DOCUMENTATION REPORT FOR THE UPPER KISSIMMEE – OPERATIONS SIMULATION (UK-OPS) MODEL

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Dr. David Anderson at the SFWMD has been a primary model user and has suggested several useful improvements and new features for testing alternative operations. Dr. Anderson and Dr. Jeff Iudicello, P.E., also at the SFWMD, reviewed the draft documentation report and offered many suggestions.

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Special thanks to Natalie Kraft at the SFWMD for applying her outstanding technical editing skills to improve and complete this final document.

EXECUTIVE SUMMARY

Over the past four decades, several regional water resource simulation models, varying in complexity and utility, have been developed by the South Florida Water Management District (SFWMD) for the Upper and Lower Kissimmee Basins. The Upper Kissimmee – Operations Simulation (UK-OPS) Model is a coarse-scale water management simulation model developed to easily and quickly test alternative water operation strategies. Additional model features were created to evaluate the effects of surface water withdrawals based on the draft Kissimmee River and Chain of Lakes Water Reservations rules.

The increasing utility and computational power of Microsoft Excel® made the spreadsheet software program a logical platform to build the UK-OPS Model. The model is a simple, daily timestep, continuous simulation model of the hydrology and operations of the primary lakes in the Upper Kissimmee Basin. Analysts can use the UK-OPS Model to test a variety of operating strategies and receive instant feedback of performance for the primary lake management objectives.

This report describes the purpose, utility, and technical details of the UK-OPS Model. It is not a users' guide, but it is prerequisite reading for analysts who wish to use the model. The UK-OPS Model has been applied to assist with seasonal operations planning, including the SFWMD's monthly Position Analysis, proposed drawdown operations for East Lake Tohopekaliga, and testing the effects of hypothetical surface water withdrawals consistent with the draft Water Reservations rules. Some of these applications are summarized in this report to illustrate appropriate uses of the UK-OPS Model.

The UK-OPS Model and the draft version of this documentation report were peer-reviewed in November 2019. Recommendations for improving the draft documentation report were implemented to complete this final documentation report in March 2020. The model was deemed technically sound, appropriately developed, and usable for the intended applications. The reviewers made some suggestions for improving the model, many of which are under way, particularly the data extension through 2018. The peer-review reports are provided in Appendix D of the main report.

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ACRONYMS AND ABBREVIATIONS

AFET	Alternative Formulation and Evaluation Tool
ALC	Alligator Chain of Lakes
cfs	cubic feet per second
DPA	dynamic position analysis
ET	evapotranspiration
ETO	East Lake Tohopekaliga
GEN	Lake Gentry
GUI	graphical user interface
HMJ	Lakes Hart and Mary Jane
KCH	Lakes Kissimmee, Cypress, and Hatchineha
KRCOL	Kissimmee River and Chain of Lakes
KRRP	Kissimmee River Restoration Project
MPJ	Lakes Myrtle, Preston, and Joel
NGVD29	National Geodetic Vertical Datum of 1929
RF	rainfall
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SPF	standard project flood
TOH	Lake Tohopekaliga
UK-OPS	Upper Kissimmee – Operations Simulation (Model)
UKB	Upper Kissimmee Basin
UKISS	Upper Kissimmee Chain of Lakes Routing Model
WNI	watershed net inflow
WRL	water reservation line

1 INTRODUCTION

The development, application, and maintenance of computer simulation models have been part of the overall strategy adopted by the South Florida Water Management District (SFWMD) to manage the complex water resources in Central and South Florida. Several regional models have been deployed over the past decades to support state and federal planning initiatives, including the Comprehensive Everglades Restoration Plan, the Lower East Coast Water Supply Plan, the Northern Everglades Plan, and Lake Okeechobee Operations Planning efforts.

In 2014, the SFWMD recognized the need for a model that would allow rapid testing and evaluation of alternative water management operations in the Upper Kissimmee Basin (UKB). The primary concern was improvement of the flow regime to the Kissimmee River Restoration Project (KRRP) to better meet restoration targets. Such improvement depends on modification of operations that control water levels in the three largest lakes/lake groups in the UKB: Lakes Kissimmee, Cypress, and Hatchineha (KCH); Lake Tohopekaliga (TOH); and East Lake Tohopekaliga (ETO). To meet this need, the SFWMD developed the Upper Kissimmee – Operations Simulation (UK-OPS) Model. The UK-OPS Model initially was developed using Microsoft Excel® 2013 (v15.0) and has been used for several years by modelers, engineers, and scientists. The model has been modified primarily to increase the options for specifying operations in KCH and to evaluate potential surface water withdrawals consistent with the draft Kissimmee River and Chain of Lakes (KRCOL) Water Reservations rules. The most recent version, and the subject of this report, is UK-OPS (v3.12).

The UK-OPS Model performs daily timestep, continuous simulations of the hydrology and operations of the UKB portion of Central and South Florida's water management system for either period-of-record simulations (continuous 49 years) or position analysis simulations (49 one-year simulations, each with the same initial conditions). It has a run time of approximately 4 minutes.

The UK-OPS Model has some limitations. Hydrologic routing is limited to KCH, TOH, and ETO. The inflow series from the smaller lakes are assumed boundary conditions; thus, operations of those lakes are not simulated. Furthermore, although the UK-OPS Model simulates flows to the Kissimmee River at the S-65 and S-65A structures, it does not simulate the complexity of flows and stages within the Kissimmee River and the Lower Kissimmee Basin. The model does not simulate the rainfall-runoff process, rather it relies on the historical record or a detailed model for simulating lateral inflows to the lakes. Detailed hydraulic computations are not performed; instead, the UK-OPS Model approximates the structure stage-discharge hydraulics. Consequently, the UK-OPS Model is not a replacement for the detailed regional hydrologic and water management simulation models that traditionally have been used for analysis and planning of South Florida's water resources.

Detailed hydrologic models, such as the Regional Simulation Model – Basins (VanZee 2011) and the Mike 11/Mike SHE application to the UKB and Lower Kissimmee Basin (SFWMD 2017), are essential for comprehensive analysis of existing and future components of the water management system. Although detailed regional models are the best available tools for performing finer-scale evaluations, they are not suitable for quickly testing a broad range of alternative operations and/or water withdrawal configurations. The UK-OPS Model complements the more detailed models by screening possible alternatives through rapid simulation and evaluation so the detailed models can focus on fewer, more promising alternatives.

UK-OPS Model input requirements include: 1) regulation schedule zones and release rules for KCH, TOH, and ETO; and 2) daily time series (currently 1965 to 2013) of lake stages, inflows, outflows, and evaporation, which are used with the varying lake surface areas to calculate evapotranspiration (ET) volume. Most of these time-series inputs come from historical data or simulated values from detailed regional models.

UK-OPS Model outputs include: 1) typical hydrologic model outputs for the primary lakes—yearly water budgets, daily stage and discharge hydrographs to facilitate in-depth comparative analyses, stage and flow duration curves, and stage and flow percentile plots; and 2) hydrologic performance indicators to summarize and compare key measures among alternative plans/scenarios—reduction in annual mean flow at S-65 to evaluate impacts on the proposed KRCOL Water Reservations, water supply withdrawal reliability, and summaries of maximum stages occurring for user-specified durations.

This report provides readers with a broad view of the basic capabilities and limitations of the UK-OPS Model as well as the details of the algorithms used to simulate the hydrology and water management of the system. This report is not intended to be a comprehensive user's manual for appropriate use of the model and does not contain that level of detail. Furthermore, because initial development of the UKOPS Model focused on immediate applications, efforts were not spent on making the model user-friendly. The model does not contain limits on parameter values or warnings to caution users when results may not be realistic; therefore, the model should be used with substantial professional judgement. Future development efforts may expand and improve the user interfaces. Reading this document is necessary to understand the UK-OPS Model. To use the UK-OPS Model in its current form, interactive training may be necessary.

The need to document and peer review the UK-OPS Model arose in 2019 during the planning effort for the proposed KRCOL Water Reservations rule. Preparation of the draft report was expedited by the Modeling Section of the Hydrology and Hydraulics Bureau of the SFWMD. Recommendations from the formal external peer review were implemented and are reflected in this final report.

This report is organized into the following sections:

1. *Introduction* – A broad summary of the UK-OPS Model and the purpose and structure of this report.

2. *System Hydrology: Water Budget Approach* – An overview of the model domain, system interconnectivity, and the subsystem components, using diagrams and the continuity equation. Data needs and sources also are presented.

3. *Water Management Operating Rules* – The regulation schedules and release rules for the primary lakes: KCH, TOH, and ETO. Options for changing operating regimes also are described.

4. *Model Structure and Organization* – An overview of the organization of the worksheets; explanations of each primary worksheet, including user interfaces; and the general data flow between worksheets.

5. *Model Output* – Various graphical and tabular display summaries of simulated performance that enable evaluation of the simulations.

6. *Model Validation* – Comparison of the UK-OPS Model output with historical data to demonstrate the accuracy of the routing algorithms.

7. *Applications* – UK-OPS Model implementations, including the monthly Position Analysis and scenarios examined to support the proposed KRCOL Water Reservations. These applications represent typical appropriate uses of the UK-OPS Model.

8. *Summary and Recommendations* – Summary of model strengths and limitations and suggestions for future enhancements to improve model accuracy and utility.

2 SYSTEM HYDROLOGY: WATER BUDGET APPROACH

The UK-OPS Model uses a simple water balance approach to simulate the water levels and discharges for the primary hydrologic components of the larger lake systems in the UKB (**Figure 2-1**). This section presents an overview of the system simulated by the model, the subsystems, and their interactions. Also described in this section are the details of the hydrologic components for each subsystem. The specific operating rules and routing procedures used by the UK-OPS Model are presented in **Sections 3** and **4**, respectively.

2.1 System Overview

The SFWMD is the largest of the five water management districts created in 1972 by the Florida Water Resources Act (Chapter 373, Florida Statutes). Within the SFWMD boundaries, from Orlando to the Florida Keys, are 18,000 square miles and a current (2019) population of more than 8.7 million residents. The SFWMD oversees the water resources of the region, and its primary responsibilities include regional flood control, water supply, water quality protection, and ecosystem restoration.

The UKB is the northernmost watershed in the SFWMD and is the headwaters to the Kissimmee-Okeechobee-Everglades ecosystem. Within the UKB, the SFWMD manages the water levels in seven groups of lakes; the three largest are KCH, TOH, and ETO (**Figure 2-1**). Water is discharged from the UKB at S-65 to manage water levels in the upstream lakes and to provide flow to the Kissimmee River and the KRRP. Except for very dry periods, the flow at S-65 eventually is discharged to Lake Okeechobee via S-65E. The S-65A structure receives runoff from the basin bounded by S-65 to S-65A and is the structure regulating inflow to the KRRP. Thus, the operation of S-65A is also important to the KRRP.

The UK-OPS Model simulates the primary water budget components for KCH, TOH, and ETO within the UKB. **Sections 2.2** to **2.4** describe the methodology used by the model for these lakes. **Section 2.5** describes the simulation methodology used by the current version of the UK-OPS Model for the smaller lake systems.

Figure 2-2 shows the flow paths through the UKB Chain of Lakes and the associated water control structures that serve as outlets from each lake or lake system. Outflows from the northern branch of the chain via TOH at S-61 flow to Cypress Lake, which also receives outflow from the eastern branch of the chain from Lake Gentry (GEN) via S-63A. Outflow from Cypress Lake travels through Lake Hatchineha to Lake Kissimmee, which is the largest lake in the UKB. Water from Lake Kissimmee is released to the Kissimmee River via S-65.

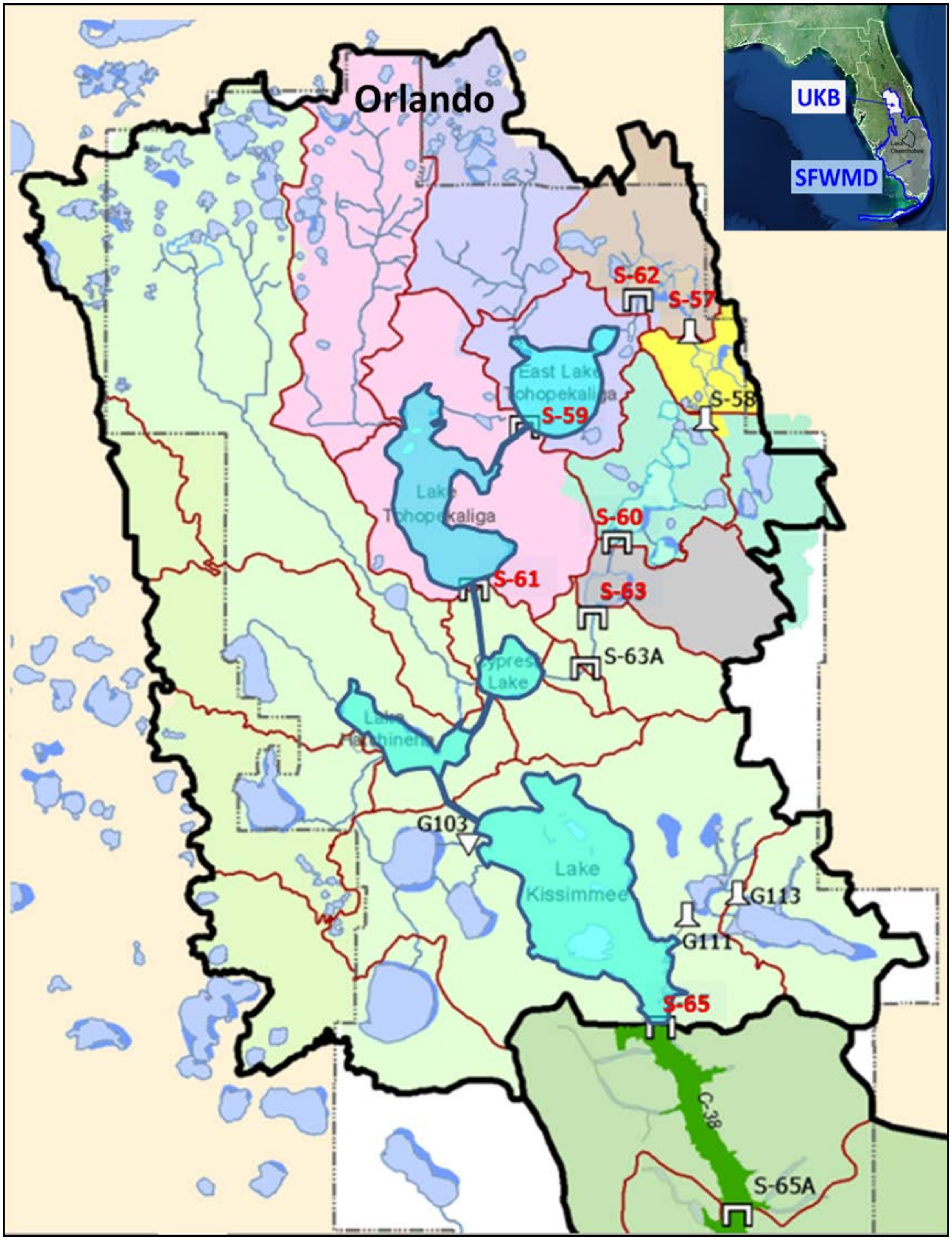


Figure 2-1. Map of the Upper Kissimmee Basin, highlighting the larger lake systems: East Lake Tohopekaliga (ETO), Lake Tohopekaliga (TOH), and Lakes Kissimmee, Cypress, and Hatchineha (KCH).

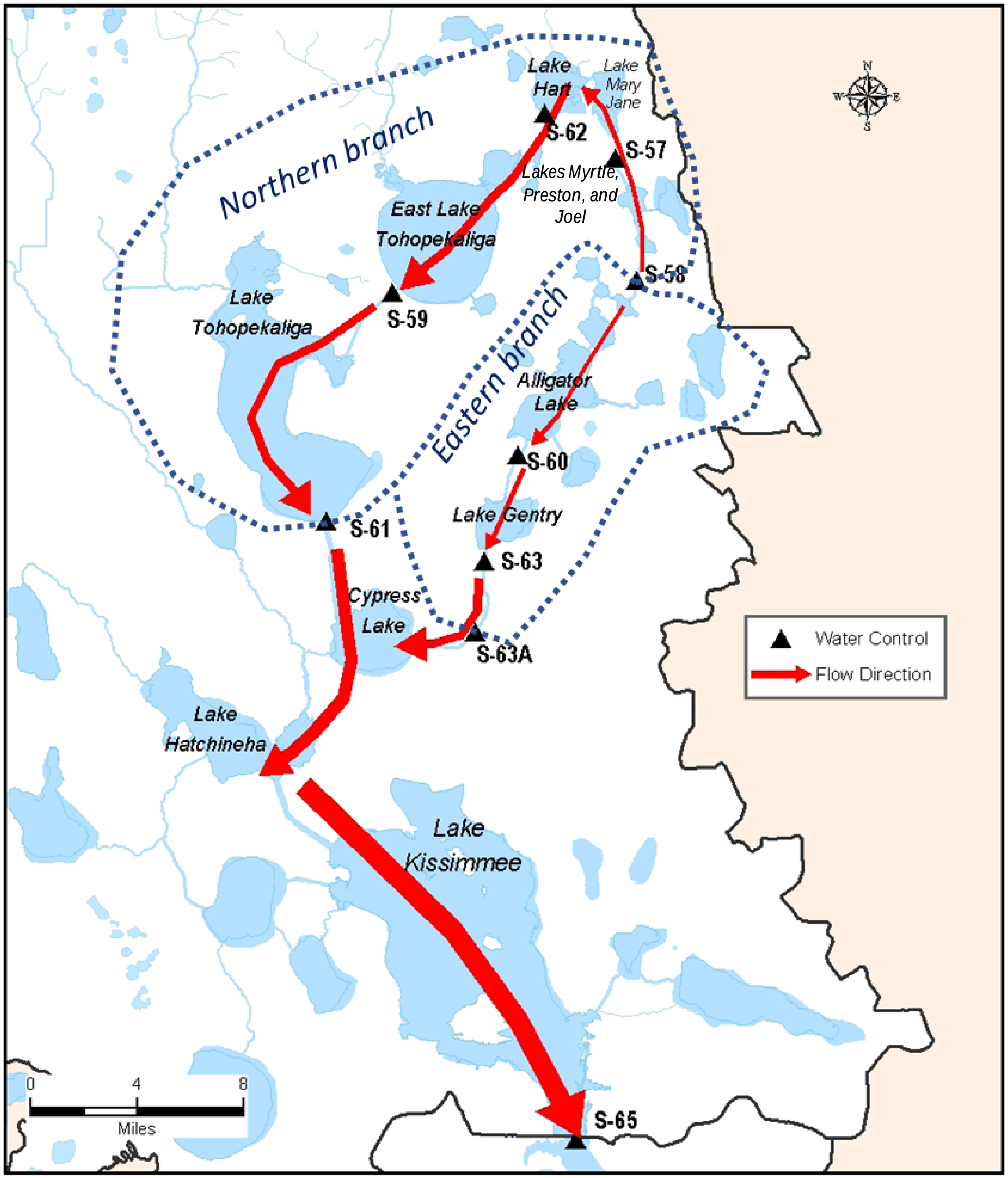


Figure 2-2. Flow paths for the Upper Kissimmee Basin Chain of Lakes.

Figure 2-3 shows the primary user interface of the UK-OPS Model, a Microsoft Excel® application that enables the user to set-up a modeling scenario, run it, and automatically generate numerous post-simulation outputs. The majority of output summaries, including performance summary graphics, can be accessed via this interface. The map is interactive and allows selection of the lake systems to be included in the simulation. The Simulation Scenario Manager allows the user to select the simulation type (continuous or position analysis) and to retrieve and/or run up to four scenarios.

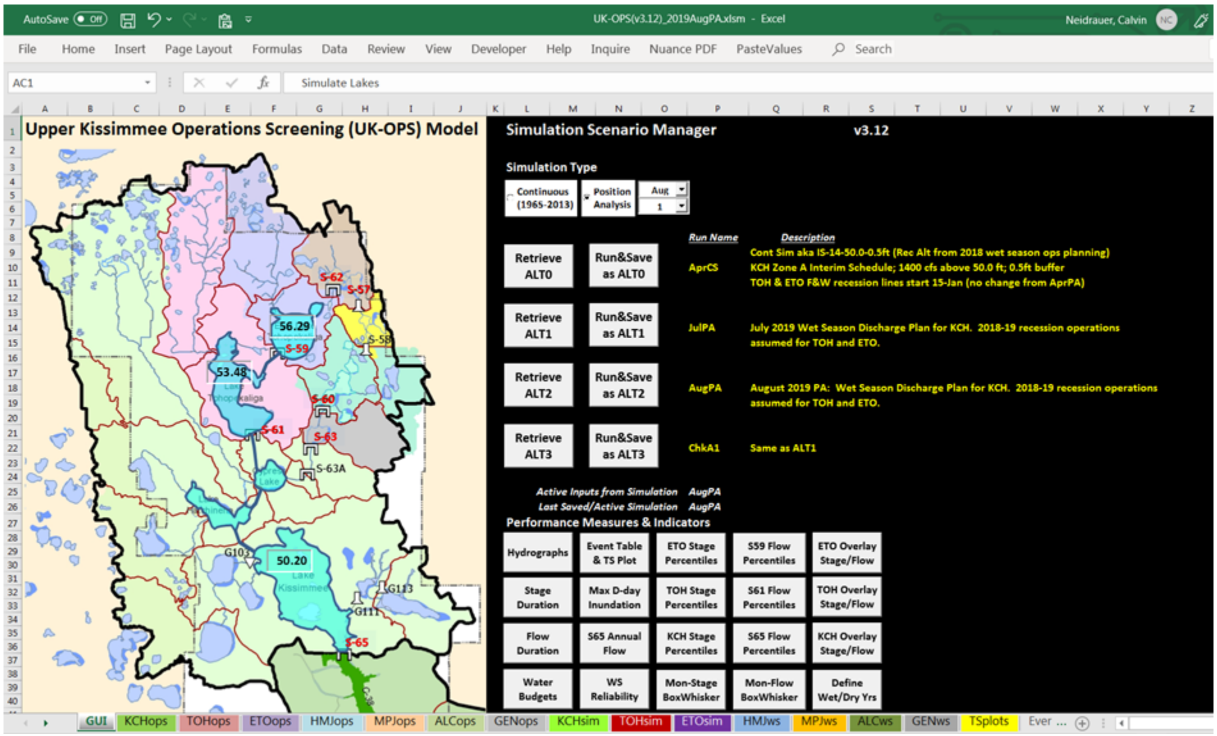


Figure 2-3. User Interface for the Upper Kissimmee – Operations Simulation (UK-OPS) Model.

The remainder of **Section 2** provides a general description of the main water bodies (East Lake Tohopekaliga, Lake Tohopekaliga, Lakes Kissimmee-Cypress-Hatchineha, and the Kissimmee River) and the derivations of the routing, or continuity equations used by the UK-OPS Model. The smaller lakes in the UKB are partially simulated by the UK-OPS Model. Routing is not performed for the smaller lakes in the current version of the model. **Section 2.5** describes the features of the smaller lakes that are included.

2.2 East Lake Tohopekaliga

ETO is the northernmost of the three largest lake systems in the UKB. At the highest stage allowed by the regulation schedule (i.e., winter pool elevation) of 58.0 feet National Geodetic Vertical Datum of 1929 (NGVD29), the surface area of ETO is approximately 12,900 acres. Inflows are from the ETO drainage basin, including Boggy Creek and its drainage basin to the north. Managed inflows via the S-62 gated spillway are from Lakes Hart and Mary Jane (HMJ) to the northeast. Managed outflows are via the S-59 gated spillway, which flows southwest to TOH.

The continuity equation used by the UK-OPS Model to describe the ETO water budget is as follows (and graphically displayed in **Figure 2-4**):

$$\Delta S = RF - ET + WNI + S62 - S59 - [WS] \qquad (2.2.1)$$

Where the terms of the water budget (in acre-feet per day) are defined as:

ΔS = change in lake storage

RF = rainfall volume over lake surface area (lumped with WNI)

ET = evapotranspiration volume over variable lake surface area

WNI = watershed net inflow (WNI lumps all other terms of the water budget, including tributary inflows, overland flow, groundwater fluxes, and other inflows and outflows assumed to not change in the simulations.)

S62 = inflow from upstream HMJ

S59 = simulated outflow from ETO

[WS] = optional simulated water supply withdrawal from ETO

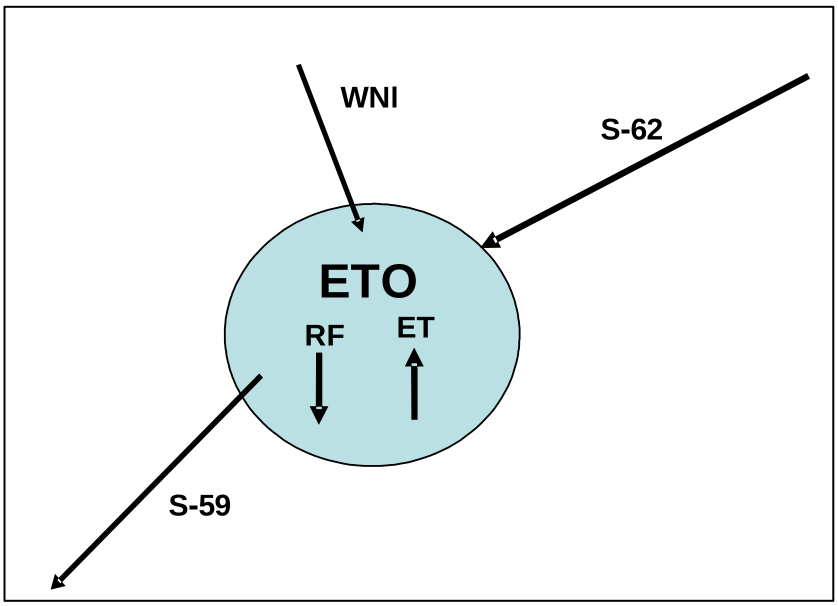


Figure 2-4. East Lake Tohopekaliga water budget components simulated by the UK-OPS Model.

The UK-OPS Model simulates S-59 releases, ET, storage change, and corresponding lake stage using the stage-storage relationship. In the current model, S-62 is an inflow boundary condition based on historical flow data. WNI+RF is an assumed persistent time series for each simulation and an input to the model. The WNI+RF values are preprocessed from historical flow data or from a detailed hydrologic simulation model like the Mike 11/Mike SHE (SFWMD 2017). Based on the continuity equation, and by knowing all the remaining terms of the water budget, WNI+RF can be computed as follows (with WS = 0):

$$\Delta S = (WNI + RF) - ET + S62 - S59$$

Solving this equation for WNI+RF yields:

$$WNI + RF = \Delta S + ET - S62 + S59 \tag{2.2.2}$$

Where all terms are daily volumes obtained from historical data or the supporting, detailed hydrologic model and are defined as follows:

WNI+RF = watershed net inflow plus rainfall volume over the lake surface area; calculated once and assumed to be a persistent time series for each simulation

$\Delta S = S(h_{t+1}) - S(h_t)$ = change in lake storage during the daily time step; calculated using lake stages and the lake stage-storage relationship

$ET = et_t \cdot A(h_{t-1})$ = evapotranspiration volume; where et_t is the daily evapotranspiration depth and $A(h_{t-1})$ is the lake surface area for the previous day calculated using the lake stage-area relationship

S62 = inflow from upstream HMJ

S59 = outflow from ETO

Once the WNI+RF series is calculated, it is unchanged for UK-OPS Model runs, which simulates the other water budget terms using **Equation 2.2.1**.

2.3 Lake Tohopekaliga

TOH is the second largest lake system in the UKB. At winter pool elevation of 55.0 feet NGVD29, the surface area is approximately 22,000 acres. Inflows are from the TOH drainage basin, including Shingle Creek and its drainage basin to the north. Managed inflows via the S-59 gated spillway are from ETO to the northeast. Managed outflows are via the S-61 gated spillway, which flows south to Cypress Lake.

The continuity equation used by the UK-OPS Model to describe the TOH water budget is as follows (and graphically displayed in **Figure 2-5**):

$$\Delta S = RF - ET + WNI + S59 - S61 - [WS] \tag{2.3.1}$$

Where the terms of the water budget (in acre-feet per day) are defined as:

ΔS = change in lake storage

RF = rainfall volume over lake surface area (lumped with WNI)

ET = evapotranspiration volume over variable lake surface area

WNI = watershed net inflow (WNI lumps all other terms of the water budget, including tributary inflows, overland flow, groundwater fluxes, and other inflows and outflows assumed to not change in the simulations.)

S59 = simulated inflow from upstream ETO

S61 = simulated outflow from TOH

[WS] = optional simulated water supply withdrawal from TOH

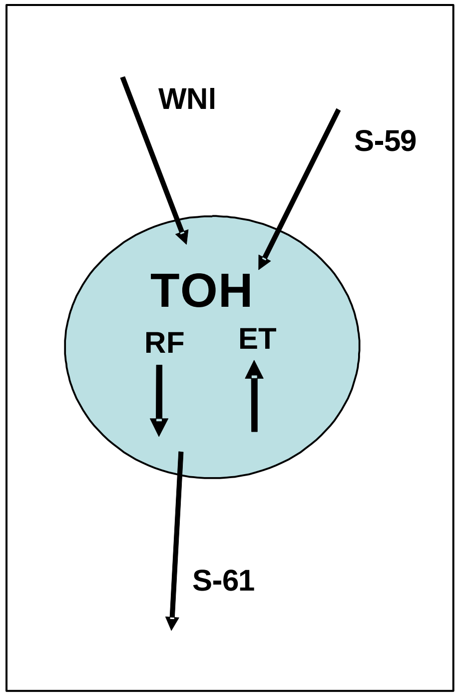


Figure 2-5. Lake Tohopekaliga water budget components simulated by the UK-OPS Model.

The UK-OPS Model simulates all the water budget components except RF and WNI, which are added to become the term WNI+RF. WNI+RF is an assumed, persistent time series for each simulation and is an input to the model. The WNI+RF values are preprocessed from historical flow data or from a detailed hydrologic simulation model like the Mike 11/Mike SHE (SFWMD 2017). Based on the continuity equation, and by knowing all the remaining terms of the water budget, WNI+RF can be computed as follows (with WS = 0):

$$\Delta S = (WNI + RF) - ET + S59 - S61$$

Solving this equation for WNI+RF yields:

$$WNI + RF = \Delta S + ET - S59 + S61 \quad (2.3.2)$$

Where all terms are daily volumes obtained from historical data or the supporting, detailed hydrologic model and are defined as follows:

WNI+RF = watershed net inflow plus rainfall volume over the lake surface area; calculated once and assumed a persistent time series for each simulation

$\Delta S = S(h_{t+1}) - S(h_t)$ = change in lake storage during the daily time step; calculated using lake stages and the lake stage-storage relationship

$ET = et_t \cdot A(h_{t-1})$ = evapotranspiration volume; where et_t is the daily evapotranspiration depth and $A(h_{t-1})$ is the lake surface area for the previous day calculated using the lake stage-area relationship

S59 = inflow from upstream ETO

S61 = outflow from TOH

Once the WNI+RF series is calculated, it is unchanged for UK-OPS Model runs, which simulates the other water budget terms using **Equation 2.3.1**.

2.4 Lakes Kissimmee, Cypress, and Hatchineha

KCH is the largest of the lake systems in the UKB. The three lakes of the KCH system are operated as a single water body because there are no intermediate water control structures in the system. The UK-OPS Model simulates the system as a single lake. At the current winter pool elevation of 52.5 feet NGVD29, the surface area is approximately 61,000 acres. Inflows are from the KCH drainage basins, including Reedy Creek and its drainage basin to the north. Managed inflows are from TOH to the northeast via the S-61 gated spillway and from eastern portion of the UKB Chain of Lakes via S-63A. Managed outflows from KCH are via the S-65 gated spillway, which flows south to the Kissimmee River.

The continuity equation used by the UK-OPS Model to describe the KCH water budget is as follows (and graphically displayed in **Figure 2-6**):

$$\Delta S = [RF + WNI + S63A] - ET + S61 - S65 \qquad (2.4.1)$$

Where the terms of the water budget (in acre-feet per day) are defined as:

ΔS = change in lake storage

RF = rainfall volume over lake surface area (lumped with WNI)

ET = evapotranspiration volume over variable lake surface area

WNI = watershed net inflow (WNI lumps all other terms of the water budget, including tributary inflows, overland flow, groundwater fluxes, and other inflows and outflows assumed to not change in the simulations.)

S61 = simulated inflow from upstream TOH

S63A = boundary condition inflow from GEN and the southeastern portion of the UKB Chain of Lakes (Note: This term is assumed to not change with the simulations. It is not explicitly used and is implicitly part of WNI.)

S65 = simulated outflow to the Kissimmee River

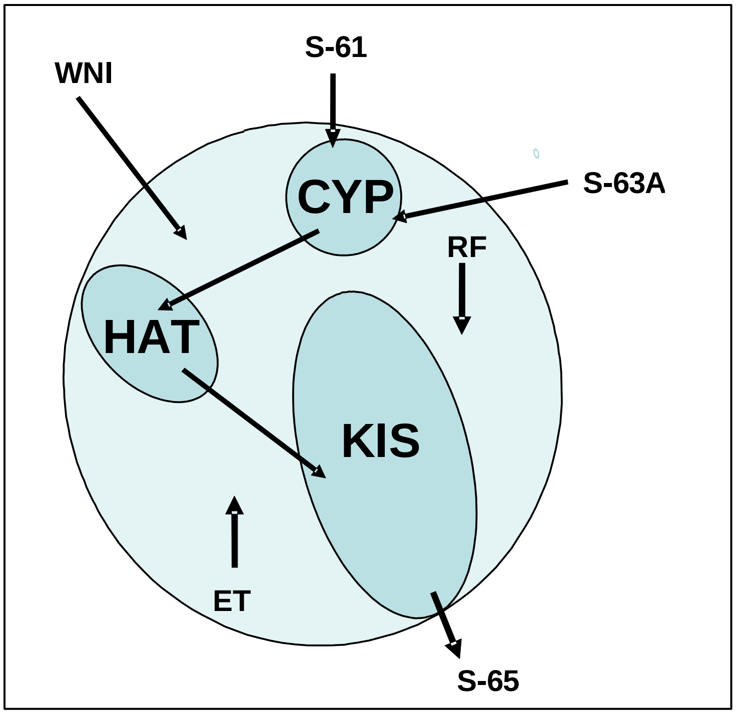


Figure 2-6. Lakes Kissimmee, Cypress, and Hatchineha (KCH) water budget components simulated by the UK-OPS Model.

