control of discharge. Lake stages and flow rose and fell together in response to rainfall. Periods of stabilized, high lake stages were relatively rare, occurred only when rainfall/inflow exactly compensated for stage-driven discharge, and were never accompanied by low discharge.

The November 2014–April 2015 period included several events in which discharge to the Kissimmee River exceeded either 1,200 cfs (channel bankfull) or 1,400 cfs (significant depth at BLM locations). The longest durations were 58 continuous days with discharge exceeding 1,200 cfs and 57 continuous days with discharge exceeding 1,400 cfs between January 15, 2015, and March 13, 2015, falling far short of KRRP restoration performance measures despite rainfall that was far above normal. These events also occurred in an outlier window of time during which prolonged floodplain inundation seldom occurred in the reference period (see *Hydrology* subsection of the Kissimmee River Restoration Evaluation Program section below for additional details). Efforts to artificially reach or maintain high lake stages by reducing discharge to the Kissimmee River therefore resulted in discontinuous periods of floodplain inundation in WY2015, and six reversal events in which discharge was increased above a level resulting in significant mean depth on the floodplain, followed by abrupt reductions in discharge that drained the floodplain. Events in the 2014–2015 dry season serve to demonstrate that the kind of rainfall conditions needed for stabilized high pool stages in KCH occur naturally without the need to manipulate discharge. Attempts to hold stage near or at high pool in KCH for prolonged periods in years of insufficient rainfall will continue to have the consequence of severely constraining the District's ability to provide the discharge needed to move toward restoration of the Kissimmee River floodplain.

KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM

A major component of the KRRP is assessment of restoration success by the KRREP, a comprehensive ecological monitoring program (Bousquin et al. 2005, Williams et al. 2007, Koebel and Bousquin 2014) mandated and designed to evaluate the ongoing status and ultimate success of the KRRP. Restoration evaluation was identified as a SFWMD responsibility in its cost-share agreement with USACE for KRRP (Department of the Army and SFWMD 1994). Initiation of the KRREP in the 1990s represented a pioneering effort to use scientific data from a set of rigorous and statistically-valid monitoring studies to evaluate the success of one of the largest river/floodplain restoration projects in the world. Success is being tracked, in part, using 25 hydrologic, biotic, and abiotic performance measures (Anderson et al. 2005) to track project success and evaluate how well the project meets its goal of reestablishment of ecological integrity to the Kissimmee River and floodplain (Koebel and Bousquin 2014). 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 the performance measures, called restoration expectations, are based on estimated conditions in the prechannelized system (reference conditions) and have undergone extensive external peer review. Trends and results from these evaluations are reported in several ways, including peer reviewed and SFWMD technical publications, scientific conferences, and annual reports. Full realization of some aspects of the restoration expectations, particularly those related to floodplain responses in specific portions of the floodplain, are tied to removal of the S-65C water control structure during an upcoming phase of construction. However, targeted, adaptive water management in the Interim Period prior to project completion can move parts of completed phases of the project in the direction required by project goals. Although final evaluations of project success will take place after all construction components are in place, the ecological and hydrologic responses being documented prior to project completion are used to evaluate the ongoing status of ecosystem recovery and to guide adaptive management of the system. Monitoring for ecological evaluation will continue for at least five years after construction is complete or until ecological responses have stabilized (USACE 1991).

Post-construction monitoring continued in the Phase I restoration area in WY2015. Results that are newly available in the past water year are presented here. Many of the Phase I studies, which involve collection and analysis of data on hydrology, geomorphology, water quality, river channel and floodplain vegetation, aquatic invertebrates, herpetofauna, fish, and birds, have already documented changes consistent with those predicted by the expectations developed for the KRREP (Anderson et al. 2005), particularly in the river channel, with responses of floodplain hydrology and vegetation lagging substantially behind (see the *Hydrology* subsection below; Anderson 2014a, Spencer and Bousquin 2014). A comprehensive update of initial responses to Phase I reconstruction was first published in Chapter 11 of the 2005 SFER – Volume I (Williams et al. 2005b), 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 (Williams et al. 2006) and in Bousquin et al. (2007). **Table 9-4** provides a directory of KRREP monitoring study updates presented in the SFER since 2005. See the subsection at the end of this section for recently published papers on KRREP topics, including a special section of the May 2014 issue of the journal *Restoration Ecology* on interim responses to Phase I reconstruction.

To contain costs, most KRREP studies do not collect data continuously, with most studies active for two to five years during the Baseline (pre-restoration), Interim, and/or Post-construction 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 remaining construction phases and implementation of the HRS. During the Interim Period, the river's physical and hydrologic characteristics are only partially reestablished. Therefore, although substantial improvements can be made in the Interim Period by appropriate water management, the full array of hydrologic management options are not available and, therefore, the hydrologic conditions that are expected to lead to full restoration of the river and floodplain are not yet all in place.

Only studies that collected new data in WY2015 are updated in this section. These new results from studies of floodplain hydrology, DO, and wading birds and waterfowl document the current status of these ecosystem components. Where applicable, the results are evaluated in relation to the associated restoration expectations.

Table 9-4 Directory of KRREP Phase I restoration response monitoring study updates in the 2005–2016 SFERs.[a]

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2016 SFERs – Volume I											
		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Kissimmee River Restoration Evaluation Program		11-8	11-37	11-22	11-28	11-36	11-26	11-25	9-16	9-19	9-20	9-22	9-27
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**	**9-26**	
Variability of flow	2					**11-40**	**11-31**	**11-32**	**9-20**	**9-23**	**9-23**	**9-28**	
Stage hydrograph	3	**11-22**				**11-41**	**11-32**	**11-33**	**9-21**	**9-24**	**9-24**	**9-30**	**9-37**
Stage recession rate	4	**11-23**	11-23	11-16	11-19	**11-42**	**11-34**	**11-35**	**9-24**	**9-27**	**9-28**	**9-33**	**9-41**
Flow velocity	5	**11-25**					**11-35**	**11-37**	**9-24**				
Broadleaf marsh indicator	None					11-43						9-33	9-37
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**	**9-30**	**9-36**	**9-45**
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	9-34	9-40	9-50
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**			**9-42**	**9-50**	
Areal coverage of broadleaf marsh	13	11-40			**11-35**			**11-47**			**9-43**	**9-51**	
Areal coverage of wet prairie	14	11-40			**11-35**			**11-47**			**9-43**	**9-51**	
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					

Table 9-4. Continued.

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2016 SFERs – Volume I											
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Herpetofauna													
Floodplain reptiles and amphibians	19	11-48	Response data will be collected after implementation of the Headwaters Regulation Schedule (HRS).								9-47		
Floodplain amphibian reproduction and development	20	11-48	Response data will be collected after implementation of the HRS								9-47		
Fish Communities													
Small fishes in floodplain marshes	21	11-50	Response data will be collected after implementation of the HRS.										
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 HRS.										
Birds													
Wading bird abundance	24	**11-58**	**11-71**	**11-32**	**11-44**	**11-72**	**11-50**		**9-36**	**9-41**	**9-53**	**9-57**	**9-51**
Waterfowl	25		**11-67**	**11-35**		**11-73**	**11-52**		**9-37**	**9-42**	**9-55**	**9-59**	**9-54**
Shore birds	None	11-57											
Wading bird nesting	None		11-68		11-40	11-72	11-47		9-33	9-38	9-47	9-53	9-56
Threatened and Endangered Species	None	11-60											

a. Bolded page numbers indicate a major update in reference to the status of a restoration expectation (performance measure)

Photos illustrating ecological conditions in the Phase I restoration area throughout WY2015 are available on the District's website in the *Library & Multimedia* section at www.sfwmd.gov/library see Kissimmee River Restoration Environmental Conditions, Water Year 2015 (compiled by B. Anderson, SFWMD). Of particular interest are the rapid increases in Kissimmee River stage followed by reductions in discharge, which cause undesirable rapid wet/dry cycles on the Kissimmee River floodplain and that inhibit prolonged floodplain inundation.

HYDROLOGY

Reestablishment of pre-channelization hydrologic characteristics is the crucial driver for restoration of the Kissimmee River/floodplain ecosystem. This will be accomplished by reconstruction of the physical habitat template and reestablishment of lost hydrologic drivers by the KRRP, with adaptive operations guided by studies conducted by the KRREP. Key hydrologic characteristics of the ecosystem were identified in five Restoration Criteria in the Final Integrated Feasibility Report and Environmental Impact Statement: Environmental Restoration Kissimmee River (USACE 1991). These criteria define the essential hydrologic drivers that need to be reestablished to achieve restoration of the habitat and ecological integrity of the river/floodplain ecosystem. Meeting the hydrologic criteria is essential for achieving ecological integrity, which is identified as the project goal in the federal project's documentation (USACE 1991, 1996). This goal is to be met by reestablishment of hydrology to ensure that the restoration project addresses the level of the ecosystem, rather than individual taxa (Andersen et al. 2005), although the project also requires monitoring and analysis of an array of specific biological and abiotic components of habitat to verify their responses.

The hydrologic restoration criteria were expressed as five restoration expectations (performance measures) for evaluation of the status and ultimate success of reestablishment of KRRP hydrology (Table 1, Anderson et al. 2005). The hydrologic expectations use long periods of pre-channelization stage and discharge data to characterize pre-channelization hydrology in terms of magnitude, frequency, duration, timing, and rates of change (Anderson et al. 2005) of hydrologic variables, which form the basis (reference conditions) for expected conditions in the future, restored system. The hydrologic expectations have been evaluated annually since 2005 to assess restoration progress since completion of the first phase of backfilling in 2001 [see 2005–2015 SFERs – Volume I (Williams et al. 2005b, 2006, 2007, Bousquin et al. 2008, 2009, Jones et al. 2010, 2011, 2012, 2013, 2014, Cheek et al. 2015) and Anderson (2014a) for examples of past hydrologic evaluations]. Previous work has shown that while hydrologic conditions in the Phase I area have showed improvement for some hydrologic criteria (e.g., more continuous flow in river channels, more but intermittent and inadequate floodplain inundation) during the Interim Period compared with the regulated Baseline Period, conditions in the Interim Period are neither meeting the restoration expectations nor showing improvement over time (Anderson 2014a and previous SFER chapters). Meeting or moving toward the hydrologic targets is dependent on rainfall, but also to a large extent on appropriate water management to make best use of available water. However, in general, operations in the 15-year Interim Period thus far has not been focused on improvement of hydrologic conditions for the Kissimmee River floodplain.

A challenge in past evaluations of the hydrologic criteria and in development of the original expectations was that the targets in the original hydrologic criteria were not necessarily stated in terms that could be readily translated into operational actions for implementation. For example, a statement that flows should be reestablished that are comparable to pre-channelization conditions requires considerable analysis of historic discharge to determine the reference condition and a target value, and an evaluation comparing current operations to baseline conditions. To make water management recommendations in the Interim Period, hydrologic goals need to be stated and quantified in operational terms, i.e., in terms of discharge and stage targets. Changes are being made to the expectations to define metrics that can be used to better guide adaptive water management operations, both during the current Interim Period and after the project is completed, while retaining clear linkages with the original hydrologic criteria. The changes include realignment of the expectations with the original hydrologic criteria and addition of new metrics to more fully capture the original criteria. Changes are based on new analysis of data from the Pre-channelization (Reference) and Interim periods and incorporate a better understanding of the hydraulics of the system (e.g., the extent of the backwater effect from the current downstream structure) gained over the 15 years of the Interim Period. This reorganization of the hydrologic expectations is intended to group metrics more logically and does not change their scope nor the pre-channelization hydrologic criteria that were the source of the expectations. Only the metrics and/or methods being used to evaluate them are being modified.

This year's hydrology section focuses on Expectation 3 (hydroperiod) and Expectation 4 (recession events). Revised statements of the expectations are included below and in **Table 9-5**, which provides a crosswalk to prior evaluation methodology. The section begins with a summary of the relationship of discharge flood events to hydroperiod, especially in relation to the requirements of BLM, an important type of wetland in the Kissimmee River floodplain, and stage recession events; this information was used to guide development of Expectations 3 and 4. The section summarizes calculations of targets for the expectations using data from the Reference Period (WY1932–WY1962), and evaluations of the Baseline (regulated) Period (WY1972–WY1999) during which the C-38 canal was in place, and the post-KRRP Phase I construction Interim Period (WY2002–WY2015); and focuses on changes in discharge management that can improve performance of these expectations during the remainder of the Interim Period.

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Table 9-5. Restoration hydrologic criteria and expectations for the Kissimmee River Restoration Project.

HYDROLOGIC CRITERION (USACE 1991)	CRITERION DETAILS (USACE 1991)	OLD EXPECTATION	NEW EXPECTATION	NEW EXPECTATION COMPONENTS (METRICS)	COMPONENT TARGETS
1. Continuous flow with duration and variability characteristics comparable to pre-channelization records.	The most important features of this criterion are (a) reestablishment of continuous flow from July to October, (b) highest annual, discharges in September–November and lowest flows in March–May, and (c) a wide range of stochastic discharge variability. These features should maintain favorable dissolved oxygen regimes during summer and fall months, provide non-disruptive flows for fish species during their spring reproductive period, and restore temporal and spatial aspects of river channel habitat heterogeneity.	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.	EXPECTATION 1 is under revision.	Under revision.	Under revision.
		EXPECTATION 2 Intra-annual monthly mean flows will reflect historical seasonal patterns and have inter-annual variability (coefficient of variation) < 1.0.	EXPECTATION 2 is under revision.	Under revision.	Under revision.
2. Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long-term variability characteristics.	Ecologically, the most important features of stage criteria are water level fluctuations that lead to seasonal wet-dry cycles along the periphery of the floodplain, while the remainder (approximately 75 percent) of the flood plain is exposed to only intermittent drying periods that vary in timing, duration and spatial extent.	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. BLM CRITERION Water depth greater than or equal to 0.3 meters for at least 210 days per water year.	NEW EXPECTATION 3 Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long-term variability characteristics.	A. Percent of water years that mean depth at broadleaf marsh sites is greater than or equal to 1 foot for 210 days consecutively in a water year. B. Percent of water years that mean depth at broadleaf marsh sites is greater than or equal to 1 foot for 210 days consecutively in the August–February window.	A. 59% of water years. B. 40% of water years.
3. Stage recession rates on the floodplain that typically do not exceed 1 foot per month.	A slow stage recession is required to restore the diversity and functional utility of floodplain wetlands, foster sustained river-to-floodplain and floodplain-to-river interactions, and maintain river water quality. Slow drainage is particularly important during biologically significant time periods, such as wading bird nesting months. Rapid recession rates, such as rates that drain most of the floodplain in less than a week, led to fish kills during monitoring of the Demonstration Project in Pool B, and thus are not conducive to ecosystem restoration.	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 meters per 30 days.	NEW EXPECTATION 4 Stage hydrographs that result in floodplain recession events with rates of water level decrease, duration, and timing that are comparable to pre-channelization events, including seasonal and long-term variability characteristics.	A. Percent of events with a mean rate less than 1 foot per 30 days. B. Percent of recession events with a mean rate <2 feet per 30 days.	A. 70%. B. 100%.
4. Average flow velocities between 0.8 and 1.8 feet per second when flows are contained within channel banks.	These velocities complement discharge criteria by protecting river biota from excessive flows, which could interfere with important biological functions such as feeding and reproduction, and provide flows that will lead to maximum habitat availability.	EXPECTATION 5 Mean velocities within the river channel will range from 0.8 to 1.8 feet per second (0.2–0.6 meters per second) a minimum of 85% of the year.	NEW EXPECTATION 5 is under revision.	Under revision	Under revision.
5. A stage-discharge relationship that results in overbank flow along most of the floodplain when discharges exceed 1,400–2,000 cubic feet per second.	This criterion reinforces velocity criteria and will reestablish important physical, chemical and biological interactions between the river and floodplain.	No expectation was developed for this hydrologic criterion.	----	----	----

Flood Pulse, Hydroperiod and Recession Event Background

Seasonal fluctuation of discharge resulting in seasonal inundation of floodplains (termed a flood pulse) is well recognized as the dominant force organizing the habitat of floodplain-river ecosystems such as the Kissimmee River (Junk et al. 1989, Toth et al. 2002, Winemiller et al. 2014). Many characteristics of the ecosystem were dependent on a flood pulse, including floodplain wetlands, fish, wading birds and waterfowl, and numerous associated species and assemblages of species (USACE 1991, USFWS 1991, Toth et al. 2002). The flood pulse concept is embedded in both the general literature of river-floodplain ecology and the KRRP hydrologic criteria, especially Criterion 1 (variable discharge comparable to pre-channelization records), Criterion 2 (seasonal and annual variability of floodplain inundation), and Criterion 3 (water level recession rate in the floodplain) (Table 1, USACE, 1991). The subsection below provides background on floodplain inundation used in Expectations 3 and 4.

Floodplain hydroperiod requirements are based on the requirements of BLM. BLM was the most prevalent wetland plant community in the Kissimmee River floodplain prior to regulation, covering approximately half of the floodplain's area (Spencer and Bousquin 2014). The BLM community is dominated by *Pontederia cordata*, *Sagittaria lancifolia*, or a mixture of both species, and may include the shrub *Cephalanthus occidentalis*. BLM is known to have long hydroperiod requirements (Kushlan 1990, Toth 2010, Spencer and Bousquin 2014). BLM requires relatively long hydroperiods estimated as > 200 days of aboveground-level inundation per year. **Figure 9-11** shows the range of hydroperiods reported for BLM and other major wetland types that occur in the Kissimmee River floodplain. Kushlan (1990) describes the hydrologic requirements of these marshes in the Kissimmee River, including wet season water depths between 1 ft (0.3 m) and 3.3 feet (1.0 m), periods of inundation longer than 200 days per year, and a seasonal drying period. During the KRRP Demonstration Project, BLM was reestablished from remnant BLM communities after 7 to 9 months (210 to 270 days) of inundation (Toth et al. 1998). Based on this review, the minimum hydrologic requirements for BLM hydroperiod are estimated as a minimum of 1 ft of depth for > 210 days. The depth estimate of 1 ft is the lower end of the range given by Kushlan (1990); the flood duration of 210 days is the lower end of the range reported by Toth et al. (1998) for BLM response in the Kissimmee River floodplain, and is approximately the midpoint of the range of minimum hydroperiod estimates for BLM as estimated by Spencer and Bousquin (2014; see **Figure 9-11**). Pre-regulation stage data for the Kissimmee River were analyzed to verify that these conditions occurred in the pre-regulation system to determine the seasonality of inundation, and to determine the frequency of years in which they occurred.

A recession event is defined as a period of time during which water depth is decreasing on the floodplain. A recession event can be characterized by its recession rate (rate of water depth decrease) and its duration; both characteristics have important implications for patterns of inundation and are standard metrics used in other studies (Poff 1997, Rood et al. 2005). Recession rates (the rate of decrease in water depth) and the durations of events are related to hydroperiod, with faster rates of recession or shorter durations of events resulting in shorter hydroperiods. The characteristics of recession events affect how and when organisms can use the floodplain, the ability of organisms to use the floodplain, and the exchange of organic and inorganic materials between the floodplain and river channel. Recession events in the pre-channelization Kissimmee River were typically slow (< 1 ft per 30 days) and of long duration (**Figure 9-17** later in this chapter; USACE 1991, Anderson 2014a). Recession rate in the Kissimmee River is positively related to reductions in inflow discharge. Conversely, an increase in inflow during a recession event will cause an increase in water depth, called a reversal. Depth reversals can be disruptive of foraging and reproductive activities in the floodplain (e.g., Frederick and Collopy 1989, Smith et al. 1995). In summary, the pre-channelized system was characterized by much slower recession rates and fewer reversals than occurred in the Baseline and Interim periods.

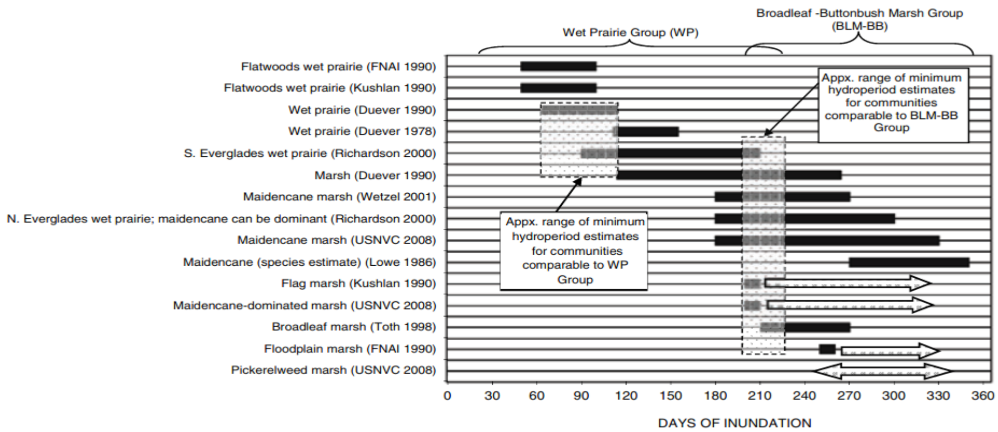

Figure 3. Published estimates of hydroperiods of Florida marsh plant communities comparable to major groups in the KR VCS BLM-BB, WP, and *Panicum hemitomon* (maidencane) (PhWP) groups. Nomenclature follows that of the cited sources. Grayscale bars with arrowheads indicate estimates for which only a minimum inundation duration was described or, in the case of pickerelweed marsh (USNVC 2008), a numerical estimate was not provided (inundation was described as "most of year"). The only sources that indicated inundation depth were Kushlan (1990, for flag marsh) and USNVCS (2008, for maidencane-dominated marsh); both estimated 0.3–1.0 m.

Figure 9-11. Estimates of hydroperiod durations for Florida marsh communities (Figure 3 from Spencer and Bousquin 2014; reproduced with permission).

Methods

Sources of stage data used to calculate the hydroperiod and recession rate metrics are summarized in **Table 9-6**. Reference Period stage data are from continuous stage recorders operated by the United States Geological Survey (Parker et al. 1955). Data for the Baseline and Interim periods are from continuous SFWMD stage recorders. Mean daily stage was converted to water depth by subtracting the floodplain ground elevation at each station; negative depths were converted to 0 ft. Measurements for calculations of depth were from locations where BLM occurred in the pre-channelization Reference Period, termed here BLM depth. For the Reference Period, BLM depth was calculated by comparing stage measurements at stations located in the river channel with an average ground elevation for the floodplain immediately adjacent to the stage recorders (Obeysekera and Loftin 1990). These stations were located upstream or downstream of but not in the Phase I area. Water depth fluctuates in parallel at these sites (**Figure 9-12**), which indicates that depth dynamics at these sites during the Reference Period were comparable to those in the Phase I area during the same time period. Thus, depth measurements at these sites are appropriate for developing restoration performance measures and were used in the development of the previous versions of Expectations 3 and 4 as shown in **Table 9-5**.

For the Baseline Period, water surface elevation was calculated as the average of the tailwater stage at S-65B in the C-38 canal (near the upper end of the Phase I area) and the headwater stage at S-65C (near the lower end of the Phase I area). Water level in the C-38 canal between these two stations was essentially flat during the Baseline Period. Depth was calculated by comparing the mean water elevation in the canal with the ground elevations at the five BLM stations in the Phase I area.

