SOUTH FLORIDA WATER MANAGEMENT DISTRICT

DRAFT
Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes

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EXECUTIVE SUMMARY

This document summarizes technical information that supports establishment of a water reservation for the Kissimmee Basin. The South Florida Water Management District will use this technical information to identify the water needed for the protection of fish and wildlife in the basin. Water for the protection of fish and wildlife means water for ensuring a healthy and sustainable native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood, and population variation.

The Kissimmee Basin water reservations involve eight different reservation waterbodies including the Kissimmee River and floodplain, and seven groups of lakes within the Kissimmee Chain of Lakes located north of the Kissimmee River. The total area associated with all of the reservation waterbodies within the Kissimmee Basin is approximately 172,500 acres. The Kissimmee Chain of Lakes is comprised of the Upper Chain of Lakes and the Headwaters Revitalization Lakes. The Headwaters Revitalization Lakes include Lakes Kissimmee, Cypress, and Hatchineha. These Headwaters Revitalization Lakes are closely associated with the Kissimmee River Restoration Project performance and have a separately authorized federal regulation schedule.

The proposed water reservation for the Headwaters Revitalization Lakes and Kissimmee River, in accordance with the authorized Kissimmee River Restoration Project including the Headwaters Revitalization Schedule, will reserve all surface water that is not already an existing consumptive use. Within the Upper Chain of Lakes, surface water at and below the “water reservation line” is necessary for fish and wildlife and existing consumptive uses; thus surface water above the water reservation line will be available for future allocation. This document outlines the technical basis of how the water reservation was established for fish and wildlife in the Upper Chain of Lakes. It also outlines the basis for the reservation in the Headwaters Revitalization Lakes and Kissimmee River and its floodplain.

The Kissimmee River Restoration Project involves a $980 million public investment and was developed to address public concerns about the effects of the Central & South Florida Flood Control Project on the Kissimmee River—specifically the altered hydrology, the loss of floodplain wetlands, and resulting loss of habitat and reduced populations of many species of fish and wildlife. An integral component of the restoration project was the development of a new regulation schedule for the S-65 water control structure, which is the outlet from the Headwaters Revitalization Lakes to the Kissimmee River. The new schedule, called the Headwaters Revitalization Schedule, was developed to provide the flows necessary to meet the ecological integrity goal of the Kissimmee River Restoration Project. The recommended plan is described in the report *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida* (USACE 1991). The recommended plan was authorized by the United States Congress in the Water Resources Development Act of 1992. The details of the Headwaters Revitalization Schedule are further described in the *Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification*

Report and Supplement to the Environmental Impact Statement (USACE 1996). The federal authorization and these two project documents are the basis for reserving all of the surface water within the Headwaters Revitalization Lakes and the Kissimmee River and its floodplain.

Once in effect, the South Florida Water Management District's consumptive use permitting program will use the water reservation rule and implementing criteria to ensure that consumptive use permit applicants do not withdraw reserved water. Due to the ephemeral nature of available water in the Upper Chain of Lakes, new consumptive use permittees will only be authorized to withdraw their permitted allocations when lake stages are above the water reservation line as measured on a daily basis. The water reservation rule includes a hydrograph for each reservation waterbody as well as a table enumerating the daily lake stages depicted by the hydrograph.

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ACRONYMS AND ABBREVIATIONS

° C	degrees Celsius
° F	degrees Farenheit
AFET	Alternative Formulation and Evaluation Tool
AFET-W	Alternative Formulation and Evaluation Tool for Water Reservation
C&SF Project	Central and Southern Florida Flood Control Project
cfs	cubic feet per second
CFWI	Central Florida Water Initiative
cm	centimeter
cm/s	centimeters per second
DCA	Department of Community Affairs
DEM	Digital Elevation Model
District	South Florida Water Management District
ET	Evapotranspiration
F.S.	Florida Statutes
ft	feet (foot)
ft/s	feet per second
ft^3/s	cubic feet per second
FWC	Florida Fish and Wildlife Conservation Commission
GIS	geographic information systems
KBMOS	Kissimmee Basin Modeling and Operations Study
KCOL	Kissimmee Chain of Lakes
km	kilometer
km^2	square kilometers
KRREP	Kissimmee River Restoration Evaluation Program
KRVC	Kissimmee River Vegetation Classification

LKB	Lower Kissimmee Basin
m	meter
m^2	square meters
MGD	million gallons per day
MIKE SHE/MIKE 11	an integrated hydrologic modeling system
NGVD	National Geodetic Vertical Datum of 1929
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
UCOL	Upper Chain of Lakes
UKB	Upper Kissimmee Basin
UKISS	Upper Kissimmee Chain of Lakes Simulation
USACE	United States Army Corps of Engineers

SECTION 1: INTRODUCTION

Overview and Purpose of Document

This document summarizes the technical and scientific data, assumptions, models, and methodology used to support rule development to reserve water for the protection of fish and wildlife for specific waterbodies located in the Kissimmee Basin. The meaning of "water needed to protect fish and wildlife" is discussed in more detail in Section 2 under the Statutory Authority for Establishing Water Reservations section. A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. A reservation may be established in such locations and quantities, and for such seasons of the year, as may be required for the protection of fish and wildlife or the public health and safety.

The waterbodies that are the subject of this water reservation are unique in that they are also components of the Central and Southern Florida Flood Control Project (C&SF Project). The C&SF Project is a multi-objective project, originally authorized by the *Flood Control Act of 1948* (U.S. Congress 1948) and modified by subsequent acts, that provides for flood control, drainage, water supply, and other purposes. The South Florida Water Management District (District or SFWMD) is the local sponsor of the C&SF Project (Section 373.1501, Florida Statutes [F.S.]). In 1992, the United States Congress authorized the C&SF Project to include ecosystem restoration of the Kissimmee River and Kissimmee River Headwaters Revitalization. In its capacity as local sponsor, the District operates and maintains the C&SF Project, including the subject reservation waterbodies. Operation of project components is required to occur in accordance with federally adopted regulation schedules. The regulation schedules, in summary, define water releases from the subject waterbodies and are particularly related to stage and time of year (USACE 1994). Therefore, the proposed water reservation must 'dovetail' with the authorized federal regulation schedules for the subject waterbodies.

The information provided in this document is presented in the sequential steps that correspond to the District's scientific and technical process for quantifying of water necessary for the protection of fish and wildlife in the Kissimmee Basin waterbodies, which are the subject of the proposed water reservations.

Reservation Waterbodies

The eight specific waterbodies that are the subject of the proposed water reservations include the Kissimmee River and floodplain, as well as seven Kissimmee Chain of Lakes (KCOL) reservation waterbodies or lake groups, which also include contributing waterbodies and tributaries. The reservation waterbodies, as shown in **Figure 1**, are as follows:

1. Kissimmee River and floodplain

2. Seven KCOL reservation waterbodies (lake groups)

   Upper Chain of Lakes (UCOL)

   a. Lakes Myrtle–Preston–Joel
   b. Lakes Hart–Mary Jane
   c. East Lake Tohopekaliga
   d. Lake Tohopekaliga
   e. Alligator Chain of Lakes
   f. Lake Gentry

   Headwaters Revitalization Lakes:

   g. Lakes Kissimmee–Cypress–Hatchineha–Tiger

The Kissimmee River and its 100-year floodplain are delineated by the United States Army Corps of Engineers (USACE) between structures S-65 and S-65D along with that portion of the Istokpoga Canal located east of the S-67 structure (**Figure 1**). It also includes the C-38 canal and remnant river channels from structures S-65 to S-65E. These waterbodies are treated as a single reservation waterbody because the hydrologic conditions within these waterbodies and canals are tightly coupled. The remaining reservation waterbodies consist of one or more lakes and canals in the KCOL, all of which are part of the C&SF Project or are hydrologically connected to the C&SF Project by man-made or natural conveyance features. The KCOL reservation waterbodies contribute flows to each other as well as to the Kissimmee River. The 17 lakes and their tributary watersheds are combined into operational groupings. Water levels and flows within each operational group are managed in accordance with water control structure regulations prescribed by USACE. These lake regulation schedules represent significant constraints that were considered in the quantification of water needed for fish and wildlife. These waterbodies are described in more detail in Section 3.

The subject reservation waterbodies are significant because, together, they form the headwaters of the Kissimmee–Okeechobee–Everglades system. The watershed for this system is composed of a diverse group of wetland, lake, and river/floodplain ecosystems. The reservation waterbodies in the KCOL represent a substantial portion of the Upper Kissimmee Basin watershed. The Kissimmee River, floodplain, C-38 canal and associated remnant river channels compose the Lower Kissimmee Basin. SFWMD and other state and federal agencies have invested considerable resources in the management of these waterbodies within the Kissimmee Basin. The single most noteworthy investment is the Kissimmee River Restoration Project. The meandering Kissimmee

River was channelized between 1962 and 1971, resulting in severe damage to the biological communities of the river and floodplain, which prompted immediate calls for restoration. The progressive steps taken toward this objective over the ensuing decades are summarized in the next section and described in detail in Appendix A.

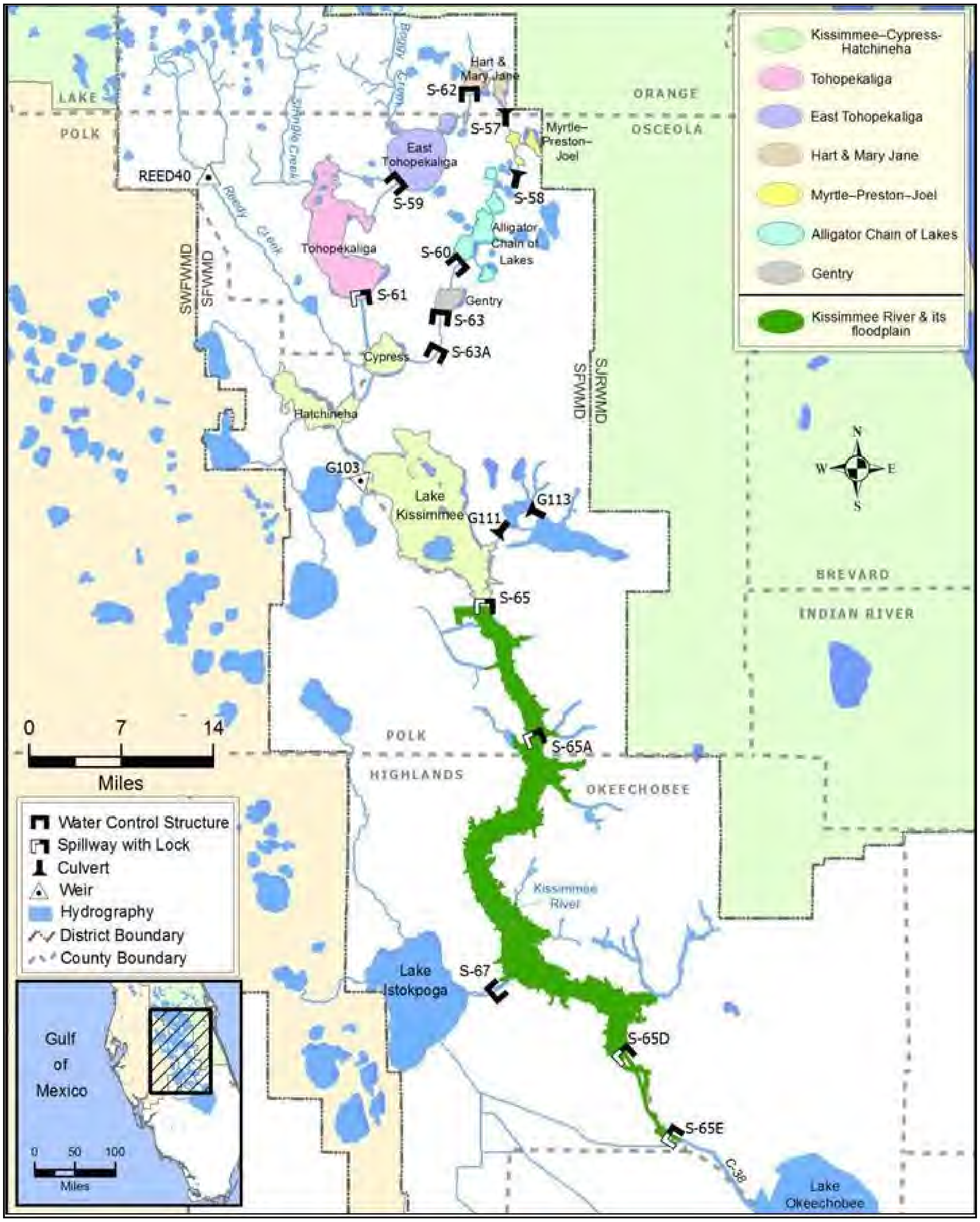

Figure 1. Map identifying the eight reservation waterbodies in the Kissimmee Basin.

Kissimmee Basin Background

The Kissimmee Basin is located in Central Florida and is the northernmost portion of SFWMD. It stretches down the middle of Florida's peninsula from Orlando to Lake Okeechobee. This section provides background information regarding events that have taken place in recent years that have helped to form the need and basis for the Kissimmee Basin water reservations.

The long-term commitment of the federal government, the State of Florida, and SFWMD to restore the Kissimmee River and floodplain must be noted, as this effort is the genesis of many supporting activities.

Table 1 provides a brief chronology highlighting major restoration actions and Appendix A provides a detailed discussion of these events.

Kissimmee River Restoration

A series of events over decades prompted the Kissimmee River Restoration Project. In 1991, the USACE completed the *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida*. The document describes the recommended plan for the Kissimmee River Restoration Project including an environmental impact statement to address the National Environmental Policy Act, Endangered Species Act, and other concerns. The *Fish and Wildlife Coordination Act Report on the Kissimmee River Restoration Project* is included as Annex E. In March 1992, the chief's report for the Kissimmee River Restoration Project was submitted to the United States Congress. Later the same year, congress passes the Water Resources Development Act of 1992 (Public Law 102-580, October 31, 1992). Section 101 of this act authorizes the Kissimmee River Restoration Project including headwaters revitalization components. This restoration project represents the culmination of state and federal planning and feasibility studies (USACE 1991, 1996), demonstration projects, legislative actions, appropriations, and other actions. Considerable public participation and investments have been made supporting this landmark project. The estimated final cost is 980 million dollars for the authorized project to restore the Kissimmee River by SFWMD and USACE.

Reconstruction of the river has been occurring in phases since the late 1990s and is approximately 65 percent complete. Positive ecological responses are evident and are being monitored. The USACE Headwaters Revitalization Water Regulation Schedule of 1996 (USACE 1996) establishes a new operation plan for the southernmost lakes (Kissimmee, Cypress, Hatchineha, and Tiger) in the KCOL and will increase storage in these lakes to provide inflows for the river that replicate historical flow characteristics. However, until the river restoration construction is complete, the Headwaters Revitalization Schedule cannot be fully implemented. An interim schedule was implemented in July 2001 at the S-65 structure to initiate restoration of habitat within the reconnected river channel and to provide floodplain inundation in those areas where restoration construction activities are complete. Fish, wildlife, and habitat responses within these "restored" areas are being tracked using river/floodplain restoration performance measures.

Table 1. Timeline of significant events related to the Kissimmee River Restoration Project.

Time Period	Significant Event
1920s–1940s	Hurricanes and flooding in the Upper Kissimmee Basin.
1954	Congress authorizes the Kissimmee portion of the C&SF Project (U.S. Congress 1954).
1962–1971	C&SF Project channelizes the Kissimmee River.
1971	Governor's Conference on Water Management recommends restoration of the Kissimmee River.
1976	Kissimmee River Restoration Act (Chapter 76-113, F.S.) creates the Kissimmee River Coordinating Council.
1978–1985	First federal feasibility study notes potential for restoration, but federal funding not feasible (USACE 1985).
1983	Kissimmee River Coordinating Council recommends the backfilling plan.
1984–1990	Kissimmee River Demonstration Project shows restoration is possible.
1986	The Water Resources Act mandates that enhancements to environmental quality in the public interest should be calculated as equal to other costs.
1988	Kissimmee River Restoration Symposium adopts the ecological integrity goal.
1991	Second federal feasibility study recommends the level II backfilling plan (USACE 1991).
1992	The Water Resources Development Act authorizes the Kissimmee River Restoration Project.
1994	The District and Department of the Army sign a project cooperative agreement (DOA and SFWMD 1994).
1994	Construct test backfill and conduct high flow tests on backfill stability.
1996	Headwaters Revitalization Feasibility Study completed (USACE 1996).
1995–1999	The District conducts baseline sampling for Phase I construction (Bousquin et al. 2005).
1999–2001	Phase I backfilling completed and monitoring continues (Bousquin et al. 2005).
2006–2009	Phase IVA and IVB backfilling completed and monitoring continues.
2014	Publication of nine manuscripts in *Restoration Ecology* on interim ecosystem response to restoration in the Phase I area (Anderson 2014a, 2014b, Bousquin and Colee 2014, Cheek et al. 2014, Colangelo 2014, Jordon and Arrington 2014, Keobel and Bousquin 2014, Koebel et al. 2014, Spencer and Bousquin 2014).
2015–2019	Phase II/III backfilling and Phase IV to be completed.
2019	Implementation of Final Headwaters Revitalization Schedule following completion of all project construction and land acquisition.
2019–2023	The District to conduct post-restoration sampling for Phase I and II/III areas

Headwaters Revitalization Project

An integral component of the Kissimmee River Restoration Project was the development of a new regulation schedule for the S-65 structure, the outlet from the Headwater Lakes to the Kissimmee River. The new schedule, called the Headwaters Revitalization Schedule, was developed to provide the flows necessary to meet the ecological integrity goal of the Kissimmee River Restoration Project. In 1994, the United States Fish and Wildlife Service completes the *Fish and Wildlife Coordination Act Report on Kissimmee Headwater Lakes Revitalization Plan* pursuant to the requirements of Fish and Wildlife Coordination Act and the Endangered Species Act of 1973 (USFWS 1994). The technical analysis associated with the Headwaters Revitalization Schedule was completed in April of 1996 and is described in the *Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement* (USACE 1996). In November 1996, the USACE issues *Record of Decision Headwaters Revitalization Project Kissimmee River, Florida*. This document approved the recommended plan described in USACE (1996) after finding it “to be economically justified, in accordance with environmental statues, and in the public interest”. The Headwaters Revitalization Schedule was authorized by congress in 1992.

As a result of these federal and state authorizations and funding, there is a need to provide assurances that the water needed to achieve hydrologic performance criteria required to meet the ecological integrity goal are not allocated to consumptive uses. Hence, the District has initiated the water reservation rule development process.

Kissimmee Chain of Lakes Long-Term Management Plan and Kissimmee Basin Modelling and Operations Study

In 2003, the Governing Board initiated the Kissimmee Chain of Lakes (KCOL) Long-term Management Plan to address emerging management challenges within the KCOL related to the C&SF Project. Collectively, the lakes located north of the Kissimmee River are referred to as the KCOL. The Governing Board directed staff to work with USACE staff and other stakeholders to develop a plan to manage the KCOLs. An early spin off of the KCOL Long-term Management Plan scoping effort was the Kissimmee Basin and Modeling Operations Study.

The Kissimmee Basin and Modeling Operations Study was initiated in 2004 and focused on a comprehensive review of the C&SF Project operating criteria to align and potentially change water control operations throughout the KCOL to enhance and sustain habitat conditions for fish and wildlife. Future operational changes within the KCOL would occur while ensuring that the discharges at the S-65 structure were compatible with the Kissimmee River Restoration Project. In 2013, the Kissimmee Basin Modeling and Operations Study was put on hold after concurrence by USACE and SFWMD to move forward with implementation of the Headwaters Revitalization Schedule after completion of the Kissimmee River Restoration Plan. If the restoration targets are not being met after implementation of the Headwaters Revitalization Schedule, USACE and SFWMD will determine if modifications to the schedules within the Upper Chain of Lakes (UCOL) are needed in the future.

Central Florida Water Initiative

In 2006, the Central Florida Coordination Area "Action Plan" was initiated between three water management districts—St. Johns River Water Management District, Southwest Florida Water Management District, and SFWMD—to address short- and long-term development of water supplies in the central Florida area, which included Orange, Osceola, Seminole, Polk, and southern Lake counties. This effort, over time, evolved into the ongoing Central Florida Water Initiative (CFWI). CFWI includes, in part, a joint water supply planning effort where there is a renewed emphasis for alternative water supply within this region.

Kissimmee Basin Water Reservations

In June 2008, the SFWMD Governing Board initiated rule development for Kissimmee Basin water reservations. The technical approach to identify the hydrologic requirements to ensure the protection of fish and wildlife is the basis for the current rule development process.

In March 2009, SFWMD developed a draft technical document to support the water reservation rule development efforts entitled *Draft for Scientific Peer Review Panel: Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*. This draft technical document was reviewed by an independent scientific peer review panel in April 2009 in accordance with the Florida Department of Environmental Protection's guidance in Rule 62-40.474(4), Florida Administrative Code. This rule states that water management districts shall require "an independent scientific peer review of all scientific or technical data, methodologies, and models, including all scientific and technical assumptions employed in each model, used to establish a reservation, if the District determines such a review is needed."

The peer review panel was asked to review the scientific and technical analyses summarized in the 2009 draft technical document and evaluate the analyses' validity and soundness. The panel focused its evaluation on all scientific or technical data, methodologies, and models, including all scientific and technical assumptions employed in each model, used to establish a reservation to determine if they were reasonable.

The peer review panel determined that "the supporting data and information used are technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information."

The initial reservation effort was suspended to take into consideration the work that was ongoing with the Kissimmee Basin Modeling and Operations Study effort to potentially change the regulation schedules within the UCOL. The SFWMD Governing Board reinitiated rule development to pursue water reservations for the Kissimmee Basin in June 2014. Once adopted, these water reservations will be implemented in the District's Consumptive Use Permitting Program to evaluate permit applications. The reservation rules will require applicants to provide reasonable assurances that their proposed use of water will not withdraw water reserved for the protection of fish and wildlife.

Technical Approach

The District's technical approach to quantify water needed for the protection of fish and wildlife for the Kissimmee Basin reservations are in Sections 3 through 7 and Section 9 and involves several steps:

1. Identification of the reservation waterbodies.
2. Identification of the fish and wildlife species and habitat to be protected.
3. Identification of the water available over a representative range of hydrologic conditions (i.e., Base Condition).
4. Identification of the hydrologic performance measures that link the biologic response of the fish and wildlife being protected with stage and/or flow.
5. Comparison of the hydrologic performance measures with the water available to identify the timing and amount of water needed for the protection of fish and wildlife across a representative range of hydrologic conditions.

SECTION 2: BASIS FOR WATER RESERVATION AND APPROACH

What is a Water Reservation?

A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, which may include a seasonal and locational component.

Statutory Authority for Establishing Water Reservations

Section 373.223(4), Florida Statutes (F.S.), provides the South Florida Water Management District's (SFWMD's or District's) authority to establish reservations:

> The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.

When water is reserved under this statute, it is not available for new allocations to consumptive uses and is protected for fish and wildlife. Water for the protection of fish and wildlife means the water needed to "ensur[e] a healthy and sustainable, native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood, and population variation." (*Assoc. of Florida Cmty. Dev., et al. v. Dep't of Envtl. Prot., et al.*, DOAH Case No. 04-0880RP, [Div. of Admin. Hr'gs Final Order Feb. 24, 2006], *aff'd* 943 So. 2d 989 [Fla. 4th DCA 2006]).

The Florida Legislature gave the Governing Board's of the state's five water management districts broad discretion when establishing a water reservation, specifically authorizing the board to exercise its judgment. This discretion is appropriate given the inherent uncertainties associated with linking fish and wildlife and their water needs, over years and between seasons. In addition, the legislature intended the board to balance their various missions when establishing a reservation. This view is bolstered by the direction to periodically review and revise the reservations. This degree of discretion is helpful in reconciling the scientific uncertainties associated with defining the water needs of fish and wildlife with the objective of establishing the water reservation.

In quantifying water to be reserved, existing legal uses of water are protected as long as they are not contrary to the public interest. An existing legal use is a water use that is authorized under a consumptive use permit issued pursuant to Part II of Chapter 373, F.S., or is exempt. Issues associated with determining whether an existing legal use of water is or is not contrary to the public interest is a matter within the discretion of the SFWMD Governing Board.

Equally important is what a water reservation is not. Part II, Chapter 373, F.S., where the authority to adopt reservations lies, is focused on authorizations related to the consumptive use of water. The District's authority to act as local sponsor of the Central and Southern Florida Flood Control Project (C&SF Project) is found in Part I, Chapter 373, F.S. The provisions of Part II, Chapter 373, F.S., do not authorize SFWMD to establish criteria for operation of the C&SF Project system; the United States Army Corps of Engineers establishes C&SF Project operational criteria that SFWMD is required to implement. Thus, a water reservation criterion has a limited scope of application and does not serve as a basis to make C&SF Project operating decisions. However, the water reservation and C&SF Project operating criteria relate to one another in that the C&SF Project operating criteria effect the timing and availability of water in the C&SF Project system. Therefore, while the C&SF Project operating criteria and the water reservation are related, they are distinct in scope and application.

Rule Development Standards

SFWMD is authorized by the Florida Legislature to adopt rules to implement provisions of Chapter 373, F.S. When adopting rules, SFWMD may not act beyond the powers, functions, and duties delegated to it by the legislature. Further, SFWMD may only adopt rules that implement a specific law.

Courts look to a number of factors set forth in Chapter 120, F.S., to determine whether a proposed SFWMD rule is an invalid exercise of delegated legislative authority. These factors, in pertinent part, include whether or not 1) the agency has exceeded its grant of rulemaking authority, 2) the rule enlarges, modifies, or contravenes the specific provisions of law implemented; 3) the rule is vague, fails to establish adequate standards for agency decisions, or vests unbridled discretion in the agency; or 4) the rule is arbitrary or capricious. As the arbitrary and capricious test is of particular relevance to the peer review process, a clear understanding of this standard is appropriate. Rules that go beyond these parameters would not withstand a rule challenge proceeding.

The District, as an agency charged with implementing the reservations statute, will be afforded deference in its interpretation of the statute. Consequently, the proposed reservations rules should be upheld if they are within the range of permissible interpretations. However, courts will determine a rule is arbitrary if it is not supported by facts or logic or is despotic. See *Fla. League of Cities, Inc. v. Dep't of Envtl. Reg.*, 603 So. 2d 1363 (Fla. 1st DCA 1992). A rule that is a capricious action is one that is taken irrationally, or without thought or reason. See *Attorney's Title Ins. Fund v. Fin. Serv. Comm'n*, DOAH Case No. 07-5387 RP (Fla. Div. of Admin. Hr'gs., June 25, 2008). See also *Bd. of Clinical Lab. Personnel v. Fla. Assoc. of Blood Banks*, 721 So. 2d 317, 318 (Fla. 1st DCA 1998). A proposed rule may be deemed arbitrary and capricious, if it relies on a technical report that was "premised in unfounded assumptions and unverifiable data." *Attorney's Title Ins. Fund* at p. 79. In *Florida Medical Association v. Department of Health*, the proposed rule was deemed arbitrary and capricious because the board "neither conducted nor reviewed any studies or treatises and received no evidence to support the definition of therapeutic equivalent in the proposed rule, and likewise reviewed no studies as to the safety or benefits/detriments of having a pharmacist substitute a drug for one prescribed by the physician, DOAH Case No. 06-2899RP Fla. Div. of Admin. Hr'gs., Nov. 1, 2006 at p. 33. However, where an agency holds numerous public meetings, thoughtfully considers public comments and complex policy issues, and then carefully weighs and balances the various issues, an administrative law judge is less likely to determine the agency acted arbitrarily or capriciously when crafting the rule. See *Fla. Power & Light v. Dep't of Envtl. Prot.*, DOAH Case No 06-2871RP Fla. Div. of Admin. Hr'gs., March 1, 2007 at p. 61, *aff'd* 970 So. 2d 401 (Fla. 3d DCA 2007). Therefore, it is SFWMD's responsibility to conduct studies and analyses to identify the linkages of water to fish and wildlife needs. There can be multiple answers, methods, and interpretations; however, the interpretation ultimately selected must be within the realm of acceptable solutions within the statutory authority granted to conduct rule development.

Process Steps and Activities

This document supports SFWMD's Kissimmee Basin water reservation rule development activities. **Figure 2** summarizes the general steps that occur during the rule development process. The first step has been accomplished. The District's Governing Board authorized publication of a notice of rule development for a reservation of water for the protection of fish and wildlife for the Kissimmee Basin in June 2014.

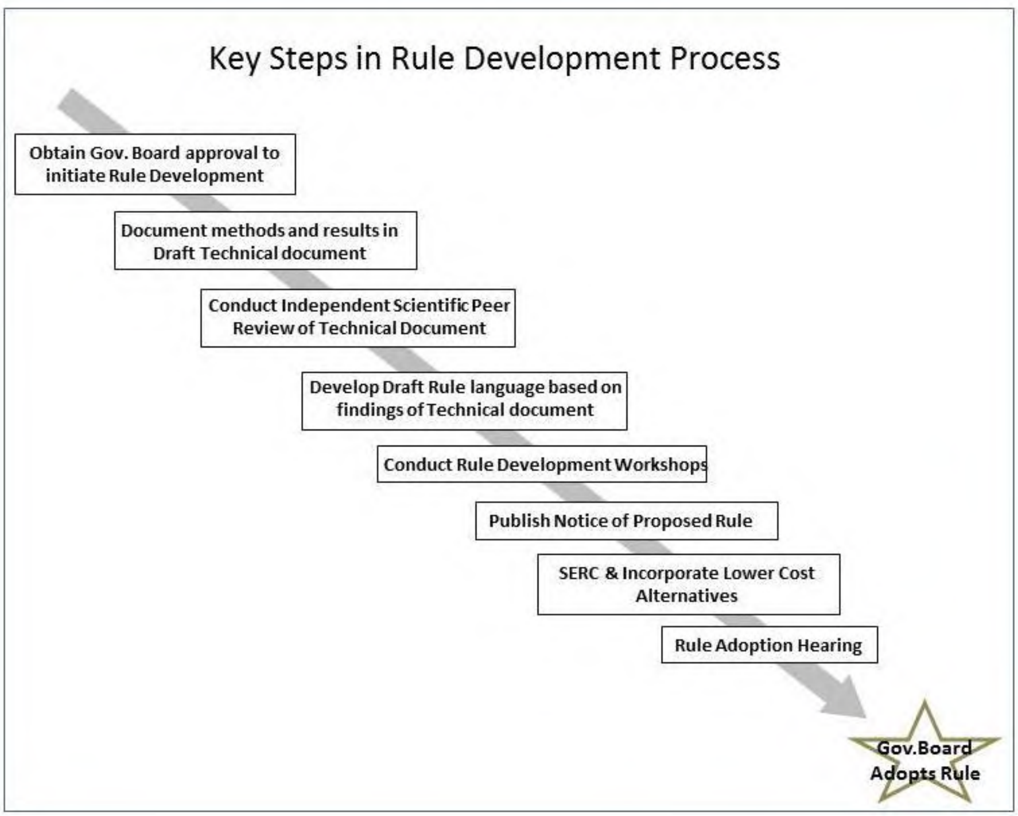

Figure 2. Process steps for developing technical information in support of a rule.

SECTION 3: RESERVATION WATERBODIES IN THE KISSIMMEE BASIN

Kissimmee Basin Overview

Located in Central Florida, the Kissimmee Basin is the northernmost basin within the boundary of the South Florida Water Management District (SFWMD or District). It is bounded on the north and east by the St. Johns River Water Management District and on the west by the Southwest Florida Water Management District. Its boundary overlaps those of six counties—Orange, Osceola, Polk, Highlands, Okeechobee, and Glades. The basin includes portions of the City of Orlando and continues southward toward Lake Okeechobee.

The Kissimmee Basin experiences a humid, subtropical climate with nearly equal length wet and dry seasons. Average yearly rainfall is 48 inches (121 centimeters [cm]) and 44 inches (114 cm) in the Upper Kissimmee Basin (UKB) and Lower Kissimmee Basin (LKB), respectively. Most precipitation falls in a distinct wet season (June–October) (SFWMD 2000). Air temperature ranges from 41 degrees Fahrenheit (° F) to 86° F (5 degrees Celsius [° C] to 30° C).

The major physiographic features of the Kissimmee Basin were formed when much of Florida was submerged (White 1970). The Kissimmee Basin has a roughly north-northwest-to-south-southeast alignment that parallels relict sandy beach ridges created by long shore currents (Warne et al. 2000). Most of the basin lies on the Osceola Plain, which is 40-miles wide and 100-miles long. The Osceola Plain is bounded on the west by the Lake Wales Ridge and on the northwest by the Mount Dora and Orlando ridges (White 1970). A scarp separates the Osceola Plain from the Eastern Valley on the northeastern and eastern borders and from the Okeechobee Plain to the south. The highest elevation of the Osceola Plain occurs in the northwest corner, where the plain rises to an elevation of 90 to 95 feet. However, most of the plain occurs between 60 and 70 feet in elevation.

The remainder of the basin lies on the Okeechobee Plain, which is 30-miles wide and 30-miles long. From the toe of the scarp separating it from the Osceola Plain, the Okeechobee Plain decreases from an elevation of 30–40 feet to 20 feet at the northern shore of Lake Okeechobee.

The sandy soils found throughout the Kissimmee Basin are derived primarily from marine-deposited silica sands. Most soil types in the UKB and LKB are classified under the Smyrna–Myakka–Basinger Soil Association. Additional information may be found in the Geotechnical Investigations Appendix of the *Central and Southern Florida Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida* (USACE 1991).

Surface Water Resources

From a water resources perspective, the Kissimmee Basin is divided commonly into the UKB and LKB at the outlet of Lake Kissimmee, which is now the S-65 structure. The UKB is 1,607 square miles (4,162 square kilometers [km^2]) in area and is more than twice the area of the LKB. The UKB contains hundreds of lakes and wetlands with the largest lakes occurring along the eastern and southern boundaries (**Figure 3**). The larger lakes include Lake Kissimmee, the third largest lake in Florida (Brenner et al. 1990). Water throughout the UKB is conveyed to the Kissimmee Chain of Lakes (KCOL), which includes the Headwaters Revitalization Lakes and the Upper Chain of Lakes located north of the Kissimmee River, through wetlands, sloughs, and tributary streams. The largest of these are Boggy, Shingle, and Reedy creeks, and Big Bend Swamp. Boggy Creek begins at the northern boundary of the basin in the City of Orlando and flows southward into the north end of East Lake Tohopekaliga. Shingle Creek also originates in the City of Orlando and carries water to Lake Tohopekaliga. Reedy Creek originates in the northwest corner of the basin. Near the mouth, Reedy Creek branches with most of the flow going into the southern branch (Dead River) into Lake Hatchineha and the rest through the northern branch into Lake Cypress. The Big Bend Swamp is located southeast of the Alligator Chain of Lakes and is connected by extensive shoreline to Brick Lake and flows into Lake Gentry. The lakes composing the KCOL are interconnected by a series of canals. Essentially all surface water draining the UKB is funneled to the KCOL, then it is discharged into the Kissimmee River (Warne et al. 2000).

The LKB is 669 square miles (1,733 km^2) in area with a long rectangular shape (**Figure 4**). The dominant hydrologic feature is the Kissimmee River, which flows from Lake Kissimmee to Lake Okeechobee. Because of the relatively narrow shape of the LKB, the drainage network is not well developed and is composed mostly of tributary sloughs. Consequently, the larger UKB is a more important source of water for the Kissimmee River than its tributary watershed.

Connectivity of the Waterbodies

The connectivity of the surface waterbodies of the Kissimmee Basin has changed over time. It is more direct in the present system than it was in the past. Before human modifications, there was a direct connection between the Kissimmee River and several of the lakes. In 1842, it was possible to travel by boat up the Kissimmee River and across Lakes Kissimmee, Hatchineha, and Cypress to Lake Tohopekaliga (Preble 1945). While well-defined channels did not connect all of the lakes, water likely moved between lakes by overland flow during wetter years and by groundwater movement under drier conditions (Warne et al. 2000).

During the 1880s, canals were dredged between lakes in the KCOL by Hamilton Disston as part of a drainage project to reclaim land. Another part of this project dredged a connection between Lake Okeechobee and the Caloosahatchee River. By 1882, it was possible to travel by steamboat from the town of Kissimmee on Lake Tohopekaliga through to Lake Kissimmee and then down the Kissimmee River, across Lake Okeechobee and down the Caloosahatchee River to Fort Myers on the Gulf of Mexico.

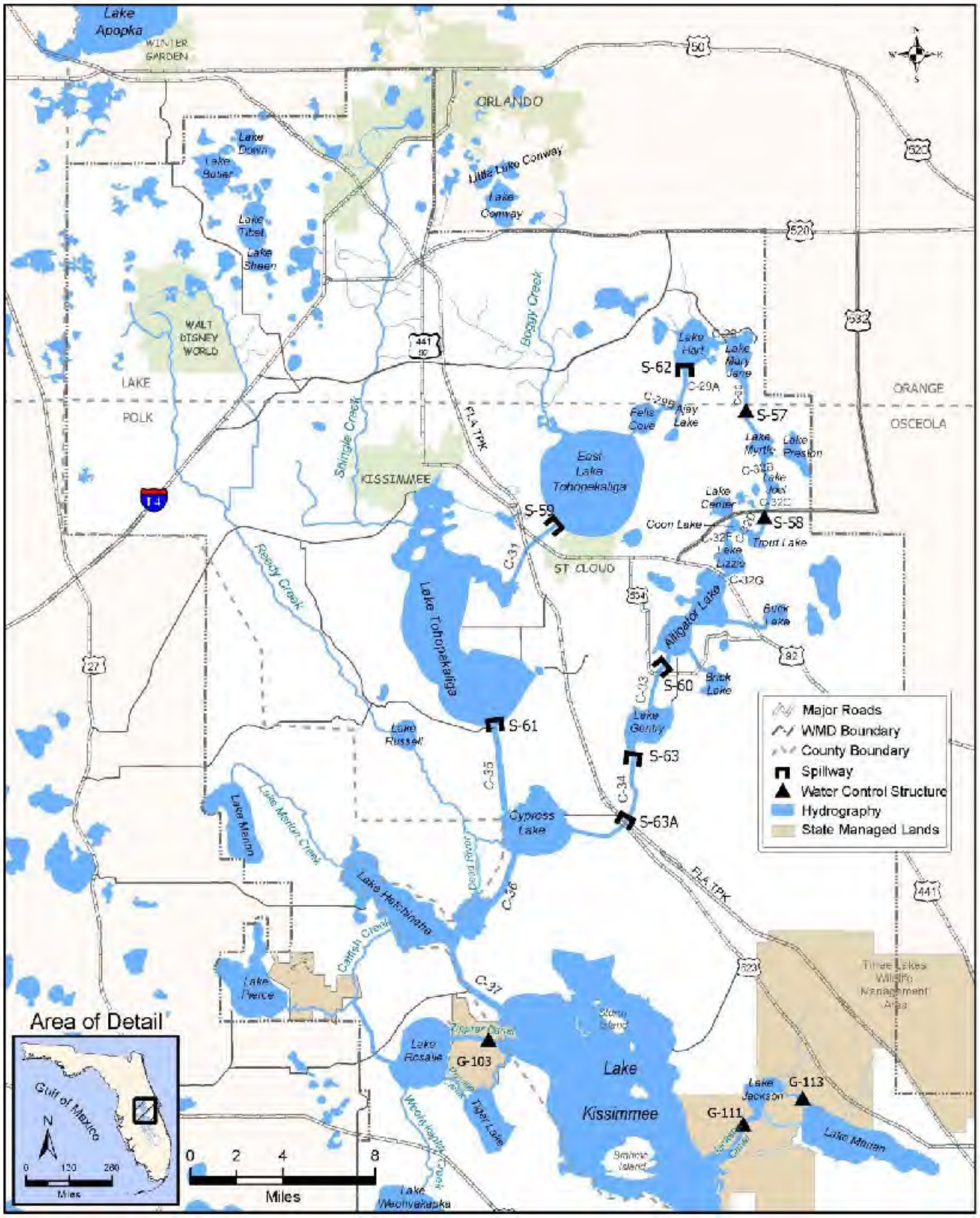

Figure 3. Map of the UKB.

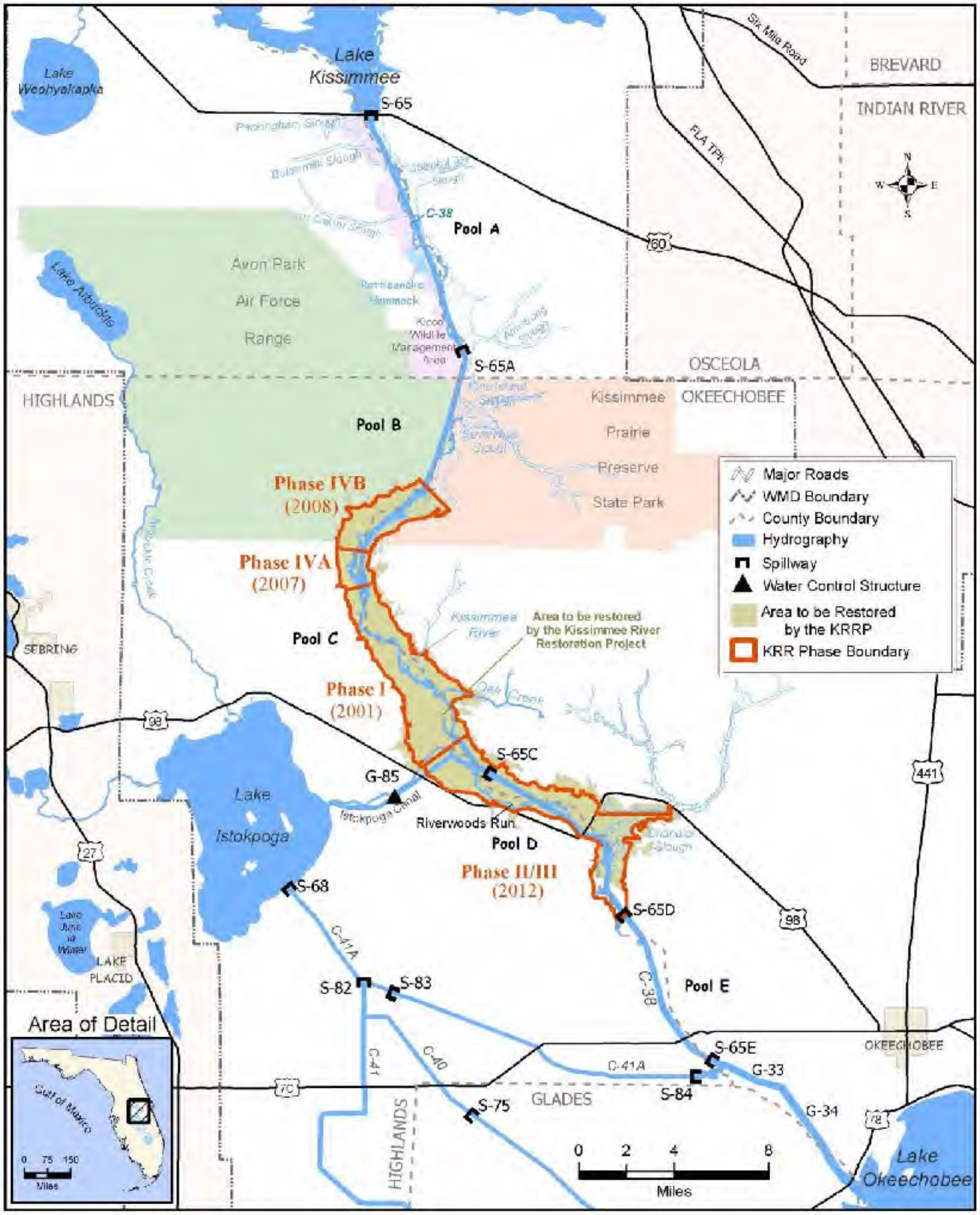

Figure 4. Map of the LKB and the area being restored by the Kissimmee River Restoration Project.

In the *River and Harbor Act of 1902*, the United States Congress authorized a federal navigation project with "a channel width of 30 feet and depth of 3 feet at the ordinary stage of the river" from the town of Kissimmee at the northern end of Lake Tohopekaliga through Lakes Cypress, Hatchineha, and Kissimmee and down the Kissimmee River to Fort Basinger. This navigation project was completed between 1902 and 1909 by the United States Army Corps of Engineers (USACE). This project involved the removal of large woody snags and the dredging of channels as necessary. In 1927, the USACE conducted the last federal maintenance dredging for this project.

In addition to these large projects, a number of small projects were conducted by private landowners and local companies. These include small structures on the Zipprer Canal between Lake Rosalie and Lake Kissimmee and a structure on the Istokpoga Canal between Lake Istokpoga and the Kissimmee River. Other small drainage ditches and levees were constructed by private landowners.

In 1947, hurricanes caused severe flooding in much of South Florida, including the Kissimmee Basin. In response to a request for help from the State of Florida, the United States Congress authorized the Central and Southern Florida Flood Control Project (C&SF Project) in 1949. Features affecting the Kissimmee Basin were authorized in 1954 and constructed between 1962 and 1972. In the UKB, these features included enlarging existing canals originally excavated by Disston, dredging a new canal to connect Lake Gentry to Lake Cypress, and installing nine water control structures. The nine structures were used to control lake water levels and the flows between the lakes. These structures are responsible for the current path of water movement through the KCOL (**Figure 5**).

Operation of the water control structures narrowed the range of water level fluctuation in the lakes. This had the effect of reducing the amount of habitat and quality of habitat for fish and wildlife. In the LKB, the C&SF Project channelized the entire length of the Kissimmee River, between Lake Kissimmee and Lake Okeechobee. In addition to the S-65 structure at the outlet from Lake Kissimmee, five water control structures were installed along the C-38 canal to step-down water levels and control the flow of water in the river. In addition, the G-85 structure was installed on the Istokpoga Canal to regulate flows from Lake Istokpoga. The G-85 structure did not contain any operable features. Due to its dilapidated condition, the G-85 structure was replaced with an operable structure (S-67) between 2011 and 2012 providing a hydraulic divide between the Lower Kissimmee and Istokpoga watersheds as part of the Kissimmee River Restoration Project. Channelization and flow regulation by the C&SF Project greatly altered flow conditions in the river and water levels on the floodplain, which had immediate effects on fish and wildlife. These changes were so dramatic in the LKB that it sparked a grass roots movement that resulted in a partnership between the District and USACE to restore the Kissimmee River. More information is provided in Appendix A about the C&SF Project, its impacts on the waterbodies in the UKB and LKB, and the Kissimmee River Restoration Project.

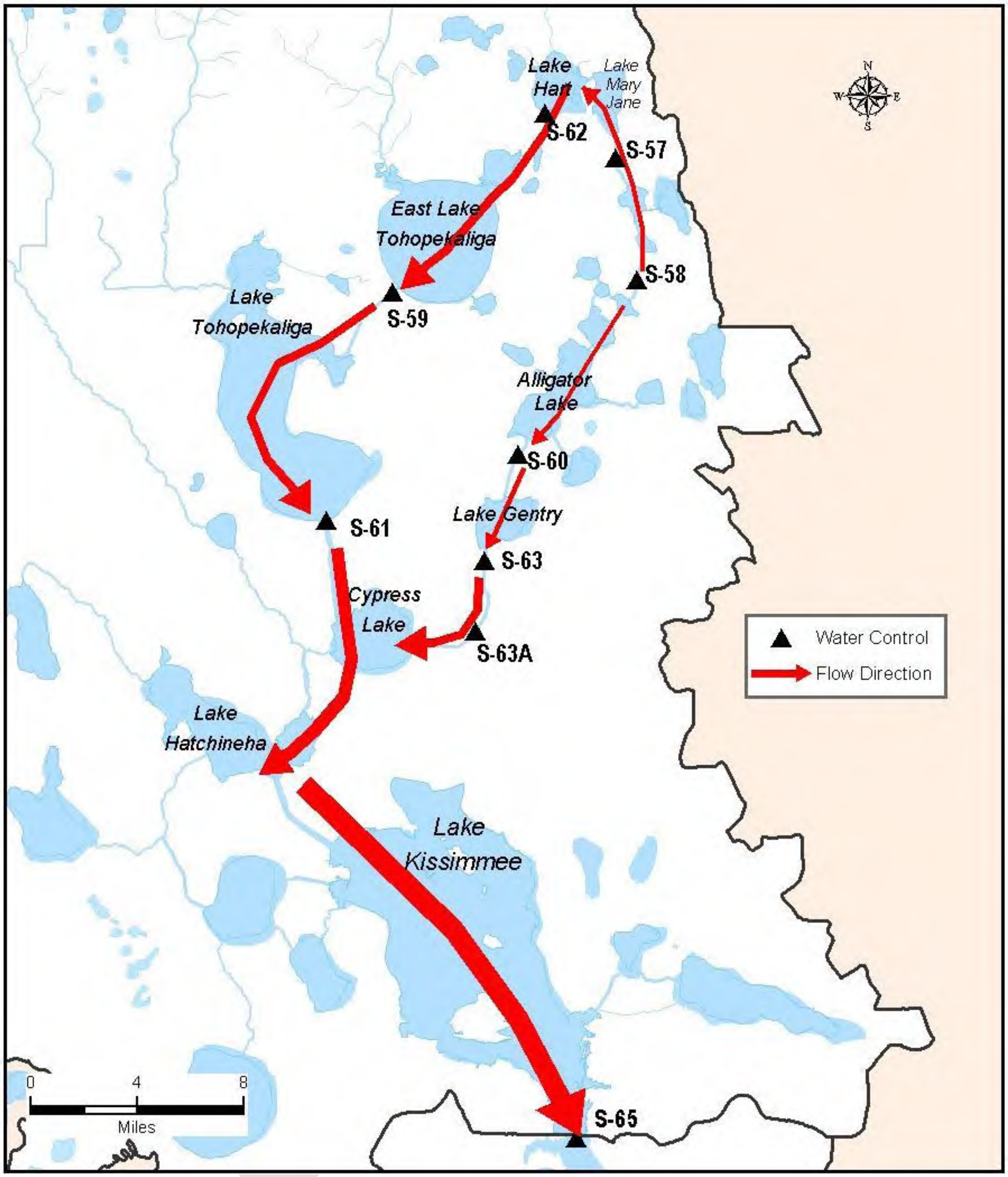

Figure 5. Flow of water through the KCOL.

Groundwater

The Kissimmee Basin has a complex groundwater system that includes three major hydrogeologic units: the surficial aquifer system, the intermediate confining unit, and the Floridan aquifer system. On a broad scale, the Floridan aquifer system is further subdivided into upper and lower aquifer units, which are separated by a semi-confining unit. The upper unit is called upper Floridan aquifer and the lower unit is called the lower Floridan aquifer, separated by the middle confining unit (Miller 1990). These units have different characteristics that influence the volume of water they contain (**Table 2**). Reese and Richardson (2008) redefined these units and provide a hydrogeologic framework for modeling the groundwater system. The framework developed by Reese and Richardson uses multiple methods for identifying hydrostratigraphic units, including lithologic and geophysical methods. This was used in the modeling done for the Kissimmee Basin reservations. The thickness of these layers varies across the basin. The magnitude and direction of water interchange between the different aquifers depends on the relative elevation of the potentiometric surfaces of the aquifers and the thickness and vertical permeability of the intervening confining units

Table 2. Characteristics and potential for water yield from the layers of the groundwater system in the Kissimmee Basin (based on SFWMD 2007).

Hydrogeologic Unit	Characteristics	Potential for Water Yield
Surficial Aquifer System	Unconfined aquifer with fine-to-medium grained quartz sand with varying amounts of silt, clays, and crushed shell. Represents the water table.	Yields low quantities of water to wells. Good-to-fair quality water. Limited to residential supply, lawn irrigation, and small-scale agricultural irrigation.
Intermediate Confining Unit	Low permeability sediments and rocks that retard the exchange of water between the surficial aquifer system and Floridan aquifer system. Contains interbedded sands, calcareous silts and clays, shell, phosphoric limestone and dolomite of the Hawthorne Group (Miocene).	Not an important source of water, except for a few isolated areas within the basin.
Floridan Aquifer System		
Upper Floridan Aquifer	High permeability. Carbonate rock (limestone and dolomite).	Source of virtually all of the water used to meet municipal, industrial, and agricultural needs in the Kissimmee Basin.
Semi-confining Unit	Less permeable	
Lower Floridan Aquifer	High permeability. Alternating beds of limestone and dolomite characterized by abundant fractures and solution cavities.	Increasingly used for water supply.

The surficial aquifer system is primarily recharged by rainfall. Aucott (1988) mapped the regional-scale areal variations in water exchange between the surficial aquifer system and upper Floridan aquifer in Florida. The upper Floridan aquifer in the northern portion of the basin is recharged by direct downward leakance (e.g., through sinkholes) from the surficial aquifer system, and where present, through the intermediate confining unit

(Aucott 1988, Shaw and Trost 1984, Adamski and German 2004). Recharge to the Floridan aquifer system is high along the Lake Wales, Mount Dora, and Bombing Range ridges where the confining layer is either thin or breached and where elevation differences between the surficial and Floridan aquifer systems are greatest (SFWMD 2007). In this area of connection, the surficial aquifer system consists of fine to medium grained quartz sand with varying amounts of silt, clay, and shell deposits. The characteristics of the aquifers and confining units are shown in **Table 2**. More information on water budgets and volumes of water can be found in Appendix G.

Reservation Waterbodies

Section 1 identifies the eight waterbodies that are being considered for development of water reservations. These waterbodies include the Kissimmee River and its floodplain in the LKB and the seven lake groups of the KCOL in the UKB. The remainder of Section 3 provides a more detailed description of each reservation waterbody, including the sources of water.

The eight waterbodies were selected for consideration of water reservation development because they are closely linked, represent substantial water resources, and have fish and wildlife resources. The outflow of surface water from the KCOL is to the Kissimmee River. The Kissimmee River is the largest tributary to Lake Okeechobee, accounting for approximately 50% of inputs (SFWMD 2014a).

Considerable fish and wildlife resources are associated with the reservation waterbodies, including a world class sport fishery and several threatened and endangered species. The fish and wildlife resources associated in the Kissimmee River are described in more detail in Section 4, while those in the KCOL waterbodies are described in Section 5. The KCOL waterbodies and the Kissimmee River are located within two separate planning areas (UKB and LKB).

The KCOL is divided into seven groups of lakes containing water control structures that regulate water levels and flows within the group in the same way. Each of the seven KCOL lake groups is considered a reservation waterbody.

For purposes of clearly identifying the water needed to protect fish and wildlife, lakes and connecting canals within each reservation waterbody are identified in Appendix I. These reservation waterbodies were formally considered in the analyses to quantify the water needed to protect fish and wildlife. Reservation waterbodies include surface waters and contiguous wetland habitats where identified fish and wildlife reside, feed, nest, den, or forage, etc. Specific descriptions of each reservation waterbody are provided below.

Many of the reservation waterbodies are connected to and continuously or intermittently receive significant inflows, in terms of timing and volumes, from other sources such as wetlands, sloughs, lakes, streams, creeks, canals, and ditches, which are called “contributing waterbodies.” For these reasons, the below identified contributing surface water inflows are integral to maintaining the hydrologic regime of the reservation waterbodies to ensure protection of fish and wildlife. These contributing surface waters can be divided into two types: 1) natural systems that include, but are not limited to, lakes, streams, creeks, sloughs, and wetlands and 2) man-made systems that include surface water conveyance ditches and canals. Under this water reservation rule, withdrawals from a source that contributes water to a reservation waterbody will be regulated. The descriptions for the natural and man-made systems below include the beginning and termination points that are regulated under the proposed rule as identified in Appendix I.

In this section, the reservation waterbodies are presented in order of the flow of water. The lakes in the KCOL that form the western chain from the Lakes Myrtle–Preston–Joel reservation waterbody to the Lake Tohopekaliga reservation waterbody are presented first, followed by the reservation waterbodies of the eastern chain, from the Alligator Chain of Lakes to Lake Gentry. The eastern and western chains discharge into the Headwaters Revitalization Lakes reservation waterbody, which in turn discharges into the Kissimmee River.

Figure 1 in Section 1 identifies the seven reservation waterbodies in the KCOL. **Table 3** provides information on the stage, surface area, volume, and depths for each of the lake reservation waterbodies. This table shows that the lakes are relatively shallow while the size and volume vary for each reservation waterbody. The regulated high stage was used to define the boundaries of the reservation waterbodies to protect and maintain the wetland habitat utilized by fish and wildlife.

Table 3. Stage, surface area, volume, average depth, and maximum depth for the lake reservation waterbodies.

Waterbody	Regulated HighStage[1] (feet)	Area[2] (acres)	Volume[3] (acre-feet)	Average Depth[4] (feet)	Maximum Depth (feet)
Lakes Myrtle–Preston–Joel	62.0	2,750	10,014	4	11
Lakes Hart–Mary Jane	61.0	3,811	25,936	7	22
East Lake Tohopekaliga	58.0	12,898	78,424	6	28
Lake Tohopekaliga	55.0	22,018	145,323	7	13
Alligator Chain of Lakes	64.0	7,401	57,381	8	32
Lake Gentry	61.5	1,947	16,655	9	19
Headwaters Revitalization Lakes	54.0	74,172	514,224	7	19

1 The extent of the lake reservation waterbodies is defined as the upper elevation of the stage regulation schedule approved by USACE. For the Headwaters Revitalization Lakes reservation waterbody, the upper elevation is based on the Headwaters Revitalization Regulation Schedule (USACE 1996).

2 Surface area is at the upper elevation of the stage regulation schedule.

3 Volume was calculated from stage storage tables.

4 Average depth was calculated as volume divided by surface area (Wetzel and Likens 1979).

This section provides additional information for each reservation waterbody and should be considered in conjunction with Appendix I, which provides supporting maps that show the reservation waterbodies, their contributing surface waters from named waterbodies, including both natural and man-made systems. It is important to understand that the majority of the natural contributing waterbodies shown in **Figures I-1** through **I-8** in Appendix I are wetlands and other surface waters; these resources are currently regulated under Section 3.3 of the *Applicant's Handbook for Water Use Permit Applications within* *the South Florida Water Management District* (SFWMD 2014b). The criteria in Section 3.3 of the handbook protect wetlands and other surface water resources using a "no harm" threshold. Therefore, as to these resources, existing allocation criteria are adequate to maintain to existing reservation hydrology such that additional regulatory criteria are not necessary. The proposed reservation rule will "dovetail" with the existing criteria. In summary, direct withdrawals of surface water from the reservation waterbodies and indirect withdrawals of surface water from contributing waterbodies are proposed to be regulated under this reservation rule. Additionally, the indirect withdrawal of groundwater from the surficial aquifer system at the landward edge of the reservation waterbody is also proposed to be regulated to ensure protection of fish and wildlife.

Lakes Myrtle–Preston–Joel

The approximate landward extent of the Lakes Myrtle–Preston–Joel reservation waterbody is shown in **Figure I-1** in Appendix I as defined by the regulated high stage of 62 feet National Geodetic Vertical Datum of 1929 (NGVD), pursuant to the USACE's lake regulation schedule (USACE 1994). As depicted on **Figure I-1**, the Lakes Myrtle–Preston–Joel reservation waterbody includes Lake Myrtle, Lake Preston, and Lake Joel. In addition to the lakes proper, the reservation waterbody includes the C-30 canal upstream of the S-57 structure, the C-32B canal, and the portion of the C-32C canal located north of the S-58 structure and the Myrtle-Preston canal because these waterbodies serve as a direct hydrologic connection to and between Lakes Myrtle, Preston, and Joel. There are no contributing waterbodies associated with this reservation waterbody that will be regulated under the proposed rule.

In addition to the lakes proper, the reservation waterbody includes the C-30 canal upstream of the S-57 structure, the C-32B canal, and the portion of the C-32C canal located north of the S-58 structure and the Myrtle-Preston canal because these waterbodies serve as a direct hydrologic connection to and between Lakes Myrtle, Preston, and Joel, and other reservation waterbodies. There are no contributing waterbodies associated with this reservation waterbody.

The main sources of water to the Lakes Myrtle–Preston–Joel reservation waterbody are the surficial aquifer system, direct rainfall and runoff from the surrounding watershed. Lake Myrtle–Preston–Joel can, physically, receive water from the Alligator Chain of Lakes via the S-58 structure. However, this structure is rarely used and generally serves as a divide structure in the system with water north of the S-58 structure flowing northward through Lakes Preston, Myrtle, and Joel and water south of the structure flowing southward through the system.

The principal outlet from Lakes Myrtle–Preston–Joel is the S-57 structure, which is located downstream from Lake Myrtle in the C-30 canal. This structure controls water levels in Lakes Myrtle–Preston–Joel and regulates the outflow through the C-30 canal, toward Lake Mary Jane. When water levels are higher in Lakes Myrtle–Preston–Joel than the Alligator Chain of Lakes, water may flow through the S-58 structure into Trout Lake. Ordinarily, this movement of water is prevented by higher water levels in the Alligator Chain of Lakes.

The Lakes Myrtle–Preston–Joel watershed is small. While the shoreline of these lakes is undeveloped, they are within Osceola County's Urban Growth area. An amendment to the *North East District Conceptual Master Plan* (Osceola County 2010) for this area was adopted in 2011 (Osceola County 2011). The land surrounding these lakes is privately owned and is currently used for low intensity agriculture (e.g., beef cattle).

Lakes Hart–Mary Jane

The approximate landward extent of the Lakes Hart–Mary Jane reservation waterbody is shown in **Figure I-2** in Appendix I as defined by the regulated high stage of 61 feet NGVD, pursuant to the USACE's lake regulation schedule (USACE 1994). As depicted on **Figure I-2**, the Lakes Hart–Mary Jane reservation waterbody includes Lake Hart, Lake Mary Jane, and Lake Whippoorwill. In addition to the lakes proper, the reservation waterbody include the Whippoorwill Canal, the C-29 canal, the C-29A canal upstream of the S-62 structure, and C-30 canal downstream of the S-57 structure. The canal features serve as direct hydrologic connections to Lakes Hart and Mary Jane for conveyance of water through the system. Lake Whippoorwill connects directly to the west side of Lake Hart via the Whippoorwill Canal; since there is no structural divide, Lake Whippoorwill and the Whippoorwill Canal is considered part of the Lakes Hart and Mary Jane reservation waterbody. There are no contributing waterbodies associated with this reservation waterbody that are regulated under the proposed rule.

This reservation waterbody receives inflow from the Lakes Myrtle–Preston–Joel reservation waterbody via the C-30 canal. It also receives water from the surficial aquifer system, direct rainfall, and runoff from the surrounding watershed.

The outlet from the Lakes Hart–Mary Jane reservation waterbody is the S-62 structure, located at the southern end of Lake Hart. This structure controls the water levels in Lakes Hart, Mary Jane, and Whippoorwill. These lakes discharge water into the C-29A canal, which is then conveyed to the East Lake Tohopekaliga reservation waterbody.

Rural residential development occurs along a portion of the shoreline of these lakes. The remaining portions of the shoreline located south of the C-29 canal between Lakes Hart and Mary Jane are part of Orange County's Moss Park and the Split Oak Forest Wildlife and Environmental Area.

East Lake Tohopekaliga

The approximate landward extent of the East Lake Tohopekaliga reservation waterbody is shown in **Figure I-3** in Appendix I as defined by the regulated high stage of 58 feet NGVD, pursuant to the USACE's lake regulation schedule (USACE 1994). As depicted on **Figure I-3**, the East Lake Tohopekaliga reservation waterbody includes East Lake Tohopekaliga, Lake Runnymede, Fells Cove, and Ajay Lake. In addition to the lakes proper, the reservation waterbody includes the C-29A canal downstream of the S-62 structure, the C-29B canal, Runnymede Canal and the C-31 canal upstream of the S-59 structure. Lake Ajay and Fells Cove are waterbodies located upstream of East Lake Tohopekaliga that are directly connected through the canals mentioned above. Lake Runnymede is located southeast of East Lake Tohopekaliga and is directly connected to the lake by the Runnymede Canal; since there is no structural divide, Lake Runnymede and the Runnymede Canal is considered part of the East Lake Tohopekaliga reservation waterbody.

Boggy Creek is a natural system contributing waterbody. The reservation waterbody does not include the stormwater management lakes located along the southern shoreline of East Lake Tohopekaliga.

In addition to surficial aquifer system contributions, direct rainfall, and runoff from the surrounding watershed, there are two major inflows into East Lake Tohopekaliga. These are Boggy Creek, which enters the lake in the northwestern corner, and the Ajay–East Tohopekaliga Canal (C-29A) from the Lakes Hart–Mary Jane reservation waterbody. The northern extent of the Boggy Creek contributing waterbody that is regulated under the proposed rule terminates at Canal Road or Highway 551 within the Orlando International Airport. Minor inflow occurs from Lake Runnymede on the southeast shore (**Figure I-3**).

The S-59 structure, located at the southern end of East Lake Tohopekaliga, controls water levels on East Lake Tohopekaliga, Fells Cove, Ajay Lake, and Lake Runnymede. The S-59 structure releases water into the C-31 canal (St. Cloud Canal), which enters the Lake Tohopekaliga reservation waterbody through Goblet's Cove.

Extensive shoreline residential development exists along these lakes. It is most intensely developed along the south shore of East Lake Tohopekaliga, where the City of St. Cloud is located.

Lake Tohopekaliga

The approximate landward extent of the Lake Tohopekaliga reservation waterbody is shown in **Figure I-4** in Appendix I as defined by the regulated high stage of 55 feet NGVD, pursuant to the USACE's lake regulation schedule (USACE 1994). As depicted on **Figure I-4**, the Lake Tohopekaliga reservation waterbody includes the largest lake within the Upper Chain of Lakes, Lake Tohopekaliga.

In addition to surficial aquifer system contributions, direct rainfall, and runoff from the surrounding watershed, the Lake Tohopekaliga reservation waterbody receives inflow from the East Lake Tohopekaliga reservation waterbody via the C-31 canal.

There are also major inflows contributed from one natural tributary stream—Shingle Creek, which flows from the City of Orlando southward and enters Lake Tohopekaliga through the northern end. Additional natural system contributing waterbodies for the Lake Tohopekaliga reservation waterbody include Fish Lake, Mill Slough, and Shingle Creek, including the branch called West Shingle Creek, and Fanny Bass Pond. The northern extent of Mill Slough and Shingle Creek terminates at Florida's Turnpike. The northwestern branch of Shingle Creek ends at the Central Florida Parkway. The branch called West Shingle Creek terminates at Camelot Country Way. The eastern extent of the Fanny Bass Pond wetland complex terminates at County Road 523.

Man-made contributing waterbodies include East City Ditch, West City Ditch, and Partin Canal between Fish Lake and Lake Tohopekaliga, including the adjoining branch of Bass

Slough located north of the Partin Canal. The northern extent of Bass Slough Branch terminates at the Florida's Turnpike. The East City Ditch extends from its junction to the West City Ditch to Lake Tohopekaliga. The northwestern extent of the West City Ditch terminates at West Martin Street. Other made-made contributing waterbodies located along the southeastern portion of Lake Tohopekaliga include Works Progress Administration Canal, Gator Bay Branch, Fanny Bass Ditch, and the Drawdy Bay Ditch. The eastern extent of Works Progress Administration Canal, Gator Bay Branch, and Drawdy Bay Ditch terminate at Florida's Turnpike. The Fanny Bass Ditch extends from Lake Tohopekaliga to County Road 523 (**Figure I-4**).

The S-61 structure controls water levels in the Lake Tohopekaliga reservation waterbody and releases water from the lake into the Southport Canal (C-35), which flows into Lake Cypress.

The City of Kissimmee is located on the northwest shore of Lake Tohopekaliga. Extensive residential development exists around much of the lake and the surrounding areas are within the Osceola County Urban Growth Area.

Alligator Chain of Lakes

The approximate landward extent of the Alligator Chain of Lakes reservation waterbody is shown in **Figure I-5** in Appendix I as defined by the regulated high stage of 64 feet NGVD, pursuant to the USACE's lake regulation schedule (USACE 1994). As depicted on **Figure I-5**, the Alligator Chain of Lakes reservation waterbody includes Lake Center, Coon Lake, Trout Lake, Lake Lizzie, Live Oak Lake, Sardine Lake, Alligator Lake, and Brick Lake. In addition to the lakes proper, the reservation waterbody includes the C-32C canal south of the S-58 structure, the C-32D canal, Center/Coon Canal, C-32F canal, C-32G canal, Live Oak Canal, Sardine Canal, Brick Canal, and the C-33 canal upstream of the S-60 structure. Live Oak Lake and Sardine Lake connect directly to the west side of Alligator Lake via the Live Oak and Sardine canals; since there is no structural divide, Live Oak and Sardine lakes are considered part of the Alligator Chain of Lakes reservation waterbody. All of these waterbodies have direct connections to the upstream, downstream, or lateral waterbodies by means of a canal.

Buck Lake and Buck Slough are natural system contributing waterbodies because their hydrologic connection to Alligator Lake occurs through an ephemeral slough system rather than directly through a canal. There are no man-made contributing waterbodies identified within this reservation waterbody.

The sources of water to the Alligator Chain of Lakes reservation waterbody are the surficial aquifer system, direct rainfall, and runoff from the surrounding watershed. As described previously, there is the potential for some inflow from the Lakes Myrtle–Preston–Joel reservation waterbody under certain conditions. It also receives water from the surficial aquifer system, rainfall, and runoff from the surrounding watershed.

The primary outlet from the Alligator Chain of Lakes is the S-60 structure, located at the southern end of Alligator Lake. This structure controls water levels in all of the waterbodies of the Alligator Chain of Lakes and releases water to Lake Gentry. As previously described, some releases can be made from the north end of the Alligator Chain of Lakes reservation waterbody through the S-58 structure to the Lakes Myrtle–Preston–Joel reservation waterbody.

Extensive residential development exists along the shorelines in the Alligator Chain of Lakes.

Lake Gentry

The approximate landward extent of the Lake Gentry reservation waterbody is shown in **Figure I-6** in Appendix I as defined by the regulated high stage of 64 feet NGVD, pursuant to the USACE's lake regulation schedule (USACE 1994). As depicted on **Figure I-6**, the reservation waterbody includes only one lake, Lake Gentry.

Big Bend Swamp and the Big Bend Swamp Canal/Gentry Ditch are natural system contributing waterbodies that drain into the east side of Lake Gentry. Big Bend Swamp Canal/Gentry Ditch was considered a natural contributing waterbody rather than a man-made contributing waterbody because it traverses many wetland areas associated with the Big Ben Swamp. The southeastern extent of the Big Bend Swamp Canal/Gentry Ditch terminates at the section line between Sections 23 and 26, Township 27, Range 31. There are no man-made contributing waterbodies associated with the Lake Gentry reservation waterbody.

In addition to surficial aquifer system contributions, direct rainfall, and runoff from the surrounding watershed, Lake Gentry receives surface water inflows from the Alligator Chain of Lakes reservation waterbody through the C-33 canal, as well as receiving inflow from the Big Bend Swamp along the eastern shore of the lake.

Water levels in Lake Gentry are regulated by the S-63 structure, located 2,900 feet downstream of the lake on the C-34 canal. This structure also controls releases from Lake Gentry into Lake Cypress via a second structure, S-63A, which is located approximately halfway between the S-63 structure and Lake Cypress. The S-63A structure is used to step-down the stages in the C-34 canal.

The shoreline of Lake Gentry is relatively undeveloped, with only some rural lakeside residences.

Headwaters Revitalization Lakes

The approximate landward extent of the Headwaters Revitalization Lakes reservation waterbody is shown in **Figure I-7** in Appendix I as defined by the regulated high stage of 54 feet NGVD pursuant to the USACE's lake regulation schedule (USACE 1996).

As depicted on **Figure I-7**, the reservation waterbody includes Lake Kissimmee, Lake Hatchineha, Tiger Lake, Tiger Creek, and Lake Cypress and their interconnecting canals—C-34 canal downstream of the S-63 structure, C-35 canal downstream of the S-61 structure, C-36 canal, and C-37 canal in Osceola and Polk counties. The reservation waterbody also includes the Zipprer Canal east of the G-103 structure located downstream of Lake Rosalie and the Jackson Canal downstream of the G-111 structure.

Natural system contributing waterbodies include Bonnet Creek, Upper and Lower Reedy Creek, Lake Russell, Lake Marion, Lake Marion Creek, Lake Pierce, Catfish Creek, Lake Rosalie, Lake Weohyakapka, Weohyakapka Creek, Otter and No Name sloughs, Fodderstack Slough, Lake Jackson, Parker Hammock Slough, and Lake Marian. The northern extent of Bonnet and Upper Reedy creeks regulated as natural contributing waterbodies under this rule terminate at US Highway 192. The western extent of Otter Slough terminates at State Road 60. Parker Hammock Slough is located between Lakes Jackson and Marian. The eastern extent of No Name Slough, located at the southeastern portion of Lake Kissimmee, terminates at the eastern property boundary of the Three Lakes Wildlife Management Area.

There are two man-made contributing waterbodies located in this reservation waterbody. The first is the portion of the Zipprer Canal located west of the G-103 structure. This man-made waterbody is located on the western shoreline of Lake Kissimmee. The second man-made contributing waterbody is located on the eastern shoreline of Lake Kissimmee and includes the portion of the Jackson Canal located upstream of the G-111 structure.

In addition to surficial aquifer system contributions, direct rainfall, and runoff from the surrounding watershed, the Headwaters Revitalization Lakes reservation waterbody receives inflow from two other reservation waterbodies that represent the rest of the KCOL. Lake Cypress receives inflow from the Lake Tohopekaliga and Lake Gentry reservation waterbodies. Upper and Lower Reedy creeks and Lake Russell, which provide flows from the northwestern corner of the basin, are collectively a major natural system contributing waterbody to Lakes Cypress and Hatchineha. On the west side of the Headwaters Revitalization Lakes reservation waterbody, there is also flow from Lake Marion via Lake Marion Creek, Lake Pierce via Catfish Creek, Lake Weohyakapka via Weohyakapka Creek to Lake Rosalie and then to Lake Kissimmee via the Zipprer Canal. Flows also come from Tiger Lake via Tiger Creek and Otter Slough. On the east side of this reservation waterbody, there is inflow from Jackson Canal, Fodderstack Slough, and No Name Slough. The S-65 structure controls the water levels in the Headwaters Revitalization Lakes reservation waterbody and governs releases from the UKB to the Kissimmee River.

Stages within the Headwaters Revitalization Lakes will be raised in the future in accordance with the new schedule called the Headwaters Revitalization Schedule as approved by the USACE to provide the flows necessary to meet the ecological integrity goal of the Kissimmee River Restoration Project.

Most of the land surrounding these lakes is in public ownership and is managed for conservation. Much of the eastern side of Lake Kissimmee is part of the Three Lakes Wildlife Management Area. Lake Kissimmee State Park is located on the western shoreline.

Kissimmee River

The approximate landward extent of the Kissimmee River reservation waterbody is shown in **Figure I-8** in Appendix I as defined by the 100-year floodplain elevation as delineated by the USACE (USACE 1991) between structures S-65 and S-65D and the portion of the Istokpoga Canal located east of the S-67 structure. It also includes the C-38 canal and remnant river channels from structures S-65 to S-65E.

As depicted in **Figure I-8**, a number of tributary sloughs supply water to the Kissimmee River and are considered contributing waterbodies. Natural system contributing waterbodies located on the eastern side of the Kissimmee River include Blanket Bay, Pine Island, and Sevenmile, Ash, Gore, Fish, Cypress, and Chandler sloughs. Packingham and Tick Island sloughs and Istokpoga Creek are natural system contributing waterbodies located on the western side of the Kissimmee River.

Man-made contributing waterbodies located on the eastern side of the river consist of Armstrong and Starvation sloughs and Oak Creek. There are two branches of Armstrong Slough. The northeastern branch of this slough terminates at State Road 60 while the southeastern branch terminates at the confluence of Armstrong and Pine Island Sloughs (southeastern branch). The two branches of Oak Creek begin at Oak Creek Road and extend approximately 2 miles upstream in either direction until they connect to natural wetland systems as shown in **Figure I-8**. The two branches of Starvation Slough begin south of Oak Creek Road and extend north until they connect to natural wetland systems.

Man-made contributing waterbodies located on the western side of the river include Buttermilk and Ice Cream sloughs. The western branch of Packingham Slough terminates at Section 9, Township 31, Range 31 while the southern branch terminates at the River Ranch Property boundary. The western extent of Buttermilk Slough terminates at the confluence of Ice Cream and Buttermilk sloughs. The western extent of Ice Cream Slough terminates at State Road 60.

The surface water contributions from the Upper Chain of Lakes as well as the Headwaters Revitalization Lakes also provide significant inflows to the river. Additionally, direct rainfall and runoff from the surrounding watershed from the LKB are important sources of water to the Kissimmee River. The largest inflow to the Kissimmee River is the discharge from the S-65 structure located at the southern end of Lake Kissimmee. A number of natural and man-made tributaries flow into the Kissimmee River as described above. The largest is Chandler Slough, which drains an area of 143.4 square miles (Abtew 1992).

Channelization of the Kissimmee River reduced the length of the river from a more than 103-mile meander (166 kilometer [km]) to a relatively straight, almost 56-mile long (90-km) canal from Lake Kissimmee to Lake Okeechobee. The Kissimmee River Restoration Project has filled 10 miles (16 km) of canal and reconnected 18 miles (29 km) of river channel (Bousquin et al. 2009). Appendix A contains more information about the Kissimmee River Restoration Project.

SECTION 4: KISSIMMEE RIVER FISH AND WILDLIFE RESOURCES AND HYDROLOGIC REQUIREMENTS

Introduction

This section identifies the fish and wildlife resources that occur in the Kissimmee River and floodplain. It focuses on species that are dependent on the river and floodplain to meet their reproductive, feeding, and survival needs for one or more life cycle stages. These species groups are fishes, amphibians and reptiles, birds, and mammals. In addition, the hydrologic requirements of each of the major groups of fish and wildlife are identified. The hydrologic requirements are expressed as hydrologic performance measures being used to define the water volume needs of fish and wildlife in the river and floodplain.

Considerable fish and wildlife resources were associated with the Kissimmee River prior to its channelization as part of the Central and Southern Florida Flood Control Project (C&SF Project). Many species of fish and wildlife decreased in abundance or disappeared after the river was channelized and its floodplain drained (Toth 1993). Monitoring conducted for the Kissimmee River Restoration Evaluation Program (KRREP) provides the understanding of the fish and wildlife currently associated with the Kissimmee River. Since the completion of Phase I construction for the Kissimmee River Restoration Project in 2001, there has been a dramatic increase in the use of the Kissimmee River by fish and wildlife (Bousquin et al. 2007, 2009; Appendix A, Figures A-21 and A-22). This significant change, consistent with predicted KRREP expectations, demonstrates the linkage between hydrologic conditions in the river channel and the floodplain and their use by fish and wildlife, which is the basis for the river restoration effort. As the changes in habitat that occurred are considered, this linkage is strengthened.

Before the river was channelized, it meandered for 103 miles between Lake Kissimmee and Lake Okeechobee (Koebel 1995). The river channel provided diverse habitats associated with sand bars, vegetation beds, and variable flow conditions, depending on channel morphology (Toth et al. 1995). The river overflowed its banks frequently and inundated the 1 to 2 mile-wide floodplain for extended periods of time, creating a mosaic of wetland plant communities. When the river was channelized through creation of the C-38 flood conveyance canal, most of the floodplain was drained and remaining portions of the historic river channel that were not destroyed by channelization no longer received flow or provided overbank flow to inundate the floodplain. Thus, the total amount of wetland habitat and the quality of the remaining wetland habitat decreased. Major changes in the use of the Kissimmee River by fish and wildlife have coincided with the reestablishment of wetland habitat following Phase I of the restoration project. In the thirteen years since completion of Phase I construction of the Kissimmee River Restoration Project, pre-channelization hydrologic conditions have been partially reestablished (Bousquin et al. 2007, 2009) and dramatic recoveries have been documented in fish, wildlife, and plant communities.

Hydrologic requirements for the restoration of fish and wildlife associated with the Kissimmee River have been expressed previously as a set of hydrologic criteria (**Box 1**). The evolution of the hydrologic criteria and their use in planning the Kissimmee River Restoration Project are described in Anderson and Chamberlain (2005) and in the description of the performance measures near the end of this section. The hydrologic criteria suggest that a range of hydrologic conditions is needed to protect fish and wildlife in a river floodplain ecosystem. The hydrologic criteria include the magnitude of flow, rates of change, timing, and duration and frequency (seasonal and annual variability), which are the major components of the natural flow regime (Poff et al. 1997). Consistency with the natural flow regime is an indication that the right criteria are being considered (Anderson and Chamberlain 2005).

Kissimmee River Floodplain Plant Communities

A major component of fish and wildlife habitat is vegetation. Floodplain wetlands are crucial breeding and foraging areas for fish and wildlife (Scheaffer and Nickum 1986, Gladden and Smock 1990). Plants provide food (both directly and as habitat for prey species); nesting substrate and materials; and hiding cover and shelter for juveniles and adult fish, birds, invertebrates, reptiles, and amphibians. Use of the Kissimmee River and its floodplain by animals is therefore often linked to hydrology via vegetation. Floodplain vegetation can serve as a surrogate for the relationships between hydrology and fish and wildlife. For these reasons, and because of its prominence in the fish and wildlife discussions that follow, vegetation is presented first in this section to introduce the major classes of floodplain vegetation and their hydrologic requirements.

Introduction

General categories of Kissimmee River Floodplain vegetation are described in the Kissimmee River Vegetation Classification (KRVC) (Bousquin and Carnal 2005). Floodplain vegetation is classified into several main groups. Of primary interest are the Wet Prairie, Broadleaf Marsh, and Wetland Shrub groups. These three wetland types historically (pre-channeliztion) comprised over 80% of the total floodplain habitat. Contribution by wetland group included Broadleaf Marsh at 52%, Wet Prairie at 29%, followed by Wetland Shrub at 1% (Spencer and Bousquin 2014). Other groups of vegetation include Wetland Forest, Miscellaneous Wetlands, and Aquatic Vegetation, which are presented in more detail in Appendix B. This section focuses on the three dominant groups because of their prominence on the floodplain, utility as indicators of floodplain hydrologic conditions, importance to fish and wildlife in the Kissimmee River and floodplain, and the use of the Broadleaf Marsh Group as a performance measure for this technical plan.

Box 1. Hydrologic Criteria for the Kissimmee River Restoration Project (USACE 1991):

- **Continuous flow with duration and variability characteristics comparable to the pre-channelization records** – The most important features of this criterion are (a) reestablishment of continuous flow from July–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.

- **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 (e.g., feeding and reproduction), and provide flows that will lead to maximum habitat availability.

- **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.

- **Stage recession rates on the floodplain that typically do not exceed 1 foot per month** – A slow stage recession rate is required to restore the diversity and functional utility of floodplain wetlands, foster sustained river/floodplain 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 (e.g., rates that will drain most of the floodplain in less than a week) have led to fish kills (i.e., during the Pool B Demonstration Project), and thus, are not conducive to ecosystem restoration.

- **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 of the (approximately 75%) of the floodplain is exposed to only intermittent drying periods that vary in timing, duration, and spatial extent.

Dominant Vegetation Types

The vegetation groups defined in the KRVC encompass more detailed plant community types, which are named for their dominant species. Dominance is usually defined as the species having the highest areal cover. The following dominant plant species of these more detailed community types describe the range of species composition of these vegetation groups.

Broadleaf Marsh Group

The KRVC Broadleaf Marsh Group is similar to a number of vegetation types described elsewhere in the literature under different regional names (**Table 4**). The Broadleaf Marsh Group in the Kissimmee River floodplain is characterized by dominance of one or both of two indicator species, pickerelweed (*Pontederia cordata*) and/or bulltongue arrowhead (*Sagittaria lancifolia*). Prominent associated species may include the shrub buttonbush (*Cephalanthus occidentalis*) and the grass maidencane (*Panicum hemitomon*). Under normal hydrologic conditions, dominant species occur in standing water for much of the year. This results in a typically low complement of understory species, which may include cutgrass (*Leersia hexandra*), cupscale (*Sacciolepis striata*), alligatorweed (*Alternanthera philoxeroides*), spatterdock (*Nuphar lutea*), smartweed (*Polygonum punctatum*), bacopa (*Bacopa caroliniana*), dollarweed (*Hydrocotyle umbellata*), and the invasive shrub primrosewillow (*Ludwigia peruviana*).

The Broadleaf Marsh Group requires extended periods of inundation, with estimates ranging from 190 to 270 days per year (**Table 4** and **Figure 6**). Toth (1991), in a study of the Kissimmee River Demonstration Project, estimated broadleaf marsh hydroperiods to range from 210 to 270 days per year. Kushlan (1990) estimated depth requirements of similar marshes ranging from 0.3 to 1.0 meters (m). Wetzel (2001) estimated 0.2–0.4 m as the minimum depth for optimal growth rates for a number of marsh types, including several types of wet prairie. Seasonal or periodic water level reduction is also important in these communities (Kushlan 1990, USNVC 2008) to avoid exceeding the upper tolerances of the dominant species, which can uproot and die (Kushlan 1990). In general, floodplain marshes may require fires at least once per decade to inhibit woody plant invasion (FNAI 1990, Kushlan 1990, Duever 1990); however, the role of fire on the pre-channelization floodplain has been disputed (Toth et al. 1995).

Table 4. Duration and depth of inundation for wetland plant communities resembling the Broadleaf Marsh and Wet Prairie groups on the Kissimmee River.

Community	Source Nomenclature	Dominant Species	Source	Duration (days)	Depth
Pickerelweed marsh	Pickerelweed Tropical Herbaceous Vegetation, Unique ID CEGL004261	Pickerelweed	USNVC 2008	Most of year, with little variation in hydroperiod	.
Floodplain marsh	Floodplain marsh, river marsh	Maidencane, buttonbush, and sawgrass; other typical plants include arrowheads and pickerelweed	FNAI 1990	>250	.
Broadleaf marsh	Broadleaf marsh	Pickerelweed and arrowhead	Toth et al. 1998	210–270	.
Maidencane-dominated marsh	Maidencane – Pickerelweed Herbaceous Vegetation, Unique ID CEGL004461 [Maidencane is dominant]	Maidencane	USNVC 2008	>200	0.3 m–1 m
Flag marsh	Flag marshes	Includes marshes dominated by maidencane, pickerelweed, arrowhead, bulrush, beakrush, and spikerush	Kushlan 1990	>200	0.3 m–1 m
Maidencane (species estimate)	Species estimate	Maidencane	Lowe 1986, Figure 5	270–350	.
Maidencane marsh	Maidencane Tropical Herbaceous Vegetation, Unique ID CEGL003980	Maidencane	USNVC 2008	180–330	.
Northern Everglades wet prairie; maidencane can be dominant	Wet prairie (northern Everglades)	Maidencane, spikerush, or beakrush	Richardson 2000	180–300	Standing water
Maidencane marsh	Maidencane marsh	Maidencane	Wetzel 2001 citing Schomer and Drew 1982, Page 117	180–270	.
Marsh	Marsh	Not specified	Duever 1990, Figure 2	114–264	.
Southern Everglades wet prairie	Wet prairie (southern Everglades)	Not specified	Richardson 2000 citing Davis 1943	90–210	Less than sloughs, but deeper than sawgrass
Wet prairie	Wet prairie	Not specified	Duever et al. 1978 (wet prairie)	111–155	.
Wet prairie	Wet prairie	Not specified	Duever 1990, Figure 2	64–114	.
Flatwoods wet prairie	Wet prairie (flatwoods)	Grasses, sedges, and fords including maidencane, cordgrass, beakrush, and muhly	Kushlan 1990	50–100	.
Flatwoods wet prairie	Wet prairie (flatwoods)	Grasses and herbs, including maidencane, spikerush, and beakrush	FNAI 1990	50–100	.

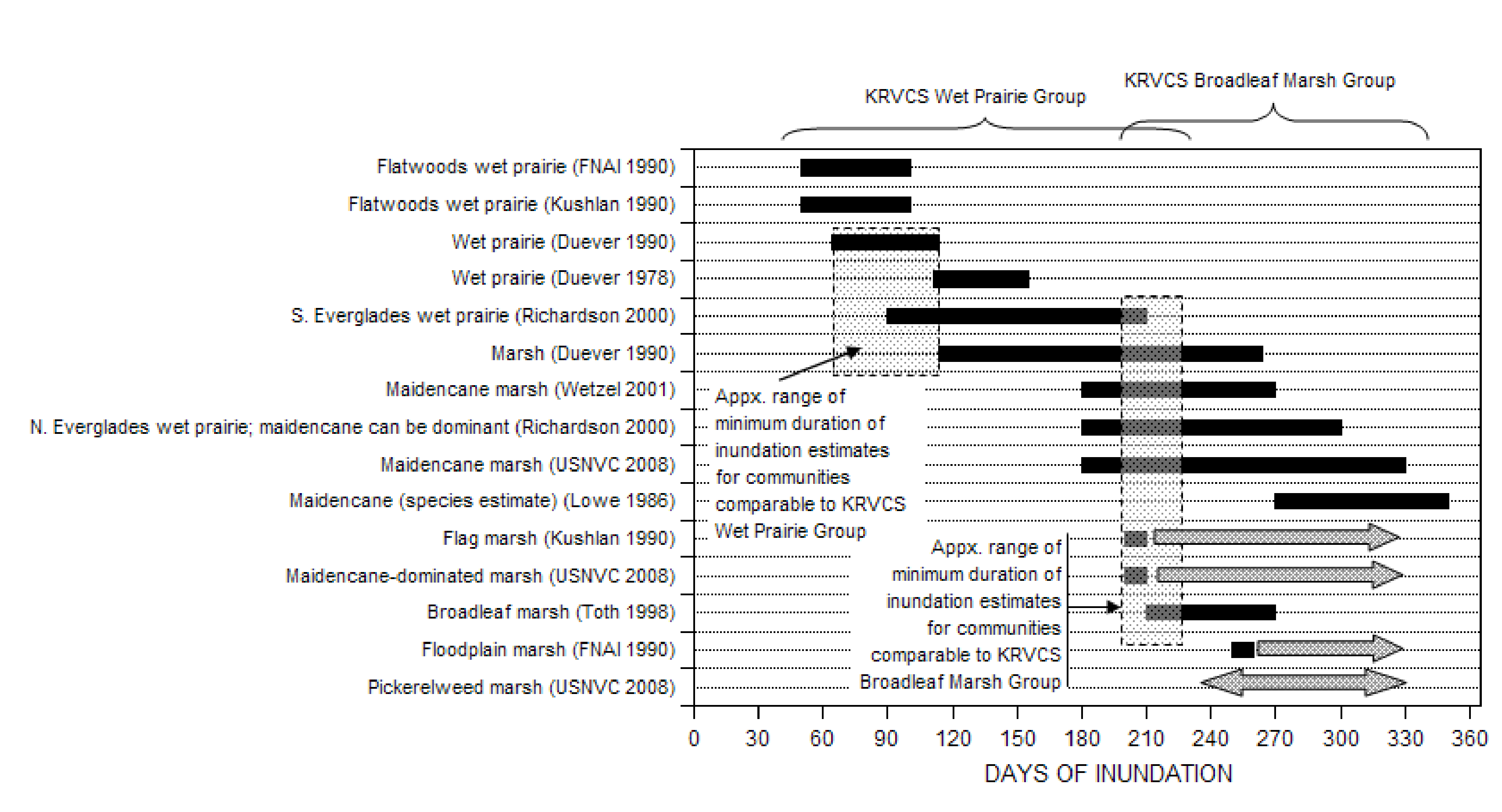

Figure 6. Published estimates of Florida marsh plant community inundation durations.
Grayscale bars with arrowheads indicate estimates for which only a minimum inundation duration was described or no numerical estimate was provided (i.e., the duration given for pickerelweed marsh was "most of year with little variation in hydroperiod" in USNVC 2008). See **Table 4-1** for additional details.

Communities in the Broadleaf Marsh Group in the pre-channelization system occurred in a broad swath that dominated the central floodplain where hydroperiods were longest and water was deepest (**Figure 7**). Broadleaf marsh communities in the 1954 (pre-channelization) map accounted for approximately 52% of floodplain vegetation within the Kissimmee River Restoration Project Phase I construction area (most of Pool C and a portion of Pool B) (Spencer and Bousquin 2014). Within a few years following completion of the C-38 canal in 1971, the Broadleaf Marsh Group coverage declined to only 3.1% of the vegetation in the Phase I area. Although coverage of the Broadleaf Marsh Group increased over the next 25 years to 15% in 1996, it occurred mostly in impounded wetlands (Spencer and Bousquin 2014) and its coverage remained much lower than the pre-channelized condition. This decline of long hydroperiod floodplain vegetation coincided with reductions in fish and wildlife populations over the same periods, as described elsewhere in this document and in Toth (1993) and Bousquin et al. (2005). The most recent Kissimmee River Restoration Project Phase I floodplain vegetation map was completed in 2011, 10 years following completion of restoration construction and implementation of an interim water regulation schedule. While sporadic inundation reestablished various kinds of wetland vegetation over much of the floodplain, the Broadleaf Marsh Group accounted for only 21% percent of the Phase I area (L. Spencer, South Florida Water Management District [SFWMD], unpublished data), with most of its former distribution occupied by communities in the Wet Prairie Group. Thus, while intermittent inundation has been achieved in the Phase I area since completion of Phase I, annual durations of inundation have proved inadequate for recovery of the Broadleaf Marsh Group. It is expected to begin expansion to its former floodplain distribution when extended hydroperiods are reestablished under the Headwaters Revitalization Water Regulation Schedule (USACE 1996), currently projected for implementation in 2019.

Wet Prairie Group

Communities included in the KRVC Wet Prairie Group are variable in species composition. The group includes a number of herbaceous, emergent plant communities that have shorter hydroperiod requirements than the Broadleaf Marsh Group. Almost all emergent marsh communities not classified as in the Broadleaf Marsh Group are classified as one of the types in the Wet Prairie Group.

The Wet Prairie Group comprises communities dominated by grasses and sedges, including maidencane, beakrushes (*Rhynchospora* spp.), soft rush (*Juncus effusus*), bushy broomgrass (*Andropogon glomeratus*), flatsedges (*Cyperus* spp.), spikerushes (*Eleocharis* spp.), Virginia iris (*Iris virginica*), cutgrass (*Leersia hexandra*), and watergrass (*Luziola fluitans*), as well as a few associations dominated by forbs, such as dotted smartweed (*Polygonum punctatum*). See Appendix B and the appendices to Bousquin and Carnal (2005) for additional details on the composition of Wet Prairie Group community types.

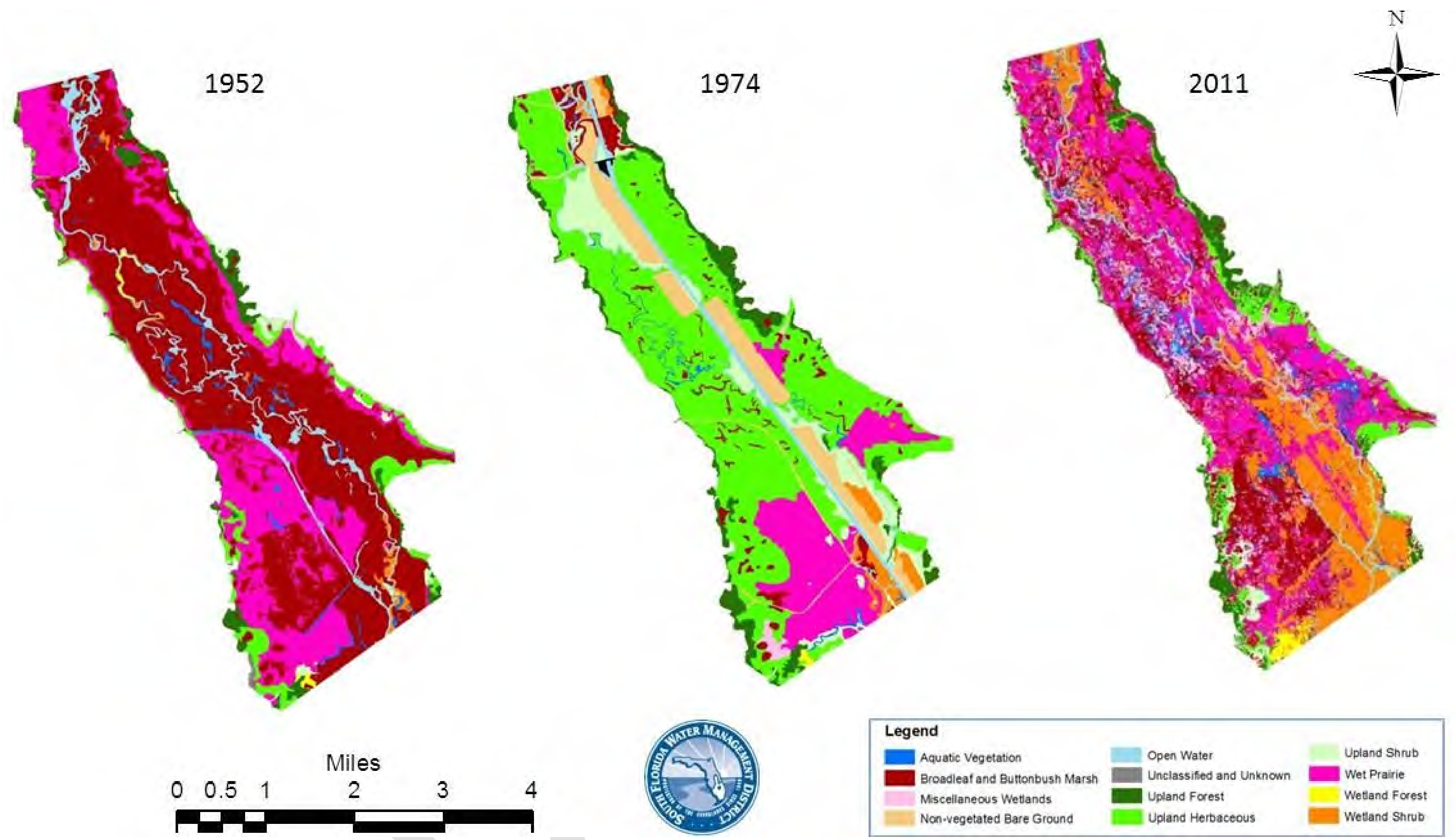

Figure 7. Vegetation on the floodplain of the Phase I area of the Kissimmee River before channelization (circa 1954), three years after channelization was completed in 1971 (circa 1974), and ten years after reestablishment of flow (2011).
The Phase I construction area includes most of Pool C and portions of Pool B where flow and partial floodplain inundation were reestablished in 2001. Reds, pinks, purple, and orange coloring denotes major wetland classes. Bright and light greens are upland classes. (Sources: Pierce et al. 1982, Milleson et al. 1980, Spencer and Bousquin 2014).

The term "wet prairie" is used in the literature to classify a variety of emergent marsh communities occurring across a range of hydrologic situations (**Figure 7**). The term is often used to describe herbaceous graminoid-dominated communities that occur in areas between longer hydroperiod wetlands and surrounding uplands, or in wet inclusions within uplands. Literature estimates of inundation duration for vegetation are approximately comparable in species composition to the KRVC Wet Prairie Group range from 60 to 180 days per year (**Table 4** and **Figure 6**). The Wet Prairie Group requires periodic drying (Barbour and Billings 2000, Goodrick and Milleson 1984) for germination and growth of seedlings. Communities within the Wet Prairie Group are believed to be adapted to fire and may be dependent on periodic burning to inhibit invasion by shrubs (Wade et al. 1980).

On the Kissimmee River floodplain, communities in the Wet Prairie Group occur between the upper elevations of the Broadleaf Marsh Group and surrounding uplands. Before channelization, Wet Prairie Group communities occurred in an irregular, relatively narrow strip around much of the floodplain's periphery, and in depressions at higher elevations covering approximately 29% of the floodplain (**Figure 7**) (Pierce et al. 1982, Spencer and Bousquin 2014). Following completion of the C-38 canal in 1971, much of the former distribution of the Wet Prairie Group converted rapidly to various upland herbaceous communities and declined to 15% coverage (**Figure 7**). Where these communities were used as pasture, shrub invasion was inhibited by grazing or mechanical maintenance; in less accessible places, large areas of upland shrub stands developed. By 1996, where conditions remained intermittently wet following channelization, the Wet Prairie and Wetland Shrub groups occupied areas that had formerly been the Broadleaf Marsh Group, but at similar coverage (13%) as in 1971. In the area where backfilling was completed in 2001 for Phase I of the Kissimmee River Restoration Project, a rapid conversion to wetland vegetation occurred by 2003, increasing Wet Prairie Group coverage to 33%, with equivalent coverage (30%) being maintained to 2011 (**Figure 7**). Much of this coverage is expected to convert to the Broadleaf Marsh Group following completion of the project in 2019 following implementation of the Headwaters Revitalization Water Regulation Schedule (USACE 1996) and reestablishment of longer floodplain hydroperiods.

Wetland Shrub Group

Several communities dominated by the following wetland-dependent shrub taxa fall into the Wetland Shrub Group: buttonbush (*Cephalanthus occidentalis*), Carolina willow (*Salix caroliniana*), primrosewillow (*Ludwigia peruviana* and/or *L. leptocarpa*,), and St. John's wort (*Hypericum fasciculatum*). The last two species are not major components of the floodplain.

Buttonbush is a native component of the Broadleaf Marsh Group that comprises understories indistinguishable from the Broadleaf Marsh Group, but is classified as shrub stands due to areal cover of buttonbush that exceeds 30%. The hydrologic requirements of buttonbush communities are therefore within the same ranges as the Broadleaf Marsh Group. Carolina willow communities occur along abandoned channel oxbows and other slight rises in elevation on the floodplain, sometimes over large areas, and are an important source of cover and nesting substrate for wading birds (M. Cheek, SFWMD, personal observation) as in the southern Everglades (Frederick and Spalding 1994). primrosewillow (*Ludwigia peruviana*), an exotic and invasive shrub, often occurs as an undesirable, but persistent element of the Broadleaf Marsh Group, particularly under the deep, stabilized water regimes that occur at water control structures in the lower regions of pools in the channelized condition where water tends to pool. Primrosewillow may brown and drop leaves when plants are flooded to ~50–70 percent of their height (B. Anderson and S. Bousquin, SFWMD, personal observation), but may rapidly resprout vegetatively when water levels recede before death of the plants.

The Wetland Shrub Group overall represented approximately 1% of the Phase I area floodplain vegetation prior to channelization, remained low at 3% within three years of channelization (1974), and increased to 19% by the most recent complete vegetation map (2011, ten years following completion of Phase I construction in 2001) (**Figure 7**). Woody species respond more slowly than herbaceous vegetation; the 2011 increase likely began during the channelized period. Wetland Shrub Group distributions may continue to be influenced by the current inability to fully reestablish pre-channelization hydroperiods (see Appendix A). This situation is expected to be resolved by the revised water regulation schedule in 2019 (USACE 1996).

Kissimmee River Fish and Wildlife Resources and Associated Hydrologic Requirements

This section describes the hydrologic requirements of four major groups of fish and wildlife associated with the Kissimmee River: fish, amphibians and reptiles, birds, and mammals.

Kissimmee River Fish

A total of 52 species of fish have been collected from the Kissimmee River and its floodplain (**Table 5**). All but five of these species were collected in baseline sampling of the channelized river (Glenn and Arrington 2005). Two species were collected following the first phase of construction: Atlantic needle fish (*Strongylura marina*) and American eel (*Anguilla rostrata*) (Lawrence Glenn, SFWMD, personal communication). The blackbanded darter (*Percina nigrofasciata*) was collected prior to channelization and has been collected recently in Morgan Hole Creek and Arbuckle Creek on the nearby Avon Park Airforce Range (Nico et al. 2000). The common carp (*Cyprinus carpio*) and the grass carp (*Ctenopharyngodon idella*) have been collected at various time in the Kissimmee River (Nico et al. 2000). Of the above-mentioned 52 species, 39 were reported in the river before channelization (FGFWFC 1957). Although there were significant changes in the structure of the fish community following channelization (described as follows), only one species, the blackbanded darter, was lost (Trexler 1995). Six exotic species have invaded or been released in the system since the 1950s. Fish species occurring in the Kissimmee River system represent a range of trophic levels (herbivore, piscivore, omnivore, invertivore, planktivore, and detritivore), consume foods from both aquatic and terrestrial environments (Karr et al. 1986), and serve as a critical link in the energy pathway between primary producers and higher trophic level consumers, including amphibians, reptiles, and birds (Karr et al. 1992, Gerking 1994).

Table 5. Species of fish recorded from the Kissimmee River and their guild, spawning season, and mode of spawning. See text for details on fish records.

Scientific Name	Common Name	Guild[1]	Spawning Season	Spawning Mode[2]
Amia calva	Bowfin	OS	April–July	N
Esox americanus	Redfin pickerel	OS	Spring and fall	SD
Esox niger	Chain pickerel	OS	Spring and fall	SD
Ameiurus natalis	Yellow bullhead	OS	April–May	N
Ameiurus nebulosus	Brown bullhead	OS	May	N
Noturus gyrinus	Tadpole madtom	OS	June–July	N
Aphredoderus sayanus	Pirate perch	OS	December–May	N/M
Jordanella floridae	Flagfish	OS	March–September	N, AVD
Lucania goodei	Bluefin killifish	OS	Spring–summer	SA
Gambusia holbrooki	Mosquitofish	OS	Late spring–summer	L
Heterandria formosa	Least killifish	OS	Most of the year	L
Poecilia latipinna	Sailfin molly	OS	Late spring/ late summer	L
Elassoma evergladei	Everglades pygmy sunfish	OS		AVD
Elassoma okefenokee	Okefenokee pygmy sunfish	OS		AVD
Enneacanthus gloriosus	Bluespotted sunfish	OS	April–September	N
Lepisosteus osseus	Longnose gar	OD – R	March–September	SV
Lepisosteus platyrhincus	Florida gar	OD – R	April–October	SV
Dorosoma cepedianum	Gizzard shad	OD – R	April–June	SD
Dorasoma petenense	Threadfin shad	OD – L	May–July	SD
Cyprinus carpio	Common carp	OD – J	Spring	SF
Ctenopharyngodon idella	Grass carp – EXOTIC	OD – R	Spring	SA
Notemigonus crysoleucas	Golden shiner	OD – R	April–July	SD
Notropis maculatus	Taillight shiner	OD – L	March–August	SD
Notropis petersoni	Coastal shiner	OD – R, L, J	March–October	SD
Opsopoedus emiliae	Pugnose minnow	OD – J	March–September	SD

[1]OS = off channel specialist; OD = off channel dependent; R = reproduction; L = larval; J = juvenile; HG = habitat generalist; FS = fluvial specialist. Habitat guild follows Glenn and Arrington (2005).

[2]N = nest builder; SD = scatters demersal eggs; N/M = nest builder/mouthbrooder; SV = scatters eggs in vegetation; SF = scatters floating eggs; SA = scatters adhesive eggs; AVD = demersal eggs attached to vegetation; L = livebearer; constructs floating nest. Spawning modes are from Trexler (2005).

Table 5. Continued.

Scientific Name	Common Name	Guild[1]	Spawning Season	Spawning Mode[2]
Erimyzon sucetta	Lake chubsucker	OD – J	May–July	SD
Ameiurus catus	White catfish	OD – J	April–July	N
Ictalurus punctatus	Channel catfish	OD – R	March–June	N
Clarius batrachus	Walking catfish – EXOTIC	OD – R	June–November	N
Hoplosternum littorale	Brown hoplo – EXOTIC	OD – R	June–November	NF
Fundulus seminolis	Seminole killifish	OD – R, L, J	April–summer	SA
Labidesthes sicculus	Brook silverside	OD – J	June–August	SA
Lepomis auritrus	Redbreast sunfish	OD – L	March–September	N
Lepomis gulosus	Warmouth	OD – R, L, J	April–October	N
Lepomis machrochirus	Bluegill	OD – R, L, J	February–October	N
Lepomis marginatus	Dollar sunfish	OD – R, L, J	April–September	N
Lepomis microlophus	Redear sunfish	OD – R, L, J	February–October	N
Lepomis punctatus	Spotted sunfish	OD – R, L, J	May–November	N
Micropterus salmoides	Largemouth bass	OD – R, L, J	December–May	N
Pomoxis nigromaculatus	Black crappie	OD – R, L, J	April–May	N
Astronotus ocellatus	Oscar – EXOTIC	OD – R, L, J		N
Oreochromis aureus	Blue tilapia – EXOTIC	OD – J		N/M
Fundulus chrysostus	Golden topminnow	OD – R	Late spring–summer	SA
Fundulus lineotus	Lined topminnow	HG		SA
Fundulus rubifrons	Redface topminnow	HG		SA
Menidia beryllina	Tidewater silverside	HG	June–August	SD
Etheostoma fusiforme	Swamp darter	HG	December–May	AVD
Anguilla rostrata	American eel	FS		SF
Strongylura marina	Atlantic needlefish	FS	Summer	AVD
Percina nigrofasciata	Blackbanded darter	FS		?
Mugil cephalus	Stripped mullet	FS		SD
Pterygoplichthys disjunctivus	Sailfin catfish – EXOTIC			N

[1]OS = off channel specialist; OD = off channel dependent; R = reproduction; L = larval; J = juvenile; HG = habitat generalist; FS = fluvial specialist. Habitat guild follows Glenn and Arrington (2005).

[2]N = nest builder; SD = scatters demersal eggs; N/M = nest builder; mouthbrooder; SV = scatters eggs in vegetation; SF = scatters floating eggs; SA = scatters adhesive eggs; AVD demersal eggs attached to vegetation; L = livebearer; constructs floating nest. Spawning modes are from Trexler (2005).

A guild classification based on hydrologic habitat (Appendix B) shows that a large proportion of the fish community is dependent on the floodplain (**Figure 8**). The Kissimmee River contains 15 native species that belong to the Off-channel Specialist Guild (**Table 5**). The Off-channel Specialist Guild contains species that are usually found in off-channel habitats or are limited to non-flowing vegetated waters throughout their life. Many of these species are small forage fish, such as mosquito fish (*Gambusia holbrooki*) and the least killifish (*Heterandria formosa*). These fish are important prey for game fish and for wading birds foraging on the floodplain. Another 23 native species and 5 exotic species belong to an Off-channel Dependent Guild. The Off-channel Dependent Guild may use diverse habitats, but require access to or use of off-channel habitats or are limited to non-flowing, vegetated waters for some portion of their life cycle. These 38 native species, which are dependent on an inundated floodplain for some stage in the life cycle, constitute 74% of the species currently in the river.

While only one fish species was lost following channelization, the fish community experienced a reorganization that was related to a change in habitat characteristics (Glenn and Arrington 2005). A comparison of relative abundance of the pre-channelization community from the 1950s (FGFWFC 1957) with post-channelization data shows a decline of gamefish (centrarchids) and an increase of Florida gar (*Lepisosteus platyrhincus*) and bowfin (*Amia calva*), which are more tolerant of environmental conditions following channelization (Glenn and Arrington 2005). It is likely that the absolute decrease in overall numbers occurred because of the significantly decreased area of inundated floodplain. Since completion of Phase I of the Kissimmee River Restoration Project in 2001, the fish community in this portion of the river has begun to change with increases in the relative abundance of important centrarchids—largemouth bass (*Micropterus salmoides*), bluegill (*L. machrochirus*), and spotted sunfish (*L. punctatus*)—and a decrease in bowfin (Bousquin et al. 2007, 2009).

Hydrologic Requirements

The species that compose riverine fish communities are adapted to seasonally fluctuating flow (Poff et al. 1997, Poff and Allan 1995) and utilize inundated floodplain habitat during the seasonal flood pulse of water onto and off the floodplain in medium to large rivers (Welcomme 1979, Junk et al. 1989). Before channelization, the Kissimmee River experienced a flood pulse that began with high flows near the end of the summer–fall wet season. The pulse inundated much of the floodplain for an extended period of time (Toth et al. 2002). The pulse had a gradual recession over the dry season, with base flow continuing until the next pulse event.

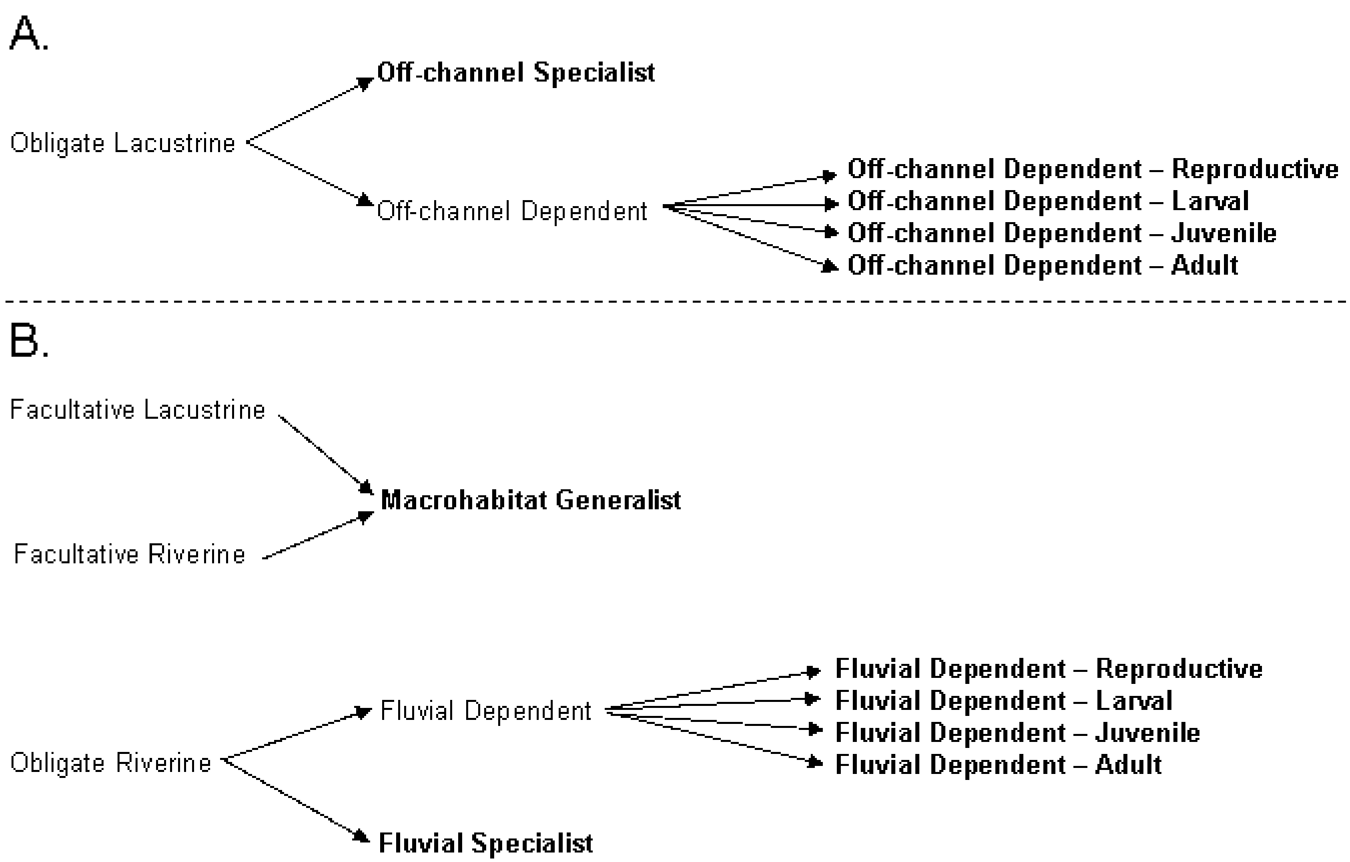

Figure 8. Schematic representation of modified macrohabitat guild structure derived by Bain (1992). (A) New guild categories based on dependence of associated taxa on off-channel habitat. The new category termed Off-channel Dependent includes species that are found in a variety of habitats, but require access or use of off-channel habitats, or are limited to nonflowing, vegetated waters at some point in their life cycle. These species may have significant riverine populations during particular life history stages. The Off-channel Specialist category refers to species that are usually found only in off-channel habitats or species that are limited to non-flowing, vegetated habitats throughout life. Occasionally, individuals may be found in the river channel, but most information about these fish pertains to off-channel habitat. (B) Original macrohabitat guild classification developed by Bain (1992).

Seasonality is an important aspect of the flood pulse. In the Kissimmee River, seasonality is reflected in the timing of the maximum and minimum average monthly flows and a gradual transition from the maximum to the minimum. If the timing of seasonal maximal and minimal flows is significantly altered, organisms may not be able to reproduce, survival of progeny may suffer, and other habitat requirements may not be met. In Florida rivers, Bonvechio and Allen (2005) found that recruitment of sunfish (Centrarchidae) was affected by the timing of high flows. High flows during or after spawning could damage nests or displace offspring. High flows before spawning allowed adults access to the floodplain where more invertebrate prey may be available. Three or more consecutive years with poor seasonality of flow may have the potential to reduce the abundance of sunfish (Bonvechio and Allen 2005).

Fish need high water levels to access the floodplain for reproduction and foraging (Scheaffer and Nickum 1986, Winemiller and Jepsen 1998). For example, largemouth bass require water depths of 2–4 feet (60–120 centimeters [cm]) for nest construction and their fry require densely vegetated habitat as refugia (**Table 5**). The time required for this process is as follows: nest construction and spawning 1–3 days; egg incubation 3–4 days; time for eggs to hatch and for hatchlings to fully develop as fry (swim-up) 5–8 days; parental guarding of fry 7–14 days; and schooling by fry after abandonment 26–31 days. Therefore, bass require appropriate inundation characteristics for 42–60 days for a single spawning event that may occur between December and May. In addition to largemouth bass, other off-channel dependent fish taxa spawn throughout the year, especially ecologically and socio-politically significant game fish (**Table 5**). For instance, both bluegill and redear sunfish (*Lepomis microlophus*) are known to spawn in Florida between February and October, whereas spotted sunfish spawn between May and November (Carlander 1977). When all centrarchid taxa are considered (including largemouth bass), spawning may occur during any month of the year (**Table 5**).

High water levels are needed to create hydroperiods and water depths to maintain large areas of Broadleaf Marsh Group plant community, which provides forage and refuge from predation for early life stages of large-bodied fish (Savino and Stein 1982, Toth 1990a, Winemiller and Jepsen 1998). Inundation of the floodplain also creates foraging opportunities by creating habitat for the secondary production of aquatic invertebrates and forage fish (Gladden and Smock 1990, Winemiller and Jepsen 1998). In tropical floodplain rivers, the yield of fish in one year is positively related to the area of floodplain inundated in previous years (Welcomme and Hagborg 1977).

When the floodplain is no longer inundated, flow is still required to maintain habitat characteristics in the river channel. Based on studies conducted during the Pool B Demonstration Project, a minimum flow of 250 cubic feet per second (ft^3/s) was needed during the summer to maintain dissolved oxygen levels suitable for fish (Wullschleger et al. 1990a). Minimum sustained flows of $\geq 247\ ft^3/s$ are needed to preserve habitat quality (Wullschleger et al. 1990b). These flows are also needed to maintain the river channel substrate and to create an appropriate distribution of vegetation within the river channel.

The velocity of water movement also appears to be a factor in the protection of fish and wildlife. Based on observations during the Kissimmee River Demonstration Project, mean channel velocities that exceeded 1.6 feet per second (ft/s) (0.5 meters per second) caused fish to seek refuge or possibly migrate (Wullschleger et al. 1990b, Miller 1990). This value agrees with reports from other systems for two species that occur in the Kissimmee River. For the redbreast sunfish (*Lepomis autitus*), water velocities up to 1.1 ft/s (35 centimeters per second [cm/s]) are good for adults and juveniles, velocities up to 0.7 ft/s (20 cm/s) are good for fry and embryo stages, and velocities > 1.1 ft/s (35 cm/s) reduce abundance (Aho et al. 1986). For the bluegill, adults prefer current velocities < 0.3 ft/s (10 cm/s), but will tolerate up to 1.5 ft/s (45 cm/s) (Stuber et al. 1982a). For largemouth bass, optimal velocities are < 0.19 ft/s (6 cm/s), and > 0.65 ft/s (20 cm/s) are unsuitable (Stuber et al. 1982b).

Kissimmee River Amphibians and Reptiles

Amphibians and reptiles (herpetofauna) are abundant and often conspicuous inhabitants of freshwater broadleaf marshes. Amphibians are of particular ecological interest because of their complex life cycle, which includes an obligate association of larvae with water. As such, both adult and larval amphibians, as well as reptiles, are particularly vulnerable to shifts in wetland hydrology (Pechmann et al. 1989).

Before 1960 and channelization of the Kissimmee River, the Broadleaf Marsh Group vegetation community was one of the dominant communities covering approximately half of the floodplain within the Kissimmee River Restoration Project area. Although detailed records of amphibian and reptile use of floodplain wetlands adjacent to the Kissimmee River are not available prior to channelization, Carr (1940) lists characteristic and frequently occurring amphibian and reptile taxa of central Florida freshwater (broadleaf-like) marshes. These taxa likely accounted for most herpetofaunal species inhabiting floodplain marshes along the pre-channelized Kissimmee River.

Channelization of the river and conversion of wetlands to uplands, combined with shortened and unpredictable hydroperiods in remnant wetlands likely altered herpetofaunal communities (Koebel et al. 2005b). Of the 24 species that are likely to occur in pre-channelization Broadleaf Marsh Group wetlands, only three were collected in the drained floodplain adjacent to the Kissimmee River (**Table 6**) These species were the green tree frog (*Hyla cinera*), the southern leopard frog (*Rana sphenocephala*), and the eastern cottonmouth (*Agkistrodon piscivorus*). The taxa that appear to be most affected are those that require long periods of inundation for reproduction (many anurans) and those that are entirely aquatic (salamanders). This reduction is a strong indicator that degraded Broadleaf Marsh Group communities no longer adequately function to support the necessary refuge, foraging, and reproductive needs of amphibians and reptiles of the river-floodplain system.

Table 6. Characteristic and frequently occurring aquatic amphibian and reptile taxa of central Florida freshwater (broadleaf) marshes (Carr 1940).

Scientific Name	Common Name	Obligate Association with Water**
AMPHIBIANS		
Amphiumidae		
Amphiuma means	Two-toed siren	A
Plethodontidae		
Eurycea quadridigitata	Dwarf salamander	A
Sirenidae		
Siren lacertina	Greater siren	A
Hylidae		
Acris gryllus dorsalis	Florida cricket frog	L
Hyla cinerea	Green tree frog*	L
Hyla squirella	Squirrel tree frog	L
Pseudacris nigrita verrucosa	Florida chorus frog	L
Pseudacris ocularis	Little grass frog	L
Ranidae		
Rana grylio	Pig frog	L
Rana sphenocephala	Southern leopard frog*	L
REPTILES		
Alligatoridae		
Alligator mississippiensis	American alligator	
Chelydridae		
Chelydra serpentine osceola	Florida snapping turtle	
Colobridae		
Farancia abacura	Eastern mud snake	
Nerodia fasciata pictiventris	Florida water snake	
Nerodia floridana	Florida green water snake	
Regina alleni	Striped crayfish snake	
Seminatrix pygaea	South Florida swamp snake	
Emydidae		
Deirochelys reticularia	Florida chicken turtle	
Pseudemys floridana	Peninsular cooter	
Pseudemys nelsoni	Peninsula red-bellied turtle	
Kinosternidae		
Kinosternon subrubrum steindachneri	Florida mud turtle	
Sternotherus odoratus	Common musk turtle	
Trionychidae		
Trionyx ferox	Florida softshell turtle	
Viperidae		
Agkistrodon piscivorus	Eastern cottonmouth*	

* Denotes taxa observed in degraded Broadleaf Marsh Group (currently pasture) adjacent to the Kissimmee River.
** A = Adult; L = Larvae

Restoration of pre-channelization hydrology, including long-term floodplain inundation, is expected to reestablish historical floodplain wetland plant communities (Carnal 2005a, 2005b) within the Kissimmee River Restoration Project area. Restoration of hydrology and wetland habitat structure within the restoration project area will be the impetus for the recolonization of amphibians and reptiles characteristic of the pre-channelized Kissimmee River floodplain ecosystem. During extreme rainfall events, events that produce standing water on the unrestored Kissimmee River floodplain, 7 of the 7 native anuran taxa and several species of reptiles likely to exist in natural wetlands of central Florida were found in limited numbers on the floodplain (B. Anderson, SFWMD, unpublished data). Recruitment from remnant isolated wetlands and unaltered wetlands adjacent to and upstream of the restored river should contribute to the rapid recolonization of the restored floodplain. For example, all 24 taxa likely to colonize restored wetlands (**Table 6**) have been documented from wetlands of the Avon Park Air Force Range, adjacent to the floodplain (Franz et al. 2000). Other studies have shown that amphibians can colonize and reproduce in restored (Lehtinen and Galatowitsch 2001, Stevens et al. 2002, Petranka 2003, Brodman et al. 2006) and constructed wetlands (Knutson et al. 2004).

Kissimmee River Birds

Background

The Kissimmee River and associated floodplain historically served as important breeding and wintering grounds for large populations of wetland-dependent wading birds (Ciconiiformes), waterfowl (Anseriformes), shorebirds (Charadriiformes), marsh birds (Podicipadidae, Ardeidae, Rallidae, and Aramidae) and song birds (Passeriformes) (National Audubon Society 1936–1959, FGFWFC 1957, Weller 1995, Williams and Melvin 2005b). However, populations of many of these bird groups were negatively impacted by channelization. Channelization substantially reduced the quantity and quality of marsh habitat during the 1960s (Perrin et al. 1982, Toth 1993, Weller 1995). Pre- and post-channelization data indicated a 92 percent reduction in the mean number of waterfowl use days for all ducks (Anatinae) and American coots (*Fulica americana*) (Perrin et al. 1982). Wading bird breeding colonies also formed more regularly, were larger, and were not dominated by cattle egrets (*Bubulcus ibis*) before channelization (National Audubon Society 1936–1959). Post-channelization changes in hydrology, vegetation communities, and associated prey communities are thought to have contributed to the reduction of wading bird and waterfowl use of the river. This idea is supported by the latest KRREP monitoring data, which indicate that the abundance of both wading birds and waterfowl have increased over baseline (channelized) conditions since the completion of Phase I of restoration in 2001 (Bousquin et al. 2009, see also Appendix A, Figure A-21 and Figure A-22). Completion of this phase periodically reflooded more than 5,792 acres of pasture and uplands and brought about the partial return of historical hydrologic conditions and vegetation communities (Bousquin et al. 2007, 2009). It is also likely to have produced a concomitant effect on prey populations of invertebrates and small fish (Bousquin et al. 2007, 2009).

Wetland habitats of the river corridor (river channel and floodplain) support at least 159 bird species, 66 of which are considered wetland-dependent. This figure includes 18 state and 3 federally listed species (Appendix D and **Table 7**). A total of 32 wetland-dependent species are breeding residents. The other 34 species depend on the Kissimmee River during some portion of their life cycle, particularly during migration and overwintering, while foraging, roosting, and seeking cover (**Table 8**). Of the remaining 93 bird species, 68 are considered facultative and 25 opportunistic users of wetlands. Facultative users may nest, forage, and seek shelter in upland habitats, but preferentially use wetlands in most geographic areas or during particular times of the year (e.g., dry season). Opportunistic wetland users are species that are typically associated with uplands, but that may periodically take advantage of abundant food or habitat resources near water in certain locations along the Kissimmee River.

All wetland associated bird species in **Table 7**, **Table 8**, and Appendix D have been documented using the floodplain in some capacity, while conducting aerial (helicopter) surveys, avian point counts, or other fieldwork. The breeding status of each species along the river was derived from direct observations of nesting, presence during the breeding season and the Florida Fish and Wildlife Conservation Commission's Breeding Bird Atlas, Distribution Maps by County (FWC 2003a). If specific measurements of water depths were not provided in the literature (primarily from *The Birds of North America Online* [Poole 2008]), water depths were taken from direct observations made during point count surveys or were estimated based on water depths associated with particular vegetation communities along the river. Habitat types were also based on field observations made during point count surveys or from descriptions in the literature that were then translated to one of the three primary vegetation types found along the Kissimmee (Broadleaf Marsh, Wet Prairie, and Wet Shrub groups).

Habitat and Hydrologic Requirements

The general hydrologic characteristics of both foraging (mean water depth) and breeding (mean water depth under nest) habitat for wetland-dependent birds of the Kissimmee River are presented in **Table 8**. Bird habitat along the Kissimmee River can be classified into four principal vegetation community types. Three of these are the Broadleaf Marsh, Wetland Shrub, and Wet Prairie groups, which are the three dominant types of marsh vegetation described previously (see the Kissimmee River Floodplain Plant Communities section). The fourth is the Wetland Forest Group, which is described in Appendix B. The plant, macroinvertebrate, fish, amphibian, reptile, bird, and small mammal communities associated with these habitats form the basis of the food web for wading birds, waterfowl, shorebirds, marsh birds, and songbirds. The distribution and structure of these habitats are a function of the timing, magnitude, and duration of the annual hydrologic cycle of flooding (typically June–November) and drying (usually December–May). As such, these functions work in tandem to dictate the location, timing, and success of foraging and reproduction along the river. Wading birds throughout South Florida, for example, are thought to cue the timing of breeding to the increased availability of prey during the dry season, when aquatic invertebrates and small fish become concentrated in isolated pools as water levels recede (Frederick and Collopy 1989a). Without this natural flood/drought cycle, which along the Kissimmee causes water levels to fluctuate an average of 5.8 feet per year, vegetative community composition, structure, and function change and can negatively impact wetland dependent bird populations (Toth 1993, Weller 1995). Reduced water levels can affect nest site selection and increase vulnerability to land-based predators (Frederick and Collopy 1989b).

Table 7. Wetland-dependent bird species of the Kissimmee River floodplain, including preferred foraging and breeding habitats.

Common Name	Order Family Genus Species	Foraging Habitat Type*	Breeding Habitat Type*
Ducks, Geese & Swans	**Anseriformes Anatidae**		
American wigeon	*Anas americana*	All	-
Black-bellied whistling duck	*Dendrocygna autumnalis*	All, OW	WF (BLM, WS, WP)
Blue-winged teal	*Anas discors*	BLM, WP	-
Fulvous whistling-duck	*Dendrocygna bicolor*	All, OW	BLM, WS, WP
Green-winged teal	*Anas crecca*	All	-
Hooded merganser	*Lophodytes cucullatus*	All and OW	-
Lesser scaup	*Aythya affinis*	OW, BLM	-
Mallard	*Anas platyrhynchos*	All, OW	-
Mottled duck	*Anas fulvigula*	BLM, WP, WS, OW	WS, WP (obligatory nester near wetlands)
Northern pintail	*Anas acuta*	BLM, WP, OW	-
Northern shoveler	*Anas clypeata*	OW, BLM, WP	-
Ring-necked duck	*Aythya collaris*	All, OW	-
Ruddy duck	*Oxyura jamaicensis*	OW, BLM, WP	-
Wood duck	*Aix sponsa*	WF, WS	WF
Grebes	**Podicipediformes Podicipedidae**		
Pied-billed grebe	*Podilymbus podiceps*	All, OW	BLM, WP, WS
Pelicans	**Pelecaniformes Pelecanidae**		
American white pelican	*Pelecanus erythrorhynchos*	BLM, WP	-
Brown pelican	*Pelecanus occidentalis*	BLM, WP, OW	-
Cormorants	**Phalacrocoracidae**		
Double-crested cormorant	*Phalacrocorax auritus*	WS, WF, OW	WF, WS
Darters	**Anhingidae**		
Anhinga	*Anhinga anhinga*	WS, WF, OW	WF, WS

* Habitat key: BLM = Broadleaf Marsh Group, WS = Wet Shrub Group, WP = Wet Prairie Group, WF = Wet Forest Group, OW = Open Water, Al l= All Habitats combined (BLM, WS, WP, and WF), excluding open water. Preferred breeding habitat is left blank for species whose breeding range occurs outside of the Kissimmee River floodplain. Species-specific foraging and breeding habitat information obtained from point count surveys and from *The Birds of North America Online* (Poole 2008). Ithaca: Cornell Lab of Ornithology; Retrieved from *The Birds of North America Online*: http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna.

Table 7. Continued.

Common Name	Order Family Genus Species	Foraging Habitat Type*	Breeding Habitat Type*
Herons, Bitterns & Allies	**Ciconiiformes Ardeidae**		
American bittern	*Botaurus lentiginosus*	BLM, WP	-
Black-crowned night-heron	*Nycticorax nycticorax*	All, OW	WF, WS
Great blue heron	*Ardea herodias*	All, OW	WF, WS
Great egret	*Ardea alba*	All, OW	WF, WS
Green heron	*Butorides virescens*	All, OW	WF, WS
Least bittern	*Ixobrychus exilis*	BLM, WS, WP	BLM, WS, WP
Little blue heron	*Egretta caerulea*	All, OW	WF, WS
Snowy egret	*Egretta thula*	All, OW	WF, WS
Tricolored heron	*Egretta tricolor*	All, OW	WF, WS
Yellow-crowned night heron	*Nyctanassa violacea*	All, OW	WF, WS
Ibises & Spoonbills	**Threskiornithidae**		
Glossy ibis	*Plegadis falcinellus*	All, OW	All
Roseate spoonbill	*Platalea ajaja*	All, OW	WF, WS
White ibis	*Eudocimus albus*	All, OW	WF, WS (BLM, WP)
Storks	**Ciconiidae**		
Wood stork	*Mycteria americana*	All, OW	WF, WS
Hawks, Kites, Eagles & Allies	**Falconiformes Accipitridae**		
Bald eagle	*Haliaeetus leucocephalus*	BLM, WP, OW	WF (< 2 kilometers water)
Osprey	*Pandion haliaetus*	All, OW	WF (obligatory nester near water)
Snail kite	*Rostrhamus sociabilis*	BLM, WP, WS, OW	WS, WF
Rails, Gallinules & Coots	**Gruiformes Rallidae**		
American coot	*Fulica americana*	All, OW	All
Common moorhen	*Gallinula chloropus*	All, OW	WS, BLM, WP
King rail	*Rallus elegans*	BLM, WS, WP	BLM, WS, WP
Purple gallinule	*Porphyrio martinica*	All, OW	BLM, WF, WS
Sora	*Porzana carolina*	BLM, WP, WS	-
Limpkin	**Aramidae**		
Limpkin	*Aramus guarauna*	BLM, WS, WF, OW	All
Cranes	**Gruidae**		
Florida sandhill crane	*Grus canadensis pratensis*	BLM, WEP	BLM, WEP, WS
Stilts & Avocets	**Charadriiformes Recurvirostridae**		
Black-necked stilt	*Himantopus mexicanus*	BLM, WS, WP, OW	BLM, WP

* Habitat key: BLM = Broadleaf Marsh Group, WS = Wet Shrub Group, WP = Wet Prairie Group, WF = Wet Forest Group, OW = Open Water, Al l= All Habitats combined (BLM, WS, WP, and WF), excluding open water. Preferred breeding habitat is left blank for species whose breeding range occurs outside of the Kissimmee River floodplain. Species-specific foraging and breeding habitat information obtained from point count surveys and from *The Birds of North America Online* (Poole 2008). Ithaca: Cornell Lab of Ornithology; Retrieved from *The Birds of North America Online*: http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna.

Table 7. Continued.

Common Name	Order Family Genus Species	Foraging Habitat Type*	Breeding Habitat Type*
Sandpipers & Allies	**Scolopacidae**		
Greater yellowlegs	*Tringa melanoleuca*	BLM, WP, OW	-
Least sandpiper	*Calidris minutilla*	BLM, WP, WS, OW	-
Lesser yellowlegs	*Tringa flavipes*	BLM, WP, WS, OW	-
Long-billed dowitcher	*Limnodromus scolopaceus*	BLM, WS, WP, OW	-
Short-billed dowitcher	*Limnodromus griseus*	BLM, WS, WP, OW	-
Solitary sandpiper	*Tringa solitaria*	BLM, WP, WS, OW	-
Spotted sandpiper	*Actitis macularius*	BLM, WP, OW	-
Wilson's snipe	*Gallinago delicata*	All	-
Skuas, Gulls, Terns, & Skimmers	**Laridae**		
Black skimmer	*Rynchops niger*	BLM, WP, OW	-
Black tern	*Chlidonias niger*	BLM, WP, OW	-
Bonapart's gull	*Chroicocephalus philadelphia*	BLM, WP, OW	-
Caspian tern	*Hydroprogne caspia*	BLM, WP, OW	-
Forster's tern	*Sterna forsteri*	OW, BLM, WP	-
Gull-billed tern	*Gelochelidon nilotica*	BLM, WP, OW	-
Herring gull	*Larus argentatus*	WP, BLM, OW	-
Least tern	*Sternula antillarum*	BLM, WP, WS, OW	-
Kingfishers	**Coraciiformes Alcedinidae**		
Belted kingfisher	*Megaceryle alcyon*	All, OW	-
Swallows	**Passeriformes Hirundinidae**		
Tree swallow	*Tachycineta bicolor*	All	-
Wrens	**Troglodytidae**		
Marsh wren	*Cistothorus palustris*	WS, WF, WP, BLM	-
Emberezids	**Emberizidae**		
Swamp sparrow	*Melospiza georgiana*	All	-
Blackbirds	**Icteridae**		
Boat-tailed grackle	*Quiscalus major*	All, OW	WF, WS (BLM, WP) (obligatory nester near water)
Red-winged blackbird	*Agelaius phoeniceus*	All	WS, BLM, WP

* Habitat key: BLM = Broadleaf Marsh Group, WS = Wet Shrub Group, WP = Wet Prairie Group, WF = Wet Forest Group, OW = Open Water, Al l= All Habitats combined (BLM, WS, WP, and WF), excluding open water. Preferred breeding habitat is left blank for species whose breeding range occurs outside of the Kissimmee River floodplain. Species-specific foraging and breeding habitat information obtained from point count surveys and from *The Birds of North America Online* (Poole 2008). Ithaca: Cornell Lab of Ornithology; Retrieved from *The Birds of North America Online*: http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna.

Table 8. Foraging and breeding habitat hydrologic requirements of wetland-dependent bird species of the Kissimmee River floodplain.

Common Name	Order Family Genus Species	Foraging Hydrologic Requirements	Breeding Hydrologic Requirements*
Ducks, Geese & Swans	**Anseriformes Anatidae**		
American wigeon	*Anas americana*	0–20 cm	–
Black-bellied whistling duck	*Dendrocygna autumnalis*	0 to ≤ 6.6 cm	near water
Blue-winged teal	*Anas discors*	13–88 (mean 30 cm)	–
Fulvous whistling-duck	*Dendrocygna bicolor*	< 0.5 m	< 0.5 m
Green-winged teal	*Anas crecca*	0–25 (mean < 12 cm)	–
Hooded merganser	*Lophodytes cucullatus*	< 1.5 m	–
Lesser scaup	*Aythya affinis*	< 3 m	–
Mallard	*Anas platyrhynchos*	0–39 (mean 31–39 cm)	–
Mottled duck	*Anas fulvigula*	< 30 cm	w/in 15–219 m of water (mean = 119 m)
Northern pintail	*Anas acuta*	0–30 cm	–
Northern shoveler	*Anas clypeata*	< 40 cm	–
Ring-necked duck	*Aythya collaris*	< 1.5 m	–
Ruddy duck	*Oxyura jamaicensis*	1–3 m	–
Wood duck	*Aix sponsa*	18–40 cm (up to 1 m)	over or near water; < 2 kilometers from water maximum
Grebes	**Podicipediformes Podicipedidae**		
Pied-billed grebe	*Podilymbus podiceps*	< 6 m	> 25 cm
Pelicans	**Pelecaniformes Pelecanidae**		
American white pelican	*Pelecanus erythrorhynchos*	0.3–2.5 m	–
Brown pelican	*Pelecanus occidentalis*	permanently flooded < 150 m	–
Cormorants	**Phalacrocoracidae**		
Double-crested cormorant	*Phalacrocorax auritus*	< 8 m	< 10 kilometers from water
Darters	**Anhingidae**		
Anhinga	*Anhinga anhinga*	< 0.5 m	1–4.6 m above water

Foraging and breeding habitat information and hydrologic requirements were obtained from point count surveys along the river and Willard (1977), Powell (1987), Stys (1997), Guillemain et al. (2000), Poole (2008), and FWC (2003a).

* Preferred breeding habitat is blank for species whose breeding range occurs outside of the Kissimmee River floodplain.

Table 8. Continued.

Common Name	Order Family Genus Species	Foraging Hydrologic Requirements	Breeding Hydrologic Requirements*
Herons, Bitterns & Allies	**Ciconiiformes Ardeidae**		
American bittern	*Botaurus lentiginosus*	mean 10 cm	–
Black-crowned night-heron	*Nycticorax nycticorax*	< 20 cm	over water > 0.5 m March–August; recession < 18.3 centimeters per week (cm/week)
Great blue heron	*Ardea herodias*	< 40 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Great egret	*Ardea alba*	< 28 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Green heron	*Butorides virescens*	< 10 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Least bittern	*Ixobrychus exilis*	1–60 cm; usually at surface	over water > 0.5 m March–August; recession < 18.3 cm/week
Little blue heron	*Egretta caerulea*	< 17 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Snowy egret	*Egretta thula*	< 17 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Tricolored heron	*Egretta tricolor*	< 18 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Yellow-crowned night heron	*Nyctanassa violacea*	< 10 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Ibises & Spoonbills	**Threskiornithidae**		
Glossy ibis	*Plegadis falcinellus*	< 10 cm	over water > 0.5 m March–August; recession < 18.3 cm/week
Roseate spoonbill	*Platalea ajaja*	< 20 cm (mean ≤ 12 cm)	over water > 0.5 m March–August; recession < 18.3 cm/week
White ibis	*Eudocimus albus*	< 20 cm (mean 5–10 cm)	over water > 0.5 m March–August; recession < 18.3 cm/week
Storks	**Ciconiidae**		
Wood stork	*Mycteria americana*	< 50 cm	over water > 0.5 m March–August; recession < 18.3 cm/week

Foraging and breeding habitat information and hydrologic requirements were obtained from point count surveys along the river and Willard (1977), Powell (1987), Stys (1997), Guillemain et al. (2000), Poole (2008), and FWC (2003a).

* Preferred breeding habitat is blank for species whose breeding range occurs outside of the Kissimmee River floodplain.

Table 8. Continued.

Common Name	Order Family Genus Species	Foraging Hydrologic Requirements	Breeding Hydrologic Requirements*
Hawks, Kites, Eagles & Allies	**Falconiformes Accipitridae**		
Bald eagle	*Haliaeetus leucocephalus*	0–2 m	< 2 kilometers from open water
Osprey	*Pandion haliaetus*	0.5–2 m	< 10–20 kilometers from open water
Snail kite	*Rostrhamus sociabilis*	0.2–1.3 m	36–93 cm
Rails, Gallinules & Coots	**Gruiformes Rallidae**		
American coot	*Fulica americana*	< 6 m	over permanent water <1.2 m from open water
Common moorhen	*Gallinula chloropus*	15–120 cm	0–60 cm
King rail	*Rallus elegans*	< 10 cm	10–46 cm
Purple gallinule	*Porphyrio martinica*	0.25–1 m	14.7 (6–26 cm)
Sora	*Porzana carolina*	< 15 (0–46 cm)	-
Limpkin	**Aramidae**		
Limpkin	*Aramus guarauna*	< 30 cm	61.2 (41–122 cm)
Cranes	***Gruidae***		
Florida sandhill crane	*Grus canadensis pratensis*	0–30 cm	13.5–32.6 cm
Stilts & Avocets	**Charadriiformes Recurvirostridae**		
Black-necked stilt	*Himantopus mexicanus*	< 13 cm	usu. over water or < 50 m from open water
Sandpipers & Allies	**Scolopacidae**		
Greater yellowlegs	*Tringa melanoleuca*	5–7.4 cm	–
Least sandpiper	*Calidris minutilla*	< 4 cm	–
Lesser yellowlegs	*Tringa flavipes*	2.6 (4–16 cm)	–
Long-billed dowitcher	*Limnodromus scolopaceus*	0–16 cm	–
Short-billed dowitcher	*Limnodromus griseus*	< 8 cm	–
Solitary sandpiper	*Tringa solitaria*	< 5 cm	–
Spotted sandpiper	*Actitis macularius*	< 4 cm	–
Wilson's snipe	*Gallinago delicata*	< 8 cm	–

Foraging and breeding habitat information and hydrologic requirements were obtained from point count surveys along the river and Willard (1977), Powell (1987), Stys (1997), Guillemain et al. (2000), Poole (2008), and FWC (2003a).

* Preferred breeding habitat is blank for species whose breeding range occurs outside of the Kissimmee River floodplain.

Table 8. Continued.

Common Name	Order Family Genus Species	Foraging Hydrologic Requirements	Breeding Hydrologic Requirements*
Skuas, Gulls, Terns & Skimmers	**Laridae**		
Black skimmer	*Rynchops niger*	< 2.5–20 cm	–
Black tern	*Chlidonias niger*	> 0.5 m	–
Bonapart's gull	*Chroicocephalus philadelphia*	> 0.5 m	–
Caspian tern	*Hydroprogne caspia*	0.5–5 m	–
Forster's tern	*Sterna forsteri*	< 1 m	–
Gull-billed tern	*Gelochelidon nilotica*	0–5 m	–
Herring gull	*Larus argentatus*	< 1–2 m	–
Least tern	*Sternula antillarum*	0–5 m	–
Kingfishers	**Coraciiformes Alcedinidae**		
Belted kingfisher	*Megaceryle alcyon*	< 60 cm	–
Swallows	**Passeriformes Hirundinidae**		
Tree swallow	*Tachycineta bicolor*	any	–
Wrens	**Troglodytidae**		
Marsh wren	*Cistothorus palustris*	< 1 m	–
Emberezids	**Emberizidae**		
Swamp sparrow	*Melospiza georgiana*	< 4 cm	–
Blackbirds	**Icteridae**		
Boat-tailed grackle	*Quiscalus major*	< 8 cm	93.1 cm
Red-winged blackbird	*Agelaius phoeniceus*	< 1 m	< 1 m

Foraging and breeding habitat information and hydrologic requirements were obtained from point count surveys along the river and Willard (1977), Powell (1987), Stys (1997), Guillemain et al. (2000), Poole (2008), and FWC (2003a).

* Preferred breeding habitat is blank for species whose breeding range occurs outside of the Kissimmee River floodplain.

Of the 32 bird species dependent on wetlands for successful reproduction, nine use primarily herbaceous marsh (i.e., Broadleaf Marsh and Wet Prairie groups) as their principal nesting habitat, while 23 depend primarily on woody wetland vegetation (i.e., Wetland Shrub and Wetland Forest groups) to serve as nesting substrate (**Table 7**). However, four of these wetland nesting species (bald eagle, boat-tailed grackle, mottled duck, and osprey) can also nest in upland habitats as long as they are in close proximity to water (e.g., < 2 kilometers [km] for bald eagles).

Snail kites build nests in flooded (36–93 cm deep) vegetation of either woody (southern willow, *Salix* spp.; buttonbush, *Cephalanthus occidentalis*; and cypress, *Taxodium* spp.) or non-woody (cattail, *Typha* spp. and bulrush, *Scirpus* spp.) species (Benedict et al. 2008). Nests are typically in close proximity (< 500 m) to appropriate foraging habitat, are > 50 m away from the shoreline, and are submerged or surrounded by water > 0.5 m deep during the January–July nesting season to serve as an effective barrier against land-based predators (e.g., raccoons) (Sykes et al. 1995).

Wading bird nesting colonies along the river are typically found in woody shrubs and trees, either submerged or surrounded by water. This is typical of many wading bird colonies throughout the state that form as follows:

1. On islands (2–10 hectares) surrounded by at least 0.5 m (1.64 feet) of water during the January–July breeding season in Florida (White et al. 2005, Frederick and Collopy 1989b)
2. > 50 m from uplands or the "mainland" if an island
3. > 100 m from human disturbance
4. Within 0.4 km of suitable vegetation with dead and live nesting materials
5. Within 10 km of suitable foraging habitat (White et al. 2005)

The Florida sandhill crane (*Grus Canadensis pratensis*) typically nests in shallow (13.5–32.6 cm deep) herbaceous wetlands composed of Broadleaf Marsh and Wet Prairie groups vegetation types (Stys 1997). Nesting sites may shift to more permanent waterbodies (e.g., lakes) when ephemeral wetlands dry too early in the nesting season or during longer-term drought conditions (Marty Folk, Florida Fish and Wildlife Conservation Commission, personal communication).

Two waterfowl species that consistently nest along the Kissimmee River are mottled (*Anas fulvigula*) and wood ducks (*Aix sponsa*). Mottled ducks were reported to nest on the ground in hayfields, grazed pasture, and natural upland prairie habitat, averaging a distance of 138 m from water (B. Dugger, Oregon State University, and S. Melvin, United States Fish and Wildlife Service, personal communication). Wood ducks are tree nesters that prefer mature forests with suitable cavity trees over or near water (< 2 km) (Poole 2008).

In addition to nesting habitat requirements, many species require contrasting habitat types to forage and provide food for their young. Of the 32 wetland obligates, 20 species will forage in all four vegetation communities in addition to open water habitat; five species specialize in Broadleaf Marsh and/or Wet Prairie groups; one species specializes in Wetland Forest and/or Wetland Shrub groups; three other species forage primarily in open water near Wetland Forest and Wetland Shrub groups; and three species forage in a mixture of habitats (**Table 7**). Preferred habitats of the facultative and opportunistic species can be found in Appendix D. Additional information about stage recession rates is available for wading birds in the Everglades based on long-term monitoring of nesting effort and water levels (Tarboton et al. 2004).

Foraging habitat for snail kites within the Kissimmee Basin is shallow water (usually $\leq$ 1.3 m) that allows birds to forage effectively for apple snails, their principal prey (Sykes et al. 1995). Kites fly low (1.5–10 m) over the water, or still hunt from perches, while searching for snails within the top 16 cm of the water column (Sykes et al. 1995).

Snail kites are almost entirely dependent on apple snails for survival; therefore, kite foraging habitat must also provide the life history requirements of apple snails, while allowing for successful visual foraging by kites. Female snails deposit eggs on emergent substrates approximately 9–25 cm above the water surface during peak apple snail cluster production in central Florida (April–May) (Turner 1996, Darby et al. 1999). Darby et al. (2008) found that snail recruitment could be reduced during seasonal dry downs by two possible mechanisms: 1) by reduced mating and egg-laying due to an early dry down before the peak egg-laying period, or 2) by decreased survival of juveniles too small to survive a late season dry down after hatching. However, dry downs occurring every two to three years are deemed important for maintaining emergent aquatic vegetation critical for egg-laying and aerial respiration (Darby et. al. 2008).

Although apple snails in Florida are naturally adapted to water level fluctuations of 3–4 feet per year, they need to migrate to deeper water during recession events or aestivate in bottom sediments to avoid stranding and desiccation. Darby et al. (2002) found that when waters receded to a depth of < 10 cm, apple snails ceased all movements and became stranded in dry marsh. Thus, extended low water levels in lakes and wetlands can significantly reduce kite access to snails via snail mortality, matting down of emergent vegetation and subsequent reduction in visibility of snails from above, or declines in recruitment during the following season (Benedict et al. 2008). Complete drying out of the vegetated littoral zone of lakes or wetlands can therefore eliminate kite foraging habitat both temporarily (e.g., up to three months during the dry season) or permanently (e.g., as the result of drainage or other human disturbance). The former is considered part of the natural hydrologic regime in central Florida. One study indicated that 75 percent of adult snails were shown to survive this period of exposure to dry-down conditions, while 50 percent survived up to four months (Darby and Percival 2000). Conversely, high water can negatively impact apple snails and their eggs by drowning egg clusters during rapid ascension events and submerging emergent vegetation so that it is unavailable for oviposition. In general, any large changes in water level (e.g., ≥ 15 cm within 2–3 weeka) during and after egg-laying can either drown egg-clusters during high water, cause adults to migrate out of the vegetated zone, or cause egg-laying vegetative substrate to collapse during rapid recession.

Wading birds will forage in small (< 10 square meter [m^2]) and large (> 1,000 m^2) habitat patches of all vegetation types, including open water, within wetlands and lake littoral zones. Wading birds will usually forage within 5–20 km of a breeding colony site. As their collective name implies, wading birds forage by wading in shallow water (5–40 cm) that varies by the morphological characteristics of each species (especially leg length) (**Table 8**). Although not part of the wading bird order Ciconiiformes, wading depths of the Florida sandhill crane (< 30 cm) are also limited by leg length (Stys 1997).

Seven species of dabbling ducks, four species of diving ducks, and three species of tree ducks use the Kissimmee River, although only four species are resident breeders. Dabbling duck foraging habitat along the Kissimmee River is generally shallow (5–30 cm) emergent wetlands with a vegetation/open water ratio between 30:70 and 70:30 (SFWMD 2008b). Emergent vegetation should be interspersed among open water areas forming a mosaic of patches varying in size and shape. Dabbling duck habitat should be available year-round (SFWMD 2008a).

Diving duck foraging habitat along the Kissimmee River is typically 30–180 cm deep with at least half the area less than 120 cm in depth (SFWMD 2008b). Quality habitat typically has vegetation coverage of at least 40% submerged or floating leaved vegetation and no more than 40% emergent vegetation. Typically, at least 30% of all vegetation within this habitat is composed of any combination of the following species: *Nymphaea odorata, Brasenia schreberi, Najas* spp., *Potamogeton* spp., *Vallisneria americana,* and *Hydrilla verticillata*. Submerged aquatics need to reach the water surface for good habitat value. Diving duck habitat is needed from November 15 through March 15, when migrant diving ducks are most commonly found along the Kissimmee (SFWMD 2008b).

Kissimmee River Mammals

Background

Currently, 26 species of mammals use the Kissimmee River corridor (river channel and floodplain), including four resident breeders and four state-listed endangered species as well as the federally-listed species, the Florida panther (*Puma concolor coryi*) (**Table 9**, Appendix E). Although mammals are not monitored along the Kissimmee River as part of the KRREP (Appendix A), it is likely that populations were negatively impacted by losses of wetland habitat and alteration of hydrology caused by channelization.

The mammals using the Kissimmee River corridor include 4 obligate wetland species, 18 facultative breeders, and 4 opportunistic foragers (**Table 9**). Brief summaries of the aquatic life history requirements of several species of mammals are described as follows. Foraging and breeding habitat hydrologic requirements of wetland-dependent species are summarized in **Table 9**. Foraging and breeding habitat requirements came from literature and field observations along the river during bird surveys and other field work, as described in the aforementioned Birds section.

Habitat and Hydrologic Requirements

The marsh rabbit (*Sylvilagus palustris*), marsh rice rat (*Oryzomys palustris*), and round-tailed muskrat (*Neofiber alleni*) depend on dense emergent aquatic vegetation for cover and to construct their houses and/or nests near water (Birkenholz 1972, Chapman and Willner 1981, Wolfe 1982). The largely vegetarian diet of all three species is composed of the roots, stems, leaves, and seeds of herbaceous wetland plants occurring in Broadleaf Marsh and Wet Prairie groups habitats.

The river otter (*Lontra canadensis*) nest in hollow trees or logs, undercut river banks, backwater sloughs, flood debris, or burrows excavated by other animals, such as the gray fox (*Uroncyon cinereoargenteus*) (Lariviere and Walton 1998). They are entirely dependent on aquatic habitats for finding and capturing their main prey, such as fish, amphibians, crayfish (*Procambarus* spp.), and other aquatic invertebrates.

Table 9. Status, hydrologic requirements of foraging and breeding of wetland dependent mammals of the Kissimmee River.

	Status[1]	Type[2,3]	Foraging Habitat Requirements[3]	Breeding Habitat Type[2,3]	Requirements[3]
Carnivora					
Mustelidae					
River otter (*Lutra canadensis)*	R	All, OW	0–10 m near permanent water	All (burrows, hollows)	Adjacent to permanent water
Rodentia					
Cricetidae					
Marsh rice rat (*Oryzomys palustris*)	R	BLM, WP, WS	< 1 m	BLM, WP, WS	> 30 cm above high water
Round-tailed muskrat (*Neofiber alleni*)	R	BLM, WP, WS	15–46 cm	BLM, WP, WS	15–46 cm
Lagomorpha					
Leporidae					
Marsh rabbit (*Sylvilagus palustris*)	R	All	< 1 m	All	Adjacent to water

1 Status key: R = breeding resident.

2 Habitat key: BLM = Broadleaf Marsh Group, WS = Wet Shrub Group, WP = Wet Prairie Group, WF = Wet Forest Group, OW = Open Water, Al l= All Habitats combined (BLM, WS, WP, and WF), excluding open water. Preferred breeding habitat is left blank for species whose breeding range occurs outside of the Kissimmee River floodplain.

3 Foraging and breeding habitat hydrologic requirements obtained from Birkenholz (1972), Chapman and Willner (1981), Wolfe (1982), and Lariviere and Walton (1998).

The 22 facultative and opportunistic wetland mammals include four listed species (FWC 2008a). Only the Sherman’s fox squirrel, (*Sciurus niger shermani*) a state species of special concern, is regularly observed. However, it is typically associated with adjacent uplands. The Florida black bear (*Ursus americanus floridanus*; state threatened) and Florida panther (*Puma concolor coryi*; state and federally endangered) have been documented on several occasions within the 100-year floodline. However, these species are considered opportunistic species on the Kissimmee. The Florida bonneted bat (*Eumops floridanus*; state endangered) was recently observed for the first time foraging over the floodplain, well outside of its reported range south and west of Lake Okeechobee (Belwood 1992, Marks and Marks 2008)

Summary of the Hydrologic Requirements of Kissimmee River Fish and Wildlife

The above sections described the hydrologic requirements of four major groups of fish and wildlife associated with the Kissimmee River: fish, amphibians and reptiles, birds, and mammals. In addition, the hydrologic requirements were described for floodplain wetland plant communities, which are an important component of fish and wildlife habitat. Here, the hydrologic requirements of these groups of species are synthesized to create a set of hydrologic requirements that are representative of the entire fish and wildlife community. These requirements are the basis for hydrologic performance measures to represent the hydrologic requirements of fish and wildlife.

Synthesis of Fish and Wildlife Hydrologic Requirements

In rivers, fish and wildlife have a complex set of hydrologic requirements that involve the magnitude, frequency, duration, timing, and rate of change of the water flow and its corresponding effects on water level or stage (Poff et al. 1997). These requirements vary among taxa. It also discusses the three principal groups of wetland vegetation present on the floodplain (Broadleaf Marsh, Wet Prairie, and Wetland Shrub groups) and their hydrologic requirements. Wetland vegetation is an important aspect of the habitat for fish and wildlife, and the hydrologic requirements are better understood, especially for the Broadleaf Marsh Group. In this section, the previously described hydrologic requirements are synthesized as a basis for developing performance measures that follow. In particular it shows how meeting the hydrologic requirements for the Broadleaf Marsh group will also meet the requirements for many species of fish and wildlife.

Changes in hydrologic conditions (i.e., stage or flow) have a complex relationship to the amount of habitat available to fish and wildlife in the Kissimmee River and its floodplain. Small changes in stage have the potential to greatly influence the area of floodplain. The Kissimmee River is a low gradient river with a slope of 0.00009 m/m in the north and 0.000057 m/m in the south (Warne et al. 2000). The floodplain is approximately 2–5 km (1.2–3.1 miles) wide. In a typical cross-section, the floodplain is fairly flat between the river channel and the transition to uplands, except for abandoned channels and depressional wetlands. At the outer edge of the floodplain, there is a sharp transition to the uplands occurring over a distance of 100–150 m (328.1–492.15 feet) and involving a change in relief of 2–3 m (6.562–9.843 ft) (Warne et al. 2000). The relationship between the area inundated and stage is non-linear with small increases occurring when the river is confined to the channel, a large increase occurring as the river overflows its banks, and a smaller increase as it inundates the very edge of floodplain. In most years, water levels fluctuate less than 2 m (6.6 feet) at stage recorders located on the floodplain (**Figure A-4** in Appendix A).

Most species of fish and wildlife associated with the Kissimmee River require seasonally varying flows and corresponding water levels. During a portion of the year, flows are needed to raise the water levels to elevations that inundate much of the floodplain for an extended period of time to meet the hydroperiod requirements of wetland plant communities. A gradual recession of water levels provides a transition to seasonally low flows needed to maintain habitat for fish and other aquatic animals that remain in the river channel. This cycle of high and low water levels is a flood pulse (Junk et al. 1989).

The relationship of the hydrologic flood pulse to the hydrologic needs of fish and wildlife in the Kissimmee River is summarized in a conceptual model (**Figure 9**). The conceptual model shows the discharge and the resulting rise and fall of water levels over a calendar year. While this conceptual model does not explicitly account for inter-annual variation, such variation is important for the long-term maintenance of habitat and persistence of fish and wildlife populations. River flow is expected to vary from one year to the next due to changes in rainfall. Some variation in seasonal and annual patterns is expected and necessary to maintain habitat characteristics, especially those of wetland plant communities. Extreme high water levels establish the upper elevation limit of wetland vegetation by limiting the growth of upland species. Extreme low levels can create conditions that allow the seeds of some wetland species to germinate (Hill et al. 1998, Keddy and Fraser 2000). Consequently, the fish and wildlife hydrologic requirements described in the performance measures are not expected to be met every year. Inter-annual and intra-annual variability are addressed directly by some of the performance measures components described in the following section. For a portion of the year, the discharge exceeds the channel capacity and overflows the banks to inundate the floodplain. This increase in stage and flow creates a flood pulse that gradually recedes. Timing of the flood pulse is important. Peak flows and stages late in the wet season or at the beginning of the dry season that are sufficient to inundate the floodplain are important for reproduction by many fishes (especially the Off-channel Dependent Guild of fish), wading birds, and waterfowl.