The UK-OPS Model simulates all the water budget components except for S-63A, RF, and WNI. Flow from S-63A is a boundary condition. S-63A flow is assumed to be the same as historical, or the same as that simulated by the detailed hydrologic model (e.g., the Mike 11/Mike SHE). RF and WNI are added to become the term WNI+RF, which is an assumed, persistent time series for each simulation and is an input to the model. The WNI+RF values also are preprocessed from historical flow data or from the supporting, detailed hydrologic simulation model. Based on the continuity equation, and by knowing all the remaining terms of the water budget, WNI+RF is computed as follows:

$$\Delta S = (WNI + RF) - ET + S61 - S65 \text{ (S63A is part of WNI)}$$

Solving this equation for WNI+RF yields:

$$WNI + RF = \Delta S + ET - S61 + S65 \qquad (2.4.2)$$

Where all terms are daily volumes obtained from historical data or the supporting, detailed hydrologic model and are defined as follows:

WNI+RF = watershed net inflow plus rainfall volume over the lake surface area; calculated once and assumed a persistent time series for each simulation

$\Delta S = S(h_{t+1}) - S(h_t)$ = change in lake storage during the daily time step; calculated using lake stages and the lake stage-storage relationship

$ET = et_t \cdot A(h_{t-1})$ = evapotranspiration volume; where et_t is the daily evapotranspiration depth and $A(h_{t-1})$ is the lake surface area for the previous day calculated using the lake stage-area relationship

S61 = inflow from TOH

S65 = outflow to the Kissimmee River

Once the WNI+RF series is calculated, it is unchanged for UK-OPS Model runs, which simulates the other water budget terms using **Equation 2.4.1**.

2.5 Small Lakes in the Upper Kissimmee Basin

This section describes the approach used in the UK-OPS Model for the small lakes that are connected and contribute inflow to the larger lake systems described in **Sections 2.2** to **2.4**. The small lake systems include HMJ; Lakes Myrtle, Preston, and Joel (MPJ); the Alligator Chain of Lakes (ALC); and GEN. **Figure 2-2** shows the flow paths and proximity of the small lake systems to the larger systems. **Figure 2-7** shows how the smaller lake systems connect to the larger systems.

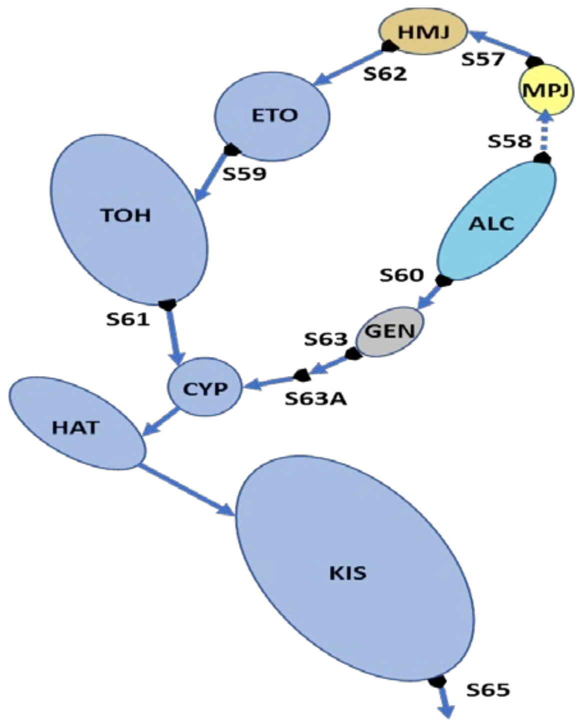


Figure 2-7. Small lake systems and their connections to the large lake systems in the Upper Kissimmee Basin.

Outflows from the small lakes generally end up in Lake Cypress. Outflows from ALC can move south via the S-60 gated spillway or north via the S-58 gated culvert. For larger flows, the southern route typically is used because it has higher capacity. The model does not simulate outflows from the small lakes. However, for evaluating water supply withdrawals from the small lakes, the model assumes flows from ALC and GEN are to Lake Cypress (KCH system) and flows from MPJ and HMJ are to ETO.

The UK-OPS Model partially simulates the small lake systems; no routing is performed for these lakes. For operations planning simulations, which usually involve only the larger lakes, the hydrology of the small lake systems is not important because the outflows from these lakes are implicitly part of the WNI term. For evaluating proposed surface water withdrawal scenarios subject to the draft KRCOL Water Reservation rules, an approximation was made, as described below.

The draft KRCOL Water Reservation rules were designed to allow water supply withdrawals to occur when they do not adversely impact the water resources and associated ecology of the lake systems and the KRRP. The rules basically define constraints that determine when water supply withdrawals can occur.

To evaluate the effects of surface water withdrawals under the draft KRCOL Water Reservation rules, the UK-OPS Model compared the small lake stage series with the water reservation line (WRL) (**Section 4.3**). If the lake stage is above the WRL and the other rule criteria are met, then water supply withdrawals can occur. Recognizing the withdrawal may reduce outflow from the small lake system and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system. Therefore, for withdrawals from MPJ and/or HMJ, the simulation determines the timing of the withdrawal using the stage and WRL of the small lake but makes the withdrawal from ETO. And for withdrawals from ALC and/or GEN, the simulation determines the timing of the withdrawal using the stage and WRL of the small lake but makes the withdrawal from KCH.

This simplifying assumption, to make the withdrawal from the next downstream large lake, was made for expediency and with recognition that building full routing capability for four more lake systems would add significantly to the computational burden of this Microsoft Excel® model. Building routing capability for the small lakes is a possible future improvement to the UK-OPS Model, but the likely minor increased benefit should be weighed with the increased computational burden and slower run times.

3 WATER MANAGEMENT OPERATING RULES

3.1 Overview

The UK-OPS Model simulates the management of releases from the larger lake systems in the UKB using rules that mimic the regulation schedules and associated release guidance criteria. This section describes these rules and their implementation in the model. Also presented in this section are some of the options built into the model for simulating alternative release strategies.

3.2 East Lake Tohopekaliga Regulation Schedule

The ETO regulation schedule (**Figure 3-1**) specifies releases at S-59 based on lake stage. The ETO regulation schedule rules traditionally have been designed to simply discharge water whenever the lake stage is above the schedule (Zone A). Releases in Zone B can be made for environmental purposes, navigation, and water supply, but are not necessary to manage the lake stage.

Figure 3-2 illustrates the ETO regulation schedule as seen by the UK-OPS Model. Up to six zones can be defined. The zones are numbered, and the labeled lines represent the bottom of each zone. The green line (Zone 4) represents the drawdown operation used in 2018 and 2019 to benefit in-lake fish and wildlife resources. The drawdowns initiated at an elevation of 57.60 feet NGVD29 on January 15. The dashed line (Zone 6) represents a 0.3-foot offset above the Zone A line (Zone 5) that can be used to transition flows up to the maximum discharge. The model can simulate a linear transition from zero to maximum discharge in this range, if specified.

The UK-OPS Model uses a zone-discharge function to specify discharge rates within the regulation schedule zones. Consistent with the regulation schedule zone labeling, the zone-discharge function places the zone number at the bottom of the zone. For ETO (**Figure 3-3**), the function is relatively simple. Zero discharge for all zones below Zone 4. Within Zone 4 (between the green line and the Zone 5 black line in **Figure 3-2**), discharge linearly increases with stage from 750 to 1,300 cubic feet per second (cfs). Above Zone 5, continue with 1,300 cfs, which is the maximum S-59 capacity assumed by the model. In this case, there is no transition specified for Zone 5. For stages above the Zone 5 line (same as bottom of Zone A), the model simulates the maximum hydraulic capacity of S-59, considering the headwater and tailwater stages approximated by the simulated stages in ETO and TOH, respectively. Note from **Figure 3-1**, the stated S-59 design capacity is 820 cfs, which is less than the 1,300 cfs maximum capacity in **Figure 3-3**.

The standard project flood (SPF) discharge rate for S-59 is 1,300 cfs, which can be reached under high stage conditions. The model simulates this capability even though it exceeds the design, which is based on 30% of the SPF discharge rate.

UK-OPS Model users can specify the breakpoints of the ETO regulation schedule and the zone-discharge function by changing the values in the color-coded tables within the ETOops worksheet. The regulation schedule and the zone-discharge function graphics automatically display changes to the inputs to enable verification of the intended changes.

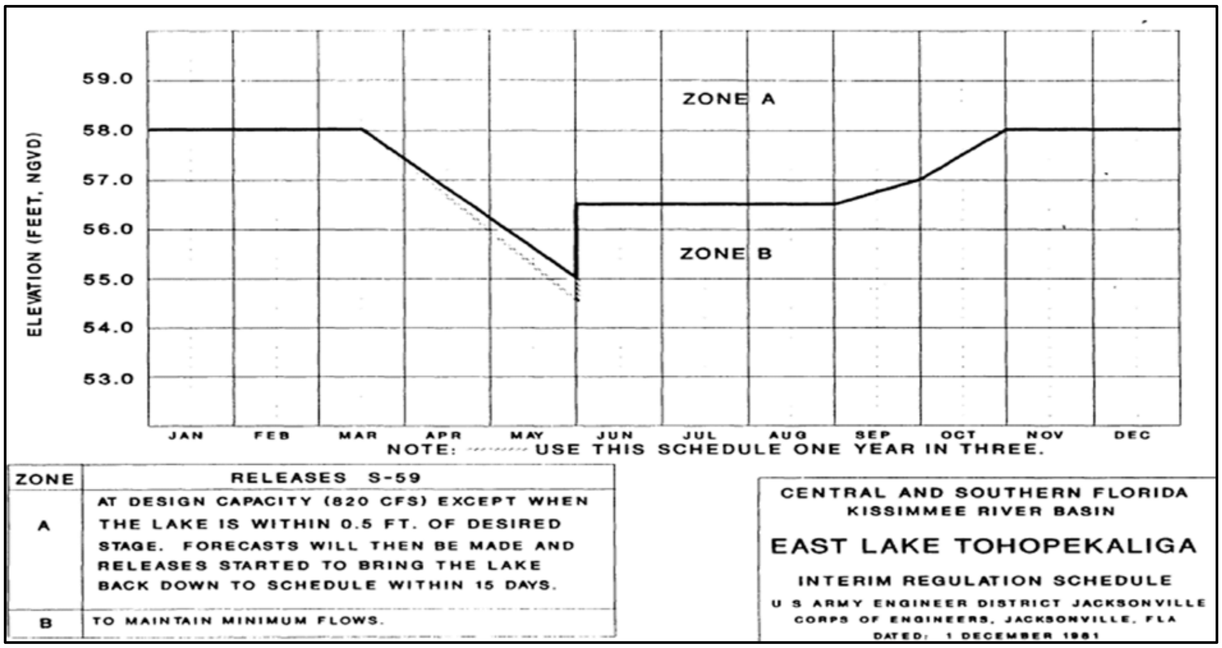


Figure 3-1. East Lake Tohopekaliga regulation schedule.

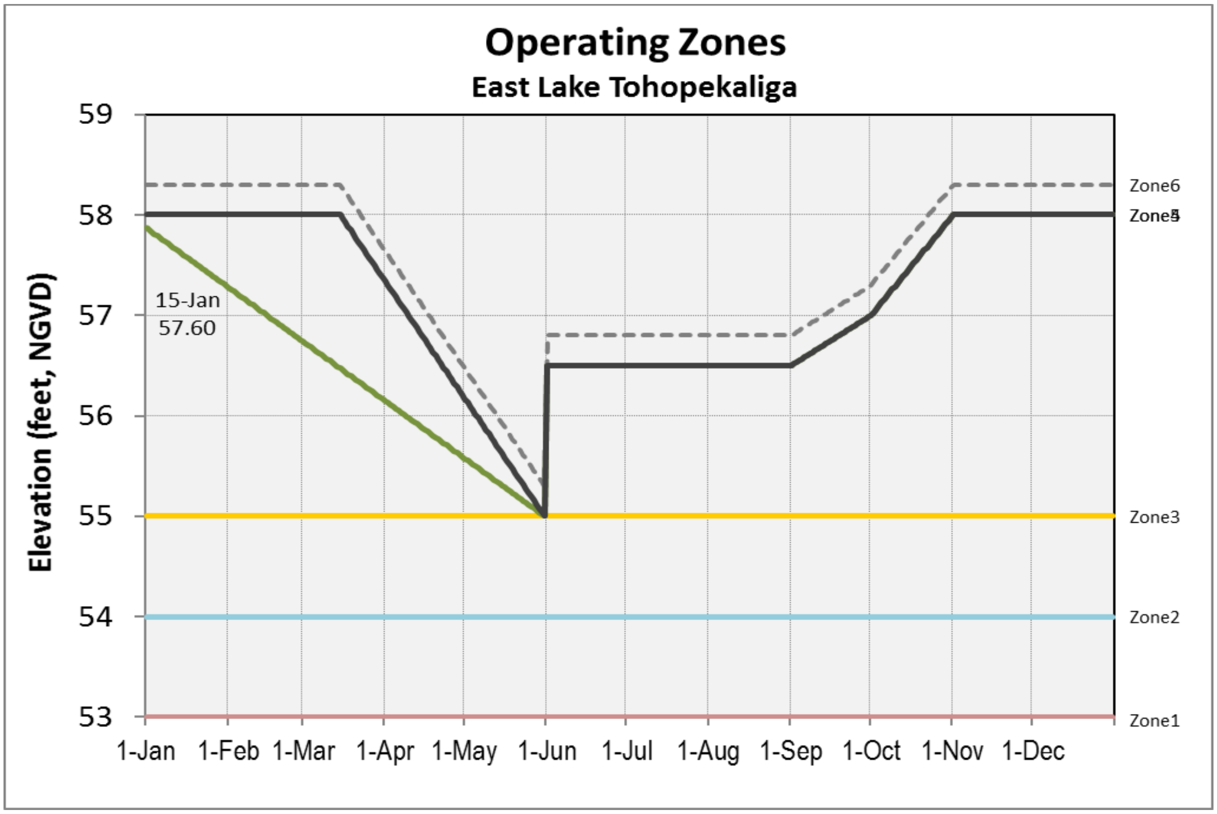


Figure 3-2. East Lake Tohopekaliga regulation schedule as seen by the UK-OPS Model.

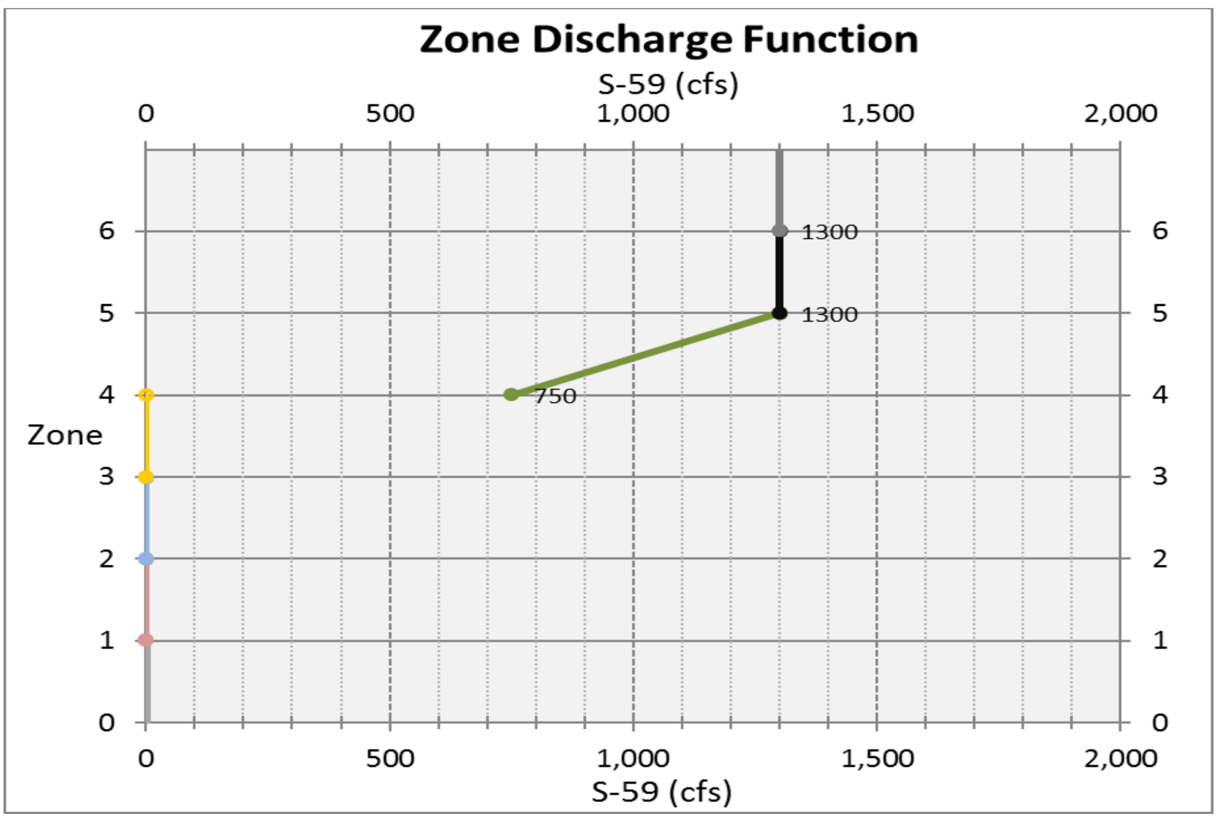


Figure 3-3. East Lake Tohopekaliga zone discharge function used by the UK-OPS Model.

3.2.1 Hydraulic Capacity Assumptions for S-59

The S-59 single-gated spillway capacity (100% of the SPF) of 1,300 cfs occurs at the SPF headwater and tailwater stages. Real system operations must account for various factors to determine the appropriate spillway gate opening and discharge rate, including maximum allowable gate opening (MAGO) criteria to keep discharge velocities from exceeding design limits and maximum permissible head (MPH) across the structure. These criteria are not explicitly considered by the daily timestep routing model, but the model does calculate the upper limit of S-59 discharge capability (S59Qcap) using the daily simulated upstream and downstream lake stages, which is capped by the user-input S59maxcap, currently set to 1,300 cfs.

The S-59 discharge capacity (1,300 cfs) also is the 99th percentile value of the historical flow data (1965 to 2005). Maximum flow during the historical period was 2,160 cfs; however, this maximum is not recommended for S59maxcap because it is excessively high and inappropriate as an upper limit for simulating long-term performance. If flood peaks are of interest, more refinement to the model or a finer timestep hydraulic model may be needed.

Details about the daily S-59 hydraulic capacity computation (S59Qcap) are contained within the ETOops and ETOsim worksheets and are described below.

S59Qcap is the structure's hydraulic capacity, which is approximated by the UK-OPS Model as:

$$\mathrm{S59Qcap} = \mathrm{K}(HWEL - CEL)\sqrt{HWEL - TWEL} \tag{3.2.1}$$

Where:

HWEL = S59Hsim

CEL = 49.1 feet crest elevation

TWEL = S61Hsim

K = 125, derived from the following traditional orifice flow equation:

$$\mathrm{Q} = \mathrm{CA}\sqrt{2g(HWEL - TWEL)} \tag{3.2.2}$$

Where:

C = empirical discharge coefficient

A = L(HWEL-CEL)

g = gravity of Earth (32.2 ft/s^2)

L = gate width

By taking the ratio of Q/Q*, where Q* is the same equation using the SPF information, **Equation 3.2.1** can be derived. **Equation 3.2.1** is used by the UK-OPS Model for daily timestep approximation of the dynamic structure capacity. As described previously, S59Qcap cannot be larger than S59maxcap, which currently is set to the SPF capacity of 1,300 cfs.

3.2.2 Temporary Pump Capacity Assumptions for S-59

For testing scenarios such as ETO stage drawdown operations, which aim to periodically lower the lake stage below the elevation of the downstream TOH, the UK-OPS Model has a feature that allows specification of temporary pumps in parallel with the S-59 gated spillway. The ETOops worksheet allows specification of the average daily pump flow rate (S59pumpcap) and has an option to supplement gravity releases with pumping when the spillway capacity is less than the target release. Simultaneous gravity flow and pumping are simulated, and the user can specify a percent reduction in gravity capacity when pumping is used simultaneously. This accounts for the reduced spillway discharge rate due to the rise in tailwater stage from pumping (**Figure 3-4**). Such a condition can happen when the water level difference across the structure (Δh) is small but positive. Thus, gravity flow capability is possible, but it may be smaller than desired, and pumping is necessary to meet the desired flow target. Such a simultaneous use condition may be short-lived as the headwater elevation recedes below the tailwater elevation and water level difference across the structure becomes negative.

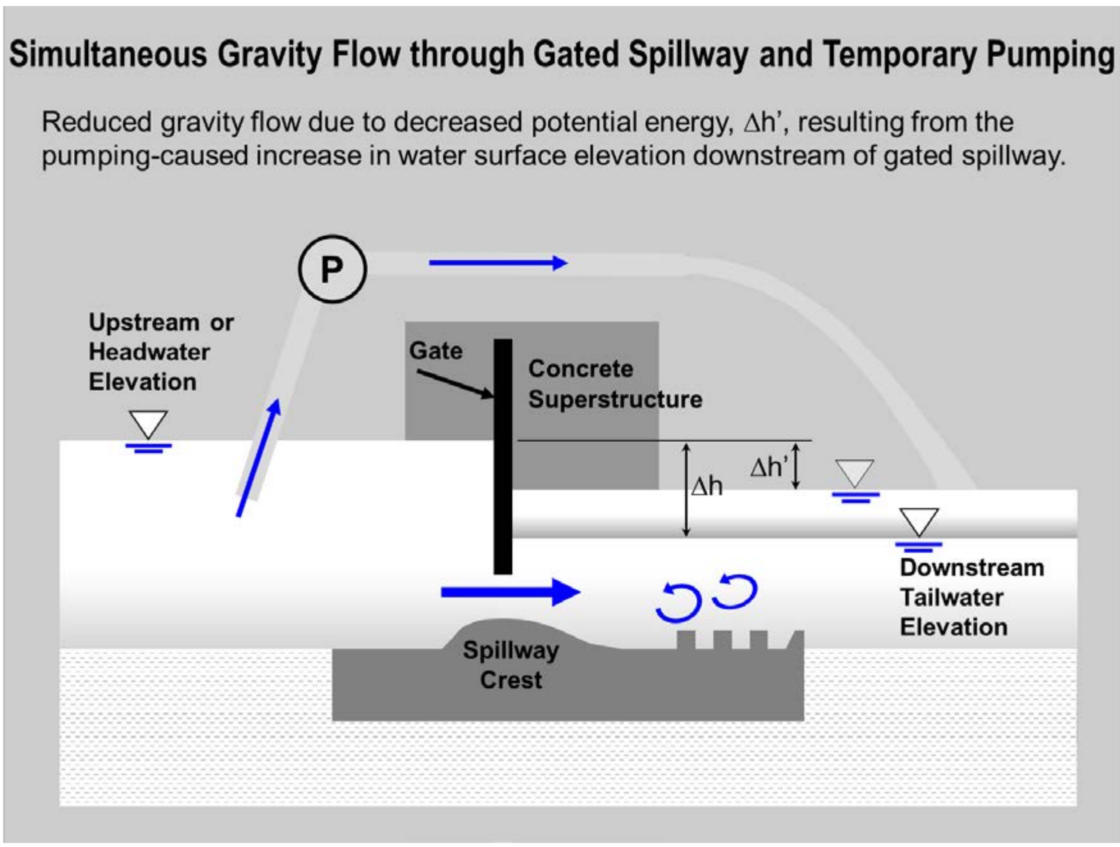


Figure 3-4. Simultaneous gated spillway gravity flow and temporary pumping.

3.2.3 Options for Simulating S-59 Operations

The UK-OPS Model has a few ways to simulate S-59 releases, which allows for testing alternative operations. **Table 3-1** shows the various settings of the parameter QoptETO, which is specified in the ETOops worksheet.

Table 3-1. Optional UK-OPS Model operations for S-59 and East Lake Tohopekaliga.

Parameter	Definition
QoptETO = 0	Flow values set to inputs for testing routing calculations
QoptETO = 1	Releases per operating zones and zone-discharge function
QoptETO = 2	Same as Option 1 but gravity releases are supplemented with pumping when the spillway capacity is less than the target release (Qregadj).
QoptETO = 3	Fixed, unrealistic 200 cubic feet per second release [placeholder for future option and code in routing worksheet (ETOsim)]
QoptETO = 4	Releases per user-specified logic in routing worksheet (ETOsim) Currently set up to determine releases necessary to achieve user-specified stage recession rates within user-specified dates

3.3 Lake Tohopekaliga Regulation Schedule

The TOH regulation schedule (**Figure 3-5**) specifies releases at S-61 depending on lake stage. The TOH regulation schedule rules traditionally have been designed to simply discharge water whenever the lake stage is above the schedule (Zone A). Releases in Zone B can be made for environmental purposes, navigation, and water supply, but are not necessary to manage the lake stage.

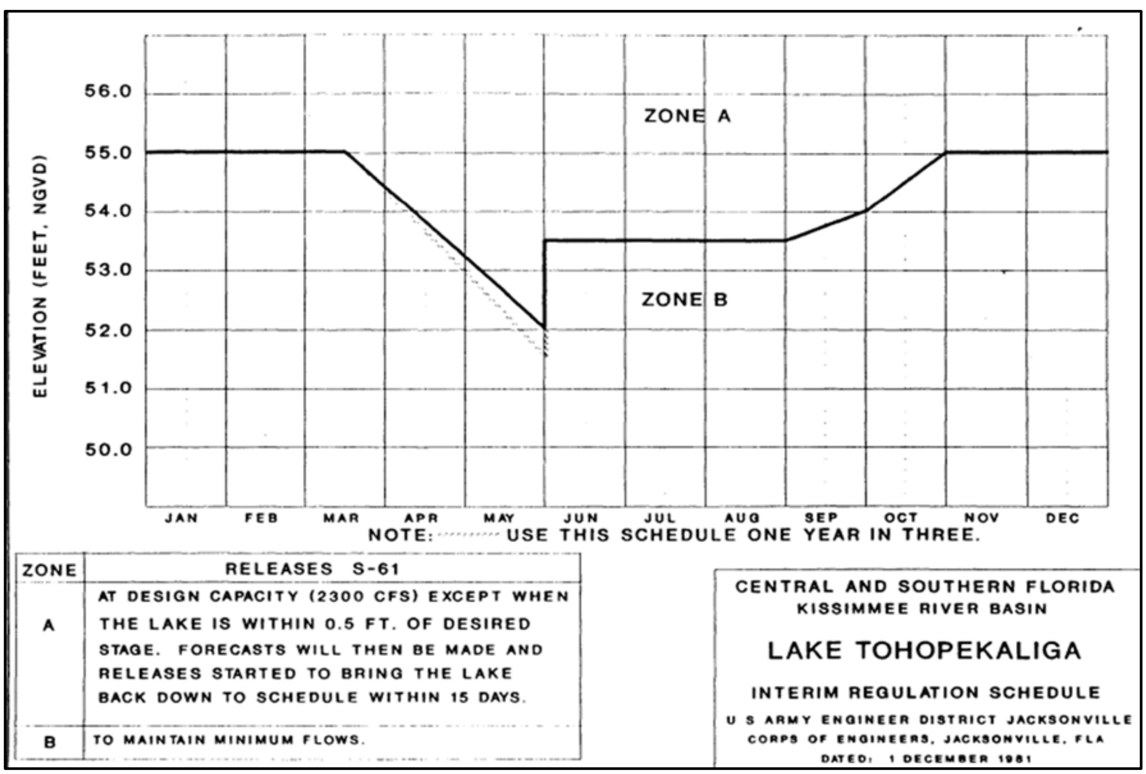


Figure 3-5. Lake Tohopekaliga regulation schedule.

Figure 3-6 illustrates the TOH regulation schedule as seen by the UK-OPS Model. Up to six zones can be defined. The zones are numbered, and the labeled lines represent the bottom of the zone. The green line (Zone 4) represents the drawdown operation used in 2018 and 2019 to benefit in-lake fish and wildlife resources. The drawdowns initiated at an elevation of 54.60 feet NGVD29 on January 15. The dashed line (Zone 6) represents a 0.3-foot offset above the Zone A line (Zone 5) that can be used to transition flows up to the maximum discharge. The model can simulate a linear transition from zero to maximum discharge in this range, if specified.

The UK-OPS Model uses a zone-discharge function to specify discharge rates within the regulation schedule zones. Consistent with the regulation schedule zone labeling, the zone-discharge function places the zone number at the bottom of the zone. For TOH (**Figure 3-7**), the function is relatively simple. Zero discharge for all zones below Zone 4. Within Zone 4 (between the green line and the Zone 5 black line in **Figure 3-6**), discharge linearly increases with stage from 1,150 to 2,300 cfs. Above Zone 5, continue with 2,300 cfs, which is the maximum S-61 capacity assumed by the model. In this case, there is no transition specified for Zone 5. For stages above the Zone 5 line (same as bottom of Zone A), the model simulates the maximum hydraulic capacity of S-61, considering the headwater and tailwater stages approximated by the simulated stages in TOH and KCH, respectively.

UK-OPS Model users can specify the breakpoints of the TOH regulation schedule and the zone-discharge function by changing the values in the color-coded tables within the TOHops worksheet. The regulation schedule and the zone-discharge function graphics automatically display changes to the inputs to enable verification of the intended changes.

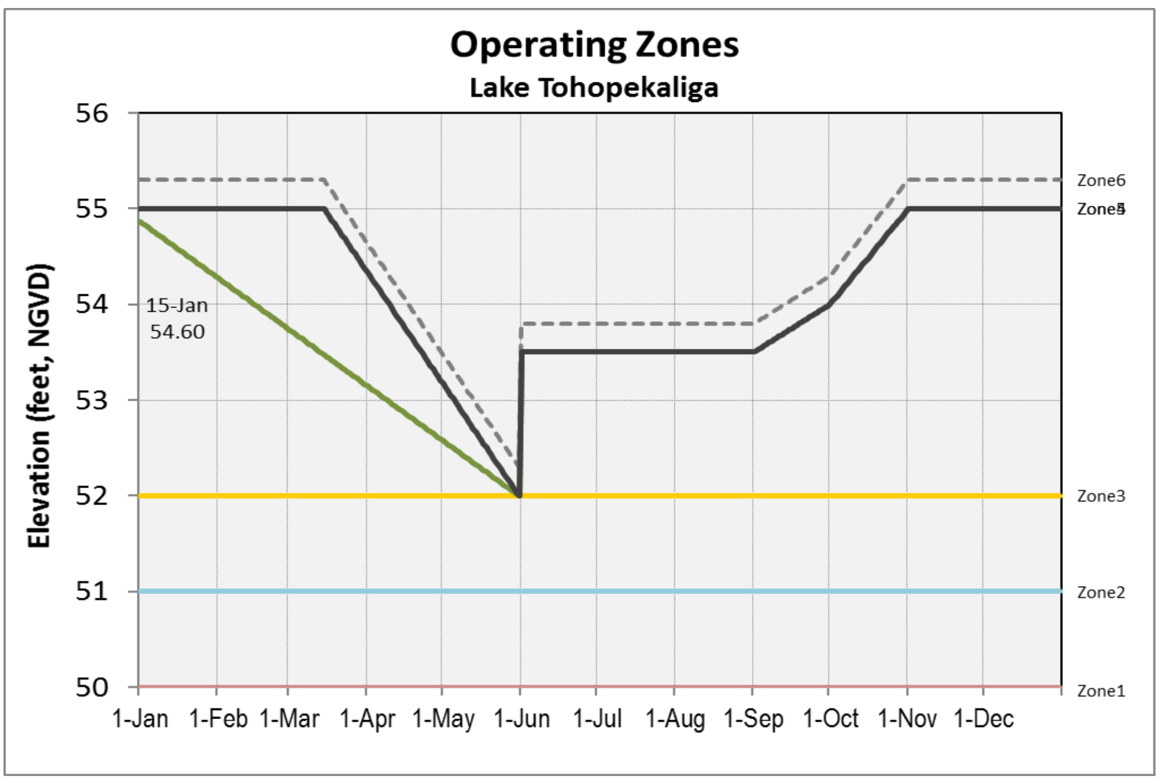


Figure 3-6. TOH regulation schedule as seen by the UK-OPS Model.

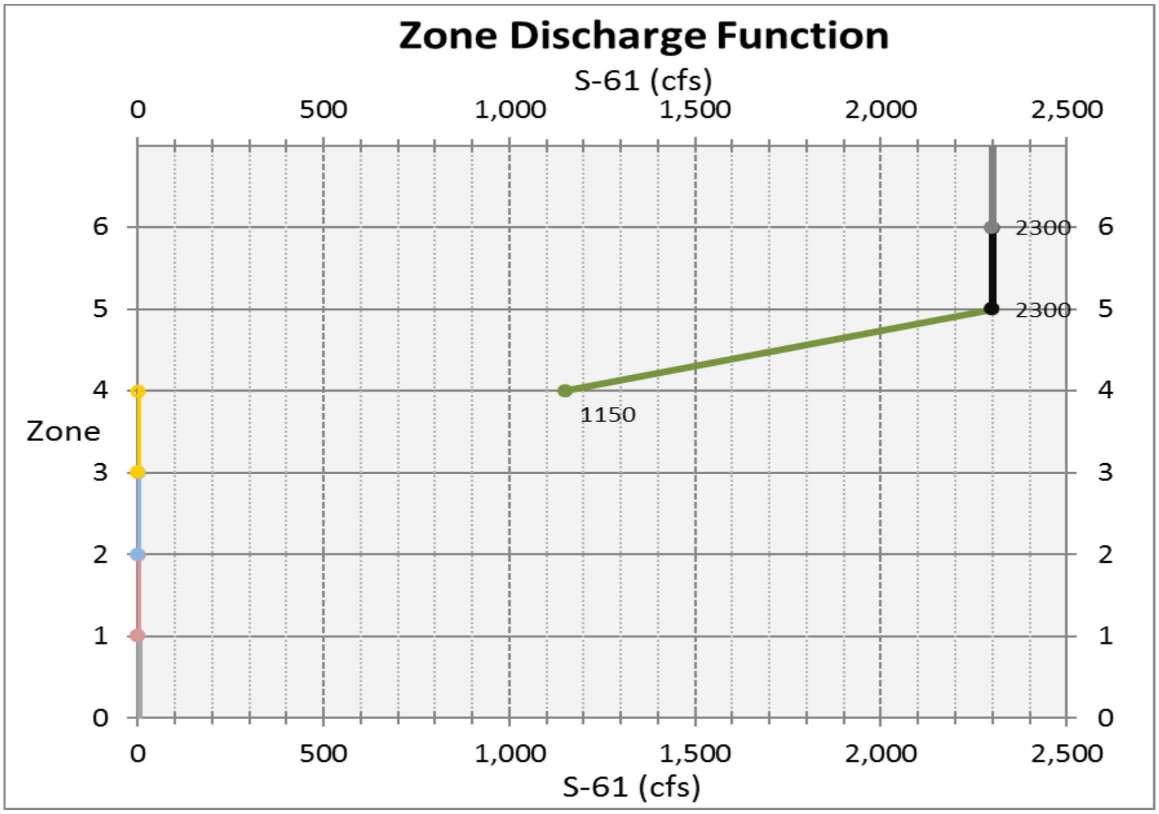


Figure 3-7. TOH zone discharge function used by the UK-OPS Model.

