Andrew Sutherland

From: Sam Upchurch [flwaterdoc@gmail.com]
Sent: Tuesday, December 29, 2015 6:06 PM
To: Sonny Hall; Andrew Sutherland
Cc: Chelsea Galcik
Subject: Review of UORB MFLs HSPF Assessment Method draft 2015
Attachments: UORB_MFLs_HSPF_Assessment_Method_draft2015.docx

Gentlemen,

I hope you had a great holiday and that the new year will be happy and successful for all.

Attached please find my review of the above referenced document. I examined the model and reviewed the draft Assessment Method manual. After reading the manual, I decided that there were many style and grammatical issues to which I might be of service. As a result, rather than writing a list of comments I converted the report to a MS Word document so I could use track changes during my edits. The OCR feature of my conversion software could not translate the figures, so they are garbled on the Word document. In order to adequately review the report and figures, therefore, I reviewed the Word and pdf documents in parallel.

The attached Word document includes both the editorial suggestions and my comments, which are numbered.

The manual adequately describes the process of constructing and running the HSPF model, and most of my comments deal with data reporting. There are two major concerns, however.

(1) Many steps in the explanation of the model and in data presentations are incomplete and assume that the reader is knowledgeable of HSPF and statistics. The comments note where these incomplete sections are located. There is also a need to address the uncertainties in the data, especially where modeled and measured metrics differ. Of special importance is a need for a discussion of what the uncertainties mean for MFL development and management. For example, it appears that there is as much as 1 ft. discrepancy between many modeled and measured results, which means that the stage-duration curves are likely to only be accurate to about a foot. What does this mean for the MFLs?

(2) The idea that the model is predicting water levels into the future is incorrect and can lead to major problems with MFL implementation and management. Basically, the District has modeled the historical data to obtain a calibrated model. It has then used current conditions in the calibrated model and simulated a long-term record of lake levels using historical rainfall and evaporation data. There is no way that this is extending the model into the future, forecasting lake levels, or predicting a lake level regime going forward. What the District has done is recreate probable stage-duration curves (SDCs) that cover historic AMO cycles, climate change, etc. The SDCs are assumed to reflect the range of probable lake-stage variations and frequencies into the future so MFLs can be developed. There is a huge difference. The use of the terms "extended" and "future" lake levels has got to go! All that has been done is create a probability density function (PDF) for lake stages given current conditions. There is no predictive power in the way the PDFs are used.

I do not want to give the impression that this document is fatally flawed. It is not. It is an excellent start, but must be cleaned up and statistical and uncertainty issues addressed.

Sam

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Sam B. Upchurch, Ph.D., P.G.

DRAFT

Lake Apopka and the Upper Ocklawaha River

Minimum Flows and Levels

Hydrologic Assessment Method Report

By

Xiaoqing Huang, PhD

Dale R. Smith, P. E.

Note: This product is a work in progress, and is subject to revision.

Certifies as to the hydrology and hydraulic modeling of the Lake Apopka and Upper Ocklawaha River for the purposes of developing Minimum Flows and Levels

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Dale R. Smith, P.E.

Florida Registration Number 32054

Table of Contents

Comment [SBU1]: Formatting inconsistent with format of other titles. There are similar format variances throughout Table of Contents and text. I have not made all of the changes necessary for consistency.

Figures

Comment [SBU2]: This will look better and be easier to use if the second line is indented. Similar conditions exist in the remainder of this list.

Tables

Comment [SBU3]: See above in re indenting the second line

1 INTRODUCTION

In 2008, the Lake County Water Authority asked St. Johns River Water Management District (District) to establish Minimum Flows and Levels (MFLs) for Lake Apopka and Ocklawaha ~~chain~~ Chain of ~~lakes~~Lakes. In response, the District added these lakes to its MFLs Priority List. As a priority listed water body, MFLs must be established for this system pursuant to Sections 373.042(2) and 373.0421, Florida Statutes (F.S.).

Lake Apopka and the Upper Ocklawaha River Basin (LAUORB) are located in central Florida, including parts or entire counties of Lake, Orange, Marion, and Polk. Together, these waterbodies and their drainage basins form the Upper Ocklawaha River Basin (UORB) (Figure 1 and **Figure** 2). The sub-basins in LAUORB can be described as a set of interconnected lakes with surrounding watersheds draining to the respective lakes. The general flow direction is south to north. Water levels and discharges in the LAUORB are largely controlled by operating water control structures. Flow in the Palatlakaha River is regulated by a series of structures before entering Lake Harris at the M1 structure just south of SR 48. The Apopka-Beauclair Lock and Dam controls the water flow from Lake Apopka to Lake Beauclair. Burrell Lock and Dam regulates water levels in lakes Harris, Eustis, Dora, and Beauclair by releasing water from Lake Eustis to Lake Griffin through Haines Creek. Moss Bluff Lock and Dam, which is located 12 miles downstream of Lake Griffin and is the LAUORB outlet, regulates water levels at Lake Griffin by controlling the flow of Lake Griffin. All these structures along the Upper Ocklawaha ~~River~~ system provide a method of water management and regulation to the St Johns River Water Management District.

Comment [SBU4]: See comment on Figure 2

Comment [SBU5]: It doesn't control the flow of the lake. It controls the discharge from the lake.

Comment [SBU6]: I thought the head of the river itself was at Lake Griffin. Wouldn't it be better to use the word system rather than river?

The MFLs are intended to support the protection of aquatic and wetland ecosystems from significant ecological harm caused by the consumptive use of water. In addition, MFLs provide technical support to SJRWMD's regional water supply planning process (Section 373.0361, F.S.), the consumptive use permitting program (Chapter 40C-2, *Florida Administrative Code [F.A.C1)*, and the environmental resource permitting program (Chapter 40C-4, *F.A.C.).*

The MFLs are determined by quantification of the hydrology required to support certain aquatic and wetland ecosystems at various places in a watershed. District biologists determine the MFLs by evaluating the ecosystem at various transects (Figure 2) and District engineers examine the long-term hydrology of the system to evaluate if an MFL is achieved. Potential ~~anthropogenic~~ land- and water-use perturbations in the watershed (i.e. surface water withdrawals, increased pumping, etc.) need~~s~~ to be quantified and assessed to determine if these~~is~~ perturbations will cause a violation to system~~its~~ MFLs. In the context of MFLs, SJRWMD uses statistical analyses of modeling results from long-term hydrologic models to make these assessments. MFL~~s~~ modeling results will provide the framework needed in Lake Apopka and the Ocklawaha Lakes for sound management decisions with regard to surface and ground water withdrawals in Lake Apopka and the Upper Ocklawaha River Basin (LAUORB).

Comment [SBU7]: Biological transects are not depicted on Figure 2.

This report documents the LAUORB MFLs hydrologic assessment method including HSPF model setup, model calibration, and long-term simulation of LAUORB baseline hydrologic conditions. A separate study/report will document assessment results for the proposed LAUORB MFLs, freeboard analyses, and prevention or recovery strategies, if they~~re~~ are needed.

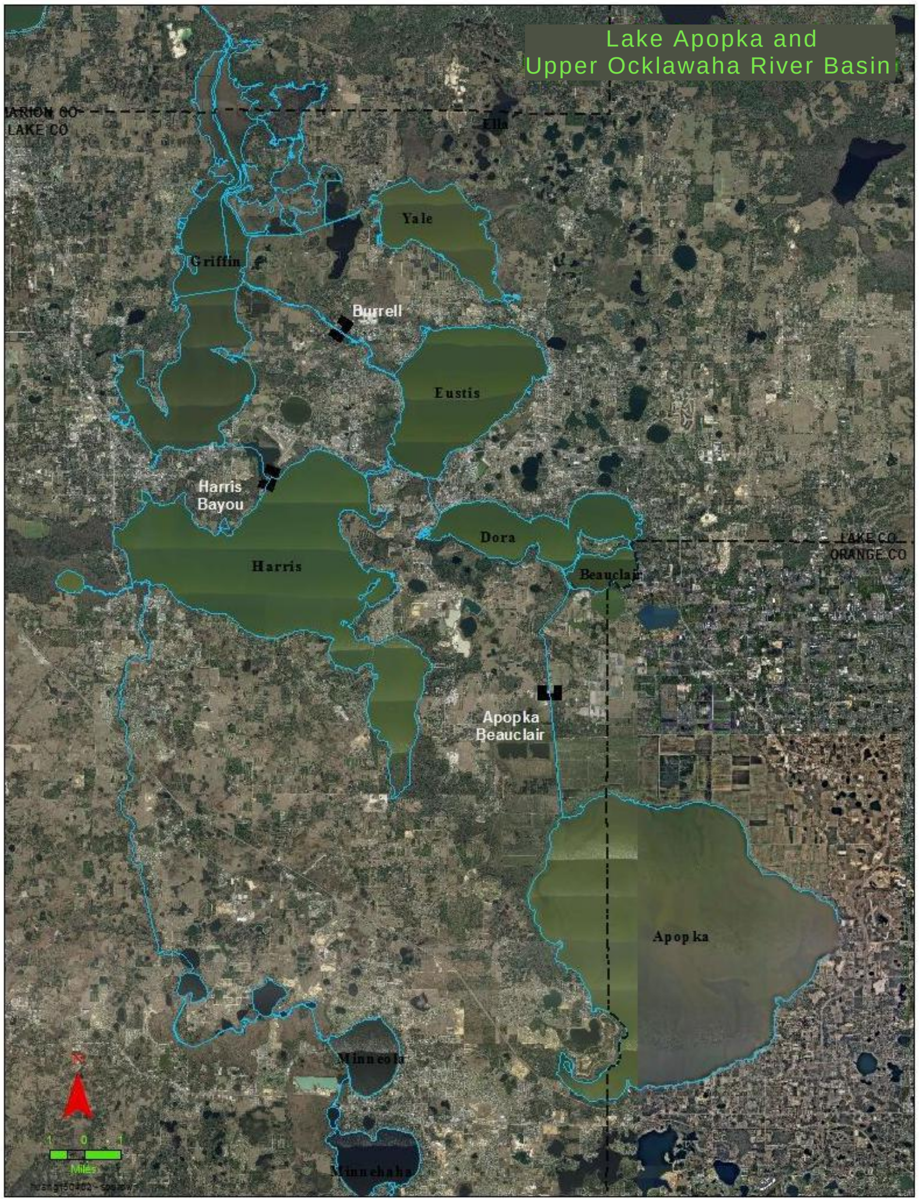

Figure 1. locations of Lake Apopka and Ocklawaha Lakes

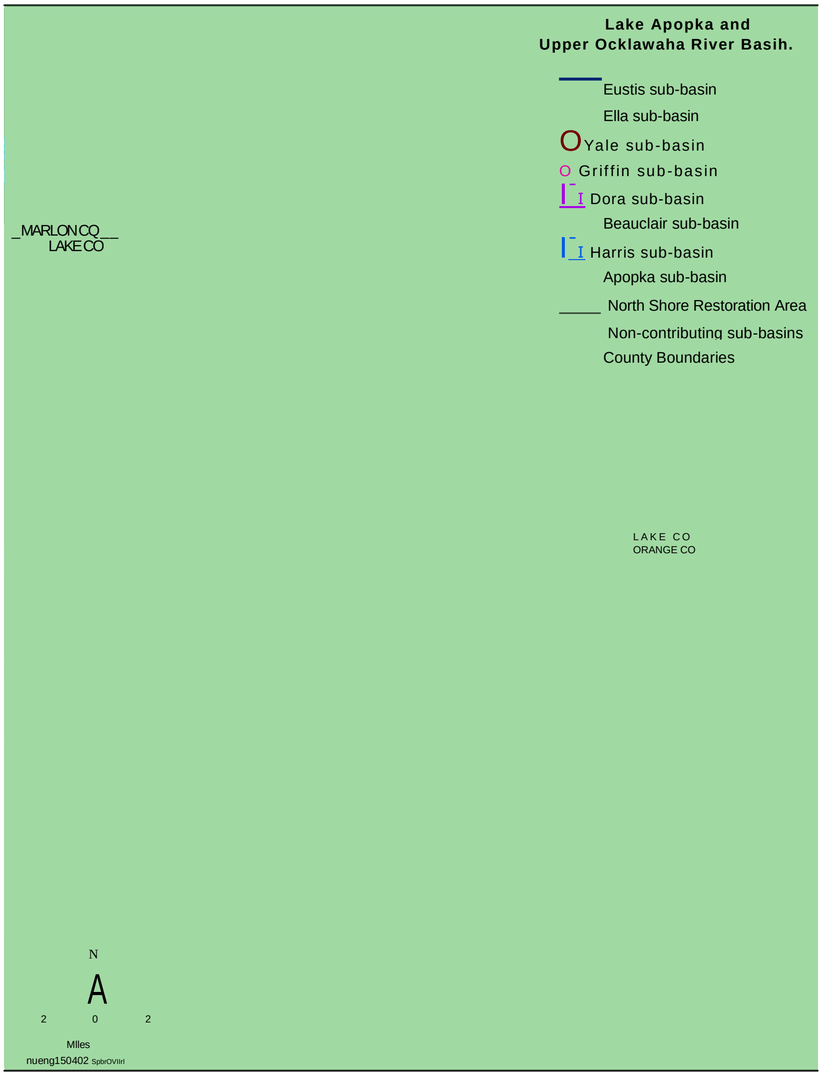

Figure 2. Lake Apopka and Upper Ocklawaha River basin watershed boundaries and structures controlling water flows in the basin

Comment [SBU8]: Add control structure symbol to Legend and add a control structure symbol to the Palatlakaha River. I don't think you need to add a symbol for ever structure, but add one to show that the river has control structures as per the text.

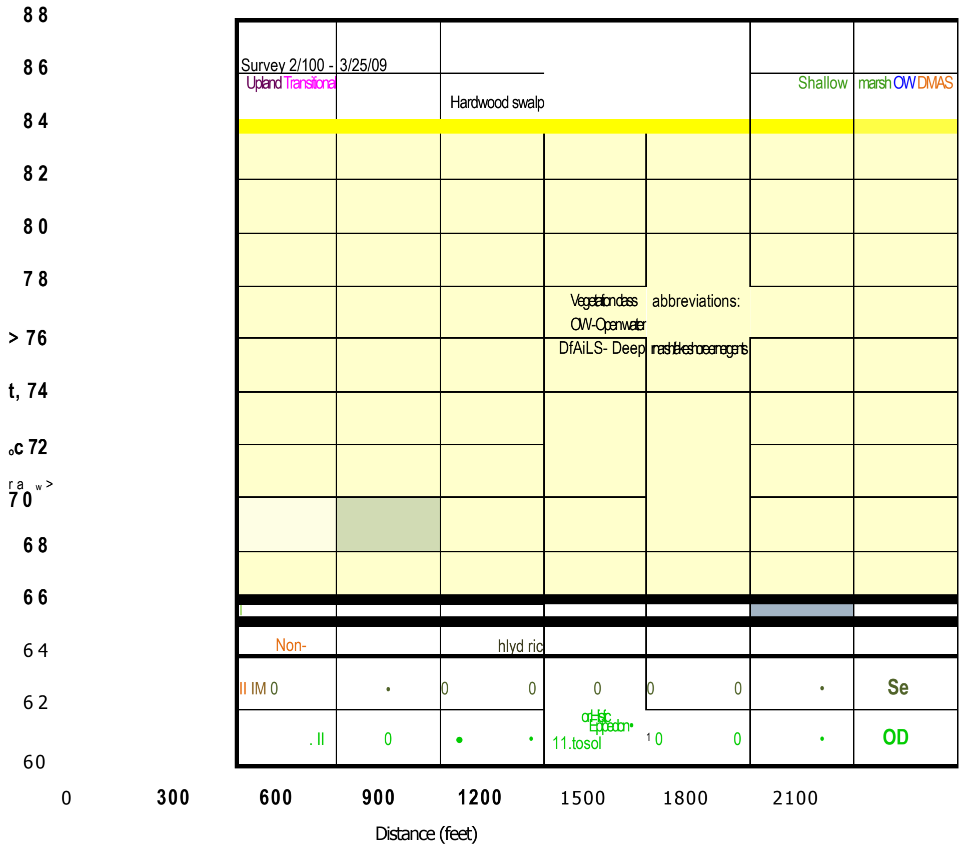

Figure 3. A typical MFL~~s~~ transect and proposed MFL~~s~~ levels for Lake Apopka (Fulton et al 2014)

Min Frequent High at 66.1 ft.~~-~~NAVD88 with duration >= 30 days and 2 year return period
Min Average at 65.6 ft.~~-~~NAVD88 with duration <= 180 days and 1.7 year return period
Min Frequent Low at 64 ft.~~-~~NAVD88 with duration <= 120 days and 5 year return period

1.1 PURPOSE AND SCOPE

Five sets of MFLs have been recommended by the District personnel for Lake Apopka, Lake Beauclair-Dora, Lake Harris-Eustis, Lake Griffin, and Lake Yale. Each set of MFLs includes a minimum frequent high ~~(MFH)~~, a minimum average ~~(MA)~~, and a minimum frequent low ~~(MFL)~~ and their respective durations and return intervals. SJRWMD developed a hydrologic model of Lake Apopka and the Upper Ocklawaha River using Hydrologic Simulation Program — Fortran (HSPF). This model simulates water levels and flows for Lake Apopka and Ocklawaha Lakes using historical rainfall, evaporation, and groundwater potentiometric levels **(Error! Reference ource not found.).** The purpose of this report is to document the results of the following tasks:

- Hydrologic model of Lake Apopka and Upper Ocklawaha River Basin: data collection, model setup, and calibration; and
- Long-term simulation of LAUORB baseline hydrologic conditions in the context of MFLs.