The magnitude and duration of the flood pulse should create sufficient depth and duration on the floodplain to meet hydroperiod requirements of wetland vegetation and allow fish and wildlife to use the floodplain. A flood pulse that meets the minimum requirements for the Broadleaf Marsh Group of water depths of 1 ft (0.3 m) for at least 210 days (see the Kissimmee River Floodplain Plant Communities – Broadleaf Marsh Group section) in the middle of the floodplain is also expected to meet the requirements for the Wetland Shrub Group, which contains many of the same species. The flood pulse should also briefly inundate the higher elevations along the outer edge of the floodplain, creating the shorter hydroperiods and shallower depths needed by most Wet Prairie Group plant species.

Meeting the requirements of the Broadleaf Marsh Group will inundate the floodplain for a long-term interval, which will allow spawning and foraging by the Off-channel Dependent Guild of fish. In Florida, largemouth bass spawn from December through May and need 42–60 days from nest construction to a free swimming fry for a single reproductive event (see the Kissimmee River Fish section). Extended periods of inundation should provide adequate water levels on the floodplain to protect nest sites and rookeries for wading birds. Extended water levels and durations are required to allow for the production of prey species—mostly macroinvertebrates and small fish. Meeting the hydrologic requirements of the Broadleaf Marsh Group is likely to meet the requirements of amphibians and reptiles. It should also meet the needs of wetland-dependent mammals, which also use maidencane wet prairies.

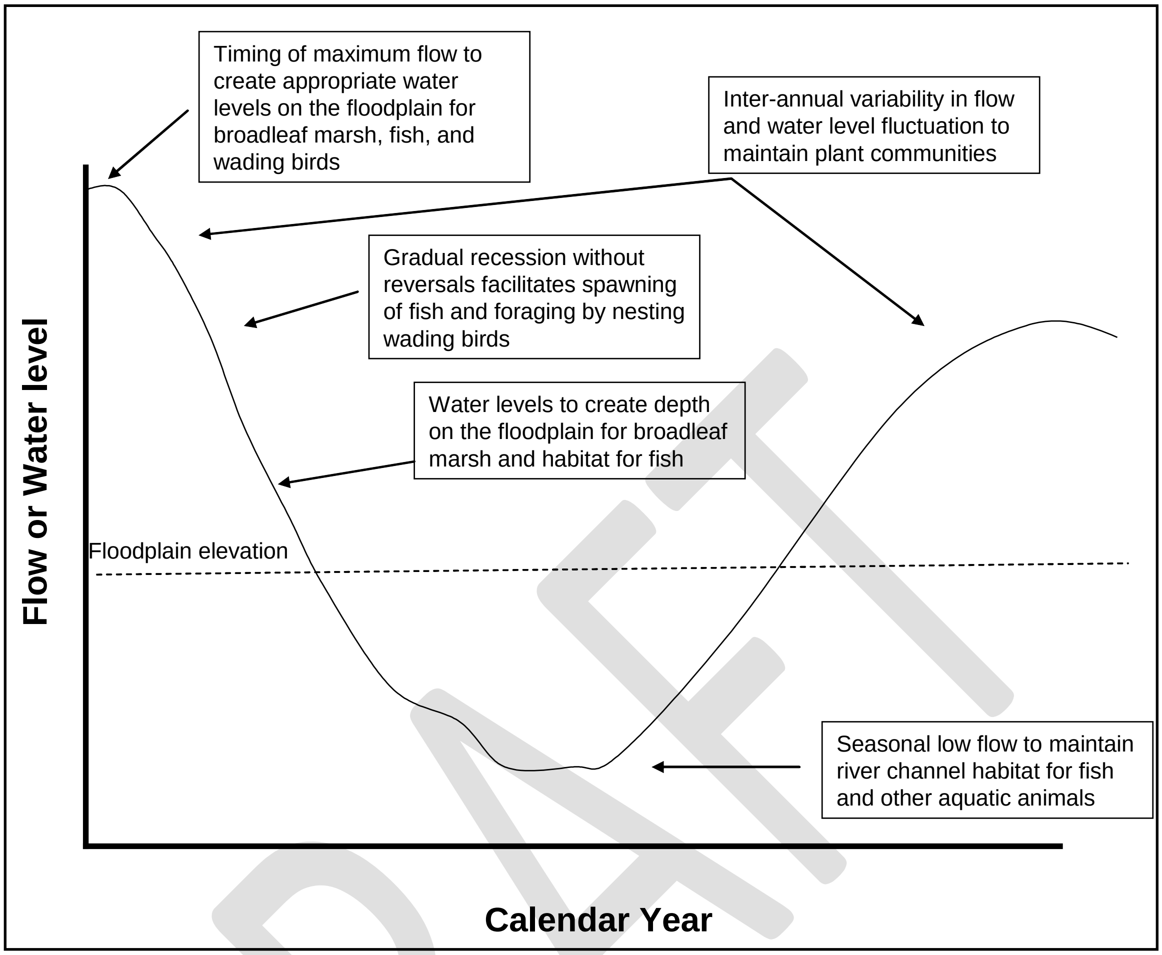

Figure 9. Relationships between fish and wildlife and flow or stage hydrograph.

Gradual recession helps create the long hydroperiod needed by the Broadleaf Marsh Group. Gradual recession rates prevent trapping large numbers of fish and invertebrates on the floodplain as well as create favorable conditions for wading bird foraging on the floodplain. The spring recession can end with high flows, which can disrupt spawning by fish and nesting by some wading birds. These high flows can also cause reversals (increases) in water levels that can disrupt reproductive activity.

Seasonally low flows are needed to maintain river channel habitat and prevent crowding of fish and other aquatic animals. Flow can help aerate the water and prevent the accumulation of organic particles on the channel bed.

This document has summarized considerable information about the fish and wildlife associated with the Kissimmee River and their hydrologic requirements. While much of the information about hydrologic requirements is quantitative (e.g., hydroperiod duration and water depth), our understanding of the linkages between hydrology and responses by fish and wildlife is still qualitative, as summarized in the conceptual model. The scientific understanding has not advanced to the point that quantitative predictions can be made of the response of fish and wildlife associated with the river and floodplain to a change in hydrology (i.e., stage or flow). Such relationships are likely to be complex because of

1) differences among taxa in their hydrologic requirements and sensitivities, 2) non-linear relationships, 3) time lags between hydrologic changes and observed responses, and 4) multi-factor nature of the relationship (i.e., it may not be just a change in stage but the duration). The evaluation program for the Kissimmee River Restoration Project is collecting data on hydrologic conditions, floodplain vegetation, fish, wading birds, and waterfowl (see Appendix A). These data provide a basis for future evaluations of the relationship between hydrologic conditions and biological responses.

SECTION 5: KISSIMMEE CHAIN OF LAKES FISH AND WILDLIFE RESOURCES AND HYDROLOGIC REQUIREMENTS

Introduction

This section provides an overview of the hydrologic requirements of fish and wildlife resources associated with each of the seven Chain of Lakes reservation waterbodies. It also identifies performance measures that relate the hydrology of each lake to its linked biological response. The performance measures are defined over a range to aid the South Florida Water Management District's (District's) Governing Board in considering policy issues associated with water supply, flood control, and natural systems protection. The wildlife that has been considered in developing the water reservation includes fish, amphibians and reptiles, birds, and mammals. The abundance of fish and wildlife is directly related to major wetland plant communities, which form the foundation and structure of the fish and wildlife habitat associated with these waterbodies. The plant communities, in turn, are dependent on certain hydrologic requirements, which form the underpinnings of the performance measures.

The Kissimmee Chain of Lakes and its surrounding area support considerable fish and wildlife resources. Many of these species depend on the lakes and, in particular, the surrounding wetlands. The wildlife resources include a nationally recognized largemouth bass (*Micropterus salmoides*) fishery, nesting colonies of the endangered wood stork (*Mycteria americana*) and snail kite (*Rostrhamus sociabilis*), and one of the largest concentrations of nesting bald eagles (*Haliaeetus leucocephalus*) in the United States. The density of fish and wildlife in and near these lakes is due in part to the large tracts of publicly owned land managed for natural resources, as well as privately owned land that is not intensively developed. This is expected to change based on Osceola County's 2025 Comprehensive Plan that concentrates development expansion within the county's urban growth area that encompasses all or portions of lake shorelines in all but the Headwaters Revitalization Lakes of the Kissimmee Chain of Lakes (KCOL).

Many of the same fish and wildlife species populate the seven waterbodies in the KCOL for which water reservations are being developed. This is due to the proximity of the lakes to each other and the canals that connect them.

The use of the seven KCOL reservation waterbodies by fish and wildlife has been linked to seasonal and annual patterns of water level fluctuation that have given rise to zones of wetland plant communities (USFWS 1958, Williams et al. 1985, Johnson et al. 2007). These vegetation zones serve as important locations for food production. Parts of plants, such as seeds and tubers, can be consumed directly as food items. Plants also provide attachment sites for algae and invertebrates, which are eaten by some species of fish and wildlife. Plants also provide shelter. Some species, especially woody shrubs and trees, serve as nesting sites for birds.

This section defines the hydrologic requirements needed to protect fish and wildlife in each of the KCOL reservation waterbodies. As discussed in Section 4 for the Kissimmee River, the science has not yet been developed to quantitatively predict the response of fish and wildlife populations to a change in hydrologic conditions for the KCOL reservation waterbodies, although water levels are already monitored.

Lake Wetland Vegetation

Littoral Vegetation Distribution

Littoral vegetation is an important component of the habitat for fish and wildlife in lake ecosystems (e.g., Williams et al. 1985, Havens et al. 2005, and Johnson et al. 2007). In lakes, vegetation is commonly distributed along an elevation gradient that might correspond to increasing light limitation with depth for submersed species and increasing hydroperiod for emergent species (Johnson et al. 2007). This section characterizes the vegetation communities present in each of the lake reservation waterbodies that comprise the Central and Southern Florida Flood Control Project (C&SF Project) system and the range of elevations, where each occurs, since these waterbodies have been monitored with regular frequency. Smaller, peripheral waterbodies that are not part of the C&SF Project system but are considered part of the greater reservation waterbody, due to their direct hydrologic connection, are assumed to behave similarly as the C&SF Project waterbodies in regards to their ecological relationship with hydrology.

The plant communities associated with each of the KCOL reservation waterbodies were characterized using 2004–2007 vegetation or land cover maps (**Box 2**). Seven broad classifications were used to describe the vegetation communities in the littoral zone of the KCOL reservation waterbodies (**Table 10**). All of the lakes contained three of the seven communities: Wetland Shrub, Marsh, and Emergent Aquatic groups (**Table 11**). Only some of the lakes contained one or more of the remaining four communities: Wetland Forest, Cypress, Wet Prairie, and Submerged Aquatic groups. However, the Submerged Aquatic Group, in particular, appears to be more common than indicated by the vegetation maps. A review of treatment records for hydrilla (*Hydrilla verticillata*) (an invasive type of submerged vegetation) shows that it is considered most problematic and in need of management on Lake Tohopekaliga, Lake Cypress, Lake Hatchineha, and Lake Kissimmee with some management required on the Alligator Chain of Lakes, Lake Gentry, and East Lake Tohopekaliga. Treatment has occurred on the following four waterbodies: Alligator Chain of Lakes, Lake Gentry, East Lake Tohopekaliga and Lake Tohopekaliga. No records exist of hydrilla treatment in Lakes Hart, Mary Jane, Myrtle, Preston, or Joel. In addition to hydrilla, native species of the Submerged Aquatic Group have been reported in the Alligator Chain of Lakes, East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee (Florida LakeWatch 2003), and are likely to occur in the other lakes.

Box 2. Analysis Methods

Analysis Methods: Littoral vegetation maps produced by the Florida Fish and Wildlife Conservation Commission (FWC) were used for Lake Tohopekaliga (2007), East Lake Tohopekaliga (2007), and Lakes Kissimmee, Cypress, and Hatchineha (Craig Mallison, FWC, personal communication, 2005). The Districts used its most recent land use/land cover map (2004–2005) for the remaining waterbodies. To focus on littoral vegetation, the land use/land cover maps were clipped to encompass only the area 1 foot above and below high pool within each explicit reservation lake as described in **Section 3** of this document. This corresponded well with the coverage of the FWC littoral vegetation maps. Elevation information was derived from the current conditions digital elevation model, which includes United States Army Corps of Engineers survey data, as well as United States Geological Survey bathymetry data acquired in the 1950s.

To quantify elevation distributions for the seven wetland vegetation types, vegetation polygons were sampled from the various FWC maps directly. Depending on the number of polygons within each vegetation class, a random sample of 10 to 50 polygons of each vegetation class was taken within each reservation lake. For each sampled polygon, one point from both the upland and lakeward edges of the polygon was selected to represent the shallowest and deepest elevation. The points were selected manually. The upland and lakeward elevations were stored in a separate geographic information system (GIS) layer for each reservation lake. Attributes for vegetation class and point position (upland versus lakeward) were recorded at the time of point acquisition. All GIS work was performed using ArcGIS version 9.2 at a zoom level of about 1:5,000. After point acquisition, an average was calculated for the upland elevations and for the lakeward elevations of each vegetation category within each reservation lake. Mean upland and lakeward elevation distributions for each category were graphed for comparison purposes (**Figures 10** through **16**). The areal coverage of each vegetation community type also was measured for each reservation lake and is contained in **Table 11**.

Table 10. Wetland classes and descriptions used for comparisons of wetland vegetation distributions across reservation lakes based on the Florida Land Use and Land Cover Classification System (FDOT 1999), as adapted by the District for its land cover map (Cameron et al. 2005).

Wetland Class	Description	Hydroperiod (days per year)
FORESTED WETLANDS		
Wetland Forest	May include red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), water oak (*Quercus nigra*), sweet gum (*Liquidambar styraciflua*), willows (*Salix caroliniana*), cabbage palm (*Sabal palmetto*), water hickory (*Carya aquatica*), water tupelo (*Nyssa aquatica*), water ash (*Fraxinus caroliniana*), and bays (*Magnolia virginiana*). Cypress is often present, but not dominant (under 25%).	0–160 days
Wetland Shrub	Includes willow (*Salix caroliniana*), buttonbush (*Cephalanthus occidentalis*), and primrose willow (*Ludwigia peruviana*).	0–365 days
Cypress	Cypress (*Taxodium distichum*) maintains at least 66% dominance in the canopy.	0–330 days
VEGETATED NON-FORESTED WETLANDS		
Marsh	Includes spikerush (*Elocharis* spp.), pickerelweed (*Pontederia cordata*)/arrowhead (*Sagittaria lancifolia*), torpedograss (*Panicum repens*), American cupscale grass (*Sacciolepis striata*), cattail (*Typha domingensis*), as well as non-dominant mixes of buttonbush (*Cephalanthus occidentalis*) and other woody species	300–365 days
Wet Prairie	Dominated by wiregrasses (*Aristida stricta*), Spikerushes (*Elocharis* spp.), beak rush (*Rhynchospora inundata*), yellow-eyed grass (*Xyris ambigua*), white top sedge (*Rhynchospora colorata*), sand cordgrass (*Spartina bakeri*), maidencane (*Panicum hemitomon*), smartweed (*Polygonum* spp.), and St. John's wort (*Hypericum fasciculatum*).	0–200 days
Emergent Aquatics	Consists of mixes or monocultures of cattail (*Typha domingensis*), maidencane (*Panicum hemitomon*), Egyptian paspalidium (*Paspalidium geminatum*), Bulrush (*Scirpus californicus*, *S. validus*), water lilies (*Nymphaea* spp.), and/or American lotus (*Nelumbo lutea*).	365 days
Submergent Aquatics	Hydrilla (*Hydrilla verticillata*), mostly, and some native vegetation like eelgrass (*Vallisneria americana*) and duckweed (*Spirodela polyrhiza*).	365 days

[1] Source Data: for Lake Tohopekaliga, East Lake Tohopekaliga, and Headwaters Revitalization Lakes reservation waterbodies, littoral vegetation maps produced by the Florida Fish and Wildlife Conservation Commission (2005, 2007); for the remaining waterbodies, the District's most recent land use/land cover map (Cameron et al. 2005). For elevation data to determine elevations at which particular communities occur, a current conditions digital elevation model, which includes United States Army Corps of Engineers survey data and United States Geological Survey bathymetry data acquired in the 1950s (Earth Tech 2007b). The District land use/land cover maps were clipped to encompass only the area 1 foot above and below high pool within each reservation lake. This corresponded well with the coverage of the Florida Fish and Wildlife Conservation Commission littoral vegetation maps.

Table 11. Areal coverage of seven littoral vegetation classes, total area of littoral vegetation, lake surface area, and the percentage of the lake with littoral vegetation for each reservation lake. All areas reported as acres represent the area below the high stage of the current regulation schedules.

Wetland Class	Lakes Myrtle-Preston-Joel	Lakes Hart-Mary Jane	East Lake Tohopekaliga	Lake Tohopekaliga	Alligator Chain of Lakes	Lake Gentry	Headwaters Revitalization Lakes
Wetland Forest	ND	92	151	182	385	65	87
Wetland Shrub	364	168	88	53	587	566	120
Cypress	221	19	ND	ND	843	171	765
Wet Prairie	82	2	ND	ND	97	ND	47
Marsh	446	285	1,888	2,536	658	73	7,225
Emergent Aquatics	186	460	1,130	3,748	385	33	4,474
Submergent Aquatics	ND	ND	ND	1,816	ND	ND	565
Total Littoral Area	1,298	1,036	3,257	8,335	2,954	907	13,283
Lake Surface Area	2,630	3,769	12,851	21,897	7,282	1,909	60,360
Percent Littoral Area	50	28	25	38	41	48	22

ND – Vegetation class not detected.

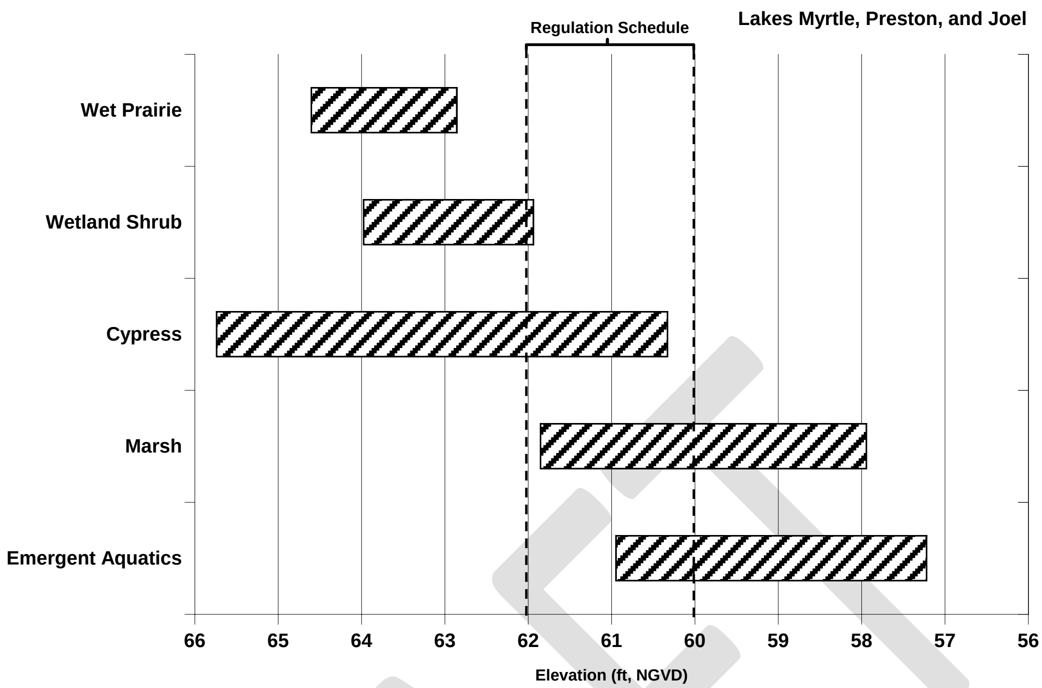

Figure 10. Distribution by elevation of wetland vegetation classes on the Lakes Myrtle-Preston-Joel reservation waterbody.

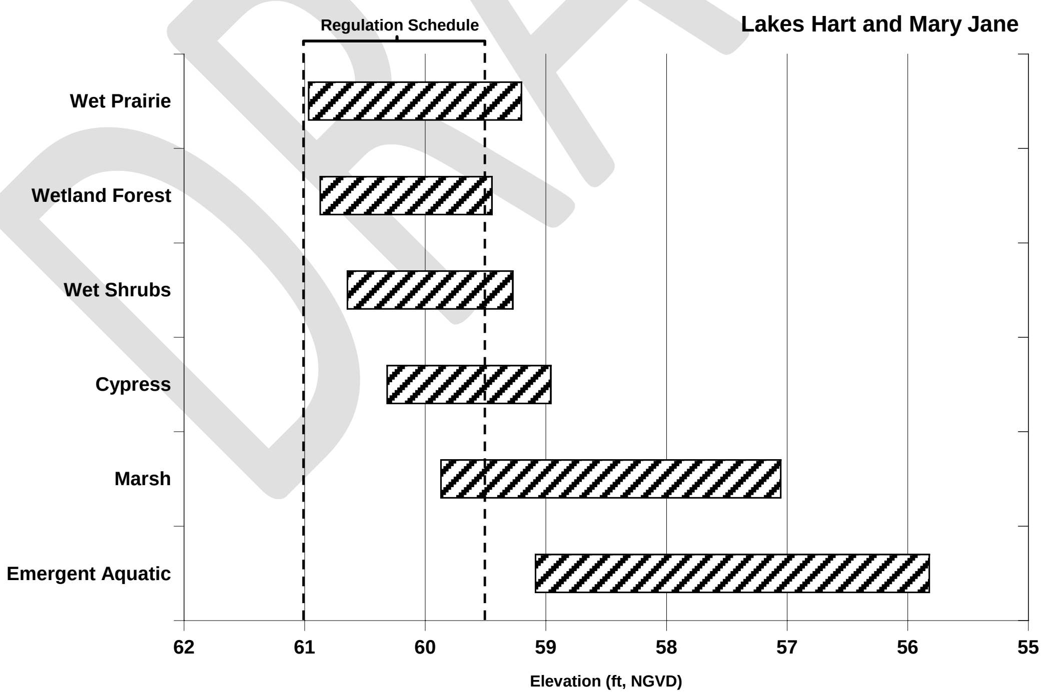

Figure 11. Distribution by elevation of wetland vegetation classes on Lakes Hart-Mary Jane reservation waterbody.

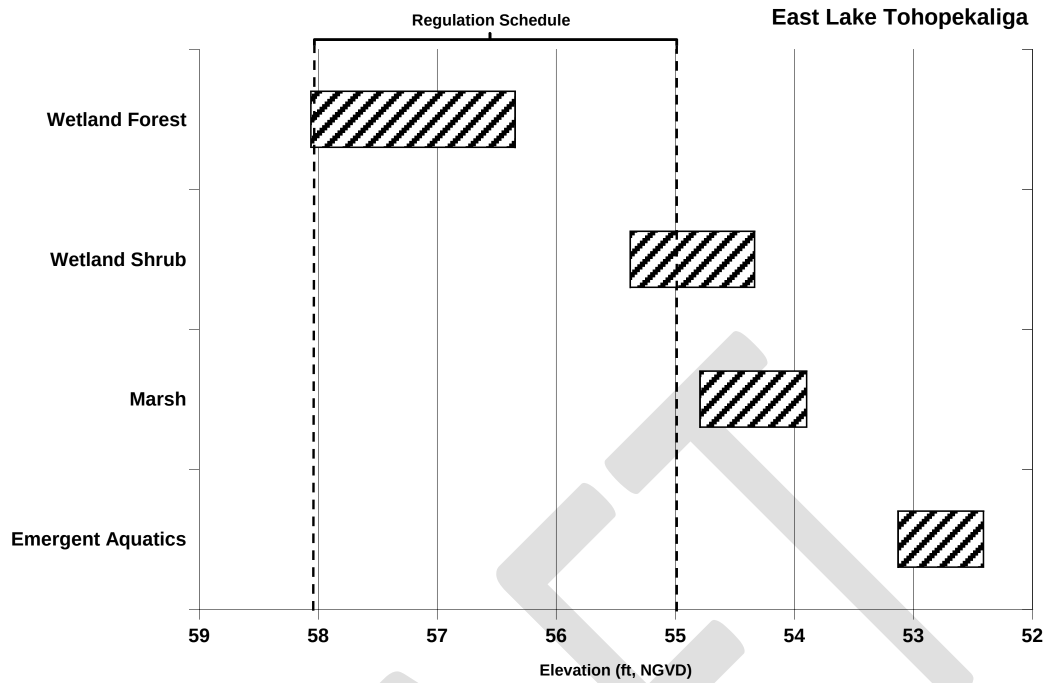

Figure 12. Distribution by elevation of wetland vegetation classes on the East Lake Tohopekaliga reservation waterbody.

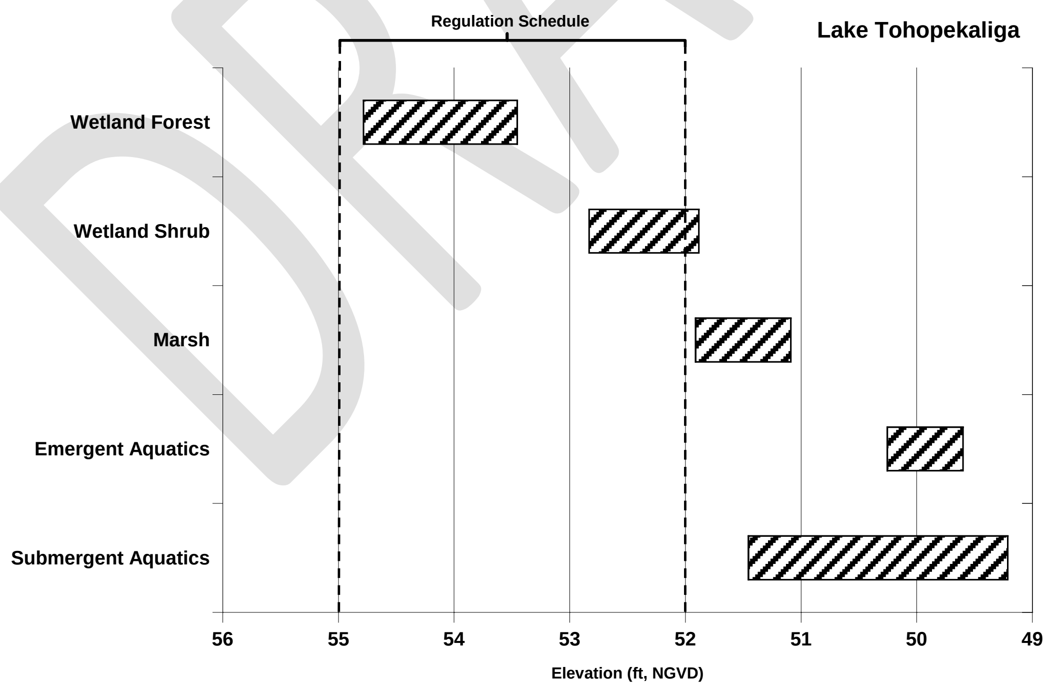

Figure 13. Distribution by elevation of wetland vegetation classes on the Lake Tohopekaliga reservation waterbody.

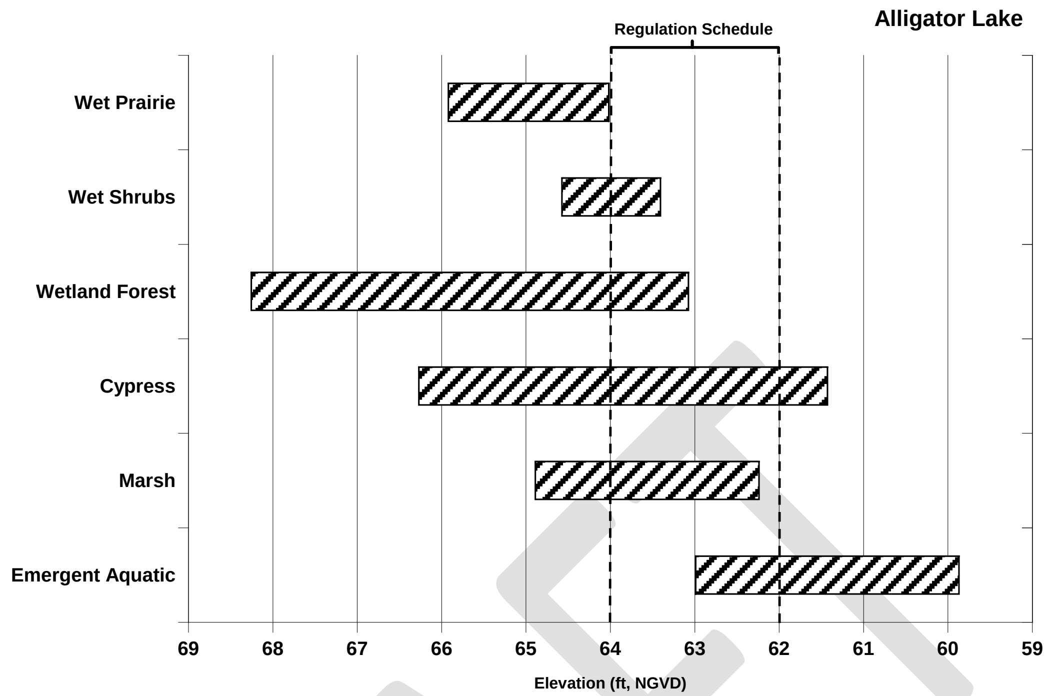

Figure 14. Distribution by elevation of wetland vegetation classes on the Alligator Chain of Lakes reservation waterbody.

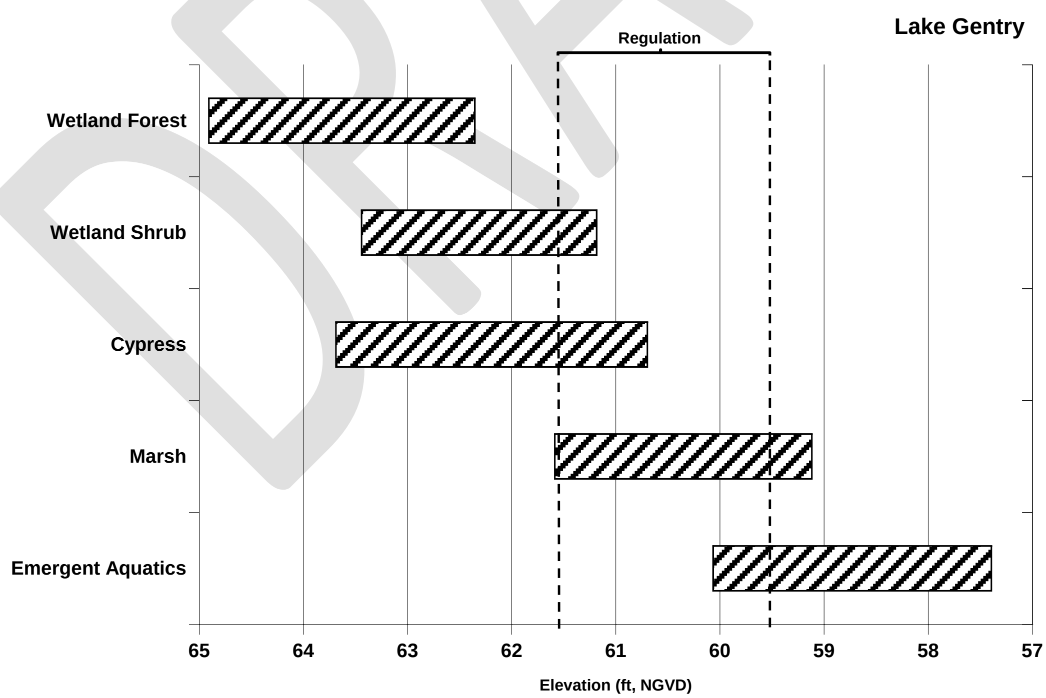

Figure 15. Distribution by elevation of wetland vegetation classes on the Lake Gentry reservation waterbody.

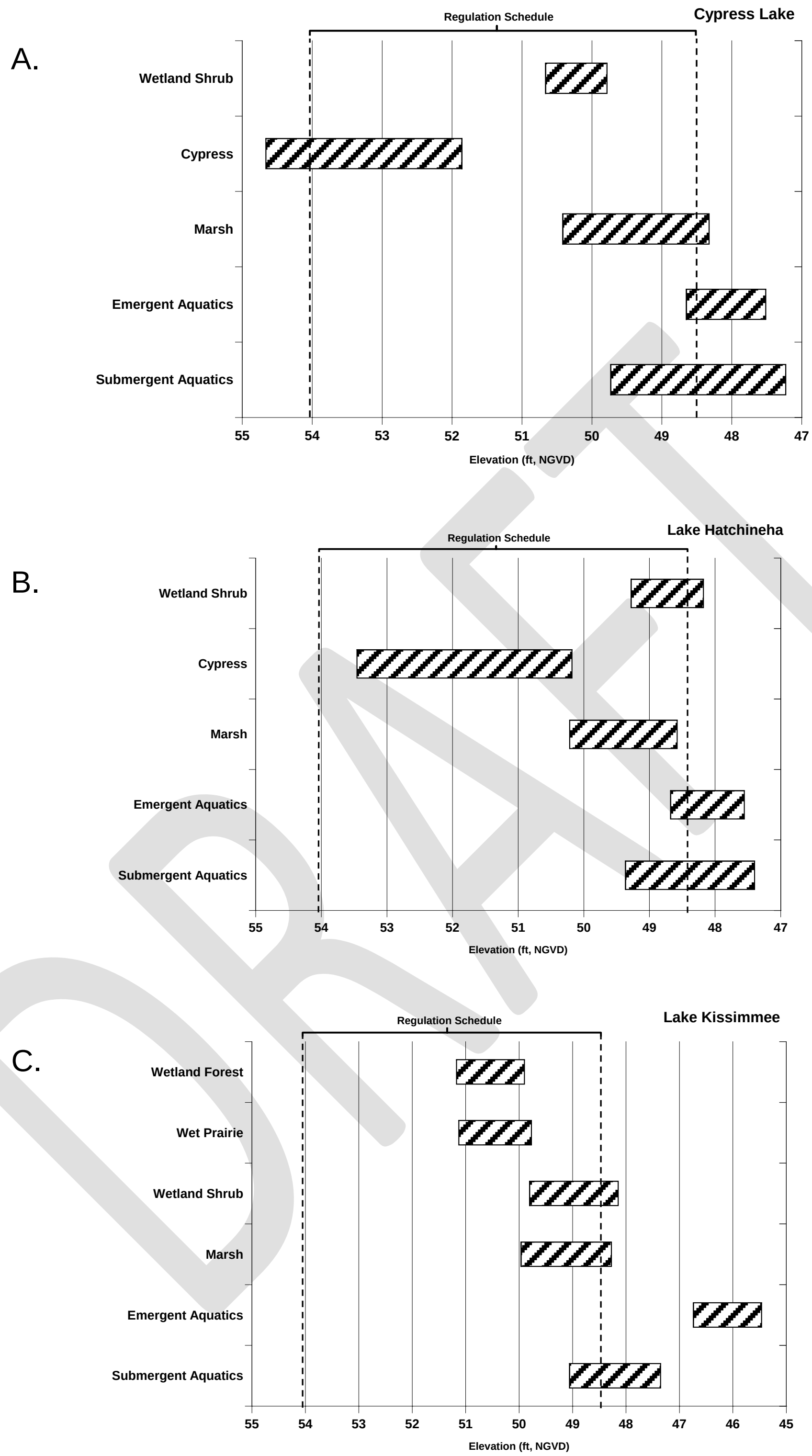

Figure 16. Distribution by elevation of wetland vegetation classes on (A) Lake Cypress, (B) Lake Hatchineha, and (C) Lake Kissimmee. The upper elevation for each vegetation class was corrected for the expected response to the implementation of the Headwaters Revitalization Regulation Schedule by adding 0.5 feet.

As might be expected, each lake has a slightly different elevational distribution of the littoral vegetation classes. However, conceptually, the classes occupy similar relative positions within each lake ecosystem (**Figure 17**). On the upland edges of the littoral zones, stands of the Wetland Hardwood, Cypress, and Wet Shrub groups predominate (short-hydroperiod woody vegetation), sometimes interspersed with Wet Prairie Group species (short-hydroperiod graminoid and broadleaf species). Often, woody plants, such as cypress (*Taxodium distichum*), willows (*Salix caroliniana* or *Salix* spp.), and buttonbush (*Cephalanthus occidentalis*) penetrate further down-slope into the littoral zone. At a slightly lower elevation under semi-permanent or permanent inundation, but relatively shallow water, marsh vegetation, such as cattail (*Typha domingensis*), pickerelweed (*Pontederia cordata*), and arrowhead (*Sagittaria lancifolia*) is predominant. Under permanent inundation, i.e., water up to 1 meter deep, emergent aquatics like bulrush (*Scirpus californicus*, *S. validus*), maidencane, and spatterdock (*Nuphar lutea)* are most often found. Further out in open water, Submerged Aquatic Vegetation Group plants are found, often in clumped distributions.

For the Lakes Hart-Mary Jane and Lakes Myrtle-Preston-Joel reservation waterbodies, the range of elevations for plant communities reported in this study (**Figures 10** and **11**) are consistent with those measured in the field (John Zahina, District, unpublished data). For most of the waterbodies, the lower elevation for emergent aquatics occurs well within the outer edge of the emergent aquatic vegetation zone identified for the Kissimmee Basin Modeling and Operations Study (SFWMD 2008a).

Hydrologic Requirements for Vegetation

Fluctuating water levels are one of the most important factors that determine the type, abundance, and distribution of vegetation in lake littoral zones (Keddy and Fraser 2000, Hill et al. 1998). In the KCOL waterbodies, water levels cycle through annual patterns with the wet and dry seasons. The seasonal pattern of water levels results in a range of hydroperiod durations and water depths along a gradient of ground elevation.

In addition to the seasonal variation in water levels, annual variation is needed. For example, extreme low water levels are needed periodically, but not every year. Low water levels allow organic components of exposed sediments to decompose more rapidly (Cooke et al. 1993) and allow the seeds of some wetland plants to germinate (Hill et al. 1998, Keddy and Fraser 2000). Extreme water levels are an important determinant of the lower limit of emergent vegetation in the KCOL reservation waterbodies (Holcomb and Wegener 1972).

A.

B.

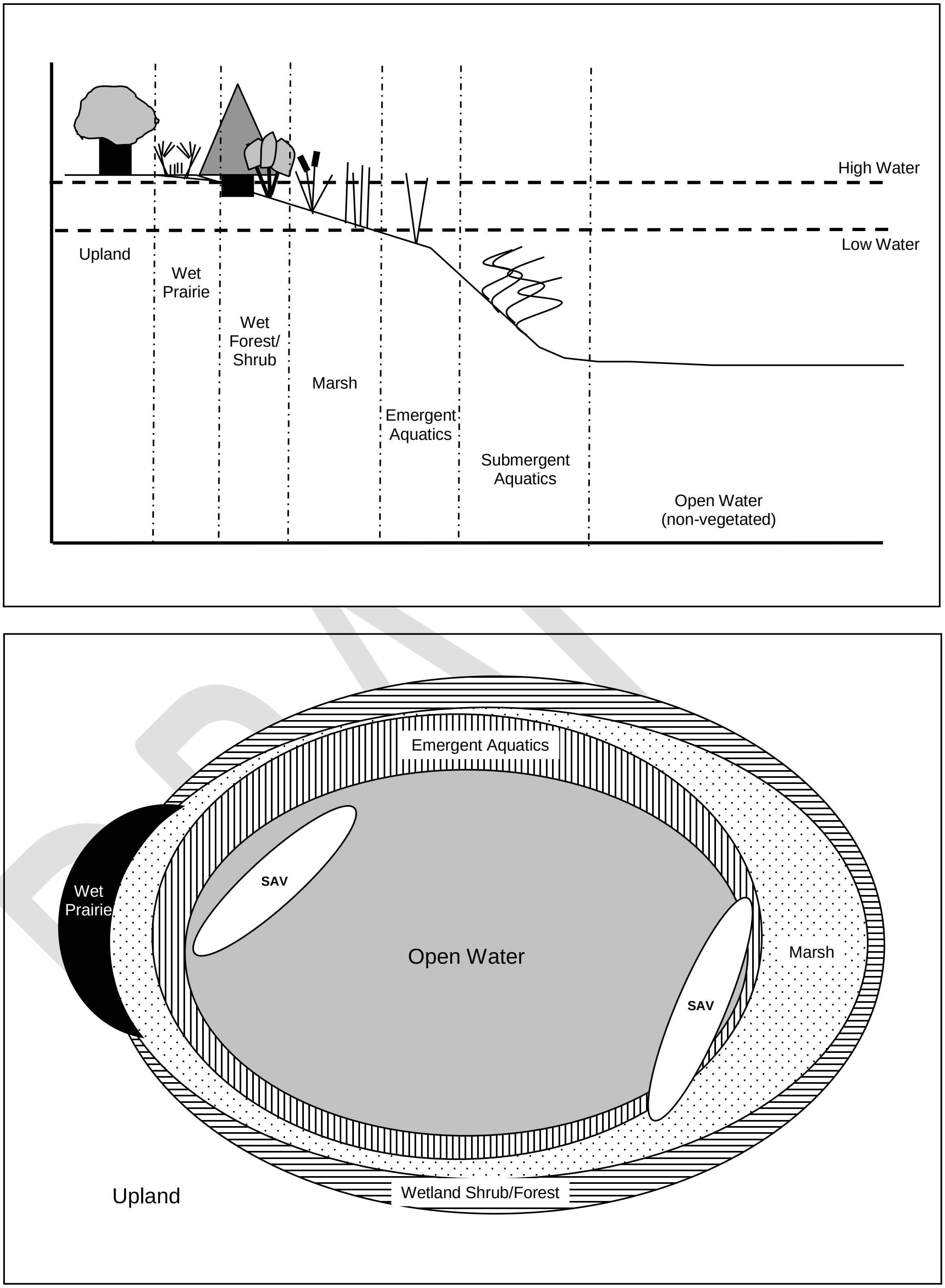

Figure 17. Conceptual diagrams of the distribution of seven vegetation community classes in a reservation lake along an elevation gradient in cross-section (A) and planform (B) view.

In addition to climate, the major factor driving water level fluctuations in the KCOL is the United States Army Corps of Engineers (USACE) regulation schedule. The operations of the water control structures follow the water control manuals developed by the USACE to implement the C&SF Project, for flood control, water supply, and environmental protection. Operations under the current regulation schedules were adopted in the early 1980s and have essentially remained unchanged. A few exceptions to this are the modification of dry season recession rates to benefit snail kite reproduction and foraging primarily in East Lake Tohopekaliga and Lake Tohopekaliga beginning in 2006 and implementation of the Interim Headwaters Revitalization Schedule for Structure S-65 in 2001. As a result, existing fish and wildlife resources have adapted predominantly around the fluctuating water levels associated with these regulation schedules. For this reason, the water reservations for all lakes except Kissimmee, Cypress, Hatchineha, and Tiger will be developed using hydrologic performance measures that reflect existing fish and wildlife and the historical water level fluctuations during the period of regulation from 1972 and extending through 2007. Lakes Kissimmee, Cypress, and Hatchineha, and Tiger Lake are evaluated under the recently approved Headwaters Revitalization Regulation Schedule and a 41-year rainfall period of record (1965–2005)

Kissimmee Chain of Lakes Fish and Wildlife Resources and Associated Hydrologic Requirements

Kissimmee Chain of Lakes Fish

In the KCOL, habitat use by fish and wildlife has long been linked to seasonal and annual patterns of water level fluctuation. This is due, in part, to how hydrology determines zonation of wetland plant communities, which in turn provide food, shelter, and breeding grounds for various communities of animals, including fish. Seasonal elevation of water level is also necessary to give fish access to littoral marsh and other vegetated areas where they spawn. During wet years, higher lake stages in the spring increase the percentage of the littoral zone that remains flooded, thereby increasing the availability of foraging and breeding habitat. Fish are of critical importance in lake ecosystems, serving as links in the food chain between primary producers and higher consumers. Fish also provide a connection between the aquatic and terrestrial systems, serving as food for wading birds and bald eagles.

The KCOL is home to at least 45 species of fish, based on Florida Fish and Wildlife Conservation Commission (FWC) sampling efforts in the 1980s (**Table 12**). More recent sampling by Florida LakeWatch on a few lakes indicates little change. A total of 58 species have been identified from samplings in systems near the KCOL, including the Lake Conway Chain, the Kissimmee River, Lake Okeechobee, and Lake Istokpoga. However, not all species were found in every lake. The total pool of fish in individual lakes ranged from 27 to 45 species. The greatest number of species was found in the larger lakes, where the greatest sampling effort occurred. Most differences in species between lakes are likely to represent differences in sampling methods and locations, except for a few exotics that have invaded from downstream or have been released and have not spread through all of the lakes. A group of 26 species has been recorded in every lake in the system surveyed by the FWC (**Table 13**). Although there is no record of collection, these common species are likely to occur in the Lakes Myrtle–Preston–Joel reservation waterbody as well. Four popular game fish species—black crappie (*Pomoxis* *nigromaculatus*), bluegill (*Lepomis machrochirus*), largemouth bass, and redear sunfish (*Lepomis microlophus*)—were collected in the six reservation waterbodies that were sampled.

Table 12. Fish species in the KCOL and other nearby waterbodies.*

Common Name	Species Name	Lakes Hart-Mary Jane	Headwaters Revitalization Lakes	EastLake Tohopekaliga	Lake Tohopekaliga	Lizzie Lake	Alligator Chain of Lakes	Lake Gentry	KCOL	Florida Lakes	Lake Conway	Lake Okeechobee	Kissimmee River	Lake Istokpoga
American eel	*Anguilla rastrata*										X	X	X	
Atlantic needlefish	*Strongylura marina*	X	X	X	X		X	X	X				X	X
Banded topminnow	*Fundulus auroguttatus*		X						X					
Black crappie	*Pomoxis nigromaculatus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Blackbanded darter	*Percina nigrofasciata*												X	
Blue tilapia	*Oreochromis aureus*		X	X	X				X	X			X	X
Bluefin killifish	*Lucania goodei*	X	X	X	X	X	X	X	X	X	X	X	X	X
Bluegill	*Lepomis macrochirus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Bluespotted sunfish	*Enneacanthus gloriosus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Bowfin	*Amia calva*	X	X	X	X		X	X	X	X	X	X	X	X
Brook silverside	*Lebidesthes sicculus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Brown bullhead	*Ameiurus nebulosus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Brown hoplo	*Hoplosternum littorale*		X		X				X				X	X
Chain pickerel	*Esox niger*	X	X	X	X	X	X	X	X	X	X	X	X	X
Channel catfish	*Ictalurus punctatus*	X	X	X	X		X	X	X				X	X
Coastal shiner	*Notropis petersoni*	X	X		X				X		X		X	
Common carp	*Cyprinus carpio*												X	
Dollar sunfish	*Lepomis marginatus*	X	X	X	X	X	X	X	X	X	X	X		X
Eastern mosquitofish	*Gambusia holbrooki*	X	X	X	X	X	X	X	X	X	X	X	X	X
Everglades pygmy sunfish	*Elassoma evergladei*	X	X	X	X	X	X	X	X	X	X		X	X
Flagfish	*Jordanella floridae*	X	X	X	X	X	X	X	X	X	X	X	X	X
Florida gar	*Lepisosteus platyrhincus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Gizzard shad	*Dorosoma cepedianum*	X	X	X	X		X	X	X	X	X	X	X	X
Golden shiner	*Notemigonus crysoleucas*	X	X	X	X	X	X	X	X	X	X	X	X	X
Golden topminnow	*Fundulus chrysotus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Grass carp	*Ctenopharyngodon idella*												X	
Inland silverside	*Menidia beryllina*		X	X					X	X		X	X	X
Lake chubsucker	*Erimyzon sucetta*	X	X	X	X	X	X	X	X	X	X	X	X	X
Largemouth bass	*Micropterus salmoides*	X	X	X	X	X	X	X	X	X	X	X	X	X
Least killifish	*Heterandria formosa*	X	X	X	X	X	X	X	X	X	X	X		X
Lined Topminnow	*Fundulus lineolatus*									X			X	
Longnose gar	*Lepisosteus osseus*	X	X	X	X		X	X	X	X	X	X	X	
Okefenokee pygmy sunfish	*Elassoma okefenokoee*		X						X				X	X
Oscar	*Astronotus ocellatus*												X	
Pirate Perch	*Aphredoderus sayanus*	X	X	X	X	X	X		X	X			X	
Pugnose minnow	*Opsopoeodus emiliae*		X	X	X	X	X	X	X			X	X	X
Pygmy killifish	*Leptolucania ommata*	X					X		X					
Redbreast sunfish	*Lepomis auritus*									X	X		X	
Redear sunfish	*Lepomis microlophus*	X	X	X	X	X	X	X	X	X	X	X	X	X
Redface topminnow	*Fundulus rubifrons*												X	
Redfin pickerel	*Esox americanus americanus*	X		X		X	X	X	X	X	X	X	X	
Sailfin catfish	*Pterygoplichthys disjunctus*		X						X	X			X	
Sailfin molly	*Poecilia latipinna*		X	X	X		X	X	X	X		X	X	X
Seminole killifish	*Fundulus seminolis*		X	X	X		X	X	X	X	X	X	X	X
Sheepshead minnow	*Cyprinodon variegatus*											X		
Spotted sunfish	*Lepomis punctatus*	X	X	X	X	X	X		X	X	X	X	X	X
Starhead topminnow	*Fundulus notti*	X		X		X	X	X	X					
Stripped mullet	*Mugil cephalus*												X	
Sunshine bass	*Morone chrysops X M. saxatilis*									X				
Swamp darter	*Etheostoma fusiforme*	X	X	X	X	X	X	X	X	X	X	X	X	X
Tadpole madtom	*Noturus gyrinus*		X		X	X	X	X	X	X	X	X	X	X
Tailight shiner	*Notropis maculatus*		X	X	X		X	X	X	X		X	X	X
Threadfin shad	*Dorosoma petenense*		X	X	X		X		X	X	X	X	X	X
Walking catfish	*Clarius batrachus*												X	X
Warmouth	*Lepomis gulosus*	X	X	X	X	X	X	X	X	X	X	X	X	X
White catfish	*Ameiurus catus*	X	X		X			X	X	X	X	X	X	X
Yellow bullhead	*Ameiurus natalis*	X	X	X	X	X	X	X	X	X	X	X	X	X
	Total Number of Species	33	42	37	38	27	37	34	45	39	33	35	50	38

*Sources Florida Lake Watch 2003, 2007; Guillory 1979; Ager 1971; and Moyer et al. 1985a–1985j, 1987.
**Shading indicates species collected in all six KCOL reservation waterbodies that were sampled.

Table 13. Trophic category, habitat, reproductive mode, and location for 26 common species of fish in the KCOL.

Common Name	Species Name	Trophic Category*	Habitat Association**	Reproductive Mode***	Breeding Location
Atlantic needlefish	*Strongylura marina*	I/P	EAV, LIM	AVD	Spawn over algal mats [3]
Black crappie	*Pomoxis nigromaculatus*	I/P	DIV	N	Nest substrates range from sand to mud; often near structures [1]
Bluefin killifish	*Lucania goodei*	I/H	DIV	SVA	Lay eggs in thick vegetation [1]
Bluegill	*Lepomis macrochirus*	O	EAV, LIM	N	Nest in shallow water [1]; bulrush communities [3]
Bluespotted sunfish	*Enneacanthus gloriosus*	I	SAV	N	Nests in thick vegetation or algae [1]
Bowfin	*Amia calva*	I/P	DIV	N	Nests in vegetation [1]
Brook silverside	*Lebidesthes sicculus*	I	EAV, LIM	SA	Spikerush [3]; eggs float or attach to objects [1]
Brown bullhead	*Ameiurus nebulosus*	O	DIV	N	Nests [1]; vegetated areas [3]
Chain pickerel	*Esox niger*	P	SAV	AVD	Adhesive eggs scattered over vegetation and detritus [1]
Channel catfish	*Ictalurus punctatus*	I/P	LIM	N	Spawns in vegetated littoral zone [3]
Dollar sunfish	*Lepomis marginatus*	I	DIV	N	Hard sand substrate[2]
Eastern mosquitofish	*Gambusia holbrooki*	O	DIV	L	Various
Everglades pygmy sunfish	*Elassoma evergladei*	I	SAV	AVD	Spawn in vegetation [1]
Flagfish	*Jordanella floridae*	O	FAV	N, AVD	Nests in gravel or attaches eggs to vegetation
Florida gar	*Lepisosteus platyrhincus*	P	DIV	SV	Weedy areas [1]
Gizzard shad	*Dorosoma cepedianum*	O	LIM	SA	Adhesive eggs in open water or near aquatic vegetation [1]
Golden shiner	*Notemigonus crysoleucas*	O	DIV	SVA	Adhesive eggs near or over aquatic vegetation [1, 2]
Golden topminnow	*Fundulus chrysotus*	I	EAV	SA	Submerged vegetation[2]
Lake chubsucker	*Erimyzon sucetta*	I/H	SAV	SD	Spawn over vegetation [1]
Largemouth bass	*Micropterus salmoides*	I/P	EAV, SAV	N	Various
Least killifish	*Heterandria formosa*	O	DIV	L	Various
Longnose gar	*Lepisosteus osseus*	P	SAV	SV	Spawn in streams [2]
Redear sunfish	*Lepomis microlophus*	I/H	SAV, DIV	N	Nest in shallow water [1]; bulrush communities [3]
Swamp darter	*Etheostoma fusiforme*	I	DIV	AVD	Vegetated areas[2]
Warmouth	*Lepomis gulosus*	I/P	EAV, DIV	N	Nest near stumps or vegetation[1]
White catfish	*Ameiurus catus*	O	LIM	N	Nests in bare sand, gravel bars[1]; vegetated areas [3]
Yellow bullhead	*Ameiurus natalis*	O	DIV	N	Around submerged snags or roots[2]

* Trophic category: D = detritivore; H = herbivore; I = invertevore; O = omnivore; and P = piscivore.

** Habitat Association: DIV = diversity of lake types and habitats; EAV = emergent aquatic vegetation; LIM = limnetic zone; and SAV = submerged aquatic vegetation.

*** Reproductive mode: AVD = demersal eggs attached to vegetation; L = livebearer; N = nest builder; SA = scatters adhesive eggs; SD = scatters demersal eggs; SF = scatters floating eggs; SV = scatters eggs in vegetation; and SVA = scatter adhesive eggs in vegetation.

Table based on Trexler (1995) and data compiled from various other sources. [1] = Hoyer and Canfield (1994a), [2] = Boschung and Mayden (2004); and [3] = Ager (1971).

The KCOL fisheries are important not only ecologically, but also economically. The lakes are known for their prized sport fishing, which is economically important to the surrounding areas. In 2001, freshwater fishing in Florida was estimated to generate an economic impact of nearly 2 billion dollars (USFWS 2002). However, because of the vast differences in densities of fish in the vegetated versus open water areas, the littoral wetlands of the lakes are disproportionately more valuable. Wegener and Holcomb (1972) evaluated the 1970 fishery of Lake Tohopekaliga from a monetary standpoint and found that the vegetated littoral areas of the lake were 415% more valuable ($1,333.33 per acre littoral versus $321.12 per acre limnetic). In total, the monetary value of the fishery of Lake Tohopekaliga alone was worth more than a half million dollars (1970). Later estimates of the lake's total outdoor recreational value suggested it generated almost $2.7 million in spending, nearly 25 jobs, and almost $405,000 in wages annually (Bell 2006). Because of the importance of their fisheries, three of the reservation waterbodies have been designated Fish Management Areas by the FWC—Headwaters Revitalization Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga. The Fish Management Area status indicates that the FWC is managing the freshwater fishery in cooperation with the local county (Osceola County).

Hydrologic and Habitat Requirements of Fish

Fish are dependent on seasonally and annually fluctuating water levels to maintain important habitat characteristics. Fluctuating water levels are needed to create appropriate inundation patterns (hydroperiods) to maintain the wetland plant communities that provide shelter, serve as spawning locations, and support the protection of food organisms. In the reservation waterbodies of the KCOL, fish use Marsh, Emergent Aquatic, and Submerged Aquatic groups plant communities. These plant communities are distributed along an elevation gradient with the Marsh Group generally at higher elevations than the other groups, the Submerged Aquatic Vegetation Group at the lower end, and the Emergent Aquatic Group in-between. All three plant communities are present throughout the KCOL reservation waterbodies. There are only data for the Submerged Aquatic Group in the the Headwaters Revitalization Lakes and Lake Tohopekaliga reservation waterbodies (see **Table 11**). High water levels are needed so that fish can access these communities during the spring because many fish species spawn at this time (**Figure 18**).

Fish are completely dependent on the hydrology of the water that forms their environment, delivers the oxygen they breathe, and dynamically constructs the wetlands that shape their habitat. Regulation schedules approximate some aspects of natural lake hydrology, which gives fish seasonal access to upper lake elevations for breeding and recruitment. Seasonally low water levels are beneficial for predators because littoral shelter becomes limited and forage fish are concentrated. This is especially true for adult largemouth bass that wait just outside patches of littoral vegetation for prey.

Water fluctuation in lake levels is also necessary to meet the hydroperiod requirements of individual plant communities. The vegetation, in turn, creates diverse habitats that support the fish community. Freshwater wetlands are important for fish recruitment of new fish into the population because they serve as a nursery for larval and juvenile fish. They also provide foraging grounds and refugia from predators. Smaller fish and invertebrates forage becoming food for larger fish, including the economically important largemouth bass (Williams et al. 1985).

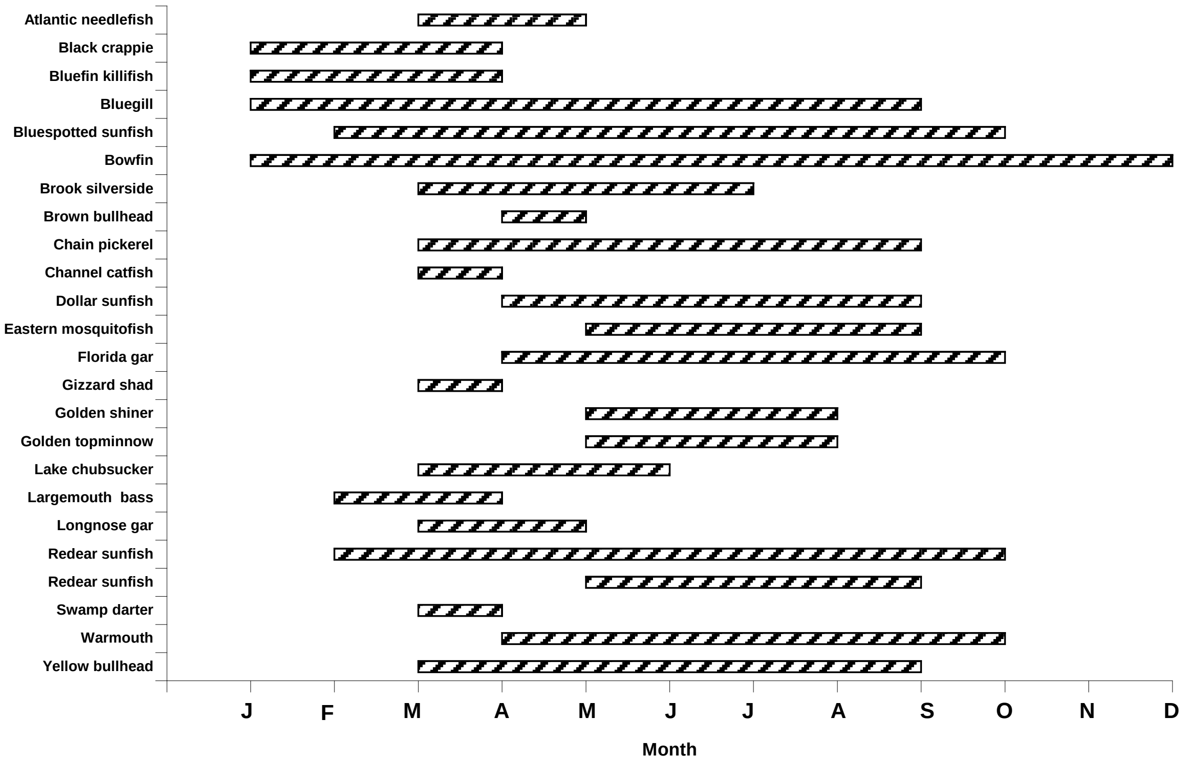

Figure 18. Spawning season for 23 species of fish found throughout the KCOL reservation waterbodies. Information was not available for three other common species—Everglades pygmy sunfish (*Elassoma evergladei*), flagfish (*Jordanella floridae*), and the least killifish (*Heterandria formosa*). Spawning seasons are based on Hoyer and Canfield (1994a), Ager (1971), and Williams et al. (1985).

Moderate coverage of aquatic macrophytes is ideal for many of the dominant fish species found in lakes (Wiley et al. 1984, Allen and Tugend 2002, Trebitz and Nibbelink 1996). Excessive vegetation can be detrimental to fish growth and abundance (Colle and Shireman 1980). Seasonal water level fluctuations prevent excessive growth of vegetation that would clog areas and make them unsuitable habitat.

Kissimmee Chain of Lakes Amphibians and Reptiles

Amphibians and reptiles (herpetofauna) are often common and sometimes conspicuous inhabitants of lakes, ponds, streams, wet prairies, marshes and other aquatic habitats of central Florida. While not extensively monitored in the KCOL reservation waterbodies, amphibians and reptiles are likely to occur throughout these lakes, especially in association with littoral wetland vegetation. A list of species likely to occur in these lakes has been compiled from regional distribution maps (Tennant 1997, Bartlett and Bartlett 1999) and the Muench (2004) study of amphibian and reptile use of littoral wetlands on Lake Tohopekaliga (**Table 14**). The listed amphibians include frogs (seven species), a toad, and six species of salamander. The reptiles include the American alligator (*Alligator mississippiensis*), eight species of turtles, and ten species of snakes.

Table 14. Aquatic amphibians and reptiles likely to occur throughout the Lake Management Regions of the KCOL. Taxa in bold are known to occur in the littoral zone of Lake Tohopekaliga (Muench 2004).

Family Genus species	Common name
AMPHIBIANS	
Hylidae	
Acris gryllus dorsalis	Florida cricket frog
Hyla cinerea	Green tree frog
Pseudacris nigrita verrucosa	Florida chorus frog
Pseudacris ocularis	Little grass frog
Microhylidae	
Gastrophryne carolinensis	Eastern narrow-mouthed toad
Ranidae	
Rana catesbeina	Bullfrog
Rana grylio	**Pig frog**
Rana sphenocephala utricularia	**Southern leopard frog**
Amphiumidae	
Amphiuma means	**Two-toed amphiuma**
Plethodontidae	
Eurycea quadridigitata	Dwarf salamander
Salamanderidae	
Notophthalmus viridescens piaropicola	Peninsular newt
Sirenidae	
Pseudobranchus axanthus axanthus	Narrow-striped dwarf siren
Siren intermedia intermedia	Eastern lesser siren
Siren lacertina	**Greater siren**
REPTILES	
Alligatoridae	
Alligator mississippiensis	American alligator
Chelydridae	
Chelydra serpentine osceola	**Florida snapping turtle**
Emydidae	
Deirochelys reticularia chrysea	Florida chicken turtle
Pseudemys floridana peninsularis	**Peninsular cooter**
Pseudemys nelsoni	Florida red-bellied turtle
Kinosternidae	
Kinosternon baurii	**Striped mud turtle**
Kinosternon subrubrum steindachneri	Florida mud turtle
Sternothernus odoratus	**Common musk turtle**
Trionychidae	
Trionyx ferox	**Florida softshelled turtle**
Colubridae	
Thamnophis sirtalis sirtalis	Eastern garter snake
Thamnophis sauritus sackenii	Peninsula ribbon snake
Nerodia fasciata pictiventris	**Florida water snake**
Nerodia floridana	**Florida green water snake**
Nerodia taxispilota	Brown water snake
Regina alleni	**Striped crayfish snake**
Farancia abacura abacura	**Eastern mud snake**
Seminatrix pygaea pygaea	**North Florida swamp snake**
Lampropeltis getula floridana	Florida kingsnake
Viperidae	
Agkistrodon piscivorus conanti	Florida cottonmouth

The American alligator is the most important reptile species associated with the KCOL. It is federally listed as a threatened species (FWC 2013a). Recreational harvesting of alligators is allowed with a permit on the Lakes Hart–Mary Jane, East Lake Tohopekaliga, Alligator Chain of

Lakes, and Lake Gentry reservation waterbodies (A. Brunell, FWC, personal communication, September 11, 2008). East Lake Tohopekaliga is an Alligator Egg Collection Area, allowing commercial harvesting of eggs by alligator farmers. The FWC surveys alligators on the following reservation waterbodies: Lakes Hart-Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga, Alligator Chain of Lakes, and Headwaters Revitalization Lakes.

Hydrologic Requirements

Most of the amphibians and reptiles likely to be associated with the KCOL reservation waterbodies prefer vegetated (often heavily vegetated) and shallow littoral zones of lakes and are likely to be associated with the Marsh, Emergent Aquatic, and Submerged Aquatic groups plant communities of these lakes. A hydrologic regime that offers protection of these three plant communities is likely to provide protection of most amphibians and reptiles. Decreasing or eliminating littoral zone habitats by artificially reducing lake stages would adversely impact amphibian and reptile communities of these lakes.

Of the amphibians and reptiles, the hydrologic requirements are best understood for the American alligator. Its hydrologic requirements are related to feeding and nesting. Alligators are opportunistic and feed on a variety of prey (Newsom et al. 1987). In north-central Florida, alligators feed on fish, reptiles, amphibians, birds, mammals (e.g., round-tailed muskrat, *Neofiber alleni*), and invertebrates (i.e., crayfish and freshwater snails) (Delany and Abercrombie 1986). Juvenile alligators consume more invertebrate prey than do adults (Delany and Abercrombie 1986, Delany 1990).

Nesting in the KCOL is associated with the vegetation that occurs in the marsh vegetation community. Alligators push together soil and vegetation to build dome-shaped nesting mounds, often near permanent water. When constructing nests, this species shows no preference for sites or for specific vegetation within the marsh and uses available material adjacent to the nest location (Goodwin and Marion 1978).

Alligators require a hydrologic regime that maintains the marsh habitat and allows access during the nesting season. Extreme water levels (high or low) can reduce the availability of nesting habitat (Johnson et al. 2007). Eggs are deposited in nests from mid-June to mid-July (Goodwin and Marion 1978, Newsom et al. 1987, Enge et al. 2000 as cited in Johnson et al. 2007). The reported incubation period for alligator eggs is 60 to 65 days (Newsom et al. 1987; Johnson et al. 2007). Eggs hatch between mid-August and mid-September. It is important that water levels from June through September be high enough to inundate the marsh community so that female alligators can construct nests and that the nests will be protected from raccoons (*Procyon lotor*) and other terrestrial predators (Goodwin and Marion 1978, Johnson et al. 2007). It is also important that water levels do not rise so rapidly that it floods nests and drowns the eggs, which might occur after several days of heavy rainfall (Goodwin and Marion 1978).

Extreme water levels can be hazardous for alligators. Hatchlings reside within the marsh where they are less exposed to predators, but lower water levels may force them to move away from more protected areas of the marsh (Woodward et al. 1987). Lower water levels can also concentrate alligators, which make them more vulnerable to cannibalism, heat stress, disease, and restricted food supply (Woodward et al. 1987).

Kissimmee Chain of Lakes Birds

A number of birds are associated with lakes in central Florida (e.g., Hoyer and Canfield 1990, 1994b) and use these waterbodies for foraging, roosting, and reproduction. Audubon of Florida's list of Important Bird Areas includes three lakes within the KCOL: Lakes Kissimmee, Tohopekaliga, and Mary Jane (Pranty 2002). The Important Bird Area designation indicates that a site supports significant populations or diversity of native birds. An indication of the number of species of birds using the KCOL reservation waterbodies can be obtained from *Florida's Breeding Bird Atlas* (FWC 2003a). The breeding bird atlas was used to compile a list of breeding birds that might use lakes in Orange, Osceola, and Polk counties (**Table 15**). This list contains 43 bird species for the three counties, with 29 of them recorded in all three counties.

In terms of developing a water reservation, this section focuses on the hydrologic requirements of waterbird nesting colonies. It also focuses on two species that are or have been listed as threatened or endangered under federal or state listing requirements: snail kite (*Rostrhamus sociabilis*) and sandhill crane (*Grus Canadensis*). The wood stork, also an endangered species, occurs in the lakes and is represented in wading bird rookeries. The whooping crane (*Grus americana*) is federally designated as threatened. This species occurs around Lake Kissimmee. While whooping cranes are considered threatened, this population has a slightly different listing because of its nonessential experimental population and experimental reintroduction of the species.

Waterbird Nesting Colonies

Many species of waterbirds nest in colonies or rookeries. The FWC tracks the status of waterbird (herons, egrets, ibises, spoonbills, storks, anhingas, cormorants, and pelicans) rookeries around the state (FWC 2003b). The FWC's online database, *Waterbird Colony Locator*, contained three active waterbird colonies in 1999 (**Table 16**). These three colonies were distributed among two of the reservation waterbodies. Two colonies (Bird Island and Rabbit Island in Lake Kissimmee) occurred in the Lakes Kissimmee–Cypress–Hatchineha reservation waterbody. The other colony (Bird Island in Lake Mary Jane) was located in the Lakes Hart–Mary Jane reservation waterbody.

In Lake Kissimmee, the Bird Island and Rabbit Island colonies have continued to be active in recent years (Mike Cheek, District, personal observation). In past years, a second rookery occurred on Bird Island, and a rookery occurred on Brahma Island as well.

The Bird Island Rookery in Lake Mary Jane also continues to be active. It contained more than 100 pairs of nesting wood storks in 2000 (Pranty 2002). This large number of endangered wood storks is part of the justification for designating Lake Mary Jane as an "Important Bird Area" by the Audubon of Florida. A more complete list of waterbirds using Bird Island is included in **Table 17**.

Table 15. Breeding birds associated with lakes in the Kissimmee Basin by county (FWC 2003a).

Common Name	County		
	Orange	Osceola	Polk
American Coot	1	1	1
Bald Eagle	1	1	1
Belted Kingfisher			1
Black Rail	1		
Black Swan	1		1
Black-bellied Whistling-Duck			1
Black-crowned Night-Heron	1	1	1
Black-necked Stilt	1	1	1
Blue-winged Teal	1		
Common Moorhen	1	1	1
Double-crested Cormorant	1	1	1
Fulvous Whistling-Duck	1	1	
Glossy Ibis			1
Great Blue Heron	1	1	1
Great Egret	1	1	1
Green Heron	1	1	1
Gull-billed Tern			1
Killdeer	1	1	1
King Rail	1	1	1
Least Bittern	1	1	1
Least Tern	1		1
Limpkin	1	1	1
Little Blue Heron	1	1	1
Louisiana Waterthrush	1		
Mallard	1	1	1
Mottled Duck	1	1	1
Muscovy Duck	1	1	1
Mute Swan			1
Osprey	1	1	1
Pied-billed Grebe	1	1	1
Purple Gallinule	1	1	1
Red-winged Blackbird	1	1	1
Ruddy Duck			1
Sandhill Crane	1	1	1
Short-tailed Hawk	1	1	1
Snail Kite		1	1
Snowy Egret	1	1	1
Swallow-tailed Kite	1	1	1
Tricolored Heron	1	1	1
White Ibis	1	1	1
Wood Duck	1	1	1
Wood Stork	1	1	1
Yellow-crowned Night-Heron			1
Total	35	31	39

Table 16. Summary of waterbird nesting colonies in KCOL reservation waterbodies that were active in and before 1999.

Colony Status	Bird Island, Lake Kissimmee (616122)				Rabbit Island, Lake Kissimmee (616122)				Bird Island, Lake Mary Jane (612037)			
	1976–1978 Survey	1986–1989 Survey	1999 Survey		1976–1978 Survey	1986–1989 Survey	1999 Survey		1976–1978 Survey	1986–1989 Survey	1999 Survey	
	Unknown	Active	Active	1999 (%)	Unknown	Active	Active	1999 (%)	Active	Active	Active	1999 (%)
Anhinga			Present	40			Present	40		Present		
Great blue heron		Present				Present						
Great egret		Present				Present			Present	Present	Present	10
Snowy egret			Present	20			Present	20	Present		Present	1
Little blue heron			Present	20			Present	20		Present	Present	1
Tricolored heron			Present	20			Present	20	Present	Present		
Cattle egret									Present	Present	Present	90
White ibis									Present	Present		
Wood stork										Present		

Table 17. Nesting start date, incubation period, and fledgling period for wading bird species using Bird Island Rookery.

Common name	Species name	Status[1]	Nest start	Incubation (d)[2]	Fledging (d)[2]
Wood stork	*Mycteria americana*	E	NA	28–32	50–55
Great egret	*Ardea alba*		Jan–Feb	28–29	60
Great blue heron	*Ardea herodias*		Jan–Feb	28	60
Little blue heron	*Egretta caerulea*	SSC	March–April	20–24	28
Anhinga	*Anhinga anhinga*		Jan–Feb	25–28	Unknown
Snowy egret	*Egretta thula*	SSC	March–April	18	25
White ibis	*Eudocimus albus*	SSC	Mar–Aug	21–22	40–50
Tri-colored heron	*Egretta tricolor*	SSC	March–April	22	16–21
Black-crowned night-heron	*Nycticorax nycticorax*		NA	24–26	42
Yellow-crowned night-heron	*Nyctanassa violacea*		NA	21–25	25
Glossy ibis	*Plegadis falcinellus*		NA	21–22	50
American coot	*Fulcia americana*		NA	21–24	60
Cattle egret	*Bubulcus ibis*		March–April	21–24	40–45

1 E denotes federally listed endangered species; SSC denotes Florida listing of Species of Special Concern.
2 Incubation and fledgling durations are from Florida Fish and Wildlife Conservation Commission (2003a). NA indicates not available.

Hydrologic Regime

A hydrologic regime that is protective of these waterbird colonies must maintain vegetation for nesting and a supply of food as well as provide a barrier to terrestrial predators through the nesting season. To serve as a barrier, water depths should be at least 1.64 feet around the colony throughout most of the nesting season (Frederick and Collopy 1989b, White et al. 2005). Hydrologic requirements to maintain vegetation and fish, which are the principal food items for waterbirds, were addressed previously. Waterbirds also need appropriate water depths for foraging.

Snail Kite

The snail kite is currently listed as an endangered species by the United States government and the State of Florida. In the United States, the distribution of snail kites is limited to Central and South Florida. In recent years, the KCOL has been an important area for snail kite nesting, especially during drought years. Snail kites inhabit three of the KCOL reservation waterbodies: East Lake Tohopekaliga, Lake Tohopekaliga, and Lakes Kissimmee–Cypress–Hatchineha.

The hydrologic requirements of the snail kite relate to the availability of suitable nesting habitat and to the availability of their principal prey, the Florida apple snail (*Pomacea paludosa*). Snail kites nest in low vegetation over water. Short trees and shrubs, such as willow (*Salix* spp.) are important nesting substrates. Such plant communities are represented by the Wetland Shrub Group community on the KCOL water reservation waterbodies. In the KCOL, many nests are also built on herbaceous vegetation (Martin et al. 2007), which is represented primarily by the marsh community.

Snail kites begin establishing nests in February in the KCOL. The average hatching date is April 27 for Lake Tohopekaliga, May 7 for East Lake Tohopekaliga, and May 5 for Lake Kissimmee (Rodgers and Schwikert 2003). These dates are consistent with an average hatching date at the end of April on the KCOL (Rodgers and Schwikert 2003). These dates assume that nest construction takes three weeks, that there is a 5-day lag between the completion of nest and egg deposition, and the incubation period is 30 days (Sykes et al. 1995). Snail kites require sufficient water levels during the nesting season to provide a barrier to terrestrial predators. A depth of 1 foot at the beginning of nesting with a slow recession rate is the minimum depth needed to protect nests (Sykes et al. 1995), but will vary depending on distance to shore or density of vegetation between the nest and shore.

The Florida apple snail also has specific hydrologic requirements. This species has a life span of a little more than one year. Populations of apple snails depend on strong recruitment from eggs laid above water on emergent vegetation or other appropriate substrates. While eggs can be laid from February to November, the peak egg-laying period is April–May, when water levels are declining (Darby et al. 2008). Rapidly declining water levels can leave the newly-hatched snails exposed to desiccation. Apple snails occur in association with emergent vegetation found in the Marsh and Emergent Aquatic groups plant communities. Apple snails have poor dispersal ability and are susceptible to desiccation when surface water disappears. Therefore, water levels that completely drain these communities can cause mortality of apple snails.

Florida Sandhill Crane

The Florida sandhill crane is listed as a threatened species by the State of Florida (FWC 2013). Its threatened status is based on low numbers due to a low reproductive rate, specialized habitat requirements, and loss of habitat due to humans (Williams 1978).

Sandhill cranes occur throughout the KCOL and are included on the species lists for Three Lakes Wildlife Management Area and Lake Kissimmee State Park. A long-term study of nesting in isolated wetlands includes ranches east of Lake Kissimmee (Walkinshaw 1982). While sandhill cranes typically nest in isolated wetlands, there are increasing reports of this species using urbanized and other developed areas (Toland 1999). Sandhill cranes nest in the marsh community on several of the KCOL water reservation waterbodies, including Lakes Hart–Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga, and Lakes Kissimmee–Cypress–Hatchineha (Welch 2004). It is likely that sandhill cranes are also using the same habitat in other reservation waterbodies, although the extent of probable use is unknown.

The hydrologic requirements of sandhill cranes relate primarily to nesting requirements. Nests are constructed in emergent marshes. Nest initiation can begin as early as December, but usually does not begin until January and can extend through August (Stys 1997). In south-central Florida, average laying dates are from February 22 to 24

(Walkinshaw 1982); the mean laying date is March 3 (Tacha et al. 1992). The average water depth at sandhill crane nests was 29.6 centimeters (0.97 feet) at the beginning of nesting season in Central Florida (Walkinshaw 1982). Most production of sandhill cranes in Osceola County (Three Lakes Wildlife Management Area) occurred in years with average or above average water levels during the nesting and post-nesting season (Bennett 1992).

Bald Eagle

The bald eagle (*Haliaeetus leucocephalus*) population has been recovering throughout the United States since it was first listed as endangered in 1978. Its status was changed in 1995 to threatened, and it was delisted in 2007. Osceola and Polk counties have the highest number of eagle territories totaling 225, which is 36 percent of the total for the top 10 counties in the state (FWC 2008b). While not all of these territories are near the reservation waterbodies, the 2007 nesting data had nests located within a 2 kilometer buffer of six of the seven reservation waterbodies. Only the Lakes Myrtle–Preston–Joel reservation waterbody did not have nests reported.

The hydrologic requirements of bald eagles include nesting habitat and foraging habitat. Most bald eagles nest in pine trees (*Pinus palustris* and *P. elliottii*); however, some may nest in cypress (*Taxodium* spp.) (FWC 2008b). In the KCOL, a few nests are located in cypress and many are in oaks (*Quercus* spp.) (D. Birdsall, District, personal communication).

The lakes are much more important for foraging habitat than nesting habitat. Bald eagle nests are typically located within 2 kilometers of waterbodies with suitable foraging habitats (Buehler 2000). In north-central Florida, bald eagles feed predominantly on fish, waterfowl, mammals, and reptiles (McEwan and Hirth 1980). During the nesting season, bald eagles prefer large fish (340 to 380 millimeters) (Buehler 2000). Fish that forage near the surface or that occur in shallow water near shore are often taken by bald eagles. A hydrologic regime that supports the prey populations is critical to meet the needs of bald eagles.

Kissimmee Chain of Lakes Mammals

Four species of mammals in the region—the marsh rice rat (*Oryzomys palustris*), marsh rabbit (*Sylvilagus palustris*), round-tailed muskrat (*Neofiber alleni*), and river otter (*Lutra Canadensis*)—are known to use wetland habitat within the KCOL (**Table 18**) (FDEP 1998). These same four species were identified for the Kissimmee River. All four species have been reported to occur in Lake Kissimmee State Park (FDEP 1998) and Lake Jackson, which is east of Lake Kissimmee (Hulon et al. 1998). All but the round-tailed muskrat have been reported to occur in the Three Lakes Wildlife Management Area, which borders Lake Kissimmee on the east (FWC 2001).

In addition to these four species, other mammals also use lake margins. For example, Hulon et al. (1998) trapped or observed seven other species of mammals on spoil islands created in the littoral zone of Lake Jackson. These included two game species: white-tailed deer (*Odocoileus virginianus*) and wild pig (*Sus scrofa*). Predators were another important group and included gray fox (*Urocyon cinereoargentus*), raccoon (*Procyon lotor*), and bobcat (*Felis rufus*).

Table 18. Mammals that might use the KCOL. [1]

Common Name	Scientific Name	Habitat	Feeding	Breeding
Marsh rice rat	*Oryzomys palustris*	Most abundant in freshwater marshes.	Eats seeds of sedges and grasses and green plants. In addition it eats berries, fruit, fungi, snails, crustaceans, small insects, and bird eggs.	Can build nests suspended in thick vegetation over land.
Marsh rabbit	*Sylvilagus palustris*	Occurs in freshwater marshes. Rests by day in thick vegetation.	Consumes diverse emergent aquatic vegetation, including grasses, sedges, maidencane, broad-leaved herbs, and weeds.	Breeds year-round with peak in December–June. Nests on elevated areas.
River otter	*Lutra canadensis*		Carnivorous eating lush, crayfish, frogs, snails, salamanders, snakes, turtles, clams, rodents, birds, and aquatic insect larvae.	
Round-tailed muskrat	*Neofiber alleni*	Occurs widely in freshwater marshes, especially maidencane.	Herbivorous eating stems, roots, leaves, and seeds of aquatic vegetation, particularly maidencane, arrowhead, rice cutgrass, water shield, green arum, caladium, and lemon bacopa.	Breeds throughout the year. Breeding limited by food and water levels. Nests in thick aquatic vegetation, such as maidencane, willow, cypress, or cattail buttonbush.

[1] Based on Brown (1997) and Whitaker and Hamilton (1998).

SECTION 6:
MODELS USED IN WATER RESERVATION ANALYSES

Introduction

Unlike hydrologic conditions (stage and discharge) in the Upper Chain of Lakes reservation waterbodies (Lakes Myrtle–Preston–Joel, Lakes Hart–Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga, Alligator Chain of Lakes, and Lake Gentry), those in Headwaters Revitalization Lakes (Lakes Kissimmee–Cypress–Hatchineha–Tiger) and Kissimmee River reservation waterbodies are expected to change after the implementation of a new regulation schedule for S-65 structure at the end of construction for the Kissimmee River Restoration Project, which is expected in 2019. The new regulation schedule, called the Headwaters Revitalization Schedule, was designed to create additional storage in the Headwaters Revitalization Lakes and to provide the discharge needed to meet the goal of the Kissimmee River Restoration Project. Since the Headwaters Revitalization Schedule has not been implemented yet, a water reservation for the Headwaters Revitalization Lakes and Kissimmee River has to be based on the modeled hydrologic conditions from the simulation of the Headwaters Revitalization Schedule.

This section describes the development and use of modeling tools to produce time series data for hydrologic conditions for the Headwaters Revitalization Lakes and Kissimmee River reservation waterbodies. First discussed is the approach and development of the Headwaters Revitalization Schedule for the Kissimmee River Restoration Project that includes the modeling tool used and a description of the final schedule. Due to the potential for changes in the basin that can affect hydrology since the original modeling for the Headwaters Revitalization Schedule (completed in 1993), the Headwaters Revitalization Schedule was simulated with a model using more up-to-date information. The development of this model and its application are also discussed.

Development of the Headwaters Revitalization Schedule

Purpose of the Headwaters Revitalization Schedule

The United States Congress authorized the Kissimmee River Restoration Project, including headwaters revitalization components, in the Water Resources Development Act of 1992. The goal of the Kissimmee River Restoration Project is to reestablish ecological integrity for fish and wildlife in the Kissimmee River and its floodplain. The recommended plan for the Kissimmee River Restoration Project is described in the document *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration of the Kissimmee River, Florida* (USACE 1991). It describes the degradation of river and floodplain habitat by channelization and the resulting declines in fish and wildlife populations. It also describes how features of the recommended plan will attain the project goal for the river by reestablishing ecological integrity for fish and wildlife. Meeting the project goal is dependent on reestablishing key features of pre-channelization hydrology as represented by five hydrologic restoration criteria in **Box 1** of Section 4. The river performance measures described in Section 7 are derived from these criteria. A key component of the recommended plan for reestablishing hydrology is a new regulation schedule for the S-65 structure that will provide the pattern of discharge from the upper basin needed for fish and wildlife in the Kissimmee River. The new schedule would increase the storage in the Headwaters Revitalization Lakes by 100,000 acre-feet by raising the upper limit of the schedule to 54 feet National Geodetic Vertical Datum and that would reestablish the pre-regulation relationship between lake stage and discharge to the Kissimmee River. Increasing storage in the Headwaters Revitalization Lakes will result in higher stages for a portion of the year; the United States Fish and Wildlife Service estimated that higher stages had the potential to reestablish approximately 7,200 acres of littoral wetlands for fish and wildlife that had been drained by regulation as part of the Central and Southern Florida Flood Control Project (C&SF Project). A preliminary version of the new regulation schedule was used in simulations of alternative plans that were evaluated in United States Army Corps of Engineers (USACE) (1991). The process used to refine the preliminary schedule for S-65 and to select the final version is described in the supplemental document—*Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement* (USACE 1996). The next two sections provide a brief description of the model that was used to simulate alternatives and the evaluation process to select the final schedule.

Description of the UKISS Model

During the development of the Headwaters Revitalization Schedule, the effects of alternative regulation schedules on lake stage and discharge were simulated with the Upper Kissimmee Chain of Lakes Simulation (UKISS) model. UKISS is described in detail in Fan (1986) and its use in the evaluation of alternative schedules for headwaters revitalization is described in USACE (1996). Briefly, UKISS simulates the operations of the C&SF Project water control structures in the upper Kissimmee Basin including S-65. The model is driven by daily rainfall and evapotranspiration (estimated from average monthly temperatures and solar radiation). Soil Conservation Service methods were used to estimate basin storage and runoff. Flows between lakes are estimated with linear reservoir routing techniques. Model outputs include time series of mean daily stage in each of the lakes, including the Headwaters Revitalization Lakes, and mean daily discharge through each of the water control structures, including S-65. The application of UKISS for evaluating alternative plans for headwaters revitalization continuously simulated an 18-year period (1970–1987).

Evaluation of Alternatives

An interagency team (USACE, South Florida Water Management District [SFWMD], United States Fish and Wildlife Service [USFWS], and Florida Fish and Wildlife Conservation Commission [FWC]) developed and evaluated 21 alternative regulation schedules beginning with the preliminary schedule that was modeling in USACE (1991). During evaluation of each new alternative, outflows from Lake Kissimmee were compared to discharge characteristics of the regulation schedule developed in the 1991 report because it produced the most desirable effects for river restoration and was used as the basis for project authorization. Upper basin environmental analyses of alternatives focused on the degree to which lake stage frequencies increased between elevations 50.8 and 54 feet, or the stages required to reestablish previously drained littoral wetlands up to the 54-foot elevation. Alternatives that first met the river performance criteria and secondarily met the upper basin requirements moved forward.

Adjustments to operating rules were made to ensure that the downstream criteria were met, while optimizing the ecological conditions in the Headwaters Revitalization Lakes. Two final alternatives that performed best for both upper and lower basin criteria were evaluated by the USFWS to select a preferred plan for concurrence by USACE, SFWMD, and FWC. Seven metrics were used to evaluate two best performing alternatives. Three metrics were used to evaluate the hydrologic conditions in the Headwaters Revitalization Lakes, with the other four metrics evaluating hydrologic conditions in the Kissimmee River. The four river metrics represented key characteristics of the five hydrologic restoration criteria (**Box 1** of Section 4). These seven metrics serve as the performance measures for the Headwaters Revitalization Lakes and Kissimmee River listed in Section 7. A final alternative was selected by consensus of the interagency team.

The recommended alternative for the Headwaters Revitalization Schedule is shown in **Figure 19**. The schedule contains zones that specify discharge and that vary with lake stage and time of year. When lake stage is in Zone A, discharge is made for flood control; discharge for the Kissimmee River is made when lake stage is in Zones B1, B2, C or D. The implementation of the schedule is described in Appendix B of USACE (1996).

The purpose of the evaluation was to develop and select a regulation schedule that provided the discharge needed to reestablish ecological integrity for fish and wildlife in the Kissimmee River. Raising the upper limit of the regulation schedule created additional storage in the Headwaters Revitalization Lakes. The USFWS (1994) estimated that higher water levels in the Headwaters Revitalization Lakes could increase the area of littoral wetlands by approximately 7,200 acres. However, all of this additional water was needed to extend the period of time that releases were made to the Kissimmee River. Also, during the iterative process of developing and evaluating alternatives, adjustments were made to alternatives to meet the hydrologic requirements of the Kissimmee River, especially for floodplain hydroperiod, and to minimize impacts to water levels in the Headwaters Revitalization Lakes. This indicates that all water in the Headwaters Revitalization Lakes and the Kissimmee River reservation waterbodies that has not already been allocated should be reserved for the protection of fish and wildlife.

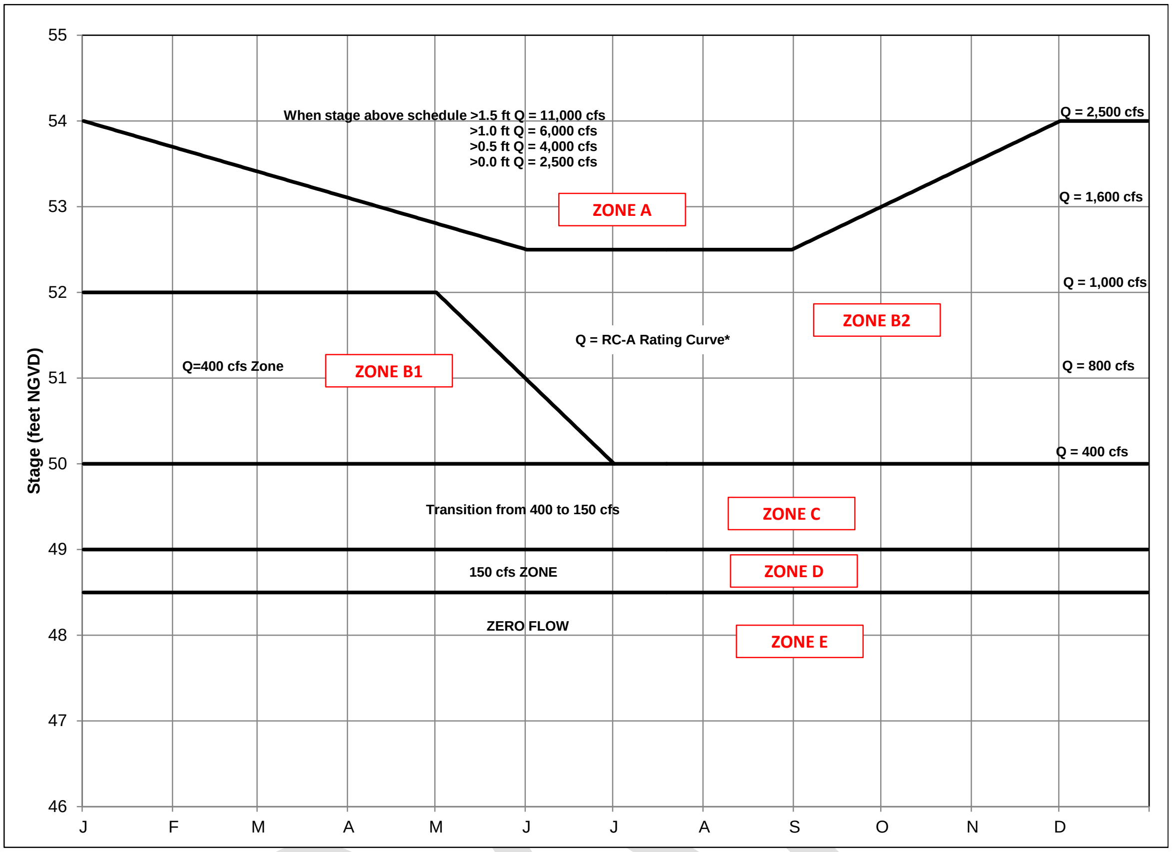

Figure 19. Operating criteria for S-65 structure Headwaters Revitalization Schedule.

Simulation of the Headwaters Revitalization Schedule for the Water Reservation

For the water reservation, the Headwaters Revitalization Schedule was simulated with more current information about basin conditions and for a longer period of time than were used in the previous UKISS simulation. The model used for the water reservation was an integrated groundwater-surface water model, called MIKE SHE/MIKE 11. MIKE SHE is a watershed model that includes overland and groundwater flow. It uses a grid-based dynamic modeling system to simulate integrated surface water and groundwater systems. MIKE11 is a one-dimensional channel flow model that can simulate channel and floodplain flow and can simulate fixed and operable hydraulic control structures. The basic hydrologic flow processes incorporated into MIKE SHE/MIKE 11 are shown in **Figure 20** and **Table 19**. When MIKE 11 is coupled with MIKE SHE, dynamic exchanges between the overland flow plain, groundwater system, and the river system are simulated.

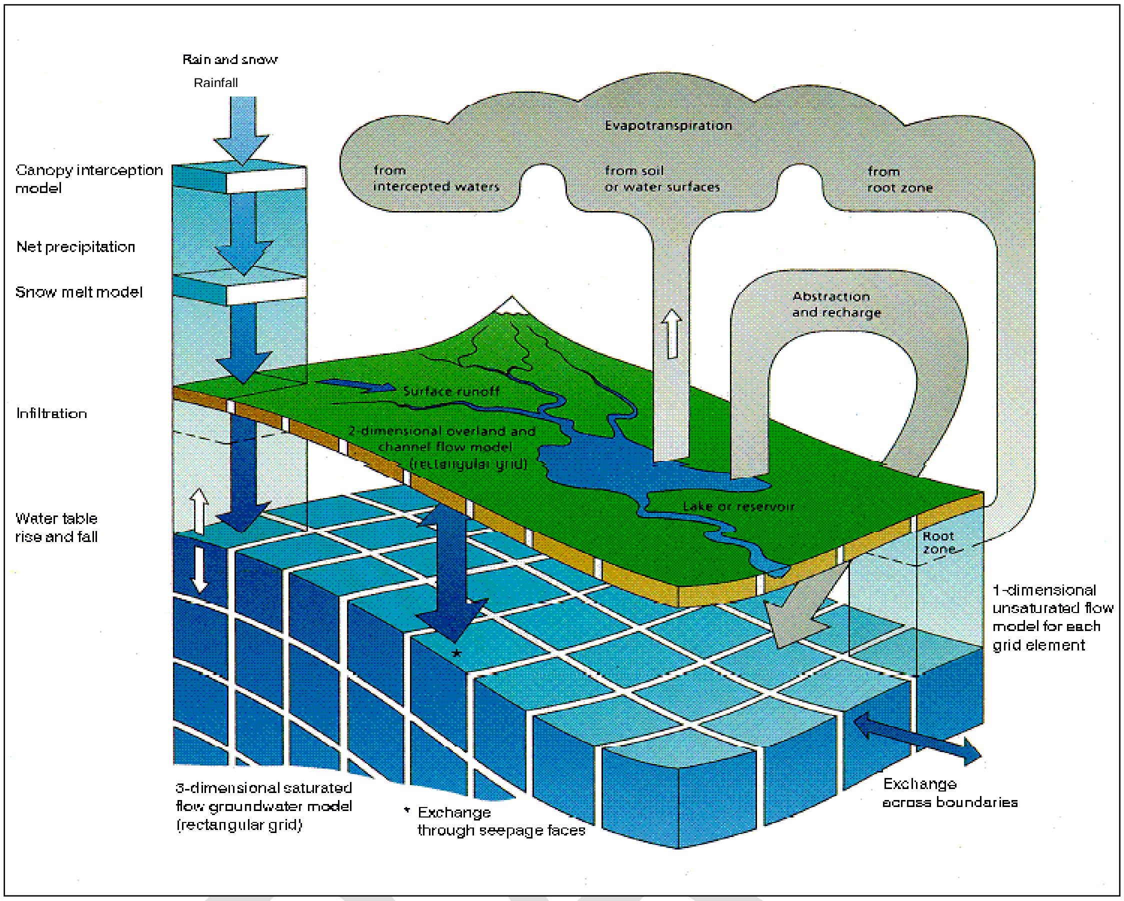

Figure 20. Hydrologic processes that can be represented in MIKE SHE/MIKE 11.

Table 19. Description of approach of hydrologic processes in MIKE SHE/MIKE 11.

Process	Approach
Overland Flow	The overland flow is simulated through a two-dimensional finite difference diffusive wave approximation of the Saint Venant equations and includes conceptual components to deal with runoff from urban areas, detention storage, and physical obstructions to flow.
Unsaturated Zone and Irrigation Demands	MIKE SHE uses a simple conceptual two-layer approach water balance method that also accounts for evapotranspiration from the canopy, ponded water, the unsaturated zone, and the saturated zone. Moisture contents or actual evapotranspiration rates simulated by the unsaturated zone module are used to determine irrigation demand.
Saturated Zone	The saturated zone is solved using a three-dimensional finite difference form of the Darcy flow equation. The saturated zone module also accounts for groundwater withdrawals.
Channel Flow	MIKE 11 simulates channel flow using a one-dimensional hydrodynamic calculation method. Lake storage is included in the definition of the cross-sections of each lake. The Kissimmee River floodplain is also included within the cross-sections defining the river. Interaction occurs between MIKE 11 and MIKE SHE overland for the lake storage and the river floodplain.

A fully integrated MIKE SHE/MIKE 11 model had been developed previously for a study to develop alternative operations for water control structures in the Kissimmee Basin. This model is called the Alternative Formulation and Evaluation Tool (AFET). The development and calibration of the AFET is documented in the *Alternative Formulation Evaluation Model Documentation and Calibration Report* (Earth Tech 2007a). Peer review of the development of AFET and its proposed application for alternative structure operations was completed in June 2008. The peer review panel recommended that newly available reference evapotranspiration (RET) data set be used to refine the calibration of the model in future efforts. The refinement of the calibration was completed in October 2008 and the resulting recalibrated model was named the Alternative Formulation and Evaluation Tool for Water Reservation (AFET-W). The calibration is documented in the *KCOL Surface Water Supply Availability Study AFET-W Calibration Report* (Earth Tech 2008). The main differences between the AFET-W and AFET are that the AFET-W was calibrated with an improved set of RET data and the AFET-W calibration included additional upper Floridan aquifer calibration criteria and calibration data.

The AFET-W was used to develop the Kissimmee Basin water reservation. The AFET-W model output are described in the report *Evaluation of the "With Project" Base Condition - Kissimmee Basin Modeling and Operations Study KBMOS*. (AECOM 2009), which is included as Appendix L. AFET-W has the spatial domain of the Kissimmee Basin to the S-65E structure. It uses RET and rainfall as climate drivers to simulate a 41-year period of record (1965–2005). It uses 2000 land use and land cover. The S-65E tailwater stage and lateral and horizontal groundwater were treated as boundary conditions. AFET-W incorporated existing legal uses through 2008. Withdrawals from public water supply wells used the permitted maximum allocation by 2008 for the SFWMD jurisdiction and were held constant during the 41-year simulation. Irrigation uses were based on actual water deficit calculated from the difference between evapotranspiration demand and the available moisture in the unsaturated zone and capped by maximum pumping capacity in the permit. It incorporates all features of the Kissimmee River Restoration Project including the demolition of S-65C, backfilling of C-38, and the U-shaped weir at the downstream terminus of backfilling. All water control structures were simulated using the existing regulation schedules except S-65, which was simulated with the Headwaters Revitalization Schedule.

Summary

Hydrologic conditions in the Headwaters Revitalization Lakes and Kissimmee River reservation waterbodies will be changed by implementation of a new regulation schedule at the S-65 structure for the Kissimmee River Restoration Project. The new schedule is named the Headwaters Revitalization Schedule and is needed to reestablish a pattern of discharge from the upper basin to meet the restoration project goal of reestablishing ecological integrity for fish and wildlife in the Kissimmee River. During the development of the Headwaters Revitalization Schedule, 21 alternative schedules were considered. Each alternative was simulated with the UKISS model to determine its effects on hydrology. The iterative process used of designing and evaluating alternatives helped ensure that the project goal for the Kissimmee River was being met while also considering conditions in the Headwaters Revitalization Lakes. The nature of this process suggests that all of the water not already allocated in these two reservation waterbodies will need to be reserved to fully attain the goal of the authorized Kissimmee River Restoration Project. For the water reservation, the Headwaters Revitalization Schedule was simulated with a more recent model, AFET-W, which was developed by the SFWMD in 2008. AFET-W uses more up-to-date information (e.g., land use and existing legal uses) and simulates a longer period of record (1965–2005) than UKISS. Output from AFET-W includes a time series of stage in the Headwaters Revitalization Lakes and one of discharge to the Kissimmee River. These two time series from AFET-W can be evaluated with the same seven metrics used in the final selection of the Headwaters Revitalization Schedule.

SECTION 7: PERFORMANCE MEASURE DEVELOPMENT

Introduction

This section describes the approach taken to develop performance measures to identify water per reservation waterbody required for the protection of fish and wildlife based on their hydrologic requirements provided in Sections 4 and 5. The wildlife considered in developing the water reservation includes fish, amphibians, reptiles, birds, and mammals. The abundance of fish and wildlife is directly related to major wetland plant communities, which form the foundation and structure of the fish and wildlife habitat associated with these waterbodies. The plant communities, in turn, are dependent on certain hydrologic requirements, which form the underpinnings of the performance measures.

Upper Kissimmee Chain of Lakes Performance Measures

Approach

The Upper Chain of Lakes (UCOL) reservation waterbodies are Lakes Myrtle–Preston-Joel, Lakes Hart–Mary Jane, Lake Gentry, Lake Tohopekaliga, East Lake Tohopekaliga, and the Alligator Chain of Lakes. The hydrologic requirements of the existing fish and wildlife resources (including habitat) are expressed as performance measures for each of these six reservation waterbodies. Each of these reservation waterbodies is represented by a single performance measure in the form of an annual stage hydrograph, which is referred to hereafter as the water reservation hydrograph or water reservation "line".

The process to develop the water reservation hydrograph involved 1) specifying a seasonal high stage; 2) specifying a seasonal low stage; 3) connecting the seasonal high to the seasonal low stage with a straight-line recession event; 4) connecting the seasonal low to the next seasonal high with a similar straight-line ascension event; 5) adjusting the resulting hydrograph to meet specific hydrologic requirements of fish and wildlife in individual reservation waterbodies, if required, and 6) adjusting the water reservation hydrograph to follow the current water regulation schedule hydrograph in instances where the regulation schedule hydrograph occurs at a stage lower than this water reservation hydrograph. The last adjustment preserves the Central and Southern Florida Flood Control Project's (C&SF Project's) federal mandate to maintain a specific level of flood protection in the region.

The water reservation hydrograph represents the annual pattern of water levels needed to protect fish and wildlife for a reservation waterbody. It defines an upper stage limit or threshold that preserves the seasonal and interannual variability in water levels required to support existing fish and wildlife resources. For all reservation waterbodies, the seasonal high was specified as the high stage limit of the current stage regulation schedule on November 1, the first day the schedule allows that stage to be reached. Selection of the seasonal low stage involves both biologic and policy considerations. The seasonal low stage was set as the 90th percentile stage for May 31 based on historical (1972–2007) conditions for each reservation waterbody. This value defines the amount of water available to fish and wildlife under a wet dry season condition that would be expected to occur once every 10 years and preserves the wide range of intra- and interannual variability that has occurred during the dry season. The resulting water reservation hydrograph does not represent a linear continuum of 90th percentile stages for each date between the seasonal high and seasonal low. The 90th percentile values for each of these dates may fall above or below the water reservation hydrograph. The observed pattern of water level fluctuation in a reservation waterbody will depend on rainfall patterns, contributing surface water inflows, and water management. The threshold approach used to develop the water reservation hydrograph does not explicitly address intra- and interannual variation in water levels. Rather it preserves the variability that occurs below the threshold. It does not represent a regulation schedule that water levels will be managed to meet.

Predicate 1: Fish and Wildlife Resources Reflect the Current Water Level Regime

The approach used to define fish- and wildlife-based performance measures was based on several foundational premises. The first predicate is that the fish and wildlife resources present in the UCOL reflect the current water level regime. It is generally accepted that the fish and wildlife resources associated with a lake are influenced by the water level regime (e.g., Williams et al. 1985, Johnson et al. 2007). Of particular importance is the influence of water levels on wetland plant communities (Hill et al. 1998, Keddy and Fraser 2000, Holcomb and Wegener 1972, Ager and Kerce 1970), which are an important component of habitat for fish and wildlife.

For each of the six reservation waterbodies in the UCOL, the current water level regime is the result of watershed runoff, water management, and climate (e.g., rainfall and evapotranspiration). Water management began when control structures were built at the outlet of each waterbody between 1962 and 1969. Operation of these structures narrowed the range of water level fluctuation by not allowing the water level to rise as high or to fall as low as it had before regulation. Elimination of the higher water levels reduced the amount of wetland habitat for fish and wildlife. For example, it has been estimated that 5,600 acres of habitat for waterfowl were lost by regulation of water levels from the Lakes Kissimmee, Cypress, Hatchineha, and Tohopekaliga (Perrin 1982).

Compared to the major changes associated with regulation of water levels, there have been relatively small adjustments to the stage regulation schedules since they were first implemented. These changes include permanent changes to the regulation schedules that shifted the range of water levels downward by 0.5 feet in Lake Gentry, raised the highest elevation by 1 foot and lowered the minimum elevation by 0.5 feet in East Lake Tohopekaliga and Lake Tohopekaliga, and raised the low elevation by 0.5 feet in Lakes Hart and Mary Jane. Most of these elevation changes were made in 1975. In addition to changes in the minimum and maximum elevations in the schedules, the shape of the schedule lines have also undergone modification. The current schedules have been in use since the early 1980s.

Almost 40 years have passed since the completion of the water control structures and more than 30 years since the current schedules were adopted by the United States Army Corps of Engineers (USACE). The existing fish and wildlife and the wetland plant communities in these lakes have had a long time to adjust to the current water level regime. The one exception is the relatively long-lived bald cypress, which has a distribution around some reservation waterbodies that reflects pre-regulation conditions.

Predicate 2: Loss of Wetland Habitat Will Result in Loss of Fish and Wildlife

The total amount of wetland habitat available within a reservation waterbody is related to the water level regime. Lowering water levels can reduce the amount of wetland habitat available to fish and wildlife. This reduction can occur in three ways: 1) lowering the water level decreases the absolute amount of inundated area available; 2) lowering the water level will shorten the hydroperiod at some elevations and may change the type of plant community present; and 3) lowering water levels may decrease the accessibility of habitat to fish and wildlife by reducing the amount of time that water levels provide adequate depth.

Several lines of evidence suggest that fish and wildlife associated with Florida lakes are influenced by water levels. In Florida lakes, the quantity of gamefish produced is related to the amount of littoral wetland habitat (Williams et al. 1985, Havens et al. 2005). In a 1999 study, the number of species of fish increased with lake surface area for 60 lakes, which ranged in surface areas from 2 to 12,400 hectares and were located mostly in north-central and central Florida (Schulz et al. 1999). The number of bird species (1 to 30 species) was positively correlated with lake area ($r = 0.86$) and shoreline length ($r = 0.82$) for 46 Florida lakes ranging in area from 0.02 square kilometers (km^2) to 2.71 km^2 (Hoyer and Canfield 1994b).

Predicate 3: Hydrologic Needs Can Be Expressed with an Annual Stage Hydrograph

A water level regime can be characterized in many ways, including magnitude (e.g., high and low water levels), timing (seasonality), duration, frequency of occurrence, and rate of change (recession and ascension rates). All of these characteristics can be represented on an annual hydrograph, except for the frequency of events occurring over a multiyear period. Most of the fish and wildlife requirements identified for the reservation waterbodies are expressed in terms of stage, seasonality, duration, and recession/ascension rate that similarly can be represented on an annual stage hydrograph. The long-term maintenance of habitat for fish and wildlife in the lakes also depends on annual variability based on rainfall patterns. These water reservation hydrographs protect this hydrologic requirement by defining an upper boundary that preserves much of the interannual variation in water levels in these lakes.

Predicate 4: Fish and Wildlife Benefit from Water Levels as High as the Maximum Elevation of the Regulation Schedule

The current stage regulation schedules constrain the maximum water level in these lakes for the protection of public health and safety. Water levels in the reservation waterbodies will rise to the regulation schedule in years with sufficient rainfall. These high water level events help define the upper limit of wetland vegetation in the lakes and maximize the quantity and distribution of habitat available for use by fish and wildlife. Prior to regulation, higher water levels occurred, which would have allowed wetland plant communities and their associated fish and wildlife to occupy higher elevations. The water reservation hydrographs capture this maximum water level on November 1 for all lakes.

Modification for Specific Biological Needs

Basing the water reservation hydrograph on a seasonal high stage and a seasonal low stage does not guarantee that all fish and wildlife needs will be met. Specific hydrologic needs have been identified for fish and wildlife associated with individual reservation waterbodies. These hydrologic needs are related to meeting fish and wildlife requirements of foraging and reproduction. The water reservation hydrograph for the Lakes Hart–Mary Jane reservation waterbody was modified to account for existing bird rookery hydrologic requirements.

Water Reservation Hydrographs

Following the method described in the above section, water reservation hydrographs were developed for the six reservation waterbodies (**Figures 21** through **26**) by specifying a seasonal high stage and a seasonal low stage. For reference, the hydrographs also show the current stage regulation schedules that have been used for approximately 30 years (**Table 20**).

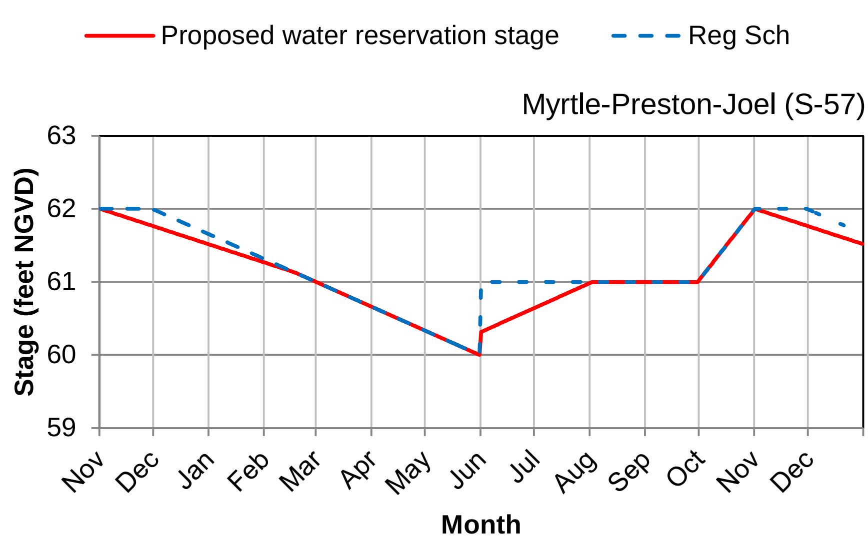

Figure 21. Water reservation hydrograph for fish and wildlife (solid line) and current regulation schedule (dashed line) for the Lakes Myrtle–Preston–Joel reservation waterbody.

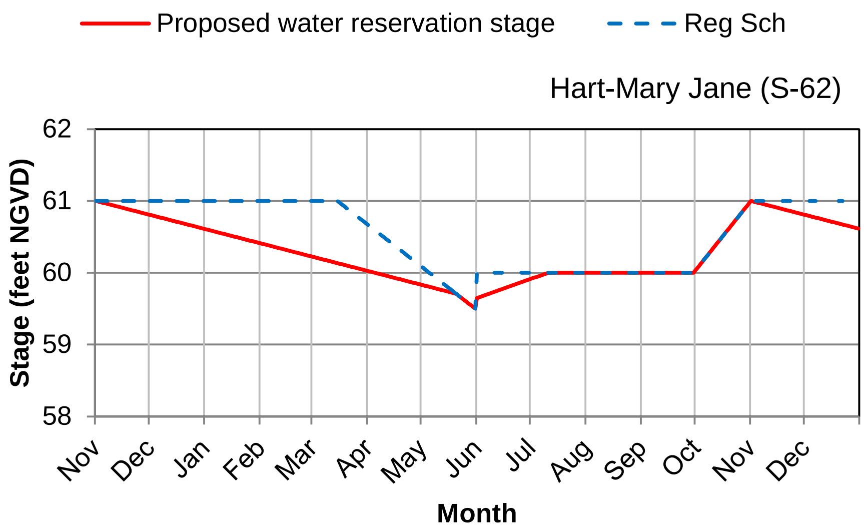

Figure 22. Water reservation hydrograph for fish and wildlife (solid line) and current regulation schedule (dashed line) for the Lakes Hart–Mary Jane reservation waterbody.

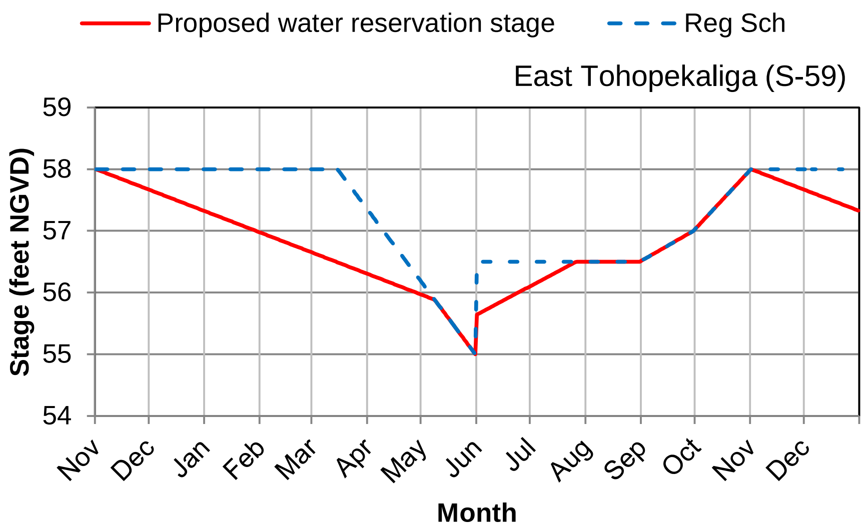

Figure 23. Water reservation hydrograph for fish and wildlife (solid line) and current regulation schedule (dashed line) for the East Lake Tohopekaliga reservation water body.

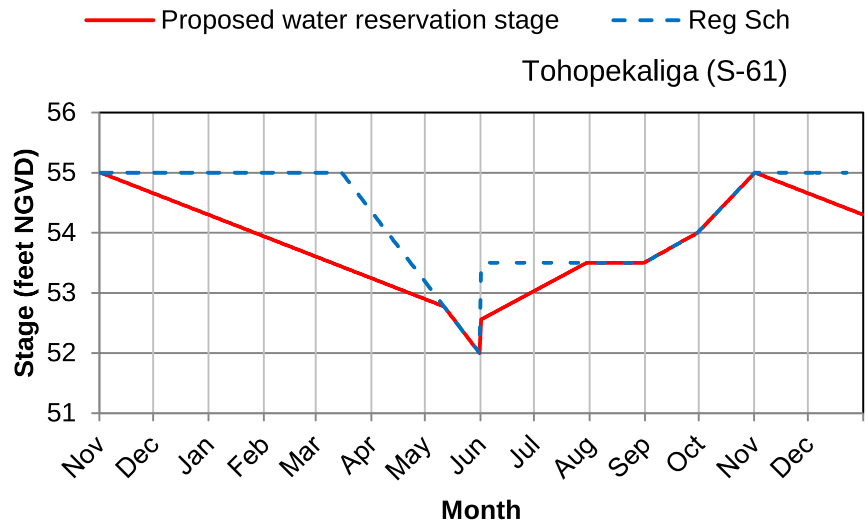

Figure 24. Water reservation hydrograph for fish and wildlife (solid line) and current regulation schedule (dashed line) for the Lake Tohopekaliga reservation waterbody.

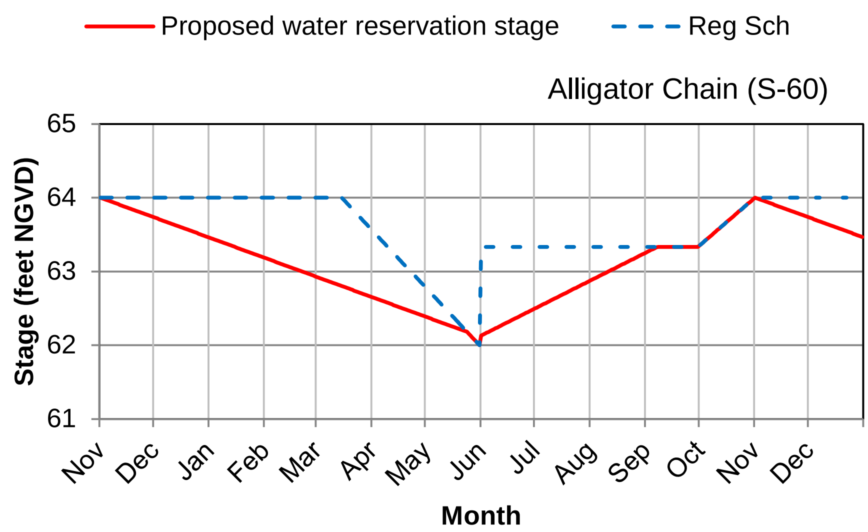

Figure 25. Water reservation hydrograph for fish and wildlife (solid line) and current regulation schedule (dashed line) for the Alligator Chain of Lakes reservation waterbody.

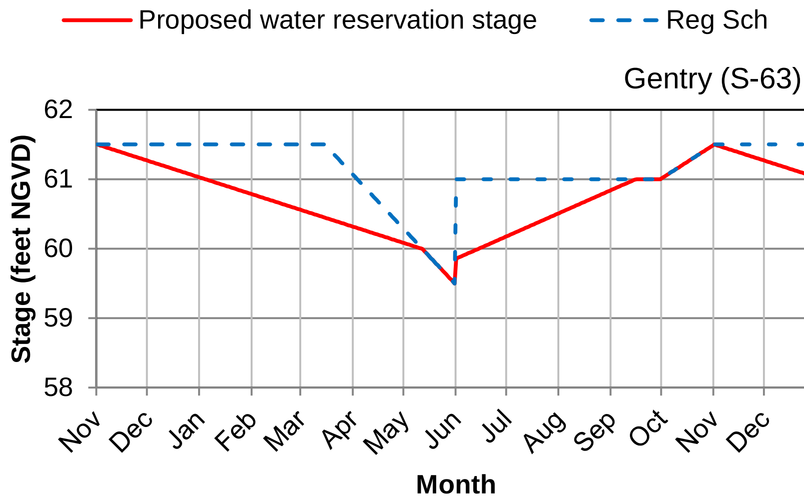

Figure 26. Water reservation hydrograph for fish and wildlife (solid line) and current regulation schedule (dashed line) for Lake Gentry reservation waterbody.

Table 20. The seasonal high and low lakes stages used to construct the water reservation hydrograph are identified by shading for each of the six water reservation waterbodies in the UCOL. Additionally, lake stages serving as inflection points to adjust the water reservation line for instances where the water reservation hydrograph occurred at a stage greater than the current regulation schedule also are identified for each reservation waterbody.

Date	UCOL Reservation Waterbody					
	Lakes Myrtle-Preston-Joel (S-57)	**Lakes Hart-Mary Jane (S-62)**	**East Lake Tohopekaliga (S-59)**	**Lake Tohopekaliga (S-61)**	**Alligator Chain of Lakes (S-60)**	**Lake Gentry (S-63)**
November 1	62.00	61.00	58.00	55.00	64.00	61.50
December 1						
February 15						
February 17	61.14					
May 8			55.89			
May 12				52.74		
May 13						60.00
May 21		59.69				
May 24					62.18	
May 31	60.00	59.5	55.00	52.00	62	59.50
June 1	60.32	59.65	55.64	52.56	62.13	59.86
July 11		60.00				
July 25						
July 27			56.50			
July 30				53.50		
August 2	61.00					
Auguts 31			56.50	53.50		
September 7					63.33	
September 15						61.00
September 30	61.00	60.00	57.00	54.00	63.33	61.00

Adjustments were made to one performance measure hydrograph to meet specific fish and wildlife requirements. For the Hart–Mary Jane reservation waterbody, a point was added to the hydrograph so that water levels declined from the seasonal high of 61 feet on November 1 to 60 feet on April 30, and then to the seasonal low of 59.64 feet on May 31. This change was made to maintain water levels that would protect the Bird Island Rookery from terrestrial predators for the major portion of the wading bird nesting season.

Adjustments also were made to the performance measures on hydrographs for all lakes to remain compliant with the existing level of flood protection provided by the currently authorized water regulation schedules. Inflection points were adjusted in instances where water reservation hydrographs occurred at a stage greater than the current regulation schedule hydrograph. In these instances, the water reservation hydrograph was modified to track with the water regulation schedule until the date when the water reservation hydrograph fell beneath the water regulation schedule. Not making these adjustments presumes that water control operations would require deviations in the regulation schedules to meet the needs of fish and wildlife. A deviation in a regulation schedule requires analysis under National Environmental Protection Act and is outside the scope of this study.

Strengths and Weaknesses of the Lake Performance Measures

The previously mentioned approach for defining and evaluating water reservation hydrographs for the UCOL reservation waterbodies is based on the current understanding of the hydrologic needs of fish and wildlife resources in these lakes. These hydrographs preserve much of the current intra- and interannual variability that supports broad ecological functions, while accounting for the specific hydrologic needs of key species (e.g., snail kites and their prey) on individual lakes. A more precise determination of fish and wildlife requirements will require additional information about the hydrologic needs of other resident species. The South Florida Water Management District's (District's) analyses are based on current conditions, empirical observations, and data under current approved operating schedules and constraints for these lakes.

Headwaters Revitalization Lakes and Kissimmee River Performance Measures

The Approach

The performance measures being used to evaluate the water required for the protection of fish and wildlife in the Headwaters Revitalization Lakes (Lake Cypress, Lake Hatchineha, Lake Kissimmee, and Tiger Lake) and the Kissimmee River and floodplain are the same as those used to develop the final Headwaters Revitalization schedule per the 1996 *Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement* (USACE 1996). The 2009 version of this draft technical document used three performance measures to evaluate hydrologic conditions in the Kissimmee River and floodplain that were developed for the Kissimmee Basin

Modeling and Operations Study (KBMOS) (R-01 through R-03 in **Figure 27**). However, since the KBMOS project has been put on indefinite hold by the USACE and the South Florida Water Management District, this version of the document uses four performance measures used to develop the Headwaters Regulation Schedule (KR-1 thorugh KR-4 in **Figure 28**). As discussed in Section 6, the Headwaters Revitalization Schedule was developed to best meet the hydrologic requirements to achieve the project goal of restoring ecological integrity to the Kissimmee River, while optimizing habitat conditions in the Headwaters Revitalization Lakes to support fish and wildlife. The Kissimmee River Restoration Project was predicated, congressionally authorized, and is being constructed based on achieving these restored hydrologic conditions. For the Kissimmee River and floodplain, ecological integrity is defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to natural habitat of the region" (Frey 1975, Karr and Dudley 1981). This definition is compatible with protection of fish and wildlife as defined for water reservation rulemaking (Assoc. of Florida Cmty. Developers, et. al. v. Dep't of Evtl. Prot., et. al., DOAH Case No. 04-0880RP). In the Headwaters Revitalization Lakes, reaching lake stages that would inundate wetlands above 52.5 feet National Geodetic Vertical Datum of 1929 (NGVD) were identified as critical for fish and wildlife. These higher stages will allow for the reestablishment of the lake littoral habitat within the Headwaters Revitalization Lakes that were lost as a result of regulation since the 1960s.

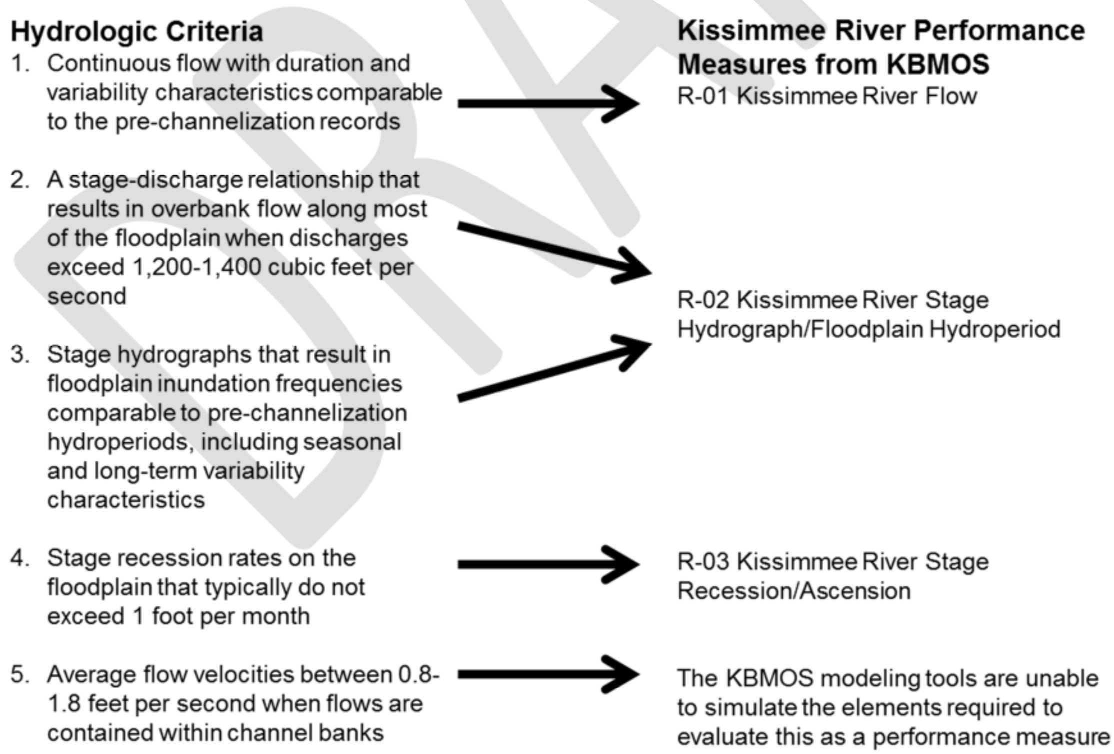

Figure 27. Relationship of the five hydrologic criteria to the river performance measures used in KBMOS and the 2009 *Draft Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*.

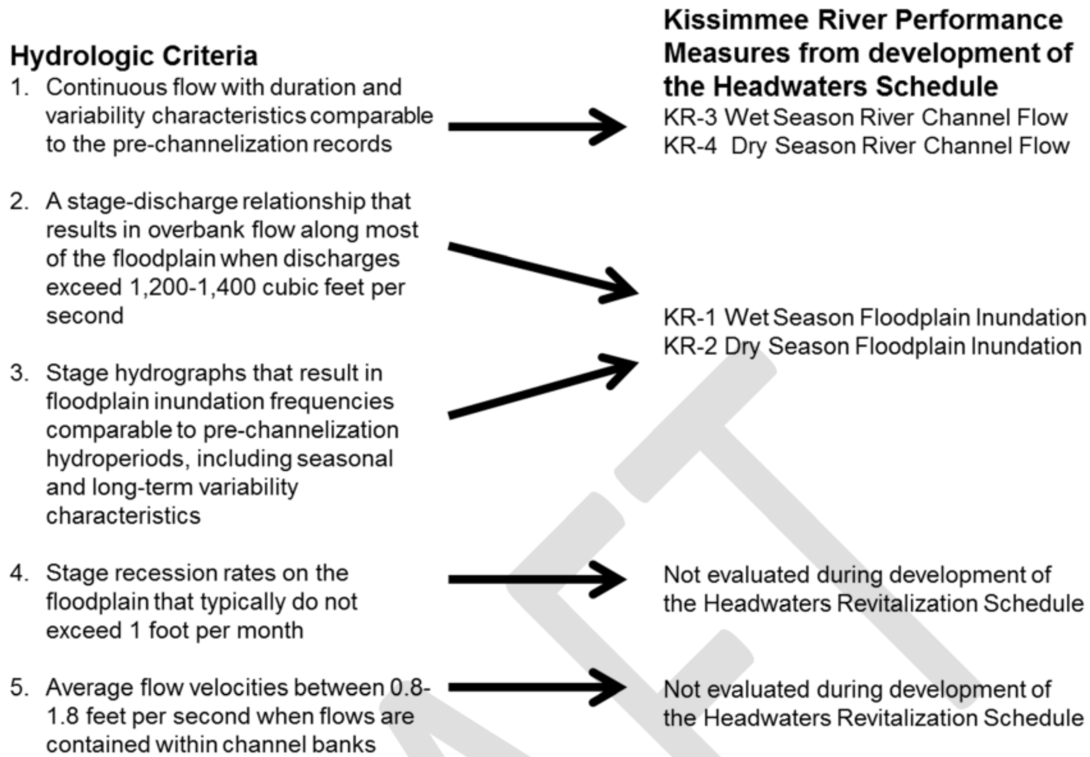

Figure 28. Relationship of the five hydrologic criteria to the river performance measures used during development of the Headwaters Revitalization Schedule and this current version of the *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*.

During the federal planning process to develop the Headwaters Revitalization schedule to achieve the project's hydrologic requirements to meet fish and wildlife requirements, numerous alternative operating plans for structure S-65 were identified and evaluated. This process was described in Section 6. Screening level performance measures that were mostly qualitative in nature were used to expeditiously cull out under-performing alternatives. Seven additional metrics were used to evaluate the two highest ranking alternatives and identify the preferred alternative. These criteria were quantitative and included four performance measures dedicated to river-floodplain performance and three that focused on lake performance. The river-floodplain performance measures evaluated three of the five hydrologic criteria believed to be most influential in achieving the restoration goal. These same seven criteria serve as the performance measures used to determine water required to be reserved for the protection of fish and wildlife in the Headwaters Revitalization Lakes and the Kissimmee River and floodplain.

Kissimmee River and Floodplain Performance Measures

Kissimmee River and floodplain performance measures focus on characteristics of floodplain inundation and periods of low flow within the river channel. In both cases, seasonality, expressed as wet and dry seasons, was considered an important aspect of each metric, since hydrologic conditions in the river channel and on the floodplain vary distinctly due to dissimilar amounts of available water associated with seasonal rainfall. Two performance measures address floodplain inundation, evaluating the percentage and duration of inundation. Percentage of inundation is important to fish and wildlife because higher percentages equate to greater areas of available habitat that are critical at various life history stages and for breeding, foraging, and refugia. Additionally, duration of inundation within a single year is biologically significant because it evaluates the amount of time floodplain habitat is available for use by fish and wildlife. The wet season (June 1–October 31) floodplain performance measure is the average duration in days with greater than 90% floodplain inundation. The dry season (January 1–May 31) floodplain performance measure is the average duration in days with greater than 25% floodplain inundation.

Flow is a critical component of river hydrology and ecology. The flow regime drives the physical, chemical, and biological components of a river. Although ecologically important and a common feature in riverine systems, extreme flows (high and low) can have varied negative impacts on fish and wildlife. For development of the Headwaters Revitalization Schedule, periods of very low flow (< 200 cubic feet per second [cfs]) were considered to be the most detrimental based on the relationship of very low to no flow on dissolved oxygen levels. Very low to no flow conditions often lead to highly depressed levels of dissolved oxygen in the water column and can result in fish kills and the death of other aquatic wildlife requiring a minimum level of dissolved oxygen for survival. This holds true especially during the wet season, when higher water temperatures naturally support lower levels of dissolved oxygen. Therefore, the performance measures for river channel flow also contain a seasonal component. The performance measure for wet season (June 1–October 31) river channel flow is the average duration in days with less than 200 cfs flow measured at the S-65 structure. The dry season (January 1–May 31) river channel flow performance measure is the average duration in days with less than 200 cfs flow measured at the S-65 structure. **Table 21** describes these performance measures.

Table 21. Performance measures for evaluating water for the protection of fish and wildlife in the Headwaters Revitalization Lakes and the Kissimmee River and Floodplain.

Kissimmee River and Floodplain Performance Measures	Performance Measure Statement
KR-1 Wet Season Floodplain Inundation	Average duration in days with > 90% floodplain inundation in the wet season (June 1–October 31)
KR-2 Dry Season Floodplain Inundation	Average duration in days with > 25% floodplain inundation in the dry season (January 1–May 31)
KR-3 Wet Season River Channel Flow	Average duration in days with <200 cfs flow at the S-65 structure in the wet season (June 1–October 31)
KR-4 Dry Season River Channel Flow	Average duration in days with < 200 cfs flow at the S-65 structure in the dry season (January 1–May 31)
Headwaters Revitalization Lakes Hydrologic Performance Measure	**Performance Measure Statement**
HRL-1 Seasonal High Lake Stage	Average duration in days water levels exceed 52.5 feet
HRL-2 Seasonal Low Lake Stage	Average duration in days water levels are below 49 feet
HRL-3 Coefficient of Variability	Coefficient of variation of water levels over the period of record

Headwaters Revitalization Lakes Performance Measures

Similar to the approach used to evaluate the water required for the protection of fish and wildlife in the UCOL for the reservation of water in this document, a seasonal high and low value were used in evaluating alternatives during development of the Headwaters Revitalization Schedule. As such, use of these performance measures to evaluate water required for the protection of fish and wildlife is appropriate. Achieving a seasonal high above 52.5 feet in Lakes Kissimmee, Cypress, and Hatchineha, and Tiger Lake inundates the full complement of littoral wetlands that provides habitat critical to the survival and maintenance of fish and wildlife associated with these lakes. Additionally, low stages allow for important ecological processes such as the drying, compaction, and subsequent oxidation of accumulated organic sediments in the littoral zone that can adversely impact wetland vegetation composition, distribution, and coverage. Decreases in these three littoral wetland characteristics reduce the size and type of habitat available and critical to the large array of fish and wildlife that use them. Moreover, high levels of accumulated organic sediments can contribute to depressed levels of dissolved oxygen, thereby diminishing a critical condition required by aquatic fish and wildlife for survival. A third component of lake hydrology evaluated the overall variability of water levels from the mean. Natural systems typically require variation in conditions to support their constituent fish and wildlife and this is true for lake systems. Interannual variation in hydrologic conditions helps to maintain the diversity of littoral vegetation that serve as habitat. In turn, greater habitat diversity is capable of supporting a greater diversity of fish and wildlife.

The first performance measure for the Headwaters Revitalization Lakes reservation waterbody is the average duration in days water levels exceed 52.5 feet. The second stage-based performance measure is the average duration in days water levels are below 49 feet. The third performance measure is the coefficient of variation of water levels over the period of record evaluated.

Strengths and Weaknesses of the Kissimmee River and Floodplain, and Headwaters Revitalization Lakes Performance Measures

The previously mentioned approach for defining and evaluating water reservation hydrographs for the Kissimmee River and its floodplain and for the Headwaters Revitalization Lakes is based on the current understanding of the hydrologic needs of fish and wildlife resources in these waterbodies. These performance measures preserve specific requirements necessary to sustain critical fish and wildlife habitat and much of the current intra-annual and interannual variability that supports broad ecological functions. A more precise determination of fish and wildlife requirements will require additional information about the hydrologic needs of other resident species. The District's analyses are limited to conditions under approved future operating schedules and constraints for these waterbodies.

SECTION 8:
SCIENTIFIC PEER REVIEW

Scientific peer review is a process through which scientific products, be they interpretation of data, development of a mathematically based model, or a summary and discussion of findings in the form of a manuscript or scientific document, are reviewed by an independent and unbiased panel of experts in the field(s) relative to the product under review. This process is commonly accepted as an essential part of the publication process in the scientific community and often is used by scientific agencies to strengthen the validity of their science products. Using this process aids in maintaining the current standards of quality inherent to specific scientific disciplines, thereby increasing the credibility of the product by reducing unwarranted or misinterpreted findings.

Peer Review of 2009 Draft Technical Document

The 2009 *Draft Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes* underwent the scientific review process. The peer review panel was made up of five experts covering the fields of applied ecology, conservation biology, freshwater fish and avian ecology, wetland ecosystem science, and hydrologic modeling. The panel was charged with evaluating the approach and supporting data for identifying the water required for protection of fish and wildlife in the Kissimmee River and floodplain and in the Kissimmee Chain of Lakes (KCOL) to determine if these methods were scientifically sound. Below are excerpted comments from the resulting positive peer review report (Appendix J):

> The Peer Review Panel determined that the supporting data and information to develop the draft "Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes" are technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information. Hydrologic models and analyses are well developed and documented, and the AFET-W [Alternative Formulation and Evaluation Tool for Water Reservation] model appears to reproduce observed surface and groundwater flow conditions satisfactorily for the intended application. The document uses appropriate hydrologic performance measures and supports their use with a thorough understanding of current scientific knowledge of wetland hydrology as related to fish and wildlife requirements, and with appropriate empirical observations and data where available. The relationship between water levels and the condition of the broadleaf marsh, for the Kissimmee River and floodplain, and the pattern and extent of littoral zone inundation, for the Kissimmee Chain of Lakes, are well developed and these aquatic plant communities serve as suitable indicators for the protection of fish and wildlife.

The current document uses the same approach for developing the performance measures (water reservation hydrographs) for the reservation water bodies in the Upper Chain of Lakes (UCOL), with only slight modifications made to ensure the current level of flood protection is provided in instances where the water reservation hydrograph exceeded the regulation schedule for each water reservation waterbody. It also uses the same simulated period of record and AFET-W model output (**Appendix L**) to generate the hydrologic time series data for evaluating fish and wildlife requirements in the Kissimmee River and floodplain and in the Headwaters Revitalization Lakes. Slight differences occur in performance measures used to evaluate fish and wildlife water requirements in the Kissimmee River and floodplain and the Headwaters Revitalization Lakes. The 2009 version of the draft technical document used three performance measures (R01 through R03) to evaluate hydrologic conditions in the Kissimmee River and floodplain that were developed for the Kissimmee Basin Modeling and Operations Study (KBMOS) (**Figure 27**). These three performance measures evaluated four of the five hydrologic criteria required to achieve the restoration project goal. However, since the KBMOS project has been put on indefinite hold by the United States Army Corps of Engineers (USACE) and the South Florida Water Management District (SFWMD or District), the current version of the draft technical document uses four performance measures (KR1 thorugh KR4) used to develop the Headwaters Regulation Schedule to be consistent with the federal authorizations (**Figure 28**). The four performance measures evaluate three of the five hydrologic criteria). Because these latter performance measures were used to identify operations upon which the Kissimmee River Restoration Project is predicated, are required to sustain fish and wildlife, evaluate three of the four hydrologic criteria, and is consistent with the previous federal authorizations. As a result of these factors, it was determined that further peer review was not necessary in this current effort.

Peer Review of the Five Hydrologic Criteria

The hydrologic criteria themselves have undergone extensive peer review. This review started with the key hydrologic determinants of ecological integrity that were determined through analysis of pre-regulation hydrologic data (Toth 1990b). These hydrologic determinants were modified slightly to become the five hydrologic criteria used by SFWMD to evaluate alternative restoration plans (Loftin et al. 1990). These hydrologic criteria were then applied by USACE in the planning and design of the Kissimmee River Restoration Project (USACE 1992) as well as the upstream conditions required to meet those criteria in the Headwaters Revitalization Lakes (USACE 1996). The evolution of the hydrologic criteria and their relationship to the components of the natural flow regime (Poff et al. 1997) are described in Anderson and Chamberlain (2005). These hydrologic criteria were translated into the four river evaluation performance measures used to develop the Headwaters Regulation Schedule, as well as to identify water for the protection of fish and wildlife in this version of the technical document.

Peer Review of the AFET-W Modeling Tool

SFWMD selected three experts to participate in the model peer review panel to evaluate the KBMOS models, including the Alternative Formulation and Evaluation Tool (AFET), and application to identify alternative structure operating criteria. The model peer review panelists were experts in the fields of modeling and application of models to water resource projects. The review goals of the KBMOS panel were to do the following:

- Find critical defects, if any, in the model and/or evaluation performance measures relative to the goal of understanding and predicting environmental, hydrologic, and hydraulic responses to alternative management scenarios.
- Suggest remedies for such defects and/or suggest the appropriate caveats to be understood by those who must interpret the model and/or evaluate performance measure results for decision support.
- Recommend avenues for future model and/or evaluate performance measure refinement.

The panel did not find any critical defect in the modeling tool as stated in the panel's report, quoted as follows (Loucks et al. 2008):

> The panel finds no critical defects in the modeling and operation study completed as of this date and no critical defects in the modeling and study activities planned for the completion of this study; thus no remedies are needed. We do identify some remaining issues and opportunities that if addressed within the time and budget constraints available might further enhance the outcomes of this study.

The peer review panel identified an opportunity to enhance the outcome of the study by using a new set of reference evapotranspiration data. The inclusion of this new data set prompted the need to revise the calibration of the AFET. This newly calibrated model was termed the AFET-W. Additional information on model development, calibration and recalibration, application, and input data can be found in Appendix K.

SECTION 9: ANALYSES TO EVALUATE WATER TO BE RESERVED

Introduction

The purpose of this section is to summarize the approach taken to identify the water that should be reserved from allocation to protect fish and wildlife in each of the Kissimmee Basin reservation waterbodies. It is important to note that the standards upon which water reservation rules are based (Section 373.223(4), Florida Statutes) afford the South Florida Water Management District's (District's or SFWMD's) Governing Board discretion and judgment in determining the quantities and timing of waters that may be reserved from use for the protection of fish and wildlife or public health and safety.

The identification of water to be reserved is first discussed for reservation waterbodies in the Upper Chain of Lakes (UCOL) and then for the Headwaters Revitalization Lakes and the Kissimmee River because the latter are influenced by the Kissimmee River Restoration Project. The reservation bodies within the UCOL include Lakes Myrtle–Preston–Joel, Lakes Hart–Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga, Alligator Chain of Lakes, and Lake Gentry. The Headwaters Revitalization Lakes include Lakes Kissimmee, Cypress, and Hatchineha, and Tiger Lake. This section also considers the proposed water reservation in relation to existing legal users.

Upper Chain of Lakes

The UCOL includes six reservation waterbodies that were identified in Section 1. The reservation waterbodies are described in detail in Section 3, including waterbodies that contribute to the water reservation. For each waterbody within the UCOL, a water reservation line was developed to capture interannual variability, which is important to fish and wildlife. The development of these water reservation lines is described in Section 7 and the reservation lines are shown in **Figures 21** through **26**. Appendix H contains graphs of the water reservation lines and tables of the daily stage values.

The technical analysis found that in the UCOL reservation waterbodies, all surface water not already allocated should be reserved to protect fish and wildlife when lake stage is at and below the reservation line. When lake stage is above the reservation line water may be available for allocation. The quantity of water available for allocation varies among waterbodies because of differences in volume (**Table 3** in Section 3) from year to year, month to month, day to day depending on climatic conditions.

Kissimmee River and Headwaters Revitalization Lakes

The identification of water to be reserved in the Headwaters Revitalization Lakes and the Kissimmee River are discussed together because the hydrology of these reservation waterbodies is closely linked to the Kissimmee River Restoration Project.

The Kissimmee River Restoration Project was developed to address concerns of the public about the effects of the Central and Southern Florida Flood Control Project (C&SF Project) on the Kissimmee River—specifically that altered hydrology, especially the loss of floodplain wetlands, had resulted in the loss of habitat and reduced populations of many species of fish and wildlife. The District, the United States Army Corps of Engineers (USACE) and other state and federal agencies engaged in a long period of planning that included a demonstration project, a physical model, and computer modeling. The recommended plan for Kissimmee River Restoration Project was described in the report *Central and Southern Florida Project Final Integrated Feasibility Report and Environmental Impact Statement Environmental Restoration Kissimmee River, Florida* (USACE 1991) and authorized by the United States Congress in the *Water Resource Development Act of 1992*. The estimated final cost of Kissimmee River Restoration Project is 980 million dollars. The project is described in more detail in Section 1 and Appendix A.

An integral component of the restoration project was the development of a new regulation schedule for the S-65 water control structure, which is the outlet from the Headwaters Revitalization Lakes to the Kissimmee River. The new schedule, called the Headwaters Revitalization Schedule, was developed to provide the flows necessary to protect fish and wildlife thus meeting the ecological integrity goal of the Kissimmee River Restoration Project. An interagency team (USACE, SFWMD, United States Fish and Wildlife Service, and Florida Fish and Wildlife Conservation Commission) conducted an extensive analysis that considered 21 alternative schedules and is described in the *Central and Southern Florida Project Kissimmee River Headwaters Revitalization Project Integrated Project Modification Report and Supplement to the Final Environmental Impact Statement* (USACE 1996). It was only after extensive analysis and completion of an environmental impact statement pursuant to National Environmental Protection Act that USACE adopted the Headwaters Revitalization Schedule. The schedule will be implemented when construction for the restoration project is completed in 2019.

The Headwaters Revitalization Schedule creates storage in the Headwaters Revitalization Lakes reservation waterbody by allowing water levels to rise higher than the current regulation schedule. This allows water to accumulate in the reservation waterbody during wetter seasons and years and be released at a range of discharges to meet the ecological integrity goals of the Kissimmee River Restoration Project that are protective of fish and wildlife and their habitat. Adjustments were made to the regulation schedule that became the Headwaters Revitalization Schedule, so that the resulting water levels in the Headwaters Revitalization Lakes reservation waterbody were protective of fish and wildlife in the lakes.

The same performance measure metrics used to select the Headwaters Revitalization Schedule were evaluated using stage and discharge time series from a model that simulated 2008 basin conditions (e.g., 2000 land use/land cover and permitted consumptive users) and the Headwaters Revitalization Schedule. The metrics, which were described in Section 7 above, focused on the duration of floodplain inundation and low flow in wet and dry seasons for the Kissimmee River, and the durations of high and low stage in the Headwaters Revitalization Lakes. The simulation model was the Alternative Formulation and Evaluation Tool for Water Reservation (AFET-W), which was described in Section 6 above and was peer reviewed (Section 8). AFET-W simulates a 41-year period of record (1965–2005). The results from the AFET-W output were consistent with the results obtained previously when Headwaters Revitalization Schedule was selected (USACE 1996). Because of this consistency and of the requirement of this water to meet the ecological goals of the federally authorized Kissimmee River Restoration Project in the Kissimmee River/floodplain and Headwater Revitalization Lakes, all waters within the Headwaters Revitalization Lakes and the Kissimmee River should be reserved from allocation except that which has already been allocated to existing legal users.

Existing Uses of Water from Proposed Reservation Waterbodies

Subsection 373.223(4), Florida Statutes states that when establishing a water reservation, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.

A review of existing consumptive use permits was performed to determine the location and volumes under current allocations from the proposed reservation waterbodies. Identification of historical existing uses also occurred. The selection included direct withdrawals of surface water from a reservation or contributing waterbody and withdrawals of groundwater from the surficial aquifer system that could potentially cause drawdown on a reservation waterbody. A search radius of one mile around each proposed reservation waterbody was used to locate permitted groundwater withdrawals from the surficial aquifer system.

Sixty-four existing permits (**Table 22**) were identified that have at least one well completed in the surficial aquifer system within one mile of a reservation waterbody. To be conservative, the allocation reported in the table below is the full allocation for the entire project regardless of the facility distance from the reservation waterbody. In total, 1.54 million gallons per day (MGD) is allocated from the surficial aquifer system within these 64 permits. Agricultural and livestock uses comprise the majority of this volume (1.30 MGD). Public water supply is allocated less than 0.1 MGD.

Thirteen existing permits (**Table 23**) were identified that withdraw surface water from reservation or contributing waterbodies with a combined allocation of 33.96 MGD. Eleven permits are for agriculture. The largest allocation belongs to Adams Ranch at 13.75 MGD from Lake Marian. The Adams Ranch permit withdrawals are constrained to specific stage elevations to meet wetland protection criteria. Under conditions when lake stages fall below the specified stages in the permit, surface water withdrawals are required to cease and pumpage shifted to wells constructed to the Floridan aquifer system. The other two permits are for the supplementation of reclaimed water supplies by pubic water suppliers.

Table 22. Surficial aquifer system wells near the reservation waterbodies.

Permit Number	Project Name	Land Use	Annual Allocation (MGD)
28-00290-W	Buckhorn Housing	public water supply	0.0106
28-00379-W	Hidden Acres Estates	public water supply	0.0192
28-00532-W	Depot Pasture Well	livestock	0.0075
28-00552-W	Ronald D Butler's Ranch	livestock	0.0010
28-00646-W	Hickory Hammock - Equestrian Center	livestock/public water supply	0.0013
28-00650-W	Hickory Hammock - Istokpoga Boat Ramp	public water supply	0.0012
47-00010-W	Lofton Ranch	livestock	0.0006
47-00025-W	Clemons Okeechobee	livestock	0.0171
47-00030-W	Bar Crescent S Ranch	livestock	0.0262
47-00032-W	One Nine Cattle Company	livestock	0.0575
47-00043-W	Eagle Island Farm	agricultural	0.2395
47-00381-W	Okeechobee Field Station	landscape	0.0018
47-00531-W	J A Tootle Property	agricultural	0.0309
47-00551-W	Four K Ranch	agricultural	0.0000
47-00706-W	Coquina Water Management (Office Well)	public water supply	0.0005
47-00737-W	United States Army Corps of Engineering	public water supply	0.0005
47-00800-W	Frances G Syfrett Ranch	livestock	0.0062
47-00815-W	Raulerson and Sons Ranch	agricultural /livestock	0.0007
47-00836-W	Emory Walker Ranch	livestock	0.0012
47-00837-W	Wallaces Brahmans	agricultural/livestock	0.0005
47-00856-W	Cabbage	industrial	0.0068
47-00894-W	Lamb Island and Dinner Island	livestock	0.0035
47-00895-W	Dixie Pasture and KICCO Ranch	livestock	0.0046
47-00911-W	Lamb Island Road	agricultural/livestock	0.1259
47-00923-W	Ruff Diamond	livestock	0.0564
47-00928-W	MICCO (Bassinger)	livestock	0.0063
47-00931-W	Horse Farm (68)	livestock	0.0107
47-00934-W	C Hooker Farm	livestock	0.0019
47-00940-W	Watford Cattle Company	livestock	0.0041
47-00988-W	101 Ranch Hwy 98	livestock	0.0024
47-01025-W	Rocking J E Ranch (Cattle)	livestock	0.0220

Table 22. Continued.

Permit Number	Project Name	Land Use	Annual Allocation (MGD)
47-01135-W	Corona Cattle Company	livestock	0.0190
47-01157-W	Robert Monroe Arnold	livestock	0.0066
48-01708-W	Orange County Convention Center	landscape	0.0005
48-02079-W	Southpark Circle Irrigation	landscape	0.0106
49-00450-W	Cypress Lake Fish Camp and RV Park	public water supply	0.0155
49-00892-W	Inn at Maingate	landscape	0.0156
49-00895-W	Sunset Tropicals	aquaculture	0.1000
49-00930-W	Harbor Oaks Marina & Campsites	landscape/public water supply	0.0290
49-00937-W	Orange Grove Campground	public water supply	0.0133
49-00951-W	Lake Marion Restaurant & Groceries	public water supply	0.0020
49-01023-W	Joh-Vannah Nursery Inc	nursery	0.0148
49-01041-W	Iglesia Bautista Central	public water supply	0.0010
49-01135-W	Kissimmee Field Station	public water supply	0.0041
49-01192-W	Flora Express Inc	nursery	0.1397
49-01253-W	Les Murdock	livestock	0.0001
49-01479-W	Adams Ranch	livestock	0.0420
49-01674-W	Silver Spurs Club	landscape/public water supply/livestock	0.0041
49-01678-W	Griffis Estates	livestock	0.0003
49-01737-W	C E Outdoor Services Nursery	nursery	0.0558
49-01827-W	Neptune Road Widening	landscape	0.0092
49-01882-W	4433 O B T-Repair Shop	public water supply	0.0002
49-01949-W	Sunshine Greenery Nursery	nursery	0.0077
49-01949-W	Sunshine Greenery Nursery	nursery	0.0077
49-01985-W	Paty Groves	agricultural	0.1885
49-02183-W	Hickory Tree Road	agricultural	0.0855
49-02256-W	Fells Cove	landscape	0.0058
49-02281-W	Premium Peach LLC	agricultural	0.0044
49-02331-W	Home Rehab Source-Zuni Road	landscape	0.0171
49-02348-W	4 H Ranch	livestock	0.0172
53-00263-W	Lake Loft Well	landscape	0.0184
53-00265-W	Highway 60 Plant Nursery	nursery	0.0300
53-00271-W	Shady Oaks Limited Use WTF	public water supply	0.0003
53-00297-W	Lake Hatchineha Ranch LLC	public water supply/livestock	0.0054
		Total	**1.54**

Table 23. Surface water pumps near the reservation waterbodies.

Permit Number	Project Name	Land Use	Source	Annual Allocation (MGD)
28-00146-W	Fort Basinger Grove	agriculture	upper Floridan aquifer/ Istokpoga Canal and C-41A canal	1.77
28-00357-W	River Grove	agriculture	C-38 canal	5.71
49-00051-W	Lakeside Groves, Inc.	agriculture	Live Oak Lake	0.23
49-00077-W	Number 4 Grove	agriculture	Pearl Lake	0.50
49-00097-W	Turkey Hammock	agriculture	Lake Kissimmee	3.15
49-00150-W	Macy Island Citrus	agriculture	Lake Tohohekaliga	0.19
49-00776-W	Adams Ranch	agriculture	Lake Marian	13.75
49-00938-W	Heart Bar Ranch Seed and Sod	agriculture	on-site canal (drains to the C-34 canal)	0.78
49-01409-W	Shingle Creek Stormwater Reuse	public water supply	Shingle Creek	4.00
49-01960-W	St Cloud Reuse Augmentation	public water supply	Lake Tohohekaliga	2.00
49-02330-W	4H Ranch	agriculture	Lake Marian	1.28
53-00031-W	Grove Number 91	agriculture	Lake Pierce	0.42
53-00032-W	Chastain Block	agriculture	Lake Pierce	0.18
			Total	**33.96**

As discussed in Section 7, the fish and wildlife within the Kissimmee Basin reservation waterbodies have adapted to the existing hydrologic conditions and the approved regulation schedules that have been in place since the early 1980s. This includes the effects of documented and any potentially undocumented historical uses that have occurred within the basin, a portion of which have been taken into account with the existing land uses in the model. These historical existing legal uses were granted water use allocations for withdrawal after all of the water use permitting criteria were met at the time of permit issuance or renewal. These historical existing uses are reflected in the observed data stages and flows that were part of the evaluation to determine the water to be reserved for the protection of fish and wildlife. The data and modeling associated with this evaluation show that the water within the Kissimmee Basin system is primarily driven by climate (rainfall and evapotranspiration) and operations rather than historical existing uses.

During the state and federal planning and feasibility studies process, it was determined that, “there would not be a significant effect on Lake Okeechobee water supply with the restoration of the Kissimmee River” (USACE 1991). The 1991 report found that the average annual inflows to Lake Okeechobee would be reduced by approximately 15,000 acre-feet or 1.6 percent as a result of additional evapotranspiration losses from increased floodplain inundation. If this 15,000 acre-feet of reduction in storage were applied at one point in time, it would only reduce the median storage of Lake Okeechobee by approximately 0.375 percent.

During wet years, floodplain inundation in the river will most likely correspond with regulatory flood control releases from Lake Okeechobee to the Caloosahatchee and St. Lucie estuaries at times when there is less demand for water. As a result, the reduction in inflows to Lake Okeechobee would not result in an equal reduction in water supply.

During dry years, when inflows to Lake Okeechobee are most critical to water supply, additional losses from evapotranspiration are expected to be reduced substantially than the average annual estimate of 15,000 acre-feet because of diminished floodplain inundation. The report also states that no resultant effects (reductions) are expected in Everglades National Park.

An evaluation was performed to ensure that the withdrawal of allocable water from the UCOL reservation waterbodies continues to allow for sufficient flows into downstream systems. The determination of an acceptable level of change in flows at the S-65 structure was based on the range of acceptability concept developed during the earlier technical work for the water reservation that was peer reviewed in 2009. In the earlier technical work, the range of acceptability was applied to the river performance by selecting targets for the performance measures that represented an upper and lower range of hydrologic conditions that should be equally protective of fish and wildlife. The use of the upper and lower performance measure targets to create an upper and lower threshold target time series of discharge is described in more detail in Section 7 of SFWMD (2009).

The average discharge at the S-65 structure was 976 cubic feet per second (cfs) for the lower threshold target time series and 1,077 cfs for the upper threshold time series. An acceptable level of change in discharge should be less than the difference between the average discharges of the upper and lower threshold target time series. Using the reduction from the upper threshold to the midpoint between the upper and lower threshold averages should provide a margin of safety. The midpoint between the average S-65 discharge for the upper and lower thresholds is 1026.5 cfs. The difference between the average discharge for the upper threshold and the midpoint between the upper and lower threshold is 50.5 cfs. A reduction from the upper threshold to the midpoint is (1077 - 1026.5)/1026.5 * 100% = 5%. This suggests that a reduction of less than 5 percent should be acceptable.

A conservative analysis was performed to look at a hypothetical reduction in flows at the S-65 structure from future withdrawals to determine what effect this would have on the performance measures associated with the Kissimmee River Restoration Project. For this analysis, mean daily discharge was reduced by 5 percent every day for a 41-year period (1965–2005). The effect of this hypothetical reduction in flows was evaluated by changes in the number of days (duration) of floodplain inundation and the duration of low flows.

It was determined that a less than 5 percent reduction in the average flows to the river would not result in impacts to the river. However, to ensure this flow reduction threshold of 5 percent is not exceeded by future withdrawals, technical staff recommended that some type of criterion be incorporated into the rule to provide a cumulative evaluation or downstream check at the S-65 structure.

The proposed water reservation will limit withdrawals within the UCOL, based on the water reservation line, while restricting all surface water withdrawals within the Headwater Revitalization Lakes and the Kissimmee River and floodplain. An added level of protection has been incorporated into the rule with a downstream check at the S-65 structure. The rule incorporates criteria to require an applicant to demonstrate that future individual and cumulative withdrawals do not reduce the average discharges at S-65 by greater than 5 percent compared to the no withdrawal scenario over a range of climatic variability between 1965 and 2005. This downstream check provides an extra level of assurance that ecological integrity goal of the Kissimmee River will be met in the future.

Summary

The proposed water reservations would restrict any new uses of surface water from the Headwaters Revitalization Lakes and the Kissimmee River while limiting the availability of future water use from the UCOL. The Kissimmee River Restoration Project's performance did not rely on reduction in historically used water and did not anticipate any curtailment of these uses in order to achieve the ecological integrity goal. Therefore, continuation of historical uses, which replicate those that existed, are compatible with the Kissimmee River Restoration Project and are not affected by the reservation.

Planning studies indicate that there will be increasing needs for new water supplies to meet future growth and to potentially augment existing sources both within and outside SFWMD boundaries over the coming years. Unreserved water above that needed for the protection of fish and wildlife in the UCOL reservation waterbodies could be used to meet some of the water supply needs in the Central Florida area. To ensure that these future withdrawals do not adversely affect the Kissimmee River Restoration Project, additional protection of the flows needed for the river are provided by a downstream verification that the average discharges (flows) at the S-65 structure are not reduced, individually and cumulatively, by greater than 5 percent.

Thus, staff recommends the Governing Board reserve from future additional allocation all surface waters at or below the water reservation line within the UCOL, aside from existing consumptive uses, and reserve all surface water within the Headwater Revitalization Lakes and the Kissimmee River and floodplain, aside from existing consumptive uses, except in cases of extreme flood conditions for the protection of property and public health and safety.

APPENDIX A: KISSIMMEE RIVER RESTORATION PROJECT BACKGROUND

Environmental and Hydrologic Conditions

Prior to the 1960s, the Upper Kissimmee Basin (UKB) and the Lower Kissimmee Basin (LKB) comprised an interconnected system of lake, river, and floodplain habitats linked by creeks and broad, shallow marshes. The Kissimmee Chain of Lakes (KCOL) drained through Lake Kissimmee to the Kissimmee River, which meandered 103 miles (166 kilometers [km]) to Lake Okeechobee through a 1- to 2-mile (1.5–3.2 km) wide floodplain (USACE 1991). The lakes overflowed seasonally, supporting adjacent wetlands, and sufficient volumes of water flowed to the river to provide year-round flow in the river channel and seasonal inundation of the river's floodplain for prolonged periods of time (USFWS 1958). These hydrologic conditions supported a vast and diverse aquatic/wetland ecosystem in the Kissimmee Basin.