3.3.1 Hydraulic Capacity Assumptions for S-61

The S-61 single-gated spillway has a design capacity of 2,300 cfs at the design headwater and tailwater stages. Real system operations must account for various factors to determine the appropriate spillway gate opening and discharge rate, including maximum allowable gate opening (MAGO) criteria to keep discharge velocities from exceeding design limits and maximum permissible head (MPH) across the structure. These criteria are not explicitly considered by the daily timestep routing model. However, the S-61 capacity (S61Qcap) is computed daily using the simulated upstream and downstream stages and is limited by the user-input S61maxcap, currently set to 2,300 cfs.

The S-61 design discharge (2,300 cfs) also is the 98th percentile value of the historical flow data (1965 to 2005). The 99th percentile was 2,600 cfs. Maximum flow during the historical period was 3,750 cfs; however, this maximum is not recommended for S61maxcap because it is excessively high and inappropriate as an upper limit for simulating long-term performance. If flood peaks are of interest, more refinement to the model or a finer timestep hydraulic model may be needed.

Details about the daily S-61 hydraulic capacity computation (S61Qcap) are contained within the TOHops and TOHsim worksheets and are described below.

S61Qcap is the structure's hydraulic capacity, which is approximated by the UK-OPS Model as:

$$\mathrm{S61Qcap} = \mathrm{K}(HWEL - CEL)\sqrt{HWEL - TWEL} \qquad (3.3.1)$$

Where:

HWEL = S61Hsim

TWEL = S65Hsim

CEL = 36.9 feet crest elevation

K = 190, derived from the following traditional orifice flow equation:

$$\mathrm{Q} = \mathrm{CA}\sqrt{2g(HWEL - TWEL)} \qquad (3.3.2)$$

Where:

C = empirical discharge coefficient

A = L(HWEL-CEL)

g = gravity of Earth (32.2 ft/s^2)

L = gate width

By taking the ratio of Q/Q*, where Q* is the same equation using the design information, **Equation 3.3.1** can be derived. **Equation 3.3.1** is used by the UK-OPS Model for daily timestep approximation of the dynamic structure capacity. As described previously, S61Qcap cannot be larger than S61maxcap, which currently is set to the design capacity of 2,300 cfs.

3.3.2 Temporary Pump Capacity Assumptions for S-61

For testing scenarios such as TOH stage drawdown operations, which aim to periodically lower the lake stage below the elevation of the downstream KCH, the UK-OPS Model has a feature that allows specification of temporary pumps in parallel with the S-61 gated spillway. The TOHops worksheet allows specification of the average daily pump flow rate (S61pumpcap) and has an option to supplement gravity releases with pumping when the spillway capacity is less than the target release. Simultaneous gravity flow and pumping are simulated, and the user can specify a percent reduction in gravity capacity when pumping is used simultaneously. This accounts for the reduced spillway discharge rate due to the rise in tailwater stage from pumping (**Figure 3-4**).

3.3.3 Options for Simulating S-61 Operations

The UK-OPS Model has a few ways to simulate S-61 releases, which allows for testing alternative operations. **Table 3-2** shows the various settings of the parameter QoptTOH, which is specified in the TOHops worksheet.

Table 3-2. Optional UK-OPS Model operations for S-61 and Lake Tohopekaliga.

Parameter	Definition
QoptTOH = 0	Flow values set to inputs for testing routing calculations
QoptTOH = 1	Releases per operating zones and zone-discharge function
QoptTOH = 2	Same as Option 1, but gravity releases are supplemented with pumping when the spillway capacity is less than the target release (Qregadj).
QoptTOH = 3	Fixed, unrealistic 200 cubic feet per second release [placeholder for future option and code in routing worksheet (TOHsim)]
QoptTOH = 4	Releases per user-specified logic in routing worksheet (TOHsim) Currently set up to determine releases necessary to achieve user-specified stage recession rates within user-specified dates

3.4 Lakes Kissimmee, Cypress, and Hatchineha Regulation Schedule

The KCH regulation schedule specifies releases at S-65 depending primarily on lake stage. The KCH regulation schedule rules originally were designed to simply discharge water whenever the lake stage was above the schedule (**Figure 3-8**). However, during construction of the KRRP, an interim regulation schedule (**Figure 3-9**) and subsequent modifications to Zone B operations, were used. Interim operations were intended to be used until the Headwaters Revitalization regulation schedule is implemented upon completion of the KRRP (**Figure 3-10**). (It is important to note that new science and experience gained during the years of KRRP construction have yielded proposed refinements to the Headwaters Revitalization regulation schedule, particularly below Zone A.)

The KCH regulation schedule is more complex than the ETO and TOH schedules. The KCH schedule includes provisions that consider hydrologic conditions in the downstream Kissimmee River. Therefore, the options in the UK-OPS Model for simulating alternative operations of KCH are more complex than for ETO and TOH.

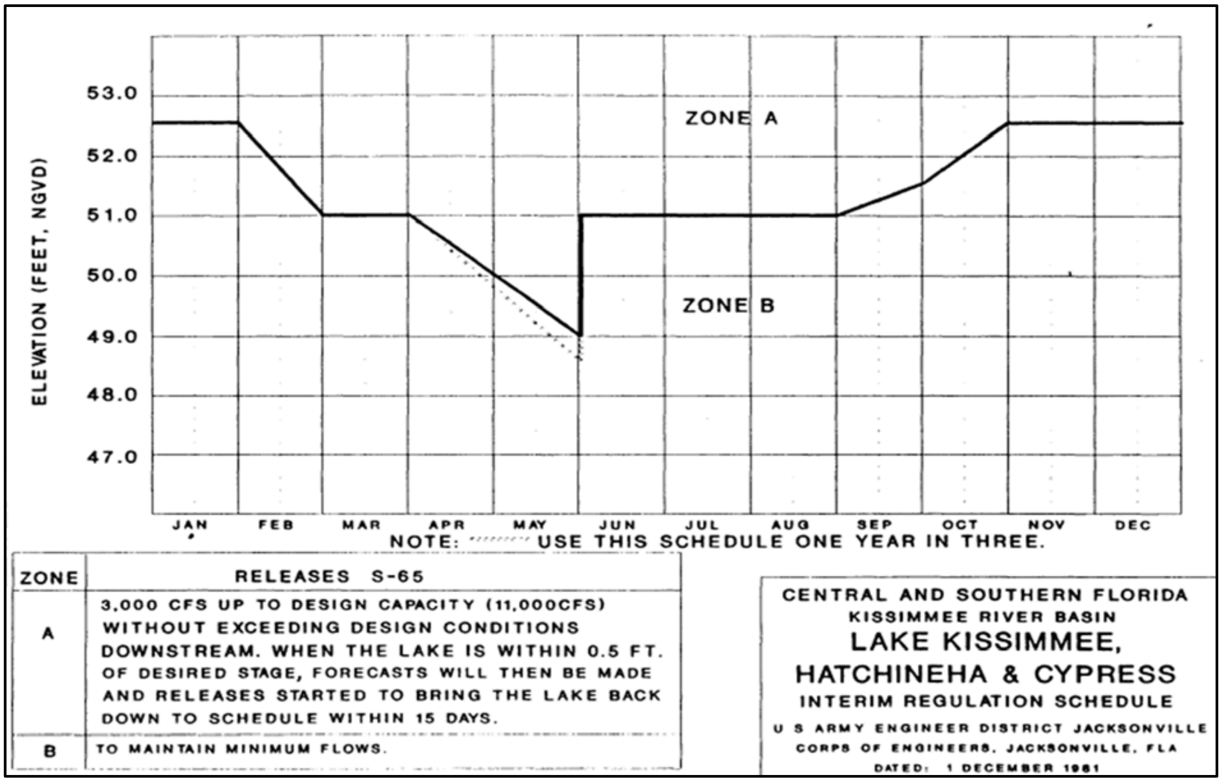


Figure 3-8. Pre-Kissimmee River Restoration Project regulation schedule for Lakes Kissimmee, Cypress, and Hatchineha.

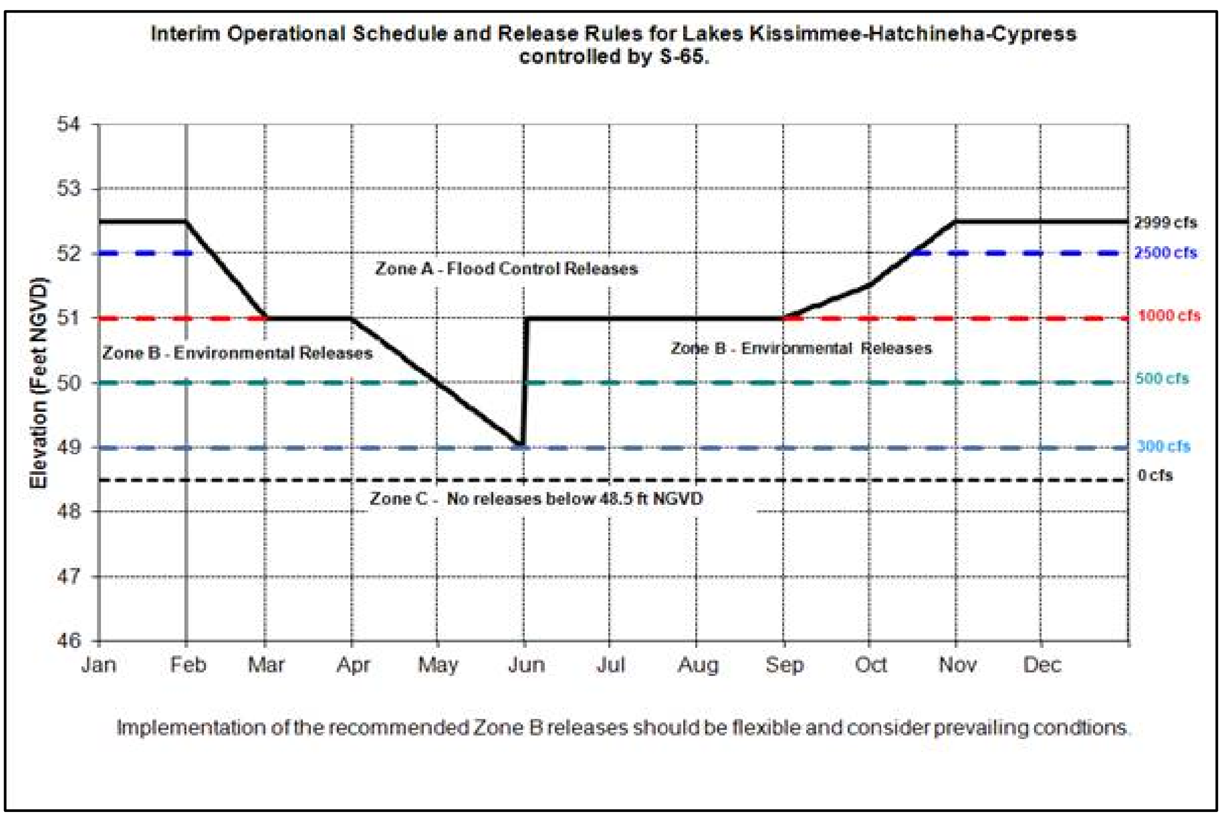


Figure 3-9. Lakes Kissimmee, Cypress, and Hatchineha interim regulation schedule.

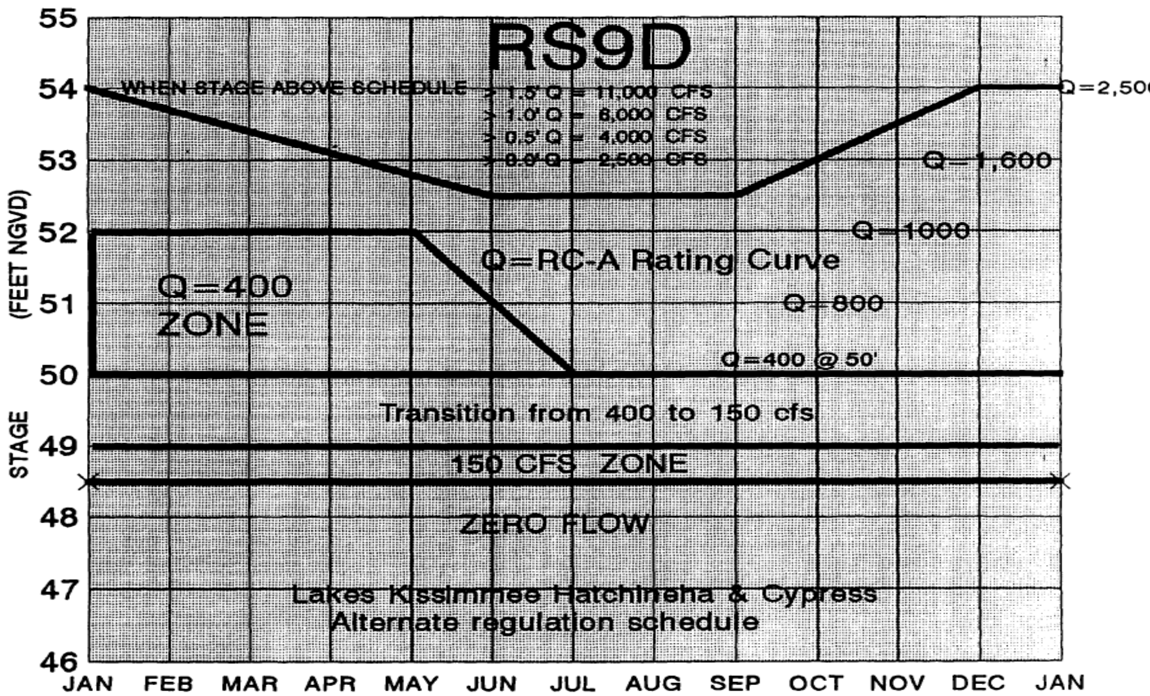


Figure 3-10. Lake Kissimmee, Cypress, and Hatchineha authorized Headwaters Revitalization regulation schedule. Recommended modified regulation schedule for the Kissimmee River Headwaters Revitalization Project (From: United States Army Corps of Engineers 1996).

Figure 3-11 illustrates the KCH regulation schedule as seen by the UK-OPS Model. Up to 10 zones can be defined. The zones are numbered, and the labeled lines represent the bottom of the zone. The various zone lines in **Figure 3-11** represent the operation designed for the 2019 wet season to benefit fish and wildlife resources for KCH and the Kissimmee River. The dashed line (Zone 10) represents a 0.3-foot offset above the Zone A line (Zone 9) that is used to transition flows up to the maximum discharge. The model can simulate a linear transition from zero to maximum discharge in this range, if specified.

The UK-OPS Model uses a zone-discharge function to specify discharge rates within the regulation schedule zones. For KCH (**Figure 3-12**), the function is more complex than for ETO and TOH. As with the other zone-discharge functions, the zone number represents the bottom of the zone. Zero discharge is prescribed for all zones below Zone 3 (elevation 48.5 feet). Within Zone 3, discharge linearly increases with rising stage from 0 to 300 cfs. Zone 4 discharge is to be a constant 300 cfs, Zones 5 to 8 also specify linear variation with stage. Zone 9 transitions the discharge from 3,000 cfs at the top of the schedule (bottom of Zone A) to maximum capacity of 11,000 cfs at the Zone 10 dashed line, which is 0.3 feet above the schedule.

UK-OPS Model users can specify the breakpoints of the KCH regulation schedule and the zone-discharge function by changing the values in the color-coded tables within the KCHops worksheet. The regulation schedule and the zone-discharge function graphics automatically display changes to the inputs to enable verification of the intended changes.

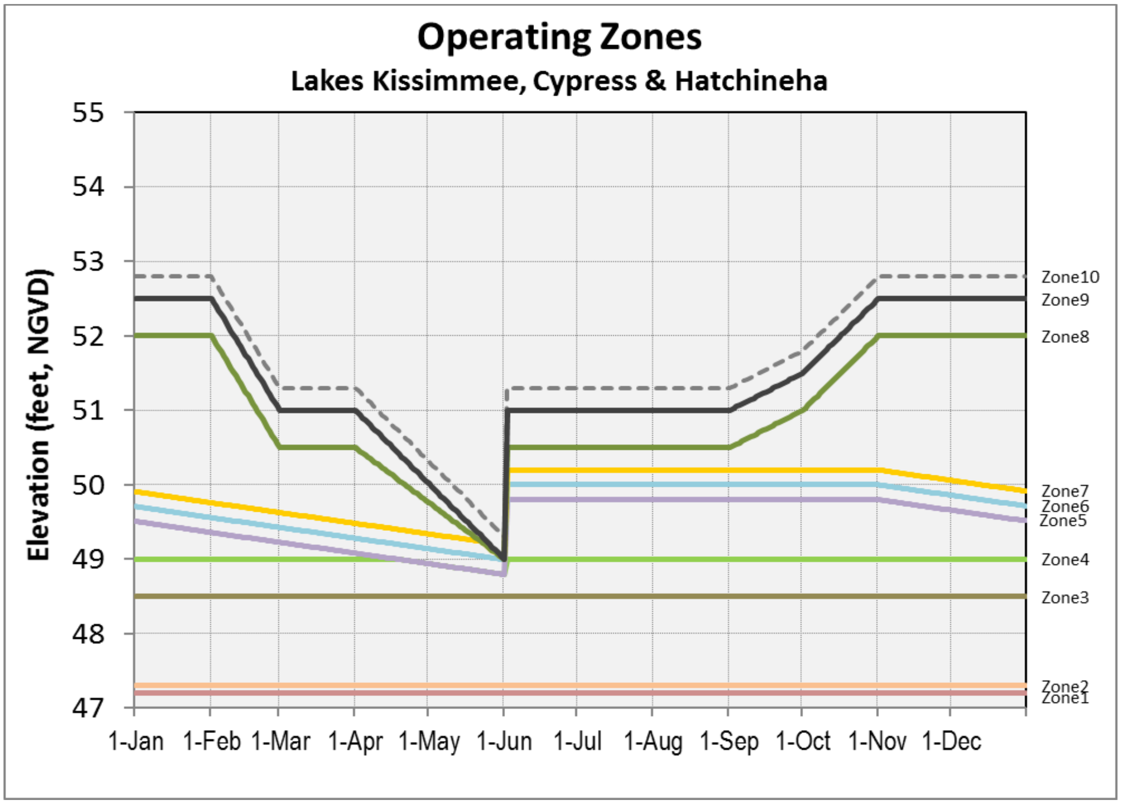


Figure 3-11. Lakes Kissimmee, Cypress, and Hatchineha regulation schedule as seen by the UK-OPS Model.

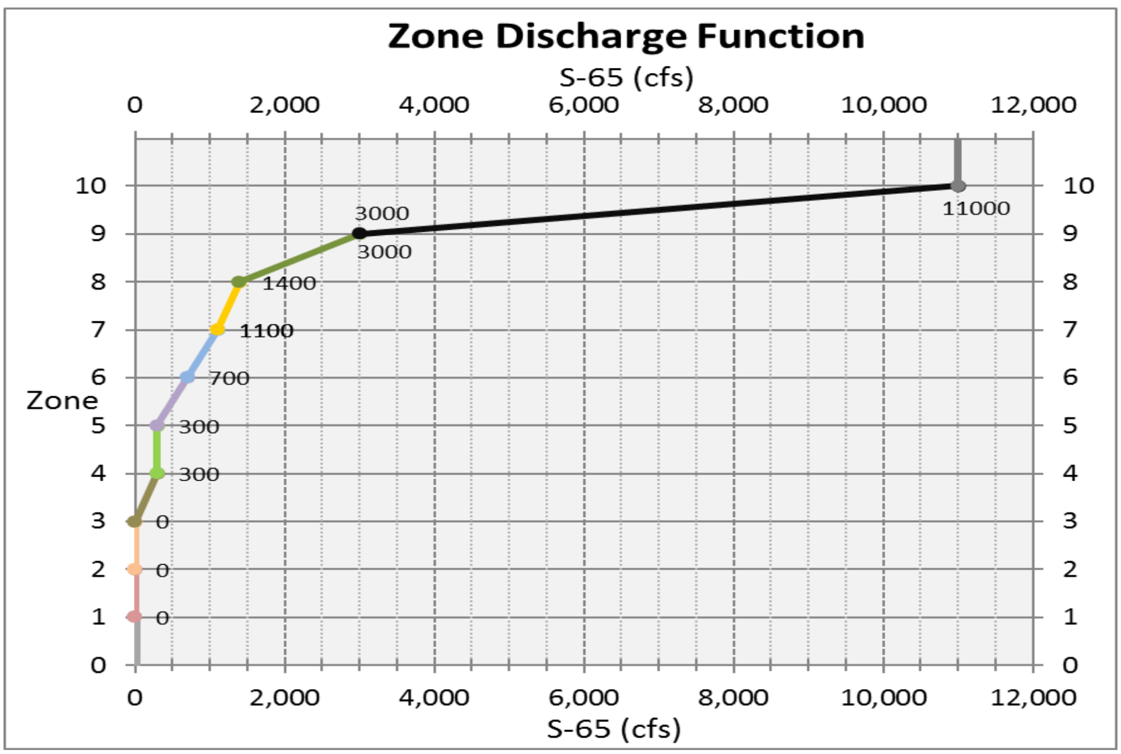


Figure 3-12. Lakes Kissimmee, Cypress, and Hatchineha zone-discharge function used by the UK-OPS Model.

3.4.1 Hydraulic Capacity Assumptions for S-65 and S-65A

The S-65 five-gated spillway is capable of discharging up to 11,000 cfs. The downstream S-65A gated spillway also has a design capacity of 11,000 cfs. However, much of the capacity at S-65A is taken up by basin runoff; therefore, releases at S-65 generally are limited to avoid exceeding S-65A discharge capacity. Additionally, the operating criteria for S-65 provides for a firm capacity of 3,000 cfs. In other words, a minimum of 3,000 cfs must be released at S-65.

The UK-OPS Model uses a time series of basin runoff entering Pool A (the river reach from S-65 to S-65A) to determine the maximum release rates each day of the simulation. The model does not simulate the C-38 Canal stage within Pool A; therefore, even a rudimentary hydraulic discharge calculation, like that used for S-59 and S-61, is not possible. This has not proven to be a limitation of the UK-OPS Model period-of-record simulations because the discharges prescribed by the regulation schedule are almost always less than the 11,000 cfs limit at S-65A. Furthermore, when KCH Zone A releases are required, simulated runoff into the C-38 Canal within Pool A has not been high enough to trigger use of the firm capacity provision. A more detailed hydraulic model like the Mike 11 application for the Kissimmee River (SFWMD 2017) is needed to perform an analysis that involves assessing discharge capacity based on C-38 Canal stage.

4 MODEL STRUCTURE AND ORGANIZATION

4.1 Overview and User Interface

This section presents the structure and organization of the UK-OPS Model Excel® workbook, particularly the various worksheets and general data flow between worksheets. Descriptions of the primary inputs and computational worksheets are provided. The model output worksheets and performance graphics are described in **Section 5**.

Figure 4-1 illustrates the basic model structure and data flow between the worksheets. From the graphical user interface (GUI) worksheet (**Figure 2-3**), the user can specify simulation type, simulation name and description, and one of four output locations (ALT0 to ALT3). Simulations are executed from the GUI worksheet using the Run and Save buttons. The Retrieve button retrieves/loads previous scenario inputs into the worksheets that contain the active operating schedules for each lake system. Then, the inputs can be modified, and a new scenario can be executed. Macros execute the simulation and automatically manage the input and output data.

Clicking on the outlet structure name links on the GUI map transfers control to the corresponding operations worksheet where modifications to the regulation schedules and changes to other operating assumptions can be made (e.g., KCHops). The outlet structure discharge and routing calculations for each lake system are handled in separate worksheets named for each lake system (e.g., KCHsim).

Each lake system has a worksheet for specifying the input operations, and each simulation has a worksheet (ALT0 to ALT3) containing all the outputs as well as a copy of the input parameter values, which can be retrieved from the GUI buttons as noted above. Simulation outputs are automatically accessed by the time-series plots and performance summary graphics. In some cases, the summary graphics have dropdown menus to specify the particular simulation and summary information to display. A single 49-year, daily timestep, simulation executes in less than 4 minutes; thus, results are quickly available for analysis.

4.2 Operations Worksheets for Large Lake Systems

The following discussions focus on the operations-related input data sets used in the UK-OPS Model for the large lake systems. The KCHops, TOHops, and ETOops worksheets contain the operations input for lake systems KCH, TOH, and ETO, respectively. The information and organizational layout are similar among the three worksheets.

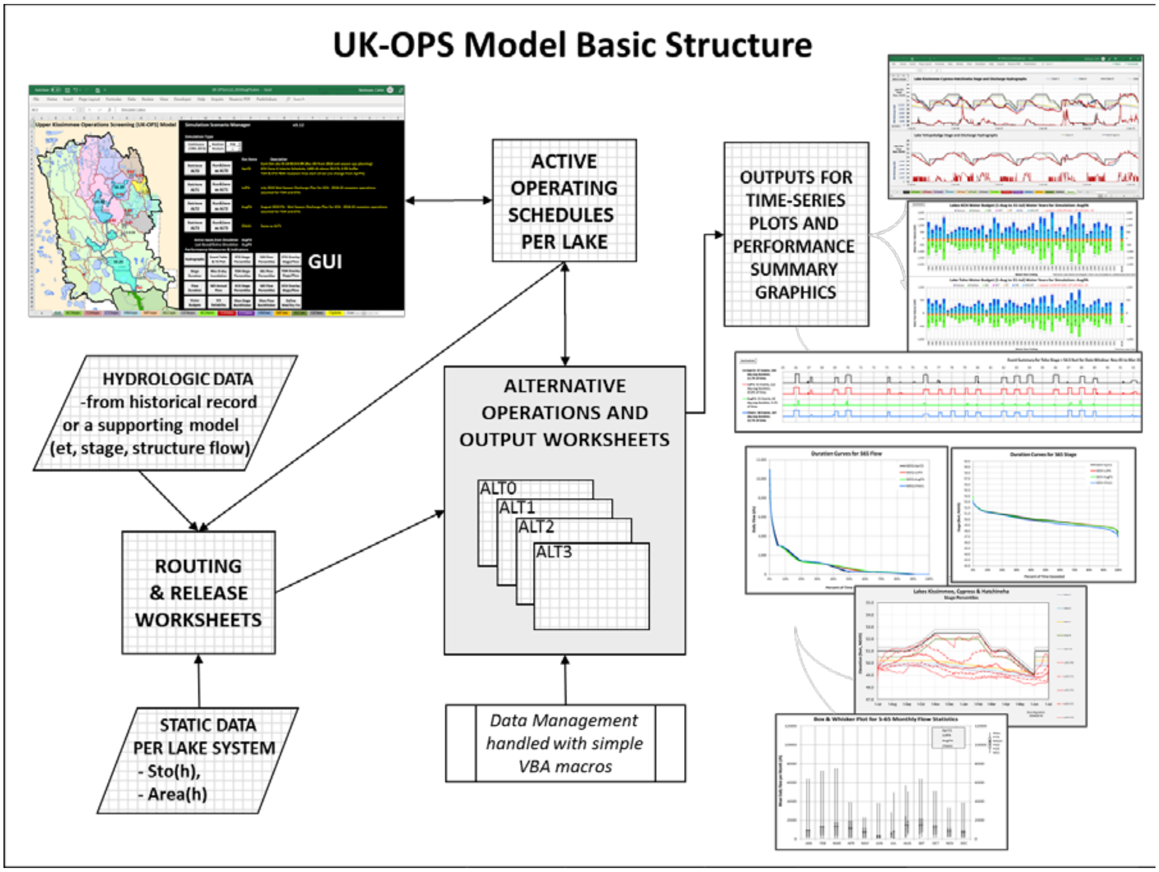


Figure 4-1. UK-OPS Model basic structure and data flow.

4.2.1 KCHops Worksheet

The KCHops worksheet contains operational information for the KCH system simulation. The model user can prescribe how to manage the KCH system by defining its regulation schedule, zone-discharge relationship, and parameters for releasing water to the Kissimmee River. In addition, various switches or flags for available operational features are defined in this worksheet.

The KCHops worksheet also contains copies of breakpoint data for past, present, and future planned KCH regulation schedules. These are located starting in column AP. The active schedule used for the simulation is in the predefined range OpZonesKCH, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints as needed to describe the desired schedule. The breakpoints are used to interpolate the daily values of each zone, which are displayed in the Operating Zones chart starting in column N. Similarly, the release rules and limits for describing the zone-discharge function, located under ReleaseRulesKCH, can be modified to reflect desired inputs. The entered breakpoints update the Zone-Discharge Function chart, which represents how the model will view the breakpoint information and serves as a helpful way to ensure the desired input is being used.

The UK-OPS Model has several ways to specify S-65 release rules. These features enable testing alternative operations to improve performance for the river and/or to improve the balance of performance between the river and KCH. The model also allows specification of an alternative regulation schedule to be used for user-specified conditions or for specifically defined years of the simulation. For example, this feature enables testing of periodic lake drawdown operations. Specifications for alternative operations begin in column AA.

Table 4-1 presents the various parameters and options available for testing alternative operations. Further details and tips are provided within the worksheet via mouse-over comments indicated by red triangles in the upper-right corner of pertinent cells.

Table 4-1. Optional UK-OPS Model operations for S-65 and Lakes Kissimmee, Cypress, and Hatchineha.

Parameter	Definition
QoptKCH = 0	Flow values set to inputs for testing routing calculations
QoptKCH = 1	Releases per operating zones and zone-discharge function
QoptKCH = 2	Option 1 with daily change in releases limited by maxDQrise and maxDQfall (**Figure 4-2**)
QoptKCH = 3	Option 2 but releases shift to zone-discharge function at zone boundaries
QoptKCH = 4	Zone B releases per user-specified flow time series Series number specified via parameter QoptS65tarQseries and points to series in the S65targetQseries worksheet
QoptKCH = 5	Releases per maximum of Options 1 and 4
QoptKCH = 6	Releases per user-specified logic in routing worksheet (KCHsim)
OptKCHalt = 1	Use alternative operations when user-specified stage conditions are met
OptKCHalt = 2	Use alternative operations for user-specified years

For QoptKCH values of 2 or 3 (**Table 4-1**), the release rate limits are specified by values shown in **Figure 4-2**. This figure represents a typical function specified to limit release rates at S-65 or S-65A depending on the previous day’s discharge rate. Limits can be specified for increasing and decreasing discharge regimes.

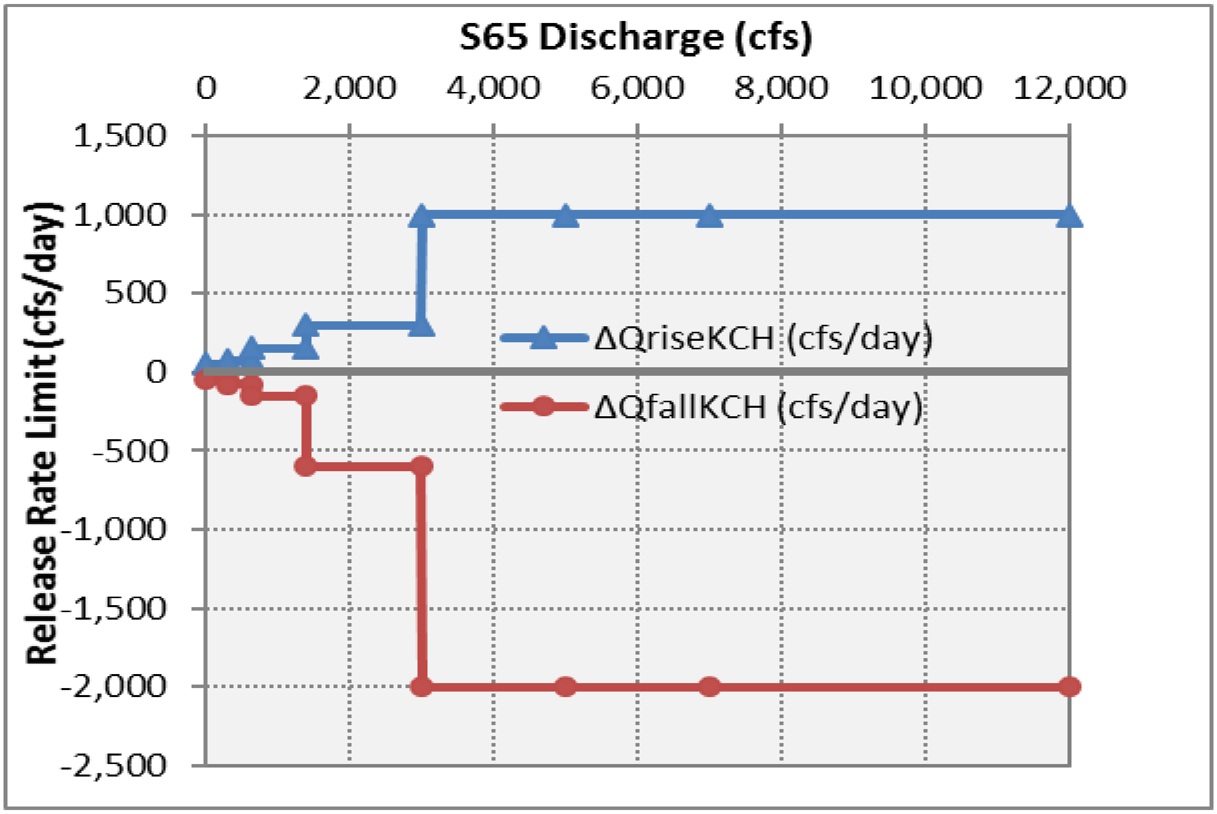


Figure 4-2. Example of S-65 release rate limits for Lakes Kissimmee, Cypress, and Hatchineha.

4.2.2 TOHops Worksheet

The TOHops worksheet contains operational information for the TOH system simulation. The model user can prescribe how to manage TOH by defining its regulation schedule, zone-discharge relationship, and other parameters. In addition, various switches or flags for available operational features are defined in this worksheet.

The TOHops worksheet contains breakpoint data for several alternative regulation schedules that have been tested or actually used for TOH. These are located starting in column AA. The active schedule used for the simulation is in the predefined range OpZonesTOH, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints as needed to describe the desired schedule. The breakpoints are used to interpolate the daily values of each zone and are displayed in the Operating Zones chart starting in column J. Similarly, the release rules and limits for describing the zone-discharge function, located in ReleaseRulesTOH, can be modified to reflect desired inputs. The breakpoints entered update the Zone-Discharge Function chart, which represents how the model will view the breakpoint information and serves as a helpful way to ensure the desired input is being used.

Other inputs in the TOHops worksheet include water supply withdrawal parameters, which enable testing user-specified withdrawals subject to the draft KRCOL Water Reservation rules. Switches are available that require up to three conditions to be satisfied before the simulated withdrawal is made.

Table 4-2 presents the various parameters and options available for testing alternative operations. Further details and tips are provided within the worksheet via mouse-over comments indicated by red triangles in the upper-right corner of pertinent cells.

Table 4-2. Optional UK-OPS Model operations for S-61 and Lake Tohopekaliga.

Parameter	Definition
QoptTOH = 0	Flow values set to inputs for testing routing calculations
QoptTOH = 1	Releases per operating zones and zone-discharge function
QoptTOH = 2	Same as Option 1, but gravity releases are supplemented with pumping when the spillway capacity is less than the target release
QoptTOH = 3	Constant 200 cubic feet per second release (placeholder for future option and code)
QoptTOH = 4	Releases per user-specified logic in routing worksheet (TOHsim)

4.2.3 ETOops Worksheet

The ETOops worksheet contains operational information for the ETO system simulation. The model user can prescribe how to manage ETO by defining its regulation schedule, zone-discharge relationship, and other parameters. In addition, various switches or flags for available operational features are defined in this worksheet.