Comment [SBU9]: This acronym is being used for Minimum Flows and Levels, too. Confusing to some readers? Since this report does not set the MFLs, why add the acronyms here? By omitting them, this confusion is avoided in this report.

Comment [SBU10]: Needs literature reference

2 THE UPPER OCKLAWAHA RIVER BASIN

The watershed delineation of the LAUORB is based on District-wide drainage basin boundaries documented in Technical Publication SJ 97-1 (Adamus, Clapp & Brown 1997) with some minor updates. According to the District's organizational scheme, the LAUORB basin includes four planning units, i.e., Palatlakaha River (7A), Lake Apopka (7B), Lake Harris (7C) and Lake Griffin (7D). Flow in the Palatlakaha River is regulated by a series of structures before entering Lake Harris at the M1 structure. The Lake Harris planning unit is divided into four subwatersheds: Lake Beauclair, Lake Dora, Lake Harris with Little Lake Harris, and Lake Eustis. The Lake Griffin planning unit is divided into Lake Griffin and Lake Yale subwatersheds.

Table 1. Planning units in the Upper Ocklawaha River Basin (7).

Planning Unit Number	Planning Unit Name	Total Area (acres)*	Model Area (acres)
7A	Palatlakaha River Planning Unit	142,435	not modeled measured time-series data used instead of simulation
7B	Lake Apopka Planning Unit	117,318	84,025
7C	Lake Harris Planning Unit	152,721	101,799
7D	Lake Griffin Planning Unit	118,217	70,410

The Upper Ocklawaha River is primarily located within the Central Lakes Subdivision of the Central Lake District Physiographic Province (Brooks 1982). The Central Lakes Subdivision is a large lowland area between the Mount Dora Ridge to the east and the Ocala Uplift District to the west. In many areas, the valley floor intersects the potentiometric surface of the Floridan aquifer, which results in large spring discharges and spring-fed lakes. As a result, surface waters receive a considerable portion of their total water budget from groundwater (Canfield 1981). Furthermore, there are ~~more than~~ hundreds of small lakes scattered throughout LAUORB that are generally isolated ~~and landlocked~~ and either do not contribute direct runoff~~s~~ to the interconnected lakes of the LAUROB ~~basin's receiving water bodies,~~ or drain to these lakes ~~,~~ only during periods of extreme runoff ~~events~~. These areas are marked as non-

Comment [SBU11]: ?? To what does the asterisk refer?

Comment [SBU12]: I know the District likes to use Brooks' geomorphology, but very few outside of the District use it. There are many misleading terms and interpretations.

Comment [SBU13]: One of the reasons Brooks' physiography is not widely used in Florida is terminology such as this. The Ocala Platform is not an uplifted feature. It is a result of subsidence to the east and west because of plate tectonics on two passive continental margins.

Comment [SBU14]: Poorly written sentence. Needs work. I've taken a crack at it contributing areas and are removed from each basin to prevent over estimating runoff in the HSPF model (grey areas in **Figure** 2). Hence, the model areas are significantly smaller than the total basin areas (Table 1).

Apopka Spring (also known as Gourd Neck Spring), located in the southwest corner of Lake Apopka, is considered one of two headwaters of the Harris Chain of Lakes. Water flows north from Lake Apopka and through the Apopka-Beauclair Canal into Lake Beauclair. Lake Beauclair is included in the Harris Chain of Lakes and drains directly into Lake Dora, which drains through the Dora Canal into Lake Eustis. The Clermont Chain of Lakes in the Palatlakaha River basin serves as another headwater to the Harris Chain of lakes. They drain into Lake Harris, which connects through the Dead River with Lake Eustis. Lake Eustis connects through the Burrell Lock and Dam on Haines Creek to Lake Griffin. Lake Yale also connects to Lake Griffin through the Yale-Griffin Canal.

The LAUORB is maintained as a series of cascading pools for flood control purposes .The District operates the Moss Bluff Lock and Dam as the local sponsor for the Four River Basins Project in accordance with the regulation schedule prescribed by the USACE to maintain a desired elevation range of 57.44 to 58.19 ft-NAVD88 in Lake Griffin (USACE 1993) (Figure 4; Table 2). The Burrell Lock and Dam on Haines Creek is operated by the District to maintain a desired regulation range of 61.47 ft to 62.22 ft-NAVD88 (Table 2) in Lake Eustis. Water elevations in lakes Harris, Little Harris, Dora, and Beauclair are also controlled by the Burrell structure. The Apopka-Beauclair Lock and Dam is operated by the District for the regulation of water levels in Lake Apopka within a desired regulation range of 65.65 ft to 66.15 ft-NAVD88 (Table 2). A representative figure illustrating the seasonal regulation schedule for Lake Griffin is provided in Figure 4. Similar schedules are used to manage the other lakes. Wet season regulation levels are typically lower than those in the dry season to accommodate additional storage that may be needed during ~~tropical~~ hurricane season (refer~~red~~ to the Army Corps of Engineers (USACE 1993) for a more technical description of the structures).

Comment [SBU15]: Not shown in Figure 2

Comment [SBU16]: Need figure showing features such as Apopka Spring that are discussed in text.

Comment [SBU17]: Define or show on map.

Comment [SBU18]: To assist in understanding terminology, it seems a good idea to provide a figure that shows the different chains of lakes.

Comment [SBU19]: Locations of canals and tributaries named in text need to be shown on a figure.

Comment [SBU20]: Throughout text, proper grammar is “ft./ NGVD”

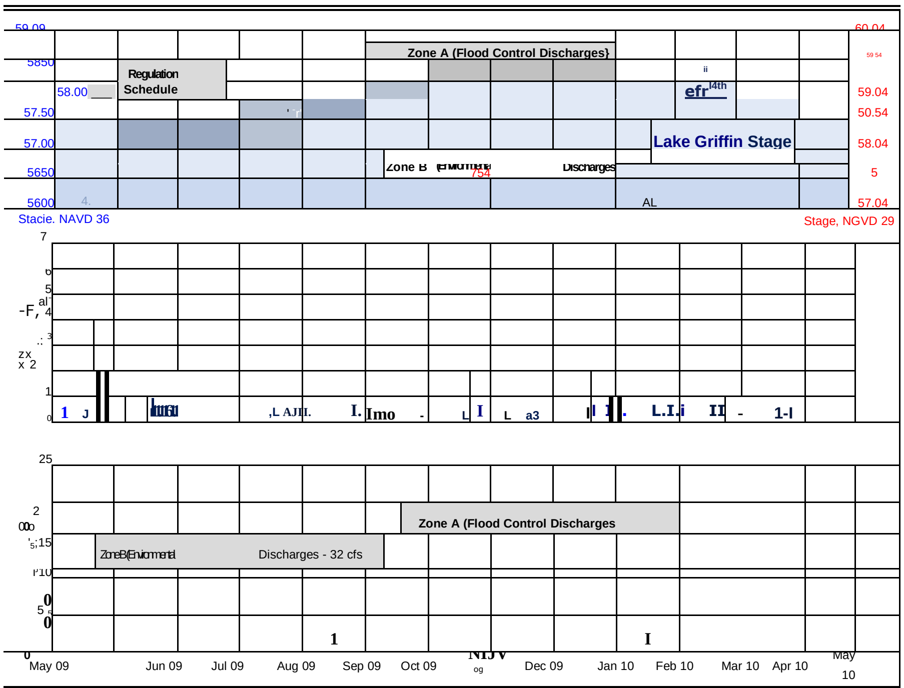

Figure 4. Lake Griffin regulation schedule illustrates seasonal regulation changes and Zones A and B discharges typical of upper Ocklawaha River basin (LAUORB) lakes.

Comment [SBU21]: Need explanation of year that rainfall records reflect and meaning of Zones A and B

Table 2. Upper Ocklawaha River Basin lake regulation schedules

Lake Name	Dry Season Elevation (ft-NAVD88)	Wet Season Elevation (ft-NAVD88)
Apopka	66.15	65.65
Eustis	62.22	61.47
Griffin	58.19	57.44

Palatlakaha River Planning Unit (7A)

The behavior of the Palatlakaha River is difficult to model because it is influenced by the Green Swamp: a large area of wetlands that ~~provides~~ forms the headwaters for four separate rivers (Withlacoochee, Peace, Hillsborough, and Palatlakaha rivers). T~~and t~~he Palatlakaha River drainage ~~portion contributing~~ to Lake Harris is regulated by control structures. Watershed delineation in the Green S~~s~~wamp is very difficult. T~~, and t~~he other three rivers ~~—Withlacoochee, Peace, and Hillsborough —~~ are separate drainage systems ~~part of the South West Florida Water Management District~~ and are not included in this study. Once water from the Green S~~s~~wamp enters the Palatlakaha River, flow is regulated by a series of structures before entering Lake Harris at the M1 structure. The Lake County Water Authority operates the structures according to a set of management guidelines. These guidelines can be overridden due to circumstances that can~~-~~not be represented in a model, which makes model calibration very difficult.

Previous modeling attempts provided poor results for the Palatlakaha River Planning Unit. The Nash—Sutcliffe statistic is a common measure of model performance. A perfect match between simulated values and observations would give a Nash—Sutcliffe statistic of 1, whereas a 0 means that the average of the observed time-series is a better predictor of all the variation than the simulated values. The Nash—Sutcliffe statistic results for the previous modeling efforts were negative because of the difficulties mentioned (Table 3). Due to the poor performance of previous models, and the relatively small contributing flow of the Palatlakaha River Planning Unit, we decided to not model this area but instead include the measured flows as an external time series into Lake Harris. The area is therefore shown as a non-modeled planning unit **(Table 1).**

Table 3. Palatlakaha River Nash—Sutcliffe modeling statistics from the previous modeling effort simulating the years 1996 to 1998.

1996	1997	1998	Overall
0.44	-11.36	-22.83	-5.60

Comment [SBU22]: This is the third time you have told audience that the Palatlakaha is regulated by a series of structures. Also, is the M1 structure a Palatlakaha structure and part of the series or a separate structure regulating Lake Harris?

Comment [SBU23]: Can this be explained?

Comment [SBU24]: Reference

Comment [SBU25]: Reference

Comment [SBU26]: Looks like a wise decision

Comment [SBU27]: Reference. If not published, why mention other than to say that early modeling attempts were unsuccessful because of the Palatlakaha flow complexity?

Because this planning unit is represented with observed data, there are no means of estimating the increased flow due to land use development for the 2009 land use scenario. The increase between the 1995 and 2009 land use scenarios can be shown to have a minimal effect on the flow estimates from the Ocklawaha River Basin for the same reasons that allow the use of the observed flow: small flow relative to the entire Ocklawaha major basin, and structural management and storage of the flow.

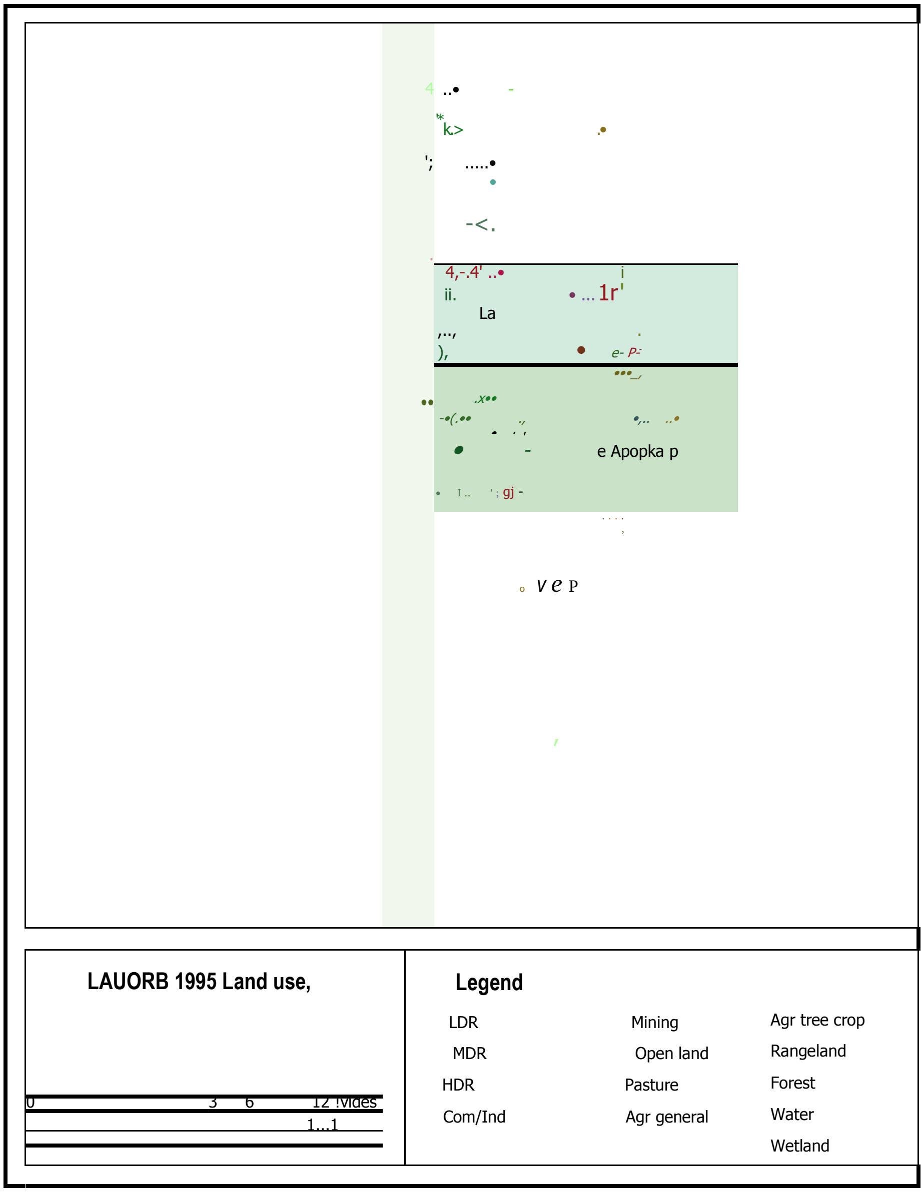

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Figure 5. 1395 land use in Lake Apopka and Upper Ocklawaha River Basin

Table 4. Palatlakaha River Planning Unit (7A) 1995 and 2009 land use comparison.

Comment [SBU28]: Need a map showing the location and extent of this planning unit and other modeled subbasins before discussing them.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		2009 land use (acres)	
Low-density residential	5520	3.88%	4782	3.41%
Medium-density residential	3102	2.18%	8411	6.00%
High-density residential	790	0.55%	5213	3.72%
Industrial and commercial	2143	1.50%	4134	2.95%
Mining	1310	0.92%	1840	1.31%
Open and barren land	1424	1.00%	2166	1.54%
Pasture	10302	7.23%	15866	11.31%
Agriculture general	7417	5.21%	8796	6.27%
Agriculture tree crops	22469	15.78%	9407	6.71%
Rangeland	21463	15.07%	8447	6.02%
Forest	9582	6.73%	12242	8.73%
Water	16953	11.90%	15783	11.25%
Wetlands	39955	28.05%	43186	30.79%
Total	142,431	100%	140,272*	100%

*: due to missing 2009 land use coverage at some areas (Figure 7), total acres of 2009 land use is less than 1995 land use. This will not affect model result as 7A is not modeled

Lake Apopka Planning Unit (7B)

Comment [SBU29]: Since these planning areas are described and their number designations uses herein, a map is needed.

Lake Apopka, the fourth largest lake in Florida, is a headwater lake for the Ocklawaha River. The Lake Apopka planning unit is located within Orange and Lake counties and includes the towns of Monteverde and Astatula. The area of the Lake Apopka drainage basin, including the surface of the lake, is approximately 117,318 acres. Several subwatersheds contribute either direct storm water runoff or runoff through small tributaries during rainfall events. Many portions of the drainage basin, however, contribute runoff infrequently. More than 60 small lakes are scattered throughout the basin but they are generally landlocked except in periods of extreme runoff events.