Hurricanes in the 1940s caused disastrous flooding in KCOL communities, prompting the State of Florida to petition the federal government for a flood control plan for the region. The Central and Southern Florida Flood Control (C&SF) Project was authorized in 1948 by the U.S. Congress to address these problems. In addition to the C&SF Project, the *Federal Rivers and Harbors Act of 1954* authorized flood control projects in the Kissimmee Basin. For more details on the C&SF Project, refer to USACE (1985).

The C&SF Project was successful in meeting its goal of flood control. However, it dramatically altered hydrologic and associated ecological conditions in the Kissimmee Basin (Obeysekera and Loftin 1990, Anderson and Chamberlain 2005, Bousquin et al. 2005b).

C&SF Project in Lower Kissimmee Basin

A major feature of the C&SF Project in the LKB was the C-38 canal, constructed between 1962 and 1971 through the Kissimmee River Valley. Following construction of the C-38 canal, the main conduit of water between Lakes Kissimmee and Okeechobee became a 56 mile (90 km) long, 30 foot (9 meter [m]) deep canal that varied from 90 to 300 feet (27 and 91 m) in width. The canal intercepted all flow from the native river channel and moved virtually all water that formerly had been conveyed by the river, and, during periods of high flow, the floodplain, thus eliminating flow in the relict river channel and preventing essential flood pulses (seasonal inundation) of the floodplain. Flow through and water levels within the C-38 canal were regulated with the S-65 structure at the outlet of Lake Kissimmee and five water control structures (S-65A through S-65E) along the length of the C-38 canal (USACE 1991). In this "channelized" condition, the river-floodplain complex was replaced by a series of deep impoundments, managed primarily for flood control and water supply, with ecological characteristics more similar to a series of regulated reservoirs rather than a natural river/floodplain ecosystem.

The C-38 canal reduced the extent of floodplain wetlands dramatically, degrading fish and wildlife habitat and resources in the Kissimmee River (USACE 1991, Bousquin et al. 2005a, 2005b, Koebel and Bousquin 2014, Spencer and Bousquin 2014). Approximately 21,000 acres (8,500 hectares) of floodplain wetlands were drained, covered with spoil material, or converted into canal (USACE 1991, Carnal and Bousquin 2005). The wetland-dominated floodplain was converted to a swath of upland vegetation within two years of completion of the canal (Carnal and Bousquin 2005, Spencer and Bousquin 2014), much of which was used to graze cattle. Lack of flow in the disconnected (remnant) river channels allowed expansion of littoral (edge) vegetation in the channel (Bousquin 2005, Bousquin and Colee 2014), which affected water chemistry as sloughed plant material covered the sand substrate with decomposing organic matter, greatly increasing the biological oxygen demand of the system (Toth 1990a, Colangelo and Jones 2005a, Colangelo 2014). These changes contributed to lower levels of dissolved oxygen, which in turn had negative impacts throughout the aquatic food web. Aquatic invertebrate communities in the channelized system became typical of those found in lakes and reservoirs rather than riverine systems (Harris et al. 1995, Koebel et al. 2005a, Koebel et al. 2014). Lack of a flood pulse greatly reduced or eliminated river-floodplain interactions, further disrupting critical food web linkages that are dependent on seasonal flooding for river-floodplain connectivity, and resulted in loss of the prolonged rates of recession of floodwater from the floodplain that were characteristic of the pre-channelized system (Harris et al. 1995, Anderson and Chamberlain 2005, Anderson 2014b, Cheek et al. 2015). With the resulting losses of suitable hydrology, habitat, and food base, the diverse and abundant wading bird populations were largely replaced by cattle egrets (*Bubulcus ibis*), a species primarily associated with terrestrial habitats (Perrin et al. 1982, Williams and Melvin 2005b, Cheek et al. 2014), and waterfowl densities and species richness declined sharply (Williams and Melvin 2005a, Cheek et al. 2014). The river's valued largemouth bass (*Micropterus salmoides*) fishery was decimated as fish species tolerant of low dissolved oxygen, reduced water quality, and the less diverse habitat such as Florida gar (*Lepisosteus platyrhincus*) replaced bass (Perrin et al. 1982, Glenn 2005). More details on the effects of channelization on the fish and wildlife and habitat components of the Kissimmee River ecosystem are available in chapters collected in Bousquin et al. (2005b) and nine papers published in a special section of the journal *Restoration Ecology* in 2014 (Anderson 2014a, 2014b, Bousquin and Colee 2014, Cheek et al. 2014, Colangelo 2014, Jordon and Arrington 2014, Keobel and Bousquin 2014, Koebel et al. 2014, Spencer and Bousquin 2014).

C&SF Project in Upper Kissimmee Basin

In the UKB, C&SF Project features were constructed between 1964 and 1970 (**Figure A-1**). Projects included dredging of canals between lakes and installation of nine water control structures regulating the amount and timing of discharges between lakes and from the lakes to the Kissimmee River (USACE 1991). Regulation of the lakes for flood control reduced the range of lake stage fluctuation from a pre-C&SF Project range of 2 to 10 feet (0.6–3.0 m) to approximately 2 to 4 feet (0.6–1.2 m) after regulation (Obeysekera and Loftin 1990). The pre-regulation seasonal pattern of fluctuation had provided periods of flooding and drying at the edges of lakes, which played a critical role in the maintenance and reproduction of a diverse range of littoral vegetation, important to plant and animal communities adapted to and dependent on these conditions (Perrin et al. 1982). Reduction of the range of fluctuation dampened the natural flooding and drying cycle. This change is believed to promote development of unnaturally dense vegetation (personal communications, M. Mann, T. Coughlin, Florida Fish and Wildlife Conservation Commission; J. Zahina, South Florida Water Management District) that can inhibit movement of fish and other wildlife and enhance accumulation rates of organic material in lake littoral zones (USACE 1996). Because water levels have not been allowed to rise as high as they did prior to C&SF Project construction, agricultural, residential, and commercial land uses have encroached on former lake flood zones, resulting in additional loss of wildlife habitat and higher nutrient inputs to the lakes (USACE 1996).

Figure A-1 shows the location of UKB C&SF Project water control structures and the direction of water flow through the 19 primary lakes of the KCOL. The S-58 structure between the Alligator Chain of Lakes and Myrtle-Preston-Joel water reservation waterbodies serves as a functional drainage divide. Depending on water levels, water may pass through this structure in either direction. However, the S-58 structure is almost always closed. Consequently, the Myrtle-Preston-Joel reservation waterbody primarily discharges water to the north through the S-57 structure, and the Alligator Chain of Lakes reservation waterbody discharges southward through the S-60 structure. Water discharged northward through the S-57 structure passes through the Mary Jane–Hart, East Lake Tohopekaliga, and Lake Tohopekaliga reservation waterbodies, where it is discharged to Lake Cypress, which is part of the Headwaters Revitalization Lakes. Lake Cypress also receives water discharged from the Alligator Chain of Lakes reservation waterbody via the Lake Gentry reservation waterbody. Eventually all of the water in the Chain of Lakes discharges into the Headwaters Revitalization Lakes (Lakes Kissimmee, Cypress, and Hatchineha, and Tiger Lake), which discharge through the S-65 structure to the Kissimmee River.

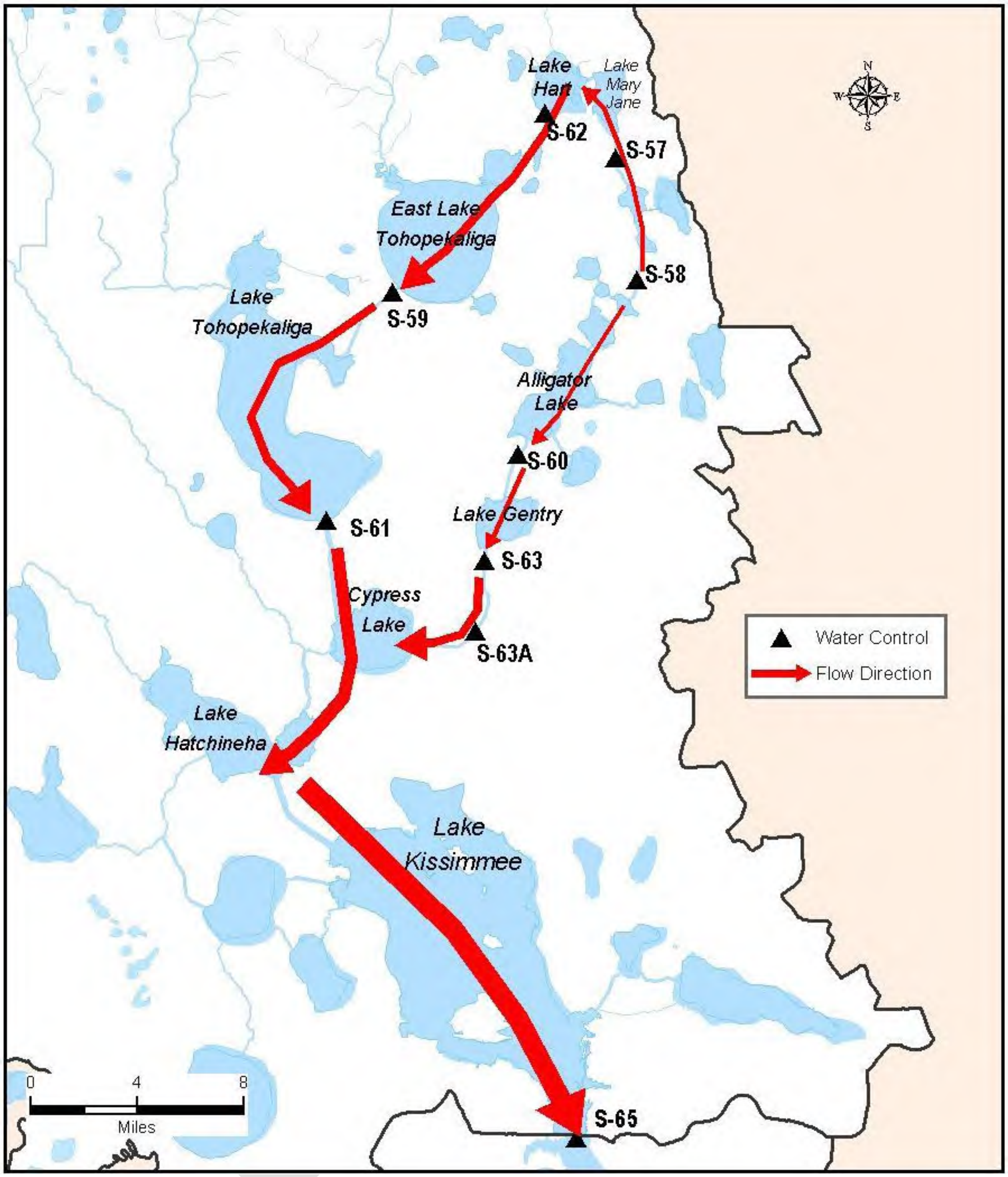

Figure A-1. Flow of water through the Kissimmee Chain of Lakes.

Kissimmee River Restoration Project

Concerns about environmental degradation and habitat loss resulting from construction of the C&SF Project in the Kissimmee River Valley, and the potential contribution of the channelized system to eutrophication in Lake Okeechobee, were the impetus for the Kissimmee River Restoration Project. As early as 1971, environmental concerns were identified by the United States Geological Survey and the Governor's Conference on Water Management in South Florida (USACE 1991). Florida's 1976 *Kissimmee River Restoration Act* specified broad goals for restoration, which were later synthesized in the project goal of "ecological integrity" (Karr et al. 1986), discussed further in the Kissimmee River Restoration Evaluation Program section below. The 1992 federal *Water Resources Development Act* (Public Law 102-580) authorized the Kissimmee River Restoration Project. Also authorized under this act was the Kissimmee River Headwaters Revitalization Project, which would make modifications in four KCOL lakes to support the water needs of the Kissimmee River Restoration Project. All project modifications and restoration under the Kissimmee River Restoration Project are to take place without jeopardizing existing levels of flood control in the Kissimmee Basin.

Successful restoration of the Kissimmee River is largely dependent on reestablishing a physical template and hydrologic conditions that are similar to those of the pre-channelized period (Toth 1990a, 1990b, USACE 1991, Koebel and Bousquin 2014), including backfilling the C-38 canal within the project area, reconnecting remnant river channels, and reestablishing the necessary hydrologic conditions for restoration and sustenance of the river and floodplain ecosystem by implementation of a new water regulation schedule for S-65. Upstream of the Kissimmee River Restoration Project, the purpose of Kissimmee River Headwaters Revitalization Project modifications is to provide storage in four headwaters lakes (Kissimmee, Cypress, Hatchineha, and Tiger, which comprise the Headwaters Revitalization Lakes reservation waterbody) to supply the water needed to maintain flow in the Kissimmee River and provide seasonal inundation of the Kissimmee River floodplain. Major components of the restoration project in the LKB include 1) acquisition of needed lands, 2) backfilling a total of approximately 22 miles (35 km) of the C-38 canal (over one-third of the canal's length) from the lower end of Pool D north to the middle of Pool B, 3) reconnecting the original river channel across backfilled sections of the canal, 4) reestablishing sections of river channel destroyed during C-38 canal construction, and 5) removing the S-65B and S-65C water control structures and their associated tieback levees. Reconstruction of the river/floodplain's physical template is being implemented in four phases of construction, currently projected for completion by 2019 (**Table A-1**).

Table A-1. Phases of Construction for the Kissimmee River Restoration Project.

Construction Sequence	Name of Construction Phase	Timeline		Backfilled Canal (miles/ kilometers)	River Channel Recarved (miles/ kilometers)	River Channel to Receive Reestablished Flow (miles/ kilometers)	Toal Area (acres/ hectares)	Wetland Gained (acres/ hectares)	Location and Other Notes
1	Phase I	June 1999–February 2001 (complete)	English	7.5	2.9	13.9	9506.1	5792.0	Most of Pool C, small section of lower Pool B
			Metric	12.1	4.7	22.4	3847.1	2344.0	
2	Phase IVA	June 2006–September 2007 (complete)	English	1.8	0.9	3.9	1351.7	512.0	Upstream of Phase I in Pool B to Wier #1
			Metric	2.9	1.4	6.3	547.0	207.2	
3	Phase IVB	June 2008–December 2009 (complete)	English	3.9	4.3	5.9	4183.5	1406.0	Upstream of Phase IVA in Pool B (upper limit approximately at location of Wier #3)
			Metric	6.3	6.9	9.5	1693.1	569.0	
4	Phase II/III	2015–2019 (projected)	English	8.5	4.0	16.4	9921.3	4688.0	Downstream of Phase I (lower Pool C and Pool D south to the CSX Railroad Bridge)
			Metric	13.7	6.4	26.4	4015.1	1897.2	
Restoration Project Totals			**English**	**21.7**	**12.1**	**40.1**	**24,962.6 (40 square miles)**	**12,398.0 (20 square miles)**	
			Metric	**34.9**	**19.5**	**64.5**	**10,102.0**	**5,017.3**	

The Kissimmee River Restoration Project will culminate with implementation of a new stage regulation schedule, called the Headwaters Revitalization Schedule, to operate the S-65 water control structure. The new schedule will allow lake water levels to rise 1.5 feet higher than the current schedule and will increase the water storage capacity of the Headwaters Revitalization Lakes reservation waterbody by approximately 100,000 acre-feet (12,340 hectare-meters) to provide the volume and timing of flow needed for restoration of the Kissimmee River and floodplain. The Headwaters Revitalization Schedule includes discharge specifications based on the historic stage-discharge relationship to ensure that water is released to the Kissimmee River in a way that reflects rainfall and seasonal availability of water.

Lands surrounding the Headwaters Revitalization Lakes reservation waterbody that will be impacted by the higher water levels have almost all been acquired, and projects to increase the conveyance capacity of canals and structures are in place to accommodate the larger storage volume. The Headwaters Revitalization Schedule is scheduled for implementation in 2019 when Kissimmee River Restoration Project backfilling and other restoration construction is complete. Because of the time lag between completion of the earliest construction phases of the restoration project and the implementation of the Headwaters Revitalization Schedule, the United States Army Corps of Engineers (USACE) authorized the South Florida Water Management District (District or SFWMD) to make releases at the S-65 structure when lake stage was in Zone B of the existing regulation schedule. Releases under this interim regulation schedule are intended to maintain flow in the restored river channel continuously through the year and allow sufficient operational flexibility to provide seasonal floodplain inundation at volumes sufficient for floodplain restoration. Environmental releases under the interim schedule began in July 2001 after Phase I of construction for the Kissimmee River Restoration Project had been completed and lakes levels began to rise following the 2000–2001 drought. While the use of Zone B releases has been beneficial, it does not provide the full benefits of the Headwaters Revitalization Schedule, nor does it enable all hydrologic and floodplain restoration performance measures to be met (Bousquin et al. 2009, Anderson 2014a, Cheek et al. 2015).

In the LKB, the Kissimmee River Restoration Project and Kissimmee River Headwaters Revitalization Project combined are expected to restore ecological integrity to approximately one-third of the length of the original river and floodplain, modifying a contiguous area of floodplain/river ecosystem of over 39 square miles (101 kilometers [km^2]). More than 20 square miles (52 km^2) of new wetlands are expected to reestablish in areas that were drained by the canal, and over 40 miles (64 km) of reconnected river channel will receive reestablished flow. In the UKB, improved conditions are expected in over 7,200 acres of littoral marsh on the periphery of four regulated lakes (USACE 1996). The Kissimmee River Restoration Project (including the Kissimmee River Headwaters Revitalization Project) is funded under a 50/50 cost-share agreement between the District and the USACE. Engineering and construction components of the project are the responsibility of USACE, while the District's purview is land acquisition and ecological evaluation of the restoration project.

Restoration Project Status

Phase I construction for Kissimmee River Restoration Project was completed in February 2001. Approximately 7.5 miles (12 km) of the C-38 canal was backfilled in Pool C and the southern portion of Pool B, nearly 1.3 miles (2.1 km) of river channel was reestablished, and the S-65B structure was demolished. These efforts reestablished flow to 14 miles (23 km) of continuous river channel and have allowed for intermittent inundation of 5,792 acres (2,344 hectares) of floodplain. The second construction phase (Phase IVA) was completed in September 2007. This work extends north into Pool B from the northern terminus of the Phase I project area. Phase IVA reconnected four miles of historic river channel by backfilling two additional miles of the C-38 canal, and is expected to recover 512 acres (207 hectares) of floodplain wetlands. Phase IVB was completed in 2009, backfilled 4 miles of canal, reestablished flow in 6 miles of river channel, and is expected to restore 1,406 acres of floodplain wetlands. The final construction phase, Phase II/III, is currently projected for completion in 2019 (**Table A-1**). It will backfill 8.5 miles of canal, reestablish flow to 16 miles of river channel, and will restore over 4,688 acres of wetlands. While the construction phases were originally named in the order of expected completion, the sequence has changed over the years for logistical reasons (i.e., budgetary considerations, coordination with land acquisition, and ease of access) (**Table A-1**). Land acquisition for the project in the UKB and LKB has been substantially completed.

Kissimmee River Restoration Evaluation Program

A major component of the restoration project is ongoing evaluation of restoration status and success through a comprehensive ecological monitoring program, the Kissimmee River Restoration Evaluation Program (KRREP) (Karr et al. 1992, Williams et al. 2007, Bousquin et al. 2005a, 2005b, Anderson et al. 2005a, 2005b, Koebel and Bousquin 2014). Evaluating the status and success of the Kissimmee River Restoration Project is a requirement of the District's cost-share agreement with the USACE (USACE 1996). Restoration responses are being tracked using 25 performance measures (Anderson et al. 2005a, Bousquin et al. 2005a) to evaluate how well the restoration is meeting the project's ecological integrity goal. The definition of ecological integrity, adapted from Karr and Dudley (1981), is a system "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."

The KRREP performance measures, called expectations, are based on estimated pre-channelized system reference conditions, have undergone an external peer review process, and have formed the basis for numerous publications on restoration response in the Kissimmee River and floodplain. Monitoring and evaluation will continue for at least five years past completion of construction and implementation of the Headwaters Revitalization Schedule, or until monitoring has shown that ecological responses have stabilized. A final evaluation of project success will be based on these data. KRREP monitoring results for the Phase I area have been reported annually in the *South Florida Environmental Report* since 2005 (Williams et al. 2005, 2006, 2007, Bousquin et al. 2008, 2009, Jones et al. 2010, 2011, 2012, 2013, 2014, Cheek et al. 2015).

The Kissimmee Watershed Program of the SFWMD was created in the early 1990s, originally to provide scientific expertise for coordination and ecological evaluation of the Kissimmee River Restoration Project, including both the restoration project and the headwaters lakes improvements included in the Kissimmee River Headwaters Revitalization Project. In recent years, the District has expanded the Kissimmee Program to include more of the Kissimmee watershed, including 19 waterbodies in the KCOL in the UKB, to more explicitly address hydrologic and management linkages between the UKB and LKB. The key strategic priority of the Kissimmee Watershed Program is to integrate management strategies within the Kissimmee watershed with restoration of the Kissimmee River (SFWMD 2006).

Interim Responses to the Kissimmee River Restoration Project

The Phase I area of Kissimmee River Restoration Project, where restoration construction was completed in 2001, has been monitored since prior to Phase I construction. Dramatic ecological responses to Phase I construction have been demonstrated by KRREP monitoring data, notably from studies tracking river channel hydrology, dissolved oxygen concentrations, littoral vegetation, geomorphology, aquatic invertebrates, fish, wading birds, and waterfowl. Some components, notably those dependent on floodplain inundation (especially those related to floodplain hydrology and vegetation response) have shown slower responses (Bousquin et al. 2008, 2009, Jones et al. 2010, 2011, 2012, 2013, 2014, Anderson 2014a, Spencer and Bousquin 2014, Cheek et al. 2015). Although more natural seasonality of flow and sporadic floodplain inundation than in the channelized system have been achieved since completion of Phase I construction, and despite changes in operations under the interim water regulation schedule, it has not been possible to maintain flow to the Phase I reach of the river during periods of extreme drought. Other aspects of the hydrologic expectations have not been met under the interim regulation schedule, and biological components that depend on floodplain inundation in particular have been slow to respond. While, in all water years since Phase I was completed in 2001, it was possible to inundate a portion of the floodplain for some period of time, the durations of floodplain inundation were too short and intermittent, recession rates were too fast, and/or the habitat requirements for long hydroperiod marshes were not achieved. As a result, recovery of taxa that are dependent on access to the floodplain during some portion of their life cycles are being impacted. Improved adaptive management of the S-65 structure's water management operations during the interim period using the existing flexibility in the interim schedule can help improve floodplain responses prior to implementation of the Headwaters Revitalization Schedule, which is projected for implementation 2019, and is expected to provide additional operational flexibility to more closely meet the hydrologic requirements of river and floodplain restoration. Recent evaluations of the responses of hydrology, geomorphology, fish and wildlife, and habitat components of the Kissimmee River ecosystem to Phase I construction are available in nine papers published in a special section of the journal *Restoration Ecology* (Anderson 2014a, 2014b, Bousquin and Colee 2014, Cheek et al. 2014, Colangelo 2014, Jordon and Arrington 2014, Keobel and Bousquin 2014, Koebel et al. 2014, Spencer and Bousquin 2014).

APPENDIX B: KR VEGETATION CLASSIFICATION

MAPCODE DESCRIPTIONS
(ALPHABETICAL BY BCODE GROUP)

Vegetation Classes

Aquatic Vegetation Bcode Group – AQ

Aquatic Vegetation - Floating mat shrublands – AQFS
Vine cover less than 50%, tree cover less than 30%, total shrub cover equal to or greater than 30%. Shrubs dominated by wetland species in aquatic habitats on floating mats. Species include *Ludwigia* spp.,*Salix caroliniana*, *Myrica cerifera*, *Decodon verticulatus*, or any combination of shrub species on floating mats.

Aquatic Vegetation - Floating Mat – AQFM
Vine cover less than 50%, tree cover less than 30%, total shrub cover less than 30%. *Scirpus cubensis* and miscellaneous floating mat dominated by combinations of species, most likely a *Scirpus* substrate although may be barely visible.

Emergent, floating, submergent herbaceous aquatic vegetation – AQES
Vine cover less than 50%, tree cover less than 30%, total shrub cover less than 30%. Miscellaneous emergent marsh species that often occur in the littoral zone in sparse mixtures where dominance is rarely determined. Common species are *Polygonum densiflorum*, *Sagittaria lancifolia*, *Pontederia cordata*, *Panicum hemitomon*, *Leersia hexandra*, *Sacciolepic striata*, *Hydrocotyle* spp., and *Paspalidium* spp.

***Nuphar lutea* – H.NL**

***Eichhornia crassipes* or *Pistia stratiotes* – AQFE**

Miscellaneous free floating aquatics – H.MxFA
Aquatic communities dominated by combinations of free floating non-invasive species and where dominance is not clear between *Salvinia* spp., *Azola* spp., *Lemna* spp., and *Limnobium* spp.

Miscellaneous submergent aquatic vegetation – H.MxSV
Submergent species include but are not limited to *Ceratophyllum* spp., *Hydrilla* spp., Utricularia spp., *Chara* spp**.** and miscellaneous submergent species.

Broadleaf Marsh Bcode Group – BLM

Vine cover less than 50%, tree cover less than 30%, total shrub cover less than 30%. Herbaceous vegetation dominated by broadleaf wetland species. All community types lumped together and original bcode group decision rules apply where greater than 50% vegetation cover must be occupied by *Pontederia cordata* or *Sagittaria lancifolia*, or dominated by *Thalia geniculata* or a species of *Canna* lily.

Miscellaneous Wetlands Bcode Group – MW

These species must be classified at the bcode level because they have little similarity in structure, signature, and location of occurrence. Sawgrass and cordgrass were mapped by Pierce and will be tracked by bcode. Want to avoid using miscellaneous wetlands as a category but see no need to track ferns.

***Cladium jamaicense* – H.CJ**

***Spartina bakeri* – H.SB**

***Typha domengensis* – H.TY**

Miscellaneous fern dominated communities **– H.MxFN**

***Hibiscus grandiflorus* – H.HG**
Without 50% understory of *Pontederia cordata* or *Sagittaria lancifolia*.

Upland Forest Bcode Group – UF
Vine cover less than 50%, tree cover equal to or greater than 30%, and dominated by upland tree species. Rules apply from the original VCS, all bcodes will be utilized.

***Sabal palmetto* – F.SP**
Forests dominated by *Sabal palmetto*

***Quercus virginiana* – F.QS**
Forests dominated by *Quercus virginiana* or *Q. hemisphaerica* or *Q. laurifolia*

***Pinus elliotti* – F.PE**
forests dominated by *Pinus elliottii*

Unclassified combinations of upland tree species – F.MxF

Upland Herbaceous Bcode Group – UP
Vine cover less than 50%, tree cover less than 30%, and total shrub cover less than 30%.

Herbaceous vegetation dominated by upland grasses – UPH
Species include *Axonopus fissifolius, A. fasciculatum, Cynodon dactylon, Paspalum notatum, Imperata cylindrical, Sporobolus indica,* and miscellaneous species of upland grasses.

Herbaceous vegetation dominated by upland species of weedy forbs – H.MxW
Species include *Eupatorium* spp., *Ambrosia* spp., *Cirsium* spp., *Euthamia* spp., and *Senna* spp.

***Hemarthria altissima* – H.HA**

Upland Shrub Bcode Group – US
Vine cover less than 50%, tree cover less than 30%, and total shrub cover equal to or greater than 30%. Shrubs dominated by upland species.

Miscellaneous upland shrub species dominant or co-dominant – S.MxUS
Species include *Psidium guajava*, *Baccharis halimifolia*, *Sambucus* spp., *Rhus copallinum, and Ilex glabra.*

***Schinus terebinthifolius* – S.ST**
Shrub cover dominated by *Schinus terebinthifolius.*

***Myrica cerifera* – S.MC**
***S**hrub cover dominated by *Myrica cerifera*.

***Serenoa repens* – S.SR**
Shrub cover dominated by *Serenoa repens*.

<u>Vines Bcode Group</u> – VN
Vine cover equal to or greater than 50%.

Mixed vine species – V.MxV
Species include but are not limited to *Milothria* spp., *Smilax* spp., *Mikania* spp., *Momordica* spp., *Ampelopsis* spp., *Ipomea* spp., *Vitus* spp., and other species dominant or co-dominant.

***Lygodium microphyllum* – V.LM**

<u>Wetland Forest Bcode Group</u> – WF

Vine cover less than 50%, tree cover equal to or greater than 30%, and dominated by wetland tree species. Most community types lumped together except for *Taxodium distichum*, which will be mapped at the bcode level.

Miscellaneous wetland forest – FWF
Forests dominated or co-dominated by *Fraxinus caroliniana*, *Magnolia virginiana*, *Acer rubrum*, *Nyssa sylvatica* va. *Biflora*, *Persea* spp., or mixtures of these and *Taxodium distichum* where dominance is unclear.

***Taxodium distichum* – F.TDF**
Forests dominated by *Taxodium distichum*.

Mixtures of upland and wetland species – **F.MTF**
Species include but are not limited to *Quercus* spp. with *Acer rubrum*, *Persea* spp., *Fraxinus caroliniana*, *Taxodium distichum*, and/or *Magnolia virginiana*) with no clear dominance.

<u>Wet Prairie Bcode Group</u> – WP
Vine cover less than 50%, tree cover less than 30%, total shrub cover less than 30%. Herbaceous vegetation dominated by wet prairie forbs and grass species. Most community types lumped together and original bcode group decision rules apply except for *Panicum hemitomon* (PH01) and *Rhynchospora* spp. (RN99).

Panicum hemitomon – **H.PH**
Cover equal to or greater than 50% (otherwise WPG).

Urochloa mutica – **H.UM**
Cover equal to or greater than 50 % (otherwise WPG).

***Rhynchospora* spp**. **– H.RN**
Consists of *Rhynchospora* spp., with *R. inundata* typically dominant.

***Panicum repens* – H.PR**
Panicum repens is dominant.

***Polygonum* – POL**
P. punctatum, *P. hirsute*, and *P. hydroperoides* are the dominant species.

Miscellaneous wetland graminoids herbaceous vegetation – **WPG**
Unclassified combinations of large graminoids, such as *Juncus effuses*, *Juncu*s spp., *Cyperus* spp., *Rhynchospora* spp. not listed above, *Fuirena* spp, *Fimbristylis* spp., *Carex* spp., *Eleocharis*

interstincta, *E. cellulosa*, *E. equisetoides*, *Scirpus californicus*, *S. validus*, and *Scirpus* spp. other than *S. cubensis*, *Leersia hexandra*, *Andropogon glomeratus*, *Phragmites australis*, *Paspalidium* spp., *Echinochloa* spp., and others.

Miscellaneous low growing wetland herbaceous vegetation – **WPL**
Unclassified combinations of low growing wetland graminoids or forbs; *Luziola fluitans*, *Eleocharis vivipara*, *E. balwinii*, *E.olivacea*, *E. flavescens*, *Bacopa* spp., *Phyla nodiflora*, *Centella asiatica*, and others.

Miscellaneous wet prairie forbs herbaceous vegetation – **WPF –** Unclassified combinations of larger wet prairie forbs and weedy wetland species, such as *Aster* spp., *Teucrium canadense*, *Bidens* spp., *Pluchea* spp., *Canna flaccida*, *Coreopsis* spp., and others.

Wetland Shrub Bcode Group – WS
Vine cover less than 50%, tree cover less than 30%, and total shrub cover equal to or greater than 30%. Shrubs dominated by wetland species.

***Ludwigia* spp. – S.LS**
Shrub cover dominated by *Ludwigia peruviana*, *L. decurrens* and, *L. leptocarpa*.

***Cephalanthus occidentalis* – BB**
Given a new code because there are several community types (bcodes) with CO01 dominance in the wetland shrub category.

***Hypericum spp. (fasiculatum)* – S.HF**
Shrub cover dominated by *Hypericum fasiculatum* or other *Hypericum* spp. that are woody in nature.

***Salix caroliniana* – S.SC**
Shrub cover dominated by *Salix caroliniana*.

Miscellaneous wetland shrub – **WTS**
Species include *Decodon verticulatus* and *Annona glabra*.

Other Classes

Bare Ground – NVBG
Living vegetation less than 10% cover and area dominated by mud, sand, silt, etc. Same decision rules apply as for original category.

Human-Made Structures and Grounds – NVH
Living vegetation less than 10% and area consists of roads, buildings, structures, including lawns. Same decision rules apply as for original category.

Open Water – NVOW
Living vegetation less than 10% cover in open water. Same decision rules apply as for original category.

Unknown Vegetation – UN
Problematic communities and signatures. Same decision rules apply as for original category.

Summary of MAPCODE Descriptions

Bold type indicates community codes used in vegetation mapping

- AQ – Aquatic Vegetation
  - **AQFS** – Aquatic Floating Mat Shrublands
  - **AQFM** – Aquatic Floating Mat herbaceous vegetation
  - **AQES** – Aquatic littoral emergent vegetation
  - **AQFE** – Aquatic Free Floating Exotics – *Pistia stratiotes* and *Eichhornia crassipes*
  - **H.NL –** *Nuphar lutea* aquatic vegetation
  - **H.MxFA** – Miscellaneous free floating aquatic vegetation
  - **H.MxSV –** miscellaneous submergent vegetation
- BLM – Broadleaf Marsh
  - **BLM** – Broadleaf Marsh
- MW – Miscellaneous Wetlands
  - **H.CJ** – *Cladium jamaicense*
  - **H.SB** – *Spartina bakerii*
  - **H.TY** – *Typha domengensis*
  - **H.MxFN** – fern dominated communities (undecided)
  - **H.HG** – *Hibiscus grandiflorus* if without understory of 50% PS
- UF – Upland Forest
  - **F.SP** – *Sabal palmetto*
  - **F.QS** – *Quercus virginiana* or *Q. hemispaerica*
  - **F. PE** – *Pinus elliotti*
  - **F.MxF** – unclassified upland tree species
- UP – Upland Herbaceous
  - **H.HA –** *Hemarthria altissima*
  - **UPH –** Upland Grasses
  - **H.MxW –** Miscellaneous invasive herbaceous vegetation
- US – Upland Shrub
  - **S.SR** – *Serenoa repens*
  - **S.MC** – *Myrica cerifera*
  - **S.ST** – *Schinus terebinthifolious*
  - **S.MxUS** – Misc. upland shrub species, *Baccharis, Schinus, Ilex, Sambucus, Rhus, Rubus, Psidium guajava*
- VN – Vines
  - **V.LM** – *Lygodium microphyllum*
  - **V. MxV** – mixed vine species
- WF – Wetland Forest
  - **F.TD** – *Taxodium distichum*
  - **F.MTF –** unclassified combination of upland and wetland tree species
  - **FWF** – unclassified wetland tree species
- WP – Wet Prairie
  - **H.PH** – *Panicum hemitomon*
  - **H.RN** – *Rynchospora* spp.
  - **H.PR –** *Panicum repens*
  - **POL –** *Polygonum* species other than *P. densiflorum*
  - **H.IV** – *Iris virginica* herbaceous vegetation
  - **H.UM** – Urochloa mutica (Para grass)
  - **WPG** – Miscellaneous wetland graminoids herbaceous vegetation
  - **WPL** – Miscellaneous low-growing wetland herbaceous vegetation
  - **WPF** – Miscellaneous wet prairie forbs herbaceous vegetation
- WS – Wetland Shrub
  - **S.HF** – *Hypericum fasciculatum*
  - **S.SC** – *Salix caroliniana*
  - **BB** – *Cephalanthus occidentalis* (Buttonbush)

S.LS – *Ludwigia* spp.
WTS – Misc. wetland shrub species, including *Decodon leptocarpa*, *Annona glabra*, etc.

Other Classes

NVBG – Non- vegetated bare ground
NVH – Human-made structures and grounds
NVOW – Open Water
UN – Unclassified and Unknown

APPENDIX C: FISH DATA AND GUILD STRUCTURE

Fish dependence on specific habitat types or environmental conditions, including hydrology, can be identified through the use of guilds (Austen et al. 1994). For ecological application, guilds have been defined as “a group of species that exploit the same class of environmental resources in a similar way” (Root 1967). Two recent guild classifications have been developed that illustrate the significance that availability of appropriate floodplain conditions plays in structuring and sustaining fish assemblages in river/floodplain ecosystems (Glenn 2005, Welcomme et al. 2006).

New guild categories based on fish dependence on off-channel habitats were constructed based on habitat required for reproduction according to Balon (1975), general habitat use listed by Lee et al. (1980), Etenier and Starnes (1993), and Mettee et al. (1996), and from results of a literature review conducted to identify off-channel habitat use by Kissimmee River fishes and their life-history stage(s). All terms follow Bain (1992), with the addition of “off-channel” meaning of, or related to, any habitat not included in the open water portion of the river channel. These areas include littoral vegetation and any floodplain habitat.

The following categories and definitions augment the macrohabitat guild structure developed by Bain (1992) to include five main classes, with four subcategories in two classes (**Figure C-1**). The new category termed off-channel includes species that are found in a variety of habitats, but require access or use of off-channel habitats, or are limited to nonflowing, vegetated waters at some point in their life cycle. These species may have significant riverine populations during particular life history stages. The off-channel specialist category refers to species that are found almost always only in off-channel habitats or species that are limited to non-flowing, vegetated habitats throughout life. Occasionally, individuals may be found in the river channel, but the vast majority of information on these fishes pertains to off-channel habitat.

This classification includes an Off-channel Specialist and an Off-channel Dependent. Off-channel Specialists are almost always found in off-channel habitats or are limited to non-flowing vegetated waters throughout life. the Off-channel Dependent group contains species that are found in a variety of habitats but require access to or use of off channel habitats or are limited to non-flowing, vegetated waters for some portion of the life cycle. Off-channel dependent species may have significant riverine populations for some portion of the life cycle. The Off-channel Dependents can be Reproductive (R), Larval (L), Juvenile (J), or Adult (A).

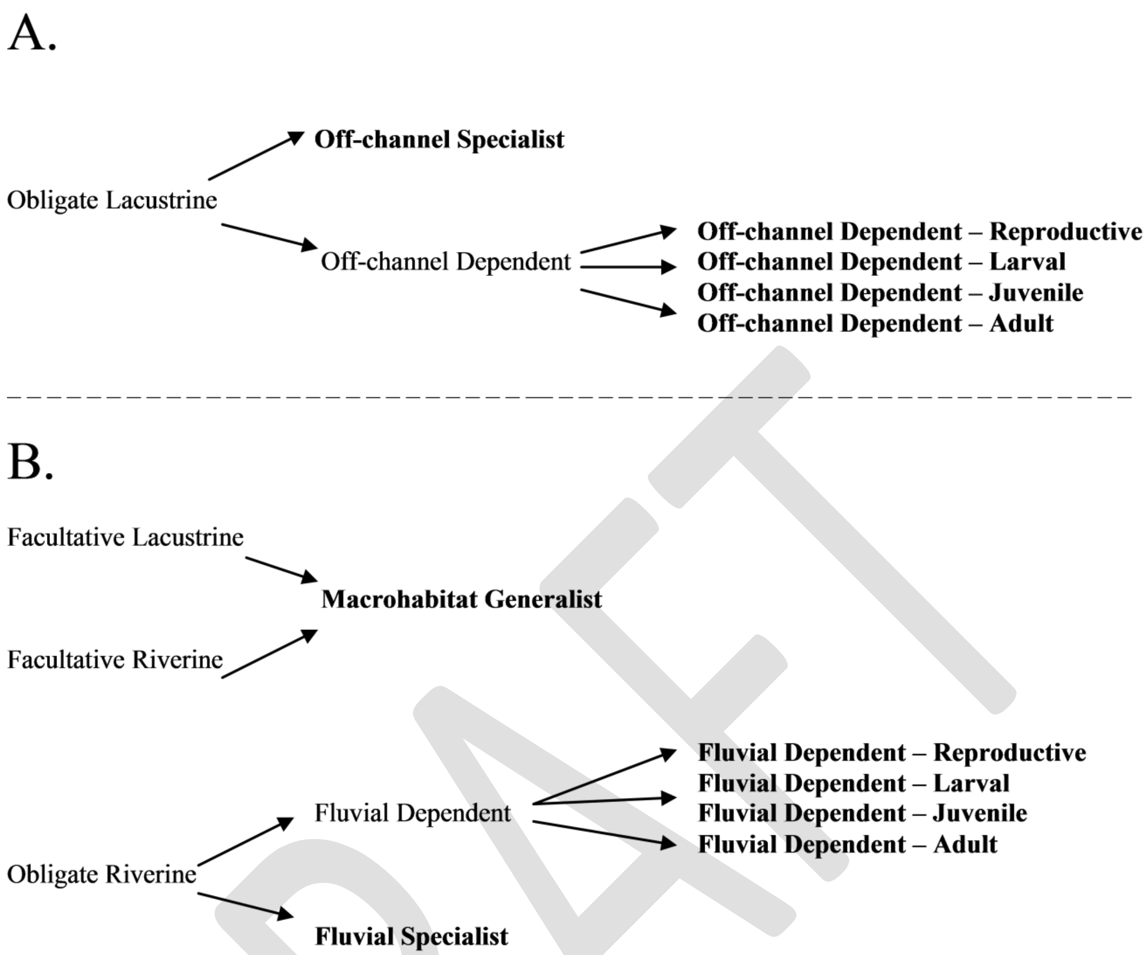

Figure C-1. Schematic representation of modified macrohabitat guild structure. Derived by Bain (1992). (A) New guild categories based on dependence of associated taxa on off-channel habitat. The new category termed Off-channel Dependent includes species that are found in a variety of habitats, but require access or use of off-channel habitats, or are limited to nonflowing, vegetated waters at some point in their life cycle. These species may have significant riverine populations during particular life history stages. The Off-channel Specialist category refers to species that are almost always found only in off-channel habitats or species that are limited to non-flowing, vegetated habitats throughout life. Occasionally, individuals may be found in the river channel, but the vast majority of information on these fishes pertains to off-channel habitat. (B) Original macrohabitat guild classification developed by Bain (1992).

APPENDIX D: BIRDS OF THE KISSIMMEE RIVER FLOODPLAIN INCLUDING SEASONALITY AND PROTECTIVE STATUS

The status key for **Table D-1** is as follows: R = breeding resident, S = uncommon straggler (non-breeding), M = transient migrant (non-breeding), V = seasonal visitor (non-breeding), SSC = species of special concern (state), e = endangered (state), t = threatened (state), T = threatened (federal), and E = endangered (federal).

Table D-1. Birds of the Kissimmee River floodplain including seasonality and protective status.

Common Name	Scientific Name	Seasonality	State Listing Status	Federal Listing Status
American bittern	*Botaurus lentiginosus*	V		
American coot	*Fulica americana*	R		
American crow	*Corvus brachyrhynchos*	R		
American kestrel (SE)	*Falco sparverius paulus*	R, V	t	
American redstart	*Setophaga ruticilla*	M		
American robin	*Turdus migratorius*	V		
American swallow-tailed kite	*Elanoides forficatus*	R		
American white pelican	*Pelecanus erythrorhynchos*	V		
American wigeon	*Anas americana*	V		
American woodcock	*Scolopax minor*	V		
Anhinga	*Anhinga anhinga*	R		
Bald eagle	*Haliaeetus leucocephalus*	R	t	
Baltimore oriole	*Icterus galbula*	V		
Barn owl	*Tyto alba*	R		
Barn swallow	*Hirundo rustica*	M		
Barred owl	*Strix varia*	R		
Belted kingfisher	*Megaceryle alcyon*	V		
Black skimmer	*Rynchops niger*	S	SSC	
Black tern	*Chlidonias niger*	M		
Black vulture	*Coragyps atratus*	R		
Black-bellied whistling duck	*Dendrocygna autumnalis*	R		
Black-crowned night-heron	*Nycticorax nycticorax*	R		
Black-necked stilt	*Himantopus mexicanus*	R		
Blue-gray gnatcatcher	*Polioptila caerulea*	R		
Bluejay	*Cyanocitta cristata*	R		
Blue-winged teal	*Anas discors*	V		

Table D-1. Continued.

Common Name	Scientific Name	Seasonality	State Listing Status	Federal Listing Status
Blue-winged warbler	*Vermivora pinus*	M		
Boat-tailed grackle	*Quiscalus major*	R		
Bobolink	*Dolichonyx oryzivorus*	M		
Bonapart's gull	*Chroicocephalus philadelphia*	S		
Brewer's blackbird	*Euphagus cyanocephalus*	S		
Brown pelican	*Pelecanus occidentalis*	S	SSC	
Brown thrasher	*Toxostoma rufum*	R		
Brown-headed cowbird	*Molothrus ater*	R		
Carolina wren	*Thryothorus ludovicianus*	R		
Caspian tern	*Hydroprogne caspia*	S		
Cattle egret	*Bubulcus ibis*	R		
Chimney swift	*Chaetura pelagica*	R		
Chuck-will's-widow	*Caprimulgus carolinensis*	R		
Common grackle	*Quiscalus quiscula*	R		
Common ground-dove	*Columbina passerina*	R		
Common moorhen	*Gallinula chloropus*	R		
Common nighthawk	*Chordeiles minor*	R		
Common yellowthroat	*Geothlypis trichas*	R		
Cooper's hawk	*Accipiter cooperii*	R		
Crested caracara	*Caracara cheriway*	R	t	T
Double-crested cormorant	*Phalacrocorax auritus*	R		
Downy woodpecker	*Picoides pubescens*	R		
Eastern bluebird	*Sialia sialis*	R		
Eastern kingbird	*Tyrannus tyrannus*	R		
Eastern meadowlark	*Sturnella magna*	R		
Eastern phoebe	*Sayornis phoebe*	V		
Eastern screech-owl	*Megascops asio*	R		
Eastern towhee	*Pipilo erythrophthalmus*	R		
Eastern wood-peewee	*Contopus virens*	M		
Fish crow	*Corvus ossifragus*	R		
Florida burrowing owl	*Athene cunicularia floridana*	R	SSC	
Florida grasshopper sparrow	*Ammodramus savannarum floridanus*	R	e	
Florida sandhill crane	*Grus canadensis pratensis*	R	t	
Forster's tern	*Sterna forsteri*	V		
Fulvous whistling-duck	*Dendrocygna bicolor*	R		

Table D-1. Continued.

Common Name	Scientific Name	Seasonality	State Listing Status	Federal Listing Status
Glossy ibis	*Plegadis falcinellus*	R		
Golden-crowned kinglet	*Regulus satrapa*	S		
Gray catbird	*Dumetella carolinensis*	R		
Great blue heron	*Ardea herodias*	R		
Great egret	*Ardea alba*	R		
Great-crested flycatcher	*Myiarchus crinitus*	R		
Greater yellowlegs	*Tringa melanoleuca*	V		
Great-horned owl	*Bubo virginianus*	R		
Green heron	*Butorides virescens*	R		
Green-winged teal	*Anas crecca*	V		
Gull-billed tern	*Gelochelidon nilotica*	S		
Hermit thrush	*Catharus guttatus*	V		
Herring gull	*Larus argentatus*	V		
Hooded merganser	*Lophodytes cucullatus*	V		
House wren	*Troglodytes aedon*	V		
Killdeer	*Charadrius vociferus*	R		
King rail	*Rallus elegans*	R		
Least bittern	*Ixobrychus exilis*	R		
Least sandpiper	*Calidris minutilla*	V		
Least tern	*Sternula antillarum*	S	t	
Lesser scaup	*Aythya affinis*	V		
Lesser yellowlegs	*Tringa flavipes*	V		
Limpkin	*Aramus guarauna*	R	SSC	
Lincoln's sparrow	*Melospiza lincolnii*	S		
Little blue heron	*Egretta caerulea*	R	SSC	
Loggerhead shrike	*Lanius ludovicianus*	R		
Long-billed dowitcher	*Limnodromus scolopaceus*	V		
Mallard	*Anas platyrhynchos*	R		
Marsh wren	*Cistothorus palustris*	V		
Merlin	*Falco columbarius*	V		
Mottled duck	*Anas fulvigula*	R		
Mourning dove	*Zenaida macroura*	R		
Northern bobwhite	*Colinus virginianus*	R		
Northern cardinal	*Cardinalis cardinalis*	R		
Northern flicker	*Colaptes auratus*	R		
Northern harrier	*Circus cyaneus*	V		
Northern mockingbird	*Mimus polyglottos*	R		

Table D-1. Continued.

Common Name	Scientific Name	Seasonality	State Listing Status	Federal Listing Status
Northern parula	*Parula americana*	R		
Northern pintail	*Anas acuta*	V		
Northern rough-winged swallow	*Stelgidopteryx serripennis*	R		
Northern shoveler	*Anas clypeata*	V		
Northern waterthrush	*Seiurus noveboracensis*	M		
Osprey	*Pandion haliaetus*	R		
Ovenbird	*Seiurus aurocapilla*	V		
Painted bunting	*Passerina ciris*	V		
Palm warbler	*Dendroica palmarum*	V		
Peregrine falcon	*Falco peregrinus*	V	e	
Pied-billed grebe	*Podilymbus podiceps*	R		
Pileated woodpecker	*Dryocopus pileatus*	R		
Pine warbler	*Dendroica pinus*	R		
Prairie warbler	*Dendroica discolor*	V		
Purple gallinule	*Porphyrio martinica*	R		
Purple martin	*Progne subis*	R		
Red-bellied woodpecker	*Melanerpes carolinus*	R		
Red-headed woodpecker	*Melanerpes erythrocephalus*	R		
Red-shouldered hawk	*Buteo lineatus*	R		
Red-tailed hawk	*Buteo jamaicensis*	R		
Red-winged blackbird	*Agelaius phoeniceus*	R		
Ring-necked duck	*Aythya collaris*	V		
Roseate spoonbill	*Platalea ajaja*	R	SSC	
Ruby-crowned kinglet	*Regulus calendula*	V		
Ruby-throated hummingbird	*Archilochus colubris*	R		
Ruddy duck	*Oxyura jamaicensis*	V		
Savannah sparrow	*Passerculus sandwichensis*	V		
Sedge wren	*Cistothorus platensis*	V		
Sharp-shinned hawk	*Accipiter striatus*	V		
Short-billed dowitcher	*Limnodromus griseus*	V		
Short-tailed hawk	*Buteo brachyurus*	R		
Snail kite	*Rostrhamus sociabilis*	R	e	E
Snowy egret	*Egretta thula*	R	SSC	
Solitary sandpiper	*Tringa solitaria*	M		
Song sparrow	*Melospiza melodia*	V		

Table D-1. Continued.

Common Name	Scientific Name	Seasonality	State Listing Status	Federal Listing Status
Sora	*Porzana carolina*	V		
Spotted sandpiper	*Actitis macularius*	V		
Summer tanager	*Piranga rubra*	R		
Swamp sparrow	*Melospiza georgiana*	V		
Tree swallow	*Tachycineta bicolor*	V		
Tricolored heron	*Egretta tricolor*	R	SSC	
Turkey vulture	*Cathartes aura*	R		
Vesper sparrow	*Pooecetes gramineus*	V		
Whip-poor-will	*Caprimulgus vociferus*	V		
White ibis	*Eudocimus albus*	R	SSC	
White-eyed vireo	*Vireo griseus*	R		
White-tailed kite	*Elanus leucurus*	S		
White-throated sparrow	*Zonotrichia albicollis*	V		
White-winged dove	*Zenaida asiatica*	R		
Wild turkey	*Meleagris gallopavo*	R		
Wilson's snipe	*Gallinago delicata*	V		
Wood duck	*Aix sponsa*	R		
Wood stork	*Mycteria americana*	R	e	E
Yellow warbler	*Dendroica petechia*	M		
Yellow-bellied sapsucker	*Sphyrapicus varius*	V		
Yellow-billed cuckoo	*Coccyzus americanus*	R		
Yellow-breasted chat	*Icteria virens*	M		
Yellow-crowned night heron	*Nyctanassa violacea*	R		
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	S		
Yellow-rumped warbler	*Dendroica coronata*	V		
Yellow-throated warbler	*Dendroica dominica*	R		

Appendix D: Birds of the Kissimmee River Floodplain Including Seasonality and Protective Status

APPENDIX E: MAMMALS OF THE KISSIMMEE RIVER FLOODPLAIN INCLUDING PROTECTIVE STATUS

The status key for Table E-1 is as follows: SSC = species of special concern (state), E = endangered (state), T = Threatened (state), T = threatened (federal), and E = endangered (federal).

Table E-1. Mammals of the Kissimmee River floodplain including protective status.

Common name	Scientific Name	State Listing Status	Federal Listing Status
Armadillo	*Dasypus novemcinctus*		
Bobcat	*Lynx rufus*		
Brazilian freetailed bat	*Tadarida b. cynocephala*		
Coyote	*Canis latrans*		
Eastern cottontail	*Sylvilagus floridanus*		
Eastern gray squirrel	*Sciurus carolinensis*		
Eastern mole	*Scalopus aquaticus*		
Eastern pipistrel bat	*Pipistrellus subflavus*		
Eastern woodrat	*Neotoma floridana*		
Evening bat	*Nycticeius humeralis*		
Feral hog	*Sus scrofa*		
Florida black bear	*Ursus americanus floridanus*	t	
Florida bonneted bat	*Eumops floridanus*	e	
Florida panther	*Puma concolor coryi*	e	E
Gray fox	*Uroncyon cinereoargenteus*		
Marsh rabbit	*Sylvilagus palustris*		
Marsh rice rat	*Oryzomys palustris*		
Northern yellow bat	*Lasiurus i. floridanus*		
Opossum	*Didelphis marsupialis*		
Raccoon	*Procyon lotor*		
River otter	*Lontra Canadensis*		
Round-tailed muskrat	*Neofiber alleni*		
Seminole bat	*Lasiurus seminolus*		
Sherman's fox squirrel	*Sciurus niger shermani*	SSC	
Striped skunk	*Mephitis mephitis*		
Whitetail deer	*Odocoileus virginianus*		

Appendix E: Mammals of the Kissimmee River Floodplain Including Protective Status

APPENDIX F: COMPARISON OF PRE-CHANNELIZATION AND BASE CONDITION RAINFALL

Introduction

There is a 4-inch difference between average rainfall from the pre-channelization period (1933–1964) and rainfall from the post-channelization period (1965–2005). This second period is also called with project base. The following table shows the average annual discharge and average rainfall for the different periods of interest. The goal for this analysis is to show whether this difference of 4 inches is statistically significant.

This memo will present the results of the analysis of the existence of statistically significant differences between the rainfall data for the following time periods (**Table F-1**):

- Pre-channelization (1933–1964) and post-channelization (1965–2005) periods.
- Pre-channelization (1933–1964) and the entire period of analysis (1933–2005).
- Post-channelization (1965–2005) and the entire period of analysis (1933–2005).

Table F-1. Discharge in cubic feet per second (cfs) and 1,000 acre-feet (kac-ft) and rainfall data for different timeframes.

Timeframe	Years	Average Annual Discharge		Average Rainfall (inches)
		cfs	kac-ft	
Entire Period of Analysis	1933–2005	1,070	775	51
Pre-channelization	1933–1964	1,185	860	53
With Project Base	1965–2005	980	710	49
Target Time Series*	1965–2005	1,076	780	

Analysis will be performed with both monthly and annual data.

Source of Rainfall Data

Monthly rainfall data (S65flowUKRrain2.xls, worksheet "UKR_MonthlyRainfall") was provided by Cal Neidrauer, South Florida Water Management District (SFWMD). According to the information provided, this data is a spatial average of the grid_io binary file that was developed by Alaa Ali, SFWMD. The data in this 2 mile x 2 mile grid for the 1965–2005 period was used for the OKISS Model, which was the initial screening tool for the Kissimmee Basin Modeling and Operations Study (KBMOS). All values are given in inches of rainfall.

To conduct the analysis for the monthly data, rainfall was separated into three sets. They were identified as follows:

- RAIN1: period from 1933–1964
- RAIN2: period from 1965–2005
- RAIN3: period from 1933–2005

On the other hand, for the analysis of annual data or cumulative rainfall per year, data was also separated into three sets:

- RAIN1A: period from 1933–1964
- RAIN2A: period from 1965–2005
- RAIN3A: period from 1933–2005

Descriptive Analysis for Monthly Data

To understand the behavior of the rainfall data, descriptive statistic as mean, standard deviation, maximum, minimum, etc. were calculated. Descriptive plots as histogram and scatterplot were also generated to visually describe the data. An additional plot to check for normality is included in each case.

Descriptive Analysis for RAIN1

Descriptive statistics for RAIN1 are presented in **Table F-2**. **Figures F-1** through **F-3** present a histogram, a normality check, and ascatterplot, respectively, for RAIN1.

Table F-2. Descriptive statistics for RAIN1.

Size	Missing	Mean	Standard Deviation	Standard Error	Confidence Interval of Mean	Range	Maximum	Minimum	Median	25%	75%
383	0	4.389	3.439	0.176	0.346	21.090	21.160	0.0700	3.620	1.630	6.490

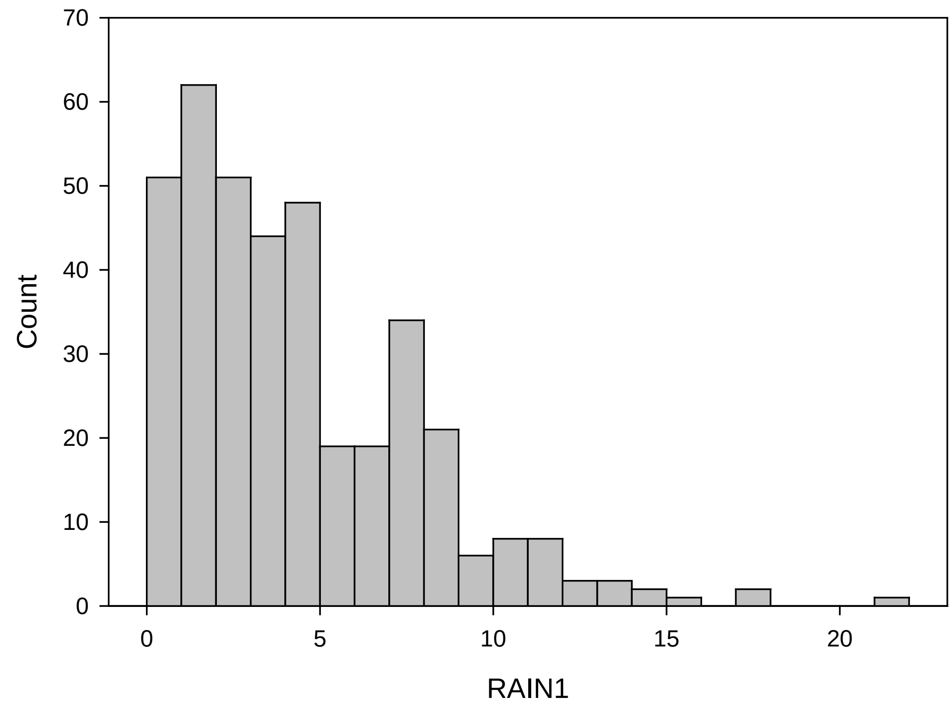

Figure F-1. Histogram for RAIN1.

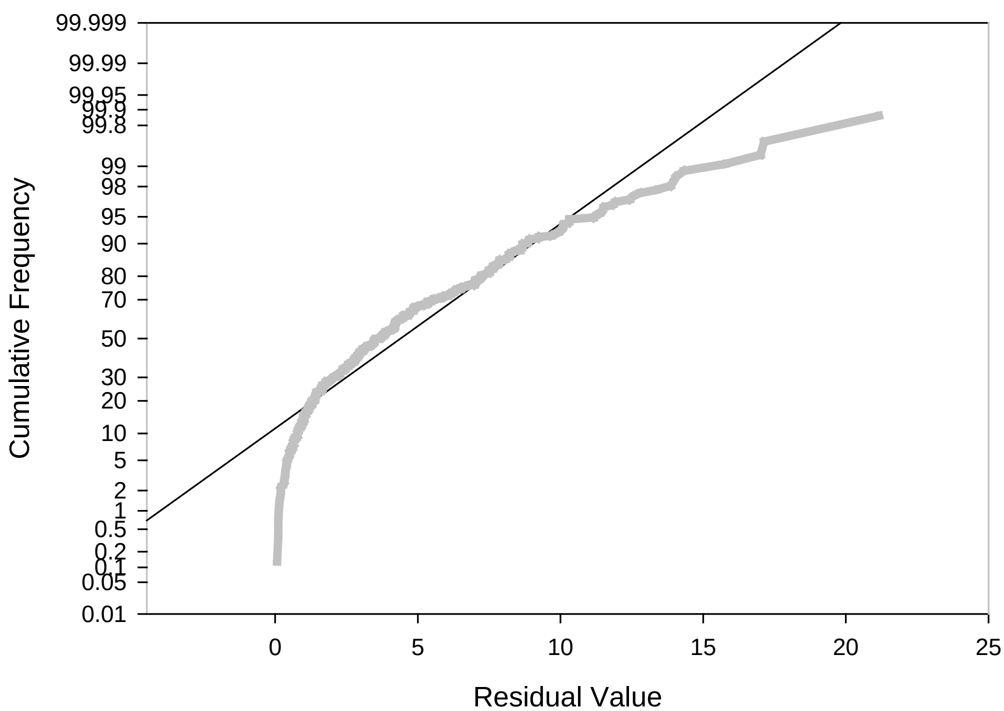

Figure F-2. Normality check for RAIN1.

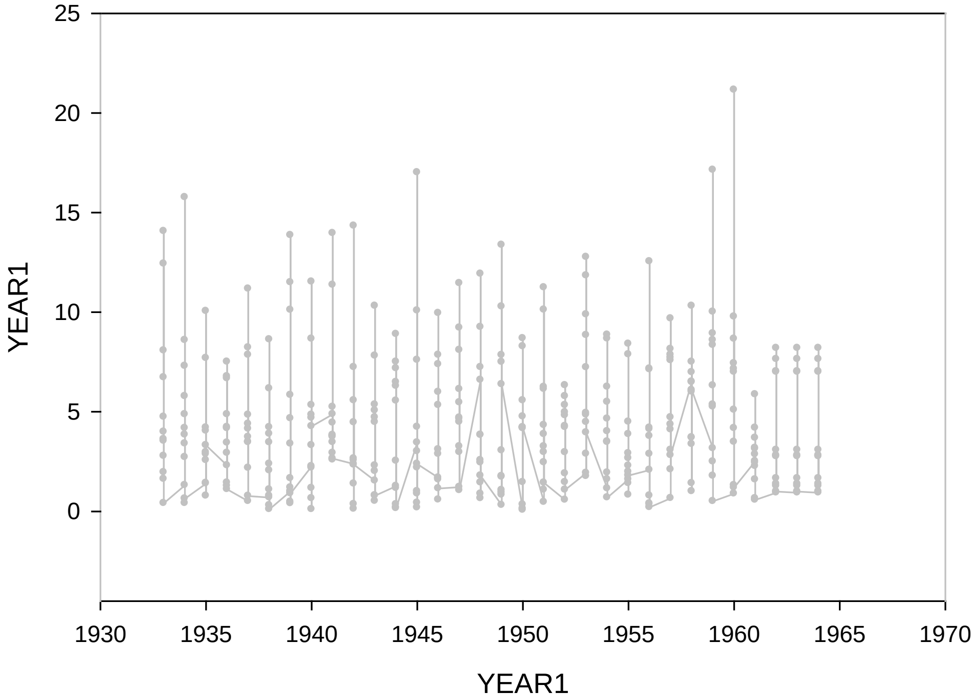

Figure F-3. Scatterplot for RAIN 1.

Descriptive Analysis for RAIN2

Descriptive statistics for RAIN2 are presented in **Table F-3**. **Figures F-4** through **F-6** present a histogram, a normality check, and a scatterplot, respectively, for RAIN2.

Table F-3. Descriptive statistics for RAIN2.

Size	Missing	Mean	Standard Deviation	Standard Error	Confidence Interval of Mean	Range	Maximum	Minimum	Median	25%	75%
492	0	4.102	3.033	0.137	0.269	17.290	17.300	0.01000	3.405	1.645	5.980

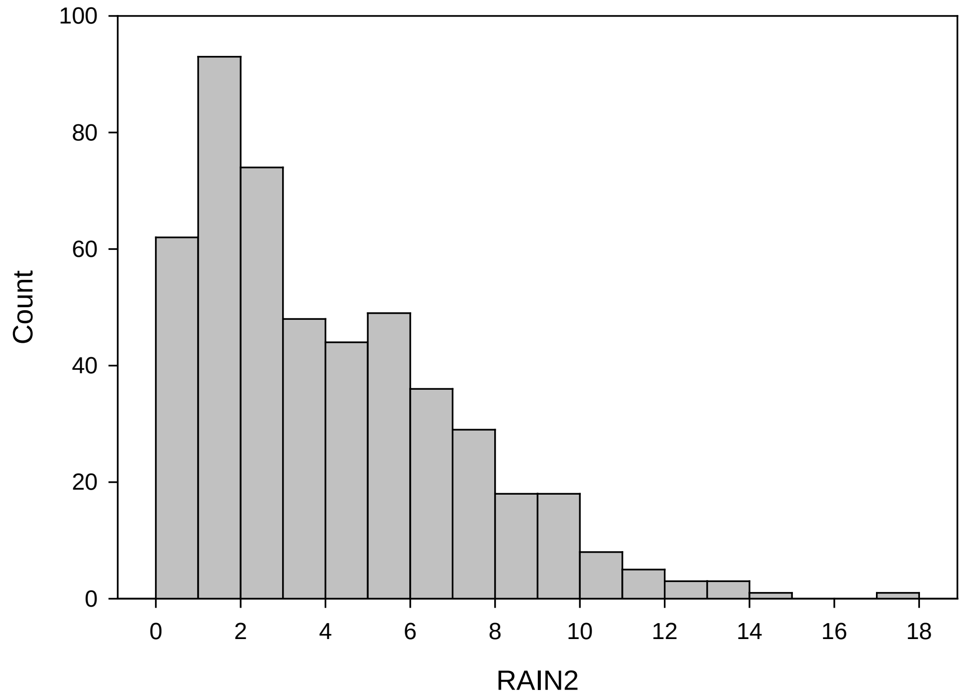

Figure F-4. Histogram for RAIN2.

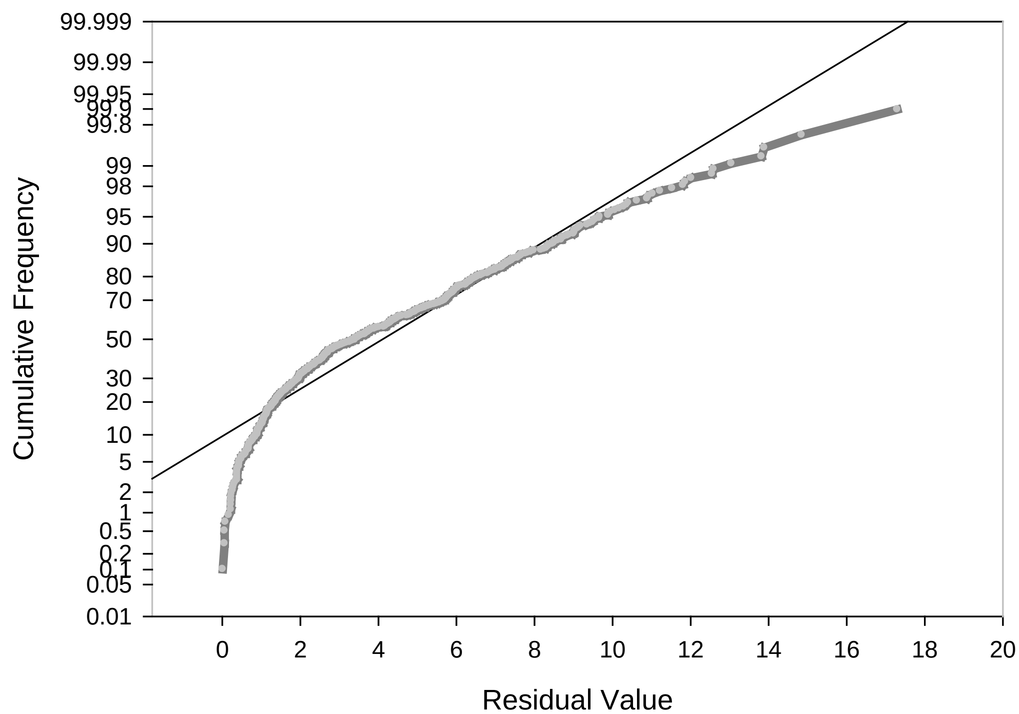

Figure F-5. Normality check for RAIN2.

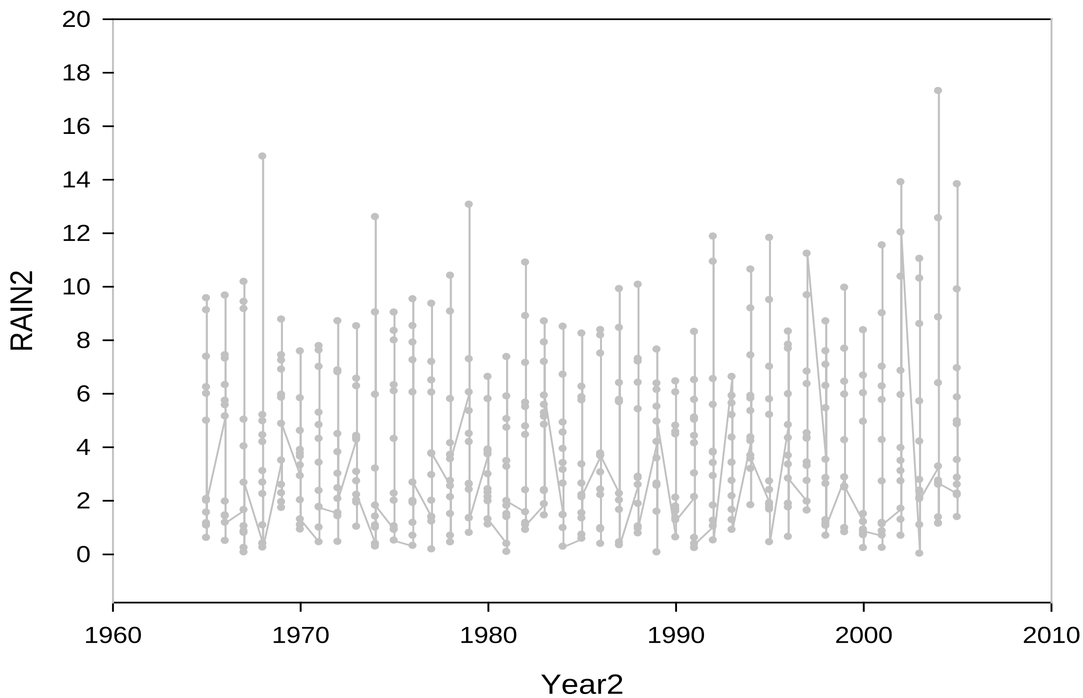

Figure F-6. Scatterplot for RAIN2.

Descriptive Analysis for RAIN3

Descriptive statistics for RAIN3 are presented in **Table F-4**. **Figures F-7** through **F-9** present a histogram, a normality check, and a scatterplot, respectively, for RAIN3.

Table F-4. Descriptive statistics for RAIN3.

Size	Missing	Mean	Standard Deviation	Standard Error	Confidence Interval of Mean	Range	Maximum	Minimum	Median	25%	75%
1092	0	4.183	3.150	0.0953	0.187	21.150	21.160	0.01000	3.490	1.610	6.155

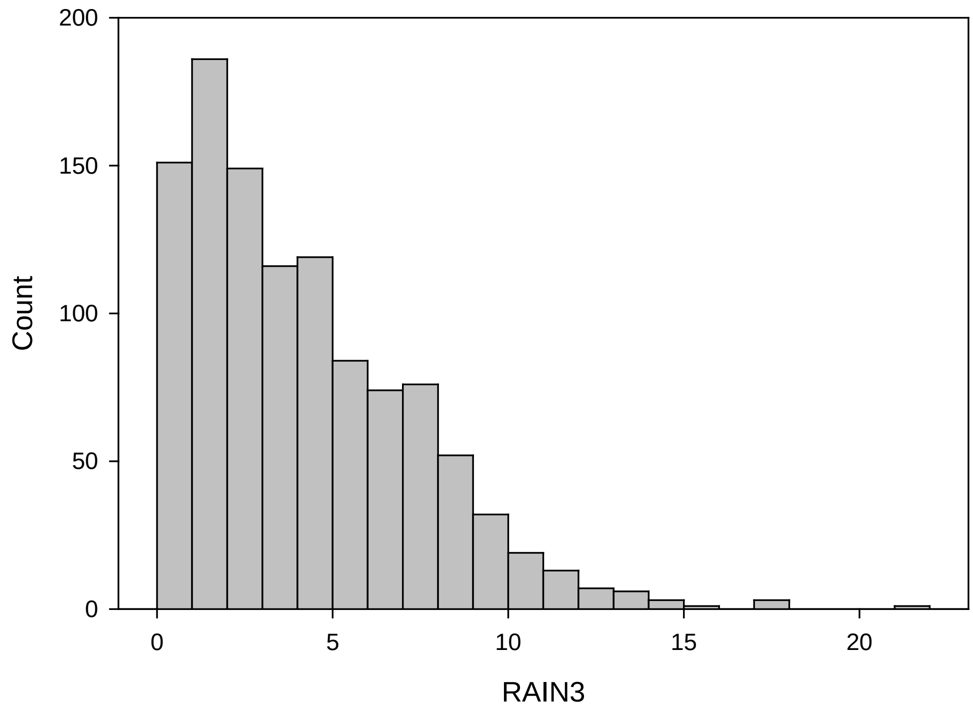

Figure F-7. Histogram for RAIN3.

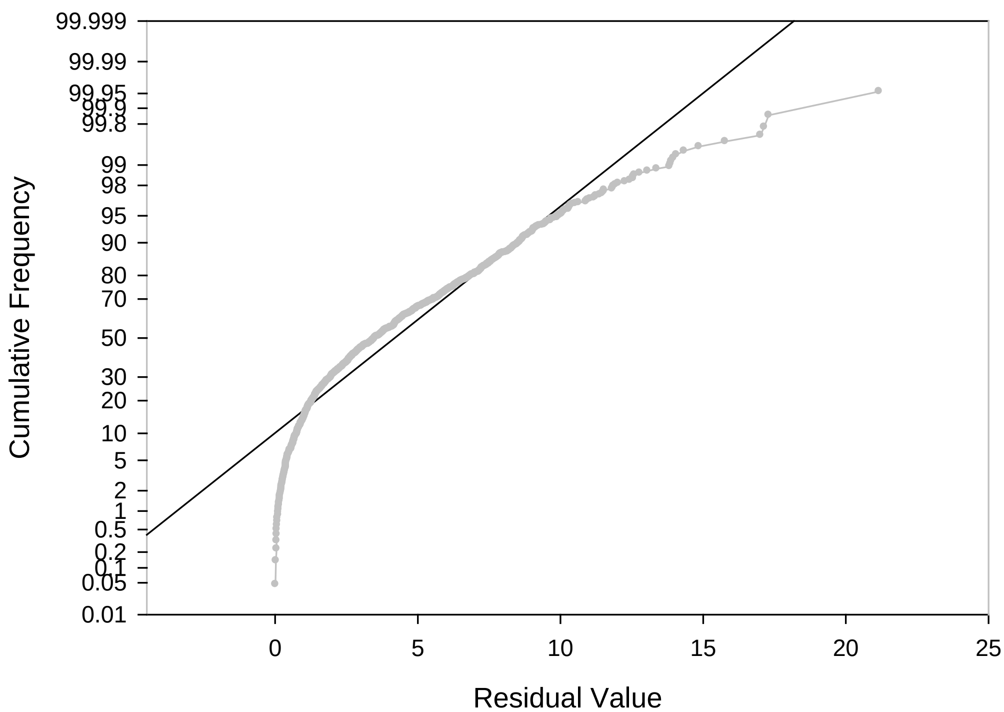

Figure F-8. Normality Check for RAIN3.

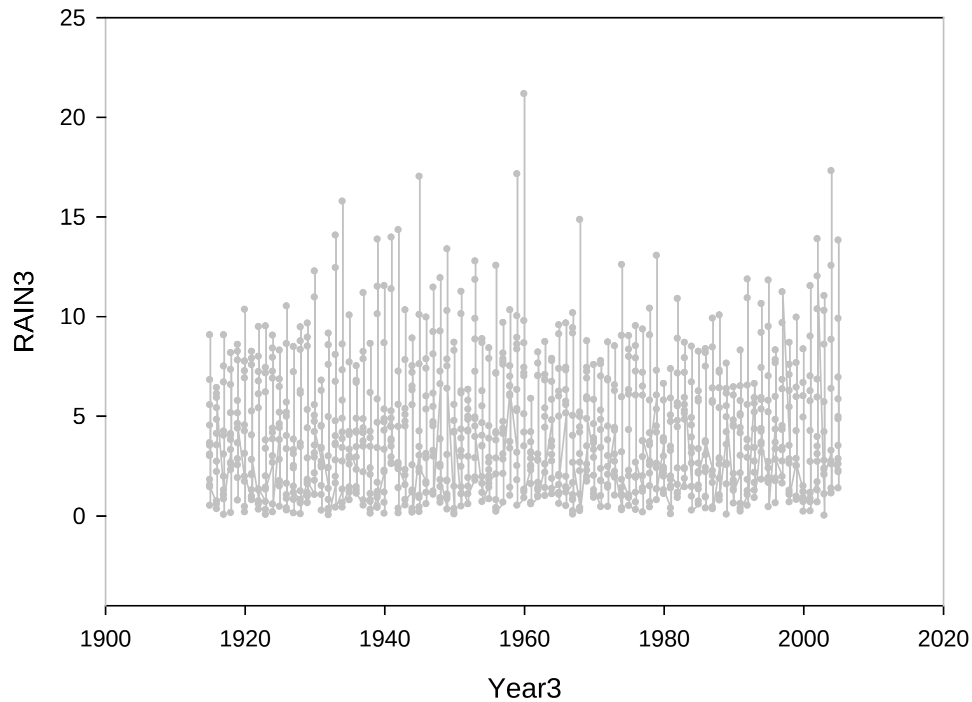

Figure F-9. Scatterplot for RAIN3.

Mean Comparison Analysis for Monthly Data

Choosing the appropriate test is a matter of determining which assumptions are been met by the data. First approach was to conduct a t-test.

The t-test assesses whether the means of two groups are statistically different from each other. This analysis is appropriate whenever you want to compare the means of two groups. The assumption of normal distribution of the populations being compared was always checked. Where the t-test assumptions were not met then a Mann-Whitney Rank Sum Test was used.

The Wilcoxon Rank-Sum (Mann-Whitney) Test is used in place of a two-sample t-test when the populations being compared are not normal.

Mean Comparison between RAIN1 and RAIN2

1. **t-test**

   Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)
   Test execution ended by user request, Mann-Whitney Rank Sum Test begun.

2. **Mann-Whitney Rank Sum Test**

Table F-5 shows the results for the Mann-Whitney Rank Sum Test.

Table F-5. Mann-Whitney Rank Sum Test results for the comparision between RAIN1 and RAIN2.

Group	Sample Size	Missing	Median	25%	75%
RAIN1	383	0	3.620	1.620	6.490
RAIN2	492	0	3.405	1.642	5.985
Mann-Whitney U Statistic = 91349.500					
T = 170622.500; n(small) = 383; n(big) = 492 (P = 0.439)					

3. **Conclusions**

The test statistic T = 170622.5 has a p-value of 0.439. Since the p-value is not less that the chosen alfa level of 0.05, the conclusion is that there is insufficient evidence to reject the hypothesis. Therefore, the data does not support the hypothesis that there is a difference between the population medians. In other words, the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability. There is not a statistically significant difference.

Mean Comparison between RAIN1 and RAIN3

1. **t-test**

Normality Test (Shapiro-Wilk)   Failed (P < 0.050)

2. **Mann-Whitney Rank Sum Test**

Table F-6 shows the results for the Mann-Whitney Rank Sum Test.

Table F-6. Mann-Whitney Rank Sum Test results for the comparision between RAIN1 and RAIN3.

Group	Sample Size	Missing	Median	25%	75%
RAIN1	383	0	3.620	1.620	6.490
RAIN3	1092	0	3.490	1.610	6.162
Mann-Whitney U Statistic = 204658.500					
T = 287113.500; n(small) = 383; n(big) = 1092 (P = 0.534)					

3. **Conclusions**

The test statistic T = 287113.500 has a p-value of 0.534. Since the p-value is not less that the chosen alfa level of 0.05, the conclusion is that there is insufficient evidence to reject the hypothesis. Therefore, the data does not support the hypothesis that there is a difference between the population medians. In other words, the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability. There is not a statistically significant difference.

Mean Comparison between RAIN2 and RAIN3

1. **t-test**

   Normality Test (Shapiro-Wilk) Failed (P < 0.050)

2. **Mann-Whitney Rank Sum Test**

   Table F-7 shows the results for the Mann-Whitney Rank Sum Test.

Table F-7. Mann-Whitney Rank Sum Test results for the comparision between RAIN2 and RAIN3.

Group N	Sample Size	Missing	Median	25%	75%
RAIN2	492	0	3.405	1.642	5.985
RAIN3	1092	0	3.490	1.610	6.162
Mann-Whitney U Statistic = 266333.000					
T = 387611.000; n(small) = 492; n(big) = 1092 (P = 0.785)					

3. **Conclusions**

   The test statistic T = 387611.000 has a p-value of 0.785. Since the p-value is not less that the chosen alfa level of 0.05, the conclusion is that there is insufficient evidence to reject the hypothesis. Therefore, the data does not support the hypothesis that there is a difference between the population medians. In other words, the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability. There is not a statistically significant difference.

Descriptive Analysis for Annual Data

Descriptive Statistics for RAIN1A

Descriptive statistics for RAIN1A are presented in **Table F-8**. **Figures F-10** through **F-12** present a histogram, a normality check, and a scatterplot, respectively, for RAIN1A.

Table F-8. Descriptive statistics for RAIN1A.

Size	Missing	Mean	Standard Deviation	Standard Error	Confidence Interval of Mean	Range	Maximum	Minimum	Median	25%	75%
32	0	53.018	11.060	1.955	3.988	44.390	77.930	33.000	51.395	45.735	60.770

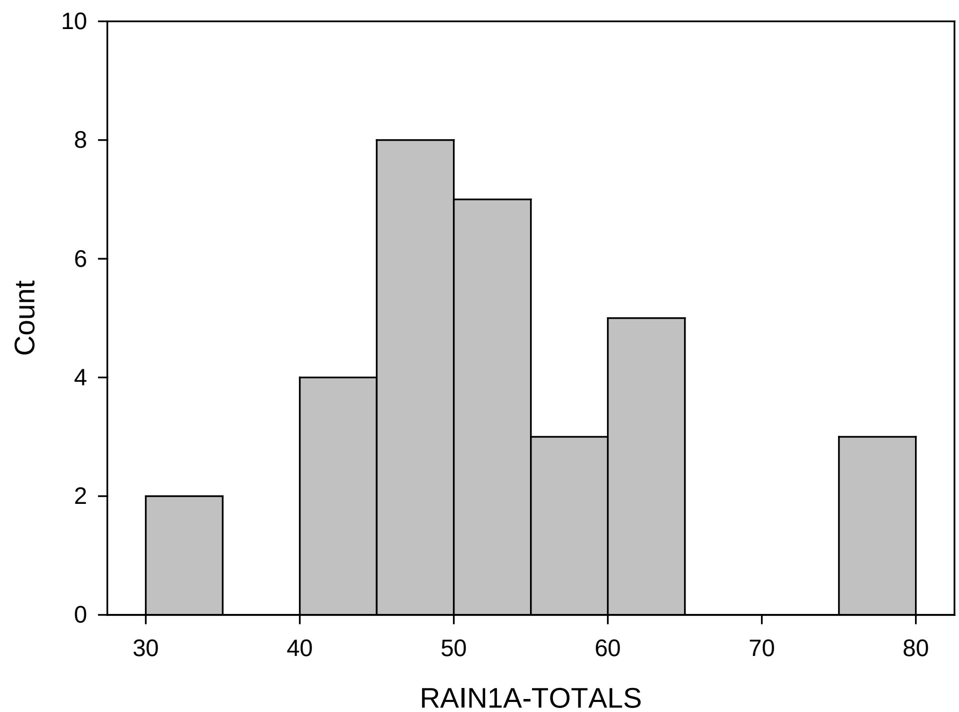

Figure F-10. Histogram for RAIN1A.

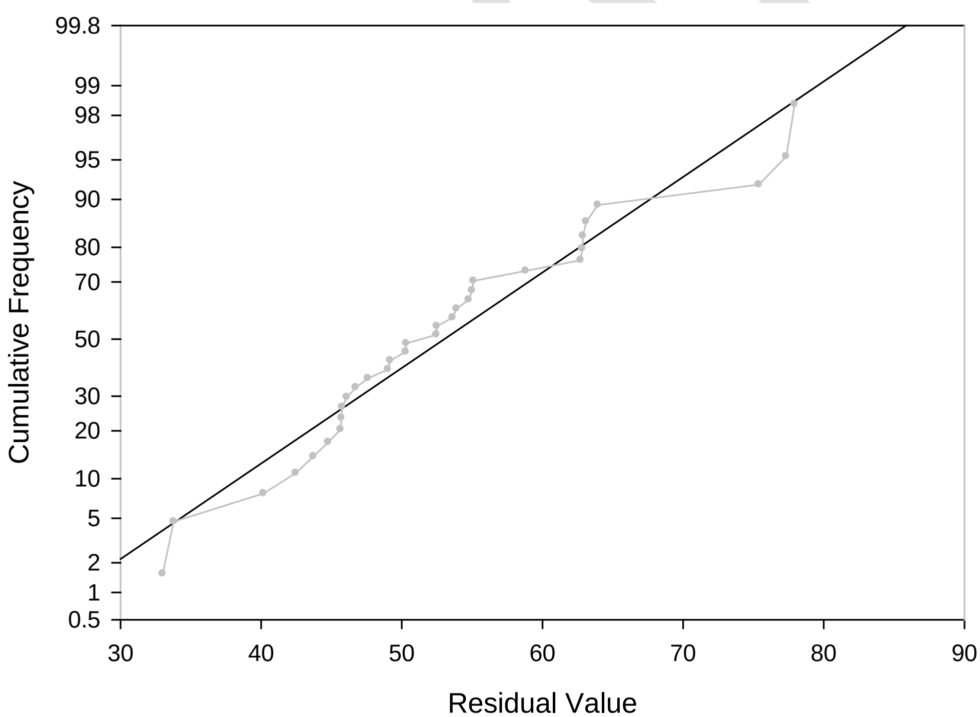

Figure F-11. Normality check for RAIN1A.

Normality test (Shapiro-Wilk) results for RAIN1A are as follows: W-Statistic = 0.946, P = 0.109, passed. Result indicates that the data matches the pattern expected if the data were drawn from a population with a normal distribution.

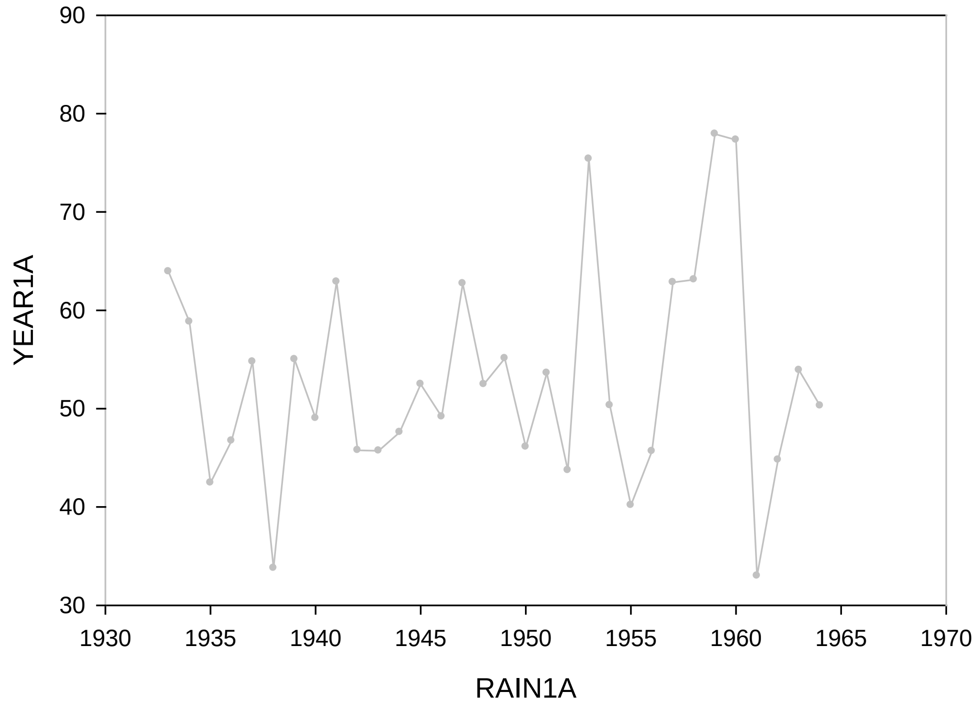

Figure F-12. Scatterplot for RAIN1A.

Descriptive Statistics for RAIN2A

Descriptive statistics for RAIN2A are presented in **Table F-9**. **Figures F-13** through **F-15** present a histogram, a normality check, and a scatterplot, respectively, for RAIN2A.

Table F-9. Descriptive statistics for RAIN2A.

Size	Missing	Mean	Standard Deviation	Standard Error	Confidence Interval of Mean	Range	Maximum	Minimum	Median	25%	75%
41	0	49.226	7.639	1.193	2.411	32.660	65.960	33.300	48.930	44.710	53.457

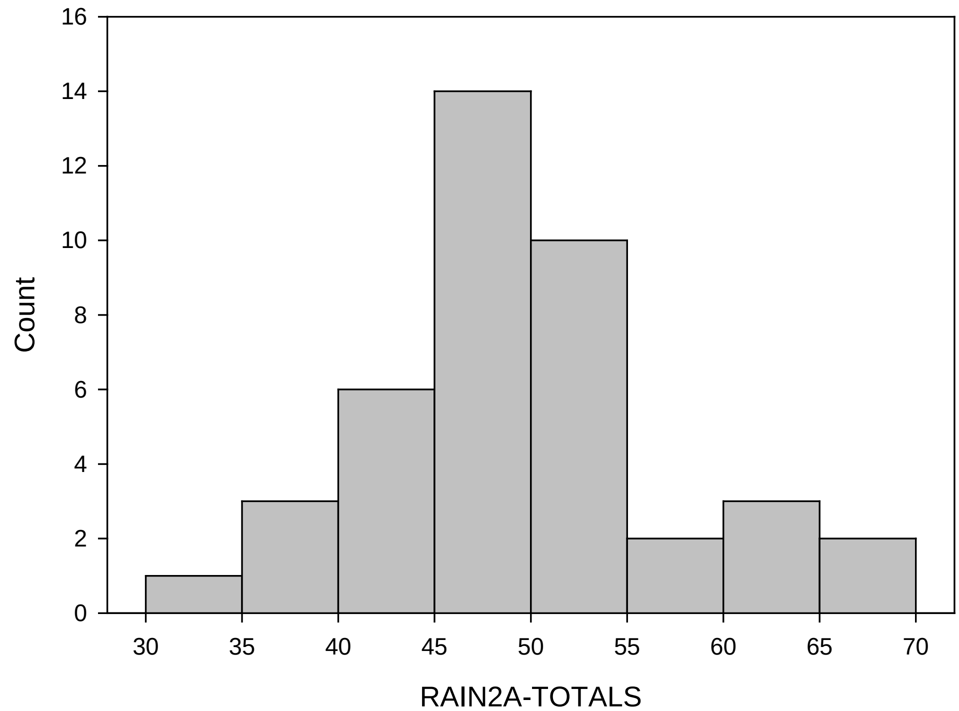

Figure F-13. Histogram for RAIN2A.

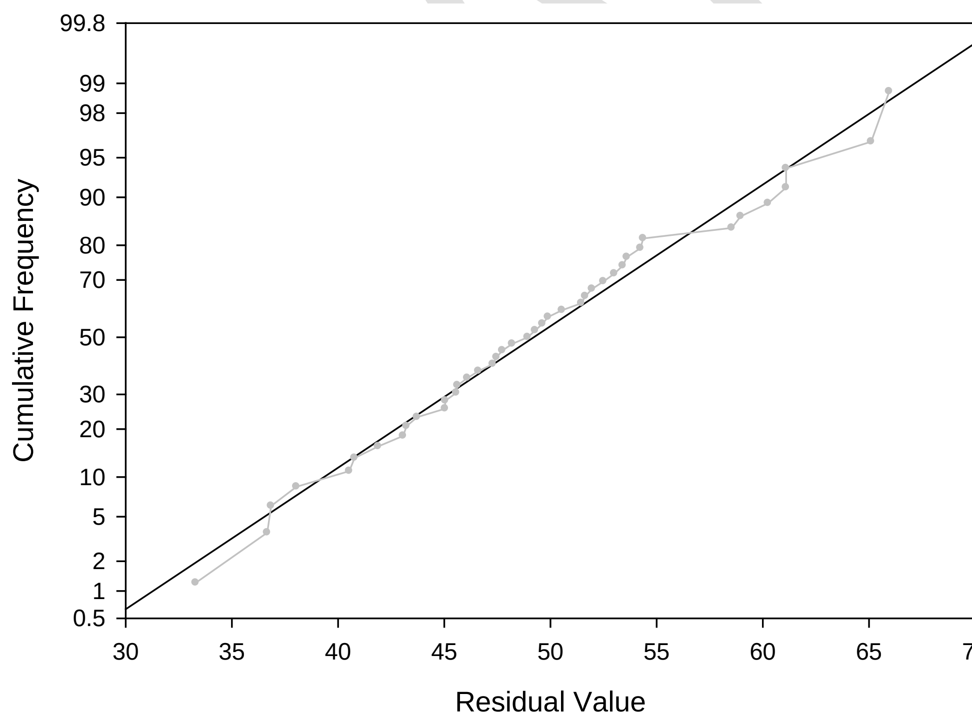

Figure F-14. Normality check for RAIN2A.

Normality test (Shapiro-Wilk) results are as follows: W-Statistic = 0.984, P = 0.832, passed. Result indicates that the data matches the pattern expected if the data were drawn from a population with a normal distribution.

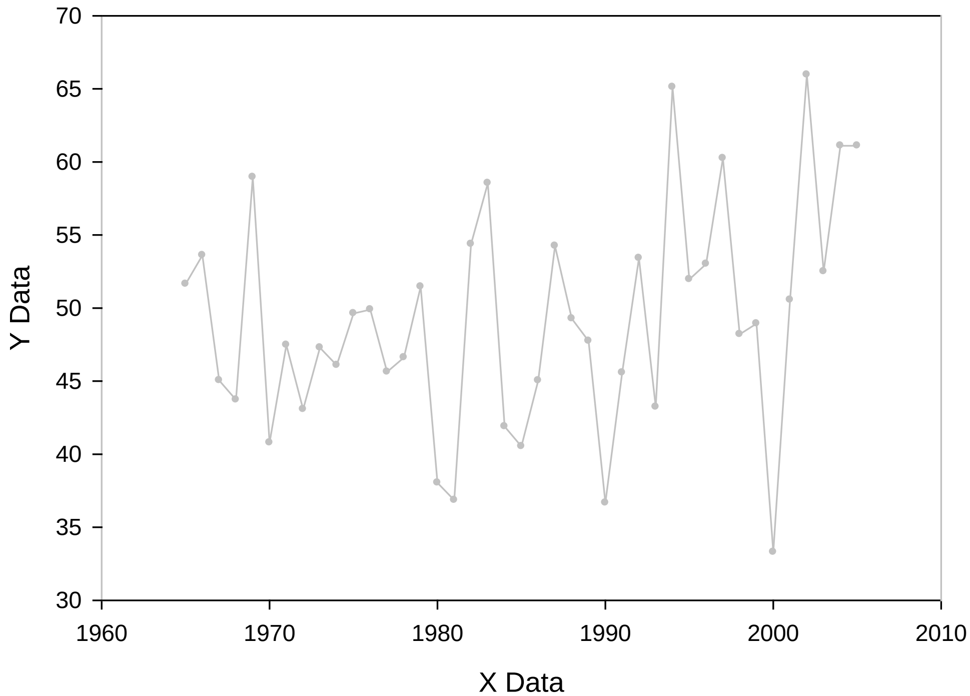

Figure F-15. Scatterplot for RAIN2A.

Descriptive Statistics for RAIN3A

Descriptive statistics for RAIN3A are presented in **Table F-10**. **Figures F-16** through **F-18** present a histogram, a normality check, and a scatterplot, respectively, for RAIN3A.

Table F-10. Descriptive statistics for RAIN2A.

Size	Missing	Mean	Standard Deviation	Standard Error	Confidence Interval of Mean	Range	Maximum	Minimum	Median	25%	75%
73	0	50.888	9.417	1.102	2.197	44.930	77.930	33.000	49.630	45.440	54.820

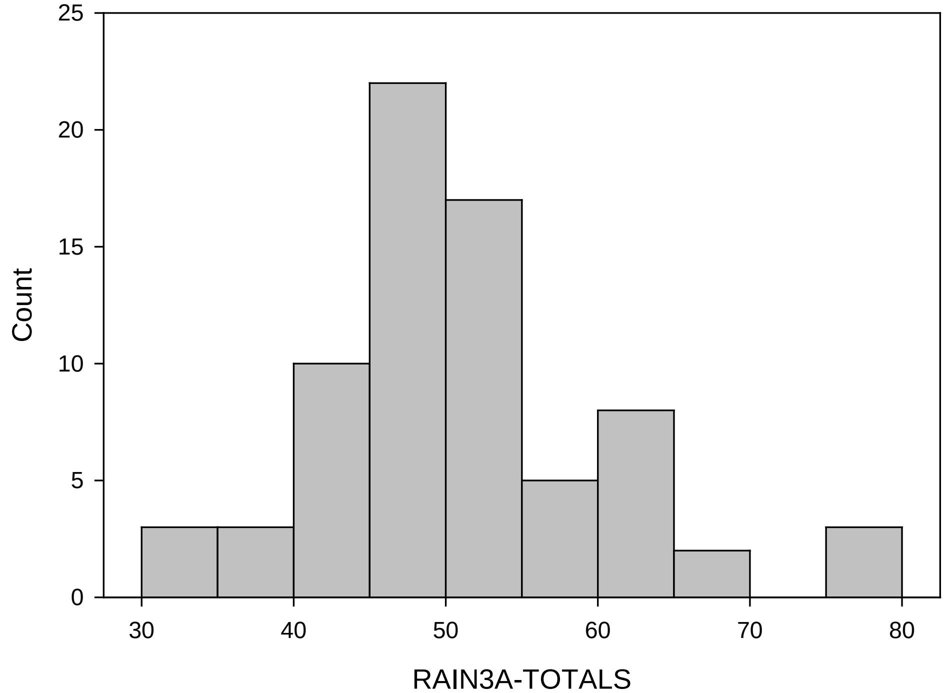

Figure F-16. Histogram for RAIN3A.

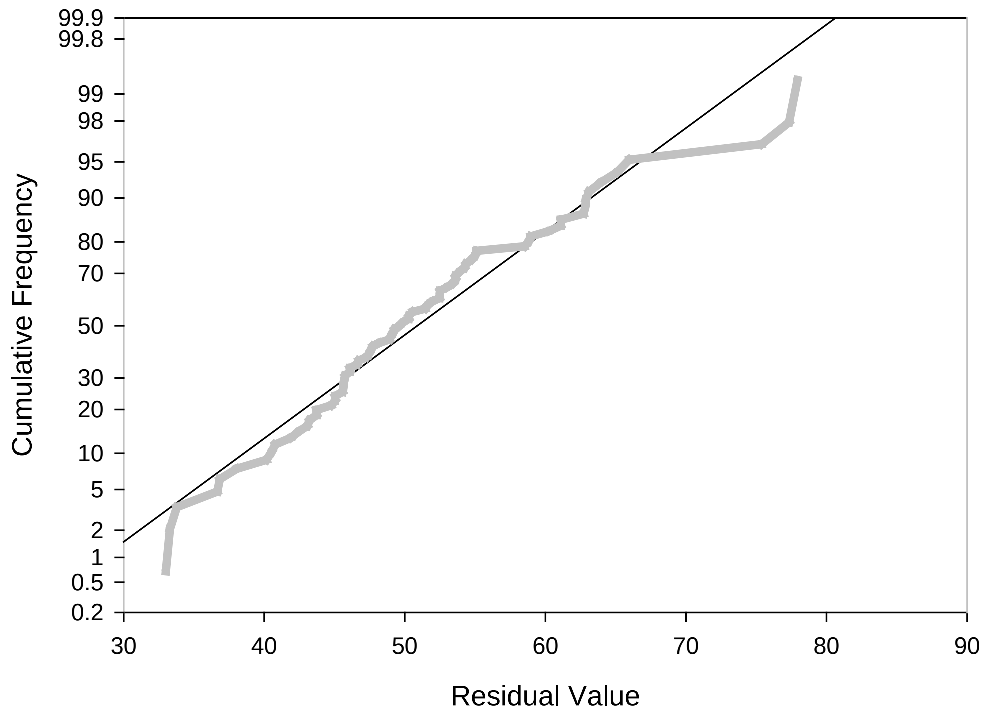

Figure F-17. Normality test for RAIN3A.

Normality test (Shapiro-Wilk) results are as follows: W-Statistic = 0.959, P = 0.018, failed. A test that fails indicates that the data varies significantly from the pattern expected if the data were drawn from a population with a normal distribution.

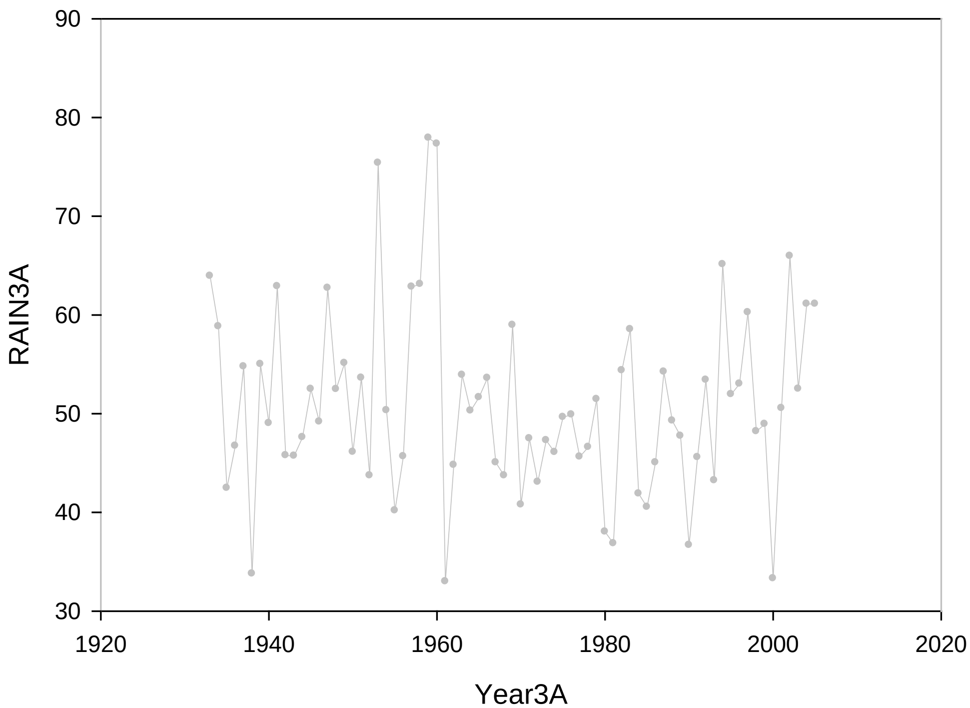

Figure F-18. Scatterplot for RAIN3A.

Mean Comparison Analysis for Annual Data

Mean Comparison between RAIN1A and RAIN2A

1. **t-test**

   Normality Test (Shapiro-Wilk): Passed (P = 0.124)

2. **Equal Variance Test**

   Equal Variance Test: Passed (P = 0.088)

   Table F-11 shows the results for the Equal Variance Test.

Table F-11. Equal Variance Test results for the comparision between RAIN1A and RAIN2A.

Group	Sample Size	Missing	Mean	Standard Deviation	SEM
RAIN1A-TOTALS	32	0	53.018	11.060	1.955
RAIN2A-TOTALS	41	0	49.226	7.639	1.193
Difference 3.793					
t = 1.731 with 71 degrees of freedom (P = 0.088)					
95 percent confidence interval for difference of means: -0.576 to 8.161					

3. **Conclusions**

The test statistic t = 1.731 has a p-value of 0.088. Since the p-value is not less that the chosen alfa level of 0.05, the conclusion is that there is insufficient evidence to reject the hypothesis. Therefore, the data does not support the hypothesis that there is a difference between the population medians. In other words, the difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. <u>There is not a statistically significant difference between the input groups</u>.

Mean Comparison between RAIN1A and RAIN3A

1. **t-test**

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

2. **Mann-Whitney Rank Sum Test**

Table F-12 shows the results for the Mann-Whitney Rank Sum Test.

Table F-12. Mann-Whitney Rank Sum Test results for the comparision between RAIN1A and RAIN3A.

Group	Sample Size	Missing	Median	25%	75%
RAIN1A-TOTALS	32	0	51.395	45.723	61.745
RAIN3A-TOTALS	73	0	49.630	45.310	54.880
Mann-Whitney U Statistic = 1036.500					
T = 1827.500; n(small) = 32; n(big) = 73 (P = 0.362)					

3. **Conclusions**

The test statistic T= 1827.500 has a p-value of 0.362. Since the p-value is not less that the chosen alfa level of 0.05, the conclusion is that there is insufficient evidence to reject the hypothesis. Therefore, the data does not support the hypothesis that there is a difference between the population medians. In other words, the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability. <u>There is not a statistically significant difference</u>.

Mean Comparison between RAIN2A and RAIN3A

1. **t-test**

   Normality Test (Shapiro-Wilk) Failed (P < 0.050)

2. **Mann-Whitney Rank Sum Test**

   Table F-13 shows the results for the Mann-Whitney Rank Sum Test.

Table F-13. Mann-Whitney Rank Sum Test results for the comparision between RAIN2A and RAIN3A.

Group	Sample Size	Missing	Median	25%	75%
RAIN1A-TOTALS	41	0	48.930	44.380	53.505
RAIN3A-TOTALS	73	0	49.630	45.310	54.880
Mann-Whitney U Statistic = 1365.000					
T = 2226.000; n(small) = 41; n(big) = 73 (P = 0.439)					

3. **Conclusions**

   The test statistic T= 2226.000 has a p-value of 0.439. Since the p-value is not less that the chosen alfa level of 0.05, the conclusion is that there is insufficient evidence to reject the hypothesis. Therefore, the data does not support the hypothesis that there is a difference between the population medians. In other words, the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability. <u>There is not a statistically significant difference.</u>

Conclusions of the Rainfall Analysis

Different periods of rainfall data were compared and tested to know if differences in means were statistically significant or not. The analysis showed the results presented in **Table F-14**.

Table F-14. Results of the rainfall analysis.

Comparison – Time Periods	Data Type	Test Performed	Results
1933–1964 versus 1965–2005	Monthly	Mann-Whitney Rank Sum	No statistically significant difference in rainfall.
1933–1964 versus 1933–2005	Monthly	Mann-Whitney Rank Sum	No statistically significant difference in rainfall.
1965–2005 versus 1933–2005	Monthly	Mann-Whitney Rank Sum	No statistically significant difference in rainfall.
1933–1964 versus 1965–2005	Annual	t-test	No statistically significant difference in rainfall.
1933–1964 versus 1933–2005	Annual	Mann-Whitney Rank Sum	No statistically significant difference in rainfall.
1965–2005 versus 1933–2005	Annual	Mann-Whitney Rank Sum	No statistically significant difference in rainfall.

The statistical analysis also generated the following conclusions:

1. Monthly data for the three periods of analysis (1933–1964, 1965–2005, and 1933–2005) is not normally distributed.
2. Annual data for period 1933–2005 is not normally distributed.
3. Annual data for periods 1933–1964 and 1965–2005 passed the normality check.

So, there is not enough evidence to say that observed differences in rainfall are not due to chance.

APPENDIX G: WATER BUDGETS FOR PROPOSED WATER RESERVATION WATERSHEDS

Calculating the Water Budget

In general, the balanced water budget is expressed in the following fashion:

Total Error = Inflows – Outflows – Change in Storage

Using the parameters described previously, the MIKE SHE water budget would be written as:

Total Error = (Precipitation + Boundary Flows in) – (ET + OL to River + Base Flow to River + Drain to River + Drain to External River + Boundary Flows out) – (ΔOL + ΔUZ + ΔSAS + ΔICU + ΔUFA)

Where,

ET – evapotranspiration

OL – overland flow

UZ – upper sone

SAS – surficial aquifer system

ICU – intermediate confining unit

UFA – upper Floridan aquifer

The parameters shown in the MIKE SHE water budget are shown graphically in **Figure G-1**.

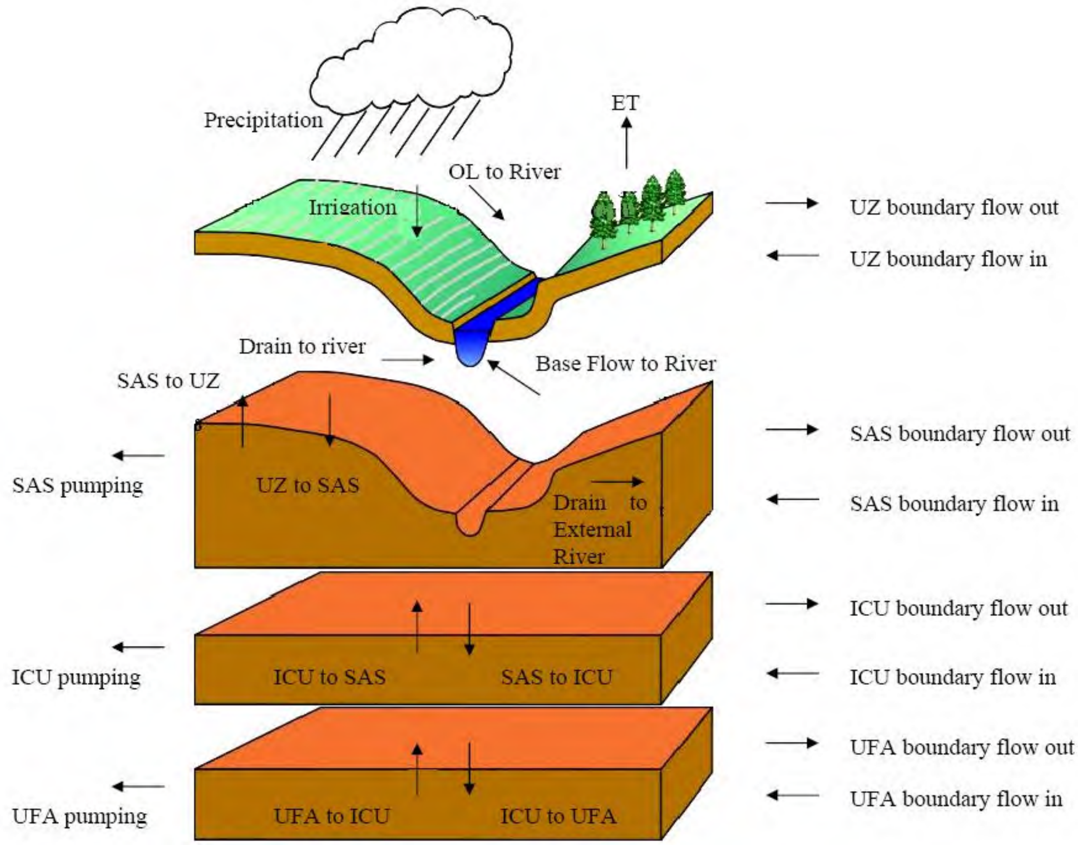

Figure G-1. Graphic representation of parameters in the MIKE SHE water budget.

Alligator Chain of Lakes Water Budget

The water budget for the Alligator Chain of Lakes is shown in **Table G-1**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is zero.

Table G-1. Alligator Chain of Lakes water budget.

Parameter	Average per Year (inches)
Precipitation	46.1
ET	38.2
Drain to river	5.2
Irrigation	0.1
Drain to external River	0.1
OL to River	0.6
UFA to ICU	0.0
ICU to UFA	2.2
ICU to SAS	0.0
SAS to ICU	2.2
SAS to UZ	1.5
UZ to SAS	9.0
Base flow to River	0.0
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.0
SAS boundary flow in	0.3
SAS boundary flow out	0.2
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	3.2
UFA boundary flow out	5.2
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.1

Lake Gentry Water Budget

The water budget for Lake Gentry is shown in **Table G-2**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is -0.1.

Table G-2. Lake Gentry water budget.

Parameter	Average per Year (inches)
Precipitation	48.0
ET	36.3
Drain to river	3.1
Irrigation	0.1
Drain to external river	0.4
OL to River	0.8
UFA to ICU	0.1
ICU to UFA	7.8
ICU to SAS	0.1
SAS to ICU	7.8
SAS to UZ	0.9
UZ to SAS	12.3
Base flow to River	0.1
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.0
SAS boundary flow in	0.4
SAS boundary flow out	0.4
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	1.0
UFA boundary flow out	8.7
UZ boundary flow in	0.0
UZ boundary flow out	-0.3
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.1

Lake Hart Water Budget

The water budget for Lake Hart is shown in **Table G-3**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is 0.1.

Table G-3. Lake Hart water budget

Parameter	Average per Year (inches)
Precipitation	47.6
ET	39.1
Drain to river	2.8
Irrigation	0.0
Drain to external River	1.2
OL to River	2.4
UFA to ICU	0.0
ICU to UFA	1.9
ICU to SAS	0.0
SAS to ICU	1.9
SAS to UZ	1.4
UZ to SAS	7.3
Base flow to River	0.0
UFA storage change	0.1
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.0
SAS boundary flow in	0.1
SAS boundary flow out	0.1
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	5.4
UFA boundary flow out	7.2
UZ boundary flow in	0.0
UZ boundary flow out	0.1
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.0

East Lake Tohopekaliga Water Budget

The water budget for East Lake Tohopekaliga is shown in **Table G-4**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is 0.2.

Table G-4. East Lake Tohopekaliga water budget.

Parameter	Average per Year (inches)
Precipitation	48.2
ET	36.0
Drain to river	5.5
Irrigation	0.2
Drain to external River	0.1
OL to River	4.7
UFA to ICU	0.0
ICU to UFA	1.9
ICU to SAS	0.0
SAS to ICU	1.9
SAS to UZ	1.4
UZ to SAS	9.1
Base flow to River	0.1
UFA storage change	0.1
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.0
SAS boundary flow in	0.2
SAS boundary flow out	0.1
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	3.5
UFA boundary flow out	5.1
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.2

Lake Tohopekaliga Water Budget

The water budget for Lake Tohopekaliga is shown in **Table G-5**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is 0.2.

Table G-5. Lake Tohopekaliga water budget.

Parameter	Average per Year (inches)
Precipitation	48.8
ET	36.6
Drain to river	5.5
Irrigation	0.3
Drain to external River	0.1
OL to River	5.0
UFA to ICU	0.5
ICU to UFA	1.9
ICU to SAS	0.5
SAS to ICU	2.0
SAS to UZ	1.7
UZ to SAS	6.9
Base flow to River	0.2
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.0
SAS boundary flow in	0.2
SAS boundary flow out	0.3
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	3.2
UFA boundary flow out	4.2
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.4

Lake Kissimmee Water Budget

The water budget for Lake Kissimmee is shown in **Table G-6**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is zero.

Table G-6. Lake Kissimmee water budget.

Parameter	Average per Year (inches)
Precipitation	50.5
ET	40.2
Drain to river	7.0
Irrigation	0.6
Drain to external River	0.0
OL to River	1.0
UFA to ICU	2.8
ICU to UFA	3.9
ICU to SAS	3.3
SAS to ICU	5.8
SAS to UZ	1.9
UZ to SAS	11.7
Base flow to River	0.0
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.1
SAS boundary flow in	0.1
SAS boundary flow out	0.1
ICU boundary flow in	0.1
ICU boundary flow out	0.0
UFA boundary flow in	0.8
UFA boundary flow out	3.0
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.4
ICU pumping	0.1
UFA pumping	0.1

Lake Cypress Water Budget

The water budget for Lake Cypress is shown in **Table G-7**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is 0.2.

Table G-7. Lake Cypress water budget.

Parameter	Average per Year (inches)
Precipitation	50.0
ET	36.3
Drain to river	5.5
Irrigation	1.0
Drain to external River	0.0
OL to River	4.5
UFA to ICU	1.8
ICU to UFA	5.8
ICU to SAS	1.8
SAS to ICU	5.8
SAS to UZ	1.3
UZ to SAS	11.3
Base flow to River	0.4
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.1
UZ storage change	0.0
OL storage change	0.1
SAS boundary flow in	0.6
SAS boundary flow out	1.3
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	1.3
UFA boundary flow out	3.5
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.1
ICU pumping	0.0
UFA pumping	1.0

Lake Hatchineha Water Budget

The water budget for Lake Hatchineha is shown in **Table G-8**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is zero.

Table G-8. Lake Hatchineha water budget.

Parameter	Average per Year (inches)
Precipitation	50.9
ET	37.3
Drain to river	8.5
Irrigation	1.0
Drain to external River	0.0
OL to River	3.4
UFA to ICU	5.9
ICU to UFA	7.5
ICU to SAS	6.6
SAS to ICU	8.4
SAS to UZ	2.0
UZ to SAS	13.0
Base flow to River	0.2
UFA storage change	0.1
ICU storage change	0.0
SAS storage change	0.1
UZ storage change	0.0
OL storage change	0.2
SAS boundary flow in	0.1
SAS boundary flow out	0.2
ICU boundary flow in	0.1
ICU boundary flow out	0.1
UFA boundary flow in	1.1
UFA boundary flow out	2.2
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.3
ICU pumping	0.2
UFA pumping	0.6

Lake Myrtle Water Budget

The water budget for Lake Myrtle is shown in **Table G-9**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is zero.

Table G-9. Lake Myrtle water budget.

Parameter	Average per Year (inches)
Precipitation	45.1
ET	38.0
Drain to river	2.0
Irrigation	0.0
Drain to external River	0.1
OL to River	3.2
UFA to ICU	0.0
ICU to UFA	1.4
ICU to SAS	0.0
SAS to ICU	1.4
SAS to UZ	1.2
UZ to SAS	4.8
Base flow to River	0.1
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.2
SAS boundary flow in	0.4
SAS boundary flow out	0.4
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	8.2
UFA boundary flow out	9.6
UZ boundary flow in	0.0
UZ boundary flow out	0.1
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.0

Pool A Water Budget

The water budget for Pool A is shown in **Table G-10**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is zero.

Table G-10. Pool A water budget.

Parameter	Average per Year (inches)
Precipitation	49.3
ET	36.1
Drain to river	7.2
Irrigation	1.4
Drain to external River	0.0
OL to River	2.3
UFA to ICU	1.4
ICU to UFA	4.5
ICU to SAS	1.5
SAS to ICU	4.6
SAS to UZ	1.6
UZ to SAS	13.7
Base flow to River	0.4
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.1
UZ storage change	0.0
OL storage change	0.2
SAS boundary flow in	0.3
SAS boundary flow out	0.4
ICU boundary flow in	0.0
ICU boundary flow out	0.1
UFA boundary flow in	0.6
UFA boundary flow out	3.6
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	1.3
ICU pumping	0.0
UFA pumping	0.1

Pools B, C, and D Water Budget

The water budget for Pools B, C, and D is shown in **Table G-11**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is zero.

Table G-11. Pools B, C, and D water budget.

Parameter	Average per Year (inches)
Precipitation	48.5
ET	36.3
Drain to river	7.9
Irrigation	0.8
Drain to external River	0.0
OL to River	1.8
UFA to ICU	0.7
ICU to UFA	3.1
ICU to SAS	0.8
SAS to ICU	3.2
SAS to UZ	1.4
UZ to SAS	12.2
Base flow to River	0.4
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.1
UZ storage change	0.0
OL storage change	0.3
SAS boundary flow in	0.3
SAS boundary flow out	0.2
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	0.9
UFA boundary flow out	2.5
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.0
ICU pumping	0.0
UFA pumping	0.7

Pool E Water Budget

The water budget for Pool E is shown in **Table G-12**. Refer to **Figure G-1** for a graphical depiction of the parameters. Total error is -0.1.

Table G-12. Pool E water budget.

Parameter	Average per Year (inches)
Precipitation	44.4
ET	35.3
Drain to river	8.2
Irrigation	0.5
Drain to external River	0.0
OL to River	3.4
UFA to ICU	3.8
ICU to UFA	0.0
ICU to SAS	3.3
SAS to ICU	0.1
SAS to UZ	2.4
UZ to SAS	8.6
Base flow to River	1.0
UFA storage change	0.0
ICU storage change	0.0
SAS storage change	0.0
UZ storage change	0.0
OL storage change	0.1
SAS boundary flow in	0.1
SAS boundary flow out	0.3
ICU boundary flow in	0.0
ICU boundary flow out	0.0
UFA boundary flow in	4.1
UFA boundary flow out	0.5
UZ boundary flow in	0.0
UZ boundary flow out	0.0
SAS pumping	0.0
ICU pumping	0.5
UFA pumping	0.0

APPENDIX H: PROPOSED WATER RESERVATION REGULATORY STAGE ELEVATIONS

The surface waters within each reservation waterbody that is reserved from allocation are identified in the graphs and tables below for reservation waterbodies in the Upper Chain of Lakes (**Figures H-1** through **H-6**; **Tables H-1** through **H-6**). The water reservation hydrograph represents the water levels needed to protect fish and wildlife for a reservation waterbody. Thus, it defines an upper stage limit that preserves the seasonal and interannual variability in water levels required to support existing fish and wildlife resources. The tables below the figures provide the daily water reservation stage for each reservation waterbody throughout the year. Water at and below this "water reservation line" is needed for the protection of fish and wildlife and is reserved from future allocation. The water reservation will reserve all surface water that is not allocated to existing consumptive use permittees. Water above this line is not reserved for fish and wildlife and may be available for future allocation provided other regulatory permitting criteria are met.

The process to develop the water reservation hydrograph involved 1) specifying a seasonal high stage; 2) specifying a seasonal low stage; 3) connecting the seasonal high to the seasonal low stage with a straight-line recession event; 4) connecting the seasonal low to the next seasonal high with a similar straight-line ascension event; 5) adjusting the resulting hydrograph to meet specific hydrologic requirements of fish and wildlife in individual reservation waterbodies; and 6) adjusting the water reservation hydrograph to follow the current water regulation schedule hydrograph in instances where the regulation schedule hydrograph occurs at a stage lower than this water reservation hydrograph. These adjustments preserve the Central and Southern Florida Flood Control Project's federal mandate to maintain a specific level of flood protection in the region. For all Upper Chain of Lake reservation waterbodies, the seasonal high was specified as the high stage limit of the current stage regulation schedule on November 1, the first day the schedule allows that stage to be reached.

Selection of the seasonal low stage involves both biologic and policy considerations. The seasonal low stages were set as the 90th percentile stage for May 31 based on historical (1972–2007) conditions for each reservation waterbody. The 90th percentile defines the amount of water available to fish and wildlife under a wet dry season condition that would be expected to occur once every 10 years. It was selected to provide for the wide range of interannual variability that has occurred during the dry season, which is beneficial to fish and wildlife in the lakes.

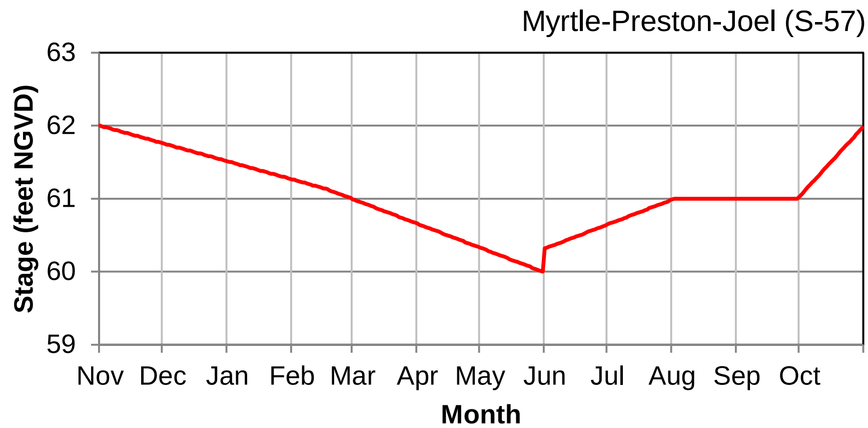

Figure H-1. Water reservation line for the Lakes Myrtle–Preston–Joel reservation waterbody.

Table H-1. Daily water reservation stages for the Lakes Myrtle–Preston–Joel reservation waterbody (S-57 structure).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	61.51	61.26	60.99	60.66	60.33	60.32	60.65	60.99	61.00	61.03	62.00	61.76
2	61.50	61.26	60.98	60.64	60.32	60.33	60.66	61.00	61.00	61.06	61.99	61.75
3	61.50	61.25	60.97	60.63	60.31	60.34	60.67	61.00	61.00	61.09	61.98	61.74
4	61.49	61.24	60.96	60.62	60.30	60.35	60.68	61.00	61.00	61.13	61.98	61.74
5	61.48	61.23	60.95	60.61	60.28	60.36	60.69	61.00	61.00	61.16	61.97	61.73
6	61.47	61.22	60.94	60.60	60.27	60.37	60.70	61.00	61.00	61.19	61.96	61.72
7	61.46	61.22	60.93	60.59	60.26	60.38	60.71	61.00	61.00	61.22	61.95	61.71
8	61.46	61.21	60.92	60.58	60.25	60.39	60.72	61.00	61.00	61.25	61.94	61.70
9	61.45	61.20	60.91	60.57	60.24	60.40	60.73	61.00	61.00	61.28	61.94	61.70
10	61.44	61.19	60.90	60.56	60.23	60.41	60.74	61.00	61.00	61.31	61.93	61.69
11	61.43	61.18	60.89	60.55	60.22	60.43	60.76	61.00	61.00	61.34	61.92	61.68
12	61.42	61.18	60.87	60.54	60.21	60.44	60.77	61.00	61.00	61.38	61.91	61.67
13	61.42	61.17	60.86	60.52	60.20	60.45	60.78	61.00	61.00	61.41	61.90	61.66
14	61.41	61.16	60.85	60.51	60.19	60.46	60.79	61.00	61.00	61.44	61.90	61.66
15	61.40	61.15	60.84	60.50	60.17	60.47	60.80	61.00	61.00	61.47	61.89	61.65
16	61.39	61.14	60.83	60.49	60.16	60.48	60.81	61.00	61.00	61.50	61.88	61.64
17	61.38	61.14	60.82	60.48	60.15	60.49	60.82	61.00	61.00	61.53	61.87	61.63
18	61.38	61.13	60.81	60.47	60.14	60.50	60.83	61.00	61.00	61.56	61.86	61.62
19	61.37	61.11	60.80	60.46	60.13	60.51	60.84	61.00	61.00	61.59	61.86	61.62
20	61.36	61.10	60.79	60.45	60.12	60.52	60.85	61.00	61.00	61.63	61.85	61.61
21	61.35	61.09	60.78	60.44	60.11	60.54	60.87	61.00	61.00	61.66	61.84	61.60
22	61.34	61.08	60.77	60.43	60.10	60.55	60.88	61.00	61.00	61.69	61.83	61.59
23	61.34	61.07	60.75	60.42	60.09	60.56	60.89	61.00	61.00	61.72	61.82	61.58
24	61.33	61.06	60.74	60.40	60.08	60.57	60.90	61.00	61.00	61.75	61.82	61.58
25	61.32	61.05	60.73	60.39	60.07	60.58	60.91	61.00	61.00	61.78	61.81	61.57
26	61.31	61.04	60.72	60.38	60.05	60.59	60.92	61.00	61.00	61.81	61.80	61.56
27	61.30	61.03	60.71	60.37	60.04	60.60	60.93	61.00	61.00	61.84	61.79	61.55
28	61.30	61.02	60.70	60.36	60.03	60.61	60.94	61.00	61.00	61.88	61.78	61.54
29	61.29	61.01	60.69	60.35	60.02	60.62	60.95	61.00	61.00	61.91	61.78	61.54
30	61.28		60.68	60.34	60.01	60.63	60.96	61.00	61.00	61.94	61.77	61.53
31	61.27		60.67		60.00		60.98	61.00		61.97		61.52

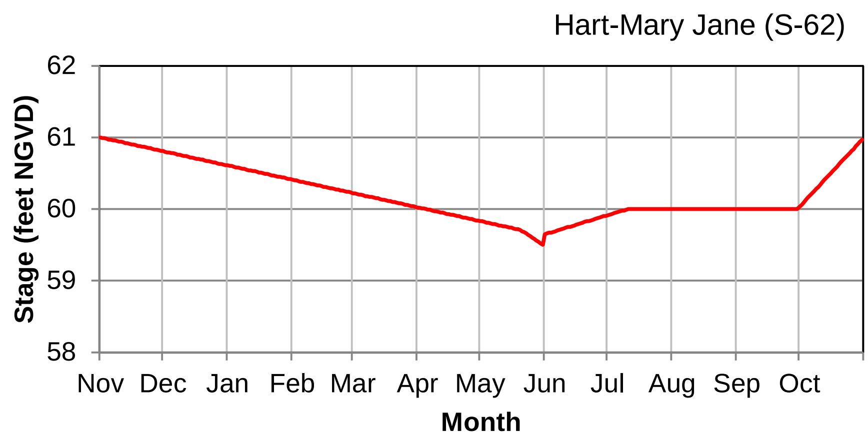

Figure H-2. Water reservation line for the Lakes Hart–Mary Jane reservation waterbody.

Table H-2. Daily water reservation stages for the Lakes Hart–Mary Jane reservation waterbody (S-62 structure).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	60.61	60.41	60.22	60.02	59.83	59.65	59.91	60.00	60.00	60.03	61.00	60.81
2	60.60	60.40	60.22	60.02	59.83	59.66	59.92	60.00	60.00	60.06	60.99	60.80
3	60.60	60.40	60.21	60.01	59.82	59.67	59.93	60.00	60.00	60.09	60.99	60.79
4	60.59	60.39	60.20	60.01	59.81	59.67	59.94	60.00	60.00	60.13	60.98	60.79
5	60.58	60.38	60.20	60.00	59.81	59.68	59.95	60.00	60.00	60.16	60.97	60.78
6	60.58	60.38	60.19	59.99	59.80	59.69	59.96	60.00	60.00	60.19	60.97	60.78
7	60.57	60.37	60.18	59.99	59.79	59.70	59.97	60.00	60.00	60.22	60.96	60.77
8	60.56	60.36	60.18	59.98	59.79	59.71	59.98	60.00	60.00	60.25	60.96	60.76
9	60.56	60.36	60.17	59.97	59.78	59.72	59.98	60.00	60.00	60.28	60.95	60.76
10	60.55	60.35	60.17	59.97	59.77	59.73	59.99	60.00	60.00	60.31	60.94	60.75
11	60.54	60.35	60.16	59.96	59.77	59.74	60.00	60.00	60.00	60.34	60.94	60.74
12	60.54	60.34	60.15	59.95	59.76	59.75	60.00	60.00	60.00	60.38	60.93	60.74
13	60.53	60.33	60.15	59.95	59.76	59.75	60.00	60.00	60.00	60.41	60.92	60.73
14	60.53	60.33	60.14	59.94	59.75	59.76	60.00	60.00	60.00	60.44	60.92	60.72
15	60.52	60.32	60.13	59.93	59.74	59.77	60.00	60.00	60.00	60.47	60.91	60.72
16	60.51	60.31	60.13	59.93	59.74	59.78	60.00	60.00	60.00	60.50	60.90	60.71
17	60.51	60.31	60.12	59.92	59.73	59.79	60.00	60.00	60.00	60.53	60.90	60.70
18	60.50	60.30	60.11	59.92	59.72	59.80	60.00	60.00	60.00	60.56	60.89	60.70
19	60.49	60.29	60.11	59.91	59.72	59.81	60.00	60.00	60.00	60.59	60.88	60.69
20	60.49	60.29	60.10	59.90	59.71	59.82	60.00	60.00	60.00	60.63	60.88	60.69
21	60.48	60.28	60.10	59.90	59.69	59.83	60.00	60.00	60.00	60.66	60.87	60.68
22	60.47	60.27	60.09	59.89	59.68	59.83	60.00	60.00	60.00	60.69	60.87	60.67
23	60.47	60.27	60.08	59.88	59.66	59.84	60.00	60.00	60.00	60.72	60.86	60.67
24	60.46	60.26	60.08	59.88	59.64	59.85	60.00	60.00	60.00	60.75	60.85	60.66
25	60.45	60.26	60.07	59.87	59.62	59.86	60.00	60.00	60.00	60.78	60.85	60.65
26	60.45	60.25	60.06	59.86	59.60	59.87	60.00	60.00	60.00	60.81	60.84	60.65
27	60.44	60.24	60.06	59.86	59.58	59.88	60.00	60.00	60.00	60.84	60.83	60.64
28	60.44	60.24	60.05	59.85	59.56	59.89	60.00	60.00	60.00	60.88	60.83	60.63
29	60.43	60.23	60.04	59.84	59.54	59.90	60.00	60.00	60.00	60.91	60.82	60.63
30	60.42		60.04	59.84	59.52	59.90	60.00	60.00	60.00	60.94	60.81	60.62
31	60.42		60.03		59.50		60.00	60.00		60.97		60.61

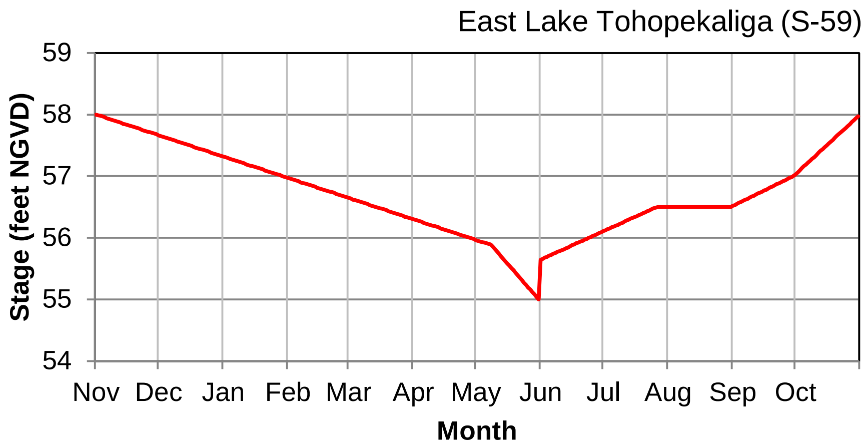

Figure H-3. Water reservation line for the East Lake Tohopekaliga reservation waterbody.

Table H-3. Daily water reservation stages for the East LakeTohopekaliga reservation waterbody (S-59 structure).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	57.32	56.97	56.65	56.30	55.96	55.64	56.11	56.50	56.52	57.03	58.00	57.66
2	57.31	56.96	56.64	56.29	55.95	55.66	56.12	56.50	56.53	57.06	57.99	57.65
3	57.30	56.95	56.62	56.28	55.94	55.68	56.14	56.50	56.55	57.09	57.98	57.64
4	57.28	56.94	56.61	56.27	55.93	55.69	56.15	56.50	56.57	57.13	57.97	57.63
5	57.27	56.93	56.60	56.26	55.92	55.71	56.17	56.50	56.58	57.16	57.96	57.62
6	57.26	56.92	56.59	56.24	55.91	55.72	56.18	56.50	56.60	57.19	57.94	57.61
7	57.25	56.90	56.58	56.23	55.90	55.74	56.20	56.50	56.62	57.22	57.93	57.60
8	57.24	56.89	56.57	56.22	55.89	55.75	56.21	56.50	56.63	57.25	57.92	57.59
9	57.23	56.88	56.56	56.21	55.86	55.77	56.23	56.50	56.65	57.28	57.91	57.58
10	57.22	56.87	56.55	56.20	55.82	55.78	56.24	56.50	56.67	57.31	57.90	57.56
11	57.21	56.86	56.53	56.19	55.78	55.80	56.26	56.50	56.68	57.34	57.89	57.55
12	57.19	56.85	56.52	56.18	55.74	55.81	56.28	56.50	56.70	57.38	57.88	57.54
13	57.18	56.84	56.51	56.17	55.70	55.83	56.29	56.50	56.72	57.41	57.87	57.53
14	57.17	56.83	56.50	56.15	55.66	55.84	56.31	56.50	56.73	57.44	57.85	57.52
15	57.16	56.81	56.49	56.14	55.62	55.86	56.32	56.50	56.75	57.47	57.84	57.51
16	57.15	56.80	56.48	56.13	55.58	55.88	56.34	56.50	56.77	57.50	57.83	57.50
17	57.14	56.79	56.47	56.12	55.55	55.89	56.35	56.50	56.78	57.53	57.82	57.49
18	57.13	56.78	56.46	56.11	55.51	55.91	56.37	56.50	56.80	57.56	57.81	57.47
19	57.12	56.77	56.45	56.10	55.47	55.92	56.38	56.50	56.82	57.59	57.80	57.46
20	57.11	56.76	56.43	56.09	55.43	55.94	56.40	56.50	56.83	57.63	57.79	57.45
21	57.09	56.75	56.42	56.08	55.39	55.95	56.41	56.50	56.85	57.66	57.78	57.44
22	57.08	56.74	56.41	56.07	55.35	55.97	56.43	56.50	56.87	57.69	57.77	57.43
23	57.07	56.73	56.40	56.05	55.31	55.98	56.44	56.50	56.88	57.72	57.75	57.42
24	57.06	56.71	56.39	56.04	55.27	56.00	56.46	56.50	56.90	57.75	57.74	57.41
25	57.05	56.70	56.38	56.03	55.23	56.01	56.48	56.50	56.92	57.78	57.73	57.40
26	57.04	56.69	56.37	56.02	55.19	56.03	56.49	56.50	56.93	57.81	57.72	57.38
27	57.03	56.68	56.36	56.01	55.16	56.04	56.50	56.50	56.95	57.84	57.71	57.37
28	57.02	56.67	56.34	56.00	55.12	56.06	56.50	56.50	56.97	57.88	57.70	57.36
29	57.00	56.66	56.33	55.99	55.08	56.08	56.50	56.50	56.98	57.91	57.69	57.35
30	56.99		56.32	55.98	55.04	56.09	56.50	56.50	57.00	57.94	57.68	57.34
31	56.98		56.31		55.00		56.50	56.50		57.97		57.33

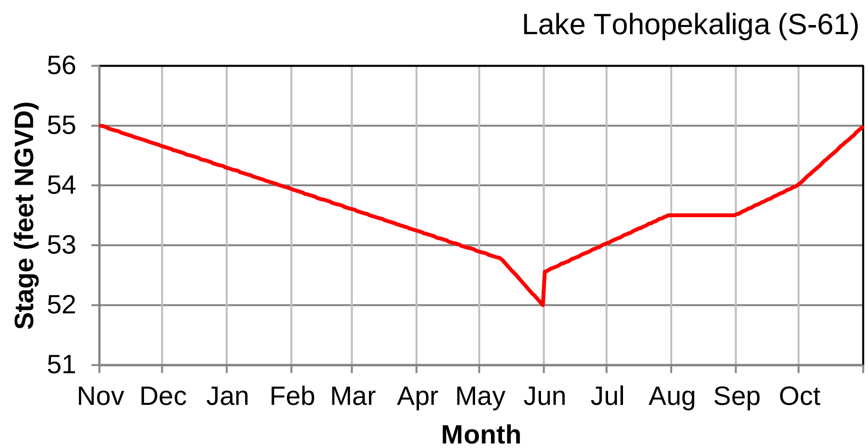

Figure H-4. Water reservation line for the Lake Tohopekaliga reservation waterbody.

Table H-4. Daily water reservation stages for the Lake Tohopekaliga reservation waterbody (S-61 structure).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	54.51	54.26	54.02	53.77	53.17	52.56	53.04	53.50	53.52	54.03	55.00	54.76
2	54.50	54.25	54.02	53.77	53.13	52.57	53.05	53.50	53.53	54.06	54.99	54.75
3	54.49	54.24	54.01	53.76	53.09	52.59	53.07	53.50	53.55	54.09	54.98	54.74
4	54.48	54.23	54.00	53.75	53.05	52.61	53.09	53.50	53.57	54.13	54.98	54.73
5	54.48	54.23	53.99	53.74	53.01	52.62	53.10	53.50	53.58	54.16	54.97	54.73
6	54.47	54.22	53.98	53.73	52.97	52.64	53.12	53.50	53.60	54.19	54.96	54.72
7	54.46	54.21	53.98	53.73	52.94	52.65	53.13	53.50	53.62	54.22	54.95	54.71
8	54.45	54.20	53.97	53.72	52.90	52.67	53.15	53.50	53.63	54.25	54.94	54.70
9	54.44	54.19	53.96	53.71	52.86	52.69	53.17	53.50	53.65	54.28	54.94	54.69
10	54.44	54.19	53.95	53.70	52.82	52.70	53.18	53.50	53.67	54.31	54.93	54.69
11	54.43	54.18	53.94	53.69	52.78	52.72	53.20	53.50	53.68	54.34	54.92	54.68
12	54.42	54.17	53.94	53.69	52.74	52.73	53.21	53.50	53.70	54.38	54.91	54.67
13	54.41	54.16	53.93	53.68	52.70	52.75	53.23	53.50	53.72	54.41	54.90	54.66
14	54.40	54.15	53.92	53.67	52.66	52.77	53.25	53.50	53.73	54.44	54.90	54.65
15	54.40	54.15	53.91	53.66	52.62	52.78	53.26	53.50	53.75	54.47	54.89	54.65
16	54.39	54.14	53.90	53.65	52.58	52.80	53.28	53.50	53.77	54.50	54.88	54.64
17	54.38	54.13	53.90	53.65	52.55	52.81	53.29	53.50	53.78	54.53	54.87	54.63
18	54.37	54.12	53.89	53.64	52.51	52.83	53.31	53.50	53.80	54.56	54.86	54.62
19	54.36	54.11	53.88	53.63	52.47	52.85	53.32	53.50	53.82	54.59	54.85	54.61
20	54.35	54.10	53.87	53.60	52.43	52.86	53.34	53.50	53.83	54.63	54.85	54.60
21	54.35	54.10	53.86	53.56	52.39	52.88	53.36	53.50	53.85	54.66	54.84	54.60
22	54.34	54.09	53.85	53.52	52.35	52.89	53.37	53.50	53.87	54.69	54.83	54.59
23	54.33	54.08	53.85	53.48	52.31	52.91	53.39	53.50	53.88	54.72	54.82	54.58
24	54.32	54.07	53.84	53.44	52.27	52.93	53.40	53.50	53.90	54.75	54.81	54.57
25	54.31	54.06	53.83	53.40	52.23	52.94	53.42	53.50	53.92	54.78	54.81	54.56
26	54.31	54.06	53.82	53.36	52.19	52.96	53.44	53.50	53.93	54.81	54.80	54.56
27	54.30	54.05	53.81	53.32	52.16	52.97	53.45	53.50	53.95	54.84	54.79	54.55
28	54.29	54.04	53.81	53.29	52.12	52.99	53.47	53.50	53.97	54.88	54.78	54.54
29	54.28	54.03	53.80	53.25	52.08	53.01	53.48	53.50	53.98	54.91	54.77	54.53
30	54.27		53.79	53.21	52.04	53.02	53.50	53.50	54.00	54.94	54.77	54.52
31	54.27		53.78		52.00		53.50	53.50		54.97		54.52

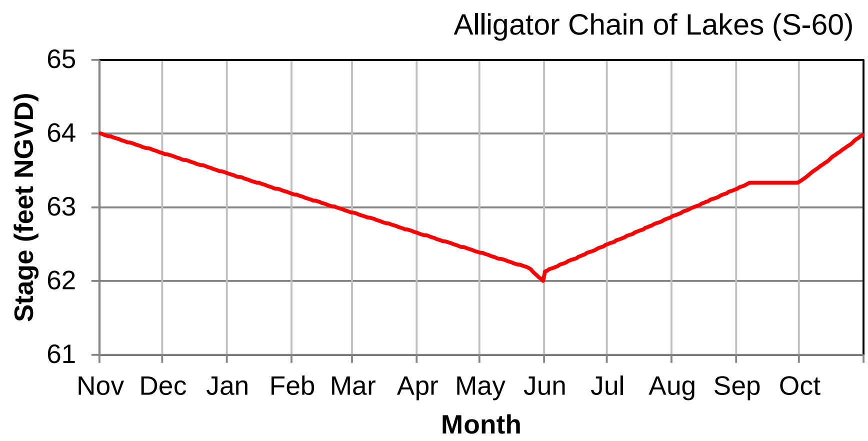

Figure H-5. Water reservation line for the Alligator Chain of Lakes reservation waterbody.

Table H-5. Daily water reservation stages for the Alligator Chain of Lakes reservation waterbody (S-60 structure).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	63.46	63.18	62.93	62.65	62.38	62.13	62.50	62.88	63.25	63.35	64.00	63.73
2	63.45	63.17	62.92	62.64	62.38	62.14	62.51	62.89	63.27	63.37	63.99	63.72
3	63.44	63.17	62.91	62.63	62.37	62.16	62.52	62.90	63.28	63.39	63.98	63.72
4	63.43	63.16	62.90	62.62	62.36	62.17	62.53	62.91	63.29	63.41	63.97	63.71
5	63.42	63.15	62.89	62.62	62.35	62.18	62.55	62.92	63.30	63.43	63.96	63.70
6	63.41	63.14	62.88	62.61	62.34	62.19	62.56	62.94	63.32	63.46	63.96	63.69
7	63.41	63.13	62.87	62.60	62.33	62.20	62.57	62.95	63.33	63.48	63.95	63.68
8	63.40	63.12	62.86	62.59	62.32	62.22	62.58	62.96	63.33	63.50	63.94	63.67
9	63.39	63.11	62.86	62.58	62.31	62.23	62.59	62.97	63.33	63.52	63.93	63.66
10	63.38	63.10	62.85	62.57	62.30	62.24	62.61	62.99	63.33	63.54	63.92	63.65
11	63.37	63.09	62.84	62.56	62.30	62.25	62.62	63.00	63.33	63.56	63.91	63.64
12	63.36	63.09	62.83	62.55	62.29	62.27	62.63	63.01	63.33	63.58	63.90	63.64
13	63.35	63.08	62.82	62.54	62.28	62.28	62.64	63.02	63.33	63.60	63.89	63.63
14	63.34	63.07	62.81	62.54	62.27	62.29	62.66	63.03	63.33	63.62	63.88	63.62
15	63.33	63.06	62.80	62.53	62.26	62.30	62.67	63.05	63.33	63.64	63.88	63.61
16	63.33	63.05	62.79	62.52	62.25	62.31	62.68	63.06	63.33	63.67	63.87	63.60
17	63.32	63.04	62.78	62.51	62.24	62.33	62.69	63.07	63.33	63.69	63.86	63.59
18	63.31	63.03	62.78	62.50	62.23	62.34	62.70	63.08	63.33	63.71	63.85	63.58
19	63.30	63.02	62.77	62.49	62.22	62.35	62.72	63.10	63.33	63.73	63.84	63.57
20	63.29	63.01	62.76	62.48	62.22	62.36	62.73	63.11	63.33	63.75	63.83	63.57
21	63.28	63.01	62.75	62.47	62.21	62.38	62.74	63.12	63.33	63.77	63.82	63.56
22	63.27	63.00	62.74	62.46	62.20	62.39	62.75	63.13	63.33	63.79	63.81	63.55
23	63.26	62.99	62.73	62.46	62.19	62.40	62.77	63.14	63.33	63.81	63.80	63.54
24	63.25	62.98	62.72	62.45	62.18	62.41	62.78	63.16	63.33	63.83	63.80	63.53
25	63.25	62.97	62.71	62.44	62.16	62.42	62.79	63.17	63.33	63.85	63.79	63.52
26	63.24	62.96	62.70	62.43	62.13	62.44	62.80	63.18	63.33	63.87	63.78	63.51
27	63.23	62.95	62.70	62.42	62.10	62.45	62.81	63.19	63.33	63.90	63.77	63.50
28	63.22	62.94	62.69	62.41	62.08	62.46	62.83	63.21	63.33	63.92	63.76	63.49
29	63.21	62.93	62.68	62.40	62.05	62.47	62.84	63.22	63.33	63.94	63.75	63.49
30	63.20		62.67	62.39	62.03	62.49	62.85	63.23	63.33	63.96	63.74	63.48
31	63.19		62.66		62.00		62.86	63.24		63.98		63.47

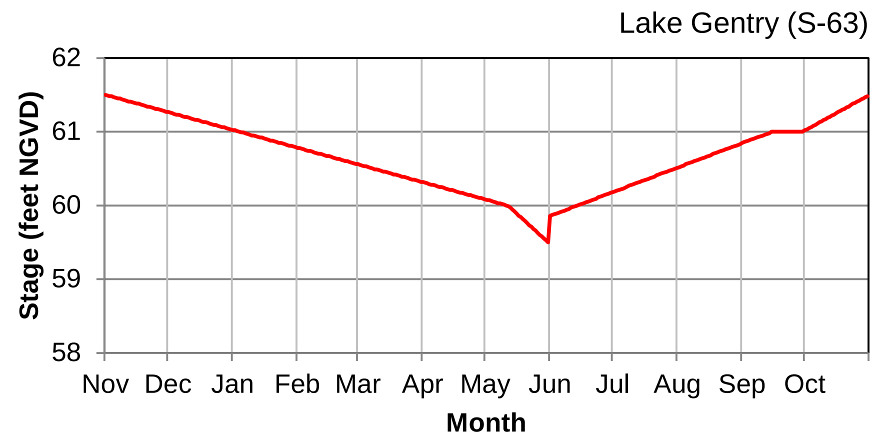

Figure H-6. Water reservation line for the Lake Gentry reservation waterbody.

Table H-6. Daily water reservation stages for the Lake Gentry reservation waterbody (S-63 structure).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	61.02	60.78	60.56	60.32	60.08	59.86	60.18	60.51	60.85	61.02	61.50	61.27
2	61.02	60.78	60.55	60.31	60.07	59.87	60.19	60.52	60.86	61.03	61.49	61.26
3	61.01	60.77	60.54	60.30	60.07	59.88	60.20	60.53	60.87	61.05	61.48	61.25
4	61.00	60.76	60.53	60.29	60.06	59.89	60.21	60.54	60.88	61.06	61.48	61.24
5	60.99	60.75	60.53	60.28	60.05	59.90	60.22	60.56	60.89	61.08	61.47	61.23
6	60.99	60.74	60.52	60.28	60.04	59.91	60.23	60.57	60.90	61.09	61.46	61.23
7	60.98	60.74	60.51	60.27	60.03	59.92	60.24	60.58	60.91	61.11	61.45	61.22
8	60.97	60.73	60.50	60.26	60.03	59.93	60.26	60.59	60.92	61.13	61.45	61.21
9	60.96	60.72	60.49	60.25	60.02	59.94	60.27	60.60	60.93	61.14	61.44	61.20
10	60.95	60.71	60.49	60.25	60.01	59.95	60.28	60.61	60.94	61.16	61.43	61.20
11	60.95	60.70	60.48	60.24	60.00	59.97	60.29	60.62	60.95	61.17	61.42	61.19
12	60.94	60.70	60.47	60.23	59.99	59.98	60.30	60.63	60.96	61.19	61.41	61.18
13	60.93	60.69	60.46	60.22	59.97	59.99	60.31	60.64	60.97	61.20	61.41	61.17
14	60.92	60.68	60.46	60.21	59.94	60.00	60.32	60.65	60.98	61.22	61.40	61.16
15	60.92	60.67	60.45	60.21	59.92	60.01	60.33	60.66	61.00	61.23	61.39	61.16
16	60.91	60.67	60.44	60.20	59.89	60.02	60.34	60.67	61.00	61.25	61.38	61.15
17	60.90	60.66	60.43	60.19	59.86	60.03	60.35	60.68	61.00	61.27	61.38	61.14
18	60.89	60.65	60.42	60.18	59.84	60.04	60.36	60.70	61.00	61.28	61.37	61.13
19	60.88	60.64	60.42	60.17	59.81	60.05	60.37	60.71	61.00	61.30	61.36	61.13
20	60.88	60.63	60.41	60.17	59.79	60.06	60.38	60.72	61.00	61.31	61.35	61.12
21	60.87	60.63	60.40	60.16	59.76	60.07	60.39	60.73	61.00	61.33	61.34	61.11
22	60.86	60.62	60.39	60.15	59.73	60.08	60.41	60.74	61.00	61.34	61.34	61.10
23	60.85	60.61	60.39	60.14	59.71	60.09	60.42	60.75	61.00	61.36	61.33	61.09
24	60.85	60.60	60.38	60.14	59.68	60.11	60.43	60.76	61.00	61.38	61.32	61.09
25	60.84	60.60	60.37	60.13	59.66	60.12	60.44	60.77	61.00	61.39	61.31	61.08
26	60.83	60.59	60.36	60.12	59.63	60.13	60.45	60.78	61.00	61.41	61.31	61.07
27	60.82	60.58	60.35	60.11	59.60	60.14	60.46	60.79	61.00	61.42	61.30	61.06
28	60.81	60.57	60.35	60.10	59.58	60.15	60.47	60.80	61.00	61.44	61.29	61.06
29	60.81	60.56	60.34	60.10	59.55	60.16	60.48	60.81	61.00	61.45	61.28	61.05
30	60.80		60.33	60.09	59.53	60.17	60.49	60.82	61.00	61.47	61.27	61.04
31	60.79		60.32		59.50		60.50	60.83		61.48		61.03

APPENDIX I: KISSIMMEE BASIN WATER RESERVATION WATERBODIES

The maps provided in this appendix (**Figures I-1** through **I-8**) are described in Section 3 of the main body of this document. They are intended to depict the water reservation waterbodies, the contributing waterbodies, and the approximate location of adjacent wetland systems. The wetlands located proximal to reservation waterbodies are shown in this series of maps to provide the reader with their approximate size and location.

It is important to understand that the majority of the wetlands mentioned in **Table I-1** and shown in **Figures I-1** through **I-8** are regulated under Section 3.3 of the *Applicant's Handbook for Water Use Permit Applications within the South Florida Water Management District*. The existing wetland criteria and other surface water criteria in Section 3.3 of the handbook protect wetlands and surface waterbodies using a "no harm" threshold, therefore additional restrictions under this reservation rule for these wetlands are unnecessary. The wetlands in **Figures I-1** through **I-8** contribute surface water flows to the reservation waterbodies, where the fish and wildlife reside that are proposed to be protected under this reservation rule, but these wetlands are not protected or regulated by this reservation rule.

The reservation waterbodies were formally considered in the analyses to quantify the water needed to protect fish and wildlife. A reservation waterbody is defined as surface waters and associated contiguous wetland habitats upon which the identified fish and wildlife are being protected under the reservation rule where they reside, feed, nest, den, forage, etc.

Many of the reservation waterbodies are connected to and receive inflows from other sources. These connected wetlands, sloughs, lakes, streams, creeks, canals, and ditches are called "contributing waterbodies." A "contributing waterbody" is defined as a conveyance feature identified in a water reservation rule that is indirectly connected to a reservation waterbody and continuously or intermittently provides significant water supplies in terms of timing and volumes that are needed for the protection of fish and wildlife. For this reason, contributing waterbodies are integral as a part of the reservation waterbody to ensure that there is adequate hydrologic regime to protect fish and wildlife. Contributing waterbodies can be divided into two types: 1) natural systems that include, but are not limited to, lakes, streams, creeks, sloughs, and wetlands and 2) man-made systems that include, but are not limited to, ditches and canals.

Table I-1. Kissimmee Basin water reservation waterbody list sorted by map identification number.

WR-ID	Water Body Name	Watershed	Rule Feature
1	C-34 upstream of S63	Gentry WCC	Reservation Waterbody
2	Lake Gentry	Gentry WCC	Reservation Waterbody
3	Big Bend Swamp	Gentry WCC	Natural System Contributing Waterbody
4	Big Bend Swamp Canal / Gentry Ditch	Gentry WCC	Man-made Contributing Waterbody
5	C-33 downstream of S60	Gentry WCC	Reservation Waterbody
6	C-33 upstream of S60	Alligator WCC	Reservation Waterbody
7	Alligator Lake	Alligator WCC	Reservation Waterbody
8	Brick Canal	Alligator WCC	Reservation Waterbody
9	Brick Lake	Alligator WCC	Reservation Waterbody
10	Buck Slough	Alligator WCC	Natural System Contributing Waterbody
11	Buck Lake	Alligator WCC	Natural System Contributing Waterbody
12	Live Oak Lake	Alligator WCC	Reservation Waterbody
13	Live Oak Canal	Alligator WCC	Reservation Waterbody
14	Sardine Lake	Alligator WCC	Reservation Waterbody
15	Sardine Canal	Alligator WCC	Reservation Waterbody
16	C-32G	Alligator WCC	Reservation Waterbody
17	Lake Lizzie	Alligator WCC	Reservation Waterbody
18	C-32F	Alligator WCC	Reservation Waterbody
19	Lake Center	Alligator WCC	Reservation Waterbody
20	Center/Coon Canal	Alligator WCC	Reservation Waterbody
21	Coon Lake	Alligator WCC	Reservation Waterbody
22	C-32D	Alligator WCC	Reservation Waterbody
23	Trout Lake	Alligator WCC	Reservation Waterbody
24	C-32C south of S58	Alligator WCC	Reservation Waterbody
25	C-32C north of S58	LP-J-M WCC	Reservation Waterbody
26	Lake Joel	LP-J-M WCC	Reservation Waterbody
27	C-32B	LP-J-M WCC	Reservation Waterbody
28	Lake Myrtle	LP-J-M WCC	Reservation Waterbody
29	Myrtle/Preston Canal	LP-J-M WCC	Reservation Waterbody
30	Lake Preston	LP-J-M WCC	Reservation Waterbody
31	C-30 upstream of S57	LH_MJ WCC	Reservation Waterbody
32	C-30 downstream of S57	LH_MJ WCC	Reservation Waterbody
33	Lake Mary Jane	LH_MJ WCC	Reservation Waterbody
34	C-29	LH_MJ WCC	Reservation Waterbody
35	Lake Hart	LH_MJ WCC	Reservation Waterbody
36	Whippoorwill Canal	LH_MJ WCC	Reservation Waterbody
37	Lake Whippoorwill	LH_MJ WCC	Reservation Waterbody
38	C29A upstream of S62	LH_MJ WCC	Reservation Waterbody
39	C-29A downstream of S62	ELToho WCC	Reservation Waterbody
40	Ajay Lake	ELToho WCC	Reservation Waterbody
41	C-29B	ELToho WCC	Reservation Waterbody
42	Fells Cove	ELToho WCC	Reservation Waterbody
43	Boggy Creek	ELToho WCC	Natural System Contributing Waterbody
44	East Lake Tohopekaliga	ELToho WCC	Reservation Waterbody
45	Runnymede Canal	ELToho WCC	Reservation Waterbody
46	Lake Runnymede	ELToho WCC	Reservation Waterbody
47	C-31 Canal upstream of S59	ELToho WCC	Reservation Waterbody
48	C-31 Canal downstream of S59	LToho WCC	Reservation Waterbody
49	Fish Lake	LToho WCC	Natural System Contributing Waterbody
50	Partin Canal DS of from Fish Lake to Lake Tohopekaliga	LToho WCC	Man-made Contributing Waterbody

Table I-1. Continued.