For the Interim Period, water depth in the Phase I area was evaluated at five stations at which BLM occurred in the pre-channelization vegetation map in the northern floodplain of the Phase I area (and which are unaffected by the backwater from S-65C). Ground elevation was calculated for each station by averaging the elevations within a 100 ft radius circle centered on the stage recorder. For the Interim Period, depth was determined using water surface elevations measured at each stage recorder minus its ground elevation. When Phase II/III of the restoration project is completed (including demolition of S-65C and its tieback levee), evaluation of hydroperiod and recession rate will be expanded to include sites in the southern Phase I area floodplain—which after the structure's removal will no longer be affected by the backwater from S-65C—and in the northern Phase II/III area floodplain downstream of the current location of S-65C. Hydroperiod was calculated by counting the number of consecutive days that BLM depth was at least 1 ft. Periods of time when BLM depth declined below 1 ft for no longer than 14 days, but stayed above 0.5 ft in BLM depth, were regarded as not resulting in a significant gap in the event's duration; these days were therefore included in counts of days within a single hydroperiod event.

Table 9-6. Sources of stage used to calculate depth in the Reference, Baseline, and Interim periods.

Period	Station	Location	Period of Record (Water Year)	Floodplain Ground Elevation (ft NGVD29)
Reference	Fort Kissimmee	Upstream of Phase I	1943 – 1962	43
Reference	Fort Basinger	Downstream of Phase I	1933–1959	28.5
Reference	Lower Kissimmee River	Downstream of Phase I	1931–1962	21
Baseline	S-65B tailwater	Upstream of Phase I	1972-1999	*
Baseline	S-65C headwater	Downstream of Phase I	1972-1999	*
Interim	PC55	Phase I area	2002-2015	37.36
Interim	PC53	Phase I area	2002-2015	37.40
Interim	PC52	Phase I area	2002-2015	37.56
Interim	PC44	Phase I area	2002-2015	35.93
Interim	PC42	Phase I area	2002-2015	36.00

*Baseline Period stage data were compared to ground elevations at the five stations in the Interim Period.

A recession event begins with a decline in water depth; it ends when depth decreases to 0 ft, levels out, or is interrupted by an increase in depth (a depth reversal) of at least 1.5 ft. A new recession event begins when depth begins to decrease following a depth reversal of at least 1.5 ft. The mean recession rate for an event was calculated by averaging the daily decrease in depth during the event. For convenience, the recession rate was multiplied by 30 days to provide a recession rate per 30 days. For purposes of counting the number of recession events in a water year, only those events that began in a water year were considered part of that year.

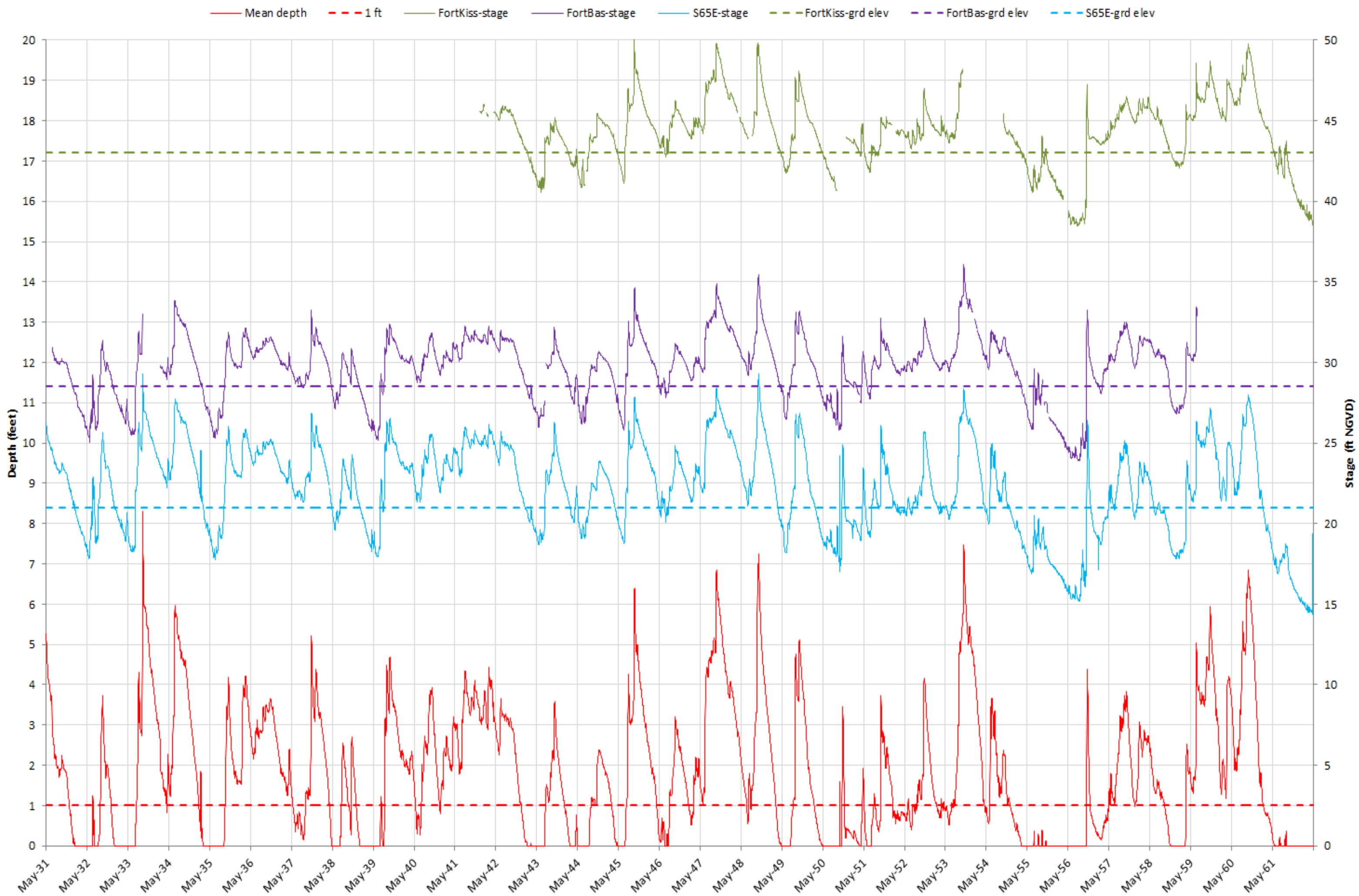

Figure 9-12. Stage at three sites relative to Kissimmee River floodplain ground elevations (dashed lines) and the resulting BLM depth averaged for three sites relative to a 1 ft reference line during the Reference Period.

Results

Expectation 3 (Hydroperiod)

> *Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long-term variability characteristics.*

Hydroperiods during the Reference Period

During the pre-regulation Reference Period, BLM depth was greater than or equal to 1 foot for at least 210 days consecutive days in 19 of 32 water years (May 1–April 30) or 59 percent of water years. This provides a metric and target (59 percent of water years) for evaluation of hydroperiod durations (Component A) (**Table 9-5**). During the Reference Period, BLM depth exceeded 1 ft in almost every year for extended periods of time, with a minimum of 120 consecutive days (**Figure 9-12**). 1 ft or more of depth occurred continuously throughout all months of six water years in the Reference Period (**Figure 9-13**). Several continuous hydroperiod events with BLM depth of at least 1 ft began in one water year and continued into the next; two events with BLM depth of at least 1 ft began in one year, continued through a second year, and into a third water year (**Figure 9-13**). BLM depth did not exceed 1 ft in only two water years, WY1956 and WY1962 (**Figure 9-13**); both years were classified as severe droughts in the Kissimmee Basin using the Palmer Drought Severity Index (Abtew et al. 2002).

Continuous periods of inundation at depths of at least 1 ft exhibited a distinct seasonality (**Figure 9-13**) in the Reference Period. This is seen most clearly by plotting the median frequency of BLM depth greater than or equal to 1 ft for each month of the Reference Period (**Figure 9-14**) The analysis indicates that BLM depth was 1 ft or more for a seven-month (212-day) window from August through February in at least 50 percent of water years, providing a dominant window of occurrence for evaluating the hydroperiod expectation (Component A). BLM depth was greater than or equal to 1 foot for 210 days consecutively in the August through February window in 11 water years. Two additional years had more than 210 days but were short by less than 10 days of 210 days in the August–February window. Given the narrowness of the difference, it is reasonable to include these two additional years, which gives a total of 13 of 32 water years or 40 percent of water years. This provides a second metric and target (Component B) for the hydroperiod expectation (**Table 9-5**).

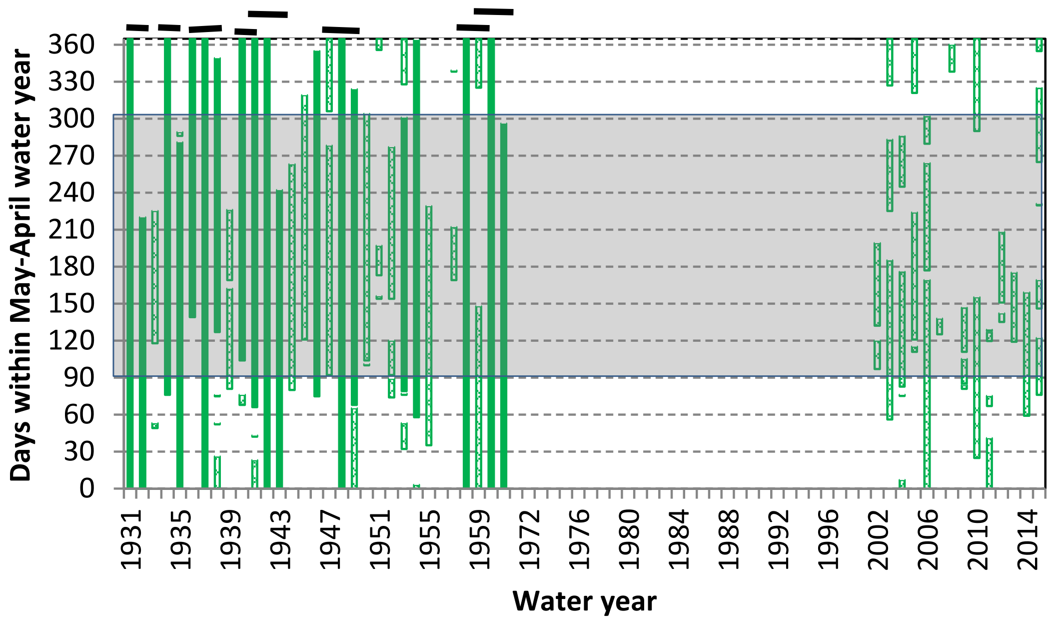

Figure 9-13. Periods and timing of Kissimmee River floodplain events with BLM depth greater than or equal to 1 ft during the Reference Period (WY1931–WY1962), the Baseline Period (WY1972–WY1999), and Interim Period (WY2002–WY2015). Continuous events are indicated by green bars; solid bars identify events that were at least 210 days long in a water year. Black bars at the top of the graph link years where an event began in one year and continued into the next. Events were identified using a 14-day 0.5-ft buffer described in the text. The shaded rectangle indicates the target window of August (day 92) through February (day 304). The horizontal axis does not include WY1963–WY1971 or WY2000–WY2001, which were periods of construction for the C&SF Project and Phase I of KRRP, respectively. During the Reference Period, 59 percent of water years had BLM depth of at least 1 ft for at least consecutive 210 days. The Baseline Period never had BLM depth of at least 1 ft. During the Interim Period to date, BLM depth of at least 1 ft occurred intermittently for relatively short intervals of time, and intervals of BLM depth of at least 1 ft were separated by long gaps, often a month or more.

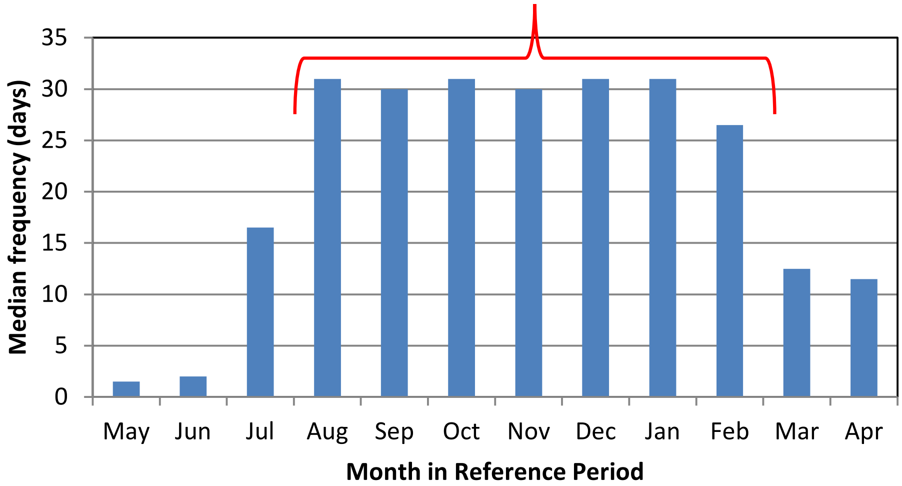

Figure 9-14. Median frequency of days in the pre-regulation Reference Period for the Kissimmee River floodplain that mean water depth was greater than or equal to 1 ft in each month of the water year. Median values were calculated for 32 years (WY1931–WY1962). The red bracket encloses the dominant target window of August through February.

Hydroperiod Evaluation for the Baseline and Interim Periods

During the Baseline Period prior to backfilling of the C-38 canal, water levels in Pool C did not exceed ground elevations at any of the five BLM sites in the Phase I area (**Figure 9-15**). Consequently, there were no events in which BLM depth equaled or exceeded 1 ft (**Figure 9-16**). Therefore, the 210 consecutive day criterion hydroperiod duration was not met in any water year nor in the August–February window in the Baseline Period.

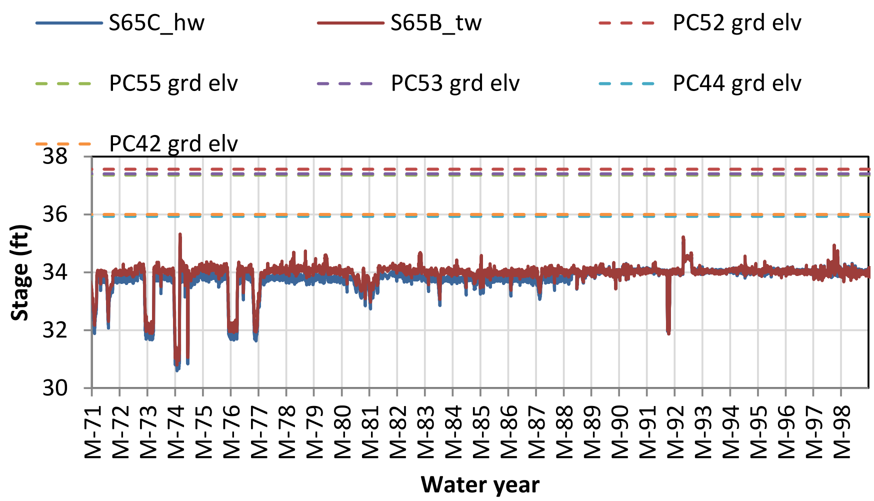

Figure 9-15. Baseline Period water surface elevation in the C-38 canal in relation to ground elevation at the Phase I area stage recorders used to calculate BLM depth for the Kissimmee River floodplain.

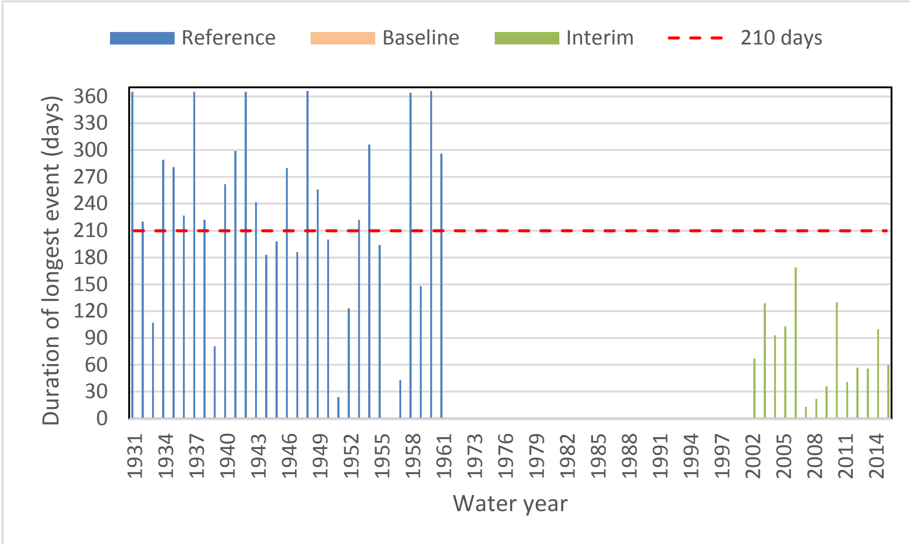

Figure 9-16. Kissimmee River floodplain duration of the longest event with BLM depth of least 1 ft in a water year during the Reference Period (WY1931–WY1962), Baseline Period (WY1972–WY1999), and Interim Period (WY2002–WY2015). The horizontal axis does not include WY1963–WY1971 or WY2000–WY2001, which were periods of construction for the C&SF Project and Phase I of KRRP, respectively. No events occurred in the Baseline Period.

Over the current Interim Period to date, every year, including drought years, had one or more events in which BLM depth exceeded 1 ft (**Figure 9-13**), but the longest event in the Interim Period was only 169 consecutive days. In the large majority of water years (11 of 14), the longest event was less than 120 days (**Figure 9-16**). None of the events in the Interim Period have met the 210-day criterion for a water year (Component A) and therefore clearly did not meet the criterion for the more restrictive August–February window (Component B). Only one year in the Interim Period (WY2006, in which Hurricane Wilma passed over the basin at the end of wet season) came close to meeting the criterion for that water year (Component A) or the seasonal window (Component B). For WY2006 to have met the 210 consecutive day criterion for Component A, the two longest periods of continuous BLM depth of at least 1 ft would have had to have been connected by disregarding a gap of 21 days. To have met the criterion during the August to February window (Component B), a second gap of 28 days also would have had to have been disregarded.

Despite a wet dry season, WY2015 included five disjunct inundation events, four of which occurred partly within the August–February window. However, the longest of these was only 60 days and the events were separated by gaps of 24 to 61 days. WY2015 therefore did not meet the criterion of BLM depth of at least 1 ft for 210 days for either the water year (Component A) or the August–February window (Component B). Operationally, the gaps between many such disjunct events could likely have been bridged, or at least reduced substantially, with discharge operations focused on meeting the hydrologic objectives of KRRP.

Expectation 4 (Recession Events)

> *Stage hydrographs that result in floodplain recession events with rates of water level decrease, duration, and timing that are comparable to pre-channelization events, including seasonal and long-term variability characteristics.*

Recession Events during the Reference Period

The Reference Period included 43 recession events, or a frequency of 1.3 events per water year (**Figure 9-16**). Only four Reference Period years had no events, although two of these (WY1932 and WY1943) had significant portions of recession events that began in the previous water year. A single recession event occurred in 15 water years (47 percent), two events occurred in 11 water years (34 percent), and three events occurred in only 2 water years (6 percent). Recession rates ranged from 0.33 to 1.86 ft per 30 days and averaged 0.85 [± 0.2 standard error (S.E.)] ft per 30 days over all events (**Figure 9-17**). Recession events in the Reference Period averaged 146 (± 17 SE) days in length. Recession rates less than or equal to 1 ft per 30 days occurred in 31 of 43 recession events, or 72 percent of events.

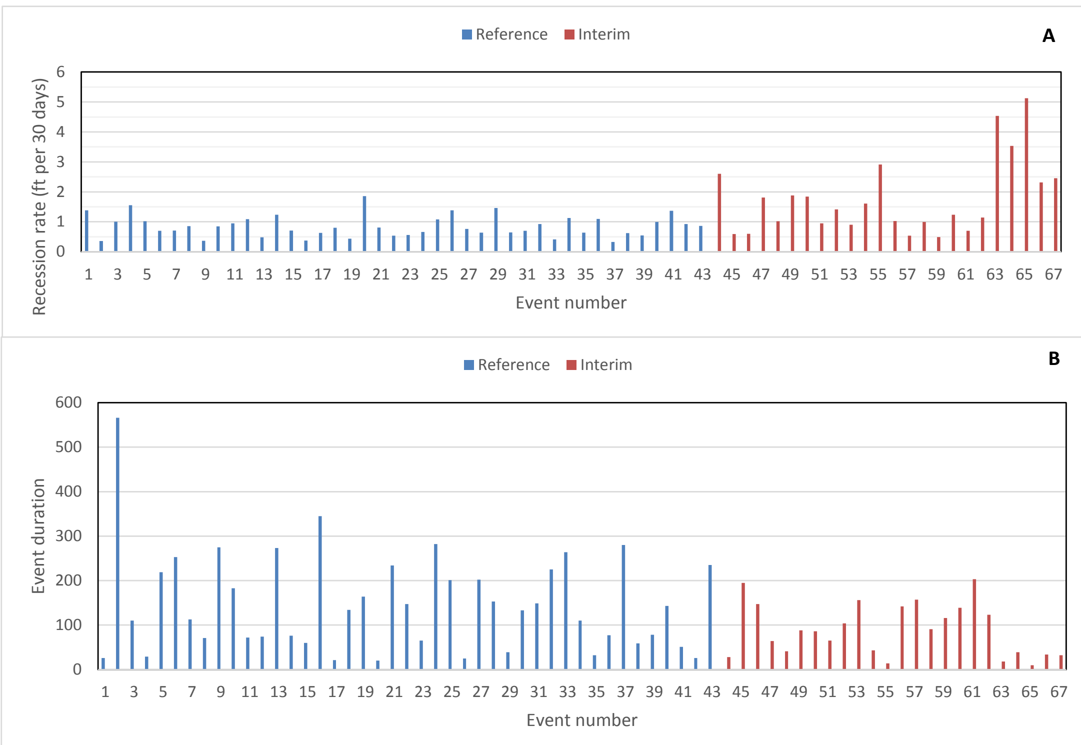

Figure 9-17. Recession rates (A) and event duration (B) for recession events during the Reference Period (WY1931–WY1962) and the Interim Period (WY2002–WY2015) in the Kissimmee River floodplain. The Baseline Period (WY1972–WY1999) is not shown because no recession event occurred.

The previous version of the recession expectation had a metric for the percent of events with recession rates less than 1 ft per 30 days (**Table 9-5**). A second metric was needed to place an upper limit on recession rates. The revised expectation therefore includes a second metric for the percent of recession events with a mean recession rate < 2 ft per 30 days, which was the maximum rate observed during the Reference Period (**Figure 9-17**).

Recession Event Evaluation for the Baseline and Interim Periods

Water levels in the C-38 canal fluctuated very little during the Baseline Period and did not exceed ground elevations at the sites used for calculating BLM depth in the Phase I area (**Figure 9-15**). Consequently, there were no recession events during the Baseline Period. The Interim Period had 24 recession events or 1.7 events per water year (**Figure 9-17**). Events had recession rates of 0.49 to 5.13 ft per 30 days and a mean rate of 1.76 (±0.25 SE) ft per 30 days (**Figure 9-17**). Recession event durations were 10 to 203 days and averaged 89 (± 12 SE) days. Only 8 events (33 percent of events) had recession rates less than 1 ft; 17 events (71 percent) had rates < 2ft per 30 days. WY2015 had five recession events; mean recession rates were 2.31 to 5.13 ft per 30 days. None of the WY2015 events had a rate less than 1 ft per 30 days or less than 2 ft per 30 days. The Interim Period had sufficient water level fluctuation and floodplain inundation to have had some recession events. Therefore, the Interim Period was in a sense an improvement over the Baseline Period, which had no recession events. However, in the Interim Period recessions have tended to be faster than those in the Reference Period. For this reason, Interim Period values for the two recession rate metrics did not meet the expectation targets based on the Reference Period data (**Figure 9-18**). Nearly a third of the Interim Period recession events were faster than occurred in the Reference Period.