The water surface of Lake Apopka is approximately 30,800 acres at a lake water level of 65.42 ft NAVD88. Average depth at this elevation is 5.4 ft. The only surface water outflow from Lake Apopka is through the Apopka-Beauclair Canal, which flows north into Lake Beauclair. Discharge from the canal is controlled at the Apopka-Beauclair Lock and Dam, which therefore influences lake stage.

The water control structure in the canal has altered the natural periodic fluctuation of Lake Apopka stage and discharge. In 1950, the first water control structure was constructed by local interests to stabilize lake levels for the purposes of agricultural water supply and navigation (Schelske, Kenney & Whitmore 2001). In 1956, the present concrete structure was installed by Lake County Water Authority (Schelske, Kenney & Whitmore 2001). A regulation schedule ~~is~~ has been enforced on the Lake Apopka water level since 1952 to stabilize the lake level (Friends of Lake Apopka, 2011). When lake level is above regulation, discharges can be made at the maximum. When the lake level is below regulation schedule, a minimum discharge is released to satisfy downstream environmental requirements. Because of the regulation schedule, the lake level fluctuates in a narrow range, varying from 61.35 ft to 67.63 ft-NAVD88 with a mean of 65.4 ft-NAVD88 from 1952 through 2011.

Comment [SBU30]: Meaning unclear

The seasonal regulation schedule is nearly the opposite of natural fluctuations in water level; the lake is lowered during the summer-wet season in order to provide flood storage capacity as needed; during winter-spring season, the lake level is raised to hold more water in the lake (Figure 6). This reversal of the natural hydrologic cycle may have negative ecological impacts on the aquatic habitats and fisheries in the basin.

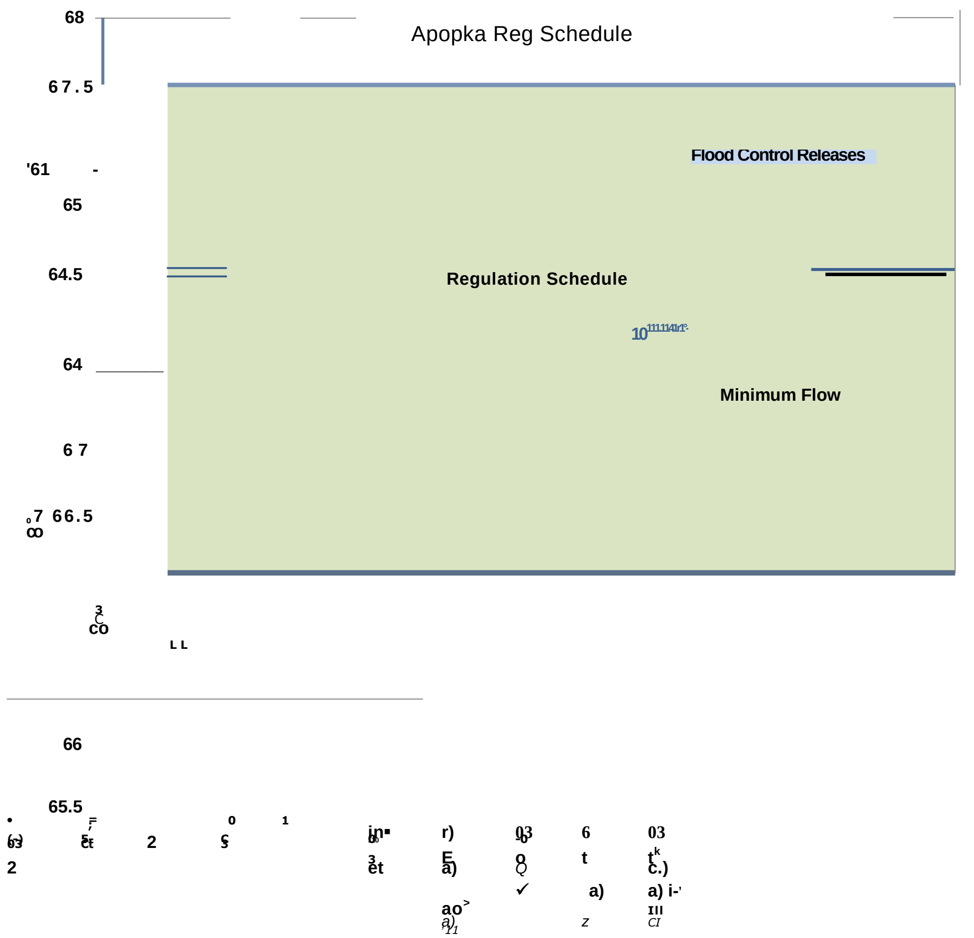

Figure 6. Lake Apopka regulation schedule.

Lake Apopka historically covered approximately 50,000 ac and had an average depth of 8 to 9 ft before Apopka-Beauclair Canal was dug. The northern third of the lake was a shallow marsh system, which afforded habitat for abundant fish and wildlife populations and provided filtration of water flowing out of the lake. Prior to its decline, the lake provided superb sport fishing of national renown. During periods of high water, the lake likely drained to the northwest into Little Lake Harris through an area known as Double Run Swamp.

Numerous activities in the nineteenth and twentieth centuries have contributed to the decline of the lake. Significant human impact affecting Lake Apopka probably began with the construction

Comment [SBU31]: Suggest explain that the range in lake stage between the two blue lines is allowed variability.

Comment [SBU32]: As noted above, the standard abbreviation of foot and feet is ft. with a period at the end.

Comment [SBU33]: Decline in environmental/ecological quality. This decline has not been established and there are no references cited prior to this statement. Need to set basis for statement.

Comment [SBU34]: Locate on map

Comment [SBU35]: This paragraph needs to precede the previous one to explain what you mean by decline.

of the Apopka-Beauclair Canal, which altered the hydrology of the lake. In order to create a waterway for navigation and agricultural use, dredging of the Apopka-Beauclair Canal lowered the water surface of Lake Apopka by about 4 ft leaving approximately 20,000 ac of wetlands dry enough for farming (Shofner 1982). Crop production was mostly unsuccessful due to difficulty in water table management and a series of freezes in the mid and late 1890s. A hurricane struck in 1926 and the entire north shore farm area reverted to marshland "under six to eight feet of water" (Shofner 1982). Due to improved technology, farming returned during World War II. In 1941, the Zellwood Drainage and Water Control District was created by a special act of the Florida Legislature and charged with facilitating agricultural production activities. In 1941, the mean elevation of the lake was approximately 67 ft (NGVD29), the same elevation as the muck and peat land along the northern shore at that time. These lands were inundated when the lake rose above the mean elevation and, during lower lake stages, these lands drained into the lake or into the Apopka-Beauclair Canal. Under the management of the Zellwood Drainage and Water Control District a levee was constructed along the north lakeshore, effectively separating the marshes from the lake and allowing drainage of the farm fields (Shofner 1982). Agricultural production peaked in the muck farms during the 1980s, with 18,000 ac of farmed land. With the final government purchase of the remaining muck farms on Aug 20, 1999, the Zellwood Drainage and Water Control District was dissolved in Feb 2000 by mandate of the 1999 Florida Legislature.

Apopka Spring is the largest spring in the basin and it discharges into Gourd Neck, a narrow water body located in the southwest corner of the lake. The spring opening is at a depth of approximately 37 ft (Rao & Clapp1996). Fed by the upper Floridan aquifer, the spring discharges from a single submerged, oval-shaped opening that is 5-6 ft in diameter. The average discharge rate of Apopka Spring was approximately 29.9 cfs from 1988 through 1998, depending on the lake stage level (German, 2006). Three other named springs exist in the basin; however, discharge information is not available. Holt Lake Spring is located just south of Holt Lake; Bear Spring and Wolf's Head Spring are located just southwest of Clay Island.

Land use in the basin is predominantly water, wetlands and agriculture (Figure 5, Figure 7 and 2009 land use in Lake Apopka and Upper Ocklawaha River Basin

Table 5). Residential, industrial, and commercial land uses are expected to increase from a 1995 level of nearly 9.1% to as high as 12.7% by 2009 (2009 land use in Lake Apopka and Upper Ocklawaha River Basin

Table 5).

Comment [SBU36]: Explain that these were the remnants of the wetland on the north shore and that the soils were histosols.

Comment [SBU37]: Figure

Comment [SBU38]: Figure showing spring locations

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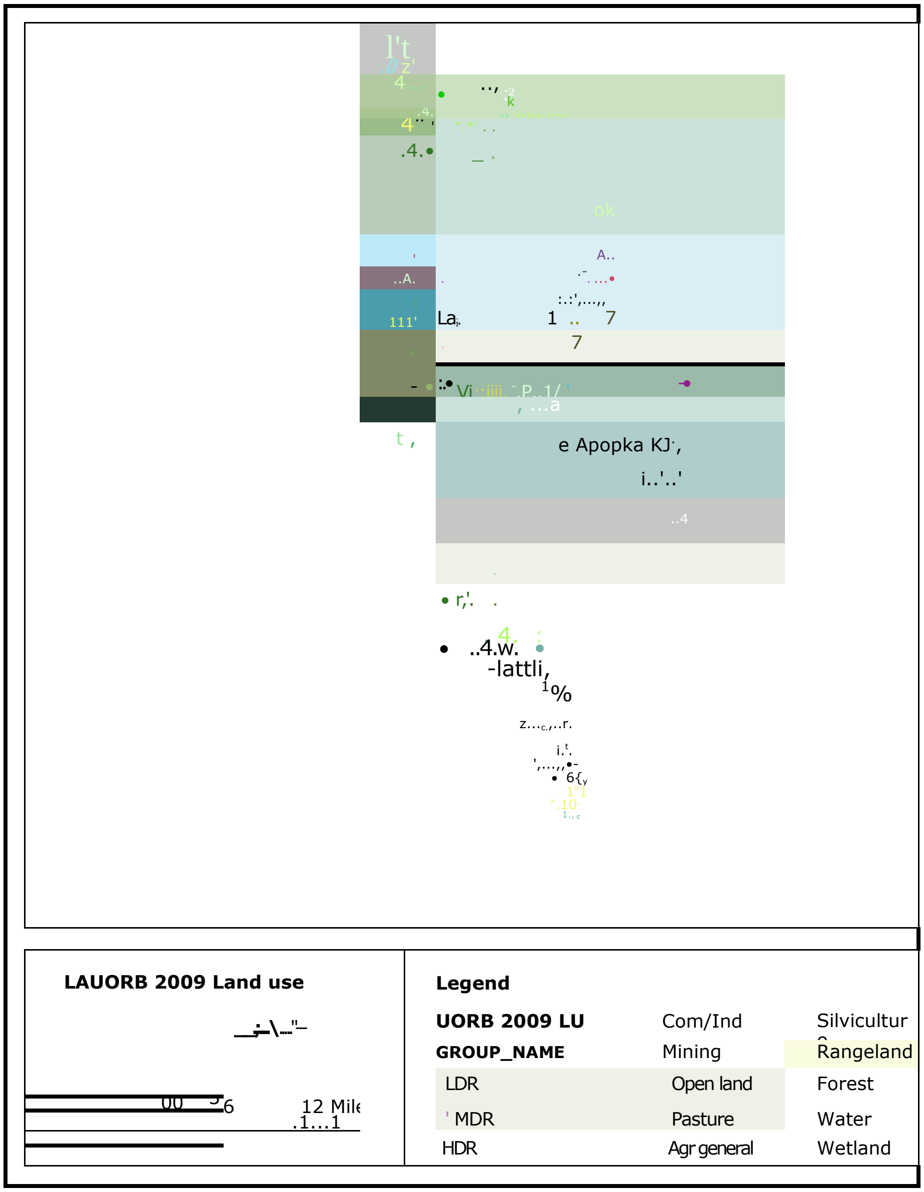

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Pgure 7. 2009 land use in Lake Apopka and Upper Ocklawaha Paver BasTn

Table 5 Lake Apopka Planning Unit (7B) 1995 and 2009 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use* (acres)		2009 land use (acres)*	
Low-density residential	2844	3.38%	2695	3.21%
Medium-density residential	2769	3.30%	4353	5.18%
High-density residential	204	0.24%	738	0.88%
Industrial and commercial	1799	2.14%	2905	3.46%
Mining	954	1.14%	546	0.65%
Open and barren land	702	0.84%	6867	8.17%
Pasture	2685	3.20%	2782	3.31%
Agriculture general	17554	20.89%	3563	4.24%
Agriculture tree crops	6363	7.57%	1052	1.25%
Rangeland	4273	5.08%	3401	4.05%
Forest	4537	5.40%	7378	8.78%
Water	32326	38.47%	33284	39.61%
Wetlands	7016	8.35%	14464	17.21%
Total	84,025	100.00%	84,028	100.00%

*: model areas excluding non-contributing areas

Lake Harris Planning Unit (7C)

Lake Beauclair is included in the Harris Chain of Lakes and drains directly into Lake Dora, which drains through the Dora Canal into Lake Eustis. The Clermont Chain of Lakes in the Palatlakaha basin serves as another headwater to the Harris Chain of L~~l~~akes. They drain into Lake Harris, which connects through the Dead River with Lake Eustis. Lake Eustis connects through Haines Creek and the Burrell Lock and Dam to Lake Griffin. The Burrell Lock and Dam on Haines Creek is operated by the District to maintain Lake Eustis at a desired regulation range of 61.47 ft to 62.22 ft NGVD88 (Figure 8). Water elevations in lakes Harris, Little Harris, Dora, and Beauclair are also affected by the Burrell structure.

Comment [SBU39]: Refers to the Clermont Chain of Lakes? Precedent unclear.

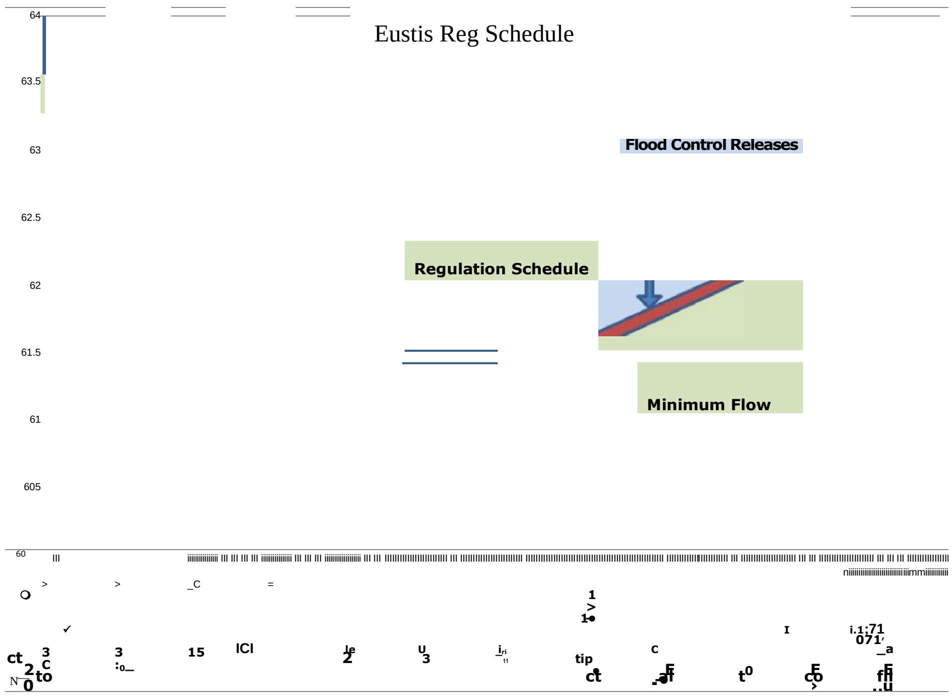

Figure 8. Lake Eustis Regulation Schedule (ft-NAVD88)

Comment [SBU40]: Again, explain that red area is allowable variation in stage

The Lake Harris planning unit's 1995 land use is represented in Figure 5 and a summary of 1995 and 2009 land use is provided in Table 6. Urban land use in the Lake Harris planning unit ~~is~~ increased from 17% in 1995 to 21% in 2009 (Table 6). Development predominantly replaces agriculture and rangeland uses.