WR-ID	Water Body Name	Watershed	Rule Feature
51	Mill Slough	LToho WCC	Natural System Contributing Waterbody
52	East City Ditch	LToho WCC	Man-made Contributing Waterbody
53	West City Ditch	LToho WCC	Man-made Contributing Waterbody
54	Shingle Creek including Western Branch (West Shingle Creek)	LToho WCC	Natural System Contributing Waterbody
55	Lake Tohopekaliga	LToho WCC	Reservation Waterbody
56A	WPA Canal	LToho WCC	Man-made Contributing Waterbody
56B	Gator Bay Branch	LToho WCC	Man-made Contributing Waterbody
57	Fanny Bass Ditch	LToho WCC	Man-made Contributing Waterbody
58	Fanny Bass Pond	LToho WCC	Natural System Contributing Waterbody
59	Drawdy Bay Ditch	LToho WCC	Man-made Contributing Waterbody
60	C-35 downstream of S-61	K-H-C WCC	Reservation Waterbody
61	Lake Cypress	K-H-C WCC	Reservation Waterbody
62	C-34 downstream of S63A	K-H-C WCC	Reservation Waterbody
63	C-34 upstream of S63A	K-H-C WCC	Reservation Waterbody
64	Lake Russell	K-H-C WCC	Natural System Contributing Waterbody
65	Lower Reedy Creek downstream of REED40 structure	K-H-C WCC	Natural System Contributing Waterbody
66	Upper Reedy Creek upstream of REED40 structure	K-H-C WCC	Natural System Contributing Waterbody
67	Bonnet Creek	K-H-C WCC	Natural System Contributing Waterbody
68	C-36	K-H-C WCC	Reservation Waterbody
69	Lake Hatchineha	K-H-C WCC	Reservation Waterbody
70	Lake Marion Creek	K-H-C WCC	Natural System Contributing Waterbody
71	Lake Marion	K-H-C WCC	Natural System Contributing Waterbody
72	Catfish Creek	K-H-C WCC	Natural System Contributing Waterbody
73	Lake Pierce	K-H-C WCC	Natural System Contributing Waterbody
74	C-37	K-H-C WCC	Reservation Waterbody
75	Lake Kissimmee	K-H-C WCC	Reservation Waterbody
76	Zipprer Canal east of G-103	K-H-C WCC	Reservation Waterbody
77	Zipprer Canal west of G-103	K-H-C WCC	Man-made Contributing Waterbody
78	Lake Rosalie	K-H-C WCC	Natural System Contributing Waterbody
79	Weohyakapka Creek	K-H-C WCC	Natural System Contributing Waterbody
80	Lake Weohyakapka	K-H-C WCC	Natural System Contributing Waterbody
81	Tiger Lake	K-H-C WCC	Reservation Waterbody
82	Tiger Creek	K-H-C WCC	Reservation Waterbody
83	Otter Slough	K-H-C WCC	Natural System Contributing Waterbody
84	Jackson Canal DS of G-111 Structure	K-H-C WCC	Reservation Waterbody
85	Jackson Canal US of G-111	K-H-C WCC	Man-made Contributing Waterbody
86	Lake Jackson	K-H-C WCC	Natural System Contributing Waterbody
87	Parker Hammock Slough	K-H-C WCC	Natural System Contributing Waterbody
88	Lake Marian	K-H-C WCC	Natural System Contributing Waterbody
89	Fodderstack Slough	K-H-C WCC	Natural System Contributing Waterbody
90	No Name Slough	K-H-C WCC	Natural System Contributing Waterbody
91	Packingham Slough	KR Pool A	Natural System Contributing Waterbody
92	Buttermilk Slough	KR Pool A	Man-made Contributing Waterbody
93	Ice Cream Slough	KR Pool A	Man-made Contributing Waterbody
94	Blanket Bay Slough	KR Pool A	Natural System Contributing Waterbody
95	Armstrong Slough	KR Pool A	Man-made Contributing Waterbody
96	Tick Island Slough	KR Pool B/C	Natural System Contributing Waterbody
97	Pine Island Slough	KR Pool B/C	Natural System Contributing Waterbody
98	Sevenmile Slough	KR Pool B/C	Natural System Contributing Waterbody

Table I-1. Continued.

WR-ID	Water Body Name	Watershed	Rule Feature
99	Kissimmee River, Floodplain, C38, and remnant river channel As Defined by Project Lands	KR Pools A-E	Reservation Waterbody
100	Starvation Slough	KR Pool B/C	Man-made Contributing Waterbody
101	Oak Creek	KR Pool B/C	Man-made Contributing Waterbody
102	Ash Slough	KR Pool D	Natural System Contributing Waterbody
103	Gore Slough	KR Pool D	Natural System Contributing Waterbody
104	Fish Slough	KR Pool D	Natural System Contributing Waterbody
105	Cypress Slough	KR Pool D	Natural System Contributing Waterbody
106	Chandler Slough	KR Pool D	Reservation Waterbody
107	Istokpoga Canal East of S-67	KR Pool B/C	Reservation Waterbody
108	Istokpoga Creek	KR Pool B/C	Natural System Contributing Waterbody
109	C-38 & Remnant River Channel Pool E	KR Pool E	Reservation Waterbody

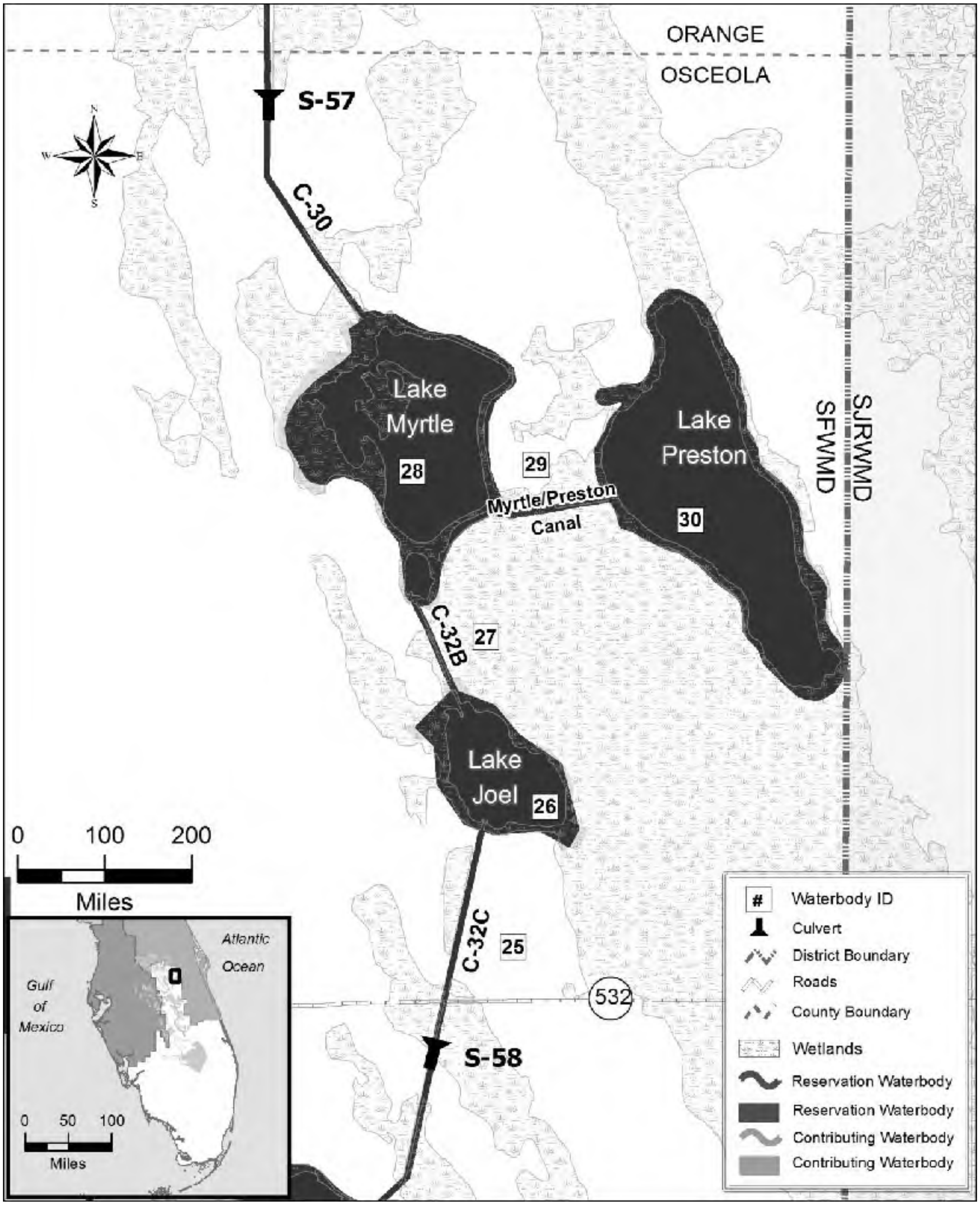

Figure I-1. Lakes Myrtle-Preston-Joel reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

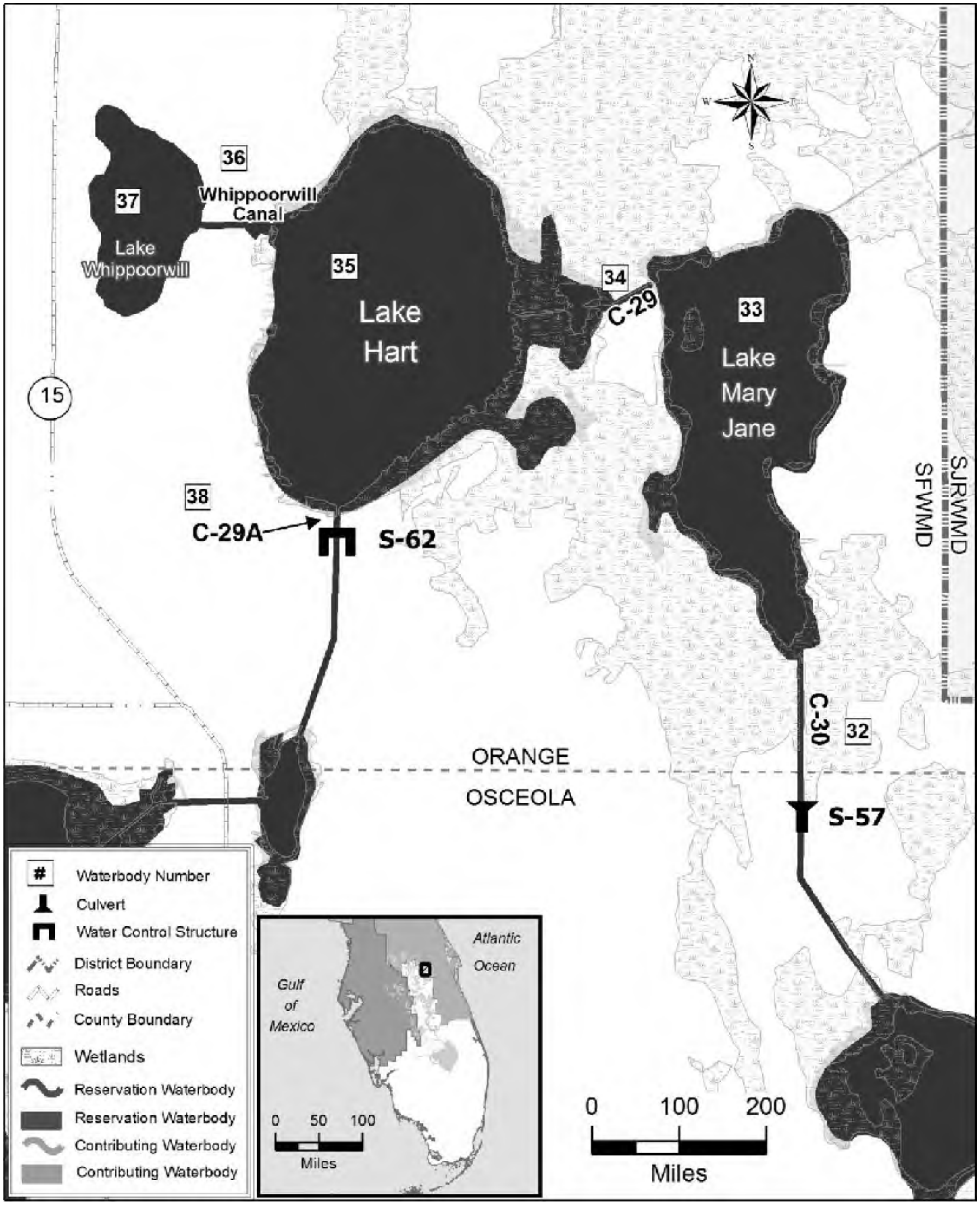

Figure I-2. Lakes Hart-Mary Jane reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

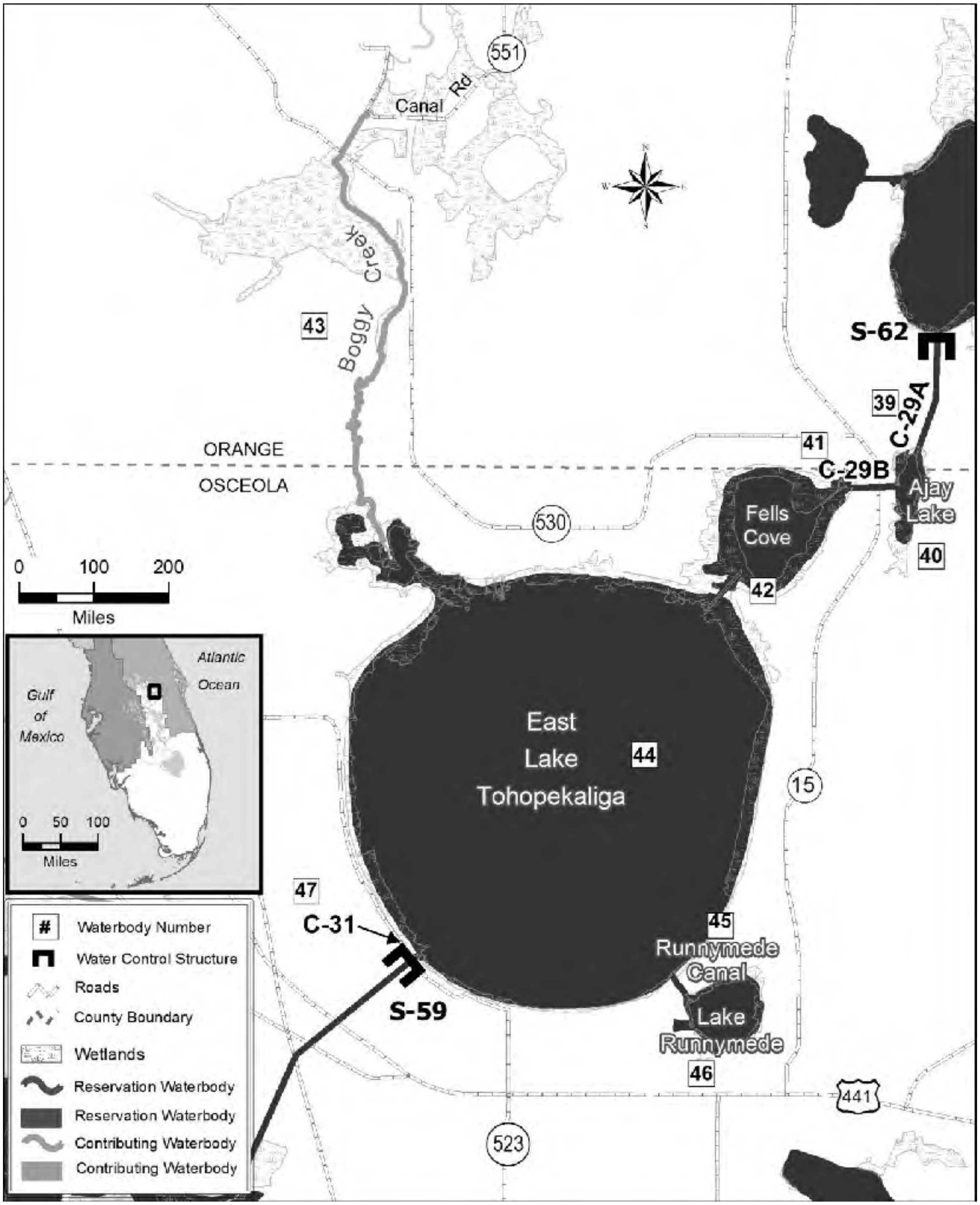

Figure I-3. East Lake Tohopekaliga reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

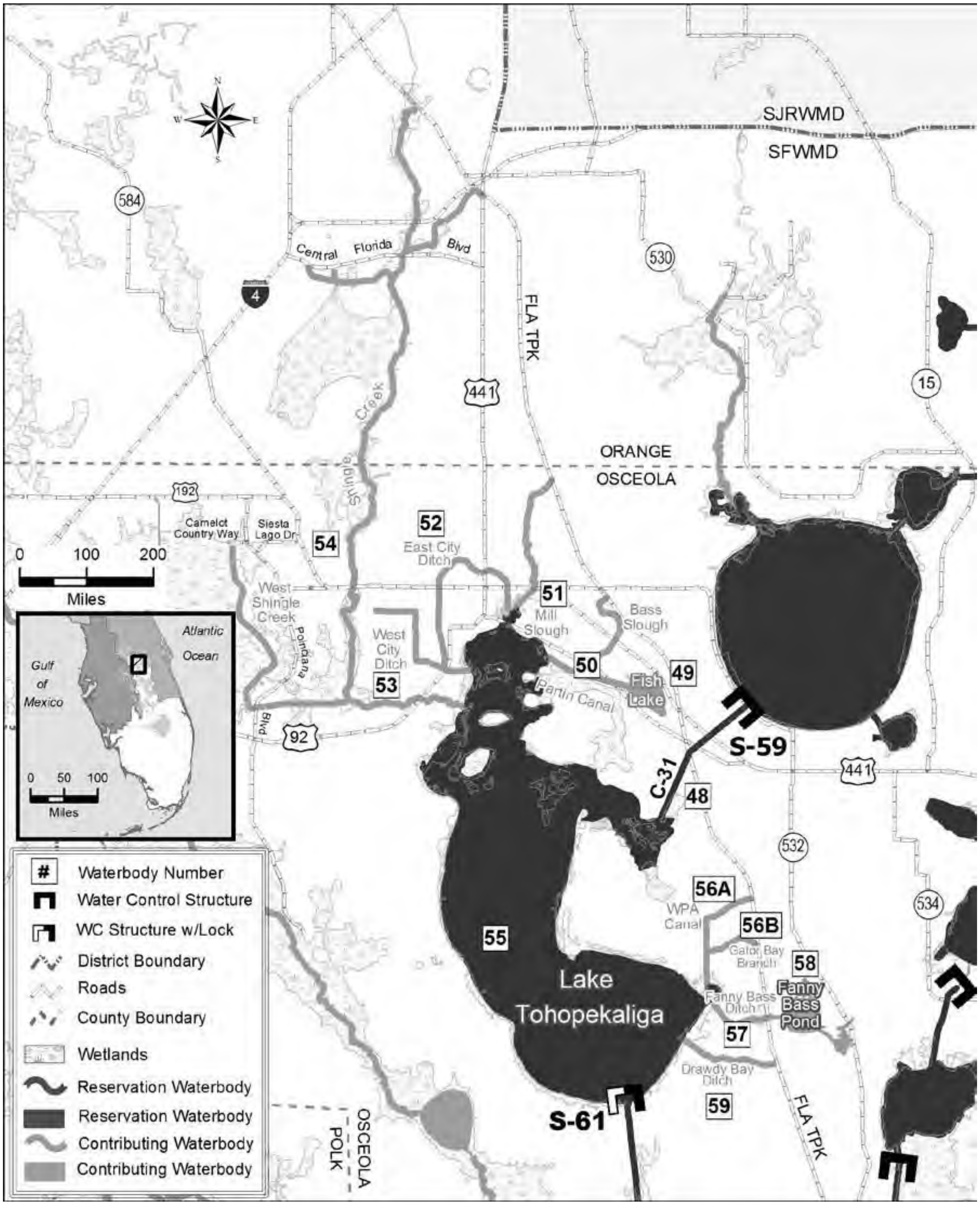

Figure I-4. Lake Tohopekaliga reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

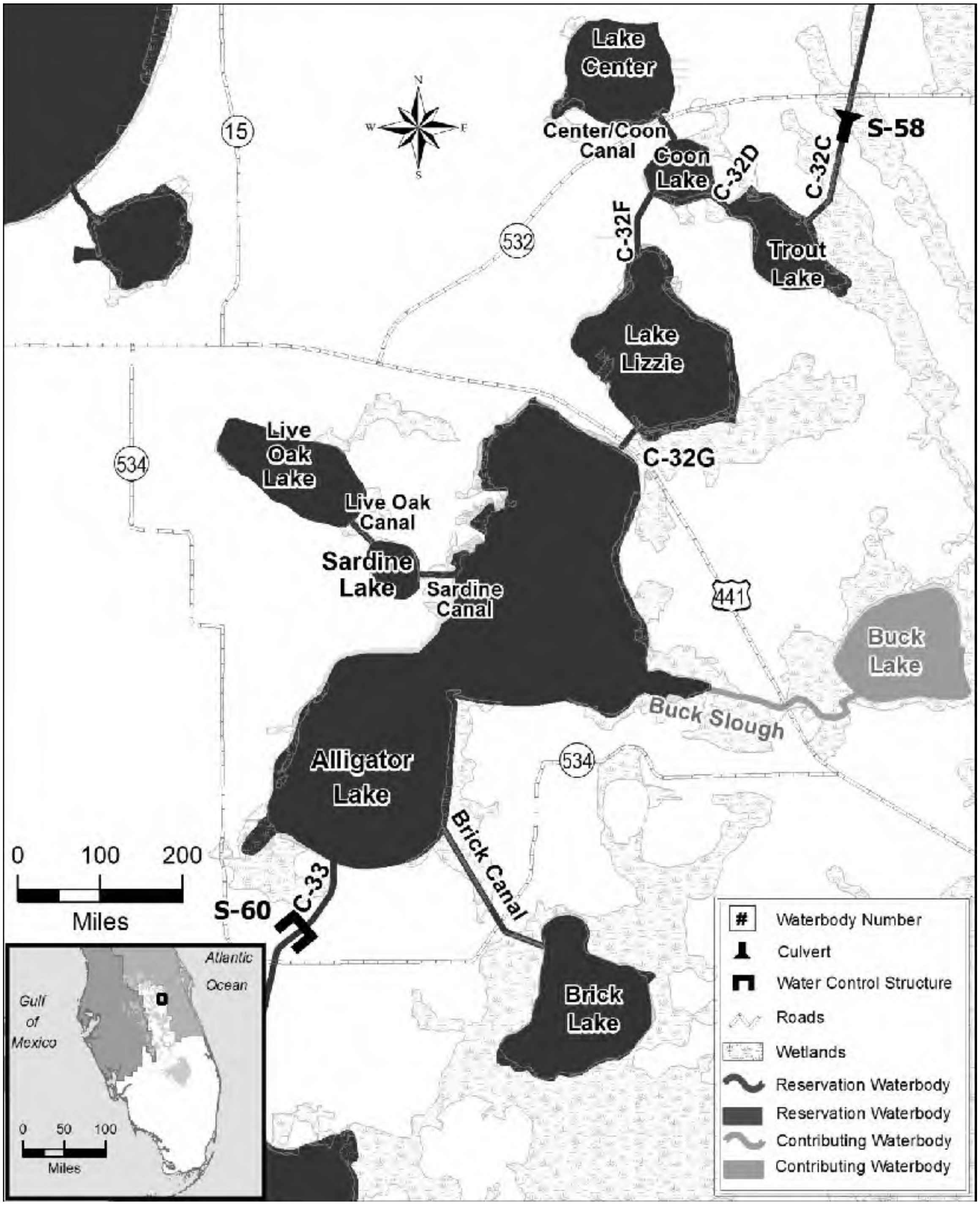

Figure I-5. Alligator Chain of Lakes reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

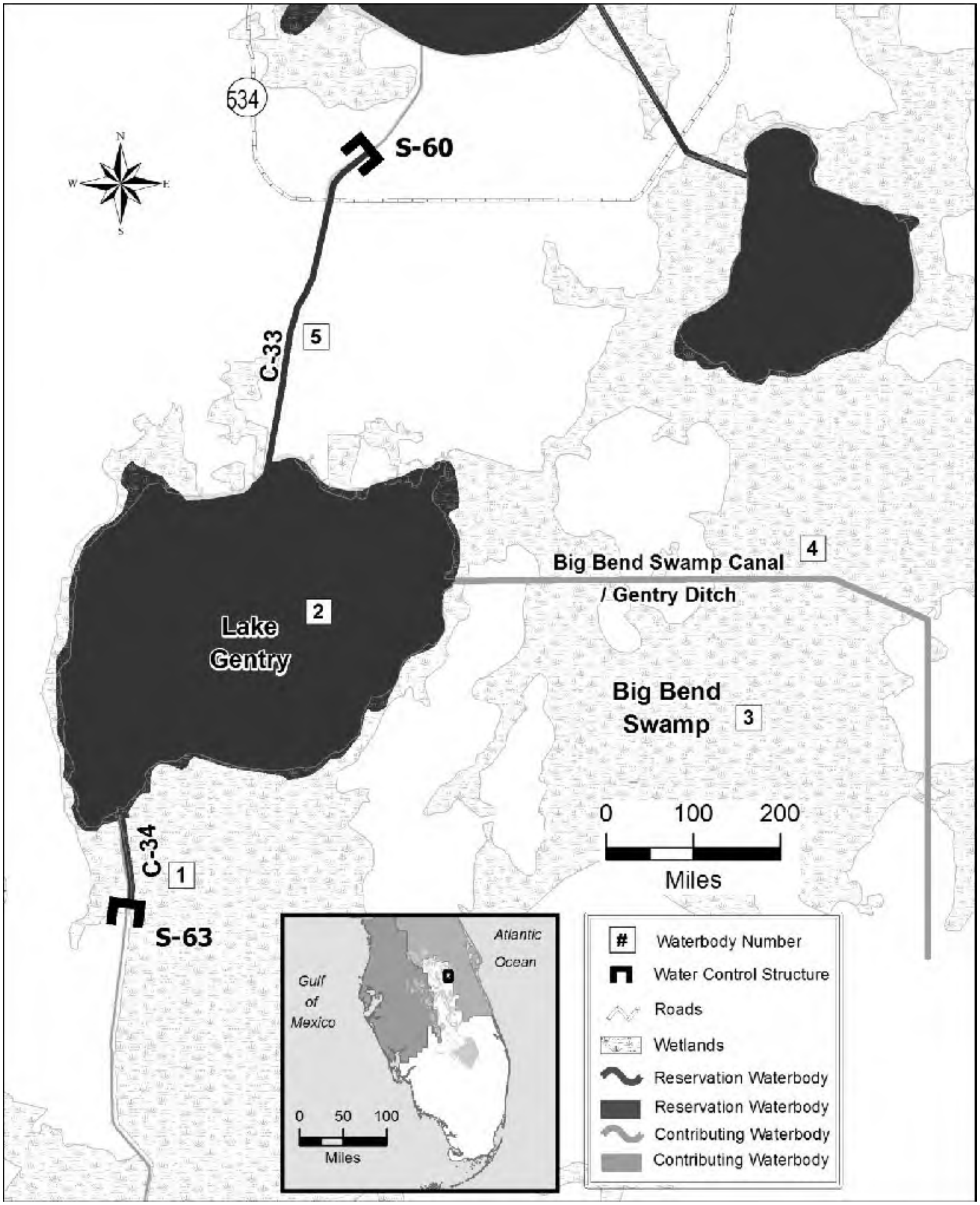

Figure I-6. Lake Gentry reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

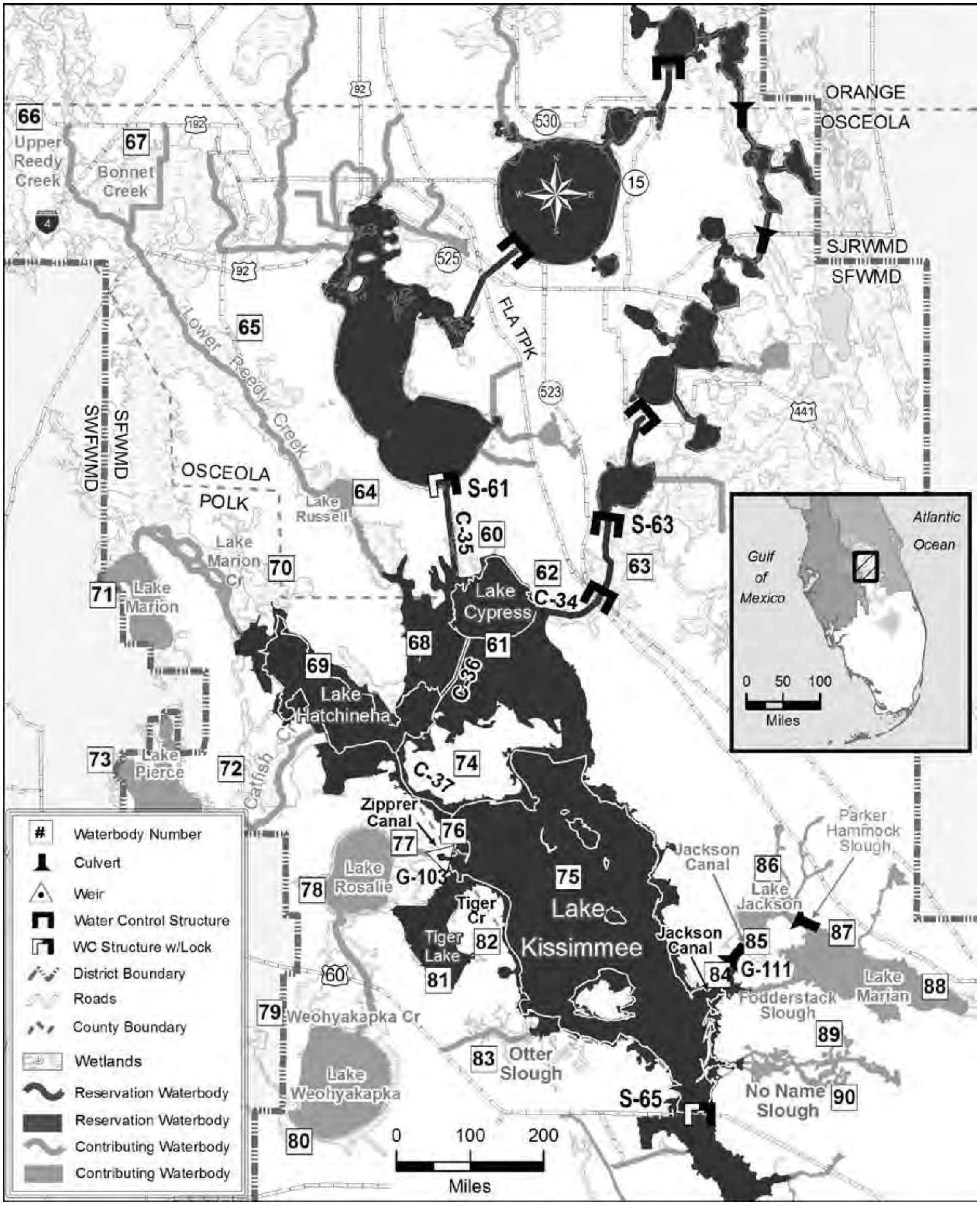

Figure I-7. Headwaters Revitalization Lakes reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

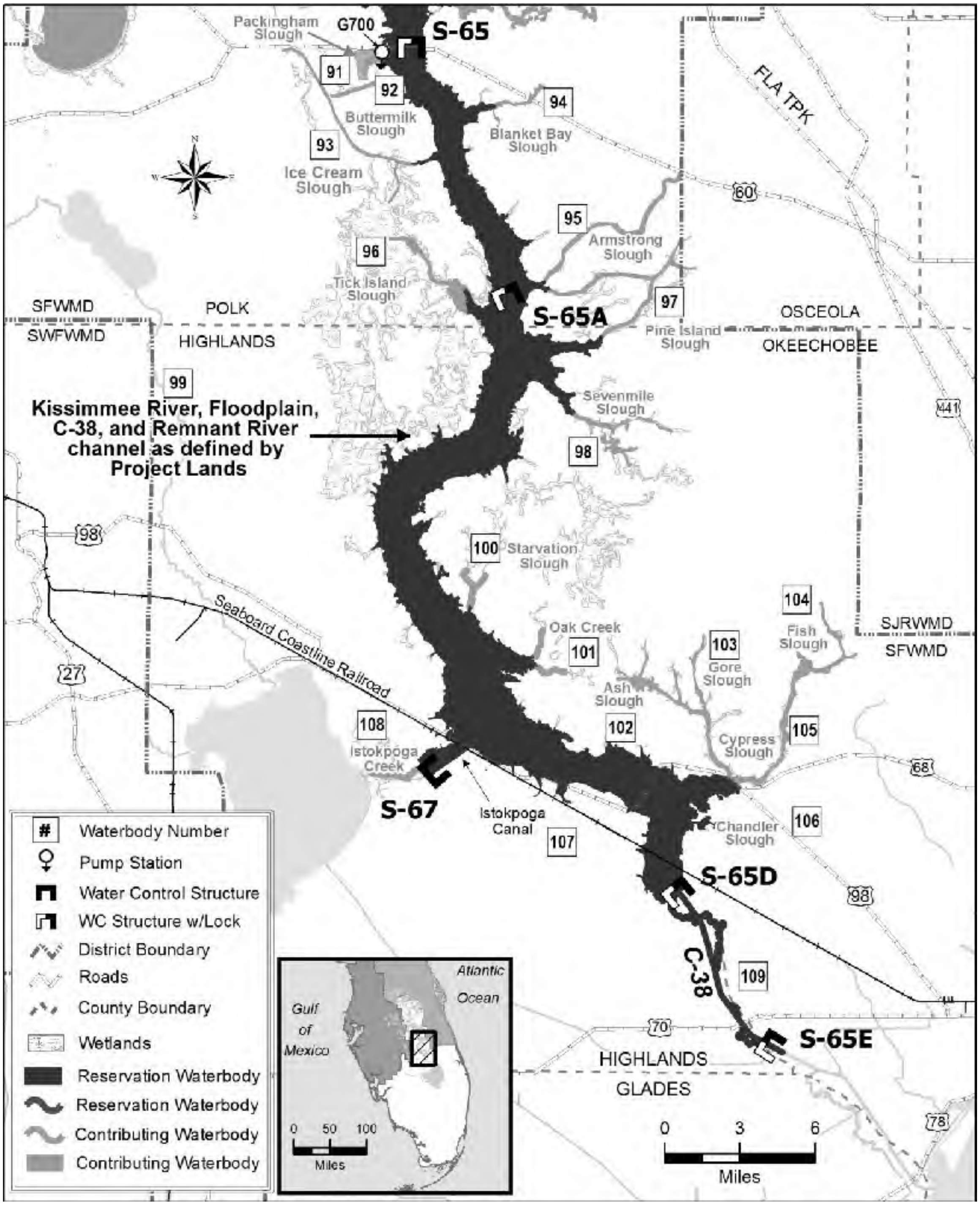

Figure I-8. Kissimmee River reservation waterbody.

SFWMD Disclaimer: *Features shown on the map are cartographic representations of reservation waterbodies and the features shown do not supersede legal descriptions or other regulatory criteria used to define such features on the ground.*

APPENDIX J:
SCIENTIFIC PEER REVIEW DOCUMENT

Scientific Peer Review of the Draft Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes

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April 17, 2009

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b. Restoration Expectations for the Kissimmee River Restoration Project

EXECUTIVE SUMMARY

The South Florida Water Management District (SFWMD) is undertaking the reservation of water for the Kissimmee River and the Kissimmee Chain of Lakes. A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, which includes both seasonal and location components for the protection of fish and wildlife in the Kissimmee River and the Kissimmee Chain of Lakes. Eight specific water bodies are the subject of the proposed water reservations, including the Kissimmee River and its floodplain (treated as a single reservation water body), and seven Chain of Lakes Reservation Water Bodies (Myrtle-Preston-Joel, Hart-Mary Jane, East Tohopekaliga, Tohopekaliga, Alligator Chain of Lakes, Gentry, and Kissimmee-Cypress-Hatchineha).

The "*Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*", which the Peer Panel reviewed, describes the technical information used by SFWMD to establish the relationship between lake and river hydrology and its associated effects on fish and wildlife. The peer review was conducted in support of the SFWMD rule development process for establishing eight water reservations in the Kissimmee basin. The Peer Review Panel was charged with determining if the technical information contained within the technical document and other supporting documents, can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife.

The Peer Review Panel determined that the supporting data and information used to develop the draft *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes* are technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information. Hydrologic models and analyses are well developed and documented, and the AFET-W model appears to reproduce observed surface and groundwater flow conditions satisfactorily for their intended application in developing performance measure hydrographs, which represent the annual pattern of water levels to protect fish and wildlife. The document uses appropriate hydrologic performance measures and supports their use with a thorough understanding of current scientific knowledge of wetland hydrology as related to fish and wildlife requirements, and with appropriate empirical observations and data where available.

The relationship between water levels and the condition of the broadleaf marsh, for the Kissimmee River and floodplain, and the pattern and extent of littoral zone inundation, for the Kissimmee Chain of Lakes, are well developed and these aquatic plant communities serve as suitable indicators for the protection of fish and wildlife. The Panel noted that considerable data are available on other taxa, especially fish and birds, facilitating the use of performance measures in hydrograph development and setting expectations for fish and wildlife responses. However, less information is available for the Chain of Lakes than for the Kissimmee River and its floodplain.

3

The Panel finds that the range in acceptability associated with reducing the seasonal low from the 90th to the 50th percentile would provide equivalent protection of fish and wildlife in the majority of water reservations, with the exception of the Kissimmee-Cyprus-Hatchineha, where reduction to the 50^{th} percentile would result in an excessive decline in littoral zone inundation and thus reduction in protection of fish and wildlife.

The Peer Review Panel recommends that future efforts be directed at explicitly quantifying the link between hydrologic performance measures and fish and wildlife protection. These data can be used to provide direct support for the assertion that broadleaf marsh is a reasonable surrogate for the link between hydrology and fish and wildlife protection. In addition, more attention to the wet prairie may be of value as an indicator of hydroperiod restoration at the upper extent of the floodplain. Further development of environmental indicators as well as greater monitoring would be helpful for the Kissimmee Chain of Lakes. Continuing to monitor the littoral zone, as well as wading birds and species of conservation concern, is appropriate, and, if feasible, monitoring of the fish species assemblage as an indicator should receive greater effort. The Peer Review Panel believes that the margin of error associated with the estimation of flow and stage can be combined with the range of acceptability associated with the biologic performance measures to show that the hydrologic uncertainty is small compared to the range of acceptability associated with biologic performance measures. The Panel recommends that SFWMD undertakes this exercise, but cautions that the results should be interpreted as relative rather than absolute measures of uncertainty. Finally, the Panel suggests expanding the conclusions section on page 7-51 to more explicitly summarize findings with respect to water needed for protection of fish and wildlife.

INTRODUCTION

Regulatory Overview

The South Florida Water Management District (SFWMD)'s Governing Board authorized the development of rules for the reservation of water to protect fish and wildlife in the Kissimmee River, its floodplain, and the Kissimmee Chain of Lakes in June 2008. A water reservation is a legal mechanism (Section 373.223(4), Florida Statutes) to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, which includes a seasonal and a location component. Eight specific water bodies are the subject of the proposed water reservations, including the Kissimmee River and its floodplain (treated as a single reservation water body), and seven Chain of Lakes Reservation Water Bodies (Myrtle-Preston-Joel, Hart-Mary Jane, East Tohopekaliga, Tohopekaliga, Alligator Chain of Lakes, Gentry, and Kissimmee-Cypress-Hatchineha).

In response, the SFWMD has produced a draft *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*. The technical information and recommendations in this document serve as the basis for the quantification of water, as well as its seasonal distribution and location, for the protection of fish and wildlife that will be adopted through the rulemaking process.

The SFWMD's Governing Board has determined that peer review of proposed reservations is, as a matter of policy, a preferred step in developing water reservation rules. Accordingly, this peer review report summarized the panel's evaluation of the scientific and technical adequacy of the *Technical Document*.

Project Background

The Reservation Water Bodies in the Kissimmee Basin are located in central Florida just south of Orlando and extending to the Kissimmee River's confluence with Lake Okeechobee. The Upper Basin consists of the Kissimmee Chain of Lakes (KCOL) including Lake Kissimmee, all interconnected today by canals with nine water control structures that regulate flow. The Kissimmee River and its floodplain extend from Lake Kissimmee to Lake Okeechobee and, like the Upper Basin, have been highly altered since 1954 by the Central and South Florida Flood Control Project authorized by Congress in 1949. Between 1962 and 1972 the entire river was channelized, greatly increasing its depth and width and reducing its length from 103 to 56 miles. These changes essentially eliminated the historic flooding patterns that had created and maintained the fish and wildlife habitat of its floodplain. Restoration began in the early 1990s, and by 2001 Phase 1 was completed with the backfill of 7.5 miles of canal. In association with this restoration activity, extensive data on 25 ecological performance measures have been collected by the District under the Kissimmee River Restoration Evaluation Program (KRREP), including data on hydrology, vegetation, other biological variables, and various physical and chemical factors.

Purpose

The purpose of this peer review is to determine if the technical information contained in the draft report (*Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*) is based on the best available information and can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife within the eight water reservation water bodies. For the purposes of this peer review, water for protection of fish and wildlife means water for "ensuring a healthy and sustainable, native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood, and population variation" (Association of Florida Developers v. Department of Environmental Protection, Case No. 04-0880RP, Final Order at 17). The fish and wildlife for which a water reservation may be established are existing native communities of fish and wildlife that would use the habitat in its restored state.

The *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes*, which this Peer Review Panel reviewed, summarizes the technical and scientific data, assumptions, models, and methodology used to support rule development to reserve water for the protection of fish and wildlife for specific water bodies located in the Kissimmee Basin. The information contained in this document includes: 1) an introduction to its purpose; 2) an explanation of water reservations; 3) identification and description of the reservation water bodies; 4) fish and wildlife resources, hydrologic requirements, and performance measures for the Kissimmee River and its floodplain; 5) fish and wildlife resources, hydrologic requirements, and performance measures for the Kissimmee Chain of Lakes; 6) hydrologic modeling for the Kissimmee Basin; and 7) quantification of water for the protection of fish and wildlife. In sum, this document describes the quantification of water, as well as its seasonality and location, to be reserved under state law in the Kissimmee Basin.

The Statement of Work is attached as Appendix A.

Peer Review Panel

The Peer Review Panel was composed of five scientists with backgrounds that complemented the scientific and technical subject areas and analyses that were relevant to rule development to reserve water for the protection of fish and wildlife in specific water bodies located in the Kissimmee Basin. The panel members were: J. David Allan, Ph.D. panel chair, (aquatic ecologist with expertise in ecological assessment and restoration); D. Derek Aday, Ph.D. (aquatic ecologist with expertise in fish ecology and fisheries biology), Barbara L. Bedford, Ph.D. (wetland ecologist with expertise in plant ecology, hydrology, and biogeochemistry), Michael W. Collopy, Ph.D. (wildlife biologist with expertise in avian ecology); and Robert Prucha Ph.D., P.E., (water resources engineer and hydrogeologist with expertise in integrated hydrologic modeling).

The Peer Review Panel conducted all of its work according to the terms of the Florida sunshine law. All meetings and communications among panelists were held at a noticed open meeting or through the SFWMD WebBoard, which is available for public viewing at http://webboard.sfwmd.gov. The Panel participated in aerial and ground tours of the Kissimmee River and Chain of Lakes. Public deliberations among panel members and District scientists encompassed one and a half days, which was followed by the preparation of this peer review report.

This peer review was conducted in support of the SFWMD rule development process for establishing eight specific water reservations for the Kissimmee River and Kissimmee Chain of Lakes. The Peer Review Panel was charged with determining if the technical information contained within the *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes* and other supporting documents can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife.

The Panel focused its review on the information contained in the draft *Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes* prepared by the SFWMD, which describes the methods used to support the water reservation rules for the eight water bodies. The Panel was also provided supplemental technical documents (viewable on the WebBoard) to facilitate making an assessment of whether best currently available technical information supports the relationship between the recommended water reservations and the anticipated fish and wildlife response. The Panel also requested that additional information, which was met by the SFWMD in a timely manner, be provided in response to the Panel's concerns.

PEER REVIEW COMMENTS

Panel Response to SFWMD Technical Questions

1. Do the environmental indicators selected provide the basis for protecting fish and wildlife in terms of ensuring sustainable native communities through natural cycles of drought, flood, and population variation?

Findings:

Kissimmee River and floodplain: For the Kissimmee River, the Technical Document summarizes extensive information for multiple components of the ecosystem, including vegetation and all vertebrate groups, indicating broad and thorough coverage of important environmental indicators. Three types of emergent herbaceous marsh (broadleaf marsh, wet prairie, and wetland shrub) are primary indicators of floodplain conditions, with particular emphasis on broadleaf marsh. Vegetation mapping over time and in combination with elevation and hydroperiod data provide a strong basis for monitoring vegetation. The Panel agreed that, given existing data, these are suitable indicators and also reasonable proxies for other fish and wildlife. However, the committee noted that a stronger empirical basis for tying fish to emergent vegetation should be acquired. Fish of the Kissimmee River also are a key environmental indicator both as an important biological assemblage and as a food supply for reptiles, birds, and mammals, and monitoring of the fish assemblage is extensive. Amphibians and reptiles appear less well known, as do mammals, whereas birds are better studied, particularly species of conservation concern and wading birds, both of which are appropriate. In the less well known groups, however, species lists and literature review adequately convey existing knowledge.

In response to reviewer questions, the District made available "Restoration Expectations for the Kissimmee River Restoration Project" (Appendix B). The specific expectations listed for plant communities, aquatic invertebrates, amphibians and reptiles, fish, and birds provide specific examples of indicators (e.g., wetland plant communities will cover > 80% of restored floodplain; fish targets at < 1% for bowfin, <3% for Florida gar, > 58% for centrarchids; long-legged wading birds > 30.6 km^{-2} on the restored floodplain). These are excellent indicators as well as specific expectations of success.

Kissimmee Chain of Lakes: Less specific information is available on which to identify environmental indicators for the seven water bodies of the KCOL under consideration. In the case of these water bodies, given the control of lake levels under the existing USACOE regulation schedule, this committee understood the goal to be maintaining the current characteristics of the lakes without further degradation, at least until the new regulation schedule is released by the USACOE. These characteristics have developed since the 1960s when the current regulation schedule was put in place, and reflect the diminished lake level fluctuations relative to those that occurred prior to regulation. The littoral vegetation that has developed under regulation is the key environmental indicator being used in this rule development. Vegetation is classified into seven categories, which differ in their representation among the seven lakes as a function of each lake's bathymetry. Although the Technical Document does not provide a great deal of guidance on how to evaluate each vegetation category, the committee's sense is that maintaining the extent of submerged aquatic vegetation and total littoral zone area, and limiting the presence of the invasive species, *Hydrilla verticillata,* are of particular importance. Given that the regulation schedule is set by the USACOE and not by the District, this approach is reasonable until the new schedule is determined. The fish assemblage contains species that are valuable from a recreational fishery standpoint, and there is adequate information on species composition, including trophic and habitat categorization and spawning season for many species based on the literature. Species lists are available for amphibians, reptiles, and mammals. Birds are better known, including the wading bird assemblage and three species of conservation concern (Everglades Snail Kite, Florida Sandhill Crane, and American Bald Eagle).

In summary, the Panel finds that that the Technical Document uses appropriate environmental indicators to provide the basis for protecting fish and wildlife. For both the River and the KCOL, multiple indicators are included, giving assurance that the broad needs of the ecosystem are met.

Recommendations:
It would be useful to have a table of indicators so that all are readily accessible. This would allow reviewers to offer more specific advice regarding development of potential metrics or additional indicators.

More attention to the wet prairie may be of value as an indicator of hydroperiod restoration at the upper extent of the floodplain.

A stronger empirical basis for tying fish to emergent vegetation should be acquired.

2: Are there any major environmental indicators not considered in our analysis that could significantly affect the quantity, timing, and distribution of water identified for protection of fish and wildlife?

Findings: The Panel agrees that the environmental indicators selected by District staff are entirely reasonable from a scientific perspective given current scientific understanding and data. As far as the panel could determine, no data exist that would indicate that any major additional indicators would affect the quantity, timing, and distribution of water identified for protection of fish and wildlife. The selected indicators are based on sound and extensive scientific knowledge of the systems at issue. However, an explicit list of the indicators in table format would make it easier for reviewers to determine if other indicators might be appropriate as more information about the systems becomes available.

Kissimmee River and floodplain: In the panel discussion with scientists from the SFWMD on day one, it was apparent that studies of the Kissimmee River associated with the restoration work provided a wealth of data, and that these studies were carried out in a highly professional manner. The Peer Review Panel did not find any significant

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shortcomings in the selection of environmental indicators for the purpose of establishing water needed to protect fish and wildlife. There may be groups that should be monitored to develop additional baseline data and insight into system function, and there may be computational approaches using existing data that provide greater insight into the response of targets. These suggestions will appear under recommendations associated with other questions, especially Question 9.

Kissimmee Chain Of Lakes: Because the KCOL are less intensively monitored than the River, additional monitoring of fish and wildlife populations, which based on information presented to the Panel does not appear to be extensive, could be considered in future work.

Recommendations:

Further development of environmental indicators as well as greater monitoring would be helpful for the KCOL. Continuing to monitor the littoral zone, as well as wading birds and species of conservation concern is appropriate, and, if feasible, use of the fish assemblage as an indicator should receive greater effort (see Question 9). A detailed table of indicators would be useful for scientists and policy makers interested in monitoring the success of these water reservations.

3A. Do the performance measures adequately represent the hydrologic requirements of fish and wildlife identified for protection?

Findings: Insofar as the District used the best scientific information, empirical data, and modeling tools available, and was operating under three identified constraints on the water available for the system, this committee thinks that the performance measures selected do adequately represent the hydrologic requirements of fish and wildlife identified for protection. Those three constraints (p. 1-8) are: (1) the existing Kissimmee Chain of Lakes (KCOL) regulations schedule set by the USACOE, which narrowed the range of water level fluctuations in the lakes and thereby reduced the quantity and quality of habitat for fish and wildlife; (2) the Headwaters Revitalization Regulation schedule for Lakes Kissimmee, Cypress, and Hatchineha; and (3) fully restoring the Kissimmee River and floodplain. These constraints impose limitations on restoring historic water flows, water level fluctuations, and seasonal and inter-annual variation to the KCOL. In addition, until more of the Kissimmee River restoration is completed, the USACOE cannot fully implement the Headwaters Revitalization schedule or restore historic hydrologic patterns to the Kissimmee River and its floodplain. The document clearly is based on understanding those three constraints and on sound conceptual understanding of the systems of concern, as well as on an impressive amount of empirical observations and data.

The document shows a sophisticated understanding of wetland hydrology in explicitly recognizing the various components of wetland hydrology – magnitude of flow, rates of change of flow and water levels, timing (seasonality) of flows and levels with respect to biota of concern, and duration and frequency of flows and levels. The document also recognizes that all of these components must be addressed in order to maintain, in the case of the KCOL, and restore, in the case of the Kissimmee River and its floodplain, the natural dynamic (spatially and temporally) mosaic of wetland communities in these systems and the fish and wildlife they support. District staff have used the best available scientific understanding and data on the linkages between hydrologic characteristics and specific organisms or groups of organisms (e.g., plant communities, fish communities, species of special concern). Their emphasis on flows, timing, and recession rates is appropriate.

3B. Do the 'range of acceptability' values proposed provide equivalent levels of protection for fish and wildlife?

Findings: There was considerable discussion among panel members about use of the word 'equivalent', particularly within the context of the headwater lakes portion of the Kissimmee Chain of Lakes (KCOL). There was strong general agreement that the range of acceptability values proposed in the technical document would, indeed, provide equivalent and adequate protection for fish and wildlife in the Kissimmee River (KR). In this case, performance measures included KR Flow (R-01), KR Stage Hydrograph/Floodplain Hydroperiod (R-02), and KR Stage Recession/Ascension (R-03). The target values and boundaries presented for these performance measures are clearly based upon sound scientific information and reasonable hydrologic assumptions. The link between hydrology and broadleaf marsh is particularly well supported; the link between broadleaf marsh and fish and wildlife protection is intuitive and conceptually sound, if somewhat lacking in empirical support. District biologists have a strong dataset on the Kissimmee River resulting from the restoration project and evaluation program, and the performance measures for quantification of fish and wildlife needs have already been externally reviewed. As such, the Panel is in full agreement that the range of acceptability values for the Kissimmee River provide equivalent levels of protection for fish and wildlife.

Panel members also agreed that the range of acceptability values in the Kissimmee Chain of Lakes provide equivalent levels of protection for fish and wildlife, with one caveat. The focus of KCOL analyses was 'performance measure hydrographs' for the seven reservation water bodies. The range of acceptability values come from sensitivity analyses associated with lowering the seasonal low of the performance measure hydrograph from the 90th to the 50th percentile of water levels on May 31 (based on historical data). To this end, the analyses considered important metrics such as recession and ascension rate, reduction in lake area and volume, and littoral zone inundation. Remarkably, reducing the seasonal low from the 90th to the 50th percentile resulted in little change in these systems, and the Panel expressed broad agreement that the range in acceptability values would provide equivalent protection of fish and wildlife. The notable exception was associated with Kissimmee-Cyprus-Hatchineha, where dropping the seasonal lows would result in a 1.7-foot decrease in water level. Of particular concern among panel members was the resulting drop in littoral zone inundation; at the 90th percentile, 90% of the littoral zone would remain inundated, whereas only 41% would remain inundated if the seasonal low was dropped to the 50th percentile. This is a significant change in littoral habitat for a system that already has the lowest percent littoral area (22%) of the reservation lakes (Table 5-10). Given the importance of littoral habitat to fish and wildlife (fish and vegetation, in particular), in the case of Kissimmee-Cyprus-Hatchoniha the Panel disagrees with the assertion that the range of acceptability values provides equivalent protection of fish and wildlife. With that caveat in mind, the Panel expressed agreement that the performance characteristics were based on sound science and reasonable assumptions, and that the range of acceptability values were reasonable and acceptable given the ecology and hydrology of the KCOL.

Recommendations:

Continued monitoring of the fish and wildlife communities in the KR and the KCOL is recommended. The Panel also recommends that data to better establish the link between fish and wildlife protection and hydrology be collected and evaluated. See also response to Question 9.

4. Are the hydrologic methodologies, models, analyses, and assumptions sufficiently supported by available scientific knowledge, research and data?

Findings: Hydrologic analyses conducted in this study relied largely on the use of a model developed using the fully integrated, physically-based hydrologic code referred to as MIKE SHE/MIKE 11. This code simulates all of the natural primary hydrologic processes that occur within the Kissimmee Basin using standard physically-based equations and allows flexible coupling between these processes, including fully-hydrodynamic channelized flow, two-dimensional overland flow, unsaturated zone flow, evapotranspiration and three-dimensional saturated zone flows. Model simulations are driven by external boundary conditions, such as rainfall and RET, and MIKE SHE allows significant flexibility in specifying input to the spatial and temporal input of this information. In fact, most parameters within the model can be specified as spatially variable. This code represents a valid tool for use in this analysis.

The AFET-W fully-integrated MIKE SHE/MIKE 11 model and the KRFHM floodplain hydraulic model (MIKE 11 model) as developed for this study are sufficiently supported by available scientific knowledge, research, and data. This report does not detail the considerable effort involved in preparing the earlier AFET model, but does provide appropriate references to this information. The AFET-W model represents a highly parameterized hydrologic flow model, which can increase the non-uniqueness of the solution. However, in most instances a physical basis for the parameter values and their distribution has been provided and thoroughly documented. In addition, the coupling of the various processes, such as channel or overland flow with unsaturated and saturated flows, provide considerable additional constraints on the parameterization compared to simulating flows using single-process codes.

The use of a spatially-variable RET time series in the AFET-W model and quantitative calibration to available groundwater data represent an improvement over the previous AFET model. Details of this calibration were somewhat limited in this report, but review of the AFET-W model calibration report (*Earth Tech, 2008. AFET-W Calibration Report KCOL Surface Water Supply Availability Study*) showed calibration of surface and groundwater improved over the AFET model. Limitations of the model, for example the limited number of groundwater wells in the southern model area, are well documented in this report.

5. Do the hydrologic methodologies, models, analyses and assumptions described in the report yield sufficiently accurate results to reasonably support their applications as described in the report?

Findings: The AFET-W model is used as the primary hydrologic tool for analysis in this study. It is used to simulate "with project" base condition surface water stages and flows, and lateral inflows. It is also used to generate upper- and lower-river target time series of stages and flows.

The degree to which the AFET-W model reproduces observed surface water flows and stages and groundwater levels throughout the basin provides an indication of the accuracy of simulated results for the "with project" base conditions. This model error appears to be small enough to reasonably support intended applications (Section 7). The AFET-W model meets most of the pre-defined calibration criteria for surface and groundwater (pages 6-9) as shown on Tables 6-1 to 6-3, though the model will never be able to exactly reproduce observed data due to error from a variety of sources. For example, some degree of error is expected in the measurement of input data such as rainfall or RET, in the conceptual or structural model framework (i.e., aquifer configuration, simplification of surface drainage, etc.), and in defining appropriate parameter values, most of which are spatially variable. Despite this inability to exactly reproduce observed system response, the AFET-W model appears to reproduce observed surface and groundwater flow conditions well enough for the intended application.

Uncertainty within the hydrologic modeling community is generally believed to be derived from three key areas; parameter, conceptual or structural, and data. Despite the increased uncertainty due to parameterization in the AFET-W model, most of the parameter values are physically based and carefully prepared and documented, and the benefit of using a model that incorporates all of the major hydrological processes is believed to greatly outweigh the inability to fully assess the model uncertainty. Plots showing the model margin of error (Figures 6-44 to 6-51) appear to be reasonable estimates of the predicted hydrologic modeling error associated with flow and stage.

Recommendations:

Revise the Draft Technical Document to discuss how the results of the margin of error, or model prediction uncertainty, will be used in Section 7.

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6. Can/should the margin of error associated with the estimation of flow and stage as defined in this report be combined with the range of acceptability associated with the biologic performance measures, for the purpose of describing to policy makers boundaries within which they are equally sure (or unsure) that the desired protection of fish and wildlife will be achieved?

Findings: The margin of error associated with simulated flow and stages in the Kissimmee River and the Chain of Lakes can and should be used to assess the impact of modeling uncertainty on the estimated volume of water required for protection of fish and wildlife. This would provide greater confidence (and transparency) that the reported targets/thresholds will protect fish and wildlife, at least within the range of hydrologic model uncertainty. It would also be useful to show that conclusions reached in this report will not be significantly affected by results of hydrologic analysis. Finally, it would validate the use of the AFET-W model in this type of application.

Recommendations:

The Peer Review Panel believes that the calibrated AFET-W model margin of error can be incorporated into final target time series relatively easily and with the information already provided in the report. For example, the margin of error calculated as upper and lower bounds around predicted "with project" stages on the duration curves for various structures (i.e., Figures 6-44 through 6-51, on pages 6-78 to 6-81) could be translated onto the lake and river target time series plots prepared in either the Preliminary Analysis Section 7 (i.e., Figures 7-23 to 7-29 for lakes, and Figures 7-30 to 7-34 for river). Additional upper-lower bounds may have to be generated for some of these figures. Because the Detailed Analysis accounts for the timing of events and yields more water, an effort should also be made to show how tables like 7-10 would change. The margins of error were calculated on a monthly basis to avoid the short-term daily offsets in flow and stage. Either daily or monthly average errors could be used to revise the estimates given in Table 7-10.

7. Are the methodologies used to develop the Target Time Series for the river and for the lakes scientifically and technically valid, given the constraints of the initial reservation?

Findings: The methodologies used appear to be valid, given the constraints of the initial reservation (i.e., existing KCOL operating schedule in the upper basin, the Headwater Revitalization Project in the headwaters of the Kissimmee, and a fully-restored Kissimmee River).

The steps for developing the lake target time series are relatively straightforward, in that the seasonal high stage was related to the high pool regulatory stage for each reservation water body, thereby protecting all of the fish and wildlife habitat possible. A range of seasonal lows was also developed for each water body, using upper and lower threshold

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values (90^{th} and 50^{th} percentile, respectively). Stage hydrographs were used to show the range of water required for the protection of fish and wildlife. In three of the reservation water bodies, species- or taxa-specific requirements were used to create a third stage in the hydrograph. These modifications were inserted to accommodate specific hydrologic needs during the nesting season of wading birds at Bird Island Rookery (at Lakes Hart and Mary Jane) and apple snails at Lakes Tohopekaliga and Kissimmee, Cypress and Hatchineha. These modifications appear to sufficiently adjust the recession rates to accommodate the life history requirements of these particular species.

In contrast, the steps for the Kissimmee River are more complex and somewhat difficult to follow. However, after reviewing two additional documents provided by SFWMD on how upper and lower targets for the Kissimmee River were determined, the Panel agreed that, while the methodology had many steps, it was well documented.

Given the importance of developing a reasonable target time series that meets performance measures R-1 to R-3, it seems unclear what sort of error is associated with the final set of Kissimmee River target time series. In other words, because the target time series are hypothetical and non-unique, if a starting point other than the "with project" base conditions time series was used with the "trial and error" methodology, how different would the resulting upper and lower target time series be from those estimated in this report, if at all? This could be clarified in the report. Part of this may be due to the difficulty following the series of steps.

It seems unclear why a preliminary and more detailed method is presented in Section 7, when the results of detailed analysis point out that the preliminary method doesn't consider timing of events, and more water appears available if daily timing is considered.

Recommendations:

Given the "trial and error" methodology used to develop upper and lower target time series for the Kissimmee River, it would be helpful to clarify why using starting conditions other than the "with Project" base conditions would not produce significantly different results.

The report should clarify why upper and lower targets are defined using a different set of performance measure components.

The report should clearly indicate which set of results (preliminary or detailed analysis) decision-makers should rely on to define the water needed for protection of fish and wildlife. For example, in the case of the lakes, the detailed analysis (Table 7-10) shows considerably more water available than the preliminary analysis (Table 7-9). If results from the more detailed analysis are more realistic and accurate, the discussion of the preliminary analysis should be removed to avoid possible confusion.

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8. Is the water identified for the protection of fish and wildlife technically supported for each of the eight reservation water bodies?

Findings: The document clearly distinguishes the water needs of the eight reservation water bodies and appropriately identifies them given the identified constraints (see 3A above). As discussed under Question 3A, the document uses appropriate hydrologic performance measures and supports their use with a thorough understanding of current scientific knowledge of wetland hydrology as related to fish and wildlife requirements, and with appropriate empirical observations and data where available. The modeling tools used appear to be at the cutting edge of current modeling practice and extend the available knowledge by integrating the hydrology of the several water bodies, where appropriate, to obtain a more thorough picture of the entire Kissimmee system. Furthermore, the modeling tools used have been developed in such a way that they can be adapted as the USACOE adopts new water regulation schedules and the Kissimmee restoration is completed.

9. What additional work, if any, should be considered to enhance the technical criteria for future updates of these water reservations?

Recommendations:

The Panel was impressed with the clarity and comprehensiveness of the technical document and there was broad agreement that the science linking hydrology to vegetation characteristics (especially broadleaf marsh) was particularly strong. Furthermore, current scientific understanding and data would support the assumption by District staff that vegetation is a strong surrogate for "habitat quality" for fish and wildlife. The Panel strongly suggested, however, that future effort be directed at explicitly quantifying the link between fish and wildlife and hydrology. These data can be used to provide direct support for the assertion (widespread in the technical document) that broadleaf marsh is a reasonable surrogate for the link between hydrology and fish and wildlife protection. To that end, there are many acceptable ways to collect and analyze relevant data. Among these, the Panel suggests the following: 1) continuous vegetation monitoring in the Kissimmee River; 2) continued data collection on the specific species (e.g., wading birds, apple snails) that were used to modify target time series in the KCOL; 3) selection and monitoring of specific fish and wildlife indicator species in the Kissimmee River and KCOL to ensure that project goals associated with protection of fish and wildlife are being met; and 4) continued monitoring of species composition for fish and wildlife in the Kissimmee River and KCOL. From these data collections, metrics that track populations (e.g., size, age structure, etc.) and communities (e.g., relative abundance, species evenness and richness, beta diversity, etc.) can be calculated through time to ensure ongoing protection of fish and wildlife in the Kissimmee River and KCOL. The Panel suggests that, if possible, additional data collections be focused specifically on amphibians. However, the Panel recognizes significant constraints associated with collecting those data.

The Panel also recommends that hydrologic uncertainty in the "with Project" base condition simulations be incorporated into the detailed target time series in Section 7. Doing so should demonstrate that even with the hydrologic uncertainty noted on Figures 6-44 to 6-51, conclusions related to the amount of water available above target time series will not change significantly.

10. Does the compiled information, including data, analyses, assumptions, and literature review, provide a reasonable basis for the conclusions reached about the water needed to protect fish and wildlife for each of the eight reservation water bodies?

The Panel is in unanimous agreement that the compiled information provides a reasonable basis regarding water needed to protect fish and wildlife for each of the eight reservation water bodies. The documentation is extremely comprehensive, well organized, intuitive, and conceptually sound. Ostensibly, the goal of this peer review panel is to identify data gaps or flaws in logic that prevent agreement with conclusions reached by SFWMD scientists. In all instances, however, questions regarding clarification of concept or methodology were readily addressed by District biologists and additional material was provided, when necessary, to support those responses (e.g., supplemental material available through the WebBoard). There was discussion among panel members and District biologists regarding the meaning of "protection of fish and wildlife", and panelists' questions were answered and concerns about how to quantify protection were resolved. Additional discussion focused on the use of broadleaf vegetation as a surrogate for the link between hydrology and fish and wildlife protection, and suggestions for strengthening that link are included in Question 9.

The presentation of the technical documentation was thorough and appropriate. However, the Panel does suggest expanding the conclusions section on page 7-51 related to water needed for protection of fish and wildlife. Given that this is the focus of the water reservation, additional detail in this section would be useful to bolster the case that these water reservations provide adequate protection of fish and wildlife, and would aid policymakers that might be less familiar with, or interested in, specific details.

The conclusion section should be very clear on the quantity of water required for protection of fish and wildlife. The discussion of results in Section 7 and the conclusions focus mostly on the amount of water available above that needed for protection of fish and wildlife. Conclusions could be improved by tabularizing the quantities of water needed for protection of fish and wildlife in each of the eight water bodies defined on pages 1-2 combined with estimates of hydrologic modeling uncertainty described in the response to Question 6. In addition, conclusions could also be improved by clarifying which set of analysis results decision-makers should rely on for assessing the amounts of water available above reservation needs. For example, results of the detailed analysis appear more realistic and indicate considerably more water is available than the preliminary analysis. To avoid potential confusion, the report should clearly show decision-makers how to use results of the preliminary and detailed analysis (i.e., tables 7-9 and 7-10). If results of the more detailed analysis are more realistic than results of the preliminary analysis, the discussion and results of the preliminary analysis could be removed. Finally, Tables 7-9 and 7-10 and Figures 7-23 to 7-34 should also be modified to reflect the approximate range of uncertainty in the "with Project" base condition simulation.

In the technical document, reference is made to the wildlife response already observed along the partially-restored sections of the Kissimmee River. Given the reliance of the overall approach to reestablishing the linkages between hydrology, vegetation, and fish and wildlife, it would be helpful if documentation of these responses could be provided. A useful place to insert relevant data summaries and explanatory text to support these initial observations would be in Technical Report Appendix A (Kissimmee River Restoration Project Background). These preliminary findings would support the statement in the document and provide more detailed information to the reader regarding fish and wildlife responses to restoration that have been documented to date.

OVERALL FINDINGS AND RECOMMENDATIONS

The Peer Review Panel commends the District staff for preparing a report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and logical in its flow. In addition, the Panel found the site visit invaluable, including the tour of Lake Toho and particularly the helicopter tour of the Kissimmee Chain of Lakes and Kissimmee River. Without this aerial tour it would have been difficult for the panelists to fully comprehend the spatial extent of the combined waterways, their interconnectedness, and the extensive floodplain area of the restored Kissimmee River. The establishment of water reservations for the eight water bodies of the Kissimmee basin is a challenging task due to the complexity of linking hydrology to fish and wildlife resources, as well as the legal, social, and economic constraints of recommending a water resource use strategy for such complex and coupled ecosystems.

The supporting data and information used to develop the draft technical report are technically sound, and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information. The premise of the draft technical report is that the hydrologic requirements of the existing fish and wildlife resources can be expressed as a performance annual hydrograph that represents the annual patterns of water levels needed to protect fish and wildlife for each reservation body. This is accomplished for the Chain of Lakes by specifying seasonal high and low stages, connecting these with ascension and recession events, and adjusting the resulting hydrograph in accord with the specific hydrologic requirements of fish and wildlife in individual lakes. In the case of the Kissimmee River and its floodplain, this is accomplished through the use of flow and stage duration curves at specific water control structures.

Regarding the sufficiency of literature and data supporting the draft technical report, the Panel noted that the data presented was scientifically sound but at times was insufficient to support the various linkages that are critical to establishing that fish and wildlife are adequately protected. The panel agreed that the District utilized the best available scientific knowledge and data to support the various linkages that are critical to establishing that fish and wildlife are protected. However, the panel also recognized that current understanding and data are insufficient for establishing these linkages more directly and for certain taxonomic groups. For example, while the hypotheses and assumptions linking hydrology to the protection of the broadleaf marsh are particularly strong, and a great deal of biological data are available for the Kissimmee River and floodplain, the Panel recommends that further effort be made to establish linkages between broadleaf marsh and fish and wildlife, or between hydrology and fish and wildlife, on an ongoing basis. This could include monitoring of vegetation in the Kissimmee River and its floodplain, of the extent of the littoral zone in the lakes, of specific species (e.g., wading birds, apple snails) that were used to modify target time series in the Chain of Lakes, of specific fish and wildlife indicator species in the Kissimmee River and Chain of Lakes, and of additional fish and wildlife in the

Kissimmee River and Chain of Lakes, including amphibians and reptiles for which information currently is sparse. Appropriate metrics that can be derived from such data include those that track populations (e.g., size, age structure, etc.) and communities (e.g., relative abundance, species evenness and richness, beta diversity, etc.)

Second, the Peer Review Panel believes that the margin of error associated with the estimation of flow and stage can be combined with the range of acceptability associated with the biologic performance measures to show that the hydrologic uncertainty is small compared to the range of acceptability associated with biologic performance measures. The Panel recommends that SFWMD undertakes this exercise, but cautions that the results should be interpreted as relative rather than absolute measures of uncertainty.

Third, the Panel suggests expanding the conclusions section on page 7-51 related to water needed for protection of fish and wildlife. Given that this is the focus of the water reservation, additional detail in this section would be useful to bolster the case that these water reservations provide adequate protection of fish and wildlife, and would aid policymakers that might be less familiar with, or interested in, specific details. The emphasis in the conclusions section should focus more on actual quantification of water needed for protection of fish and wildlife for the eight reservations, rather than on the amount available for other uses. The conclusions should also clearly describe why both preliminary and detailed analyses were conducted and how decision-makers should utilize this information. It was unclear why discussion of the preliminary analysis is needed if the more detailed analysis provides more realistic quantities.

APPENDICES

Peer Panel Statement of Work

Restoration Expectations for the Kissimmee River Restoration Project

APPENDIX A

STATEMENT OF WORK FOR PEER REVIEW OF TECHNICAL DOCUMENTATION TO SUPPORT DEVELOPMENT OF WATER RESERVATIONS FOR THE KISSIMMEE RIVER AND CHAIN OF LAKES

Date:	January 29, 2009
Project Name:	Kissimmee River Water Reservation
Peer Review Coordinators:	Jason Godin and John Zahina, Water Supply Planning Division Water Supply Department
Project Manager:	Lawrence Glenn, Kissimmee Division, Watershed Management Department
Requesting Offices:	Watershed Management and Water Supply Departments

1 Introduction

This request for peer review pertains to the draft project technical report entitled "Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes." This peer review is being conducted to support the rule development process for establishing a water reservation for the area encompassed by the Kissimmee Basin. The South Florida Water Management District (SFWMD) is a regional water resource protection and management agency with legal authorities identified by state law, specifically Chapter 373 Florida Statutes (F.S.). Pursuant to Section 373.223 F.S., the Governing Board of the SFWMD has directed staff to develop a reservation or allocation of water to protect water identified for the protection of fish and wildlife in the Kissimmee Basin.

The purpose of this peer review is to determine if the technical information contained within the draft technical report based on the best available information and other reference materials can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife. For the purposes of this peer review, water for protection of fish and wildlife means water for "ensuring a healthy and sustainable, native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood, and population variation." (Association of Florida Community Developers v. Department of Environmental Protection, Case No. 04-0880RP, Final Order at 17). The fish and wildlife for which a water reservation may be set are existing native communities of fish and wildlife that would use the habitat in its restored state.

1.1 Peer Review Overview

The peer review panel shall read the draft technical report and related background information identified in this statement of work, participate in the technical workshop, submit written comments on the draft project technical report, and work with the panel chairperson to develop a final peer review panel. The panel chairperson shall submit a

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comprehensive final peer review report to the SFWMD that meets the objectives noted above.

This review will include a response to the SFWMD questions asked of the panel, a summarization as to whether the panel agrees or disagrees with staff's estimation of water needed for protection of fish and wildlife, and recommendation of action to resolve outstanding technical issues. The expert panel is requested to provide specific recommendations to address deficiencies in the information presented in the document. Florida's Government-in-the-Sunshine Law requires that all discussion and interactions related to the peer review are conducted in a publicly accessible format, such that they should only take place at the peer review workshop or through the SFWMD web-board. The panel members shall have no direct or potential conflicts of interest and will comply with Florida Sunshine Laws (see section 1.2).

1.2 Panelist Requirements and Expertise

It is required that each panelist shall have the following skills:

- Expertise in one or more of the following: (1) freshwater wetland / plant ecology, (2) avian ecology, (3) riverine fish ecology, (4) lacustrine fish ecology, (5) hydrologic modeling, or (6) hydrology and hydrogeology linking freshwater flow (surface and groundwater) to ecological resources.
- Effective communication and writing skills
- Availability to dedicate significant time resources during the peer review period
- Availability to participate in the technical workshop
- Ability to conduct an objective and independent scientific review

In addition to the above requirements, the chairperson must also have excellent communication, writing, and report organization skills. Experience chairing peer review panels and consolidating comments from multiple panelists is preferred. It is preferred, but not required, that each panelist have a demonstrated ability to understand the potential impacts to the hydrologic system in the South Florida region from simulated changes in hydrologic conditions, operational guidelines, and management objectives.

The SFWMD has organized the peer review process in accordance with accepted scientific review practices. Care will be taken in selecting the panelists to assure they are independent of the SFWMD. Panelists should have no substantial personal or professional relationship with the SFWMD or any other organization involved in environmental management in Central Florida. The panel can therefore be reasonably assumed to be objective in evaluating materials presented. Such objectivity is the cornerstone of any true independent peer review process. Each panelist shall submit a signed disclosure of potential conflicts of interest and current curriculum vitae.

1.3 Guidelines for Peer Review

All panelists will receive payment for their participation on the panel. The chairperson shall have additional duties and will receive payment accordingly based on an estimate of additional hours for aggregating and reporting panel findings. All panelists shall attend a

one day field trip and 2-day workshop in Orlando, Florida (see Table 1). Once individuals have accepted their position and their contract is executed, they shall begin to review the project technical report and supporting reference materials provided in preparation for their participation in the public workshop. All notes and questions about the technical document from each panelist shall be recorded using the web board following the format in section 4.1.2. The workshop is a venue for panelists to work face-to-face with each other and staff and to ask questions and clarify any items as needed.
The web board serves as a repository to allow panelists to submit their comments on the draft project technical report and to distribute documents such as the peer review report. It also allows the SFWMD to disseminate other relevant information about the review, and it allows the general public to closely follow the development of the review. Discussions among panelists relating to this peer review shall occur only during the public workshops or through the web board.
Review of the technical documents by individual panel members shall be done independently prior to the public workshop. The panel will interact with one another to formulate a consensus of opinions at the public workshop. During the final workshop session the panel shall collaborate on recommendations and proposed changes to the technical document. The chairperson shall then write a final peer review report incorporating the SFWMD team responses and the panel's conclusions following the workshop.
The panel members will comply with s.286.011, F.S. (ATTACHMENT A) and therefore may not have discussions amongst each other outside the public forum. A publicly accessed web board provided by the SFWMD (Kissimmee River section of the Natural System Technical Document Peer Review Web Board: http://webboard.sfwmd.gov/default.asp?boardid=NSTDPR&action=0) shall provide the only means of communication between panel members outside of a public workshop. The peer review panel web board shall be used by the panelists and the public to post questions to the SFWMD Project Team and to post their work in progress following the format in section 4.1.2. This web board will be conducted in accordance with Florida's 'government in the sunshine' statutes. Panelists are required to read the information on the sunshine laws contained in ATTACHMENT A. Panelists may post materials, but may not respond to, or have discussions with, other members of the panel or have discussions via a liaison. SFWMD staff will provide a set of instructions for using the web board to each panelist.

2 Summary of Time Line and Responsibilities

Table 1: Time Line and Responsibilities

Task/Action	Responsible Party	Deliverable & Due Date for 2009
Execution of Purchase Order	Procurement	
Send Materials to Panelists	SFWMD	March 20, 2009
Task 1a: Acknowledgement of Receipt of Materials	Chairperson and panelists	Within 48 hours of receiving materials
Task 1b: Review of Documentation and Questions for SFWMD	Chairperson and panelists	March 26, 2009
Task 2. Field Excursion and Workshop	Panelists, chairperson and SFWMD team	March 30-April 1, 2009 (3-days)
Task 3: Final Peer Review Report	Chairperson submits report to SFWMD	April 17, 2009

3 Scope of Work

3.1 Duties and Tasks of Panel and Chairperson

During this project, the panelists will complete all tasks listed below.
Duties for Panelists

1. Review and evaluate the technical documentation (e.g., explanation of methods and approach used, tools, data sources, and assumptions)

2. Review all scientific or technical data, methodologies, and models used.

3. Review all scientific and technical analyses. Identify strengths and weaknesses of the analyses.

4. Review and evaluate materials provided to the panel during the course of the peer review process. All materials (excluding reference/background materials) provided up to the final peer review workshop shall be included in the evaluation by the panel.

5. Actively participate in the technical workshop.

6. Respond to the SFWMD questions of the peer panel in ATTACHMENT D.

7. Contribute to the final peer review report.

In addition to the panelist duties described above, the chairperson shall also perform the following duties:

1. Submit a draft workshop agenda. SFWMD will be taking minutes during each day of the workshop.

2. Assign tasks to panelists for completion of various sections the draft peer review report and ensure that they fully understand the requirements for each task.

3. Organize materials from other panelists and submit a draft peer review report and final peer review report. Each panelist shall read and review the materials provided independently, and then the panelists shall collaborate with the chairperson to develop the peer review report during the public workshop and through the web board. The chairperson shall coordinate all the activities and products of the panel. The chairperson shall be the editor of the peer review report and shall compile and reconcile the contributions from the other panelists.

4. Panel concurrence on each topic is recommended but not required. In the event that differences of opinion cannot be reconciled by the chairperson, then they may be reported as such or as minority opinions.

4 Work Breakdown Structure

4.1 Tasks for Panel

4.1.1 Task 1. Receipt of Materials

The technical documentation will be delivered to the panel by March 20th, 2009. The panelists shall acknowledge that they have read the statement of work and agree to the terms therein along with receipt of the following:

1. Documentation entitled, "Technical Document to Support Water Reservations for the Kissimmee River and Chain of Lakes."

2. Reference materials contained that accompany the draft technical document.

The panelist shall mail (electronic or post office) a signed and dated acknowledgment form (ATTACHMENT B) to the SFWMD once receiving a copy of the technical documentation.
The panelists shall read the statement of work and begin review of the project technical report and supporting reference materials that accompany the draft technical document. The reference materials are provided so the panelists may become familiar with tools, data, or other information that was synthesized in the technical document. The reference material is provided only as informative reference material; it is not under review and is not necessary that it be reviewed. Some of the reference material will be provided in the form of links to PDF files on the SFWMD's web site, or ftp site, or links to other web sites.

Deliverable 1a: Acknowledge receipt of materials by emailing the SFWMD peer review facilitator

Due Date: 48 hours after receiving materials. A signed form (ATTACHMENT B) should be mailed to the SFWMD peer review facilitator.

4.1.2 Task 1: Questions for SFWMD

The panelists shall provide questions to be considered by the SFWMD team in preparation for the workshop using the classification listed in Table 2. The panelists will develop specific and general questions regarding items in the project technical report and post them on the web board 5 days prior to the public workshop (March 26, 2009).

Table 2: Format for Questions

Major issues for discussion	
Minor issues requiring further clarification	
Typos and editorial comments in documentation	To be provided on electronic copy of documentation
Major strengths	

The panel shall review the project technical report in regards to its approach and review the documentation itself. The panel shall provide comments and recommendations on, but not limited to, the following:

- Format and clarity of the documentation in explanation of technical approach, data sources and assumptions, overall structure, and readability of text, tables, and figures.
- Suitability of analyses for its intended application.
- Capabilities, limitations, and future improvements.
- In areas where the panel identifies deficiencies, specific recommendations to resolve the deficiencies are required to facilitate revision of the documentation.

It is recognized that each member of the panel shall comment most substantively on areas within their primary expertise, but comments are welcome on other appropriate aspects of the technical document. In addition to comments and recommendations, the peer review report shall include responses to the topic questions. The responses by the panel shall be stated in the most unambiguous manner possible. The peer review report shall address the questions that accompany the draft technical document.

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Deliverable 1b: A list of initial questions and concerns from each panelist will be posted on the web board 5 days prior to the workshop. For the chairperson only – a categorized list of the single set of outstanding questions from the panel that require written response from the SFWMD team at the last day of the workshop. This list would contain questions that were not fully addressed at the workshop and needed to finalize the peer review report.

Due Date: April 1, 2009 the last day of the peer review workshop

4.1.3 Task 2: Peer Review Field Excursion and Workshop

The peer review workshop will last 2 days after the 1-day field trip. All portions of the 2-day workshop are open to the public. The field excursion will provide a driving and aerial tour of the project areas and is not a public forum. Therefore the panelists shall not discuss the project with each other aside from the public workshop. The workshop shall be held for panelists to discuss their individual findings in their reviews and to work together to reach a consensus on all sections of the peer review report. Up to a one half day portion of the workshop shall be dedicated to incorporating the SFWMD team's responses to the panel questions. The panel shall also consider other comments and clarifications made by the SFWMD team. Time will be allocated for public comments. The final part of the workshop will include an executive panel session. During this time, the chairperson will compile a list of any outstanding questions needed to complete the peer review report and give these questions to the SFWMD team prior to the conclusion of the workshop. At the conclusion of the workshop, a draft peer review report should be nearly completed. The chairperson is responsible for coordinating and delivering the final peer review report. The field excursion will be held prior to public workshops, and will consist of a helicopter flight and van tour of the Kissimmee River Floodplain and adjacent areas. All participating panelists will be required to sign a liability waiver (ATTACHMENT C). Panelists need to plan to be in Osceola County, Florida for a total of three 8-hour working days. The final peer review report is due two weeks after the peer review workshop (April 17, 2009).

The agenda for the workshop will be developed through consultation between the SFWMD and the chairperson. The SFWMD shall post a draft agenda on the web board one week prior to the start of the workshop. Final comments to the agenda shall be posted to the web board no later than two business days prior to the start of the workshop. The agenda will include, at a minimum, the following items:

1. SFWMD presentation including introductions, a brief overview, and meeting logistics
2. Question-and-answer session between the panel and SFWMD team.
3. Review of schedule and logistics for the final peer review report.

4. SFWMD responses to panel questions.
5. Public comment.
6. An executive work session for the panel to discuss and reach consensus on the peer review report. During this time the chairperson should compile a list of any outstanding questions needed to complete the peer review report and give to the SFWMD team prior to the end of the executive work session.

The peer review workshop will be conducted between the hours 8:30AM–5:00PM with up to a one-hour break for lunch each day. Lunch is not provided during the workshop.

Deliverable 2: Panelists will make their own travel arrangements to Orlando, Florida and actively participate in the workshop and field excursion. "Active participation" is defined as adhering to ground rules established by the workshop facilitator and the Florida Sunshine Law, attending all presentations, letting presenters know when any part of the presentation is not understood, be familiar with the SFWMD expectations for the peer review, and be ready to work within the schedule and through the logistics for the peer review. Personal appearance at the workshop is required. No panelist shall be allowed to attend via teleconference.

Due Date: The workshop will be March 31-April 1, 2009.

4.1.4 Task 3: Develop Peer Review Report

The peer review report is the final deliverable of this statement of work. The panel shall work collaboratively during the public workshop and through the web board to produce a report appropriate for a broad audience that includes scientists, stakeholders, and other interested parties. The chairperson shall seek consensus among the panelists. Each panelist is responsible for cooperating with the chairperson in the development of the peer review report.

The chairperson shall be the editor of this report and shall coordinate all the activities of the panel to this end. Panelists shall provide their products to the chairperson in a timely fashion closely following the review schedule provided in this statement of work. Panelists shall be contributors to the peer review report.

The peer review report shall include an executive summary, which includes the panel's recommendations. The SFWMD team's responses to these recommendations shall be included in the peer review report as part of the executive summary. The peer review report shall include responses to topic questions that accompany the draft technical document. The questions posed by the panel in Task 2, at the workshop and from the web board will be answered by the SFWMD team in a question/answer format. All questions will be answered in writing on the web board. The peer review report shall include minutes taken by the SFWMD from the public workshops as an appendix. The peer review report shall also summarize the key points made during the workshop. A video or audio tape of the meeting will also be made for SFWMD records.

The peer review report will at a minimum include the following sections (section names can be modified):

1. Executive Summary
2. Introduction
3. Panel responses to the questions that will accompany the draft technical document
4. Overall Findings and Recommendations

The peer review report shall use a Microsoft Word template for styles and formatting. Questions regarding the use of the template will be addressed by the peer review coordinators. The peer review report shall display line numbers for each page and display page numbers.

Deliverable 3: Completion and submission of a final report. The report shall be written in Microsoft Word and posted to the web board and emailed to the peer review facilitator.

Due Date: Chairperson shall post on the web-board the final report on or prior to April 17, 2009.

4.2 Duties and Tasks of SFWMD

The technical documentation and internet addresses to background materials will be provided to each panelist by SFWMD staff. SFWMD will perform the following duties, with the responsible person in parenthesis (see Section 8):

1. Prepare the technical documents to be distributed to the panel (technical lead)
2. Post background materials to panelists and provide the project technical report (peer review coordinators)
3. Finalize workshop agenda (peer review coordinators)
4. Handle logistics for the field trip and workshop (peer review coordinators)
5. Take minutes of the workshops and post on web board(peer review coordinators)
6. Respond to panelists' questions and comments at the workshop (technical lead)
7. Establish and monitor web board (peer review coordinators)

8. Review and approve all deliverables associated with this scope of work (all).

9. Staff will provide support to the panel during the workshop. The chairperson should inform SFWMD personnel what technical assistance they anticipate needing prior to the workshop.

10. The SFWMD will electronically record all workshop meetings (peer review coordinators).

The SFWMD agrees to perform its duties within the timeframes of this statement of work.

5 Evaluation Criteria for Acceptance of Deliverables

Task 1a Criteria for the acceptance of the Task 1a deliverable is acknowledgment of receipt of review materials and signing off on scope of work.

Task 1b Criteria for the acceptance of the Task 1b deliverable is the compilation of questions prior to March 20, 2009. The panel's questions, concerns, and information to the SFWMD should reflect thoughtful reading of the documents provided.

Task 2 Criteria for the acceptance of the Task 2 deliverable is active participation in the peer review workshop held March 30-April 1, 2009 (3 days) in Orlando, Florida.

Task 3 Criteria for the acceptance of the Task 3 deliverable will be the submittal of the final peer review report, representing a consensus view of the entire panel. The report shall include all of the sections outlined in this statement of work. The report shall summarize the key points made during the peer review workshop and include constructive steps to be taken to correct any deficiencies identified by the panel. The final peer review report shall respond to all the questions that accompany the draft technical document and to additional questions or issues raised in the workshop. It will also reflect a thoughtful and substantive evaluation of the technical document. The report should be objective in its evaluation and written so that it can be understood by a broad audience.

6 Payment for Services

A summery of deliverables and schedule by task associated with this project are set forth below in Table 3. Each panelist must provide a cost for each item in Table 3. Panelists are responsible for making and paying for their own travel and meal arrangements. Based on the hourly unit rate, the total task cost for each task in Table 3 should be completed. The unit rate shall include the costs incurred for travel, meals, phone calls, overhead, etc. All deliverables submitted hereunder are subject to review and approval by the SFWMD. Upon satisfactory completion of all services required, the panelists will be paid at the specified hourly unit rate that includes all labor and expenses.

The chairperson hereby agrees to provide the SFWMD all deliverables described in the statement of work in Microsoft Word format. Acceptability of all work will be based on the judgment of the SFWMD that the work is technically defensible, accurate, precise, and timely.

After issuance of the purchase orders, payment will be made following receipt and acceptance by the SFWMD of project deliverables in accordance with the schedule set forth below, and after receipt of an invoice. Payment by the SFWMD for all work completed herein will not exceed the TOTAL in the table below. The Panelist should submit invoices to the peer review coordinators for approval upon completion of all the indicated tasks in Table 3.

Table 3: Schedule of Deliverables and Rate Schedule

Task Number	Deliverables	Due Date	Estimated Hours	Unit cost	Task Cost	Payment
Task 1a	Acknowledgement of Materials	48 hours after receiving materials				
Task 1b	Review of Documentation and Questions for SFWMD	Post questions on SFWMD web-board by Thursday, February 26, 2009	24			
Task 2	Participation in Workshop and Field excursion in Kissimmee, FL	Monday, March 2, 2009 through Wednesday, March 4, 2009 (3 days)	24			
Task 3	Complete Peer Review Report	Friday, March 20, 2009	12			
		TOTAL	**60**			

7 Definitions

Key terms have been defined to aid in the readability of this statement of work. These terms are as follows:

Chairperson	Panelist who leads the peer review process and prepares the final report
SFWMD	South Florida Water Management District
SFWMD District HQ	Headquarters of the South Florida Water Management District: 3301 Gun Club Road, West Palm Beach, FL 33406
Email Addresses	Addresses to be used by chairperson to submit panel products to the SFWMD.
Mailing Address	Water Supply Department, Mail Code 4350, South Florida Water Management District, P.O. Box 24680, West Palm Beach, FL, 33416-4680
SFWMD Team	A team of scientists and planners from the SFWMD
Panel	The peer review panel, a group of six experts (five panelists and one chairperson) assembled to peer review the project technical report
Panelist	A member of the peer review panel
Peer Review Coordinator	Responsible for the development, oversight and implementation of this statement of work. Activities

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	include being the point of contact for inquiries and mailings, scheduling and tracking of completed tasks, booking of meeting rooms and field trips, setting up and maintenance of the web board, procurement, and all other logistical considerations.
Project Technical Lead	Responsible for the completion of the project technical report and all support materials to be reviewed by the panel, the selection of the panel questions, concurrence of the panel and chairperson, and overseeing all technical elements of the peer review.
Reference Materials	This includes a set of important supporting reference documents that will accompany the draft technical document.
Peer Review Report	Peer review documentation prepared by the panel to be submitted to the SFWMD as the final product of the peer review.
Project Technical Report	Technical report summarizing the project for the panel, to be prepared by the project technical lead.
SFWMD	South Florida Water Management District
Web Board	An internet site implemented by the SFWMD and accessible to the public at: Kissimmee River section of the Natural System Technical Document Peer Review Web Board: http://webboard.sfwmd.gov/default.asp?boardid=NSTDPR&action=0 This site will be used as repository for all draft/final chapters and versions of peer review report and agendas for the workshop and teleconference. Under Florida's Sunshine Law, it is mandatory that all communications between two or more panelists occur in a forum open to the public. However no discussions, between panelists, can occur on the web board prior to the workshop to insure an independent review. Data may be posted and read by members of the board, SFWMD staff as well as the public. Anyone experiencing difficulty in accessing the web board should contact the web board administrator. Discussions on posted items shall occur during teleconferences and workshop.
Web Board Administrator	The peer review facilitator will assist anyone with difficulties posting or reading web board messages.
Workshop	A public meeting of the panel to be held in Osceola County, Florida. Personal attendance of panel members is required. Presentations will be given by

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the SFWMD to answer questions from the panel and the public. The panel shall discuss and work on peer review and tasks for peer review reports.

ATTACHMENT A
Sunshine Rules

General links:
http://myfloridalegal.com/pages.nsf/main/b2f05db987e9d14e85256cc7000b28f6!OpenDocument
https://my.sfwmd.gov/portal/page?_pageid_2934,19738785,2934_19738944&_dad_portal&_schema=PORTAL

Statute link:
http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=Ch0286/SEC011.HTM&Title=-%3e2007-%3eCh0286-%3eSection%20011

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ATTACHMENT B

Task 1
Acknowledgement – Receipt of Draft Documentation and Background Materials

1. I have read the statement of work and I will complete my assigned tasks.

2. I received the draft documentation and background materials on ____________
Date

______________________________ ______________________________
Name Signed

Please mail to:
Jason Godin
Senior Environmental Scientist
SFWMD
Water Supply Department
Mail Code 4350
West Palm Beach, FL 33416-4680

ATTACHMENT C

Liability Waiver

WHEREAS, ______________________________("PARTICIPANT") has
[Print full name]
voluntarily requested, from the South Florida Water Management District ("DISTRICT"), to participate in
on or about which may involve the use
(Types of activities) (Date)
of DISTRICT transportation (automobiles, airboats, aircraft, and other transportation) and other equipment, as well as use of canals, property, and surrounding rights of way owned and operated by the DISTRICT; and

WHEREAS, DISTRICT is willing to allow use of its transportation, equipment, canals, property, and surrounding rights of way to facilitate the above identified activities upon the representations and conditions that PARTICIPANT agrees to abide by all safety procedures, agrees to obey all directions and demands of DISTRICT personnel, if any, and PARTICIPANT specifically acknowledges and assumes any and all risks associated with the above identified activities;

NOW THEREFORE, in consideration of the premises set forth above, I hereby release and agree to indemnify and hold harmless the District (including, but not limited to its Governing Board members, employees, agents, attorneys, legal representatives, and their successors and assigns) from all liability, personal injuries, claims, damages, attorneys fees, costs, judgments, claims bills, etc. (under the laws of the State of Florida, and of any other state of the United States of America and/or of the United States of America) arising, in whole or in part, from the acts, omissions, or negligence of the District or any third person that arises out of or is related to the above referenced use of District transportation, equipment, canals, right of ways, personal property and real property.

PARTICIPANT'S SIGNATURE DATE

PRINT PARTICIPANT'S NAME WITNESS SIGNATURE

PRINT PARTICIPANT'S ADDRESS PRINT PARTICIPANT'S PHONE

PRINT PARTICIPANT'S CITY & ZIP

ATTACHMENT D

Kissimmee Basin Water Reservations Peer Review Panel Technical Questions

Questions on Fish and Wildlife Indicators and Hydrologic Linkages for Each Reservation Waterbody

1. Do the environmental indicators selected provide the basis for protecting fish and wildlife in terms of ensuring sustainable native communities through natural cycles of drought, flood, and population variation?

2. Are there any major environmental indicators not considered in our analyses that could significantly affect the quantity, timing, and distribution of water identified for the protection of fish and wildlife?

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3. Do the performance measures A) adequately represent the hydrologic requirements of fish and wildlife identified for protection and B) do the 'range of acceptability' values proposed provide equivalent levels of protection of fish and wildlife?

Questions on Analyses Including Modeling

4. Are the hydrologic methodologies, models, analyses and assumptions sufficiently supported by available scientific knowledge, research and data?

5. Do the hydrologic methodologies, models, analyses and assumptions described in the report yield sufficiently accurate results to reasonably support their applications as described in the report?

6. Can/Should the margin of error associated with the estimation of flow and stage as defined in this report be combined with the range of acceptability associated with the biologic performance measures, for the purpose of describing to policy makers, boundries within which they are equally sure (or unsure) that the desired protection of fish and wildlife will be achieved.

Questions on Water Reservation Criteria

7. Are the methodologies used to develop the Target Time Series for the river and for the lakes scientifically and technically valid, given the constraints of the initial reservation?

8. Is the water identified for the protection of fish and wildlife technically supported for each of the eight reservation water bodies?

9. What additional work, if any, should be considered to enhance the technical criteria for future updates of these water reservations?

Question on the Overall Technical Document

10. Does the compiled information, including data, analyses, assumptions, and literature review, provide a reasonable basis for the conclusions reached about the water needed to protect fish and wildlife for each of the eight reservation water bodies?

APPENDIX B

RESTORATION EXPECTATIONS FOR THE KISSIMMEE RIVER RESTORATION PROJECT

This document is available as a pdf on the Web Board.

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APPENDIX K: DESCRIPTION OF THE DEVELOPMENT AND APPLICATION OF THE MODELING USED FOR THE KISSIMMEE BASIN WATER RESERVATIONS

Appendix K is a document that summarizes modeling tools used to develop the Kissimmee Basin water reservations including performance measures evaluation tools, as part of the Kissimmee Basin Modeling and Operations Study (KBMOS). This appendix covers the process used in selection of the alternatives; selection of the model to be used in the KBMOS study; description of the modeling and performance measures evaluation tools; data collection for model input; model development including continued further improvement of the Alternative Formulation and Evaluation Tool for Water Reservation (AFET-W), which was used to develop Kissimmee Basin water reservations; application of the calibrated tools to the reservations efforts; sensitivity analysis of the calibrated model; and development of the base conditions. Sections 4 and 5 are the most relevant to a reader trying to understand the tools and their application in the reservations efforts. Section 5.4 specifically focuses on the base conditions model, the results of which were used directly in developing the Kissimmee Basin water reservations.

FINAL
Modeling Tools Development Summary
Deliverable 2.4.4

Kissimmee Basin Modeling and Operations Study KBMOS
(Contract No. CN040920-WO02)

Prepared for:

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3301 Gun Club Road
West Palm Beach, FL 33406
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Prepared by:

AECOM

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13450 West Sunrise Boulevard, Suite 200
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March 2011

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Appendix A: Report outline summarizing references cited

1 INTRODUCTION

The Kissimmee Basin Modeling and Operations Study (KBMOS) is a South Florida Water Management District (SFWMD) initiative to identify alternative water control structure operating criteria for the Kissimmee Basin (KB) portion of the Central and Southern Florida (C&SF) Flood Control Project (Figure 1-1). The KBMOS was initiated in September 2004 in response to stakeholder concerns with how water was being managed in the Kissimmee Chain of Lakes (KCOL) relative to the Kissimmee River Restoration Project (KRRP) and Lake Okeechobee.

Phase I of the KBMOS, completed in June 2005, performed a comprehensive assessment of basin conditions (Earth Tech 2005) and identified KB operating objectives, the KBMOS planning approach and modeling tools. As part of the final deliverable for the Phase I KB Assessment Report, the AECOM Team (f.k.a Earth Tech) created the Task 1.9 Work Plan (Earth Tech 2005a). The work plan identified the recommended approach for the next phase of the KBMOS required to implement the Alternative Plan Selection Process. This document summarizes the modeling tool development activities completed during Phase II of the KBMOS effort.

1.1 Purpose

The purpose of this report is to provide a summary of work to develop the KBMOS modeling tools during Phase I and II of KBMOS from project initiation through the Fall of 2009. The original documentation and deliverables referenced in this summary provide details on the development of the modeling tools. This report was developed to serve as a single resource to describe the overall modeling approach including the initial collection of data used to construct and calibrate the modeling tools and the testing performed to validate these tools. The references section lists the major modeling deliverables produced during this study and described in this summary. A table found in Appendix A organizes the references cited along with an outline of this report.

The KBMOS Work Plan for Phase II is divided into five work areas, or tasks. The tasks follow a sequential approach from the initial data collection through the preparation of the final planning documents. The following summarizes these tasks:

> Task 2.1 – Project Management: Work under Task 2.1 included both the administrative requirements of the study as well as support tasks not specifically addressed in the remaining tasks. This task included the development of the Study Communications Plan, support to the SFWMD during the Peer Review Process and the development of data management processes.

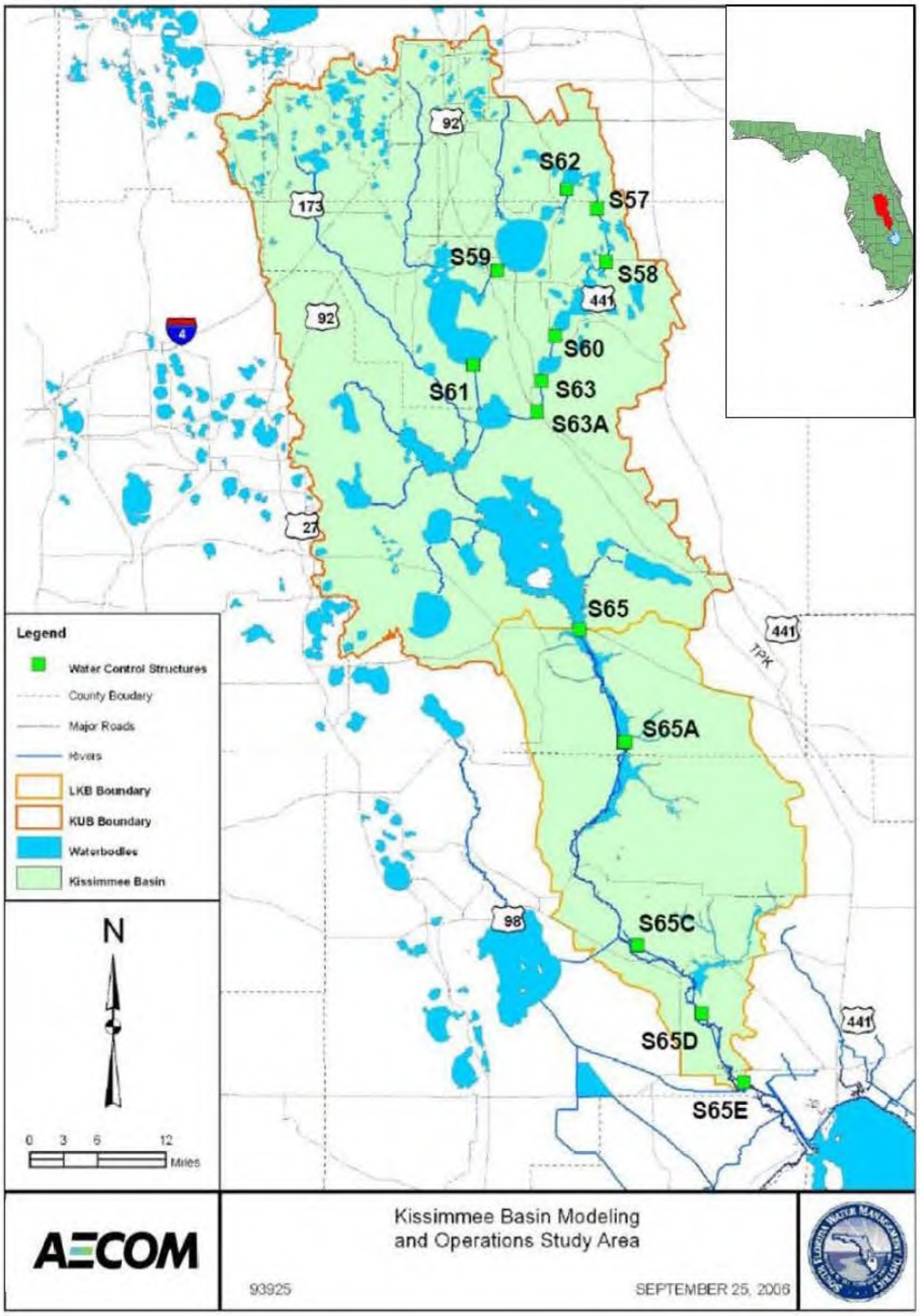

Figure 1-1: Kissimmee Basin

Task 2.2 – Hydrologic Performance Measure Development: Work under Task 2.2 included the development of the evaluation performance measures and evaluation performance indicators and the Alternative Evaluation System. These two pieces were consolidated during the implementation of the Performance Measure Evaluation Tool.

Task 2.3 – Preliminary Model Description: Work under Task 2.3 included the work necessary to compile and review the data needed to construct the modeling tools. The initial design of the modeling tools was included in these activities along with the testing required to demonstrate the applicability of the tools for the intended purpose.

Task 2.4 – KB Modeling Tool Development: Work under Task 2.4 included the development and calibration of the modeling tools to be used in the Alternative Plan Selection Process.

Task 2.5 – KB Water Control Operation Plan Development: Work under Task 2.5 includes the application of the modeling tools as part of the Alternative Plan Selection Process and the subsequent documentation to transmit the SFWMD's recommended interim and long term water control structure operating criteria for the KB portion of the C&SF Project.

1.2 Background

The technical approach applied in the KBMOS includes the sequential development and application of a suite of modeling tools to represent the movement of water through the KB portion of the C&SF Project. The suite of modeling tools includes three separate applications, starting at a very simple water budget model and progressing to a fully integrated groundwater surface water model that represents the complex hydrology and hydraulics of the C&SF Project.

The modeling strategies developed for this study focus on the "big picture" in terms of the overall goal of the project to achieve a more acceptable balance among the various water management objectives, including flood control, water supply and natural systems. These overarching objectives, represented as evaluation performance measures and evaluation performance indicators, have driven the model development process.

This document summarizes the development of the modeling tools that occurred concurrently with development of performance metrics specific to each lake management area in the Kissimmee Upper Basin (KUB) and the Kissimmee River. The approach followed in this project allowed the modeling team to frequently check and validate the three models' ability to simulate the hydrology necessary to represent the performance measures.

The planning approach was developed around the MIKE SHE/MIKE 11 tool (DHI 2007), which was selected as the model for the evaluation of alternatives. The MIKE SHE/MIKE 11 model (also known as the Alternative Formulation and Evaluation Tool, or, AFET-W) was used to simulate the hydrology of the system and is the model that will be used in the final evaluation of the top performing alternative plans. To simplify the initial screening and development of potentially hundreds of alternative plans, the modeling strategy included the development and application of two screening-level modeling tools (OASIS and MIKE 11). The simulated hydrology of the KB, that was developed using AFET, was then used to simulate the distributed daily runoff time-series that were the drivers for the two simpler modeling tools, MIKE 11 and OASIS.

The OASIS modeling code (Hydrologics 2006) was used to develop an the initial screening tool (known as OKISS) to allow the project team to screen and refine a large number of potential alternative plans and better understand the inter-related nature of control structure operations and hydrology. Operating strategies developed during alternative plan screening were translated into the MIKE 11 model (DHI 2007). The MIKE 11 model (known as the Alternative Formulation Tool (AFT)) was used to further refine the alternative plans to address the hydraulics of the system.

1.3 Report Organization

The following summarizes the content of this report:

Section 1: Introduction – This section presents the study background and the purpose for this report.

Section 2: Alternative Plan Selection Process – Section 2 summarizes the Alternative Plan Selection Process and the components that make up the AES that was developed to evaluate alternative plan performance for this study.

Section 3: KBMOS Modeling and Evaluation Tools – Section 3 provides a background on the modeling tools that were considered for KBMOS and the background on the selection of the suite of modeling tools applied in KBMOS.

Section 4: Preliminary Modeling Activities – Section 4 describes the compilation of data, model planning activities and testing that preceded the development and calibration of the modeling tools.

Section 5: Model Development Activities – This section summarizes the work to calibrate the KBMOS modeling tools and their initial application for the Base Conditions.

Section 6: References – Section 6 contains a summary of the references cited in the report. Appendix A includes a table that contains the document outline and identifies the references cited in each section of the report, along with a brief description of the reference.

2 ALTERNATIVE PLAN SELECTION PROCESS

The KBMOS Alternative Plan Selection Process was developed to systematically evaluate alternative plan performance at three increasing levels of detail and sophistication (Figure 2-1). The process is initiated with the development of an alternative plan describing a set of modified water control structure operating criteria for the KB. The alternative plan is simulated using the Alternative Plan Screening Tool. Screening model results are post-processed and sent to the Alternative Evaluation System for scoring to identify operating criteria strategies that best meet the basin's operating objectives. The Alternative Evaluation System uses the evaluation performance measures to score alternative plans and evaluation performance indicators to report on constraints and opportunities. Alternative plan scores are used to rank alternative plans. The best performing alternative plans are simulated in the AFT and refined and finalized to meet constraint indicator requirements. The Alternative Evaluation System is used to score alternative plans and report alternative plan performance relative to constraints and opportunities. The final round of evaluation is simulation of the top performing alternative plans from Formulation in the fully integrated Alternative Formulation and Evaluation Tool (AFET-W). The final step in the process is preparation of a Decision Package that summarizes alternative plan performance across all evaluation performance measures and evaluation performance indicators.

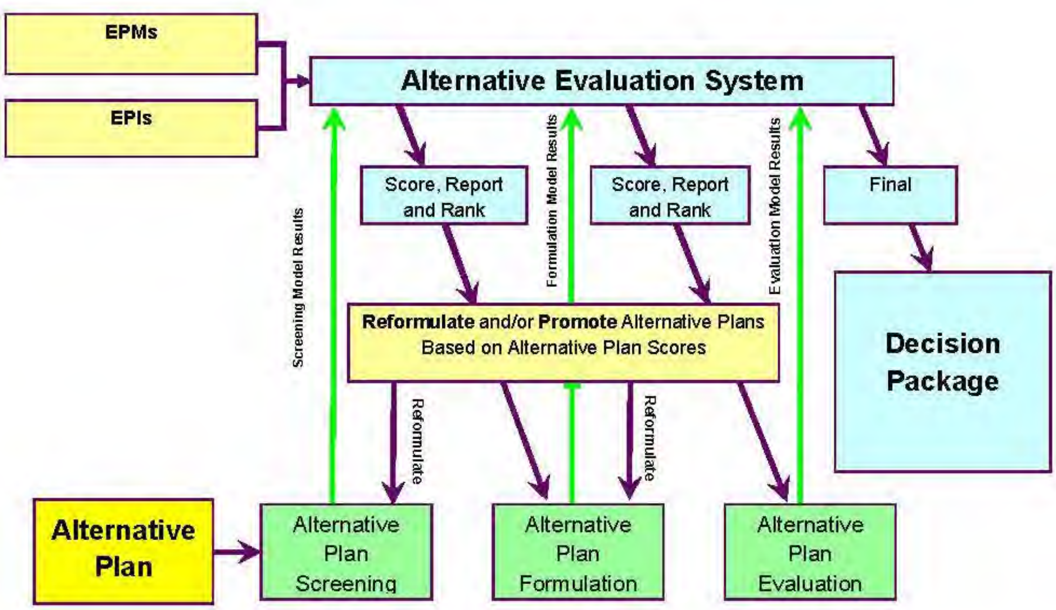

Figure 2-1: Alternative Plan Selection Process

2.1 Alternative Evaluation System

The Alternative Evaluation System (AES) for the KBMOS is a grading process that provides a systematic means for comparing alternative plans using a set of shared standards. The shared standards are the evaluation performance measures and the evaluation performance indicators. The components, rationales, justifications and evaluation protocols for the evaluation performance measures and evaluation performance indicators will be presented in the Alternative Plan Selection Document. Once finalized, the Alternative Plan Selection Document will serve as the Decision Package and will include detailed information on the scoring methodology and components used to calculate alternative plan scores. This approach was chosen to provide an objective, unbiased, transparent, repeatable, implementable and documented means for differentiating and ranking alternative plans.

All components of the AES were developed in consultation with basin stakeholders. Interagency Study Team and stakeholder participation was facilitated through team workshops, teleconferences and public meetings. These forums were used to provide information about the study, solicit input, review deliverables, refine tools and develop and evaluate alternative plans. The Interagency Study Team was comprised of representatives from the SFWMD, USACE, Florida Fish and Wildlife Conservation Commission (FWC), United States Fish and Wildlife Service (USFWS), Florida Department of Environmental Protection (FDEP), United States Environmental Protection Agency (USEPA), Florida Department of Agriculture and Consumer Services (FDACS) and Osceola County. Local stakeholder group participants included the Alligator Chain of Lakes Homeowners Association, Audubon of Florida, Deseret Ranch and Lake Mary Jane Alliance, as well as local utility and water supply interests.

Figure 2-2 illustrates the relationship between the refinement of the AES (represented by the Performance Measure Evaluation Tool) and the initial application of the modeling tools during the screening portion of the Alternative Plan Selection Process. The AES component and tool development activities are shown on the left side of the diagram. Alternative Plan Selection Process activities are shown on the right side of the diagram. The activity on the right side of the diagram is anchored to the Alternative Plan Selection Process that is divided into the three levels of analysis including screening, formulation and evaluation.

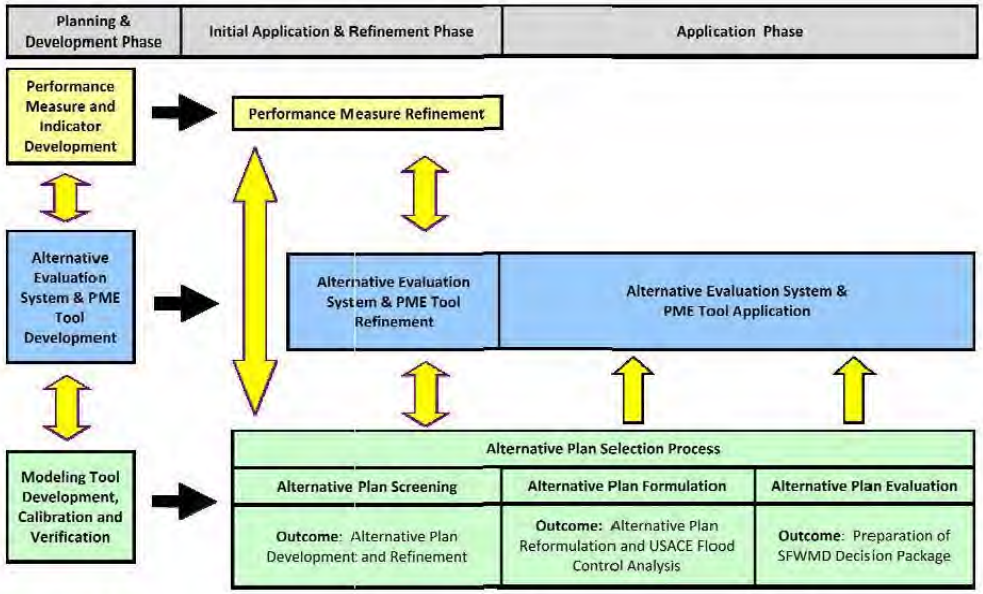

Figure 2-2: Development and Refinement of the Alternative Plan Selection Process Tools

Although some of the initial refinement activities took place during tool development (indicated by two-way arrows between development activities), the majority of the refinement activities took place during alternative plan screening. During tool development, key check-in points were identified to verify that the metrics defined in the evaluation performance measures and evaluation performance indicators could be simulated by the models and that the models could provide the necessary resolution to evaluate alternative plans.

The proposed development of the AES was described in Alternative Evaluation System Technical Design Document (AES TDD) (Earth Tech 2007d). The concepts and components that comprise the AES were presented, as well as how the components were to be integrated and applied in the KBMOS. The AES TDD was a guide that was used for the development of the Performance Measure Evaluation Tool.

2.1.1 Evaluation Performance Measures and Indicators

The evaluation performance measures (EPMs) and evaluation performance indicators (EPIs) developed for the KBMOS form the basic units of measurement for the AES and drive the Alternative Plan Selection Process. They are used in conjunction with the hydrologic and hydraulic modeling tools to determine how well a plan meets the study's operating objectives.

2.1.1.1 Evaluation Performance Measures

EPM targets define the hydrologic conditions desired to meet the natural resource requirements of water bodies controlled by KB C&SF Project structures. River EPM targets were derived from the restoration criteria defined for the Kissimmee River Restoration Project and analyses of pre-channelization data. Lake EPM targets were derived from a combination of pre-regulation data, lake management and fish and wildlife literature and professional judgment.

Each EPM has one or more evaluation components that represent specific hydrologic characteristics that will be assessed from simulation model output. Each evaluation component has a specified target or target range that is location specific. For the lake EPMs, there is only one location per measure and that location applies to all evaluation components. For the Kissimmee River, each performance measure has more than one evaluation location and each evaluation component is assessed at each of these locations. The EPMs developed for the KBMOS are listed in Table 2-1.

Table 2-1: KBMOS EPMs

No.	Name
River EPMs	
R-01	Kissimmee River Flow
R-02	Kissimmee River Stage Hydrograph/Floodplain Hydroperiod
R-03	Kissimmee River Stage Recession/Ascension
Lake EPMs	
L-01	Stages in Lakes Kissimmee, Hatchineha and Cypress
L-02	Stages in Lake Tohopekaliga
L-03	Stages in Lake Gentry
L-04	Stages in Lakes Joel, Myrtle and Preston
L-05	Stages in East Lake Tohopekaliga, Fells Cove and Lake Ajay
L-06	Stages in Lakes Alligator, Brick, Lizzie, Coon, Center and Trout
L-07	Stages in Lakes Hart and Mary Jane

2.1.1.2 Evaluation Performance Indicators

EPIs are similar to EPMs, except that they are not used to score and rank alternative plans. They provide additional information to help differentiate between alternative plans. There are constraint indicators and opportunity indicators. Constraint indicators must be met. Opportunity indicators report information on whether conditions created by an alternative plan meet, improve or degrade a desired condition. No specific goals or targets were specified for the opportunity indicators. Opportunity indicator information is reported so that the relative differences between alternative plan opportunity indicator information can be compared and considered during the

Alternative Plan Selection Process. Table 2-2 lists the EPIs, their type and applicable operating objectives.

Table 2-2: KBMOS EPIs, Indicator Types and Associated Operating Objectives

No.	Name	Indicator Type	Operating Objective
I-01	Probable High Lake Stages	Constraint	Flood Control
I-02	Kissimmee River Probable Flood Extents	Constraint	Flood Control
I-03	Lake Discharges and Stages for Hydrilla Management	Opportunity	Aquatic Plant Management
I-04	Water Supply for Consumptive Use	Opportunity	Water Supply
I-05	Kissimmee River Inflows to Lake Okeechobee	Constraint	Downstream Ecosystem
I-06	Stage Duration for Navigation and Recreation	Opportunity	Navigation/Recreation
I-07	Kissimmee River Channel Velocity	Constraint	Downstream Ecosystem

2.1.2 Development and Refinement of Evaluation Performance Measures and Indicators

The development of EPMs and EPIs began in July 2005 but were not completed until 2010. Refinement and consolidation was completed at the end of the screening level of evaluation. Figure 2-3 provides an overview of the development and refinement process. This process relied on the knowledge and participation of the Interagency and Consultant Team.

Figure 2-3: Performance Measure and Indicator Development, Refinement and Consolidation Process

As shown in Figure 2-3, performance metrics evolved through this step-wise process from preliminary through final EPMs and EPIs. All were developed using available science and tools and represent the current understanding of the major drivers and desired attributes for the KB.

2.1.3 Alternative Plan Selection Document

The Alternative Plan Selection Document describes the final version of the EPMs and EPIs, as well as the system for integrating the objective and subjective information into a final score. The implementation of the AES as a modeling tool is described in the Updated PME Tool Documentation, Version 1.3b (AECOM 2010).

3 KBMOS MODELING AND EVALUATION TOOLS

Three water resource modeling tools and the Performance Measure Evaluation tool have been developed as part of the KBMOS:

- **Screening Tool:** The screening tool is a water budget model that represents water bodies in a node-link network and applies operating rules to move water through the system. The screening tool selected for the KBMOS is a management simulation model, OASIS, developed by Hydrologics, Inc. (Earth Tech 2005).

- **Formulation Tool:** The formulation tool is a surface water hydraulic routing model similar to the screening tool, except that it uses the St Venant equations to route water through the system, providing a greater level of detail on the conveyance of water. The formulation tool will be used to evaluate whether alternative plans meet United States Army Corps of Engineers (USACE) flood control requirements and for ranking and promotion of alternative plans to the final evaluation round of the Alternative Plan Selection Process. The formulation tool selected is the MIKE 11 modeling package by DHI Water and Environment, Inc. (Earth Tech 2005).

- **Evaluation Tool:** The evaluation tool is a fully integrated hydrologic and hydraulic model that couples the formulation tool with a watershed model that includes overland and groundwater flow (MIKE SHE). The evaluation tool has the greatest complexity and is capable of examining the full set of EPMs. The fully integrated modeling tool will be used to develop the Governing Board Decision Package that is included with this report for the final three alternative plans. The evaluation tool selected for this project is MIKE SHE/MIKE 11 by DHI Water and Environment, Inc. (Earth Tech 2005).

- **PME Tool:** The PME Tool implements the scoring calculation defined within the AES. The tool uses a series of scripts and macros in a spreadsheet shell to automate calculations and graphics from the screening, formulation and evaluation tools. The PME Tool provides a standardized report for each alternative plan. This report outputs alternative plan and evaluation component scores and includes the graphical and tabular information described in the EPM and EPI evaluation protocols (AECOM 2010).

Each of the modeling tools were designed to be used in conjunction with the PME Tool.

3.1 Modeling Tool Selection

The development of the modeling tools for the KBMOS during Phase II was preceded by an investigation of the basin's operating objectives and known water resource issues and concerns within the KUB and the Lower Kissimmee Basin (LKB) in Phase I. Once the study team reviewed and understood these issues and objectives, available modeling tools capable of simulating changes to operating criteria were identified and evaluated. The purpose of the evaluation was to select a modeling tool (or suite of modeling tools) capable of simulating the change in hydrology and hydraulics resulting from modified operating criteria. The investigation utilized three evaluation criteria to select the modeling tool(s): functionality, defensibility and cost-effectiveness.

3.2 MIKE SHE/MIKE 11 Model Selection

During the Phase I Basin Assessment, the Study Team performed an evaluation of potential modeling tools capable of simulating surface and ground water interactions for use in this study. The functionality, defensibility, and implementation costs for these model tools were considered as part of this evaluation. Selection criteria were developed and applied to short list six models for further, more detailed evaluation by the interagency team in a workshop forum. The following is a list of six models that were considered:

- WASH123D (USACE)
- FTLOADDS (USGS)
- MOD-HMS (Hydrogeologic)
- MIKE SHE / MIKE 11 (Danish Hydrologic Institute)
- MODFLOW (USGS)
- XP-SWMM (XP-Software)

Experts for each of the short-listed models were given an opportunity to address how their assigned model best met the project needs based on the pre-selected criteria. The interagency team, including the SFWMD, USACE, and USFWS staff participated in the evaluation and selection process. During the workshop, the members of the team considered how well each model could simulate water resources problems and rainfall/runoff relationships within the data constraints identified during the Phase I Basin Assessment. The MIKE SHE/MIKE 11 modeling tool was selected through this process to be used for the final evaluation of alternative plans and to compile information for submittal to the USACE.

3.3 OASIS Model Selection

OASIS was selected to serve as the Kissimmee Basin Screening Tool. The screening tool was used to evaluate the one hundred plus alternative water management plans that were considered during the initial stages of KBMOS. A secondary objective of the development of the Kissimmee Basin Screening Tool was to have a fast running model that can be applied in public forums to assist in the development of structure operating criteria. The OASIS modeling software

(Hydrologics 2006) was selected through a proof-of-concept approach that compared OASIS performance to the UKISS model in use by SFWMD at that time. The proof-of-concept approach included an evaluation by members of the Interagency Study Team of the two modeling packages. The team met in a one-day workshop to implement the Screening Tool Proof of Concept Test Plan (Earth Tech 2005c). Based on the results of this effort, the OASIS model was selected.

4 PRELIMINARY MODELING ACTIVITIES

The preliminary modeling activities can be broken into two main areas. The first is the collection and review of basin hydrologic and hydraulic data necessary for development of the modeling tools. The second is the preparation of planning documents that describe the source of data and initial parameters for development of the modeling tools.

4.1 Data Collection and Compilation

Data collection and compilation was started early in Phase II and continued, as needed, throughout the project. Initial data collection requirements were identified during Phase I as part of the development of the modeling strategy documented in the KB Assessment (Earth Tech 2005). Data sets collected included time series data, spatial data (geographic information system (GIS) shape files), previously completed modeling efforts and aerial photographs. The following briefly summarizes the data collection activities.

4.1.1 Data Acquisition and Review

The AECOM team worked closely with the SFWMD in acquiring data. During the early stages of the study, an AECOM team member downloaded and collected data required for the study. Subsequent data compilation activities were coordinated with SFWMD staff.

4.1.1.1 Daily Data

The initial collection activities focused on daily data over a recent period that was intended to include the calibration/verification periods. The data collected included rainfall depth, surface water flow and stage, groundwater heads and gate openings, as well as spatial data sets and recent modeling work. Available time series data were collected at a daily time scale over the period from January 1990 through December 2004. However, the period of record for each data source at each station was also documented. These data were compiled in the Interim Data Summary Table (Earth Tech 2005b) that was submitted to the SFWMD in September 2005. Following an initial review of the data collected by the modeling team, a subset of stations was identified for further review prior to their application in the modeling efforts (Earth Tech and Marco Water Engineering 2006).

4.1.1.2 Hourly Data Summary

Hourly data was required for the event calibration/verification activities during the development of the AFET in 2006/07. Data collected was limited to surface water stage and structure flow data. The data collected went through a visual review and verification to evaluate and identify potential anomalies (Earth Tech 2006).

4.1.2 Rainfall Data

Rainfall is the primary source of water that drives the hydrology of the KB. Various data sets were collected for the modeling effort. Available data from rainfall gauging stations, compiled in the Interim Data Summary Table (Earth Tech 2005b), were used to create raster files for the calibration/verification periods. The period of data collected is from January 1, 1993 to December 31, 2004. The methodology for the review of the data and creation of the daily rainfall depth raster files are documented in the Phase II, Alternate Formulation and Evaluation Tool Development - Interpolated Rainfall Grids Technical Memorandum (Earth Tech 2006a).

Hourly rainfall depth raster sets were created for the event calibration/verification activities during the development of the AFET in 2006/07. These raster files were created using 15-minute Next Generation Radar (NEXRAD) data provided by the SFWMD over the period from August 1, 2004 to October 15, 2004. The review of these data was completed through a visual comparison of maps for specific high rainfall periods. The methodology for the creation of the NEXRAD raster files and the data review are documented in the NEXRAD Rainfall Grids Technical Memorandum (Earth Tech 2007).

Rainfall depth for calendar years 1965 through 2005 were provided from the SFWMD's daily rainfall depth data over a 2-mile by 2-mile grid. These raster files were converted into a scale and format that could be input directly into the modeling tools. Double mass analyses were performed to compare this accumulated 2-mile by 2-mile rainfall data to the previously collected interpolated rainfall data collected over the period from 1993 to 2004. The processing and review of these data sets are documented in the Processing of SFWMM 2mi. x 2mi. Rainfall Grids to Create AFET Input Files Technical Memorandum (Earth Tech 2007a).

4.1.3 Topographic Data

The structure of the KB represented in the modeling tools is based on multiple sources of topographic information from various agencies. In the KUB, there were two main sources including the United States Geological Survey's (USGS's) National Elevation Data Set that was expressed as a 1 one-arc second Digital Elevation Model (DEM) and bathymetry data collected by the USACE. For the LKB, the primary sources of information within the Kissimmee River floodplain are pre- and post-construction surveys collected as part of the Kissimmee River Restoration Project and the (USGS's) National Elevation Data Set. The processing and creation of the KB DEM was completed over two separate efforts, with considerable input by the USACE. The processing and creation of the DEM that describes the topography of the KB is documented in the Digital Elevation Model of the Kissimmee Basin (Earth Tech 2007b).

5 MODEL DEVELOPMENT ACTIVITIES

5.1 Preliminary Model Preparation Activities

Prior to initiation of model tool development, the approach to model construction and calibration was summarized in Technical Design Documents for review by the Interagency Study Team. The following describes the preliminary work that was completed for each modeling tool.

5.1.1 MIKE SHE/MIKE 11 Technical Design Document

As the first step in the MIKE SHE/MIKE 11 model development, the modeling team created the Kissimmee Basin Modeling and Operations Study, Alternative Formulation Evaluation Tool (AFET) Development Technical Design Document (Earth Tech 2006b) to describe the initial conceptualization of the fully integrated surface and groundwater model for the KB. The AFET Technical Design Document included the following:

- An evaluation of watershed stability;
- Review of the quality and quantity of input data;
- Preparation of graphical and tabular format of input files for model development;
- Preparation of preliminary MIKE 11 model input data sets; and
- Preparation of Alternative Formulation/Evaluation TDD describing the model development for calibration and verification.

Development of the MIKE SHE/MIKE 11 model was based on an expansion of the Lake Tohopekaliga Drawdown Model documented in the Integrated Surface and Groundwater Model for Lake Tohopekaliga Drawdown Project (DHI and GeoModel 2001). The domain of the original modeling effort included C&SF lakes north of the S-61 and S-63 Structures in the KUB. The intent documented in this approach was to add the remaining lakes, from Cypress Lakes south into the Kissimmee River in the LKB.

A complimentary document, the Kissimmee Basin Modeling and Operations Study, Alternative Formulation/Evaluation Tool Acceptance Test Plan (Earth Tech 2006c), was created to describe the calibration and verification time periods for continuous and event simulations and to define the statistical criteria that was to be used as the starting point to assess model calibration. The model was calibrated against best available observed surface water discharges, surface water elevations and groundwater levels at locations for which data were available. Statistically based surface water and groundwater targets were defined for long-term calibration/verification periods and for a storm period representing the 2004 hurricane season. Additionally, a qualitative inspection of the overall model performance was identified to compare the long-term water budget of the KB with water budgets derived from concurrent modeling efforts studies.

5.1.2 OASIS Model Technical Design Document

As the first step in OASIS model development, the modeling team created the Kissimmee Basin Modeling and Operations Study, Screening Tool Technical Design Document (Earth Tech 2006d). The Screening Tool Technical Design Document established the required specifications for the development of the screening tool and its application to the study objectives. The Technical Design Document included the following:

- A conceptual approach for design of the KB screening tool;
- A proposed design methodology for construction and calibration of the model;
- A definition for creating a linkage between OASIS operating goals and the KB decision tree;
- A proposal to apply the screening tool in public computer-aided participation sessions;
- An update storage area elevation data in the lakes to be consistent with the bathymetry data used for the MIKE SHE/MIKE 11 model development; and
- A methodology to represent the Kissimmee River.

5.2 Development of the KBMOS Modeling Tools

Following the review and acceptance of the Technical Design Documents for the modeling tools, the AECOM team initiated the construction and calibration of the modeling tools. Three teams were formed: one to work on the watershed components in MIKE SHE, a second to work on the hydraulics of the surface water conveyance in MIKE 11, and a third to work on the OASIS implementation concurrent with the MIKE SHE and MIKE 11 teams. Coordination meetings and discussions occurred on a monthly basis.

At the same time as the models were being developed, the SFWMD had a full-time 'contract hydrologist' on-site coordinating the development and documentation of the hydrologic EPMs and EPIs. In this role, the contract hydrologist assisted the SFWMD and Interagency Study Team to develop the linkage between the science and biology and the hydrology (flows and stages) simulated in the modeling tools.

Construction of the modeling tools was advanced sequentially, with deliverables at key points in the process to allow the SFWMD and the Interagency Study Team the opportunity to review the status of the modeling tools.

5.2.1 Development of the Fully Integrated Hydrologic/Hydraulic Model

5.2.1.1 Initial Model Development – AFET

The MIKE SHE/MIKE 11 modeling effort kicked off in 2005. This work culminated in the AFET model. The following describes the initial development of this model.

5.2.1.1.1 MIKE SHE Model Development of the Kissimmee Basin – AFET

The watershed modeling team started with the Lake Tohopekaliga Drawdown Model and added the southern portion of the KUB and LKB. Data sources for the initial construction of the model were derived from the past groundwater modeling efforts by the SFWMD and included the East Central Florida Groundwater Model (in conjunction with the St. John's River Water Management District (SJRWMD)) and the Glades-Okeechobee-Highlands MODFLOW Model. Summaries of these models are provided in the Phase I Kissimmee Basin Assessment (Earth Tech 2005).

Once the MIKE SHE model was constructed and debugged (verified that the model ran without errors), the initial construction was documented in an interim report and the model files were submitted to the SFWMD and Interagency Study Team for review. This interim status was documented in the Alternative Formulation/Evaluation Tool Development of MIKE SHE Documentation (Earth Tech 2006h).

5.2.1.1.2 MIKE 11 Model Development of the Kissimmee Basin – AFET

The surface water conveyance features of the KB portion of the C&SF Project are simulated in MIKE 11. Similar to the MIKE SHE development, the initial source of model information was the Lake Tohopekaliga Drawdown Model developed by DHI. Additional canal cross sections and hydraulic data were obtained from past modeling by the SFWMD and the USACE in UNET and HEC-RAS in the KB.

Once the MIKE 11 model was constructed and debugged (verified that the model ran without errors), the initial construction and source of the hydraulic information used was documented in an interim report and the model files submitted to the SFWMD and Interagency Study Team for review. This interim status was documented in the Phase II, Alternate Formulation and Evaluation Tool Development – Development of MIKE 11 Documentation (Earth Tech 2006i).

5.2.1.1.3 Merged MIKE SHE / MIKE 11 Model of the Kissimmee Basin – AFET

The initial modeling culminated with the merging of the two separately developed models. The work required to merge the models included:

- **The Definition of the Runoff/Groundwater Links:** The model development team defined the runoff/groundwater links for the model that allow exchange of water to occur between MIKE SHE and MIKE 11. Streambed leakage coefficients that control the interaction of MIKE 11 with the saturated zone models were defined based on the best data available for these parameters.
- **Definition of Flood Inundation:** Flooding can occur in many areas of the KB. This effort included the definition of the areas where flooding from the river network is allowed to occur and to develop the data sets required to simulate flooding in the model.

- **Completion of Test Simulations:** After the model was fully linked and debugged, test simulations were completed. The model results were evaluated to verify that the model was stable and not generating unreasonably high or low values at specific locations within the model domain.

Upon completion of the test simulations, the merged and debugged code was submitted to the SFWMD. The submittal included an interim technical memorandum that described the definition of the links and flood inundation data described above. This initial effort was documented in an interim deliverable. Comments were addressed in the final draft of the model documentation report entitled Kissimmee Basin Modeling and Operations Study, Phase II, AFET Model Documentation/Calibration Report (Earth Tech 2007e).

5.2.1.1.4 Calibration and Verification of MIKE SHE/MIKE 11 – AFET

5.2.1.1.4.1 Initial Sensitivity Analysis of the Merged MIKE SHE/MIKE 11 Model – AFET

A sensitivity analysis of a select number of parameters was performed prior to the beginning of the KBMOS model calibration process. The parameters selected for evaluation in the sensitivity analysis were based on the modeling team's understanding of parameter sensitivities developed in previous integrated surface and groundwater projects conducted for the SFWMD. The purpose of the MIKE SHE/MIKE 11 sensitivity analysis was to evaluate the sensitivity of several key parameters. The sensitivity analyses were used to identify the parameters that have a significant effect on model results and guide the calibration process (Earth Tech 2007e).

5.2.1.1.4.2 Calibration and Verification of MIKE SHE/MIKE 11 Model – AFET

AFET was constructed and calibrated along the guidelines established for the study. Those guidelines identified the need for a simulation of flow and stage in the surface water features in the KB and their sensitivity to alternate structure operations. Statistical criteria used to define the acceptance of the model were defined and applied during the calibration and verification processes.

The approach used to calibrate the model was defined along with the criteria that were applied to evaluate model performance in the Acceptance Test Plan. These criteria were further refined during the calibration process based on data limitations identified and discussions with SFWMD staff.

The calibration and verification process included three time periods. The calibration period represented the hydrology and hydraulics of the post-Phase I restoration conditions, over the period from November 1, 2001 through December 31, 2004. The purpose of the selection of this time period was that it represented a recent condition with a portion of the C-38 Canal back-fill in place and a long term simulation typical of the expected planning period model runs. Two separate verification periods were selected. The first was another long term period, but represented the pre-Phase I condition in the basin. These two models used a daily time-step (end of day) being driven by accumulated daily rainfall. However, calculations occurred on a much shorter duration. A second verification period was selected to evaluate performance of the model for the simulation of flood events. The time frame selected for the flood event verification was the 2004 hurricane season (from August 1 to October 15, 2004), when three back-to-back hurricanes past over the KB.

As part of the flood event verification, a site specific MIKE 11 model was developed for the Phase I portion of the restored Kissimmee River (Pool B-C between the S-65A and S-65C Water Control Structures). The purpose of this sub-model was to refine the surface water hydraulics conceptualization used in the KBMOS model to be consistent with the witnessed stage and flows. The objectives and results of the small-scale MIKE 11 model were key to defining some of the complex hydraulics of the restored river reaches, especially in the area of the unintended connection between the restored river and the upstream extent of the un-restored C-38 Canal. Development of this model was essential to simulate the restored portion of the Kissimmee River and was used as a guide to develop the remaining portions of the restored portions of the Kissimmee River in the future conditions model developed in a subsequent phase of the KBMOS.

Calibration of this first-ever regional model of the KB was challenging because of the complexity and size of the area. The calibrated model met the criteria defined for the project and adequately represented the hydrologic processes in the KB and was determined sufficient for use in the evaluation of operational criteria modifications in the KB. The results of this calibration process are documented in the Kissimmee Basin Modeling and Operations Study, Phase II, AFET Model Documentation/Calibration Report (Earth Tech 2007e).

5.2.1.2 Daily Planning Model Re-calibration – AFET-W

During the initial application of the fully integrated modeling tools to develop the base conditions for the planning study, it was observed that the model was over-predicting runoff from the KB. Although this issue was not evident in the observed and simulated runoff during the calibration and verification time periods, it was apparent when the model was applied to the longer term application in the base conditions simulation. Two theories were developed to explain the potential source of this over-simulation of runoff. The first possible source was the assumptions used to develop the future condition land use. The second possible source was the reference evapotranspiration used in the original modeling effort. Because of the uncertainties associated with the future land use, it was decided to eliminate the 'future' base condition from future simulations.

Following the initial development of the AFET model, the development of a more robust evapotranspiration data set was completed by the SFWMD (SFWMD 2008

). Comparing these data with those applied in the calibration and application of the AFET revealed that the original data set (which represented the best available data at the time) may have been under-predicting a major component of the hydrologic cycle.

Based on the modeling team's review of the data sets and recommendation from the Modeling Peer Review Panel (Loucks, et al. 2008), the SFWMD directed the modeling team to re-calibrate the AFET with the new reference evapotranspiration data set. In addition to the new reference evapotranspiration data, the recalibration effort incorporated information from the project team working on the calibration of the East Central Florida Transient (ECFT) MODFLOW Model (Project Communication).

The revised model was given the designation "AFET-W". The "W" in AFET-W refers to water supply. This designation was given to the model to differentiate it from the original AFET model and to identify it as the version of the model that would be used to evaluate surface water availability in the KCOL (AECOM. 2008). This version of the model was later selected as the tool to use for rule development for the Kissimmee Basin Water Reservations.

5.2.1.2.1 AFET-W Calibration Approach

The intent of the calibration of AFET-W was to incorporate the revised reference evapotranspiration data and improve the AFET ground water calibration. SFWMD modelers working on the ECFT MODFLOW Model assisted with the ground water portion of the recalibration effort.

A report summarizing the proposed calibration approach was submitted and reviewed by the SFWMD concurrently with the initiation of the modeling (AECOM 2008). The calibration approach identified target calibration statistics to be used in the calibration process. The specified calibration period was similar to the original AFET verification period and was selected to overlap with the concurrent ECFT calibration effort. Since one of the goals of this modeling effort was to improve the simulation of runoff within the KB, a 10-year verification period was also used (from 1995 through 2004) to compare simulated cumulative discharges at the S-65 and S-65E Water Control Structures.

5.2.1.2.2 AFET-W Acceptance

Following the development of the AFET-W model and review by the SFWMD, the simulation was determined to be superior to the AFET. As a result, the modeling team was directed to replace the AFET with the AFET-W as the daily simulation modeling tool to be applied as part of the KBMOS (AECOM 2008).

5.2.2 Kissimmee River Floodplain Hydraulic Model

The development and calibration of the AFET-W model addressed the watershed condition that existed within the recent history of the KB. However, the calibration period did not consider the completed portions of the Kissimmee River Restoration Project (Phase I was complete in 2001) nor the future fully restored condition. Therefore, the modeling team proceeded with a separate modeling effort to address the future condition hydraulics in the restored Kissimmee River floodplain. This was not a calibration effort.

The MIKE 11 network and cross sections of the Kissimmee River floodplain currently in the KBMOS future condition model were used in this modeling effort to represent the hydraulic condition of the fully implemented restoration project. The MIKE 11 network was reviewed to ensure accurate representation of restoration project features. Special attention was paid to areas where structural modifications have been made or will be made as part of project implementation. These areas included the structures adjacent to the S-65A Structure (tieback levees and weirs), the floodplain in the vicinity of the former Pool B weirs and the U-Shaped Weir and other Pool D structures. The model setup was reviewed to make sure that the cross sections in the selected branches would not intersect each other. Cross sections were also extended based on available topographic data to ensure that the entire floodplain was incorporated in the hydraulic representation. Some cross sections in Pool A were extended and one cross section on Meander 17 was extended to reach the floodplain (Earth Tech | AECOM 2008).

This effort was important to demonstrate how the hydraulics of the proposed restoration project would perform under the pre-channelization hydrologic conditions that existed from the 1930's through the 1960's. This modeling tool was used to refine and validate the river evaluation performance measure targets at key locations in Pool B-C-D (Earth Tech | AECOM. 2008).

Once completed, the revised MIKE 11 network was incorporated into the AFET-W model to represent the fully restored condition in the Kissimmee River floodplain for application in the 'With-Project' Base Condition Model (Earth Tech | AECOM. 2008).

5.2.3 Flood Event Model Development: AFET-FLOOD

The AFET-FLOOD model is being developed for application by the USACE in their flood analyses and evaluations of alternative plans for KBMOS. It is being derived from the AFET-W model and calibrated to the 2004 hurricanes and verified using Tropical Storm Fay in 2008. The effort is a joint effort between the USACE and the SFWMD as part of the Kissimmee River Restoration Project. The ultimate goal is to deliver a flood routing model that can be applied in support of operations for the Kissimmee River Restoration Project.

5.2.4 Development of the Screening Tool

5.2.4.1 Initial Model Development

The OASIS modeling effort kicked off in 2005 with the implementation of the proof-of-concept approach discussed in Section 3.1.3. This work culminated in the OKISS model. The following describes the development of this model.

5.2.4.1.1 OASIS Model Development of the Kissimmee Basin

The first step in the development of the OKISS model was development of a model with the same domain as the UKISS model. The OASIS model created for this domain was named O-KCOL to indicate it was specific to the KCOL. The development of O-KCOL was documented in the OASIS KCOL Model Report (Earth Tech 2006e). O-KCOL was then updated to include the Kissimmee River (Earth Tech 2006k), creating OKISS, which is the name used for the OASIS model applied during the Alternative Plan Screening Process for the KBMOS. OKISS was developed following the guidelines established in the Screening Tool TDD (Earth Tech 2006d).

A history matching exercise was performed to verify the results produced by OKISS. This exercise is documented in the OKISS Model Development and History Matching Report (Earth Tech 2007f). The version of OKISS used in the 2006 history matching was updated using information obtained from the calibration of the KBMOS AFET (MIKE SHE/MIKE 11) (Earth Tech 2007e). An additional history matching exercise was performed to validate the refined version of OKISS to be used in the KBMOS alternative screening.

5.3 Model Testing of Operating Criteria

Of critical importance to KBMOS is the ability of the modeling tools to simulate the complex operating rules employed in the KB to manage the water control structures. During the initial development of the modeling tools, the team completed activities to document current operational policies and to demonstrate the ability of the models to simulate these rules.

5.3.1 Operating Criteria Framework

As part of the initial data collection and compilation in Phase II, the modeling team needed to develop a basic level of understanding of the operational issues within the basin. To document this, the SFWMD created the Operating Criteria Framework Document (Konyha 2005) to describe the decision-making process used by the SFWMD and the USACE to manage water control structures in the KB. The intent of this document was to communicate sufficient information to the computer modelers to translate this process into a code and build this code into the modeling tools.

Following the completion of this SFWMD document, it was distributed to the modeling team and a code was developed (Hydrologics and DHI) for review and comment. The AECOM team then hosted a teleconference with key members of the modeling team and the SFWMD to provide an opportunity for discussion of issues and methodologies that would be implemented to develop the logic required to convert these operating criteria into model code.

5.3.2 Initial Comparison of Modeling Tools

The models selected for the planning effort use two similar but different methodologies to simulate the operating rules. The OASIS code from Hydrologics, Inc. uses the Operating Control Logic (OCL) module that applies a linear programming approach to solve the complex, multi-dimensional relationship of hydrology to define operations. Application of the OCL approach was demonstrated successfully through the proof-of-concept testing during the selection of OASIS, which was documented in the OASIS KCOL Model Report (Earth Tech 2006e). This demonstration was successfully completed with the implementation of OASIS in the KCOL and its favorable comparison to the existing SFWMD UKISS model. In the DHI MIKE 11 model, structure operations are simulated in the Structure Operations Module, using a series of nested if-then type statements.

Although the code developers (DHI and Hydrologics) felt confident that the two approaches would generate similar results, testing of the operational rules simulation was implemented to demonstrate that the results were similar enough to support the approach defined by the Alternative Plan Selection Process. The process to compare the two approaches was documented in the Operating Criteria Simulation Engine Proof of Concept Approach (Earth Tech 2006f).

As part of the demonstration of the OASIS KCOL Model, the team developed modified operating criteria for the S-61 Structure that discharges from Lake Tohopekaliga into Cypress Lake. The intent of the operating criteria simulation engine proof-of-concept approach was to implement the same operating criteria in MIKE 11 and demonstrate that the two methods for simulation of water control structure operations was sufficiently similar to support the overall modeling strategy. The Alternate Formulation and Evaluation Tool Development – AFET Operating Criteria Simulation Engine OCSE Demonstration Report (Earth Tech 2006g) demonstrated that the MIKE 11 structure operations were able to implement the same modified operating criteria that were simulated in OASIS in the KCOL and provide similar results. Although there were some minor differences in the peak stages and flows, this was explained by the more detailed representation of hydraulics and better temporal resolution in MIKE 11.

5.3.3 Demonstration of Transition Rules

The operating criteria simulation engine proof-of-concept was able to demonstrate that the OASIS and MIKE 11 approaches to the simulation of operating criteria were able to produce similar results. Additional testing was performed to compare the simulation of a more complex set of operation criteria and to demonstrate the level of effort required to program and debug structure operations in OASIS and MIKE 11, respectively. To perform this testing, the SFWMD developed proposed operating criteria for the S-65 Water Control Structure that defined releases when headwater stages transition from Zone A to Zone B. The intent was to develop a 'soft landing' rule that would conserve water in Lake Kissimmee for environmental needs later in the season. The SFWMD created a white paper entitled Kissimmee Basin Modeling and Operations Study Proposed Operational Rules KR_Transition_Rules (Konyha 2006).

The transition rule is an example of the type and complexity of the operating criteria that was expected in the KBMOS Alternative Plan Selection Process. The Demonstration of Transition Rule Operating Criteria Technical Memorandum (Earth Tech 2007c) explained and documented the programming of the proposed transition rule in AFET and OKISS. This document includes the following:

- How operating rules are entered into the AFET structure operations and OKISS OCL;
- How operating rules developed in OKISS will be adapted for incorporation into the MIKE 11 logic structure; and
- The level of effort associated with putting together an alternative plan so that appropriate time and resources can be estimated for alternative plan evaluations.

5.3.4 Development of the PME Tool

The PME Tool is a common model tool interface that displays modeling results relative to the EPMs and EPIs developed to differentiate between alternative plans. The PME Tool was developed from specifications outlined in the Alternative Evaluation System Technical Design Document (Earth Tech 2007d). The concepts and components that comprise the AES were presented, as well as how the components were to be integrated and applied in the KBMOS. Components of the AES as well as the PME Tool were updated throughout the Alternative Plan Screening Process, based on knowledge gained through the application of the modeling tools and interactions with the Interagency Study Team and basin stakeholders. The Alternative Plan Selection Document describes the final version of the EPMs and EPIs, as well as the system for integrating these data into a final score. The implementation of the AES as a modeling tool is described in the Updated PME Tool Documentation, Version 1.3b (AECOM 2010).

The PME Tool includes a set of utilities that sequentially convert model output into a "report card" for each alternative plan. These utilities are grouped in a "shell" using a Microsoft Excel platform. The main components of the PME Tool, as depicted in Figure 5-1, are the "Data Extraction Utilities" and the "Excel Shell (Scoring Utility Tool)". These can be described as follows:

- **Data Extraction Utilities:** Obtains relevant (user specified) information from the model results files. OKISS results for each evaluation location are obtained from Data Storage System (DSS) files generated by OASIS. AFET output is extracted from MIKE 11 (.res11) and MIKE SHE (.dfs0 and .dfs2) result files.

- **<u>Excel Shell (Scoring Utility Tool):</u>** Consists of an Excel spreadsheet with automated macros that call the calculation scripts and import their results into the spreadsheet environment. The macro produces the Alternative Plan Report, which documents all information relevant to the evaluation of the metrics that comprise the alternative plan score.

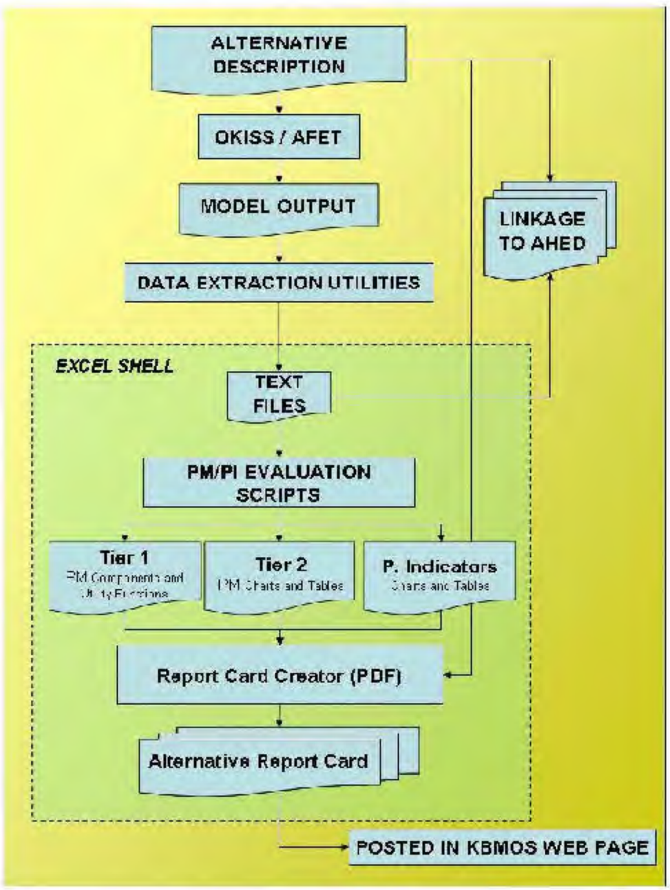

Figure 5-1: Flow Diagram of the PME Tool

The PME Tool has undergone extensive testing and validation throughout the Alternative Plan Screening Process. The documentation has been annotated and revised to document these updates with a versioning control section that describes these updates.

5.4 Application of the Modeling Tools

As mentioned previously, the Alternative Plan Selection Process calls for the sequential application of three increasingly complex modeling tools. Because the approach utilizes three different models, the first effort was to demonstrate that the three tools were able to provide similar results. The comparison was done using a simulation of the 'With-Project' Base Conditions.

The 'With-Project' Base Condition is the basis or platform to which the effectiveness of alternative plans can be compared, based on their ability to meet the desired conditions defined by the EPMs. Establishing base conditions involves the identification of key basin characteristics (and associated periods) that will serve as the basis for the alternative plan evaluation.

Once the hydrology and hydraulics of the basin are obtained through model calibration, the parameters of the basin are applied under a fixed set of conditions, or model drivers, to predict the basin response. This set of fixed conditions is called the base condition. The base condition combines the existing hydrologic conditions of the watershed (year 2000 land use and year 2008 water use) with the future infrastructure and geometry of the Kissimmee River Restoration Project (infrastructure, operations, etc.). These two components were augmented by climate drivers and other boundary conditions that were witnessed over the period from 1965 to 2005. The land use and water use data sets represent the best available data that existed at the beginning of each effort in the study. The year 2000 land use was the data set used during calibration of both the original AFET and the subsequent AFET-W model and represents the best available information at the time the 'with project' Base Condition was developed. The application of the 2008 water use was selected to represent the existing permitted uses of water that existed during the initial development of the water reservation. The development, implementation and results obtained from the base condition are documented in the Evaluation of "With Project" Base Conditions Report (AECOM 2009).

5.4.1 Development of Base Condition Models

The 'with project' base condition represents basin characteristics that are understood based on data collected to date or the experience of the basin stakeholders. It includes all features of the fully implemented Kissimmee River Restoration Project including the Headwater Revitalization Project. Base conditions are summarized in the KBMOS Base Conditions Summary Report (Earth Tech 2007g). This document describes the base conditions to be used during the evaluation of alternative operating criteria being considered for the future operation of the C&SF Project water control structures in the KB.

With the implementation of the AFET-W model and as a result of the modeling peer review (discussed below), the modeling team updated several assumptions related to the simulated base conditions. As a result, the 2008 Base Conditions Summary Report was updated to reflect the ongoing KB water reservations activities. The revised base conditions were described in the

Kissimmee Chain of Lakes Surface Water Supply Availability Study, Summary of "With Project" Base Conditions - Technical Memorandum (AECOM 2009a). The summary of the Base Conditions Report included references to the development of the material described below.

5.4.1.1 Downstream Boundary Condition – Lake Okeechobee

All of the discharges from the 2,279 square mile KB are directed through the S-65E Structure into Lake Okeechobee. The downstream boundary condition represents the influence that stages in Lake Okeechobee would have on these discharges. The KBMOS Draft Evaluation of Downstream Boundary Conditions Technical Memorandum (Earth Tech 2007h) describes the evaluation that was performed to define this boundary condition.

5.4.1.2 Interim Operation of the S-65D Structure

Prior to the development of the KBMOS modeling tools, interim operating criteria for the S-65D Structure had not been considered. A revision to the operating criteria for the S-65D Structure was required to develop the future conditions in the KBMOS models. The proposed interim operating criteria was documented in the KBMOS Draft Operating Criteria for Modeling S-65D Future Conditions (Earth Tech 2007i) Technical Memorandum. This was necessary because of the head loss that could result from the flow constraints represented by the U-shaped weir and the CSX Railroad crossing over the remnant channel between the US Highway 98 crossing and the S-65D Structure.

The description of the operating criteria included in this effort is to be used only as part of the modeling activities within the KBMOS. Additional analysis will be required to adapt the terms in which the proposed operating criteria are expressed to the language commonly used by the structure operators, once the downstream features of the KRRP have been finalized. Also, the effect of the proposed operating criteria on the flood control level of service within the Kissimmee River floodplain and in the overall stability of the structure will also need to be further evaluated.

5.4.1.2.1 Future Condition Water Use

The approach to simulating water use in the KB was described in both base condition summary documents. However, as part of the AFET-W implementation, these water use data were updated. One of the AFET-W's intended applications was to be used for water supply planning and the development of water reservations in the KB. Therefore, the modeling tool needed to include the influence of existing legal uses of water on the surface and groundwater resources of the KB. The modeling team published the Technical Approach to create the Existing Legal Users database included in the "With Project" base condition model (Earth Tech 2008), describing the inclusion of the existing legal users in the 'with project' base condition modeling effort.

5.4.2 Validation and Testing of the Modeling Tools

The KBMOS Work Plan included a process to validate the study modeling tools by comparing the results obtained for each performance measure. The validation process is needed to evaluate the effect of the differences in model conceptualization on the Alternative Plan Selection Process. The three modeling tools used in the study have very different technical approaches to simulate the hydrology and hydraulics of the KB, OKISS being the most unique approach of the three. OKISS is a water management model that runs in daily time-steps. OKISS has been adapted to model the hydraulics of the KB through the addition of a series of surrogate computations, while the AFT (MIKE 11 decoupled) and hydrology (MIKE SHE) both include sophisticated hydraulic computations and smaller time-steps (in the order of minutes). The approach that each model uses to simulate structure operations is also very different between OKISS and the AFET-W. These differences would explain discrepancies in model results for the same type of simulation. However, the selection of an alternative requires a smooth transition through the three levels of the Alternative Plan Selection Process.

Even though each modeling tool has been subject to model calibration and/or history matching, the validation process provides the required confidence in model results by comparing them under the wide range of climatic conditions found in the base condition period of simulation (1965-2005).

Three types of comparisons were performed to validate the results of the KBMOS modeling tools. The first comparison is to look at the calibration locations used in the development of the AFET-W over the period of simulation. This analysis compared each model to the other two models using the calibration statistics to define 'goodness of fit' metrics.

The second two comparisons were done with the data that defined the KBMOS performance measures. One comparison uses the same model output data that are used to calculate the values of the performance measure components, namely, the time-series of stages and flows of those locations identified as evaluation locations. Duration curves and stage hydrographs were used in this analysis. The second comparison is based on the numeric values of the performance measure components. Each KBMOS EPM is sub-divided into a series of evaluation components. Targets for the EPMs relate to the natural resource requirements of the KRRP and the KCOL and were derived based on analyses of hydrologic data obtained during the pre-regulation period and the recent history of management practices that have yielded positive ecological observations. The comparison, performed within the validation process, used the selected targets as a reference. Comparison results were presented as a series of charts and tables for each performance measure component.

The results of these comparisons demonstrated that the KBMOS modeling tools produce comparable component values for the EPMs. Furthermore, the results of this validation demonstrated that there should be a smooth transition from the screening tool (OKISS) to the more sophisticated MIKE SHE/MIKE 11 models. The results of these comparisons are contained in the Evaluation of Base Conditions Report – AFET-W (AECOM 2009).

5.4.3 AFET Sensitivity Analysis

The AFET Sensitivity Analysis was performed as part of the development of the original AFET model. Although the original intent of this effort was to be an uncertainty analysis, the peer review panel felt the approach taken didn't meet the general intent of an uncertainty analysis. The approach was more consistent with a parameter uncertainty analysis similar to a sensitivity analysis. As a result, the modeling team agreed to re-conceptualize the report as a sensitivity analysis.

This sensitivity analysis provided a quantitative analysis of the impact of parameter uncertainty in the AFET modeling tool predictions on the evaluation of performance measures. This analysis has been conducted to demonstrate the AFET model sensitivity to the predicted effectiveness of existing operating rules developed using the model and how this parameter uncertainty is translated into the evaluation of the components of each performance measure during the alternative evaluation.

Special interest was added to the model's sensitivity to the runoff quantities produced by the AFET. Runoff is a result of several model parameters and does not constitute a specific model input. Therefore, runoff depths were calculated and the propagation of the parameter uncertainty in runoff was propagated to the values of each individual performance measure component. An evaluation of this propagation was performed by comparing the obtained component values with each one of their targets. Furthermore, a linear relationship was established between different values of potential runoff and the values of performance measure components.

5.5 KBMOS Peer Review Panels

The SFWMD convened two peer review panels to review the modeling tools and performance metrics for the KBMOS.

5.5.1 Environmental Peer Review Panel

The Environmental Peer Review Panel was convened to review the EPMs and EPIs in March and April 2007. The panel included experts with backgrounds in ecology, biology and water resource management. These panelists judged the quality and credibility of the science and assumptions used to develop the EPMs, particularly their applicability to provide the linkage between system ecology and hydrology (Karr, et al. 2007).

Several revisions were made to the EPMs to address the Environmental Peer Review Panel recommendations. These modifications included reorganizing KCOL performance measures into seven lake EPMs, improving documentation for linkages between EPM components and expected ecological responses and incorporating EPM and EPI documentation into a more comprehensive document that summarizes the Alternative Plan Selection Process and components. To confirm revisions were consistent with peer review panel recommendations, the SFWMD conducted a third party review of the Draft Alternative Plan Selection Document that included the revised measures (Wetzel 2008).

5.5.2 Modeling Peer Review Panel

The overall goal of modeling peer review was to provide an unbiased expert assessment of the KBMOS planning effort to improve operational rules for water control structures within the KB. The intent of the modeling peer review was to assess the quality and credibility of the science used to develop the OKISS and the AFET models and their applicability to decision-making for operational management of structures in the KB (Loucks, et al. 2008). The modeling peer review panel included experts with backgrounds in modeling and application of modeling tools to water resource planning projects. These panelists judged the quality and credibility of the science behind the selection of the modeling tools and their suitability for evaluating existing and proposed KB structure operating criteria (Loucks, et al. 2008).

Comments received from the Modeling Peer Review Panel were addressed in the modeling tools. These revisions included a recalibration of the fully integrated model (MIKE SHE/MIKE 11) to an updated reference evapotranspiration data set, as well as several updates to the documentation for modeling tool development and their application to the Base Conditions.

5.5.3 Modeling Peer Review Activities

The modeling peer review consisted of two sessions to review the proposed planning process and modeling tools for the KBMOS. The first session was a formative review of the approach to the modeling tools and planning process. The following summarizes the objectives of the first session:

- Objective 2A: Assessment of the Process Used to Select Modeling Tools
- Objective 2B: Assessment of Modeling Tools and Performance Measures
- Objective 2C: Assessment of the AES

In their report at the conclusion of the first session, the panel concluded that "overall, the panel finds that the KBMOS plan for identifying suitable alternative operating criteria for hydraulic structures in the Kissimmee Basin is sound" (Loucks, et al. 2007). The conclusion was accompanied by a number of recommendations that the modeling team was able to incorporate into the planning effort.

During the second session, the panel was re-convened to evaluate the development and application of the base conditions in the original AFET model. As with the first session, the second session was also a formative review. The review was completed on the draft reports and the panel's comments were used to clarify parts of these reports that were judged unclear and make suggestions relative to possible additional work that would clarify the project goals. The objectives of the second session were the following:

- Objective 3A: Assess whether the selected models have been appropriately formulated and calibrated to evaluate existing and proposed KB structure operating criteria
- Objective 3B: Determine if the results from the base condition simulations provide an appropriate benchmark for use in the Alternative Plan Selection Process

From Loucks, et al. (2008), the following is the conclusion of the panel's review:

> "The panel finds no critical defects in the modeling and operation study completed as of this date and no critical defects in the modeling and study activities planned for the completion of this study; thus no remedies are needed. We do identify some remaining issues and opportunities that if addressed within the time and budget constraints available might further enhance the outcomes of this study.