The ETOops worksheet contains breakpoint data for several alternative regulation schedules that have been tested or actually used for ETO. These are located starting in column AA. The active schedule used for the simulation is in the predefined range OpZonesETO, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints as needed to describe the desired schedule. The breakpoints are used to interpolate the daily values of each zone and are displayed in the Operating Zones chart starting in column J. Similarly, the release rules and limits for describing the zone-discharge function, located in ReleaseRulesETO, can be modified to reflect desired inputs. The entered breakpoints update the Zone-Discharge Function chart, which represents how the model will view the breakpoint information and serves as a helpful way to ensure the desired input is being used.

Other inputs in the ETOops worksheet include water supply withdrawal parameters, which enable testing user-specified withdrawals subject to the draft KRCOL Water Reservation rules. Switches are available that require up to three conditions to be satisfied before the simulated withdrawal is made.

Table 4-3 presents the various parameters and options available for testing alternative operations. Further details and tips are provided within the worksheet via mouse-over comments indicated by red triangles in the upper-right corner of pertinent cells.

Table 4-3. Optional UK-OPS Model operations for S-59 and East Lake Tohopekaliga.

Parameter	Definition
QoptETO = 0	Flow values set to inputs for testing routing calculations
QoptETO = 1	Releases per operating zones and zone-discharge function
QoptETO = 2	Same as Option 1, but gravity releases are supplemented with pumping when the spillway capacity is less than the target release
QoptETO = 3	Constant 200 cubic feet per second release (placeholder for future option and code)
QoptETO = 4	Releases per user-specified logic in routing worksheet (ETOsim)

4.3 Operations Worksheets for Small Lake Systems

This section describes the operations-related input data sets used in the UK-OPS Model for the small lake systems. The HMJops, MPJops, ALCops, and GENops worksheets contain the operations input for lake systems HMJ, MPJ, ALC, and GEN, respectively. The information and organizational layout are similar among the four worksheets. There is no routing of inflows and outflows through the small lake systems in the current configuration of the UK-OPS Model. Boundary inflows are defined in the WNI calculation, as described in **Sections 2.2** to **2.5**. The small lakes are included only to test water supply withdrawal scenarios subject to the draft KRCOL Water Reservation rules. As described in **Section 2.5**, withdrawals from the small lakes are simulated as withdrawals from the next downstream large lake system.

4.3.1 HMJops Worksheet

The HMJops worksheet contains operational information for simulating the HMJ system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The HMJ regulation schedule is in the predefined range OpZonesHMJ, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other draft KRCOL Water Reservation rule criteria, determine when water supply withdrawals can occur.

The UK-OPS Model has five optional conditions in the HMJops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. HMJ stage above its WRL?
2. ETO stage above its WRL?
3. TOH stage above its WRL?
4. KCH stage above its WRL?
5. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1 and 2 or conditions 1, 2, and 5 are set to TRUE to determine when the prescribed HMJ withdrawal capacity can be taken. Withdrawals can occur if the HMJ and ETO stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, ETO in this instance.

4.3.2 MPJops Worksheet

The MPJops worksheet contains operational information for simulating the MPJ system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The MPJ regulation schedule is in the predefined range OpZonesMPJ, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other proposed KRCOL Water Reservation criteria, determines when water supply withdrawals can occur.

The UK-OPS Model has six optional conditions in the MPJops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. MPJ stage above its WRL?
2. HMJ stage above its WRL?
3. ETO stage above its WRL?
4. TOH stage above its WRL?
5. KCH stage above its WRL?
6. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1, 2, and 3 or conditions 1, 2, 3, and 5 are set to TRUE to determine when the prescribed MPJ withdrawal capacity can be taken. Withdrawals can occur if the MPJ, HMJ, and ETO stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, ETO in this instance.

4.3.3 ALCops Worksheet

The ALCops worksheet contains operational information for simulating the ALC system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The ALC regulation schedule is in the predefined range OpZonesALC, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other draft KRCOL Water Reservation criteria, determines when water supply withdrawals can occur.

The UK-OPS Model has four optional conditions in the ALCops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. ALC stage above its WRL?
2. GEN stage above its WRL?
3. KCH stage above its WRL?
4. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1, 2, and 3 or all four conditions are set to TRUE to determine when the prescribed ALC withdrawal capacity can be taken. Withdrawals can occur if the ALC, GEN, and KCH stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, KCH in this instance.

4.3.4 GENops Worksheet

The GENops worksheet contains operational information for simulating the GEN system. The modeled operational information is limited to specification of the WRL. Various switches or flags for available KRCOL Water Reservation criteria also are defined in this worksheet.

The GEN regulation schedule is in the predefined range OpZonesGEN, located in the upper left section of the worksheet in the shaded columns. Users can change the breakpoints of the schedule, but it has no bearing on the simulation; only changes to the WRL can affect the simulation. The WRL, along with other draft KRCOL Water Reservation criteria, determines when water supply withdrawals can occur.

The UK-OPS Model has three optional conditions in the GENops worksheet that can be evaluated to determine if water supply withdrawals can occur:

1. GEN stage above its WRL?
2. KCH stage above its WRL?
3. Lake Okeechobee discharging excess water to tide?

Typically, conditions 1 and 2 or all three conditions are set to TRUE to determine when the prescribed GEN withdrawal capacity can be taken. Withdrawals can occur if the GEN and KCH stages are above their respective WRLs and the other draft KRCOL Water Reservation rule criteria are met. Recognizing the withdrawal may reduce lake outflow and affect the downstream large lake system, the UK-OPS Model assumes the withdrawal is directly from the downstream large lake system, KCH in this instance.

4.4 Routing Worksheets for Large Lake Systems

This section describes the routing worksheets for the three large lake systems simulated by the UK-OPS Model. Most simulation calculations occur in the routing sheets using traditional Microsoft Excel® formulas. Routing calculations are not handled by Visual Basic for Applications (VBA) program code via Microsoft Excel® macros. Macros are used by the model but primarily to manage the data. The ETOsim, TOHsim, and KCHsim worksheets contain calculations for determining releases and stages for lake systems ETO, TOH, and KCH, respectively. The information and organizational layout are similar among the three routing worksheets. To best understand the worksheets, readers should have the UK-OPS Model workbook open to follow along with the descriptions.

4.4.1 ETOsim Worksheet

The ETOsim worksheet performs the primary simulation for the ETO system. The worksheet contains: 1) the daily timestep computations for processing boundary conditions, namely WNI+RF; 2) calculations of lake outflows and stages using user-prescribed operating rules; and 3) processing of several metrics of performance, which are used to automatically update the output performance measures and charts (refer to **Section 5**).

4.4.1.1 Boundary Conditions

Calculations for computing the WNI+RF boundary series are contained in columns B through K of the ETOsim worksheet. **Equation 2.2.2** was derived for WNI+RF (**Section 2.2**) and is computed in column K. Because WNI+RF is a persistent time series, it only needs to be calculated once. The shaded cells in the worksheet have formulas, whereas the unshaded cells (starting in row 18) contain only values. If input hydrology data values change, then the ETO_ResetInputData macro (button near cell E4) must be executed to recalculate the WNI+RF values.

4.4.1.2 Routing

Simulation calculations for ETO stages and S-59 discharges begin in column L of the ETOsim worksheet. The fundamental routing equation (**Equation 2.2.1**) used was presented in **Section 2.2**. The calculation uses the beginning-of-day stage, storage, and area for calculating ET volume (column T) and structure discharge (column AK). Water supply withdrawals, if any, are totaled in column AT. Storage change, end-of-day storage, and stage are computed in columns AU through AX. The end-of-day values become the beginning-of-day values for the next day. Calculations proceed for each day of the simulation.

When the simulation is executed, the ETO_Expand_Formulas macro expands the routing formulas starting January 7, 1965 (row 17) for all the simulation days. Then the execution runs the ETO_Formulas2Values macro to save the computed formulas as values for further processing. This procedure saves workbook space and computational resources. Buttons at the top of column T are available to execute the macros (e.g., if needed for testing), independent of the simulation execution.

4.4.1.3 Summary Statistics

After routing is completed, the UK-OPS Model processes the simulation output in many different forms. Daily stage and flow tables are automatically updated via the RunSaveETOStgStats and RunSaveS59FlowStats macros, respectively. The stage tables are within worksheet range BD7 through DK393, and the flow tables are within worksheet range BD407 through BK793. Water budget calculations are within workbook range DO8 through EF62. Water supply reliability calculations are within workbook range EI8 through EY17907.

4.4.2 TOHsim Worksheet

The TOHsim worksheet performs the primary simulation for the TOH system. The worksheet contains: 1) the daily timestep computations for processing boundary conditions, namely WNI+RF; 2) calculations of lake outflows and stages using user-prescribed operating rules; and 3) processing of several metrics of performance, which are used to automatically update the output performance measures and charts (refer to **Section 5**).

4.4.2.1 Boundary Conditions

Calculations for computing the WNI+RF boundary series are contained in columns B through K of the TOHsim worksheet. **Equation 2.3.2** was derived for WNI+RF (**Section 2.3**) and is computed in column K. Because WNI+RF is a persistent time series, it only needs to be calculated once. The shaded cells in the worksheet have formulas, whereas the unshaded cells (starting in row 18) contain only values. If input hydrology data values change, then the TOH_ResetInputData macro (button near cell E4) must be executed to recalculate the WNI+RF values.

4.4.2.2 Routing

Simulation calculations for TOH stages and S-61 discharges begin in column L of the TOHsim worksheet. The fundamental routing equation (**Equation 2.3.1**) was presented in **Section 2.3**. The calculation uses the beginning-of-day stage, storage, and area for calculating ET volume (column T) and structure discharge (column AK). Water supply withdrawals, if any, are evaluated in column AP. Storage change, end-of-day storage, and stage are computed in columns AQ through AT. The end-of-day values become the beginning-of-day values for the next day. Calculations proceed for each day of the simulation.

When the simulation is executed, the TOH_Expand_Formulas macro expands the routing formulas starting January 7, 1965 (row 17) for all the simulation days. Then the execution runs the TOH_Formulas2Values macro to save the computed formulas as values for further processing. This procedure saves workbook space and computational resources. Buttons located at the top of column T are available to execute the macros (e.g., if needed for testing), independent of the simulation execution.

4.4.2.3 Summary Statistics

After routing is completed, the UK-OPS Model processes the simulation output in many different forms. Daily stage and flow tables are automatically updated via the RunSaveTOHStgStats and RunSaveS61FlowStats macros, respectively. The stage tables are within worksheet range BD7 through DK393, and the flow tables are within worksheet range BD407 through BK793. Water budget calculations are within workbook range DO8 through EF62. Water supply reliability calculations are within workbook range EI8 through EY17907.

4.4.3 KCHsim Worksheet

The KCHsim worksheet performs the primary simulation for the KCH system. The worksheet contains: 1) the daily timestep computations for processing boundary conditions, namely WNI+RF; 2) calculations of lake outflows and stages using user-prescribed operating rules; and 3) processing of several metrics of performance, which are used to automatically update the output performance measures and charts (refer to **Section 5**).

4.4.3.1 Boundary Conditions

Calculations for computing the WNI+RF boundary series are contained in columns B through K of the KCHsim worksheet. **Equation 2.4.2** was derived for WNI+RF (**Section 2.4**) and is computed in column K. Because WNI+RF is a persistent time series, it only needs to be calculated once. The shaded cells in the worksheet have formulas, whereas the unshaded cells (starting in row 18) contain only values. If input hydrology data values change, then the KCH_ResetInputData macro (button near cell E4) must be executed to recalculate the WNI+RF values.

4.4.3.2 Routing

Simulation calculations for KCH stages as well as S-65 and S-65A discharges begin in column M of the KCHsim worksheet. The fundamental routing equation (**Equation 2.4.1**) was presented in **Section 2.4**. The calculation uses the beginning-of-day stage, storage, and area for calculating ET volume (column T) and structure discharge (columns AU and AV). Water supply withdrawals, if any, are totaled in column AY. Storage change, end-of-day storage, and stage are computed in columns AZ through BC. The end-of-day values become the beginning-of-day values for the next day. Calculations proceed for each day of the simulation.

When the simulation is executed, the KCH_Expand_Formulas macro expands the routing formulas starting January 7, 1965 (row 17) for all the simulation days. Then the execution runs the KCH_Formulas2Values macro to save the computed formulas as values for further processing. This procedure saves workbook space and computational resources. Buttons located at the top of column T are available to execute the macros (e.g., if needed for testing), independent of the simulation execution.

4.4.3.3 Summary Statistics

After routing is completed, the UK-OPS Model processes the simulation output in many different forms. Daily stage tables are automatically updated via the RunSaveKCHStgStats macro, and daily flow tables for S-65 and S-65A are automatically updated via the RunSaveS65FlowStats and RunSaveS65AFlowStats macros, respectively. The stage tables are within worksheet range BG7 through DN393, and the flow tables for S-65 and S-65A are within worksheet ranges BG407 through DN793 and BG807 through DN1193, respectively. Water budget calculations are within workbook range DR8 through EI62. There are no water supply reliability calculations in the UK-OPS Model for the KCH system because the draft KRCOL Water Reservation rules do not permit withdrawals from this lake system.

4.5 Water Supply Worksheets for Small Lake Systems

This section describes the water supply worksheets for the four small lake systems simulated by the UK-OPS Model. As previously mentioned, routing currently is not simulated for the small lake systems in the UK-OPS Model. The small lake systems are used only to determine the timing and volume of potential water supply withdrawals subject to the proposed KRCOL Water Reservation rule constraints. The HMJws, MPJws, ALCws, and GENws worksheets contain calculations for simulating water supply withdrawals from lake systems HMJ, MPJ, ALC, and GEN, respectively. The information and organizational layout are similar among the four worksheets. To best understand the worksheets, readers should have the UK-OPS Model workbook open to follow along with the descriptions.

4.5.1 HMJws Worksheet

The HMJws worksheet determines if user-prescribed water supply withdrawals can be made from the HMJ lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The HMJws worksheet: 1) contains the daily timestep computations that compare the HMJ input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the HMJ system are simulated as withdrawals from the next downstream large lake system, ETO in this instance. The assumption is that withdrawals from HMJ would reduce inflows to ETO, thus the model makes the withdrawal, subject to constraints, from ETO.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The HMJ_Expand_Formulas and HMJ_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.5.2 MJPws Worksheet

The MPJws worksheet determines if user-prescribed water supply withdrawals can be made from the MPJ lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The MPJws worksheet: 1) contains the daily timestep computations that compare the MPJ input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the MPJ system are simulated as withdrawals from the next downstream large lake system, ETO in this instance. The assumption is that withdrawals from MPJ would reduce inflows to ETO, thus the model makes the withdrawal, subject to constraints, from ETO.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The MPJ_Expand_Formulas and MPJ_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.5.3 ALCws Worksheet

The ALCws worksheet determines if user-prescribed water supply withdrawals can be made from the ALC lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The ALCws worksheet: 1) contains the daily timestep computations that compare the ALC input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the ALC system are simulated as withdrawals from the next downstream large lake system, KCH in this instance. The assumption is that withdrawals from ALC would reduce inflows to KCH, thus the model makes the withdrawal, subject to constraints, from KCH.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The ALC_Expand_Formulas and ALC_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.5.4 GENws Worksheet

The GENws worksheet determines if user-prescribed water supply withdrawals can be made from the GEN lake system. The worksheet is much simpler and smaller than the routing worksheets for the large lake systems. The GENws worksheet: 1) contains the daily timestep computations that compare the GEN input stages and stages in the downstream lakes with their respective WRLs; and 2) processes the number of days per month that water supply withdrawals were simulated.

Withdrawals allowed from the GEN system are simulated as withdrawals from the next downstream large lake system, KCH in this instance. The assumption is that withdrawals from GEN would reduce inflows to KCH, thus the model makes the withdrawal, subject to constraints, from KCH.

To save computation resources, this worksheet expands the formulas for the simulation period to make the necessary computations, then saves the formulas as values. The GEN_Expand_Formulas and GEN_Formulas2Values macros are executed automatically during a simulation. Buttons in column R can run the macros independent of the simulation for testing.

4.6 Other Input Worksheets

The remaining input worksheets for the UK-OPS Model are described in this section. The following input worksheets contain the various time-series input data generated by the more detailed hydrologic models: DATAforUKOPS, UKISSforUKOPS, and AFETforUKOPS. As mentioned in **Section 1**, the UK-OPS Model does not simulate the rainfall-runoff hydrologic process. Instead, it computes watershed inflows to each lake using key hydrologic information from detailed hydrologic models or the historical record.

Other UK-OPS Model input worksheets include S65TargetQseries, which provides flow targets for optional use with KCH operations, and StageStoArea, which contains the static data representing the geometric, or stage-area and stage-storage, relationships used for the routing computations.

4.6.1 DATAforUKOPS Worksheet

The DATAforUKOPS worksheet contains historical lake stage and structure flow data for optional use in computing the boundary condition inflows (WNI+RF), as defined in **Section 2** and calculated in the routing worksheets (**Section 4.4**).

The DATAforUKOPS worksheet is a product of two separate Microsoft Excel® workbooks used to assemble various stage and discharge data sets and to estimate missing values: DataPrepForUKOPSmodel.xlsx and StructureQHWTW_DBHydro_AFET-LT(CN18Aug2015).xlsx. Using the historical data in this worksheet as the basis for the boundary conditions has the advantage of not relying on a particular model for the rainfall-runoff simulation. To evaluate the effects of proposed water withdrawals on the draft KRCOL Water Reservation rules, historical data for a specific 41-year period (1965 to 2005) are specified. This establishes a fixed data set and period that will not change over time.

4.6.2 UKISSforUKOPS Worksheet

The UKISSforUKOPS worksheet contains simulated lake stage and structure flow data for optional use in computing the boundary condition inflows (WNI+RF), as defined in **Section 2** and calculated in the routing worksheets (**Section 4.4**). The UKISSforUKOPS worksheet contains the output from the Upper Kissimmee Chain of Lakes Routing Model (UKISS) (Fan 1986). Specific UKISS output files are referenced in the worksheet. Using these data to compute the boundary conditions implicitly uses the rainfall-runoff methods and other assumptions of UKISS. UKISS was the only regional hydrologic and water management model for the basin in the 1980s and 1990s. Several models have been developed in the past 20 years that have replaced UKISS, the most recent being the Regional Simulation Model – Basins Model (VanZee 2011).

4.6.3 AFETforUKOPS Worksheet

The AFETforUKOPS worksheet contains simulated lake stage and structure flow data for optional use in computing the boundary condition inflows (WNI+RF), as defined in **Section 2** and calculated in the routing worksheets (**Section 4.4**). The AFETforUKOPS worksheet contains output from the Alternative Formulation and Evaluation Tool (AFET), an application of the Mike 11/Mike SHE Model to the Kissimmee Basin (SFWMD 2009, 2017). Specific AFET output files are referenced in the worksheet. Using these data to compute the boundary conditions implicitly uses the rainfall-runoff methods and other assumptions of AFET and Mike 11/Mike SHE. AFET was developed by the SFWMD with assistance from the Architectural and Engineering Company (AECOM) and the Danish Hydraulic Institute (DHI) in support of the Kissimmee Basin Modeling and Operations Study (KBMOS), which ended prematurely in 2013. The modeling tools were further refined by the SFWMD in 2016 to 2018.

4.6.4 S65TargetQSeries Worksheet

The UK-OPS Model has an option to use a target flow time series at S-65 or S-65A for environmental flows to the Kissimmee River. This concept is similar to the Everglades' Shark River Slough Rainfall Plan and the Tamiami Trail Flow Formula for delivering target environmental flows. Up to 11 series can be input in the S65TargetQSeries worksheet. Currently, this worksheet contains only one input series, RDTSv5r, which mimics the pre-channelization rainfall-runoff response of the UKB. Development of this series is a separate topic.

4.6.5 StageStoArea Worksheet

The StageStoArea worksheet contains stage-storage and stage-area information for the three large lake systems: KCH, TOH, and ETO. The data used for these relationships (**Figure 4-3**) came from the development work done by Ken Konyha of the SFWMD when AFET was being developed in 2007. The stage-storage relationship is used with the daily routing to relate storage to stage. The stage-area relationship is used to compute lake surface areas to calculate corresponding ET volumes.

Although small lakes are not included in the StageStoArea worksheet (or in **Figure 4-3**), it should be noted that the large lakes represent 86% of the total storage capacity and total surface area of all managed lakes in the UKB at winter pool stages.

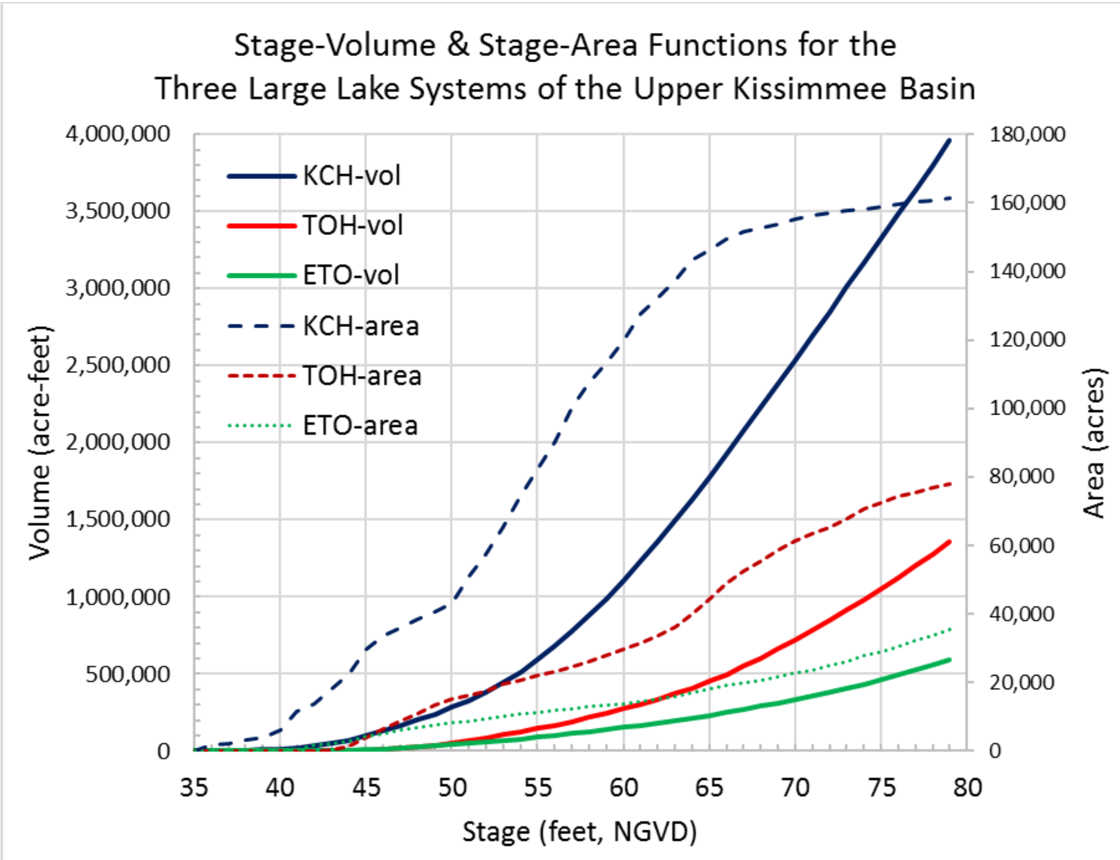


Figure 4-3. Stage-volume and stage-area relationships used by the UK-OPS Model.

5 MODEL OUTPUT

The UK-OPS Model outputs daily time series of stages and releases from the UKB's three largest lake systems into the user-specified ALT0, ALT1, ALT2, and ALT3 worksheets. The model also automatically generates graphical and tabular summaries of simulated performance for evaluating current or proposed operations and/or water supply withdrawal scenarios. These summaries access the pertinent outputs from the ALT worksheets and can be accessed via the buttons on the lower-right portion of the GUI (**Figure 2-3**). This section describes the specific outputs available in the current version of the model.

5.1 Measures of Performance

Simulation model outputs can be summarized in many ways. Traditional outputs include hydrographs (time-series plots of stage and/or flow), water budgets, and various statistical summaries of stage and flow critical to analysts and/or stakeholders. The term "performance measure" has a specific definition for hydrologic simulation modeling analysis in Central and South Florida. Performance measures are quantitative indicators of how well (or poorly) a simulation scenario meets a specific objective. They are a means to make relative comparisons among different test scenarios. Characteristics of a good performance measure are that it

- is quantifiable,
- has a specific target,
- indicates when that target has been reached, and/or
- measures the degree of improvement towards the target when the target has not been reached.

Performance measures are a special class of model outputs that enable a more conclusive interpretation of the simulations. Most UK-OPS Model outputs do not meet this definition of a performance measure. Rather, the UK-OPS Model outputs are better classified as performance indicators, or more generically, measures of performance. These do not have specific targets but are useful for making relative comparisons among alternative scenarios.

The UK-OPS Model output summary measures are hydrologic in nature, and many are considered ecological surrogates (e.g., S-65 annual average flow has a specific limit tied to the ecological health of the Kissimmee River). The UK-OPS Model automatically generates more than 20 output summary measures, classified into two groups: 1) daily stage and flow displays, and 2) hydrologic performance summaries.

5.2 Daily Stage and Flow Displays

The fundamental outputs from a hydrologic simulation model are flows and stages, commonly displayed using hydrographs. Typically, stage and flow series also are displayed as duration curves and percentile plots, which indicate the data distribution. These displays are produced by the UK-OPS Model and are described below.

5.2.1 Hydrographs

The TSplots worksheet can be accessed using the Hydrographs button. The worksheet contains stage and outflow hydrographs for the UKB’s three large lake systems and have been very useful for detailed analyses. **Figure 5-1** is an example worksheet showing KCH and TOH. The plots have options to turn on/off particular simulations and regulation schedules. The slider bar enables viewing the entire plot, which also can be scaled to a specified time window. The hydrographs are aligned for easy comparison of the timing and magnitude of the stages and flows between the lakes.

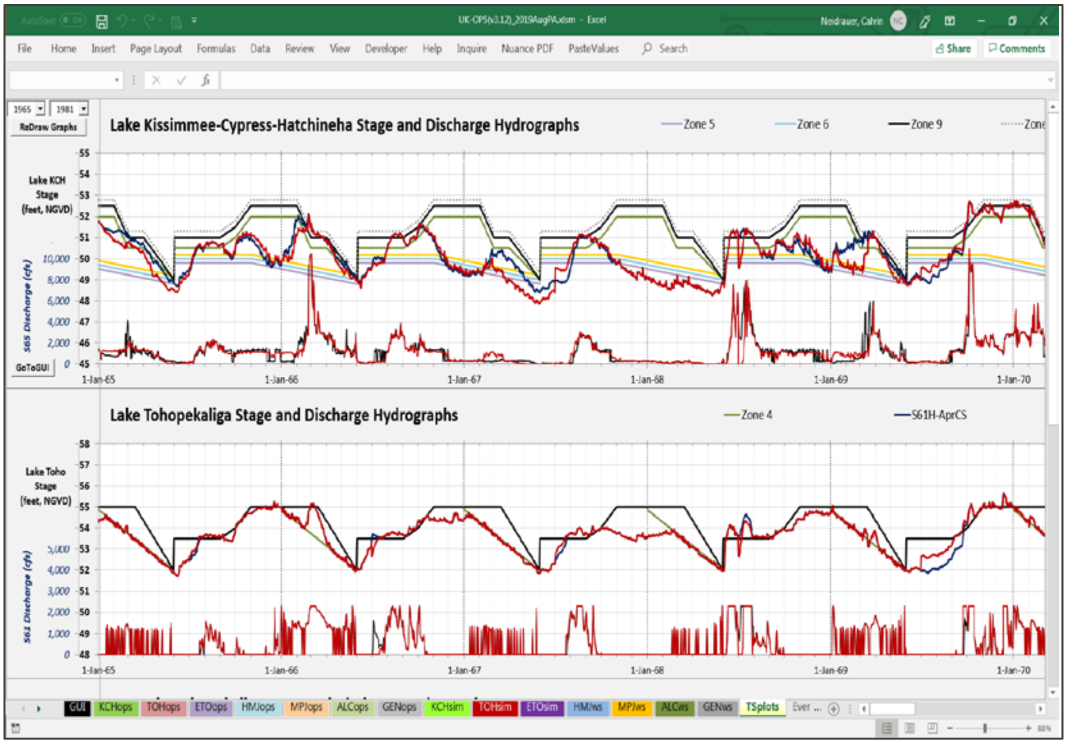


Figure 5-1. Sample stage and discharge hydrographs for Lakes Kissimmee, Cypress, and Hatchineha (top) and Lake Tohopekaliga (bottom).

5.2.2 Stage and Flow Duration

The StageDur and FlowDur worksheets can be accessed using the Stage Duration and Flow Duration buttons, respectively. Duration curves display the sorted output series, similar to a cumulative probability distribution function. The duration curves show the data range and indicate the value distribution. **Figures 5-2** and **5-3** are example stage and duration curves for KCH and S-65, respectively. The plots include options to select one of the three large lake systems and to turn on/off particular simulations.

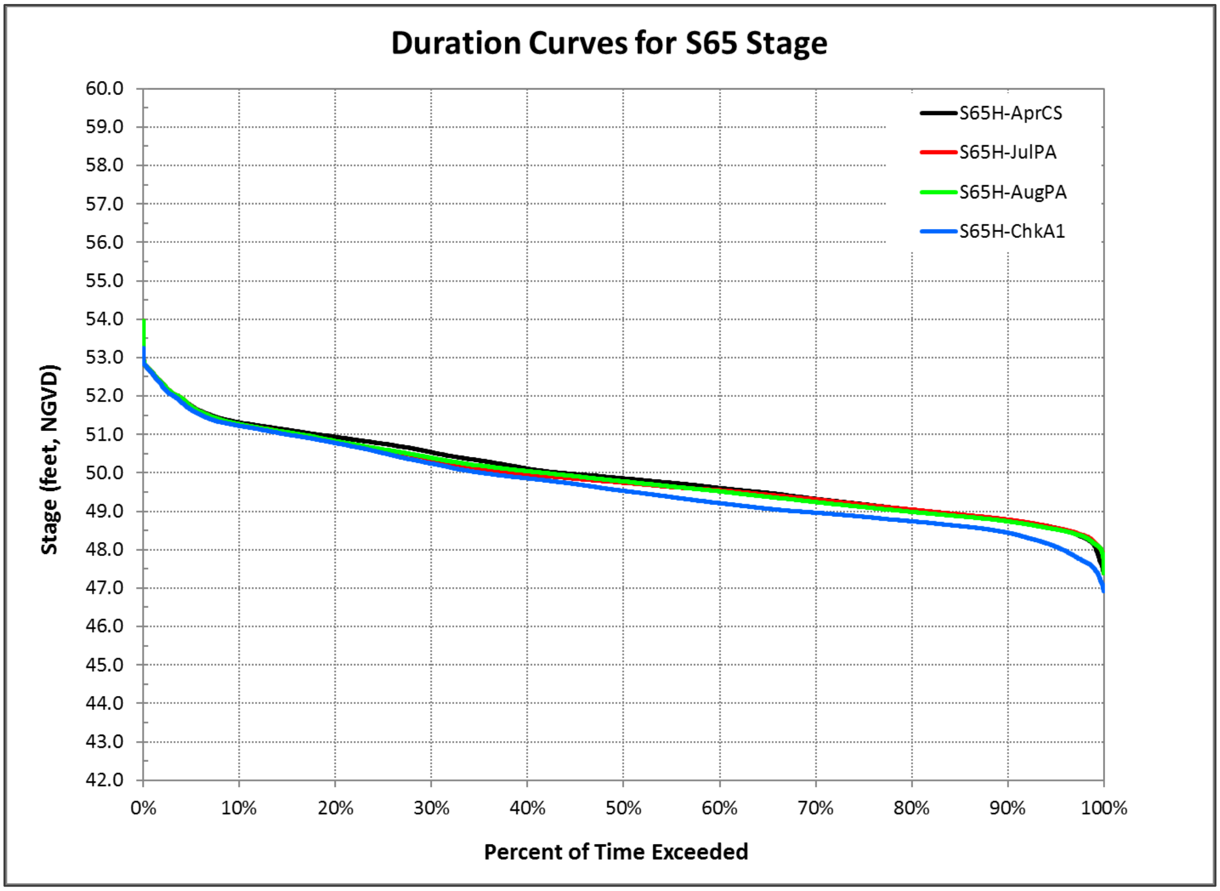


Figure 5-2. Sample stage duration curves for Lakes Kissimmee, Cypress, and Hatchineha.

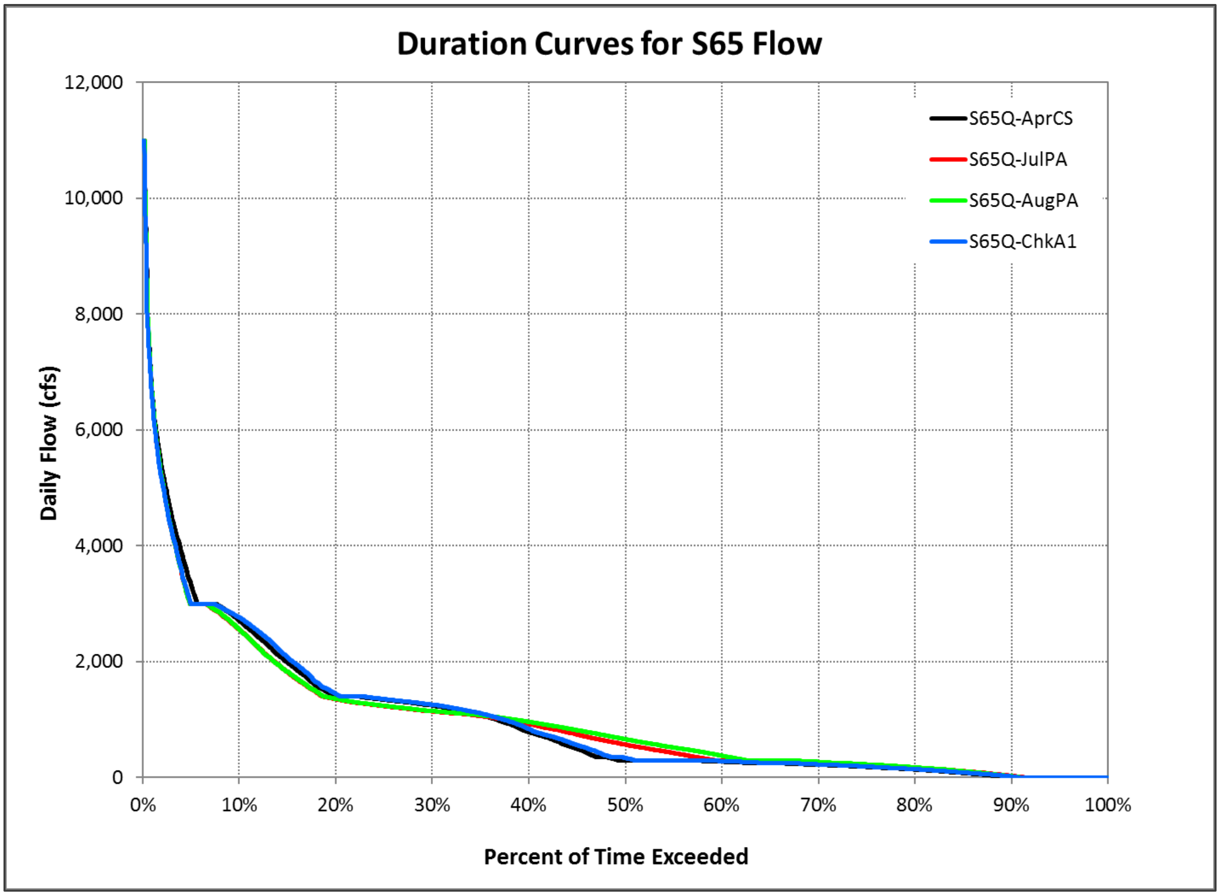


Figure 5-3. Sample flow duration curves for the S-65 structure.