Table 6 Lake Harris Planning Unit (7C) 1995 and 2009 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use* (acres)		2009 land use* (acres)	
Low-density residential	5544	5.45%	5209	5.12%
Medium-density residential	6157	6.05%	8227	8.08%
High-density residential	2117	2.08%	3252	3.19%
Industrial and commercial	3718	3.65%	4736	4.65%
Mining	385	0.38%	197	0.19%
Open and barren land	1645	1.62%	967	0.95%
Pasture	3934	3.86%	4266	4.19%
Agriculture general	5055	4.97%	5508	5.41%
Agriculture tree crops	6691	6.57%	3978	3.91%
Rangeland	7251	7.12%	3193	3.14%
Forest	5648	5.55%	8017	7.88%
Water	35503	34.88%	35621	34.99%
Wetlands	18151	17.83%	18628	18.30%
Total	101,796	100.00%	101,799	100.00%

*: model areas excluding non-contributing areas

Lake Griffin Planning Unit (7D)

The total drainage area of Lake Griffin is approximately 97 mi excluding the Lake Yale basin. Two major tributaries—Haines Creek and the Yale-Griffin Canal—discharge directly into Lake Griffin. Haines Creek receives discharge from upstream Harris Chain of Lakes and Apopka Basin at the Burrell Lock and Dam structure. The Yale-Griffin Canal connects the two lakes and delivers flow from Lake Yale into Lake Griffin. Most of the land surface areas around the lakes and the Ocklawaha River are low-lying wetlands ~~and~~ that have been developed for agricultural production, predominantly muck farms. In most of these agricultural areas, drainage systems with perimeter levees and pump stations ~~were~~ have been constructed to provide flood protection. Most upland areas or ridges were used for citrus groves, with most contributing minimal runoff because the soils that support the groves~~y~~ typically have high infiltration rates. There is urban or community development throughout the region, both in waterfront and ridge areas.

Comment [SBU41]: Like the abbreviation of feet, miles are abbreviated with a period (mi.)

Comment [SBU42]: Refer to Figure here

Comment [SBU43]: Griffin and Yale? Which lakes?

Comment [SBU44]: Past tense?

Comment [SBU45]: Mention that groves were large killed and abandoned in the 1980s and are being replaced by suburban communities here.

From Lake Griffin, water flows northward through the **J.** D. Young Canal (C-231) to the Moss Bluff Lock and Dam, which controls water levels in Lake Griffin. The Moss Bluff structure is located on the Ocklawaha River, 12 mi. downstream from Lake Griffin. Most of the river between Lake Griffin and SR 40 has been channelized. Flow has been altered from the natural river course into canals for most of this reach, and much of the floodplain has been converted to farmland.

The water surface elevation of Lake Griffin is currently regulated to allow a narrow fluctuation of 0.75 ft from 57.44 to 58.19 ft NAVD88 (Figure 9). However, levels regularly deviate from these control elevations due to rainfall and drought conditions. This fluctuation range is designed to facilitate navigation and to provide floodwater storage capacity.

The District operates the Moss Bluff Lock and Dam as the local sponsor for the Four River Basins Project in accordance with regulations prescribed by the USACE to maintain a desired elevation range of 57.44 ft to 58.19 feet NAVD88 in Lake Griffin (USACE 1993). The Moss Bluff structure also influences water levels in Lake Yale.

The water control structures have altered the natural periodic fluctuations in lake stages and stream discharges. In addition, the seasonal regulation schedules are nearly the opposite of natural seasonal fluctuations in water levels; the lakes are held at their lowest levels during the summer-wet season in order to provide flood storage capacity. These reversals of the natural hydrological cycles may contribute to habitat degradation and deterioration in water quality in the basin.

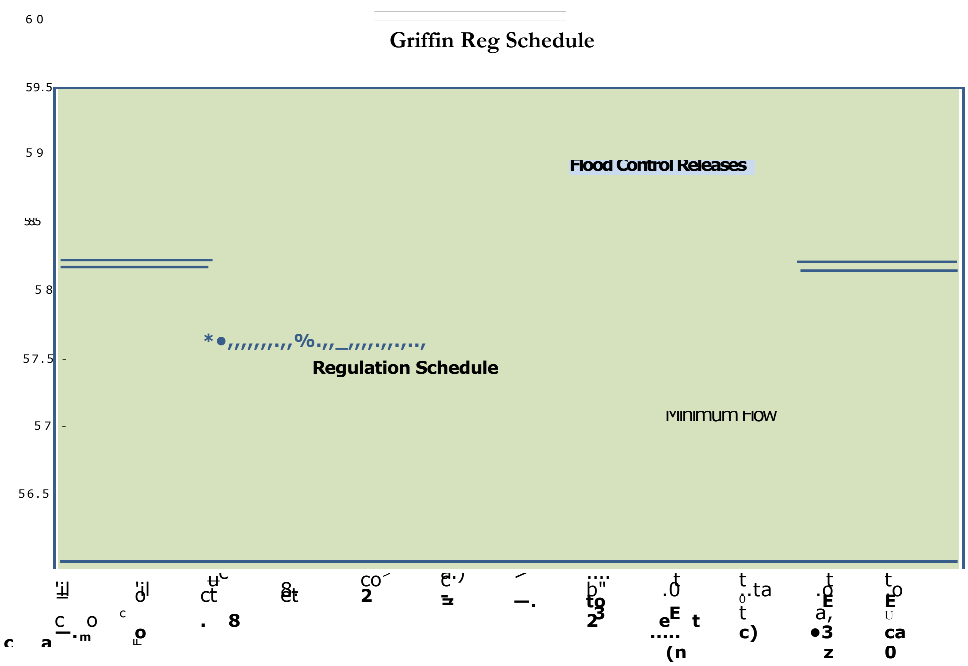

Figure 9. lake Griffin Regulation Schedule (ft-NAVD88)

Table 7. Lake Griffin (7D) 1995 and 2009 land use comparison

HSPF Hydrologic Modeling Land Use Group	1995 Land Use* (acres)		2009 land use* (acres)	
Low-density residential	3565	5.06%	2870.25	4.08%
Medium-density residential	2041	2.90%	2955	4.20%
High-density residential	1043	1.48%	1050	1.49%
Industrial and commercial	1750	2.49%	1902	2.70%
Mining	388	0.55%	272.644	0.39%
Open and barren land	2898	4.12%	317.719	0.45%
Pasture	4029	5.72%	5320.09	7.56%
Agriculture general	4696	6.67%	2097.5	2.98%
Agriculture tree crops	2710	3.85%	1794.12	2.55%
Rangeland	3492	4.96%	3047.39	4.33%
Forest	9010	12.80%	12394.5	17.60%
Water	18358	26.07%	17506.7	24.86%
Wetlands	16430	23.34%	18881.1	26.82%
Total	70,410	100%	70,409	100%

*: model areas excluding non-contributing areas

3 HYDROLOGIC MODEL OF LAKE APOPKA AND THE UPPER OCKLAWAHA RIVER

Results from the hydrologic model will provide the framework for evaluating and implementing MFLs for Lake Apopka and Ocklawaha Lakes. The model can provide ~~the~~ useful information for sound management decisions in regard to water withdrawals from Floridan aquifer or from the surface water bodies in the LAUORB area. This chapter discusses the following topics:

- Model selection
- History of LAUORB HSPF model
- Model data requirements

3.1 MODEL SELECTION

In 2002, the St. Johns River Water Management District (SJRWMD) determined that the development of basin-scale framework computer models would best meet current and future needs to assist SJRWMD in managing water resources in a cost and time efficient manner. A framework model is a large-scale computer model that simulates the hydrologic and water quality processes in a basin with adequate detail to be meaningful. The simulation environment must address relevant issues related to the computer simulation of hydrologic, hydrodynamic, and water quality processes in selected SJRWMD watersheds and SJRWMD-receiving water bodies. For watershed modeling, SJRWMD chose the Hydrological Simulation Program—FORTRAN (HSPF) hydrologic model as the modeling framework.

The Hydrological Simulation Program—FORTRAN (HSPF) is a comprehensive hydrologic modeling system, which is integrated into EPA's BASINS (Better Assessment Science Integrating Point & Nonpoint Sources), a multipurpose environmental analysis system designed to help regional, state, and local agencies perform watershed- and water quality-based studies. HSPF is highly regarded as a complete and defensible watershed model. The HSPF model has been successfully and widely applied in various climatic conditions around the world. The model was developed in the early 1960s as the Stanford Watershed Model, and was continually improved through 1970s, 1980s, and 1990s. Through the sponsorship of EPA and USGS, HSPF continues

Comment [SBU46]: Earlier, the text called the District, "District". Suggest that text be consistent.

Comment [SBU47]: References

Comment [SBU48]: References

Comment [SBU49]: References as to use?

Comment [SBU50]: Same

Comment [SBU51]: Reference

to undergo refinement and enhancement of its component simulation capabilities as well as users' technical supports through EPA's BASINS list server.

Comment [SBU52]: URL for the server here

A watershed is conceptually represented as land surfaces and water bodies in HSPF as a series of storage compartments (e.g., PERLND /IMPLND (surface depressions, soil zones, groundwater zones) and RCHRES (river segments or reservoir/lakes)). Based on the principal of mass conservation, HSPF performs continuous budget analysis of water quantity and quality for these storage compartments. Given the inputs of meteorological time series and the parameter values related to watershed characteristics, HSPF generates time series of runoff, stream flow, loading rates, and concentrations of various water quality constituents.

Although most parameters of HSPF can be specified by watershed spatial and physical data (e.g., land use, topography, stream characteristics, and soil properties), a few parameters, such as those related to infiltration, evaporation, and in-stream kinetics, need to be determined in the model calibration process. Model calibration is the process of adjusting values of model parameters to accurately reproduce the observed flow and/or water level data for a given compartment. Once calibrated, the HSPF model is considered to accurately represent the general hydrologic and water quality processes in a watershed and can be used for scenario analysis.

A watershed and its stream network are characterized in HSPF by various pervious land segments (PERLND, Figure 10), impervious land segments (IMPLND, Figure 11), and reaches/reservoirs (RCHRES, Figure 12**)** based on topography and land uses. As described in the WSIS hydrologic report (2012), land uses in the watersheds are grouped into 14 categories, with the wetland category split~~ting~~ into riparian and non-riparian wetlands (Table 9). The first four consolidated land uses in Table 9 are further divided into pervious and impervious fractions. The pervious portion of a land use category is represented as PERLND while the impervious portion of a land use is represented as IMPLND. For modeling purposes, the stream network in a sub-watershed is grouped together and represented as a RCHRES. The geometric and hydraulic properties of a RCHRES are represented in HSPF by FTABLE, which describes the relationships among stage, surface area, volume, and discharge for that reach segment. Detailed description of these modules or sub-modules can be found in HSPF manual (Bicknell et al 2001).

Comment [SBU53]: Shouldn't these be called modules ?

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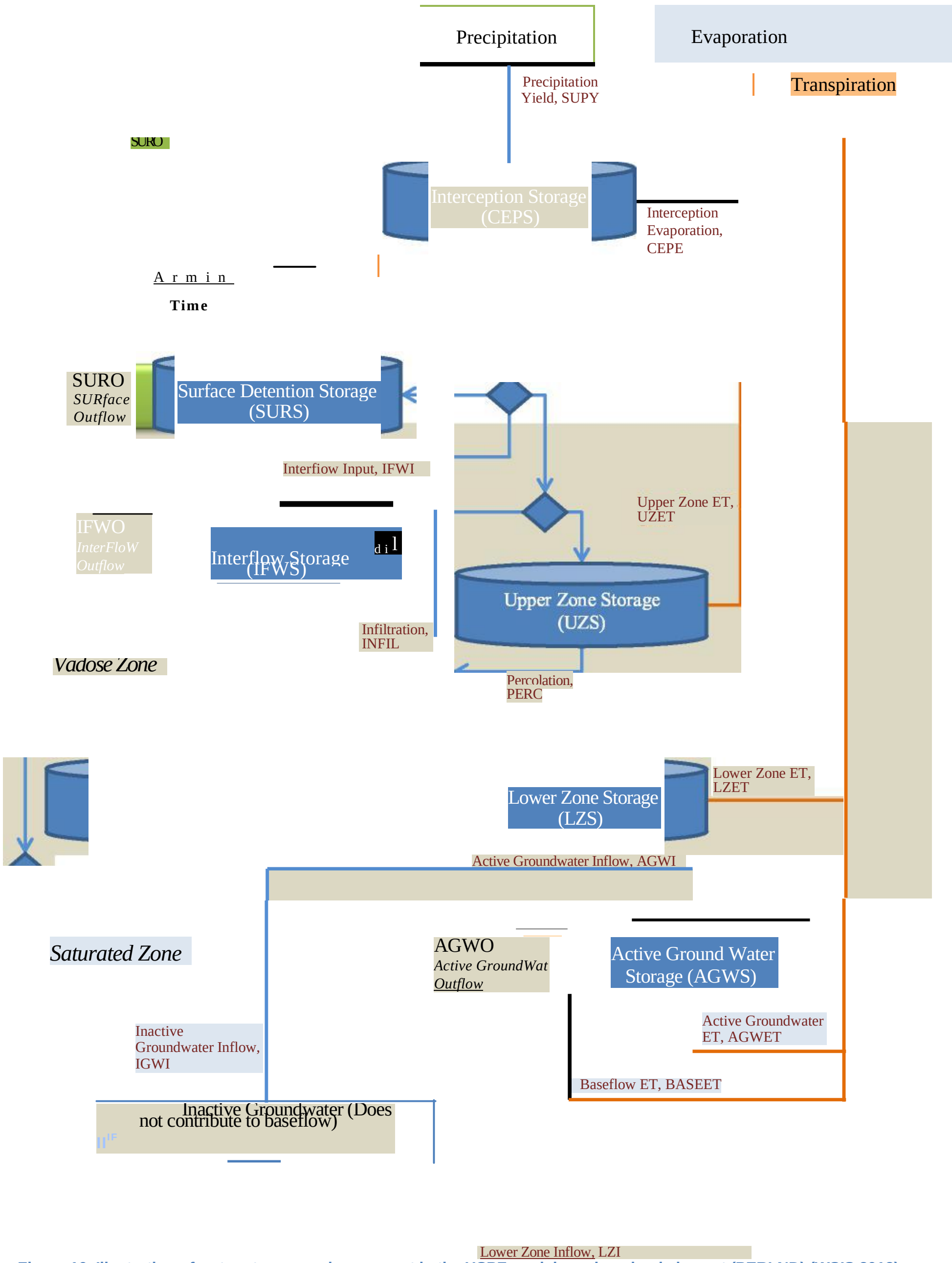

Figure 10. Illustration of water storage and movement in the HSPF model pervious land element (PERLND) (WSIS 2012).

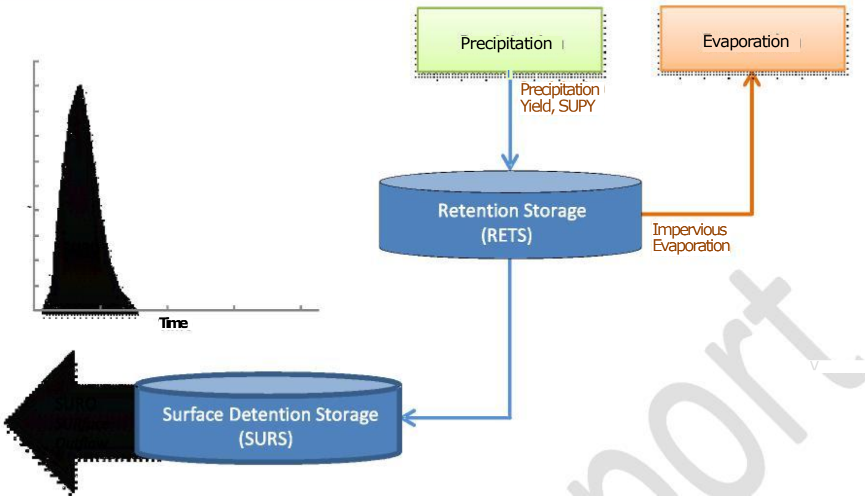

Figure 11. Illustration of water storage and movement in the HSPF model impervious land element (IMPLND) (WSIS 2012).