Specific to the objectives of the second session, the following is the panel's assessment:

> Objective 3A: The selected models have been appropriately formulated and calibrated and are ready to use to evaluate existing and proposed Kissimmee Basin structure operating criteria.
>
> Objective 3B: The results from the past and future base conditions simulations provide an appropriate benchmark for use in the Alternative Plan Selection Process. The base conditions are appropriately formulated and there are no significant shortcomings.

During the peer review process, the panel had a number of comments and recommendations that were addressed either through modifications to the documentation, presentations to the panel during the final workshop, or updates to ongoing efforts. The major modification to the KBMOS, as a result of the peer review panel, was the recommendation relative to reference evapotranspiration used in the modeling effort. This recommendation, along with the need to develop a water supply planning tool, resulted in the development of the AFET-W modeling tool.

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APPENDIX A

REPORT OUTLINE SUMMARIZING REFERENCES CITED

Section ID	Section Title	Reference	Reference Topic
1	INTRODUCTION	Earth Tech 2005	comprehensive assessment of basin conditions
1.1	Purpose	Earth Tech 2005a	Task 1.9 Work Plan
1.2	Background	DHI 2007	the MIKE SHE/MIKE 11 tool
		Hydrologics 2006	the OASIS modeling code
2.1	Alternative Evaluation System	Earth Tech 2007d	Alternative Evaluation System Technical Design Document
2.1.3	Alternative Plan Selection Document	AECOM 2010	Updated PME Tool Documentation version 1.3b
3	KBMOS MODELING AND EVALUATION TOOLS	Earth Tech 2005	
3.3	OASIS Model Selection	Hydrologics 2006	OASIS modeling software
		Earth Tech 2005c	Screening Tool Proof of Concept Test Plan
4.1	Data Collection and Compilation	Earth Tech 2005	modeling strategy documented in the KB Assessment
4.1.1.1	Daily Data	Earth Tech 2005b	Interim Data Summary Table
		Earth Tech and Marco Water Engineering 2006	further review
4.1.1.2	Hourly Data Summary	Earth Tech 2006	Hourly data for event calibration/verification of AFET
4.1.2	Rainfall Data	Earth Tech 2005b	Interim Data Summary Table
		Earth Tech 2006a	Phase II, Alternate Formulation and Evaluation Tool Development - Interpolated Rainfa Technical Memorandum
		Earth Tech 2007	2004 Hourly rainfall depth raster sets from 15-minute Next Generation Radar (NE NEXRAD Rainfall Grids Technical Memorandum
		Earth Tech 2007a	Daily Rainfall:1965 through 2005 Processing of SFWMM 2mi. x 2mi. Rainfall Grids to AFET Input Files Technical Memorandum

Section ID	Section Title	Reference	Reference Topic
4.1.3	Topographic Data	Earth Tech 2007b	processing and creation of the DEM that describes the topography of the KB is docume the Digital Elevation Model of the Kissimmee Basin
5.1.1	MIKE SHE/MIKE 11 Technical Design Document	Earth Tech 2006b	the Kissimmee Basin Modeling and Operations Study, Alternative Formulation Evaluatic (AFET) Development Technical Design Document
		DHI and GeoModel 2001	Lake Tohopekaliga Drawdown Model documented in the Integrated Surface and Groun Model for Lake Tohopekaliga Drawdown Project
		Earth Tech 2006c	the Kissimmee Basin Modeling and Operations Study, Alternative Formulation/Evaluatic Acceptance Test Plan () describes the calibration and verification time periods for cont and event simulations and to define the statistical criteria that was to be used as the s point to assess model calibration
5.1.2	OASIS Model Technical Design Document	Earth Tech 2006d	the Kissimmee Basin Modeling and Operations Study, Screening Tool Technical Document
5.2.1.1.1	MIKE SHE Model Development of the Kissimmee Basin – AFET	Earth Tech 2005	Summaries of these models are provided in the Phase I Kissimmee Basin Assessment
		Earth Tech 2006h	interim status was documented in the Alternative Formulation/Evaluation Tool Developr MIKE SHE Documentation
5.2.1.1.2	MIKE 11 Model Development of the Kissimmee Basin – AFET	Project Communication	Additional canal cross sections and hydraulic data were obtained from past modeling SFWMD and the USACE in UNET and HEC-RAS in the KB
		Earth Tech 2006i	interim status was documented in the Phase II, Alternate Formulation and Evaluatic Development – Development of MIKE 11 Documentation
5.2.1.1.3	Merged MIKE SHE / MIKE 11 Model of the Kissimmee Basin – AFET	Earth Tech 2007e	model documented in Kissimmee Basin Modeling and Operations Study, Phase II, Model Documentation/Calibration Report
5.2.1.1.4.1	Initial Sensitivity Analysis of the Merged MIKE SHE/MIKE 11 Model – AFET	Earth Tech 2007e	The sensitivity analyses
5.2.1.1.4.2	Calibration and Verification of MIKE SHE/MIKE 11 Model – AFET	Earth Tech 2007e	The results of this calibration process are documented in the Kissimmee Basin Modeli Operations Study, Phase II, AFET Model Documentation/Calibration Report
5.2.1.2	Daily Planning Model Re-calibration – AFET-W	Loucks, et al. 2008	recommendation from the Modeling Peer Review Panel
		SFWMD 2008	new reference evapotranspiration data set
		Project communication	the East Central Florida Transient (ECFT) MODFLOW Model

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Section ID	Section Title	Reference	Reference Topic
		AECOM. 2008	AFET-W
5.2.1.2.1	AFET-W Calibration App	AECOM 2008	proposed calibration approach
5.2.1.2.2	AFET-W Acceptance	AECOM 2008	
5.2.2.	Kissimmee River Floodplain Hydraulic Model	Earth Tech | AECOM 2008	MIKE 11 network and cross sections of the Kissimmee River floodplain currently KBMOS future condition model
		Earth Tech | AECOM. 2008	refine and validate the river evaluation performance measure targets at key locations B-C-D
		Earth Tech | AECOM. 2008	'With-Project' Base Condition Model
5.2.4.1.1	OASIS Model Development of the Kissimmee Basin	Earth Tech 2006e	The development of O-KCOL OASIS KCOL Model Report
		Earth Tech 2006k	update to include the Kissimmee River
		Earth Tech 2006d	established in the Screening Tool TDD
		Earth Tech 2007f	compare OKISS to measured data OKISS Model Development and History Matching Re
		Earth Tech 2007e	additional history matching in KBMOS AFET (MIKE SHE/MIKE 11)
5.3.1	Operating Criteria Framework	Konyha 2005	Operating Criteria Framework Document
5.3.2	Initial Comparison of Modeling Tools	Earth Tech 2006e	OASIS KCOL Model Report proof-of-concept testing
		Earth Tech 2006f	Operating Criteria Simulation Engine Proof of Concept Approach - compare OAS MIKE11 OPERATIONS
		Earth Tech 2006g	Alternate Formulation and Evaluation Tool Development – AFET Operating Criteria Sim Engine OCSE Demonstration Report
5.3.3	Demonstration of Transition Rules	Konyha 2006	Proposed Operational Rules KR_Transition_Rules- The SFWMD created a white entitled Kissimmee Basin Modeling and Operations Study
		Earth Tech 2007c	Demonstration of Transition Rule Operating Criteria Technical Memorandum
5.3.4	Development of the PME Tool	Earth Tech 2007d	Design according to Alternative Evaluation System Technical Design Document
		AECOM 2010	implementation of the AES as a modeling tool is described in the Updated PMI Documentation, Version 1.3b

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Section ID	Section Title	Reference	Reference Topic
5.4	Application of the Modeling Tools	AECOM 2009	development, implementation and results obtained from the base condition are docume the Evaluation of "With Project" Base Conditions Report
5.4.1	Development of Base Condition Models	Earth Tech 2007g	features of the fully implemented Kissimmee River Restoration Project includi Headwater Revitalization Project. Base conditions are summarized in the KBMOS Conditions Summary Report
		AECOM 2009a	updated to reflect the ongoing KB water reservations activities and described in the Kiss Chain of Lakes Surface Water Supply Availability Study, Summary of "With Project Conditions - Technical Memorandum
5.4.1.1	Downstream Boundary Condition – Lake Okeechobee	Earth Tech 2007h	The KBMOS Draft Evaluation of Downstream Boundary Conditions Technical Memor describes the evaluation that was performed to define this boundary condition.
5.4.1.2	Interim Operation of the S-65D Structure	Earth Tech 2007i	proposed interim operating criteria was documented in the KBMOS Draft Operating Crit Modeling S-65D Future Conditions Technical Memorandum
5.4.1.2.1	Future Condition Water Use	Earth Tech 2008	Technical Approach to create the Existing Legal Users database included in the "With F base condition model
5.4.2	Validation and Testing of the Modeling Tools	AECOM 2009	demonstrate that the KBMOS modeling tools produce comparable component values EPMs. Evaluation of Base Conditions Report – AFET-W
5.5.1	Environmental Peer Review Panel	Karr, et al. 2007	The Environmental Peer Review Panel was convened to review the EPMs and EPIs in and April 2007
		Wetzel 2008	To confirm revisions were consistent with peer review panel recommendations, the S conducted a third party review of the Draft Alternative Plan Selection Document that in the revised measures
5.5.2	Modeling Peer Review Panel	Loucks, et al. 2008	modeling peer review assessed the quality and credibility of the science used to deve OKISS and the AFET models and their applicability to decision-making for oper management of structures in the KB
5.5.3	Modeling Peer Review Activities	Loucks, et al. 2007	Peer review report
		Loucks, et al. 2008	Peer review panel conclusions

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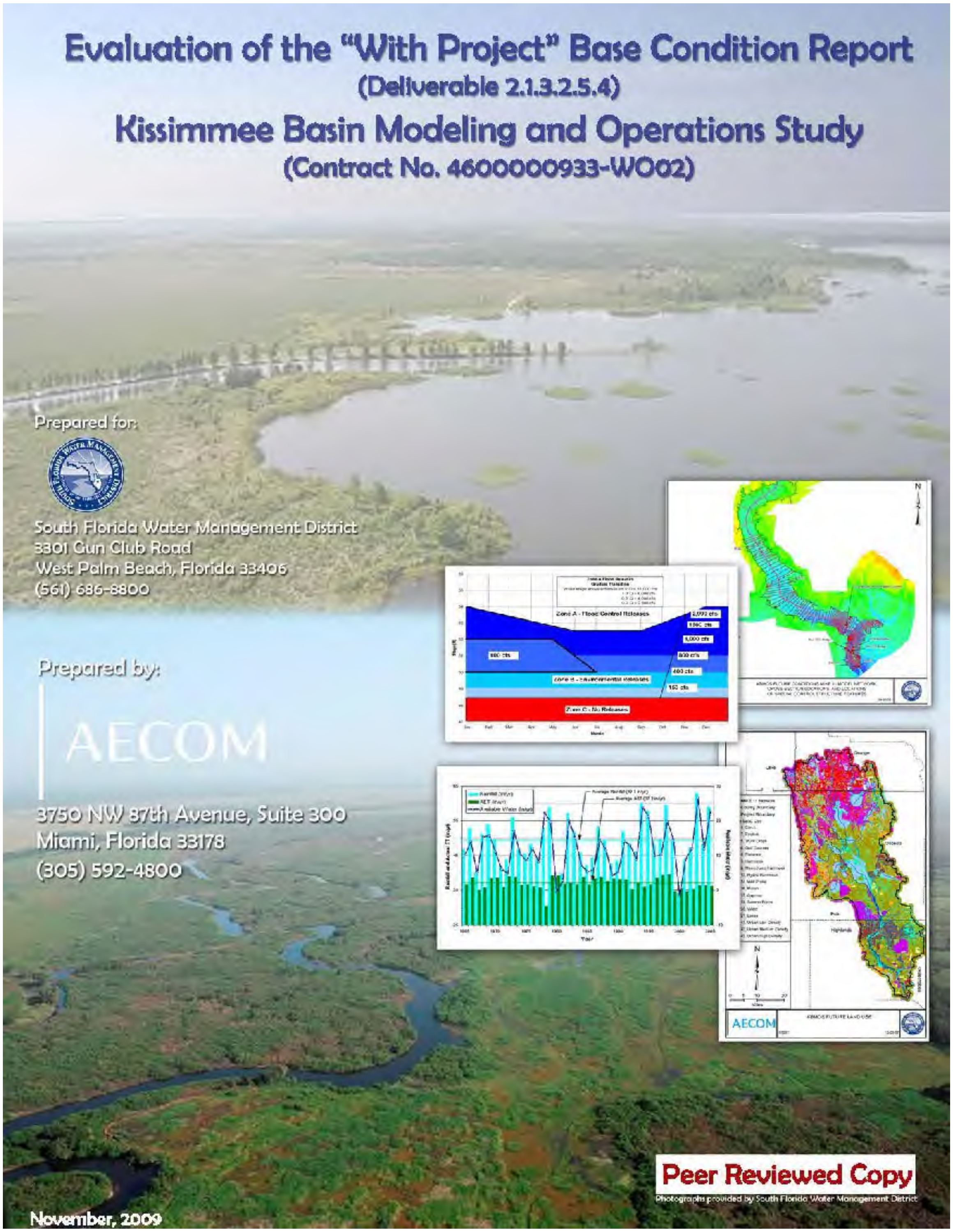
APPENDIX L: DEVELOPMENT AND VALIDATION OF MODELING TOOLS USED FOR KISSIMMEE BASIN WATER RESERVATIONS

This appendix contains a report that presents the development and validation of the tools used for the Kissimmee Basin water reservations including the screening model (OKISS), detailed models, and performance measures evaluation tools. The Alternative Formulation and Evaluation Tool for Water Reservation (AFET-W) is the fully coupled MIKE SHE/MIKE 11 model for the Kissimmee Basin (The decoupled MIKE 11 is known as the Alternative Formulation Tool [AFT]). This was the basis for the screening and alternative formulation tools. The report includes a description of AFET-W, comparison of the results of the screening and alternative evaluation, and formulation tools using the performance measures evaluation tools. Section 3.3 describes performance measures evaluation tool application to the AFET. For details on the performance measures locations in the Upper and Lower Kissimmee basins, and comparison of the results of models (OKISS, AET, and AFT) at these locations, the reader is referred to Section 5.


Evaluation of the "With Project" Base Condition Report
(Deliverable 2.1.3.2.5.4)
Kissimmee Basin Modeling and Operations Study
(Contract No. 4600000933-WO02)
Prepared for:
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Zone A - Flood Control Releases
Zone B - Environmental Releases
Zone C - No Releases
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Peer Reviewed Copy
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November, 2009

Evaluation of the "With Project" Base Condition

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Kissimmee Basin Modeling and Operations Study KBMOS

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LIST OF ACRONYMS

AET	Alternative Evaluation Tool
AFET	Alternative Formulation/Evaluation Tool
AFT	Alternative Formulation Tool
ASCII	American Standard Code for Information Exchange
C&SF	Central and Southern Florida
CAP	Computer-Aided Participation
cfs	cubic feet per second
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
ECFT	East Central Florida Transient
EIS	Environmental Impact Statement
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FWC	Florida Fish and Wildlife Conservation Commission
GUI	Graphical User Interface
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HESM	Hydrologic and Environmental Systems Modeling
HW	Headwater
ICA	Irrigation Command Area
ICU	Intermediate Confining Unit
KBMOS	Kissimmee Basin Modeling and Operations Study
KCOL	Kissimmee Chain of Lakes
KRRP	Kissimmee River Restoration Project
KUB	Kissimmee Upper Basin
LKB	Lower Kissimmee Basin
LMA	Lake Management Area
LTMP	Long Term Management Plan
LP	Linear Program
MAE	Mean Absolute Error
MAGO	Maximum Allowable Gate Opening
ME	Mean Error
MPHD	Maximum Permissible Head Difference
OASIS	Operational Analysis and Simulation of Integrated Systems
OCL	Operational Control Language
OKISS	OASIS Modeling for the Kissimmee Basin
PET	Potential Evapotranspiration
PME	Performance Measure Evaluation
PWS	Public Water Supply
RET	Reference Evapotranspiration
RMSE	Root Mean Squared Error
SAS	Surficial Aquifer System
SFWMD	South Florida Water Management District
TW	Tailwater
UFAS	Upper Floridan Aquifer System

UKISS	Upper Kissimmee Lakes Model
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WRDA	Water Resources Development Act

1 INTRODUCTION

The Kissimmee Basin Modeling and Operations Study (KBMOS) is a South Florida Water Management District (SFWMD) initiative to identify alternative water control structure operating criteria to meet the flood control, water supply, aquatic plant management and natural resource operating objectives for the Kissimmee Basin and its associated water resource projects. The KBMOS is a component of the Kissimmee River Restoration Project (KRRP) and will define the required water control structure operations needed to meet river restoration hydrologic requirements, while also achieving a more acceptable balance between operating objectives associated with flood control, water supply, aquatic plant management and the natural resource requirements of the Kissimmee Chain of Lakes (KCOL). Additionally, the KBMOS will ensure that modified Kissimmee Basin operations will not increase impacts on Lake Okeechobee, although the selected water control structure operating criteria are not intended to meet the desired inflow envelope for Lake Okeechobee. Operating criteria will be developed to effectively meet these various objectives with complete reliance on the existing water management infrastructure and the land interests of the State of Florida and the SFWMD.

This document describes the results and the drivers of the "With Project" base run. This base condition run was defined for use in the evaluation of KBMOS alternative plans, development of the "With Project" target and reservation time series for the Kissimmee Basin water reservation and the evaluation of proposed surface water supply withdrawals made under the selected plan for the KBMOS. The "With Project" base model incorporated Alternative Formulation/Evaluation Tool (AFET) model improvements associated with the recalibration effort (Earth Tech | AECOM 2008) and the Kissimmee River Floodplain Hydraulic Model (Earth Tech | AECOM 2008a), including use of a new reference evapotranspiration (RET) data set produced by the SFWMD (SFWMD 2008). The recalibrated model is referred to as the AFET-W. The "With Project" base run was executed using the SFWMD accepted version of the AFET-W.

Base conditions are the results from a calibrated model simulation that used a fixed set of conditions over a defined period of record. Base conditions are used to predict basin response under those conditions. The base condition defined and used for the "With Project" base condition combines the existing hydrologic conditions of the watershed (land use, water use) with the future hydraulic conditions (infrastructure, operations, etc.). These two components were augmented by climate drivers and other boundary conditions that were held constant throughout the study. The following sections describe the components of the "With Project" base condition definition in detail, along with the following:

- Definition of the period of simulation (1965 to 2005)
- Climate drivers (RET and rainfall)
- Boundary conditions
  - Tailwater (TW) time series for the S-65E Structure
  - Lateral and horizontal groundwater boundary conditions
- Hydrologic conditions of the basin (land use, water use)

- Year 2000 Land Use/Cover
- Existing Legal Uses of Water
- Hydraulic conditions of the basin (operations, infrastructure, etc.)
  - Complete restoration of the Kissimmee River including the Kissimmee River Headwaters Revitalization Project

1.1 Background

The KBMOS was initiated in September 2004. Phase I of the KBMOS was completed in June 2005. Findings from the Phase I Kissimmee Basin Assessment (Earth Tech 2005) were used to define operating objectives, a planning approach, a modeling tool set and a study work plan. Phase II was initiated in July 2005. This effort implemented the planning approach and modeling tools defined in Phase I and includes the following:

- Model development, calibration, verification and application
- Performance measure and indicator development
- Alternative Evaluation System and Performance Measure Evaluation (PME) Tool development
- Performance measure, Alternative Evaluation System and PME Tool refinement
- Implementation of the Alternative Plan Selection Process

The KBMOS' final deliverable will include modified interim and long-term operating criteria for Kissimmee Basin water control structures. These will be developed after a preferred alternative plan is selected by the SFWMD Governing Board for recommendation to the United States Army Corps of Engineers (USACE).

The USACE has the responsibility and authority to modify Kissimmee Basin water control structure operating criteria. The USACE initiated the Draft Environmental Impact Statement (EIS) required for the modification of Kissimmee Basin structure operating criteria in May 2005, to run in parallel with the KBMOS. The Draft EIS includes participation of USACE staff in the KBMOS and completion of National Environmental Policy Act investigations associated with modifying a Federal project. The Draft EIS is expected to be completed 9 to 12 months after the completion of the KBMOS.

The study area for both the KBMOS and the EIS includes the Kissimmee River, the KCOL and the associated tributaries and drainage areas (Figure 1-1). The lakes include the following:

- Lakes Kissimmee, Hatchineha and Cypress
- Lake Tohopekaliga
- East Lake Tohopekaliga, Fells Cove and Lake Ajay
- Lakes Hart and Mary Jane
- Lakes Joel, Myrtle and Preston
- The Alligator Chain of Lakes (Lakes Alligator, Brick, Lizzie, Coon, Center and Trout)

- Lake Gentry

An Interagency Study Team was formed at the beginning of Phase II to assist in the development, review and refinement of performance measures and indicators, modeling tools and the Alternative Evaluation System and the development and evaluation of alternative plans. The Interagency Study Team is composed of representatives from the following:

- SFWMD
- USACE
- Florida Fish and Wildlife Conservation Commission (FWC)
- United States Fish and Wildlife Service (USFWS)
- Florida Department of Environmental Protection (FDEP)
- United States Environmental Protection Agency (USEPA)
- Florida Department of Agriculture and Consumer Services (FDACS)
- Osceola County

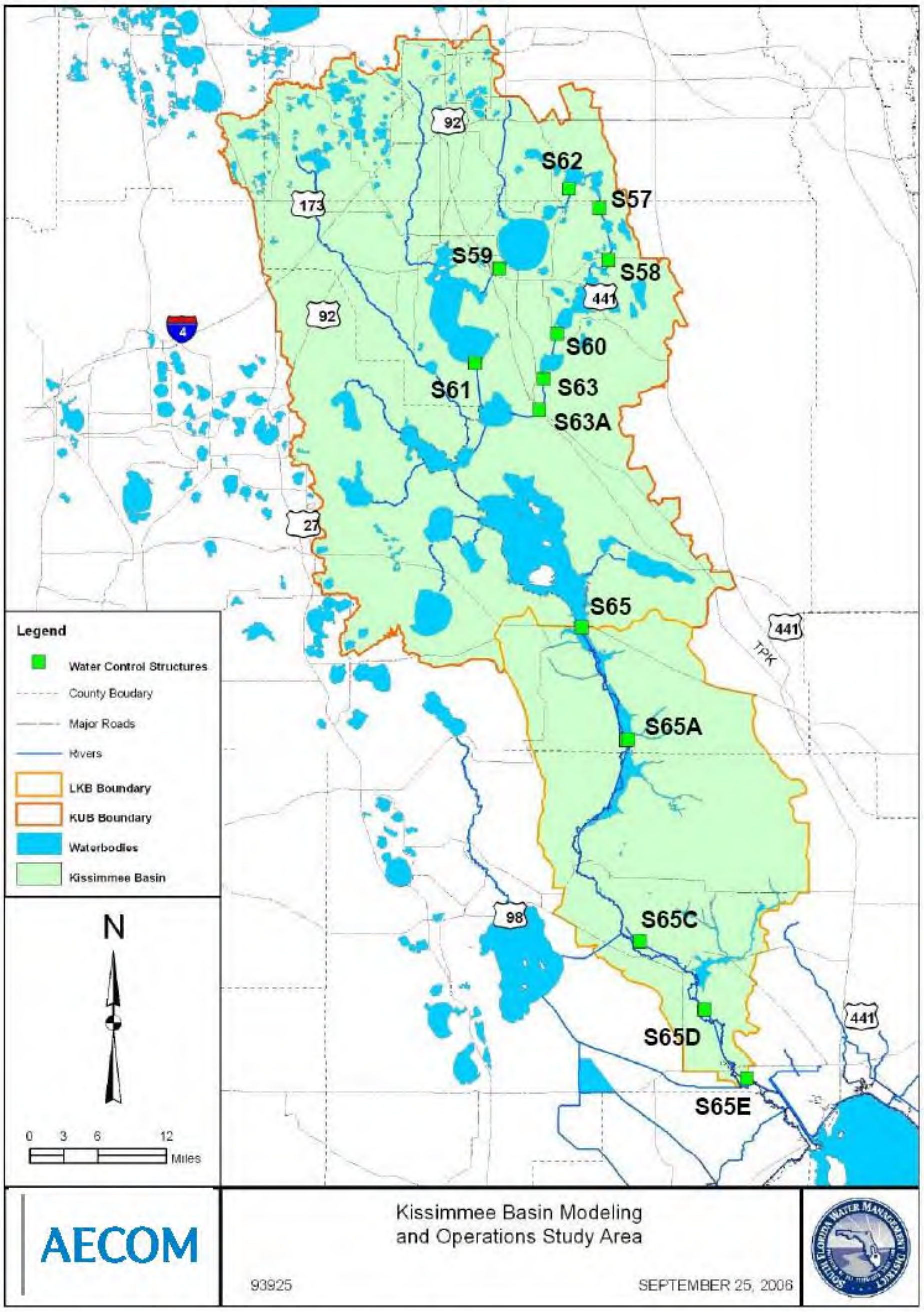

Figure 1-1: Kissimmee Basin Circa 2001

AECOM

In addition to Interagency Study Team participation, the public has been encouraged to participate. Communication and information gathering has been facilitated through email, interagency workshops and public meetings. Interagency Study Team workshops were held to solicit input, review deliverables, refine planning tools and develop and evaluate alternative plans. Public workshops were held to provide information about the study and to solicit input for and encourage participation in the development of performance measures and indicators and alternative plans. Local stakeholder group participants include:

- Alligator Chain of Lakes Home Owners Association
- Audubon of Florida
- Deseret Ranch
- Lake Mary Jane Alliance

The Evaluation of the "With Project" Base Condition Report has been prepared as part of the KBMOS. This document describes the development and validation of the base condition models that are being used for the evaluation of alternative operating criteria for the future operation of the Central and Southern Florida (C&SF) Project in the Kissimmee Basin. Detailed documentation for modeling tool development, calibration and verification, the Alternative Evaluation System and the alternative plan screening, formulation and evaluation process can be found in the following reports:

- Phase I Kissimmee Basin Assessment (Earth Tech 2005)
- AFET-W Calibration Report (Earth Tech | AECOM, 2008)
- OASIS Modeling for the Kissimmee Basin (OKISS) Model Development and History Matching Report, Peer Reviewed Copy (AECOM 2009)
- Updated PME Tool Documentation (AECOM 2009b)
- Alternative Evaluation System Consultant's Recommendation For Objective Weights (Earth Tech 2007)

1.2 Purpose and Scope

The purpose of the Evaluation of the "With Project" Base Condition Report is to document the development of the base condition models and present a validation of model output relative to the evaluation performance measures. This effort demonstrates that the three models provide comparable results under the conditions established as the "With Project" base condition for use in the Alternative Plan Selection Process.

1.2.1 KBMOS Background

Throughout the KCOL and the Kissimmee River, 13 water-control structures are opened and closed to release or hold back water. The SFWMD has been working with basin stakeholders since 2004 to develop and implement this planning effort. As part of this process, stakeholders were consulted to determine study operating objectives and to translate those into performance measures and indicators. After modeling tools were developed and calibrated and base conditions were defined, the process for identifying the potential changes to water control structure operating rules was initiated. This was a three step process, including screening, formulation and evaluation. The first step, screening, involved the definition of plan components and their combination into alternative plans. The second and third steps involve the application of more detailed modeling tools for the analysis of the top performing alternative plans.

Water control structure operating rules tell water managers when and how to open and close structures based on how wet or dry it is during the year. Plan components contain proposed water control structure operating rules for a structure. Plan components are combined to produce alternative plans. An alternative plan describes water control structure operating rules for each of the 13 structures controlling the movement of water through the lakes and rivers in the Kissimmee Basin.

KBMOS alternative plans have been developed through a collaborative effort with the Interagency Study Team and basin stakeholders using a "computer-aided participation" (CAP) process. During CAP workshops, participants are asked to identify proposed changes to water control structure operations. Modeling tools are used to evaluate proposed changes and to determine whether these changes produce the conditions described in the performance measures and indicators. Multiple iterations of changes are modeled. This iterative process of making water control operational changes and evaluating water level and flow responses facilitates the refinement of operating criteria and alternative plans and increases participant knowledge and understanding of Kissimmee Basin hydrology and hydraulics. The workshop environment allows for information sharing and the leveraging of multidisciplinary expertise.

An Alternative Evaluation System was developed to assist in the evaluation and differentiation of alternative plans. This system uses an approach similar to a score card. Modeling results, in combination with performance measures, are used to calculate a score. Performance indicator results are also reported. This information is used during CAP workshops to evaluate and differentiate plan performance. The same system is used in formulation and evaluation.

At the end of the Alternative Plan Selection Process, the top three alternatives will be presented to the SFWMD Governing Board in a "decision package." The decision package provides a synopsis for the top performing alternative plans and is formatted to allow comparison of plan performance across all evaluation performance measures and indicators. The decision package, in combination with the contents of this report, will be submitted to the USACE for use in preparation of the EIS. Additionally, this report will be updated with the information required to justify the recommendation of a preferred alternative to the USACE. The final step in the study will be preparation of an Operational Guidance Memorandum describing the interim and long-term operating criteria for Kissimmee Basin structures.

1.2.2 KBMOS Phase I: Kissimmee Basin Assessment

During Phase I of the KBMOS, the Interagency Study Team performed a comprehensive assessment of basin conditions (Earth Tech 2005). The assessment included:

- Review and update to sub-basin boundary delineations
- Interviews with basin stakeholders and documentation of basin conditions
- Preliminary evaluation of data available for the development and application of modeling tools

- Review and selection of a suite of modeling tools for the planning study
- Preparation of basin hydrologic monitoring recommendations
- Identification of study operating objectives
- Development of a modeling strategy
- Development of the KBMOS planning process and work plan

The operating objectives identified in Phase I have served as the drivers for the selection of the modeling tools and the development of the evaluation performance measures and indicators that are the cornerstone of the Alternative Evaluation System. The following is a summary of these operating objectives, along with one additional objective added in Phase II to support the USACE EIS.

1.2.2.1 Flood Control Operating Objectives Associated with the C&SF Project

The Kissimmee Basin portion of the C&SF Project currently includes thirteen water control structures. These include eight water control structures in the Kissimmee Upper Basin (KUB) and five water control structures in the Lower Kissimmee Basin (LKB). The Federal Government authorized the Kissimmee Basin portion of the C&SF Project to protect lands adjacent to the lakes and along the Kissimmee River from frequent and prolonged flooding.

1.2.2.2 Water Supply

For the KBMOS, the water supply operating objective applies to both human and environmental demands. Water utilities serving the communities within the KUB recognize that groundwater supplies are limited and are considering the option of using surface water. Before water can be allocated to meet public water supply (PWS) demand, environmental demands associated with restoring ecological integrity to the Kissimmee River floodplain and maintaining healthy lake ecosystems must be met.

1.2.2.3 Aquatic Plant Management

Lakes Kissimmee, Hatchineha, Cypress and Tohopekaliga, in the KCOL, have been impacted by an invasive exotic submersed plant (hydrilla) that frequently has reached nuisance levels. Unmanaged, it is expected that some or all of these lakes could develop potential infestations that would impact navigation and recreational use, tourism, real estate values, native plant communities, water quality, fisheries and flood control. The most cost-effective and environmentally compatible method for controlling large areas of hydrilla is whole-lake or large-scale applications of herbicide. These applications, made between January and April, require lake levels to be lowered and gates to be closed to provide low flow or no flow conditions for the required chemical residence time (100 - 120 days).

1.2.2.4 Natural Resource Requirements for the KRRP, KCOL LTMP and Lake Okeechobee

The original C&SF Project, the KRRP and the KCOL Long Term Management Plan (LTMP) all have natural resource management objectives that are intended to provide quality habitat for the fish and wildlife resources based on the preservation, enhancement and/or restoration of rivers, floodplains, lakes and littoral, lacustrine and other basin wetland habitats.

1.2.2.5 The KRRP

The KRRP was authorized under the Water Resources Development Act (WRDA) of 1992. The KRRP includes the Headwaters Revitalization Project and the Level II Backfilling Plan for the Kissimmee River. The goal of the KRRP is to reestablish ecological integrity to the river channel and floodplain. Meeting the KRRP hydrologic criteria is a balancing act between the KCOL and the LKB and is essential to the successful implementation of the KRRP.

1.2.2.6 The KCOL LTMP

The maintenance of lake stages at desirable levels for fish and wildlife purposes was part of the original C&SF Project's natural resource management objectives. The purpose of the KCOL LTMP is to improve, enhance and/or sustain lake ecosystem health. Current lake operating criteria stabilize water levels and allow for very limited inter-annual variability. These operating criteria have degraded lake littoral habitat quality and have impacted the diversity and abundance of fish and wildlife resources. While the Kissimmee River Headwaters Revitalization Project addresses some of the hydrologic requirements for Lakes Kissimmee, Hatchineha and Cypress, it does not meet all of the hydrologic requirements needed to address the ecological health goal for these lakes.

1.2.2.7 Lake Okeechobee

The Kissimmee Basin is the largest watershed discharging to Lake Okeechobee and flows from the Kissimmee Basin have the potential to negatively impact lake water levels during flood and drought conditions. Although a desired Kissimmee Basin inflow envelope has been developed, it is not the intention of this study to meet that target. Instead, this study will ensure that modified Kissimmee Basin inflows to Lake Okeechobee do not make inflow conditions worse than the current condition.

1.2.2.8 Navigation and Recreation

Although not one of the four original operating objectives identified in Phase I, navigation and the impacts of water levels on recreational opportunities are being evaluated as part of the KBMOS to provide input to the USACE EIS. The Federal Navigation Project, within the Kissimmee Basin, extends from the Town of Kissimmee to Lake Okeechobee. The authorization provides for continuous navigation through the system during the daylight hours of lock operations.

1.2.3 KBMOS Phase II: Model Tool Development and Alternative Plan Development and Evaluation

Phase II of the KBMOS implements the planning approach and modeling tools defined in Phase I. Specifically, it includes:

- Model Development, Calibration, Verification and Application
- Performance Measure and Indicator Development

- Alternative Evaluation System and PME Tool Development
- Performance Measure, Alternative Evaluation System and PME Tool Refinement
- Alternative Plan Selection Process Implementation

Work in Phase II revolves around the Alternative Plan Selection Process and the tools developed to systematically evaluate alternative plan performance at three increasing levels of detail and sophistication. Figure 1-2 shows the Alternative Plan Selection Process. The process is initiated with the development of an alternative plan describing a set of modified water control structure operations for the Kissimmee Basin. The alternative plan is then simulated using the Alternative Plan Screening Tool. Screening model results are post-processed and sent to the Alternative Evaluation System for scoring. The Alternative Evaluation System uses evaluation performance measures to score alternative plans and evaluation performance indicators to report on constraints and opportunities. Alternative plan scores are used to rank alternative plans. The highest scoring alternative plans are promoted to alternative plan formulation, where the same Alternative Evaluation System is used to score, report and rank plans. The three alternative plans with the highest formulation scores are promoted to alternative plan evaluation. The last step in the Alternative Plan Selection Process is the SFWMD Decision Package. The decision package summarizes alternative plan evaluation results in a format that allows comparison of plan performance across all evaluation performance measures and indicators. The components that make up the Alternative Plan Selection Process are described below in more detail.

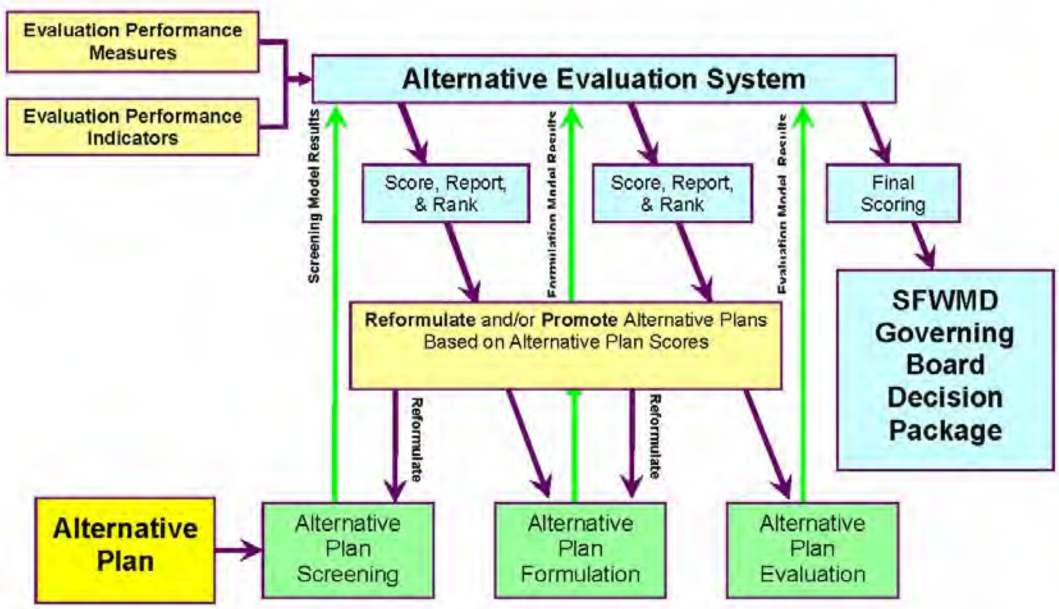

Figure 1-2: Alternative Plan Selection Process

Alternative Plans: Alternative plans describe water control structure operating rules for each of the 13 structures controlling the movement of water through the KCOL and the Kissimmee River.

Evaluation Performance Measures: Evaluation performance measures define hydrologic targets that are used to score and rank alternative plans. The KBMOS evaluation performance measures define the hydrologic conditions required to meet the natural resource requirements of water bodies controlled by Kissimmee Basin C&SF Project structures.

Evaluation Performance Indicators: Evaluation performance indicators are similar to evaluation performance measures with the exception that they are not used to score and rank alternative plans. They provide additional information to help differentiate between alternative plans. There are constraint indicators and opportunity indicators. Constraint indicators must be met. Opportunity indicators report information on whether conditions created by an alternative plan meet, improve, or degrade a desired condition.

Alternative Evaluation System: The Alternative Evaluation System is a grading system that can be consistently applied to alternative plan model output to calculate an alternative plan score. Alternative plan scores differentiate alternative plan performance using evaluation performance measures. Performance indicators provide an additional means for differentiating between alternatives by providing information related to study constraints and opportunities. The Alternative Evaluation System, as a whole, provides a systematic means for comparing alternative plans using a set of shared standards.

PME Tool: The PME Tool implements the scoring calculation defined within the Alternative Evaluation System. The tool uses a series of scripts and macros in a spreadsheet shell to automate calculations and graphics from the screening, formulation and evaluation tools. The PME Tool provides a standardized report for each alternative plan. The standardized report populates the alternative plan score card, along with evaluation component scores and other supplemental information described within the evaluation protocols for each of the evaluation performance measures and indicators.

"With Project" Base Condition: To achieve the goal of the KBMOS the study modeling tools will be used to screen, formulate and evaluate alternative plans. Alternative plans are limited to plan components, which describe operating rules for each of the C&SF water control structures in the Kissimmee Basin. Other conditions within the basin are assumed to remain constant through a range of hydrologic conditions that mimic the historic climatic conditions from 1965 to 2005. Therefore, a complete description of the full set of model input is needed to apply the study modeling tools. The alternative plan description(s) will then be superimposed on watershed conditions common to all alternatives. The watershed conditions that will be common to all alternatives during the alternative selection process are known as the KBMOS base conditions. The "With Project" base condition includes a description of the following:

- Definition of the period of simulation (1965 to 2005)
- Climate drivers (evapotranspiration, rainfall)
- Boundary conditions
  - TW time series for the S-65 Structure

- Lateral and horizontal groundwater boundary conditions
- Current hydrologic conditions (land use, water use)
  - Year 2000 land use/cover
- Future hydraulic conditions (completion of all phases of the KRRP)

The land use and hydrologic conditions will remain unchanged for each time period during the alternative plan selection process, to provide the results/impacts of implementing the alternative plans only. These sets of conditions, representing the specific time period with existing operating rules for the Kissimmee Basin water control structures, are referred to herein as the "With Project" base condition. The description of the components of the base condition is presented in Section 2.

Screening Tool: The screening tool is a water budget model that represents water bodies in a node-link network and applies operating rules to move water through the system. The screening tool selected for the KBMOS is a management simulation model, Operational Analysis and Simulation of Integrated Systems (OASIS), developed by Hydrologics, Inc. (Earth Tech 2006).

Formulation Tool: The formulation tool is a surface water hydraulic routing model similar to the screening tool, except that it provides a greater level of detail on the conveyance of water. The formulation tool will be used to evaluate whether alternative plans meet USACE flood control requirements and for ranking and promotion of alternative plans to the final evaluation round of the Alternative Plan Selection Process. The formulation tool selected is the MIKE 11 modeling package by Danish Hydraulic Institute (DHI) Water and Environment, Inc. (Earth Tech 2005).

Evaluation Tool: The evaluation tool is a fully integrated model that couples the formulation tool with a watershed model that includes overland and groundwater flow (MIKE SHE). The evaluation tool will have the greatest complexity and is capable of examining the full set of evaluation performance measures. The fully integrated modeling tool will be used to develop the Governing Board Decision Package. The evaluation tool selected for this project is MIKE SHE/MIKE 11 by DHI Water and Environment, Inc. (Earth Tech 2005).

SFWMD Decision Package: The SFWMD Decision Package provides a synopsis for the top performing alternative plans formatted to allow comparison of plan performance across all evaluation performance measures and indicators.

Development and refinement of the Alternative Plan Selection Process tools consumed the majority of time associated with Phase II. Figure 1-3 illustrates the relationship between tool development, tool refinement and Alternative Plan Selection Process activities. The three major tool development activities are shown on the left side of the diagram. Alternative Plan Selection Process activities are shown on the right side of the diagram. The activity on the right side of the diagram is anchored to the Alternative Plan Selection Process, which is divided into the three levels of evaluation described above.

Although some refinement activities did take place during tool development, the majority of the refinement activities took place during alternative plan screening. During tool development, key check-in points were identified to verify that the metrics defined in the performance measures and indicators could be simulated by the models and that the models could provide the necessary resolution to evaluate alternative plans. During alternative plan screening, model results from the "With Project" base condition and initial alternative plans were run through the PME Tool. Interagency Study Team members were provided with preliminary results for each evaluation performance measure. These results included the Tier 1 components that are used in the Alternative Evaluation System to calculate scores and the Tier 2 components, which provide tabular and graphical output to assist in interpretation of model results. Refinement was carried out in association with the CAP workshops. The workshop environment provided the Interagency Study Team and other participants the opportunity to share knowledge and insight.

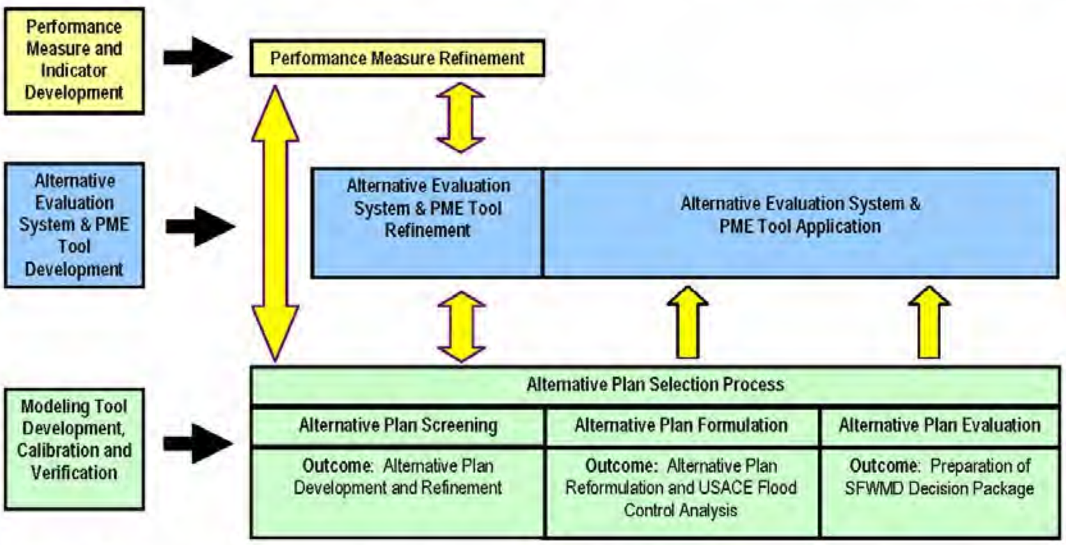

Figure 1-3: Development and Refinement of the Alternative Plan Selection Process Tools

The initial refinement activities focused on interpretation of the Tier 2 components and determining whether Tier 1 component scores seemed appropriate relative to the Tier 2 tabular and graphical output. The second phase of refinement focused on alternative plan performance and whether the evaluation component specifications and targets were appropriate relative to the resolution of the modeling results and the limitations and uncertainties of the data and modeling tools. Once Tier 1 component evaluations were complete, refinement activities focused on the scoring functions and weights used by the Alternative Evaluation System to calculate alternative plan scores. The two-way arrows shown in Figure 1-3 between performance measure refinement, Alternative Evaluation System and PME Tool refinement and alternative plan screening represent the iterative process used to validate the screening tool, evaluation performance measures and the Alternative Evaluation System components relative to one another.

Alternative Plan Screening: The Alternative Plan Screening Process will produce the complete set of alternative plans that will be considered as part of the KBMOS, along with the finalized version of the Alternative Evaluation System and PME Tool. Alternative plan screening uses a simple water budget model to develop an initial understanding of the relationship between operating criteria and evaluation performance measures and indicators and includes CAP workshops to assist in the development of alternative plans and the refinement of evaluation performance measures and Alternative Evaluation System scoring and weighting functions.

Alternative Plan Formulation: The Alternative Plan Formulation Process will identify the three top scoring alternative plans that meet all constraint indicators. These alternative plans will be promoted to alternative evaluation. Alternative plan formulation evaluates alternative plans promoted from alternative plan screening using a more detailed modeling tool that incorporates the full hydraulics of the surface water system. Flood control evaluations will be performed using the same tool, concurrent with the KBMOS formulation evaluations, to ensure plans identified for promotion to evaluation meet USACE flood control requirements. Plans that violate flood control constraints will be refined to meet those constraints. During alternative plan formulation, only the parameters within the plan components from screening will be adjusted to improve the performance of the alternative plans. There will be no new alternative plans or additional modifications to the performance measures or scoring and weighting functions. The final Alternative Evaluation System will be applied once all evaluations and refinements are complete to identify the top three performing alternative plans to promote to the final round of evaluation.

Alternative Plan Evaluation: The Alternative Plan Evaluation Process will produce the SFWMD Decision Package, comparing performance measure and performance indicator results for the three top scoring alternative plans. Alternative plan evaluation performs the final evaluations of the three top scoring alternative plans using the fully integrated watershed model.

1.3 Overview of AFET and AFET-W Calibration Efforts

The AFET is a fully integrated model that coupled the formulation tool (MIKE 11) with a watershed model that included overland and groundwater flow (MIKE SHE) that was developed for application as part of the KBMOS. The development and calibration of the AFET is documented in the "Alternative Formulation Evaluation Tool Model Documentation and Calibration Report" (AECOM 2009a). Peer Review of the development and proposed application of the AFET was completed in June 2008. The Peer Review Panel recommended that new RET data be used to calibrate the model. This work was completed and documented in the Draft Calibration AFET-W Calibration Report (Earth Tech | AECOM 2008). The main differences between the AFET-W and the AFET were that the AFET-W was calibrated with an improved set of RET data (differences between RET data sets will be detailed later in the document) and the AFET-W was also calibrated to match the behavior of observation wells in the Floridan Aquifer, while the AFET used a qualitative approach based on seasonal potentiometric maps.

Both the AFET and the AFET-W are run in two stages. The first stage involves the running of a 3-layer model that includes the Upper Floridan Aquifer System (UFAS), the Intermediate Confining Unit (ICU) and the Surficial Aquifer System (SAS), in addition to the surface water network. This model has a 3,000 foot grid cell size. Fluxes between the UFAS and the ICU are extracted from this model run (a.k.a. the 3K model) and used as boundary conditions in a more detailed model that only includes one layer in the groundwater portion (SAS). The one-layer model has a finer grid (1,000 feet) and is known as the 1K model. Results from the 1K model are used to evaluate stages and flow in the Kissimmee Basin. The calibration of the AFET and the

AFET-W followed the same approach, where successive model runs were made for the 3K and 1K models to refine the model parameters to achieve the calibration targets. (AECOM 2009a and Earth Tech | AECOM 2008)

The original calibration of the AFET used the following periods:

- Model Calibration - 2001 through 2004
- Model Verification - 1994 through 1998
- Storm Event Verification - 2004 Hurricane Season (August 1 – October 15, 2004)

The AFET-W calibration process focused only on model calibration and simulated the AFET verification period of record minus the year 1994 (1995 – 1998). This period was chosen for its overlap with the SFWMD East Central Florida Transient (ECFT) MODFLOW model. During calibration, qualitative assessments of groundwater responses were made between the two models to determine reasonableness of fit between observed and predicted and between the AFET-W and ECFT models.

Groundwater calibration criteria used during the AFET-W calibration were also modified. The original AFET calibration used a qualitative comparison with seasonal potentiometric maps to calibrate the UFAS. The AFET-W calibration used UFAS observation wells. The AFET used the qualitative comparison because most of the observation wells did not have data during the AFET calibration period (2001-2004). The AFET-W calibration criteria were:

Calibration Criteria

- Surface Network
  - Stages*
    - Root mean squared error (RMSE) ≤ 2.5
    - $R \geq 0.5$
  - Flow*
    - CE ≤ 15 percent
    - $R \geq 0.84$
- Groundwater (both SAS and UFAS)
  - Heads
    - For primary wells, the mean error (ME) and the mean absolute error (MAE) should be less than or equal to ± 2.5 feet for 50 percent of the wells.
    - For primary wells, the ME and MAE should be less than or equal to ± 5.0 feet for 80 percent of the wells.
    - For primary wells, the RMSE should be less than or equal to ± 5.0 feet for 80 percent of the wells.
    - The overall ME should be within ± 1.0 feet and should approach zero.
    - $R \geq 0.5$

*: For surface water calibration, only stations listed in the AFET documentation as "high" priority were used in the calibration refinement (AECOM 2009a).

1.4 Report Structure

As mentioned above, the purpose of the Evaluation of the "With Project" Base Condition Report is to present the development and validation of the base condition models. The following summarizes the content of this report:

Section 1 Introduction and Project Background – The introduction provides the background of the KBMOS and presents the general concepts and issues that will support the Alternative Plan Selection Process.

Section 2 "With Project" Base Condition – This section describes the conceptual components that have been used to develop modeling tools under the "With Project" base condition.

Section 3 Development of the AFET-W "With Project" Base Model – The AFET-W model development is described in the AFET-W Model Documentation / Calibration Report (Earth Tech |AECOM 2008). The AFET-W is the model that will be used for the final evaluation of the alternative plans and will also be used to prepare the SFWMD Governing Board Package that will be summarized in the final Alternative Plan Selection Document. The AFET-W includes the fully coupled watershed model, (MIKE SHE/MIKE 11) also referred to as the Alternative Evaluation Tool (AET) and the de-coupled MIKE 11 model, also referred to as the Alternative Formulation Tool (AFT). The fully coupled model was used to develop the water budget for the KBMOS that is being used in the screening and formulation tools. This section describes the transition from the calibration model to the "With Project" base AFET-W model.

Section 4 OKISS Development – The original OKISS model development was described in the KBMOS OKISS Model Development and History Matching Report (AECOM 2009). This section describes the transition from the history matching model to the "With Project" base OKISS model.

Section 5 Validation of KBMOS Modeling Tools – The purpose of this report is to compare the hydrologic simulation provided but the screening and evaluation models relative to the evaluation performance measures for the KBMOS. This section provides stage flow hydrographs, duration curves and mean daily stage hydrographs comparing results obtained with the three KBMOS model tools (OKISS, AFT and AET). The AFT and AET are both obtained from the AFET-W. These comparisons were performed for the time series of stages and flows that are directly linked to evaluation performance measures. Section 5 also presents a comparison of the evaluation components for each of the performance measures.

Section 6 Conclusions – The conclusions of the validation effort are presented in Section 6.

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2 DESCRIPTION OF THE "WITH PROJECT" BASE CONDITION

2.1 "With Project" Base Condition

Generally, basin conditions affect the basin's hydrologic and hydraulic responses to rainfall events. Examples of these basin conditions include land use that affects rainfall-runoff relationships, basin storage and wetlands, water use that affects low flows, aquifer recharge and surface (lakes, wetlands, canals) and groundwater water levels, physical infrastructure changes such as the KRRP and its various completion phases and operational changes that affect the timing and distribution of water in the basin.

While these key basin conditions were in a state of flux and change over time, the establishment of base conditions required that they be static (frozen) over the simulation period. This approach is common practice in planning studies and essential to isolate the hydrologic and hydraulic impacts of any proposed changes. The objective is to assess the range of hydrologic and hydraulic responses if the basin experienced the same long-term rainfall patterns witnessed in the past, while basin conditions remain static. Basin conditions can then be modified (i.e. new operating criteria, a different withdrawal scenario, etc.) and the model can be run using the same rainfall record to evaluate the basin's response (as represented by a set of evaluation performance measures) to the new set of conditions.

The combination of these key conditions into simulations also required careful consideration. The "With Project" base condition combines some current watershed conditions (i.e. land use and water use) with other future features (i.e. future infrastructure and operations). The "future" features included in the "With Project" base condition relate to the implementation of the KRRP and the Kissimmee River Revitalization Project in the Kissimmee Basin.

This section divides the description of the "With Project" base condition into three parts. The first part describes the model setup (i.e. period of simulation, model used, etc.). The second part describes the model drivers portion of the base conditions and the third part describes the components of the base conditions that are a function of the description of the watershed.

2.1.1 Model Setup

The "With Project" base model was run for 41 calendar years, including 1965 through 2005. The model used to run the "With Project" base condition was the recently calibrated AFET-W, whose calibration was documented in the AFET-W Calibration Report (Earth Tech | AECOM 2008).

2.1.1.1 Downstream Boundary Conditions (S-65E-TW)

The modeling tool used a time series of TW stages at the S-65E Structure as the downstream boundary conditions. During the entire Alternative Plan Selection Process, a single time series was used. The USACE Lake Okeechobee Regulation Schedule Study was selected to be used as boundary conditions in the KBMOS. The criteria used for this selection is presented in AECOM 2009.

2.1.1.2 Groundwater Boundary Conditions

The "With Project" base condition was run in two stages. The first stage was the 3-layer, 3,000 foot grid size model (a.k.a. the 3K model). This model used a repeating annual pattern of lateral boundary conditions obtained from United States Geological Survey (USGS) seasonal potentiometric maps for the UFAS (included in Figure 2-1 and Figure 2-2) and no flow boundaries for the SAS. The second stage, the 1-layer, 1,000 foot grid size, used boundary conditions extracted from the 3K model and no boundary flows for the SAS.

There were four sets of boundary conditions, including the lateral flow boundary conditions along the SAS, the lateral flow boundary conditions for the UFAS, the vertical flow boundary conditions at the bottom of the UFAS for the 3-layered configuration of the AFET-W and the vertical flow boundary conditions of the SAS for the 1-layered configuration of the AFET-W. These sets were defined as follows:

- Lateral flow for the SAS - A no flux boundary was used in the "With Project" base condition as was the case during the calibration of the AFET-W. The base condition evaluation should not use a set of boundary conditions that is different from the one used in the calibration.
- Lateral flow in the UFAS - A variable-head boundary condition was used in the "With Project" base condition. This variable head was obtained from the USGS available potentiometric maps similar to the maps shown in Figure 2-1 and Figure 2-2. Since these maps were seasonal, linear interpolation was used to obtain daily values.
- Vertical flow boundary conditions at the bottom of the SAS throughout the model domain were needed for the 1-layered configuration of the AFET-W. These boundary conditions were extracted from the 3-layer results. Extracted values corresponded to daily heads at each cell grid (3,000 foot grid cell).
- Vertical flow boundary conditions at the bottom of the UFAS throughout the model domain were needed for the 3-layered configuration of the AFET-W. A no flux condition was assumed for both the calibration and the "With Project" base simulation.

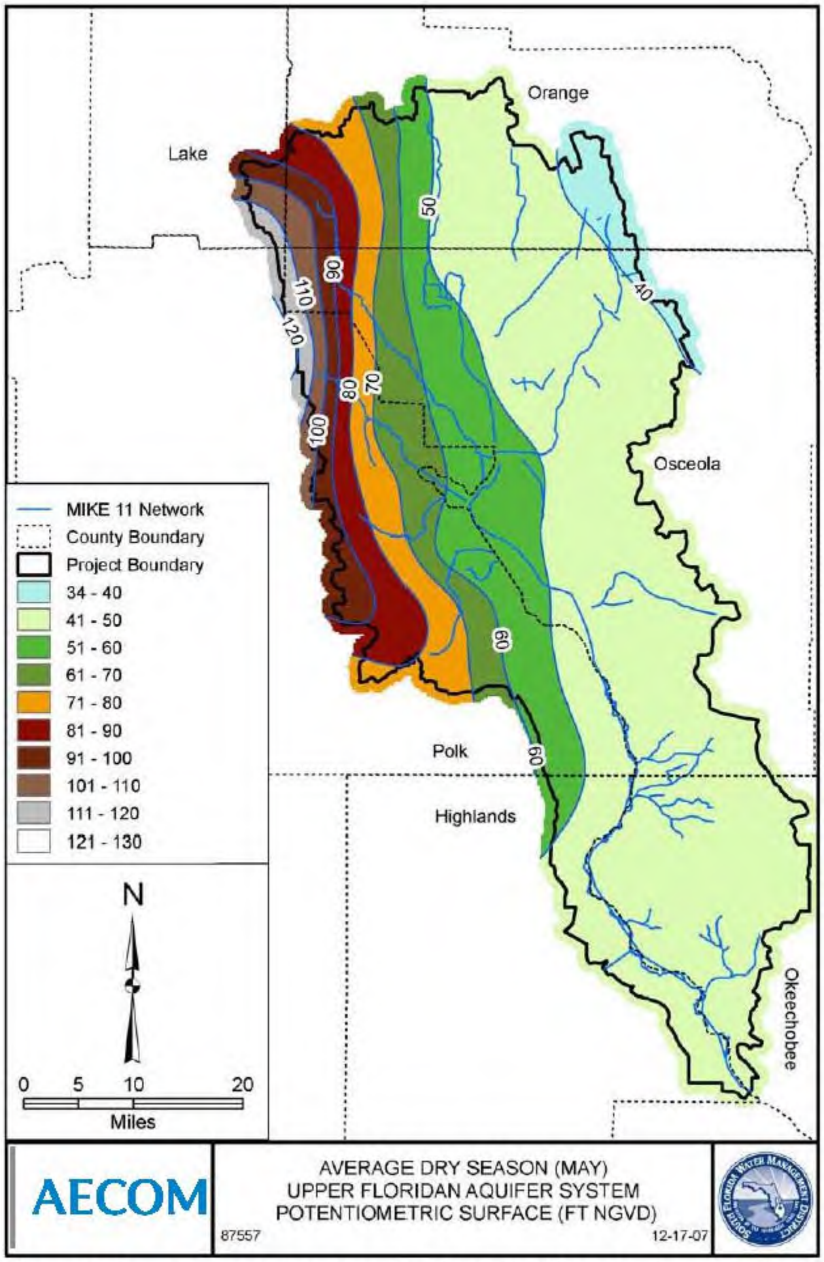

Figure 2-1: Average Dry Season (May) UFAS Potentiometric Surface Used to Extract Lateral Boundary Conditions (USGS)

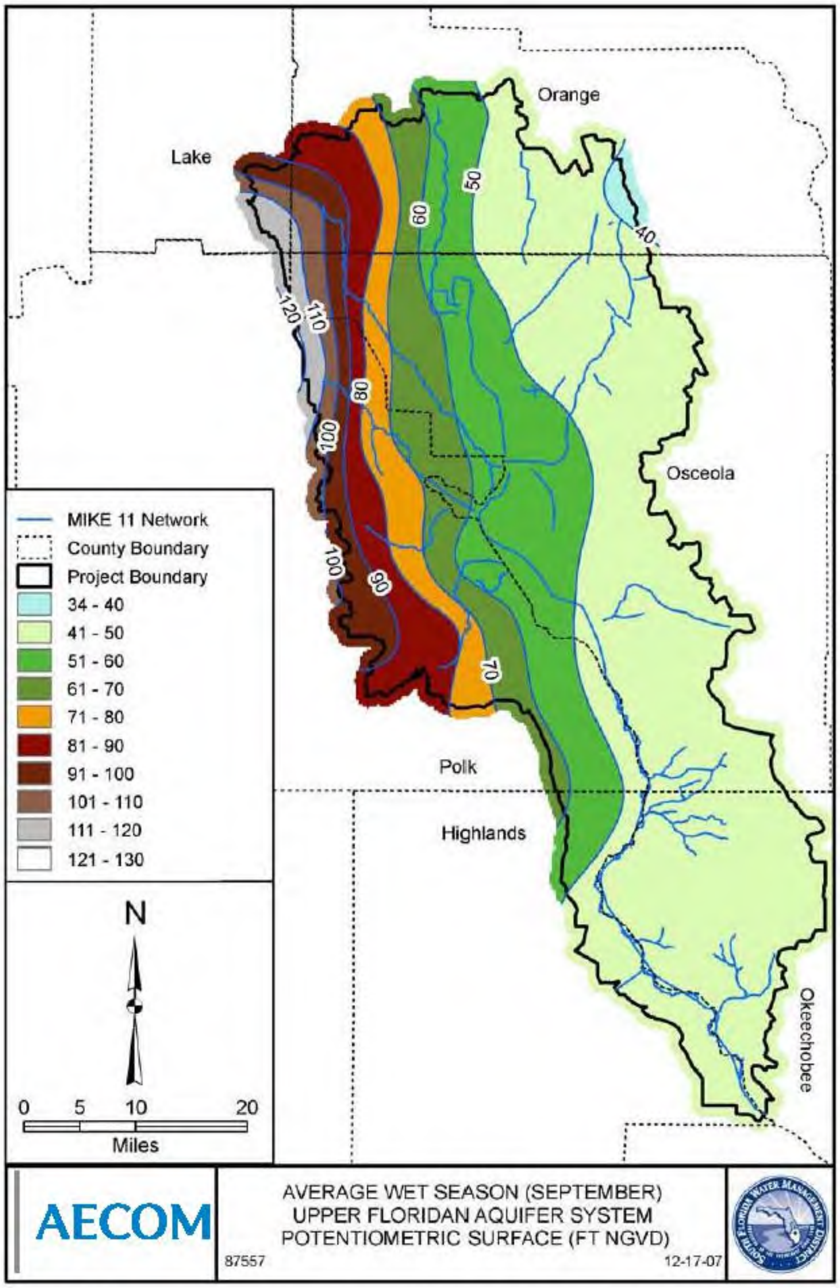

Figure 2-2: Average Wet Season (September) UFAS Potentiometric Surface Used to Extract Lateral Boundary Conditions. (USGS)

2.1.2 Model Drivers

2.1.2.1 Historic Rainfall (1965 – 2005)

The model used spatially varied rainfall data obtained from a 2-mile square grid matrix provided by Hydrologic and Environmental Systems Modeling (HESM) – SFWMD for the 1965 to 2005 period. This period included a wide variety of wet and dry years (Figure 2-3), as well as years where extreme conditions were observed (1994 and 2000). Figure 2-4 shows a frequency analysis of the rainfall being used to drive the study modeling tools. This figure shows that the annual rainfall during the simulation period was evenly distributed around the mean. This distribution was similar to the normal distribution, also included in the figure. This indicated that the selected period of simulation encompassed the range of climatic conditions required to achieve a fair evaluation of alternatives.

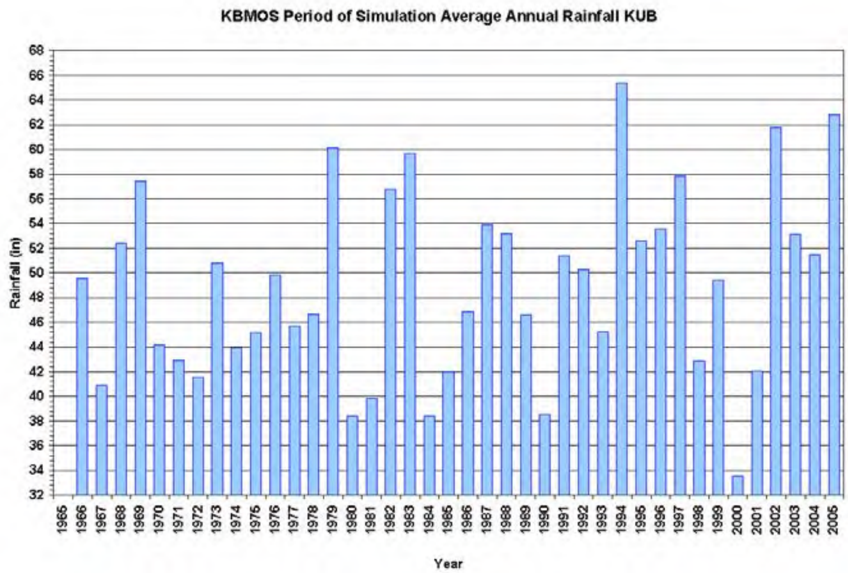

Figure 2-3: Annual Rainfall During the "With Project" Base Condition

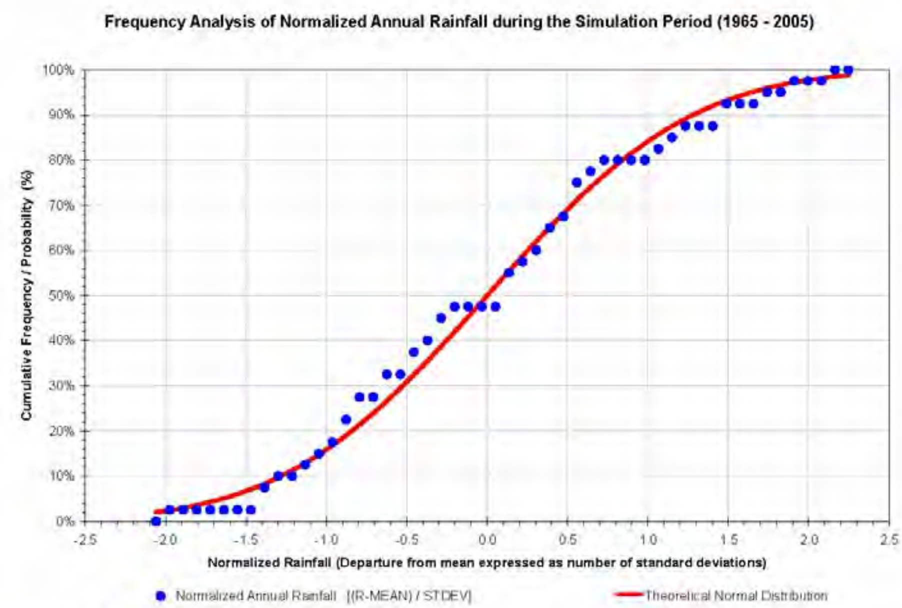

Figure 2-4: Frequency of Normalized Annual Rainfall Kissimmee Basin 1965-2005

2.1.2.2 RET

Revision Two of the RET (1965 – 2005) data set was used in the "With Project" base condition as described in Appendix A. Data were provided by HESM – SFWMD.

2.1.3 Watershed Description

Post-Phase 1 watershed conditions represented the Kissimmee Basin for the "With Project" base condition. An overview of changes in the Kissimmee Basin through recent history was presented in the Phase I Kissimmee Basin Assessment Report (Earth Tech 2005: Section 1). By 1999, the KUB was (and still is) the most heavily populated and intensively developed part of the Kissimmee Basin.

The total surface area of the managed lakes at normal water surface elevation, in the KUB, was approximately 10 percent of the total area of the KUB (USACE 1996). The LKB included the channelized and partially restored Kissimmee River and extended approximately 56 miles from the outlet at Lake Kissimmee to Lake Okeechobee. The final eight mile portion of the canal, known as Government Cut, was constructed as part of the Lake Okeechobee Levee Project and had an open water connection to Lake Okeechobee. It was hydraulically separated from the LKB by the S-65E Structure and was not considered to be part of the Kissimmee Basin.

2.1.3.1 Current Land Use (2000)

Watershed hydrologic conditions in the AFET models (both the AFET and the AFET-W) were represented by the land use layer used to drive them. Land use was probably one of the watershed components that had experienced the most changes during the previous decades. Over the past twenty years, the northern portion of Osceola County, above Lake Cypress (in the KUB), had become increasingly urbanized. Development related to Orlando's vacation attractions was a major factor in the over sixty percent population increase in Osceola County from 1990 to 2000 (Earth Tech 2005). Citrus in the KUB, located mainly north of Lake Cypress, was the primary existing and projected water user in the Kissimmee Basin. Agriculture remains a significant land use in the Kissimmee Basin and was the primary land use activity in the LKB, being dominated by extensive beef cattle production and dairy activities. Yet, the citrus industry was shifting southward due to a series of severe freezes that occurred in the 1980s and sugar cane was becoming a significant crop in Highlands County (Earth Tech 2005: Section 1.3). The land use spatial distribution presented during 1999 was captured by the SFWMD 2000 Kissimmee Basin Land Use Layer. This layer was used to describe the watershed hydrologic conditions for the "With Project" base condition. The "With Project" base condition used the current land use, which was the same land use used for the calibration of the AFET and the AFET-W. This land use coverage was consistent with current Kissimmee Basin water supply planning efforts. A summary of the current land use is presented in Table 2-1.

Table 2-1: Summary of Year 2000 (Current) Kissimmee Basin Land Use to be used in the "With Project" Base Condition

Land Use Category *	Land Use Code Range	Number of Parcels	Acres	Percentage of Total Parcels
Residential	**1009 – 1390**	**11,112**	**612,873**	**4.80**
Commercial	**1400 – 1490**	**3,394**	**66,636**	**1.47**
Industrial	**1500 – 1660**	**1,182**	**236,461**	**0.51**
Institutional	**1700 – 1760**	**1,556**	**32,989**	**0.67**
Recreational	**1800 – 1890**	**1,144**	**43,134**	**0.49**
Open Land	**1900 – 1940**	**726**	**65,122**	**0.31**
Agricultural	**2100 – 2610**	**15,711**	**2,389,817**	**6.79**
Upland Non-Forested	**3100 – 3300**	**14,489**	**618,967**	**6.26**
Upland Forests	**4100 – 4430**	**22,571**	**1,056,544**	**9.76**
Water	**5000 – 5600**	**23,767**	**1,139,389**	**10.28**
Wetlands	**6100 – 6530**	**132,178**	**1,842,261**	**57.15**
Barren Land	**7100 – 7430**	**1,775**	**53,047**	**0.77**
Transportation	**8100 – 8191**	**473**	**63,837**	**0.20**
Communication and Utilities	**8200 – 8390**	**1,194**	**24,463**	**0.52**
Other	**9000**	**1**	**43**	**0.00**

2.1.3.2 Status of the KRRP Infrastructure

In addition to the features of the KRRP already in place, the following future infrastructure was included in the model:

- Demolition of the S-65C Structure

- U-shaped weir and downstream berm (Figure 2-5)
- Phase II and IV, as defined in Bousquin et al. 2005
- Future Conditions Digital Elevation Model (DEM) (berms, removal of levees, etc.)

Figure 2-5: KRRP Features in Pool D

2.1.3.3 Water Use

- **PWS**

The "With Project" base condition included the ***Existing Legal Users*** or the Existing Permitted Surface Water and Groundwater Uses. These permits were extracted from the SFWMD Permit Database and included Large General and Individual Permits. The methodology used to prepare the PWS data sets used in the "With Project" base model was described in the "Technical

Approach to Create the Existing Legal Users Database included in the "With Project" Base Condition Model Technical Memorandum" (Earth Tech 2008). The appendices of the referenced technical memorandum include all of the databases used in the process.

PWS wells in the model domain were represented in the AFET-W by pumping wells. Water pumped from the PWS wells was extracted from the specified screen interval and removed from the model. The primary source of water in the Kissimmee Basin was the Floridan Aquifer System. There were virtually no wells that withdrew water from the SAS.

PWS data from the water use permit and well shapefiles, recently developed by the SFWMD, were reviewed and used as the primary source of data to define the characteristics of each well. Data previously provided by the neighboring water management districts was used for the other two districts with jurisdiction within the Kissimmee Basin. The water use permit and well shapefiles from each district were merged together and clipped to the model domain. These shapefiles were joined based on permit numbers and a data file containing the necessary information for each well that was created and imported into the MIKE SHE well database.

The current withdrawal conditions (permitted maximum allocation by 2008 for the SFWMD jurisdiction) were held constant during the 41 years of the "With Project" base simulation.

- **Irrigated Areas**

A similar approach was used for the irrigated areas where the ***Existing Legal Users*** were maintained under the "With Project" base condition. Irrigation in the AFET-W was handled through Irrigation Command Areas (ICAs). These ICAs in MIKE SHE were used to define unique spatially distributed areas in the model where irrigation was applied. Irrigation sources and rates were defined for each ICA. Furthermore, multiple prioritized sources were defined for each ICA. Irrigation applications were simulated for each MIKE SHE cell in an ICA. The Irrigation Command Module tracked soil moisture, determined irrigation demands and supplied the demand from sources described in the model. Therefore, the agricultural water use is estimated based on crop evapotranspiration and water availability but capped to the maximum capacity specified in the irrigation permits of each area.

The ICAs in the "With Project" base condition were based on water use permit areas from the SFWMD. Water use permit areas and the locations of surface water pumps and groundwater wells were obtained from each water management district. Irrigated areas and associated sources in the model domain were identified and unique integer grid codes were defined for each of the identified ICAs based on permit numbers. Only existing permits with corresponding permit areas and abstraction information were included in the irrigation setup. ICAs correspond to Citrus, Truck Crops, Golf Courses, Low Urban Density, Medium Urban Density and High Urban Density land use classifications defined in the model. The methodology used to prepare the irrigated area data sets used in the "With Project" base model was described in detail in the "Technical Approach to Create the Existing Legal Users Database Included in the "With Project" Base Condition Model Technical Memorandum" (Earth Tech 2008). The appendices of the referenced technical memorandum include all of the databases used in the process.

2.1.3.4 Operations

Operations of C&SF structures included:

- Operating criteria set for the S-65 Structure by the Kissimmee Headwaters Revitalization Project - Figure 2-6
- Interim schedule proposed in KBMOS for the S-65D Structure to avoid steep hydraulic gradients in upstream crossings - Figure 2-7 (Earth Tech 2007a)
- Current regulation schedules in all other structures (Figure 2-8 through Figure 2-13)

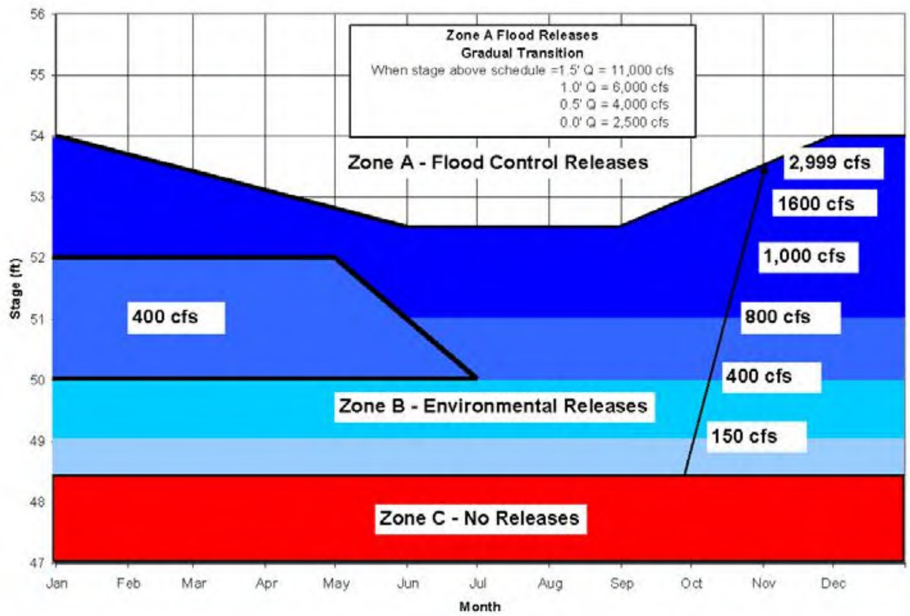

Figure 2-6: Operating Criteria for S-65 Structure "With Project" Base Condition

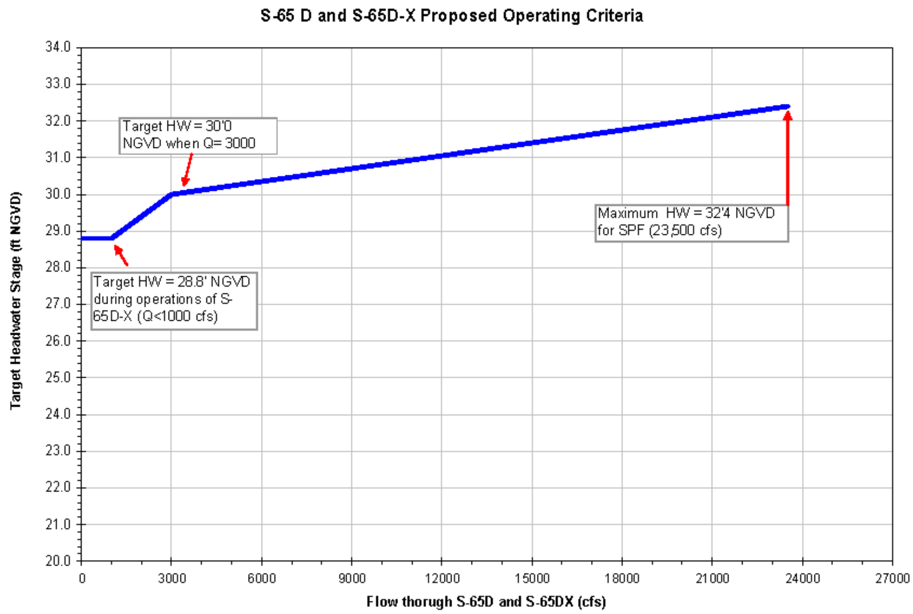

Figure 2-7: Operating Criteria for S-65D Structure "With Project" Base Condition

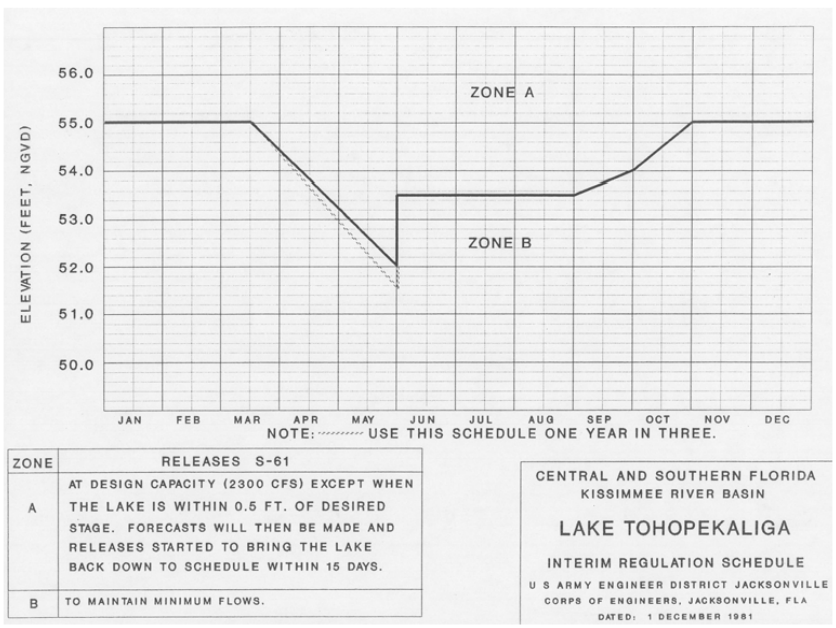

Figure 2-8: Operating Criteria for S-61 Structure "With Project" Base Condition

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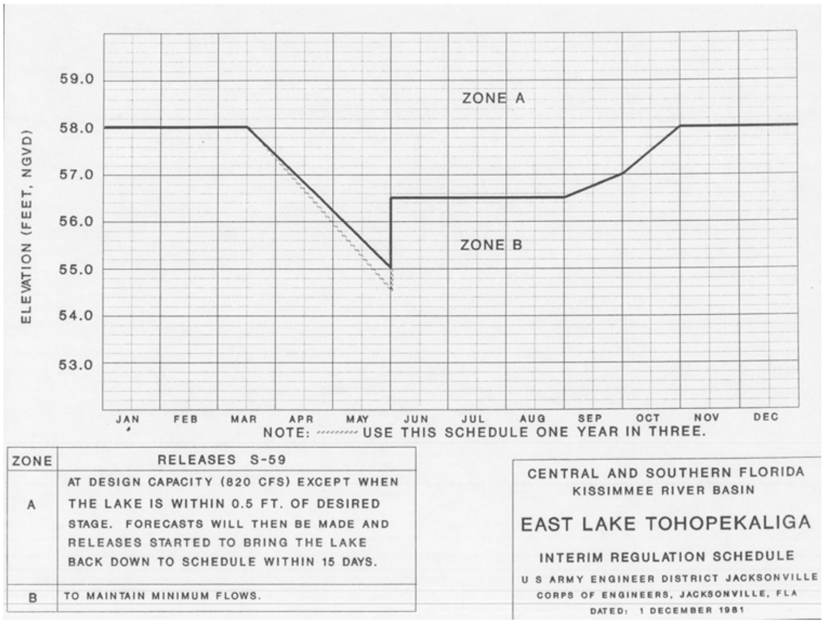

Figure 2-9: Operating Criteria for S-59 Structure "With Project" Base Condition

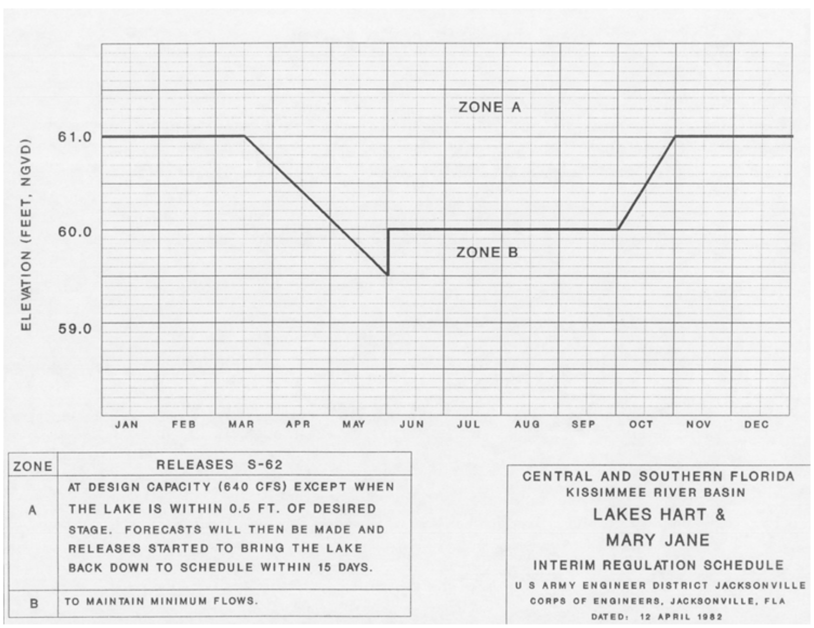

Figure 2-10: Operating Criteria for S-62 Structure "With Project" Base Condition

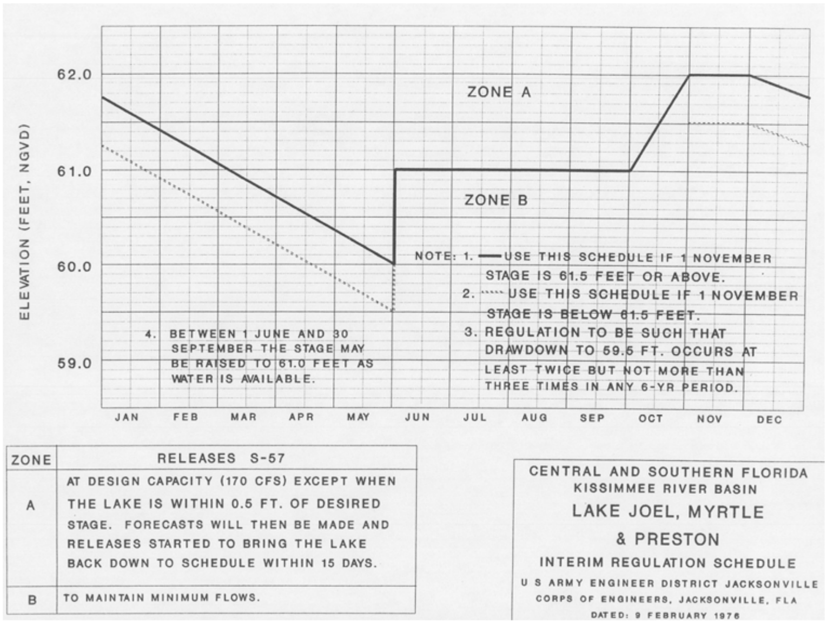

Figure 2-11 : Operating Criteria for S-57 Structure "With Project" Base Condition

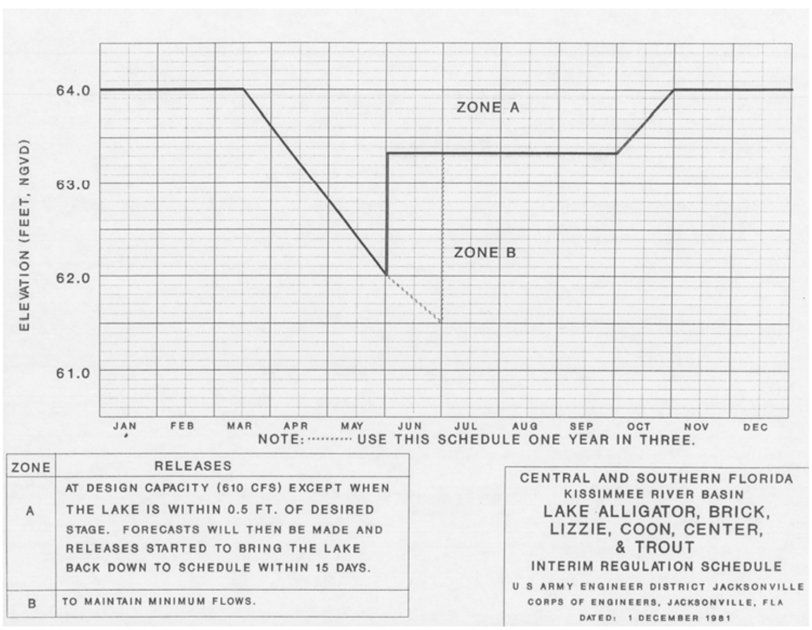

Figure 2-12: Operating Criteria for S-60 Structure "With Project" Base Condition

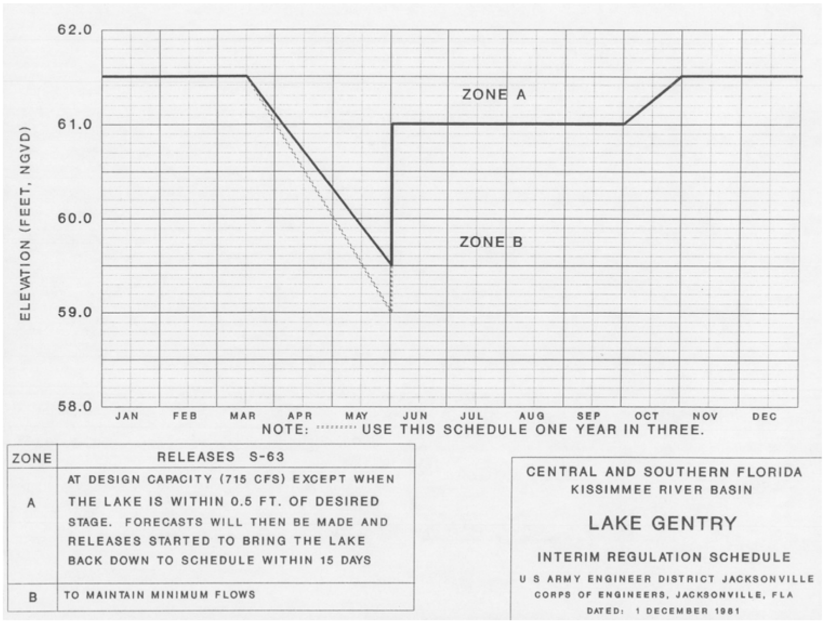

Figure 2-13: Operating Criteria for S-63 (S-63A) Structure "With Project" Base Condition

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3 "WITH PROJECT" BASE AFET-W MODEL

3.1 Development of the "With Project" Base Model in the AFET-W

The "With Project" base AFET-W model was developed from the KBMOS MIKE SHE/MIKE 11 models developed and calibrated earlier in the study. A number of modifications were made to the calibrated AFET-W model to develop the "With Project" base model that represents the base condition described in the previous sections. The modifications made to the calibrated AFET-W are described in detail in this section.

The "With Project" base model was set up to run for a 41-year period of time using hydrologic conditions observed in the Kissimmee Basin from 1965 through 2005.

3.1.1 Operating Criteria Coded in MIKE 11 for the "With Project" Base Model

3.1.1.1 Operating Criteria in the KUB (not including the S-65 Structure)

The operating criteria used in the "With Project" base AFET-W model uses existing regulation schedules for water control structures in the KUB with the exception of the S-65 Structure, which uses the operating criteria defined in the Headwaters Revitalization Project. The control logic was identical for each of the structures, except for the S-63A Structure. A generic description of the MIKE 11 control structure logic for the KUB structures is given in Table 3-1. Regulation schedules for each KUB control structure, except for the S-63A Structure, are shown in Figure 3-1 through Figure 3-6. Stages in the aforementioned figures are given in NGVD-29. The S-63A Structure is operated using an automatic control mechanism to open and close the gate to maintain an optimum headwater (HW) stage of 56.5 feet-NGVD. The control logic used in the "With Project" base model at the S-63A Structure is based on the SFWMD Structure Book and is summarized in Table 3-2. As described in the table, the AFET-W performs gates operations only once every 24 hours.

Logical Operands 3 and 4, used in the control logic for the S-63A Structure (Table 3-2), were added after evaluating simulated HW stages at the S-63A Structure for preliminary model runs with logic limited to the criteria listed in the SFWMD Structure Book. The added operands (3 and 4) were included to better maintain the optimal HW stage of 56.50 feet-NGVD.

3.1.1.2 Operating Criteria in the S-65A and S-65E Structures

Operations for the S-65A and S-65E Structures were similar to modifications made to the KUB structures. The S-65A and S-65E Structures have defined control elevations instead of regulation schedules, but the operational criteria are similar for the aforementioned structures. The generic control structure logical operands for these structures are summarized in Table 3-3. The control elevations used in the "With Project" base model in the LKB for the S-65A and S-65E Structures were 46.30 and 21.00 feet-NGVD, respectively.

Table 3-1: Generic MIKE 11 Control Structure Logical Operands for All Major KUB Control Structures except the S-63A Structure

Priority	Condition	Operation
1	Dry season; gate has not been operated in last 24 hours and HW stage is greater than regulation schedule	Open Gate proportionally until HW is 0.5 feet above regulation [1]
2	Wet season; gate has not been operated in last 24 hours and HW stage is greater than regulation schedule	Open Gate proportionally until HW is 0.5 feet above regulation [1]
3	Transition periods between dry and wet seasons; gate has not been operated in last 24 hours and HW stage ≥ 0.50 feet above regulation schedule	Fully Open Gate
4	Transition periods between dry and wet seasons; gate has not been operated in last 24 hours and HW stage exceeds regulation stage be is less than 0.50 feet above regulation schedule	Open Gate 1 feet
5	HW stage less than regulation schedule	Close Gate
6	Default condition	Leave Gate Opening Unchanged

[1] Fully open gate if HW stage is ≥ 0.50 feet above the regulation stage

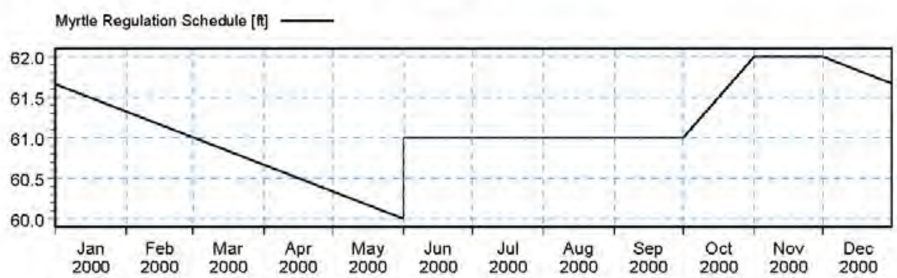

Figure 3-1: Lake Myrtle (S-57) Regulation Schedule

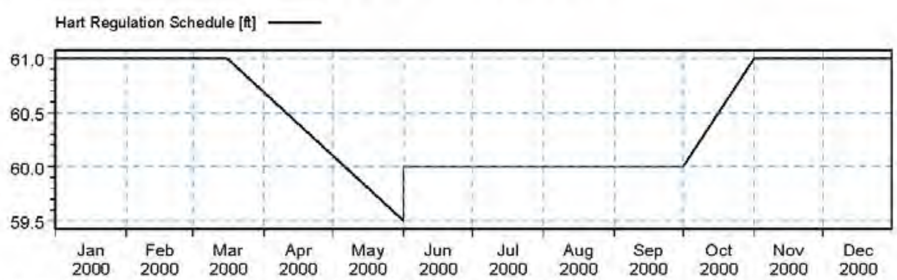

Figure 3-2: Lake Hart (S-62) Regulation Schedule

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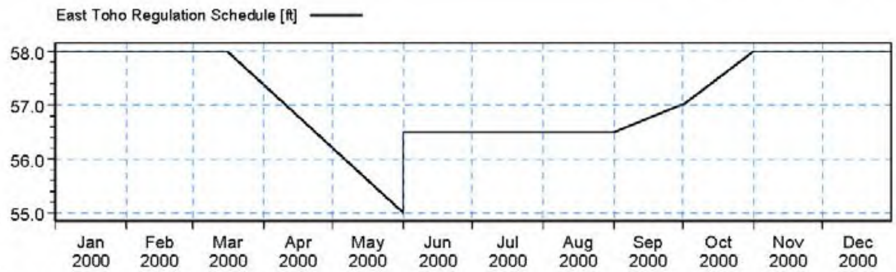

Figure 3-3: East Lake Tohopekaliga (S-59) Regulation Schedule

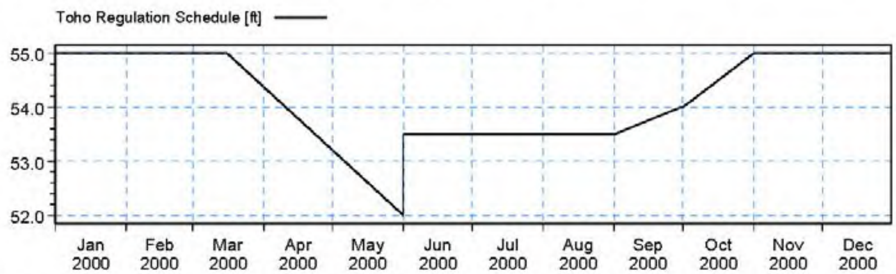

Figure 3-4: Lake Tohopekaliga (S-60) Regulation Schedule

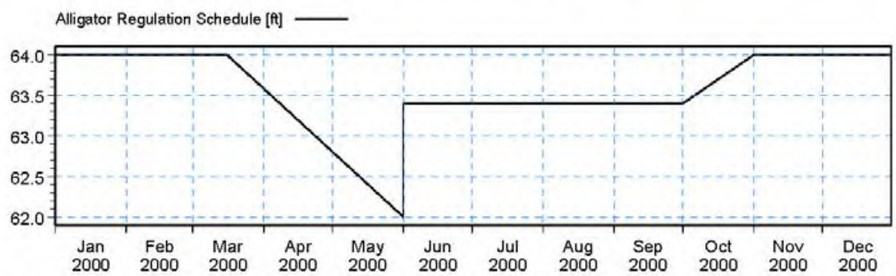

Figure 3-5: Alligator Lake (S-58 and S-60) Regulation Schedule

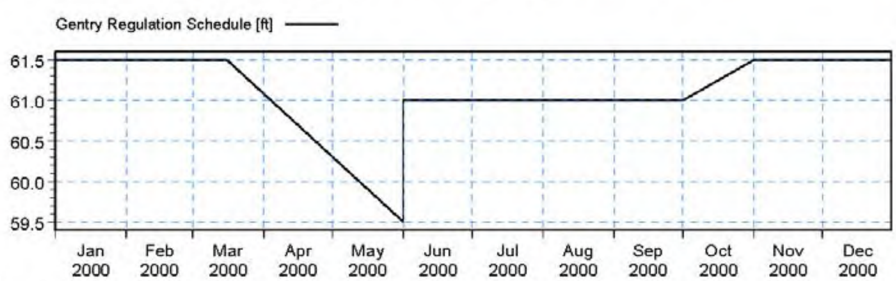

Figure 3-6: Lake Gentry (S-63) Regulation Schedule

Table 3-2: MIKE 11 Control Structure Logical Operands for the S-63A Structure

Priority	Condition	Operation
1	HW stage greater than 57.25 feet-NGVD	Fully open gate [1]
2	HW stage less than 56.19 feet-NGVD	Fully close gate[1]
3	HW stage less than 56.50 feet-NGVD	Gate closes gradually (1 foot at a time, limited by max gate speed)
4	HW stage greater than 56.50 feet-NGVD	Gate opens gradually (1 foot at a time, limited by max gate speed)
5	Default condition	Leave gate opening unchanged

[1] The maximum opening/closing speed is set to 2.4 inches/minute

Table 3-3: Generic MIKE 11 Control Structure Logical Operands for the S-65A and S-65E Structures

Priority	Condition	Operation
1	HW stage greater than control elevation and gate has not been operated in the last 24 hours	Open Gate[1]
2	HW stage ≤ control elevation and S-65 Structure discharge is greater than 0.0 cubic feet per second (cfs)	Open Gate to discharge environmental flows from the S-65 Structure[2]
3	HW stage is ≤ control elevation and gate has not been operated in the last 24 hours	Close Gate
4	Default condition	Leave Gate Opening Unchanged

[1] The S-65A Structure is opened and closed 1 foot at a time until the control elevation is reached. The S-65E Structures is opened and closed 2 feet at a time until the control elevation is reached. The maximum opening/closing speed for these gates is 2.4 inches/minute.

[2] The relationship between gate opening and flows under controlled submerged conditions was used for each structure to match the environmental releases of the S-65 Structure.

3.1.1.3 Operating Criteria in the S-65 Structure (Headwaters Revitalization Operating Criteria)

The MIKE 11 structure operation of S-65 Structure gates in the "With Project" base model is based on the headwaters revitalization schedule of the S-65 Structure, which is shown in Figure 3-7. The control logic for the S-65 Structure has been coded to meet the target flows for each zone based on the HW stage. To operate the S-65 Structure to discharge the flow shown in Figure 3-7, a flow-gate opening relation was developed for the S-65 Structure using available 15-minute observed data. The initial flow-gate relation was used to develop a HW stage-gate opening relation that was implemented in the model for each flow zone. The initial HW stage-gate opening relation was refined during model development to better match target discharge rates for each flow zone. The final flow-gate opening relation that was used to simulate interim operating criteria of the S-65 Structure is summarized in Table 3-4.

The control logic for the S-65 Structure determines which regulation zone (Zone A through C) Lake Kissimmee is at during each MIKE 11 time-step and then opens the gate to allow the specified amount of flow, shown in Figure 3-7, to pass through the structure. Table 3-5 shows the MIKE 11 control structure logical operands implemented in the model.

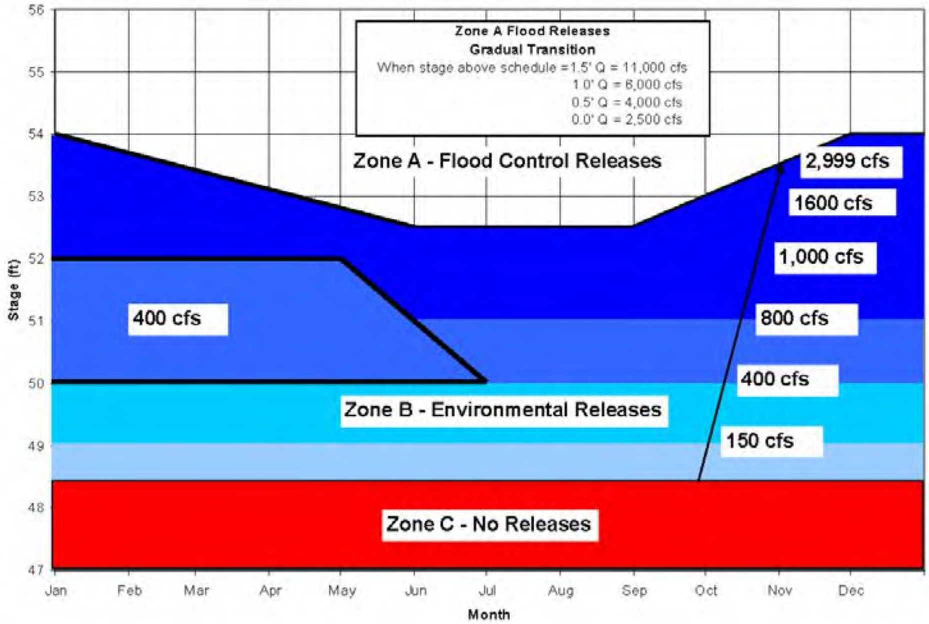

Figure 3-7: "With Project" Base Condition Lake Kissimmee (S-65) Headwaters Revitalization Regulation Schedule

Table 3-4: Estimated Flow at the S-65 Structure - Gate Opening Relationship

Flow (cfs)	Gate Opening (feet)*
0	0.00
150	0.14
400	0.30
3,000	1.60
4,000	2.10
6,000	3.10
11,000	5.60

*This relationship is independent of the operating criteria. It depends only on the structure's geometry.

Table 3-5: MIKE 11 Control Structure Logical Operands for the S-65 Structure

Priority	Condition	Target Flows (cfs)	
1	HW Elevation ≥ Zone A Elevation	HW	Q
		52.5	3000
		53	4000
		53.5	6000
		54	11000
2	HW Elevation ≥ (Zone A Elevation - 0.5) and Q during previous hour > 3500	Close gate gradually to 3000cfs	
3	Zone A Elevation > HW Elevation ≥ Zone C Min Elevation	HW	Q
		50	400
		51	800
		52	1000
		53	1600
		54	3000
4	Zone C Min Elevation > HW Elevation ≥ 50	400	
5	50 > HW Elevation ≥ 49	150 - 400	
6	49 > HW Elevation ≥ 48.5	150	
7	HW Elevation < 48.5	0	

For gate operations above Zone A and in the upper part of Zone B (Priorities 1 and 2), a non-linear relationship between the HW elevation and the target range of flows (2,500 to 11,000 cfs for Zone A and 150 to 2,999 cfs for Zone B) has been used. This relationship however, varies with time, because the range of HW elevations in Zone B varies throughout the year (Figure 3-7). To capture the variation of discharge with HW stages in Zone B during the year, a calculation node was added to the network (calculation node is a dummy structure used to store the value of a variable). If the HW elevation at the S-65 Structure is in Zone B, the simulated calculation node output is the fractional height of the HW stage relative to the minimum Zone A and Zone B elevations at the given time. The equation used by the calculation node to calculate the fractional value (F_t) is:

$$F_t = \frac{HW_t - minB_t}{minA_t - minB_t} \qquad \text{Eq. 1}$$

where,

HW_t is the simulated HW elevation at the S-65 Structure at time t
$minB_t$ is the minimum Zone B elevation at time t
$minA_t$ is the minimum Zone A elevation at time t

If the fraction F_t is close to zero, the HW elevation is close to the minimum Zone B elevation at time t and the flow will be approximately 150 cfs. If the fraction F_t is close to one, then the HW elevation is close to the minimum Zone A elevation at time t and the flow will be approximately 3,000 cfs. The flow at the S-65 Structure will vary according to the headwaters revitalization schedule rating curve 150 - 2,999 cfs at intermediate values of the fraction F_t.

Zone A discharges vary according to the stage and not according to the distance from the Zone A line. This coincides with the description obtained from SFWMD operations (Ron Mierau) at the

Pre-CAP meetings.

The relation of simulated HW stage at the S-65 Structure to calculate flow through the S-65 Structure for each of the priorities listed in Table 3-5 are shown graphically in Figure 3-8 and Figure 3-9. These figures indicate that simulated flow is consistent with the stage-flow relation shown in Figure 3-7.

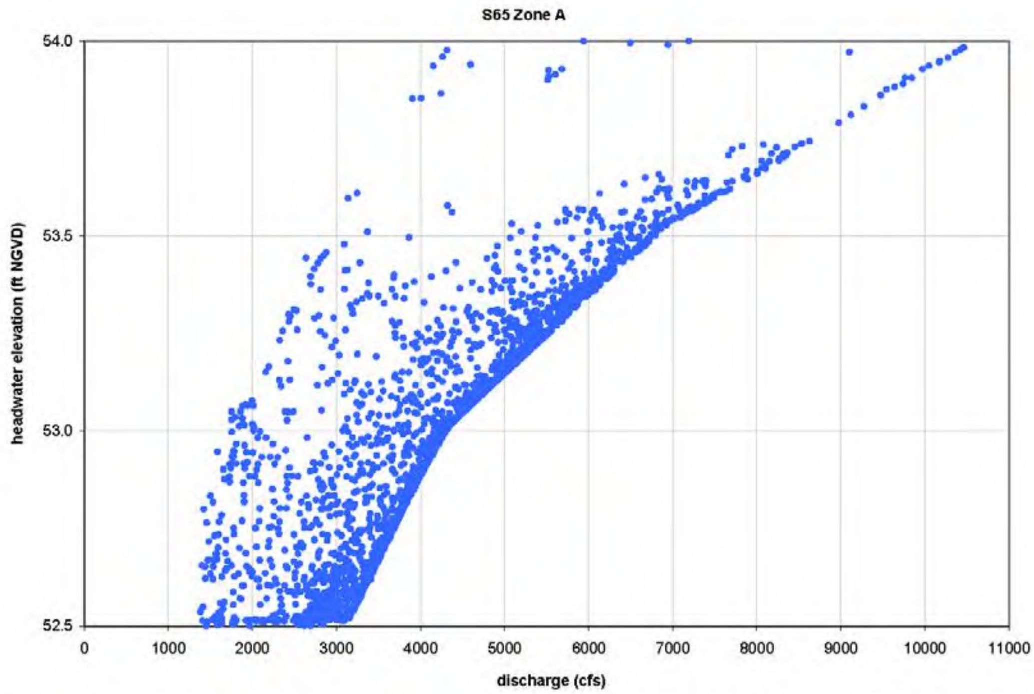

Figure 3-8: Relation of Simulated Stage to Simulated Gradually Increasing Flow above the Zone A Regulation Schedule (Priority 2)

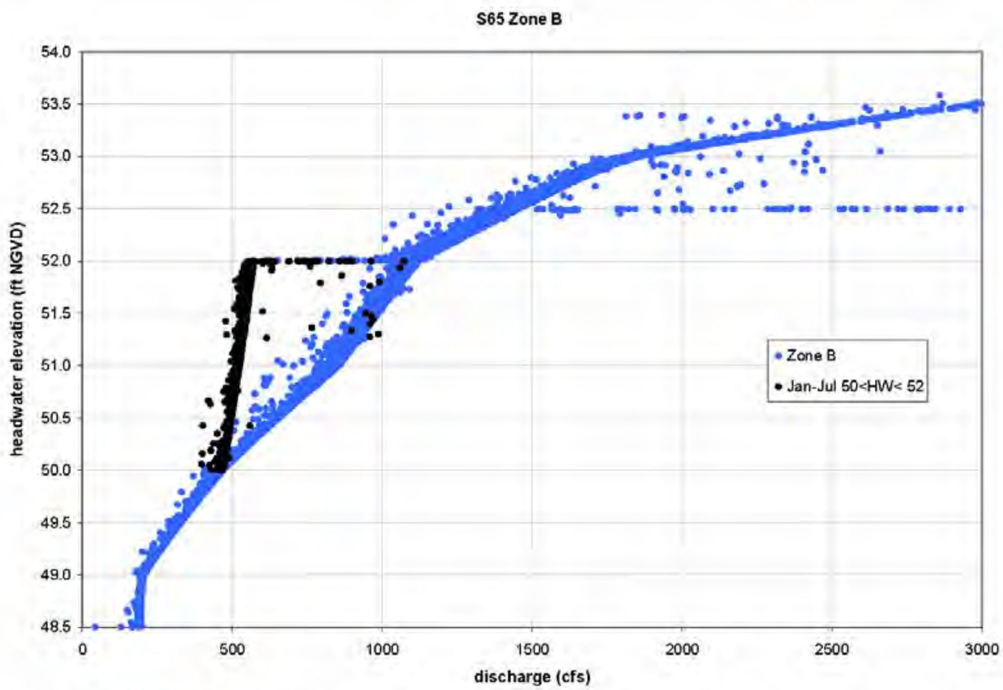

Figure 3-9: Relation of Simulated Stage to Simulated Flow at the S-65 Structure for HW Stages in Zone B (Priority 2)

3.1.1.4 Interim S-65D Structure Operating Criteria

The MIKE 11 structure operation of S-65D Structure gates in the "With Project" base model is based on the KBMOS Draft Operating Criteria for Modeling S-65D Future Conditions Memo (Earth Tech 2007a). The revised S-65D Structure operations for the "With Project" base model must be able to handle the larger volume of Pool B-C-D after the removal of the S-65C Structure, while meeting the goals of the Kissimmee River Revitalization Project. Furthermore, the existing operational criteria for the S-65D Structure causes steep gradients to form at the CSX Railroad and US-98 bridges and culverts, located upstream of the structure. To reduce these steep gradients, future operational criteria maintain HW stages at the S-65D Structure at a higher elevation (minimum of 28.8 feet) than the currently maintained elevation (26.8 feet). The proposed "With Project" base condition design flow-HW stage relation at the S-65D Structure is shown in Figure 3-10. For flows less than 1,000 cfs, the S-65D Structure, in the C-38 Canal, will be closed and the S-65DX Structure (a culvert that is considered part of the S-65D Structure group), in the restored portion of the Kissimmee River, will operate when HW stages exceed 28.8 feet to maintain the stages, as shown in Figure 3-10. For flows larger than 1,000 cfs, S-65D Structure gates operate to maintain the stages shown in Figure 3-10. In the case of severe flooding, when the S-65D Structure is fully opened and HW stages still exceed 28.8 feet, the

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S-65DX2 Structure can be operated to allow additional flow from the restored portion of the river to the C-38 Canal.

In the model, the S-65D Structure opens whenever the HW elevation at the S-65D Structure is greater than 28.8 feet and the S-65D Structure remains closed when the flow through the S-65DX Structure is less than or equal to 1,000 cfs. The flow capacity of the S-65DX Structure was evaluated using the model and model results indicate the flow capacity is greater than 1,000 cfs (~2,000 cfs). As a result, the simulated flow through the S-65DX Structure was used during development of the flow-gate opening relationship for the S-65D Structure. For example, when the HW elevation is 30 feet, the flow through the S-65DX Structure is approximately 1,500 cfs. This flow quantity was subtracted from the 3,000 cfs to determine the S-65D Structure gate opening required to discharge 1,500 cfs through the S-65D Structure. The flow-gate opening relation for the S-65D Structure was calculated using 15-minute observed data for the structure (HW, TW, gate-opening and calculated flows). The flow-gate opening relationship of the S-65D Structure was used to develop the HW stage to gate opening relation for the structure. The flow-gate opening relation for the regulation schedule of the S-65D Structure is summarized in Table 3-6.

The combined flows through the S-65D and S-65DX Structures, as a function of the HW stage at the S-65D Structure, are shown in Figure 3-10. Model results show that the operational criteria implemented in the "With Project" base model at the S-65D and S-65DX Structures produce a rating curve that compares closely to the design curve developed (Earth Tech 2007a). Deviations are most noticeable at low flows (less than 3,000 cfs) and are most likely a result of the S-65DX Structure being fully opened and allowing flows that exceed 1,000 cfs (Figure 3-11).

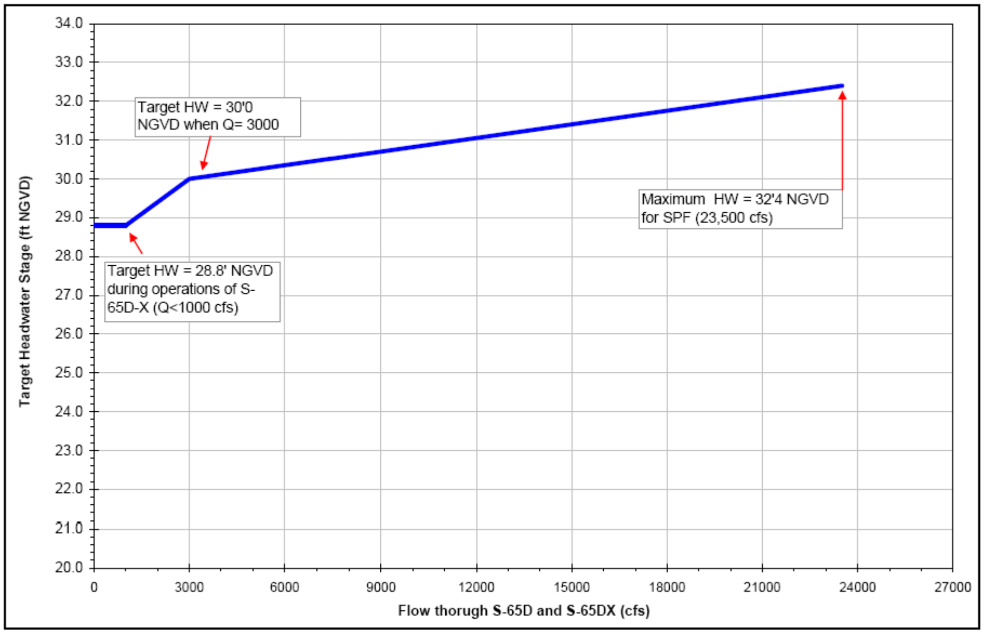


Figure 3-10: "With Project" Base Condition HW-Flow Relation for the S-65D and S-65DX Structures (Earth Tech 2007a)

Table 3-6: Estimated Flow - Gate Opening Relationship at the S-65D Structure

Stage (feet-NGVD)	Flow (cfs)	Gate Opening (feet)
28.8	0	0.0
30.0	1,500	0.9
32.4	23,500	13.8

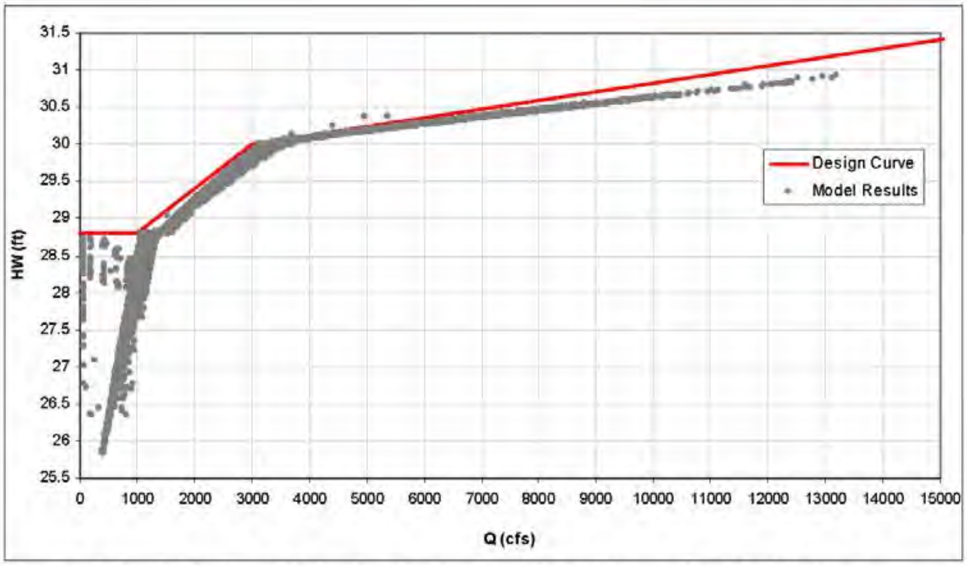


Figure 3-11: Relation of Simulated Flows at the S-65D and S-65DX Structures to the HW Stage at the S-65D Structure

3.1.2 Base Condition Boundary and Stresses

To run a synthetic 41-year "With Project" base simulation, the boundary conditions and applied stresses had to be modified. The modifications made to historic boundary conditions and applied stresses are described below.

3.1.2.1 "With Project" Base Boundary Conditions

Observed TW stages at the S-65E Structure were used in the calibrated AFET-W model to represent downstream boundary conditions in the MIKE 11 component of the model. The simulated time series of the Lake Okeechobee Regulation Schedule Study, which is an updated regulation schedule for the lake, was used as a boundary condition. The selection of this time series as the boundary conditions is documented in the "Evaluation of Downstream Boundary Conditions Technical Memorandum" (Earth Tech 2007b). The synthetic stage boundary used at the S-65E Structure in the "With Project" base model is shown graphically in Figure 3-12.

In the calibrated AFET-W MIKE SHE/MIKE 11 model, seasonal potentiometric surface contours developed by the USGS for the UFAS were used to define lateral groundwater boundary conditions for the UFAS (Groundwater Calculation Layer 3) in the 3,000-foot regional model. Seasonal UFAS potentiometric surface contours are available for the period from May 1993 through September 2005. Average seasonal UFAS potentiometric surfaces for May and September were calculated using contours from 1993 through 2005 and were applied for the period from 1965 through 2005 in the "With Project" base model. Average UFAS potentiometric surfaces for May and September are shown in Figure 3-13 and Figure 3-14. Internally, MIKE SHE performs a linear interpolation between these two potentiometric surfaces to determine lateral boundary conditions at intermediate times. The 3,000-foot regional model was run for the

41-year period. Results from this run were used to extract boundary conditions for the bottom of the surficial aquifer to be used in the 1,000-foot grid model.

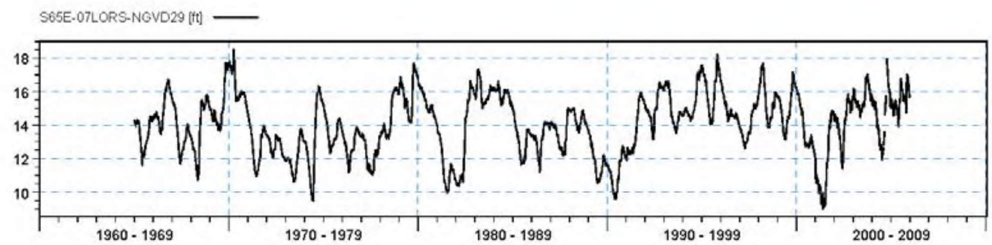


Figure 3-12: Synthetic Stage Used at Downstream End of the MIKE 11 Model to Represent TW Conditions at the S-65E Structure in the "With Project" Base AFET-W Model

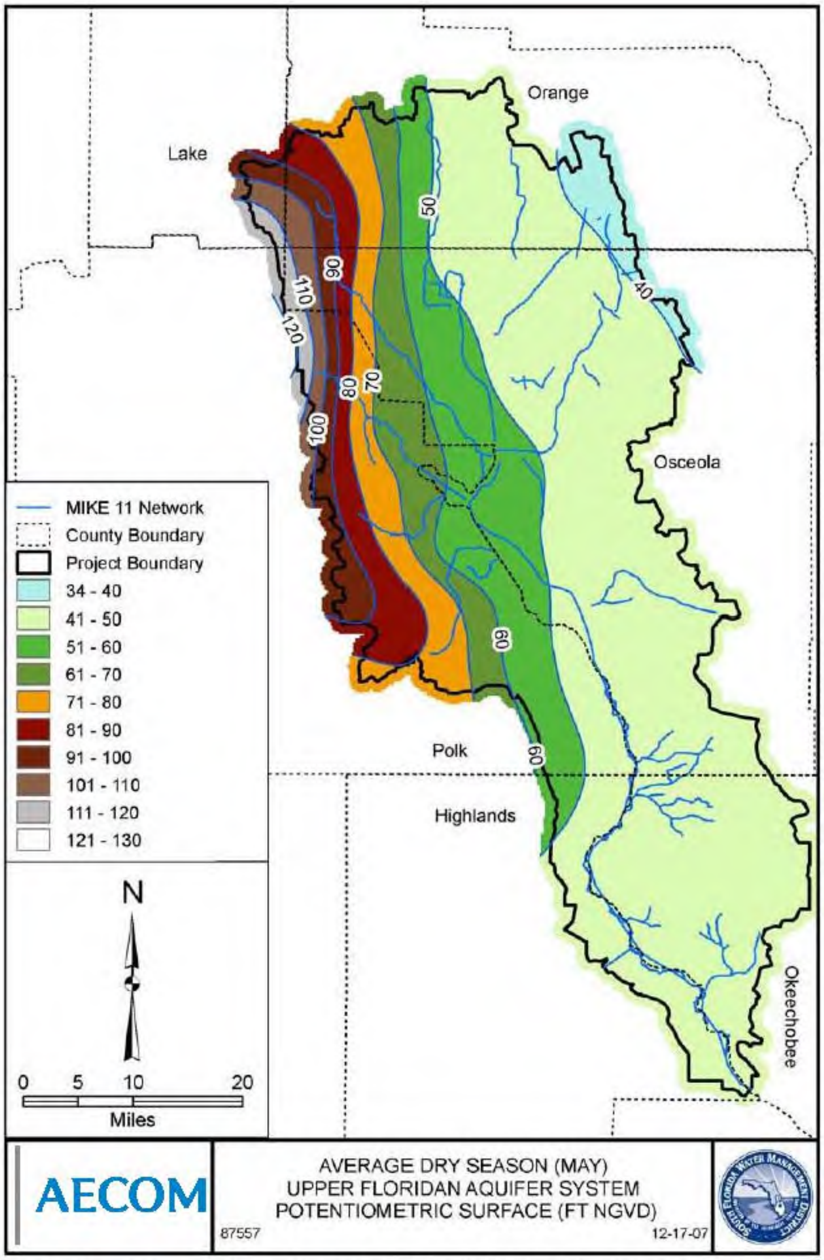


Figure 3-13: Average Dry Season (May) UFAS Potentiometric Surface Used to Extract Lateral Boundary Conditions. (USGS)

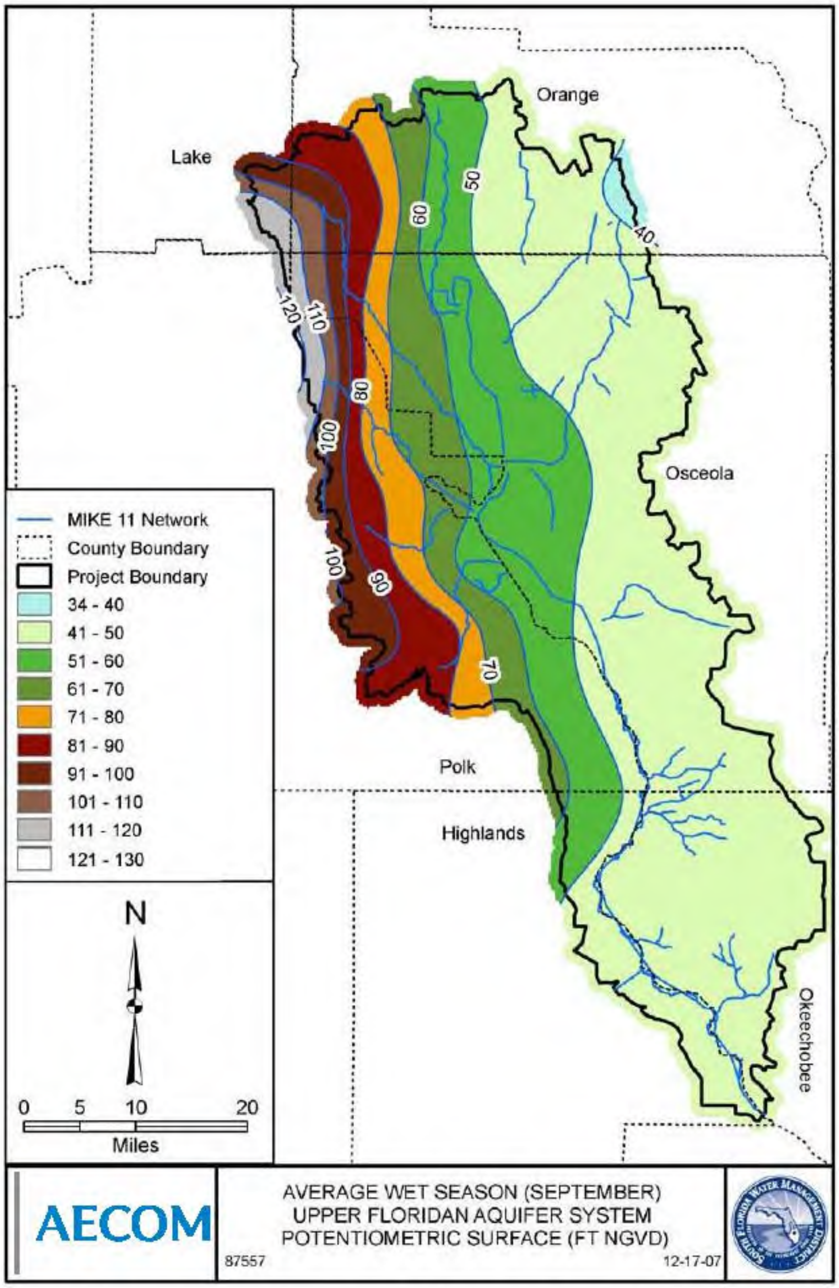


Figure 3-14: Average Wet Season (September) UFAS Potentiometric Surface Used to Extract Lateral Boundary Conditions. (USGS)

3.1.2.2 Applied "With Project" Base Condition Stresses

Meteorological and groundwater withdrawal data representative of the "With Project" base condition were developed to run the "With Project" base model for the period from 1965 through 2005. The meteorological and groundwater withdrawal data used in the "With Project" base model are described below.

3.1.2.2.1 Rainfall

Figure 3-15 shows the spatial distribution of the average rainfall used to drive the "With Project" base model. Rainfall grids were provided by the SFWMD in American Standard Code for Information Exchange (ASCII) format and converted to a DHI dfs2 format to be used as input in the model.

3.1.2.2.2 RET

The revised RET was provided by the SFWMD as a separate time series for individual cells throughout the model domain. This file was used to create a dfs2 file that contained a spatially varied time series for each of the 1,000 x 1,000 foot grids of the model domain. The maximum and mean RET for the model domain are shown in Figure 3-16 and Figure 3-17. Appendix A includes a summary of the RET data used in the "With Project" base model and the effect of this parameter on the results of the previous KBMOS base runs.

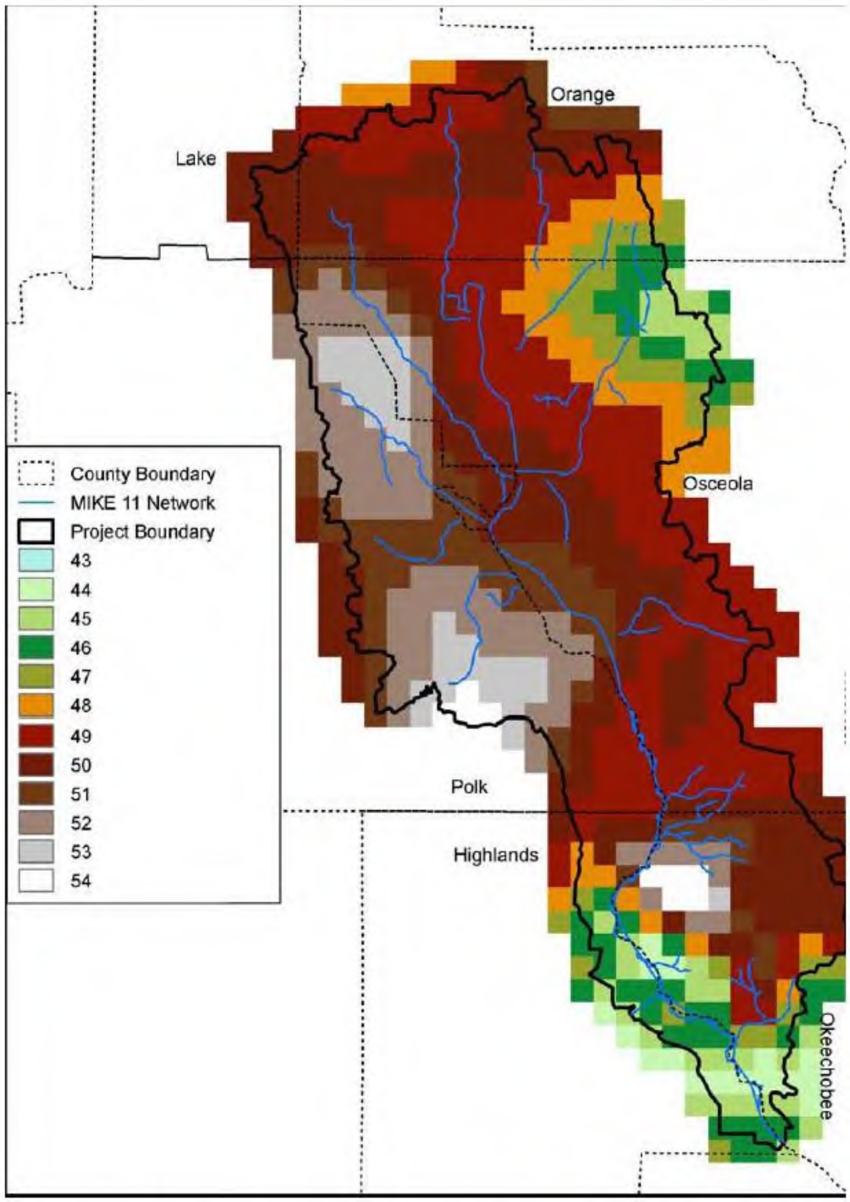


Figure 3-15: Spatially-Distributed Average Annual Rainfall in the Kissimmee Basin from 1965 through 2005

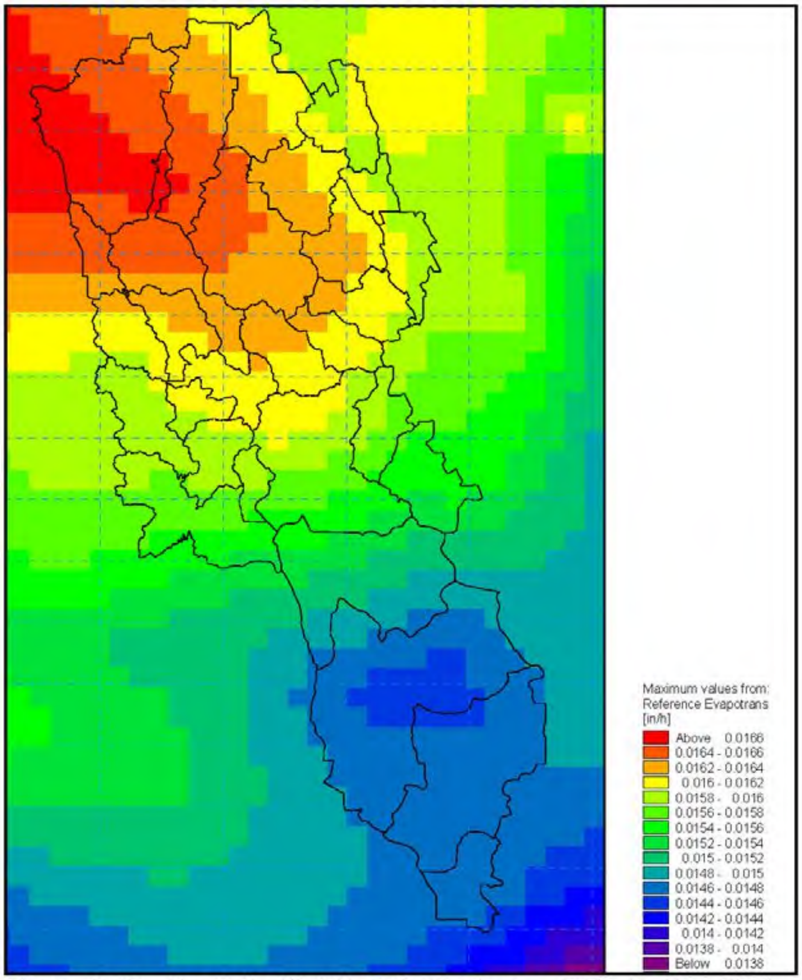


Figure 3-16: Spatially-Distributed Maximum RET in the Kissimmee Basin from 1965 through 2005

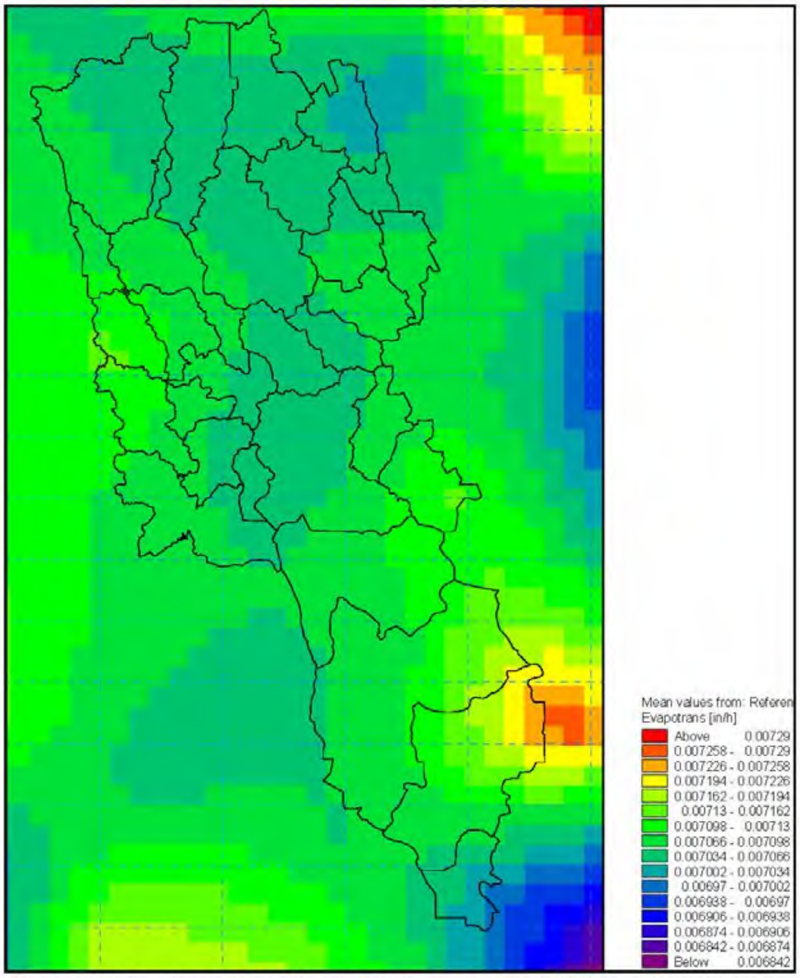


Figure 3-17: Spatially-Distributed Average RET in the Kissimmee Basin from 1965 through 2005

3.1.2.2.3 Water Use Data

Groundwater withdrawals were added to the model as local withdrawals (PWS) and irrigation areas (ICA) as described in Section 2.1.3.3. The groundwater withdrawals correspond to the 2008 existing legal users.

3.1.3 MIKE 11 Network

The MIKE 11 network used during the calibration of the AFET-W was reconfigured to account for all storage within KUB lakes based on an analysis of historic maximum stages. KUB modifications included extending cross-sections to the maximum defined flood extent of the KUB lakes shown in Figure 3-18. These modifications were made to better represent lake storage in decoupled MIKE 11 simulations planned for the alternative formulation.

In addition to the modification of the MIKE 11 component to better represent KUB storage, the calibration MIKE 11 network was modified to reflect restoration activities in Pool B-C-D. The modifications made to the calibration MIKE 11 model in Pool B-C-D are detailed below.

3.1.3.1 LKB – Restored Pool B-C-D

The MIKE 11 network used during calibration was modified to incorporate the floodplain data in the restored Pool B-C-D. The future phases of the KRRP and the C-38 Canal in this portion of the "With Project" base MIKE 11 model was revised to incorporate floodplain data from the high resolution fully restored condition DEM developed in previous stages of the study. The "With Project" base condition network includes a single branch to represent the floodplain from the upstream end of Phase IV of the restoration project (Pool B) to the split between the old C-38 Canal and the historic Kissimmee River, just north of the CSX railroad crossing of the Kissimmee River floodplain. Weirs 1, 2 and 3 were removed from the network as the C-38 Canal in that area was backfilled. Two branches south of this split, representing the former main channel of the Kissimmee River and the C-38 Canal, were represented in MIKE 11. A re-carved connection between the Kissimmee River and the C-38 Canal, just upstream of the S-65D Structure, was implemented in the "With Project" base MIKE 11 model. The general layout of the "With Project" base condition MIKE 11 network is shown in Figure 3-19.

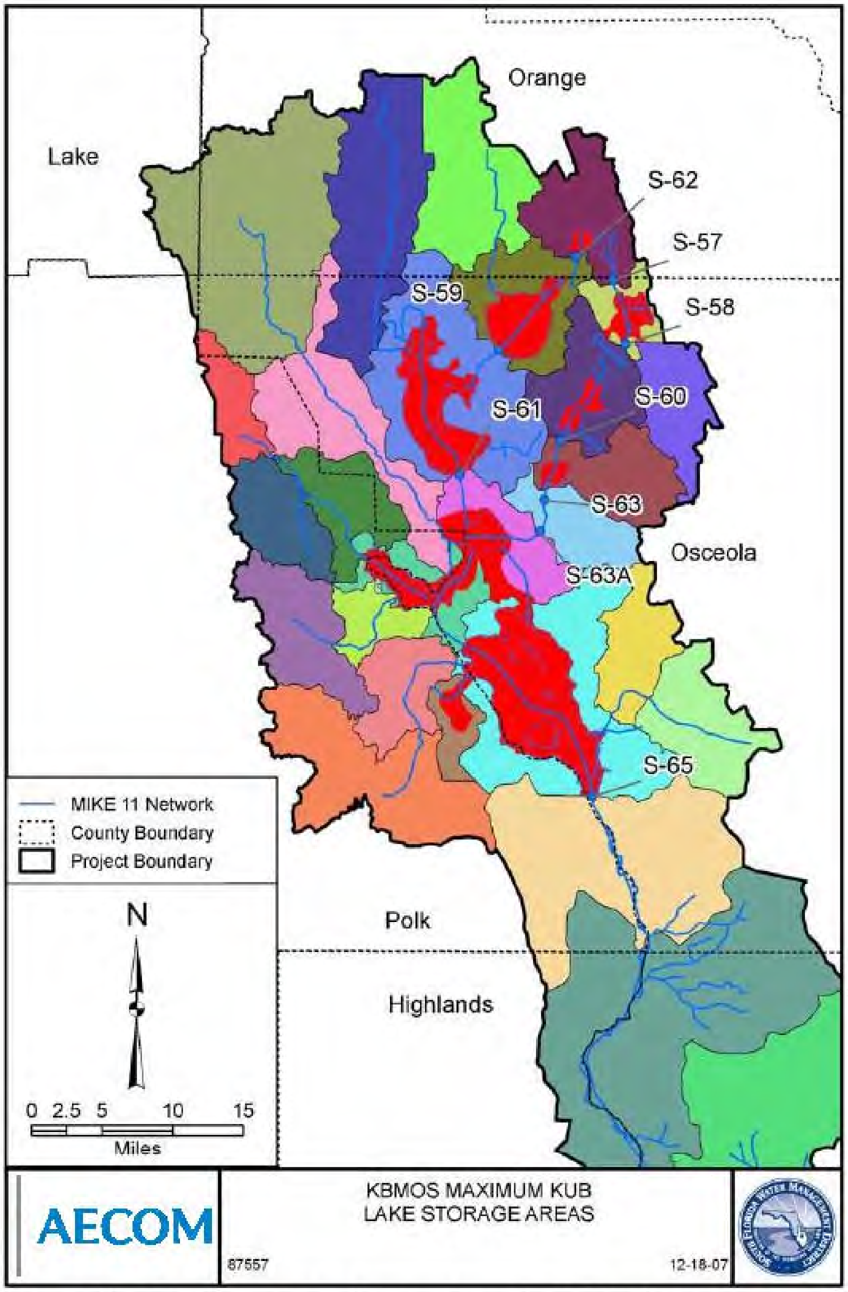


Figure 3-18: Maximum Lake Storage Areas in the KUB. Maximum Lake Storage Areas were used to define the extent of the KUB cross-sections

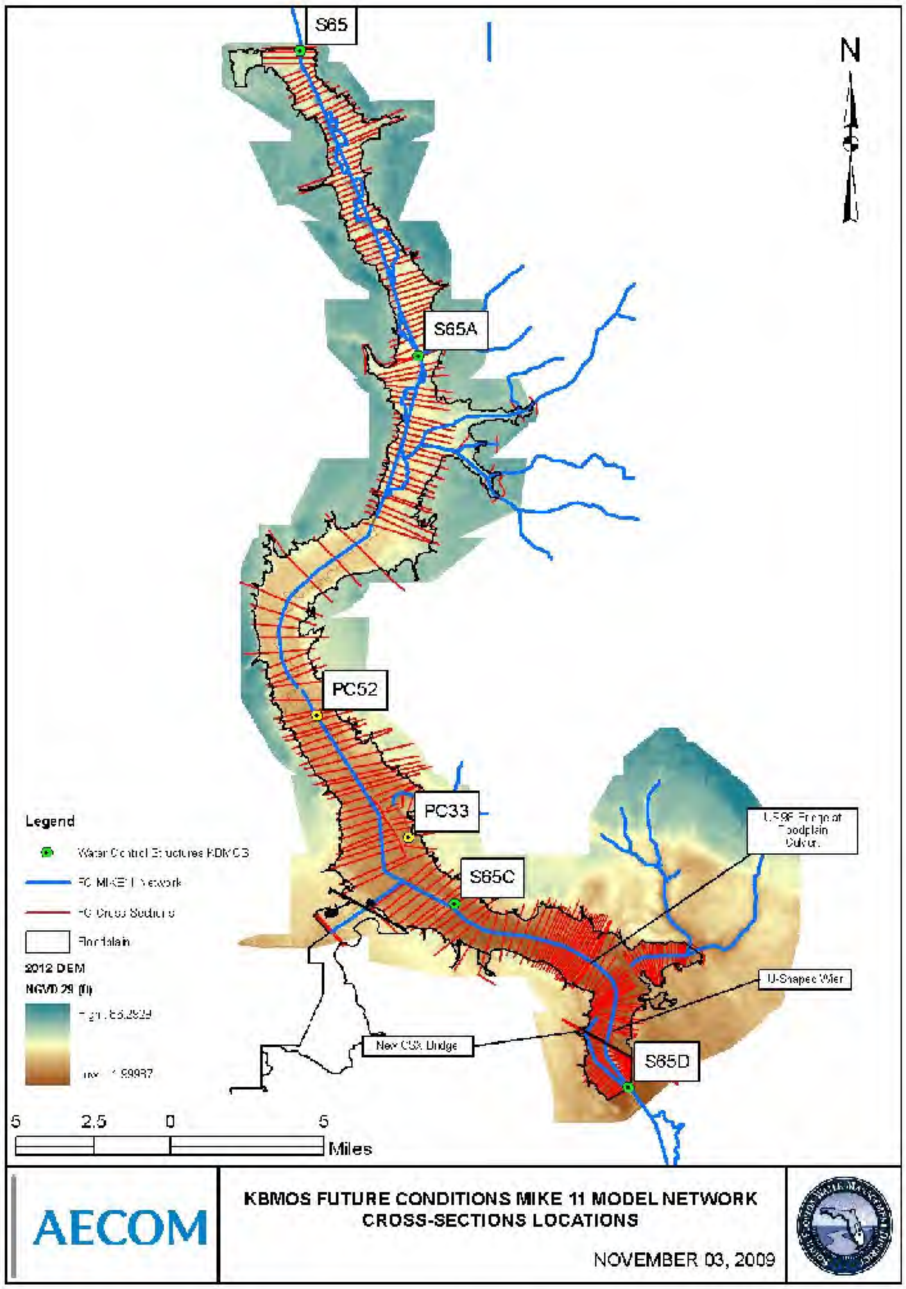


Figure 3-19: "With Project" Base Condition MIKE 11 Network and Pool C-D Floodplain Cross-Sections. The Location of Special Surface Water Control Features in Restored Pool C-D and Performance Measure Locations are also shown

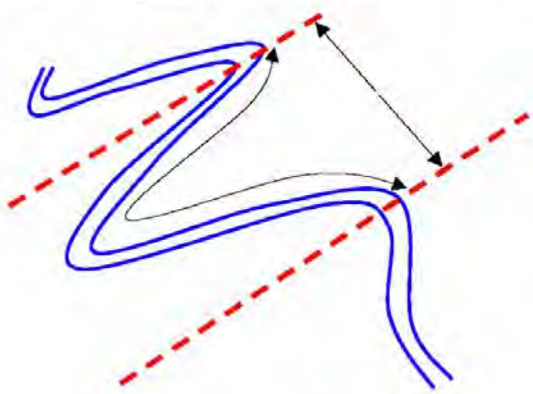
3.1.3.1.1 Cross-sections in the LKB

Cross-sections for the "With Project" base condition network described above were developed from several sources:

- Since the AFET-W used a pre-Phase I configuration and the hydraulic calibration of the floodplain in the AFET was not modified during the calibration of the AFET-W, cross-sections corresponding to the area included in Phase I of the KRRP and areas outside of the KRRP were taken from the MIKE 11 network of the AFET.
- Cross-sections corresponding to the branches located in the rest of the KRRP (not yet constructed) were taken from the high-resolution DEM developed for Pool B-C-D. The high-resolution DEM had a 100-foot grid resolution and cross-sections were extended to the full extent of the defined 100-year floodplain in Pool B- D.

Locations of cross-sections used in the "With Project" base model in the LKB are shown graphically in Figure 3-19. The number of cross-sections was optimized to reduce the numerical overhead of the MIKE 11 model, while accurately representing floodplain storage.

The cross-sections in the restored Pool D were cut perpendicular to the defined extent of the 100-year floodplain. As shown in Figure 3-19, the meandering Kissimmee River is not perpendicular to the cross-sections in many locations. To accurately represent head-losses in the main channel of the Kissimmee River, the roughness coefficients for the main channel were adjusted to account for the additional flow length for in-bank flows. A simple linear scaling factor was used to adjust the channel roughness coefficients. The equation used to modify channel roughness coefficients is:



$$M_c = M_{\max} \frac{L_{xi}}{L_{mi}} \qquad \textbf{Eq. 3}$$

Where:

M_c is the effective Manning's M roughness coefficient in the main channel,

M_x is the maximum channel Manning's M roughness coefficient (calibrated value)

L_{xi} is the sum of the linear distance between the mid-points between the upstream and downstream cross-sections and cross-section i and

L_{mi} is the length of the meander between the mid-points between the upstream and downstream cross-sections and current cross-section i.

The mid-points between the upstream and downstream cross-sections and cross-section i were used to calculate the cross-section and meander lengths to be consistent with the finite-difference formulation MIKE 11 uses to discretize roughness coefficients. Manning's roughness coefficients in the main channel (M_c) were obtained by comparing the fully restored Kissimmee River Network with pre-chanelization data as described in the Kissimmee River Floodplain Hydraulic Model Documentation (EarthTech | AECOM 2008a).

3.1.3.1.2 Special Surface Water Control Features

A few special features that control surface water flow in the restored portions of Pool B and C were added to the "With Project" base model. The geometry and location of these features were developed from a Hydrologic Engineering Centers River Analysis System (HEC-RAS) model developed by the USACE and subsequently improved by the Earth Tech Team. These special surface water control features are described below.

3.1.3.1.2.1 U-Shaped Weir

The U-shaped weir is meant to control discharge from the restored Kissimmee River to the C-38 Canal during high flow conditions when the conveyance of the main river channel is not sufficient to handle the flow in restored Pool C-D. The U-shaped weir has a 1,650 foot low-flow crest at an elevation of 31 feet-NGVD and a 4,500 foot high-flow crest at an elevation of 45 feet. The location of the U-shaped weir is shown in Figure 3-19.

3.1.3.1.2.2 CSX Bridge

A new bridge was added in the restored portion of the river, where the CSX railroad crosses the Kissimmee River floodplain. The new CSX bridge has an overflow length of 300.0 feet, waterway length of 52.8 feet and a high and low chord elevation of 47.0 and 41.0 feet, respectively. The existing CSX bridge has an overflow length of 452.0 feet, waterway length of 52.8 feet and a high and low chord elevation of 47.0 and 41.0 feet, respectively. The cross-section geometry of the new and existing CSX bridges are shown in Figure 3-20 and their locations are shown in Figure 3-19.

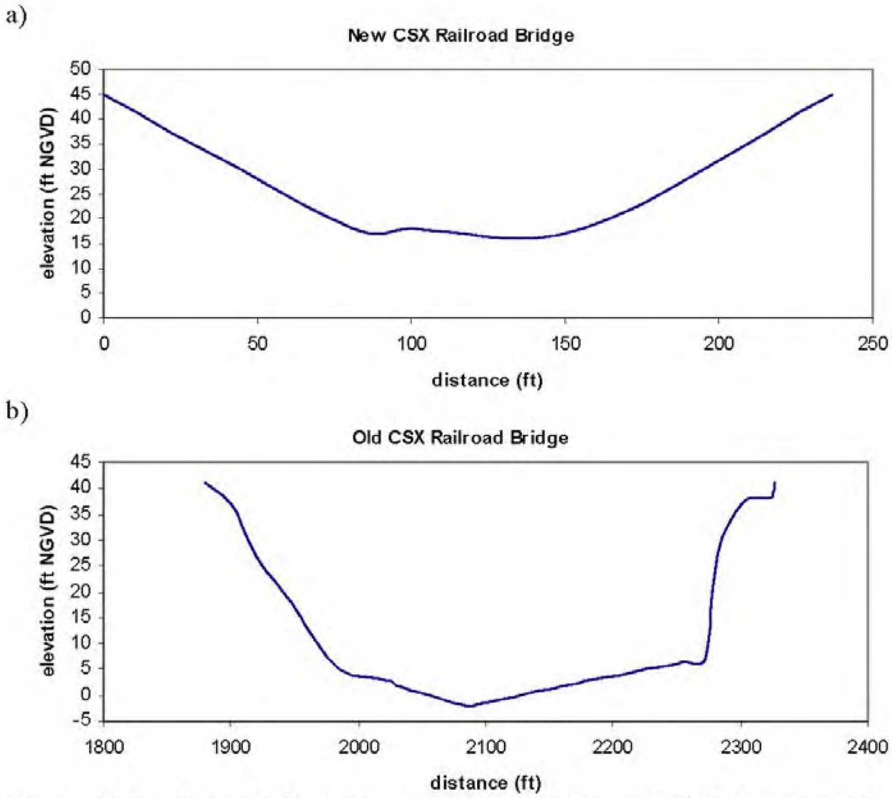


Figure 3-20: Cross-Section Geometry for a) the New CSX Bridge in the Restored Portion of the Kissimmee River and b) the Existing CSX Bridge Included in the "With Project" Base Model

3.1.3.1.2.3 US-98 Culverts and Bridge

The existing bridge at US-98 will be modified to increase the conveyance at this location. The modified bridge has an overflow length of 240.0 feet, waterway length of 52.8 feet and a high and low chord elevation of 51.4 and 48.0 feet, respectively. The cross-section geometry of the modified US-98 Bridge is shown in Figure 3-21 and its location is shown in Figure 3-19.

In addition to modification of the US-98 Bridge, 11 floodplain culverts were added to the "With Project" base model along US-98. The intent of the US-98 floodplain culverts is to reduce the hydraulic effects of US-98 and provide additional conveyance. The geometry of the US-98 floodplain culverts are summarized in Table 3-7 and the locations are shown in Figure 3-19.

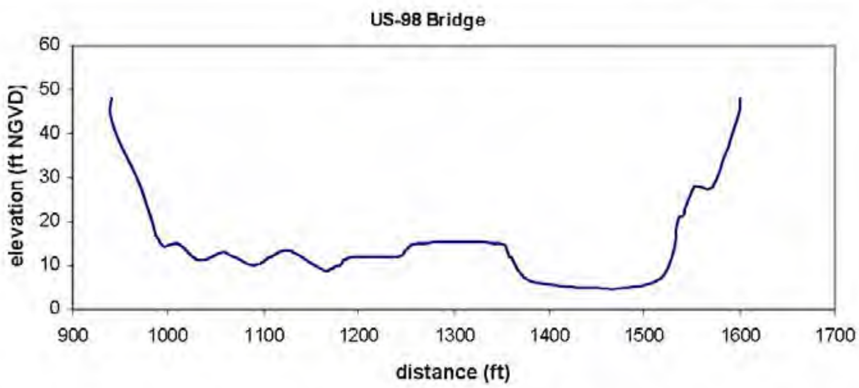


Figure 3-21 Cross-Section Geometry for the Modified US-98 Bridge in the "With Project" Base Model

Table 3-7: Geometry of the US-98 Floodplain Culverts Represented in the "With Project" Base Model

Number of Culverts	Length (feet)	Invert (feet-NGVD)	Width (feet)	Height (feet)
1	50.0	28.8	8.0	8.0
3	50.0	29.5	8.0	8.0
4	50.0	29.0	8.0	8.0
2	50.0	28.0	8.0	8.0
1	50.0	28.0	400.0	8.0

3.1.3.2 KUB Network

The C-37 Canal, between Lake Hatchineha and Lake Kissimmee, was widened by 20 feet. The bottom widths of the existing cross-sections of the C-37 Canal were increased by 20 feet but the same bottom elevations were maintained. Berm and floodplain data were not modified.

3.2 "With Project" Base Model Results

In addition to evaluation of stage and discharge data at those locations where the performance measures are evaluated (Figure 3-22), MIKE SHE and MIKE 11 water budgets were calculated for the "With Project" base model. The MIKE SHE water budget was calculated for the 29 watersheds shown in Figure 3-23. Maximum lake or floodplain storage areas were used to calculate the MIKE 11 water budget and are shown in Figure 3-24.

Annual rainfall amounts for the 1965 through 2005 "With Project" base simulation periods are shown in Figure 3-25. Actual evapotranspiration and available water calculated from the "With Project" base model results are also shown in Figure 3-25. Annual available water was the difference between rainfall and actual evapotranspiration and represents the amount of water available for runoff and infiltration processes in a given year. Average annual rainfall, actual evapotranspiration and available water for the period from 1965 through 2005 were 49.1, 40.2 and 9.0 inches, respectively. Figure 3-26 compares the runoff values obtained with the "With Project" base models with those values obtained with the AFET-W calibration run. This plot also includes a summary of the RET data used in the model runs. These values explain the actual evapotranspiration values seen in Figure 3-25.

Annual rainfall, RET, actual evapotranspiration and available water amounts for the "With Project" base model are summarized in Table 3-8. Although actual evapotranspiration rates in the "With Project" base models were different, actual evapotranspiration differences between the models were not as significant as the observed year to year differences in rainfall.

3.2.1 Stage and Flow Results

Results for the "With Project" base model for key locations in both the KUB and in the LKB are included in Appendix B.