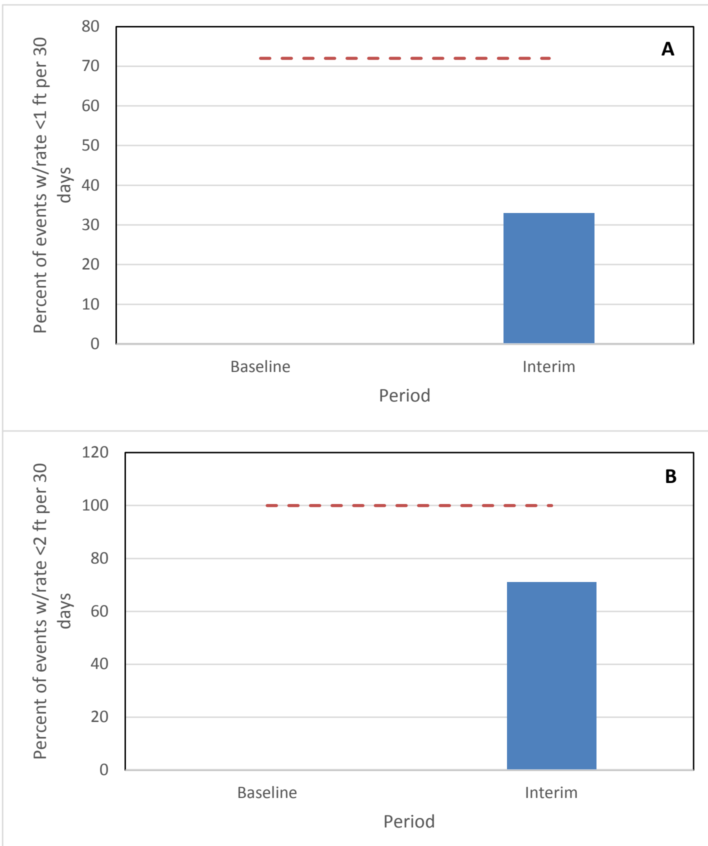

Figure 9-18. Comparison of the percent of Kissimmee River floodplain recession events that had rates < 1ft per 30 days (A) and rates < 2 ft per 30 days during the Baseline Period (WY1927–WY1999) and Interim Period (WY2002–WY2015). Dashed red lines are the target percentages based on the frequency of events during the pre-channelization Reference Period (WY1932–WY1962). Frequent reductions to low discharge result in disjunct floodplain inundation events.

Comparisons among the Reference, Baseline, and Interim Periods indicate that recessions in the natural (reference) system were prolonged, in sharp contrast to recessions in both the Baseline and Interim periods. Excessively fast recession rates have important implications for restoration success. A slow recession rate was an important characteristic of floodplain inundation during the Reference Period, and interacted with other aspects of the hydrologic regime to produce the long hydroperiods or flood pulses typical of the unregulated ecosystem. Faster recession rates, as seen in the Interim Period, disrupt the duration of flood pulses, resulting in conditions that are unsuitable for the floodplain's signature marshes (Spencer and Bousquin 2014). Extreme changes in stage (called stage reversals), which are typical of the Interim Period (**Figure 9-17**) due to rapid increases in discharge to control upstream lake stages, have been identified as a problem for restoration of the Kissimmee River (Cheek et al. 2014). Reversals as small as 0.3 ft (smaller than the 1.5-ft reversal used here to identify new recession events) have been associated with abandonment of nests by wading birds (Frederick and Collopy 1989, Smith et al. 1995).

Relationship of Expectations 3 and 4 to Discharge

BLM depth is influenced by direct rainfall and associated LKB runoff, but it is almost completely dependent on inflow discharge through S-65 via S-65A (Anderson 2014a). The way in which these structures are operated directly influences hydrologic performance in the Phase I area as evaluated by Expectations 3 and 4, as well as the biota that depend on improvement and eventual reestablishment of pre-regulation hydrology for recovery. That these expectations are not being addressed operationally in the Interim Period underscores the need to modify S-65 operational strategies to improve hydrologic performance for the KRRP, as required by USACE (1991) and USACE (1996).

Hydrologic performance for Expectation 3 can be improved by increasing the number of consecutive days of inflow discharge of sufficient magnitude to maintain a depth of at least 1 ft at BLM sites for longer continuous periods. Comparisons of BLM depth and discharge over the Interim Period indicate that the discharge needed for 1 ft of depth is approximately 1,400 cfs (**Figure 9-19**). Maintaining this discharge over periods of months will require that, in many circumstances, discharge not be decreased to low levels to reach higher or maintain stable high stages in upstream lakes. For the lakes, the resulting relationship of variation of lake stage with discharge would be similar to what happened in the pre-channelization system (see **Figure 9-10** in the *Hydrologic Conditions* subsection above) and is characteristic of the natural variability seen in healthy lakes (NRC 1992). In some years this will mean lower lake stages than occur without use of a stage-discharge relationship. Although it is unlikely that the hydroperiod expectation can be fully met in the Interim Period, substantial improvements in performance for KRRP can be made without the additional storage of the HRS. The WY2015 standing recommendation that is currently in use (summer/fall 2015, within WY2016) is an example of a hydrologically and ecologically balanced operational plan that links discharge for KRRP to lake stage to achieve mutually beneficial operations for these two parts of the Kissimmee Basin ecosystem.

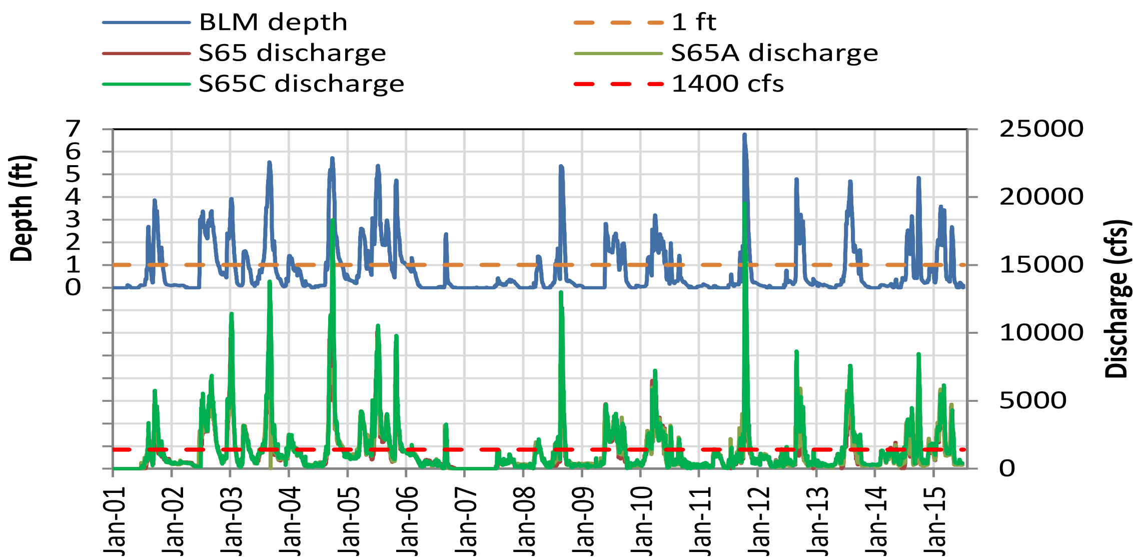

Figure 9-19. Time series of Kissimmee River floodplain BLM depth and S-65 discharge during the Interim Period.

Hydrologic performance for Expectation 4 can be improved in the Interim Period by slowing the rates at which inflow discharge is reduced, which would slow the floodplain recession rate; and minimizing the number of discharge increases, which cause floodplain stage reversals large enough to register as a new event. Current guidelines allow maximum rates of discharge decrease and increase that are much faster than occurred in the Reference Period. Operations to maintain high stages near the regulation line in the Headwaters Lakes (and to a lesser extent in East Lake Tohopekaliga and Lake Tohopekaliga) or to precisely follow stage recession lines in these lakes creates conditions where all or most inflow from rainfall events is discharged to the river, rather than balancing reversals between the lakes and the river. The resulting abrupt reductions and increases in depth on the Kissimmee River floodplain are harmful to the river and inhibit improvements in performance of the hydrologic goals of the KRRP.

Summary

- Expectation 3 (hydroperiod) has been modified to incorporate requirements for BLM.
- The criteria for Expectation 3 have not been met in any year of the Interim Period and have not shown signs of improvement.
- A minimum inflow discharge of 1,400 cfs was identified as needed to meet the depth component for Expectation 3. Performance for Expectation 3 can be improved by implementing operations designed to increase the number of consecutive days that inflow discharge of 1,400 cfs or greater is maintained.
- Expectation 4 (recession events) was modified to include a metric for an upper limit on recession rates.
- The criteria for Expectation 4 were not met in the Interim Period.

- Performance for Expectation 4 can be improved by slowing the rate of recession, especially by eliminating the practice of decreasing discharge to low levels to hold the Headwaters Lakes stable at high stages for extended periods.
- The targets for Expectation 3 and Expectation 4 were not met in WY2015.
- Improved hydrologic performance is being addressed in the 2015 wet season (WY2016) operational plan, which links S-65 discharge to KCH lake stage.

DISSOLVED OXYGEN

Expectation 8

Mean daytime concentration of DO in the Kissimmee River channel at 0.5 to 1.0 m depth will increase (a) from < 1 to 2 mg/L to 3 to 6 mg/L during the wet season (June–November) and (b) from 2 to 4 mg/L to 5 to 7 mg/L during the dry season (December–May). (c) Mean daytime DO concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50 percent of the time. (d) Mean daily (24-hour) DO concentrations will be > 2 mg/L more than 90 percent of the time (updated from Colangelo and Jones 2005).

DO directly affects aquatic life through oxygen (O_2) availability and the metabolism of aquatic ecosystems (Hauer and Lamberti 2007). The concentration of DO can influence growth, distribution, and structural organization of aquatic communities and impact the productivity of aquatic ecosystems (Wetzel 2001). DO is a function of many factors including biological metabolic rates, temperature, diffusion, and proximity to the atmosphere (Dodds and Whiles 2010), and is an indicator of water quality and an ecosystem's response to change (Colangelo 2014). For this reason, DO was chosen as one of the expectation metrics for evaluating the status and success of the KRRP (Colangelo and Jones 2005).

Based on reference and baseline data, restoration of the Kissimmee River is expected to improve DO concentrations in the river channel by reintroducing flow to the river channel, which should increase rates of reaeration and reduce the amount of organic matter that accumulated on the channel bed after the river was channelized (Colangelo and Jones 2005), which cut off flow by construction of the C-38 canal. To date, most components of Expectation 8 have showed positive responses to reestablishment of flow by Phase I construction, which was completed in 2001 (Colangelo 2014).

Data Collection and Analysis Methods

Reference and Baseline Data

DO data from the Kissimmee River were not available from pre-channelization. For this reason, available daytime DO data from nearby free-flowing, blackwater streams where DO had been measured frequently from 1973 to 1999 were used to estimate reference (pre-channelization) conditions for the Kissimmee River. For some of these streams, more than ten years of data were available (Colangelo and Jones 2005). Baseline (channelized period) DO data were obtained from monitoring stations in non-flowing remnant river runs of the Kissimmee River and the C-38 canal prior to Phase I construction. For these data, grab samples were collected monthly within a time window between 10 am and 2 pm from 1996 to 1999. Based on these reference and baseline data, Expectation 8 components a, b, and d were developed. Component c was developed based on weekly DO depth profiles sampled within Micco Bluff Run within the former Pool C of the Kissimmee River from May to October 1999. Details and summaries of reference and baseline data and expectation development are available in Colangelo and Jones (2005).

Interim Data

DO monitoring at some of the stations used to establish reference and baseline DO conditions has continued in the Phase I Interim Period (post-Phase I construction) using the same or similar methods to provide data for evaluation of changes in DO before and after restoration construction. Grab samples used for evaluation of components a and b were collected monthly from sampling stations KREA91, KREA 92, and KREA97 in Pool A and KREA93, KREA94, KREA95, and KREA98 in Pool C, within a time window between 10 am and 2 pm. Daytime DO concentrations within 1 m of the channel bottom were measured at stations KREA93, KREA94, and KREA98 in former Pool C for evaluation of component c. Daytime-only measurements were used for compatibility with the available reference data, as described above and in Colangelo and Jones (2005).

For evaluation of component d during the interim period, autosampler monitoring of daily (24-hour) DO at stations KRBN and PC62 was conducted using stationary DO sondes at a depth of approximately 1 m from the water surface in the Phase I river channel. These data were collected continuously at a 15-minute interval, day and night. Data from stations KRBN and PC62 were used to evaluate component d and to provide technical guidance for adaptive management of discharge at water control structures S-65, S-65A, and S-65C.

For statistical evaluation of a restoration effect on DO, the difference between the impact and control means (ICd) was calculated for daytime DO collected monthly at the KREA stations using a before-after, control-impact paired series (BACIPS) sampling design (Bousquin and Colee 2014). The ICd data for DO were tested for autocorrelation using a Durbin-Watson test, which indicated no significant autocorrelation. A t-test was used to test the difference between the ICd means for daytime DO in the before (Baseline) and after (Interim) periods (Stewart-Oaten et al. 1992). The difference in daytime DO in the dry and wet seasons between the baseline and interim periods as well as between WY2014 and WY2015 was examined with a t-test, respectively. Statistical significance was determined at a = 0.05.

Post-Construction Dissolved Oxygen through Water Year 2015

Following completion of Phase I construction, DO in Pool C averaged 3.3 ± 0.2 mg/L (one standard error) during the wet season and 6.6 ± 0.1 mg/L during the dry season (**Figure 9-20**). By comparison, post-construction DO in the control area (Pool A) was significantly lower at 1.8 ± 0.1 and 3.3 ± 0.1 mg/L during the wet and dry seasons, respectively ($p < 0.001$). Annual daytime DO has been significantly higher in Pool C, 5.0 ± 0.2 mg/L than in Pool A, 2.5 ± 0.1 mg/L for the 14 water years following completion of Phase I construction ($p < 0.001$, **Figure 9-21**). A t-test on the mean ICd indicates that DO greatly improved in the Phase I impact area from WY2002 to WY2015 but did not change significantly in the Pool A control area. The ICd mean for DO was significantly higher for post-construction period (2.5 ± 0.2 mg/L) than for the baseline period (-0.1 ± 0.35 mg/L) ($p < 0.001$).

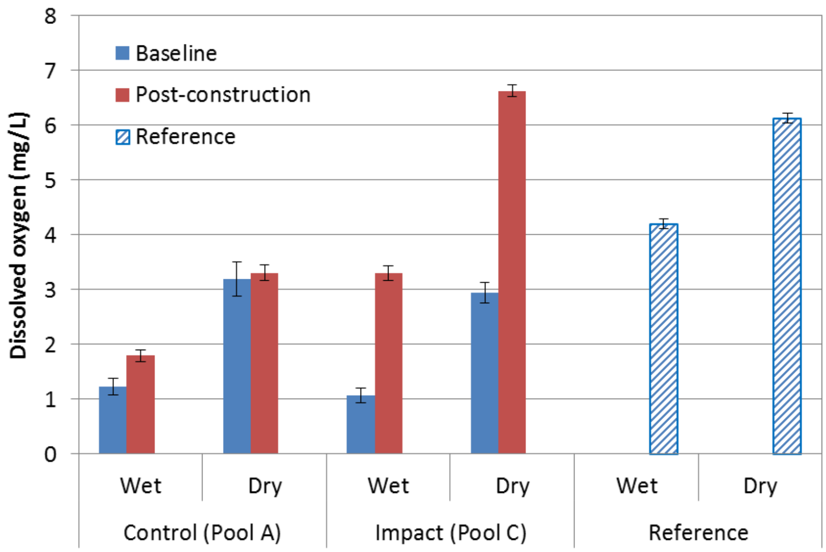

Figure 9-20. Daytime DO concentrations (Mean ± SE) in reference streams (period of record is WY1973–WY1999) and control and impact areas in wet and dry seasons during the Baseline (WY1997–WY1999) and Interim (WY2002–WY2015) periods. For evaluation of KRREP Expectation 8, components a and b.

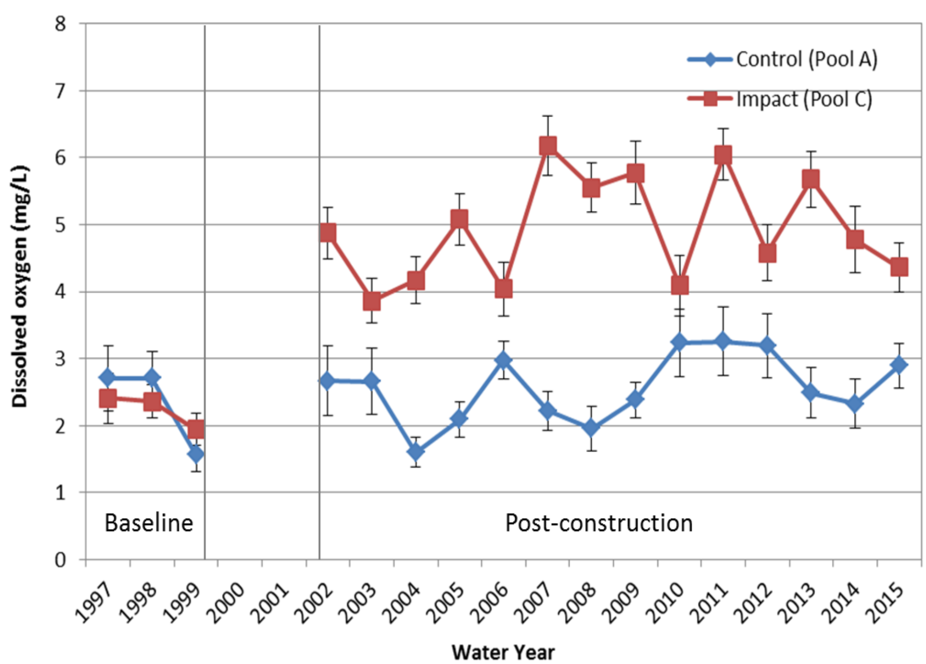

Figure 9-21. Daytime DO concentrations (mean ± SE) of sampling stations KREA 91, KREA 92, and KREA 97 in Pool A and sampling stations KREA 93, KREA 94, and KREA 98 in Pool C of the Kissimmee River for each water year during the Baseline (WY1997–WY1999) and Interim (WY2002–WY2015) periods.

Water Year 2015 Dissolved Oxygen Update

In WY2015, two of the four expectation metrics, components a and c, were met (**Table 9-7**). Mean daytime DO concentration in the dry season in the Phase I area decreased from 7.1 ± 0.2 mg/L in WY2014 to 4.9 ± 0.4 mg/L in WY2015 ($p < 0.001$), not meeting component b of 5 to 7 mg/L. Daytime DO was 3.9 ± 0.6 mg/L in the wet season and met component a of 3 to 6 mg/L. Annual concentration of DO within 1 m of the channel bottom was >1 mg/L for 92 percent of the time, meeting component c.

Table 9-7. Restoration expectation component metrics and WY2015 values for DO.

Expectation Components	WY2015 Value	Metric Achieved in WY2015	Data Source
a. Mean daytime DO concentration in the river channel at 0.5–1.0 meter (m) depth will increase from < 2 milligram per liter (mg/L) to 3–6 mg/L during the wet season (June–November).	3.9 ± 0.57 mg/L	YES	KREA93, KREA94, and KREA98
b. 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).	4.9 ± 0.44 mg/L	NO	KREA93, KREA94, and KREA98
c. DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50 percent of the time annually.	92%	YES	KREA94 and KREA98
d. Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90 percent of the time annually.	81%	NO	PC62 and KRBN

Mean annual daily DO concentration was > 2.0 mg/L 81 percent of the time (**Figure 9-22**), not meeting component d target of > 90 percent of the time. This outcome reflects hypoxic event that occurred in WY2015, in which monthly DO concentration showed a common wet season pattern (**Figure 9-23**) of hypoxic conditions (DO < 2 mg/L) after increases in discharge (see *Hypoxia in the Kissimmee River: Consequences, Causes and Water Management* section for more information).

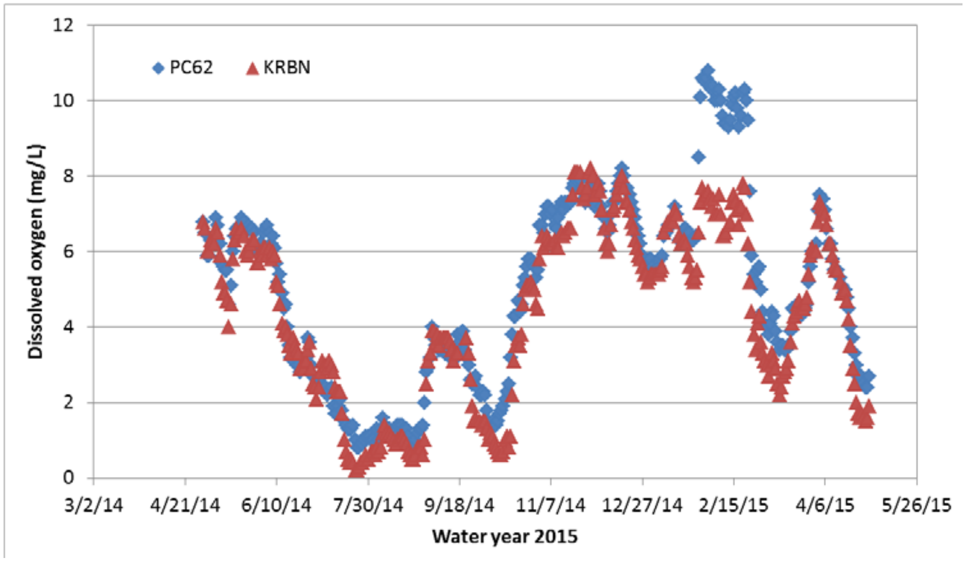

Figure 9-22. Daily DO concentrations (mg/L) in stations PC62 and KRBN in the river channel of the impact area (Pool C) in WY2015. For evaluation of KRREP Expectation 8, component d.

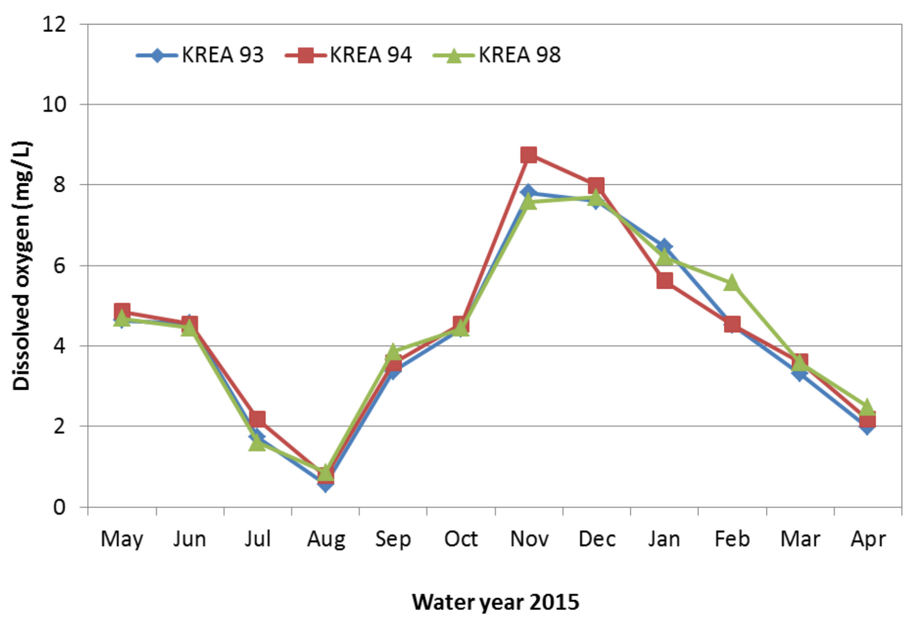

Figure 9-23. Monthly daytime DO concentrations (mg/L) in stations KREA93, KREA94, and KREA98 in the river channel of the impact area (Pool C) in WY2015.