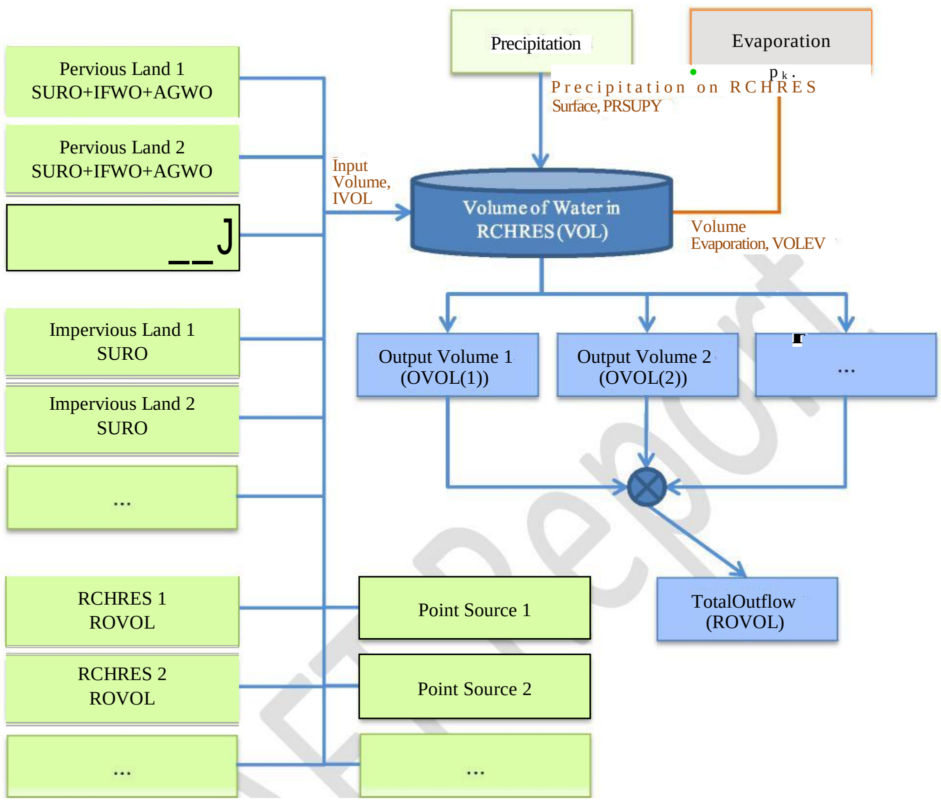

Figure 12. Illustration of water collection and movement in the HSPF model reach/reservoir element (RCHRES) (WSIS 2012).

3.2 HISTORY OF LAUORB HSPF MODEL

The LAUORB HSPF model has gone through a series of revisions from the original LAUORB model developed by former Engineering staff using HSPF in 2003. The LAUORB HSPF model went through another important revision in 2009 for the District's St Johns River Water Supply Impact Study (WSIS 2012). As part of the 2009 WSIS study, this LAUORB model went through stringent external peer review along with other basin models; first by a consulting engineer firm and then by the National Academy of Sciences. The model was used again in 2012 to analyze various interim discharge regulation schedules for Lake Apopka and Ocklawaha lakes. During this current project, LAUORB HSPF model was further revised to allow the lakes to interact with the Upper Floridan Aquifer (UFA). The model was then calibrated with the Central Florida Water Initiative's (CFWI) East-Central Florida — Transient (ECFT) groundwater model simulated UFA potentiometric levels together with meteorological and other input data. This was the latest major revision and the current MFL~~s~~ study is based on this version of model with further improvements and recalibration documented in this report.

Comment [SBU54]: Reference?

Comment [SBU55]: Reference their report/conclusions

3.3 LAKE APOPKA AND UORB HSPF MODEL CONCEPTUAL DESIGN

As shown in Figure 14 and Table 8, the UORB HSPF model was conceptualized with 8 basins:~~,~~ Lake Apopka (basin number is 9), Lake Beauclair (6), Lake Dora (5), Lake Harris (4), Lake Eustis (3), Lake Ella/Holly (10), Lake Yale (2) and Lake Griffin (1). Within each basin, there is only one single reach/reservoir (RCHRES) representing the basin's main receiving waterbody, whose RCHRES ID is the same as its basin number. Within each basin, there are 14 pervious land segments (PERLNDs) representing pervious land uses and 4 impervious land segments (IMPLNDs) representing the impervious fractions of the urbanized land use segments (Table 9). The wetland land use category is split into two types of wetland, i.e., riparian (adjacent to the river or stream) or non-riparian (i.e., an upland or isolated wetland) wetlands depending on ~~how~~ ~~close~~proximity to a river system. Pervious and impervious land segments use a common numbering convention that concatenates the basin number to the land use number (Table 9) with the exception of Lake Ella/Holly. For example, the pervious land segments from the Lake Apopka basin and Lake Yale Basin that simulated low-density residential land use are named PERLND

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Comment [SBU56]: Clumsy sentence. Proximity to a river and not a lake? I tried to improve the sentence.

Comment [SBU57]: Not previously introduced. Location? Refer to Figure 2 for location? Holly is not shown on Figure 2.

901 and PERLND 201, respectively. For Lake Ella/Holly basin, land segments are numbered by adding 220 and

land use number together (Table 9). Following that convention, all land segments ending in "1" represent low-density residential land uses. Four land use types (low-, medium-, and high-density residential and industrial) were identified as having pervious and impervious land segments, while the remaining 11 land uses were simulated with pervious land segments only.

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HSPF Basin Number	Basin Name
1	Lake Griffin
2	Lake Yale
3	Lake Eustis
4	Lake Harris
5	Lake Dora
6	Lake Beauclair
9	Lake Apopka
10	Lake Ella/Holly

As shown from Figure 13, the LAUORB consists of East Branch and West Branch, which confluences at Lake Eustis. The Burrell Lock and Dam on the Haines Creek releases water from Lake Eustis to Lake Griffin according to regulation schedules. Then Moss Bluff Lock and Dam release water to the Lower Ocklawaha River according to regulation schedule of Lake Griffin.

Isolated water bodies, riparian and non-riparian wetlands, and surface Ftable: isolated water bodies and wetlands tend to slow movement of water because of surface storage. One result of this is that wetland areas have a larger potential for evapotranspiration. HSPF provides the option to define surface outflow as a function of surface detention depth. This feature allows improved representation of the surface storage and attenuated surface runoff typical of wetlands or isolated water bodies.

Comment [SBU58]: Locations? Explain what these are

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Comment [SBU59]: “Merge”

Comment [SBU60]: FTABLEs? It does not appear that a model data set should be included with a list of existing land-use and hydrologic features.

Comment [SBU61]: Larger than what? This is a comparative term without a counterpart. Use “increased”?

Surface FTABLEs were used to implement this storage, which are part of the high water table algorithms, in the HSPF hydrologic model. The surface FTABLEs are used to represent the storage in wetlands/isolated water bodies.

GIS was used to delineate the areas that drain to nonriparian wetlands. The surface runoff from these areas will be routed first to the non-riparian wetlands and then to the downstream streams or lakes. The base flow from these areas will be routed to the downstream streams or lakes directly (Figure 15).

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Comment [SBU62]: Caption of Figure 15 hyphenates this term. I believe the hyphenated version is correct. You hyphenated it in the next line of this paragraph.

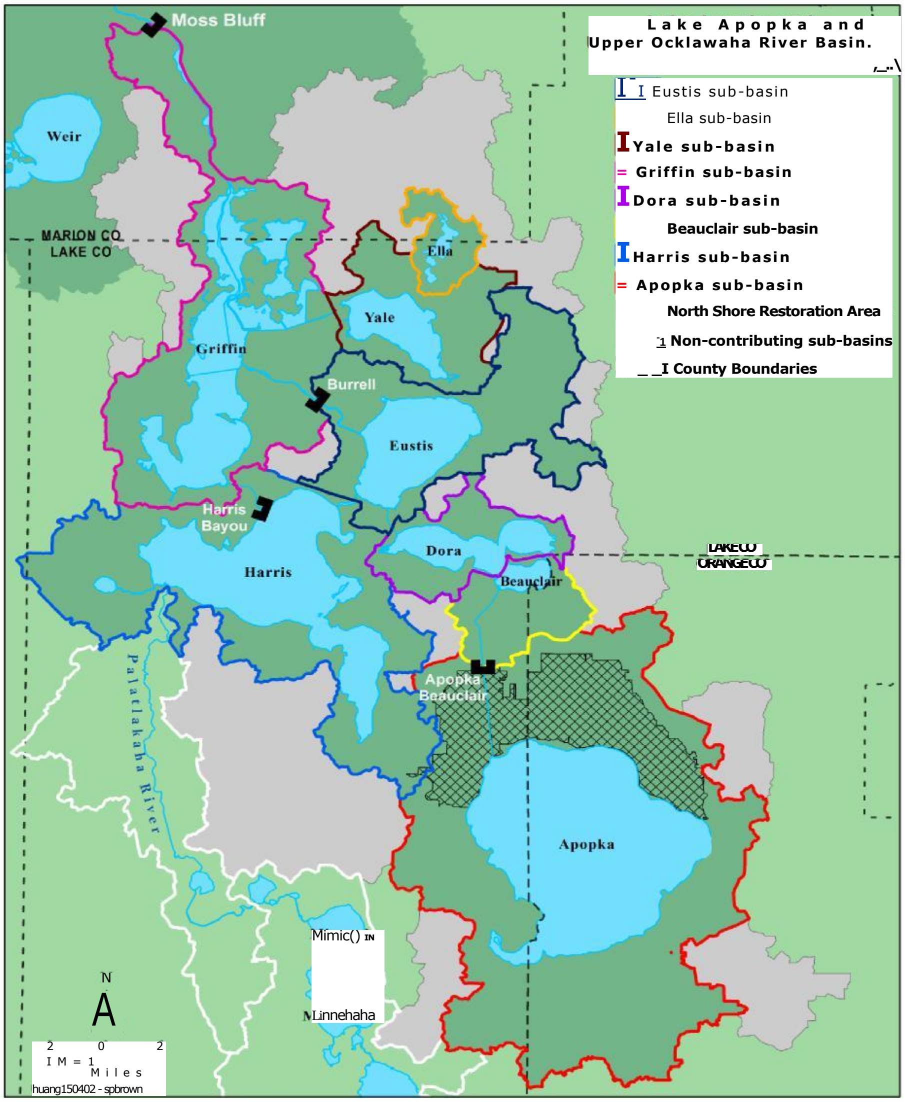


Figure 13. Map of the Upper Ocklawaha River basin. There are four water structures in this basin, namely, Apopka-Beauclair Lock and Dam, Harris Bayou, Burrell Lock and Dam, and Moss Bluff Lock and Dam. Gray areas are non-contributing sub-basins.

Comment [SBU63]: To be consistent with the figures, you should drop Holly from the Ella/Holly terminology in the text.

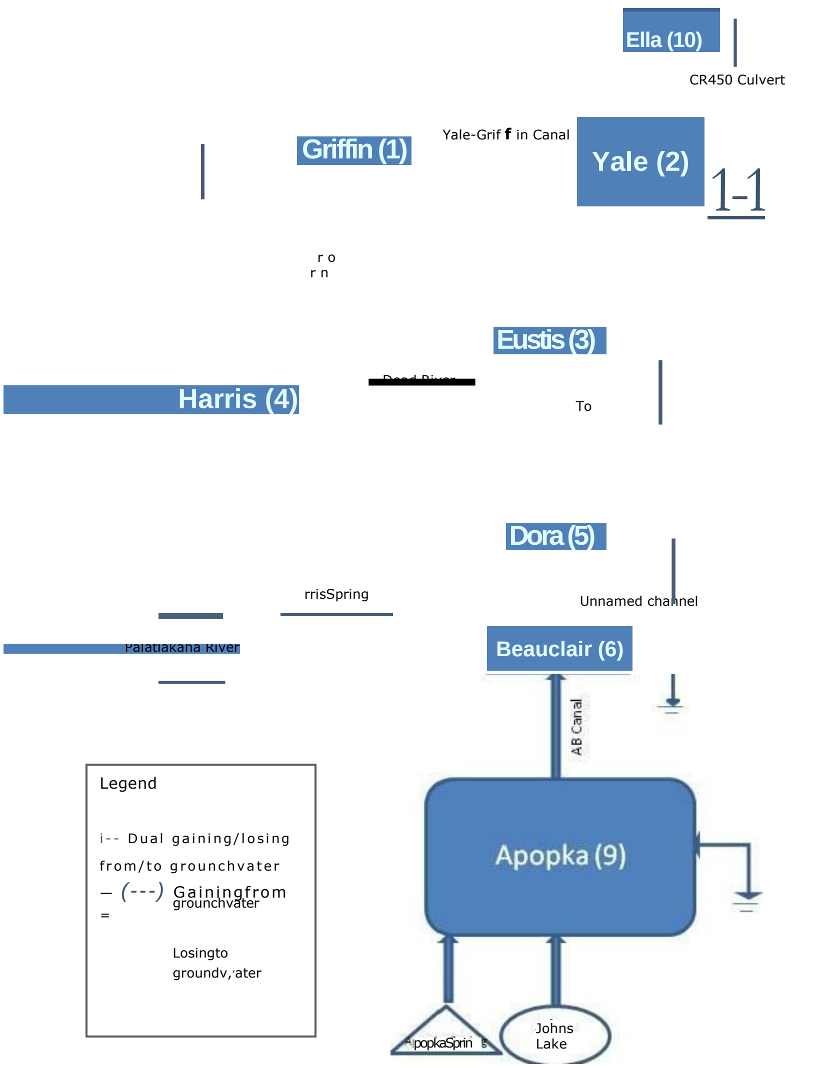
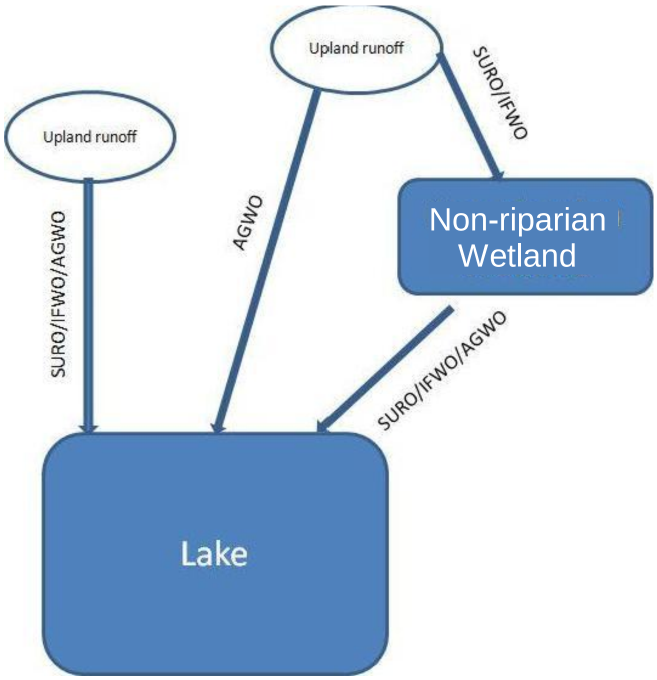


Figure 14, Schematic of Lake Apopka and UORR FOPF Model, The numbers in parentheses are FOPF basin 111.i



Rpm IL Schematic of Non-riparian wetland routine

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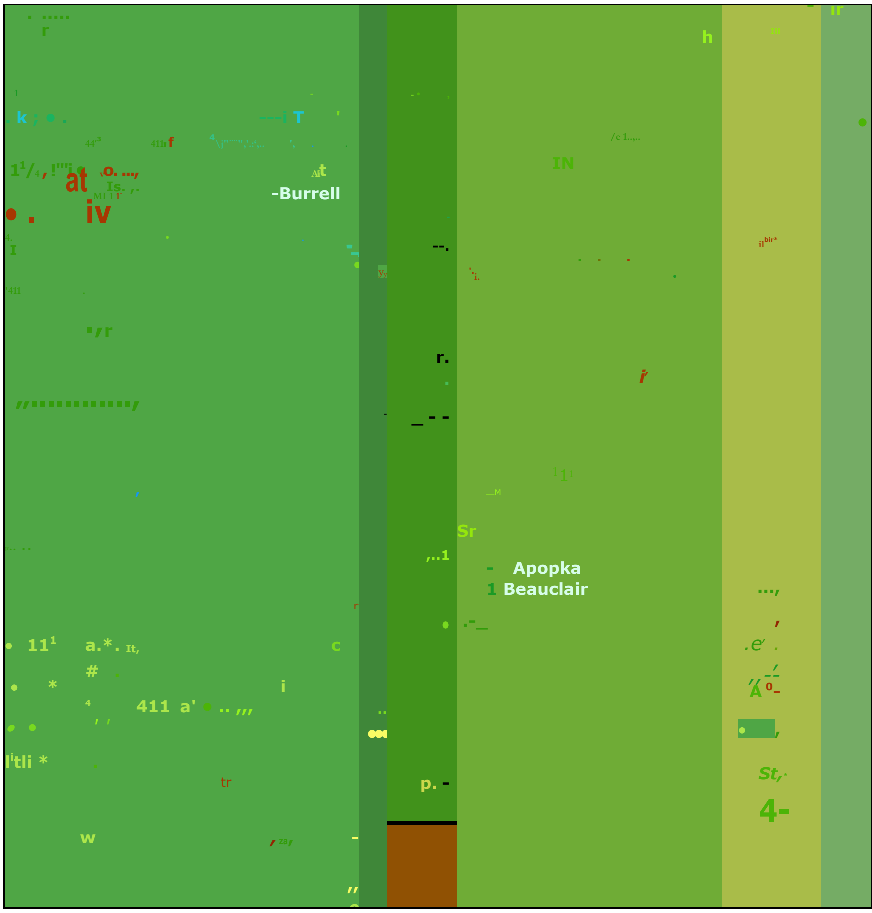