5.2.3 Stage and Flow Percentiles

The StagePercsKCH, StagePercsTOH, and StagePercsETO worksheets contain charts of the stage percentiles for KCH, TOH, and ETO, respectively. These worksheets can be accessed using the corresponding KCH Stage Percentiles, TOH Stage Percentiles, and ETO Stage Percentiles buttons. Similarly, the FlowPercsKCH, FlowPercsTOH, and FlowPercsETO worksheets display flow percentiles for KCH, TOH, and ETO, respectively.

Percentiles are not hydrographs; rather, they are statistical summaries of the stage or flow distribution each day of the year. Percentiles are computed using all the years in the output; thus, for a 49-year simulation, each of the 365 days would have 49 data values for calculating each percentile statistic. The charts then connect the same percentile values for each day and display the iso-percentile curves. The percentile charts are helpful, particularly for position analysis simulations, to determine the probability of stages or flows exceeding particular values over time.

Figures 5-4 and **5-5** display example percentile plots for ETO stage and for KCH flow at the S-65 structure, respectively. The plots include options to specify the time window, percentiles of interest, and simulations to compare. The sample figures show outputs from a position analysis simulation, which initialized each of the 49 one-year simulations on July 1. The percentile plots also can be used for period-of-record simulations (i.e., a single 49-year simulation). Such plots are sometimes called cyclic analysis plots.

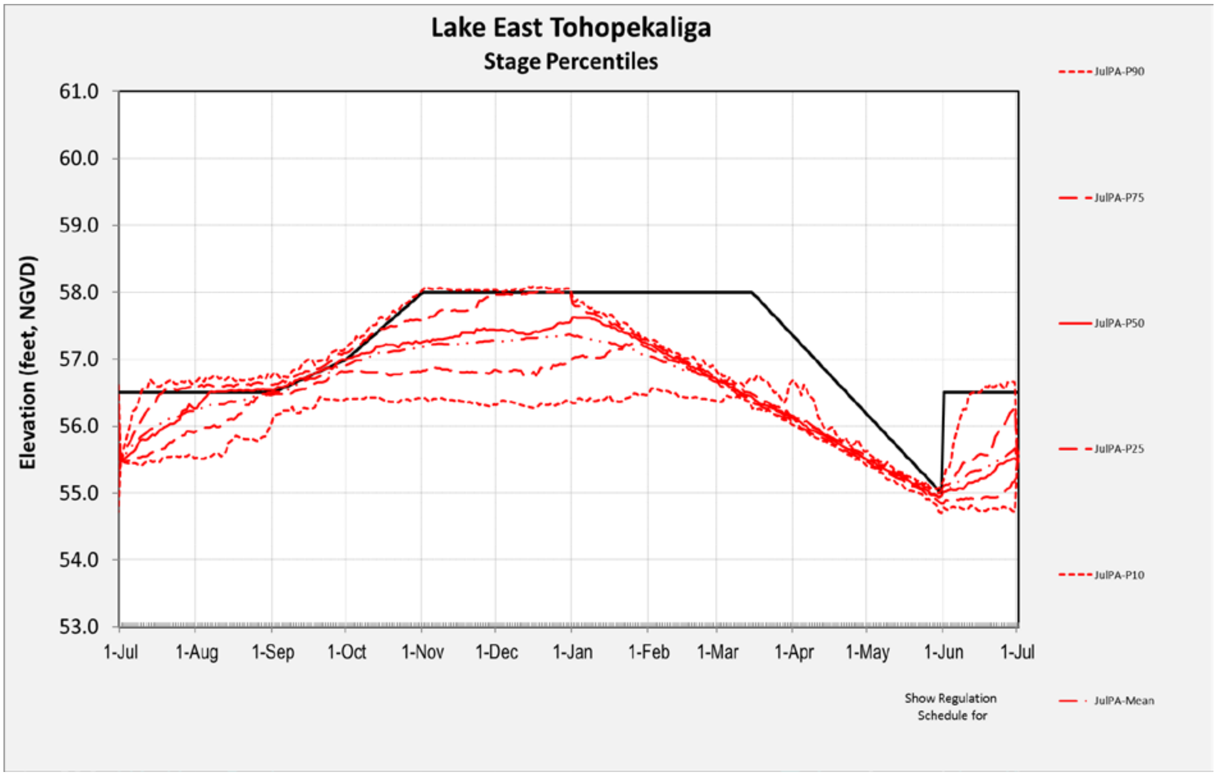


Figure 5-4. Sample stage percentile plot for East Lake Tohopekaliga.

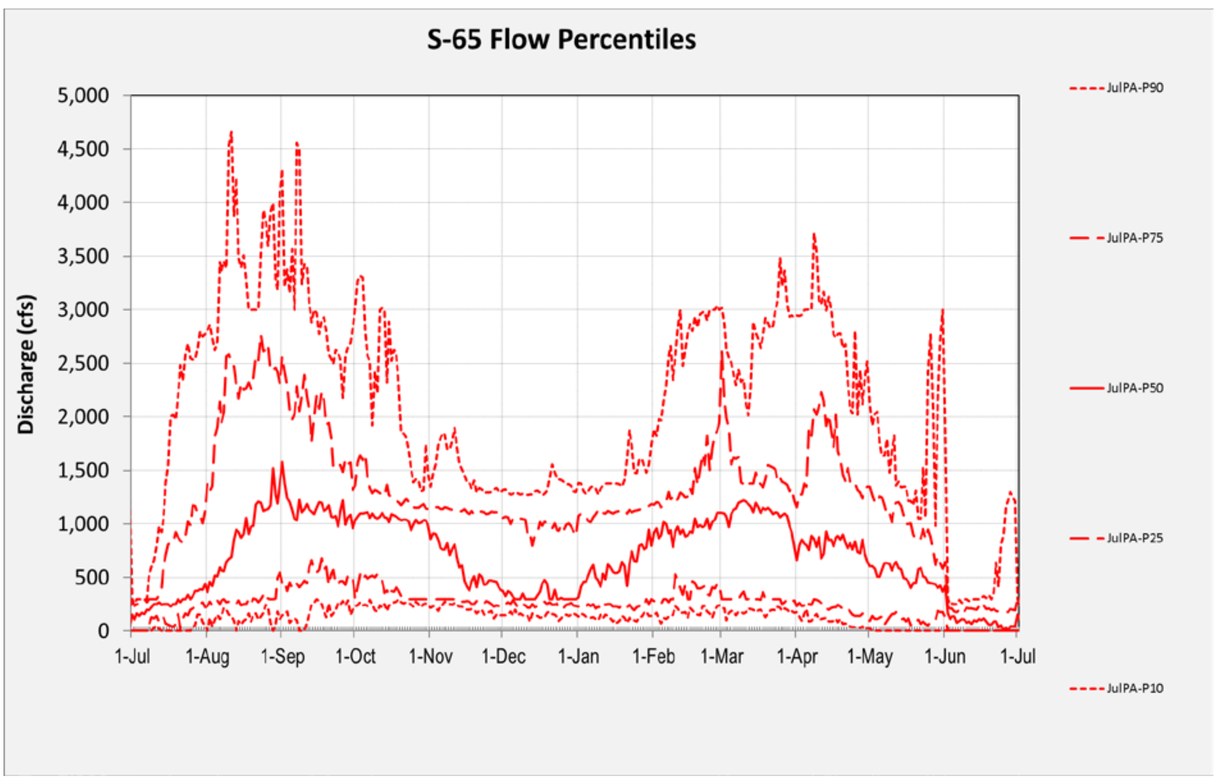


Figure 5-5. Sample flow percentile plot for Lakes Kissimmee, Cypress, and Hatchineha flows at the S-65 structure.

5.3 Hydrologic Performance Summaries

The UK-OPS Model automatically generates several measures of performance, most of which are derivatives of the fundamental stage and flow outputs and surrogates for ecological and/or water supply performance. New measures of performance typically are created based on the user's needs. Because the UK-OPS Model is a Microsoft Excel® application, modifying it to incorporate new measures, if desired, is relatively easy.

5.3.1 Water Budgets

The WatBuds worksheet can be accessed using the Water Budgets button. This worksheet contains charts that display the annual series of simulated water budget components for KCH, TOH, and ETO. **Figure 5-6** is an example showing KCH and TOH. The charts display the inflow components (WNI+RF and structure inflows) as positive values above the x-axis and the outflow components (ET, structure outflows, and water supply withdrawals) as negative values below the x-axis. Each year shows these components as stacked bars. The water year starts with the first month of position analysis simulations. For period-of-record simulations, the water year starts in January.

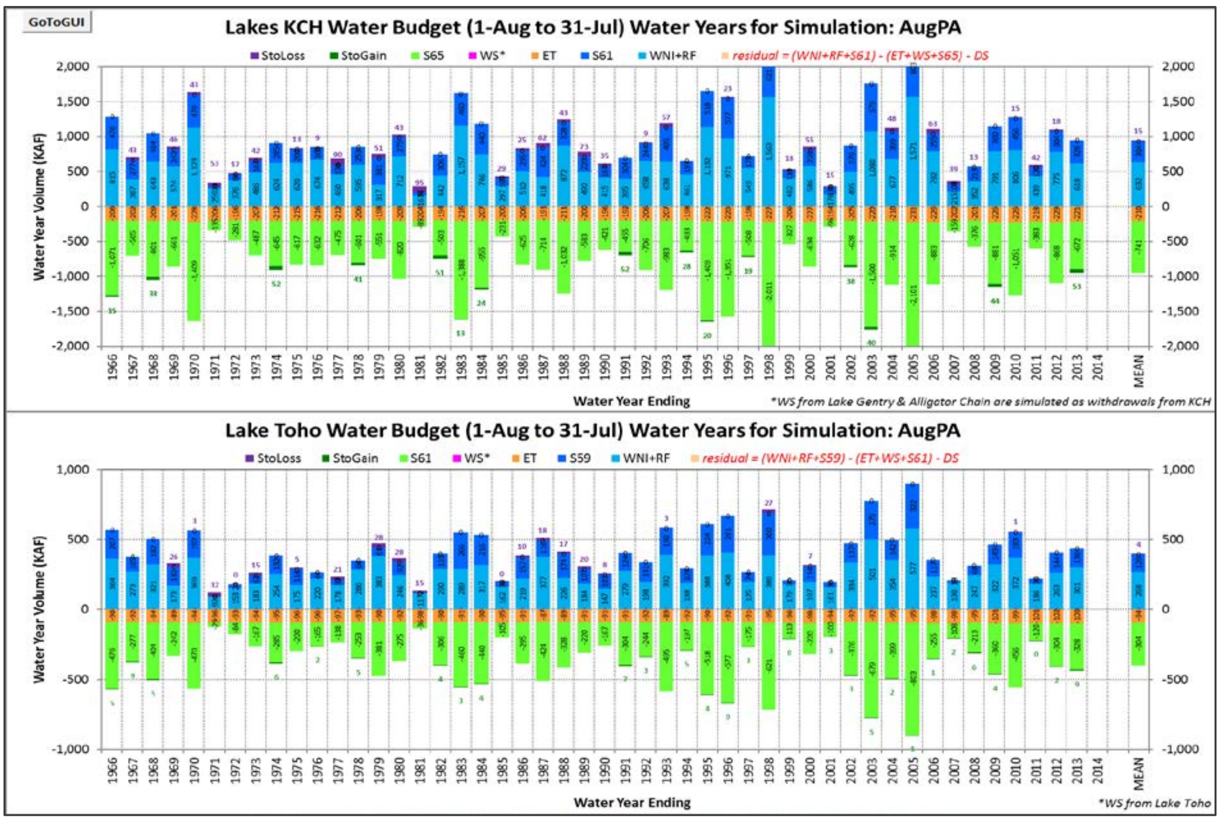


Figure 5-6. Sample water budgets for Lakes Kissimmee, Cypress, and Hatchineha and Lake Tohopekaliga.

For years with inflows exceeding outflows, the storage gain is displayed at the bottom of the bars. For years with outflows exceeding inflows, the storage loss is displayed at the top of the bars. Thus, the height of the positive components should always equal the height of the negative components. If the heights differ, then there is a problem with the mass balance. The residual term should always be zero and is displayed on the budget chart as a data label along the x-axis. Mass is conserved if the residual is zero, and non-zero values indicate a possible error in the mass balance, which would require correction prior to using the simulation results. Good modeling practice includes verifying mass conservation for every simulation; these charts help make that check.

5.3.2 Event Table and Plot

The Events worksheet can be accessed using the Event Table & TS Plot button. This worksheet enables analysis of user-specified stage and flow events for KCH, TOH, and ETO. The upper half of the worksheet allows selection of the site and data type, stage or flow threshold and whether to count events above or below the threshold, definition of a significant event duration, and optional specification of a seasonal window to limit the analysis. The lower half of the worksheet displays a time series of the events (**Figure 5-7**). The chart uses rectangles to indicate the start and end dates of each event, and the rectangle height represents the average magnitude of each event. Event summary statistics are shown on the left margin of the chart for each simulation. Note that the graphic is not generic enough to allow particular simulation outputs to be turned off. Furthermore, results for position analysis simulations may not be meaningful unless the event window is selected to not overlap with the start date of the 1-year position analysis simulations.

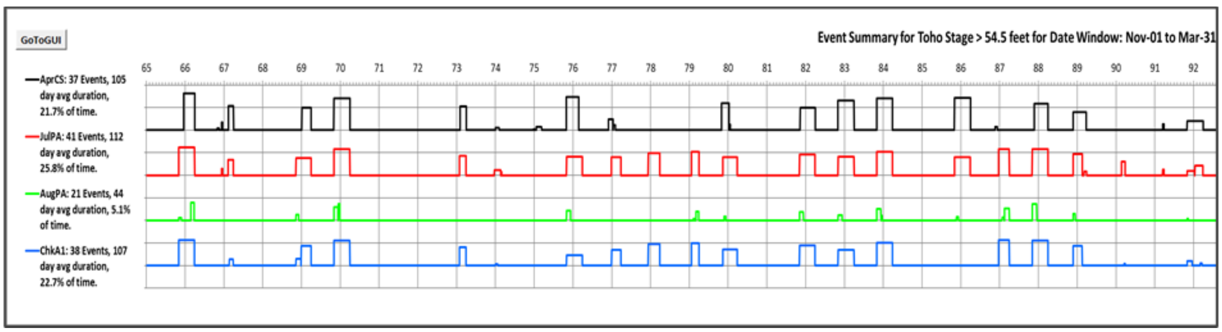


Figure 5-7. Sample event summary for Lake Tohopekaliga simulated stage.

5.3.3 Max D-day Inundation

The MaxStages worksheet can be accessed using the Max D-day Inundation button. This worksheet enables analysis of the maximum yearly stage that occurred for a user-specified minimum duration of consecutive days and during a user-specified date window. The example chart in **Figure 5-8** shows a sample for KCH. The specified duration (D) was 30 days. The date window was August 1 to December 31. The chart compares four simulations year-by-year by showing the yearly maximum stage meeting the aforementioned criteria. The chart also has a dropdown menu to select the desired large lake system. Some of the less frequently used parameter inputs (e.g., the date window) are located under the chart and can be changed by temporarily moving the chart. Dropdown menus can be added to enable easier selection of the date window.

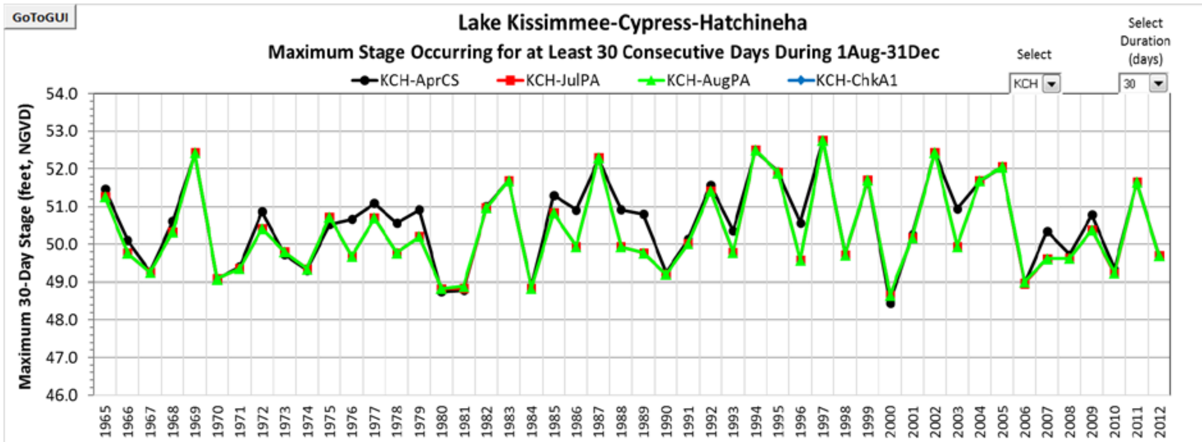


Figure 5-8. Sample maximum annual stage comparison at Lakes Kissimmee, Cypress, and Hatchineha.

An additional chart is displayed in the MaxStages worksheet to make relative comparisons between simulations (**Figure 5-9**). The annual values from the maximum stage chart for a prescribed baseline (AprCS in this example) are subtracted from the year-by-year values of the other simulations. Then the distribution of the yearly differences is displayed for each simulation using box and whisker plots. This relative performance comparison is similar to calculations for a paired T-test and helps illustrate the magnitude of the difference in maximum stages across the entire simulation period.

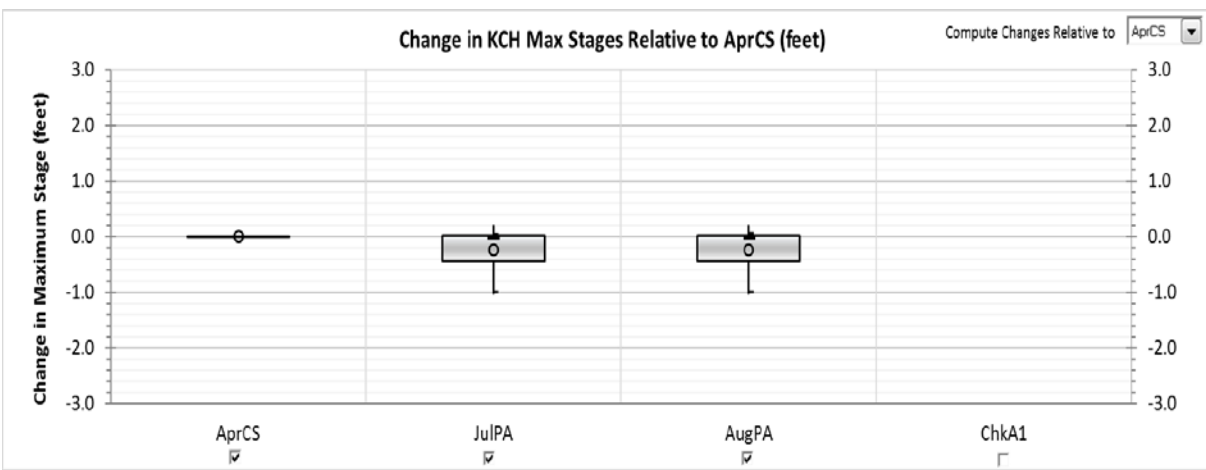


Figure 5-9. Sample event summary for Lake Tohopekaliga simulated stage.

A final note about the above two charts pertains to the check boxes located below the simulation names at the bottom of **Figure 5-9**. The check boxes control the display of the simulation output. The simulation named “ChkA1” is not displayed on either chart.

5.3.4 S-65 Annual Flow

The S65VolComp worksheet can be accessed using the S65 Annual Flow button. This worksheet enables evaluation of the effects of upstream operations and/or water supply withdrawals on the annual S-65 outflows from KCH.

The KRCOL Water Reservation set a maximum S-65 flow reduction limit of 5% for the period between 1965 and 2005. The baseline for evaluating proposed water supply withdrawals is the mean annual simulated S-65 flow for that period. The baseline simulation used historical data for WNI+RF, assumed the future expected operation under the authorized Headwaters Revitalization Schedule for KCH, and assumed the current authorized regulation schedules for ETO and TOH. The 41-year mean annual S-65 flow from this baseline simulation is 704,000 acre-feet/year.

The performance metric shown in **Figure 5-10** was developed for the UK-OPS Model to compare simulations of proposed water supply withdrawals with the baseline flow limit. The chart shows the distribution of annual simulated flow at the S-65 structure via box and whisker plots. The mean annual flow is shown as a labeled dot on the plots. The x-axis labels display the percent change relative to the baseline simulation 41-year mean. The ChkHRS simulation in **Figure 5-10** represents the baseline condition. The mean for the ChkHRS simulation is 704,000 acre-feet/year and the percent change on the axis label is zero.

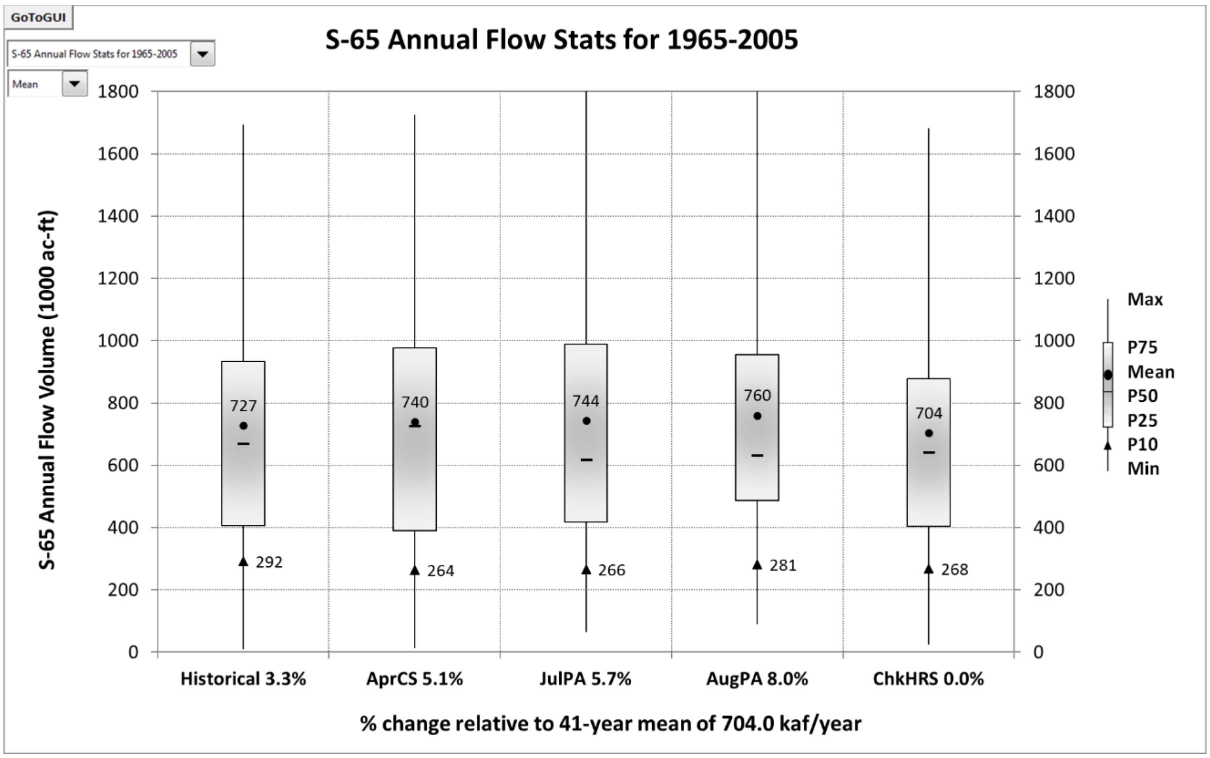


Figure 5-10. Sample annual flow statistics for the S-65 structure.

5.3.5 Water Supply Reliability

The WS_Table worksheet can be accessed using the WS Reliability button. This worksheet contains a table showing the number of days per month that water supply withdrawals occurred during the simulation. User controls allow specification of the lake system of interest: TOH, ETO, HMJ, MPJ, ALC, or GEN. Water withdrawals from KCH are not allowed by the draft KRCOL Water Reservation rules, so KCH is not included in the table. User controls also enable selection of the simulation name, a target reliability (percentage of time with water supply withdrawals) for computing performance, and the period for computing summary statistics.

Table 5-1 is an example water supply reliability table for a TOH water supply withdrawal scenario. The shaded cell values indicate the number of days in each month of each simulation year that water withdrawals occurred. The greens designate more days of withdrawals, whereas the oranges/reds indicate fewer days. The right side of the table summarizes the volumes withdrawn and the percent of time they occurred by season and by year. The summary at the bottom shows frequency statistics and the number of years that meet the user-specified reliability.

Table 5-1. Sample water supply reliability table for Lake Tohopekaliga.

	Lake TOH Water Supply Reliability Table for JF_WS															Percent of Time WS Withdrawal			
	No. of Days per Month with Lake Toho WS Withdrawals at 23.2 cfs (15.0 MGD)												Days	Vol(kaf)	AvgMGD	CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	5	16	22	28	1	13	31	8	12	0	16	152	7.00	6.25	41.6%	50.5%		
1966	11	6	7	22	31	14	31	24	9	6	0	0	161	7.41	6.62	44.1%	62.5%	43.9%	42.5%
1967	0	15	18	22	24	1	13	31	20	1	0	0	145	6.68	5.96	39.7%	48.9%	37.3%	46.6%
1968	0	0	0	12	26	27	31	31	10	0	0	0	137	6.31	5.61	37.4%	67.9%	17.8%	27.9%
1969	23	9	6	22	29	1	0	0	6	30	8	6	140	6.45	5.75	38.4%	35.9%	42.0%	50.7%
1970	7	6	7	22	23	1	4	20	0	0	0	0	90	4.14	3.70	24.7%	26.1%	37.3%	33.4%
1971	0	0	0	3	18	0	0	0	0	0	0	0	21	0.97	0.86	5.8%	9.8%	9.9%	14.0%
1972	0	0	0	21	23	5	31	26	8	0	0	0	114	5.25	4.67	31.1%	50.5%	20.7%	10.7%
1973	0	25	18	21	23	1	0	16	30	5	0	0	139	6.40	5.71	38.1%	40.8%	41.0%	43.0%
1974	0	1	13	30	29	3	31	31	14	1	0	0	153	7.04	6.29	41.9%	59.2%	34.4%	32.6%
1975	0	0	0	22	28	1	0	30	24	8	5	0	118	5.43	4.85	32.3%	49.5%	23.6%	35.9%
1976	5	19	7	22	25	16	31	28	10	1	0	0	164	7.55	6.72	44.8%	60.3%	39.0%	40.7%
1977	7	23	7	23	27	1	0	5	15	4	0	3	115	5.29	4.73	31.5%	28.3%	41.0%	46.8%
1978	23	17	7	21	28	1	12	29	4	0	0	0	142	6.54	5.84	38.9%	40.2%	46.7%	33.7%
1979	4	28	12	22	31	1	0	2	27	9	0	0	136	6.26	5.59	37.3%	38.0%	45.8%	38.4%
1980	21	11	8	21	27	1	0	0	0	0	0	0	89	4.10	3.65	24.3%	15.2%	41.3%	35.8%
1981	0	0	0	0	6	1	0	3	29	1	0	14	54	2.49	2.22	14.8%	21.7%	2.8%	7.7%
1982	18	7	6	21	31	30	21	21	9	4	0	0	168	7.73	6.90	46.0%	63.0%	45.8%	29.0%
1983	9	17	7	21	29	22	30	21	9	6	7	6	184	8.47	7.56	50.4%	63.6%	39.2%	46.6%
1984	7	7	8	22	29	1	29	30	7	0	0	0	140	6.45	5.74	38.3%	52.2%	40.4%	47.5%
1985	0	0	3	30	26	1	6	31	26	2	0	0	125	5.75	5.14	34.2%	50.0%	27.8%	35.3%
1986	23	7	7	23	25	0	0	23	17	0	0	0	125	5.75	5.14	34.2%	35.3%	40.1%	41.6%
1987	30	12	6	21	29	1	0	0	0	0	20	21	140	6.45	5.75	38.4%	16.3%	46.2%	36.7%
1988	6	7	8	22	26	1	0	12	28	0	2	22	134	6.17	5.49	36.6%	36.4%	51.6%	31.1%
1989	7	4	10	22	26	0	0	18	20	9	0	0	116	5.34	4.77	31.8%	39.7%	43.9%	36.7%
1990	0	4	31	23	23	1	0	21	3	0	0	0	106	4.88	4.36	29.0%	26.1%	38.2%	35.9%
1991	0	0	20	30	31	30	23	21	5	9	0	0	169	7.78	6.95	46.3%	64.7%	38.2%	26.8%
1992	0	13	21	20	30	13	31	27	9	4	6	10	184	8.47	7.54	50.3%	62.0%	39.4%	47.3%
1993	7	6	6	22	27	1	9	3	15	0	0	0	96	4.42	3.95	26.3%	29.9%	39.6%	46.8%
1994	1	28	14	21	29	22	28	20	8	4	10	7	192	8.84	7.89	52.6%	60.3%	43.9%	32.6%
1995	7	7	7	22	29	1	6	31	23	7	8	6	154	7.09	6.33	42.2%	52.7%	42.0%	46.8%
1996	7	7	7	21	30	25	27	20	8	7	0	0	159	7.32	6.52	43.4%	63.6%	40.4%	41.8%
1997	11	16	7	21	31	1	19	30	7	0	1	26	170	7.83	6.99	46.6%	47.8%	40.6%	47.1%
1998	7	6	7	22	28	1	0	0	5	7	0	0	83	3.82	3.41	22.7%	22.3%	45.8%	43.0%
1999	0	25	18	22	28	4	31	29	15	7	7	7	193	8.88	7.93	52.9%	62.0%	43.9%	29.0%
2000	7	7	8	22	26	1	0	10	14	0	0	0	95	4.37	3.89	26.0%	27.7%	39.4%	47.0%
2001	0	0	0	13	24	1	28	27	17	2	0	0	112	5.16	4.60	30.7%	53.8%	17.5%	17.5%
2002	0	18	18	22	22	16	31	26	9	2	12	6	182	8.38	7.48	49.9%	57.6%	37.7%	43.0%
2003	7	7	6	22	30	23	27	19	9	4	2	15	171	7.87	7.03	46.8%	60.9%	42.5%	45.5%
2004	7	7	7	22	30	1	28	30	13	8	7	7	167	7.69	6.84	45.6%	59.8%	42.3%	47.0%
2005	7	6	7	21	31	28	20	20	2	7	12	7	168	7.73	6.90	46.0%	58.7%	40.6%	45.2%
2006	8	7	7	22	27	0	19	16	29	0	0	0	135	6.21	5.55	37.0%	49.5%	42.5%	46.8%
2007	0	25	16	22	20	24	31	23	13	3	1	1	179	8.24	7.36	49.0%	62.0%	39.2%	42.2%
2008	12	15	8	21	26	1	12	30	21	5	0	0	151	6.95	6.19	41.3%	51.6%	39.4%	47.0%
2009	0	2	14	30	28	30	28	21	9	1	0	12	175	8.06	7.19	47.9%	63.6%	34.9%	38.6%
2010	13	6	5	21	31	30	23	2	0	2	0	0	133	6.12	5.47	36.4%	47.8%	41.5%	47.7%
2011	0	15	26	22	25	1	18	31	19	7	6	4	174	8.01	7.15	47.7%	54.9%	41.5%	41.4%
2012	3	14	8	22	26	6	31	31	13	3	0	0	157	7.23	6.43	42.9%	59.8%	39.0%	43.2%
2013	0	0	13	30	30	24	31	24	9	3	0	0	164	7.55	6.74	44.9%	65.8%	34.4%	41.9%
MEANS																			
48YR	6	10	9	21	27	9	16	20	12	4	2	4	140	6.46	5.76	38.4%	47.5%	37.5%	38.4%
41YR	7	9	9	21	27	7	14	19	12	4	3	4	137	**6.29**	**5.61**	**37.4%**	45.7%	37.4%	37.4%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	**49**	**49**	**48**	**48**
Years used for stats	**'65-'13**	**'65-'13**	**'66-'13**	**'66-'13**
# Yrs with WS duration > 50%	**4**	**26**	**1**	**1**
Annual Exceedance Frequency	**8.2%**	**53.1%**	**2.1%**	**2.1%**
Return Period (1-in-Nyrs)	**12.3**	**1.9**	**48.0**	**48.0**

5.3.6 Seasonal Distributions of Stage and Flow

The BoxWhiskerStage and BoxWhiskerFlow worksheets can be accessed using the Mon-Stage BoxWhisker and Mon-Flow BoxWhisker buttons, respectively. The stage chart compares the average daily stage for each month of each simulation (**Figure 5-11**). The flow chart compares the mean daily flow for each month of each simulation (**Figure 5-12**). These charts allow comparison of the monthly distributions for the user-specified simulations and sites; they also show the seasonal distributions of stages and flows. The box and whisker plots within each month are not labeled but are in the same order as shown in the legend.