PHOSPHORUS

The C-38 canal, completed in 1971, conveyed virtually all flow from the UKB to Lake Okeechobee until completion of the first phase of construction for the KRRP. Prior to construction of the canal, this water had formerly been carried by the native Kissimmee River and its floodplain. The canal eliminated floodplain inundation and contact with wetland vegetation and soils, and thereby reduced opportunities for P assimilation and retention by the river's floodplain. One of the original concerns raised about the canal during planning for the KRRP was its effect on eutrophication of Lake Okeechobee due to increased nutrient loading. Although reductions of nutrient loading were anticipated, the KRRP was designed to address habitat restoration, not nutrient retention, unlike a treatment wetland. Backfilling of a central section of the C-38 canal was completed in 2001 under Phase I of the KRRP, which partially reestablished intermittent inundation of the floodplain, raising questions of whether KRRP has to date affected nutrient loading to the lake, and whether the longer periods of inundation and development of long-hydroperiod vegetation that are anticipated after KRRP is completed will enhance nutrient assimilation.

P loads and concentrations at C-38 canal structures S-65, S-65A, S-65C, S-65D, and S-65E during the post-Phase I period in comparison to the pre-construction, Baseline Period presented in the SFER since 2005 have indicated that TP loads and concentrations were higher during the Interim Period than in the Baseline Period, with most of the structures releasing significantly more P during the Interim Period than in the Baseline Period (Cheek et al. 2015). TP load increased by 160, 132, 88, and 66 percent at C-38 canal structures S-65, S-65A, S-65C, and S-65D, respectively, compared to the Baseline Period (Cheek et al. 2015). Given that S-65 received significantly higher TP load during the Interim Period than in the Baseline Period (Cheek et al. 2015), it is clear that the higher loading at S-65A and S-65C in the Interim Period is at least partly related to this higher loading at S-65. While current monitoring efforts in the Kissimmee Basin provide basic knowledge about the transport of P in the river itself (Steinman et al. 2010), whether the P retention capacity of the LKB has improved due to Phase I construction cannot be determined given current monitoring.

The KRRP's P retention capacity is a result of multiple interactions among a number of factors including hydrologic and hydraulic loading, external and internal P loading, soil P storage capacity (SPSC), vegetation conditions, and water management decisions. The Basin Management Action Plan for the Implementation of Total Maximum Daily Loads for Total Phosphorus by the Florida Department of Environmental Protection in Lake Okeechobee (FDEP 2014) estimated a TP reduction of 17.75 metric tons per year (mt/yr) within the KRRP, with the LKB contributing a TP load of 103 mt/yr, or 23 percent of all TP loads entering Lake Okeechobee. These estimates were based on the Watershed Assessment Model/Load Estimate Tool. The best management action plan recognizes that additional work will need to be done to verify these estimates. These estimates did not include P load from tributaries and internal P loads from soils and vegetation residues (legacy P) and they ignore the roles of vegetation communities in nutrient removal within the system.

Legacy P storage in soils of the KRRP was estimated at approximately 2,130 mt with ~65 percent reactive P in soil P, using the ratio of the area of the KRRP to the Northern Lake Okeechobee Basin and the soil P storage in the basin (Reddy et al. 2011). The available P pool in soil is approximately 140 mt if only 10 percent (a conservative estimate) of reactive P is available for release to the water column (H. Chen, SFWMD, unpublished data). Soil surveys suggest that most areas of the KRRP had positive SPSC values, suggesting the potential of soils to retain P, while dredged and backfilled materials had negative SPSC values, suggesting a potential for P release (Osborne et al. 2012). After the regrading of surface materials in the backfilled areas of KRRP, the spatial extent of elevated soil P increased, but the potential for P release to the water column is not known. Also, periodic dry-out conditions likely increased P release to the water column by soil oxidation after rewetting.

Further evaluation of P status within the KRRP is needed to address the questions above. District scientists continue to study the potential of Kissimmee River floodplain to retain P. P contributions from tributaries and point sources in the LKB as well as internal P loading (including soil P and leaching of P from vegetation residues and litter) within the KRRP area need to be better understood to evaluate the current and future potential of KRRP for P sequestration. For these reasons, the KRREP nutrient monitoring plan is currently being reassessed to better address these questions.

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; FGFWFC 1957). Restoration is expected to reproduce the necessary conditions to once again support such an assemblage. Since many bird groups (e.g., wading birds and 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 (Williams et al. 2005b) and in a recent research article published in the journal Restoration Ecology (Cheek et al. 2014). The objective of this section is to highlight portions of the avian program for which data were collected during winter and spring 2014–2015 and compare recent data to restoration expectations.

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/km^2 (Williams and Melvin 2005a).*

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 (±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, annual abundance has ranged from 102.3 ± 31.7 birds/km^2 to 11.0 ± 1.9 birds/km^2 (mean (2001–2015) = 42.4 ± 6.8 birds/km^2) **(Figures 9-24** and **9-25**). Mean monthly wading bird abundance within the restored portions of the river during the 2014–2015 breeding season was 57.9 ± 31.7 birds/km^2, bringing the three-year (2013–2015) running average to 37.1 ± 10.5. The mean annual three-year running mean (2001–2015) is 41.7 ± 4.7 birds/km^2, significantly greater than the expected value of 30.6 birds/km^2 (one-sample t-test, $p < 0.04$, SAS Version 9.3; Williams and Melvin 2005a), although the individual three-year running means were not significantly different from the restoration target of 30.6 birds/km^2 when examined on an annual basis (one-sample t-test, SAS Version 9.3). The lower number of birds reported during the 2007–2009 period was due to the drought conditions of 2006–2007, when floodplain foraging habitat was completely dry for over 13 months.

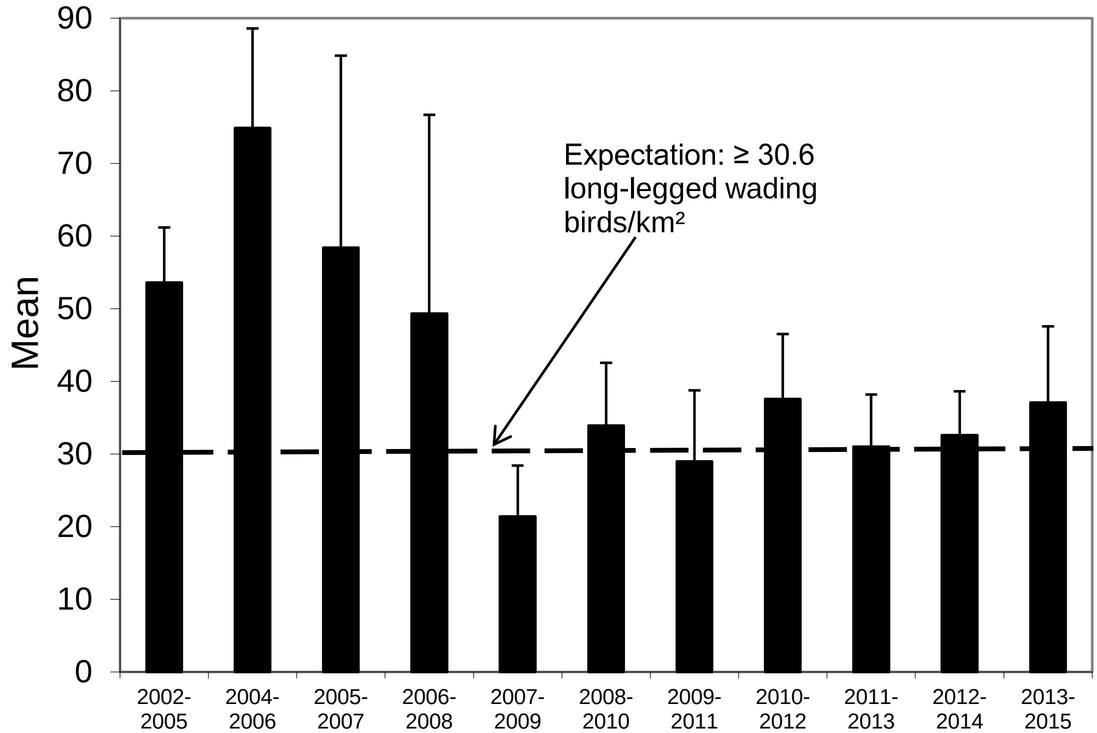

Figure 9-24. Post-restoration abundance as three-year running averages ± S.E. of long-legged wading birds/km^2 excluding cattle egrets during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River. Each three-year running mean was not significantly different from the restoration target of 30.6 birds/km^2 when examined on an annual basis, TTEST, SAS Institute 2011.

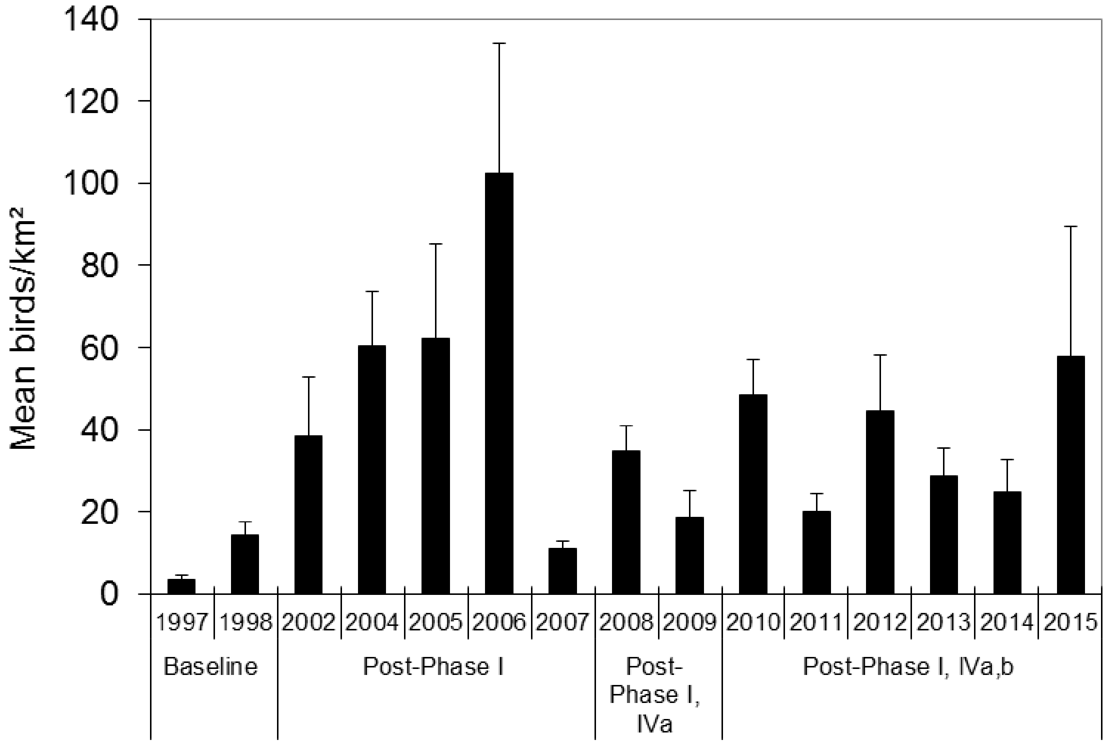

Figure 9-25. Baseline and post-Phases I, IVA, and IVB mean abundance ± S.E. of long-legged wading birds/km^2 (excluding cattle egrets) during the dry season (December–May) within the 100-year floodline of the Kissimmee River.

The 2015 seasonal mean was greatly affected by the large number of birds observed in March, which moved the mean higher during what would have otherwise been a below-average season had the March survey been closer to the long-term average. Wading bird foraging conditions were relatively poor in November following a relatively short and discontinuous period of floodplain inundation (69 days total ≥ 1ft deep) during the preceding wet season (June–October 2014; see the *Hydrology* subsection in the *Kissimmee Restoration Project Evaluation Project* section above). Conditions improved slightly with a recession event in December before water depths became too deep for foraging (> 1.3 ft) throughout most of the floodplain (both BLM and wet prairie habitat) by the end of January through March (SFWMD 2015). Water depth peaked on approximately March 6 (~2.8 ft) before receding quickly (~1.6 ft per 13 days) prior to the March survey, when over 214 birds/km^2 were recorded; one of the largest monthly bird abundances observed since 2001. Water levels then stabilized between the March 18 and April 8 surveys at a depth of approximately 1.0 ft. Average water depth began to increase again on April 13 through April 26 to approximately 2.0 ft, then receded to approximately 1.6 ft deep during the May 4 survey. The relatively deep foraging conditions in April and May were reflected in the relatively low bird counts in those same months. It should be noted that the minimum target inundation depth of ≥ 1.0 ft in BLM habitat during the wet season (see the *Hydrology* subsection above) is not incompatible with wading bird foraging, since wet prairie habitat, which occurs at higher relative elevations, is still at a suitable foraging depth for most species when BLM is up to 2.6 ft deep.

White ibis dominated the surveys numerically, followed in order of abundance by glossy ibis (*Plegadis falcinellus*), great egret, cattle egret, small white heron [snowy egrets (*Egretta thula*) and juvenile little blue heron (*Egretta caerulea*)], great blue heron, small dark heron [tricolored heron

(*Egretta tricolor*) and adult little blue heron], wood stork, black-crowned night heron (*Nycticorax nycticorax*), and roseate spoonbill (*Platalea ajaja*).

Waterfowl Abundance

Expectation 25

> *Winter densities of waterfowl within the restored area of the floodplain will be ≥ 3.9 ducks/km². Species richness will be ≥ 13 (Williams et al. 2005a).*

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 Period aerial surveys. During the same period, casual observations of wood ducks (*Aix sponsa*) were made during ground surveys for other projects (Williams and Melvin 2005b). 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.

Waterfowl abundance during the 2014–2015 survey was 7.3 ± 4.6 ducks/km², bringing the three-year (2013–2015) running average to 7.6 ± 1.0 birds/km² (**Figures 9-26** and **9-27**). The mean was raised by the large number of birds observed in November (> 25 birds/km²). Since 2001, annual duck abundance has ranged from 37.0 ± 22.5 birds/km² to 1.3 ± 1.3 birds/km² (mean (2001–2015) = 10.8 ± 2.4 birds/km²) (**Figures 9-26** and **9-27**). The mean annual three-year running average (2001–2015) of waterfowl abundance is 10.5 ± 1.2 birds/km², significantly greater than the restoration expectation of 3.9 birds/km² (TTEST, $p < 0.0002$; SAS Institute 2011, Williams and Melvin 2005a). However, when examined on an annual basis, only the period of 2011–2013 was significantly greater than the restoration target of 3.9 birds/km² (TTEST, p-value = 0.05, SAS Institute 2011). Mottled duck dominated numerically, followed by teal (*Anas* sp.) and a small number of ring-necked duck (*Aythya collaris*) (n = 13).

During November, water depths were suitable (~0.22 ft) across most of the floodplain for the two most common species of ducks occurring on the river, teal (*Anas* sp.) and mottled ducks, both dabbling species that prefer shallow water (SFWMD 2015). During most of December and January, water depths were relatively deep (~1.0 ft) for those same species before becoming too deep in most areas for mottled duck and teal in February and March, when water depth averaged over 1.8 ft. Water depths above 1.0 ft are more suitable to diving duck species, which prefer deeper water and require more open water habitat for access to prey. Diving ducks have not been prevalent on the river floodplain during the Interim Period (2001–2015; Cheek et al. 2014). This is likely due to insufficient inundation depth and duration to support significant open water habitat, submerged aquatic vegetation, and large invertebrate populations.

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

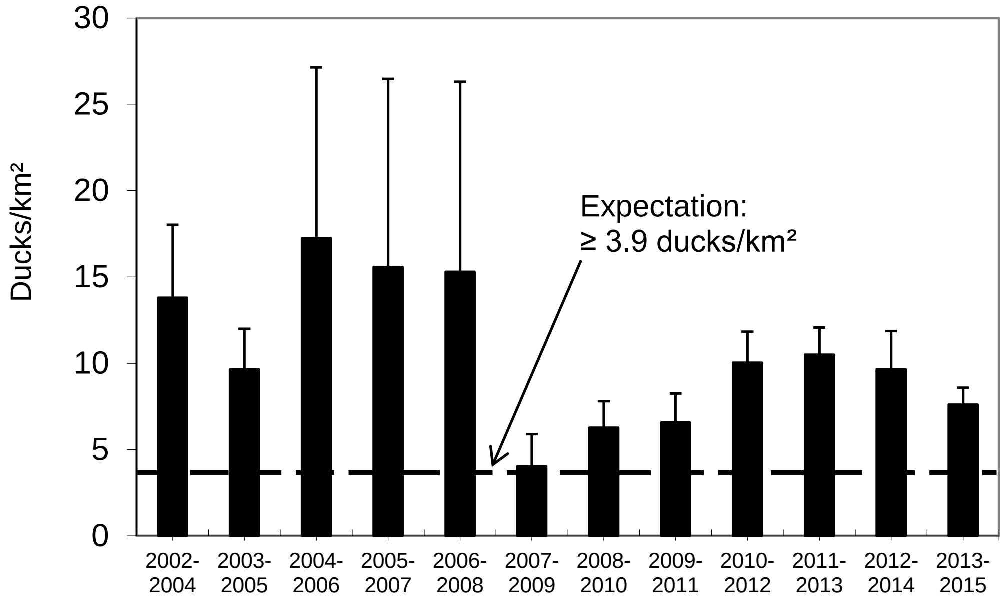

Figure 9-26. Post-restoration abundance as three-year running averages ± S.E. of waterfowl during the winter (November–March) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

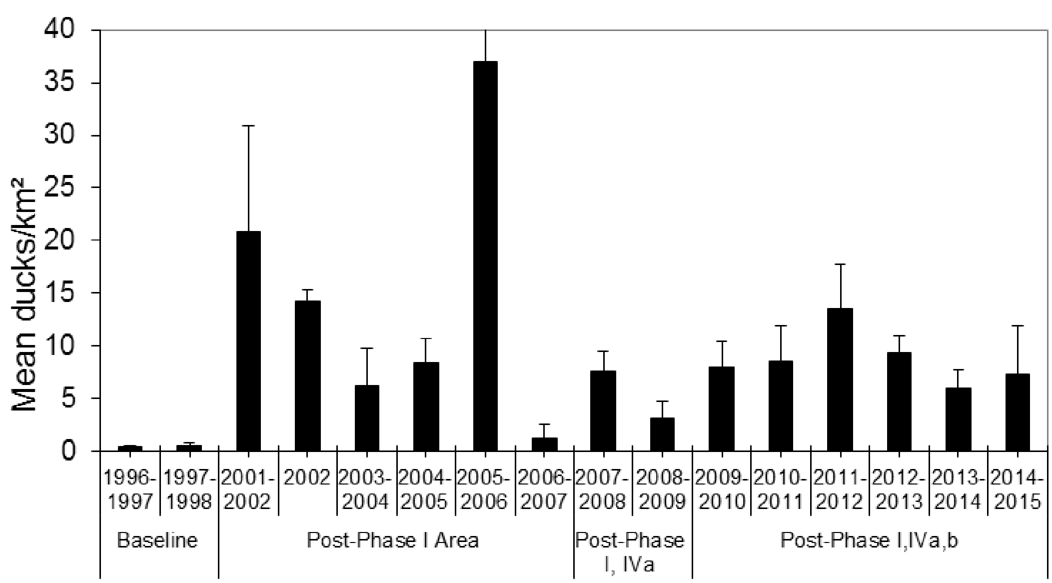

Figure 9-27. Baseline and post-Phases I, IVA, and IVB mean abundance ± S.E. of waterfowl during winter (November–March) within the 100-year floodline of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately nine months following completion of Phase I.

Wading Bird Nesting Colonies

Expectation

No formal expectation has been established for wading bird nesting colonies.

As part of the KRREP, in WY2015 SFWMD performed four aerial surveys (March 6, April 15 and 29, and May 28) to visit known wading bird nesting colonies and search for others in the Kissimmee Basin and Lake Istokpoga. Compared to previous years, the surveys were reduced this season due to several weather-related flight cancellations. Nesting colonies were also recorded, when encountered, during separate aerial surveys of foraging wading birds on November 20 and December 10, 2014, and January 21, February 11, March 18, April 8, and May 4, 2015. Known colonies in Lakes Mary Jane, Kissimmee (Rabbit Island), and Istokpoga (Bumblebee Island) were surveyed at least once. The numbers of nests reported here represent the maximum number of nests for each species observed.

Twenty-three colonies were surveyed during the 2015 season, 15 of which were active (**Tables 9-7** through **9-11**; **Figures 9-28** and **9-29**). The inactive colonies were Cat Island (Lake Conlin), Lake Russel, Orange Grove SW, S-65C structure, S-65C boat ramp, two colonies on Lake Marian (Lake Marian North and South), and C-38 Caracara Run. However, all but two colonies [Rabbit Island (Lake Kissimmee) and Bumblebee Island (Lake Istokpoga)] were surveyed only once this season, and four (Lakeshore and Indian Lakes Estates colonies on Lake Weohyakapka, Lake Arbuckle, and Arbuckle Creek) were not surveyed at all due to multiple flight cancellations. Thus, the peak of nesting activity (April–May) for some colonies, in particular Lake Mary Jane, may not have been observed and so the seasonal total is likely a conservative estimate. It is likely the nests for a relatively small number of dark-colored wading birds, such as little blue heron, glossy ibis, tricolored heron, yellow-crowned night heron (*Nyctanassa violacea*) and black-crowned night heron, were undercounted during the aerial surveys because of their lower visibility from above (Frederick et al. 1996). Thus, the colony totals presented in **Tables 9-7** through **9-11** are considered conservative. Nest fate and nesting success were not monitored.

In 2015, all Kissimmee Basin colonies combined were dominated by nearly equal numbers of cattle egret (*Bubulcus ibis;* 1,198), white ibis (*Eudocimus albus*; 1,161), and great egret (1,132), followed by smaller numbers of great blue heron (145), and wood stork (83). The largest colony to form in the Kissimmee Basin this season was on Rabbit Island (1,523 nests), followed by Bumblebee Island (1,443 nests) and Lake Mary Jane (445 nests) (**Figures 9-28** and **9-29**). The peak number of wading bird nests (excluding cattle egret) documented throughout the basin was 2,521.

Of the 21 active colonies reported in last year's report, ten were active this season, seven were inactive, and four were not surveyed so their status was unknown. Similar to last season, none of the colonies occurred within 3 kilometers of the partially restored portions of the Kissimmee River, but several did occur in unrestored portions of the river both north, east, and south of the restoration area (**Figures 9-28** and **9-29**). The Orange Grove NW colony was inactive during the March 6 survey, but a long-dormant colony (Orange Grove) was active this season just over one mile to the southeast (**Figure 9-29**).

Table 9-7. Peak (maximum) number of wading bird nests within the UKB lakes[a] 2010–2015. Sites surveyed in March only during 2015.