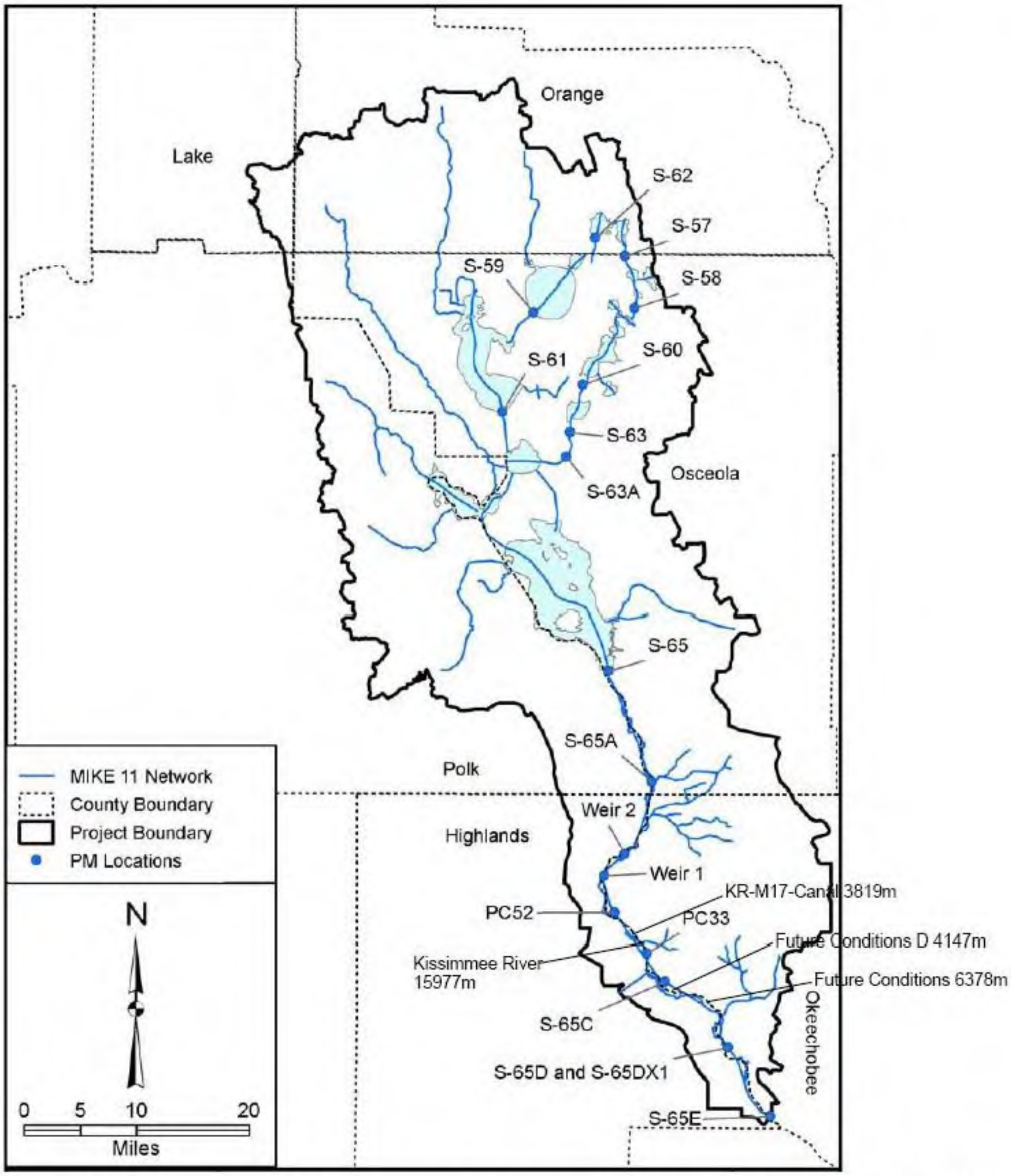


Figure 3-22: Structure and Performance Measure Locations Evaluated in the "With Project" Base Models

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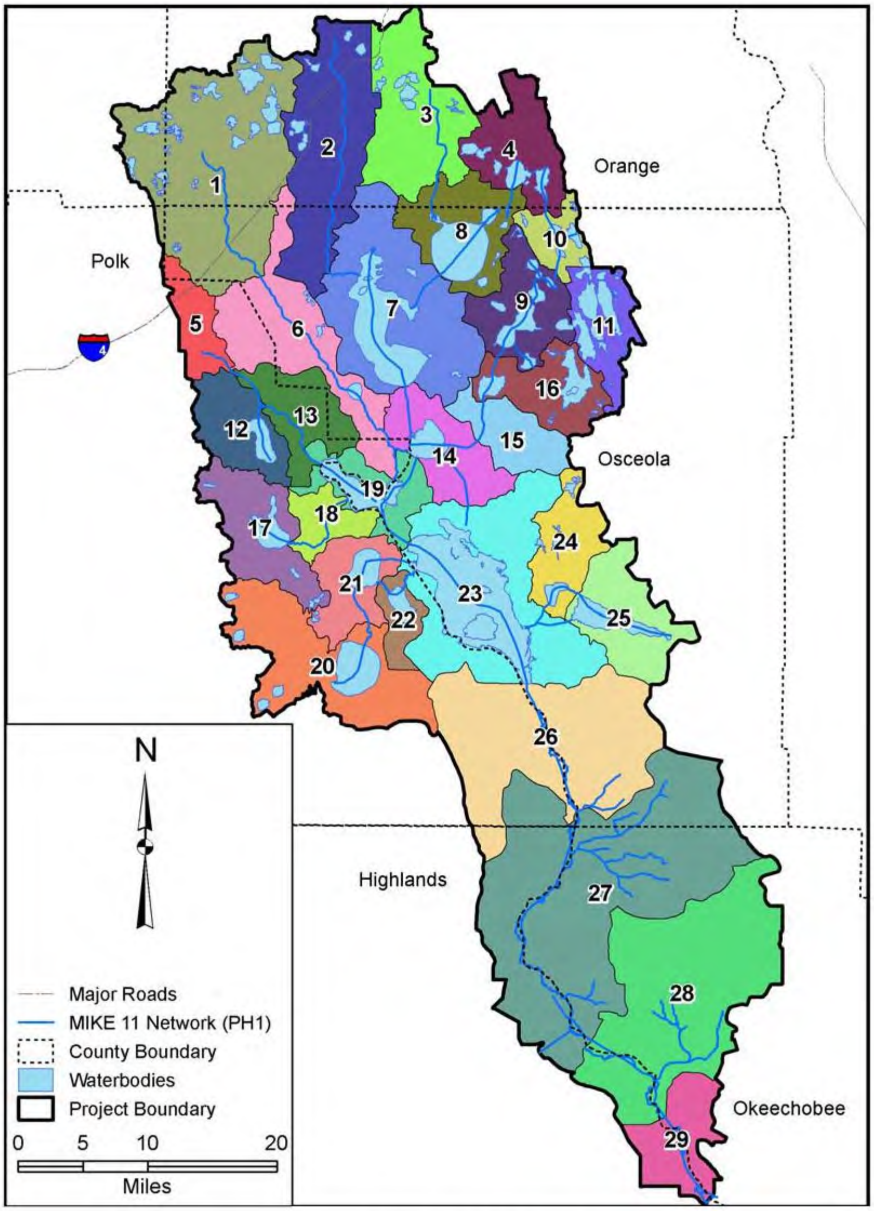

Figure 3-23: Kissimmee Basin Watersheds Used to Calculate Water Budgets for the "With Project" Base Simulations

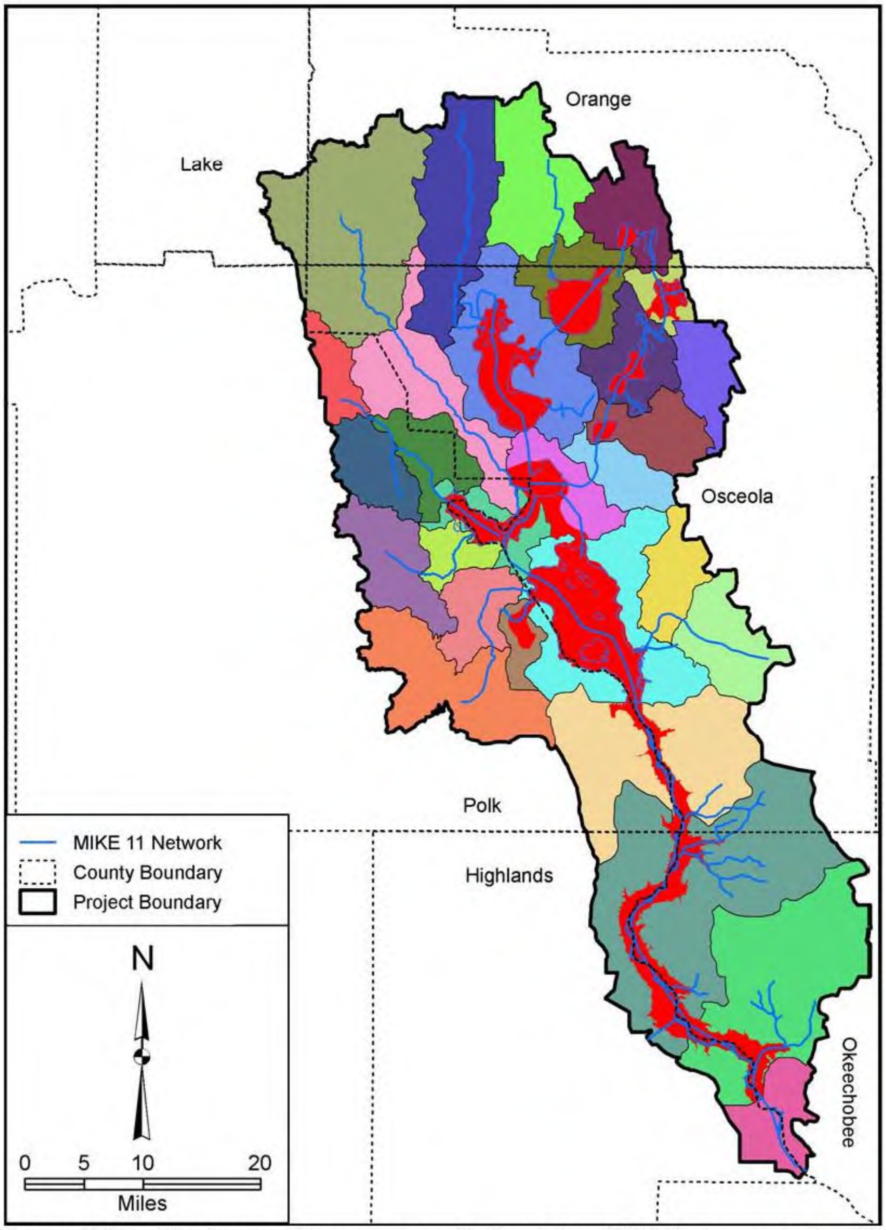

Figure 3-24: Maximum Storage Area Defined for KUB Lakes and the LKB Floodplain. Maximum Storage Areas were used to Define the Extent of Areas Used to Calculate MIKE 11 Water Budgets

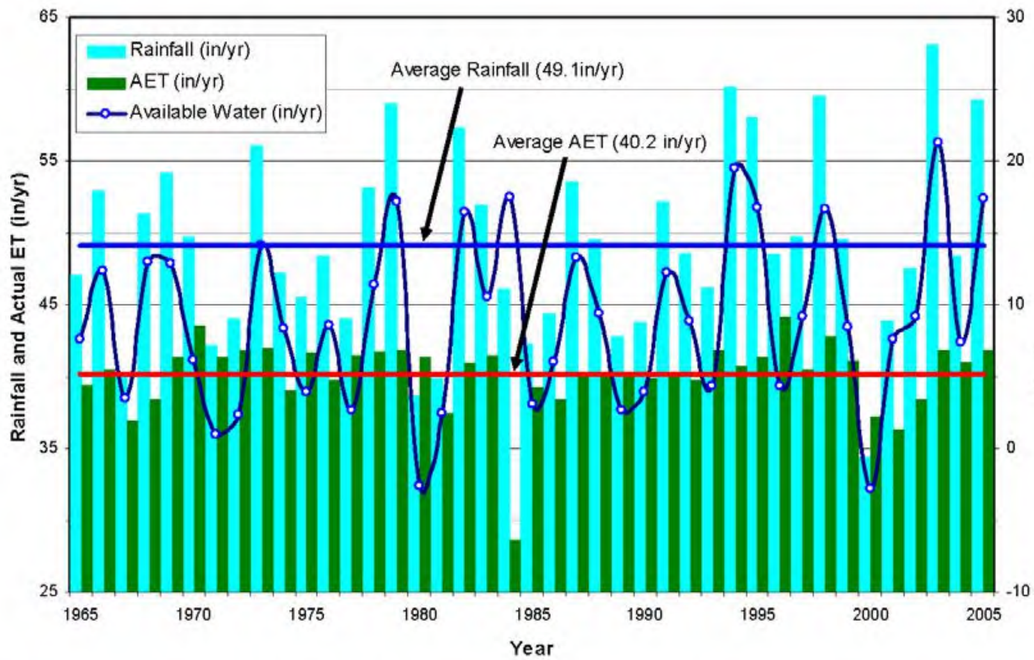

Figure 3-25: Annual Rainfall, RET, Simulated Actual Evapotranspiration and Simulated Available Water Rates (inches/year) in the Kissimmee Basin for the Period from 1965 through 2005. Simulated Actual Evapotranspiration and Available Water Data were from the "With Project" Base Model. Available Water was calculated as the Difference between Annual Rainfall and Simulated Actual Evapotranspiration Rates

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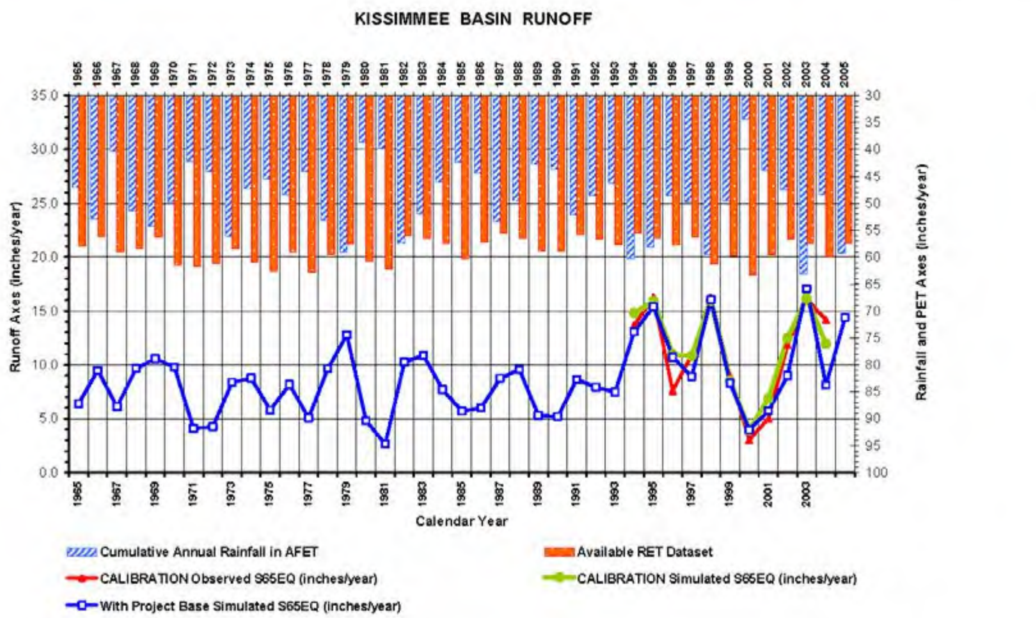

Figure 3-26: Simulated Annual Runoff for the "With Project" Base Model runs as compared to the Calibration Model Run Annual Runoff Rates (inches/year). Rainfall and RET Rates (inches/year) also Included for Reference

3.2.2 MIKE SHE Water Budgets

Average annual "With Project" base condition MIKE SHE water budgets for the 29 watersheds, shown in Figure 3-23 for the period from 1965 through 2005, are summarized in Table 3-9.

Table 3-8: Annual Rainfall, RET, Simulated Actual Evapotranspiration and Simulated Available Water Rates (inches/year) in the Kissimmee Basin

Year	Rainfall (inches/year)	RET (inches/year)	Actual Evapotranspiration (inches/year)	Available Water (inches/year)
1965	47.01	57.99	39.40	7.61
1966	52.86	56.10	40.50	12.36
1967	40.31	58.97	36.86	3.45
1968	51.36	58.42	38.37	12.99
1969	54.17	56.38	41.33	12.84
1970	49.69	61.50	43.54	6.15
1971	42.18	61.80	41.27	0.91
1972	44.07	61.08	41.80	2.27
1973	56.10	58.36	41.99	14.11
1974	47.26	60.85	38.99	8.27
1975	45.54	62.57	41.63	3.91
1976	48.33	59.02	39.77	8.56
1977	44.05	62.79	41.45	2.60
1978	53.12	59.45	41.74	11.38
1979	59.00	57.46	41.88	17.12
1980	38.71	60.73	41.33	-2.62
1981	39.86	62.14	37.45	2.41
1982	57.29	56.00	40.88	16.41
1983	51.93	56.47	41.43	10.50
1984	46.10	57.40	28.61	17.49
1985	42.31	60.24	39.26	3.05
1986	44.37	57.17	38.35	6.02
1987	53.51	55.58	40.26	13.25
1988	49.48	56.49	40.14	9.34
1989	42.81	58.85	40.19	2.62
1990	43.73	58.89	39.82	3.91
1991	52.17	55.77	39.97	12.20
1992	48.53	56.61	39.69	8.84
1993	46.21	57.60	41.85	4.36
1994	60.20	55.48	40.69	19.51
1995	58.09	56.47	41.31	16.78
1996	48.51	57.72	44.16	4.35
1997	49.69	56.31	40.50	9.19
1998	59.51	61.29	42.84	16.67
1999	49.49	59.79	41.07	8.42
2000	34.37	63.20	37.25	-2.88
2001	43.83	59.56	36.24	7.59
2002	47.50	56.60	38.36	9.14
2003	63.11	57.32	41.89	21.22
2004	48.36	59.89	40.96	7.40
2005	59.24	57.35	41.82	17.42

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3.2.3 Comparison of Cumulative Flow at the S-65 and S-65E Structures

Cumulative plots were prepared to compare modeled with observed flows at the S-65 and S-65E Structures. Figure 3-27 and Figure 3-28 show these comparisons. These figures, in addition to the comparison shown in Figure 3-26, show that the base condition modeled flows were in agreement with the recorded flows, especially in the S-65E Structure. It is important to emphasize that the watershed and operating conditions used in the "With Project" base condition differ from the watershed and operating conditions present in the basin at the time the flow record was established. Therefore, it was not the intention of the base condition simulation to match the historical record.

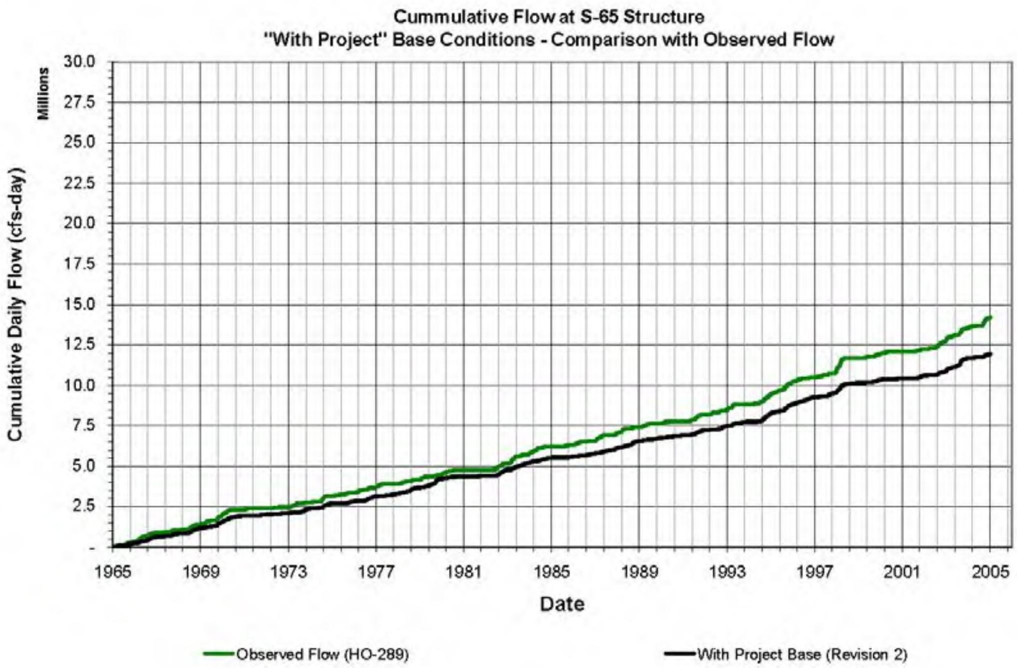

Figure 3-27: Cumulative flow at the S-65 Structure. Modeled and observed flows

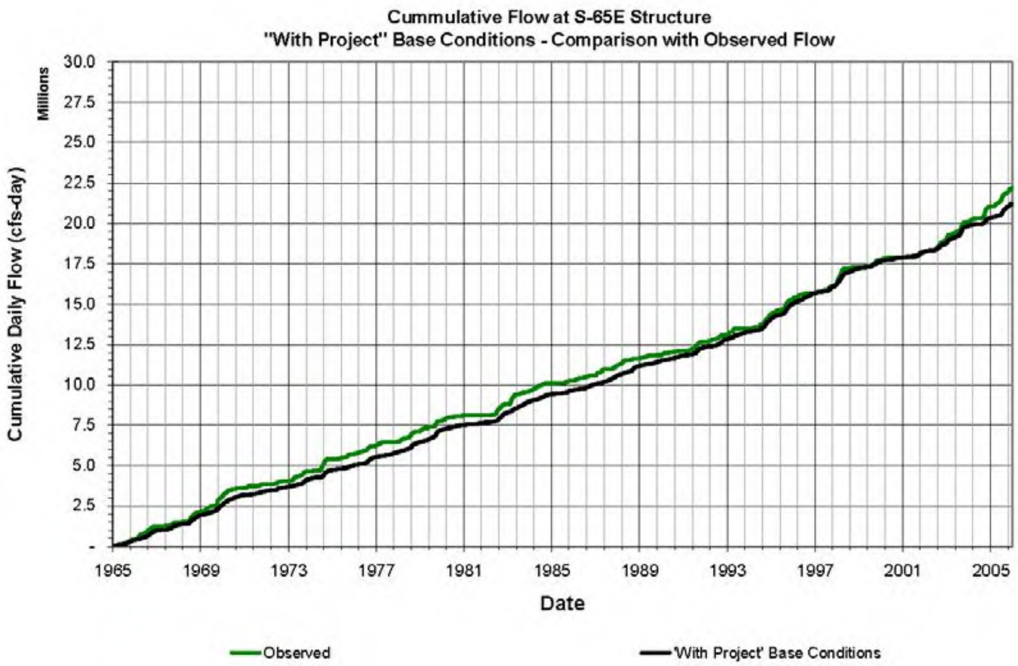

Figure 3-28: Cumulative flow at the S-65E Structure, modeled and observed flows

3.2.4 MIKE 11 Water Budgets – Extraction of Lateral Inflows

Lateral inflows to each lake and pool in the Kissimmee Basin were extracted from MIKE SHE/MIKE 11.

Table 3-10 includes yearly summaries of the lateral inflows in inches and Figure 3-29, Figure 3-30 and Figure 3-31 show the temporal variation of the lateral inflows for the KUB, LKB and Kissimmee Basin.

Table 3-9: "With Project" Base Condition Water Budget for 29 Watersheds in the Kissimmee Basin

Sub-Watershed	ID	Rain (*Rai*)	Actual ET (*AET*)	Canopy-OL Storage Change *ΔOL*	Runoff (*Ro*)	OL Boundary Flows (OL_{BC})	Baseflow (*BF*)	Drainage To River (*D*)	Irrigation (*Irr*)	PWS Pump (GW_P)	Irrigation Pump (GW_I)	SZ Boundary Flow (SZ_{BC})	Subsurface Storage Change ($\Delta SZ+\Delta UZ$)	Total Error (*Err*)
Upper Reedy Cr.	1	49.59	38.10	0.15	1.88	0.00	0.36	6.25	0.57	0.00	0.00	-3.31	0.11	0.00
Shingle Creek	2	48.90	35.70	0.07	3.40	0.00	0.62	7.16	0.21	0.00	0.00	-2.10	0.03	0.00
Boggy Creek	3	48.78	35.61	-0.03	3.45	0.00	0.20	8.73	0.12	0.00	0.00	-0.94	-0.02	0.00
Lake Hart	4	47.42	43.09	-0.70	0.58	0.03	0.07	4.12	0.00	0.00	0.00	-0.26	-0.05	0.00
Horse Creek	5	51.74	36.79	0.89	8.17	0.03	1.75	0.00	1.22	0.00	0.00	-3.81	1.52	0.00
Lower Reedy Cr.	6	50.87	41.63	0.24	1.10	0.00	0.60	6.83	0.15	0.00	0.00	-0.36	0.26	0.00
Lake Toho	7	48.43	42.73	0.01	-1.49	0.00	0.19	6.97	0.19	0.00	0.00	-0.18	0.03	0.01
East Lake Toho	8	47.00	44.67	-0.07	-3.28	0.00	0.37	5.58	0.27	0.00	0.00	0.02	0.01	0.00
Alligator Lake	9	46.48	42.43	-1.53	-0.12	0.00	0.20	5.96	0.49	0.00	0.00	-0.04	0.00	0.00
Lake Mrytle	10	44.97	42.58	-0.88	-0.01	0.03	0.57	2.16	0.00	0.00	0.00	-0.63	-0.10	0.00
Lake Conlin	11	45.47	40.65	-0.09	0.00	0.03	0.00	4.73	0.00	0.00	0.00	-0.26	-0.10	0.00
Lake Marion	12	51.53	37.75	0.09	0.09	-0.04	0.03	9.70	0.10	0.00	0.00	-3.57	0.45	0.01
Marion Creek	13	50.91	41.60	0.14	1.13	0.03	0.51	6.68	0.05	0.00	0.00	-0.74	0.13	0.00
Lake Cypress	14	49.08	41.94	-0.91	-0.46	0.01	0.65	8.48	0.51	0.00	0.00	0.07	-0.04	0.01
S63A	15	48.48	38.42	0.00	0.25	0.01	0.22	9.71	0.66	0.00	0.00	-0.50	0.05	0.01
Lake Gentry	16	47.86	40.83	-0.26	0.26	-0.73	0.23	7.08	0.16	0.00	0.00	-0.57	0.03	0.01
Lake Pierce	17	50.71	35.10	0.26	2.05	0.02	0.00	8.17	0.21	0.00	0.00	-4.82	0.46	0.00
Catfish Creek	18	50.44	38.06	0.08	1.57	-0.01	2.01	8.80	0.49	0.00	0.00	-0.31	0.12	0.00
Lake Hatchineha	19	49.91	47.94	0.37	-3.39	-0.05	0.71	4.39	0.18	0.00	0.00	-0.12	0.01	0.00
Lk Weohyakapaka	20	51.70	38.27	0.12	0.55	0.01	0.02	10.96	0.04	0.00	0.00	-1.58	0.22	0.00
Lake Rosalie	21	51.25	42.17	0.13	0.82	0.02	0.23	6.33	0.05	0.00	0.00	-1.45	0.12	0.00
Tiger Lake	22	51.36	45.12	0.21	-1.42	-0.01	0.14	7.77	0.18	0.00	0.00	0.25	-0.02	0.00
Lake Kissimmee	23	49.95	48.32	0.15	-4.00	0.01	0.04	6.29	0.81	0.00	0.00	0.05	0.00	0.00
Lake Jackson	24	48.80	41.66	0.11	-0.84	-0.01	0.04	6.58	0.03	0.00	0.00	-1.07	0.21	0.00
Lake Marian	25	48.63	43.85	0.04	-1.84	0.00	0.01	7.59	1.03	0.00	0.00	0.06	0.07	0.00
S-65A	26	49.10	39.05	0.20	0.88	0.03	0.69	8.58	1.15	0.00	0.00	-0.56	0.25	0.00
S-65BC	27	48.41	38.02	0.18	-0.50	-0.01	0.98	9.97	0.20	0.00	0.00	0.10	0.07	0.00
S-65D	28	47.96	38.06	0.08	1.36	0.01	0.28	9.89	2.03	0.00	0.00	-0.29	0.04	0.01
S-65E	29	44.32	36.09	-0.01	-0.95	1.19	2.05	7.77	1.00	0.00	0.00	0.74	-0.06	0.01

Table 3-10: Lateral inflows for the "With Project" Base Condition – 1965-2005, Annual

	Toho	Hart	East Toho	Myrtle	Alligator	Gentry	Kissimmee, Hatchineha and Cypress	Pool A	Pool BCD	Pool E	Kissimmee Upper Basin	Lower Kissimmee Basin	Kissimmee Basin
Drained Area (acres)	153,040	34,408	91,750	13,939	59,430	29,943	645,793	103,353	295,353	29,157	1,028,303	427,863	1,456,166
% of the Kissimmee Basin	10.5%	2.4%	6.3%	1.0%	4.1%	2.1%	44.3%	7.1%	20.3%	2.0%	70.6%	29.4%	100.0%
Water Year	Hydrologic Yield of the area draining to the WCU (A.K.A. Lateral Inflows) per Water Year in Inches												
1965-1966	7.5	8.2	14.1	6.8	8.7	1.1	6.6	10.7	7.6	2.5	7.4	8.0	7.6
1966-1967	6.3	7.9	11.0	4.2	3.4	0.7	5.1	8.4	10.5	14.4	5.7	10.3	7.0
1967-1968	6.3	2.5	6.9	-1.3	1.7	0.6	3.4	7.6	10.5	5.5	3.9	9.4	5.5
1968-1969	12.2	9.1	18.1	6.8	9.0	0.7	10.4	15.8	15.5	21.5	10.9	16.0	12.4
1969-1970	15.3	12.9	22.4	10.0	15.5	2.8	12.0	16.2	16.0	20.7	13.4	16.4	14.2
1970-1971	-0.4	1.1	0.2	-0.2	-1.5	0.0	2.2	5.6	9.1	3.6	1.3	7.9	3.2
1971-1972	1.2	1.6	3.3	-0.3	0.3	0.6	3.1	7.0	12.2	14.5	2.5	11.1	5.0
1972-1973	1.5	1.3	4.2	0.1	-0.4	0.4	3.4	9.8	11.3	1.4	2.7	10.3	5.0
1973-1974	5.8	1.5	6.7	-0.8	1.5	0.7	6.3	11.5	11.5	8.7	5.6	11.3	7.2
1974-1975	4.2	4.1	8.6	1.9	3.1	0.5	7.4	12.9	13.1	12.3	6.4	13.0	8.3
1975-1976	4.6	1.5	5.3	-1.5	-0.4	0.7	4.0	8.7	9.5	2.9	3.7	8.8	5.2
1976-1977	3.7	3.9	9.0	1.8	0.7	0.7	9.6	13.7	11.2	4.6	7.6	11.3	8.7
1977-1978	5.6	2.2	6.8	1.5	0.6	0.6	8.0	8.6	8.1	1.4	6.6	7.8	6.9
1978-1979	7.3	3.2	9.5	0.8	-0.1	0.7	9.1	12.4	14.0	7.2	7.8	13.1	9.3
1979-1980	10.0	5.7	11.6	-0.4	0.6	1.1	15.1	15.7	11.6	10.5	12.2	12.5	12.3
1980-1981	-3.0	0.1	-1.9	-2.4	-4.1	0.3	-0.2	4.6	8.8	1.4	-1.0	7.3	1.4
1981-1982	4.5	1.7	8.2	0.0	1.9	0.6	1.1	4.1	10.8	2.6	2.2	8.7	4.1
1982-1983	14.0	7.6	19.6	4.3	6.9	1.4	15.3	19.7	14.9	16.8	14.2	16.2	14.8
1983-1984	9.8	4.8	10.5	1.1	0.6	0.6	9.5	13.9	7.7	6.3	8.6	9.1	8.7
1984-1985	2.6	1.9	2.9	-3.1	-4.3	0.3	2.5	7.5	9.7	7.9	2.0	9.0	4.1
1985-1986	5.5	3.9	9.6	2.6	1.9	0.7	3.1	6.7	10.8	6.0	3.9	9.5	5.6
1986-1987	7.5	3.6	9.5	0.3	0.5	0.7	7.6	11.8	9.1	10.7	6.9	9.9	7.8
1987-1988	9.3	4.2	11.9	0.3	1.8	1.0	8.7	15.6	12.1	6.7	8.2	12.6	9.5
1988-1989	10.7	3.3	11.9	-0.5	0.6	0.5	8.1	9.1	6.8	2.5	7.9	7.1	7.7
1989-1990	6.8	0.7	5.6	-1.9	-1.6	0.6	3.9	5.5	8.2	2.6	3.9	7.2	4.8
1990-1991	2.6	0.7	3.4	-1.2	-1.4	0.4	2.8	5.3	11.5	7.5	2.4	9.7	4.6
1991-1992	9.6	2.1	11.5	-2.0	0.6	0.8	7.5	10.8	12.4	9.3	7.3	11.8	8.6
1992-1993	11.8	4.1	14.8	1.7	3.8	0.9	10.2	18.0	13.4	13.8	9.9	14.5	11.3
1993-1994	0.6	0.4	2.6	-0.9	-2.8	0.2	1.9	8.8	10.3	6.8	1.3	9.7	3.8
1994-1995	22.5	10.7	26.6	6.8	7.9	0.9	14.6	19.5	18.5	22.1	15.8	19.0	16.7
1995-1996	19.4	5.1	18.4	0.0	2.7	1.8	14.8	19.4	17.8	18.8	14.2	18.2	15.4
1996-1997	4.2	5.0	8.2	1.2	-0.9	1.4	6.7	9.0	10.3	6.2	5.7	9.7	6.9
1997-1998	22.4	15.8	28.9	11.9	11.6	1.2	16.4	22.2	23.8	15.7	17.6	22.9	19.2
1998-1999	-0.7	0.9	-0.2	-0.4	-3.9	0.1	0.9	9.4	16.3	5.1	0.3	13.8	4.3
1999-2000	8.1	4.0	11.1	0.9	1.2	0.7	5.3	4.8	18.1	13.2	5.7	14.5	8.3
2000-2001	0.3	-0.6	0.2	-2.2	-1.5	0.5	2.1	7.1	6.1	2.4	0.1	8.2	2.5
2001-2002	4.5	2.2	7.7	1.0	1.1	0.7	10.5	10.6	6.9	6.0	5.3	10.3	6.8
2002-2003	17.3	8.9	22.3	7.6	7.6	0.4	21.2	16.1	6.1	12.2	13.1	16.7	14.2
2003-2004	14.2	9.9	18.7	7.1	4.6	1.2	14.8	11.5	7.7	12.2	12.2	12.1	12.1
2004-2005	3.5	2.6	9.8	1.2	1.4	0.1	14.7	14.9	8.9	7.4	6.2	14.5	8.6
Average Annual	7.5	4.3	10.2	1.6	2.0	0.7	7.7	11.3	11.5	8.8	6.8	11.7	8.2

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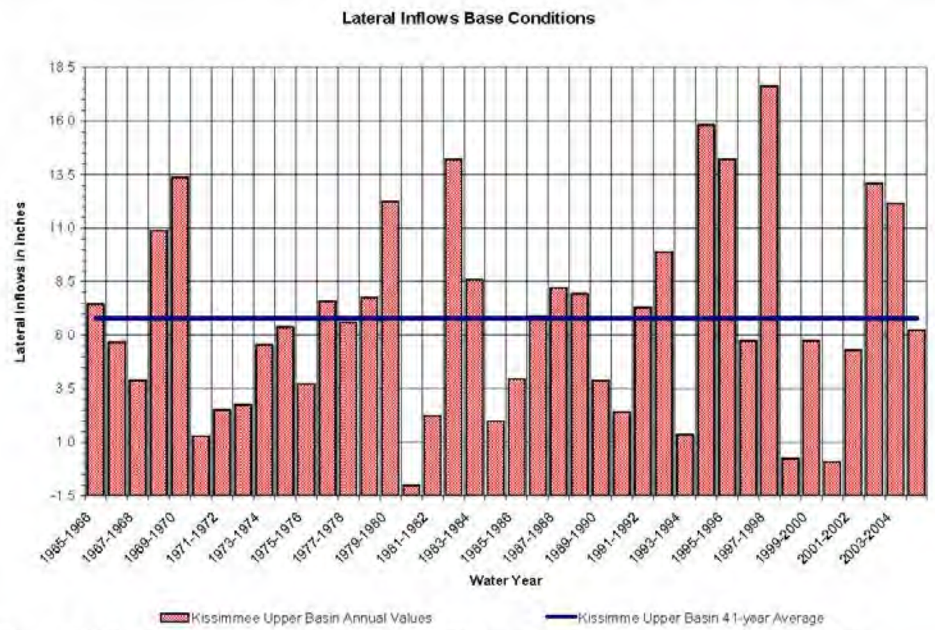

Figure 3-29: "With Project" Base Condition – Lateral inflows for the KUB

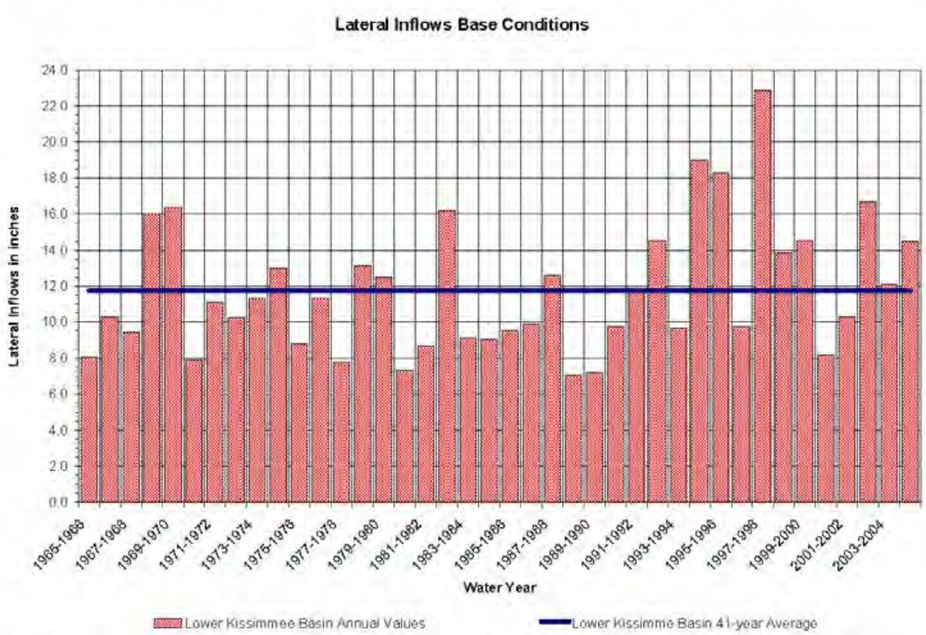

Figure 3-30: "With Project" Base Condition – Lateral inflows for the LKB

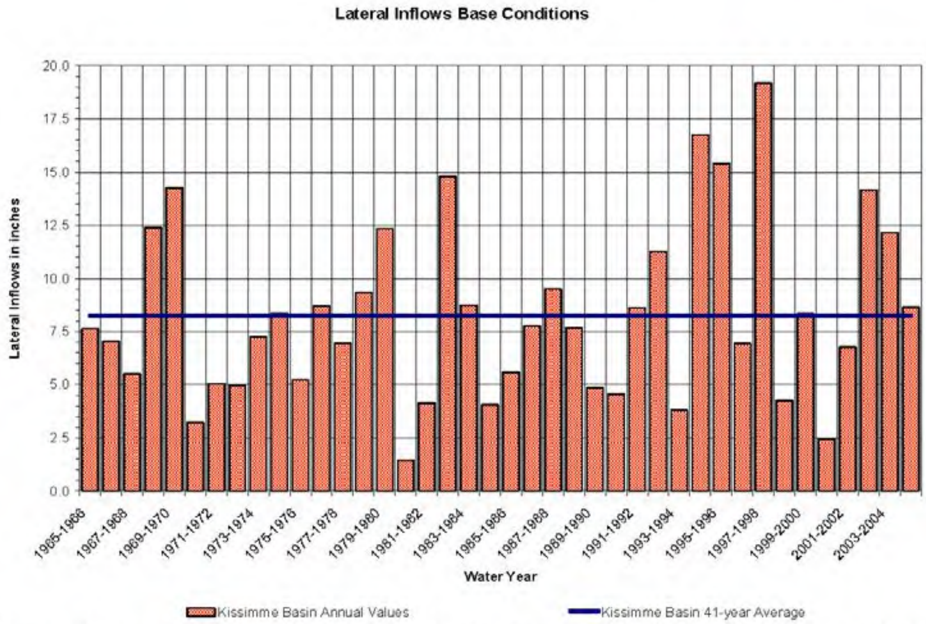

Figure 3-31: "With Project" Base Condition – Lateral Inflows for the Kissimmee Basin

Table 3-11: "With Project" Base Condition Annual Runoff from Boggy, Single and Reedy Creeks

	BOGGY CREEK	SHINGLE CREEK	REEDY CREEK
Drained Area (acres)	*52,664*	*68,383*	*170,653*
Water Year		Runoff in inches	
1965-1966	18.3	11.0	5.9
1966-1967	18.3	12.6	7.6
1967-1968	12.7	11.4	7.3
1968-1969	22.0	15.2	9.6
1969-1970	26.7	19.4	13.8
1970-1971	4.7	4.1	4.6
1971-1972	8.1	5.8	5.0
1972-1973	10.5	6.5	3.5
1973-1974	13.1	11.0	7.3
1974-1975	13.4	9.2	7.1
1975-1976	10.8	8.4	6.0
1976-1977	13.7	7.6	7.2
1977-1978	10.9	9.6	10.7
1978-1979	15.5	12.4	11.2
1979-1980	16.6	14.0	13.2
1980-1981	4.2	1.9	1.5
1981-1982	13.4	7.5	3.9
1982-1983	23.7	18.0	13.0
1983-1984	15.1	13.3	9.9
1984-1985	9.8	8.1	5.6
1985-1986	15.5	9.9	6.4
1986-1987	15.7	11.9	8.0
1987-1988	16.7	12.4	8.2
1988-1989	16.4	12.4	9.9
1989-1990	10.3	8.9	6.8
1990-1991	8.7	6.5	4.7
1991-1992	18.3	13.2	7.8
1992-1993	19.7	14.4	9.9
1993-1994	7.2	4.6	2.6
1994-1995	33.5	26.1	16.4
1995-1996	23.1	22.0	14.7
1996-1997	13.2	8.0	6.0
1997-1998	34.5	24.8	18.4
1998-1999	5.7	5.5	4.1
1999-2000	17.6	13.1	5.8
2000-2001	4.1	3.9	1.7
2001-2002	12.3	8.5	4.2
2002-2003	27.4	19.6	11.8
2003-2004	24.9	18.6	12.9
2004-2005	11.2	7.7	4.7
Average Annual	**15.4**	**11.5**	**8.0**

3.3 PME Tool Application to AFET Base Condition Results

Output obtained from the "With Project" base condition evaluation in the AFET was run through the PME Tool. The PME Tool is a set of utilities that was used sequentially to convert the model output into a desired "report card" for each alternative. These utilities were grouped by a "shell" using an Excel platform. (AECOM 2009b)

The main components of the PME Tool are:

- ***Data Extraction Utilities:*** Data extraction utilities were used to obtain relevant (user specified) information from the model result files. OKISS results for each evaluation location were obtained from .dss files generated by OASIS. The AFET outputs were extracted from MIKE 11 (.res11) and MIKE SHE (.dfs0 and .dfs2) result files.
- ***Excel Shell (Scoring Utility Tool)***. The Excel shell consists of an Excel spreadsheet with automated macros that call the calculation scripts and import their results into the spreadsheet environment. The macro also prints and/or produces the Alternative Report.

3.4 Water Surface Profiles

Figure 3-32 through Figure 3-35 present water surface profiles for the "With Project" base condition for various flows. These figures show the hydraulic gradient obtained in the Kissimmee River/C-38 Canal system.

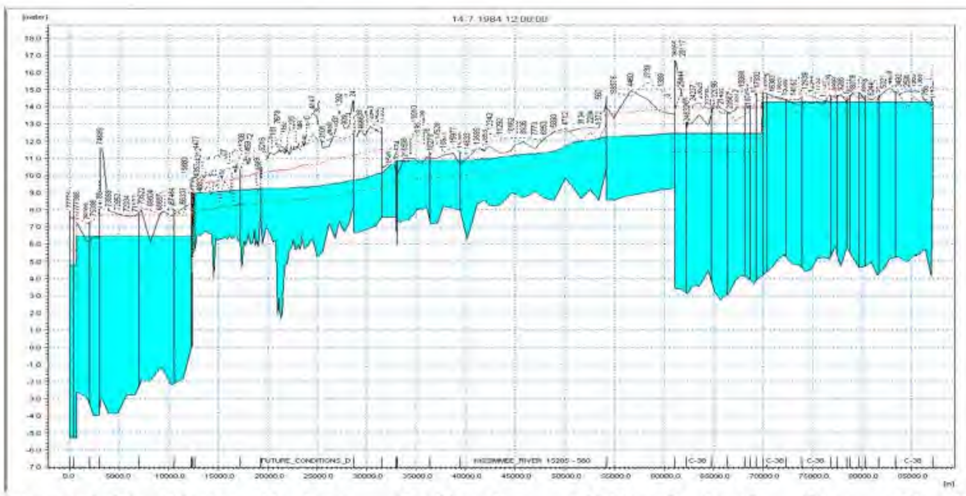

Figure 3-32: Water Surface Profile for "With Project" Base Condition at Approximately 1500 cfs

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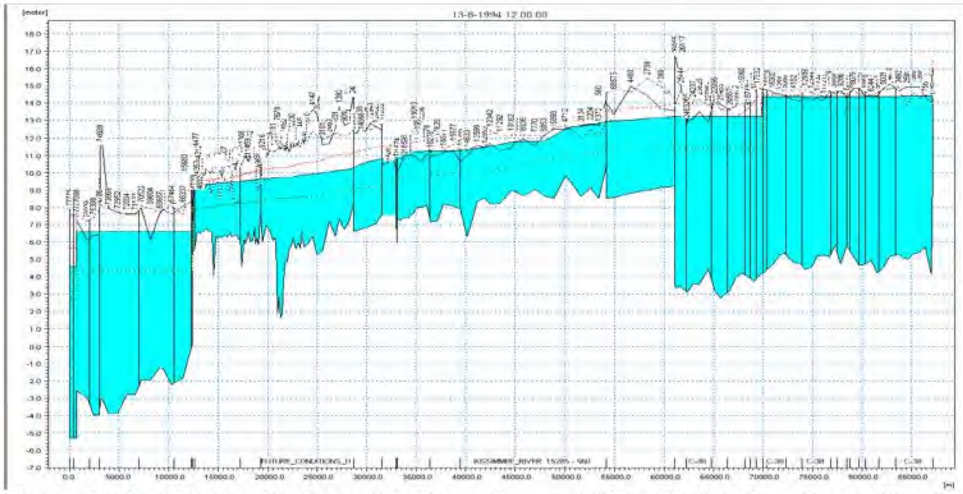

Figure 3-33: Water Surface Profile for "With Project" Base Condition at Approximately 3500 cfs

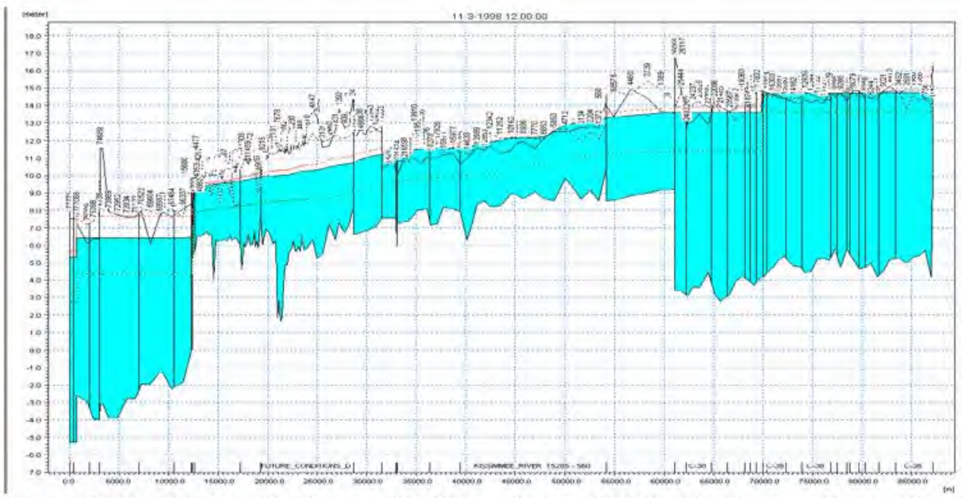

Figure 3-34: Water Surface Profile for "With Project" Base Condition at Approximately 6500 cfs

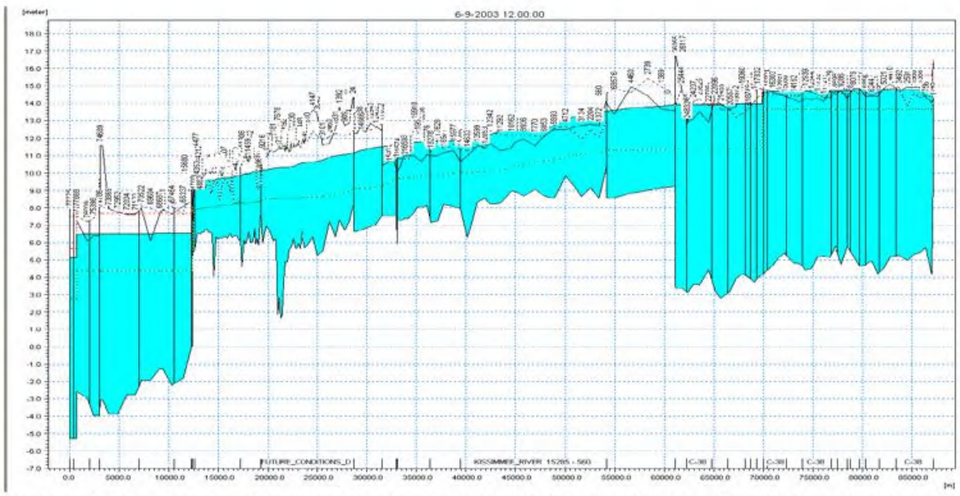

Figure 3-35: Water Surface Profile for "With Project" Base Condition at Approximately 9000 cfs

4 OKISS DEVELOPMENT

4.1 Development of the "With Project" Base OKISS Model

The "With Project" base OKISS model is described in this section. This model includes current regulation schedules in the KUB, with the exception of Lake Kissimmee. Operations at the S-65 Structure were replaced with the operating criteria proposed in the Headwaters Revitalization Project. This schedule separates environmental and flood releases.

In the LKB, the S-65C Structure was removed from the configuration used in the "history matching" procedure and documented in the OKISS Model Development and History Matching Report (AECOM 2009). Additionally, the LKB hydraulics were updated to reflect fully restored Pool B-C-D conditions, as simulated with the Kissimmee River Floodplain Hydraulic Model (MIKE 11) (Earth Tech | AECOM 2008b). Conveyance of the S-65D Structure channel and operations at the S-65D Structure were altered to adapt it to the draft operating criteria proposed for the S-65D Structure, as documented in Earth Tech 2007a.

4.2 Model Overview

OASIS by Hydrologics, Inc. was the computer program used to build the KBMOS Screening Tool (OKISS). OASIS with Operational Control Language™ (OCL) is a generalized program for modeling the operations of water resource systems. OASIS simulates the routing of water through a system represented by nodes and arcs. This routing accounts for both human control and physical constraints on the system.

OASIS contains both arcs and nodes. Arcs represent conveyance from one node to another, while a node represents a point of interest in the system. There are three node types:

- **Junction Nodes**: Junction nodes are not automatically associated with any special operating rules. These nodes are used to model a point in the system where inflow (or outflow) occurs, a point where there is a water-quality boundary condition, or a point where conveyance features (represented by arcs) meet.
- **Reservoir Nodes**: Reservoir nodes are nodes at which water can be stored. OASIS computes the storage at the end of every time-step, which then becomes the storage at the beginning of the next time-step.
- **Demand Nodes**: Demand nodes are nodes to which water is delivered.

With the exception of the terminal node (a junction node), all nodes in the OKISS model are reservoir nodes. In some cases a single reservoir node is used to denote a group of lakes or a reach of the Kissimmee River. Note that OASIS does not differentiate between "reservoirs" and "lakes". Reservoir nodes are used for anything that can store water. Nodes are connected by water conveying arcs. Arcs cannot store water.

Unlike other reservoir management models that simultaneously solve a series of equations imposed by flow continuity and operational rules to find a solution, which includes the flow through each arc, OASIS simulates decisions about routing water by solving a linear program (LP). The LP contains linear equality and inequality relationships between the **decision** variables of the system. The decision variables are the average flow of the time-step in each system arc and the end-of-period storage for the time-step in each system reservoir node. The modeler can define new decision variables that are linear expressions of flow and storage. By solving the LP each time-step, OASIS obtains a simultaneous solution of all decision variables.

The LP contains two types of rules, including operating goals (also referred to as operating objectives in this report) and operating constraints. Operating constraints are rules that cannot be violated (i.e. conservation of mass). Operating goals are rules that OASIS attempts to satisfy. Operating goals are, however, in competition with each other by their very nature. Therefore, a specific operating goal may not be satisfied due to constraints or conflict with other goals. Goals and constraints are expressed as linear relationships between decision variables.

When solving the LP, OASIS always finds a system operation that maximizes the number of "points," although in some cases there may be more than one such solution. For determining "points," each operating goal is assigned a **weight or a priority**. The weight associated with an operating goal is expressed as the number of points per unit (in most cases acre-feet) of water that OASIS gets for satisfying that goal. To maximize the number of points earned, OASIS routes water to satisfy goals with higher weight in preference over goals with lower weight. The word **"penalty"** simply denotes a weight of negative value. While the units of the terms in a target do not have to be the same, by converting everything to acre-feet the penalties can be directly compared.

At each time-step, OASIS re-evaluates the goals and constraints before solving the LP. Prior to a solution, all decision variables are treated as unknowns. Goals and constraints can only be expressed as linear relationships between the unknown decision variables. In other words, it is not possible to simulate a non-linear relationship between decision variables such as storage in a lake and flow through a structure. If there is a non-linear relationship that must be simulated, it is often possible to approximate the relationship with a piecewise linear approximation. When using piecewise linear approximations, OASIS automatically ensures that the segments of the function enter in the correct order. This is accomplished by automatically defining the necessary integer variables and additional constraints.

It is important to clarify that the LP solver does not optimize operating criteria for the long term. The solver is used on a daily basis to best meet the operating criteria on that day. It generates a solution that meets all constraints for the day and provides the highest number of "points" using the operating criteria specified by the user. The weights that generate the points usually indicate which use, flow, or storage is more important on that day, or that storage or shortages should be balanced to the extent possible on that day. The user must specify the operation criteria used by the solver for day-to-day optimization. It is the operating criteria that determine the long term performance of the system and the values of the performance measures. OASIS does not optimize the operating criteria and is therefore a simulation, rather that an optimization model. To obtain more detail information about OASIS, the reader is to refer to the OASIS User Manual (Hydrologics Inc. 2006).

Operations in the screening tool model are directed by weights on operating objectives or goals. The weights are generally hierarchical, because if OASIS must decide between two goals (such as to store water or release it downstream), it will choose the goal with the higher weight. The weights assigned to each operating goal will depend entirely on the operating criteria being analyzed. An analogy to a decision-tree type of management model (which is based on IF-THEN-ELSE statements) would be that the weights in OASIS let the program know the order in which the decision-tree branches will be evaluated or which condition is going to be checked (or satisfied) first. An equivalent function in the MIKE 11 operating criteria model would be the priority of the logical operands.

OKISS uses weights and targets to specify the physical conditions and operations in the Kissimmee Basin. For example, a target aimed at having a lake follow a regulation schedule will cause OKISS to release the amount of water necessary to bring the stage back to its schedule (subject to other constraints and targets with higher weights in the model). OKISS includes high penalties if the flow exceeds the maximum flow (the flow that would occur at the maximum allowable gate opening (MAGO)). Therefore, the releases made each day in OKISS will be less than the flow through the structure when the gates are at their maximum allowable opening. While OKISS does not specify a gate opening, the gate opening which yields the simulated flow is within the range of allowable openings. In practice, operators choose appropriate gate openings to bring the stage down to the regulation schedule. OKISS calculates necessary flows to do the same.

OASIS uses its LP solver to route water through the system based on the specified operations. It is not used to optimize the rule itself. Simulated operations are known before their implementation in the model, thus the operating rules do not need to be extracted from model results. The ease with which the operations can be implemented in practice is a function of the rule itself, not its OASIS implementation. Rules can be implemented in OASIS with or without results from MIKE SHE/MIKE 11.

When using an LP solver it is possible to have alternate optima, or multiple solutions, for water routing in a single day that provide equal objective function values. Weights are staggered in OKISS in order to avoid this.

Figure 4-1 shows the nodes used to represent the "With Project" base condition in OKISS. The red triangles represent each lake management area (LMA) in the KUB and pools in the Kissimmee River. For Pool B-C-D, two nodes are used (179, 180) as explained in Section 4.3.6.2. A yellow trapezoid was used for Node 179 to distinguish it from other nodes. In essence, this node serves as storage within that reach of the Kissimmee River. Both the red triangles and yellow trapezoid are standard OASIS reservoir nodes. The arcs are the lines between the nodes. The black lines show one-way arcs, while the orange lines show canals (C-36, C-37) that allow two-way flow. The purple arrows mark locations where lateral inflows (runoff and tributary inflow) enter the model.

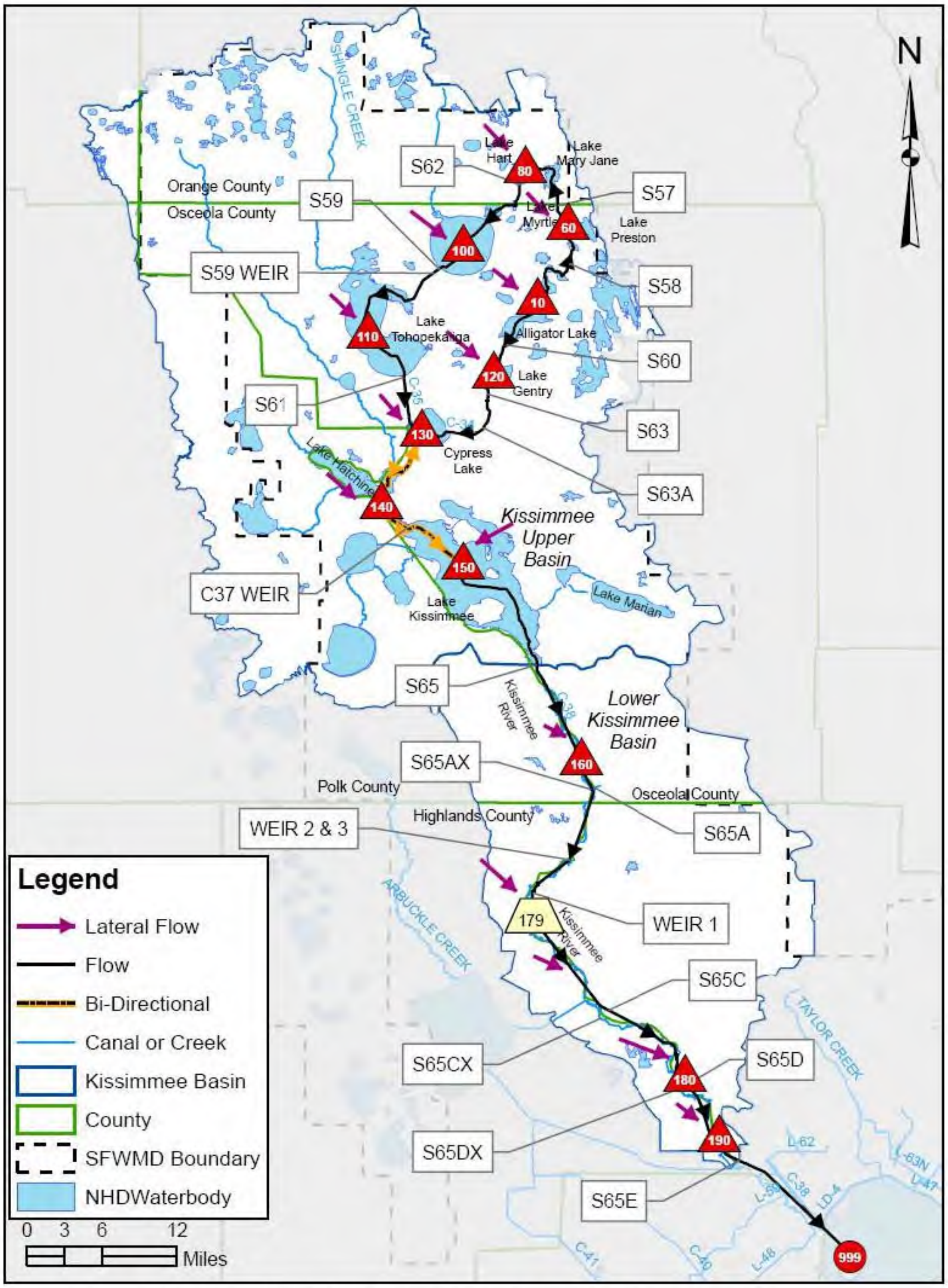

Figure 4-1: Schematics Used for the "With Project" Base OKISS Model

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Performance measures are evaluated for each LMA in the KUB (Node 010 to 150) as well as flow through the S-65 and S-65E Structures (Arcs 150.160 and 190.999). Stages at Cross-sections 5 and 9, located within Pool B-C-D, are calculated from S-65A Structure releases (Arc 160.179) and lateral inflows to Pool B-C-D.

The OKISS model description that follows includes references to the locations of the code that implement various model components. The code is found within OCL files. A list of OCL files is given below along with a brief description. The reader is referred to the OKISS Model Development and History Matching Report (AECOM 2009) and the OASIS Users Manual (Hydrologics 2006) for a description of the use of OCL files in an OASIS model.

_main.ocl. Lists the databases and other OCL files used by the model.

Inflow_wpb.ocl. Assigns time series of lateral inflows derived from the AFET-W to the appropriate OKISS nodes.

O_KCOL_wpb.ocl. Lists the OCL files that specify operations and hydraulics in the KCOL.

Evap.ocl. Sets evaporation to zero, since evaporative losses are included in the lateral inflow time series.

EOP_El_Est.ocl. Specifies equations for the end-of-period elevations in the KUB lakes. These elevations are used to determine the MAGO for the day in *Capacites.ocl.*

CanalFlows_WPB.ocl. Calculates flow within the C-36 and C-37 Canals.

S-65_WPB.ocl. Specifies operations at the S-65 Structure. In the "With Project" base run, the headwaters revitalization schedule is coded here.

Capacities.ocl. Maximum allowable flows are calculated here based on the MAGO. Two other OCL files are also used in these calculations, including *DISCH_Spillway.ocl and DISCH_Culvert.ocl.*

RegSchedule_WPB.ocl. Regulation schedules for the KUB lakes are assigned here.

Set_MPHD.ocl. Maximum permissible head difference (MPHD) for structure stability are set here for the KUB.

Structure_Seepage.ocl. Leakage through the KUB structures is calculated here, as described in Section 4.1.5 below.

LKB_evap_WPB.ocl. Estimates of surface area in the LKB pools is done here (note that evaporation in the pools is set to zero in *evap.ocl*)

Est_LKB_Flows_WPB.ocl. Estimates of flow in the LKB are made here. The estimates are used in the LKB hydraulic calculations.

LKB_Ops_WPB.ocl. Operations of the LKB structures (target stages) are provided here.

LKB_Hydraulics_WPB.ocl Hydraulic equations in the LKB are specified here (see Section 4.1.1.3 below).

Solve.ocl. To model C-36 and C-37 Canal flows accurately while limiting runtime, multiple solves of the same time-step are needed on occasion. This OCL file sets up those multiple solves.

LKB_*PoolBCD_Stages_WPB.ocl.* After each time-step, the resulting flows in Pool B-C-D are used to calculate stages at PC-33, PC-52, Cross-section 5 and Cross-section 9. These calculations are done here.

4.3 Configuration of the "With Project" Base OKISS Model (OCL)

There are 78 terms in the screening tool objective function for the "With Project" base run. Each term in the objective function is shown below. "TARGET" describes the name of the objective function component. "CONDITION" describes the events that must occur for that target to be used in the objective function. "Default" means the target is written for every time-step. "Penalty" describes the weight that the target has in the objective function. Penalties are negative weights, e.g. a penalty of 5000 means that the term goes into the objective function with a coefficient of -5000. The reader is directed to the OASIS User's Manual (Hydrologics 2006) for a more detailed description of these terms.

4.3.1 Physical Flow Equations

The very highest weights (50,000 to 80,000 points) are used to ensure that the model follows the physical flow equations. Because these weights are higher than all others, the physical flow equations will always be followed. Note that the LKB hydraulics equations developed from the HW - TW - Storage-Flow relationships simulated in MIKE 11 runs are entered as constraints.

The highest weights are set to ensure that the MPHD is respected at all structures. The MPHD values for each structure are given in Table 4-1.

Table 4-1: MPHD

Structure	MPHD (feet)	Source
S-57	2.2	Water Control Manual, Kissimmee River and Lake Istokpoga. USACE August 1994
S-58	4.0	from "Stability Info Sheet 1.doc" provided by A. Stuart
S-59	8.0	Water Control Manual, Kissimmee River and Lake Istokpoga. USACE August 1994
S-60	7.0	from Water Control Manual, confirmed in "Stability Info Sheet 1.doc"
S-62	7.2	Water Control Manual, Kissimmee River and Lake Istokpoga. USACE August 1994
S-63*	11	Water Control Manual, Kissimmee River and Lake Istokpoga. USACE August 1994
S-61	-	no MPHD
S-65	10	Water Control Manual, Kissimmee River and Lake Istokpoga. USACE August 1994

*: Since the S-63A Structure is not modeled in OKISS, the head difference evaluated at the S-63 Structure also includes the MPHD for the S-63A Structure.

A penalty of 80,000 is set to ensure that the head difference never exceeds the maximum permissible value. Additionally, a penalty of 70,000 is set to prevent the head difference from coming within 0.5 feet of the MPHD. The structure release is set to its maximum value when the head difference is within 0.5 feet by assigning a penalty for flow below the maximum release.

TARGET	CONDITION	Penalty-	Penalty+
MPHD_59_1	default	0	80000
MPHD_59_2	default	70000	0
MPHD_60_1	default	0	80000
MPHD_60_2	default	70000	0
MPHD_62_1	default	0	80000
MPHD_62_2	default	70000	0
MPHD_63_1	default	0	80000
MPHD_63_2	default	70000	0
MPHD_57_1	default	0	80000
MPHD_57_2	default	70000	0
MPHD_58_1	default	0	80000
MPHD_58_2	default	70000	0
MPHD_65_1	default	0	80000
MPHD_65_2	default	70000	0

A penalty applied to the difference between flow and average of the beginning of period and estimated end of period instantaneous flows for the C-36 and C-37 Canals. These are physical constraints and therefore, the penalties are very high.

TARGET	CONDITION	Penalty-	Penalty+
C36Flow	default	60000	60000
C37Flow	default	60000	60000

There is a difference between structure flow and structure capacity for the listed structures when it is greater than the maximum. For spillways, maximum gate openings were calculated using the equations used by the SFWMD's Upper Kissimmee Lakes Model (UKISS), which were derived by the SFWMD from the USACE MAGO Charts, included in the Kissimmee Basin Water Control Plan. The flows corresponding to these gate openings were then calculated using the flow equations proposed in "Dimensionless Flow Ratings at Kissimmee River Gated Spillways" by Matahel Ansar, Zhiming Chen, Juan A. Gonzalez and M.J. Chen (Technical Publication, SHDM REPORT, December 2005, SFWMD). For culverts, to ensure that screening tool flows through the S-57 and S-58 Structures match the theoretical hydraulic capacity, the equations from the original UKISS configuration were used. Note that maximum flows (constraints) are also in effect at these structures (S-57 Structure max flow = 230 cfs and S-58 Structure max flow = 110 cfs). These are all physical constraints and therefore, the penalty+ is set very high.

The penalty - of 20 points on flow through the S-60 Structure directs the model to release excess Alligator Lake water through the S-60 Structure instead of through the S-58 Structure. This weight does not cause the model to release Alligator Lake water from below schedule, because the 1500 points for Alligator Lake water are greater than the 20 points for flow through the S-60 Structure.

TARGET	CONDITION	Penalty-	Penalty+
Qmax_S59	default	0	50000
Qmax_S60	default	20	50000
Qmax_S61	default	0	50000
Qmax_S62	default	0	50000
Qmax_S63	default	0	50000
Qmax_S-65	default	0	50000
Qmax_S57	default	0	50000
Qmax_S58	default	0	50000
MaxFlow_targ_160.179	default	0	50000
MaxFlow_targ_180.190	default	0	50000
MaxFlow_targ_190.999	default	0	50000

A penalty is applied to differences between flow and target flow in Pool B-C-D. Section 4.1.4.2 explains how the flow within Pool B-C-D is calculated. The actual flow between the nodes is set to this calculated flow using a target with a very high penalty.

TARGET	CONDITION	Penalty-	Penalty+
PoolC_reach_outflow	default	60000	60000

There is a difference between the head (HW – TW) on LKB structures and the maximum allowable head for structural stability when the head is greater than the maximum. Note that while still large, these weights are multiplied by a stage difference rather than a volume, so their value in the objective function is lower than weights multiplied by volumes. Also note that TW at the S-65E Structure is not currently modeled in the screening tool, so while the target on structural stability is included in the model for potential future use, the weight is currently set to zero.

TARGET	CONDITION	Penalty-	Penalty+
Struct_targ1_160	default	0	60000
Struct_targ1_180	default	0	60000
Struct_targ1_190	default	0	0

4.3.2 Structure Leakage/Seepage

During their calibration, the hydraulic models (AFET and AFET-W) include leakage/seepage through the structures as culvert flow equations calibrated to field data across the structures. Versions of the screening tool prior to 2009 did not include these leakage/seepage flows. The leakage/seepage flow equations added to OKISS are found in *Structure_Seepage.ocl*. Leakage/seepage in OKISS is simulated using the same surrogates used by the AFET-W (flow governed by a culvert equation where discharge is a function of the head differential). Culvert equations with the same parameters as those used in the AFET-W are entered here. Large penalties are applied to ensure that flows through the structures are at least as high as the seepage value.

TARGET	CONDITION	Penalty-	Penalty+
Culvert_Leak_S59	default	55000	0
Culvert_Leak_S60	default	55000	0
Culvert_Leak_S61	default	55000	0
Culvert_Leak_S62	default	55000	0
Culvert_Leak_S63	default	55000	0
Culvert_Leak_S-65	default	55000	0
Culvert_Leak_S57	default	55000	0
Culvert_Leak_S58	default	55000	0

4.3.3 Flood Control in the KUB

Flood control releases are made whenever the stage in a lake exceeds its regulation schedule. In the KUB, the interim regulation schedules are followed. These are given in the OCL patterns "*name of lake*_full."

The interim regulation schedules also show an alternate regulation schedule to be followed occasionally. These have not been included in the "With Project" base run. The same regulation schedule is followed every year.

After the physical flow equations, the next highest weights (16,000-1,850 points) are used to simulate a portion of the current flood control operations in which stages are brought back down to the regulation schedule over 15 days once the stage is within 0.5 feet of the regulation schedule. This is referred to as "soft landing" operations.

A penalty is applied to the difference between the soft landing flood control release target and the actual release for the respective lakes. Weights decrease in the downstream direction to provide guidance to the screening tool in the event that not all of the target flows can be met in the same time-step. There are two targets for Alligator Lake, one for each structure.

TARGET	CONDITION	Penalty-	Penalty+
Flood_rel_Myrtle	#1	16000	16000
	#2	0	0
Flood_rel_Hart	#1	15000	15000
	#2	0	0
Flood_rel_East_Toho	#1	14000	14000
	#2	0	0
Flood_rel_Toho	#1	13000	13000
	#2	0	0
Flood_rel_Gentry	#1	12000	12000
	#2	0	0
Flood_rel_Kiss	#1	1850	1850
	#2	0	0
Flood_rel_Alligator1	#1	16500	16500
	#2	0	0
Flood_rel_Alligator2	#1	17000	17000
	#2	0	0

In reality, operators use forecasts of inflows to determine this release. Because such forecasts are not currently available in the screening tool, the average inflow for the month was used. For modeling purposes, the soft landing release for a given day is calculated as the sum of the volume of water above the regulation schedule on the previous day and the projected inflow for the next 15 days divided by 15, plus the calculated release for that day from the upstream lake.

$$\frac{\text{(Water above Reg Schedule)} + \text{(15 Day Projected Inflow)}}{15} + \text{(Upstream Calculated Release)}$$

These calculations can be found in *RegSchedule_WPB.ocl*. OASIS handles monthly inflow in acre-feet (a volume) differently than cfs (a rate). Specifically, monthly values of volume are divided by the number of days in the month, while flow rates are unaltered. In the current base condition run, the lateral inflows are in acre-feet, so the monthly inflow time series is multiplied by 31 (approximate number of days in the month). In the future base condition run, the lateral inflows were given in cfs, so there is no need to multiply the monthly time series by 31. Both could be converted to the same units, but this would not prevent future problems if new lateral inflow time series' are used. Instead, a prominent (all caps) comment was included in *RegSchedule_WPB.ocl*.

The aforementioned soft landing targets are only in effect for a particular lake when the stage is between the regulation schedule and 0.5 feet above the regulation schedule. The target is also not in effect during scheduled draw-downs. This is the only conditional target in the "With Project" base run of the screening tool, meaning it is in effect during some time-steps and not others. This can be seen in the target summary above as Condition #1 (target is in effect) and Condition #2 (no penalties is equivalent to no target).

The next highest weights are the penalties for storing water above the lake regulation schedules (7000-200 points) in the KUB. The model releases as much water as it can from above the schedules to avoid these penalties.

There is a difference between lake storage and storage at lake regulation schedule for the respective lakes when it is greater than the maximum. Weights decrease in the downstream direction so that storage above the rule in the uppermost lake is voided preferentially.

TARGET	CONDITION	Penalty-	Penalty+
reg_sched_Alligator	default	0	7000
reg_sched_Myrtle	default	0	6000
reg_sched_Hart	default	0	5000
reg_sched_East_Toho	default	0	4000
reg_sched_Toho	default	0	3000
reg_sched_Gentry	default	0	2000

The penalties for storing water above schedule are highest for the most upstream lakes and decrease as one goes downstream. Because the weights for being above schedule decrease in the downstream direction, upstream lakes will release water (up to structure capacity), even if this will cause downstream lakes to rise above schedule. If it were otherwise, the screening tool might choose not to release excess water from Alligator Lake because it might mean incurring a higher penalty at a downstream lake such as Lake Cypress. Because Alligator Lake has the highest penalty, the penalties on downstream lakes do not prevent releasing excess water from Alligator Lake (and the same is true for every upstream lake).

The net effect of these targets and the soft landing targets described above is that during floods, the maximum allowable flow will be released until the stage falls within 0.5 feet of the regulation schedule, at which time "soft landing" releases will be made.

4.3.4 Storing Water in the KUB

Only one screening tool zone (referring to OASIS zoning that is different from the regulation schedule operating rule zones) is defined. Thus, the simulated volume of storage in each of the lakes is multiplied by the corresponding coefficient from the table below. The rationale for the ordering of the weights is to keep water in the volume below the regulation schedule as high as possible in the system, thus preventing downstream lakes from pulling water out of upstream lakes. This is consistent with the UKISS and the hydraulic model.

The lower lakes are balanced by the canal flow targets, which have very high penalties for + and -. The weight order for the lower lakes is reversed for computational efficiency (convexity in the larger portion of the piecewise linearization of the canal functions), but the solution is the same regardless of weight order for these three lakes. Solution times are two to three times faster with this weight order. The weights on the upper lakes are higher to avoid any chance that a small imbalance in the canal equations could draw water from the upper lakes.

NODE NUMBER	Wt: A-Zone
010	1500.00
060	1450.00
080	1400.00
100	1350.00
110	1300.00
120	1450.00
130	250.00
140	300.00
150	350.00

4.3.5 Releases from the S-65 Structure – (Headwaters Revitalization Schedule)

The next highest weight is given to making releases from the S-65 Structure based on the headwaters revitalization schedule.

TARGET	CONDITION	Penalty-	Penalty+
S-65_Headwaters_Release	default	700	700

A weight of 700 is given to matching target flows at the S-65 Structure. This weight is higher than the weights for storing water in Lakes Cypress, Hatchineha and Kissimmee and lower than the weight for storing water in all other KUB lakes. Water will therefore be taken from these three lakes only to satisfy the target releases of the S-65 Structure. The penalty for exceeding the scheduled release is sufficiently low so that flood control releases from all KUB lakes will be made if necessary (above the regulation schedule).

The headwaters revitalization schedule is described in the *s-65_WPB.ocl* and *RegSchedule_WPB.ocl*. This schedule is divided into six zones at different elevations. The repeating annual pattern, separating each of the zones, is given in the OCL pattern table under the name "Kiss_Zone[*letter*]_Bot." For example, "Kiss_ZoneC_Bot" separates Zone C from Zone B from January to July and Zone C from Zone D for the rest of the year. Note that the target flow specified by the headwaters revitalization schedule is given by the user-defined variable "S-65_Headwaters_Release." The penalty for deviating from the schedule is 700, which is low enough to prevent upstream lakes from making releases to meet the schedule at the S-65 Structure.

The headwaters revitalization schedule was not entirely clear on making Zone A flood releases, so details on how those releases should be made were decided in conjunction with operators at the November 27, 2007 KBMOS Pre-CAP Meeting at the SFWMD. Specifically, it was decided that the zones for flood releases should be horizontal all year, rather than parallel to the regulation schedule. This is summarized in Table 4-2. When the stage is above its regulation schedule and within the stage range shown, the specified release is made. With this approach, up to 11,000 cfs will always be released when the stage is over 54 feet.

Table 4-2: Flood Control (Zone A) Releases from the S-65 Structure, "With Project" Base Run

Stage Range (feet)	Release (cfs)
52.5 – 53	Gradual transition from 3,000 to 4,000
53 – 53.5	Gradual transition from 4,000 to 6,000
53.5 – 54	Gradual transition from 6,000 to 11,000
> 54	11,000

A transition for times of the year when the releases change from 3,000 to 11,000 cfs at 54 feet is needed to avoid oscillations, as suggested by the operators at the November 27, 2007 meeting. A target was created (Target "ZoneA_Transition" in *s-65_WPB.ocl*) to ensure that flood control releases do not change by more than a specified value from day to day. The chosen maximum daily range was 3,000 cfs. In practice, this target rarely comes into play, because the maximum allowable flows dictated by the head difference at the S-65 Structure rarely allow for 11,000 cfs to be discharged. This target was given a penalty of 7,000, which is greater than the headwaters revitalization schedule target penalty of 700.

TARGET	CONDITION	Penalty-	Penalty+
ZoneA_Transition1	default	7000	0
ZoneA_Transition2	default	0	7000

In *RegSchedule_WPB.ocl*, the regulation schedule for Lake Kissimmee is set to the pattern "Kiss_ZoneA_Bot." Additionally, Lake Kissimmee is excluded from all flood release targets (the penalty for targets "reg_sched_Kiss" and "Flood_rel_Kiss" are set to zero). Flood releases for Lake Kissimmee are instead set in *s-65_WPB.ocl* as part of the headwaters revitalization schedule, as discussed above.

The LKB structures are operated to maintain a fixed or optimum HW stage, equal to the value simulated in the hydraulic model. The target stage at each structure is set with a single target statement. The penalties for deviating from these stages are low, relative to those in the KUB, to ensure that water is not pulled from the KUB to meet these goals. The stages are converted to volumes in the target statements, so these weights are comparable to those in the KUB.

The operating criteria for the S-65D Structure, included in the "With Project" base run, was expressed as a flow versus HW stage relationship. The Draft Operating Criteria for Modeling S-65D Future Conditions Memo (Earth Tech 2007a) describes these operating criteria in detail.

The current structure and hydraulic limitations will still be valid after the completion of the KRRP. According to the SFWMD Structure Book, these limitations are:

- *Structure Limitations: The maximum water level drop across the structure will be 8 feet.*
- *Hydraulic Limitations: To prevent damage from high velocity discharge, the gate opening will be limited in accordance with the MAGO curve.*

The target flow value at the S-65D Structure is set in *Est_LKB_Flow_WPB.ocl*. The set command was moved from *LKB_Ops_WPB.ocl* because the target value is needed to determine the maximum allowable flow through the S-65D Structure. This is not ideal, but a comment (in all caps) in *LKB_Ops_WPB.ocl* points the user to the proper location.

The target stage at the S-65D Structure is a function of flow through the S-65D Structure, as described above. To reduce the run time, an estimate of the flow, "Q_est_179.180", is used and is exactly equal to the actual flow at all time-steps in the "With Project" base run. The OCL lookup table used to set the target flow is "Targ_HW_180."

For consistency with the hydraulic model, the LKB stages are permitted to deviate from the target stage by up to 2 feet above or 1 foot below. Each structure therefore, has three targets guiding its operation. A relatively small number of points (6 - 100) are lost for deviating at all from the target stage and then more points (1200 - 5500) are lost for exceeding the permitted envelope of stages.

The target statements can be found in *LKB_ops_ WPB.ocl.*

TARGET	CONDITION	Penalty-	Penalty+
Targ_HW_Ops160	default	9	9
Targ_HW_Ops160	default	0	5500
Targ_HW_Ops160	default	5500	0
Targ_HW_Ops180	default	100	100
Targ_HW_Ops180	default	0	2000
Targ_HW_Ops180	default	2000	0
Targ_HW_Ops190	default	6	6
Targ_HW_Ops190	default	0	1200
Targ_HW_Ops190	default	1200	0

Very small negative weights are added to storage in the LKB to reduce run time.

NODE NUMBER	Wt: A-Zone
160	-0.01
169	-0.01
170	-0.01
180	-0.01
190	-0.01

4.3.6 Configuration of OKISS to Model Lower Basin Hydraulics

4.3.6.1 Pool A and Pool E

Pools A and E in the LKB are modeled as tilted pools.

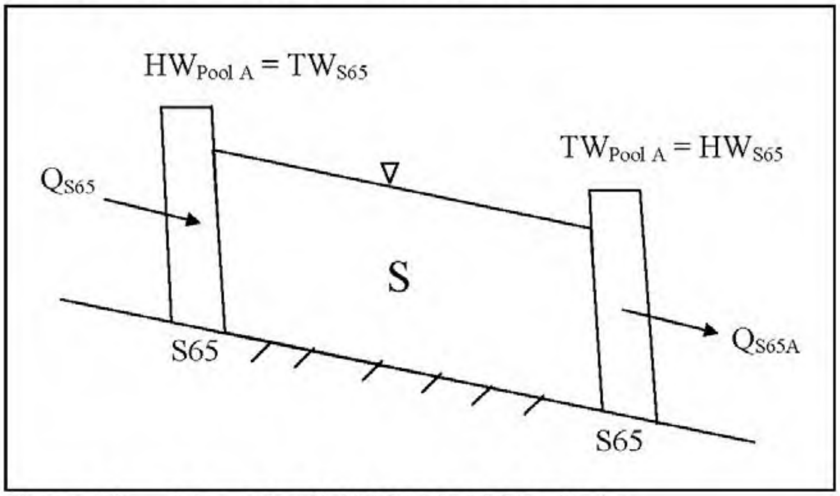

Figure 4-2: Schematic of MIKE 11 Model for Pool A

Hydraulics in the LKB were developed using the results of MIKE 11 model runs. Three different MIKE 11 models were created, including one for Pool A, one for Pool B-C-D and one for Pool E. A schematic of the Pool A model is shown in Figure 4-2. The model was run for various flows ($Q_{S\text{-}65}$) to steady state. Model output of flow ($Q_{S\text{-}65}$), pool storage (S), pool HW ($HW_{Pool\ A}$) and pool TW ($TW_{Pool\ A}$) was used to develop regression equations relating these four variables. These equations are found in "*LKB_hydraulics_WPB.ocl*" and are described below. Note that Pool B-C-D's bathymetry is significantly different than that of the other pools and is therefore treated separately.

MIKE 11 model results for Pool A are shown in Figure 4-3. Storage in Pool A is a function of HW at the S-65A Structure and flow into Pool A (S-65 Structure release). Because storage is a weak function of flow (274 acre-feet difference between 100 cfs and 8250 cfs), an estimate of flow is used instead of the actual flow. This simplification removes one decision variable from the calculation. Storage (decision variable) is set equal to a function of HW at the S-65A Structure (decision variable) using a constraint command.

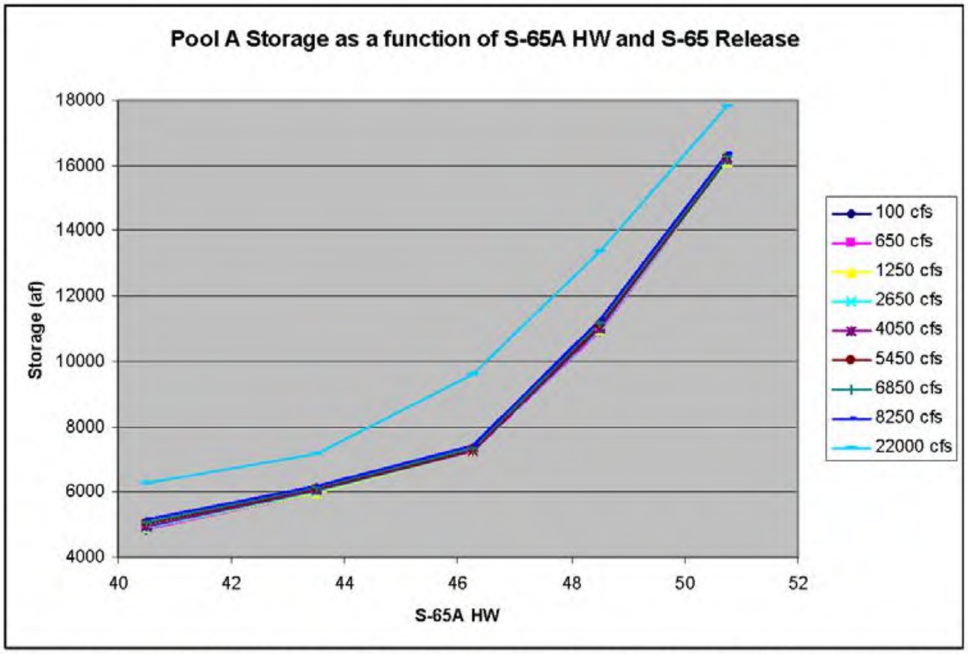

Figure 4-3: MIKE 11 Model Results Showing the Relationship Between S-65A Structure HW, S-65 Structure Release and Pool A Storage.

MIKE 11 model results are also used to calculate the TW at the upstream structure (the S-65 Structure in the case of Pool A). The results for Pool A are shown in Figure 4-4. Unlike the storage calculation, there are three decision variables in this case, including TW at the S-65 Structure, HW at the S-65A Structure and releases at the S-65 Structure, so the linearization process is more complex.

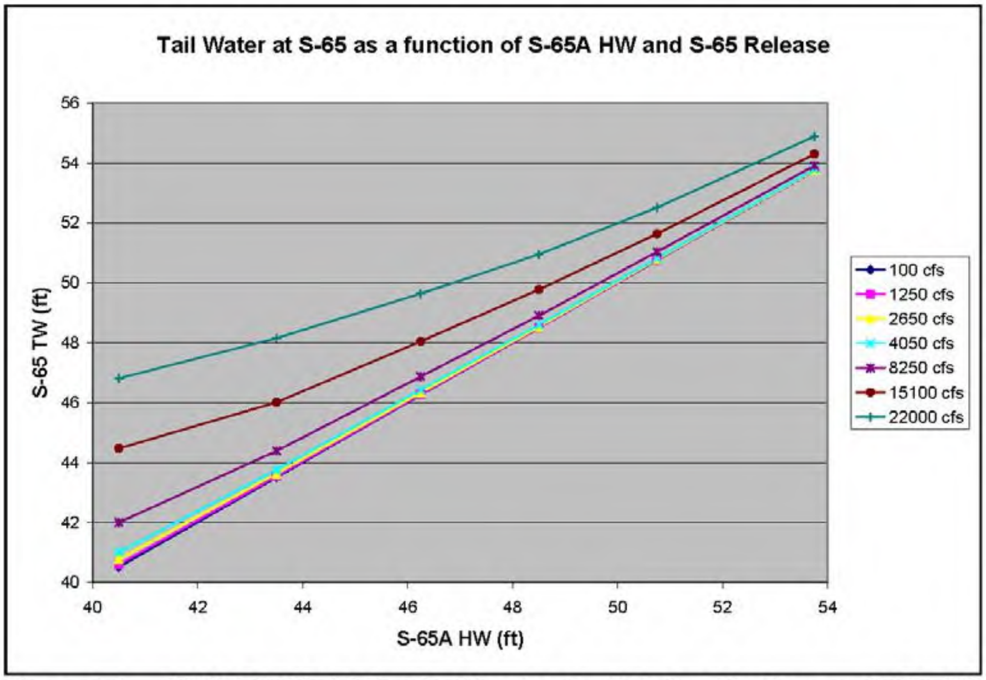

Figure 4-4: MIKE 11 Model Results Showing the Relationship Between S-65A HW, S-65 Release and S-65 TW.

The HW-TW relationship is linear, with the slope and intercept of the line varying with flow. Figure 4-5 shows stage HW-TW-flow curves for a generic pool. Say that the solution on a hypothetical day is given by the red circle in Figure 4-5. To specify that point, start at the lowest data point in the bottom left, which is data point for the lowest HW, TW and flow. A function, f_1 was developed to account for the actual flow on the day in question. However, as seen in Figure 4-5, f_1 overshoots the solution because the slope of the lowest flow line is less steep than the actual flow line (red dashed line).

AECOM

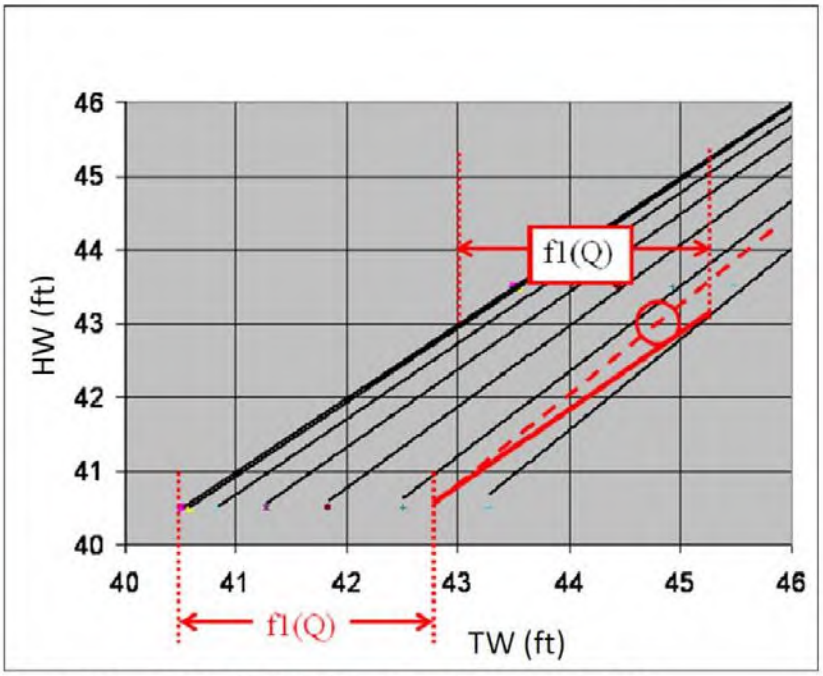

Figure 4-5: Stage HW-TW-Q curves for a generic pool

Therefore, a second function, f2, is needed to correct for this difference in slope. Figure 4-6 and Figure 4-7 show the development of that function based on the geometry of the dashed red (HW-TW relationship at actual flow) and solid red (HW-TW relationship at lowest flow) lines in Figure 4-5.

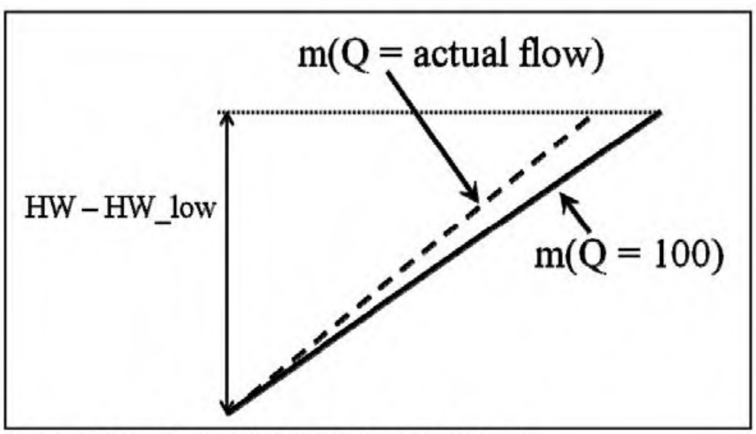

Figure 4-6: Geometry used in calculating f_2

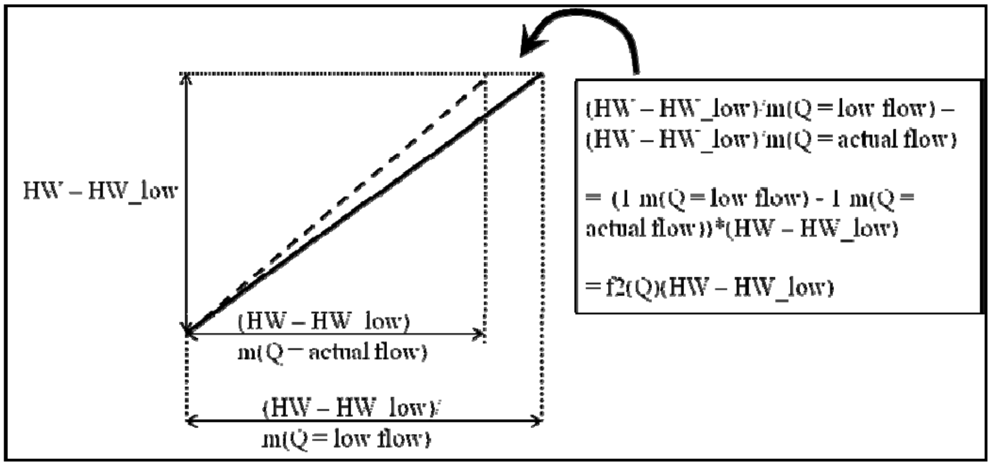

Figure 4-7: Calculation of f_2

The resulting equation for TW is:

TW_upstream_node = HW + f_1(Q) - f_2(Q)(HW - HW_low) ....Equation 1

Where f_1(Q) represents the effect of flow on TW (under the assumed conditions HW = low historic) and is calculated as the difference between TW at Q = low flow cfs and Q = the actual flow at the lowest HW on historic record (given in *l_basin_substitutes.ocl*):

$$f_1(Q) = TW_{actual} - TW_{low}$$

Where TW_{actual} = TW from table when HW = HW_low and Q = actual Q and
TW_{low} = TW from table when HW = HW_low and Q = low Q

f_2(Q) then accounts for the fact that the HW may be different than HW_low. The f_1(Q) correction will overshoot the data for other HWs. This function is the difference of the slopes (m) of the HW-TW line for Q = low flow and for Q = the actual flow:

$$f_2(Q) = 1/m_{\text{(for Q = low flow)}} - 1/m_{\text{(for Q = actual flow)}}$$

where:

$$m = (TW2 - TW1)/(HW2 - HW1).$$

The last term in Equation 1 (f_2(Q)(HW - HW_low)) is nonlinear with respect to f_2(Q) and HW. In OKISS, this term is approximated as the sum of two linear terms by using the beginning of period (t) HW and the flow estimated for that pool as follows:

$$f_2(Q)(HW_{t+1} - HW\_low) = f_2(Q)(HW_t - HW\_low) + f_2(Q\_est)(HW_{t+1} - HW_t)$$

This equation provides a close approximation, since the pools are operated to maintain a constant and any error that does occur from a change in HW is corrected for in the final term. To approximate the data closely, f_1 and f_2 were carefully segmented. The ability of these equations to approximate the data was assessed by comparing model results to three-dimensional non-linear regression equations fit to the data. This exercise, included in Appendix B of the report that was prepared to document a preliminary version of OKISS (Earth Tech 2006a), shows the average of the absolute value of the difference between the calculated (regression equation) and simulated HW to be 0.3, 0.2, 0 and 0.2 feet for each structure respectively. The difference for all of the pools is always less than 0.5 feet, with the exception of seven occurrences, at times when the flow into the node was less than the storage.

4.3.6.2 Pool B-C-D

Pool B-C-D has a very different functional relationship from the other pools and therefore, is treated separately. The restored Pool B-C-D does not have a large conveyance element like the C-38 Canal. The thalweg of the restored river is at least 10 feet higher than the invert elevation of the C-38 Canal and the conveyance of the restored river is less than the conveyance of the C-38 Canal. As a result, the hydraulic gradient of the restored Pool B-C-D is much steeper than that of the other pools. The stages are therefore more dependent on the hydraulic conditions in the river, which are controlled by the flow. Therefore, variables like storage volume and HW stage are also more dependent on flow values and storage in the restored Pool B-C-D, increasing dramatically with flow.

At the same time, flow is independent of HW in the restored Pool B-C-D, within the historic range of HW, TW and flows. In fact, the HW would have to exceed the maximum for structural stability before the pool would extend to the upstream structure (S-65A), causing HW to affect flow. Instead, flow is simply a function of TW at the upstream structure.

For its application in OKISS, this function was linearized in segments (or piecewise linearized), based on the data in Appendix D. The flow is segmented at increments to closely approximate the data.

During the development of OKISS, it became evident that Pool B-C-D did not reach steady-state conditions in a single day. Hence, the direct use of the MIKE 11 results, which assumed steady-state conditions, was not possible for this pool. Instead, a function was needed that conserved mass, provided a time-lag between the arcflows into and out of Pool C comparable to that seen in the flow data and approached the steady-state solution over time. The inverse of the storage-flow function developed from the MIKE 11 results used with the storage from the *previous* time-step (Q(Stor(-1)) meets all these criteria. It provides the needed time lag and converges to the steady-state solution at times when the flow into floodplain storage is stable.

Figure 4-8 illustrates Pool B-C-D formulation in OKISS. Flow out of Node 179 is based on the previous day's storage in Node 179. Storage in Node 180 is held constant. This separate node is used simply to add a portion of Pool B-C-D's lateral inflows.

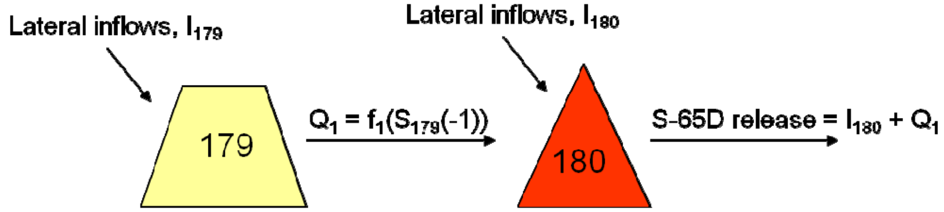

Figure 4-8: Pool B-C-D formulation in the OKISS model

The treatment of Pool B-C-D was adjusted based on the AFET-W simulation results to determine two things:

- The percentage of lateral inflow to Pool B-C-D partitioned between the two nodes
- The time lag between flows into the floodplain (flow160.179) and the flow between the nodes (flow179.180)

To select these parameters, S-65A Structure flows were set equal to the values from the AFET-W run and the resulting flows at the S-65D Structure were compared. Figure 4-9 shows the resulting best fit for the period between January 1, 1965 and January 1,1979 (R^2 = 0.9529 for the period of record).

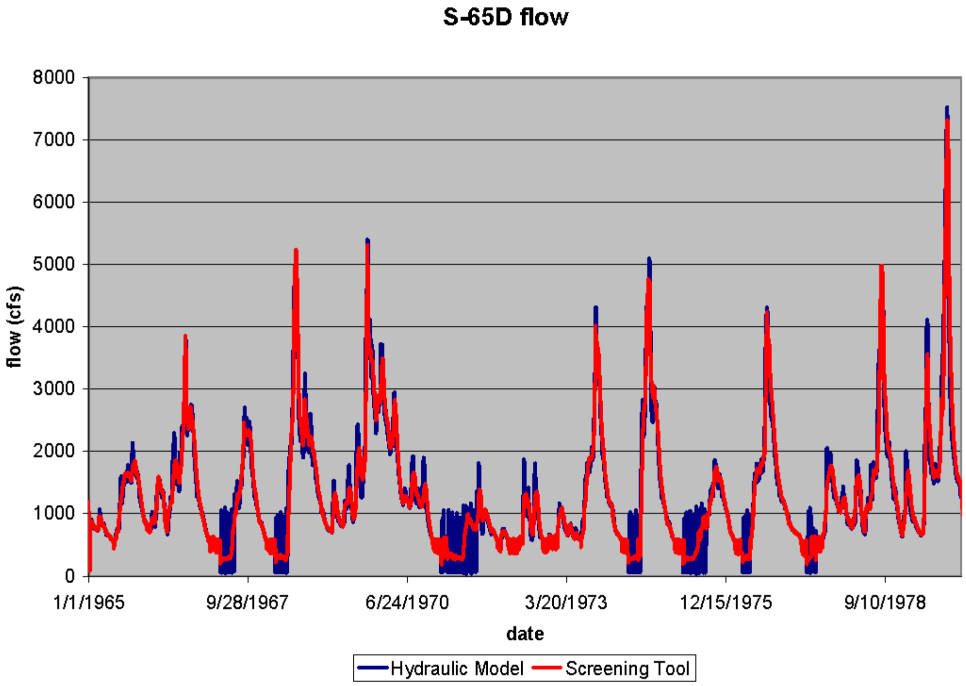

Figure 4-9: Flow at the S-65D Structure in the Hydraulic Model and Screening Tool Formulation with Fixed S-65A Structure Flows, "With Project" Base Run

The exercise showed the following:

- The R^2 values changed very little with changes to lateral inflow partitioning. A 65 percent to floodplain storage, 35 percent to structure storage partition was used in the "With Project" base run.
- A one-day time lag between flow into floodplain storage and flow out provided the best fit. R^2 values were 0.9529 for a one-day lag, 0.9487 for a two-day lag and 0.9435 for a three-day lag. Therefore, storage in the floodplain from the previous day was used as the independent variable when determining flow out of the floodplain.

Appendix D shows the release from the S-65D Structure in the "With Project" base condition and the AFET-W runs in three year increments. Qualitatively, the fit is close and in some cases, almost the same (e.g. November 1971 to July 1973). R^2 for the period of record is 0.93. The HW stage at the S-65D Structure is determined by the operating criteria for the S-65D Structure described in Section 3.1.1.4 and The Draft Operating Criteria for Modeling S-65D Future Conditions Memo (Earth Tech 2007a).

The TW stage at the S-65A Structure is primarily a function of flow through the S-65A Structure, developed from the MIKE 11 results. An adjustment is made at low flows (less than 1000 cfs) for which the HW at the S-65D Structure also influences the TW level at the S-65A Structure.

4.3.6.3 Stages at Interim Locations in Pool B-C-D

Since some of the evaluation performance measures require time series of intermediate locations in Pool B-C-D, MIKE 11 model results were also used to calculate stages at Cross-sections 5 and 9, evaluation locations of the river performance measures (see Figure 4-10). These calculations are done in *LKB_PoolBCD_Stages_WPB.ocl,* which is included *after* the LP is solved, meaning that the calculation of the stages at an interim location is done once the *arcflows* are calculated for each time-step. As a result, each day the flows and stages are determined throughout the basin, the flows at the S-65A Structure are used to calculate the stages at the interim locations. A best fit exercise with the AFET-W results showed that the flow at the S-65A Structure from the previous day was the most appropriate indicator of the stages at these locations. This flow is therefore used in the lookup tables Stage_XSect5 and Stage_XSect9.

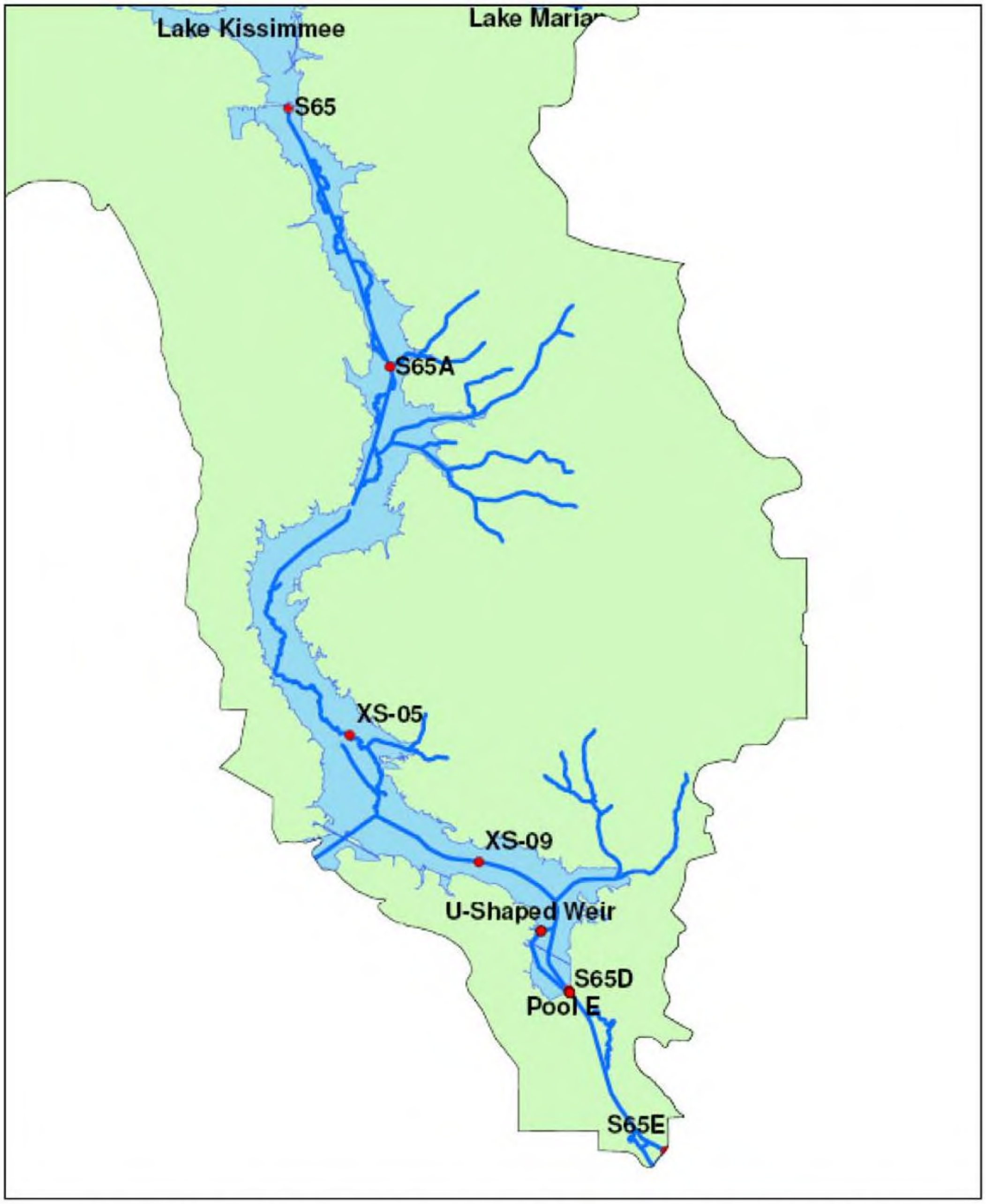

Figure 4-10: River Performance Measures Evaluation Locations (XS-05 and XS-09)

4.3.7 Summary

Below is a summary of the weights used in the "With Project" base run.

Table 4-3: Operating Goals and Corresponding Weights, "With Project" Condition Run

Operating Goal	Weight
Do not simulate more or less than the calculated flow in the C-36 and C-37 Canals.	60,000
Do not exceed calculated flow through spillways and culverts.	50,000
Do not store water above lake schedules.	7,000 to 0
When the stage is within 0.5 feet of the regulation schedule, bring the stage down to the regulation schedule gradually over 15 days.	17,000 to 0
Release the scheduled flow through the S-65 Structure.	700
Maintain water in lakes up to schedule.	1500 to 6
Release as much water as possible through the S-60 Structure.	20
Respect structural stability requirements in the KUB and LKB.	80,000 to 40,000
Do not simulate more or less than the calculated flow using the floodplain storage in Pool B-C-D[1].	60,000
Do not release more than 3000 cfs more than was released yesterday through the S-65 Structure when Lake Kissimmee is in Zone A.	7,000
Do not simulate more or less than the calculated seepage/leakage flow through KUB structures.	55,000

A different weight value is assigned to each lake, as shown in Table 4-4.

[1] All other LKB hydraulics are treated as "constraints" in the model.

Table 4-4: Weight Values for KUB Lakes, "With Project" Condition Run

Lake	Screening Tool node number	Weight for storing water below schedule	Weight for storing water above schedule	Weight for deviating from the "soft landing" flow[2]
Alligator	010	1,500	-7,000	-17,000 & -16,500[3]
Myrtle	060	1,450	-6,000	-16,000
Hart	080	1,400	-5,000	-15,000
East Tohopekaliga	100	1,350	-4,000	-14,000
Tohopekaliga	110	1,300	-3,000	-13,000
Gentry	120	1,450	-2,000	-12,000
Cypress	130	250		
Hatchineha	140	300		
Kissimmee	150	350	0[4]	0

The weights for storing water below schedule are highest for the most upstream lakes and decrease as one goes downstream. Therefore, the screening tool keeps the water in the upstream lakes and does not release it to downstream lakes unless it is above the regulation schedule. Because the flows between the three lowest lakes are controlled by the canal flow equations (which have much higher weights for violations), the weights on the downstream lakes are configured to increase the speed of the solution of the LP and otherwise have no relative significance.

The screening tool allows flows through the S-58 Structure when additional releases through the S-60 Structure would raise Lake Gentry above the regulation schedule and when releases through the S-58 Structure would not cause stages over the schedule in any of the lakes downstream of the S-58 Structure.

Table 4-5 includes the weights or priorities used for the LKB, as well as the target stages. These target values are set in *LKB_Substitutes.ocl*.

[2] "Soft landing" refers to current operations which gradually bring the stage back down to the regulation schedule over 15 days once the stage is within 0.5 feet of the regulation schedule.
[3] Water is sent through the S-60 Structure up to the maximum allowable flow with a penalty of 17,000. If additional releases are needed for the "soft landing," they are sent through the S-57 Structure with a penalty of 16,500.
[4] Flood releases are controlled by the S-65 Structure's headwaters revitalization schedule instead.

Table 4-5: Weight Values for LKB Pools, "With Project" Condition Run

Lake	Screening Tool node number	Target stage (feet)	Weight for storing water below target	Weight for storing water above target	Weight for storing water < 1' below target	Weight for storing water > 2' above target
Pool A	160	46.3	-9	-9	-5500	-5500
Pool B-C-D	180	28.8 - 32.4	-100	-100	-2000	-2000
Pool E	190	21.0	-6	-6	-1200	-1200

4.4 "With Project" Base Condition Lateral Inflows

Lateral inflows used in the "With Project" base run were extracted from the AFET-W model and are summarized in the "basedata_WithProjectBase.011509.dss". Lake rainfall and evapotranspiration are included in these values.

4.5 Verification of the Seepage/Leakage Term through KUB Structures

The seepage flow equations are found in *Structure_Seepage.ocl*. Culvert equations with the same parameters as those used in the AFET and AFET-W are entered here. There are four possible flow conditions, depending on the HW and TW stages relative to the invert location, including zero flow, open channel flow, orifice flow and full pipe flow.

Following the implementation of the culvert equations and because the culvert equations in OKISS use the lake stages that correspond to the average in the LMA, which are higher than the stages used by the AFET and the AFET-W that correspond to the HW of each structure, the leakage in the OKISS model was consistently higher than the AFET-W leakage at some of the structures. As an example, the leakage in the S-59 Structure is shown in Figure 4-11 along with the AFET-W flows below 10.5 cfs (flows above this threshold may have been intended releases). Because previous versions of OKISS did not include leakage at all, underestimating the leakage compared to the AFET-W was a more conservative change to OKISS than overestimating. The OKISS leakage was therefore multiplied by a "stage correction coefficient" to bring the leakage down within the bounds of the AFET-W leakage, as seen in Figure 4-12.

The discrepancy in leakage was likely due to a difference in the implementation of the culvert equations between the two models. Because the leakage is small, the "stage correction coefficient" approach seemed more appropriate than attempting to pinpoint the difference in calculations between the two models.

The calculated seepage flows act as minimum flow requirements through KUB structures. The weight of 55,000 assigned to these flows (see Section 4.3.2) gives them a higher priority than the regulation and the HW schedules (i.e., the seepage will occur when the gates are closed because the upstream lake is below the regulation schedule and when the HW release is less than the seepage).

While the inclusion of structure seepage dramatically reduced stage differences between the screening tool and the AFET-W (see Appendix C), a flag "IncludeSeepage" was added to the OCL Constants Table in the graphical user interface (GUI) in case leaking control measures are implemented in the future. Seepage is included when this flag is set to one. Otherwise, seepage will not be included.

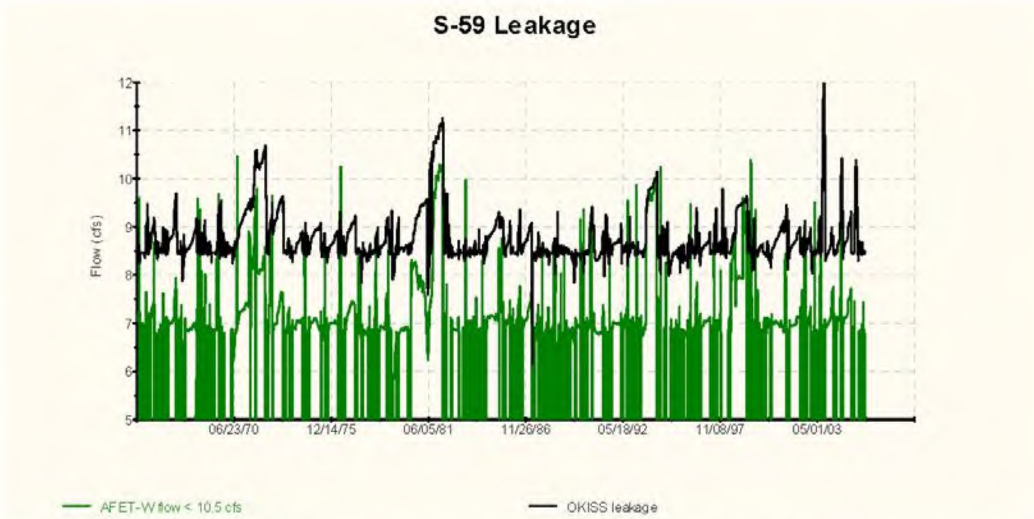

Figure 4-11: Leakage through the S-59 Structure *before* the stage correction coefficient was implemented and S-59 Structure flows below 10.5 cfs from the AFET-W model

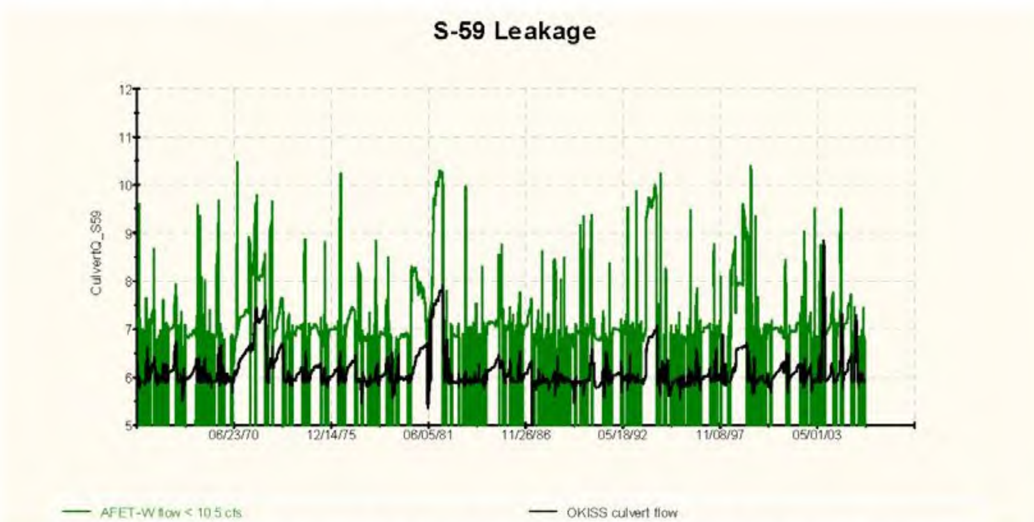

Figure 4-12: Leakage through the S-59 Structure *after* the stage correction coefficient was implemented and S-59 Structure flows below 10.5 cfs from the AFET-W model

4.6 OKISS (Screening Tool) "With Project" Base Condition Results

Figure 4-11 through Figure 4-19 shows the results obtained for the "With Project" base condition for the KUB and Figure 4-20 through Figure 4-27 show the results obtained for the LKB. Stages at Lake Cypress, Lake Hatchineha and Lake Kissimmee (Figure 4-19) are set by the headwaters revitalization schedule. The releases specified by the headwaters revitalization schedule are shown with the green line in Figure 4-20. The actual releases (shown with the black line) follow the schedule exactly, except when the maximum release possible with the HW and TW at the S-65 Structure (yellow line) are less than the flood control releases specified by the headwaters revitalization schedule.

For Pool B-C-D, the stages at Cross-sections 5 and 9, PC33, PC52 and the S-65D Structure are all shown (Figure 4-22 to Figure 4-25). Additionally, the flows through Pool B-C-D for a sample year are provided in Figure 4-25 . This shows that the Kissimmee River flows are lagged by a day and smoothed in Pool B-C-D. Stages in the HW and TW of the S-65E Structure are shown in Figure 4-26 and flows to Lake Okeechobee are shown in Figure 4-27.

Appendix A shows comparisons of stages obtained with OKISS with those obtained with the AFET-W.

4.6.1 KUB Plots

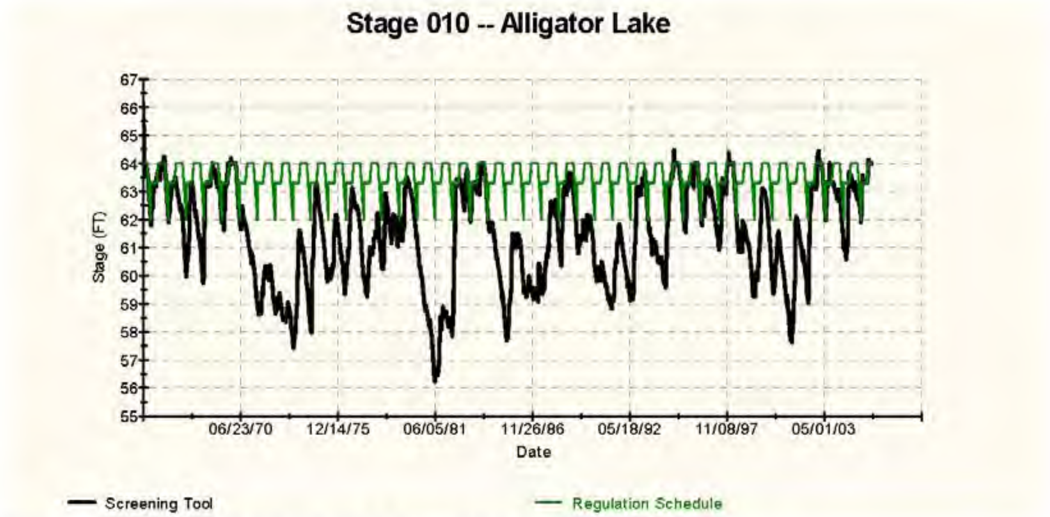

Figure 4-13: Stage in Alligator Lake, "With Project" Base Run

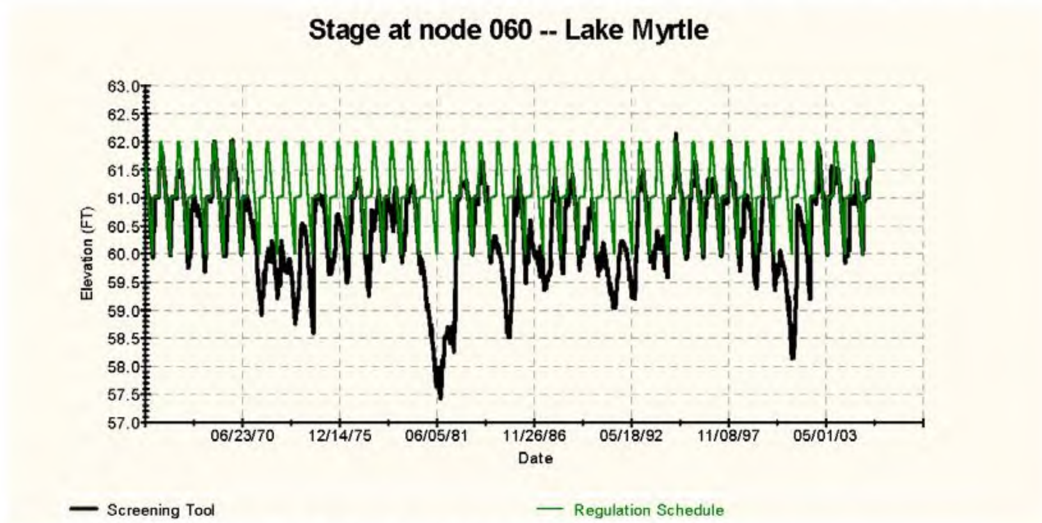

Figure 4-14: Stage in Lake Myrtle, "With Project" Base Run

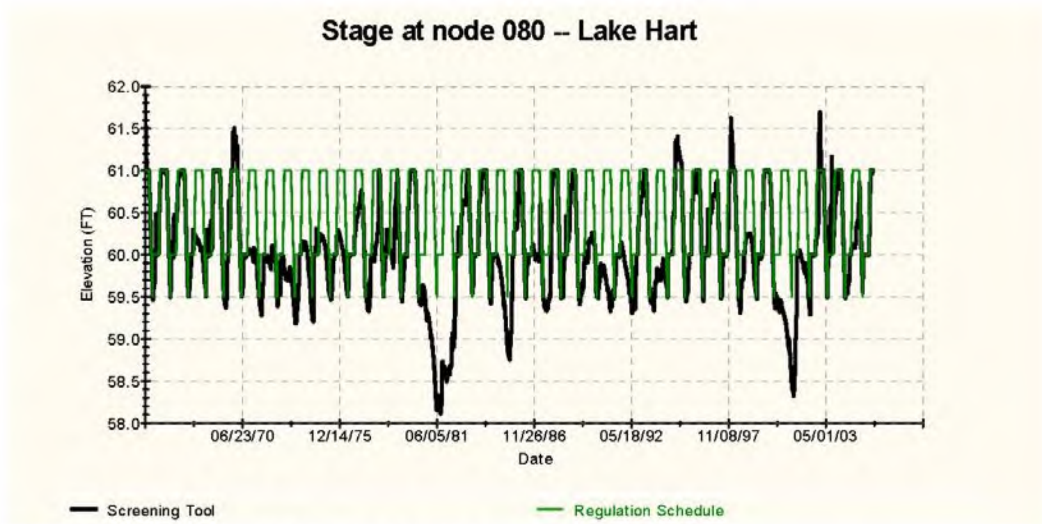

Figure 4-15: Stage in Lake Hart, "With Project" Base Run

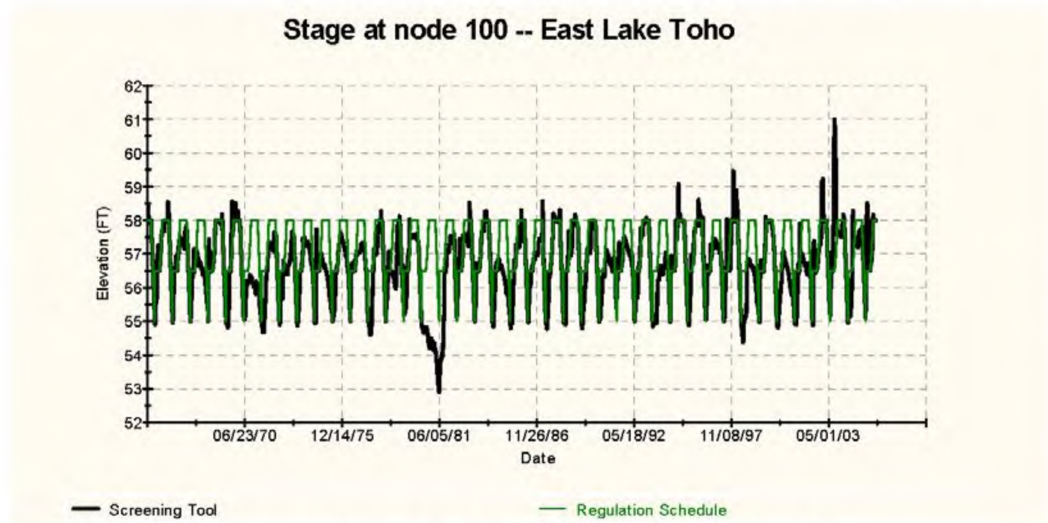

Figure 4-16: Stage in East Lake Tohopekaliga, "With Project" Base Run

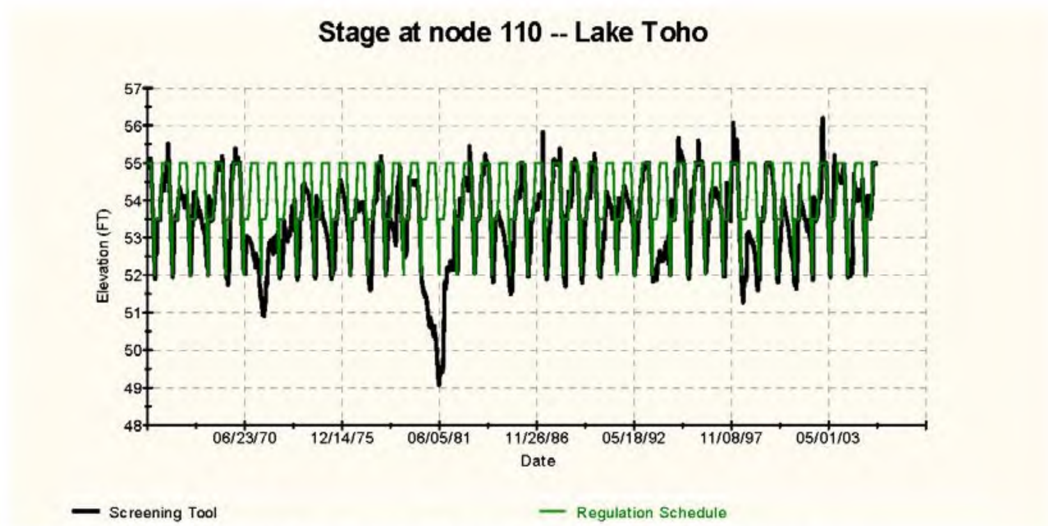

Figure 4-17: Stage in Lake Tohopekaliga, "With Project" Base Run

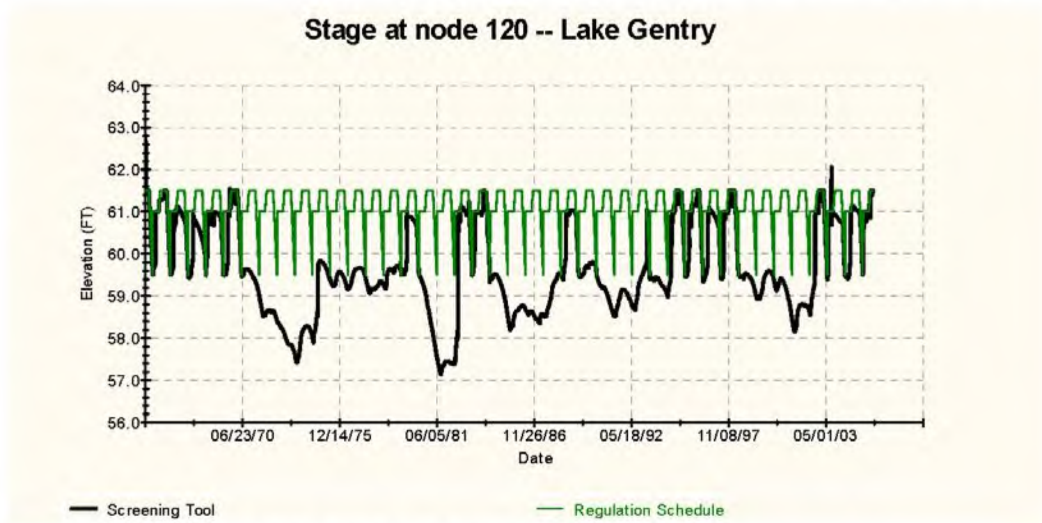

Figure 4-18: Stage in Lake Gentry, "With Project" Base Run

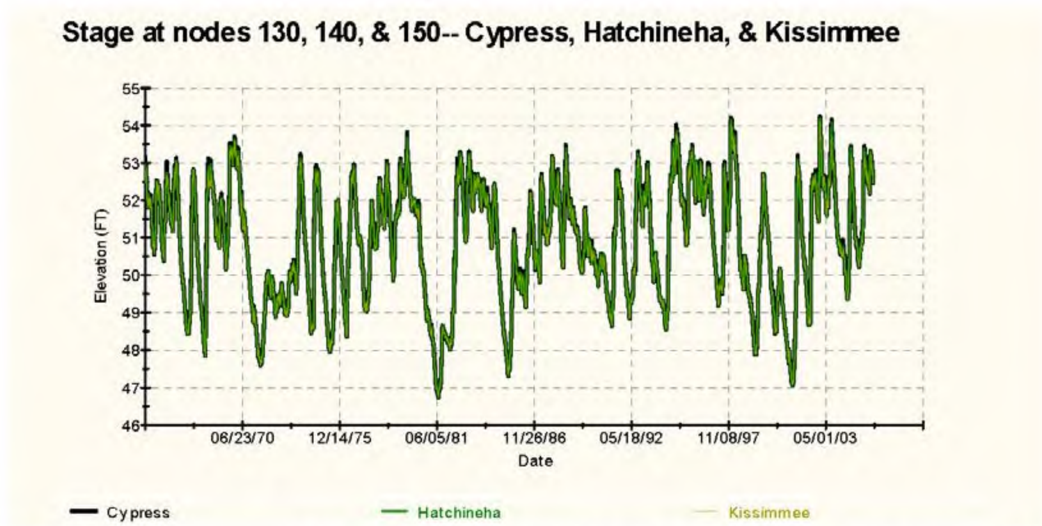

Figure 4-19: Stage in Lake Cypress, Lake Hatchineha and Lake Kissimmee, "With Project" Base Run

4.6.2 LKB Plots

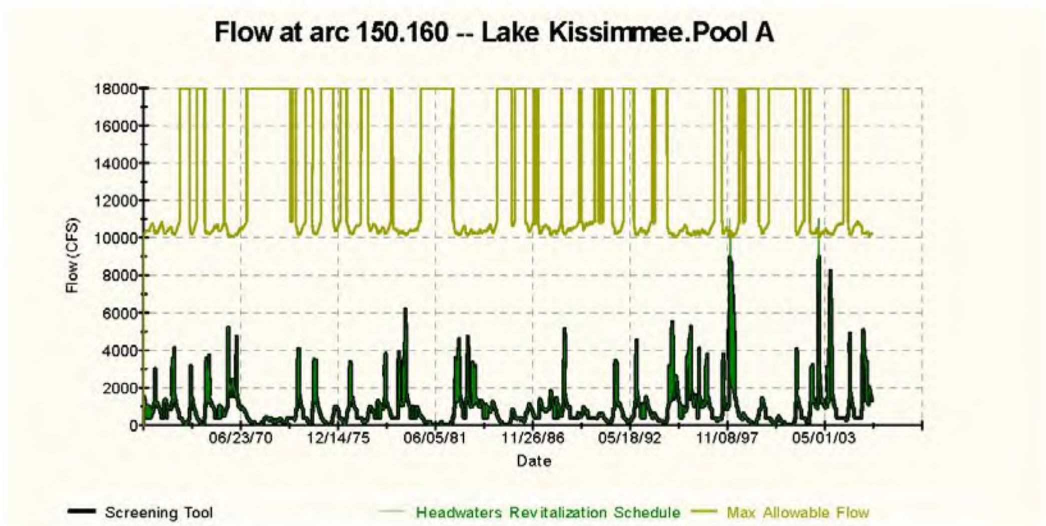

Figure 4-20: Flow through the S-65 Structure, "With Project" Base Run

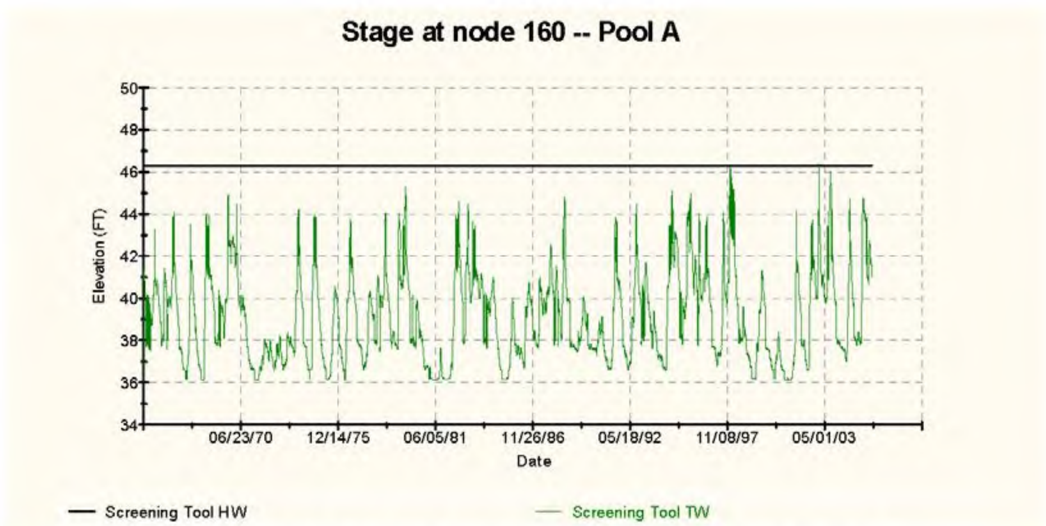

Figure 4-21: HW and TW at the S-65A Structure, "With Project" Base Run

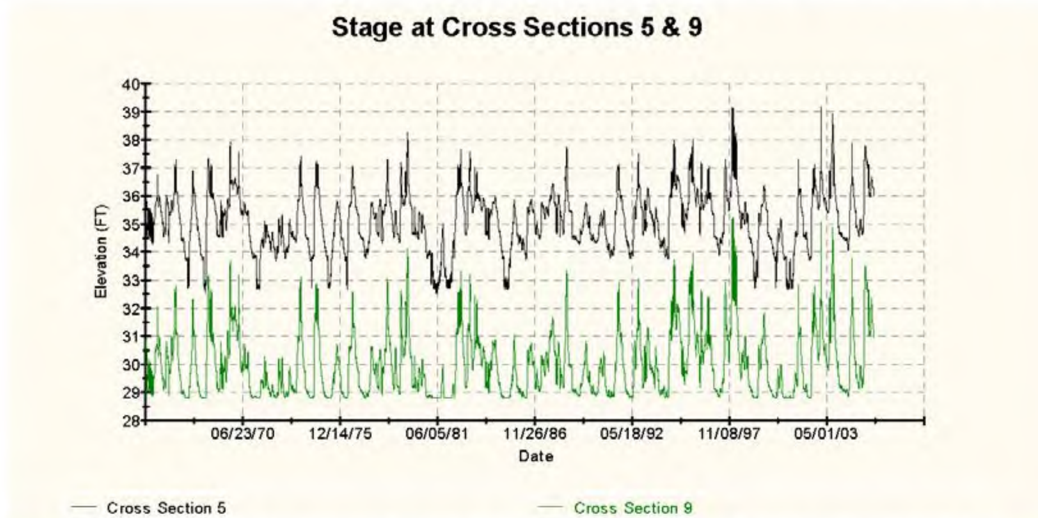

Figure 4-22: Stages at Cross-sections 5 and 9 in Pool B-C-D, "With Project" Base Run

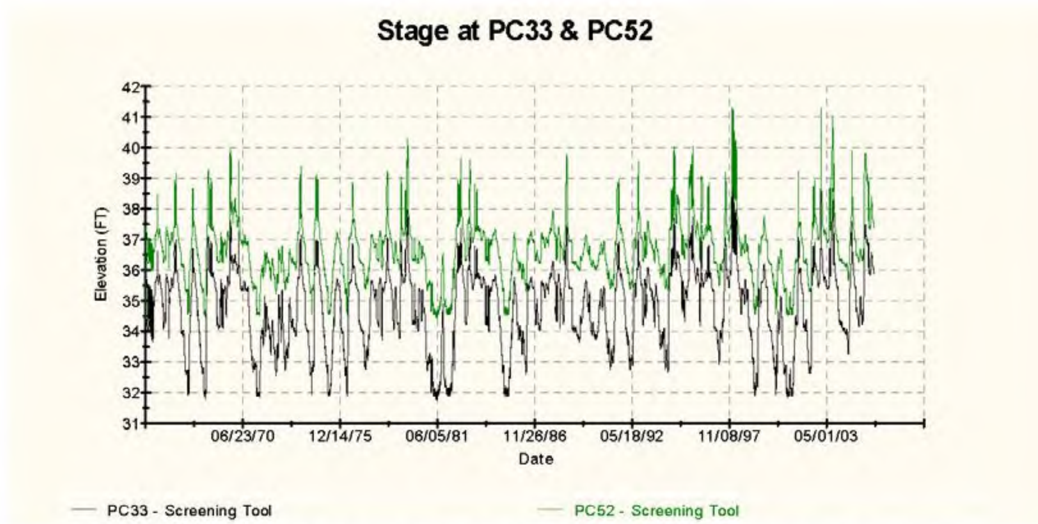

Figure 4-23: Stages at PC52 and PC33 in Pool B-C-D, "With Project" Base Run

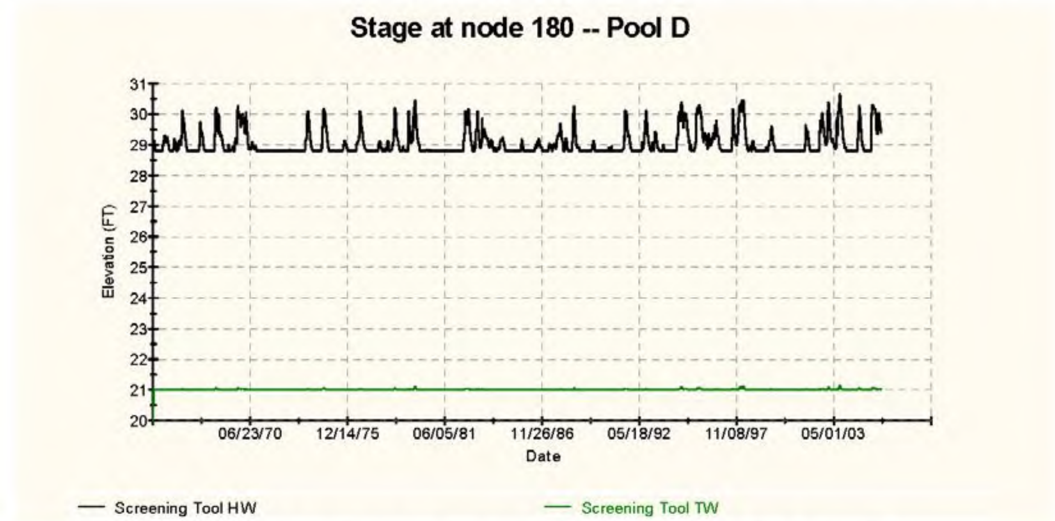

Figure 4-24: HW and TW at the S-65D Structure, "With Project" Base Run

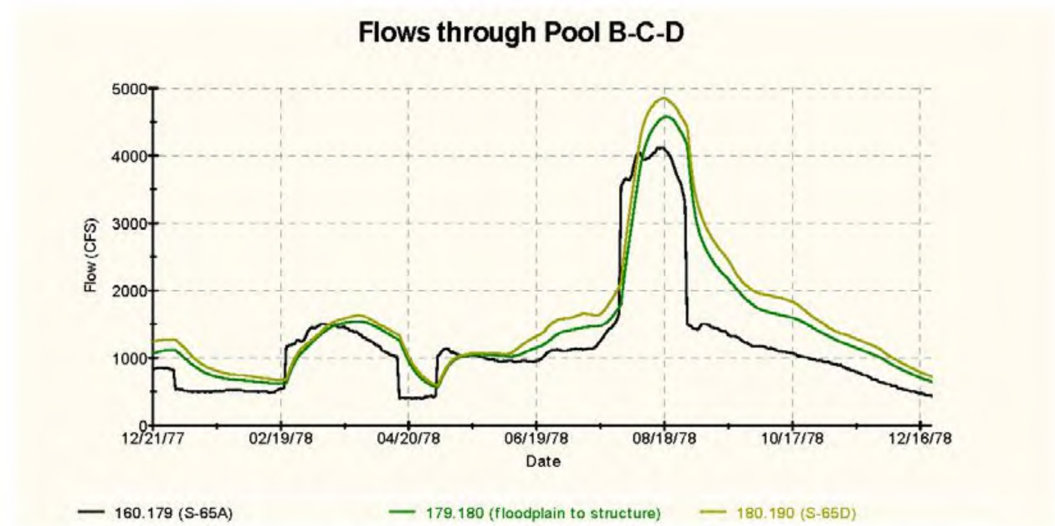

Figure 4-25: Flows through Pool B-C-D, "With Project" Base Run

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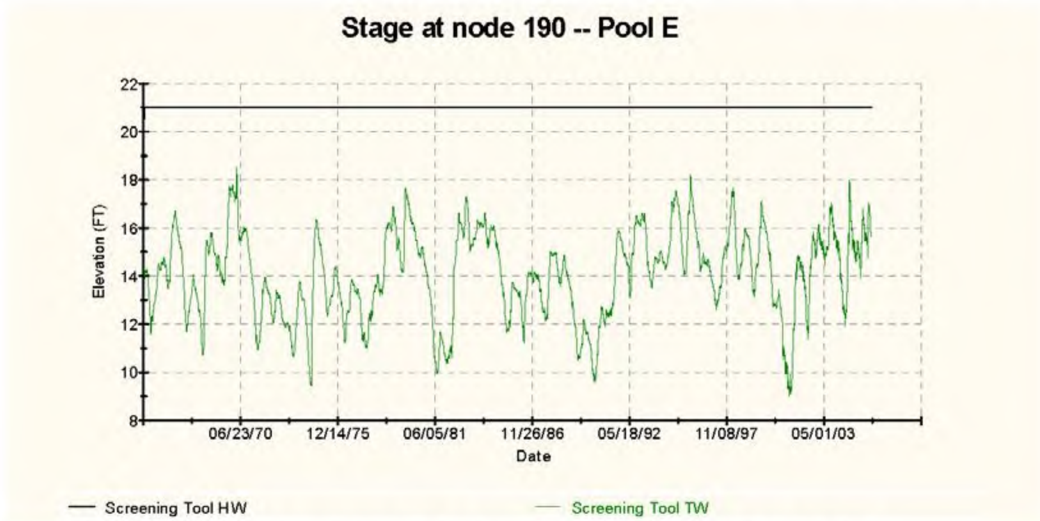

Figure 4-26: HW and TW at the S-65E Structure, "With Project" Base Run

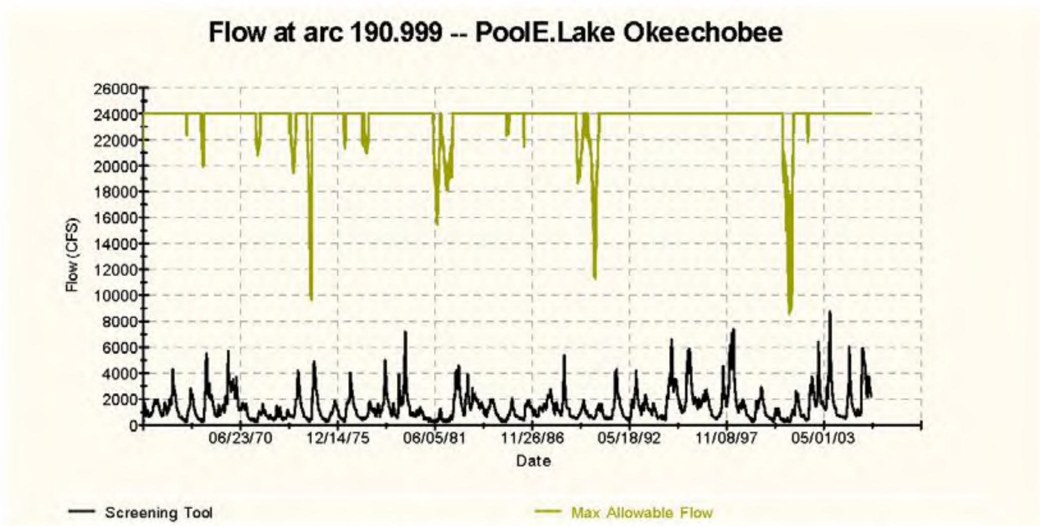

Figure 4-27: Flows through the S-65E Structure, "With Project" Base Run

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5 VALIDATION OF KBMOS MODELING TOOLS

The KBMOS Work Plan included a process to validate the results of the study modeling tools by comparing the results obtained for each performance measure. The validation process is needed to evaluate the effect of the differences in model conceptualization on the alternative selection process.

The following is the nomenclature used in the comparison plots, charts and tables included in this section:

- Screening Tool : **OKISS**
- Alternative Formulation Tool: **AFT** – MIKE 11 decoupled from MIKE SHE. Results from AFT were extracted from the corresponding component in the AFET-W.
- Alternative Evaluation Tool: **AET** – MIKE SHE / MIKE 11 coupled. This model corresponds to the full version of the AFET-W.

The modeling tools used in the study have very different technical approaches to simulate the hydrology and hydraulics of the Kissimmee Basin, OKISS being the most different approach of the three. OKISS is a water management model that runs in daily time-steps. OKISS has been adapted to model the hydraulics of the Kissimmee Basin through the addition of a series of surrogate computations, while the AFET-W based models include sophisticated hydraulic computations and smaller time-steps (in the order of minutes). The approach that each model uses to simulate structure operations is also very different between OKISS and the AFET-W based models. Additionally, when MIKE 11 is fully coupled with MIKE SHE (AET), the exchanges between MIKE SHE and MIKE 11 are evaluated at each time-step. That means that transfers of flows or "lateral inflows" between the hydrological and the hydraulic modules is done every 5 to 10 minutes, while in OKISS and AFT these transfers are done daily. These differences would explain discrepancies in model results for the same type of simulation. However, the alternative selection process requires a smooth transition from screening to formulation and from formulation to evaluation. Potential differences in model results need to be identified in this stage, prior to those transitions.

Even though each modeling tool has been subject to model calibration and/or history matching, the validation process provides the required confidence in model results by comparing them under the wide range of climatic conditions found in the base condition period of simulation (1965-2005). Results of this comparison are shown in the following sections.

5.1 Comparison Methodology

Two types of comparisons were performed to validate the results of the KBMOS modeling tools. Both comparisons are based on the definitions of the KBMOS performance measures. The first comparison was made using the same model output data that are used to calculate the values of the performance measure components, namely the time series of stages and flows of those locations identified as evaluation locations. Duration curves and stage hydrographs were prepared and are presented in this section.

The second comparison is based on the performance measure component values. Each KBMOS evaluation performance measure comprises a set of evaluation components. Targets for the evaluation performance measures related to the natural resource requirements of the KRRP and the KCOL were derived based on analyses of hydrologic data obtained during the pre-regulation period and the recent history of management practices that have yielded positive ecological observations. The comparison performed within the validation process used the selected targets as a reference. Comparison results are presented as a series of charts and tables for each performance measure component.

5.1.1 Lake PME Location

The following list relates each lake performance measure with its corresponding evaluation location and driver model output.

- Lake Performance Measure L01 : Stages in Lakes Kissimmee, Hatchineha and Cypress
- Lake Performance Measure L02 : Stages in Lake Tohopekaliga
- Lake Performance Measure L03 : Stages in Lake Gentry
- Lake Performance Measure L04 : Stages in Lakes Joel, Myrtle and Preston
- Lake Performance Measure L05 : Stages in East Lake Tohopekaliga
- Lake Performance Measure L06 : Stages in the Alligator Chain of Lakes
- Lake Performance Measure L07 : Stages in Lakes Hart and Mary Jane

With the exception of Lakes Kissimmee, Hatchineha and Cypress, which have independent nodes for each lake within the OKISS model, all of the other groups of lakes are represented by individual nodes within OKISS. This contrasts with the AFET-W, which represents each lake with several cross-sections. The information used to run the PME Tool for the AFET-W was extracted from a point/cross-section located approximately at the center of each lake group.

5.1.2 River PME Location

The following list relates each river performance measure with its corresponding evaluation location and driver model output.

- River Performance Measure R01: Kissimmee River flow, evaluated at the S-65 and S-65E Structures
- River Performance Measure R02: Kissimmee River stage hydrograph/floodplain hydroperiod was evaluated at the XS-5 transect, located in Pool C just upstream of Oak Creek and at the XS-9 transect, located in Pool D. These evaluation locations are displayed in Figure 5-1
- River Performance Measure R03: River recession/ascension rate (evaluated in the same locations as Performance Measure R02)

5.2 Comparison of Model Output

5.2.1 Lake Stages

Lake stage time series obtained from the model output were used to generate plots similar to those plots included in Tier 2 of the PME Report. These plots are stage hydrographs, stage duration curves and mean daily stage hydrographs for those locations where Performance Measures L01 through L07 are calculated.

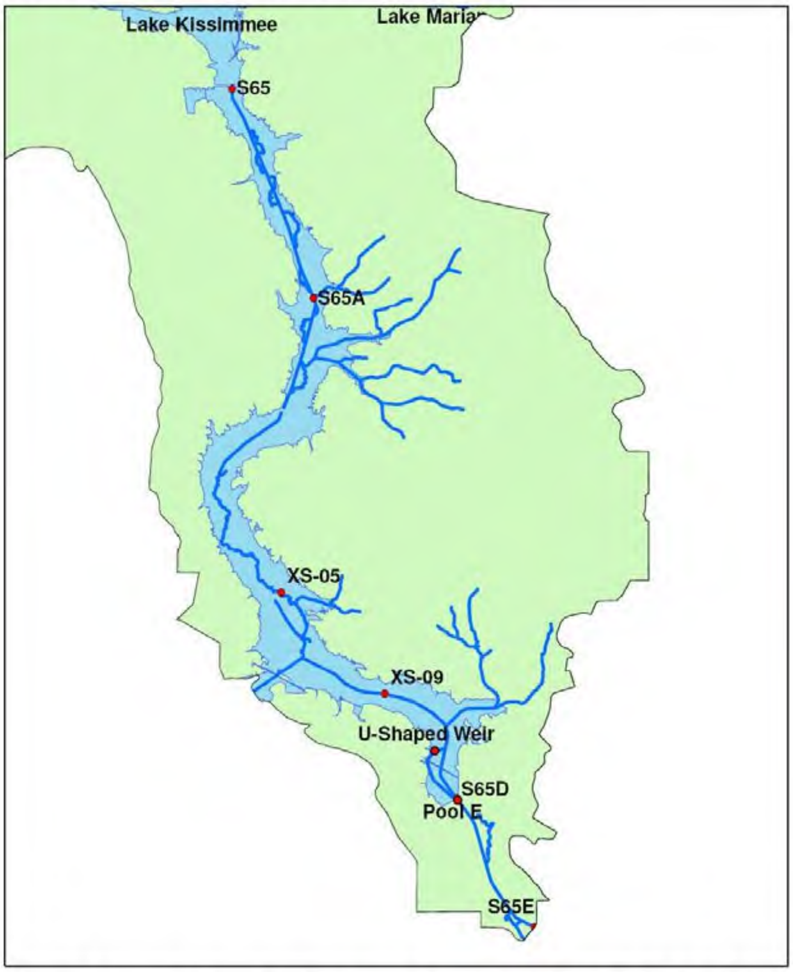

Figure 5-1: Evaluation Locations for R02 and R03: XS-5 and XS-9

Comparisons of model results for the base condition are shown in Figure 5-2 through Figure 5-22. These figures contain stage hydrographs, stage duration curves and mean daily hydrographs for the evaluation location of the lake performance measures. Generally, the majority of evaluation locations consistently show a very good match among model tools. Some differences are observed in medium to high stages in Lake Gentry (Figure 5-8 and Figure 5-9). These differences are due to the methodology used to calculate the leakage in the S-63 Structure. Since OKISS does not explicitly model the S-63A Structure, it uses surrogates to calculate the head differential that drives the leakage calculations. Additionally, a correction in the operation of the S-63A Structure was added to the AFT. This correction accounted for a more stable water level immediately upstream of the S-63A Structure. Some differences are also observed in extreme low levels is the Alligator Chain of Lakes and in the Hart and Mary Jane LMA (Figure 5-17 through Figure 5-22). These differences are also due to the accuracy of the leakage through the structures and the difference in the way each model (OKISS and AFET-W) conceptualizes the available storage. At lower levels, a small difference in volume accounts for larger differences in stages than in upper levels.