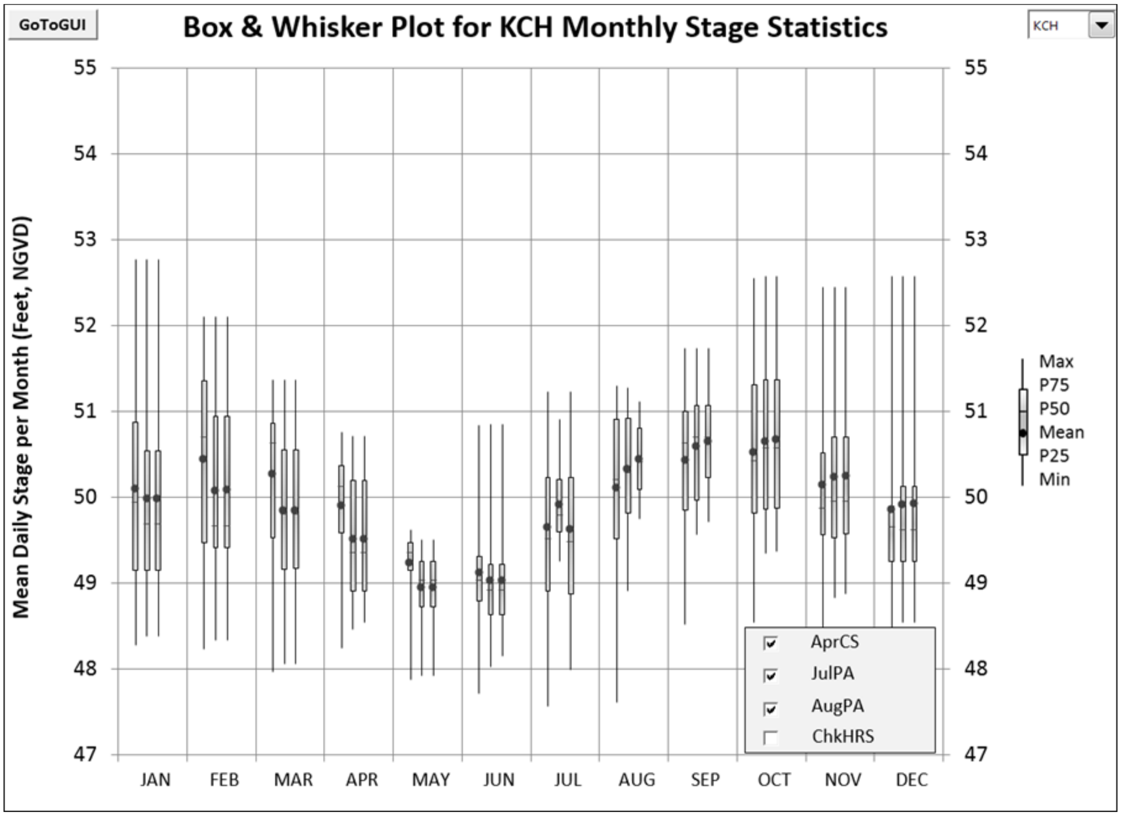


Figure 5-11. Sample monthly stage distributions at Lakes Kissimmee, Cypress, and Hatchineha.

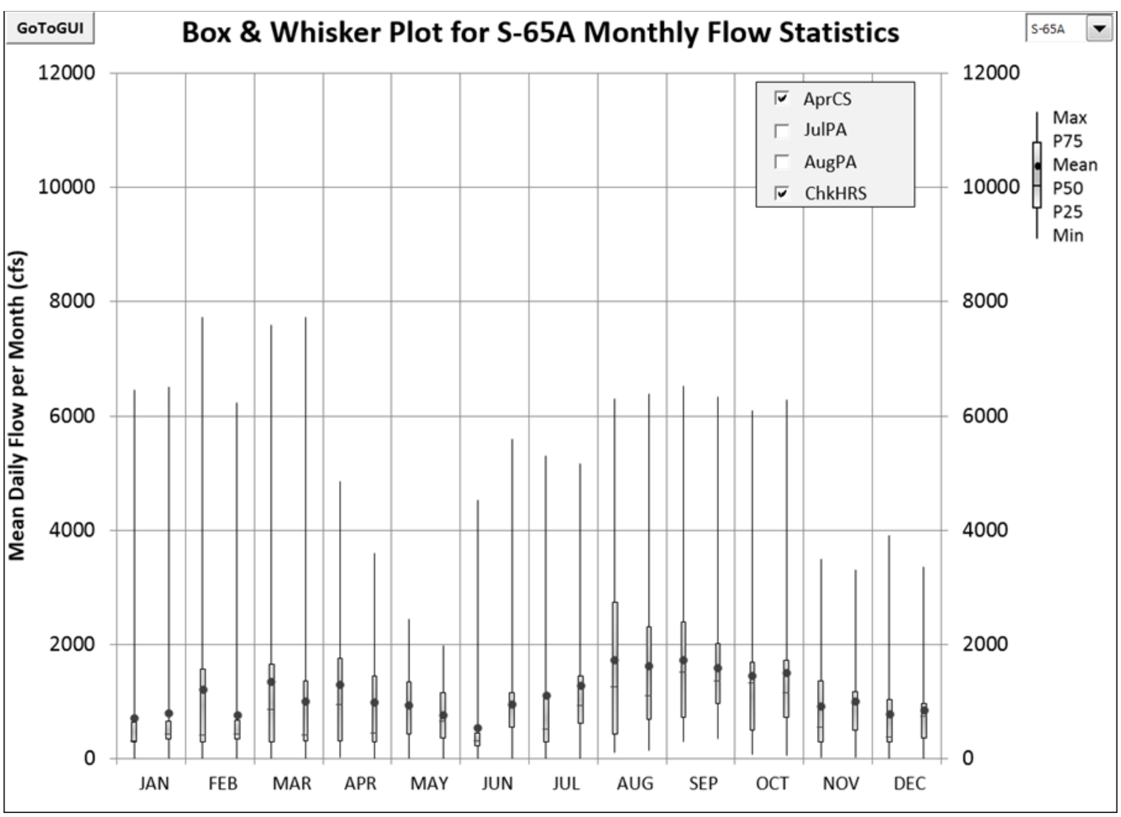


Figure 5-12. Sample monthly flow distributions at the S-65A structure.

6 MODEL VALIDATION

This section compares UK-OPS Model outputs to corresponding input data to demonstrate that the model produces reliable outputs. As described in **Sections 1** and **4**, the UK-OPS Model does not simulate the rainfall-runoff hydrologic process. Instead, it computes watershed inflows to each lake using key hydrologic information from detailed hydrologic models or the historical record. The version of the UK-OPS Model described in this report used the historical data record as the input data set for calculating the boundary condition inflows, namely the WNI+RF. Thus, the UK-OPS Model is not calibrated and validated in the same way as the supporting hydrologic models.

A validation simulation was performed that set the simulated outflows from the UKB's three large lake systems equal to the outflows used to calculate the boundary conditions (WNI+RF). This test aimed to validate the routing calculations by demonstrating the simulated stages were consistent with historical stages.

6.1 Lake Stage Comparisons

By setting the simulated outflows equal to the outflows used to calculate the boundary conditions (WNI+RF), the routing equations were expected to replicate the stage series used to calculate the boundary inflows. For the version of the UK-OPS Model described in this report, historical data were used to calculate the boundary conditions.

Figures 6-1 and **6-2** illustrate the stage and discharge hydrographs for KCH, TOH, and ETO for the first and last 8 years, respectively, of the 49-year simulation. The red traces represent the validation simulation (Val1), and they completely coincide with, and cover, the black traces representing the historical data (Hist). From these comparisons it is concluded that the routing equations in the UK-OPS Model are correct.

Figures 6-3, **6-4**, and **6-5** show the stage duration curves for KCH, TOH, and ETO, respectively, for the entire 49-year simulation period. These figures also show the red curves for the validation simulation completely coincide with, and cover, the black traces representing the historical values.

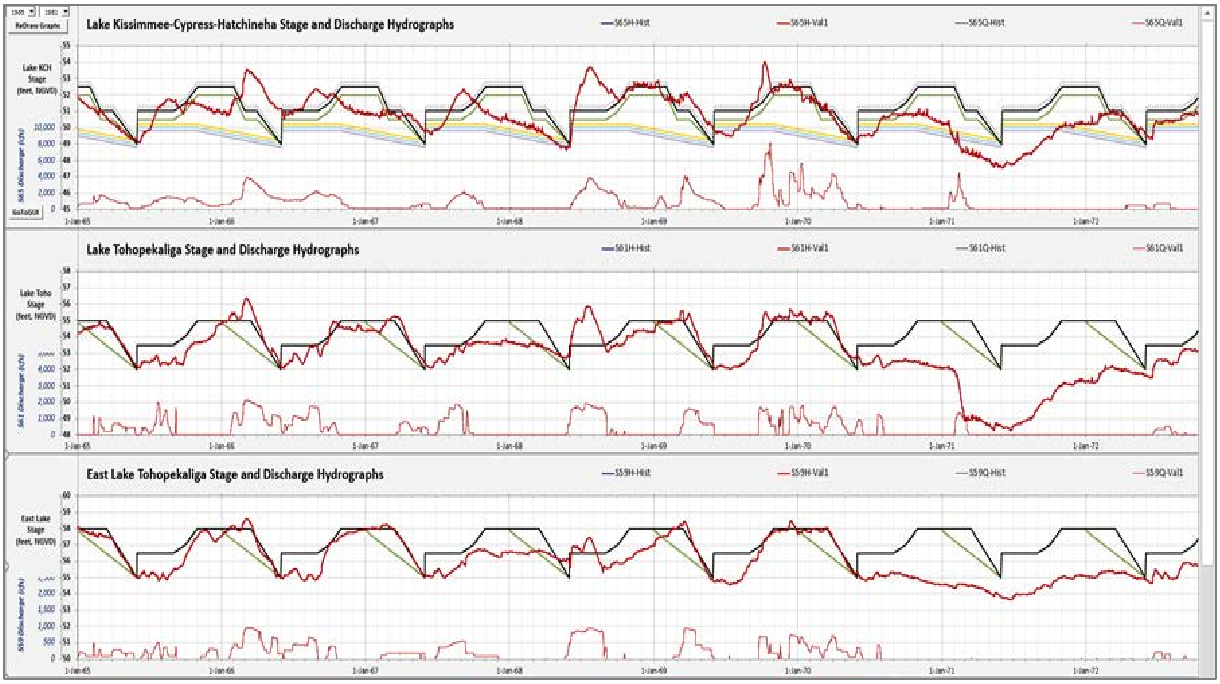


Figure 6-1. Simulated validation (red) and historical (black) hydrographs for 1965 to 1972.

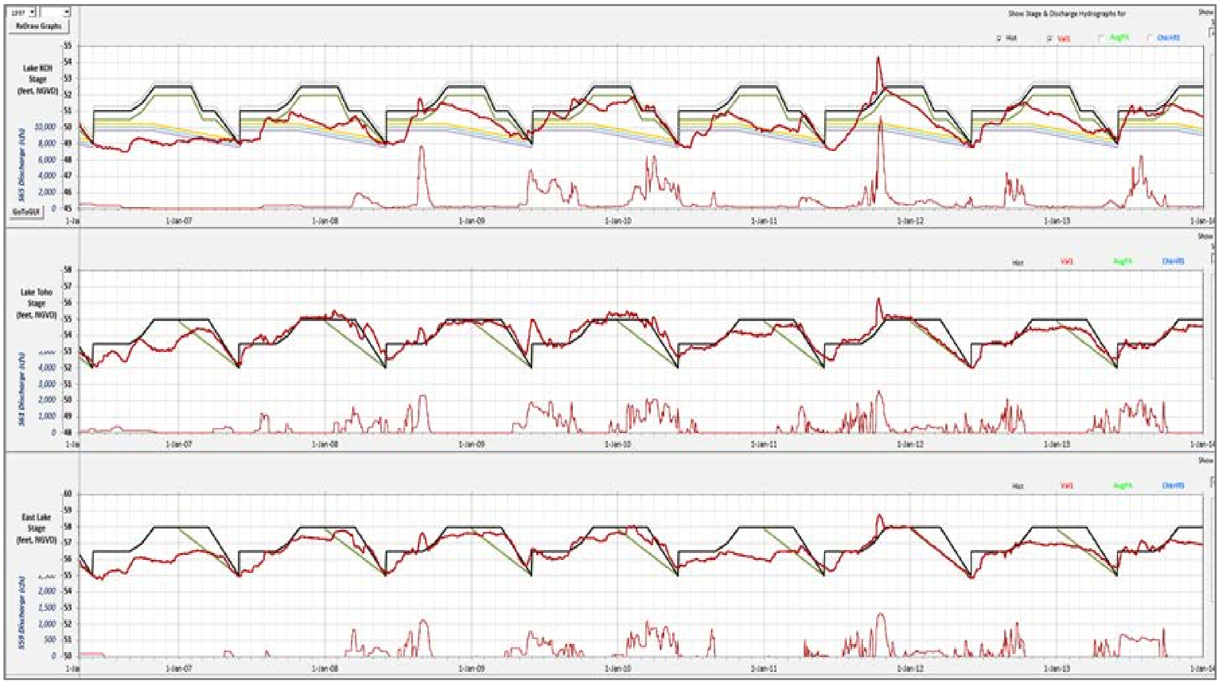


Figure 6-2. Simulated validation (red) and historical (black) hydrographs for 2006 to 2013.

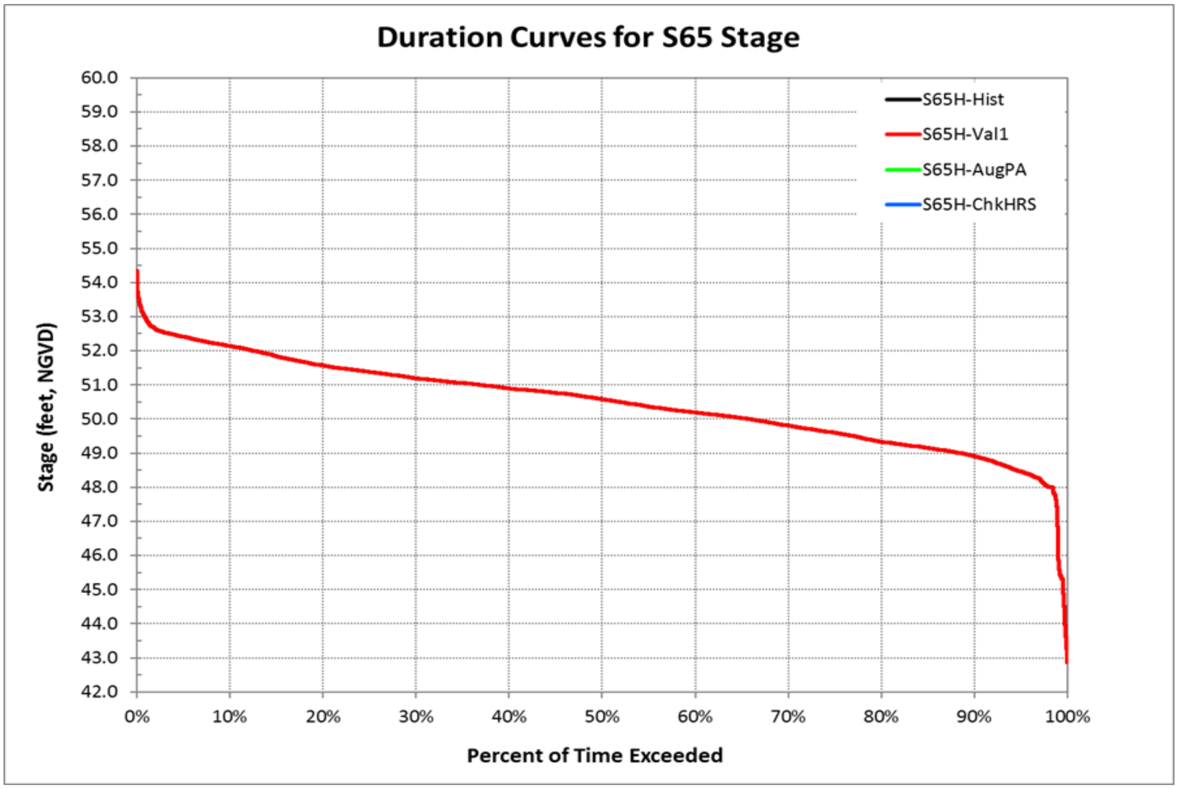


Figure 6-3. Lakes Kissimmee, Cypress, and Hatchineha stage duration curves: simulated validation (red) and historical (black; directly behind red line).

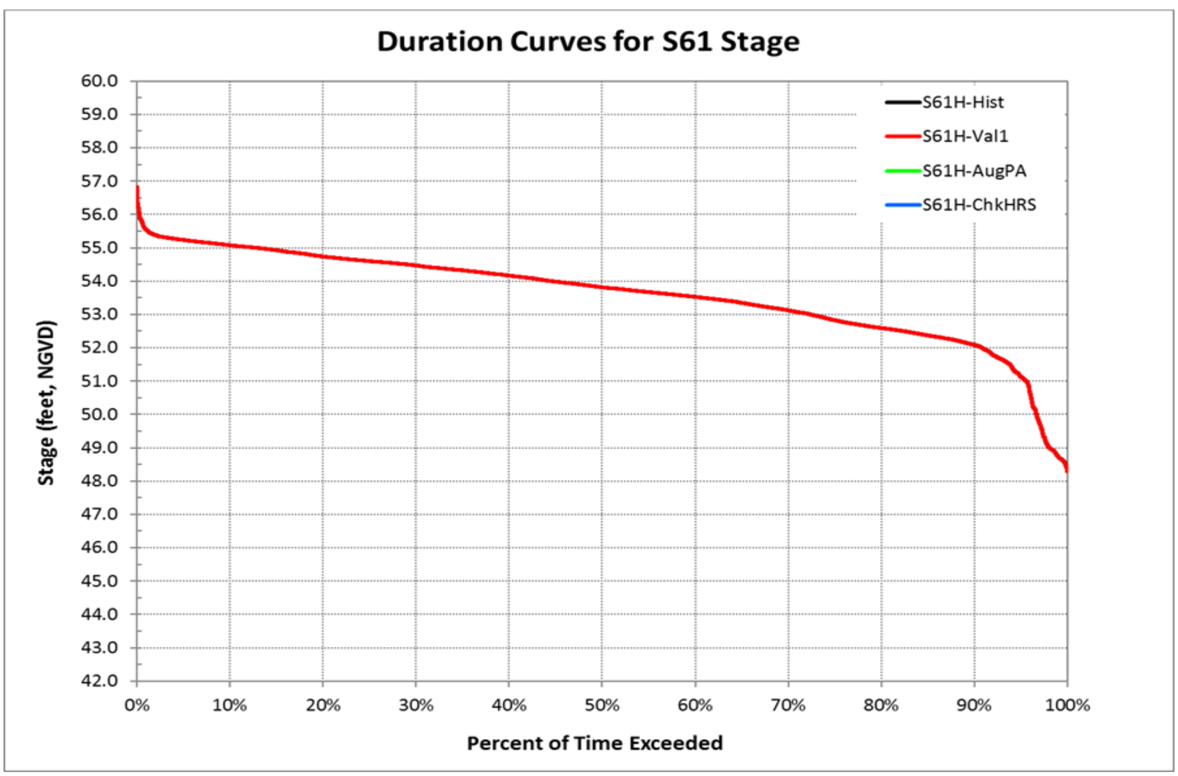


Figure 6-4. Lake Tohopekaliga stage duration curves: simulated validation (red) and historical (black; directly behind red line).

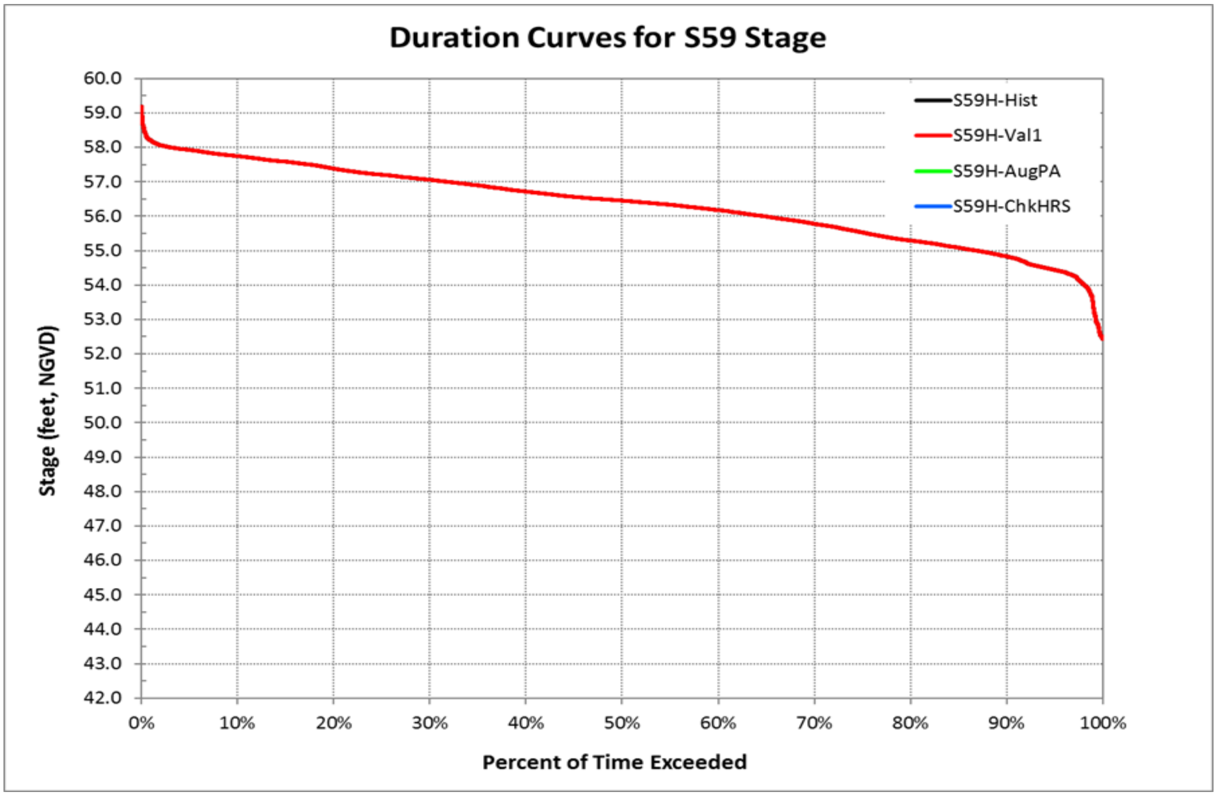


Figure 6-5. East Lake Tohopekaliga stage duration curves: simulated validation (red) and historical (black; directly behind red line).

6.2 Water Budget Comparisons

A fundamental requirement of any hydrologic model is that it conserves mass. In other words, the flows must be accounted for and the model should not create or destroy water (mass). **Figures 6-6**, **6-7**, and **6-8** compare the validation simulation and historical annual water budgets for KCH, TOH, and ETO, respectively. Residuals in the water balance are calculated as inflows minus outflows minus storage change, and zero values demonstrate mass balance. Inspection of these budgets shows identical results, verifying the validation simulation reproduces the historical input data and thus conserves mass.

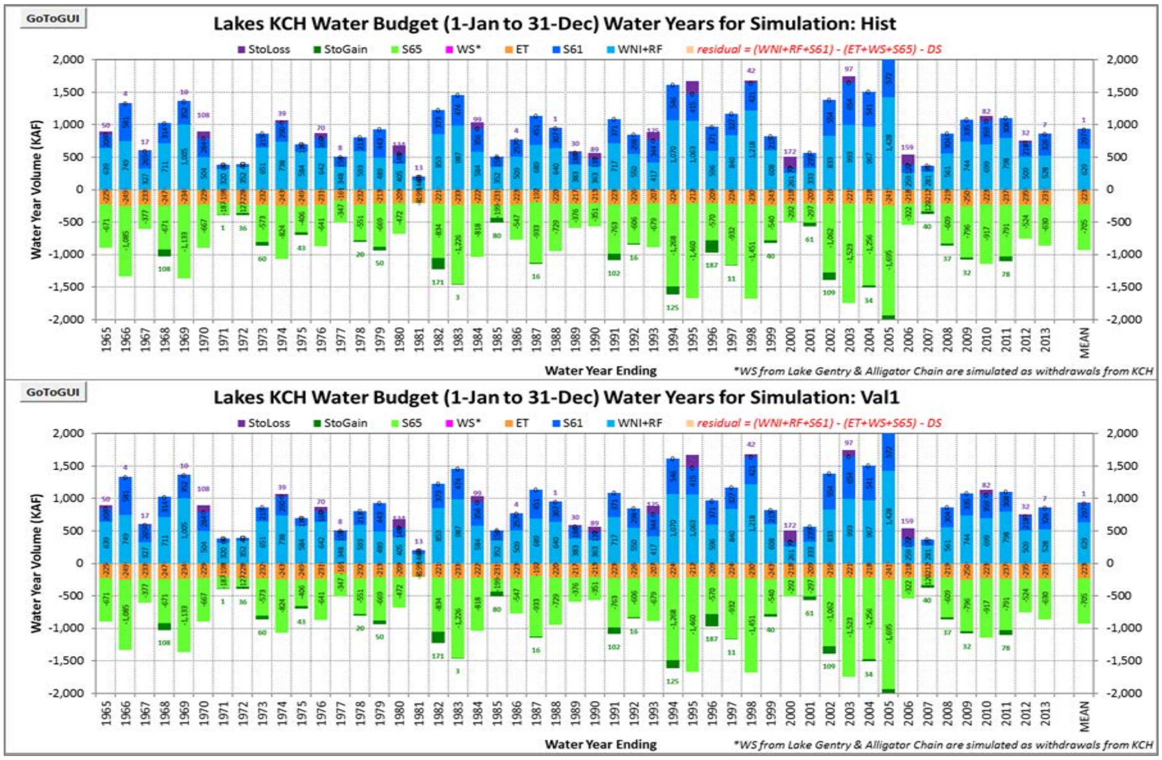


Figure 6-6. Lakes Kissimmee, Cypress, and Hatchineha annual water budgets: historical (top) and simulated validation (bottom).

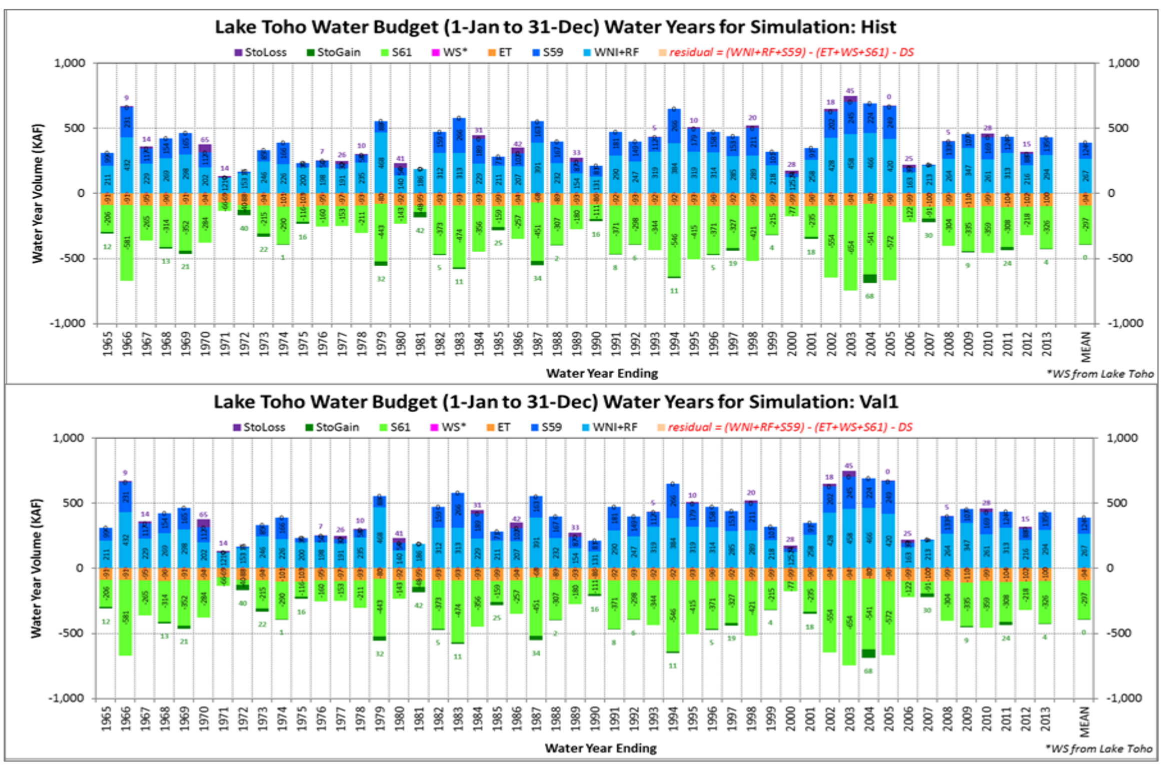


Figure 6-7. Lake Tohopekaliga annual water budgets: historical (top) and simulated validation (bottom).

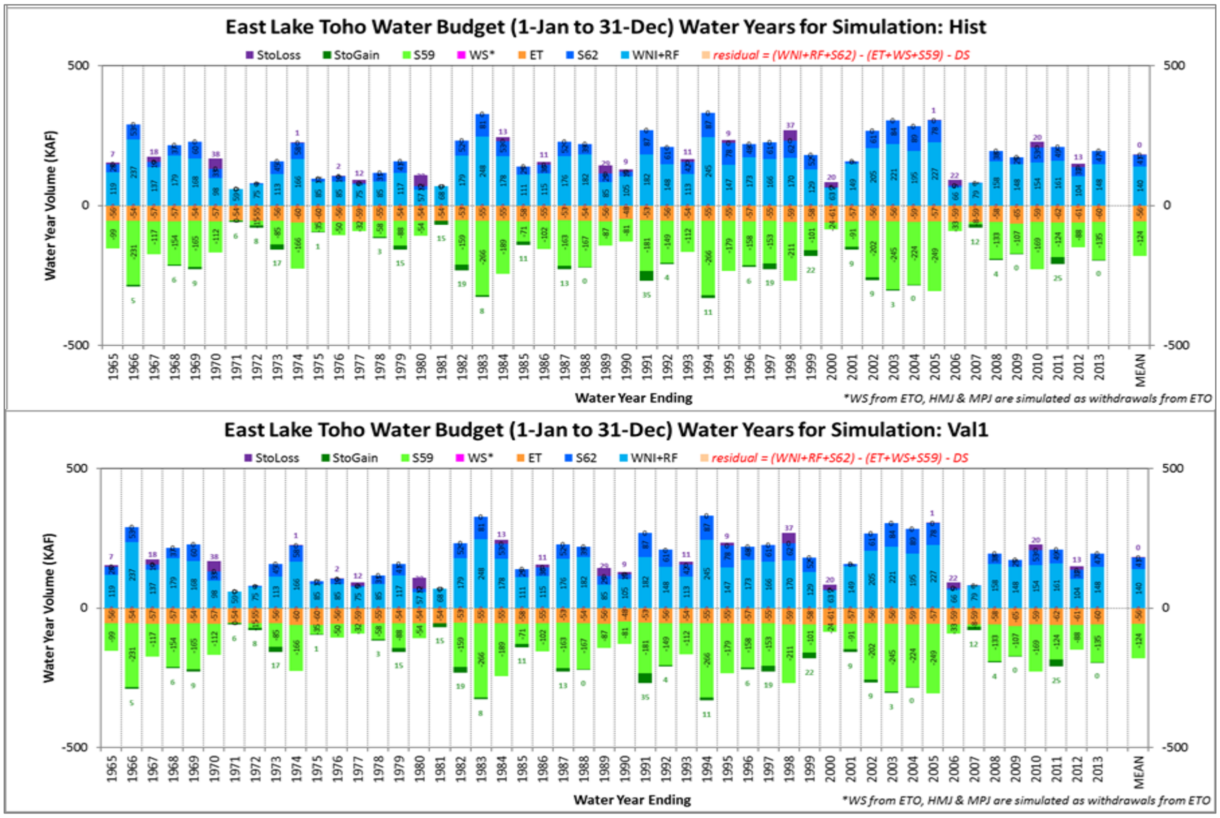


Figure 6-8. East Lake Tohopekaliga annual water budgets: historical (top) and simulated validation (bottom).

7 APPLICATIONS

The UK-OPS Model has been used for several applications since it was originally developed in 2014. This section briefly summarizes the purposes and findings from two of these applications to demonstrate some of the typical and appropriate uses of the model: 1) the SFWMD's monthly position analysis in support of the Operations Planning Program; and 2) a sensitivity analysis to demonstrate potential effects of the draft KRCOL Water Reservation rules from a hypothetical water withdrawal scenario.

Other applications of the UK-OPS Model not described in this report include: 1) pump sizing analysis to support the planning of the proposed ETO drawdown; 2) seasonal operations planning to design and evaluate alternative operations for KCH, TOH, and ETO; and 3) evaluation of the proposed Lake Toho Restoration/Alternative Water Supply Project. The Lake Toho Restoration/Alternative Water Supply Project evaluation was the first use of the UK-OPS Model to test impacts of proposed water withdrawals subject to the draft KRCOL Water Reservation rules.

7.1 SFWMD Position Analysis

Position analysis is a special form of risk analysis evaluated from the present position of the system. A position analysis evaluates water resource systems and the risks associated with operational decisions (Hirsh 1978). The SFWMD Dynamic Position Analysis (DPA) is an application of the South Florida Water Management Model (SFWMM) (SFWMD 2005) to estimate the probability distributions of stages and flows for Lake Okeechobee and the system south of the lake for the upcoming 11 months. The SFWMM DPA is deemed dynamic because it includes a 1-month warmup period to synchronize the simulated antecedent hydrology with the actual hydrology. Details of the DPA are available on the SFWMD's Operations Planning webpage: https://www.sfwmd.gov/science-data/operational-planning.

The SFWMM relies on S-65E boundary inflows from another model. The UK-OPS Model has provided the S-65 flow boundary condition since 2015 when it was discovered that the previous model, the Upper Kissimmee Chain of Lakes Routing Model (UKISS) significantly underestimated S-65 flows for the 1997-1998 El Niño (very wet) period. Because the UK-OPS Model had the option to base the UKB hydrology on historical data, it was selected to support the SFWMM DPA until detailed basin models were updated and recalibrated.

Whenever a DPA is needed, usually at beginning of each month, the following UK-OPS Model steps are executed to produce the S-65 flow series, which is further processed by a river routing model for the Lower Kissimmee Basin to yield the SFWMM boundary flows at the S-65E structure.

1. Review seasonal operating strategy and modify the UK-OPS Model assumptions, as necessary.

2. Determine the initial stage values using real-time posted stage values for KCH, TOH, and ETO, and enter initial stages and start date in the UK-OPS Model GUI.

3. Run the model and evaluate key performance metrics, including water budgets, stage and discharge hydrographs, and percentile plots.

4. Communicate results to the operations planning team for further processing and preparation of the SFWMM DPA. The **Attachment** contains an example email communicating the assumptions and results for the August 2019, UK-OPS Model position analysis simulations.

Figure 7-1 illustrates the S-65 flow percentile chart for the August position analysis simulation. The distribution shows the high variability in flow as early as 2 to 4 weeks after the August 1 initialization. It is important to note that the position analysis is not a forecast but rather a distribution of possible outcomes based on the variability of historical rainfall conditions.

Figures 7-2, **7-3**, and **7-4** show the stage percentile plots for the August position analysis simulations for ETO, TOH, and KCH, respectively. These percentile plots illustrate the distribution of stages each day of the 1-year look-ahead period. The charts represent the probability distributions of lake stages for each day of the upcoming year, assuming current initial conditions and the rainfall for each simulation year is equally likely to occur.

The percentile charts for TOH and ETO show the relatively tight distribution of stages during the January to May spring recession operation. The KCH percentiles show wide variability, particularly during the November to May dry season. Stages in KCH tend to track well-below the top of the regulation schedule because the operations are designed to discharge meaningful flows to the Kissimmee River when the stage is below the top of the regulation schedule.