Year	Cattle Egret	Great Egret	White Ibis	Great Blue Heron	Small Dark Herons[b]	Glossy Ibis	Black-crowned Night Heron	Small White Herons[c]	Wood Stork	Total Nests	Total Colonies	Nests of Aquatic Species
2010[d]		250					1		100	351	1	351
2011[d]		200							200	400	1	400
2012[d]	235	176	119					25	172	727	1	492
2013	100	376	566	1	50				172	1,265	2	1,165
2014[e]		343	1,254	40	53	2	15	35	282	2,024	8	2,024
2015		416		65					83	564	4	564

a. UKB includes Cat Island (Lake Conlin), Lake Marian (East, North, and South), Lake Russel, Mary Jane, Rosalie, Marion (Twin Islands); all Upper Basin Lakes *excluding* KCH).

b. Small dark herons include little blue heron and tricolored heron.

c. Small white herons include snowy egret and juvenile little blue heron.

d. Only active colony was Lake Mary Jane in 2010, 2011, and 2012.

e. Survey effort was expanded in 2014 to include all Central and South Florida waterbodies in the UKB.

Table 9-8. Peak (maximum) number of wading bird nests within the KCH and Pool A 2003–2015. Sites surveyed during March, April, and May 2015).[a]

Year	Cattle Egret	Great Egret	White Ibis	Great Blue Heron	Small Dark Herons[b]	Glossy Ibis	Black-crowned Night Heron	Small White Herons	Wood Stork	Total Nests	Total Colonies	Nests of Aquatic Species
2003[d]										0	0	0
2004[d]										0	0	0
2005[d]	400									400	1	0
2006[d]										0	0	0
2007[d]	193	1		1	5		1			201	1	8
2008[d]	325	30		10	29			7		401	1	76
2009	740	150	75	50	129	10	3	10		1,167	1	427
2010	200	249	1,156	59						1,664	3	1,464
2011	350	250	540	75				75		1,290	1	940
2012	645	252	156	89				195		1,337	3	692
2013	675	152	95	28	36	5	5	7		1,003	3	328
2014	85	211	157	82				15		550	3	465
2015	764	442	332	49						1,587	6	823

a. Colonies include Rabbit Island, East Lake Kissimmee, Kissimmee East Shore, Melaleuca Island, Brahma Island NW, River Ranch C-38 Island, Three Lakes Ranch, and 42W.

b. Small dark herons include little blue heron and tricolored heron.

c. Small white herons include snowy egret and juvenile little blue heron.

d. KCH were not surveyed during these years. Surveys started on these lakes in 2009.

Table 9-9. Peak (maximum) number of wading bird nests within the KRRP area[a] 2003–2015. Sites surveyed during March and May in 2015.

Year	Cattle Egret	Great Egret	White Ibis	Great Blue Heron	Small Dark Herons[a]	Glossy Ibis	Black-crowned Night Heron	Small White Heron[b]	Wood Stork	Total Nests	Total Colonies	Nests of Aquatic Species
2003	20									20	1	0
2004										0	0	0
2005		81								81	2	81
2006	500	133		9						642	4	142
2007	226				1					227	1	1
2008		2		4						6	1	6
2009	240	126		27	14					407	3	167
2010	891	35		31	37					994	2	103
2011	751	14		35	35			8		843	2	92
2012	1,202			18	108			18		1,346	2	144
2013	599	33		37						669	5	70
2014[d]	5	23		28	1					57	5	52
2015		94		31						125	4	125

a. Colonies are those within approximately 10 kilometers of the backfilled C-38 canal: multiple Kissimmee Prairie sites, Bluff Hammock, Cypress West, Oak Creek Marsh, C-38 Caracara Run, Chandler Slough East, Chandler Slough New, Chandler Slough, Cypress West, Orange Grove, Orange Grove NW, Orange Grove SW, Pine Island Slough, S-65C Boat Ramp, S-65C Structure, S-65D Boat Ramp, and Seven Mile Slough, Pool E Spoil Island, and S-65E colony.

b. Small dark herons include little blue heron and tricolored heron.

c. Small white herons include snowy egret and juvenile little blue heron.

d. Expanded survey effort in 2014.

Table 9-10. Peak (maximum) number of wading bird nests within Lake Istokpoga (Bumblebee Island) 2010–2015. Sites surveyed during April and May in 2015.

Year	Cattle Egret	Great Egret	White Ibis	Great Blue Heron	Small Dark Herons[a]	Glossy Ibis	Black-crowned Night Heron	Small White Heron[b]	Wood Stork	Total Nests	Total Colonies	Nests of Aquatic Species
2010	103	325	110	75						613	1	510
2011	381	200	50	45						676	1	295
2012	75	175		75						325	1	250
2013	250	343		55						648	1	398
2014	658	210	75	55						998	1	340
2015	434	180	829							1443	1	1009

a. Small dark herons include little blue heron and tricolored heron.

b. Small white herons include snowy egret and juvenile little blue heron.

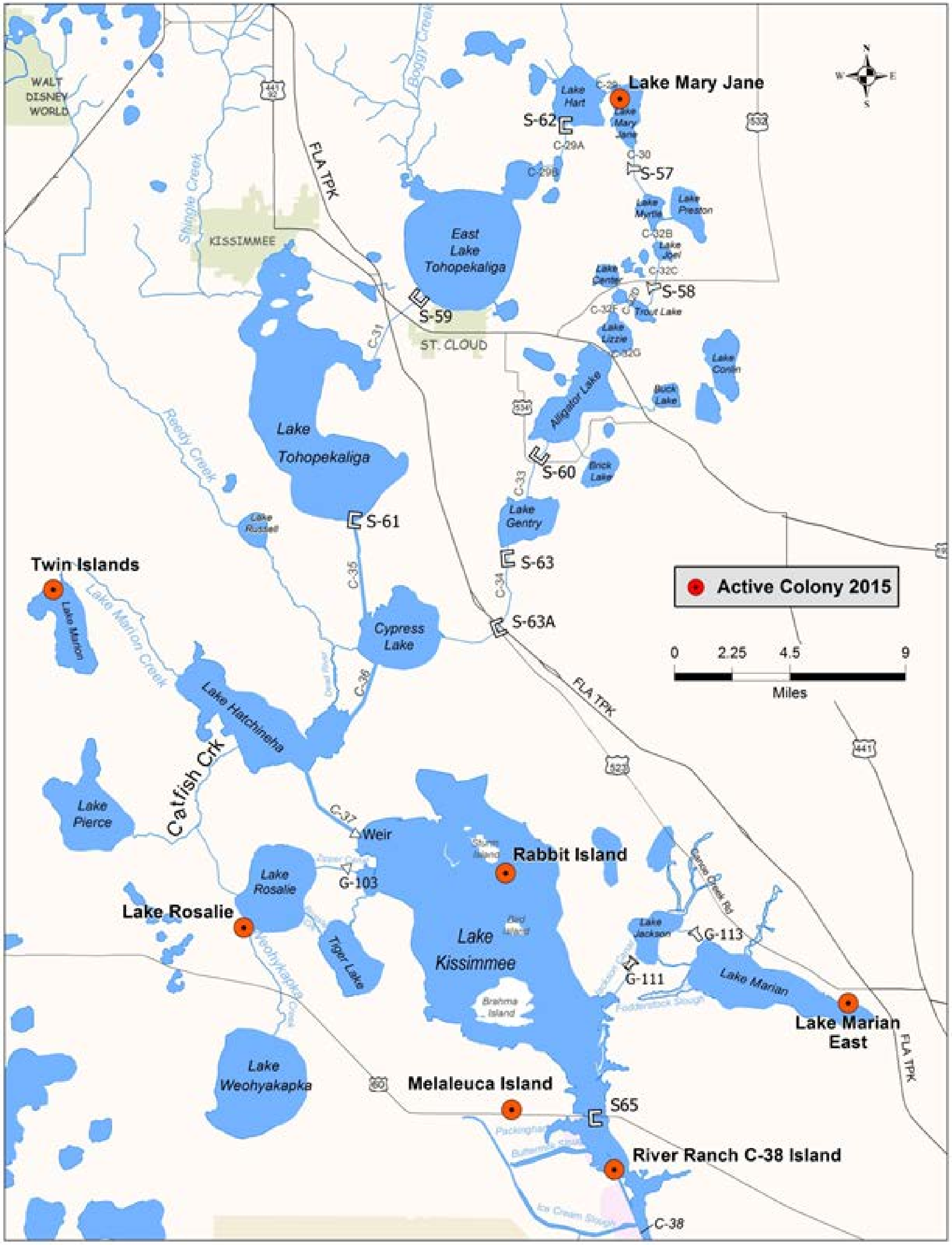

Figure 9-28. Active 2015 colornies in the UKB.

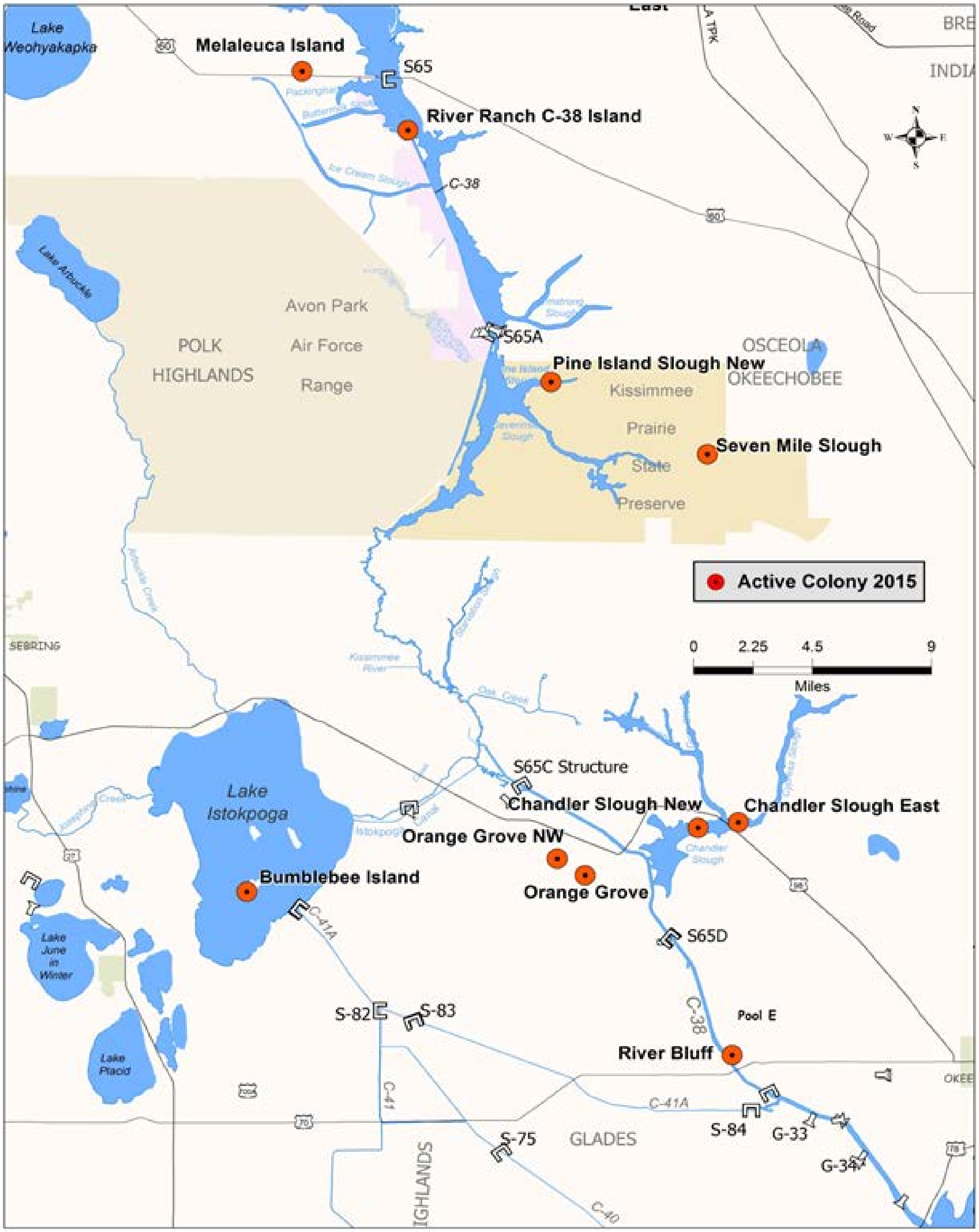

Figure 9-29. Active 2015 colornies in the UKB.

Most nesting of both aquatic wading bird species and cattle egrets continues to occur outside of the KRRP area on islands in the UKB and Lake Istokpoga. To date, only one colony of aquatic bird species (S-65C Boat Ramp Colony) has formed within 3 kilometers of the partially restored portion of the Kissimmee River, and during most years it contains less than 50 nests of aquatic species. The continued small numbers of aquatic species nesting along the restored portion of the river suggest that prey availability on the floodplain is not yet sufficient to support the completion of breeding for these wetland-dependent birds. While foraging conditions on the floodplain can become optimal for wading birds during certain times of the year (see the *Wading Bird Abundance* section), the timing and magnitude of floodplain inundation and recession is not currently optimal for rookery formation due to constraints and other demands on water control operations. Implementation of the HRS in 2019 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. Survey efforts next season will focus primarily within 10 kilometers of the KRRP area and the Kissimmee River headwaters.

INVASIVE, NONINDIGENOUS PLANTS IN THE KISSIMMEE RIVER AND FLOODPLAIN

This section presents a brief update on the status of four nonindigenous, invasive plants that appear to have significantly expanded their areal coverage within the KRRP area and are cause for management concern. This summary is an abbreviated follow-up to the initial Kissimmee River nonindigenous species section in Chapter 11 of the *2010 South Florida Environment Report – Volume I* (Jones et al. 2010). The goal of this evaluation is to identify the potential negative effects of each species on the outcome of one of the world's largest river restoration projects, with the broader objective of planning, organizing, prioritizing and funding control efforts to avoid future negative impacts. Nonindigenous, invasive species can disrupt the outcome of ecosystem restoration by changing the structure of plant and animal communities or displacing native species.

None of the four species [West Indian marsh grass (*Hymenachne amplexicaulis*), limpograss (*Hemarthria altissima*), paragrass (*Urochloa mutica*), and Peruvian primrose willow (*Ludwigia peruviana*)] are on the District's established priority species list or considered an emerging threat. However, West Indian marsh grass, paragrass, and Peruvian primrose willow are listed as Category I species, and limpograss a Category II species, on the Florida Exotic Pest Plant Council's (FLEPPC) 2015 List of Invasive Plant Species (FLEPPC 2015). These invasive plants are currently posing a significant management concern within the KRRP area.

The District recently observed an explosive expansion of West Indian marsh grass within the KRRP area, along with reexpansion in areal coverage of paragrass, limpograss, and Peruvian primrose willow. The following subsections summarize observations for each species within the partially restored portions of the Kissimmee River regarding the occurrence in the restoration project area, known and possible impacts on native systems, current status of existing control programs (if any), availability of effective control methods, and potential effects of the species on restoration efforts. Recommendations were then made for what actions, if any, should be taken for each species in light of its possible effects on the KRRP. The resulting list and recommendations presented below show concurrence with regional invasive species control programs. Chapter 7 of this volume provides additional information about invasive species in the Kissimmee Basin.

Limpograss (*Hemarthria altissima*)

- An exotic grass introduced to the floodplain as cattle forage. Forms dense, almost monospecific stands.
- Listed as a Category II Invasive by FLEPPC.

- Experimental control efforts are in place and being closely monitored and evaluated.

Studies were initiated in 2006 on the Kissimmee River floodplain. A 30-acre plot was established in a monoculture of *Hemarthria altissima* on the east-central side of the Phase I floodplain of Pool B/C to evaluate the potential efficacy of large-scale aerial herbicide treatments with two commonly used herbicides. Pretreatment monitoring data on plant community structure were collected in this plot and an adjacent control plot in early May 2006. The herbicides imazapyr and glyphosate were applied by helicopter to separate 15-acre subplots. Subsequent monitoring indicated that these herbicides were equally effective in inducing almost 100 percent mortality of limpograss within the treated plots. Follow-up spot treatments by ground applicators of limited regrowth within the 30-acre plot were conducted in 2007 and 2008. Posttreatment sampling to track the recovery of plant community structure and cover was conducted in summer and spring 2007–2009 and is ongoing. Based on promising results from the aerial treatment, a larger 490-acre aerial application of glyphosate was carried out in fall 2007 to treat populations that had continued to spread in the restoration area floodplain. Ten 100-square meter study plots were established to evaluate the effectiveness of the treatment in promoting reestablishment of a native wetland community. Community structure and cover data were collected from impact and control plots prior to the herbicide treatment, and semiannual measurements have continued since spring 2008 to monitor vegetation responses.

Prognosis for Restoration Impacts:

- This species has demonstrated a measureable negative impact in the KRRP area floodplain, in particular by hindering the successful reestablishment of the native wet prairie community composition and function (Toth 2015).

Recommendations:

- Develop BMPs and secure funding for control of this species within the entire KRRP area.

Paragrass (*Urochloa mutica*)

- Although not yet formally mapped using aerial photo-interpretation, field observations show that dense monocultures of this species have taken over several thousand acres of wet prairie habitat throughout the floodplain, including large areas interspersed with both native [e.g. maidencane (*Panicum hemitomon*)] and invasive species including limpograss and West Indian marsh grass. The banks of the main river channel are also dominated by paragrass along long stretches of the restoration area.
- Listed as a Category I Invasive by FLEPPC.
- Occupies a floodplain niche similar to the native floodplain dominant, maidencane (*Panicum hemitomon*), and is difficult to distinguish from that species in aerial photography, making broad-scale monitoring difficult.
- Develop BMPs and secure funding for control of this species within the entire KRRP area.

Prognosis for Restoration Impacts:

- This species is hindering the successful reestablishment of the native wet prairie community composition and function on the floodplain, including limiting access by foraging wading birds and waterfowl to prey due to the dense thatching of both live and dead material occurring in this species.

Recommendations:

- Develop BMPs and secure funding for control of this species within the entire KRRP area.

Peruvian Primrose Willow (*Ludwigia peruviana*)

- This Category I invasive wetland shrub tends to be concentrated in the lower portions of pools above tieback levees, where water levels have remained deep. The species appears to be moving northward along the backfilled C-38 canal (Spencer and Bousquin 2014).
- Primrose willow populations experience temporary frost impacts in very cold weather (e.g., winter 2009) but can quickly reestablish dense cover. Extended periods of deep inundation also cause dieback, but with rapid vegetative regrowth when water levels recede.
- May pose a threat to restoration of moderate-to-long hydroperiod native wetland marsh and shrub communities on the floodplain. The reestablishment of more-variable hydroperiods following the implementation of a revised water regulation schedule in 2015 may make conditions less favorable to this species.
- Experimental aerial control plots were established along the river channel in lower Pool B/C in fall 2008 and are being monitored.

Prognosis for Restoration Impacts:

- This species has potential to negatively impact the KRRP.

Recommendation:

- Continue monitoring and evaluation of experimental treatment plots for development of BMPs and the effects of herbicide treatments on reestablishment of associated native plants.

West Indian Marsh Grass (*Hymenachne amplexicaulis*)

- Forms dense, almost monospecific stands.
- Listed as a Category I Invasive by FLEPPC.
- Although not yet formally mapped using aerial photo interpretation, field observations show that dense monocultures of this species have taken over hundreds of acres of BLM and wet prairie habitat throughout the floodplain, including large areas interspersed with both native (e.g., maidencane) and invasive species including paragrass and limpograss. This species appears to be dominating in lower elevation wetlands and depressions more than either paragrass or limpograss.
- Of the four invasive species mentioned here, West Indian marsh grass has experienced the most rapid expansion in areal coverage throughout the floodplain over the past five years.

Prognosis for Restoration Impacts:

- Given the current rate of expansion of this large and robust grass, the species presents a significant ecological threat to the KRRP area. The wide leaves and dense growth habit can reduce run-off volumes, diminish or stop natural water flows, and reduce the amount of available habitat for foraging, breeding and shelter of native fauna such as wading birds, waterfowl, and other marsh birds. The rapid expansion of this plant can result in a reduction in light entering the wetland, depletion in oxygen levels, reduction in fish recruitment success, and in some cases, fish kills (Diaz et al. 2013).

Recommendation:

- Develop BMPs and secure funding for control of this species within the entire KRRP area.

Conclusions

The overarching goal of the KRRP, one of the largest river restoration projects undertaken anywhere, is to restore ecological integrity to much of the Kissimmee River and its floodplain. Given the significant areal coverage and rapid expansion rate of these four invasive plant species within the restoration area over the last few years, the District is developing a plan of action aimed at long-term control of these species within the restoration area and enable long-term restoration success. The three grass species require a comprehensive plan utilizing a variety of management techniques that may include hydrological manipulations, controlled fire, and herbicide applications. Peruvian primrose willow may also be controlled using these same techniques with the addition of mechanical removal or reduction. Of the four species discussed above, West Indian marsh grass appears to be the most rapid invader in the floodplain, while paragrass covers the largest area, followed by a lesser areal extent of limpograss and Peruvian primrose willow. The District should also continue its ongoing control program for Japanese climbing fern (*Lygodium* sp.), Brazilian pepper (*Schinus terebinthifolius*), and floating aquatics within the floodplain.

KEY RESTORATION PROJECT NOTES

First Meander Breakthrough on Kissimmee River in Over 25 Years

In mid-March 2014, a meander cutoff formed in the Kissimmee River Phase I area in the former Micco Run (**Figure 9-31**). This is the first cutoff to be documented along the Kissimmee River since 1988, when a cutoff formed within the Kissimmee River Restoration Demonstration Project area (Scarlatos et al. 1990). That cutoff occurred as the result of high hydraulic gradients created by discharge tests near Weir 3 of the demonstration project, or what is now the northernmost reach of the C-38 canal backfill within Phase IVB of the KRRP. The new cutoff (initially reported in Cheek et al. 2015) appears to be developing into an oxbow lake as the meander cutoff is isolated from the main river channel by movement of sediments, changing the dominant path of flow, which had been reestablished to the river channel in 2001 following Phase I construction. However, patterns of sandbars observed during low water in May 2015 suggest that some flow continues through the meander (**Figure 9-31**, right photo). KRREP staff continue to monitor the cutoff during WY2015 through both aerial photography and cross-sectional surveys to document bank erosion and channel widening over time. Fixed survey monuments were established on either side of the breakthrough and surveyed monthly (when environmental conditions permitted). Substantial geomorphological changes occurred in WY2015 as seasonal high discharges redistributed sediments, creating new sandbars and scouring out the new river channel to nearly seven meters deep and more than 50 meters wide (**Figure 9-32**).

Figure 9-31. A newly formed meander cutoff (left) created an island in the former Micco Run in the Kissimmee River Phase I restoration area. The cutoff began to form in mid-March 2014, has continued widen through May 2015 (right), and is now the main conduit of flow.