Recharge Map of the Upper Ocklawaha River Basin

0 2 4 8 Miles

RECHARGE 2005

RECH _RANGE

Discharge Area

0-4 In/Yr

4.001- 8 In/Yr

8.001 12 In/Yr

12.001-20 In/Yr

More than 20 In/Yr

Figure 16. Recharge map of the Upper Ocklawaha River Basin

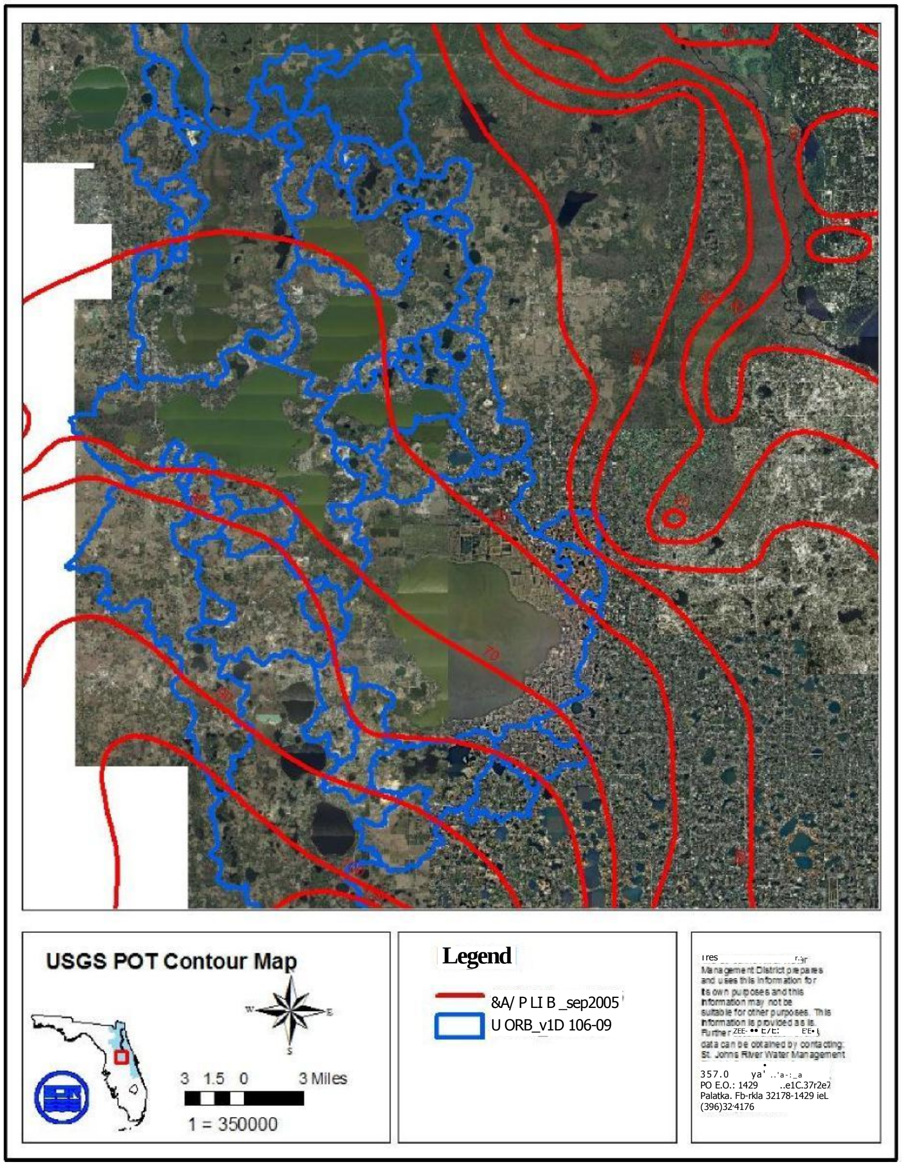

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Figure 17. Upper Floridan Aquifer (UFA) potentiometric-surface contours in the month of Sept 2005, published by USGS. Across Lake Apopka, UFA level declined roughly 20 ft from 80 ft-NGVD29 to 60 ft-NGVD29 (Note: ~~UFA~~ isopotential contour interval ~~is in~~ 10 ft. ~~interval~~)

Comment [SBU64]: Make this a reference.

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Comment [SBU65]: During what period.

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Comment [SBU66]: Need to add the elevatio ...

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3.4 MODEL DATA REQUIREMENTS

The UORB HSPF calibration model is based on the 1995 District's land use map (Reference). The District has ~~developed~~ identified 14 land use categories for hydrologic modeling as presented in Table 9. These 14 land use categories were developed by aggregating the 140 Florida Land Use and Cover Classification System (FLUCCS) codes into hydrologically similar land uses.

Impervious areas include all surface areas that prevent water from infiltrating into the ground. Typical impervious areas are buildings/roofs, paved roads, and parking lots. These impervious areas can be classified into two categories: Directly Connected Impervious Area (DCIA) and non-directly connected impervious area (NDCIA). DCIAs are the impervious areas that directly connect to the drainage network with no opportunity for infiltration (e.g., a parking lot that drains directly to a creek). NDCIAs are the impervious areas that drain to pervious areas (e.g., a rural home surrounded by a vegetated area). In this study, only DCIAs are modeled as IMPLND and NDCIAs are part of the PERLND land use element.

Among the 14 land uses, the first four land use groups are assumed to have some DCIA. These four land use groups are low-density residential, medium-density residential, high-density residential, and industrial and commercial (Table 10). Estimation of the percent DCIA for WSIS in each urban land use category stems from observed flows of small storm events~~,~~ because most runoff during small storms is generated from DCIA. Impacts of changing percentages of DCIA on total mass balance and seasonal flow distribution were also considered. The proportion of DCIA in each urban land use category attributed to IMPLND for the HSPF hydrologic model is presented in Table 10~~.~~. The remaining nine land use categories are assumed to consist of only pervious (PERLND) elements.

Comment [SBU68]: The report desperately needs a table of acronyms at the beginning. After a while, they become confusing in a text like this.

Table 9. Land use groups for HSPF hydrologic model.

HSPF Hydrologic Modeling Land Use Number	HSPF Hydrologic Modeling Land Use Group	PERLND Operation Number*	IMPLND Operation Number*	Note
1	Low-density residential	X01	X01	< 2 dwelling units
2	Medium-density residential	X02	X02	2 to 5 dwelling units per acre
3	High-density residential	X03	X03	> 5 dwelling units per acre
4	Industrial and commercial	X04	X04	
5	Mining	X05		
6	Open and barren land	X06		
7	Pasture	X07		
8	Agriculture general	X08		
9	Agriculture tree crops	X09		
10	Rangeland	X10		
11	Forest	X11		
12	Water	X12		
13	Riparian Wetland	X13		Adjacent to reach
15	Non-riparian Wetland	X15		Not adjacent to reach

* "X" in the Operation Number is the Basin number from Table 8 except Lake Ella~~/Holly~~

Table 10. Percentages of directly connected impervious area (WSIS 2012)

HSPF Hydrologic Modeling Land Use Number	HSPF Hydrologic Modeling Land Use Group	% Imperviousness
1	Low-density residential	5
2	Medium-density residential	15
3	High-density residential	35
4	Industrial and commercial	50

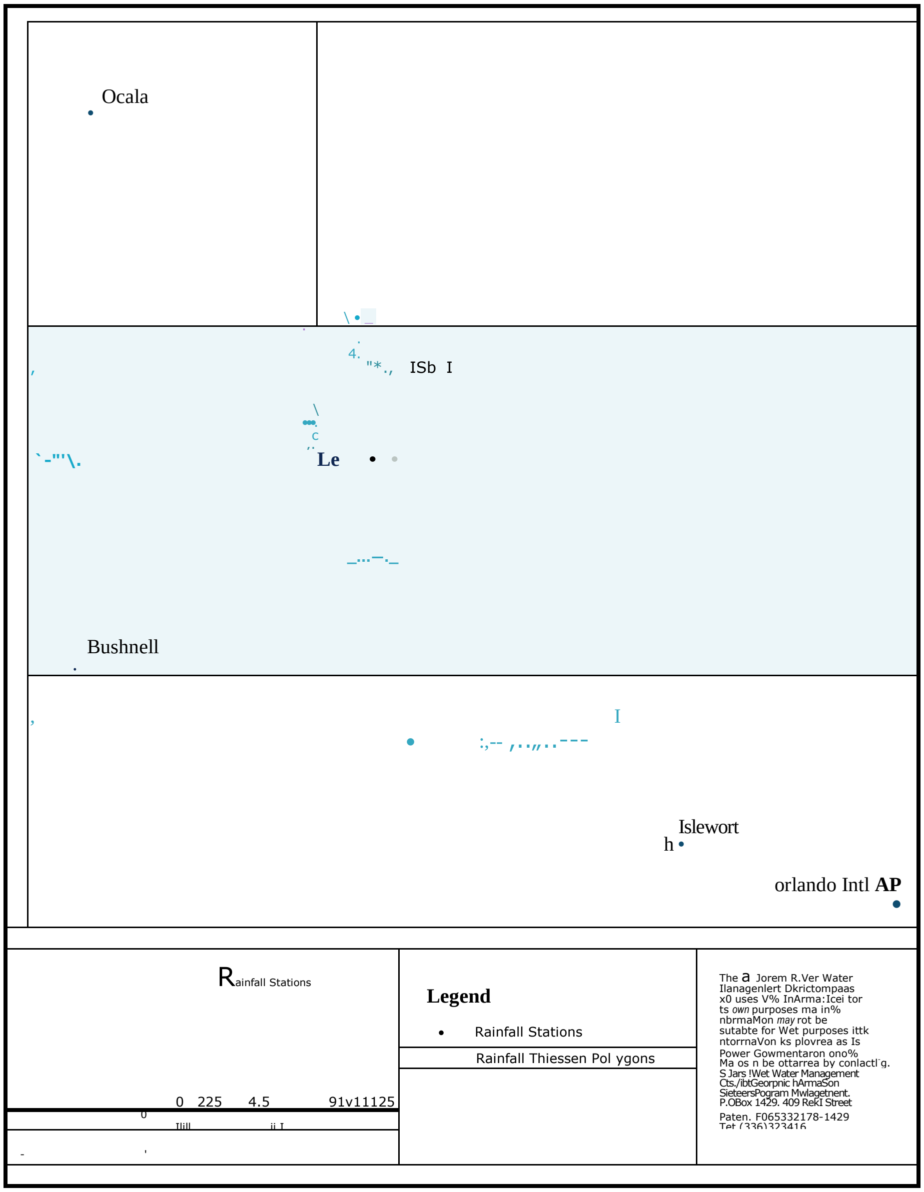

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Figure 18. Rainfall stations and Thiessen Polygons

Comment [SBU69]: Most scientists and engineers will know this process, but lay folks will not. Either give a reference or explain what Thiessen polygons are and what they are used for.

The MFLs model requires a long-term period of climate ~~record~~ data to determine if the various levels and return periods are achieved. The District~~'s~~ currently uses radar-determined rainfall based on NEXRAD for many of its projects. Unfortunately the radar rainfall data do~~es~~ not meet the requirements for ~~our~~ long-term MFLs modeling. Therefore, the UORB HSPF model uses NOAA rainfall records from nearby Florida stations located at Isleworth, Leesburg, and Lisbon (Figure 18 and Table 11). Due to missing values or weather station relocation, the rainfall ~~se~~ time series data~~of rainfalls~~ may be composited or substituted from nearby stations. The daily rainfall was then disaggregated to hourly rainfall by the software package Watershed Data Management Utility (WDMUtil). The daily or hourly rainfall data were loaded into a WDM file where WDMUtil was used to estimate an hourly rainfall distribution for each daily record site based on its two closest hourly rainfall stations (see Appendix 13.5 Excepts from the WSIS 2012 for detailed methodology). The rainfall station was assigned to each basin by Thiessen polygon method: Isleworth rainfall was assigned to Lake Apopka basin, Leesburg rainfall was assigned to Lake Harris basin, and Lisbon rainfall was assigned to all other basins **(Figure 18).**

Table 11. NOAA rainfall stations used in the HSPF model (data compiled by District hydrologist D. Clapp)

NOAA Rainfall Station	Composite Period of Record	Mean Annual Rainfall (inches)	Max Annual Rainfall (inches)	Min Annual Rainfall (inches)
Isleworth, FL	1916-2012	50.3	78.8	22.3
Leesburg, FL	1942-2012	48.1	67.6	22.2
Lisbon, FL	1914-2012	48.4	67.6	29.3

Potential evaporation was estimated using the Hargreaves method adjusted by a scaling factor to USGS GOES evaporation estimate that uses the Priestly-Taylor method. The Priestly-Taylor method was applied by the USGS in a cooperative project with the District to use satellite measurements of radiation for the evaporation estimate. This method provides evaporation

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Comment [SBU70]: For modeling, I don't have much of a problem with this, but if you start interpreting the time series data, then you need to provide it and critique it for errors where substitutions and composites are introduced. What are the errors associated with this method of time series reconstruction? How big are the gaps you are filling?

Comment [SBU71]: Reference

Comment [SBU72]: ?? Right word?

Comment [SBU73]: Thiessen polygons do not conform to the drainage basins (Fig. 18). Rainfall was assigned to the polygons, not the basins. Right?

Comment [SBU74]: Reference

Comment [SBU75]: Reference

Comment [SBU76]: Reference. This report will be reviewed by lay persons and scientists/engineers who are likely not familiar with the methods cited in many parts of this report. Good technical writing requires that the references be given so that one can become informed if not familiar with a particular process. This is a fault throughout the report, so far.

estimates both spatially (in 2 x 2 km grid cells) and temporally across the District (see Appendix 13.5 Excepts from the WSIS 2012 for detailed methodology). Similar to ~~ly as~~ rainfall, hourly Hargreaves evaporation data were assigned to each basin by the Thiessen polygon method (Figure 19): Clermont Hargreaves evaporation, adjusted by a scaling factor of 0.8714, was assigned to Lake Apopka basin while Lisbon Hargreaves evaporation, adjusted by a scaling factor of 0.9114, was assigned to all other basins.

Comment [SBU77]: See comment above in re rainfall. Evaporation data were assigned to polygons, not basins.

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Comment [SBU78]: Why? Explain, or is this part of the calibration process? If calibration, say so. If based on some bias or other issue, explain. Do not just leave this standing as an arbitrary action without justification.

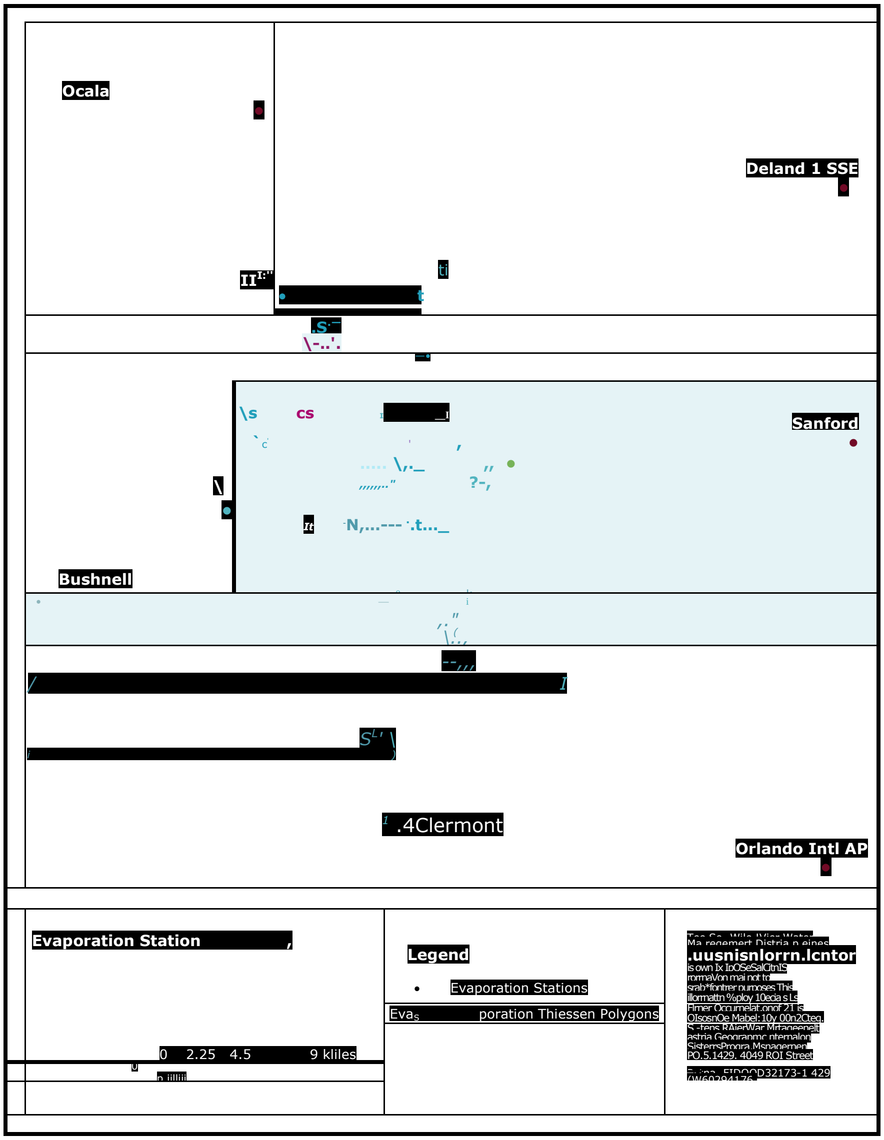

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Figure 19.1Evaporation stations and Thiessen Polygons

3.4.4 HYPSOGRAPHIC CURVES FOR LAKE APOPKA AND OCKLAWAHA LAKES

Bathymetry data for the Ocklawaha Lakes had been obtained from a study by ECT in 1991 (ECT 1991). However, these bathymetry data were limited to typical lake levels, and did not extend to the near shore. Later in 1999, additional data gathered by ECT in near-shore areas were added to bathymetric databases for these lakes (ECT 1999). Combining ECT survey data (1991 & 1999) with LiDAR 1-ft contour data for areas above typical lake level, Pachhai et al. (2013) generated stage-area-volume relationships for the Ocklawaha l~~L~~akes. Similarly, with combined bathymetry survey and LiDAR 1-ft contour VanSickle (2013 & 2014) produced hypsographic curves for Lake Apopka, and for the Emeralda restoration cells connected with Lake Griffin. In this LAUORB HSPF model, ECT's (1991) bathymetric curves were~~as~~ utilized as much as possible. For elevation above ECT's (1991) lake level, VanSickle and Pachhai et al. (2013) results were added on top of ECT's 1991 results.