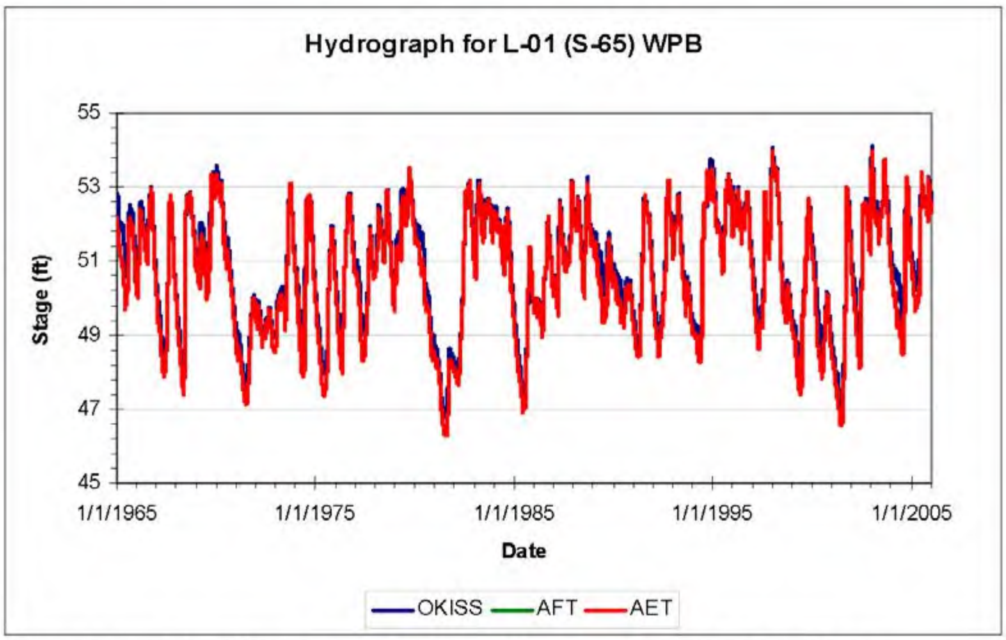

Figure 5-2: Lake Kissimmee (L01) Stage Hydrograph for Base Condition

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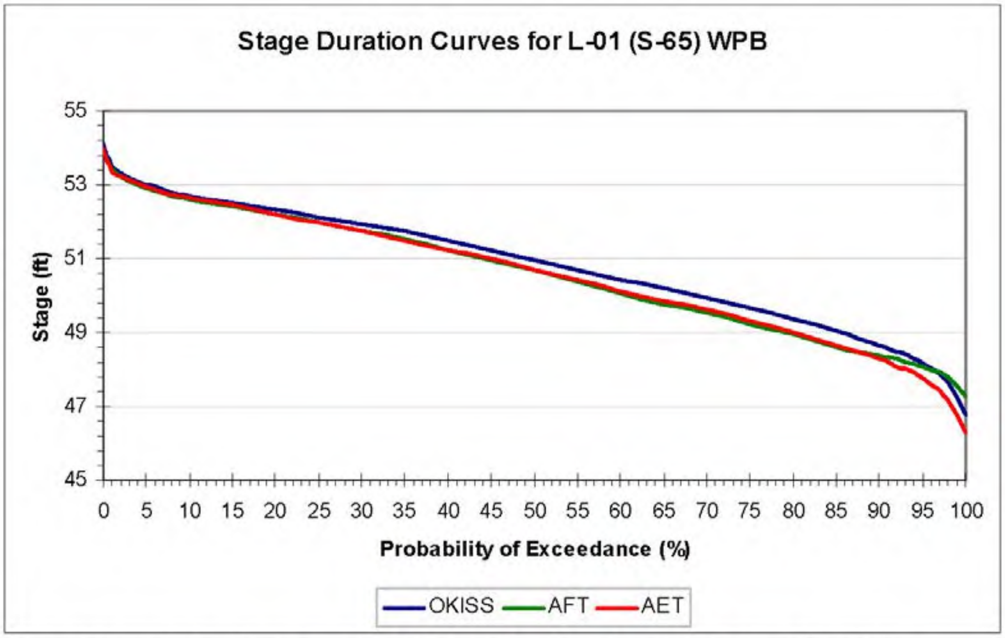

Figure 5-3: Lake Kissimmee (L01) Stage Duration Curves for Base Condition

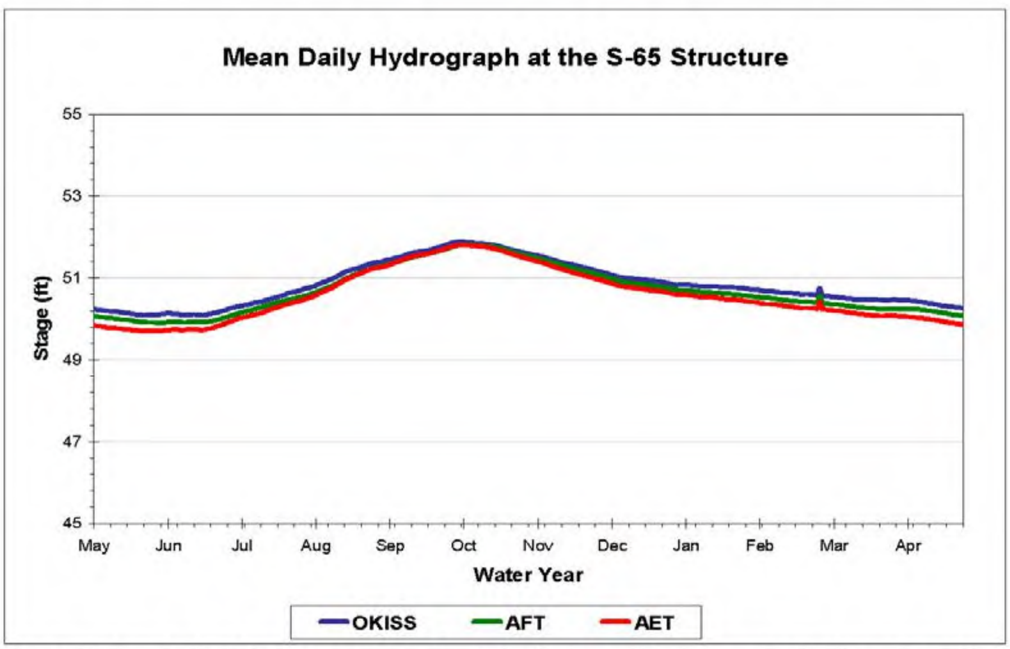

Figure 5-4: Lake Kissimmee (L01) Mean Daily Stage Hydrograph for Base Condition

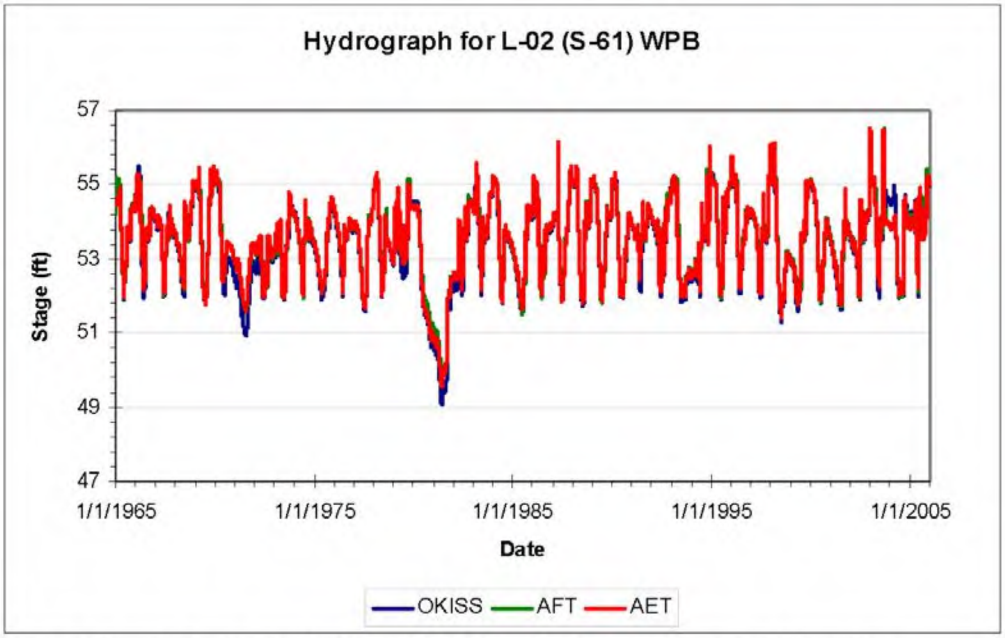

Figure 5-5: Lake Tohopekaliga (L02) Stage Hydrograph for Base Condition

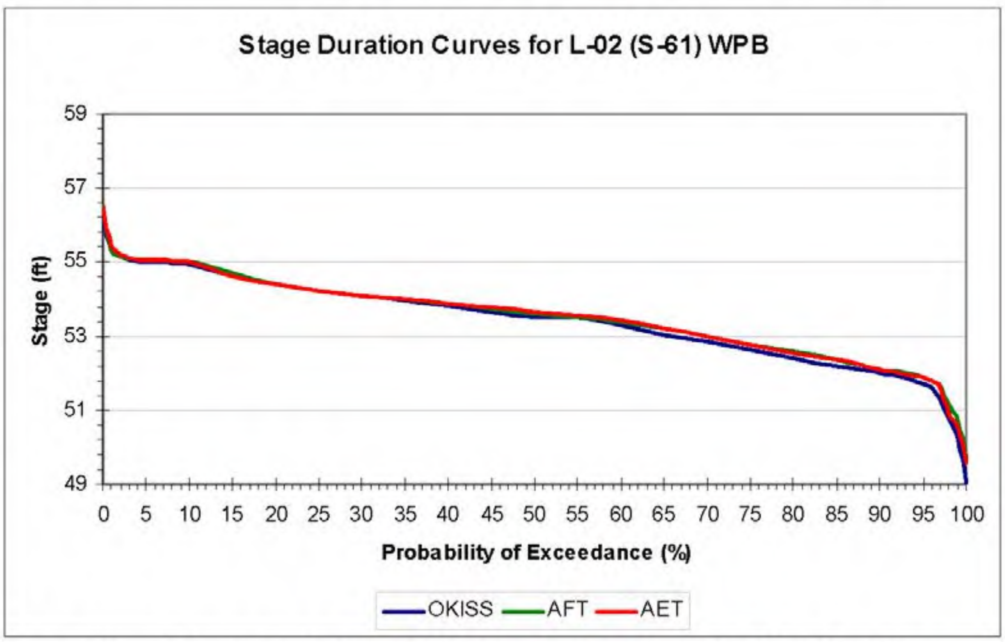

Figure 5-6: Lake Tohopekaliga (L02) Stage Duration Curve for Base Condition

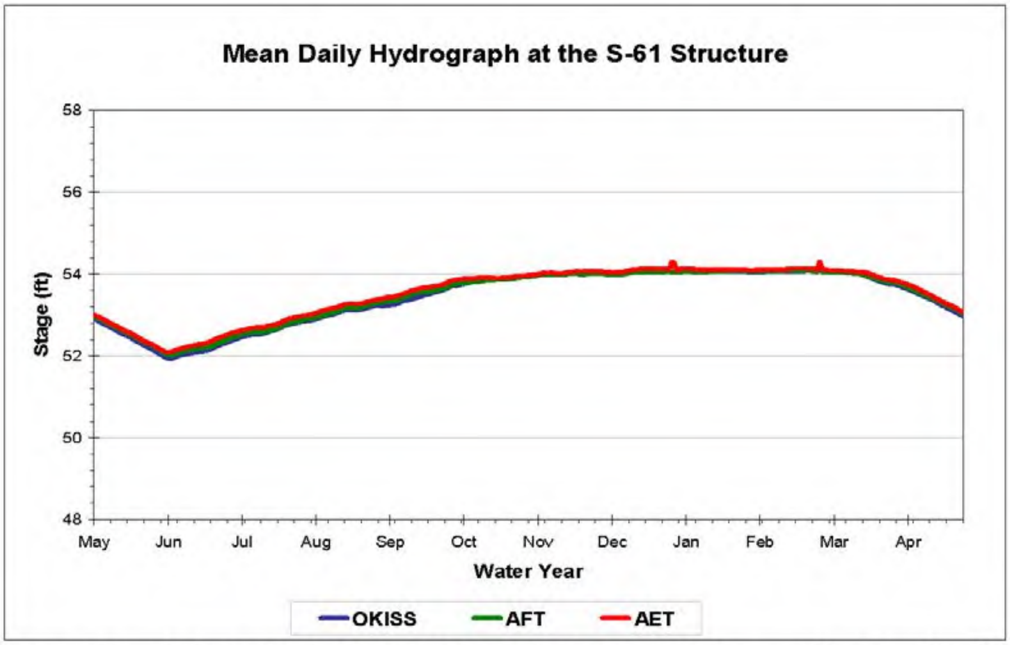

Figure 5-7: Lake Tohopekaliga (L02) Mean Daily Stage Hydrograph for Base Condition

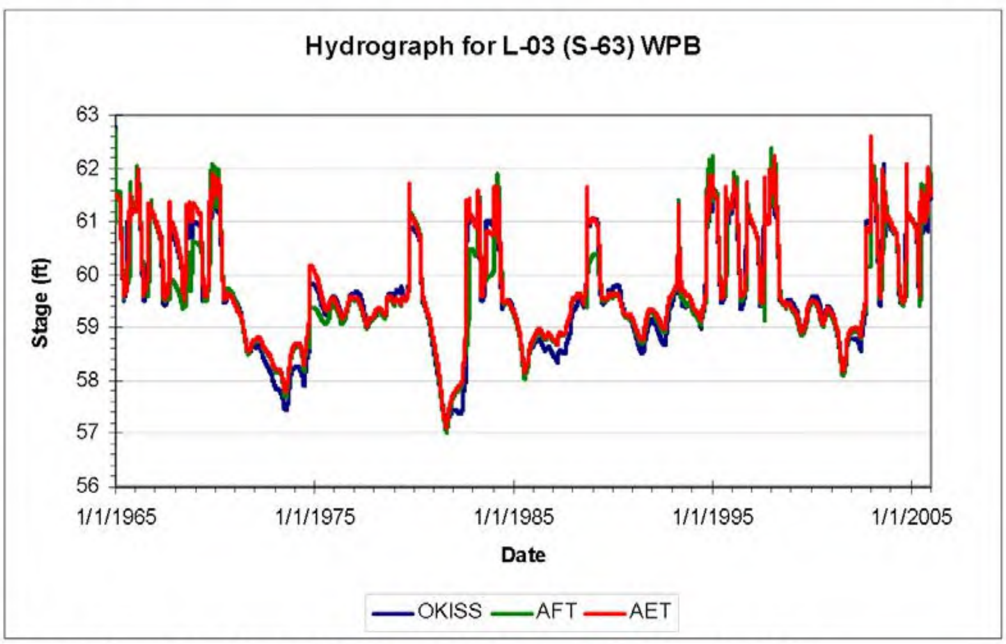

Figure 5-8: Lake Gentry (L03) Stage Hydrograph for Base Condition

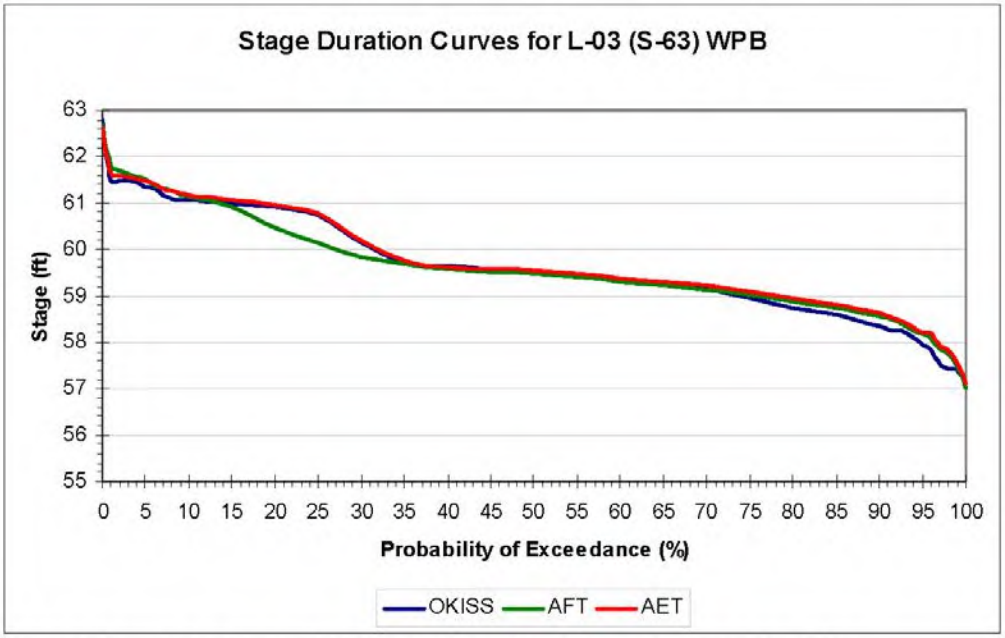

Figure 5-9: Lake Gentry (L03) Stage Duration Curve for Base Condition

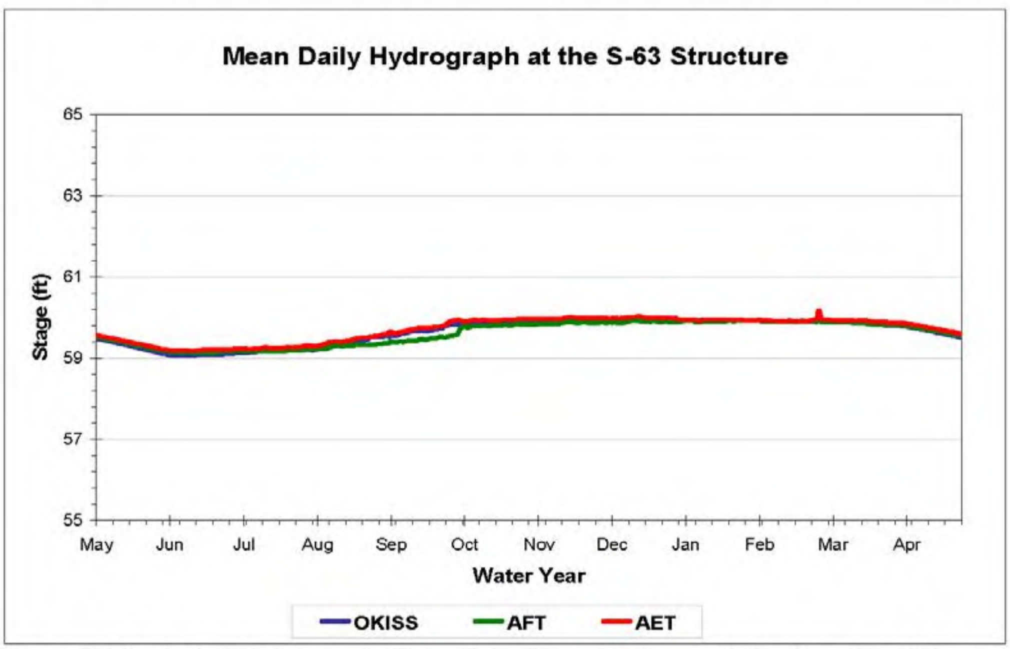

Figure 5-10: Lake Gentry (L03) Mean Daily Stage Hydrograph for Base Condition

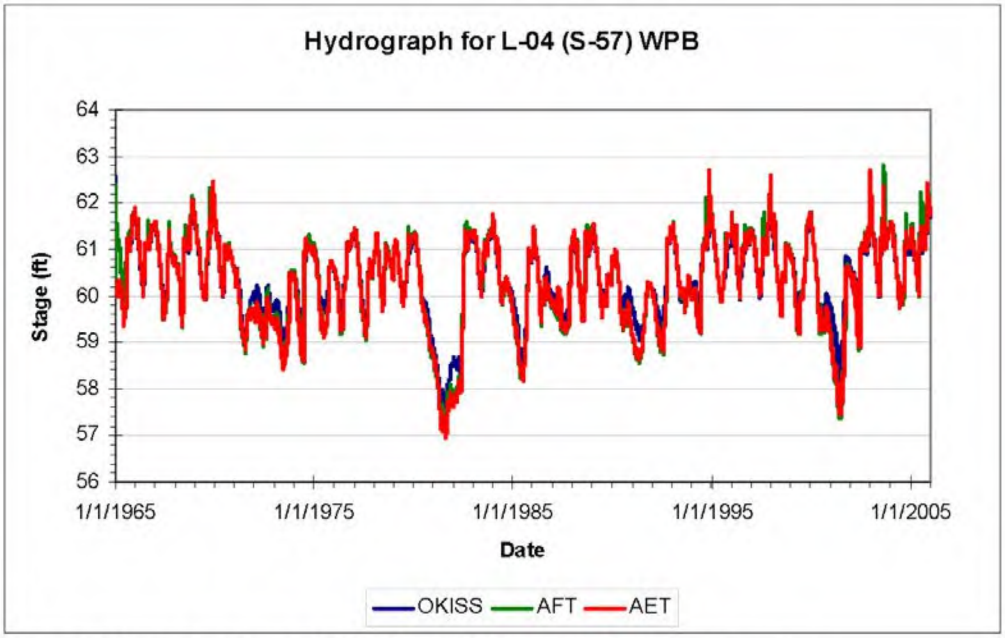

Figure 5-11: Lake Myrtle (L04) Stage Hydrograph for Base Condition

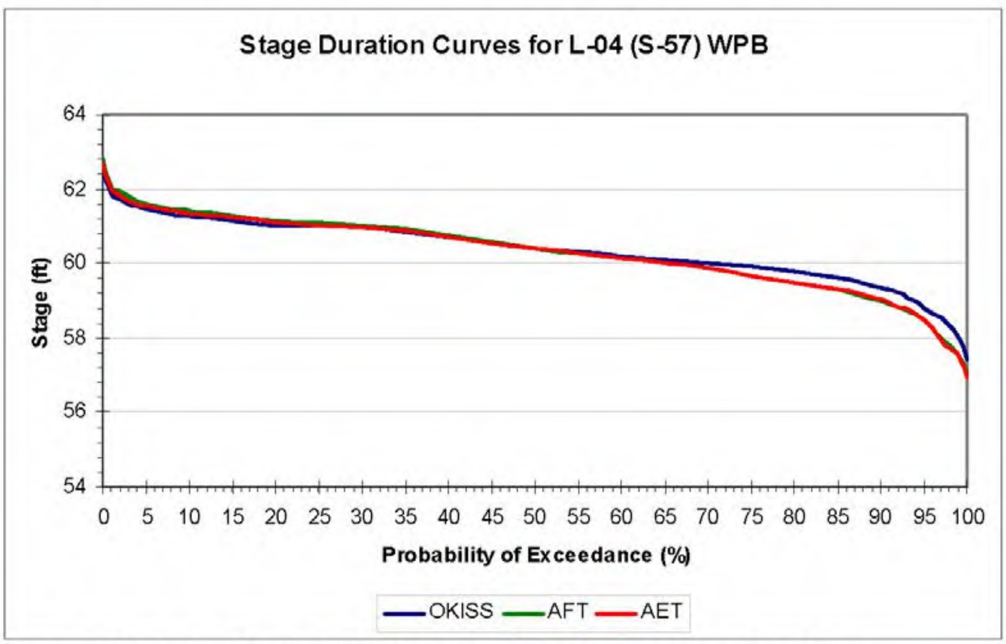

Figure 5-12: Lake Myrtle (L04) Stage Duration Curve for Base Condition

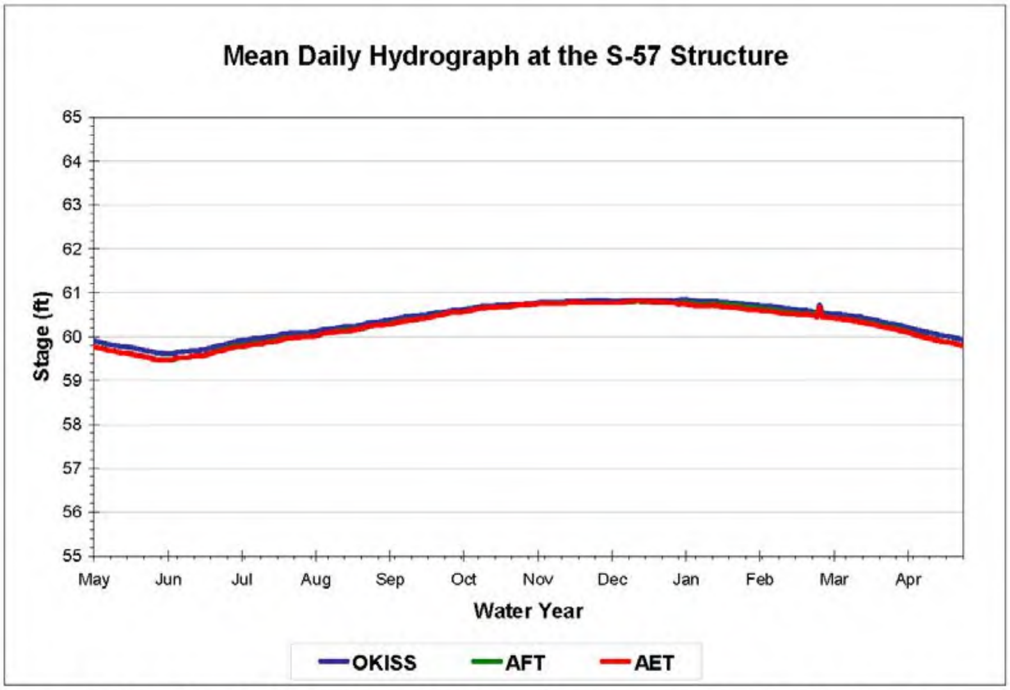

Figure 5-13: Lake Myrtle (L04) Mean Daily Stage Hydrograph for Base Condition

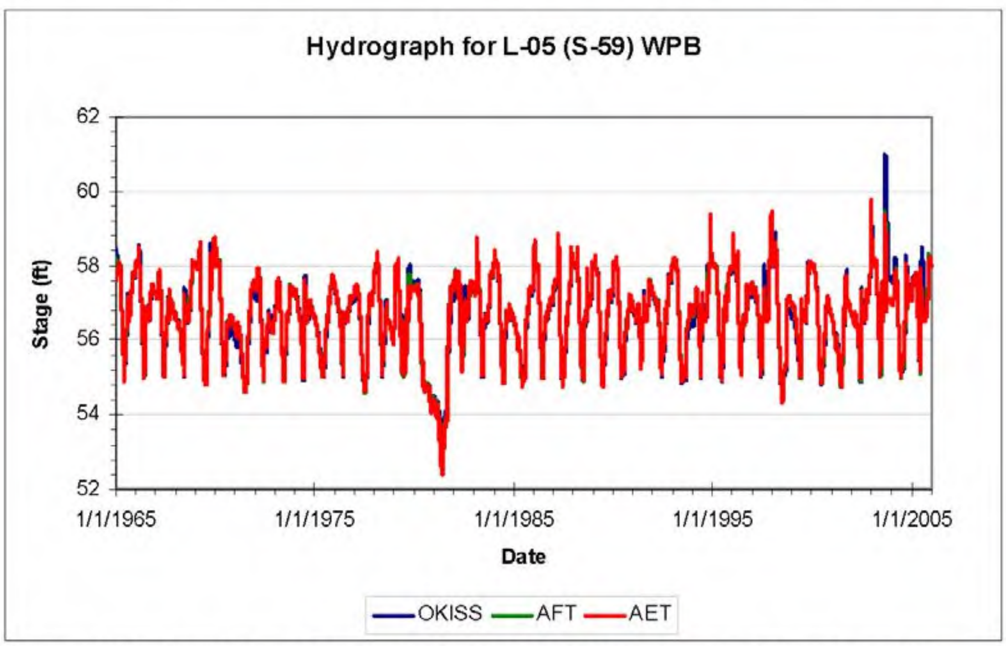

Figure 5-14: East Lake Tohopekaliga (L05) Stage Hydrograph for Base Condition

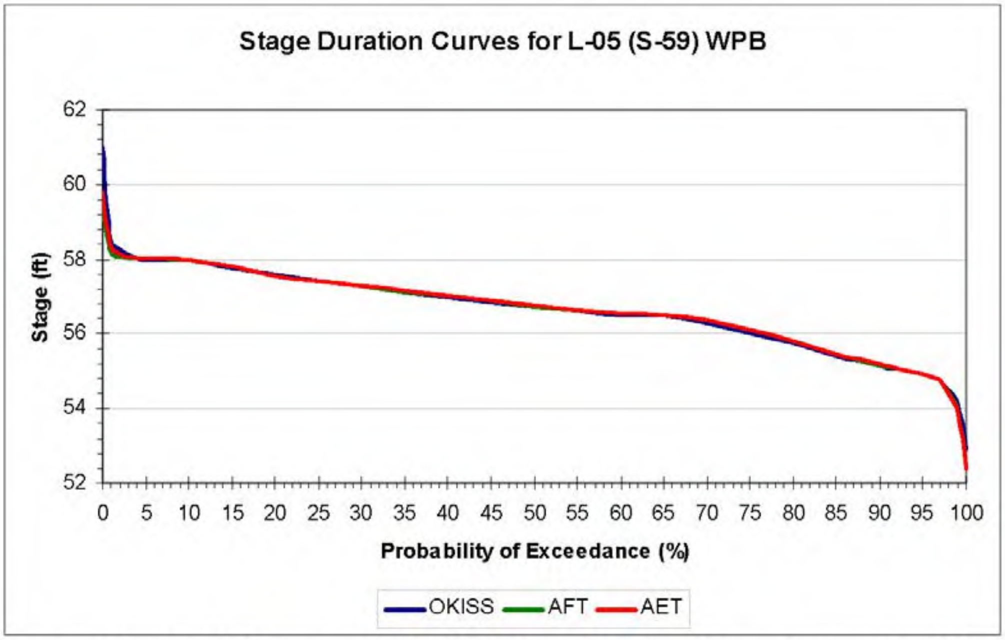

Figure 5-15: East Lake Tohopekaliga (L05) Stage Duration Curve for Base Condition

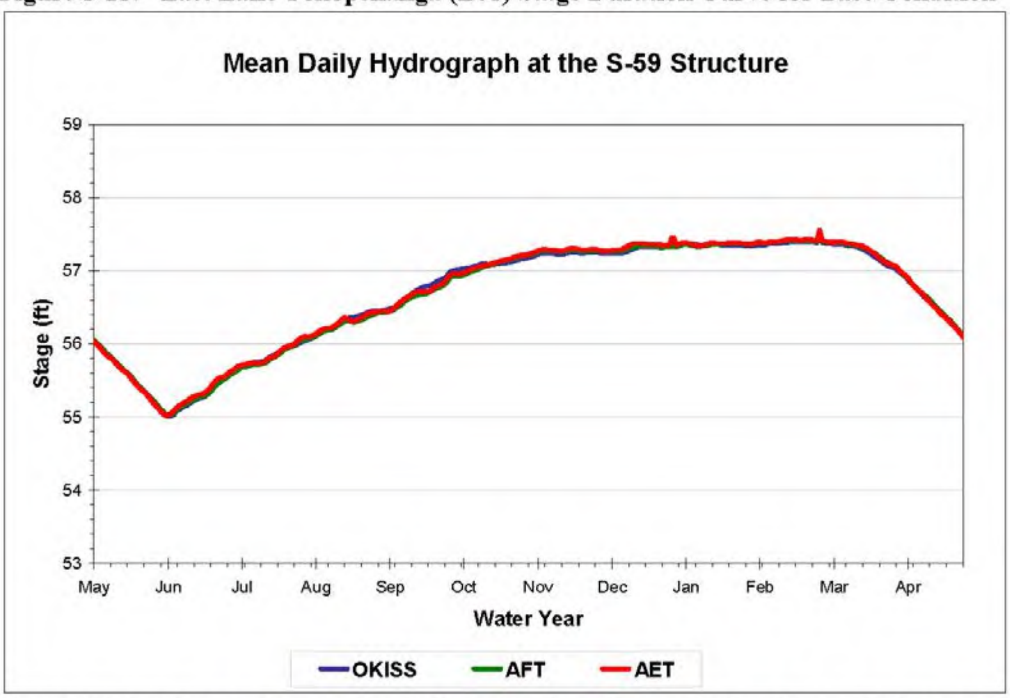

Figure 5-16: East Lake Tohopekaliga (L05) Mean Daily Stage Hydrograph for Base Condition

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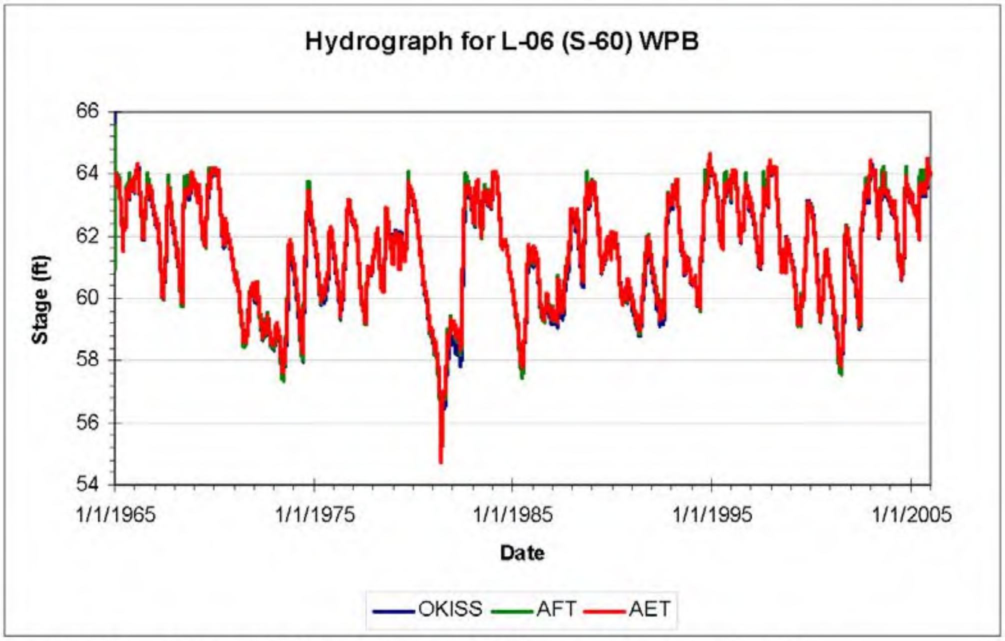

Figure 5-17: Alligator Lake (L06) Stage Hydrograph for Base Condition

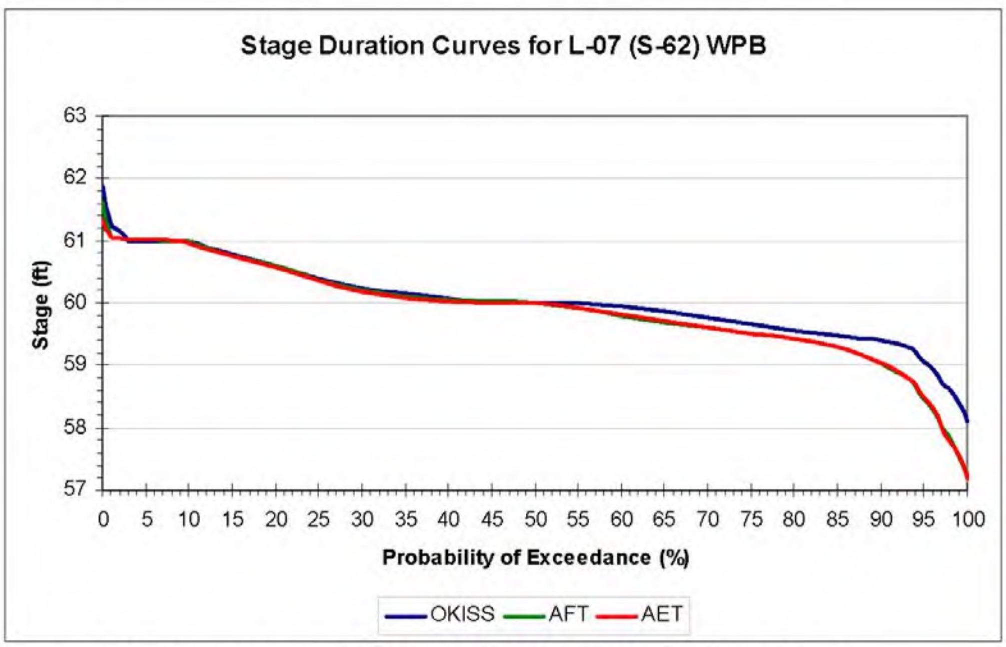

Figure 5-18: Alligator Lake (L06) Stage Duration Curve for Base Condition

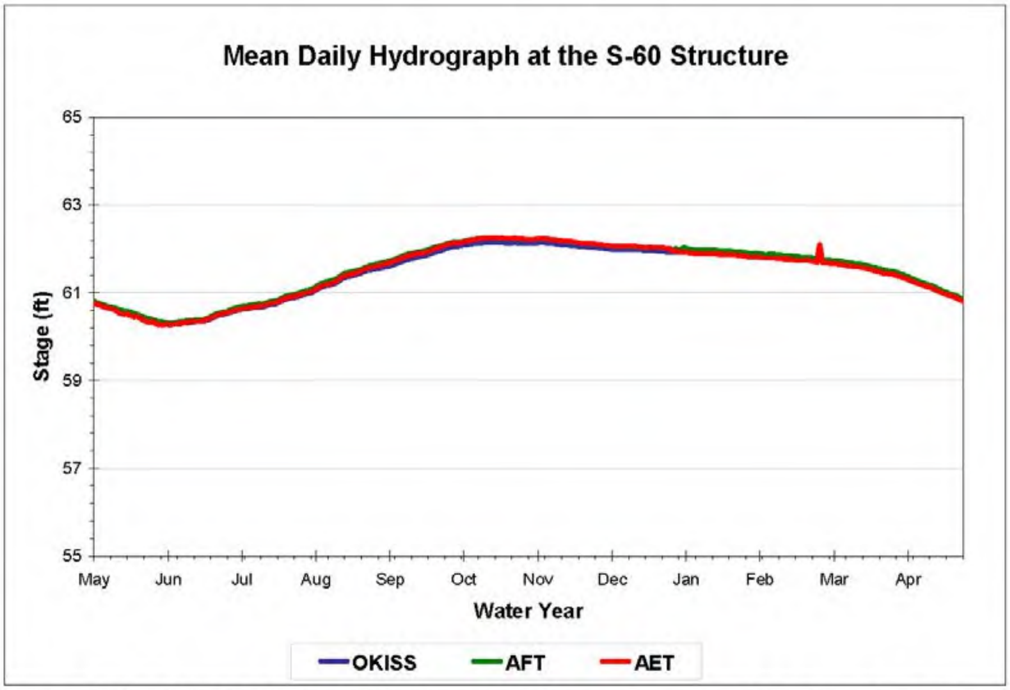

Figure 5-19: Alligator Lake (L06) Mean Daily Stage Hydrograph for Base Condition

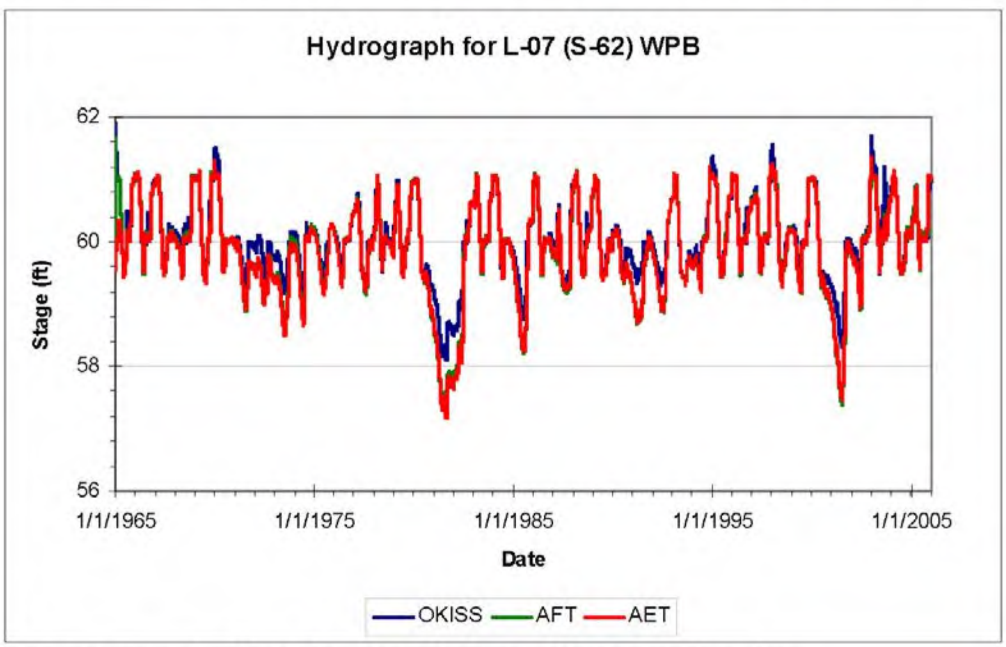

Figure 5-20: Lake Hart (L07) Stage Hydrograph for Base Condition

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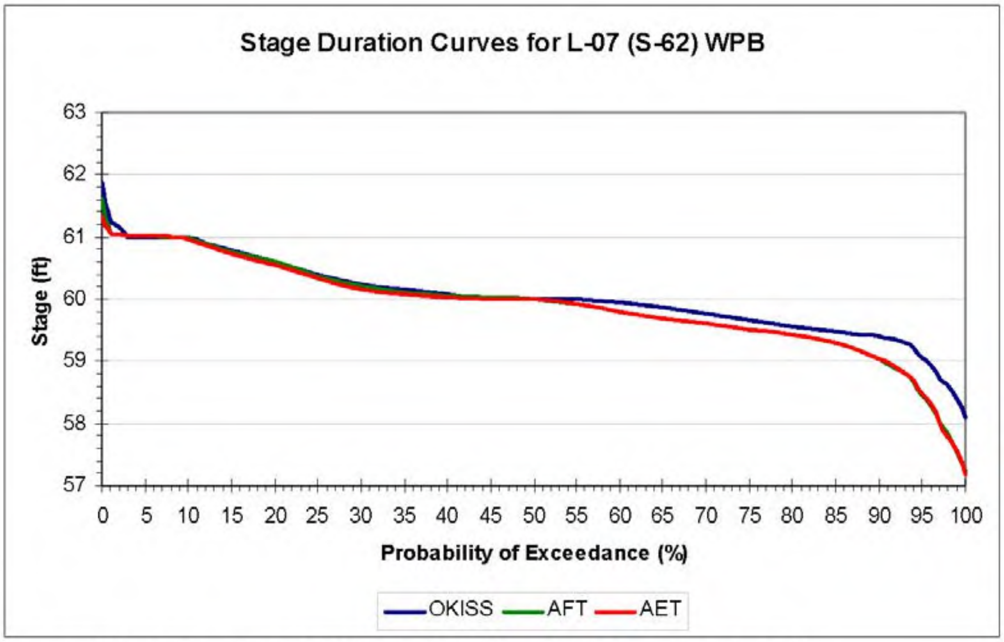

Figure 5-21: Lake Hart (L07) Stage Duration Curve for Base Condition

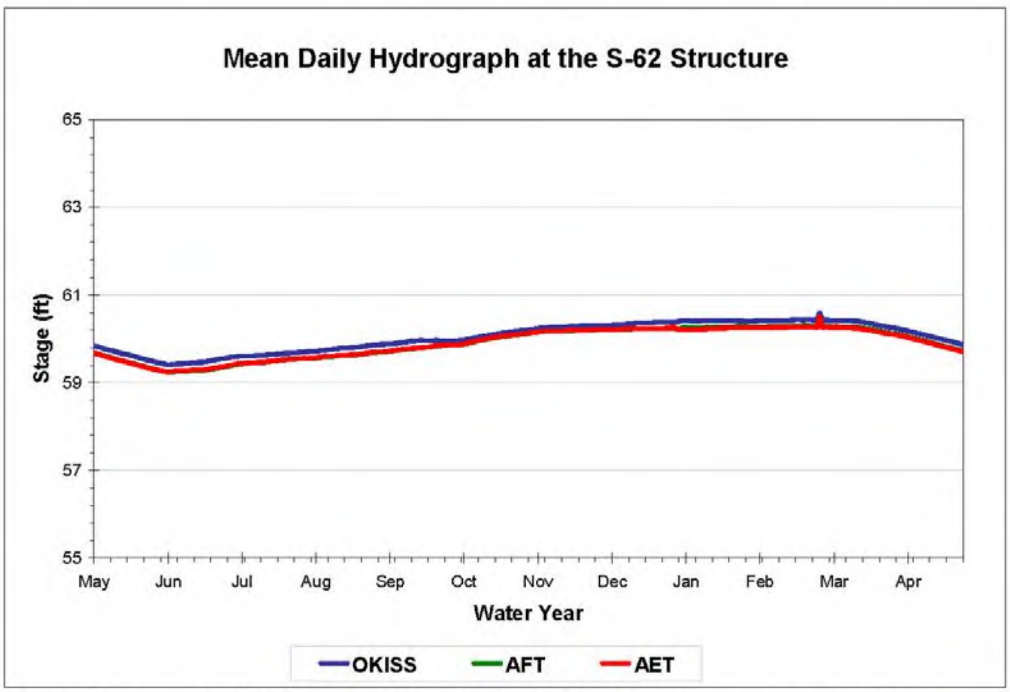

Figure 5-22: Lake Hart (L07) Mean Daily Stage Hydrograph for Base Condition

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5.2.2 Kissimmee River Stages and Flow

Kissimmee River stage and flow time series obtained from the model output were used to generate plots similar to those plots included in the Tier 2 of the Performance Measures Evaluation Report. These plots are stage and flow hydrographs and stage and flow duration curves for those locations were Performance Measures R01 to R03 are calculated.

Figure 5-23 through Figure 5-28 display the results for the "With Project" base model. Figure 5-23 shows a very good agreement between model results. Figure 5-25 to Figure 5-28 reflect that there are some small differences due to the better accuracy obtained with the AFET-W models as opposed to the surrogate computation added to OKISS to simulate the hydraulics of the Kissimmee River floodplain. These differences are acceptable and expected since the Alternative Evaluation System being used in the KBMOS was designed to incrementally increase the accuracy of the modeling tools as the study stages progress.

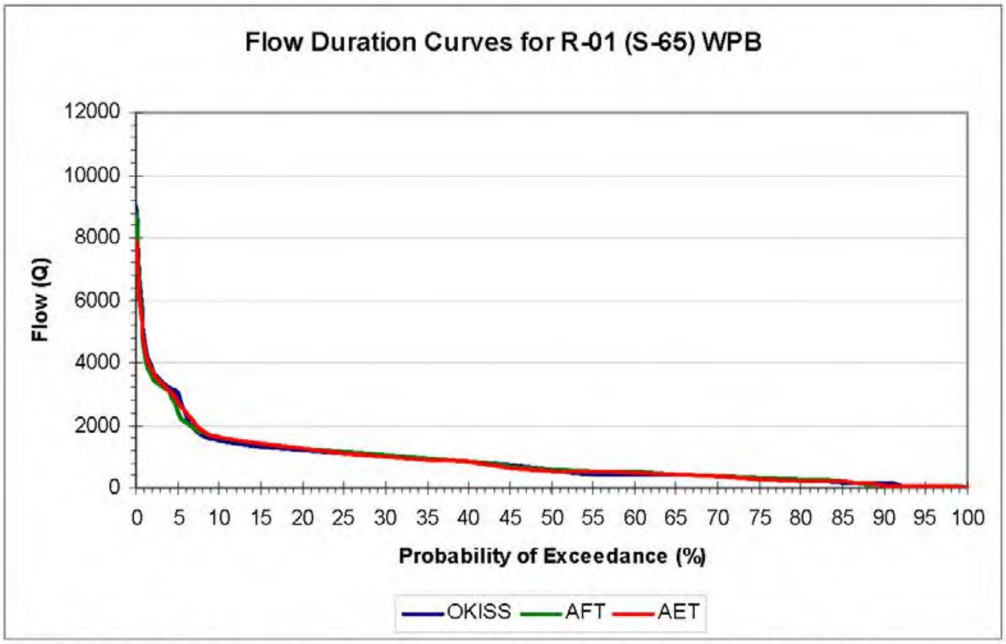

Figure 5-23: S-65 Structure Flow (R-01) Duration Curve for Base Condition

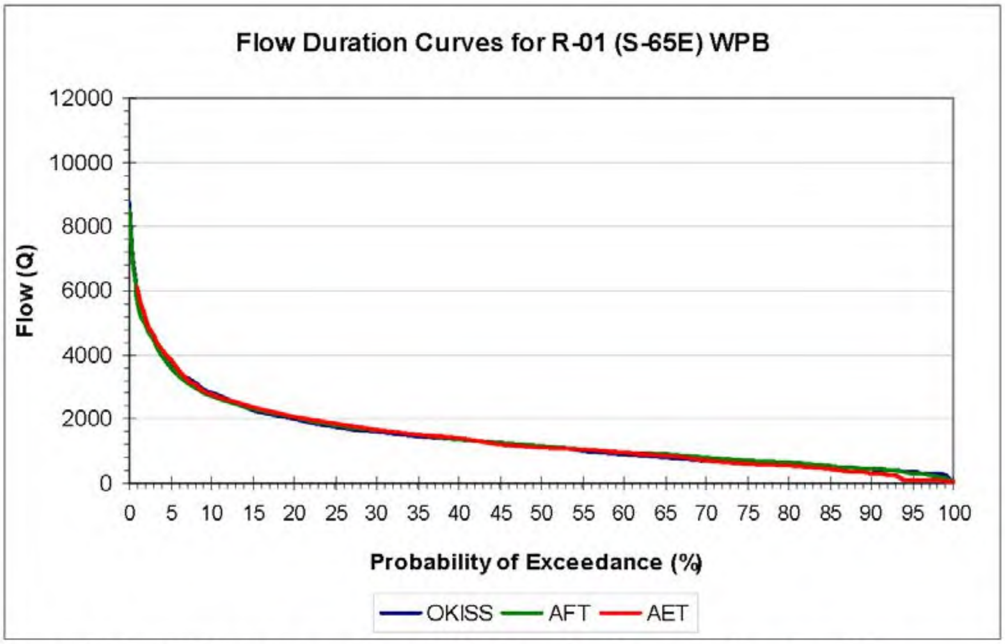

Figure 5-24: S-65E Structure Flow (R-01) Duration Curve for Base Condition

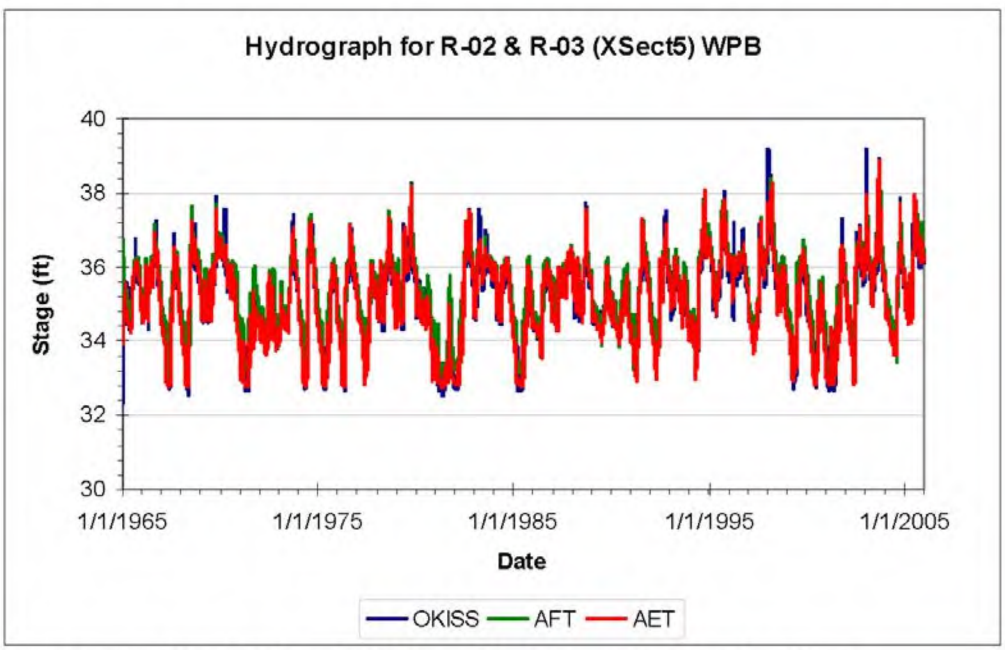

Figure 5-25: XS-5 (R-02 and R-03) Stage Hydrograph for Base Condition

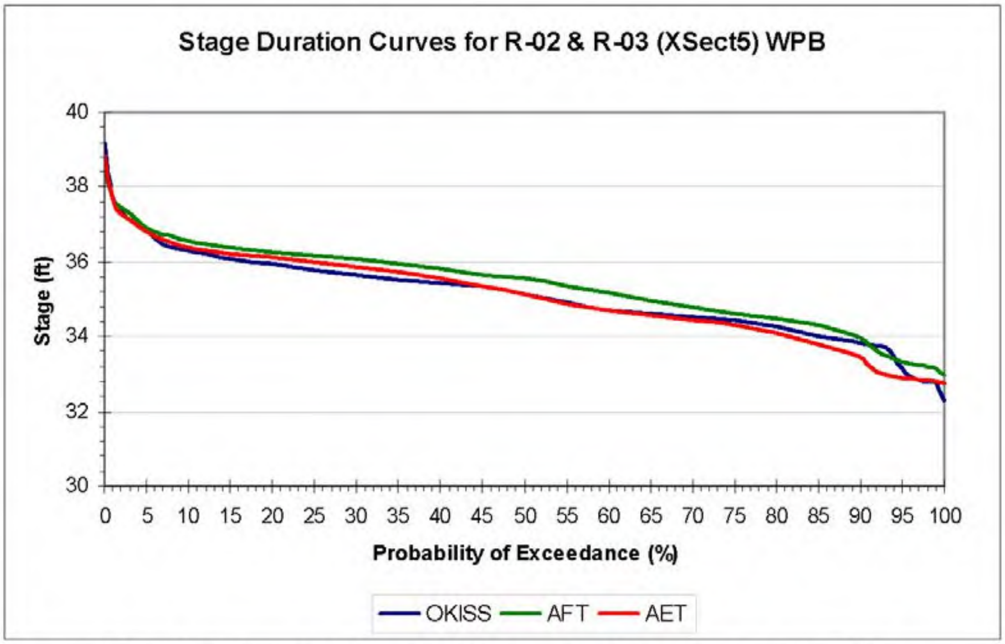

Figure 5-26: XS-5 Stages (R-02 and R-03) Duration Curve for Base Condition

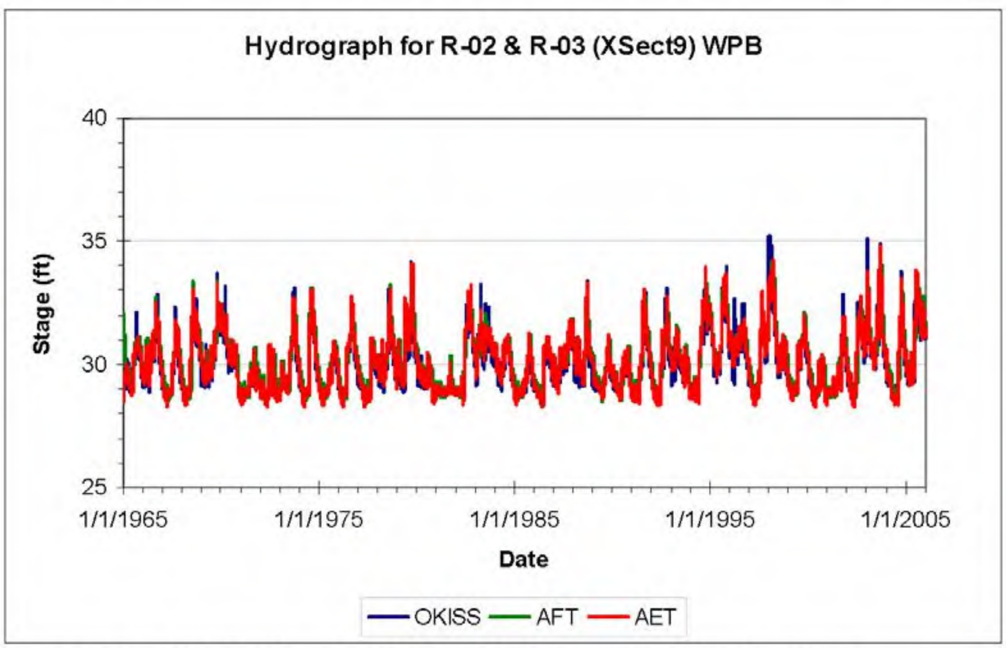

Figure 5-27: XS-9 (R-02 and R-03) Stage Hydrograph for Base Condition

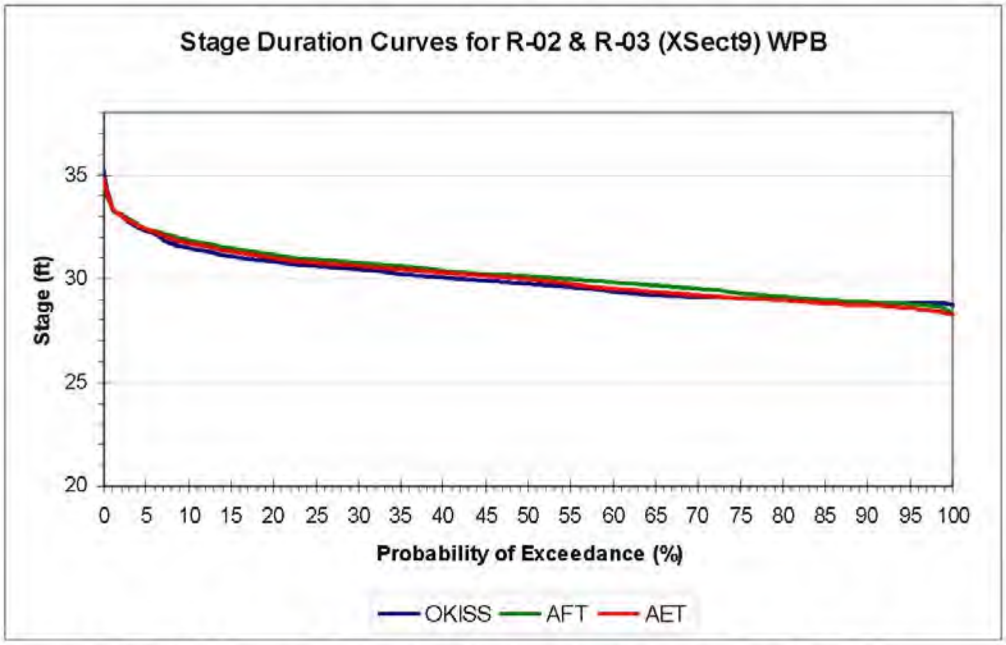

Figure 5-28: XS-9 Stages (R-02 and R-03) Duration Curve for Base Condition

5.3 Comparison of Performance Measure Component Values

The model output was run through the PME Tool. This tool calculates the value of all components of the lake and river performance measures. Appendix E contains lists with the component values computed for each one of the study modeling tools. Appendix E also contains a graphical representation of these components relative to their targets. Tables included in Appendix E also contain a description of all components of the performance measures.

The information included in Appendix E has been summarized in scatter plots, shown in Figure 5-29 to Figure 5-31. These plots were constructed by expressing the component values obtained with the PME Tool for all components, all performance measures in terms of percentage of their target. Three comparisons are performed, including OKISS versus AFT, AET versus AFT and OKISS versus AET. In each one of the figures, the percentage obtained with the first model is included in the X-axis and the percentage obtained with the second model is included in the Y-axis. Theoretically, if all of the component values had a perfect match across models, the points in the scatter plots would fall within a 45 degree angle line. For comparison purposes, this 45 degree line has been added to the plots (red line). Most of the points in all three plots fall close enough to the 45 degree line used as referenced, with the only exception being Performance Measure L03, Component L. This performance measure is evaluated at Lake Gentry. Component L corresponds to the maximum inter-annual lake stage amplitude. This confirms the observation made in Section 5.2.1 about the leakage in the S-63 Structure and the operation of the S-63A Structure. The alternative evaluation stage of the process will include the modifications made to the operation of the S-63A Structure to address this issue.

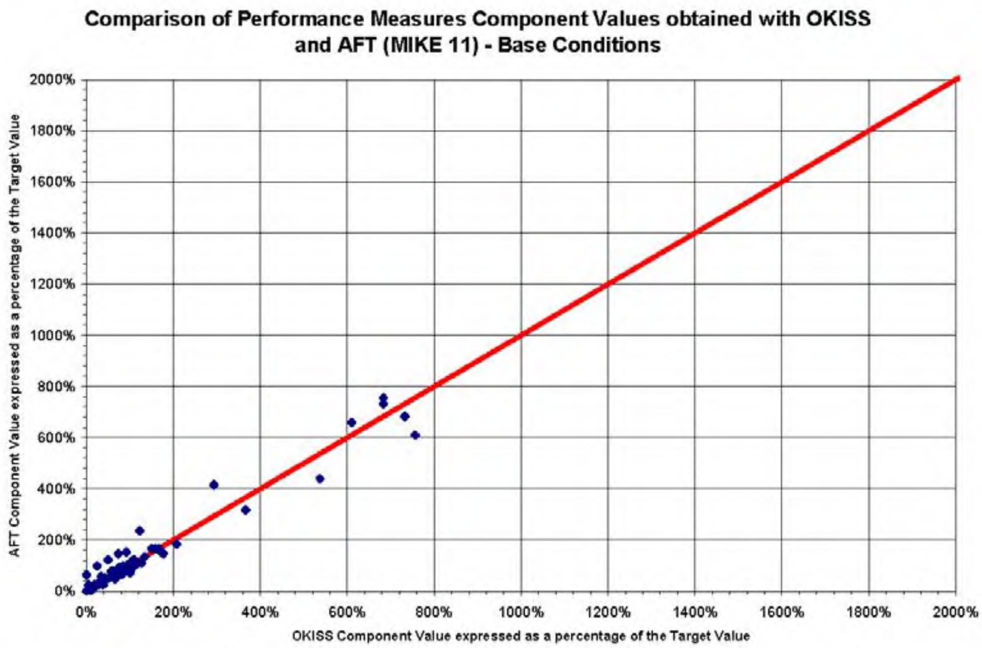

Figure 5-29: Comparison of Performance Measure Component Values obtained with OKISS and AFT for the Base Condition

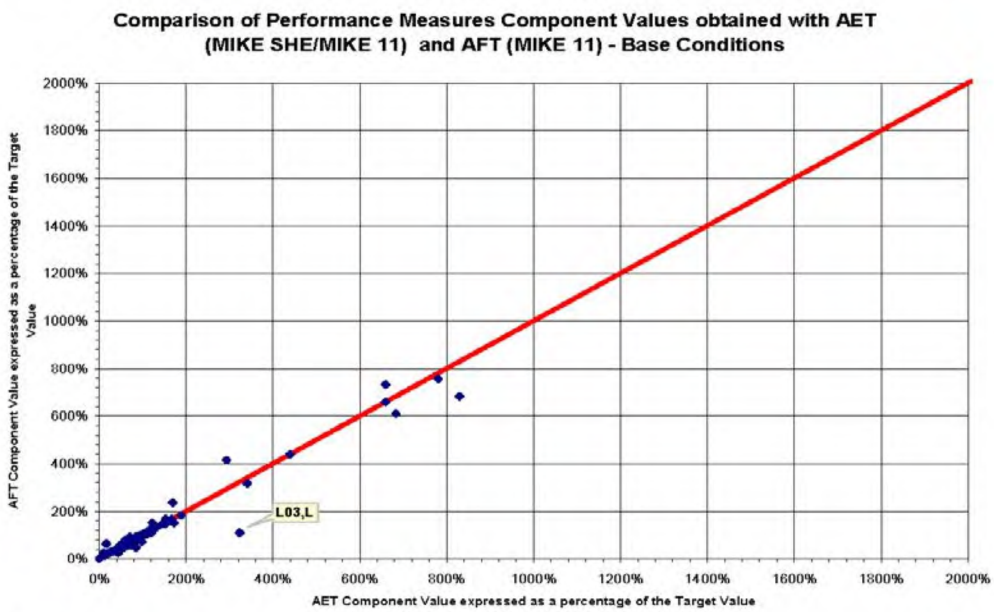

Figure 5-30: Comparison of Performance Measure Component Values obtained with AET and AFT for the Base Condition

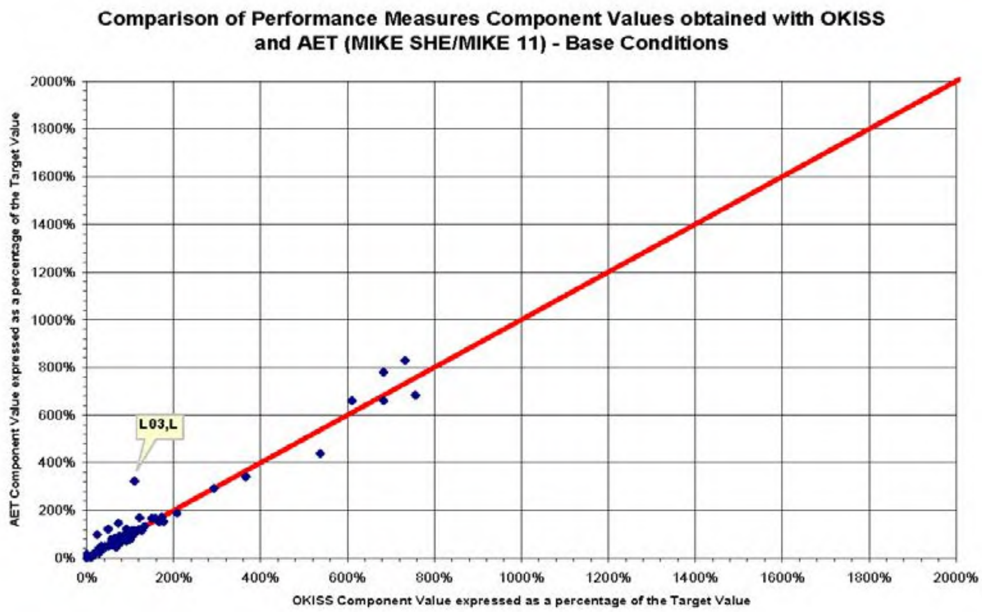

Figure 5-31: Comparison of Performance Measure Component Values obtained with OKISS and AET for the Base Condition

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6 CONCLUSIONS

6.1 Compatibility of Model Results

The KBMOS modeling tools produce comparable component values for the majority of the lake performance measures. There are some explainable deviations between the model output, resulting from the differing treatment of some structures (i.e. S-63A) and the surrogate methodology used to model the hydraulics of the Kissimmee River floodplain in the screening tool. The results of this validation demonstrate that there will be a smooth transition from the screening tool (OKISS) to the more sophisticated AFET-W (MIKE SHE/MIKE 11) models. No definitive conclusion can be drawn of those components that resulted in a value of zero for all models.

To support the analysis described in Section 5, a statistical assessment of the model results was performed using the calibration statistic targets applied during the calibration of the AFET and AFET-W. In this analysis, the results of one model were treated as the "observed" data to be compared to the results obtained of the other model, which were treated as the "simulated" data. Table 6-1 summarizes the results of the analysis.

Table 6-1: Application of AFET and AFET-W calibration statistics to the comparison of the base condition model results

Performance Measure	Variable	*RMSE – "With Project" Base Condition* OKISS versus AFT	OKISS versus AET	AET versus AFT	Calibration Criteria
L-01	S-65 HW Stage	0.34	0.35	0.20	1.00
L-02	S-61 HW Stage	0.22	0.22	0.12	1.00
L-03	S-63 HW Stage	0.33	0.20	0.32	1.50
L-04	S-57 HW Stage	0.24	0.25	0.15	1.50
L-05	S-59 HW Stage	0.22	0.23	0.07	1.00
L-06	S-60 HW Stage	0.17	0.15	0.11	1.50
L-07	S-62 HW Stage	0.25	0.26	0.04	1.50
R-01A	S-65 Flow	N/A	N/A	N/A	N/A
R-01B	S-65E Flow	N/A	N/A	N/A	N/A
R-02/R-03 A	XS-5 Stage	0.43	0.32	0.45	1.00
R-02/R-03 B	XS-9 Stage	0.45	0.35	0.37	1.00
		R - "With Project" Base Condition			
Performance Measure	**Variable**	**OKISS versus AFT**	**OKISS versus AET**	**AET versus AFT**	**Calibration Criteria**
L-01	S-65 HW Stage	0.99	0.99	0.99	0.75
L-02	S-61 HW Stage	0.99	0.98	0.99	0.45
L-03	S-63 HW Stage	0.95	0.99	0.96	0.45
L-04	S-57 HW Stage	0.99	0.98	0.99	0.45
L-05	S-59 HW Stage	0.98	0.98	1.00	0.75
L-06	S-60 HW Stage	1.00	1.00	1.00	0.45
L-07	S-62 HW Stage	0.97	0.97	1.00	0.45
R-01A (flow)	S-65 Flow	0.93	0.93	0.96	0.84
R-01B (flow)	S-65E Flow	0.98	0.95	0.93	0.84
R-02/R-03 A	XS-5 Stage	0.96	0.96	0.96	0.75
R-02/R-03 B	XS-9 Stage	0.95	0.96	0.96	0.75
		CE%- "With Project" Base Condition			
Performance Measure	**Variable**	**OKISS versus AFT**	**OKISS versus AET**	**AET versus AFT**	**Calibration Criteria**
R-01A	S-65 Flow	0.40%	0.07%	0.47%	15%
R-01B	S-65E Flow	1.86%	0.08%	1.75%	15%

As seen in the aforementioned table, all of the locations passed the criteria used in the calibration of the AFET-W with no exceptions.

6.2 Application of KBMOS Models

The comparisons and evaluations documented in this report validate the use of the KBMOS model to screen, formulate and evaluate alternative plans. Time series of stages and flows obtained by the KBMOS models at each stage of the Alternative Plan Selection Process are suitable to compute PME Tool scores and component values. A smooth transition is expected between the study stages (screening, formulation and evaluation).

Although the AFET-W is more suitable than OKISS to evaluate flood events, the fact that all models either use lateral inflows developed on daily time-steps (OKISS and AFT), or are driven by daily rainfall (AET), caution should be use when applying the current models to evaluate storm events. It is recommended that a storm event calibration/verification be performed using rainfall data with sub-daily time-steps. This storm event calibration will need to make an emphasis on the effect that downstream conditions have on the capacity of the structures to discharge during storm events.

7 REFERENCE

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APPENDIX A

Comparison of Previous KBMOS Base Conditions Results

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1 BASE CONDITION RUNS PREVIOUSLY DEFINED IN KBMOS

KBMOS future and current base conditions are described in the Evaluation of Base Conditions Report (AECOM 2008). This section analyzes the results obtained in terms of total basin runoff as compared to the available information.

1.1 Future Base Conditions

A future base condition run was defined within KBMOS. These base conditions corresponded to the fully restored Kissimmee River under a future land use scenario. The first model results obtained from these base conditions indicated a large difference in basin runoff, as compared to the total basin runoff obtained with the model run corresponding to the current base conditions. Since the rest of the model drivers are kept constant in the base conditions, these differences in basin runoff were all due to changes in land use. These results raised concerns over the assumptions made to generate the "future" land use coverage. Therefore, base conditions used for ongoing Kissimmee Basin planning efforts will only use the current land use.

1.2 Current Base Conditions

The basic description of the KBMOS current base conditions is included below:

- Current Land Use (2000):
  - Consistent with Current Kissimmee Basin Water Supply Planning Efforts
- Historic Rainfall (1965 to 2005)
  - Data derived from the 2-mile square grid data (HESM Standard)
- RET
  - Single data point RET (composite time series)
- Completed KRRP
  - USACE Infrastructure
- Existing Permitted Surface Water and Groundwater Uses as of August 31, 2008
  - SFWMD Permit Database
- Operations
  - Headwaters Revitalization Schedule at the S-65 Structure
  - Current Regulation Schedules all other structures

Prior to the development of the "With Project" base condition, the KBMOS team ran two versions or revisions of the current base condition, as described below.

1.2.1 Base Conditions Revision Zero

The initial current base condition run included a set of RET data that consisted of a single time series for the entire basin (not spatially distributed) and was compiled from multiple data sources.

Figure A-1 and Figure A-2 show comparisons of runoff and cumulative flow at the S-65 Structure for the current base condition Revision Zero. As seen in these figures, the current base condition Revision Zero is over-predicting basin runoff.

However, it is important to emphasize that data collection and management is a very complex and challenging task within the SFWMD. The SFWMD is constantly updating the time series of recorded flows and stages. Flow recording is particularly challenging. Flow is calculated by the SFWMD using an equation that represents the flow through the type of structures where the flow is being computed (mostly gated spillways and gated culverts). Therefore, the time series of flows is affected by errors associated with the data used by those equations (stages and gate openings) and by errors associated with the equations. The SFWMD has been updating the equations used to compute the flows and identifying datum issues that could be affecting the calculation of flows. As a result of these efforts, there are several time series or "DBKEYS" with available information. In addition to the QA/QC efforts carried out by the SFWMD, there had been several changes in the methodologies used to collect the stage information used to compute flows. Stages are currently recorded using digital devices, but in the past they had been recorded with graphical devices. Gate openings were collected manually in the past. For the main structures representing total runoff from the KUB and LKB (S-65 and S-65E Structures, respectively) the SFWMD has been responsible for the data collection activities only after 1996. Therefore, the study team believed that recent data (1996 to present) may have had the level of accuracy sufficiently reliable to be compared to the results of the base condition simulations.

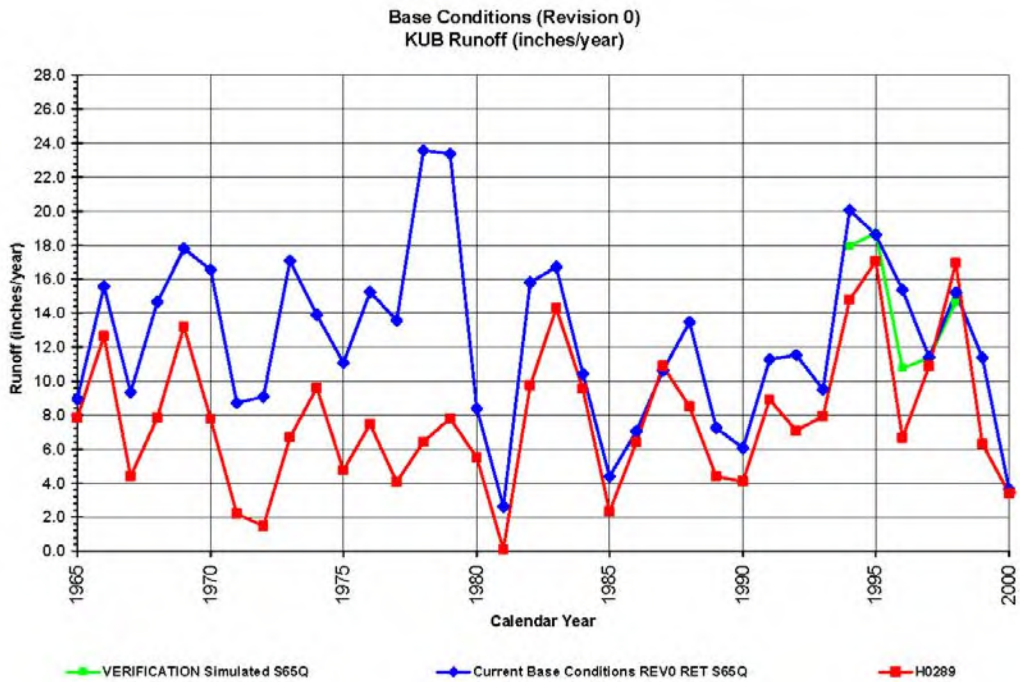

Figure A-1: Comparison of Annual Runoff at the S-65 Structure – Current Base Condition Revision Zero versus Observed Flow

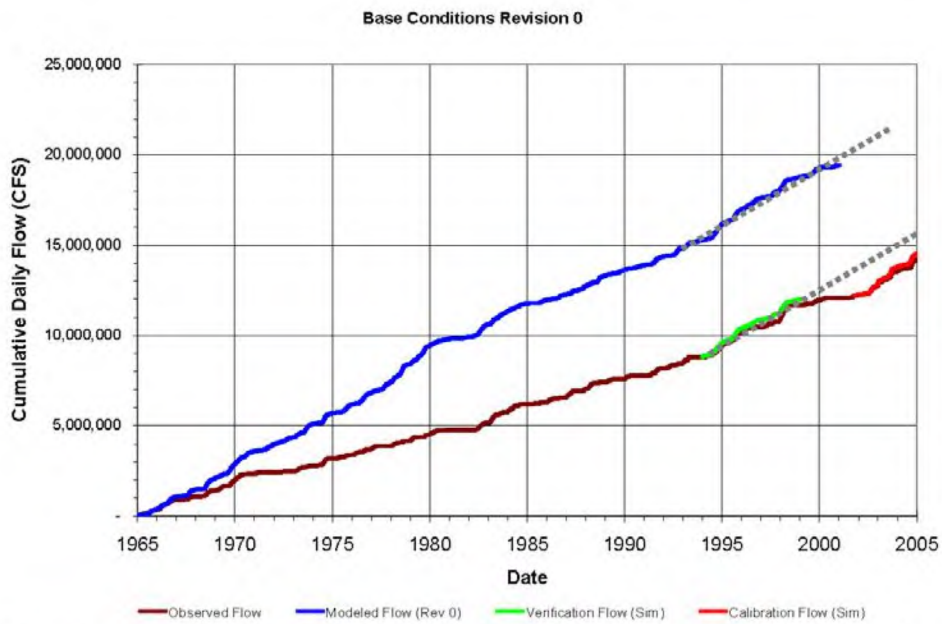

Figure A-2: Comparison of Cumulative Flow through the S-65 Structure – Current Base Condition Revision Zero versus Observed Flow

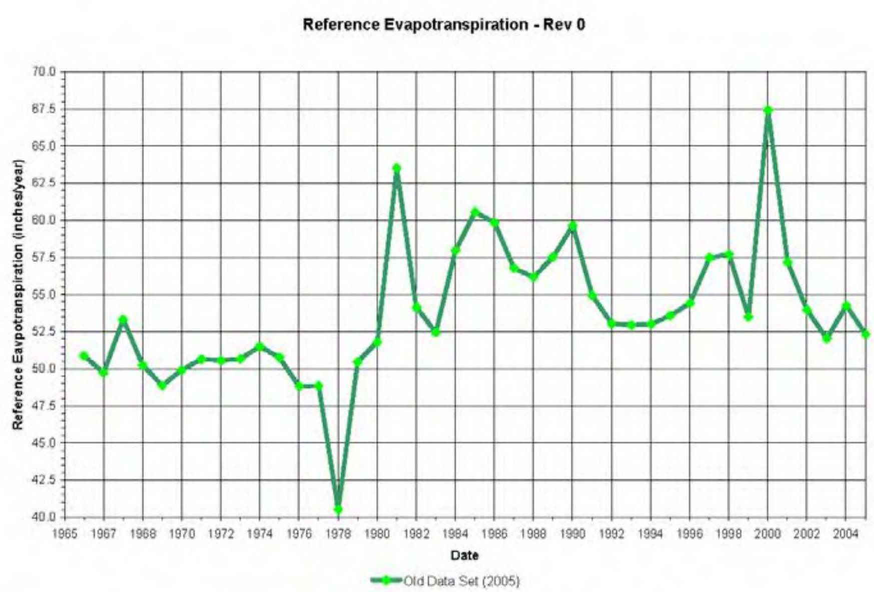

Figure A-3: Annual Summary of RET Data used in Revision Zero

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The differences between modeled results and observed data cannot be explained by the lack of accuracy in the observed data. The plot included in Figure A-3 shows that the RET values used to drive Revision Zero had a shift in their average after 1980. This shift is not explained by any climatologic phenomenon and it may be an artifact of the methodology used to calculate the RET time series. This shift in RET is also evident in the simulated runoff for the same time period shown in Figure A-4. Based on these data, the RET was identified as a potential source of a portion of the cumulative error evident in Figure A-2.

Since at the time Revision Zero was run there was no other data source available, it was decided to manually adjust the RET data set and re-run the current base conditions. This adjustment process created what is called "Revision One".

1.2.1.1 Revision One

As mentioned in the previous section, the RET values used in Revision Zero had annual values that were, on average, five inches per year lower in the period from 1965 to 1980 than in the period from 1980 through 2005. As is the case with the flow records, it is believed that the most recent data are more accurate than older information due to the advances in the methodologies to collect, process, transmit and store the information. For those reasons and given the lack of a better source of data, a manual adjustment was introduced to the RET data. The RET data set was adjusted with monthly multipliers that were applied to the RET time series (1965 to 1980). Table A-1 summarizes the adjustment factors applied to the original RET time series .In addition to the adjustments done to the pre-1980 data, evident outliers were removed in January and February of 2000. The annual summary of the resulting RET time series is depicted in Figure A-3.

Table A-1: Adjustment Factor Applied to the RET Data (1965 to 1980) Revision Zero

Month	Multiplier
JAN	1.16
FEB	1.18
MAR	1.08
APR	1.09
MAY	1.11
JUN	1.14
JUL	1.12
AUG	1.12
SEP	1.08
OCT	1.12
NOV	1.14
DEC	1.17

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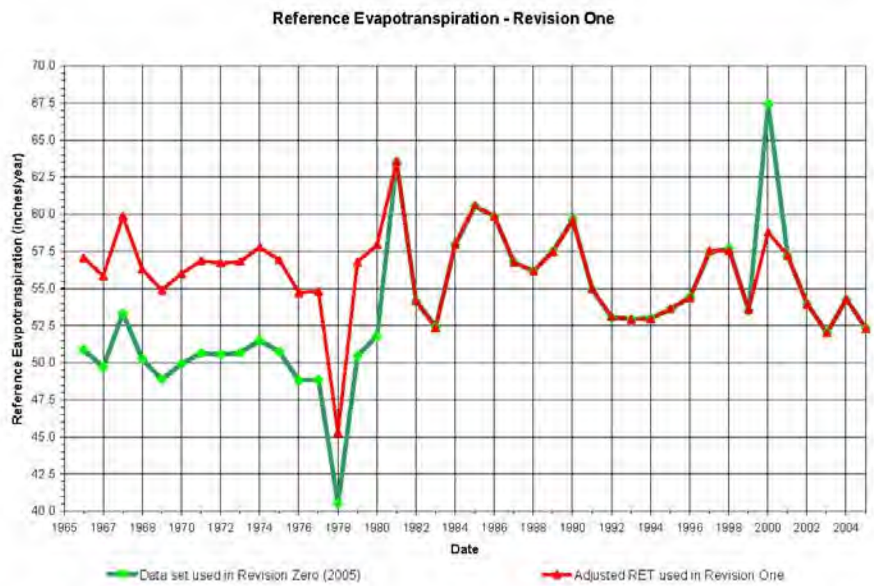


Figure A-4: Annual Summary of RET Data used in Revisions One and Zero

This time series was still not the desired data set since it was a unique time series for the entire basin, meaning that it was not spatially distributed. The same data were being applied in the vicinity of the S-65E Structure as was being applied near Orlando. Additionally, as seen in Figure A-4, the adjusted time series still had some oddities or peaks that needed to be resolved or explained.

Figure A-5 shows the results of Revision One in terms of the KUB total runoff (inches/year) measured at the S-65 Structure. This figure shows an improvement from Revision Zero (red line). It is also evident in this figure, as pointed out before, that almost all series coincide after 1996, which is the time period with more confidence in the observed flow data. Perhaps the largest discrepancy observed in the plot is the peak discharge seen in 1978. This coincides with the "oddity" mentioned in the previous paragraph. The RET time series show an unusual dip in that year, when the average annual RET is almost ten inches lower than the average in the entire period.

In June 2008, the SFWMD completed the work associated with the construction of a spatially distributed data set of RET for the entire Kissimmee Basin. This newly available data set generated the need to run Revision Two, described in the following sections.

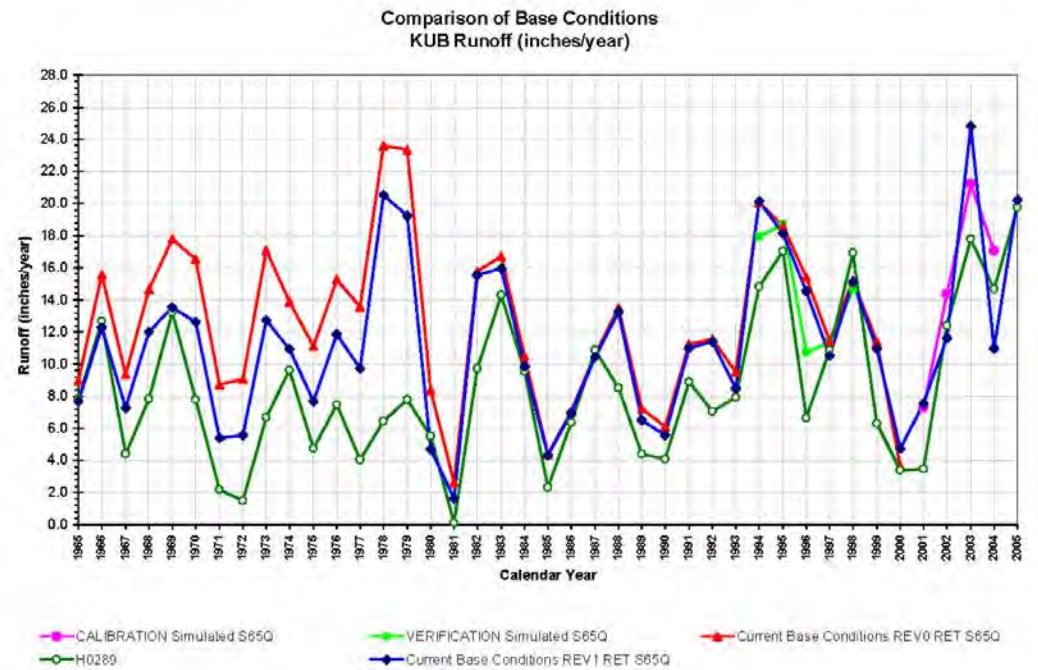


Figure A-5: Comparison of Annual Runoff at the S-65 Structure – Current Base Condition Revision One, Revision Zero and Observed Flow

1.2.1.2 Revision Two - Spatially distributed RET Data

The "With Project" base condition described later in this document used the spatially distributed RET data produced by the SFWMD. This section offers a comparison between the time series used in the latest revision of the base condition run within KBMOS and the newly available data.

1.2.1.2.1 Comparison of RET Daily Data

Figure A-6 shows a plot of the RET daily values for the period used in the calibration of the AFET-W. In comparing the data shown in the figure, it was noted that the revised data and original data both track the same general pattern, but the original data were much more sporadic with more pronounced deviations. In addition to the graphical comparison, statistics were extracted (also only for the period being used to calibrate the AFET-W) and is presented in Table A-2. The statistics show that overall, the revised RET data set was slightly higher (110 percent of original) at the point of comparison. The revised RET data however, had a lower maximum and lower standard deviation.

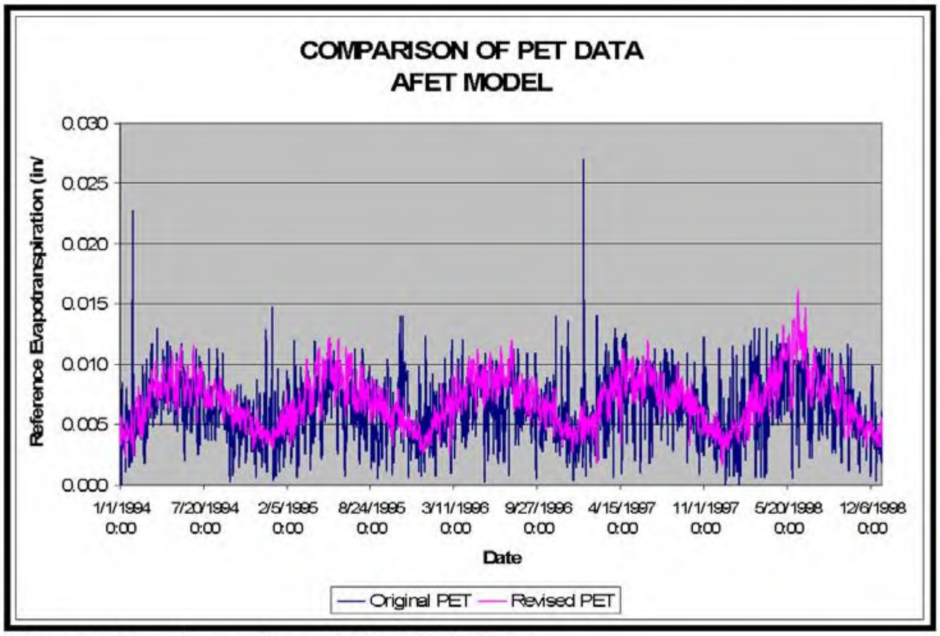


Figure A-6: Comparison of RET Daily Data

Table A-2: RET Statistics (1994 to 1998)

Statistic	Original Potential Evapotranspiration (PET) in/hr	Revised PET in/hr
Mean	0.0063	0.0069
Maximum	0.0270	0.0168
Minimum	0.0000	0.0014
Standard Deviation	0.0027	0.0021

1.2.1.2.2 Comparison of RET Annual Averages

The blue line in Figure A-7 corresponds to the average of the spatially distributed RET data. This new time series is the RET data that were used in the "With Project" base condition, also referenced as Revision Two. This new time series is higher than the previous time series in the period between 1970 and 1980. This period is also the period when the base condition simulated runoff in the previous base condition simulations fell the farthest from the observed data.

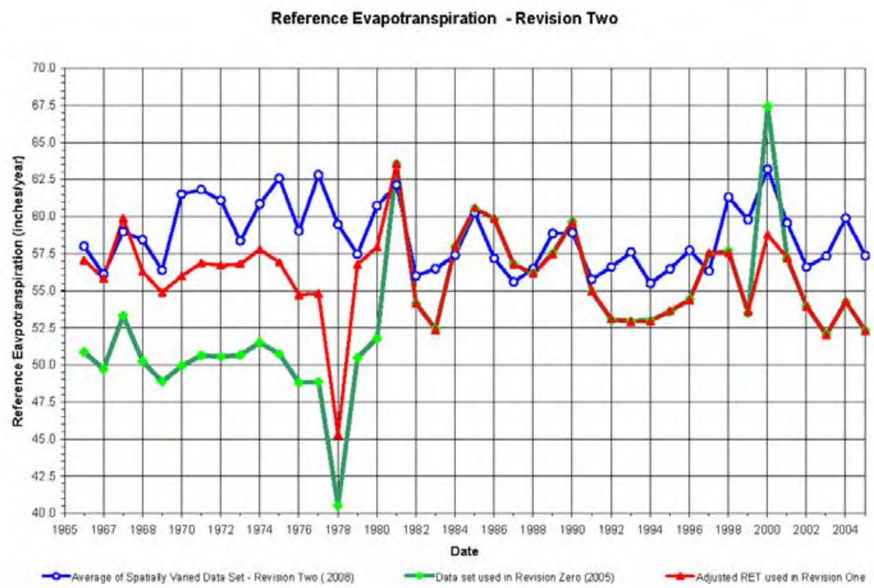


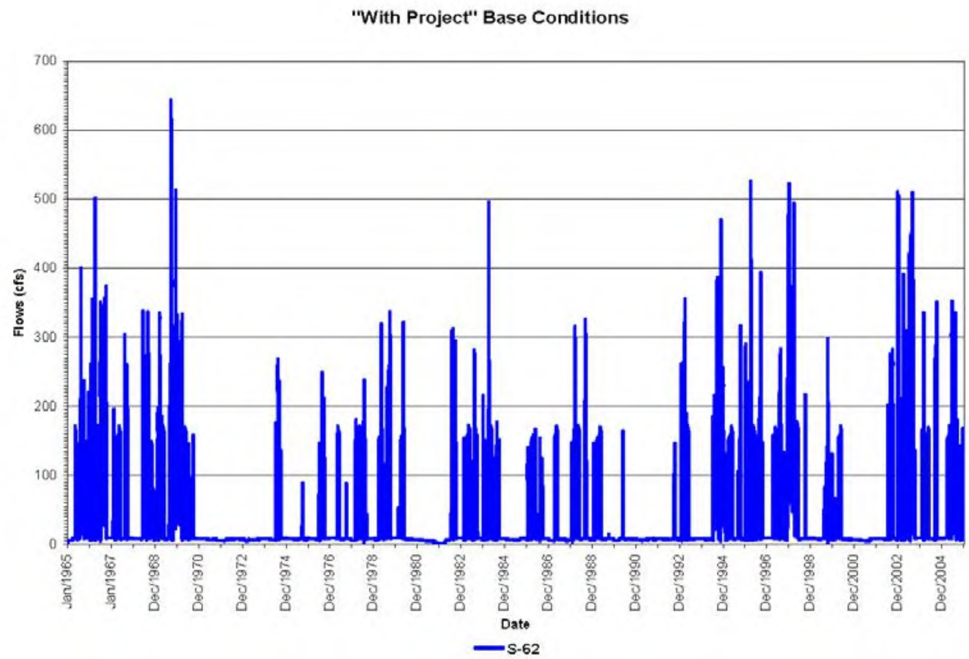
Figure A-7: Annual Summary of RET Data to be used in the "With Project" base condition

APPENDIX B

Stage and Flow Hydrographs at Key Location Obtained for the "With Project" Base Condition Run

AECOM

FLOWS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Flows (cfs)
700
600
500
400
300
200
100
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Jan/1965
Jan/1967
Dec/1968
Dec/1970
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Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
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Dec/1996
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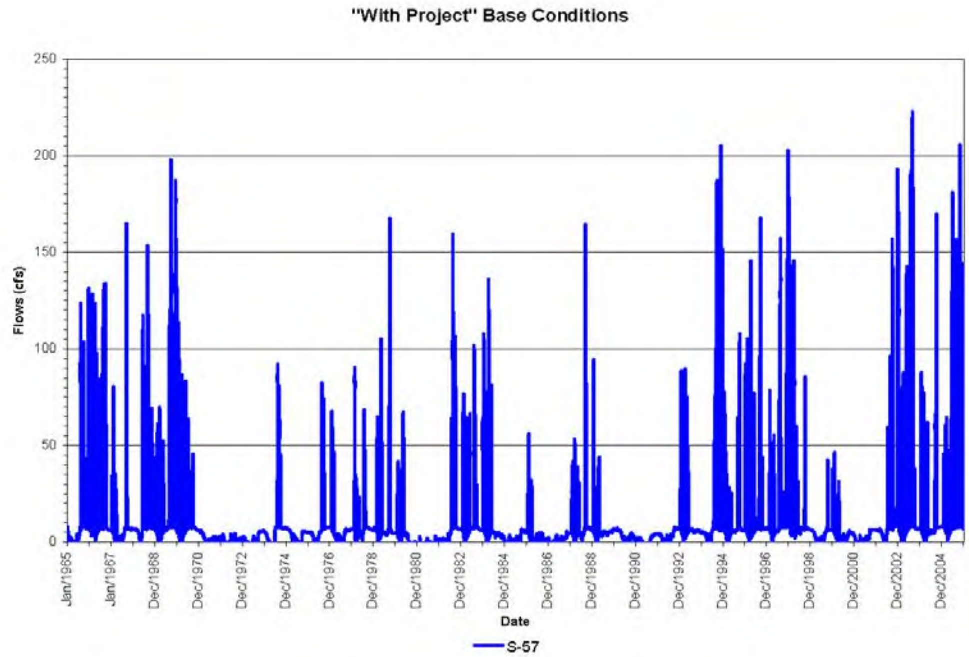
Dec/2000
Dec/2002
Dec/2004
Date
S-62


"With Project" Base Conditions
Flows (cfs)
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200
150
100
50
0
Jan/1965
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Dec/1970
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Dec/1976
Dec/1978
Dec/1980
Dec/1982
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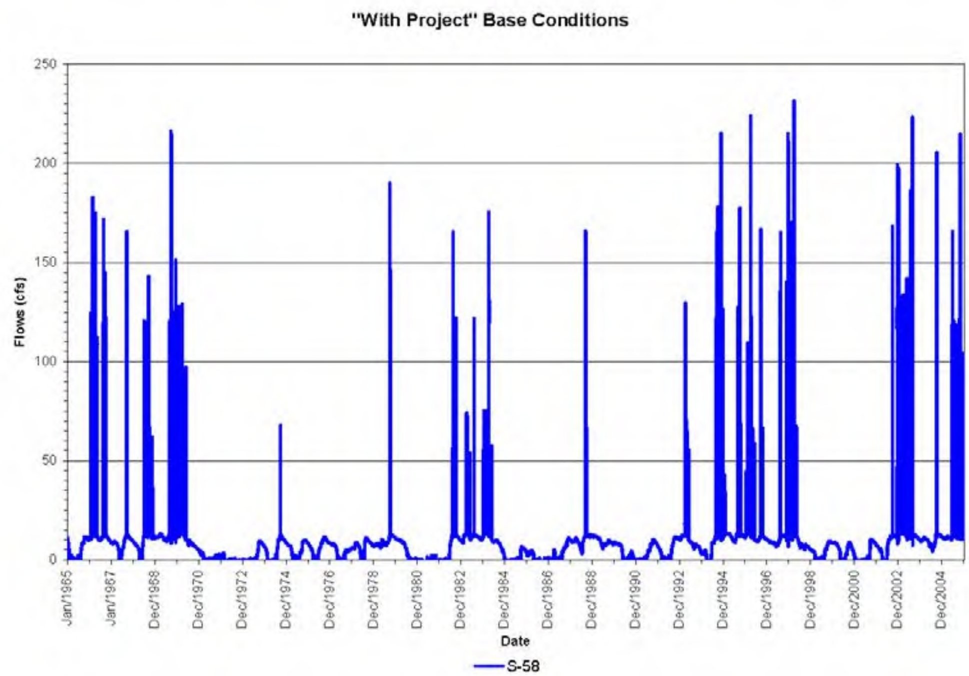
Dec/2004
Date
S-57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Flows (cfs)
250
200
150
100
50
0
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
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Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
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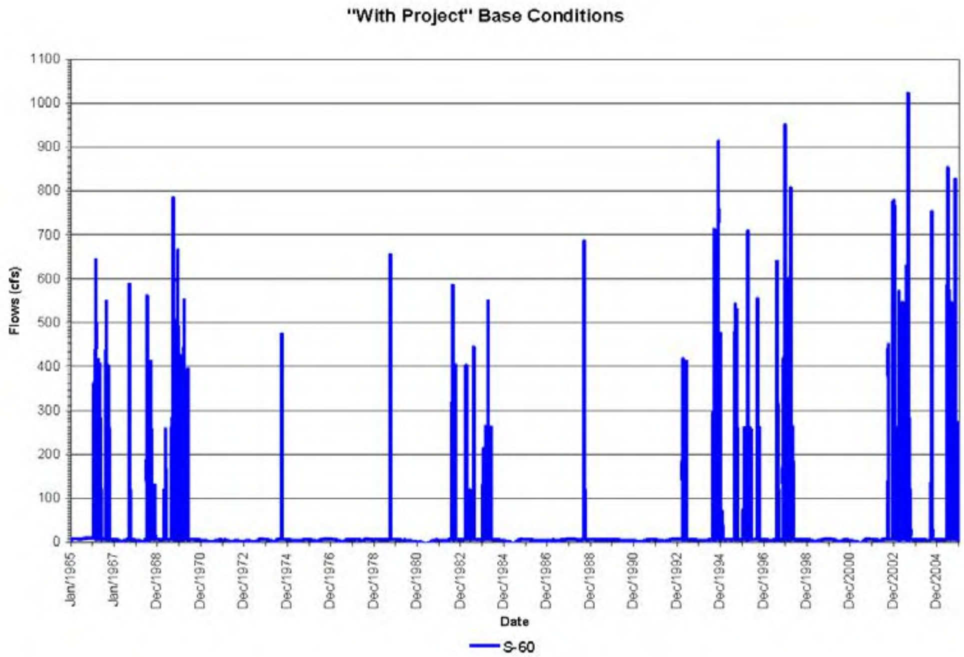
Dec/2004
Date
S-58

AECOM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1100
1000
900
800
700
600
500
400
300
200
100
0
Flows (cfs)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
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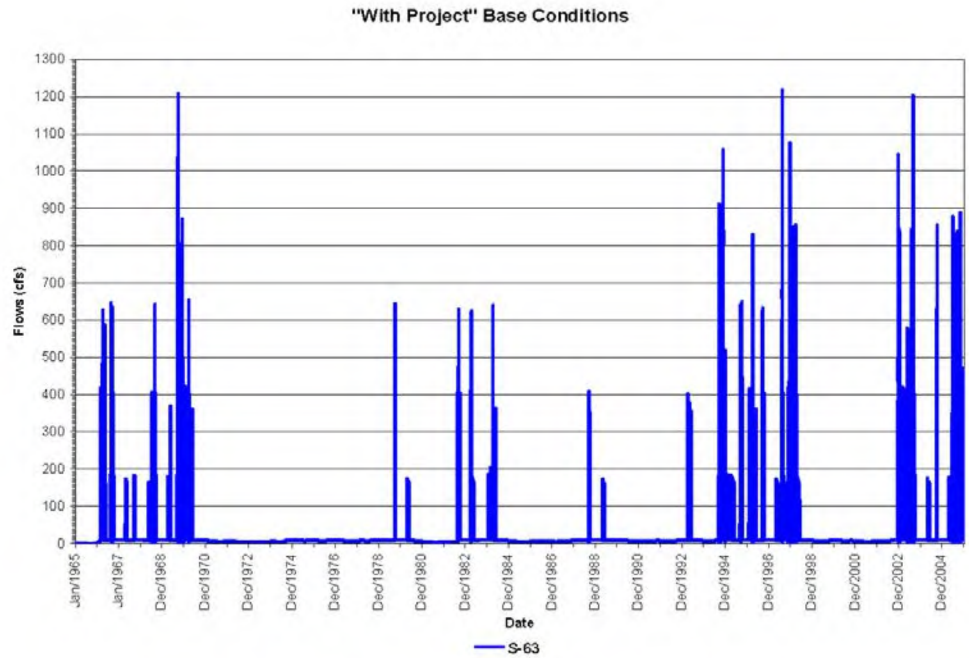
Dec/2004
Date
S-60

AECOM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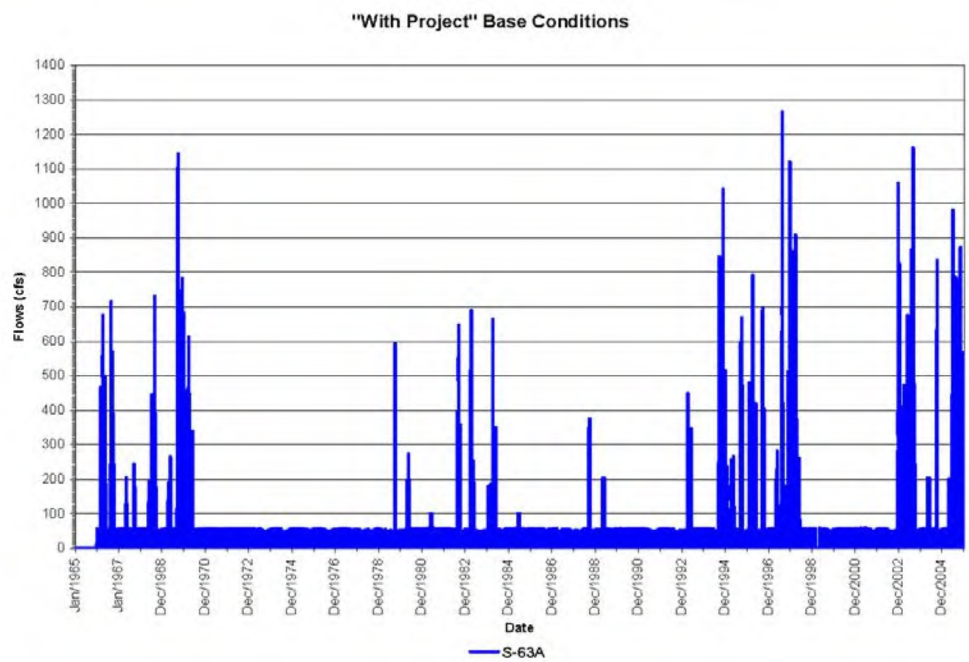
Flows (cfs)
Date
S-63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Flows (cfs)
Date
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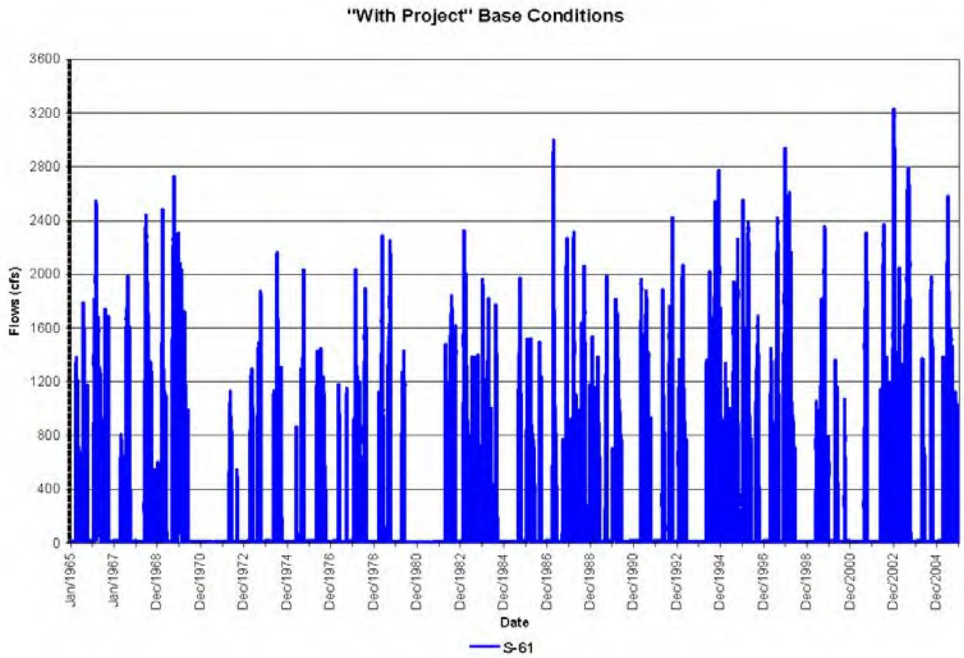
AECOM

B-4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Flows (cfs)
Date
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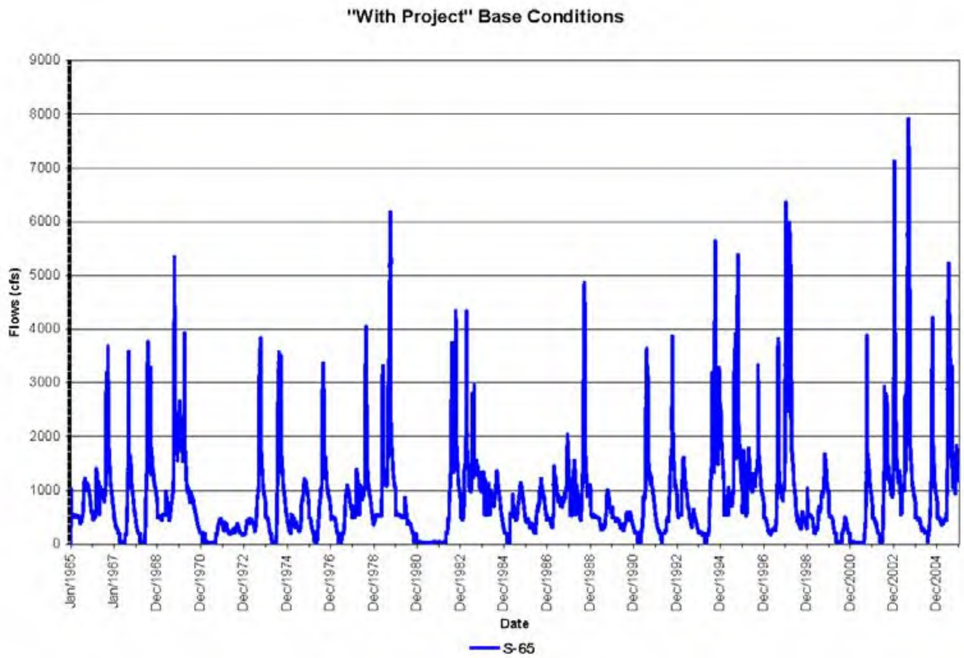
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Flows (cfs)
Date
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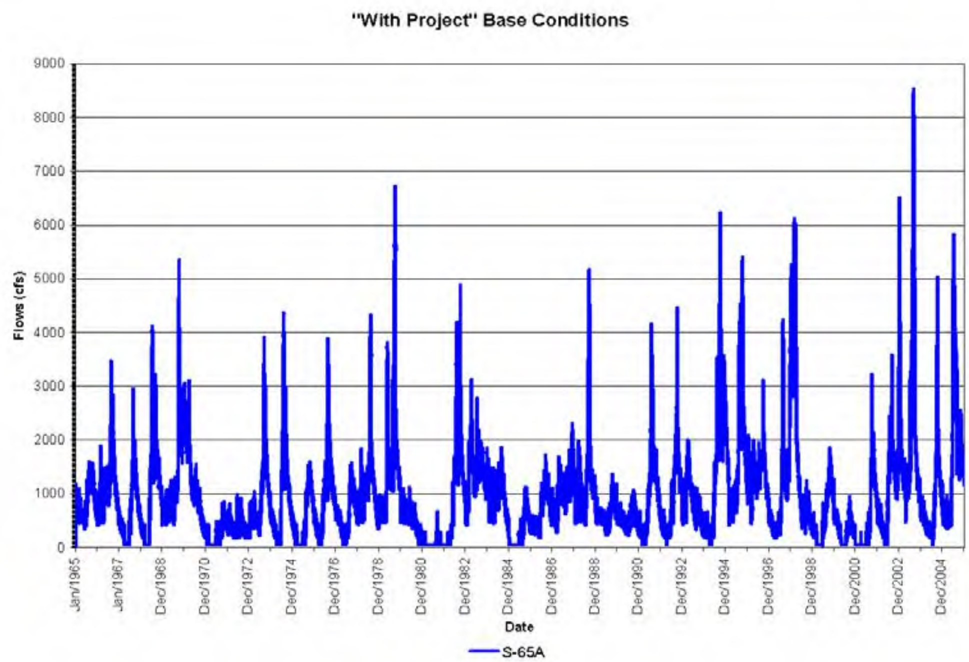
AECOM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7000
6000
5000
4000
3000
2000
1000
0
Jan/1965
Jan/1967
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Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
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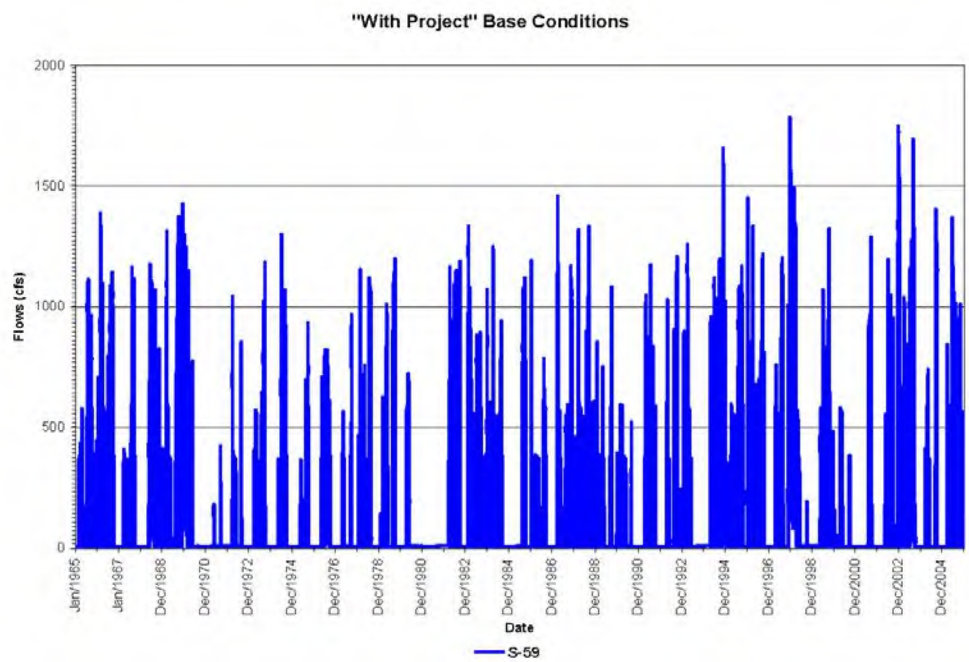
Dec/2000
Dec/2002
Dec/2004
Date
S-65A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Flows (cfs)
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1500
1000
500
0
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
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Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
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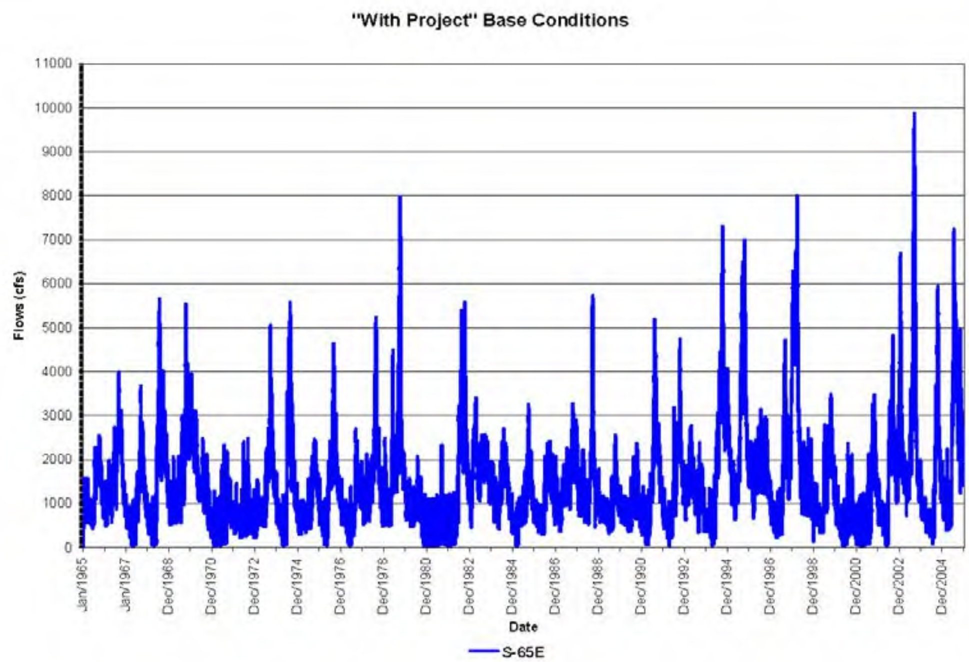
Dec/2002
Dec/2004
Date
S-59

AECOM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9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Flows (cfs)
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Dec/1972
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Dec/1980
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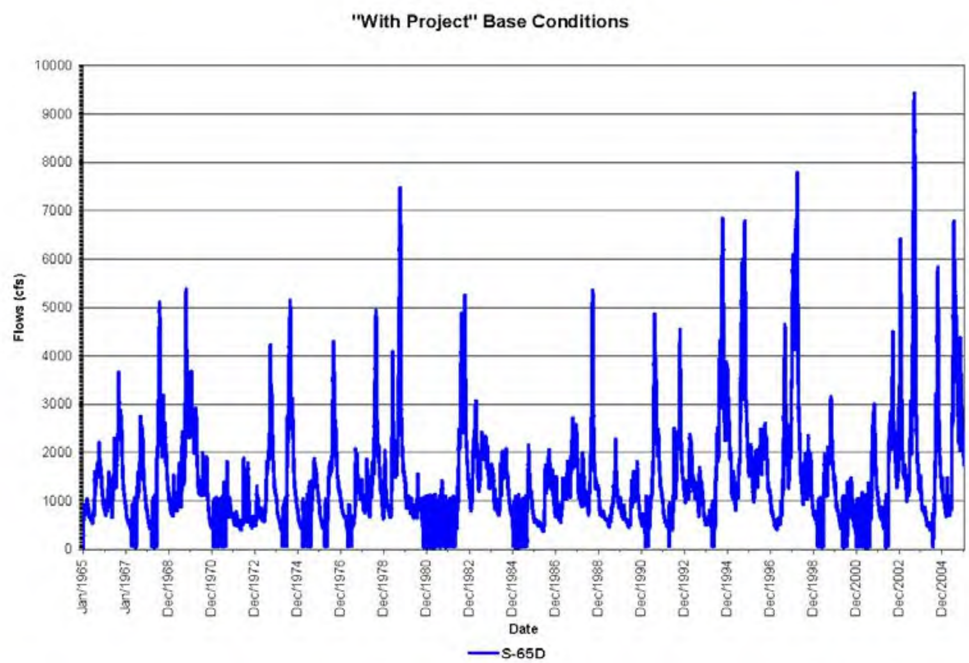
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7000
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5000
4000
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2000
1000
0
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Dec/1980
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Dec/1986
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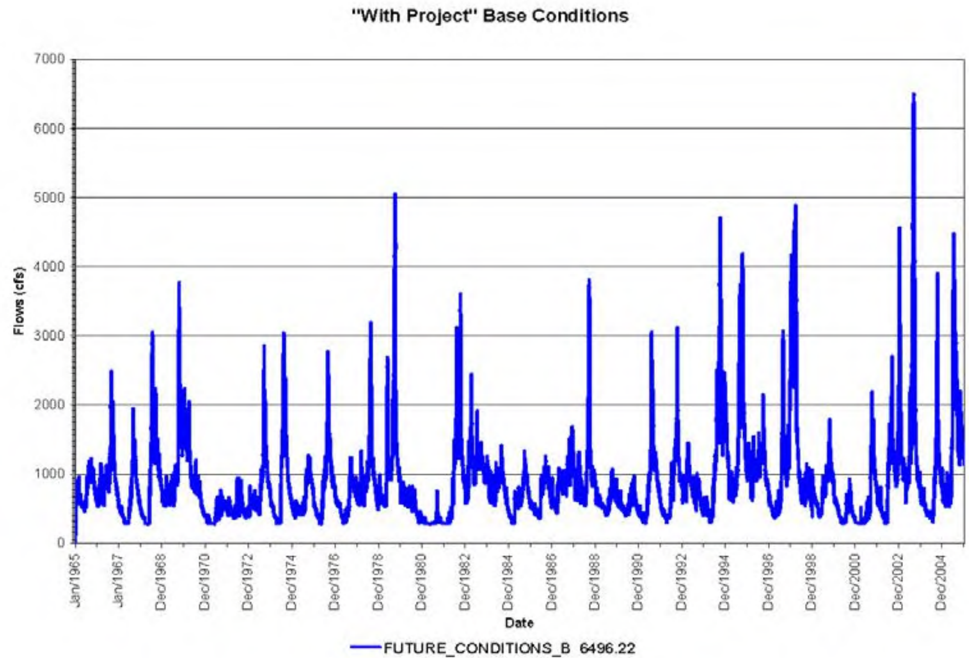
Date
S-65D

AECOM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5000
4000
3000
2000
1000
0
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Jan/1967
Dec/1968
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Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
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Date
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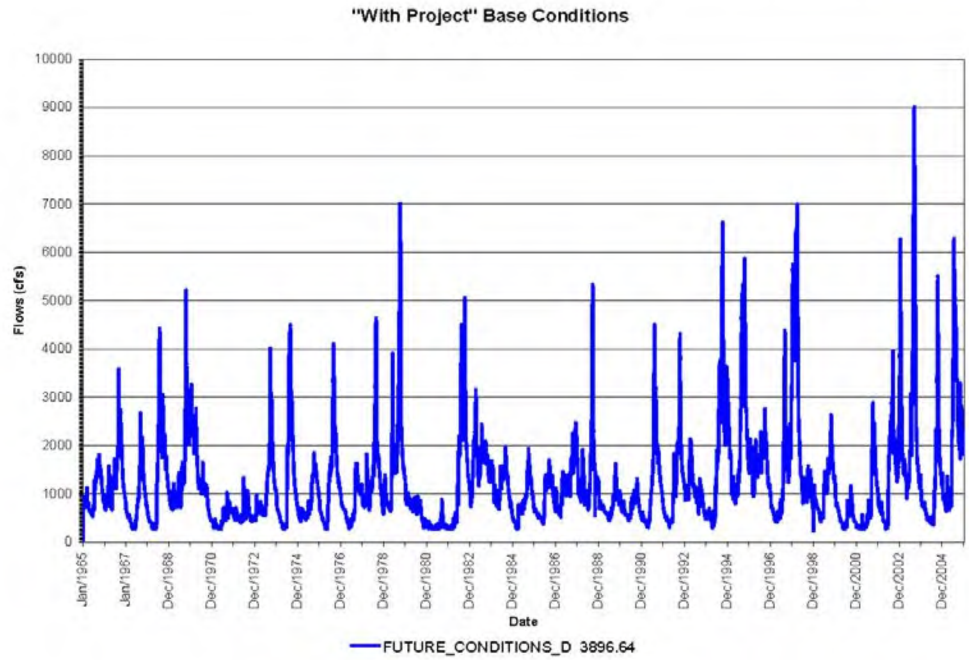
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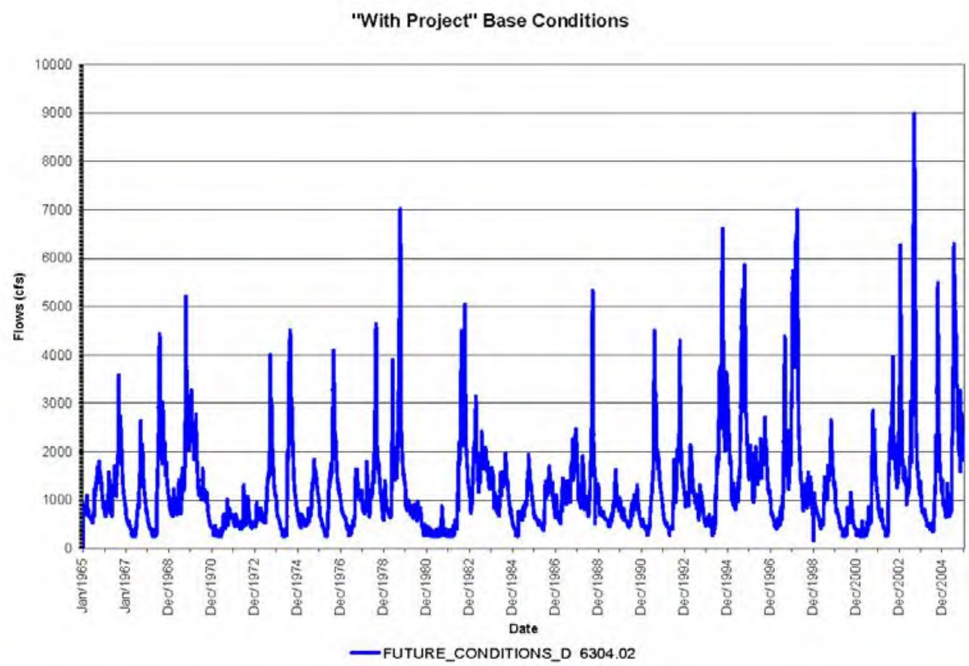
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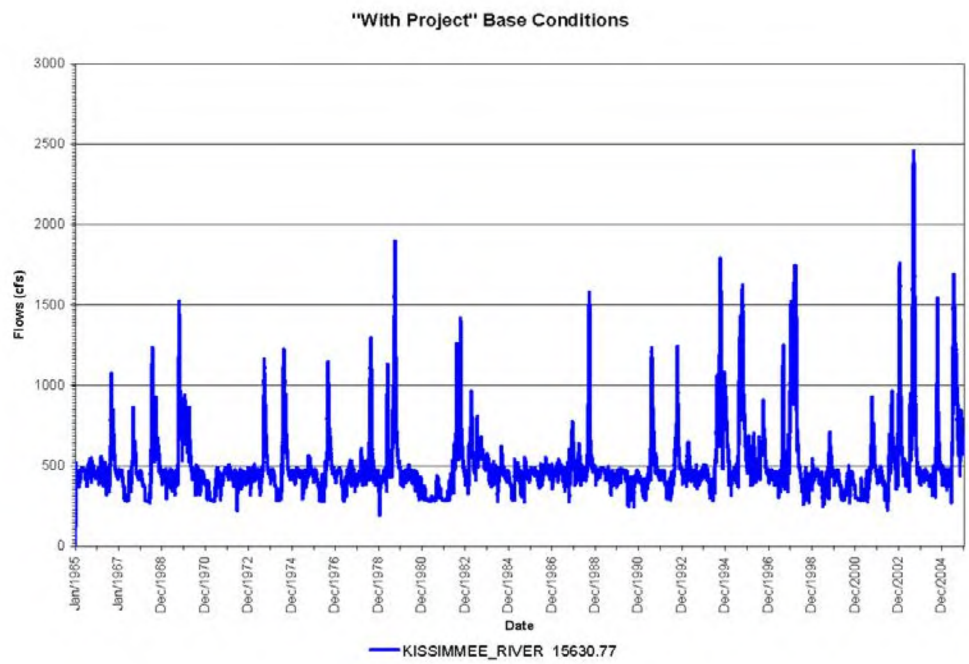
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2000
1500
1000
500
0
Jan/1965
Jan/1967
Dec/1968
Dec/1970
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Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
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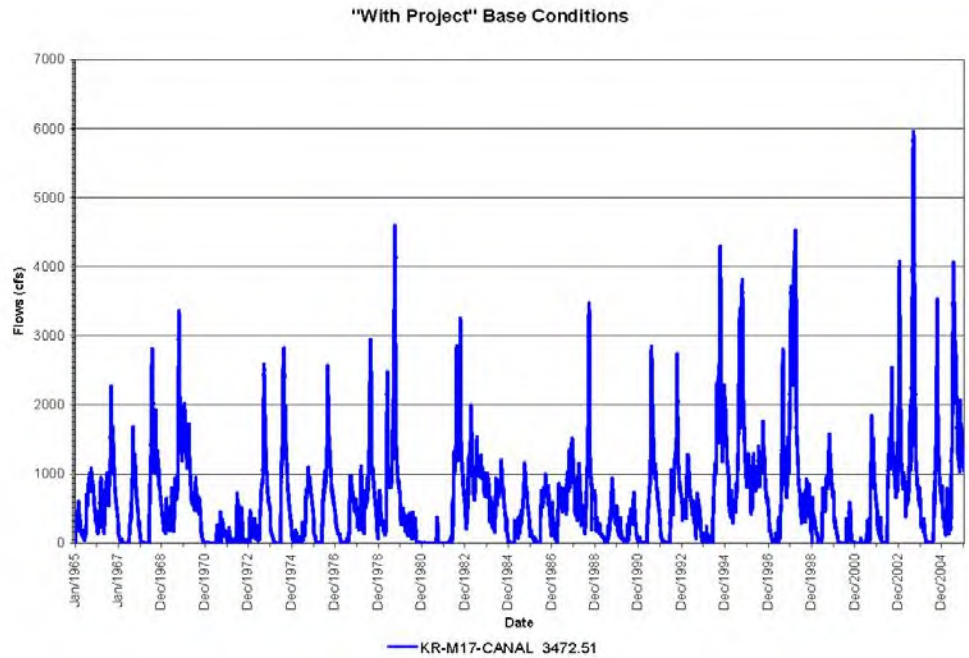
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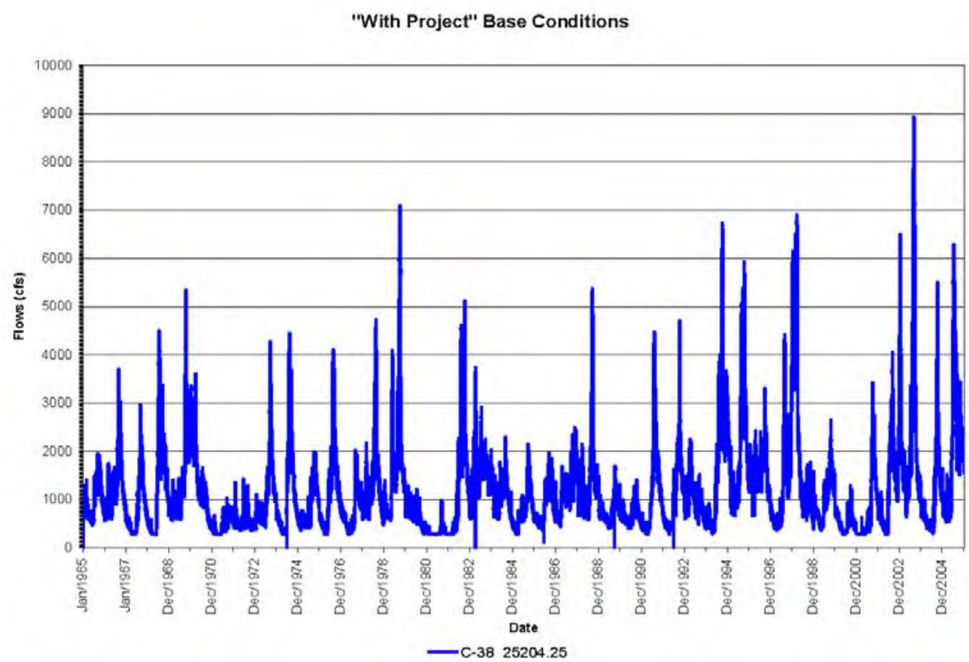
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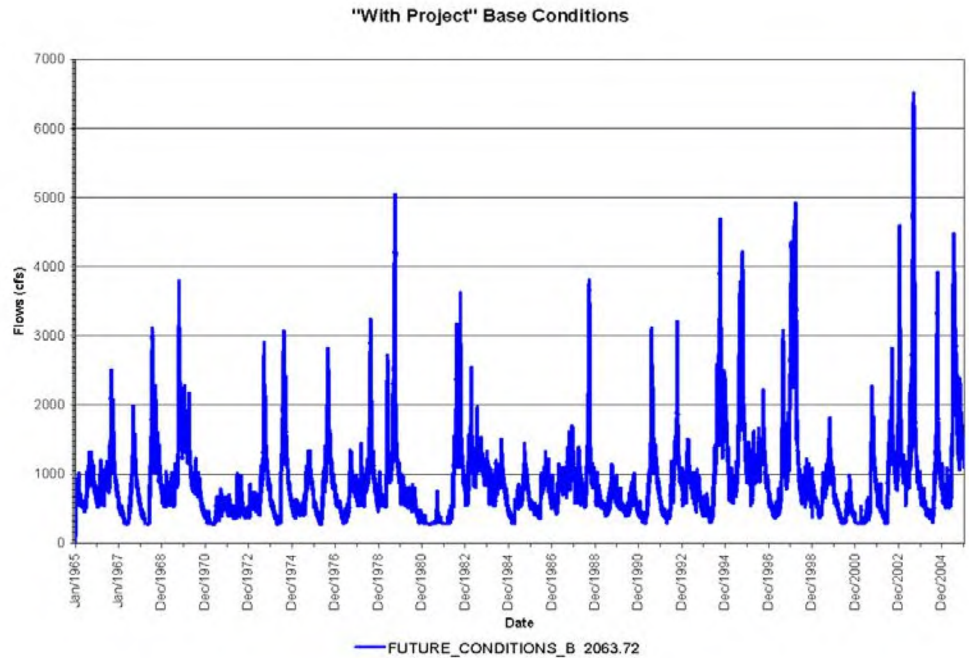
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Dec/1978
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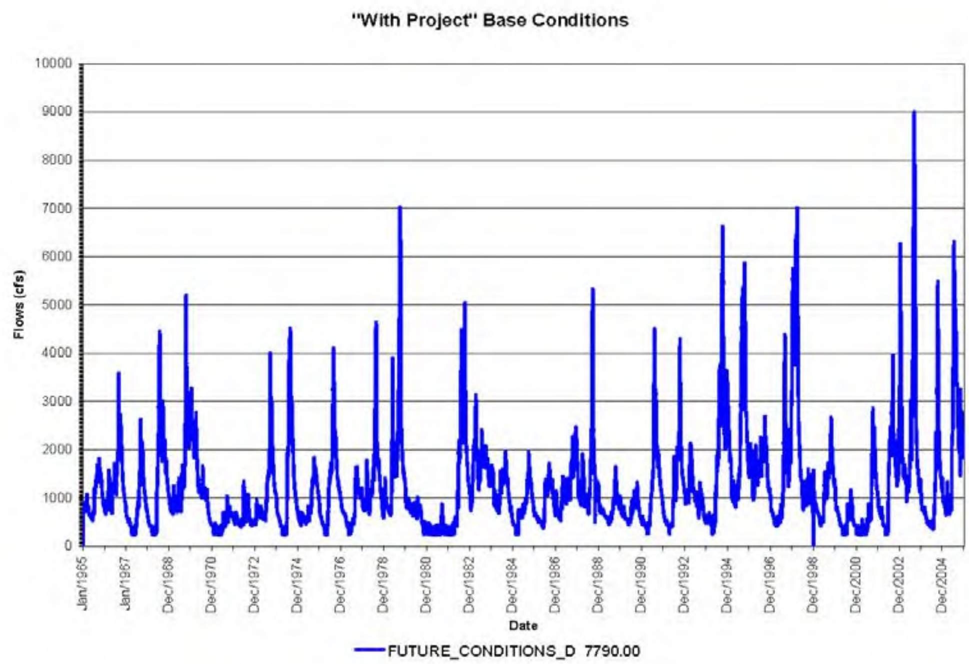
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6000
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Dec/1970
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Dec/1980
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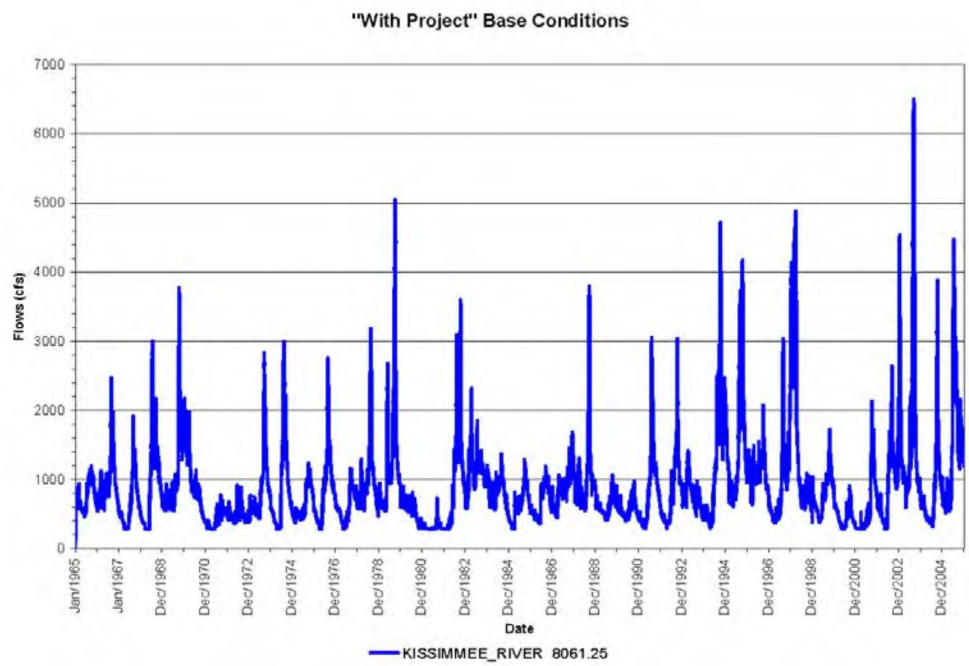
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Flows (cfs)
7000
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5000
4000
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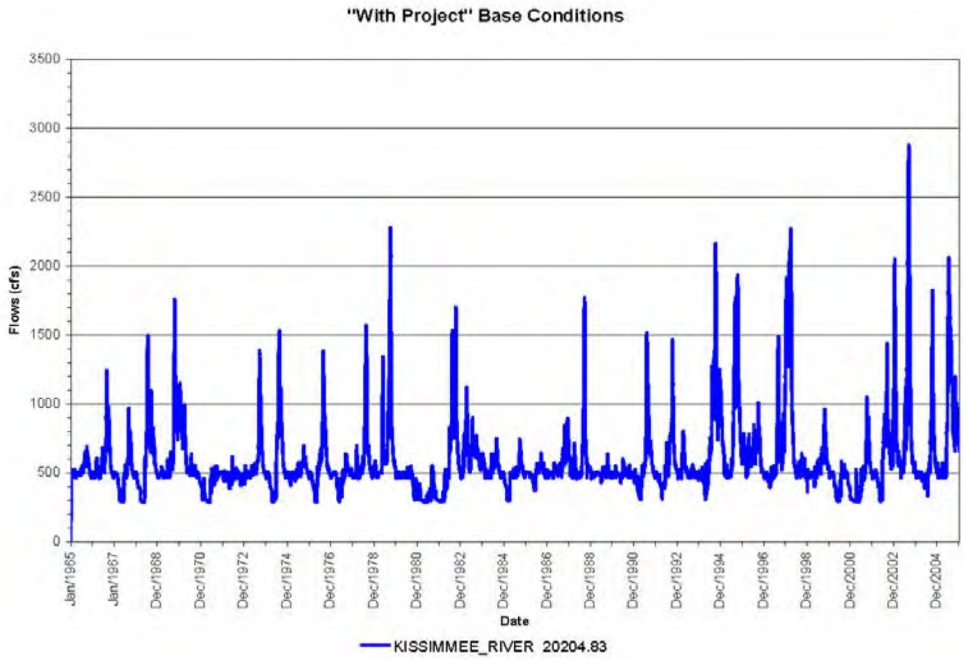
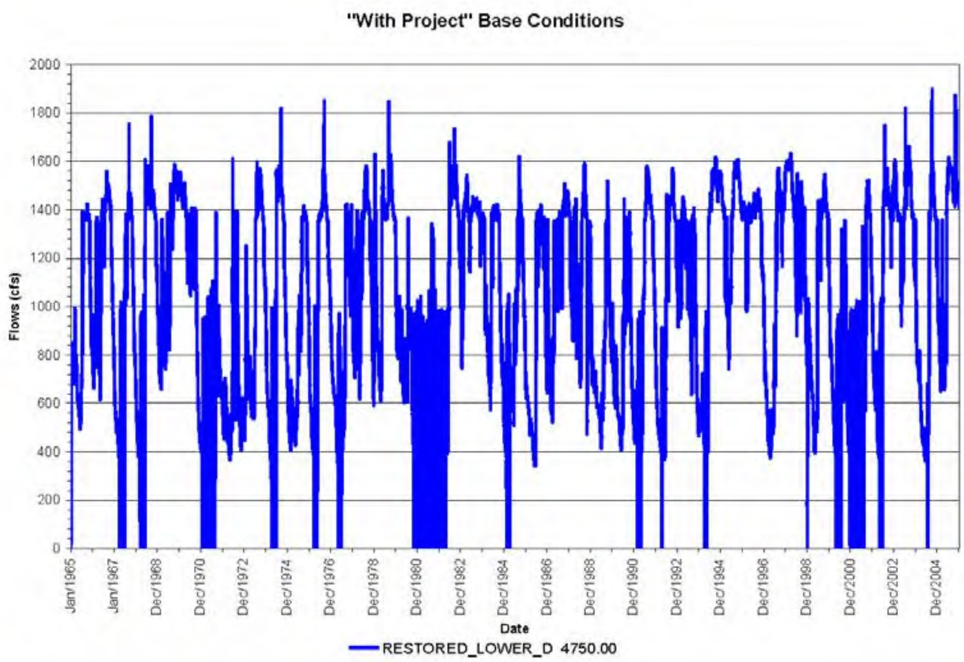
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
KISSIMMEE_RIVER 8061.25

AECOM

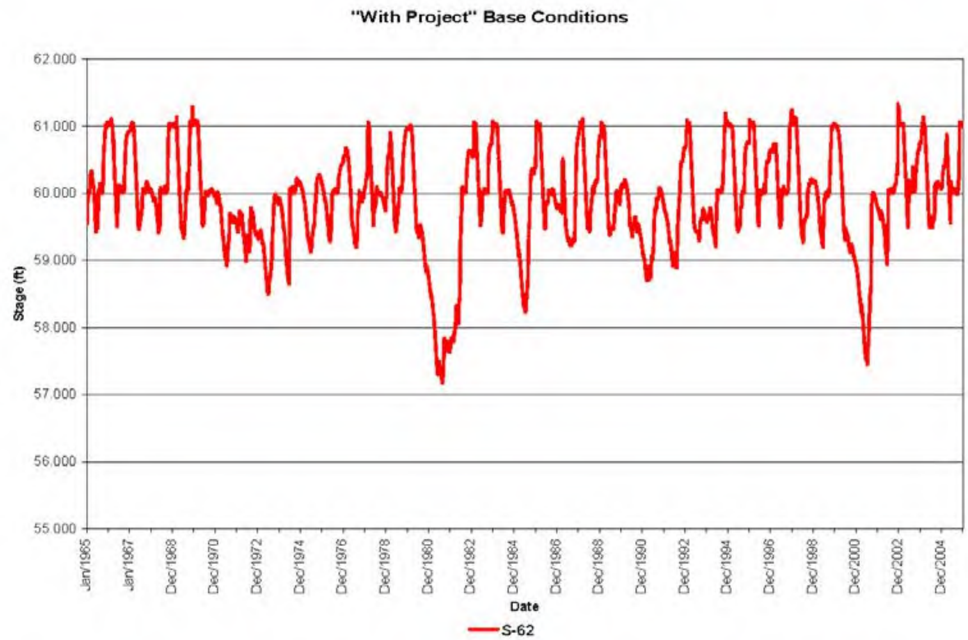
B-13

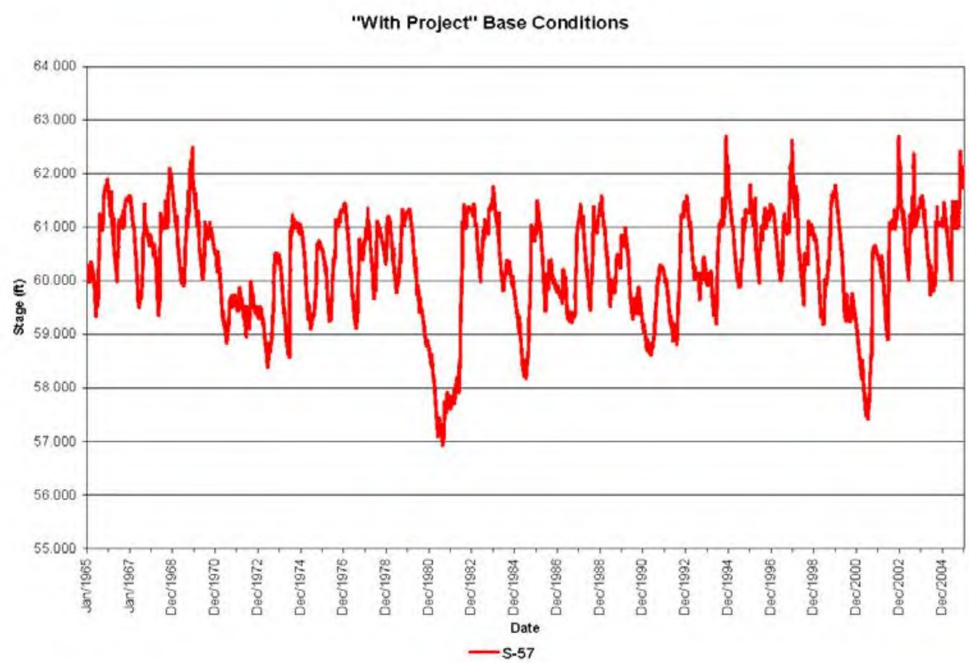

"With Project" Base Conditions
Flows (cfs)
0
500
1000
1500
2000
2500
3000
3500
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
KISSIMMEE_RIVER 20204.83


"With Project" Base Conditions
Flows (cfs)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
RESTORED_LOWER_D 4750.00

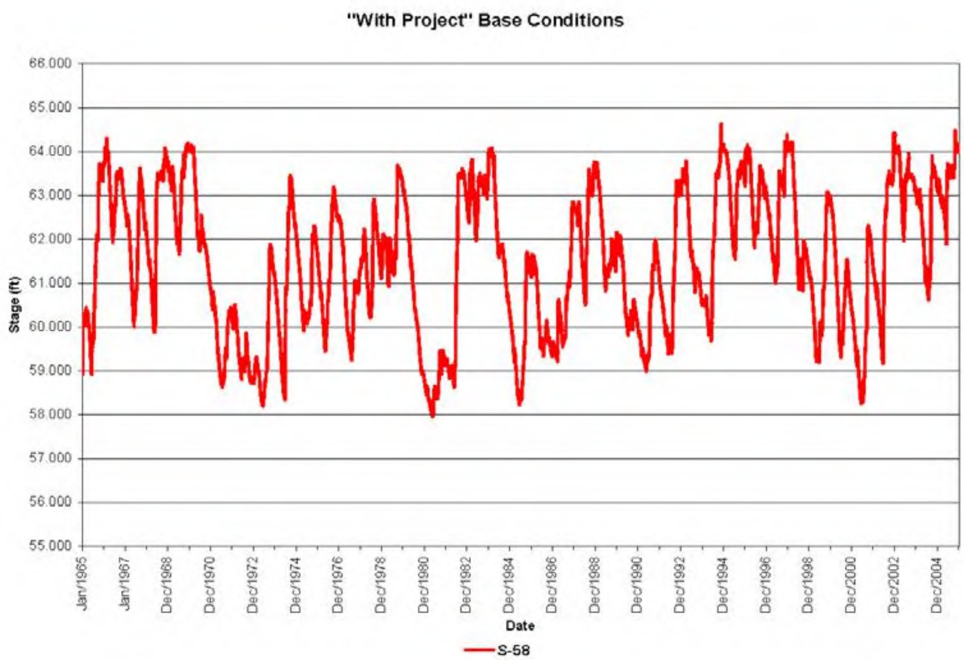
AECOM

STAGE

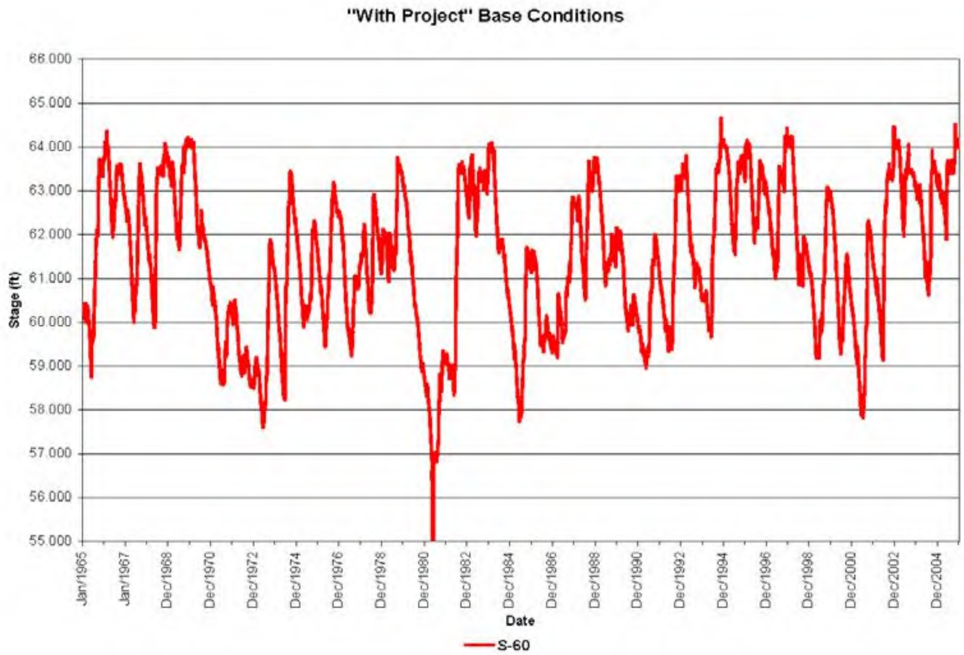

"With Project" Base Conditions
62.000
61.000
60.000
59.000
58.000
57.000
56.000
55.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-62

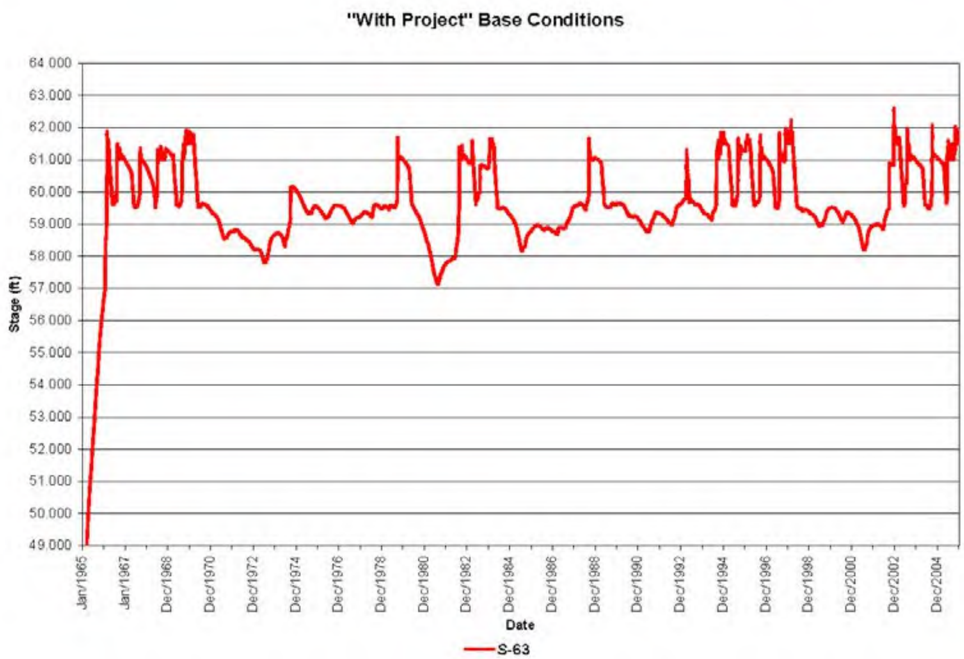

"With Project" Base Conditions
64.000
63.000
62.000
61.000
60.000
59.000
58.000
57.000
56.000
55.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-57

AECOM

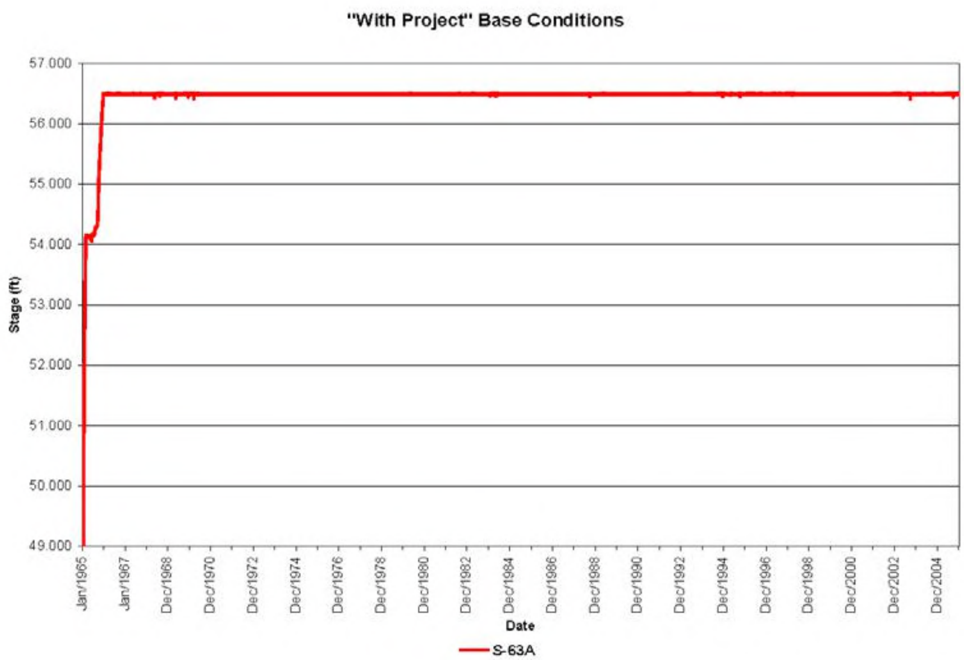

"With Project" Base Conditions
Stage (ft)
66.000
65.000
64.000
63.000
62.000
61.000
60.000
59.000
58.000
57.000
56.000
55.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-58

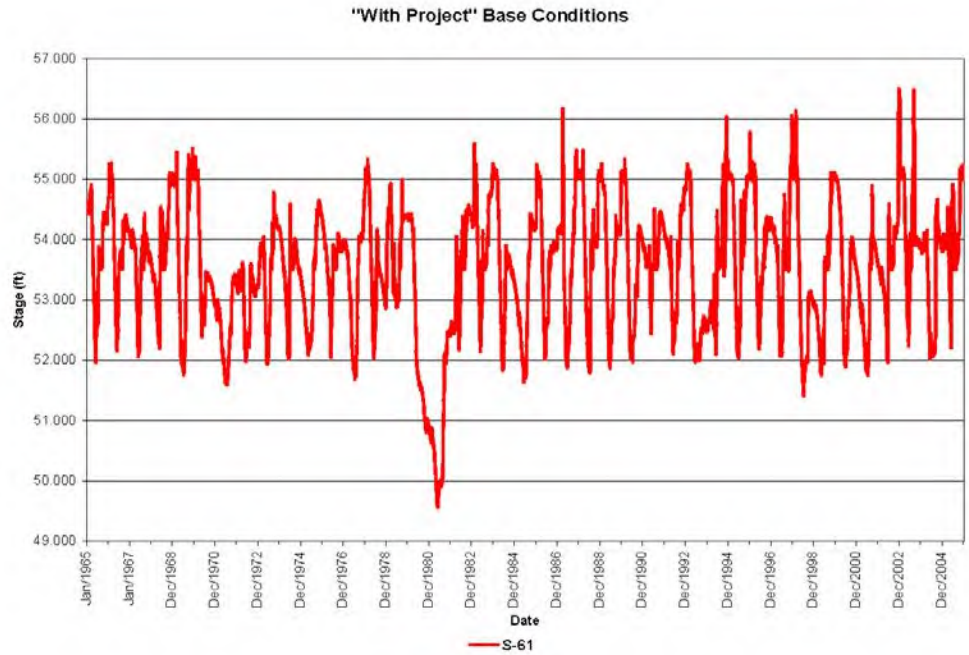
AECOM

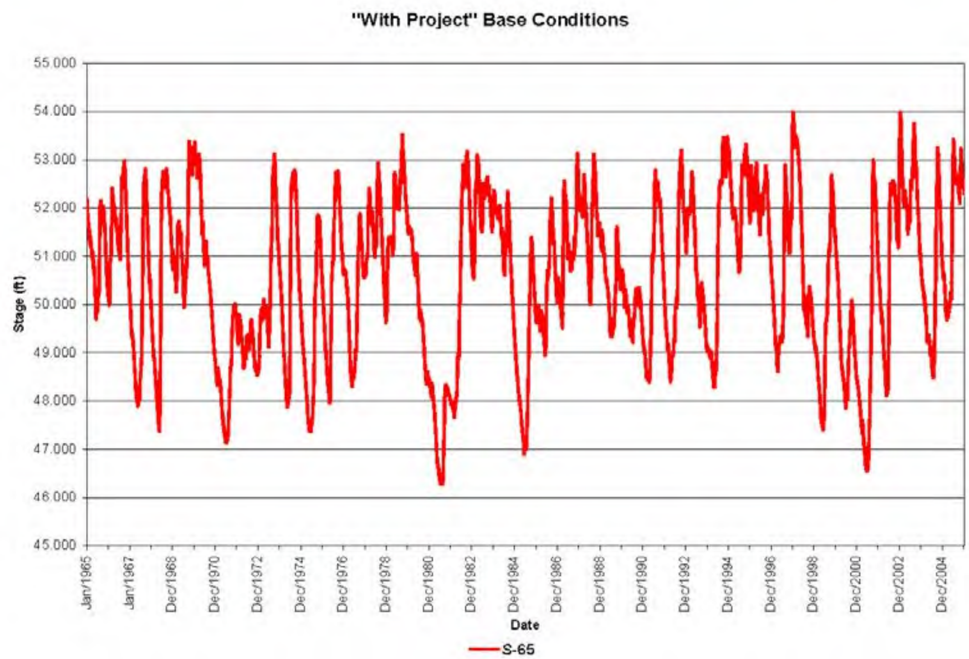

"With Project" Base Conditions
Stage (ft)
Date
S-60


"With Project" Base Conditions
Stage (ft)
Date
S-63

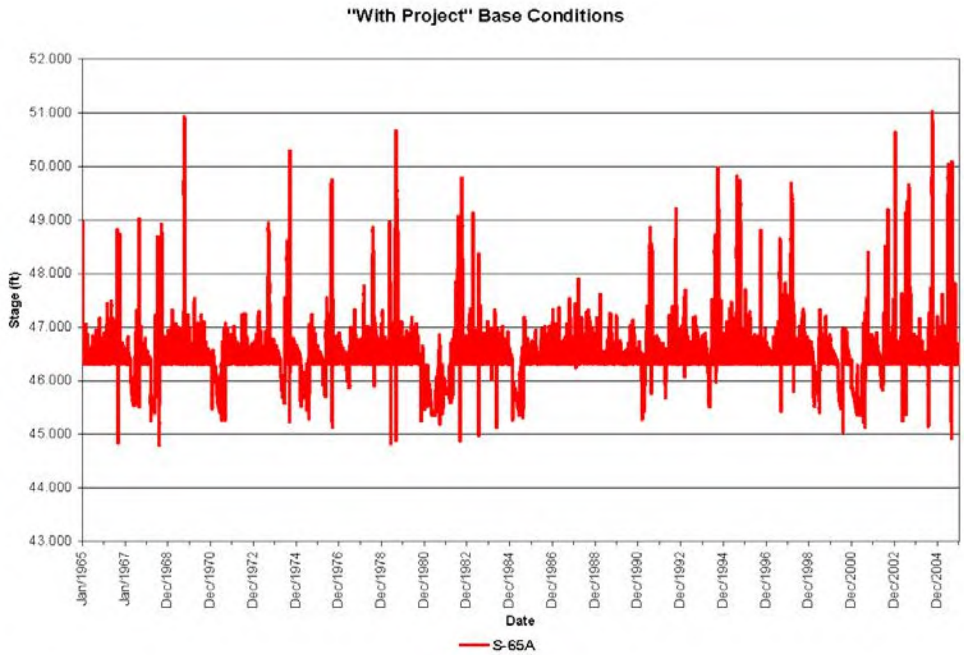
AECOM


"With Project" Base Conditions
57.000
56.000
55.000
54.000
53.000
52.000
51.000
50.000
49.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-63A

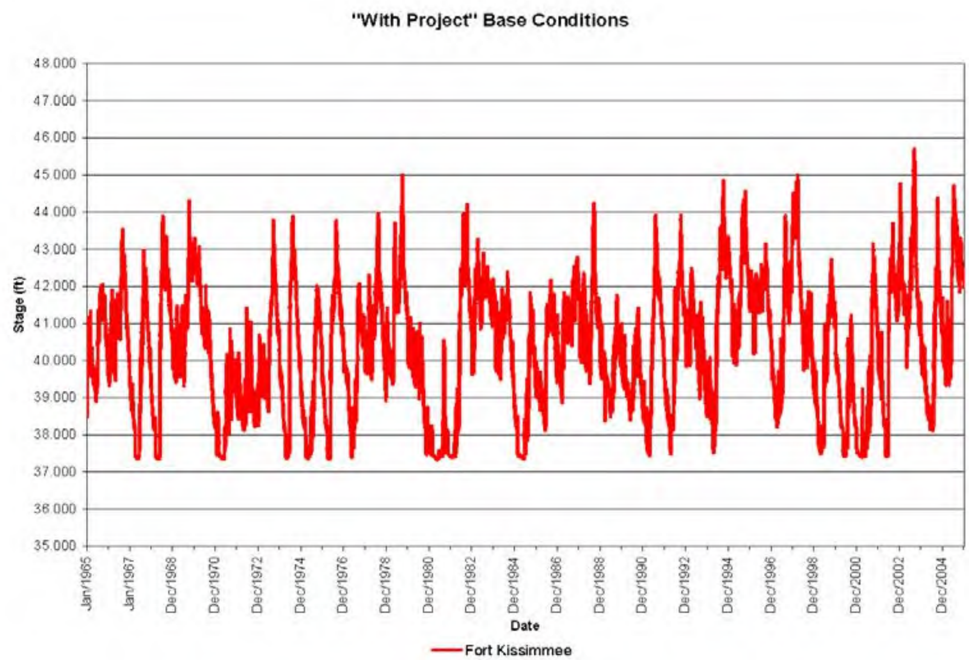

"With Project" Base Conditions
57.000
56.000
55.000
54.000
53.000
52.000
51.000
50.000
49.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-61

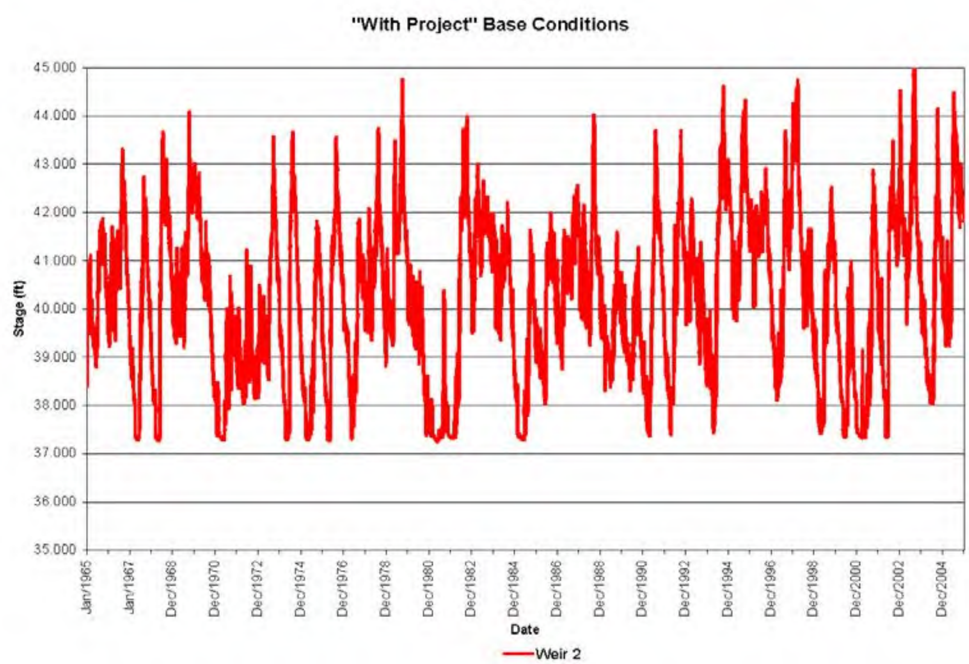

"With Project" Base Conditions
55.000
54.000
53.000
52.000
51.000
50.000
49.000
48.000
47.000
46.000
45.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-65

AECOM


"With Project" Base Conditions
52.000
51.000
50.000
49.000
48.000
47.000
46.000
45.000
44.000
43.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-65A

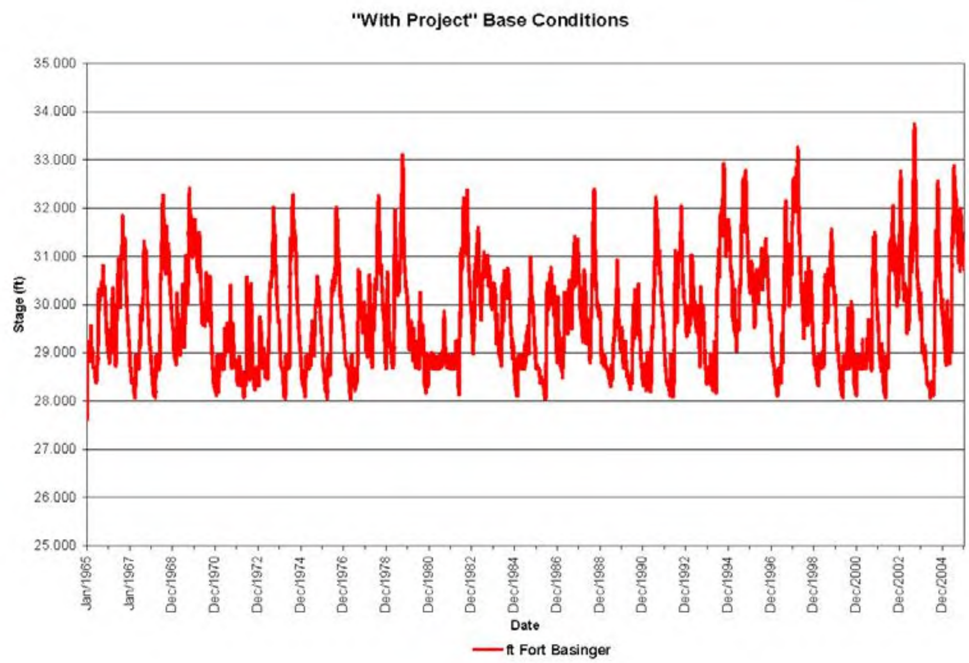
AECOM

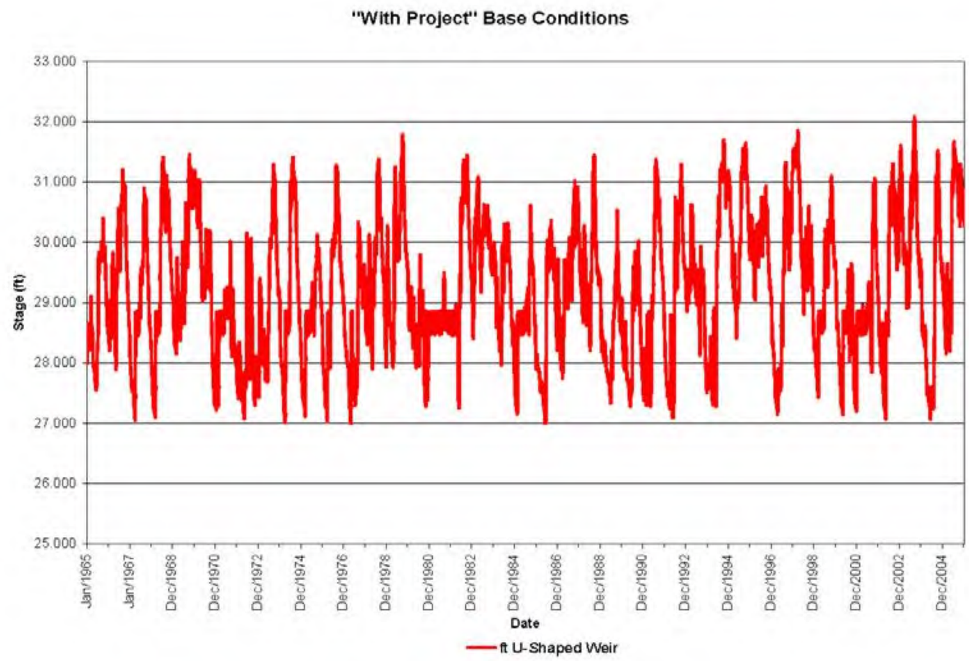

"With Project" Base Conditions
Stage (ft)
Date
Fort Kissimmee

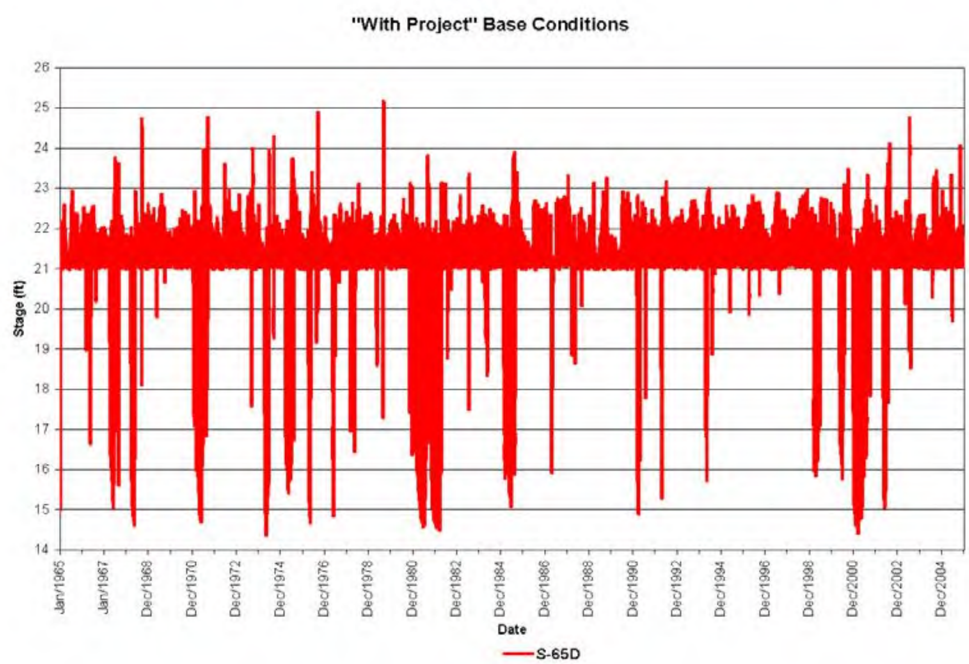

"With Project" Base Conditions
Stage (ft)
Date
Weir 2

AECOM

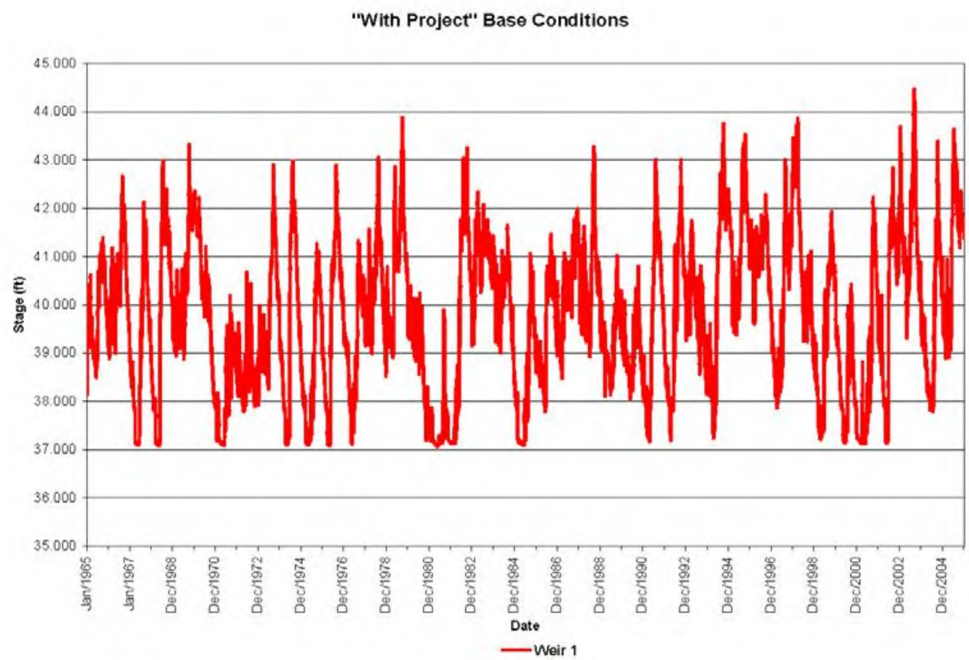
B-21


"With Project" Base Conditions
Stage (ft)
35.000
34.000
33.000
32.000
31.000
30.000
29.000
28.000
27.000
26.000
25.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
ft Fort Basinger

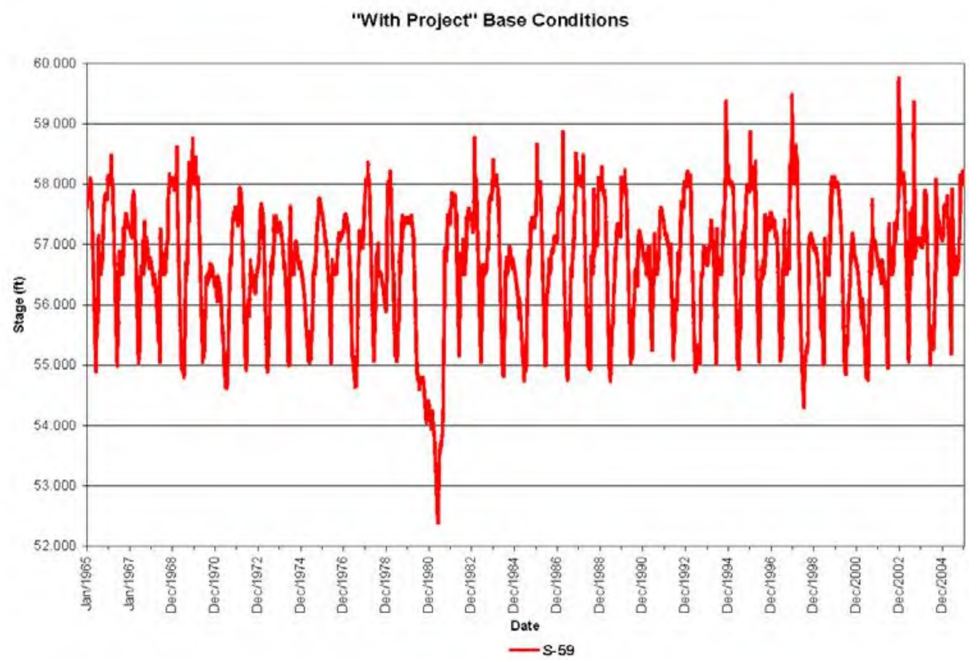

"With Project" Base Conditions
Stage (ft)
33.000
32.000
31.000
30.000
29.000
28.000
27.000
26.000
25.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
ft U-Shaped Weir