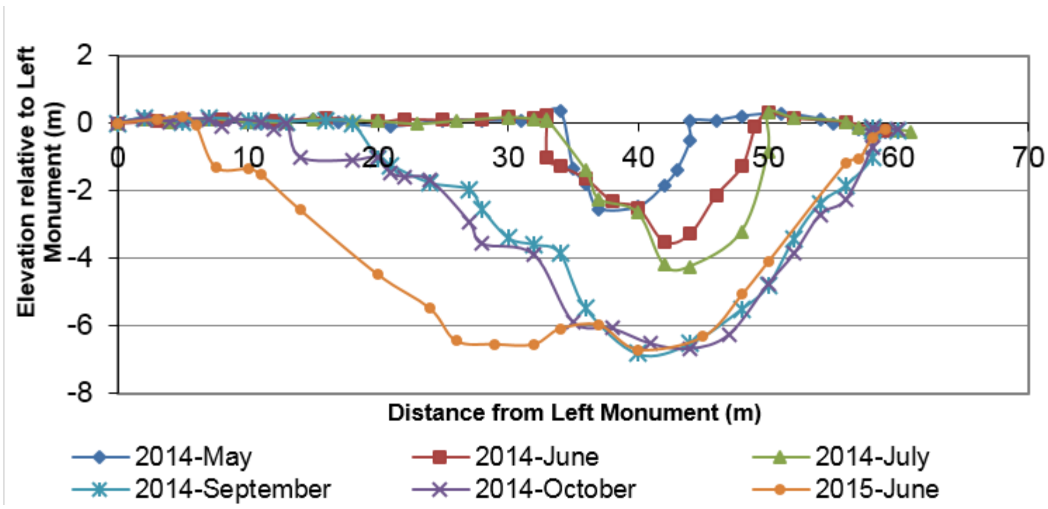

Figure 9-32. Cross-section analysis of Micco Run breakthrough over the course of 15 months.

Kissimmee River Lower Pool C Suspended Vegetation Mats

The S-65C water control structure, which regulates discharge from pool B/C, creates a backwater effect in the lower Phase I restoration area of the KRRP (Anderson 2014b). Stabilized stages north of S-65C and its associated tieback levee creates a large area that is often continuously inundated with little seasonal stage fluctuation. This has resulted in the development of a thick, semi-buoyant vegetation mat dominated by shrubs and herbaceous plants rooted in a suspended substrate composed of dead plant material and other accumulated organic debris (Milleson et al. 1980). In WY2015, KRREP staff randomly selected points throughout the area to characterize the mat, measuring its thickness and delineating its extent. Based on these initial surveys it is estimated that the mat covers approximately 139 hectares and has an average thickness of 59.2 centimeters (**Figure 9-33**). With a better understanding of the size and structure of the vegetation mat, KRREP staff will be able to better assess the potential water management challenges associated with the mat when S-65C is removed, and will aid scientists and engineers considering potential solutions for the fate of this accumulated biomass.

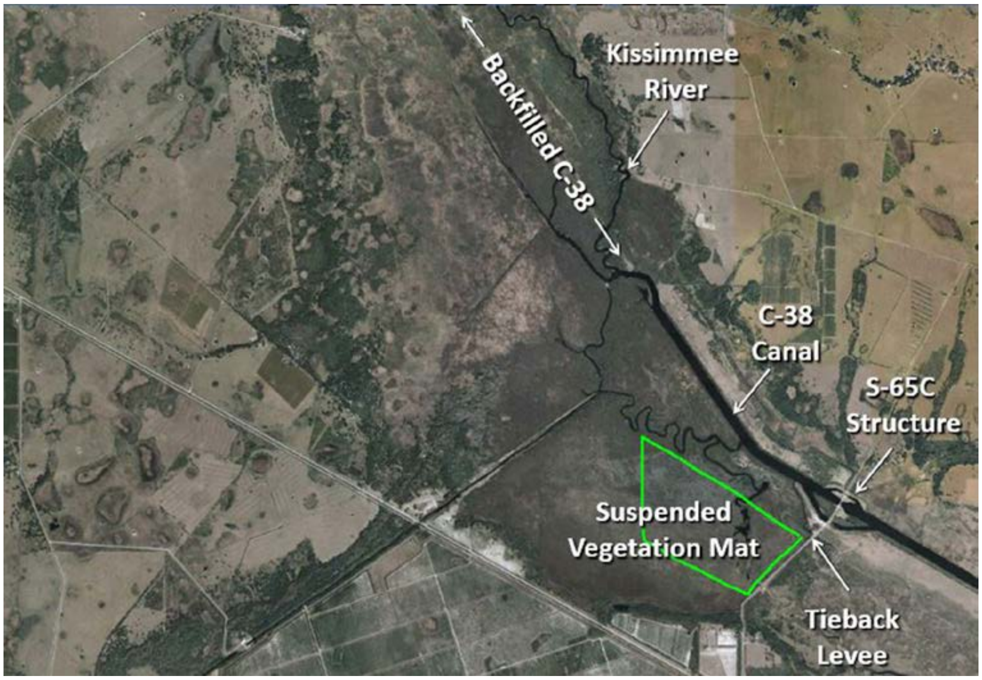

Figure 9-33. Lower Kissimmee River Phase I restoration area delineating the areal coverage of the suspended vegetation mat. The green polygon is the estimated outer perimeter of the mat.

Kissimmee River Restoration Project Construction Resumes

A $4.65 million contract was awarded by USACE in March 2015 to backfill the three mile-long MacArthur Ditch. The MacArthur Ditch contract will eliminate an artificial drainage feature in the floodplain created more than 50 years ago by the MacArthur family to protect part of their property from flooding. A small borrow canal resulting from construction of a levee around the property grew to almost three miles in length and up to 60 feet wide after reintroduction of flow to the Phase I area in 2001 (**Figure 9-34**). This dated feature quickly drains the floodplain back into the C-38 canal, while continuing to increase in length and width. If not backfilled, it would decrease the depth and duration of water in floodplain wetlands and continue to impact the quality of fish and wildlife habitat. The ditch is also disrupting the flow pattern in the southern portion of the Kissimmee River. Backfilling of the ditch began in June 2015 and is scheduled for completion by the end of Fiscal Year 2015-2016 (October 1, 2015–September 30, 2016).

Figure 9-34. KRREP Phase I restoration area MacArthur Ditch Backfill Project.

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 includes data collection, evaluation, and reporting to support the District's mission to manage and protect water resources. Project products support management decision making and are used to determine whether management intervention is required or whether the ecosystem is responding as intended to management actions. Key focus areas include the following:

- Data collection and evaluations to define linkages/relationships between hydrology and fish and wildlife resources, and between hydrology and the lake littoral vegetation response to seasonal water level conditions.
- Lake and watershed water and nutrient budget development to document directions in basin water quality and lake assimilative capacities.
- Coordination with agency and environmental stakeholders to ensure non-redundant and complementary data collection and evaluation, to annually report on ecological conditions within the KCOL and UKB, and to facilitate information sharing and identification of emerging issues and concerns.

The scope of this year's report includes a discussion of an emerging concern with the presence of the cyanobacteria linked to AVM in KCOL waterbodies; updates on Osceola county projects; and an overview of watershed assessment, monitoring, and research results. The results provide an overview of ecological conditions and water quality trends in the basin by combining data and information from SFWMD's monitoring activities with those of our KCOL partner agencies.

Avian Vacuolar Myelinopathy, an Emerging Issue

AVM is a neurological disease that comes from direct or indirect consumption of neurotoxins produced by a blue-green algae (cyanobacteria) that can grow on the leaves of submersed plants. Research suggests that a recently discovered species of cyanobacteria in the order Stigonematales produces this neurotoxin, and that leaf surfaces of hydrilla (*Hydrilla verticillata*) can have particularly high densities of this algae in some waterbodies (Wilde et al. 2005, 2014). When herbivores consume hydrilla while the cyanobacteria and the neurotoxin are present, they can display loss of muscle control resulting in difficulty flying and swimming, and eventual death.

Herbivorous waterfowl, fish (Haynie et al. 2013), turtles (Mercurio et al. 2014), and even apple snails (Wilde and Netherland 2015) have been identified as capable of accumulating the toxin, though not all show clinical signs of the disease. Unfortunately, feeding trials have verified that a primary food source of the endangered snail kite (*Rostrhamus sociabilis plumbeus*) in the KCOL, the exotic apple snail (*Pomacea maculata*) can accumulate the toxin from hydrilla and cause AVM in their predators (chickens in the feeding trial).

Several studies on the KCOL have confirmed that at least some portions of hydrilla populations in lakes East Lake Tohopekaliga and Lakes Tohopekaliga, Cypress, Hatchineha, and Kissimmee have the cyanobacteria present, and that hydrilla with the cyanobacteria on it from Lake Tohopekaliga can pass AVM to consumers (Wilde and Netherland 2015). A smaller, follow-up study found that feeding exotic apple snails collected directly from Lake Tohopekaliga to chickens did produce some signs of AVM (2 of 3 birds had mild brain lesions upon necropsy) but none of the birds showed any clinical signs of the disease (Wilde and Netherland 2015). Further, biologists collected coots from Lake Tohopekaliga that they suspected may be showing clinical signs of AVM (slower flying, erratic flight, inability or reluctance to fly, etc.) and necropsies confirmed several had mild AVM lesions (5 of 22). However, given their migratory nature, it was unclear whether they contracted AVM from the KCOL or from reservoirs in the southeastern United States where AVM is more prevalent.

To date, no sightings of eagles or snail kites displaying signs of AVM have been reported. Some researchers speculate that differences in temperature between Florida and other reservoirs in the southeastern United States may reduce the level of neurotoxin produced, and therefore lower the overall threat of AVM in the KCOL (Wilde, personal communication). Currently, researchers are developing a method to detect the presence of the neurotoxin itself, which would be a better indicator of the potential for AVM than whether or not the cyanobacteria is present. KCOL managers are watching closely to determine whether hydrilla control efforts need to be increased to reduce the potential for AVM and have requested support from the public to report any signs of possible AVM issues with coots, eagles, snail kites, or waterfowl.

KCOL WATERSHED MANAGEMENT PROJECTS

Osceola County Project Updates

Light Detection and Ranging Survey

Osceola County received a cost-share grant from the United States Geological Survey to acquire detailed elevation data (1-foot contour LiDAR) for the entire county footprint, including the two municipalities of Kissimmee and St. Cloud, and the portion of Reedy Creek Improvement District that lies within Osceola County. The three jurisdictions, SFWMD, and many local partners will share the cost-match financially and/or with in-kind services to produce this very valuable product. Similar elevation data are already available for many areas in the state, including most of the surrounding counties. These one-foot contour lines across the county will allow emergency managers, county planners, natural resources staff, and engineering staff to better plan for development impacts, emergency response to flooding, and many other important functions. At this time the recipient agencies are waiting for the best time to acquire the data, which is collected via aerial surveys. Ideally, flights will occur during a dry period in order to minimize standing water in the region, which increases the extent and quality of the final product.

Osceola County Lakes Management Plan

Osceola County approved a Lakes Management Plan at its September 14, 2015, Board of Commissioners meeting. The plan lays out an operational framework for the county to work with other agencies involved in lake management, including SFWMD, to improve coordination among the diverse interests in the KCOL for the benefit of the resource and the stakeholders. The plan identifies challenges in lake management, such as county funding and staffing, gaps in existing aquatic plant management programs, and access and boating safety issues, as well as guidance on citizen involvement within the county. The plan also reviews water quality issues related to the recent total maximum daily loads assigned to several county lakes by FDEP and how staff in the county's lakes section works with the county's Stormwater Management Team to improve the lakes. More information on the plan is on the Osceola County website at http://www.osceola.org/agencies-departments/community-development/offices/community-resources/lakes-management/index.stml.

KCOL ASSESSMENT, MONITORING AND RESEARCH

Kissimmee Upper Basin Monitoring and Assessment Project and Headwaters Revitalization Monitoring

The Kissimmee River HRP will increase regulatory stages and change the operating schedule on three major waterbodies in the KCOL (USACE 1996). The HRP is designed to increase storage in the headwater lakes to provide appropriate flow patterns to the restored Kissimmee River floodplain upon completion of restoration (expected date 2019–2020), and the increased storage is expected to improve the quantity and quality of littoral habitat in the headwater lakes as well. Vegetation monitoring within the existing littoral zones and up to future lake regulation elevations will be necessary to determine the effects of the HRP (USACE 1996). The need for vegetation monitoring was also identified in the Kissimmee Upper Basin Monitoring and Assessment Project (initiated in October 2010) to address data gaps and knowledge uncertainties that were identified during the development of the KCOL Long-Term Management Plan (SFWMD et al. 2011). By combining monitoring efforts between these projects, expected improvements from HRP can be better isolated from other management activities in the basin, and monitoring efforts can be expanded to include wildlife responses in the future as well.

Currently, there are two vegetation monitoring studies on the KCOL that can help fill these needs. The first is being conducted by SFWMD and is currently in a design and implementation phase and involves tracking changes in specific community types over time and documenting any distributional shifts up or down slope if they occur. The second is being conducted by FWC and involves quantifying specific littoral communities via aerial imagery on a 3 to 5 year rotation in the major KCOL waterbodies to assess habitat conditions for select faunal guilds (alligator, snail kites, sportfish, wading birds, and waterfowl). Below is a summary of each of the projects.

Permanent Monitoring Stations

Long-term, permanent monitoring stations will be established on four of the major waterbodies in the KCOL; East Tohopekaliga, Tohopekaliga, Cypress, and Lake Kissimmee. These stations will include permanent quadrats that are stratified by water depth throughout the littoral zone and transects set perpendicular to shore in the upper reaches of the littoral zone. Plant percent cover will be monitored in 5 m^2 quadrats located in specific communities that represent different depth strata or habitat types, including: wet prairie (high diversity, annuals present), emergent marsh (lower diversity, perennials), broadleaf marsh [pickerelweed (*Pontederia cordata*) and/or duck potato (*Sagittaria lancifolia*)], floating leaf (water lilies), and deep-water emergent grasses [Egyptian paspalidium (*Paspalidium geminatum*) and maidencane (*Panicum hemitomon*)]. Transects will be established perpendicular to shore between the low and high water elevations under the current lake regulation schedules, and on the headwater lakes (Cypress and Kissimmee) will extend upslope to what will be the high water elevation under the HRP regulation schedule. Plant percent cover will be monitored in two, 1x2 m quadrats set perpendicular to either side of the transect at 0.5 ft (15 cm) elevation intervals. Together, these monitoring efforts will assist managers in determining effects of hydrological changes as HRP is implemented, as well as improve habitat metrics for ongoing or future faunal studies.

Aerial Imagery Classification

FWC has been creating vegetation community maps from aerial imagery of the major waterbodies in the KCOL (and Lake Istokpoga) since 2005. The monitoring effort was initiated to develop lake management plans using quantifiable habitat targets for a suite of representative wildlife species. In order to better assess littoral vegetation and to monitor efficacy of management actions, FWC developed a classification system using vegetation types that were common and/or representative of specific habitat value for fish and wildlife. The classes were based on an amended version of the Florida Land Use, Cover and Forms Classification System (FDOT, 1999), and also contained estimates of plant coverage (sparse, medium, or dense) for each.

The resulting vegetation classifications were then assigned values according to their relative habitat value for a variety of fish and wildlife taxa, including alligators, imperiled species, sportfish, wading birds, and waterfowl. For example, a dense, floating mat of vegetation might be scored low as sportfish foraging habitat, but high for alligator nesting habitat. The rankings provide an estimate of available habitat for each of the focal wildlife taxa on each lake, as well as where it occurs. These efforts allow lake managers to balance habitat needs among various fish and wildlife and focus management in specific areas to maximize efficiency and reduce costs.

Fish Population Monitoring

The status of the fishery in the KCOL is monitored on a regular basis by FWC via electrofishing and creel surveys. Electrofishing surveys provide an opportunity to assess the size distribution of the largemouth bass populations, as well as their relative health based on established relationships of length:weight ratios. These surveys occur in the spring every 2 to 3 years on the major lakes in the chain, with the most recent conducted on Lake Cypress, East Lake Tohopekaliga, Lake Kissimmee, and Lake Tohopekaliga in spring 2014. Catch-per-unit-effort in the electrofishing surveys ranged from 33.2 to 57.4 bass per hour (**Table 9-12**). Mean relative weights for largemouth bass on Lakes Kissimmee and Tohopekaliga were 99 (scale of 0 to 100, with 90 to 100 representing healthy weights), meaning the fish populations appeared healthy (**Figure 9-35**). Results indicate all of the surveyed lakes support good bass populations, but Lakes Tohopekaliga, Cypress, and Kissimmee have a greater number of large bass (> 498 millimeter [19.7 inches] total length) than East Lake Tohopekaliga.

Table 9-12. Mean catch-per-unit-effort (fish per hour) values by length group [millimeters (mm) total length (TL)]for largemouth bass collected by electrofishing from random transects in Lake Cypress (n=20), East Lake Tohopekaliga (n=31), Lake Tohopekaliga (n=32), and Lake Kissimmee (n=27) in spring 2014. Each transect was sampled for 15 minutes. Standard error and coefficient of variation values are in parentheses and brackets, respectively.

Lake	< 201 mm TL	201–355 mm TL	356–498 mm TL	499–598 mm TL	> 599 mm TL	Total
Lake Cypress	7.2	13.2	9.8	2.6	0.4	33.2 (3.4) [46]
East Lake Tohopekaliga	12.8	13.2	7.1	0.3	0.0	33.5 (4.2) [69]
Lake Kissimmee	13.6	14.5	8.6	1.3	0.3	38.4 (3.4) [47]
Lake Tohopekaliga	28.8	19.8	7.6	1.0	0.3	57.4 (5.3) [54]

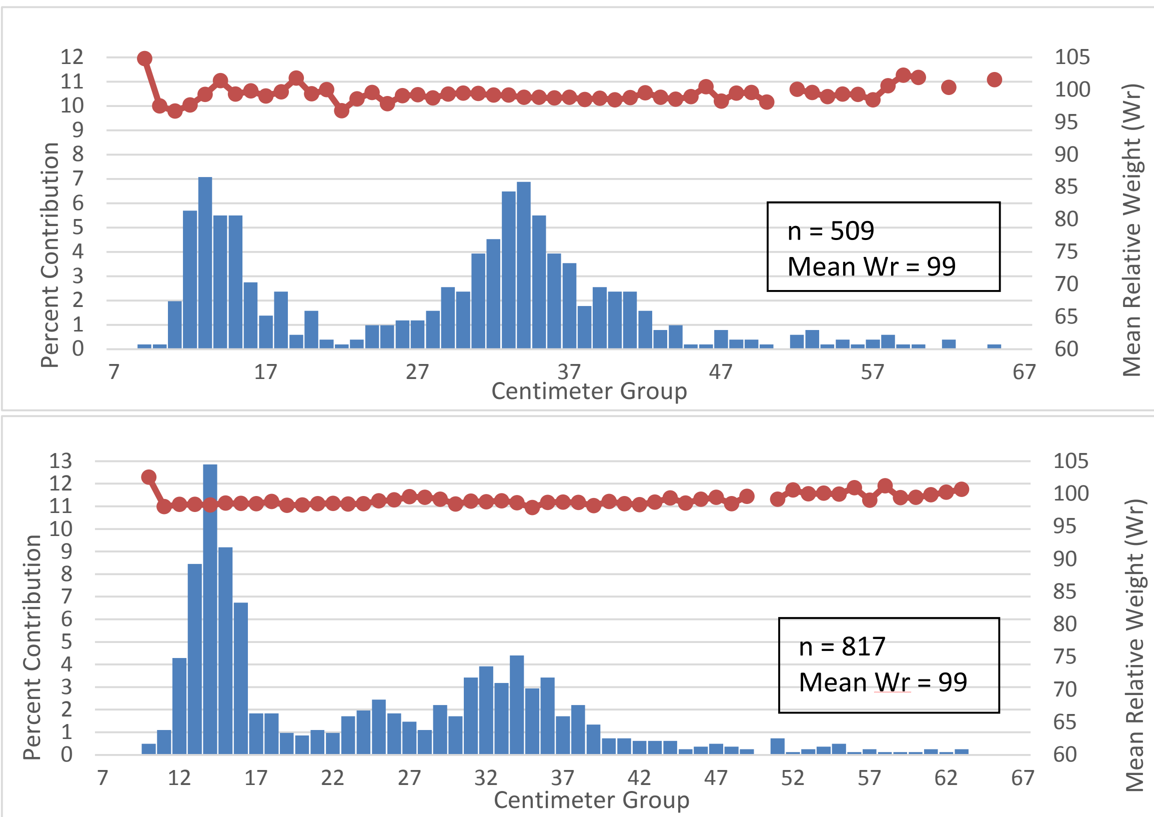

Figure 9-35. Length-frequency distribution (bars) and mean length-specific relative weight (Wr, red points) for largemouth bass collected by electrofishing at Lake Tohopekaliga (top) and Kissimmee (bottom) during spring 2014. Fish lengths were placed into centimeter groupings (e.g., 10-centimeter group = 10.00–10.99 centimeter total length).

Snail Kite Population Monitoring

Statewide snail kite (*Rostrhamus sociablilis plumbeus*) nesting effort, distribution, and population size are systematically monitored by the University of Florida on an annual basis (see Fletcher et al. 2014 for details). This monitoring effort covers all wetlands in which breeding activity has been observed within the last decade or more, statewide. In the KCOL region, surveyed waterbodies include East Lake Tohopekaliga, and Lakes Tohopekaliga, Runnymede, Jackson, Cypress, Hatchineha, and Kissimmee. The number of kites observed in each waterbody are counted and identified by their alpha-numeric leg bands, if possible. Survey crews also record nesting information including the location, status (building, incubating, nestlings, failed, or successful), leg bands of parents (if possible), and other important characteristics. Following the first survey in January, each nest is revisited on subsequent surveys at about three-week intervals until it is no longer active. Alpha-numeric leg bands are put on most nestlings when they are 24 days old for future identification and for estimating population size.

Survey crews located a total of 311 active nests (i.e., containing eggs or nestlings) throughout the snail kite's range in Central and South Florida in the 2014 breeding season (roughly January—September). As has usually been the case since 2005, a large proportion of those nests (78 total) were located in the KCOL, accounting for 25 percent of the range-wide nesting effort in 2014; however, this was down from 43 percent in 2013 and 57 percent in 2012 (**Figure 9-36**, panel a). The downward trend in the relative nesting contribution of the KCOL is partly due to an expansion of the nesting distribution, as nesting activity has increased in southern portions of the state over the last few years. However, the total number of nests observed in the KCOL in 2014 was sharply lower than the numbers observed in each of the previous three years. In fact, for the first time since at least 2007, the KCOL did not have the most nests of any other region in 2014. Also, unlike the previous five years, nesting in the KCOL was confined to East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee; and was not observed on Lakes Jackson, Hatchineha, or Runnymede (nesting activity on Lake Cypress has never been observed).

Within the KCOL, there were 48 nests located on Lake Tohopekaliga in 2014, which accounted for 15 percent of the statewide nesting effort. Lake Kissimmee had 17 nests (6 percent of the statewide nesting effort) and East Lake Tohopekaliga had 13 nests (4 percent of the statewide nesting effort) (**Figure 9-36**, panel b). Of these 78 total nests in the KCOL, only 16 (22 percent) were observed to be successful (fledged at least one young) (**Figure 9-36**, panels c and d). The 2014 breeding season was the first year in recent history where the KCOL did not produce the most successful nests of any other region in the state. The Everglades, Lake Okeechobee, and the STAs all produced more successful nests than the KCOL in 2014 (**Figure 9-36**, panel c).

In summary, the KCOL region has played a declining role relative to other regions in the state in recent years, and 2014 continues that trend. Total active nests, total successful nests, success rate, and numbers of young fledged have all declined in the KCOL recently as well, not all of which can be attributed to higher nesting activity in other portions of the state. However, concentrated snail kite nesting activity has historically shifted between regions every few years and it is unclear whether this recent trend is representative of a change in habitat or prey availability in the KCOL, or whether it is even cause for concern.