3.4.5 SPRING FLOW DATA

There are springs or spring groups that discharge to Lake Apopka or UORB lakes. Apopka Spring, located at southwest corner of Lake Apopka, discharges to Lake Apopka from the Upper Floridan Aquifer; and Harris Springs, ~~which are~~ a group of springs including Bugg, Blue, Holiday, and Double Run Springs, discharge to Lake Harris from either the Upper Floridan Aquifer or Surficial Aquifer. Discharge from Apopka Spring has been ~~is~~ measured monthly since the 1990s by the District's Bureau of Water Resource Information, and spring flows are estimated through regression method assisted by German~~e~~ et al. (2006). For the Harris Springs, the District started to regularly measure monthly spring flows at Bugg, Blue, Holiday ~~since~~ in 1991. All these spring flows were combined into one time series of monthly values. Harris Springs flows before 1991 were assumed to be ~~at~~ the average flow between 1991 and 2013 at 18.4 cfs (see appended **Table** 22).The Apopka and Harris spring flows are then input as external point sources to the LAUORB HSPF model.

Comment [SBU79]: There is a consistency problem here. Sometimes Lake Apopka is included as one of the Ocklawaha Lakes and sometimes it is separated out, such as in this title.

Comment [SBU80]: The term bathymetry is being used as an adjective here. The adjective bathymetric is better grammar.

Comment [SBU81]: The lake level is the same in open water as in nearshore regions unless a wind setup, seiche, or other stress is affecting the lake. I am sure that is not the case here. I assume the sentence refers to lake depths in open water as opposed to nearshore areas. Please clarify.

Comment [SBU82]: Again, the reader will not know what these are, Put on map or explain here.

Comment [SBU83]: Map location

Comment [SBU84]: Map location

Comment [SBU85]: The other springs? This is unclear. If you mean the other springs, what is the independent variable (random discharge measurements) and independent variables (???).

Comment [SBU86]: There is a serious absence of use of articles, such as "the" and "a", in this report.

Comment [SBU87]: Explain. I assume that the individual synthesized time series data were summed on a daily (?) basis to produce an aggregate discharge time series for the Harris spring group. If that is what happened, say so.

Comment [SBU88]: You have tables in the text and designated Appendices. Is this another type of appendix?

Comment [SBU89]: At the kickoff meeting, we were told that the District was using thermal imaging to identify seeps and/or springs in the lakes. Where are these discussed. If they are being lumped with general groundwater flux, I would discuss here.

4 HSPF SPECIAL ACTIONS

HSPF hydrologic modeling permits the user to perform certain "Special Actions" during the course of a run. A special action instruction specifies the following:

- The operation on which the action is to be performed (e.g., PERLND 10)
- The date/time at which the action is to be taken.
- The variable name and element (if the variable is an array) to be updated.
- The action to be performed—The most common actions are to reset the variable to a specified value and to increment the variable by a specified value, but a variety of mathematical functions are available.

Comment [SBU90]: This word is interesting. Did you use a "lagged endogenous variable" or some other means to correct for drift in the model runs through time? Kind of sounds like you did.

The Special Action module is used to accommodate unique characteristics of a watershed, such as the following.~~:~~

- Modeling human interventions in a watershed. For example, e~~: E~~vents such as plowing, cultivation, fertilizer and pesticide application, and harvesting can be simulated with this module~~in this way~~.
- Changing parameter values. ~~: ~~For example, a user may wish to alter the value of a parameter for which 12 monthly values cannot be supplied. This can be done by specifying a special action for that variable. The parameter can~~ould~~ be reset to its original value by specifying a later action.
- Preventing double accounting for water and wetland areas.~~:~~ Special Actions were used to separate the riparian wetland PERLND areas and RCHRES water areas.
- Describing connections between groundwater and surface water.~~:~~ Special Actions for connections between groundwater and surface water was used to estimate recharge through sinks into the groundwater or discharge from the groundwater through spring flow or seepage.
- Accounting for different conditions during a simulation run.

Comment [SBU91]: No example?

4.1.1 ACCOUNTING FOR VARIABLE SURFACE AREA BETWEEN RCHRES AND PERLANDS

The Special Actions module was ~~were~~ used to account for variable PERLND and RCHRES. During a simulation run, the riparian wetland PERLND areas will change as the RCHRES surface expands and contracts. If these areas were not separated, it would cause some double counting of rainfall and evaporation during high water levels and some undercounting during low water levels. As long as the overlap is small, this error is considered insignificant to the overall model, but when the RCHRES variable surface area becomes large, the error can become significant. To prevent double accounting for water and wetland areas, the Special Actions ~~were~~ module was used to separate the riparian wetland PERLND areas and RCHRES water areas. Different areas of water and wetlands were assigned to PERLND and RCHRES so the model would not use the same area at the same time during simulations. The Special Actions for variables PERLND and RCHRES calculate the RCHRES area in each time step and subtract it from the total water and wetland area for the subwatershed. Then the model uses this number as the riparian wetland PERLND area.

Comment [SBU92]: Is there a threshold used to judge the need for use of the module here?

4.1.2 SEEPAGE FLOW BETWEEN LAKE AND THE UPPER FLORIDA AQUIFER

Lake Apopka and UORB are located in ~~the~~ central Florida's karst landscape, where a leaky confining unit separates the Surficial Aquifer, of which the lake water bodies are part ~~of~~, from the Upper Floridan Aquifer (UFA). If hydraulic conductivity is large enough or there is ~~crack~~ breach in the confining unit that connects the UFA directly with the lake bottom, seepage flow forms an important part of the water budget for the lake. The amount of seepage and flow direction between lake and aquifer will depend on the head difference between lake level and the UFA potentiometric surface level. In LAUORB HSPF model, the rate of groundwater recharge/discharge from/to the lake was estimated as a function of the head difference as represented in the Darcy's Equation:

Comment [SBU93]: This reads like you are concerned with seepage into the lakes, not leakage from them. Both certainly occur, depending on the relationship of the UFA pot surface to the lakes or SAS levels.

Comment [SBU94]: Or leakage

Comment [SBU95]: Yes.

$$Q = K \, AH \text{ — } AL \, A \qquad (1)$$

Where Q is the rate of lake seepage, ft^3/s; K is hydraulic conductivity, ft/s; A

is the cross-sectional area of the porous medium through which water exchanges between lake and the aquifer, ft^2; AL is the vertical distance between the lake bottom and Upper Florida Aquifer, ft; and OH is the head difference between lake water level and UFA potentiometric surface, ft. If K, A and AL do not change and stay constant, then these three parameters can be lumped into K', where

$$= K \text{ — } A$$

A L

Hence, the Equation (1) can be simplified as:

$= If' \, OH$ (2)

K' can be ~~calibrated~~ adjusted as an individual parameter for each lake during model calibration process.

Comment [SBU96]: Avoiding use of calibrate twice in the sentence.

4.1.3 THE UPPER FLORIDAN AQUIFER POTENTIOMETRIC LEVELS UNDER LAKE BOTTOMS

For Equation 2 to work, OH has to be calculated from the difference between lake water level and average UFA potentiometric level under lake bottom. This is especially true for l~~L~~akes Apopka and Griffin, where UFA levels change significantly ~~change~~ across the lakes. In both cases, ~~so~~ groundwater discharges in part of the lake ~~is discharging~~ and the other part is recharging to the lake **(Figure 16** and **Figure 17).** There are no measured data on discharge/recharge through the lake bottoms, so these were estimated using a regional groundwater model.

The East Central Florida Transient (ECFT) Model: ~~the~~ The East Central Florida Transient (ECFT) Model is a regional-scale groundwater flow model covering East-Central Florida using USGS's customized MODFLOW groundwater modeling computer program, and it was calibrated from Jan 1, 1995 to Dec 31, 2006. The USGS led ~~the~~ ECFT Model development with assistance from St. Johns River Water Management District and Southwest Florida Water Management District (SWFWMD). The ECFT model simulates both the Surficial Aquifer System and Floridan Aquifer System (FAS), with the main emphasis on the FAS. The ECFT model outputs monthly UFA potentiometric surface levels averaged under each lake bottom from 1995 to 2006.

Comment [SBU97]: Is there a reference yet? If so, please cite.

MOVE-3 (Maintenance of Variance) statistical method (Hirsch 1982): The ECFT model was calibrated from 1995 to 2006 and can simulate average UFA levels under each lake bottom during this period. For MFLs modeling, a long-term average UFA level was needed to run the MFLs model. As indicated in **Figure 20,** there are three long-term wells located near Lake Apopka or UORB, i.e., Blue House (M-0483), Lake Yale Groves (L-0043), and Orlo Vista (OR-0047). All three wells have UFA level measurements at least back to Jan. 1, 1964. The MOVE-3 method was used to calculate regression equations between concurrent ECFT simulated UFA average

Comment [SBU98]: Will this be published? This is a source of uncertainty and, like other regressions and time-series data gap filling efforts, the errors should be discussed somewhere. Discussion would include analysis of residuals for the regressions.

A visual review of the stage-duration curves and time series graphs indicates that the uncertainty is at least a foot. What is the effect of this uncertainty on MFLs? When a stage is set in a lake-level regime as a MFL, it appears that it is no more accurate than ±0.5 to 1 ft.

levels and observed well UFA data. T~~hen t~~he regression equations were applied to extend estimated average UFA levels under the lake bottoms during the period from 1964 to 2011 based on observed UFA levels from 1964 to 2011.

USGS Streamflow Record Extension Facilitator (SREF) (Granato 2009): T~~t~~his USGS computer program has a built-in MOVE-3 method and was used to facilitate the transformation from well data to average lake bottom UFA potentiometric levels **(Figure 21** and **Figure 22).** SREF calculates a correlation between concurrent data of ECFT simulation and well data **(Figure** 22) and the user can choose the best well (typically the closest well with the highest R) to estimate average lake bottom UFA potentiometric levels. **Table 12** lists the R-values and the corresponding well to estimate average lake bottom UFA potentiometric levels for each lake. **Figure 23** through **Figure 26** shows extended average lake bottom UFA levels from 1964 to 2011.

Comment [SBU99]: Define. Typically, the goodness of fit is characterized by R^2, not R. You need to explain what the coefficient of determination is based on (modeled vs. measured regression?).

Comment [SBU100]: See above. Are these coefficients of determination or correlation coefficients? If they are correlation coefficients, the goodness of fit is not overwhelming (a R of 0.77 means the regression only accounts for 60% of the variability. I hope they are coefficients of determination (R^2).

Again, the results of this method are complicated by use of wells along the probable strike of the pot surface under the lakes.

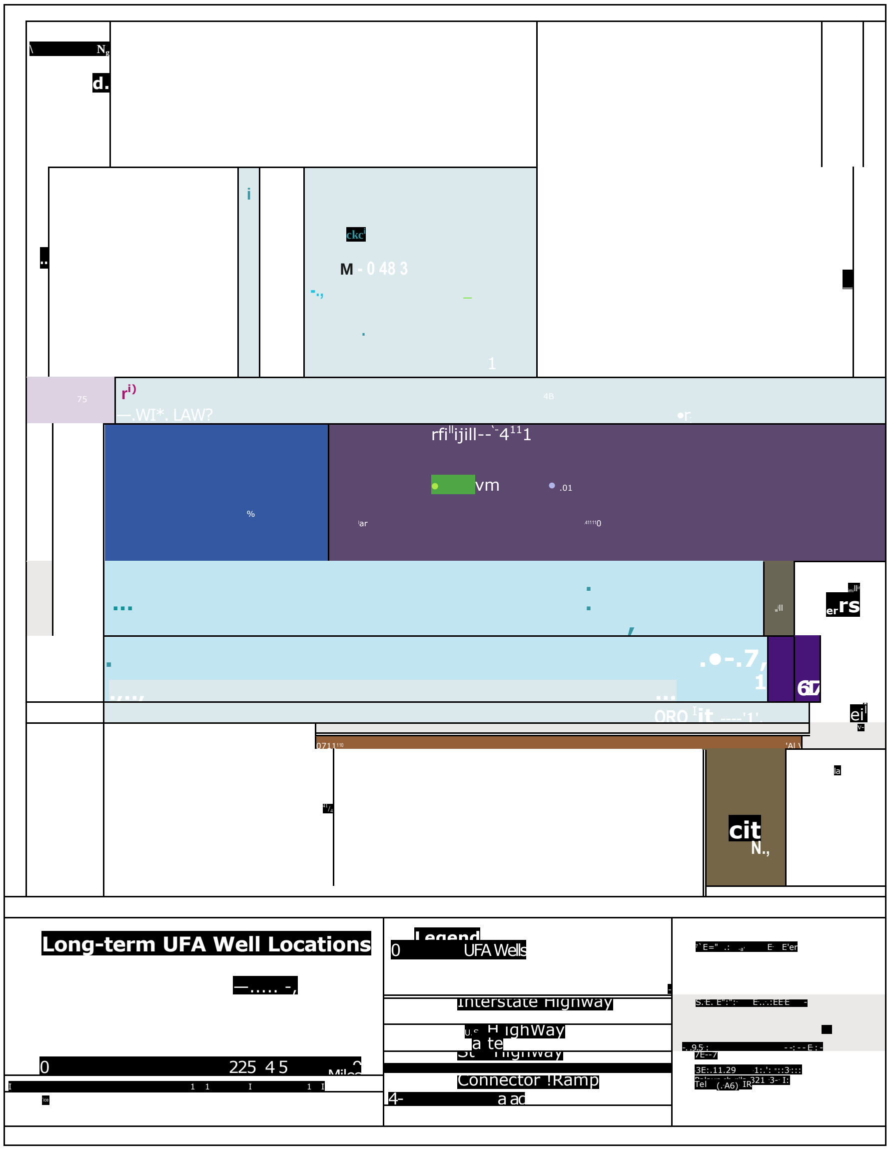


Figure 20. Three long-term monitoring UFA wells: Blue House (M-0483), Lake Yale Groves (L-0043), and Orlo Vista (OR-0047)

Comment [SBU101]: Since the pot surface of the UFA generally dips from west to east, use of three monitoring wells along the strike of the pot surface slope does not capture good data for calibration/verification of potentiometric surfaces and fluxes to the lakes off strike.

Also, I think it would make the report easier to read and understand if a potentiometric surface map is included in the report near here.