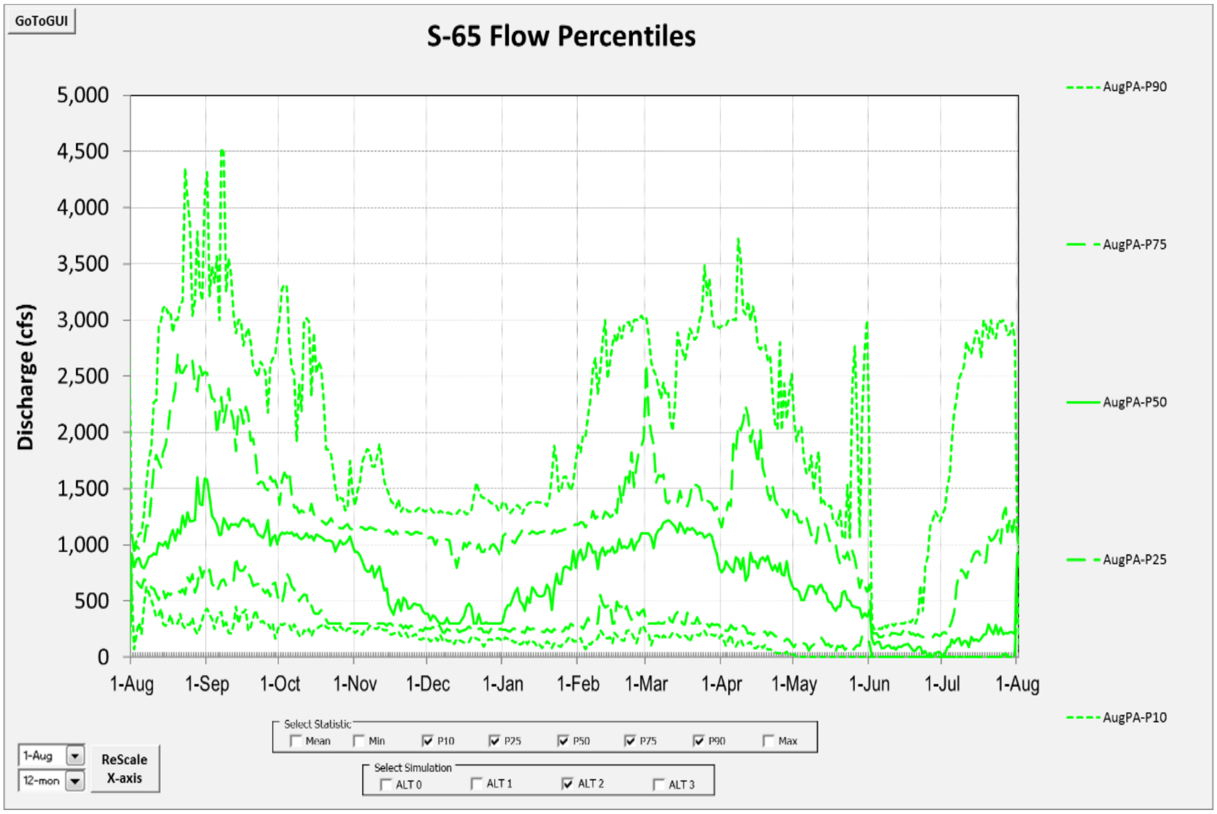


Figure 7-1. S-65 flow percentiles for the August 2019 position analysis.

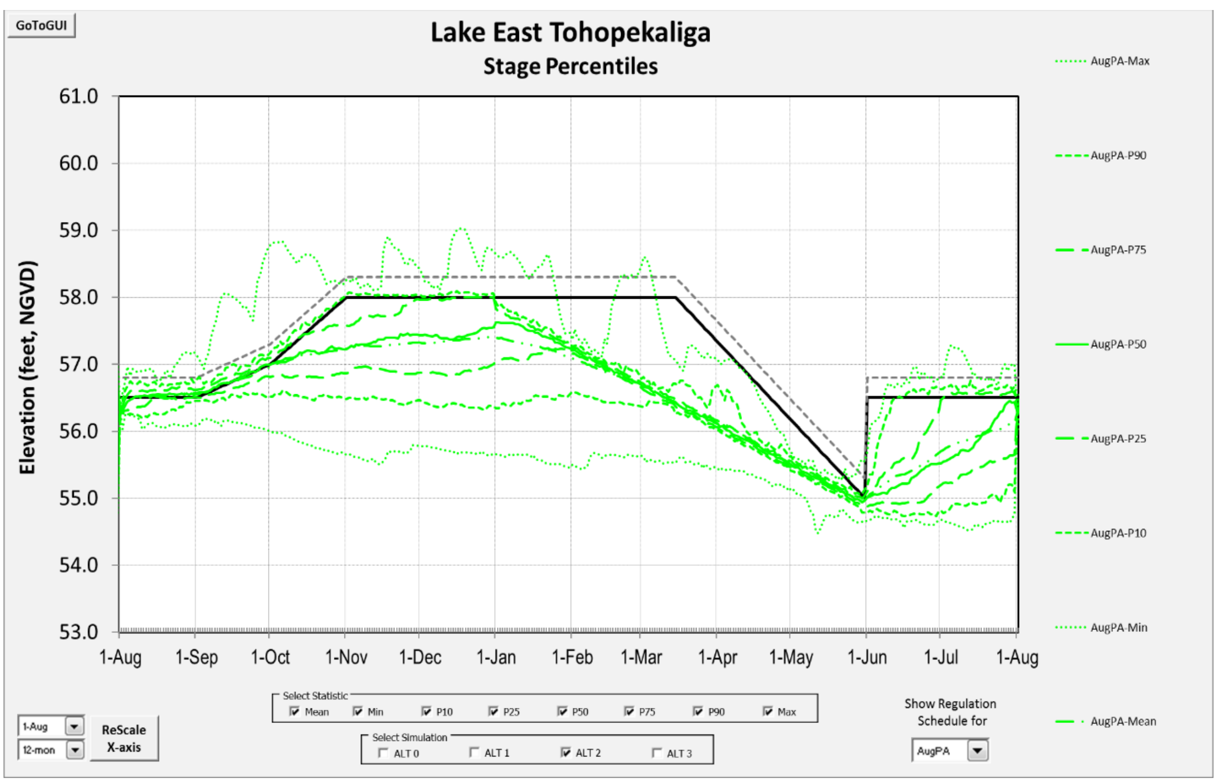


Figure 7-2. East Lake Tohopekaliga stage percentiles for the August 2019 position analysis.

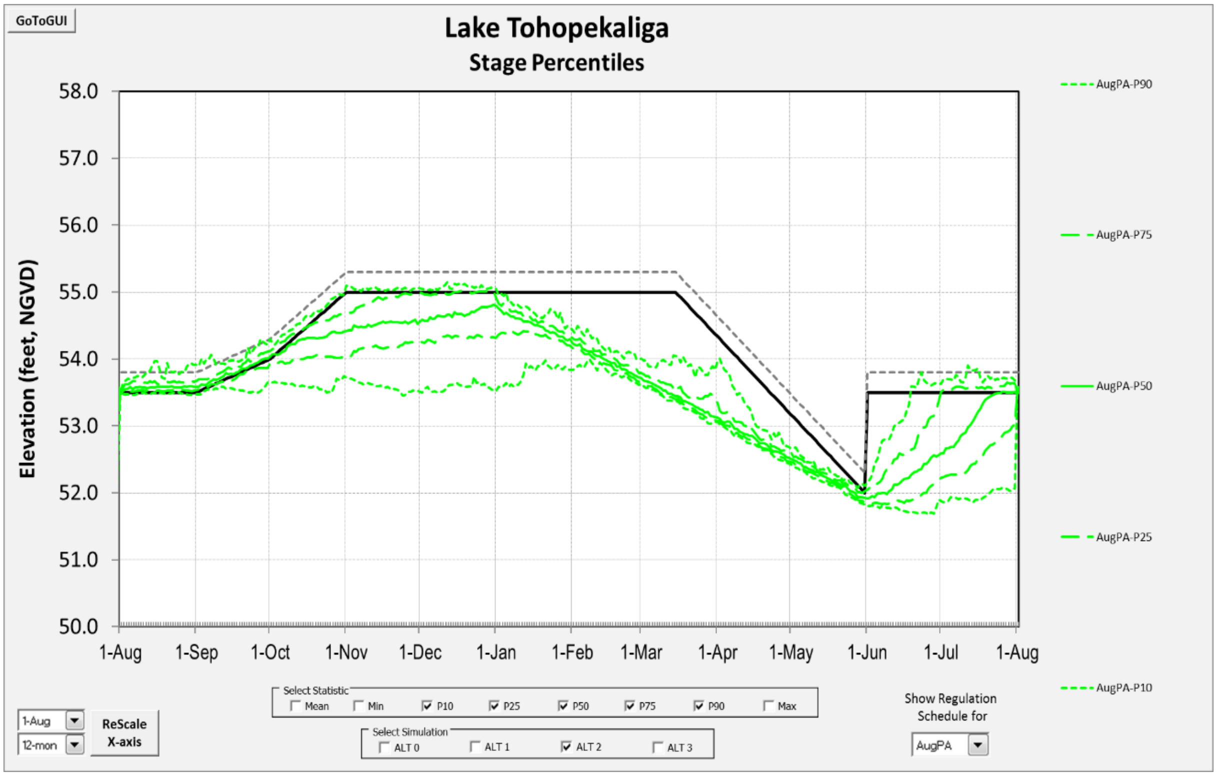


Figure 7-3. Lake Tohopekaliga stage percentiles for the August 2019 position analysis.

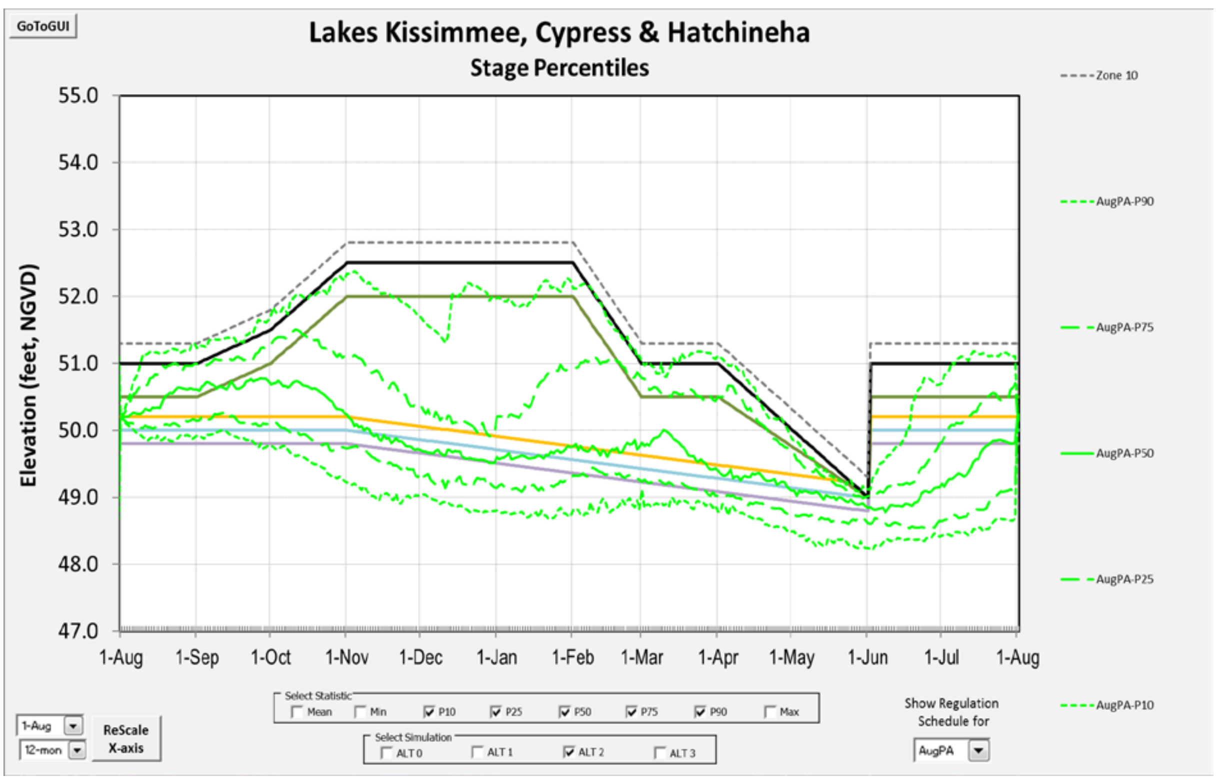


Figure 7-4. Lakes Kissimmee, Cypress, and Hatchineha stage percentiles for the August 2019 position analysis.

7.2 Sensitivity Analysis of Hypothetical Water Supply Withdrawals with Draft KRCOL Water Reservation Rule Criteria

This application of the UK-OPS Model investigated the effects of hypothetical water supply withdrawals from TOH with the draft KRCOL Water Reservation rule criteria. Water supply withdrawal reliability also was assessed with and without the proposed Lake Okeechobee constraint. Results of the sensitivity analysis are presented in this section, following a short summary of the components of the draft KRCOL Water Reservation rule criteria.

The draft KRCOL Water Reservation rules set WRLs in six of the lake systems in the UKB. **Figures 7-5** and **7-6** illustrate the WRLs for ETO and TOH, respectively. The red dashed line denotes the WRL, which was designed to protect the water needed for fish and wildlife of the lake system. The general concept is that water withdrawals can occur if the lake stage is above its respective WRL. However, there can be additional constraints on withdrawals. For example, if water withdrawals are considered for HMJ, then the stage in HMJ must exceed its WRL and the stage in ETO also may need to exceed its WRL. However, if Lake Okeechobee is not releasing water to the estuaries in order to manage the lake stage (i.e., regulatory discharges), then withdrawals from HMJ are restricted. If the all the conditions are met, then withdrawals can occur on that day. The process repeats each day of the simulation.

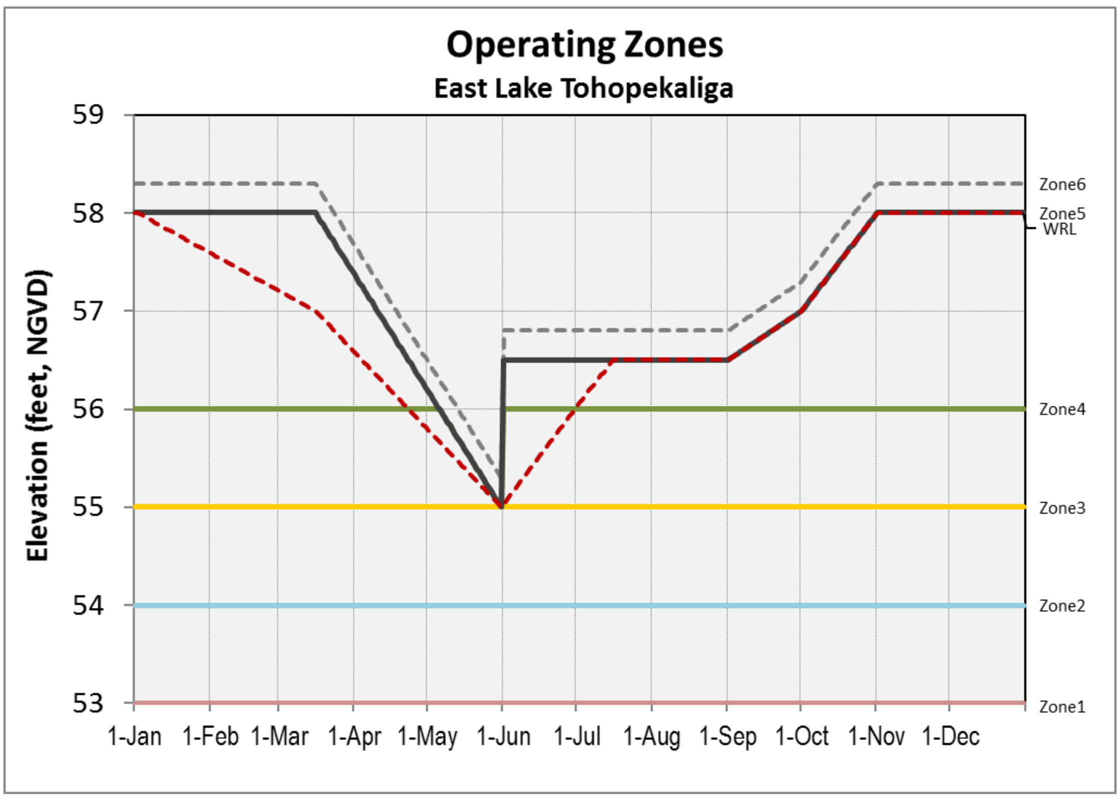


Figure 7-5. East Lake Tohopekaliga regulation schedule with proposed water reservation line (red dashed line).

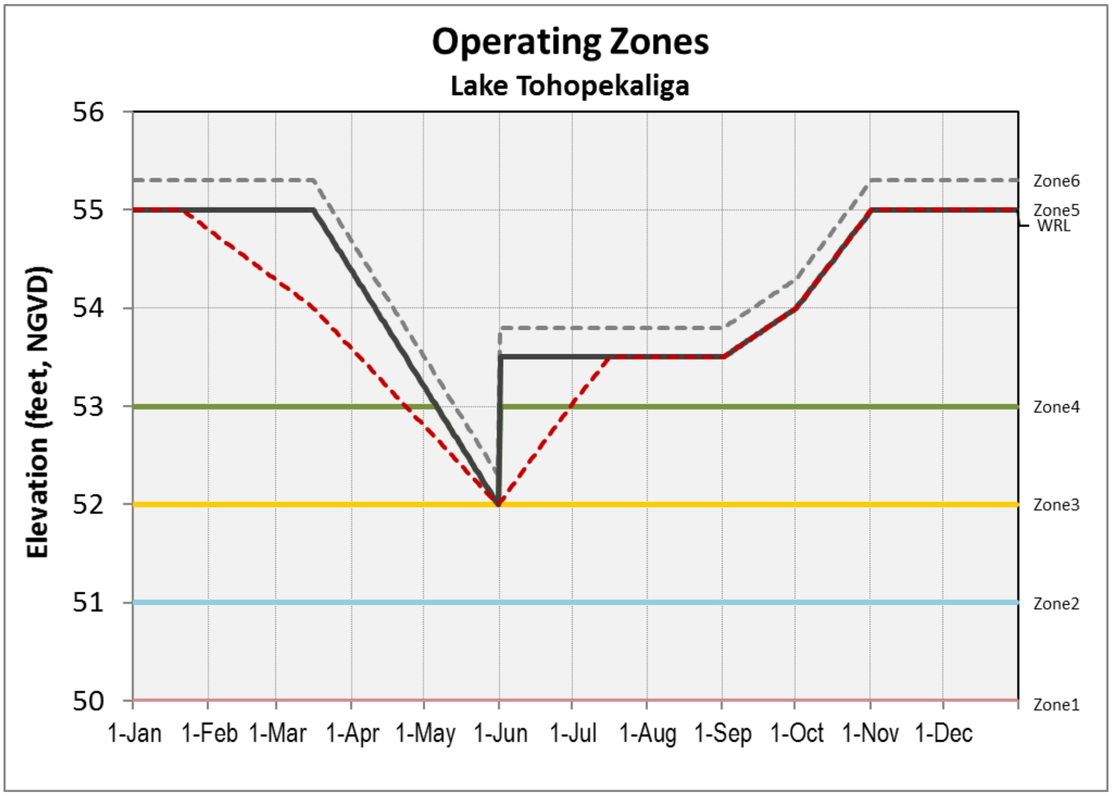


Figure 7-6. Lake Tohopekaliga regulation schedule with proposed water reservation line (red dashed line).

7.2.1 Baseline Scenario

The first scenario simulation (hereafter referred to as Base) was a baseline that used KCH Headwaters Regulation Schedule (**Figure 3-10**) and the standard regulation schedules for ETO and TOH (**Figures 3-1** and **3-5**, respectively; **Figures 7-5** and **7-6**, respectively). No water supply withdrawals were assumed.

7.2.2 Water Supply Withdrawal Scenario 1

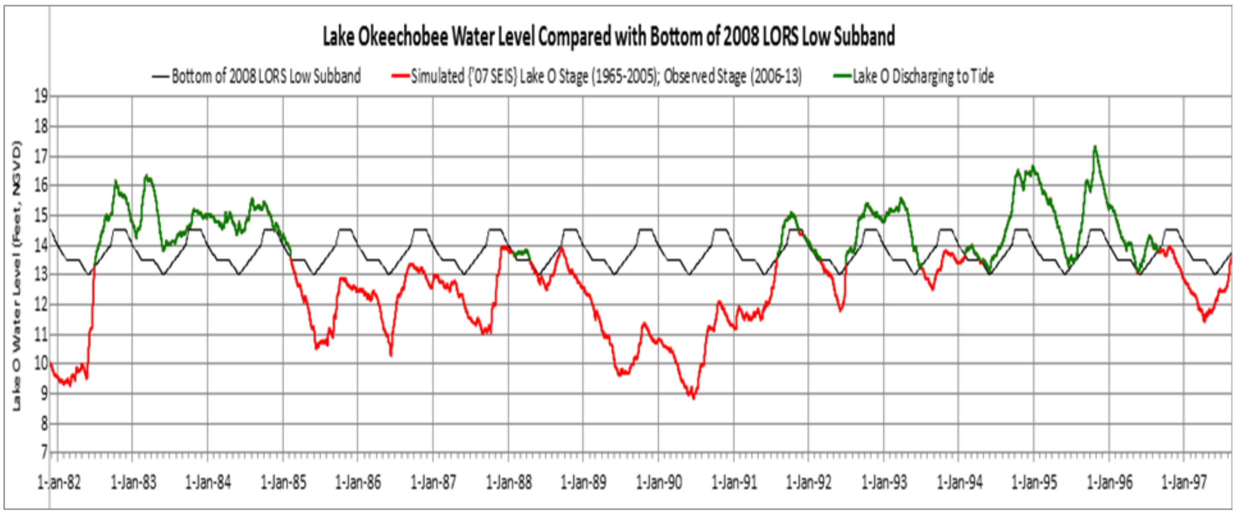
Scenario 1, hereafter WSmax, used the same assumptions as Base but included water supply withdrawals from TOH. The capacity of the infrastructure needed to make the withdrawal was fixed at 64 million gallons per day (99 cfs), but the daily withdrawal rate was subject to the constraints of the draft KRCOL Water Reservation rules. No water supply withdrawals from the other lake systems were assumed in this hypothetical scenario.

7.2.3 Water Supply Withdrawal Scenario 2

Scenario 2, hereafter WSmaxL, was identical to the Scenario 1 except for the addition of the Lake Okeechobee constraint. The same baseline simulation (Base) was used for the relative comparison. Withdrawals from UKB lakes could reduce water availability downstream. The Lake Okeechobee constraint was designed to limit adverse impacts to permitted water users downstream of the UKB by limiting withdrawals from UKB lakes to when regulatory releases from Lake Okeechobee are being made to one or both of the coastal estuaries (Caloosahatchee River and/or St. Lucie Estuary).

The approximation of this constraint is depicted in **Figure 7-7**. The Lake Okeechobee hydrograph for a portion of the simulation of the 2008 Lake Okeechobee Regulation Schedule is colored green when the stage is above the Low Sub-band, indicating regulatory releases are being made to either the Caloosahatchee River or St. Lucie Estuary. The lake stage is colored red when the stage is below the Low Sub-band of the 2008 Lake Okeechobee Regulation Schedule, indicating relatively low water conditions with no regulatory releases being made to either the Caloosahatchee River or St. Lucie Estuary. When the lake stage is colored red, the Lake Okeechobee constraint is met, and no water supply withdrawals can be made from UKB lakes. When the stage is green, then water supply withdrawals can be made from UKB lakes.

Lake Okeechobee constraint limits withdrawals to occur only when Lake O regulatory releases are made to tide



Green = stage above LORS Low Subband, Lake O regulatory discharges to tide, WS from UK Lakes not limited by Lake O

Red = stage below LORS Low Subband, no Lake O regulatory discharges to tide, NO WS from UK Lakes (59% of time)

Figure 7-7. Lake Okeechobee constraint used by the UK-OPS Model.

7.2.4 Simulation Results

The UK-OPS Model simulation of the Base, WSmax, and WSmaxL scenarios revealed the effects of one possible withdrawal scenario on the draft KRCOL Water Reservation rule criteria. The outputs examined and presented here are limited to comparisons of TOH water budgets, TOH stage percentiles, S-65 annual flow, and water supply reliability.

7.2.4.1 Lake Tohopekaliga Water Budget

Figure 7-8 shows the TOH annual water budget for the WSmax and WSmaxL simulations. The water supply withdrawal component is shown for each simulation year and is small relative to the other water budget components. Note that the WSmaxL scenario has less withdrawal volume. Annual average withdrawal decreases from 39,000 acre-feet/year for WSmax to 19,000 acre-feet/year for WSMaxL, a 51% reduction that is due to the Lake Okeechobee constraint, which significantly reduces the number of days withdrawals can be made.

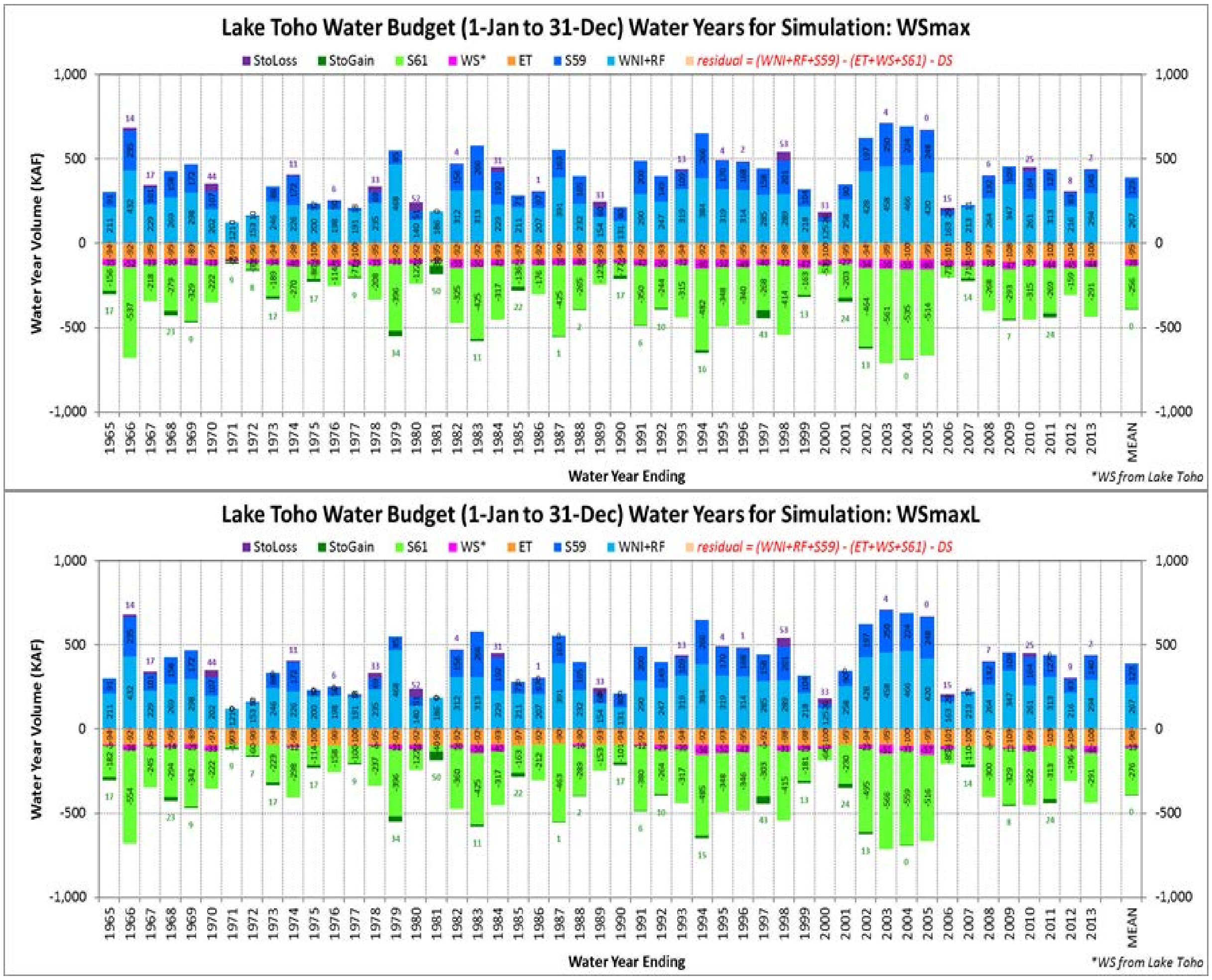


Figure 7-8. Water budget comparison of WSmax and WSmaxL for Lake Tohopekaliga.

7.2.4.2 Lake Tohopekaliga Stage Percentiles

Figure 7-9 compares the TOH stage percentiles for the three simulations (Base, WSmax, and WSmaxL). Results demonstrate a downward shift in the percentiles of the WSmax scenario (red) relative to the Base (black). The WSmaxL scenario (green) falls between the other simulations because the withdrawals are less than those of the WSmax simulation.

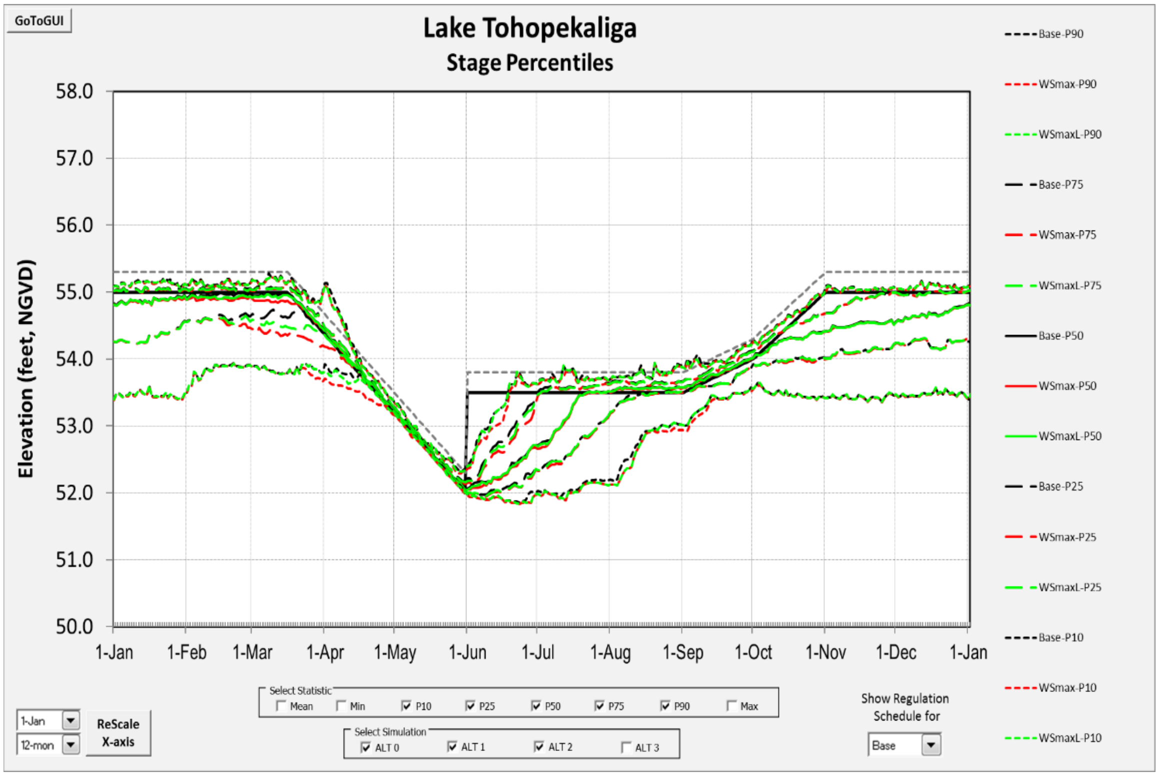


Figure 7-9. Lake Tohopekaliga stage percentiles for the Base, WSmax, and WSmaxL scenarios.

7.2.4.3 S-65 Annual Flow

A key criterion of the draft KRCOL Water Reservation rules is that the reduction in mean annual flow for the 41-year simulation period cannot exceed 5%[1]. This is a permitting criterion to evaluate proposed withdrawals. This criterion cannot be used for real-time operations to determine whether withdrawals can or cannot occur.

Figure 7-10 shows the mean annual flow for the WSmax scenario is exactly -5.0%. In fact, the max withdrawal capacity of 64 million gallons per day was determined by iteratively running the model until this limit was reached. If all future water supply withdrawals were to come from TOH, then they could not exceed a total of 64 million gallons per day. In reality, permitted withdrawals will be in various amounts and from any of the six lake systems that allow withdrawals, subject to the WRL and downstream constraints. This is one reason why the UK-OPS Model is needed as regulatory tool: to evaluate each proposed individual withdrawal in the context of the cumulative withdrawals that already have been permitted. Once the 5% limit is reached, no further withdrawals will be permitted.

[1] The 5% threshold was established from prior technical work (SFWMD 2009). The UK-OPS Model was used to determine the reduction in the mean annual flow as a result of withdrawals from a water use permit issued to Toho Water Authority (49-02549-W). This permit resulted in a 0.82% reduction in mean annual flow at S-65, thereby reducing the 5% threshold to 4.18%, which is reflected in the draft Water Reservation rules.

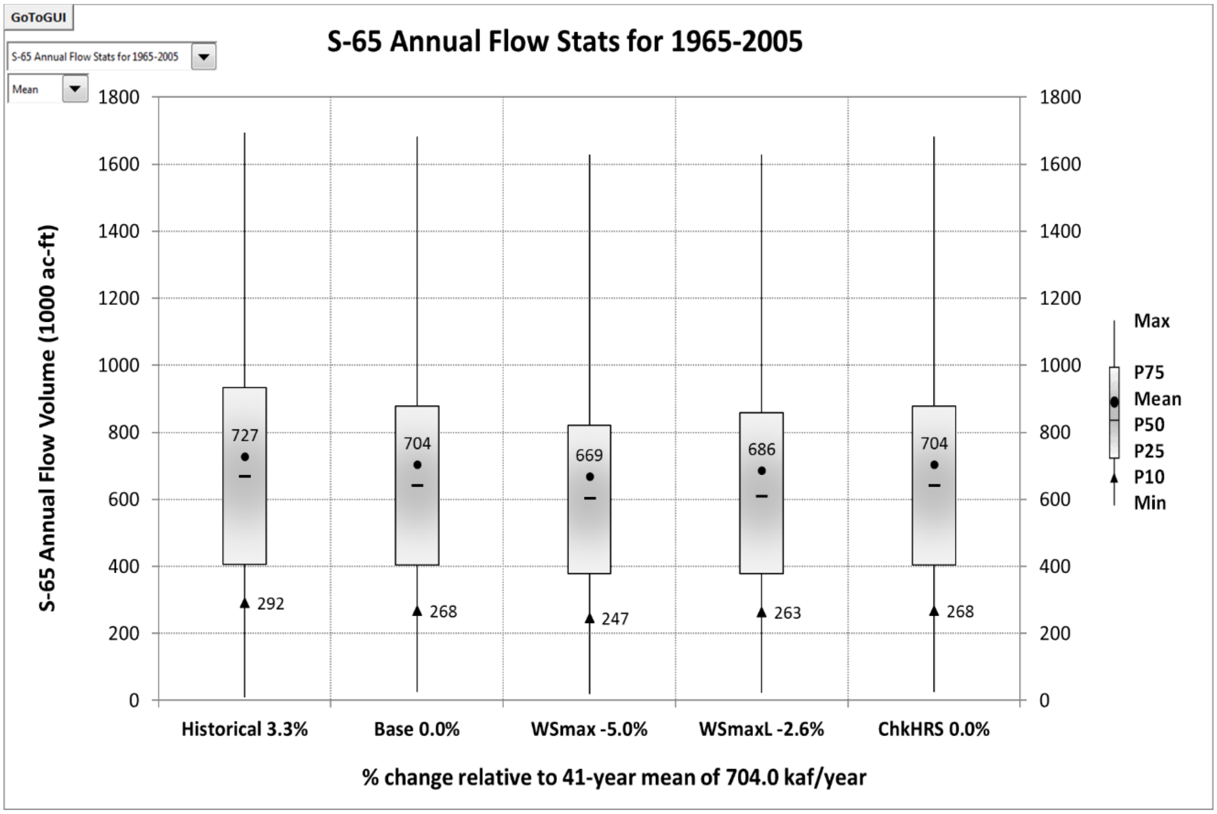


Figure 7-10. Mean annual flow at the S-65 structure under the WSmax scenario.