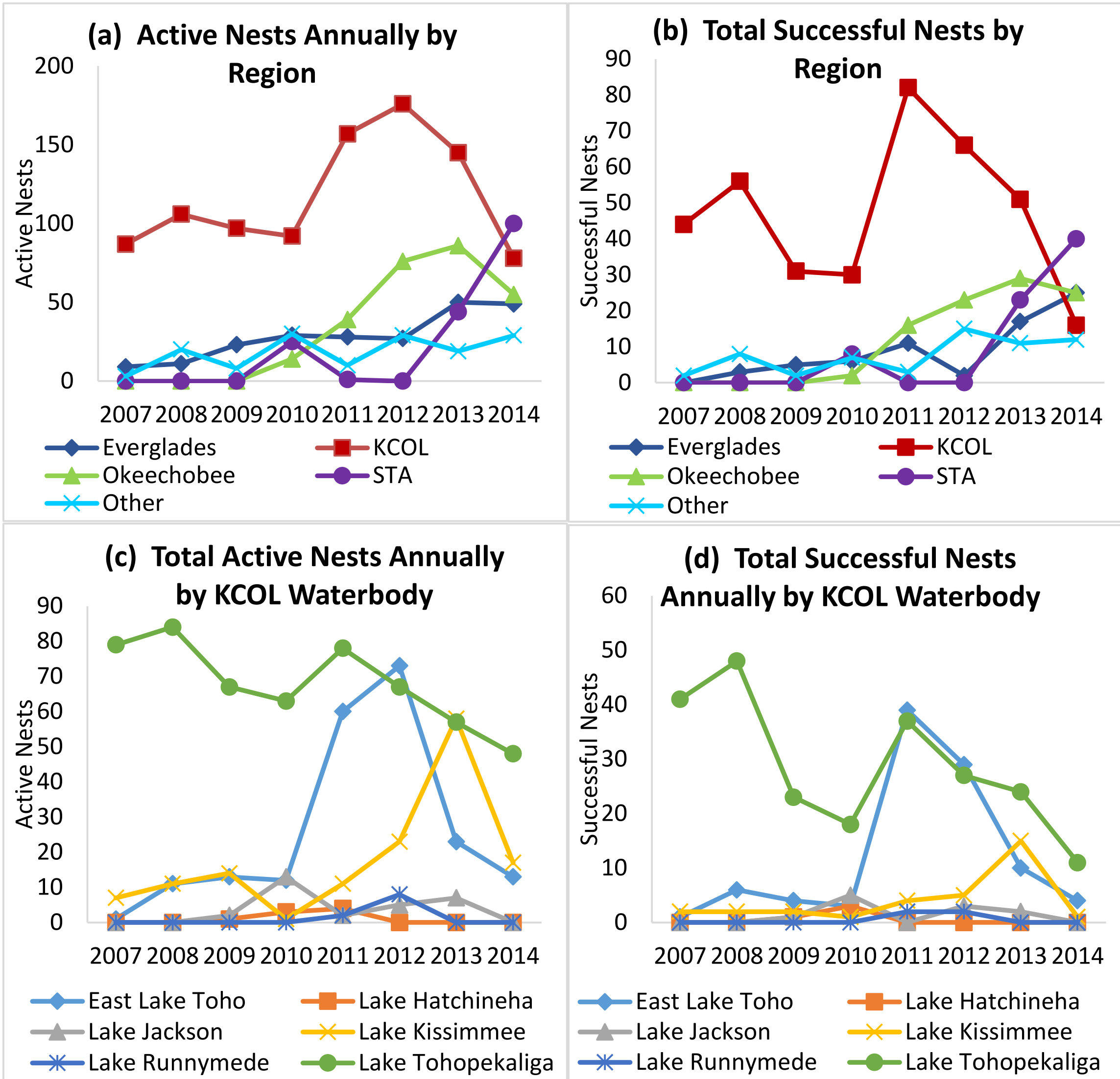

Figure 9-36. (a) Active snail kite nests for each region from 2007 to 2014, (b) active snail kite nests for each region for each major waterbody in the KCOL region, (c) total successful snail kite nests annually, and (d) total successful snail kite nests for each KCOL waterbody from 2007 to 2014.

Alligator Population Monitoring

The FWC conducts alligator monitoring studies in many public waterbodies throughout the state to obtain relative abundance of their populations (Hutton and Woolhouse 1989). Alligator activities vary seasonally (Lutterschmidt and Wasko 2006), so night light surveys are conducted from May through mid-June (spring surveys) and July through mid-August (summer surveys), and are analyzed separately. Survey routes are standardized and follow the perimeter of a lake along the open water-shoreline or marsh interface (Woodward and Marion 1978), or middle or centerline of a river or canal section, depending on width. Spotlights (200,000 candlepower) are used to locate alligator eye reflections and sizes are estimated to the nearest 1 ft if possible. In cases where the exact size cannot be determined, broader size categories (0–2 ft, 2–4 ft, 4–6 ft, ≥ 4 ft, ≥ 6 ft, and ≥ 9 ft) are used, or they are recorded as unknown size.

For trend analysis by year, counts are summed in each size category, and average date, water level, and water temperature within replicates are determined for each year. FWC uses Turnbull's (1976) approach for interval censored data via the "%ice" SAS macro (So et al. 2010) in order to allocate counts into size categories. A modified version of this macro is used to produce an overall probability distribution function describing the estimated proportions of unit-interval lengths for each replicate-unit-year sample. The probability distribution function is summed for specified portions of the alligator size range to produce the cumulative distribution function for each replicate-unit-year. Standard errors and 95 percent confidence intervals for cumulative distribution function are determined via the macro as well, and these are multiplied by the total number of all alligators counted for each replicate-unit-year sample to estimate the total count, its standard error, and confidence limits.

FWC models year trends in the natural logarithms of the estimated counts using the Generalized Additive Modeling Package of the R statistical environment (Hastie 2009). Akaike's information criterion is used to select the best of six models with the following predictors plus intercept: (1) linear year effect; (2) 4-knot spline for year; (3) linear year and linear water level; (4) linear year and 4-knot spline for water level; (5) linear water level and 4-knot spline for year; (6) 4-knot spline for year and 4-knot spline for water level. A fixed detectability coefficient of 0.14 is applied to survey counts to generate population estimates from the generalized additive modeling analyses (Woodward et al. 1996).

Lake Kissimmee

Total population estimates on Lake Kissimmee have continued to stay strong in recent years. The 2014 estimated population was 12,030, which is an increase of approximately 160.1 percent since population monitoring began in 1991 (**Figure 9-37**, panel a). The estimated number of juvenile (1–4 ft) alligators was 6,974, which is a 326 percent increase over the 1991 estimated population. The adult (6 ft and larger) segment of the alligator population also increased, and was estimated at 3,217.

Lake Tohopekaliga

Total population estimates on Lake Tohopekaliga have continued to stay strong. The 2014 estimated population was 5,003, an approximate increase of 133 percent since population monitoring began in 1994 (**Figure 9-37**, panel b). The estimated number of juvenile (1–4 ft) alligators was 4,526, a 310 percent increase over the 1994 estimated population. The adult (6 ft and larger) segment of the alligator population has also increased, and was estimated at 1,306; a 74 percent increase over the 1994 estimated population.

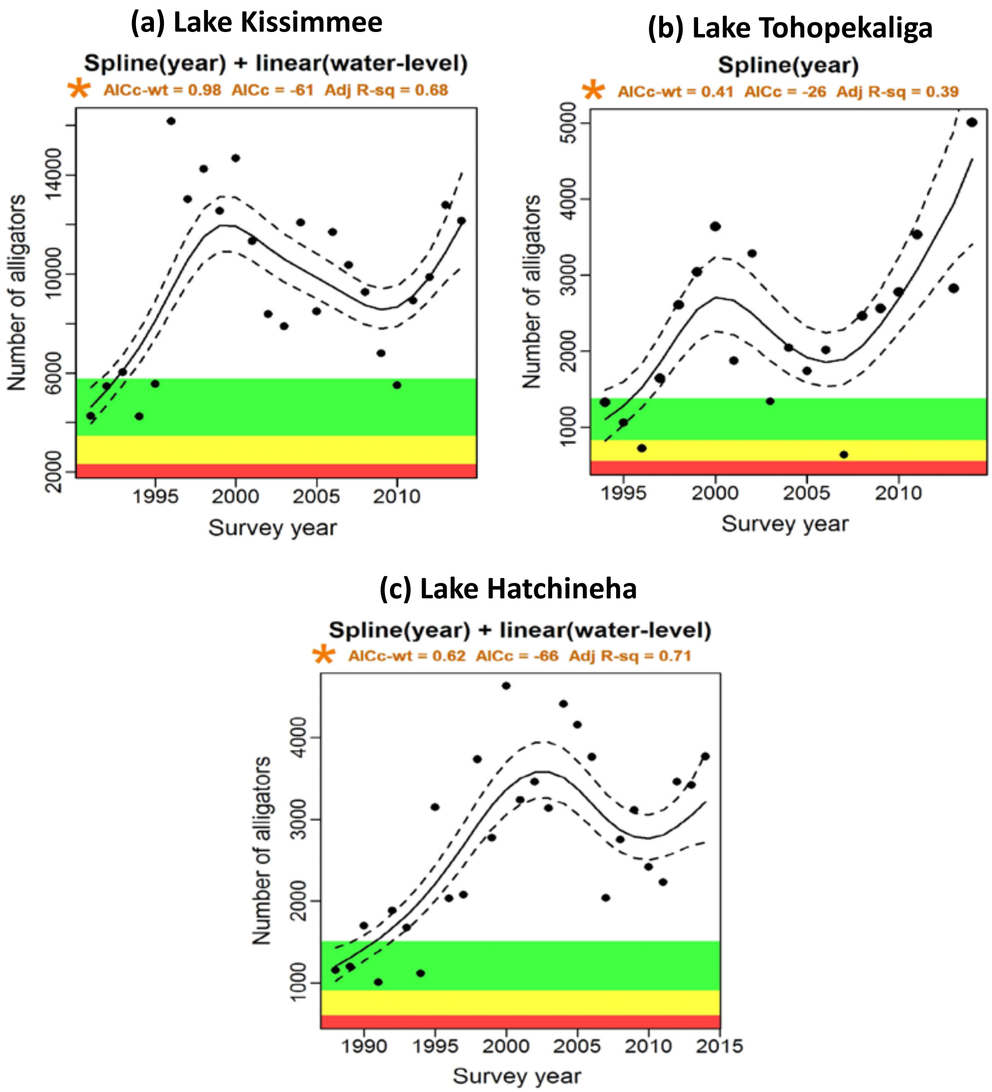

Figure 9-37. Alligator population trends on (a) Lake Kissimmee, (b) Lake Tohopekaliga, and (c) Lake Hatchineha, based on night light surveys conducted between 1988 and 2014. Green-shaded areas represent ±25 percent of the starting population estimate; yellow-shaded areas represent a 25–50 percent decline; and the red-shaded areas represents > 50 percent decline. Dashed lines represent 70 percent confidence intervals around the solid trend line. Note that both the x- and y-axes scales vary between figures.

East Lake Tohopekaliga

Total population estimates on East Lake Tohopekaliga have remained relatively stable over time. The 2014 estimated population was 121, an increase of approximately 15 percent since population monitoring began in 2003. The estimated number of juvenile (1–4 ft) alligators was 17, a 56 percent decline from the 2003 estimated population. The adult (6 ft and larger) segment of the alligator population increased to 92, a 156 percent increase over the 2003 estimated population.

Lake Hatchineha

Total population estimates on Lake Hatchineha have remained strong. The 2014 estimated population was 3,217, an increase of approximately 166 percent since population monitoring began in 1988 (**Figure 9-37**, panel c). The estimated number of juvenile (1–4 ft) alligators was 2,175, a 248 percent increase since 1988. The adult (6 ft and larger) segment of the alligator population also increased and was estimated at 885, a 114 percent increase over the 1988 estimated population.

Cypress Lake

Total population estimates on Cypress Lake have remained stable over time. The 2014 estimated population was 951. The estimated number of juvenile (1–4 ft) alligators was 187, while the estimated number of adult alligators was 535. Those estimates represent a 46 percent decline and an 83 percent increase from the 2000 estimated population, respectively.

Water and Nutrient Budgets for Kissimmee-Cypress-Hatchineha

Nutrient budgets of lakes provide information on the sources, sinks and outflows of these nutrients, which can aid lake the management. To support the KCOL and the Kissimmee Upper Basin Monitoring and Assessment Project, preliminary hydrologic, chloride (CL), and P budgets based on Calendar Years 1996 to 2014 have been developed for a combined KCH system using the methods of James (2014a, b). Inflows were measured at stations REEDYLOU (Reedy Creek), S61 (Lake Tohopekaliga), and S63 (Lake Gentry), while outflows were measured at S-65 (Lake Kissimmee, **Figure 9-38**). Stage storage relationships for each lake were used to determine volumes that were summed daily to represent the storage volume for the whole system. End of month storage values were used to calculate monthly volume changes. The monthly net inflow (e.g., inflow + rainfall – outflow - evaporation) was subtracted from monthly volume changes and the difference was considered unmeasured inflow (if positive) or outflow (if negative). Using these monthly estimates, measured surface inflows were 44 percent of the total inflow followed by unmeasured inflow (38 percent) and rainfall (18 percent, **Figure 9-39**, panel a). Discharge through S-65E was nearly 79 percent of the outflow, while evaporation was 21 percent, unmeasured was less than 1 percent (**Figure 9-39**, panel b).

Using the same methods as James (2014a, b) hydrologic budgets were checked using C—a conservative tracer. Water samples taken from the lakes at various locations (C03, D02, D04, E02, and E04), Reedy Creek (CREEDY), and S61 (B09 in Lake Tohopekaliga) were analyzed for CL. These CL measurements were multiplied by the appropriate volume estimates to determine mass or mass loads per day. The monthly change in mass was compared to the monthly net input loads. Using a constant value of 15 mg/L CL for the unmeasured runoff and a constant value of 21 mg/L CL for S63 (an average value from data obtained in the 1980s at location CS-63), resulted in an overall residual of 1.3 percent (**Figure 9-39**, panel c). Measured surface inflows made up 60 percent of the loads to the lakes followed by unmeasured inflow (38 percent) and atmospheric deposition (0.9 percent). Unmeasured outflow was less than 1 percent (**Figure 9-39**, panel d).

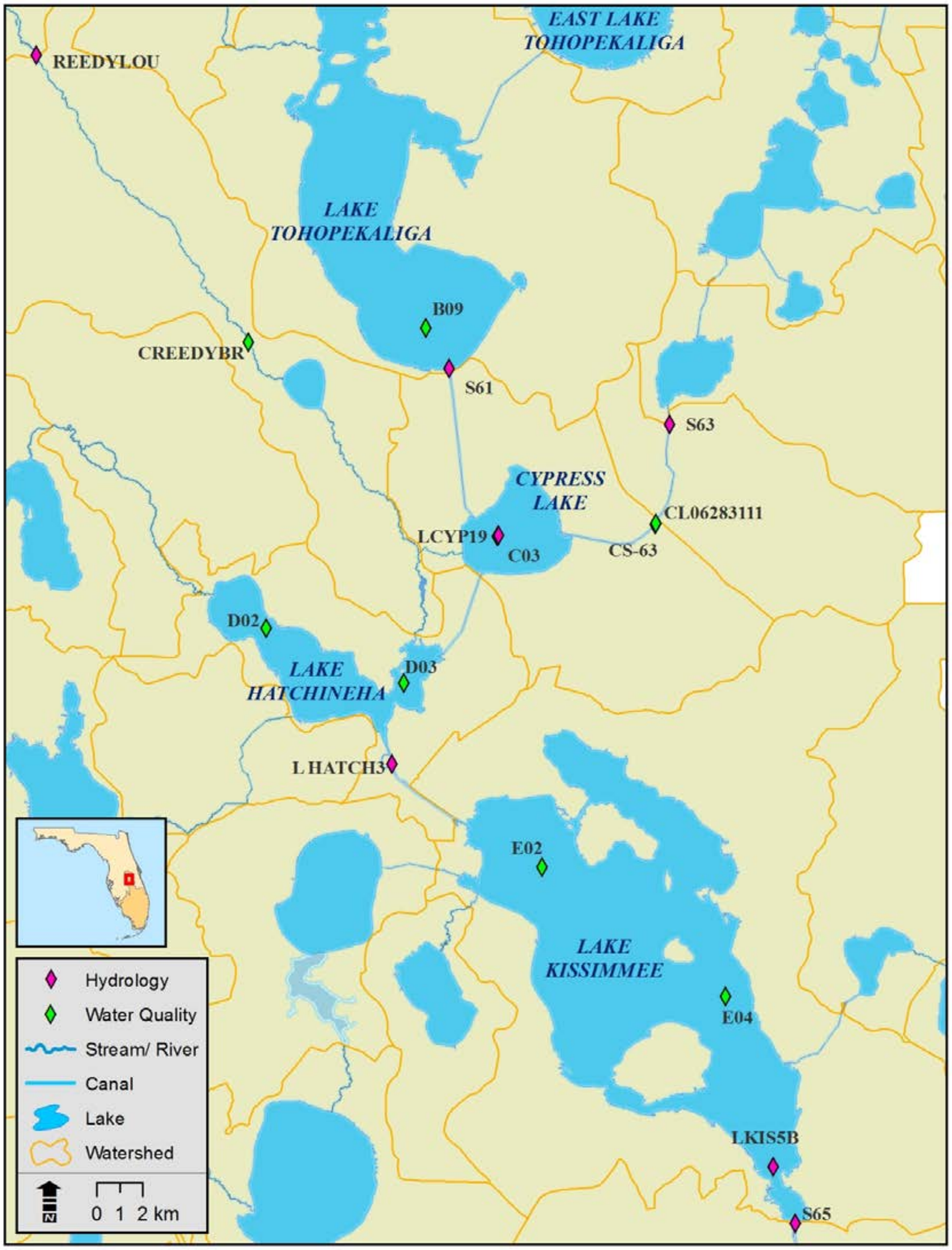

Figure 9-38. Hydrological and water quality sampling locations in the KCH area (including major and minor tributaries).

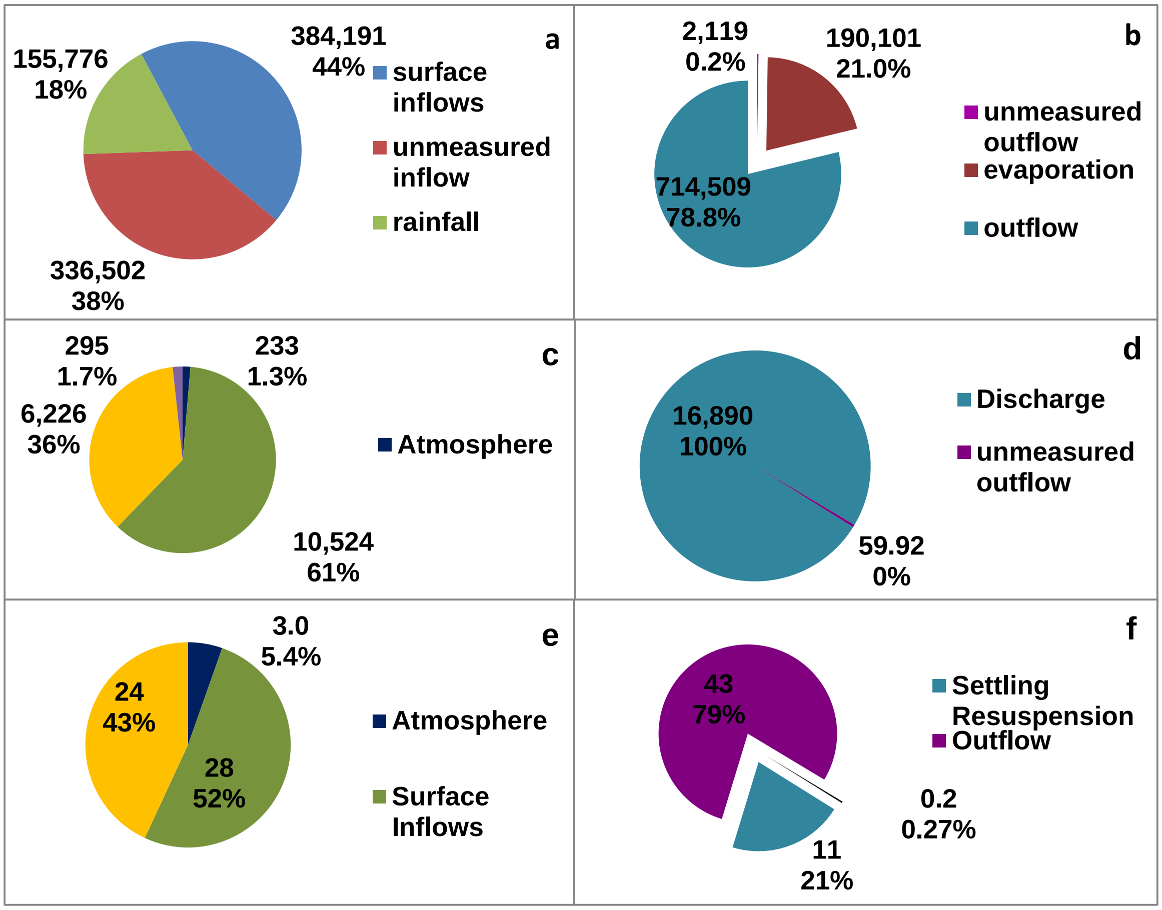

Figure 9-39. Inflows, loads, and discharge estimates of water CL and P for KCH based on hydrologic and CL budgets from CY1996–CY2003 and 2006–2014: (a) inflows (ac-ft per year), (b) outflows (ac-ft per year), (c)CL loads (mt per year), (d) CL discharges (mt per year), (e) P loads (mt per year), and (f) P discharges (mt per year).

The P budget was developed in the same way as the CL budget. In this instance the difference between the monthly net inflow and monthly change in mass was considered sediment water interactions (e.g., settling or resuspension). Unmeasured inflow concentration was set to 0.057 mg/L, a median value of all measured inflow discharges. Missing values for S63 were set to 0.05 mg/L, the median of all measurements made at S63. Calendar Year 2004 (CY2004) and CY2005 were excluded from these summary figures because of the extreme conditions experienced in these two years: these lakes were drawn down in 2004 to allow for Lake Tohopekaliga restoration, and the lakes were directly affected by Hurricanes Charley, Frances, and Jeanne in 2004 and Wilma in 2005. Given these exclusions, measured surface flows were 52 percent of the P load to the lake system, unmeasured inflows 43 percent and atmospheric deposition 5 percent (**Figure 9-39**, panel e). Outflow was 79 percent of the total removal, while settling was 21 percent and unmeasured outflow less than 0.3 percent (**Figure 9-39**, panel f). The budget indicates a significant amount of load is unmeasured and the lake is a sink for P.

KCOL Watershed Nutrient Budget

A watershed-focused nutrient budget study completed in 2013 identified relative contributions of P from land uses and related sources as part of the Lake Okeechobee Watershed Protection Program (JGH Engineering 2013). PN-Budget, a nutrient budget tool, also was developed to estimate the amount of P that enters, exits or remains within a study area, as well as P load and concentrations from all major contributing basins of the KCOL.

The PN-Budget tool estimates the total amount of nutrients that enter and exit a user-specified area on an annual average basis. Two sources of nutrients are considered. The first is rainfall, which was estimated as a constant value based on average rainfall amount for the selected area and concentration. The second is the net nutrient contribution resulting from anthropogenic land use activities, also known as net import. The export component includes the runoff P estimated with WAM (SWET 2011a, b). WAM is a process-based hydrologic and water quality model that uses land use, soils, rainfall, fertilization practices, and location within the drainage basin to estimate flow and P load of both direct runoff and attenuated discharge to the lake. On-site storage is the amount of nutrients retained in the soils and is calculated as the nutrients in rainfall plus net nutrient import minus the nutrients in runoff (source load) (**Figure 9-40**).