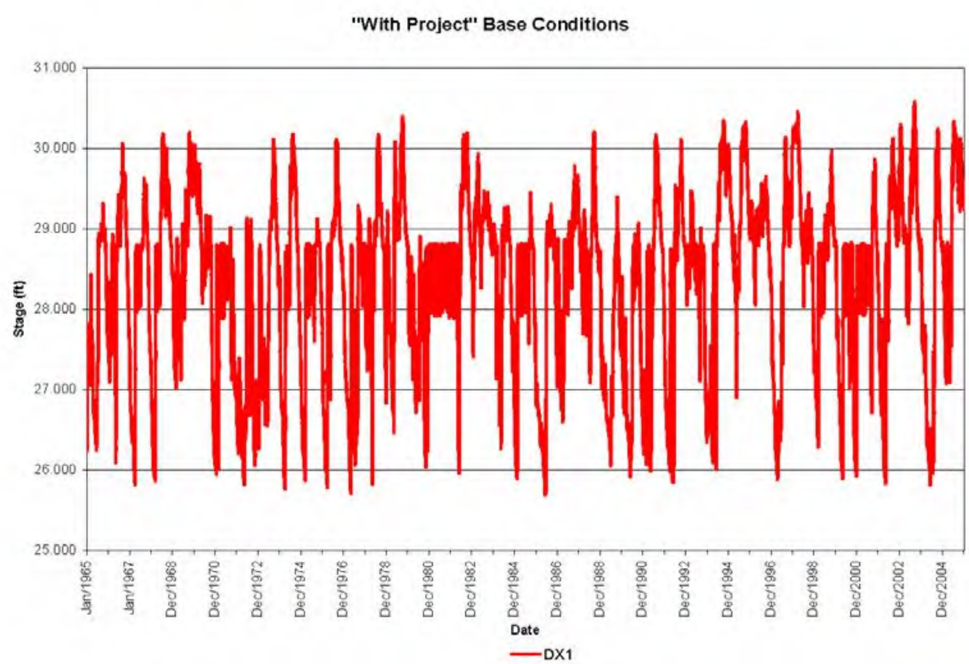

"With Project" Base Conditions
Stage (ft)
26
25
24
23
22
21
20
19
18
17
16
15
14
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-65D

AECOM

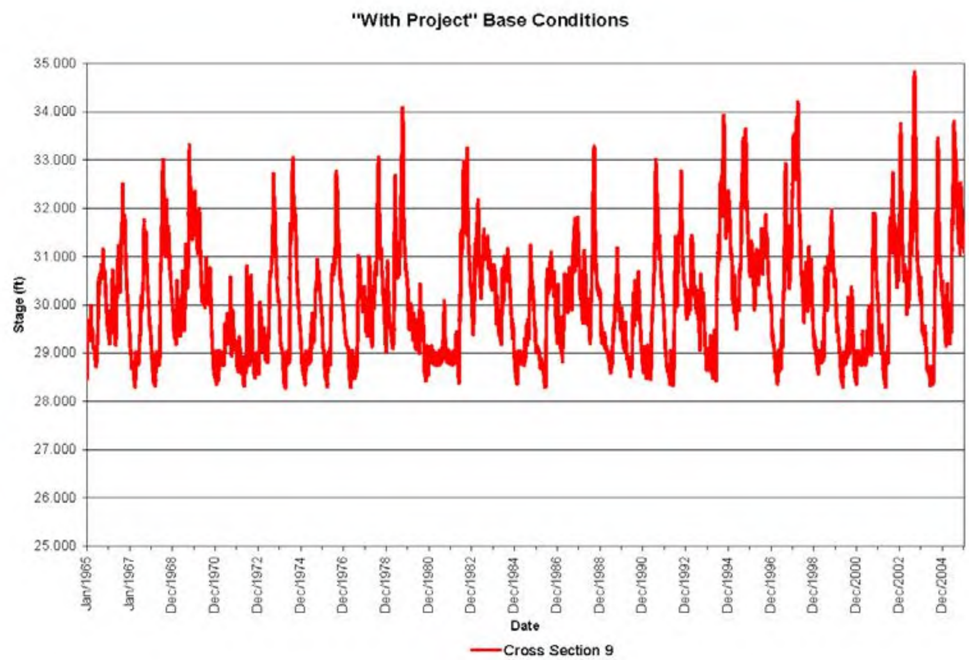

"With Project" Base Conditions
Stage (ft)
45.000
44.000
43.000
42.000
41.000
40.000
39.000
38.000
37.000
36.000
35.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
Weir 1

AECOM

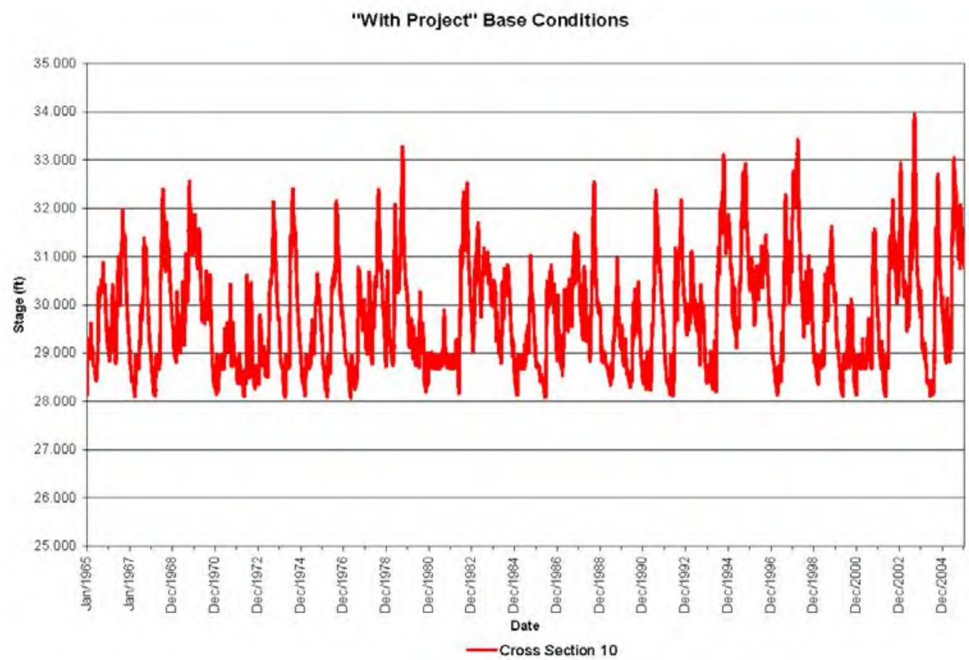

"With Project" Base Conditions
Stage (ft)
60.000
59.000
58.000
57.000
56.000
55.000
54.000
53.000
52.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
S-59

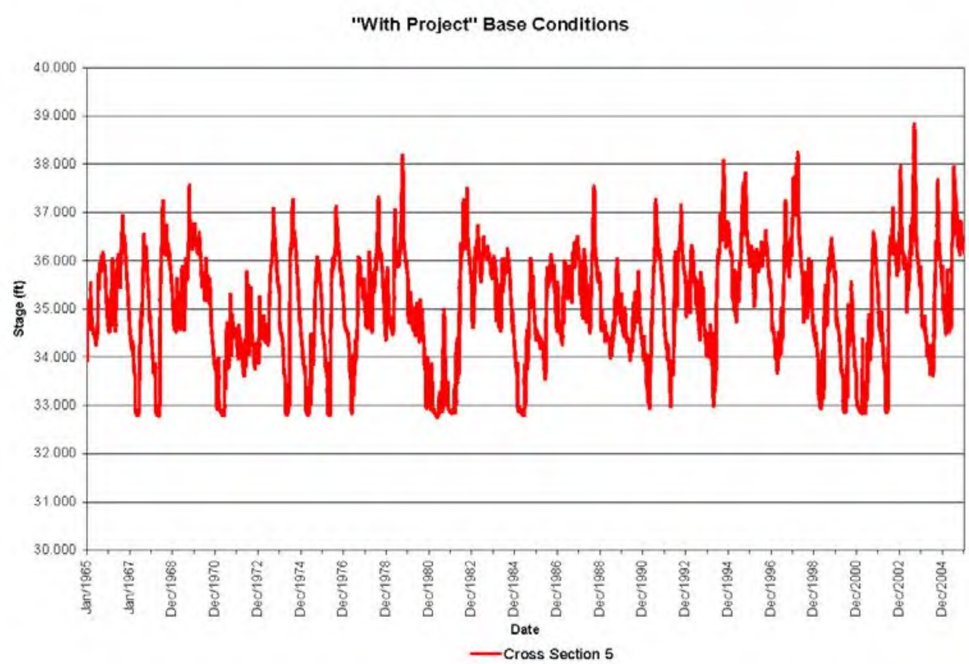

"With Project" Base Conditions
Stage (ft)
31.000
30.000
29.000
28.000
27.000
26.000
25.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
DX1

AECOM

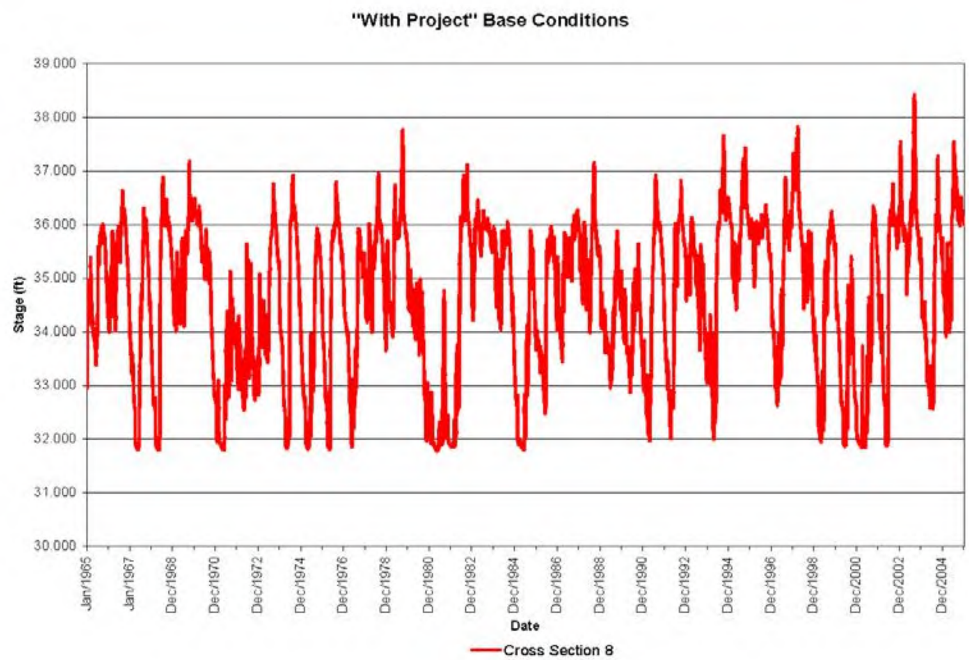

"With Project" Base Conditions
35.000
34.000
33.000
32.000
31.000
30.000
29.000
28.000
27.000
26.000
25.000
Stage (ft)
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
Cross Section 9

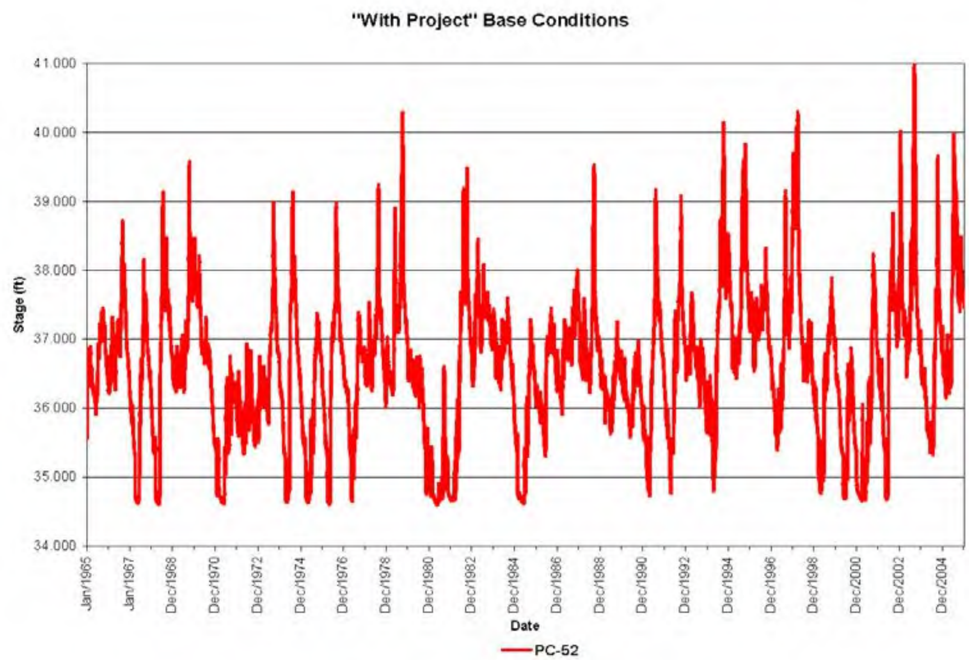
AECOM

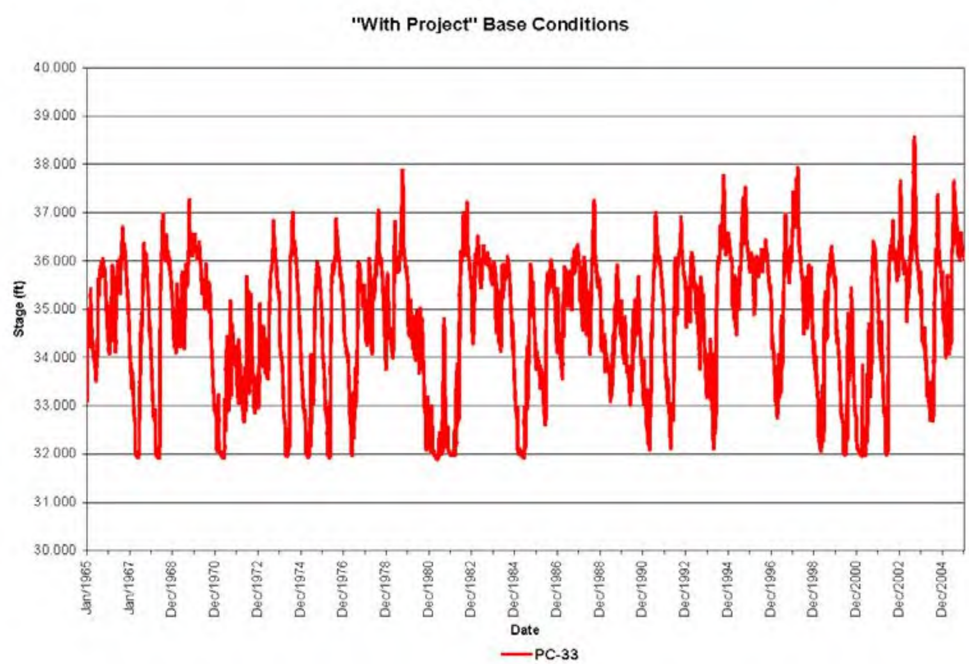

"With Project" Base Conditions
Stage (ft)
35.000
34.000
33.000
32.000
31.000
30.000
29.000
28.000
27.000
26.000
25.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
Cross Section 10


"With Project" Base Conditions
Stage (ft)
40.000
39.000
38.000
37.000
36.000
35.000
34.000
33.000
32.000
31.000
30.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
Cross Section 5

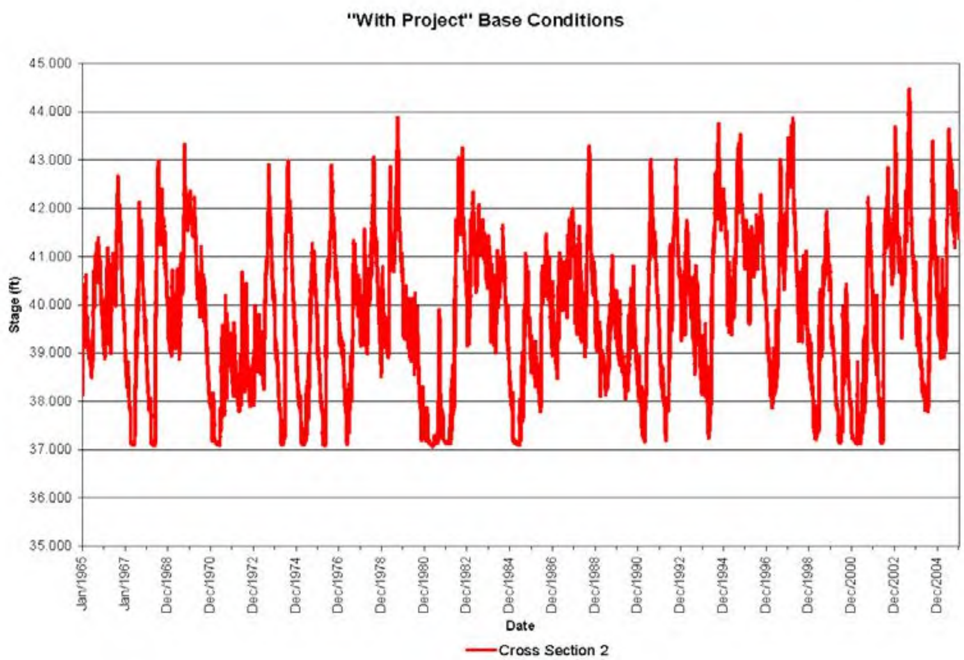
AECOM


"With Project" Base Conditions
Stage (ft)
39.000
38.000
37.000
36.000
35.000
34.000
33.000
32.000
31.000
30.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
Cross Section 8


"With Project" Base Conditions
Stage (ft)
41.000
40.000
39.000
38.000
37.000
36.000
35.000
34.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
PC-52


"With Project" Base Conditions
Stage (ft)
40.000
39.000
38.000
37.000
36.000
35.000
34.000
33.000
32.000
31.000
30.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
PC-33

AECOM

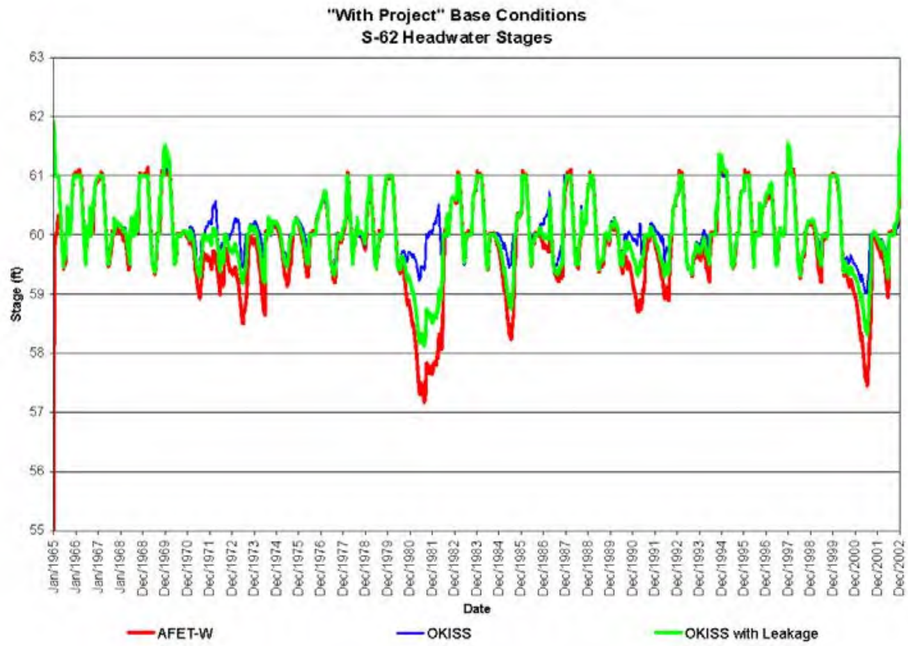

"With Project" Base Conditions
Stage (ft)
45.000
44.000
43.000
42.000
41.000
40.000
39.000
38.000
37.000
36.000
35.000
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
Dec/1992
Dec/1994
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
Cross Section 2

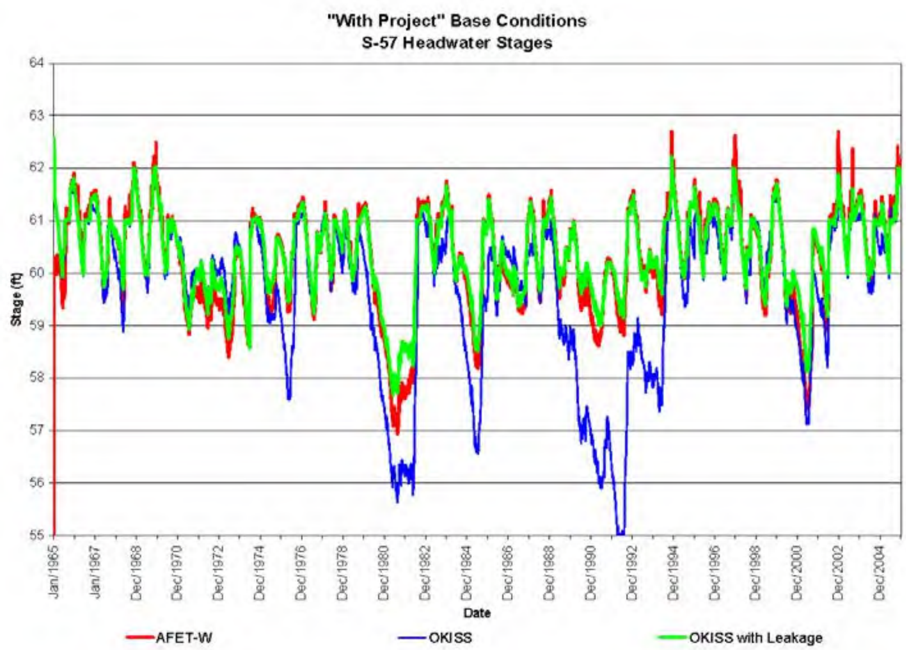
AECOM

APPENDIX C

"With Project" Base Condition Headwater Stages OKISS versus AFET-W

AECOM


"With Project" Base Conditions
S-62 Headwater Stages
Stage (ft)
63
62
61
60
59
58
57
56
55
Jan/1965
Jan/1966
Jan/1967
Jan/1968
Dec/1968
Dec/1969
Dec/1970
Dec/1971
Dec/1972
Dec/1973
Dec/1974
Dec/1975
Dec/1976
Dec/1977
Dec/1978
Dec/1979
Dec/1980
Dec/1981
Dec/1982
Dec/1983
Dec/1984
Dec/1985
Dec/1986
Dec/1987
Dec/1988
Dec/1989
Dec/1990
Dec/1991
Dec/1992
Dec/1993
Dec/1994
Dec/1995
Dec/1996
Dec/1997
Dec/1998
Dec/1999
Dec/2000
Dec/2001
Dec/2002
Date
AFET-W
OKISS
OKISS with Leakage


"With Project" Base Conditions
S-57 Headwater Stages
Stage (ft)
64
63
62
61
60
59
58
57
56
55
Jan/1965
Jan/1967
Dec/1968
Dec/1970
Dec/1972
Dec/1974
Dec/1976
Dec/1978
Dec/1980
Dec/1982
Dec/1984
Dec/1986
Dec/1988
Dec/1990
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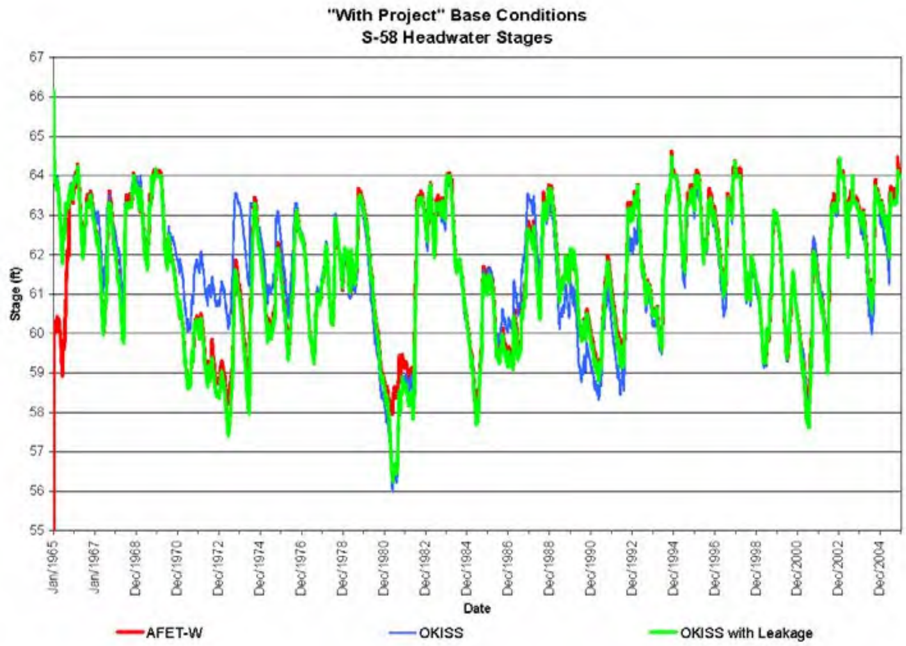
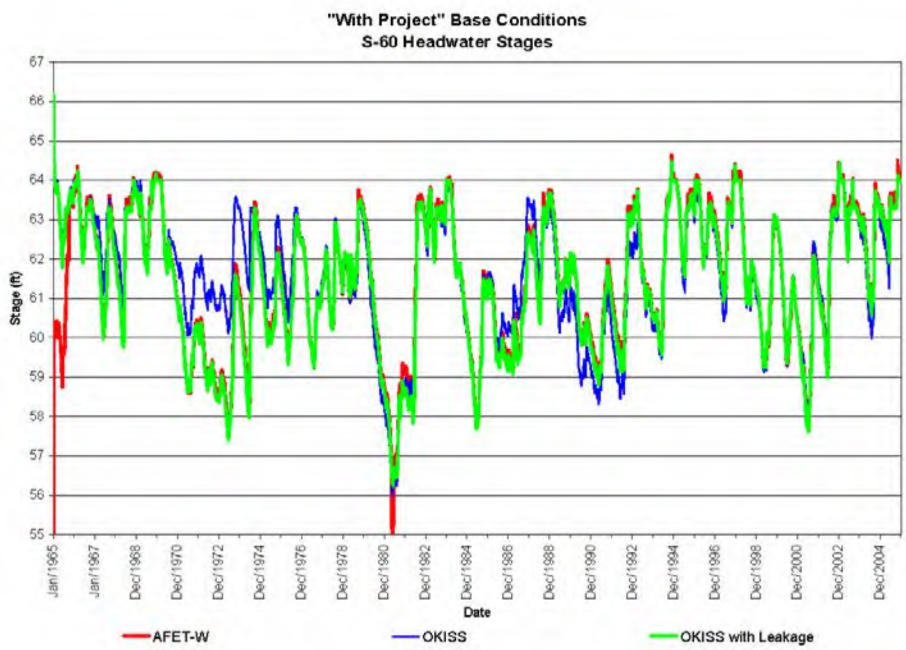
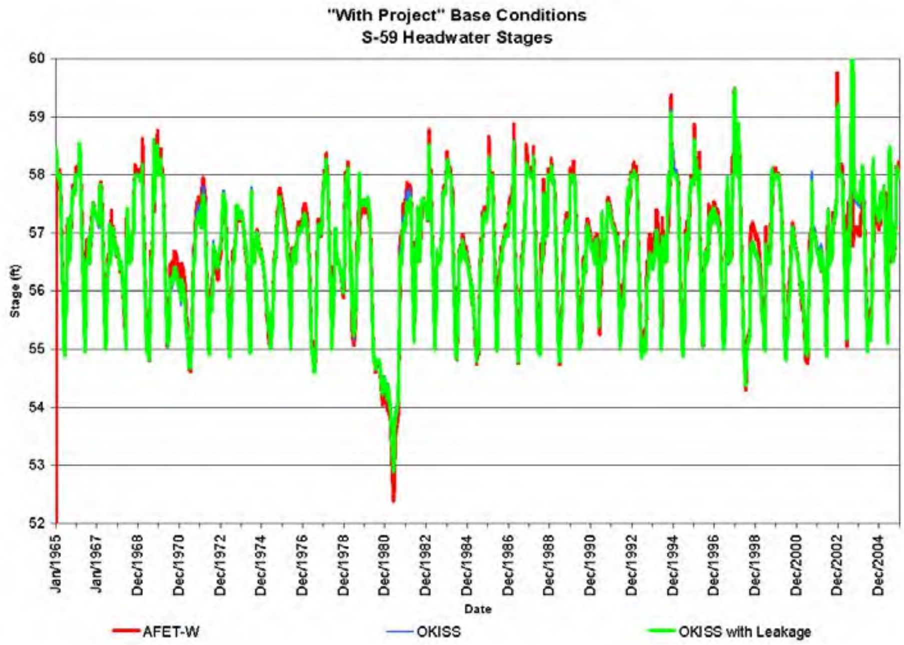
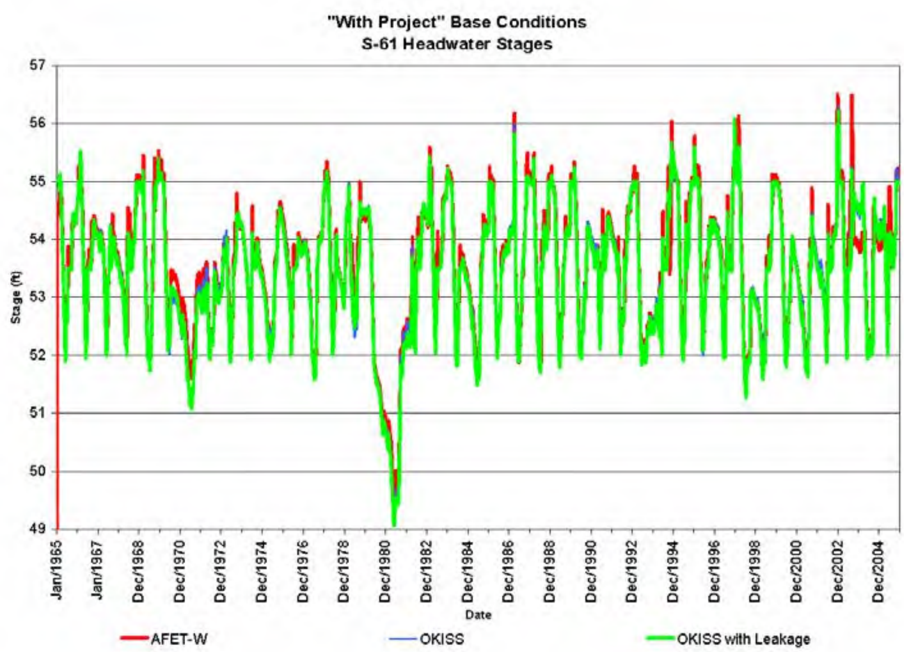
Dec/1996
Dec/1998
Dec/2000
Dec/2002
Dec/2004
Date
AFET-W
OKISS
OKISS with Leakage


"With Project" Base Conditions
S-58 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS
OKISS with Leakage

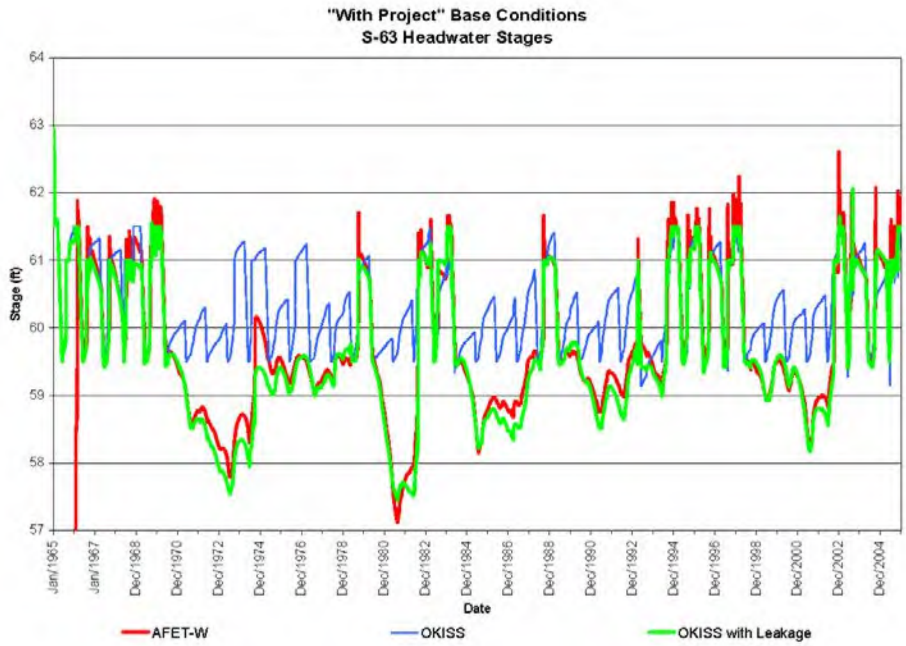

"With Project" Base Conditions
S-60 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS
OKISS with Leakage

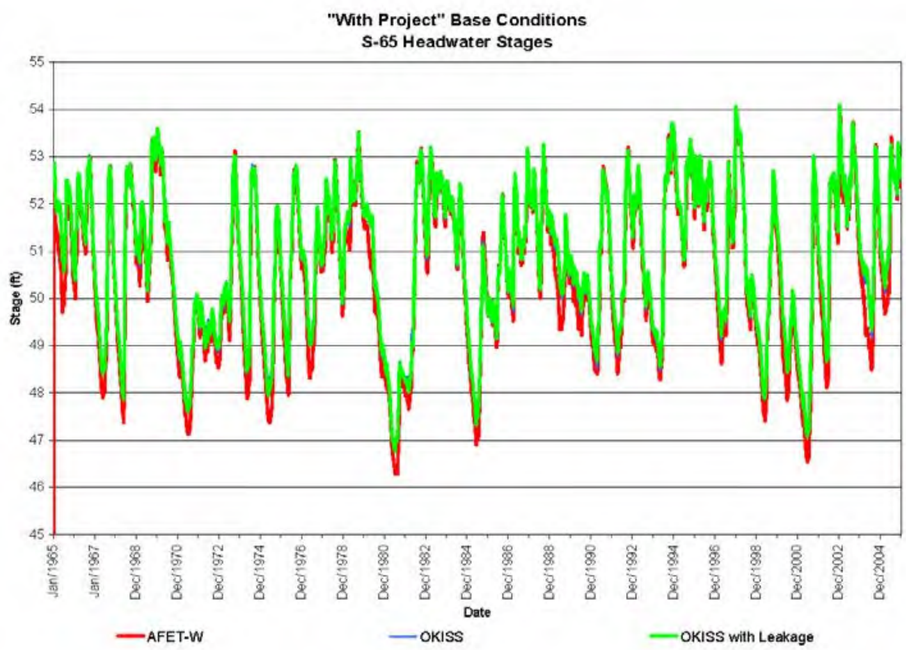
AECOM


"With Project" Base Conditions
S-59 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS
OKISS with Leakage


"With Project" Base Conditions
S-61 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS
OKISS with Leakage

AECOM


"With Project" Base Conditions
S-63 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS
OKISS with Leakage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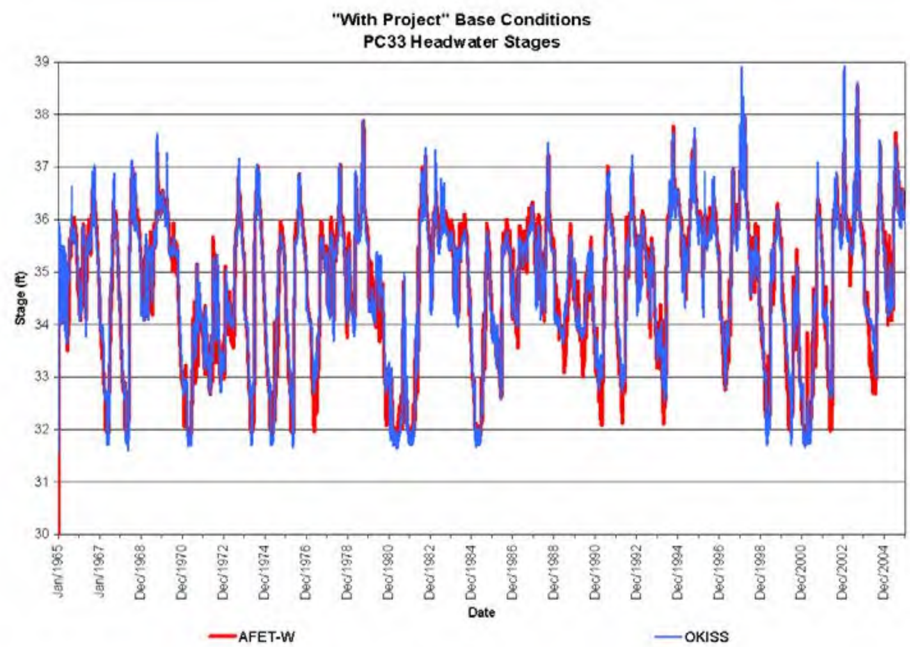
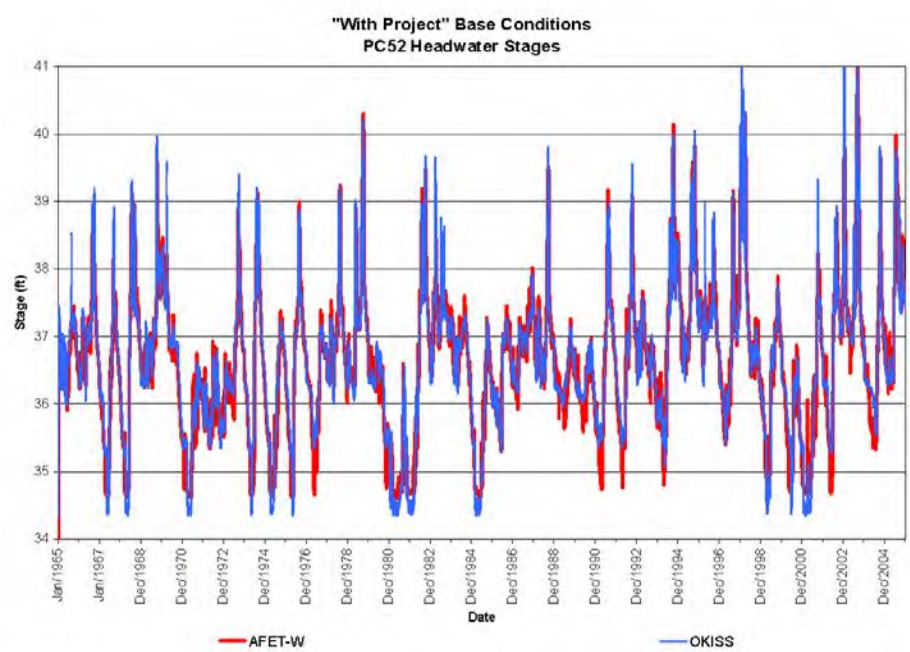
S-65 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS
OKISS with Leakage

AECOM


"With Project" Base Conditions
PC33 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS


"With Project" Base Conditions
PC52 Headwater Stages
Stage (ft)
Date
AFET-W
OKISS

AECOM

APPENDIX D

"With Project" Base Condition S-65D Releases OKISS versus AFET-W

AECOM

Table 1: Pool BCD Storage Volume (Total Volume in ACRE-FT)

Volume in Acre-ft

Qin (cfs)/H(ft)	28.8	29.4	30	30.1	30.2	30.4	30.8	31.4	32	Qout (cfs)
250	21527	21527	21527	21527	21527	21527	21527	21527	21527	360
500	21912	21912	21912	21912	21912	21912	21912	21912	21912	570
1000	28954	28954	28954	28954	28954	28954	28954	28954	28954	1030
2000	46820	46820	46820	46820	46820	46820	46820	46820	46820	2000
3000	63498	63498	63498	63498	63498	63498	63498	63498	63498	3050
4000	76049	76049	76049	76049	76049	76049	76049	76049	76049	4045
5000	87770	87770	87770	87770	87770	87770	87770	87770	87770	5085
7500	115344	115344	115344	115344	115344	115344	115344	115344	115344	8300
10000	145387	145387	145387	145387	145387	145387	145387	145387	145387	10650
15000	188969	188969	188969	188969	188969	188969	188969	188969	188969	15160
20000	234149	234149	234149	234149	234149	234149	234149	234149	234149	20105

Table 2: Pool BCD Headwater - Tailwater in S-65A

Q(cfs\H ft)	22	25	28	29	30	30.5	31	31.5	32	33
0		34.231	36.76434	36.76721	36.7754	36.78028	36.79	36.80193	36.81684	36.86404
1000		39.521	39.91484	39.91572	39.91649	39.91754	39.91871	39.92024	39.92314	39.93361
2000		42.435	42.45364	42.45365	42.45367	42.45601	42.45604	42.45612	42.45647	42.45764
3000		43.461	43.46145	43.46145	43.46145	43.46147	43.46147	43.46147	43.46147	43.46149
4000		44.038	44.03767	44.03767	44.03767	44.03767	44.03767	44.03767	44.03767	44.03769
6000		45.102	45.10193	45.10193	45.10205	45.10205	45.10205	45.10205	45.10205	45.10209
8000		45.984	45.98425	45.98425	45.98441	45.98442	45.98442	45.98443	45.98443	45.98448
10000		46.718	46.71761	46.71761	46.7176	46.71759	46.71759	46.71759	46.71759	46.71753
12000		47.39	47.39	47.39	47.39001	47.39001	47.39001	47.39001	47.39	47.39001
15000		48.261	48.26061	48.26061	48.26068	48.2607	48.26071	48.26073	48.26075	48.26101
20000		49.799	49.79839	49.79843	49.79925	49.79935	49.79943	49.79951	49.79964	49.80038

AECOM

Table 3: Volume of Pool A

Storage Volume (acre-ft)						
Q(cfs\H ft)	40.50	43.50	46.25	48.50	50.75	53.75
100	4870	5977	7235	10949	16126	23316
650	4878	5981	7237	10951	16127	23317
1250	4888	5987	7240	10957	16132	23319
2650	4919	6008	7251	10985	16152	23332
4050	4961	6037	7271	11032	16187	23354
5450	5012	6077	7307	11100	16236	23384
6850	5072	6125	7349	11188	16300	23424
8250	5144	6183	7407	11297	16377	23472
15100	5626	6594	7981	12121	16953	23834
22000	6288	7179	9628	13378	17833	24398

	40.50	43.50	46.25	48.50	50.75
100 cfs	4870	5977	7235	10949	16126
650 cfs	4878	5981	7237	10951	16127
1250 cfs	4888	5987	7240	10957	16132
2650 cfs	4919	6008	7251	10985	16152
4050 cfs	4961	6037	7271	11032	16187
5450 cfs	5012	6077	7307	11100	16236
6850 cfs	5072	6125	7349	11188	16300
8250 cfs	5144	6183	7407	11297	16377
22000 cfs	6288	7179	9628	13378	17833

Table 4: Headwater of Pool A

Headwater (ft)						
Q(cfs\H ft)	40.50	43.50	46.25	48.50	50.75	53.75
100	40.5	43.5	46.3	48.5	50.8	53.74
650	40.6	43.5	46.3	48.5	50.8	53.74
1250	40.6	43.5	46.3	48.5	50.8	53.74
2650	40.8	43.6	46.3	48.5	50.8	53.76
4050	41.0	43.8	46.4	48.6	50.8	53.78
5450	41.3	43.9	46.5	48.7	50.9	53.82
6850	41.6	44.1	46.7	48.8	50.9	53.86
8250	42.0	44.4	46.9	48.9	51.0	53.91
15100	44.5	46.0	48.0	49.8	51.6	54.30
22000	46.8	48.2	49.6	50.9	52.5	54.88

AECOM

Table 5: Volume of Pool E

Q(cfs\H ft)	Storage Volume (acre-ft)						
	15.75	18.75	21.00	22.00	23.00	24.50	26.00
100	9204	10716	12031	12779	13698	15483	18370
900	9204	10716	12031	12780	13698	15483	18371
1700	9205	10717	12032	12780	13699	15484	18373
5000	9216	10724	12039	12788	13709	15496	18391
8250	9238	10738	12053	12803	13728	15520	18427
11500	9270	10759	12074	12827	13757	15556	18480
14750	9312	10787	12104	12858	13796	15604	18550
18000	9363	10821	12139	12899	13845	15664	18638
21000	9417	10858	12179	12945	13901	15732	18734
24000	9478	10900	12226	13000	13967	15811	18845

Table 6: Headwater of Pool E

Q(cfs\H ft)	Headwater (ft)						
	15.75	18.75	21.00	22.00	23.00	24.50	26.00
100	15.75	18.75	21.00	22.00	23.00	24.50	26.00
900	15.76	18.75	21.00	22.00	23.00	24.50	26.00
1700	15.85	18.76	21.01	22.00	23.00	24.50	26.00
5000	16.01	18.81	21.04	22.04	23.03	24.53	26.02
8250	16.26	18.91	21.12	22.10	23.09	24.57	26.06
11500	16.55	19.06	21.23	22.20	23.18	24.64	26.11
14750	16.91	19.26	21.38	22.33	23.29	24.74	26.19
18000	17.29	19.52	21.55	22.48	23.44	24.86	26.28
21000	17.33	19.75	21.76	22.65	23.57	24.98	26.38
24000	17.75	20.04	21.96	22.87	23.74	25.11	26.48

Table 7: Stages at Cross Sections 5 and 9

Flow-Volume Table for pool BCD

	Cross Section 9	Cross Section 5
	FUTURE_CONDITIONS	KISSIMMEE_RIVER 15977
Qin (cfs)	H Xsect (ft)	H Xsect (ft)
-1000	28.6	32.3
0	28.6	32.3
100	28.6	32.3
250	28.73	33.69
500	28.88	34.45
1000	29.63	35.33
2000	30.99	36.27
3000	31.83	36.62
4000	32.39	37.06
5000	32.96	37.49
7500	34.13	38.42
10000	35.13	39.24
15000	36.76	40.82
20000	38.23	42.48

AECOM

APPENDIX E

Component Values and Performance Measures for the Study Modeling Tools

AECOM

Table 1: Component Values and Performance Measures for the Study Modeling Files

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
Evaluation Performance Measure Score for S-65 / L-01. Stages in Lakes Kissimmee, Hatchineha, and Cypress				
L01 - Component A. Percent of years that Extreme High stages occur for 30 or more consecutive days during September 1st – January 31st.	30.0	45.0	50.0	50.0
L01 - Component B. Percent of years that Normal High stages occur for 90 or more consecutive days during September 1st – January 31st.	70.0	20.0	15.0	17.5
L01 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	9.8	9.8	9.8
L01 - Component D. Percent of years that Wet Low stages occur for 40 or more days during April 1st – June 30th.	50.0	39.0	34.1	36.6
L01 - Component E. Percent of years that Normal Low stages occur for 40 or more consecutive days during April 1st – June 30th.	40.0	31.7	26.8	29.3
L01 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	7.3	14.6	14.6
L01 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 ft/30 days.	90.0	67.5	70.0	70.0
L01 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	53.7	48.8	58.5
L01 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	75.6	68.3	61.0
L01 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	61.0	41.5	48.8
L01 - Component K. Mean Intra-annual Lake Stage Variation (feet).	5.0	3.5	3.9	3.6
L01 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	9.0	7.3	7.7	6.7
Evaluation Performance Measure Score for S-61 / L-02. Stages in Lake Tohopekaliga				
L02 - Component A. Percent of years that Extreme High stages occur for 30 or more consecutive days during September 1st – January 31st.	30.0	40.0	40.0	40.0
L02 - Component B. Percent of years that Normal High stages occur for 90 or more consecutive days during September 1st – January 31st.	70.0	60.0	55.0	57.5

AECOM

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
L02 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	0.0	0.0	0.0
L02 - Component D. Percent of years that Wet Low stages occur for 40 or more days during April 1st – June 30th.	50.0	2.4	4.9	12.2
L02 - Component E. Percent of years that Normal Low stages occur for 40 or more consecutive days during April 1st – June 30th.	40.0	12.2	12.2	12.2
L02 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	2.4	2.4	2.4
L02 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 ft/30 days.	90.0	72.5	75.0	82.5
L02 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	26.8	24.4	26.8
L02 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	68.3	78.0	75.6
L02 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	78.0	65.9	78.0
L02 - Component K. Mean Intra-annual Lake Stage Variation (feet).	4.5	3.1	3.1	3.0
L02 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	6.3	7.1	6.9	6.8
Evaluation Performance Measure Score for S-63 / L-03. Stages in Lake Gentry				
L03 - Component A. Percent of years that Extreme High stages occur for 30 or more consecutive days during September 1st – January 31st.	30.0	15.0	15.0	15.0
L03 - Component B. Percent of years that Normal High stages occur for 90 or more consecutive days during September 1st – January 31st.	70.0	20.0	30.0	20.0
L03 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	0.0	0.0	0.0
L03 - Component D. Percent of years that Wet Low stages occur for 40 or more days during April 1st – June 30th.	50.0	0.0	0.0	0.0
L03 - Component E. Percent of years that Normal Low stages occur for 40 or more consecutive days during April 1st – June 30th.	40.0	43.9	46.3	48.8
L03 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	9.8	9.8	7.3

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
L03 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 ft/30 days.	90.0	72.5	62.5	60.0
L03 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	63.4	63.4	61.0
L03 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	29.3	29.3	41.5
L03 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	65.9	53.7	53.7
L03 - Component K. Mean Intra-annual Lake Stage Variation (feet).	2.8	1.6	2.0	1.6
L03 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	5.2	5.7	16.8	5.7
Evaluation Performance Measure Score for S-57 / L-04. Stages in Lakes Joel, Myrtle, and Preston				
L04 - Component A. Percent of years that Extreme High stages occur for 30 or more consecutive days during September 1st – January 31st.	30.0	10.0	15.0	12.5
L04 - Component B. Percent of years that Normal High stages occur for 90 or more consecutive days during September 1st – January 31st.	70.0	12.5	15.0	17.5
L04 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	0.0	0.0	0.0
L04 - Component D. Percent of years that Wet Low stages occur for 40 or more days during April 1st – June 30th.	50.0	0.0	0.0	0.0
L04 - Component E. Percent of years that Normal Low stages occur for 40 or more consecutive days during April 1st – June 30th.	40.0	82.9	75.6	73.2
L04 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	4.9	12.2	12.2
L04 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 ft/30 days.	90.0	90.0	85.0	87.5
L04 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	95.1	85.4	90.2
L04 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	61.0	65.9	65.9
L04 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	87.8	85.4	85.4

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
L04 - Component K. Mean Intra-annual Lake Stage Variation (feet).	4.5	1.9	2.2	2.3
L04 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	5.0	5.2	5.8	5.8
Evaluation Performance Measure Score for S-59 / L-05. Stages in East Lake Toho, Fell's Cove, and Lake Ajay				
L05 - Component A. Percent of years that Extreme High stages occur for 30 or more consecutive days during September 1st – January 31st.	30.0	47.5	50.0	50.0
L05 - Component B. Percent of years that Normal High stages occur for 90 or more consecutive days during September 1st – January 31st.	70.0	65.0	70.0	70.0
L05 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	2.4	2.4	2.4
L05 - Component D. Percent of years that Wet Low stages occur for 40 or more days during April 1st – June 30th.	50.0	4.9	0.0	0.0
L05 - Component E. Percent of years that Normal Low stages occur for 40 or more consecutive days during April 1st – June 30th.	40.0	4.9	4.9	4.9
L05 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	2.4	2.4	2.4
L05 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 ft/30 days.	90.0	87.5	82.5	85.0
L05 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	17.1	14.6	14.6
L05 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	73.2	82.9	68.3
L05 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	75.6	82.9	85.4
L05 - Component K. Mean Intra-annual Lake Stage Variation (feet).	4.7	3.3	3.4	3.3
L05 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	6.4	8.1	7.4	7.0
Evaluation Performance Measure Score for S-60 / L-06. Stages in Lakes Alligator, Brick, Lizzie, Coon, Center & Trout				
L06 - Component A. Percent of years that Extreme High stages occur for 30 or more consecutive days during September 1st – January 31st.	30.0	22.5	27.5	27.5
L06 - Component B. Percent of years that Normal High stages occur for 90 or more consecutive days during September 1st – January 31st.	70.0	25.0	30.0	30.0

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
L06 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	0.0	0.0	0.0
L06 - Component D. Percent of years that Wet Low stages occur for 40 or more days during April 1st – June 30th.	50.0	0.0	0.0	0.0
L06 - Component E. Percent of years that Normal Low stages occur for 40 or more consecutive days during April 1st – June 30th.	40.0	14.6	14.6	14.6
L06 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	36.6	34.1	31.7
L06 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 ft/30 days.	90.0	82.5	80.0	85.0
L06 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	34.1	39.0	22.0
L06 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	68.3	65.9	73.2
L06 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	58.5	51.2	41.5
L06 - Component K. Mean Intra-annual Lake Stage Variation (feet).	3.3	3.3	3.4	3.5
L06 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	5.8	9.9	9.9	8.7
Evaluation Performance Measure Score for S-62 / L-07. Stages in Lake Hart and Mary Jane				
L07 - Component C. Percent of years that Spring High stages occur for 100 or more days during January 1st – June 30th.	10.0	0.0	0.0	0.0
L07 - Component F. Percent of years that Extreme Low stages occur for 60 or more consecutive days during February 1st – June 30th.	10.0	2.4	9.8	9.8
L07 - Component G. Percent of years with a stage recession event from August 1 – July 31st with an overall recession rate ≤ 1 foot/30 days	90.0	90.0	87.5	87.5
L07 - Component H. Percent of years with a stage recession event from February 1st – May 31st with an overall recession rate ≤ 0.5 feet/30 days	90.0	51.2	70.7	70.7
L07 - Component I. Percent of years with stage reversals greater than 0.5 feet during December 1st – May 31st.	10.0	53.7	43.9	43.9
L07 - Component J. Percent of years with a stage ascension event during May 1st – September 30th with an overall ascension rate ≤ 1.0 feet/30 days.	90.0	78.0	73.2	73.2

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
L07 - Component K. Mean Intra-annual Lake Stage Variation (feet).	4.5	1.5	1.7	1.7
L07 - Component L. Maximum Inter-annual Lake stage Amplitude (feet).	4.5	3.8	4.2	4.4
L07 - Component M. Percent of years that stages greater than or equal to 60.5 feet-NGVD occur from September 1st through February 15th	90.0	0.0	0.0	0.0
L07 - Component N. Percent of years that Normal Low stages occur for 40 or more consecutive days during May 1st – June 30th.	40.0	70.7	61.0	58.5
L07 - Component O. Percent of years that Wet Low stages occur for 40 or more days during May 1st – June 30th.	50.0	0.0	0.0	0.0
Evaluation Performance Measure Score for S-65 and S-65E / R-01. Kissimmee River Flow				
R01 - S65 - Component A. Percent of years (water years) that the maximum mean monthly flow occurs in September, October or November (%).	57.1	50.0	47.5	52.5
R01 - S65 - Component B. Percent of years (water years) that the maximum mean monthly flow occurs in July, August, December or January (%).	25.0	30.0	30.0	27.5
R01 - S65 - Component C. Percent of years (calendar years) that the minimum mean monthly flow occurs in April, May or June (%).	44.8	46.3	41.5	39.0
R01 - S65 - Component D. Percent of years (calendar years) that the minimum mean monthly flow occurs in February, March, July or August (%).	24.1	22.0	29.3	36.6
R01 - S65 - Component E. Average intra–annual (calendar year based) monthly flow variation (kac–feet/mth).	124.0	110.0	114.0	106.0
R01 - S65 - Component F. Standard deviation of intra-annual (calendar year based) monthly flow variation (kac–feet/mth).	110.0	73.0	74.0	68.0
R01 - S65 - Component G. Return Frequency of 14–day low flow (Q<250 cfs) events (calendar years).	5.0	1.7	1.6	1.6
R01 - S65 - Component H. Number of times that the maximum mean monthly flows occurs during February – June for more than 3 consecutive years (calendar years).	0.0	0.0	0.0	0.0
R01 - S65 - Component I. Return Frequency of 3-day high flow (Q>5000 cfs) events (calendar years).	4.2	5.1	7.1	9.9
R01 - S65E - Component A. Percent of years (water years) that the maximum mean monthly flow occurs in September, October or November (%).	69.0	62.5	67.5	62.5
R01 - S65E - Component B. Percent of years (water years) that the maximum mean monthly flow occurs in July, August, December or January (%).	18.0	30.0	27.5	30.0

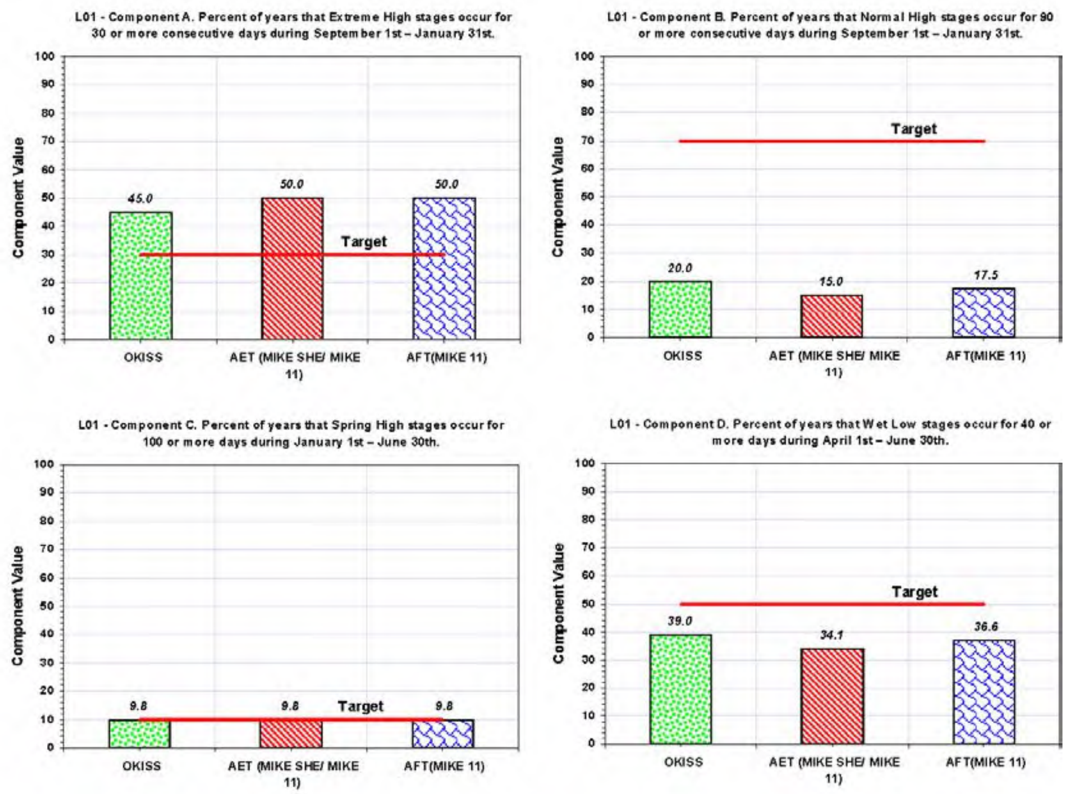
AECOM

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
R01 - S65E - Component C. Percent of years (calendar years) that the minimum mean monthly flow occurs in April, May or June (%).	57.6	53.7	61.0	58.5
R01 - S65E - Component D. Percent of years (calendar years) that the minimum mean monthly flow occurs in February, March, July or August (%).	24.2	22.0	17.1	22.0
R01 - S65E - Component E. Average intra–annual (calendar year based) monthly flow variation (kac–feet/mth).	247.0	154.0	161.0	151.0
R01 - S65E - Component F. Standard deviation of intra-annual (calendar year based) monthly flow variation (kac–feet/mth).	170.0	86.0	94.0	87.0
R01 - S65E - Component G. Return Frequency of 14–day low flow (Q<250 cfs) events (calendar years).	17.1	0.0	2.8	10.8
R01 - S65E - Component H. Number of times that the maximum mean monthly flows occurs during February – June for more than 3 consecutive years (calendar years).	0.0	0.0	0.0	0.0
R01 - S65E - Component I. Return Frequency of 3-day high flow (Q>5000 cfs) events (calendar years).	n/a	n/a	n/a	n/a
Evaluation Performance Measure Score for XS05 and XS09 / R-02. Kissimmee River Stage Hydrograph / Floodplain Hydroperiod				
R02 -XS5 - Component A. Percent of water years (May 1- April 30) in the simulation where the floodplain inundation is greater than or equal to + 1.0 ft for 210 or more days.	75.0	45.0	45.0	60.0
R02 -XS5 - Component B. Mean intra-annual river channel stage fluctuation per calendar year (feet).	2.9	3.3	3.2	3.0
R02 -XS5 - Component C. Standard deviation of intra-annual (calendar year based) stage fluctuations (feet).	1.2	1.0	0.9	0.8
R02 -XS9 - Component A. Percent of water years (May 1- April 30) in the simulation where the floodplain inundation is greater than or equal to + 1.0 ft for 210 or more days.	75.0	25.0	35.0	42.5
R02 -XS9 - Component B. Mean intra-annual river channel stage fluctuation per calendar year (feet).	3.8	3.5	3.6	3.3
R02 -XS9 - Component C. Standard deviation of intra-annual (calendar year based) stage fluctuations (feet).	1.4	1.4	1.1	1.0
Evaluation Performance Measure Score for XS05 and XS09 / R-03. Kissimmee River Stage Recession / Ascension				
R03 -XS5 - Component A. Percent of years with a stage recession event of 173 days or more during September – June with an overall recession rate ≤ 1.0 feet/30 days (%)	65.0	57.5	62.5	60.0

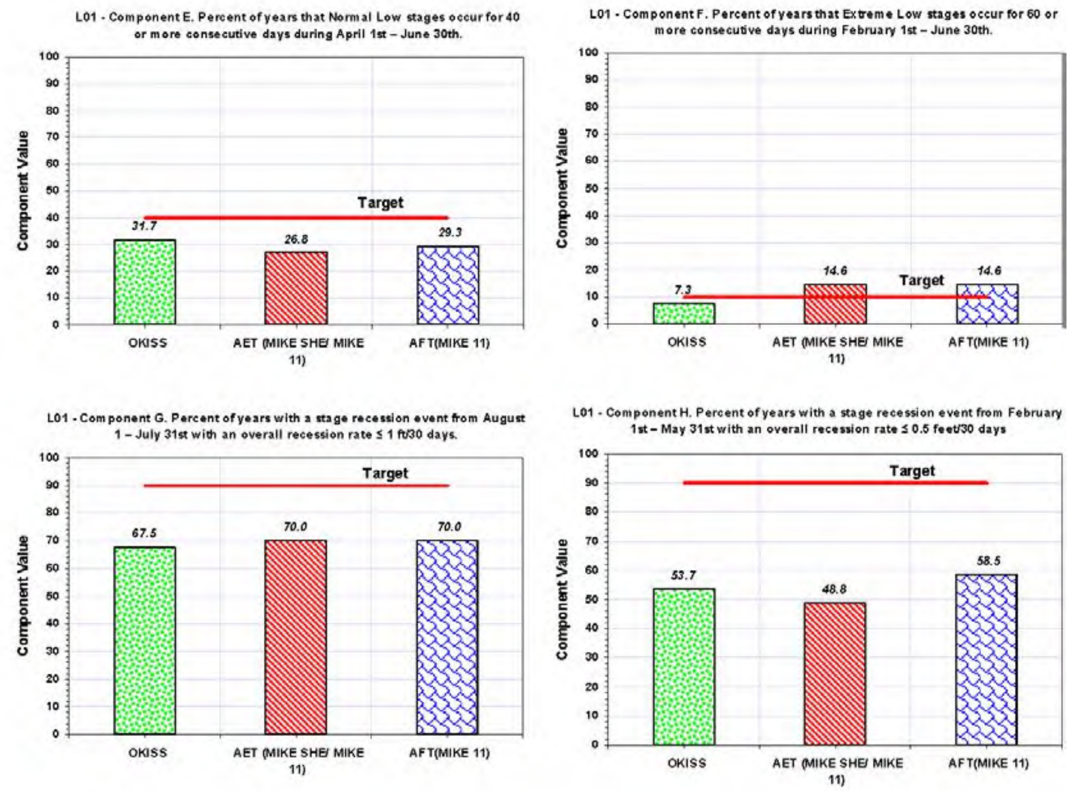
AECOM

PM - Evaluation Component	Target	OKISS	AET (MIKE SHE/ MIKE 11)	AFT(MIKE 11)
R03 -XS5 - Component B. Percent of years with stage reversals > 0.5 feet during December – June	41.0	32.5	32.5	30.0
R03 -XS5 - Component C. Percent of years with a stage ascension event of 78 days or more during May – October with an overall ascension rate ≤ 2.7 feet/30 days (%)	53.0	35.0	45.0	25.0
R03 -XS9 - Component A. Percent of years with a stage recession event of 173 days or more during September – June with an overall recession rate ≤ 1.0 feet/30 days (%)	59.0	60.0	62.5	52.5
R03 -XS9 - Component B. Percent of years with stage reversals > 0.5 feet during December – June	24.0	32.5	30.0	27.5
R03 -XS9 - Component C. Percent of years with a stage ascension event of 78 days or more during May – October with an overall ascension rate ≤ 2.7 feet/30 days (%)	56.0	42.5	47.5	47.5

AECOM

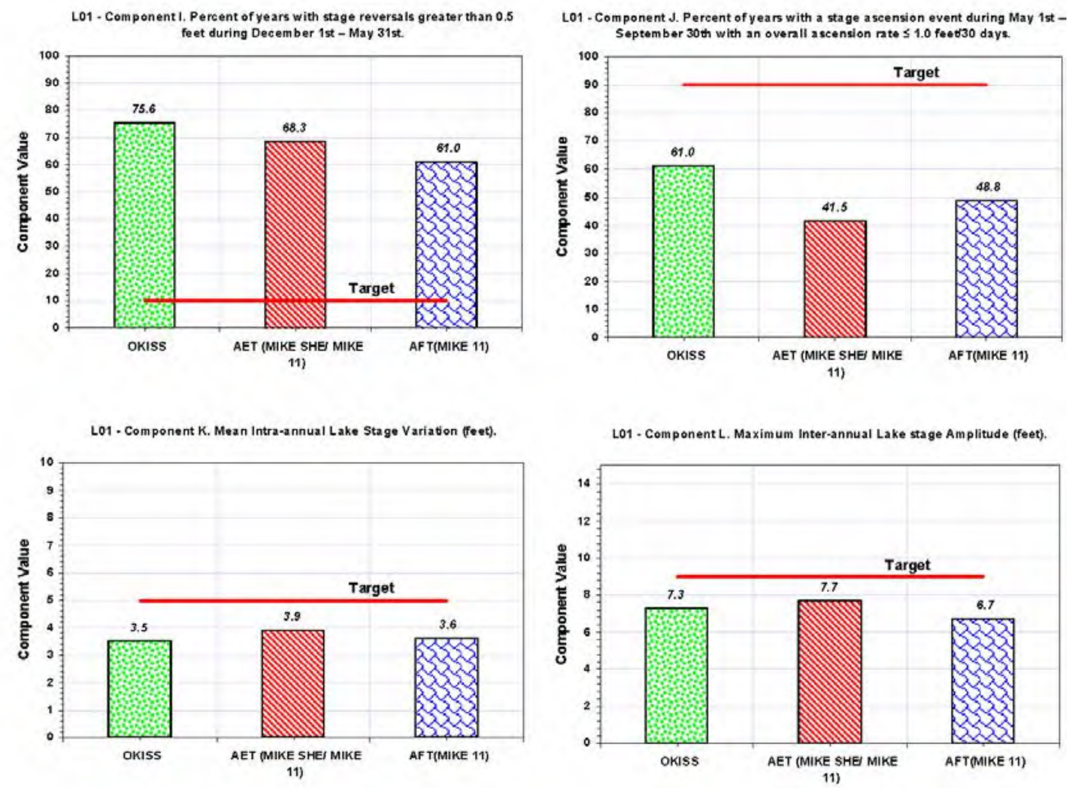


L01 - Component A-C.

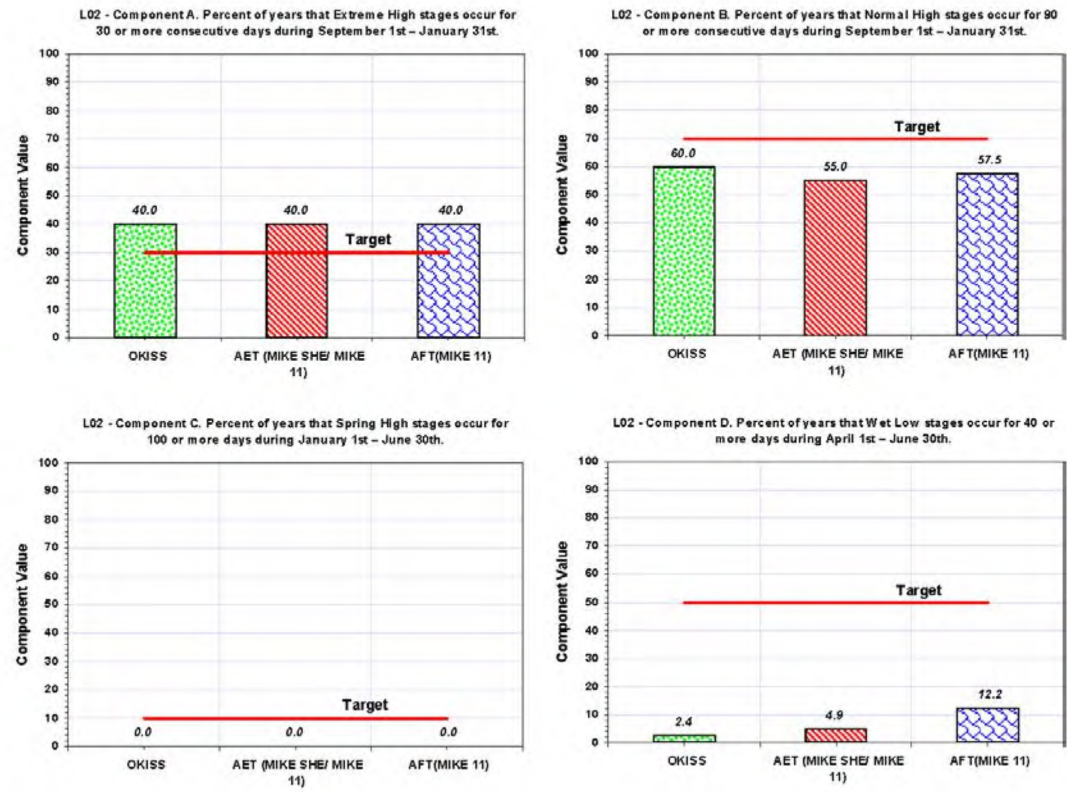


L01 - Component E-H.

AECOM



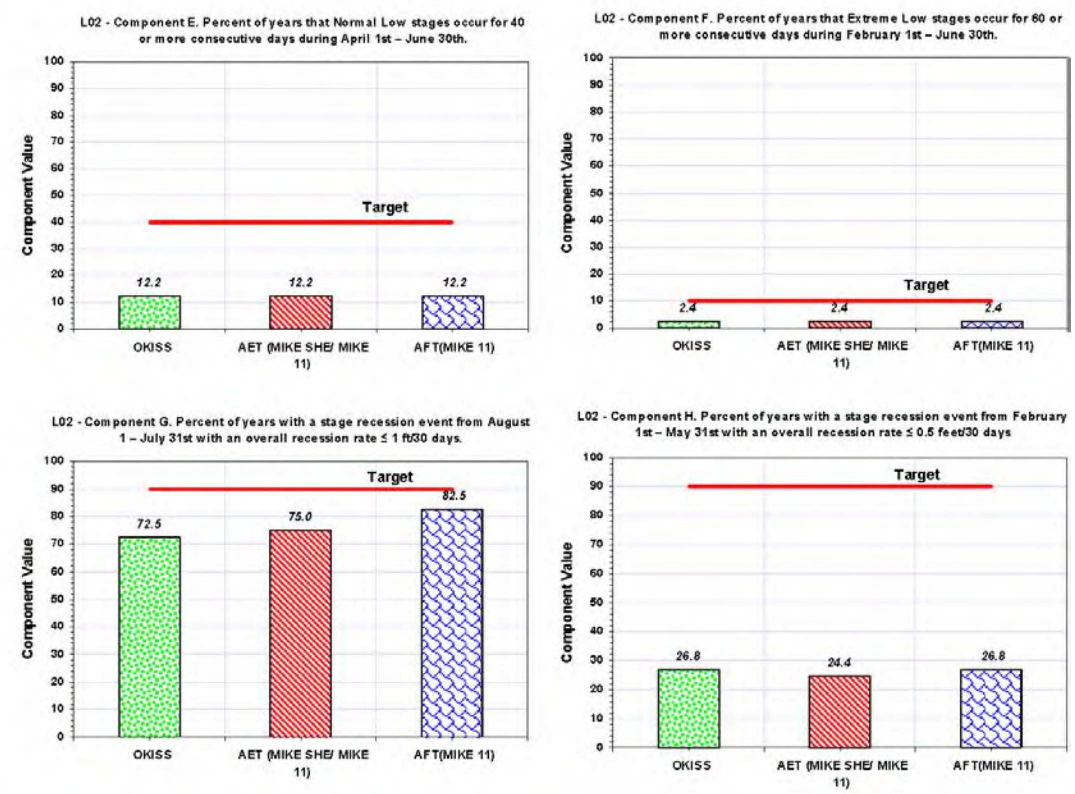
L01 - Component I-L.



L02 – Component A-D.

AECOM

E-12



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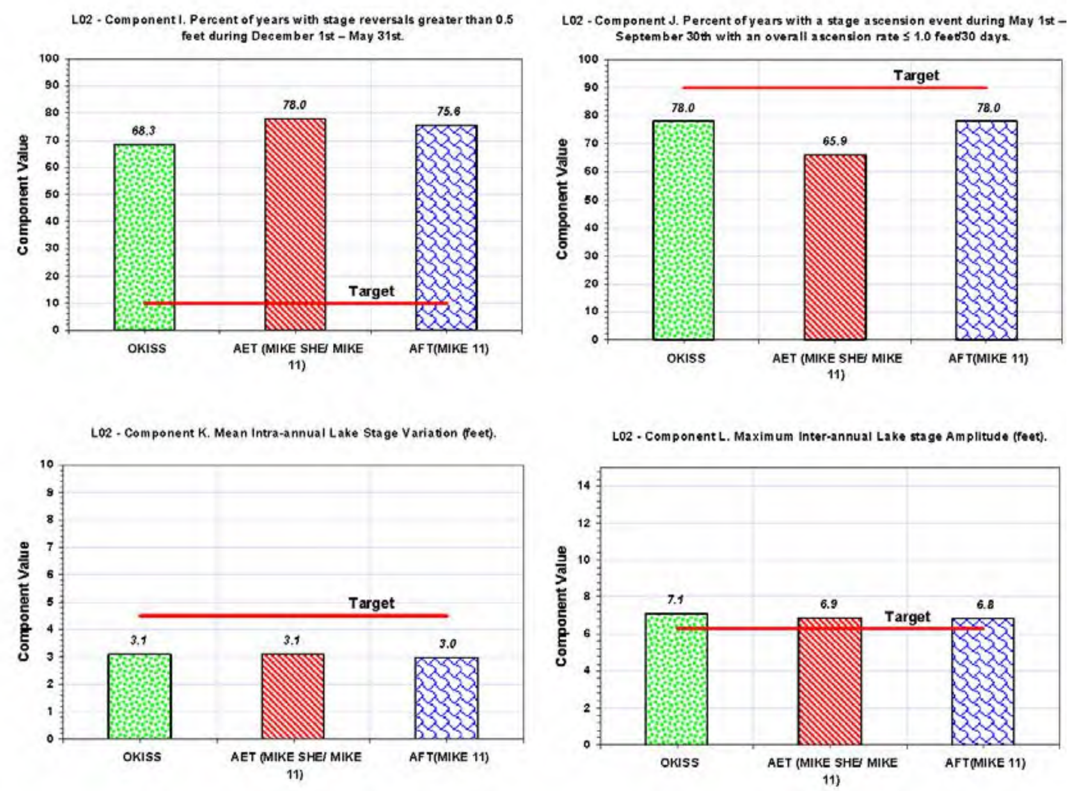
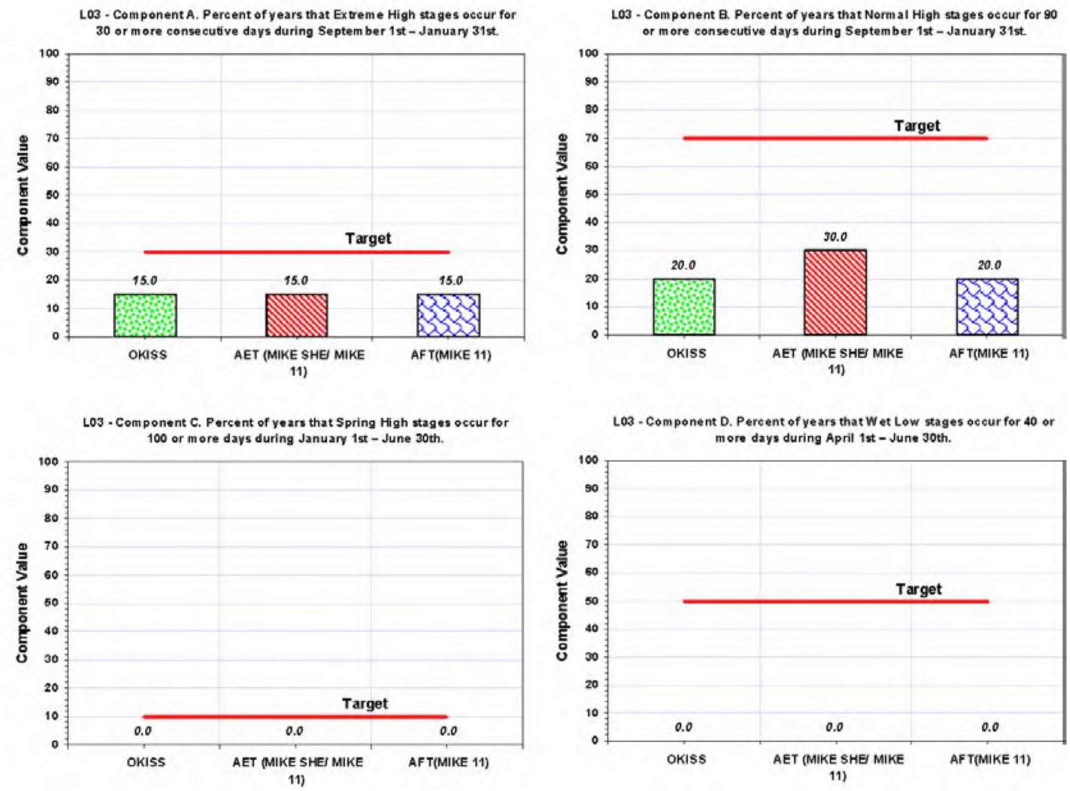


LO2 – Component I-L.



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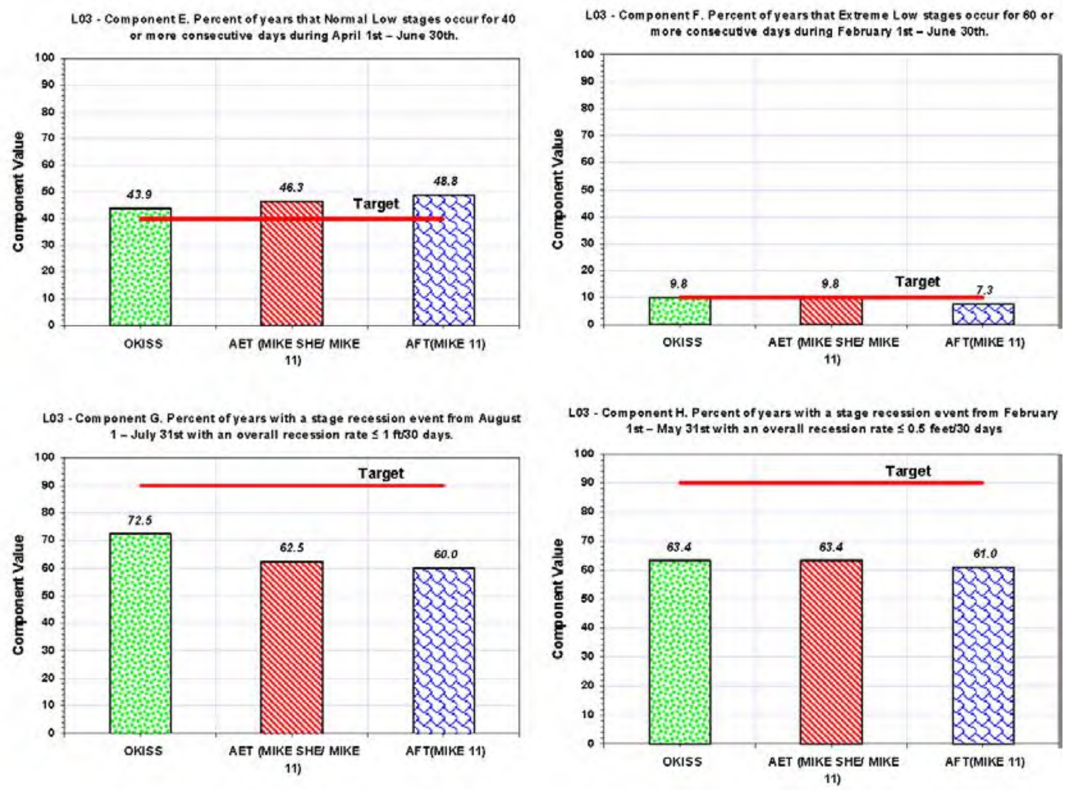
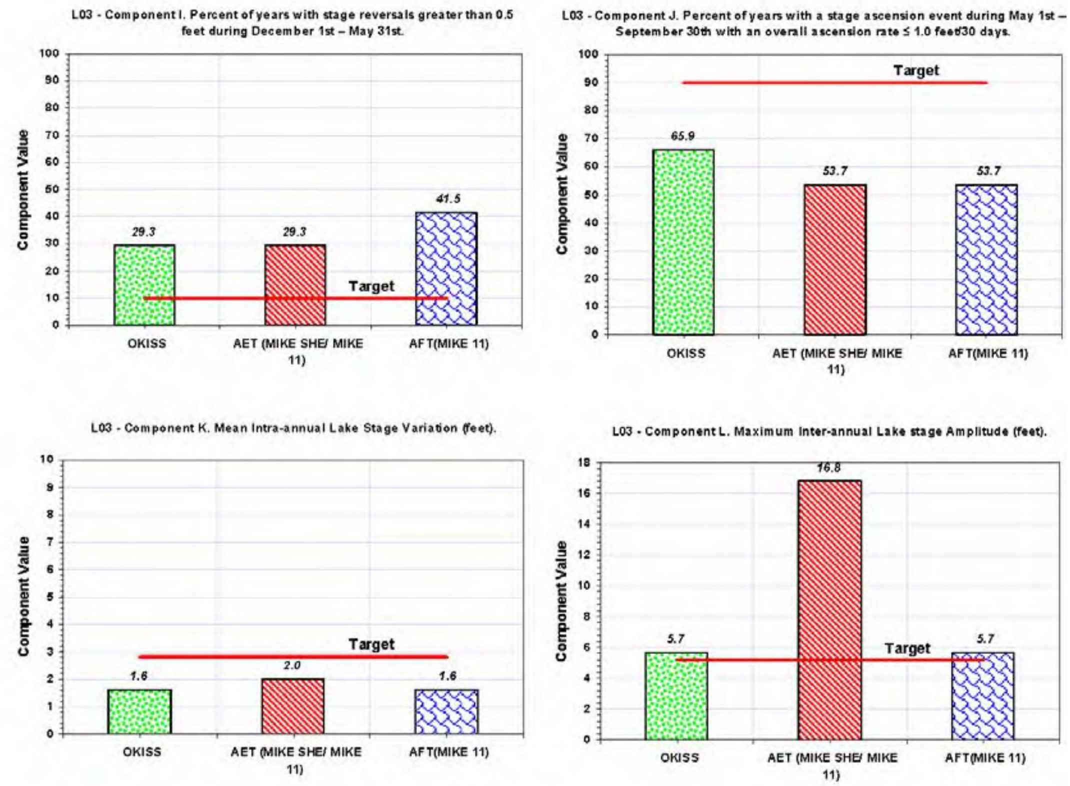


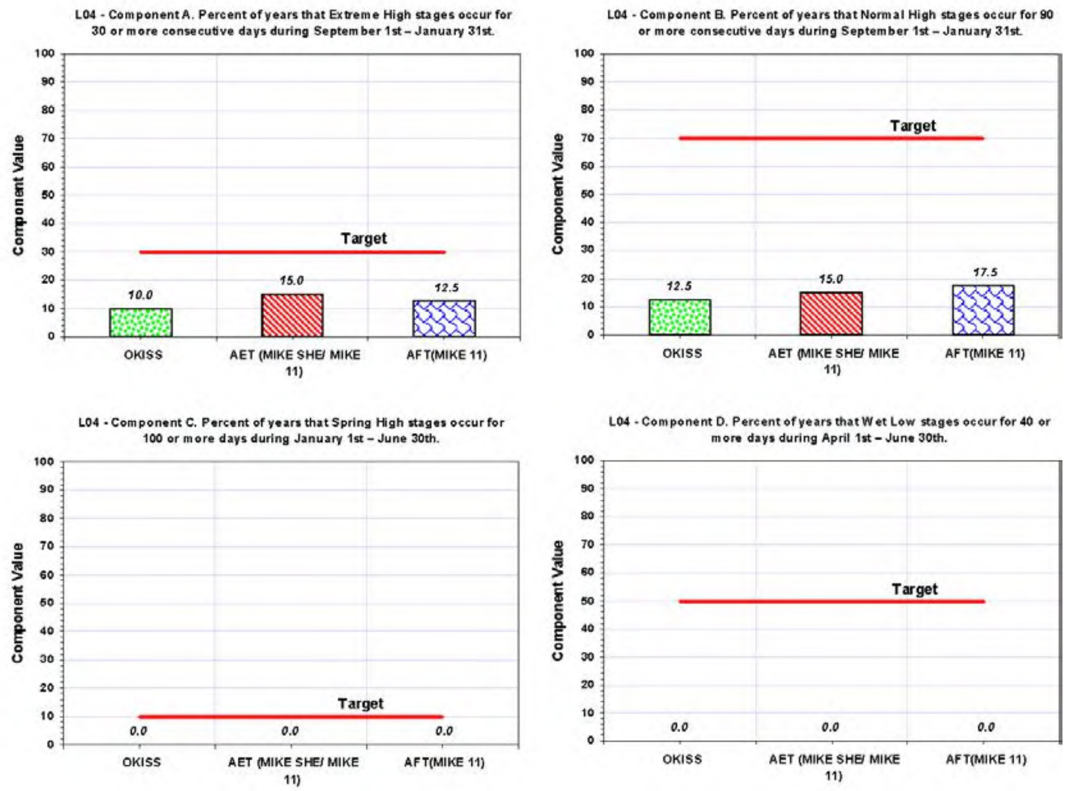
LO3 – Component E-H.

AECOM

E-16

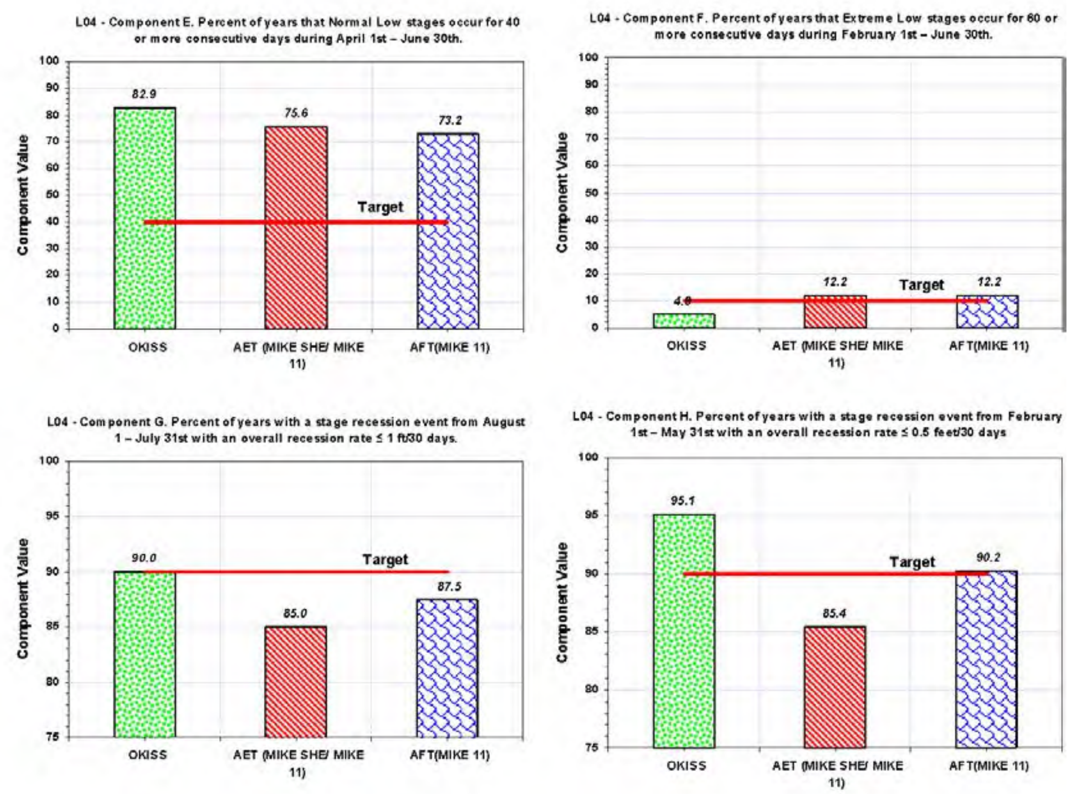


LO3 – Component I-L.



LO4 – Component A-D.

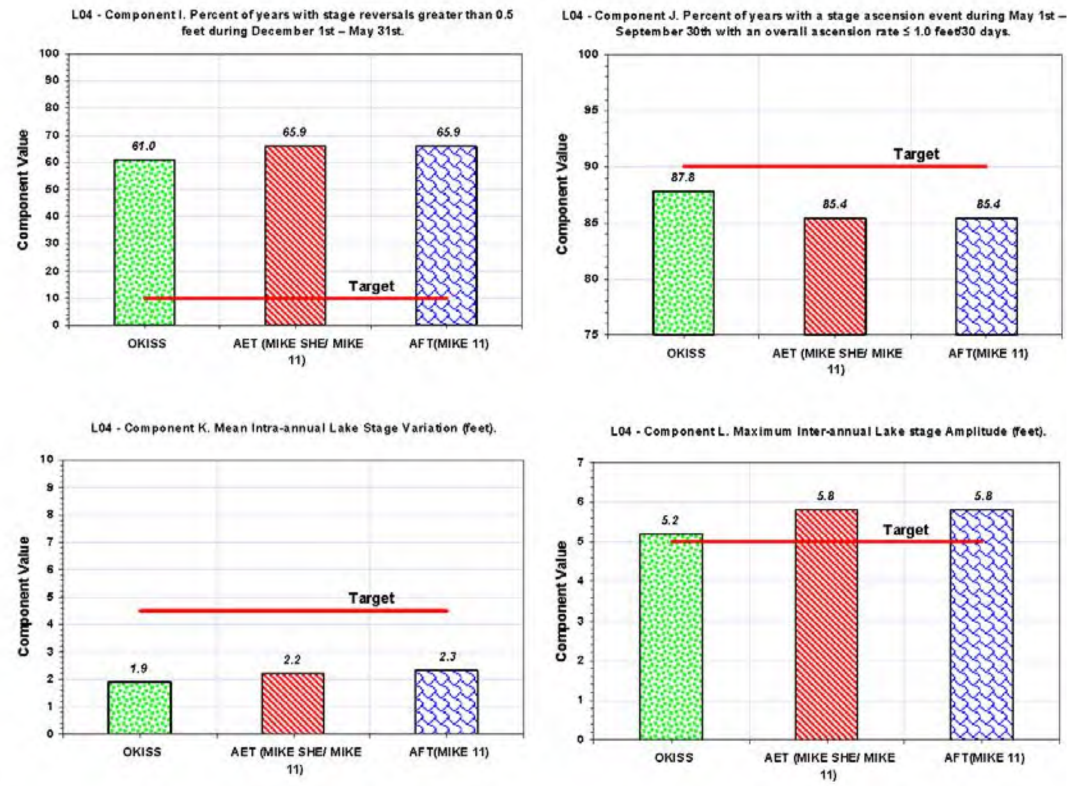
AECOM



LO4 – Component E-H.

AECOM

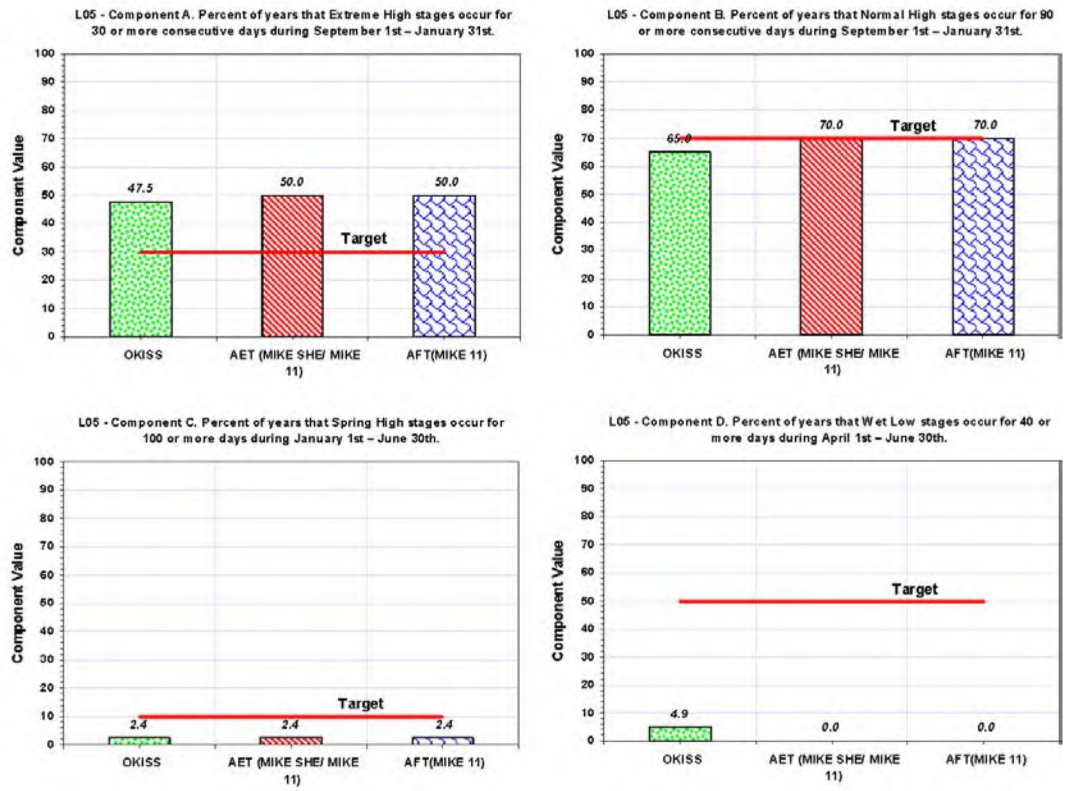
E-19



LO4 – Component I-L.

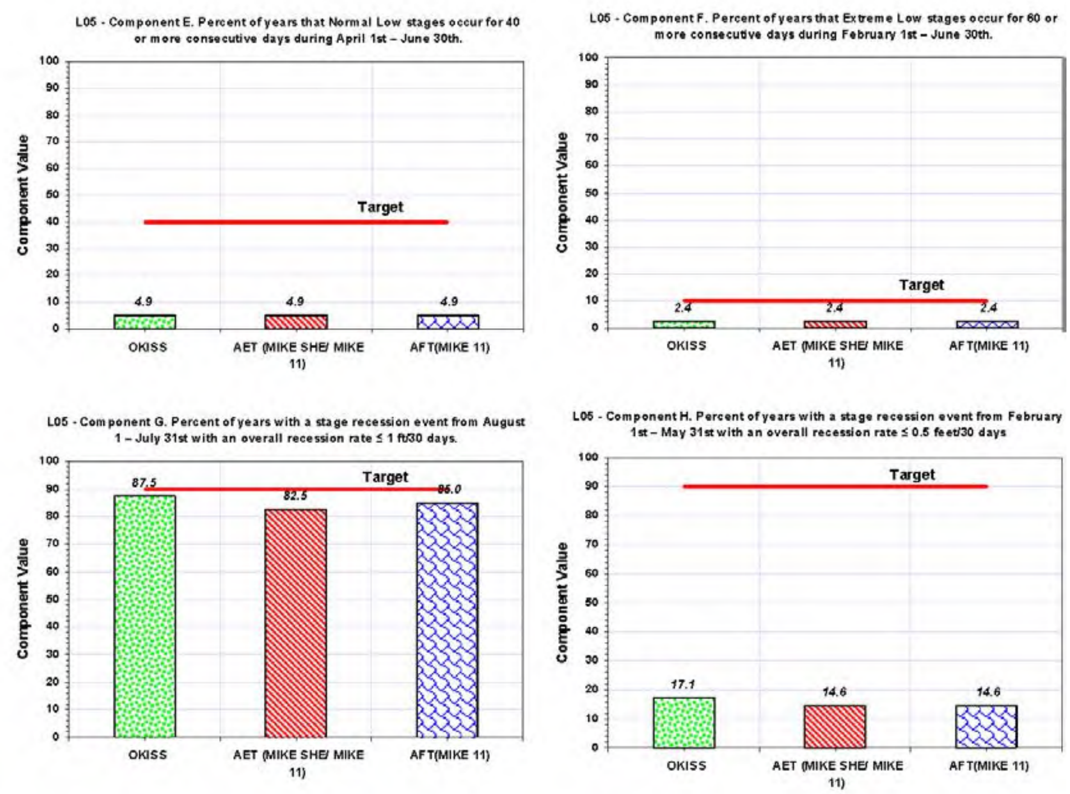
AECOM

E-20



LO5 – Component A-D.

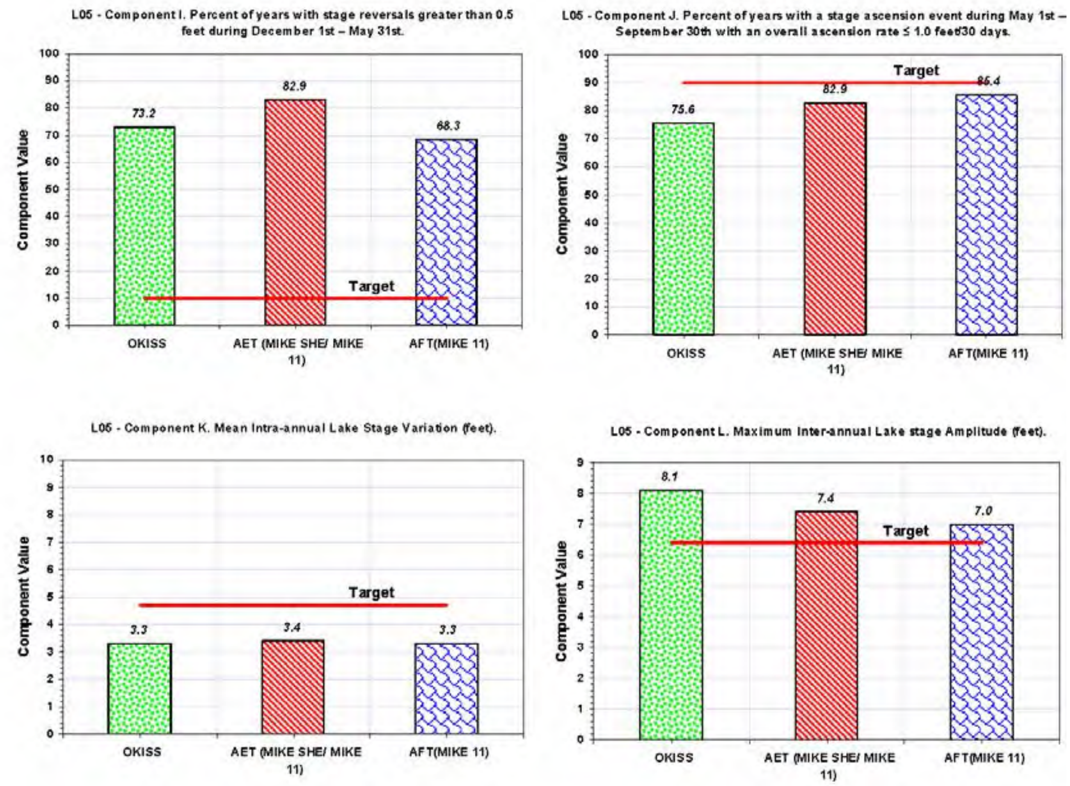
E-21



LO5 – Component E-H.

AECOM

E-22



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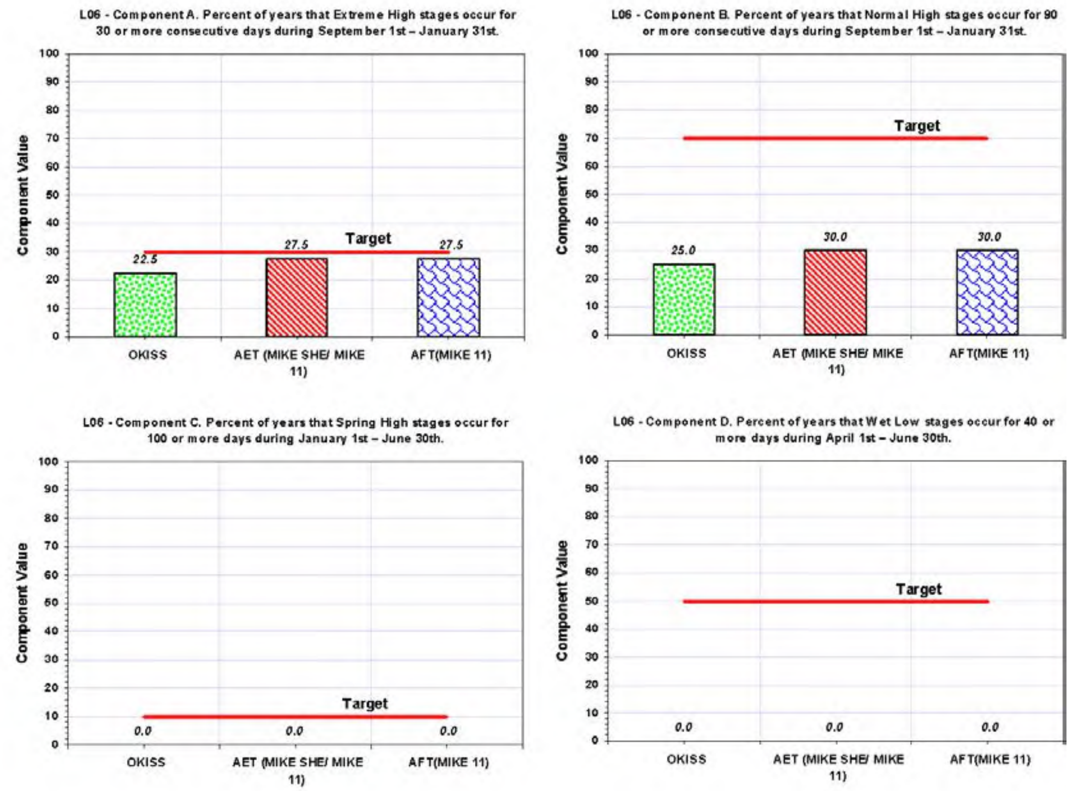
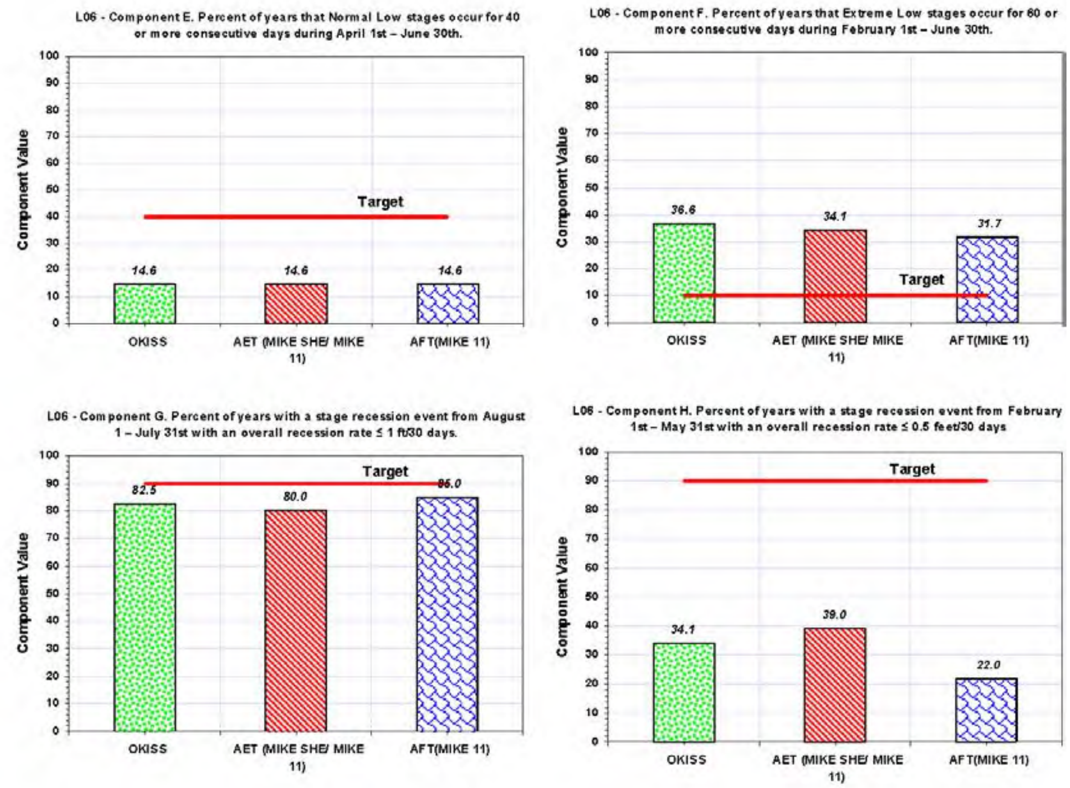


LO6 – Component A-D.

AECOM

E-24



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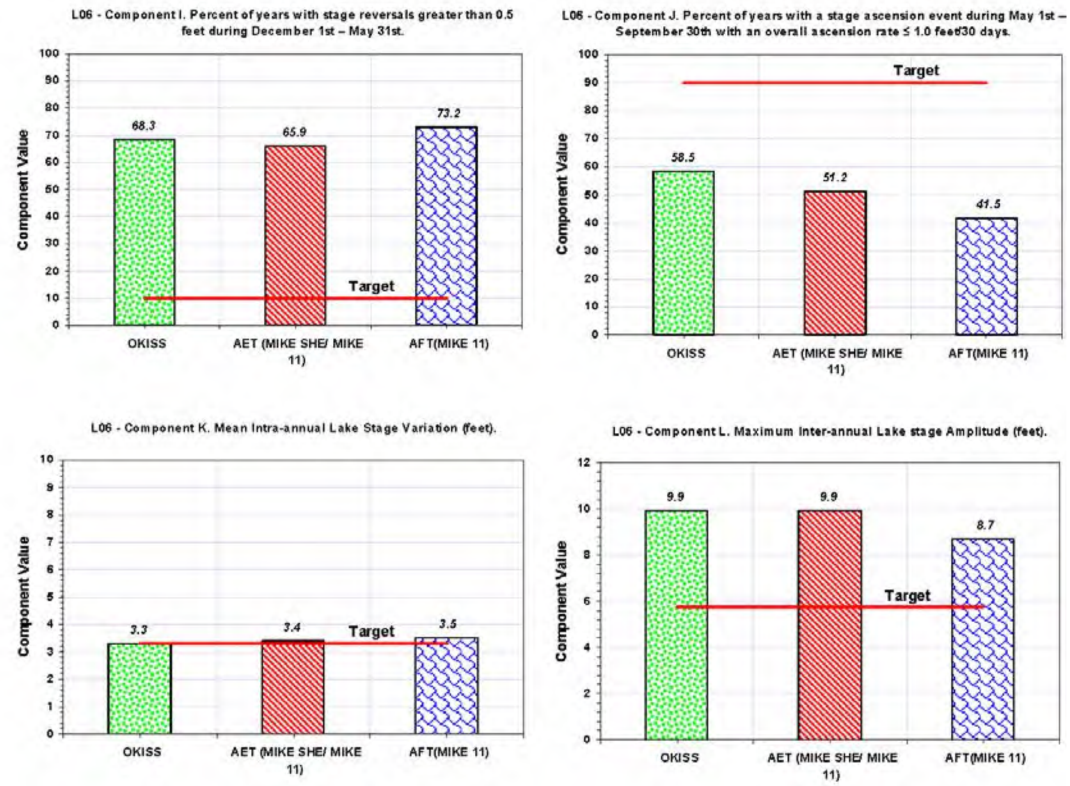
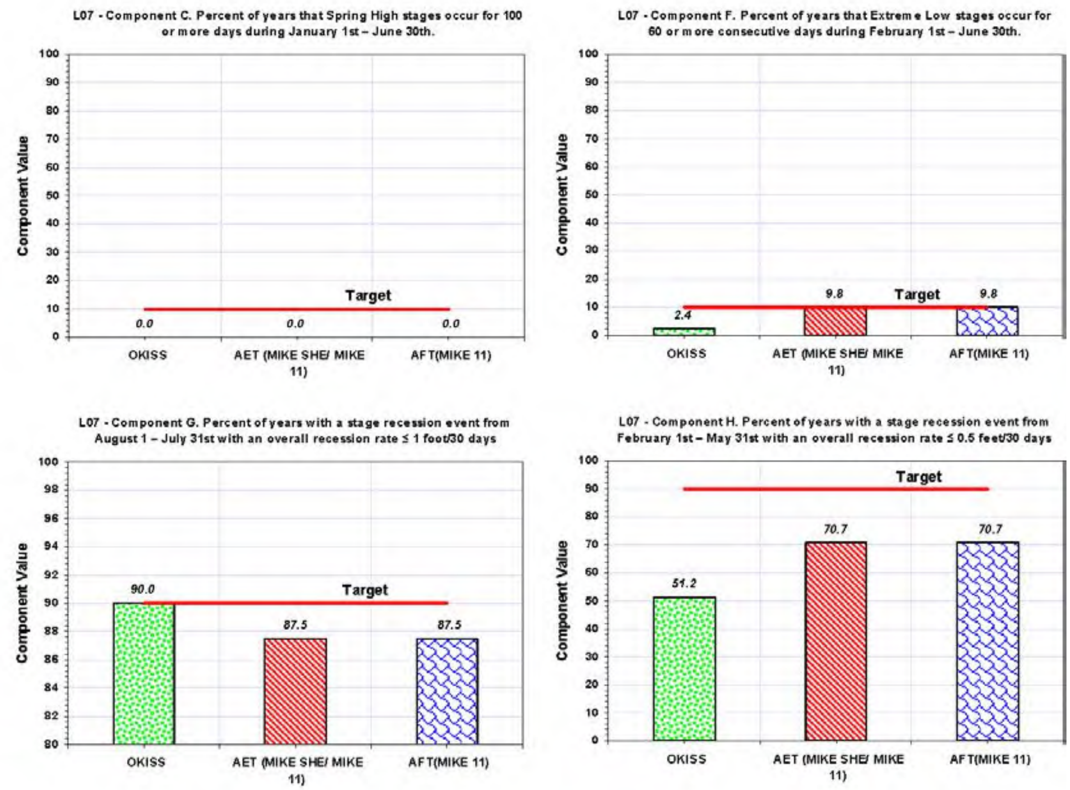
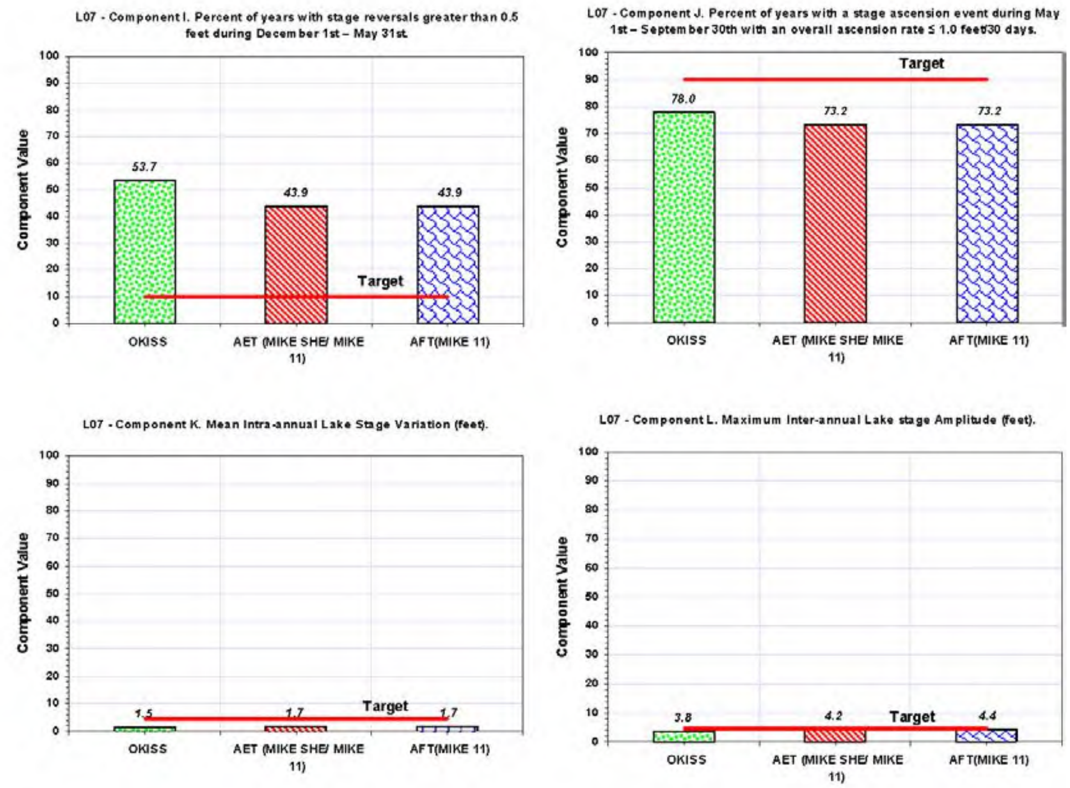


LO6 – Component I-L.

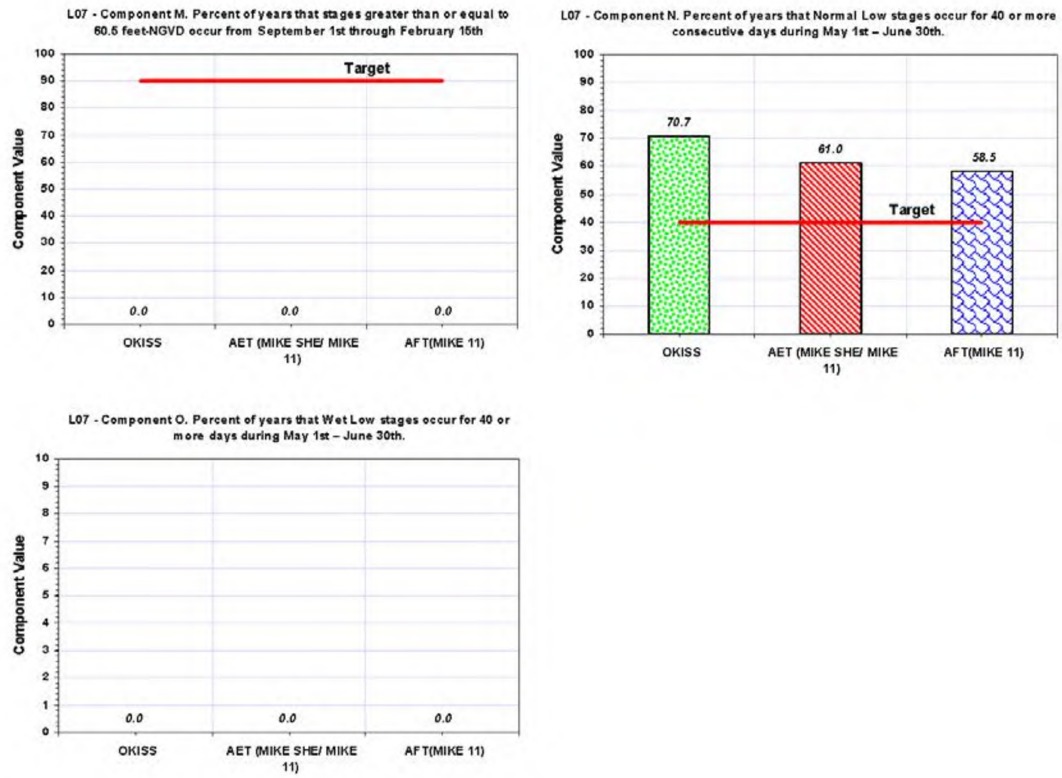


LO7 – Component C-H.

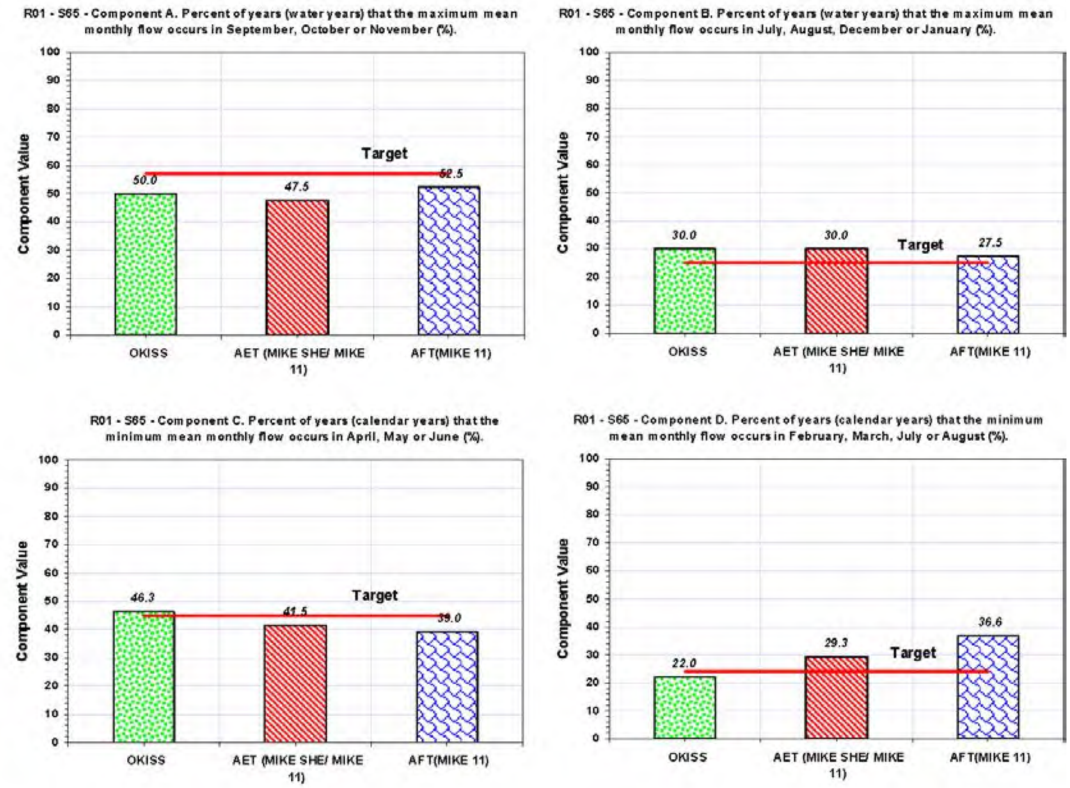
AECOM



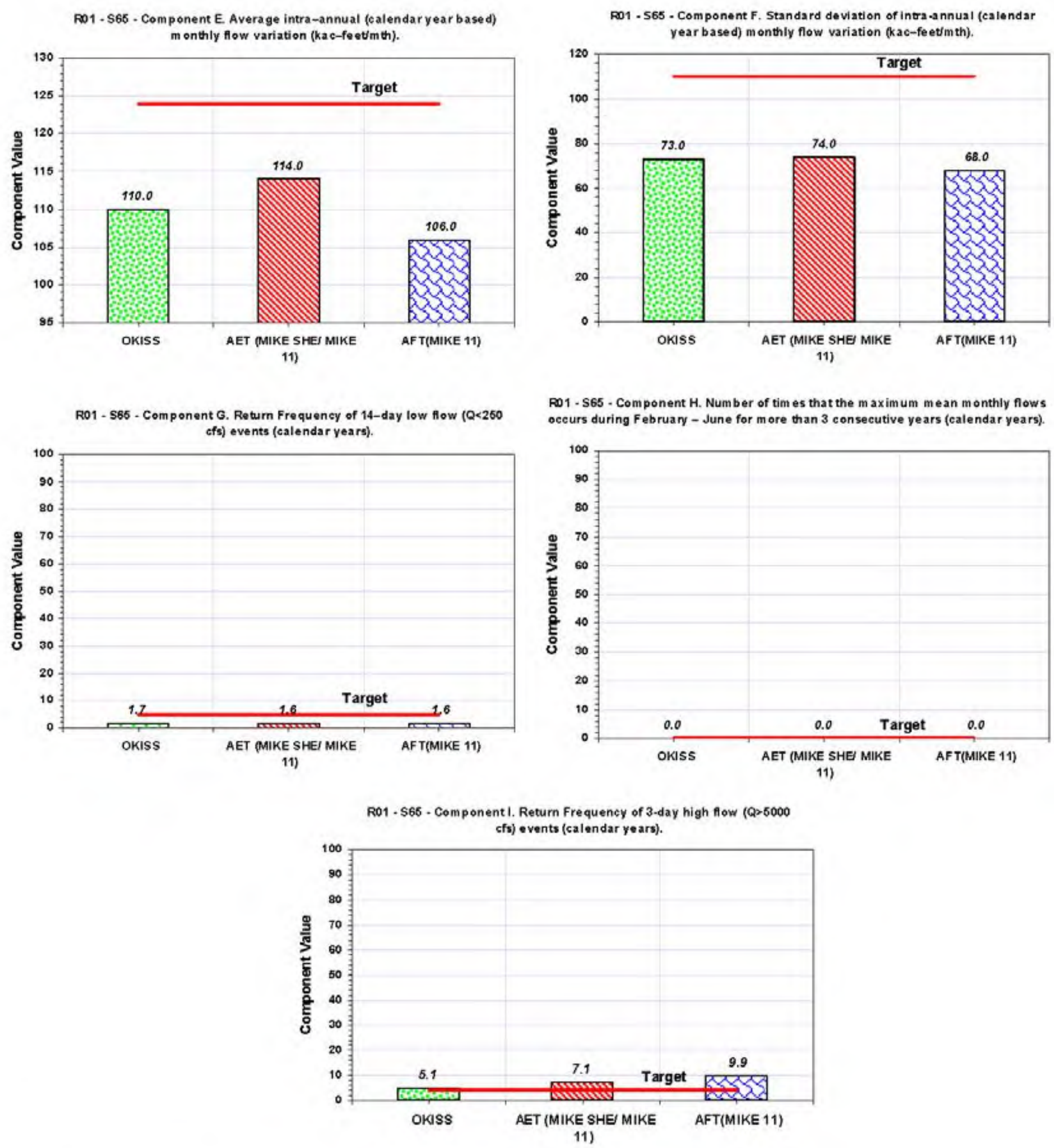
LO7 – Component I-L.



LO7 – Component M-O.

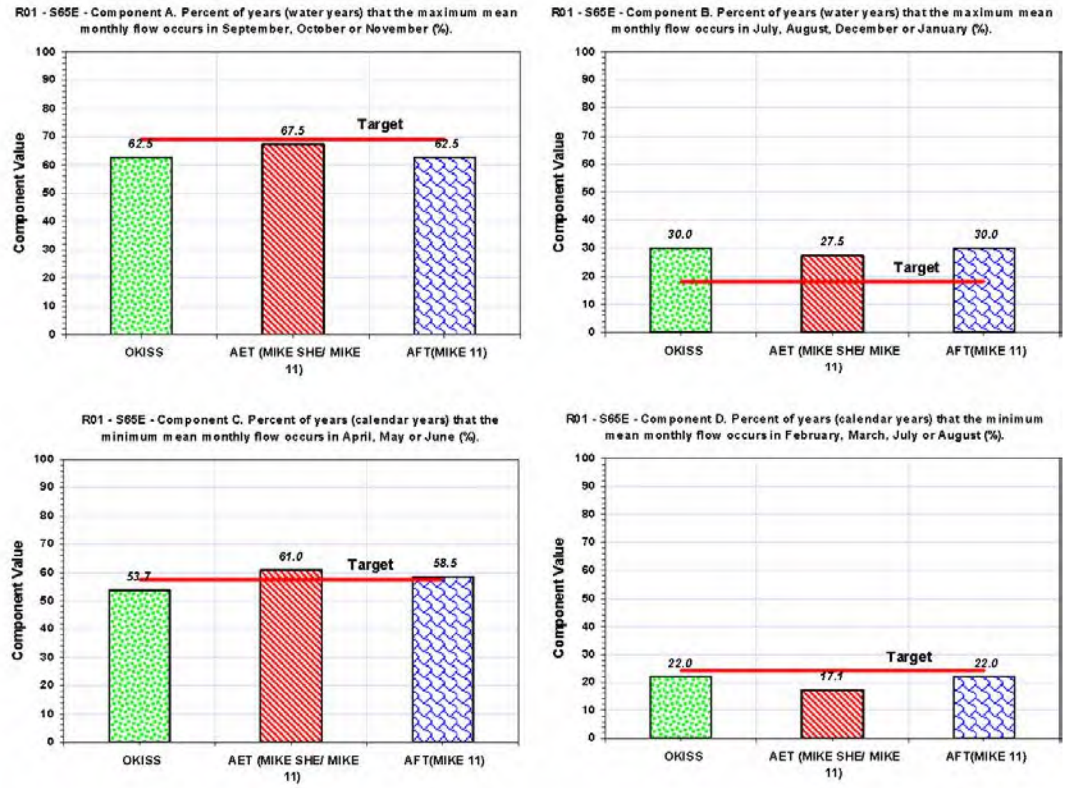


R01 – S65 – Component A-D.



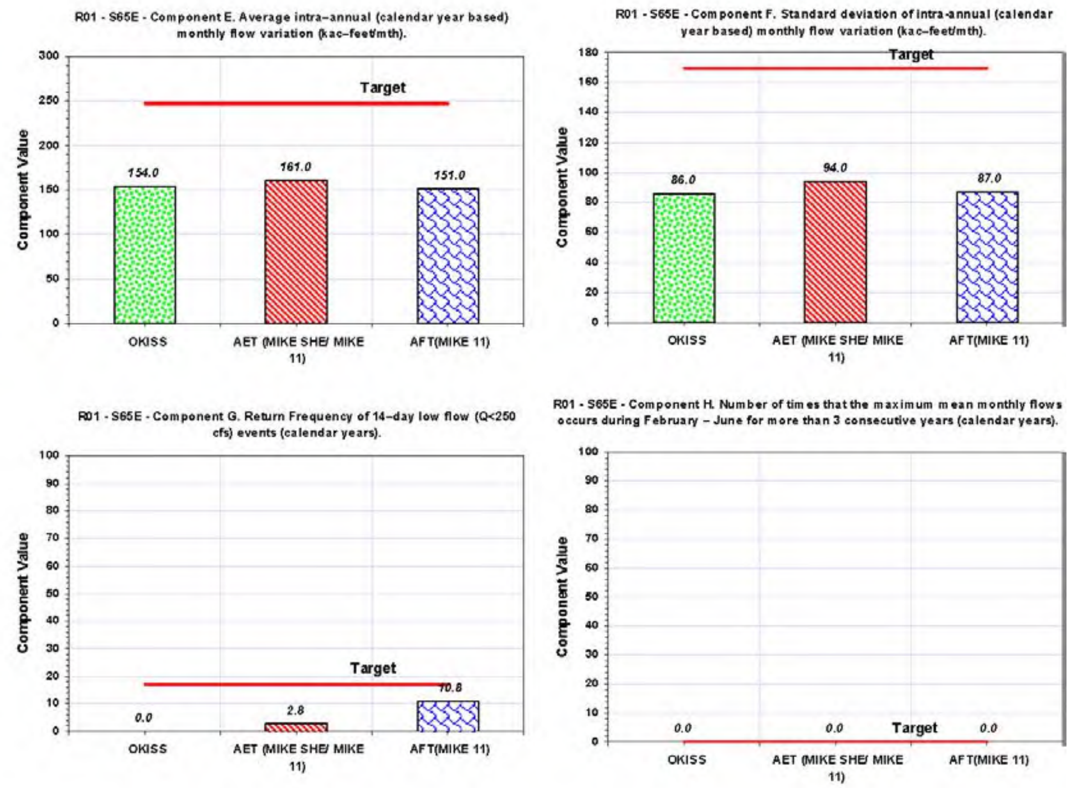
R01 – S65 – Component E-I.

AECOM



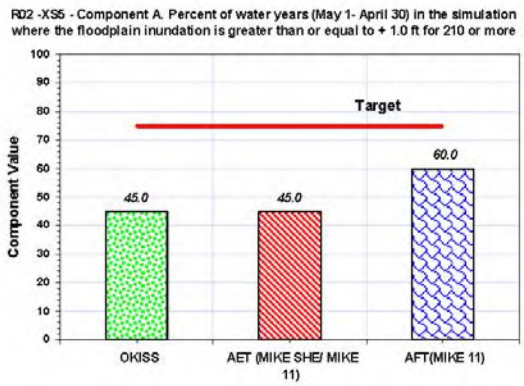
R01 – S65E – Component A-D.

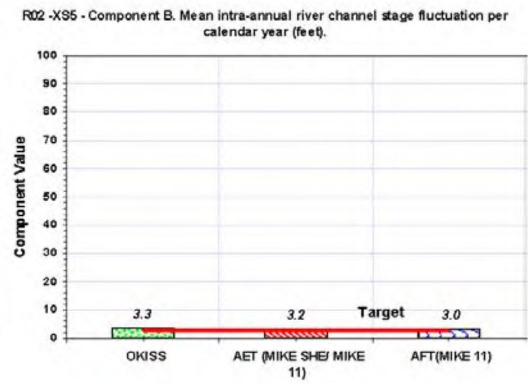
AECOM

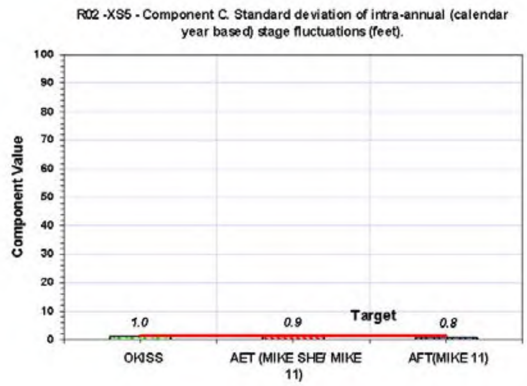


R01 – S65E – Component E-H.

AECOM



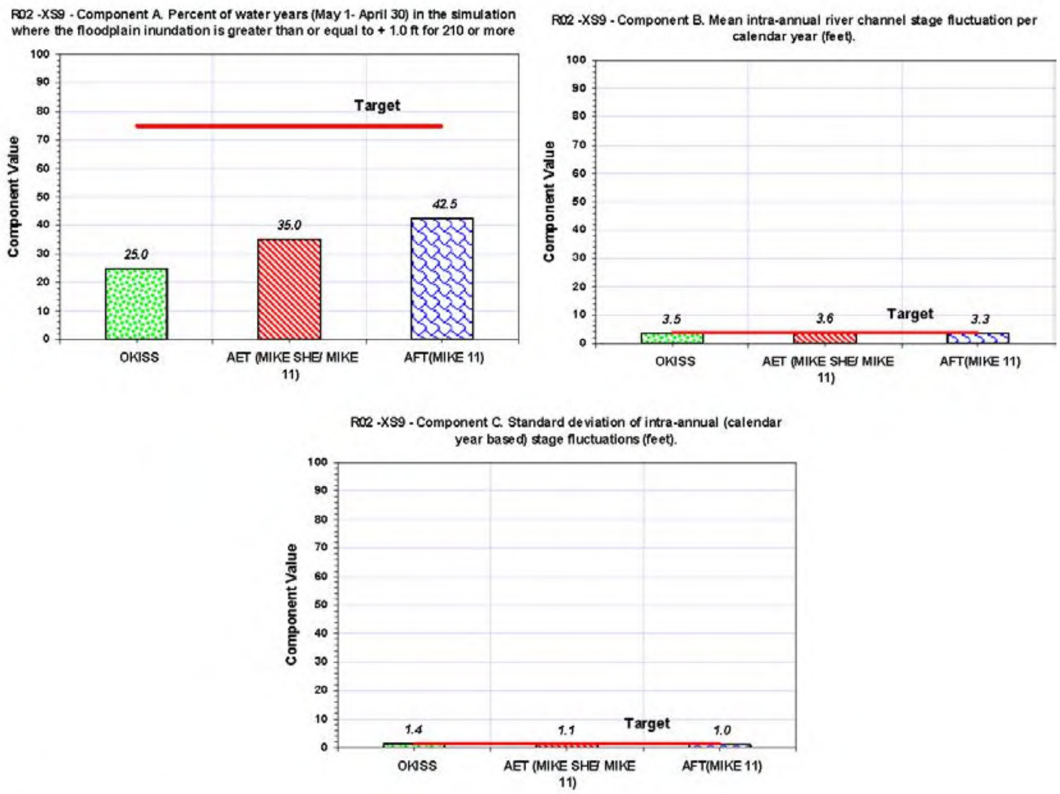




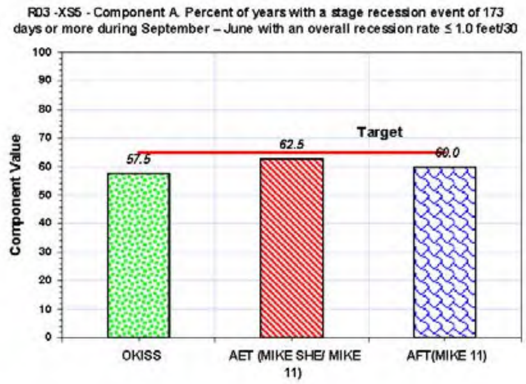
R02 – XS5 – Component A-C.

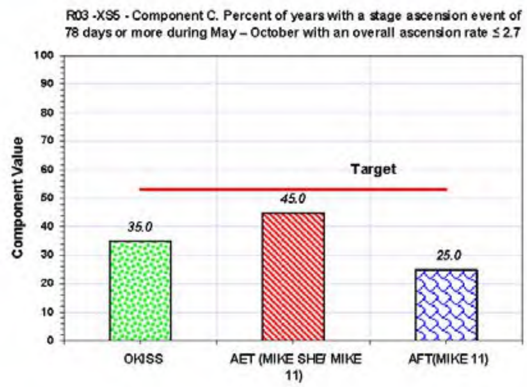
AECOM

E-34



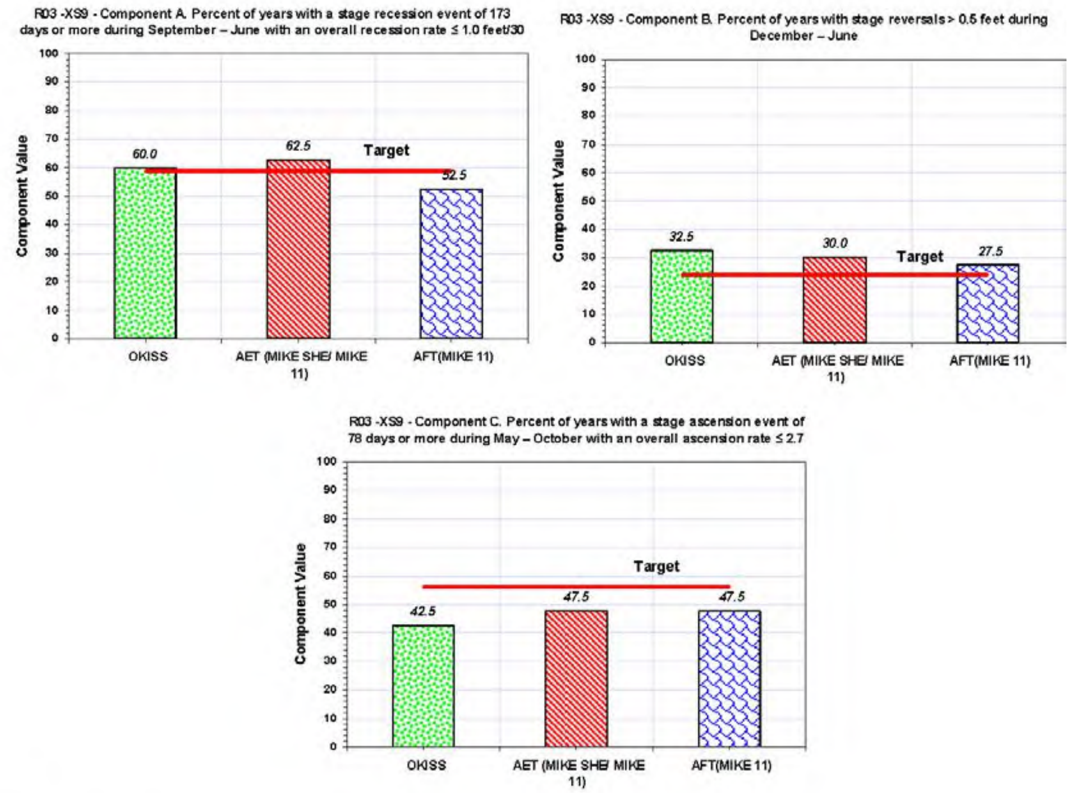
R02 – XS9 – Component A-C.





R03 – XS5 – Component A-C.

E-36



R03 – XS9 – Component A-C.

AECOM

E-37


AECOM
Alligator Chain of Lakes looking south from Structure S-60
Photographs provided by South Florida Water Management District

GLOSSARY

1-in-10 year level of certainty A water supply planning goal to assure at least a 90 percent probability during any given year that all the needs of reasonable-beneficial water uses will be met, while also sustaining water resources and related natural systems during a 1-in-10 year drought event.

Acre-foot, acre-feet The volume of water that covers 1 acre to a depth of 1 foot; 43,560 cubic feet; 1,233.5 cubic meters; 325,872 gallons, which is approximately the amount of water it takes to serve two typical families for one year.

Actual evapotranspiration A MIKE SHE water budget outflow term that represents an outflow from the model calculated as the sum of evaporation and transpiration.

Algae Simple single-celled, colonial, or multicelled (mostly aquatic) plants, containing chlorophyll, and lacking roots, stems, and leaves.

Anurans Any member of the order (Anura) of amphibians comprising the frogs, toads, and tree frogs, all of which lack a tail in the adult stage and have long strong hind limbs suited to leaping and swimming.

Alternative Formulation Evaluation Tool (AFET) AFET is a fully integrated model that couples the formulation tool (MIKE 11) with a watershed model, which includes overland and groundwater flow (MIKE SHE), developed for application as part of the Kissimmee Basin Modeling and Operations Study (KBMOS). The development and calibration of AFET is documented in the *Alternative Formulation Evaluation Model Documentation and Calibration Report* (Earth Tech 2007a).

Alternative Formulation Evaluation Tool for Water Reservation (AFET-W) Updated version of the AFET model that is calibrated using an improved set of reference evapotranspiration data and quantitative groundwater calibration criteria.

Aquatic Consisting of, relating to, or being in water; living or growing in, on or near the water.

Aquatic life All forms of living things found in water, ranging from bacteria to fish and rooted plants. Insect larva and zooplankton are also included.

Aquifer A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent. (American Geological Institute 1997)

Aquifer system A heterogeneous body of (interbedded or intercalated) permeable and less permeable material that functions regionally as a water yielding hydraulic unit and may be composed of more than one aquifer separated at least locally by confining units that impede ground-water movement, but do not greatly affect the hydraulic continuity of the system. (Laney and Davidson 1986)

Ascension rate Rise in water level per unit time, expressed in units of feet per 30 days.

Base Condition Fixed set of conditions or model drivers, used to predict the basin response using a calibrated model. For AFET-W, the Base Condition simulates hydrologic conditions for 1965 to 2005 using rainfall and evapotranspiration. It includes all features of the fully restored Kissimmee River Restoration Project, the Kissimmee River Headwaters Revitalization Water Regulation Schedule, current land use (2000), existing legal users (as of 8/31/2008), and existing regulation schedule (S-61, S-59, S-62, S-57, S-58, S-60, S-63/S-63A). This condition is the starting point for development of the target time series. The "Base Condition" is also known as the "with project," "with project base," or "with project base condition" as referenced in earlier presentations and documentation.

Base flow Sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by groundwater discharges.

Basin (Groundwater) A hydrologic unit containing one large aquifer, or several connecting and interconnecting aquifers.

Basin (Surface Water) A tract of land drained by a surface waterbody or its tributaries.

Bathymetry Topographic map of a lake showing the distribution of water depths and the shape of the lake bottom.

Biota The plant and animal life of a region or ecosystem, as in a stream or other body of water.

Canal A human-made channel used to move water (e.g., drainage, irrigation) or to allow navigation by boat.

Central and Southern Florida Flood Control Project (C&SF Project) A complete system of canals, storage areas, and water control structures spanning the area from Lake Okeechobee to both the east and west coasts and from Orlando south to the Everglades. It was designed and constructed during the 1950s by the U.S. Army Corps of Engineers (USACE) to provide flood control and improve navigation and recreation.

Central Florida Water Initiative (CFWI) A joint collaborative effort between the South Florida, Southwest Florida, and St. Johns River water management districts and other stakeholders. It addresses existing and future water demands in Orange, Osceola, Seminole, Polk, and southern Lake counties.

Centrarchid Fish belonging to the family Centrarchidae.

Channel A natural or artificial watercourse with a definite bed and banks to confine and conduct continuously or periodically flowing water.

Channelization Any of the man-made alterations of stream channel that enlarge, straighten, embank, or protect an existing channel. It is undertaken for flood control, improved drainage, maintenance of navigation channels, reduction of bank erosion, and relocation of the channel.

Confined aquifer (1) Water-bearing stratum of permeable rock, sand, or gravel overlaid by a thick, impermeable stratum. An aquifer that contains groundwater, which is confined under pressure and bounded between significantly less permeable materials, such that water will rise in a fully penetrating well above the top of the aquifer. In cases where the hydraulic head is greater than the elevation of the overlying land surface, a fully penetrating well will naturally flow at the land surface without means of pumping or lifting. (2) Also known as artesian or pressure aquifer, the confined aquifer exists where the groundwater system is between layers of clay, dense rock, or other materials with very low permeability. Water is under more pressure in a confined aquifer than in an unconfined aquifer. Thus, when tapped by a well, water is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed.

Confining unit (1) A body of significantly less permeable material than the aquifer, or aquifers, that it stratigraphically separates. The hydraulic conductivity may range from nearly zero to some value significantly lower than that of the adjoining aquifers. (2) A relatively low permeability geologic unit that impedes the vertical movement of water.

Conservation (See *Water Conservation*.)

Consumptive use Any use of water that reduces the supply from which it is withdrawn or diverted**.**

Consumptive use permitting The issuance of permits by the SFWMD, under the authority of Chapter 40E-2, Florida Administrative Code, allowing withdrawal of water for consumptive use.

Control structure A man-made structure designed to regulate the level/flow of water in a canal or waterbody (e.g., weirs, dams).

Creek A small stream of water that serves as the natural drainage course for a drainage basin of nominal or small size. The term is a relative one as to size; some creeks in the humid section would be called rivers if they occurred in the arid portion.

Cubic feet per second (cfs) A rate of the flow (e.g., in streams and rivers). It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One "cfs" is equal to 7.48 gallons of water flowing each second. As an example, if your car's gas tank were 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.

Department of Community Affairs (DCA) The DCA's mission is to assist Florida communities in meeting the challenges of growth, reducing the effects of disasters, and investing in community revitalization.

Detention The delay of stormwater runoff before discharge into receiving waters.

Direct withdrawals Removal of water from a specific waterbody.

Discharge The rate of water movement past a reference point, measured as volume per unit time (usually expressed as cubic feet or cubic meters per second).

Dissolved oxygen The concentration of oxygen dissolved in water, sometimes expressed as percent saturation, where saturation is the maximum amount of oxygen that theoretically can be dissolved in water at a given altitude and temperature.

Drawdown (1) The vertical distance between the static water level and the surface of the cone of depression. (2) A lowering of the ground-water surface caused by pumping.

Drought A long period of abnormally low rainfall that causes a hydrologic imbalance that adversely affects growing or living conditions.

Ecology The study of the inter-relationships of plants and animals to one another and to their physical and biological environment.

Ecosystem Biological communities together with their environment, functioning as a unit.

Emergent aquatic vegetation Wetland plants that extend above the water surface. Cattail and rushes are two examples.

Emergent macrophytes Wetland plants that extend above the water surface. Cattail and rushes are two examples.

Endangered species (1) As designated by the Commission, a species, subspecies, or isolated population of a species or subspecies, which is so few or depleted in number or so restricted in range or habitat due to any man-made or natural factors that it is in imminent danger of extinction, or extirpation from Florida, as determined by paragraph (a), (b), (c), (d), or (e) in accordance with Rule 68A-27.0012, Florida Administrative Code. (2) Any plant or animal species threatened with extinction by man-made or natural changes throughout all or a significant area of its range; identified by the Secretary of the Interior as "endangered," in accordance with the *1973 Endangered Species Act* (ESA).

Environmental impact statement The most detailed level of analysis required in the process described by the *National Environmental Policy Act*. It involves a detailed analysis of an action proposed by a federal agency and its alternatives. It is required when the action of a federal agency may have significant environmental consequences.

Ephemeral surface water that carries or a waterbody that holds water only during and immediately after periods of rainfall.

Evapotranspiration (ET) The total loss of water to the atmosphere by evaporation from land and water surfaces and by transpiration from plants.

Existing legal use of water A water use authorized under a District water use permit or is existing and exempt from permit requirements.

Exotic species A nonnative species introduced into an area.

Floodplain Land next to a stream or river that is flooded during high-water flow.

Floodplain wetland Palustrine wetland area adjacent to a lake and separated by a natural berm in which flooding occurs during high water events. May or may not have been a littoral wetland historically.

Florida Administrative Code The Florida Administrative Code is the official compilation of the administrative rules and regulations of state agencies.

Florida Department of Environmental Protection The SFWMD operates under the general supervisory authority of the Florida Department of Environmental Protection, which includes budgetary oversight.

Florida Fish and Wildlife Conservation Commission (FWC) State agency charged with managing fish and wildlife resources for their long-term well-being and benefit of the people.

Florida Statutes (F.S.) The Florida Statutes are a permanent collection of state laws organized by subject area into a code made up of titles, chapters, parts, and sections. The Florida Statutes are updated annually by laws that create, amend, or repeal statutory material.

Floridan aquifer system A highly used aquifer system composed of the upper Floridan and lower Floridan aquifers. It is the principal source of water supply north of Lake Okeechobee, and the upper Floridan aquifer is used for drinking water supply in parts of Martin and St. Lucie counties. From Jupiter to south Miami, water from the Floridan aquifer system is mineralized (total dissolved solids are greater than 1,000 mg/L) along coastal areas and in southern Florida.

Flow The amount of water passing a particular point over some specified time. Flow is frequently expressed in millions of gallons per day (MGD) or in cubic feet per second (cfs). See Discharge.

Flow regime Characteristics, including magnitude, frequency, duration, timing, and rate of change, which describe changes in hydrologic conditions over a period of time.

Food web A representation of the feeding relationships among the members of a community and consequently of the energy flow paths.

Geographic information systems (GIS) The abstract representation of natural (or cultural) features of a landscape into a digital database, geographic information system.

Governing Board Governing Board of the South Florida Water Management District.

Groundwater Water beneath the surface of the ground, whether or not flowing through known and definite channels. Specifically, that part of the subsurface water in the saturated zone, where the water is under pressure greater than the atmosphere.

Habitat The area or environment where an organism lives or an ecological community occurs.

Headwater Water on the controlled or upstream side of a structure that is typically of higher elevation than on the downstream (tailwater) side.

Hectare In the metric system, a unit of area equal to 2.47 acres (10,000 square meters).

Herpetofauna Amphibian and reptile community.

Hydraulic conductivity A coefficient of proportionality describing the rate at which water can move through an aquifer or other permeable medium.

Hydrilla (*Hydrilla verticillata*) A submerged plant with slender stems that can grow to the surface and form dense mats. It may be found in all types of waterbodies.

Hydrogeologic unit Any rock unit or zone that because of its hydraulic properties has a distinct influence on the storage or movement of groundwater.

Hydrologic condition The state of an area pertaining to the amount and form of water present.

Hydrologic probability curve A graphical summary of a time series of observed data or simulation model output, which shows the frequency with which hydrologic conditions (i.e., stage, flow, or volume) occur in the time series. Also called an exceedance curve.

Hydrology The scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Indicator species An organism, species, or community that indicates the presence of certain environmental conditions.

Indirect withdrawals Removal of water at a location away from a waterbody, which was affected by the removal.

Inflow The movement of water into a waterbody.

Invasive species Species of plants or animals, usually nonindigenous, which can sometimes aggressively invade habitats and cause multiple ecological changes, including the displacement of native species.

Kissimmee Basin Modeling and Operations Study (KBMOS) The KBMOS is a SFWMD initiative to identify alternative water control structure operating criteria to meet the flood control, water supply, aquatic plant management, and natural resource operating objectives for the Kissimmee Basin and its associated water resource projects. This initiative was put on hold after concurrence by the United States Army Corps of Engineers and the South Florida Water Management District to move forward with implementation of the Headwaters Revitalization Schedule after completion of the Kissimmee River Restoration Plan.

Kissimmee Chain of Lakes (KCOL) A group of lakes in the Upper Kissimmee Basin that have water levels regulated by structures from the C&SF Project.

Lake Okeechobee Located in central Florida, the lake, at 730 square miles, is the second-largest freshwater lake wholly within the United States and the largest freshwater lake in Florida.

Leakance The vertical movement of water from one aquifer to another across a confining zone or zones due to differences in hydraulic head. Movement may be upward or downward depending on hydraulic head potential in source aquifer and receiving aquifer. This variable is typically expressed in units of gallons per day per cubic foot.

Levee An embankment to prevent flooding or a continuous dike or ridge for confining the irrigation areas of land to be flooded.

Level of Certainty A water supply planning goal to assure at least a 90 percent probability during any given year that all the needs of reasonable-beneficial water uses will be met, while sustaining water resources and related natural systems during a 1-in-10 year drought event.

Limnetic zone The open water zone in lakes, which may be colonized by submergent and floating plant species.

Littoral Of, relating to, situated, or growing on or near a shore.

Littoral zone (1) The zone within a lake that is inundated at least part of the year by changes in lake stage and characterized by littoral wetland vegetation. (2) The area between the perimeter of lake or in shallow areas within a lake that is inundated year-round and contains emergent, floating-leaved, and submerged rooted plants.

Macroinvertebrate Aquatic invertebrates including insects, crustaceans, mollusks, and worms, which inhabit a river channel, pond, lake, wetland, or ocean.

Macrophytes Visible (non-microscopic) plants found in aquatic environments. Examples in south Florida wetlands include sawgrass, cattail, sedges, and lilies.

Marsh A frequently or continually inundated non-forested wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

Metric A specific variable used to quantify and serve as an indicator of the condition or state of an attribute. For example, for an attribute called largemouth bass, the relative abundance of largemouth bass may be one of several metrics chosen for measurement.

MIKE SHE/MIKE 11 A modeling package by the Danish Hydraulic Institute Water and Environment, Inc. used as to simulate surface water hydraulic routing, structure operations, and overland and groundwater flow.

Million gallons per day (MGD) A rate of flow of water equal to 133,680.56 cubic feet per day, or 1.5472 cubic feet per second, or 3.0689 acre-feet per day. A flow of one million gallons per day for one year equals 1,120 acre-feet (365 million gallons). To hold one million gallons of water, you would need to build a swimming pool approximately 267 feet long (almost as long as a football field), 50 feet wide, and 10 feet deep.

Model A computer model is a representation of a system and its operations, and provides a cost-effective way to evaluate future system changes, summarize data, and help understand interactions in complex systems. Hydrologic models are used for evaluating, planning, and simulating the implementation of operations within the SFWMD's water management system under different climatic and hydrologic conditions. Water quality and ecological models are also used to evaluate other processes vital to the health of ecosystems.

National Environmental Policy Act Federal law [42 U.S.C. 4321 et seq. - enacted on January 1, 1970] establishing a national environmental policy, goals for the protection, maintenance, and enhancement of the environment, and a process for implementing these goals within the federal agencies.

National Geodetic Vertical Datum of 1929 (NGVD) A geodetic datum derived from a network of information collected in the United States and Canada. It was formerly called the "Sea Level Datum of 1929" or "mean sea level (msl)." Although the datum was derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific coasts, it does not necessarily represent local mean sea level at any particular place.

Nuisance plant species Native plant species that spread rapidly under disturbed conditions and displace more desirable plant communities.

Outflow The movement of water out of a waterbody.

Overland flow The flow of rainfall or snowmelt over the land surface toward stream channels. After overland flow enters a watercourse it becomes runoff.

Performance measure A representation of the hydrologic requirements of fish and wildlife associated with a reservation waterbody. For the Kissimmee River, performance measures contain one or more components (metrics) that are evaluated with stage or flow output for specific locations from the simulation model and compared to target values based on pre-channelization conditions. Each reservation waterbody in the Chain of Lakes has a performance measure represented as an annual stage hydrograph. When this hydrograph is repeated through time, it represents a threshold below which the water is needed for the protection.

Permeability The capacity of a porous rock, sediment, or soil for transmitting a fluid.

Potentiometric surface A surface that represents the hydraulic head in an aquifer and is defined by the level to which water will rise above a datum plane in wells that penetrate the aquifer.

Primary producer In an ecosystem, an organism that uses the energy of the sun and inorganic molecules from the environment to synthesize organic molecules.

Public water supply Water that is withdrawn, treated, transmitted, and distributed as potable or reclaimed water.

Recession rate The rate of water level decrease per unit of time. Usually expressed as feet/30 days.

Recharge (natural) Precipitation or other natural surface flows making their way into groundwater supplies.

Reservation waterbody A lake, river, or wetland for which a water reservation is being considered or has been adopted as a rule.

Restoration The return of an ecosystem to a close approximation of its condition before disturbance.

Rule Of or pertaining to the District's regulatory programs, which are set forth in various rules and criteria.

Runoff That component of rainfall, which is not absorbed by soil, intercepted and stored by surface waterbodies, evaporated to the atmosphere, transpired and stored by plants, or infiltrated to groundwater, but which flows to a watercourse as surface water flow.

Saturated zone The part of the subsurface that is saturated with water. The upper surface of this zone, open to atmospheric pressure, is known as the water table (phreatic surface).

Seasonal high water level One of the points used to construct a lake performance measure hydrograph for a reservation waterbody. It is the highest water level in the stage regulation schedule and occurs on November 1 for all of the lake reservation waterbodies, except Kissimmee–Cypress–Hatchineha, which attains the seasonal high on December 1.

Seasonal low water level One of the points used to construct a lake performance measure hydrograph for a reservation waterbody. It is the 90^{th} percentile of the stages on May 31.

Secondary production The creation of biomass by heterotrophic organisms for a unit area and during a period of time, regardless of its fate. Usually expressed as annual secondary production with units of mg m^{-2} y^{-1}.

Slough (1) A channel in which water moves sluggishly, or a place of deep muck, mud, or mire. Sloughs are wetland habitats that serve as channels for water draining off surrounding uplands and/or wetlands. (2) A slow flowing shallow swamp or marsh (Mitsch and Gosselink 2000).

Soil moisture Water diffused in the upper part of the soil mantle that is lost by the transpiration of plants or by soil evaporation.

Spawning The depositing and fertilizing of eggs (or roe) by fish and other aquatic life.

Species of special concern As designated by the Commission, a species, subspecies, or isolated population of a species or subspecies, which is facing a moderate risk of extinction, or extirpation from Florida, in the future, as determined by paragraph (a), (b), (c), (d), or (e) in accordance with Rule 68A-27.0012, Florida Administrative Code.

Stage The height of a water surface above an established reference point (datum or elevation).

Stage reversals An increase in stage when water levels have been decreasing.

Stream A general term for a body of flowing water; a natural watercourse containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.

Submerged aquatic vegetation Wetland plants that exist completely below the water surface.

Substrate (1) The substances used for food by microorganisms in liquid suspension, as in wastewater treatment. (2) The physical surface upon which an organism lives; the natural or artificial surface upon which an organism grows or to which it is attached. (3) The layer of material beneath the surface soil.

Surface water Water above the soil or substrate surface, whether contained in bounds, created naturally or artificially, or diffused. Water from natural springs is classified as surface water when it exits from the spring onto the earth's surface.

Surficial aquifer system Often the principal source of water for urban uses within certain areas of south Florida. This aquifer is unconfined, consisting of varying amounts of limestone and sediments that extend from the land surface to the top of an intermediate confining unit.

Swamp A frequently or continuously inundated forested wetland.

Tailwater Typically of lower elevation or on the discharge side of a structure.

Target time series Time series describing the water required for the protection of fish and wildlife that meets the targets specified in the river and lake performance measures.

Taxon (taxa) A taxonomic group of any rank, including all the subordinate groups; any group of organisms, populations or taxa considered to be sufficiently distinct from other such groups to be treated as a separate unit; a taxonomic unit.

Time series A statistical process analogous to the taking of data at intervals of time.

Tributary A stream that flows into a larger stream or other body of water.

Trophic level Position in a food chain determined by the number of energy transfer steps to that level.

Unconfined aquifer (1) A permeable geologic unit or units only partly filled with water and overlying a relatively impervious layer. Its upper boundary is formed by a free water table or phreatic surface under atmospheric pressure. Also referred to as water table aquifer. (2) An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well.

United States Army Corps of Engineers (USACE) As part of the Department of the Army, the USACE has responsibilities in civil and military areas. In civil works, the USACE has authority for approval of dredge and fill permits in navigable waters and tributaries thereof; the USACE enforces wetlands regulations, and constructs and operates a variety of water resources projects, mostly notably levee, dams, and locks. It also approves changes to operating rules for water control structures built by the Central and Southern Florida Flood Control Project.

United States Fish and Wildlife Service A bureau within the Department of the Interior. Its mission is to work with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

United States Geological Survey The federal agency chartered in 1879 by Congress to classify public lands, and to examine the geologic structure, mineral resources, and products of the national domain. As part of its mission, it provides information and data on the nation's rivers and streams that are useful for mitigation of hazards associated with floods and droughts.

Unsaturated zone The zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.

Uplands An area with a hydrologic regime that is not sufficiently wet to support vegetation typically adapted to life in saturated soil conditions; nonwetland; upland soils are non-hydric soils.

Water available for allocation Water not reserved for fish and wildlife.

Water budget An accounting of the inflow, outflow, and change in storage of water for a waterbody (hydrologic unit).

Water column The volume of water above the bottom of a stream, lake, or ocean.

Waterfowl Collectively the members of the Family Anatidae (ducks, geese, and swans), which are characterized by webbed feet, dense waterproof plumage, and spend most of their time swimming.

Water management The general application of practices to obtain added benefits from precipitation, water or water flow in any of a number of areas, such as irrigation, drainage, wildlife and recreation, water supply, watershed management, and water storage in soil for crop production. Watershed management is the analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents. Watershed management for water production is concerned with the quality, quantity and timing of the water, which is produced.

Water quality (1) A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. (2) The physical, chemical, and biological condition of water as applied to a specific use. Federal and state guidelines set water quality standards based on the water's intended use, which is, whether it is for recreation, fishing, drinking, navigation, shellfish harvesting, or agriculture.

Water Reservation A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, which includes a seasonal and a location component.

Watershed A region or area bounded peripherally by a water parting and draining ultimately to a particular watercourse or body of water.

Water Supply Plan Detailed water supply plan developed by the District under Section 373.0361, Florida Statutes, providing an evaluation of available water supply and projected demands, at the regional scale. The planning process projects future demand for 20 years and recommends projects to meet identified needs.

Water table The surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere; defined by the level where water within an unconfined aquifer stands in a well.

Water use Any use of water that reduces the supply from which it is withdrawn or diverted.

Water year The 12-month period, May 1 through April 30. The water year is designated by the calendar year in which it ends.

Weir A barrier placed in a stream to control the flow and cause it to fall over a crest. Weirs with known hydraulic characteristics are used to measure flow in open channels.

Wetland An area that is inundated or saturated by surface water or groundwater with vegetation adapted for life under those soil conditions (e.g., swamps, bogs, and marshes).

Withdrawal Water removed from a ground- or surface-water source for use.

Yield The quantity of water (expressed as rate of flow or total quantity per year) that can be collected for a given use from surface or groundwater sources.

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