7.2.4.4 Water Supply Reliability

The simulated water supply reliability information for the WSmax and WSmaxL scenarios are shown in **Tables 7-1** and **7-2**, respectively. The target reliability (percent of time water supply withdrawals occur) was arbitrarily set at 70%. Users can change this target to match the level of performance desired for their particular project. The table summaries show the reliability under the WSmax scenario is 8 calendar years out of the 49 years simulated. The WSmaxL scenario has only 4 years out of the 49 years that meet or exceed the 70% reliability target. This result illustrates the impact from the Lake Okeechobee constraint. Additionally, a larger pump size can be tested to determine if supply targets can be better met. The reliability measures reflect the timing of withdrawals, but larger withdrawals could occur during the allowable days if they do not exceed the 5% cumulative limit. These scenarios can be tested with the UK-OPS Model.

Table 7-1. Lake Tohopekaliga water supply reliability for the WSmax scenario.

Lake TOH Water Supply Reliability Table for WSmax																Percent of Time WS Withdrawal			
	No. of Days per Month with Lake Toho WS Withdrawals at 99.0 cfs (64.0 MGD)												Days	Vol(kaf)	AvgMGD	CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	16	31	30	31	1	9	31	8	7	0	14	178	34.96	31.21	48.8%	47.3%		
1966	23	28	31	30	31	14	31	31	30	15	0	0	264	51.85	46.29	72.3%	82.6%	74.1%	58.4%
1967	0	16	31	30	31	0	8	31	20	1	0	0	168	33.00	29.46	46.0%	49.5%	50.9%	62.7%
1968	0	0	0	25	31	26	30	31	10	0	0	0	153	30.05	26.75	41.8%	69.6%	26.3%	31.7%
1969	19	28	31	30	31	0	0	0	6	27	21	22	215	42.23	37.70	58.9%	34.8%	65.6%	64.7%
1970	31	28	31	30	31	9	0	10	0	0	0	0	170	33.39	29.81	46.6%	27.2%	91.5%	62.2%
1971	0	0	3	28	31	0	0	0	0	0	0	0	62	12.18	10.87	17.0%	16.8%	29.2%	22.2%
1972	0	0	13	30	31	0	6	23	6	0	0	0	109	21.41	19.06	29.8%	35.9%	34.7%	20.2%
1973	0	26	31	30	31	3	0	13	29	11	0	0	174	34.18	30.51	47.7%	47.3%	55.7%	41.9%
1974	0	14	31	30	31	2	30	31	30	4	0	0	203	39.87	35.59	55.6%	69.6%	50.0%	44.4%
1975	0	0	21	30	31	0	0	27	19	11	2	0	141	27.70	24.72	38.6%	47.8%	38.7%	49.0%
1976	4	29	31	30	31	19	28	29	26	2	0	0	229	44.98	40.04	62.6%	73.4%	59.6%	50.3%
1977	5	28	31	30	31	1	0	5	13	2	0	3	149	29.27	26.13	40.8%	28.3%	59.0%	62.7%
1978	19	28	31	30	31	0	6	29	3	0	0	0	177	34.77	31.04	48.5%	37.5%	67.0%	44.7%
1979	4	28	31	30	31	1	0	0	27	7	0	0	159	31.23	27.88	43.6%	35.9%	58.5%	44.4%
1980	20	29	31	30	31	3	0	0	0	0	0	0	144	28.28	25.18	39.3%	18.5%	66.2%	48.1%
1981	0	0	0	0	11	4	0	3	21	0	0	13	52	10.21	9.12	14.2%	21.2%	5.2%	9.3%
1982	25	28	31	30	31	30	31	31	28	13	0	0	278	54.60	48.74	76.2%	89.1%	74.5%	45.5%
1983	7	28	31	30	31	13	20	31	28	13	7	15	254	49.89	44.54	69.6%	73.9%	59.9%	71.2%
1984	31	29	31	30	31	3	27	30	4	0	0	0	216	42.43	37.77	59.0%	51.6%	81.7%	76.2%
1985	0	0	9	30	31	0	0	30	27	10	0	0	137	26.91	24.02	37.5%	53.3%	33.0%	36.7%
1986	30	28	31	30	31	0	0	23	12	0	0	0	185	36.34	32.44	50.7%	35.9%	70.8%	59.5%
1987	29	28	31	30	31	2	0	0	0	0	19	29	199	39.09	34.89	54.5%	17.9%	70.3%	50.4%
1988	18	29	31	30	30	0	0	12	26	0	2	28	206	40.46	36.02	56.3%	37.0%	87.3%	51.6%
1989	11	11	29	30	31	0	0	18	17	6	0	0	153	30.05	26.83	41.9%	39.1%	67.0%	49.0%
1990	0	5	31	30	31	0	0	20	0	0	0	0	117	22.98	20.51	32.1%	27.7%	45.8%	37.8%
1991	0	2	29	30	31	30	31	31	13	16	0	0	213	41.84	37.35	58.4%	82.6%	43.4%	30.7%
1992	0	22	31	30	31	13	20	27	29	19	6	27	255	50.09	44.59	69.7%	75.5%	53.5%	64.2%
1993	29	28	31	30	31	5	0	0	10	0	0	0	164	32.21	28.76	44.9%	25.0%	85.8%	79.5%
1994	2	28	31	30	31	23	25	31	30	16	28	31	306	60.10	53.65	83.8%	84.8%	57.5%	37.5%
1995	30	28	31	30	31	0	5	31	27	28	13	10	264	51.85	46.29	72.3%	66.3%	98.6%	91.5%
1996	30	29	31	30	31	30	23	21	19	5	0	0	249	48.91	43.54	68.0%	70.1%	81.7%	72.4%
1997	7	28	31	30	31	4	12	29	5	0	1	28	206	40.46	36.12	56.4%	44.0%	59.9%	61.6%
1998	31	28	31	30	31	2	0	0	5	3	0	0	161	31.62	28.23	44.1%	22.3%	84.9%	63.0%
1999	0	26	31	30	31	1	13	27	14	30	26	12	241	47.34	42.26	66.0%	63.0%	55.7%	35.1%
2000	18	29	31	30	31	0	0	9	7	0	0	0	155	30.45	27.10	42.3%	25.5%	83.1%	71.6%
2001	0	0	0	26	31	3	16	27	30	5	0	0	138	27.11	24.20	37.8%	60.9%	26.9%	20.0%
2002	0	24	31	30	31	22	31	31	30	3	12	28	273	53.62	47.87	74.8%	80.4%	54.7%	54.0%
2003	31	28	31	30	31	25	31	31	21	8	2	16	285	55.98	49.97	78.1%	79.9%	90.1%	84.4%
2004	21	29	31	30	31	0	12	29	30	31	26	12	282	55.39	49.31	77.0%	72.3%	75.1%	75.4%
2005	30	28	31	30	31	30	29	31	9	7	27	21	304	59.71	53.30	83.3%	74.5%	88.7%	79.5%
2006	10	28	31	30	31	0	2	12	21	0	0	0	165	32.41	28.93	45.2%	35.9%	84.0%	77.8%
2007	0	26	31	30	31	20	21	20	14	8	0	1	202	39.68	35.42	55.3%	62.0%	55.7%	41.9%
2008	10	29	31	30	31	0	8	30	23	4	0	0	196	38.50	34.27	53.6%	52.2%	62.0%	58.7%
2009	0	19	31	30	31	30	31	31	25	1	0	11	240	47.14	42.08	65.8%	81.0%	52.4%	48.2%
2010	16	28	31	30	31	30	19	2	0	0	0	0	187	36.73	32.79	51.2%	44.6%	69.3%	72.6%
2011	0	20	31	30	31	0	9	31	25	26	20	3	226	44.39	39.63	61.9%	66.3%	52.8%	44.7%
2012	4	27	31	30	31	6	28	29	29	13	0	0	228	44.78	39.87	62.3%	73.9%	68.5%	64.8%
2013	0	14	31	30	31	25	31	31	28	3	0	0	224	44.00	39.28	61.4%	81.0%	50.0%	57.8%
MEANS																			
48YR	11	21	27	29	31	9	13	21	17	7	4	7	197	38.71	34.53	54.0%	52.9%	61.5%	54.0%
41YR	12	21	27	29	30	8	12	21	16	7	5	8	195	**38.27**	**34.14**	**53.4%**	51.1%	61.9%	53.4%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	49	49	48	48
Years used for stats	'65-'13	'65-'13	'66-'13	'66-'13
# Yrs with WS duration > 70%	8	15	16	11
Annual Exceedance Frequency	16.3%	30.6%	33.3%	22.9%
Return Period (1-in-Nyrs)	6.1	3.3	3.0	4.4

Table 7-2. Lake Tohopekaliga water supply reliability for the WSmaxL scenario.

	Lake TOH Water Supply Reliability Table for WSmaxL															Percent of Time WS Withdrawal			
	No. of Days per Month with Lake Toho WS Withdrawals at 99.0 cfs (64.0 MGD)												Days	Vol(kaf)	AvgMGD	CalYear	WetSeas	DrySeas	WatYear
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	May-Oct	Nov-Apr	May-Apr
1965	0	16	29	0	0	0	0	0	0	0	0	0	45	8.84	7.89	12.3%	0.0%		
1966	1	28	30	11	0	4	31	31	30	15	0	0	181	35.55	31.74	49.6%	60.3%	33.0%	19.2%
1967	0	16	15	0	0	0	0	0	0	0	0	0	31	6.09	5.44	8.5%	0.0%	14.6%	38.9%
1968	0	0	0	0	0	2	30	31	10	0	0	0	73	14.34	12.76	19.9%	39.7%	0.0%	0.0%
1969	0	0	22	26	22	0	0	0	6	27	21	22	146	28.68	25.60	40.0%	29.9%	33.0%	33.2%
1970	31	28	31	30	31	9	0	10	0	0	0	0	170	33.39	29.81	46.6%	27.2%	91.5%	59.7%
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	13.7%
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1974	0	0	0	0	0	0	0	29	30	4	0	0	63	12.37	11.05	17.3%	34.2%	0.0%	0.0%
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	17.3%
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1978	0	0	0	0	0	0	0	29	3	0	0	0	32	6.29	5.61	8.8%	17.4%	0.0%	0.0%
1979	4	28	31	30	31	1	0	0	27	7	0	0	159	31.23	27.88	43.6%	35.9%	58.5%	34.2%
1980	20	29	31	30	31	3	0	0	0	0	0	0	144	28.28	25.18	39.3%	18.5%	66.2%	48.1%
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	9.3%
1982	0	0	0	0	0	1	31	31	28	13	0	0	104	20.43	18.24	28.5%	56.5%	0.0%	0.0%
1983	7	28	31	30	31	13	20	31	28	13	7	15	254	49.89	44.54	69.6%	73.9%	59.9%	54.8%
1984	31	29	31	30	31	3	27	30	4	0	0	0	216	42.43	37.77	59.0%	51.6%	81.7%	76.2%
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	26.0%
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1988	5	28	31	16	0	0	0	0	0	0	0	0	80	15.71	13.99	21.9%	0.0%	37.6%	21.9%
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
1991	0	0	0	0	0	0	0	30	13	16	0	0	59	11.59	10.35	16.2%	32.1%	0.0%	0.0%
1992	0	20	0	0	0	0	22	27	29	19	6	27	150	29.46	26.23	41.0%	52.7%	9.4%	21.6%
1993	29	28	31	30	31	5	0	0	0	0	0	0	154	30.25	27.00	42.2%	19.6%	85.8%	67.9%
1994	1	28	31	20	31	23	25	31	30	16	28	31	295	57.94	51.73	80.8%	84.8%	52.4%	31.8%
1995	30	28	31	30	31	0	5	31	27	28	13	10	264	51.85	46.29	72.3%	66.3%	98.6%	91.5%
1996	30	29	31	30	24	30	23	16	0	0	0	0	213	41.84	37.25	58.2%	50.5%	78.4%	72.4%
1997	0	0	0	0	0	0	0	0	2	0	0	21	23	4.52	4.03	6.3%	1.1%	0.0%	25.5%
1998	31	28	31	30	31	2	0	0	1	4	0	0	158	31.03	27.70	43.3%	20.7%	81.1%	39.2%
1999	0	26	26	0	0	0	8	7	14	30	26	12	149	29.27	26.13	40.8%	32.1%	24.5%	24.7%
2000	18	29	31	10	0	0	0	0	0	0	0	0	88	17.28	15.39	24.0%	0.0%	59.2%	50.5%
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	0.0%
2002	0	25	2	0	0	0	7	31	30	3	0	21	119	23.37	20.87	32.6%	38.6%	12.7%	7.4%
2003	31	28	31	22	12	27	31	31	21	8	2	16	260	51.07	45.59	71.2%	70.7%	68.4%	55.9%
2004	21	29	23	0	0	0	0	0	16	31	26	12	158	31.03	27.63	43.2%	25.5%	42.7%	60.4%
2005	30	25	31	30	22	30	29	31	9	7	27	21	292	57.35	51.20	80.0%	69.6%	83.0%	55.1%
2006	10	28	31	30	4	0	0	0	0	0	0	0	103	20.23	18.06	28.2%	2.2%	71.2%	75.3%
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	1.1%
2008	0	0	0	0	0	0	0	4	23	4	0	0	31	6.09	5.42	8.5%	16.8%	0.0%	0.0%
2009	0	0	0	0	0	0	0	31	25	1	0	0	57	11.20	9.99	15.6%	31.0%	0.0%	8.5%
2010	0	11	31	30	31	30	19	2	0	0	0	0	154	30.25	27.00	42.2%	44.6%	48.6%	35.3%
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.0%	0.0%	0.0%	22.5%
2012	0	0	0	0	0	0	0	0	29	13	0	0	42	8.25	7.34	11.5%	22.8%	0.0%	0.0%
2013	0	14	31	30	31	25	31	31	28	3	0	0	224	44.00	39.28	61.4%	81.0%	50.0%	32.1%
MEANS																			
48YR	7	12	14	10	9	4	7	11	9	5	3	4	96	18.80	16.77	26.2%	24.6%	27.9%	26.2%
41YR	8	13	14	10	9	4	7	11	9	6	4	5	100	**19.55**	**17.44**	**27.3%**	24.6%	29.7%	27.3%

SUMMARY STATISTICS	CalYear	WetSeas	DrySeas	WatYear
No. of years used for stats	49	49	48	48
Years used for stats	'65-'13	'65-'13	'66-'13	'66-'13
# Yrs with WS duration > 70%	4	4	8	4
Annual Exceedance Frequency	8.2%	8.2%	16.7%	8.3%
Return Period (1-in-Nyrs)	12.3	12.3	6.0	12.0

8 SUMMARY AND RECOMMENDATIONS

This section summarizes the strengths and limitations of the UK-OPS Model and suggests future enhancements to improve model accuracy and utility. The UK-OPS Model uses a simple water balance approach to simulate water levels and discharges for the primary hydrologic components of the larger lake systems in the UKB. The model was developed to quickly test alternative operating strategies for KCH, TOH, and ETO specifically. It was later modified to serve as a water use permit evaluation tool to assess the effects of proposed water supply withdrawals, subject to the draft KRCOL Water Reservation rule criteria. Original model development was done expeditiously; user-friendly interfaces and documentation beyond comments within the worksheets were not included in the initial development effort. The need to document and peer review the UK-OPS Model arose during the planning phase of the draft KRCOL Water Reservation rules.

This report describes the purpose, utility, and technical details of the UK-OPS Model. The report is not a users' guide, but it is prerequisite reading for analysts who want to use the model. Included in this report are details on model structure, inputs and outputs, and model validation. Two applications of the UK-OPS Model were described in this report: 1) seasonal operations planning, including the SFWMD's monthly position analysis; and 2) testing the effects of hypothetical surface water withdrawals on the draft KRCOL Water Reservation rule criteria. These applications illustrate appropriate uses of the UK-OPS Model.

Strengths of the UK-OPS Model include the ability to rapidly test alternative operating ideas (i.e., run time of 4 minutes versus days or even weeks for more detailed models), ease of use in a readily available environment (i.e., Microsoft Excel®), broad range of options for specifying alternative operations, immediate updating of the outputs and performance metrics, and flexibility to modify the Microsoft Excel® worksheets to add additional features and/or performance summary graphics.

Model users have made the following comments regarding the usefulness of the UK-OPS Model:

- Key strengths of the UK-OPS Model are its quick simulation time and ability to immediately visualize outputs.
- Time-series plots provide a useful way to visualize and confirm the input operations are being correctly simulated.
- Water budgets are a helpful way to quickly confirm mass is conserved.
- The S-65 mean annual discharge and water supply reliability summaries enable rapid assessment of the effects of proposed water supply withdrawals on the draft KRCOL Water Reservation rule criteria.

Limitations of the UK-OPS Model include the potential need for routing computations for the small lakes, lack of extensive documentation within the workbook, and dependence on another model or historical data to generate the boundary inflows.

There are several areas where the UK-OPS Model may be exploited by more users with varying levels of expertise in water management, hydrology, and hydraulics. Some initial recommendations are listed below, and additional recommendations are expected based on input from internal and external peer reviewers.

1. Extend the simulation period by updating the inputs using available historical data and/or outputs from detailed regional hydrologic models.
2. Simplify the effort required to perform simulation period extensions by leveraging additional Microsoft Excel® features (e.g., making range names more dynamic).

3. Improve the GUI of the UK-OPS Model to appeal to more users and enable better utility of the model.
4. Expand the instructions for users within the model. Online documentation and built-in tutorials would greatly enhance usability of the model.

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ATTACHMENT

SAMPLE EMAIL COMMUNICATION OF AUGUST 2019 UK-OPS POSITION ANALYSIS

From: Neidrauer, Calvin
Sent: Thursday, August 01, 2019 5:42 PM
To: Morancy, Danielle <dmorancy@sfwmd.gov>
Cc: Wilcox, Walter <wwilcox@sfwmd.gov>; Barnes, Jenifer <jabarne@sfwmd.gov>; Bousquin, Steve <sbousqu@sfwmd.gov>; Glenn, Lawrence <lglenn@sfwmd.gov>; Kirkland, Suelynn <skirklan@sfwmd.gov>; Anderson, H. David <dander@sfwmd.gov>; Mohottige, Dillan <dmohotti@sfwmd.gov>; Godin, Jason <jgodin@sfwmd.gov>
Subject: August PA UK-OPS Simulation Assumptions

FYI:

The UK-OPS Model simulation for the August PA was completed today (01-August). Operations assumptions for Lake KCH changed from the June PA, and were informed by the 2019 wet season discharge plan developed by the SFWMD with input from the USFWS & FFWCC. Assumptions for TOH & ETO were consistent with last month; the spring fish & wildlife (F&W) recessions are assumed to start on 15-Jan-2019 at 0.4 feet below the regulation schedules.

Results are to be used as input to the corresponding SFWMM simulation. A copy of the Excel workbook is available in the following server folder:

\\ad.sfwmd.gov\dfsroot\data\hesm_pa\PA_BASE_DIR\PA\UK-OPSmodel\

Filename = UK-OPS(v3.12)_2019AugPA.xlsm

Use the **ALT2** simulation output (Run name = **AugPA**).

The simulated stages and flows are in the **ALT2 worksheet tab**.

Initial (31-July) Conditions:

E. Lake Toho: 56.29 feet, NGVD (TOHOEE+)

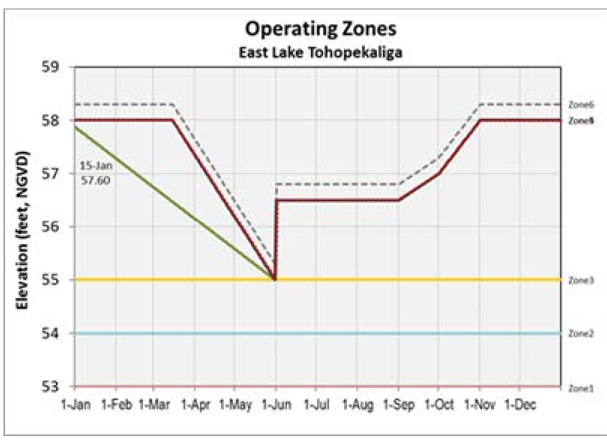
Lake Toho: 53.48 feet, NGVD (LTOHOW AVG)

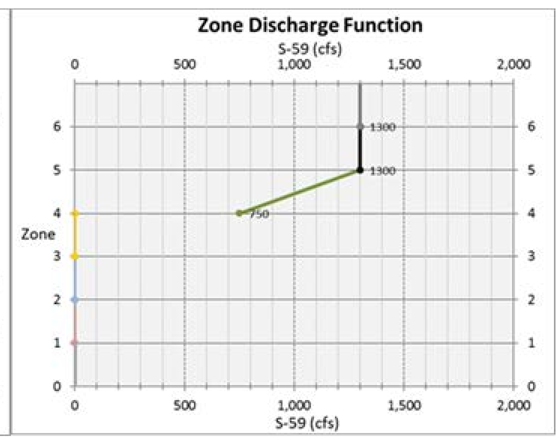
Lake KCH: 50.20 feet, NGVD (LKISS AVG)

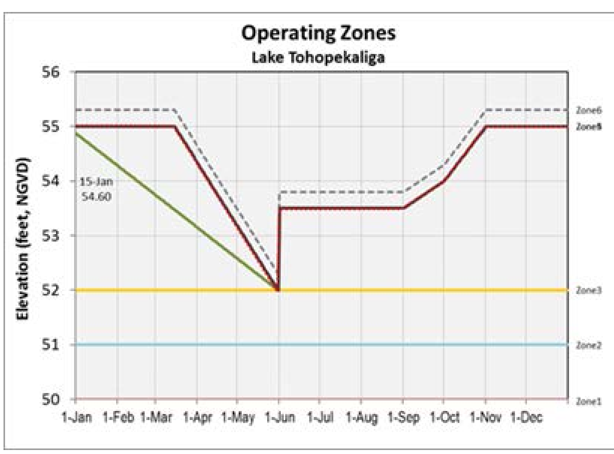
For the August 2019 Position Analysis the Upper Kissimmee Operations Screening (UK-OPS) Model was used to simulate water levels and releases from Lakes Kissimmee-Cypress-Hatchineha, Tohopekaliga, and East Lake Tohopekaliga. The UK-OPS Model assumptions for operations are listed below. Details regarding model version features are listed at the end of this e-mail.

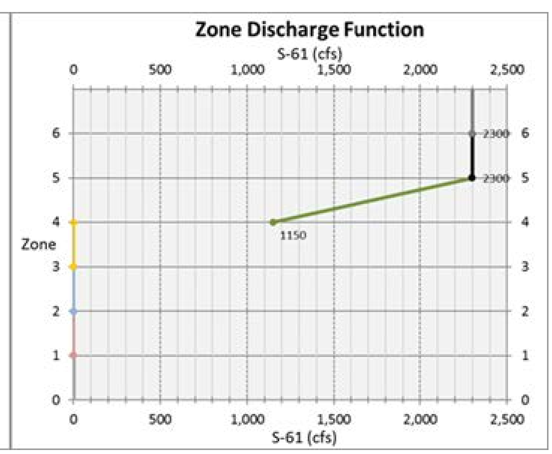
UK-OPS Model assumptions for the August-2019 PA:

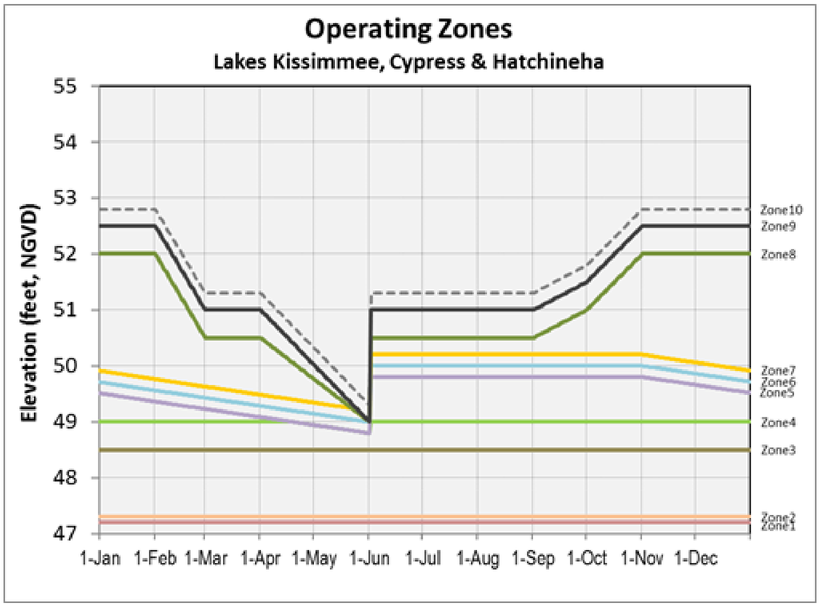
1. Hydrology (lake inflows) based on historical/observed stage and flow data from DBHYDRO (same assumption since Jan 2016).
2. Regulation of Lakes Toho and East Lake Toho according to the standard Regulation Schedules with spring recession operations approximated as shown below. Recession ops start 15-Jan. Note the red dotted lines represent the standard regulation schedule Zone A line.
3. Regulation of Lakes Kissimmee, Cypress and Hatch according to 2019 wet season operations designed to achieve desired river flows and lake stage recession rates. See graphic of discharge plan below. Rate of change limits for S-65A flows shown below were set in May 2019. The rate of change limits apply for stages below Zone A of the KCH schedule.
4. Starting with the Nov-2017 PA, KCH simulated outflows were measured at S-65A. So S-65 releases are made with consideration of Pool A runoff contribution to S-65A.

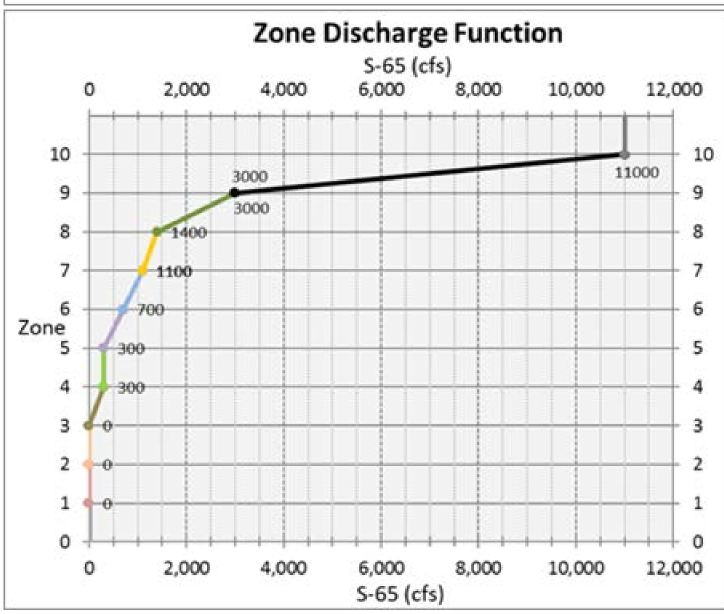


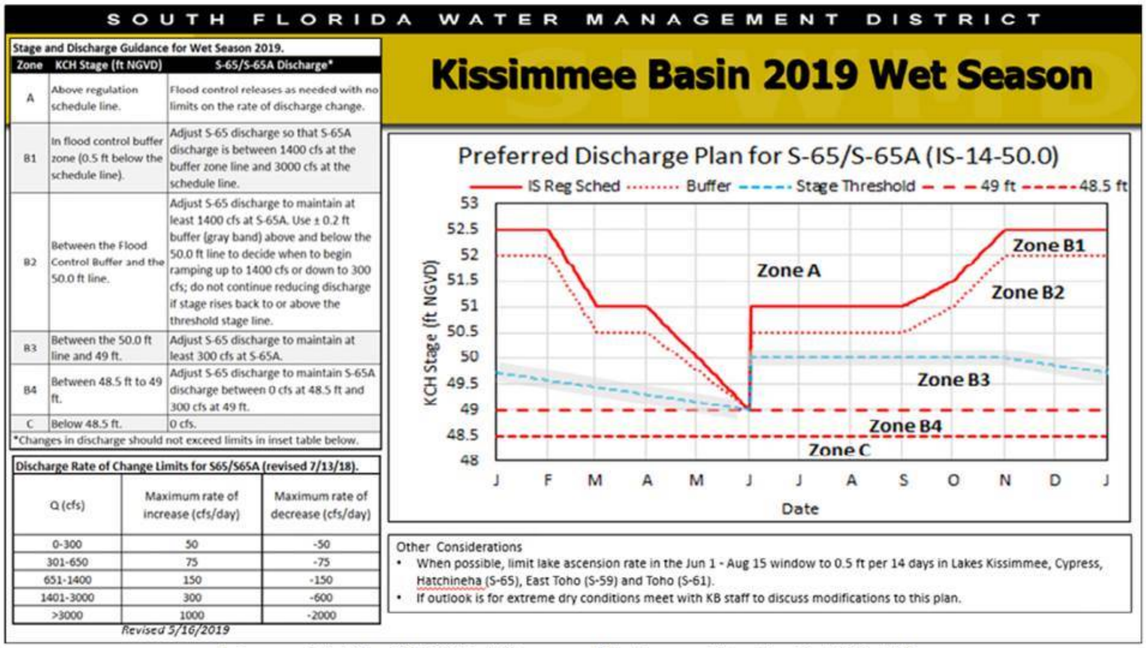







Operating Zones
Lakes Kissimmee, Cypress & Hatchineha
Elevation (feet, NGVD)
55
54
53
52
51
50
49
48
47
1-Jan 1-Feb 1-Mar 1-Apr 1-May 1-Jun 1-Jul 1-Aug 1-Sep 1-Oct 1-Nov 1-Dec
Zone10
Zone9
Zone8
Zone7
Zone6
Zone5
Zone4
Zone3
Zone2
Zone1


Zone Discharge Function
S-65 (cfs)
0 2,000 4,000 6,000 8,000 10,000 12,000
Zone
0 1 2 3 4 5 6 7 8 9 10
11000
3000
3000
1400
1100
700
300
300
0
0
0
S-65 (cfs)



Stage and Discharge Guidance for Wet Season 2019.

Zone	KCH Stage (ft NGVD)	S-65/S-65A Discharge*
A	Above regulation schedule line.	Flood control releases as needed with no limits on the rate of discharge change.
B1	In flood control buffer zone (0.5 ft below the schedule line).	Adjust S-65 discharge so that S-65A discharge is between 1400 cfs at the buffer zone line and 3000 cfs at the schedule line.
B2	Between the Flood Control Buffer and the 50.0 ft line.	Adjust S-65 discharge to maintain at least 1400 cfs at S-65A. Use ± 0.2 ft buffer (gray band) above and below the 50.0 ft line to decide when to begin ramping up to 1400 cfs or down to 300 cfs; do not continue reducing discharge if stage rises back to or above the threshold stage line.
B3	Between the 50.0 ft line and 49 ft.	Adjust S-65 discharge to maintain at least 300 cfs at S-65A.
B4	Between 48.5 ft to 49 ft.	Adjust S-65 discharge to maintain S-65A discharge between 0 cfs at 48.5 ft and 300 cfs at 49 ft.
C	Below 48.5 ft.	0 cfs.

*Changes in discharge should not exceed limits in inset table below.

Discharge Rate of Change Limits for S65/S65A (revised 7/13/18).

Q (cfs)	Maximum rate of increase (cfs/day)	Maximum rate of decrease (cfs/day)
0-300	50	-50
301-650	75	-75
651-1400	150	-150
1401-3000	300	-600
>3000	1000	-2000

Revised 5/16/2019

Other Considerations

- When possible, limit lake ascension rate in the Jun 1 - Aug 15 window to 0.5 ft per 14 days in Lakes Kissimmee, Cypress, Hatchineha (S-65), East Toho (S-59) and Toho (S-61).
- If outlook is for extreme dry conditions meet with KB staff to discuss modifications to this plan.

Figure 11. The 2019 Wet Season Discharge Plan for S-65/S-65A.

<u>UK-OPS Model Version notes</u>:

The November, 2015 investigation of the UKISS Model output (2007 version) indicated a significant underestimation of S-65 flows for the 1997-98 very wet period. So while SFWMD H&H Bureau staff efforts continue toward improving the modeling tools for the Kissimmee basins, the intermediate solution is to continue to use the UK-OPS Model with the lateral lake inflows computed using observed data.

Version 3.12 of the UK-OPS Model was used beginning with the July 2019 PA. V3.12 includes features to allow testing alternative operations and water reservation lines. These features are not used for the current PA simulations.

Version 3.10 of the UK-OPS Model was used beginning with the January 2019 PA. Version 3.10 includes options to simulate lake stage recession operations for lakes KCH, TOH, and ETO. The new logic determines daily releases necessary to achieve a user-specified stage recession rate. Options for KCH include constraining the S-65 release rates-of-change by the user-specified release rate limits. See the Notes page and comments in the routing worksheets for more detail. These changes are not used for current PA simulations.

Version 3.07 of the UK-OPS Model was used beginning with the March 2018 PA. Version 3.07 includes new features to enable testing alternative strategies for the Kissimmee Reservation, particularly a water reservation line for Lakes KCH (to limit upstream withdrawals). Other changes include separation of the WRL zone specification from the regulation schedules. See the Notes tab for further detail. These changes do not affect the position analysis simulations.

Version 3.05 of the UK-OPS Model was used beginning with the March 2017 PA. Version 3.05 includes additional capability to view individual year stage and discharge hydrographs for the three primary lake systems (KCH, TOH, and ETO). Use the buttons in the 5th column of the PM & Indicator buttons to access the new hydrographs. Thanks to Naiming Wang for this addition to the model.

Cal

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