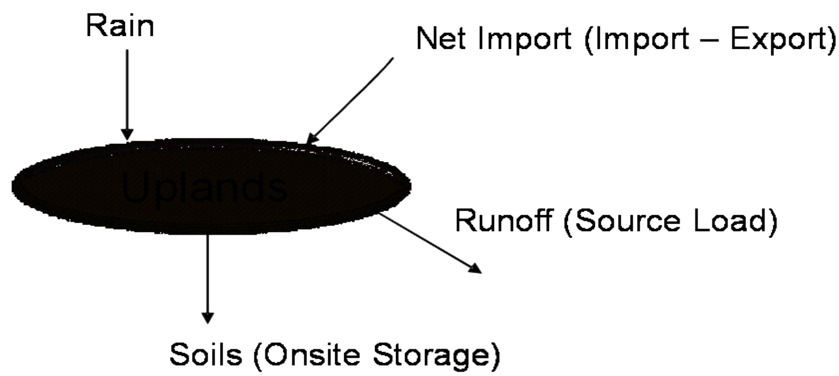

Figure 9-40. P budget mass balance components for uplands in the Upper Kissimmee Subwatershed. Net import was determined based on surveys and runoff value was calculated using WAM.

The specifics of imports and exports were considered through assessment of the most probable land use activities, such as fertilizing crops, feeding livestock, sewage outflows, stocking, and harvesting rates. Research was conducted including a literature review, landowner surveys, and interviews with local regulatory agents and other experts to determine P imports and exports associated with anthropogenic activities for major land uses in the Lake Okeechobee Watershed. Based on previous studies, types of P imports, and exports associated with anthropogenic activities are common across the various land uses. P imports included fertilizers (P delivered to the land in fertilization practices), feeds (P consumed and deposited by livestock, people, and pets), and cleaners (P in products used to disinfect livestock), whereas exports included livestock (sale and culling of livestock), harvest (removal and sale of crops), hay (production of hay for feed), sod (sold out of the region), milk (sold out of the region), and septic (cleaning of septic tanks and removal of waste). The net P import coefficients were determined based on average information obtained for each land use and developed by region because land use activities vary in different geographic locations due to soil and climate conditions. The net P import coefficients are applied spatially to the land use data set to derive the areal extent and distribution of the net P imports (**Figure 9-41**). Areas in green indicate a net exporter, e.g., more nutrients are removed from the basin than added. Areas in brown indicate that the land use is a net importer and nutrient reduction measures will need to be implemented.

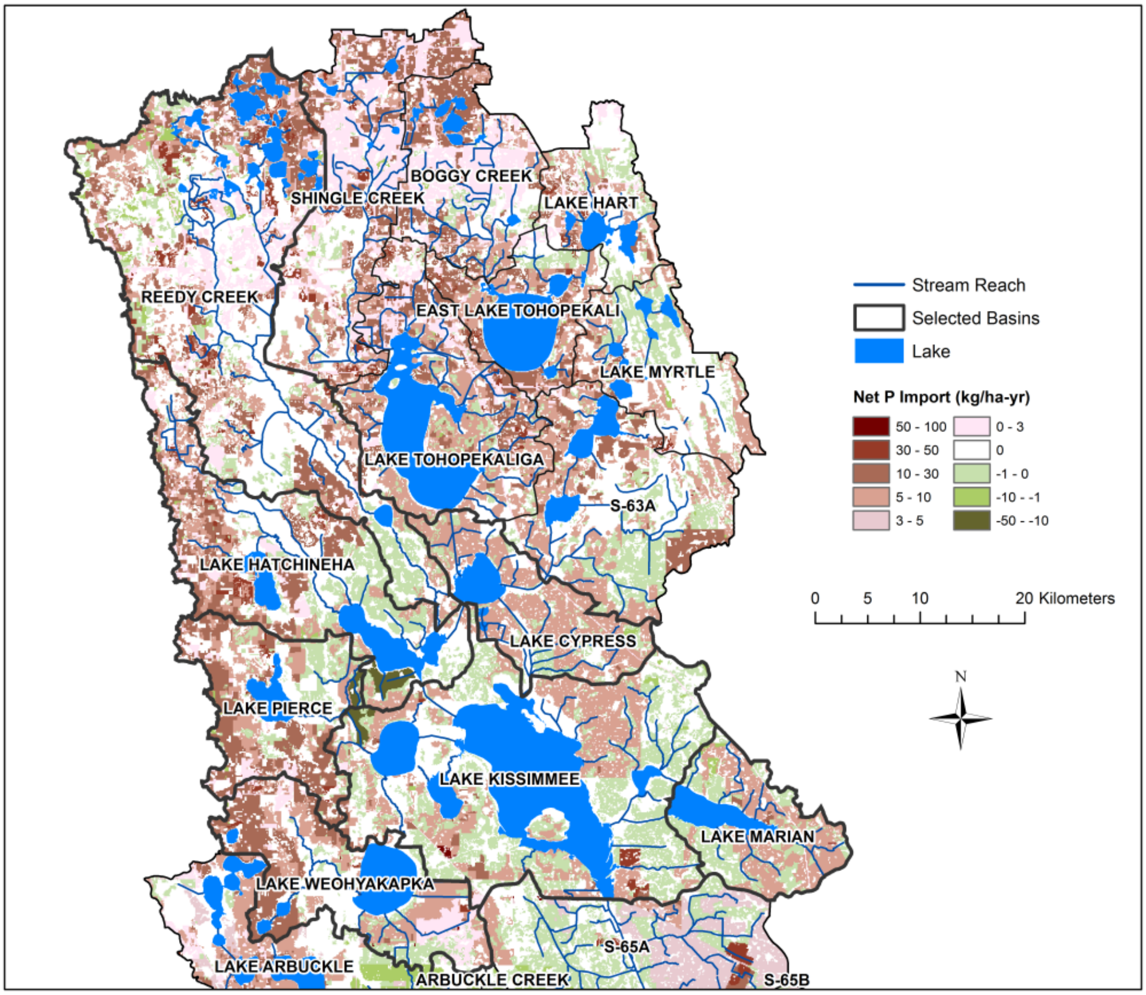

Figure 9-41. Areal extent and distribution of net P imports within KCH and the upstream drainage areas (areas in brown indicate that the land use is a net importer and green areas indicate a net exporter, e.g., more nutrient removed from the basin than added).

The total net P imports within the KCH and other selected contributing basins (**Figure 9-41**) are based on calculated area and net imports for 24 land uses (**Table 9-13**). The land use with the highest net import contribution was improved pasture followed by residential-medium density and Citrus. Rainfall contributed about 53 mt per year to the basin. An estimated 77 mt per year (net imports + rainfall – on-site storage) was discharged via runoff and groundwater from the individual land uses into wetlands, streams, and lakes. It is estimated that as much as 960 mt per year could be retained annually in the soils, referred to as on-site storage.

Table 9-13. Summary of P import, export, net import, and on-site storage for the selected drainage basins.

Land Use	Area (hectares)	P Import (mt)	P Export (mt)	Net Import (mt)	Rainfall (mt)	Source Load (mt)	On-site Storage (mt)
Aquaculture	106	6.7	0.5	6.2	0.0	0.2	6.1
Barren Land	3,189	0.0	0.0	0.0	0.6	1.9	-1.3
Citrus	15,218	290.1	83.0	207.1	3.0	3.1	207.1
Commercial Forestry	2,410	33.8	38.1	-4.4	0.5	0.2	-4.1
Field Crops	2,290	92.5	74.5	18.0	0.5	3.1	15.4
Forested - Coniferous	8,610	0.0	0.0	0.0	1.7	0.1	1.6
Forested - Deciduous	8,577	0.0	0.0	0.0	1.7	0.1	1.6
Golf Course	2,761	89.2	0.0	89.2	0.6	0.5	89.3
Horse Farms	14	0.3	0.0	0.3	0.0	0.0	0.3
Improved Pasture	36,566	295.0	24.8	270.2	7.7	15.0	262.9
Ornamentals	46	1.0	1.4	-0.4	0.0	0.1	-0.5
Other Urban	13,801	24.7	0.0	24.7	2.9	10.2	17.5
Poultry	37	0.0	0.0	0.0	0.0	0.0	0.0
Residential - High Density	2,754	26.1	0.4	25.6	0.6	0.9	25.3
Residential - Low Density	9,389	93.1	0.3	92.8	1.9	1.6	93.0
Residential - Medium Density	11,442	262.4	1.6	260.8	2.4	1.7	261.4
Residential - Mobile Home Units	533	35.4	11.4	24.0	0.1	1.6	22.5
Sod Farm	1,404	52.9	74.0	-21.1	0.3	7.9	-28.8
Tree Nurseries	146	3.3	0.6	2.7	0.0	0.4	2.4
Truck Crops	447	36.5	21.8	14.7	0.1	0.1	14.7
Unimproved Pasture	39,180	0.0	26.0	-26.0	8.2	7.2	-25.0
Water Bodies	33,079	0.0	0.0	0.0	6.9	8.0	-1.1
Wetlands	62,604	0.0	0.0	0.0	13.0	13.4	-0.3
Total	**254,603**	**1,342.9**	**358.4**	**984.5**	**52.9**	**77.3**	**960.1**

The PN-Budget Tool provided estimates of loads from various reaches of tributaries to KCH for CY2006 to CY2010. These were summed to estimate both the major and minor tributary inputs to these lakes (**Table 9-14**). These PN-Budget Tool tabulations were compared to the estimates from the lake nutrient budget for the same period. This comparison of essentially a top down (e.g., PN-Budget Tool; JGH Engineering 2013) and bottom up (Lake Nutrient Budgets; James 2014a, b) approach should determine if the original estimates of minor tributaries from the Lake Nutrient Budgets are reasonable and if the PN-Budget Tool can be used to improve the Lake Nutrient Budgets. Flow estimates of the PN-Budget Tool are within a standard deviation of the average values for the Lake Nutrient Budgets. P load estimates of the PN-Budget Tool for these lakes are also within a standard deviation of the Lake Nutrient Budget values. In summary, both the Lake Nutrient Budgets and PN-Budget Tool estimates seem reasonable.

Table 9-14. Comparison of average (±1 standard deviation) of flows and load estimates from KCH lake nutrient budget estimates and the average estimated values (JGH Engineering 2013) from the PN-Budget Tool for CY2006–CY2010.

Estimate	Nutrient Budget	PN-Budget Tool
Measured tributary flows (S61, REEDY, & S63) (ac-ft per year)	297,272 ± 167,844	388,940
Unmeasured (other) inflows (ac-ft per year)	246,870 ± 129,213	160,949
Total inflows (ac-ft per year)	544,142 ± 297,057	549,889
Measured tributary (S61, REEDY, & S63) P loads (mt per year)	21.9 ± 11.0	24.0
Unmeasured (other)P loads (mt per year)	17.4 ± 9.1	11.3
Total P load (mt per year)	39.3 ± 20.0	35.3

Upper Kissimmee Subwatershed Water Quality Analyses

To better understand the current water quality health of many areas within the Upper Kissimmee subwatershed, Osceola County undertook a preliminary assessment of 15 waterbody identification units in February 2015. Water quality data from the state's STORET database was reviewed and analyzed using all the requirements set forth in the rules. The data covered CY2000 to CY2012 with between 5 to 468 TP samples, 7 to 140 TN samples, and 2 to 212 chlorophyll *a* (Chla) samples per water body (**Table 9-15**). The median and mean values for TP and TN were very close to one another with a few exceptions. TP ranged from 0.018 at Trout Lake to 0.170 at Gator Bay. TN ranged from 0.39 at BB Slough to 1.94 mg/L at Center Lake. Chla ranged from less than 1 at Boggy Creek to 32.8 at BB slough. Based on the improved condition and analysis methodology, East Lake Tohopekaliga and Lake Hatchineha have improved and now fall below the nutrient thresholds.

In addition, water quality trends were analyzed as part of the Lake Tohopekaliga Nutrient Reduction Plan First Biennial Update (Honour et al. 2014). Statistically significant decreases in concentrations from CY2000 to CY2012 were observed for P at East Lake Tohopekaliga, Lake Tohopekaliga, Shingle Creek, and St. Cloud Canal and for TN at East Lake Tohopekaliga, Boggy Creek, Mill Slough and Hart Branch. Significant increasing nitrogen (N) concentrations were also observed at Shingle Creek, Lake Tohopekaliga, and St. Cloud Canal.

P, N, and CL have been measured in 26 locations within the watershed (**Figure 9-42**) in support of the Lake Tohopekaliga Nutrient Reduction Plan. Monthly sampling trips were conducted and a sample was taken at each location if water flow was observed. Most locations have been sampled at least 20 times since September 2011 (**Table 9-16**). Three sample locations (King's Highway Ditch, South Stewart Street, and Seaman Ditch) were determined to be non-representative of area discharge due to no/low flow, depth, or existing base flow conditions; therefore, sampling was discontinued and these sites are not included. The average TP values for this period ranged from 0.018 mg/L at Turnberry to 0.527 mg/L at East Lake Boulevard with a grand mean of 0.134 mg/L. Variation within stations was rather large averaging 0.070 mg/L, which is 55 percent of the mean value.

The mean N value was also lowest at Turnberry (0.70 mg/L) and highest at Judges Ditch (2.72 mg/L) with a grand mean of 1.28 mg/L. The variation of N was not as great as P with an average value of 0.39 mg/L, which is only 31 percent of the mean value.

The mean CL values ranged from a low of 14.2 at Jim Branch to a high of 95 at Gator Bay. The grand mean was 33.1 mg/L. The average variation was only 9.6 mg/L, which was 29 percent of the average value.

Table 9-15. Summary statistics for TP, TN, and Chla samples collected from CY2000 to CY2012 in waterbodies within the Upper Kissimmee watershed. Data were downloaded from Florida STORET and analyzed for trends (Honour et al. 2014).

Waterbody	TP				TN				CHLA			
	Mean	Median	Sample Size	Standard Deviation	Mean	Median	Sample Size	Standard Deviation	Mean	Median	Sample Size	Standard Deviation
Alligator	0.019	0.019	257	0.011	0.57	0.56	24	0.24	3.0	3.0	27	1.9
Bass Slough	0.067	0.075	6	0.018	0.76	0.77	7	0.11	1.1	1.1	6	0.8
BB Slough	0.090	0.060	26	0.079	0.39	0.31	82	0.25	32.8	6.3	32	75.2
Boggy Creek	0.040	0.030	105	0.021	0.61	0.56	99	0.20	1.0	1.0	14	0.3
Center Lake	N/A[a]	N/A	N/A	N/A	1.94	1.96	30	0.13	9.1	7.5	22	5.0
East Lake Tohopekaliga	0.020	0.020	392	0.006	0.71	0.69	140	0.15	4.8	3.7	132	4.2
Fish Lake	0.051	0.049	156	0.009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gator Bay	0.170	0.160	5	0.031	1.01	1.02	5	0.28	18.0	18.0	2	8.2
Lake Gentry	0.023	0.022	173	0.011	1	0.97	12	0.15	4.4	2.7	38	5.1
Hatchineha East	0.070	0.060	143	0.028	1.46	1.43	134	0.39	21.5	19.2	106	14.3
Hatchineha Mid	0.050	0.050	201	0.023	1.44	1.42	134	0.30	20.1	19.0	136	12.5
Lake Lizzie	0.020	0.020	222	0.005	1.04	0.97	12	0.23	3.9	3.3	12	2.0
Shingle Creek Central	0.060	0.060	46	0.024	0.65	0.6	37	0.18	1.6	1.3	37	1.2
Single Creek South	0.060	0.060	185	0.028	0.95	0.87	131	0.37	N/A	N/A	N/A	N/A
Southport Canal	0.060	0.060	30	0.033	1.37	1.35	18	0.35	21.7	17.7	15	12.9
Tohopekaliga Goblets Cove	0.030	0.030	144	0.015	0.89	0.84	113	0.23	9.3	6.9	95	7.8
Tohopekaliga Mid	0.060	0.050	460	0.039	1.08	1.09	42	0.23	21.3	17.0	32	12.1
Tohopekaliga North	0.080	0.060	468	0.139	1.13	1.02	132	0.49	13.1	8.4	212	13.1
Tohopekaliga South	0.050	0.050	320	0.018	1.23	1.18	124	0.32	25.0	23.0	116	19.7
Trout Lake	0.018	0.018	112	0.003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

a. N/A – not applicable.

Table 9-16. Summary statistics for TP, TN, and CL samples collected from September 2011 to May 2015 at 23 sampling locations in support of the Lake Tohopekaliga Nutrient Reduction Plan. Samples were taken only if flow was detected during a monthly sampling event.[a]

Station	TP			TN			CL		
	Mean	Standard Deviation	Sample Size	Mean	Standard Deviation	Sample Size	Mean	Standard Deviation	Sample Size
CIRCLE K	0.115	0.061	16	1.19	0.65	16	30	9.3	10
ET05253114	0.038	0.011	30	1.22	0.13	30	20.8	2.8	24
E LK BLVD	0.527	0.251	18	1.4	0.3	18	37.1	7.9	13
FANNY_BASS	0.077	0.022	30	0.92	0.23	30	37.4	9.5	25
FISH LAKE	0.069	0.019	28	1.33	0.16	28	27.8	2.9	23
GATOR_BAY	0.398	0.258	23	1.47	0.57	23	95	52.8	18
JIM BRANCH	0.107*	0.073	28	0.72	0.27	28	14.2	3.5	23
JUDGES_DCH	0.277	0.208	19	2.72	1.99	19	20.6	6.5	15
KISS VIEW	0.074	0.027	17	0.87	0.2	17	22.3	4.3	11
NARCOOSEE	0.031	0.01	24	1.98	0.59	24	37.9	6.6	21
N GRANADA	0.093	0.098	30	0.98	0.21	30	31.5	4.5	25
N STEWART	0.074	0.038	21	1.24	0.26	21	33	23	16
ORNGWOOD	0.227	0.171	13	1.63	0.5	13	46.4	27.2	8
PARTIN CNL	0.073	0.029	33	0.87	0.17	33	25.2*	3.6	27
PEBBLE PT	0.071	0.044	27	0.95	0.2	27	22.5	3.8	22
PH_MHPK	0.307	0.111	16	2.59	0.65	16	56.5	15.1	14
POIN FIRE	0.111	0.039	18	1.57	0.38	18	15.9	3	13
QUAIL RDG	0.033	0.011	12	0.84	0.34	12	16.8	2.8	10
REMINGTON	0.15	0.052	21	1.25	0.24	21	28	3.1	16
RUNNYMEDE	0.046	0.015	24	0.86	0.13	24	31.3	7.1	19
S GRANADA	0.089	0.035	24	1.09	0.49	24	28.6	7.2	19
TURNBERRY	0.018	0.008	26	0.7	0.19	26	22.9	4.1	21
WPA CNL	0.053	0.021	32	0.95	0.23	32	50.6	11.3	26
Grand Mean	**0.134**	**0.070**		**1.28**	**0.39**		**33.1**	**9.6**	

a. Significant ($p < 0.05$) decreasing linear trend detected using a Kendall's Tau seasonal trend analysis (Reckhow et al. 1992). No significant increasing trend detected.

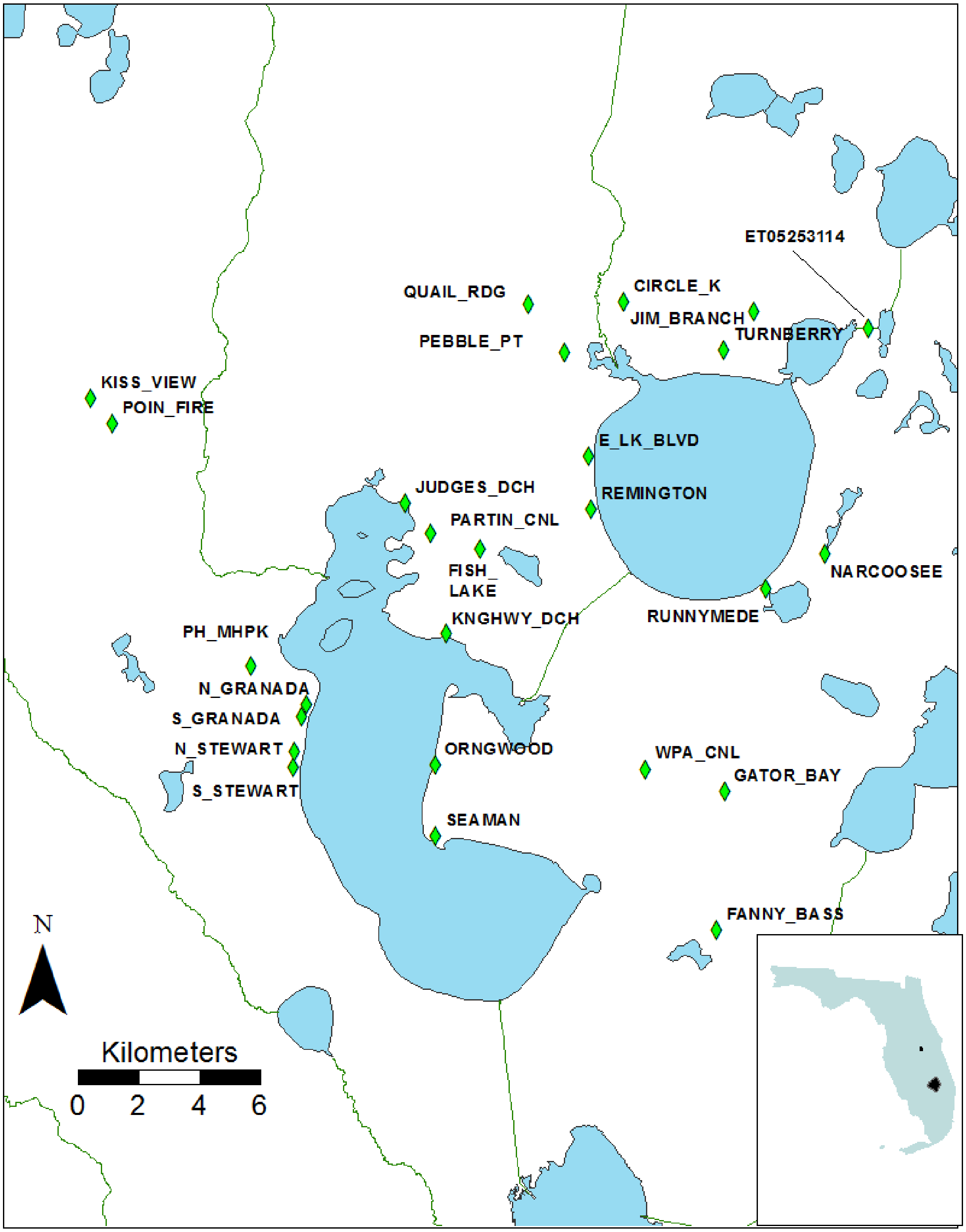

Figure 9-42. Sampling locations used in support of the Lake Tohopekaliga Nutrient Reduction Plan.

To determine if any significant linear trends existed, a Kendall's Tau trend analysis (Reckhow et al. 1992) was performed for each location and nutrient. Only two significant trends were found (both decreasing **Table 9-16**): Jim Branch for TP and Partin Canal for CL. No significant trends were observed for N. This lack of trends was expected due to the low number of years of data (less than five, see Meals et al. 2011).

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