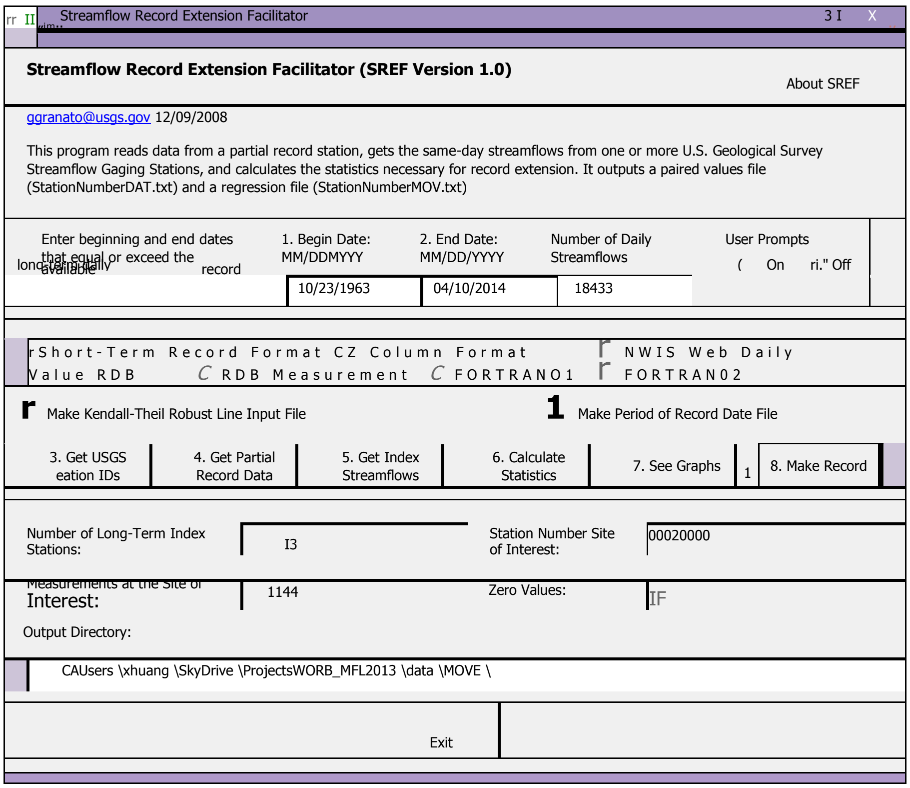


Figure 21. USGS computer program: Streamflow Record Extension Facilitator (http://pubs.usgs.gov/of/2008/1362/1

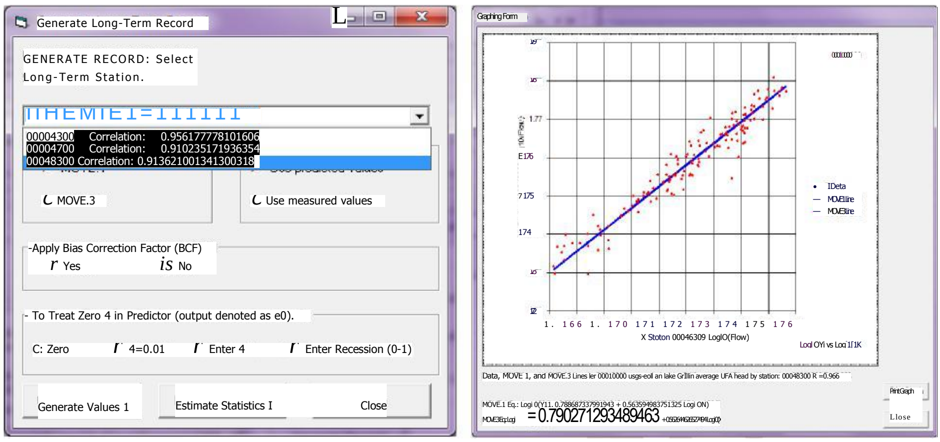


Figure 22. USGS computer program: Streamflow Record Extension Facilitator

Table 12. Correlation for concurrent data between ECFT simulated UFA head and observed well data

Lake Name	Base well	R
Lake Apopka	Orlo Vista (OR-0047)	0.77
Lake Beauclair	Lake Yale Groves (L-0043)	0.82
Lake Dora	Lake Yale Groves (L-0043)	0.87
Lake Eustis	Lake Yale Groves (L-0043)	0.92
Lake Harris	Lake Yale Groves (L-0043)	0.93
Lake Yale	Blue House (M-0483)	0.91
Lake Griffin	Blue House (M-0483)	0.97

Comment [SBU102]: See comments about R above.

Formatted Table

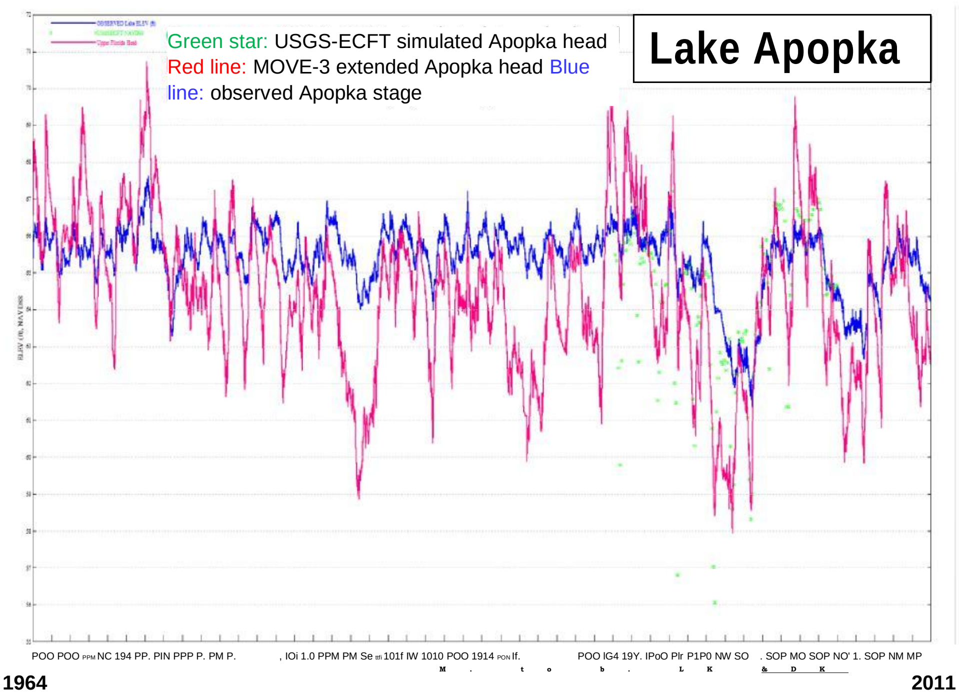


Figure 23. The average daily UFA potentiometric level (red line) from 1964 to 2011 under the lake bottom extended from nearby long-term well Orlo Vista by the statistical method of MOVE-3

Comment [SBU103]: Change star to stars in legend.

This graph is complicated, but appears to indicate that the modeled head and extended head do not correspond well to each other. Also, there are unexplained changes in relative differences between the head time series and lake stage. These should be explained.

Again, where are the residuals and why do median values agree up to about 1970, then differ greatly to the early 1980s, then track each other with great uncertainty after that time? What effects do these apparently noisy input data have on model results?

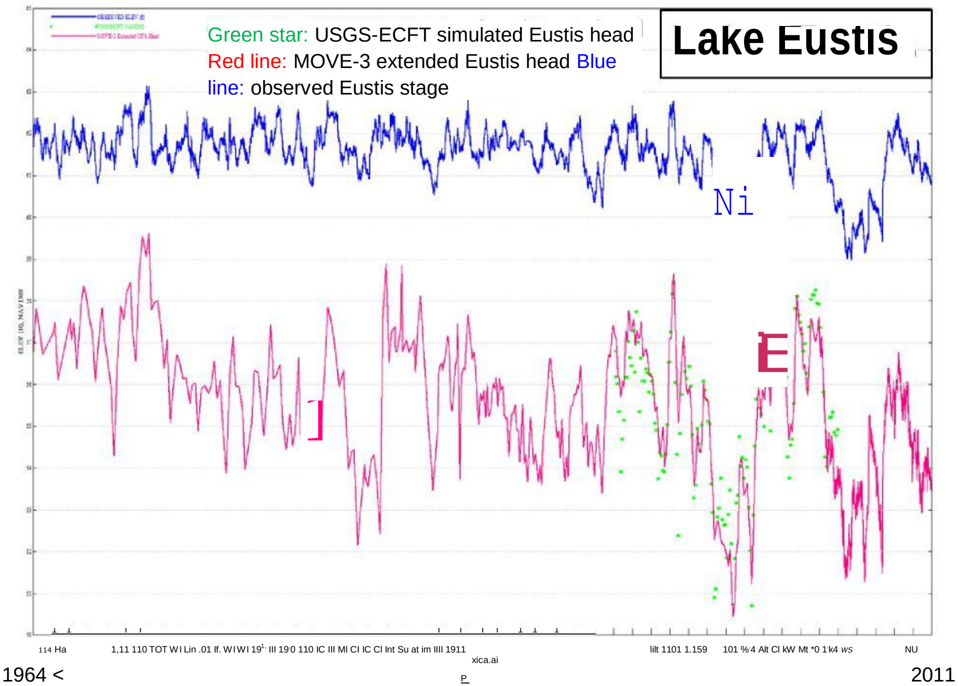


Figure 24. The average daily UFA potentiometric level (red line) from 1964 to 2011 under the lake bottom extended from nearby long-term well Lake Yale Groves by the statistical method of MOVE-3

Comment [SBU104]: These data look better. Again, a residual analysis is called for here. Based on these graphs, it appears that the R values are coefficients of determination (R^2, not r, the proper designation for the correlation coefficient).

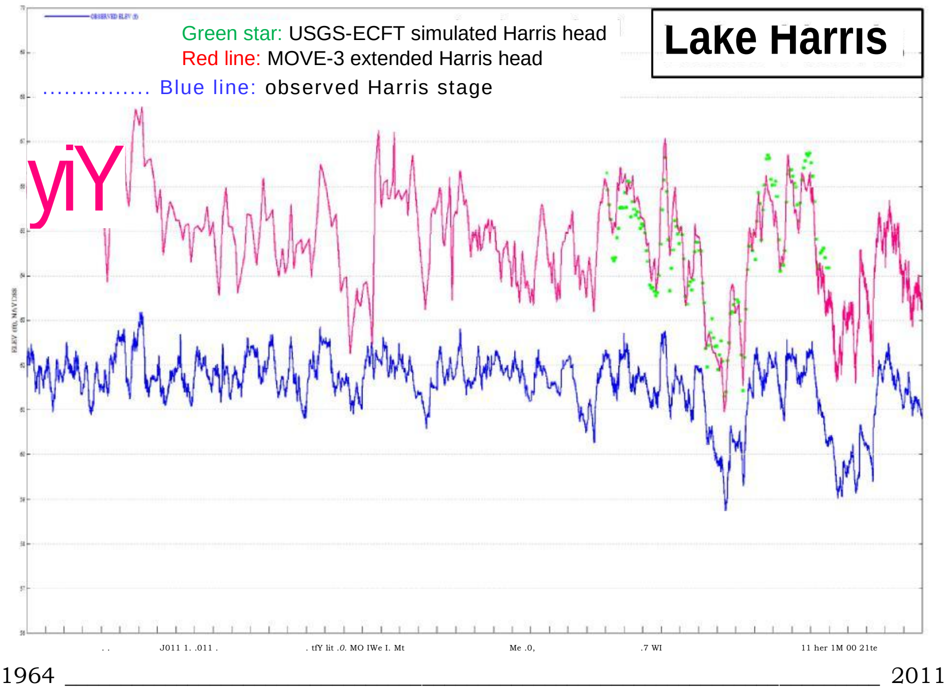
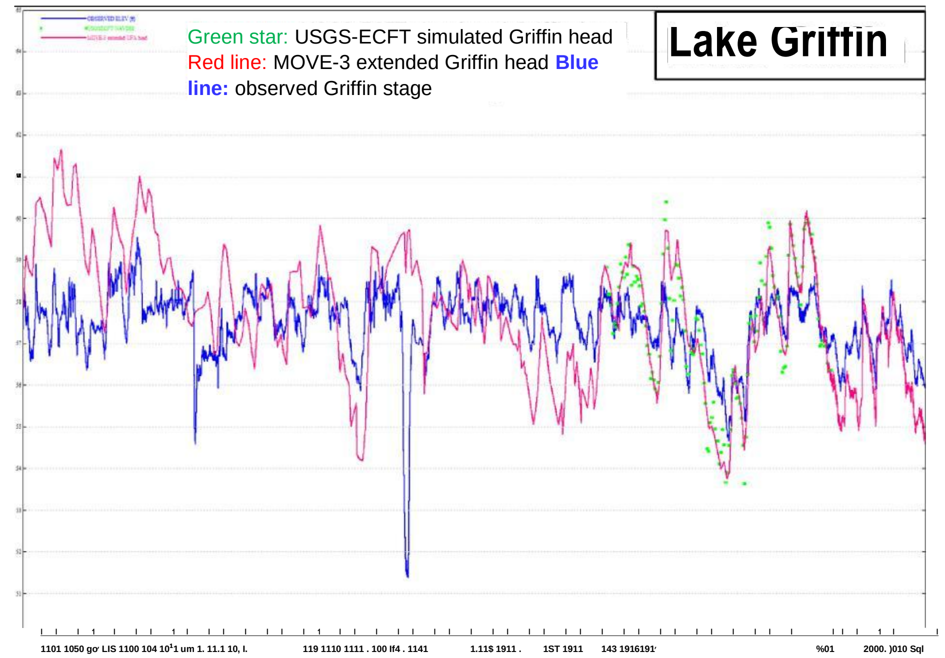


Figure 25. The average daily UFA potentiometric level (red line) from 1964 to 2011 under the lake bottom extended from nearby long-term well Lake Yale Groves by the statistical method of MOVE-3

Comment [SBU105]: Fits are better yet. Residuals analysis is called for. BTW, use of the green dots makes comparison of the two head time series difficult. Please use a more easily seen color scheme.



1964____ **2011**

Figure 26. The average daily UFA potentiometric level (red line) from 1964 to 2011 under the lake bottom extended from nearby long-term well Blue House by the statistical method of MOVE-3

Comment [SBU106]: Residuals analysis! These data are the best fits yet, which corresponds to the highest R^2 values in Table 12. Discuss goodness of fit of modeled and measured data.

4.1.4 OUTLET RATING CURVE FOR UORB STRUCTURES

Discharges from l~~L~~akes Apopka, Eustis, and Griffin are controlled by the Apopka-Beauclair Lock and Dam, Burrell Lock and Dam, and Moss Bluff Lock and Dam, respectively. Water levels in these lakes are controlled by regulation schedules adopted ~~since~~ in 1960s. The typical regulation schedule draws down lake levels during spring/summer, and brings ~~back~~ lake levels up in November. These~~is~~ regulation schedules were ~~was~~ designed to provide water storage during the wet periods to minimize flooding.

Each lake's water control structure is operated by the District according to the~~its~~ regulation schedule for the structure. Obviously, different operators take different steps to follow regulation schedule. ~~The~~ B~~b~~alancing of the system is as much ~~of~~ an art as ~~it is~~ an engineering decision. Variable rainfall, watershed lag times, headwater and tailwater relationships, and human interventions make~~s~~ ~~the~~ development of stage~~-~~discharge relationships for each structure difficult to achieve. To model ~~the~~ release of water from these structures, the average discharges according to lake level above regulation schedules were calculated for each structure based on the actual operation records obtained from District's senior engineer, John Richmond. When lake level is below regulation schedule, a minimum discharge is released as long as the level is above the sill invert elevation (Tables 13-15).

Comment [SBU107]: Reference or cite Figure above that shows the schedules

Comment [SBU108]: New subject. Important to emphasize difficulties. Do not hide at the end of a paragraph.

Comment [SBU109]: The District is the operator according to the previous sentence. Do you mean that each structure requires different steps to follow the schedule?

Table 13. Water discharge schedule at Apopka-Beauclair Lock and Dam used in LAUORB HSPF model (cfs)

Comment [SBU110]: Can these tables be related back to the graphs showing the proscribed levels in each lake?

Water level above regulation schedule (ft)	A-B Canal Q (cfs)
<A	23
<A.1	116
<A.2	138
<A.3	269
<A.4	340
<A.5	377
<A.6	437
<A.7	464
<A.8	540
<A.9	600
>0.9	600

Table 14.. Water discharge schedule at Burrell Lock and Dam used in LAUORB HSPF model (cfs)

Water level above regulation schedule (ft)	Jan-Feb/Nov-Dec	Mar-May	Jun-Jul	Aug-Oct
<Al	28	28	28	28
<A.1	225	277	624	600
<A.2	338	277	777	600
<A.3	1450	1067	948	700
<A.4	1450	1370	1154	880
<A.5	1450	1500	1500	1500
<A.6	1450	1500	1500	1500
<A.7	1450	1600	1600	1600
<A.8	1450	1650	1650	1650
>0.8	1650	1650	1650	1650

Table 15.. Water discharge schedule at Moss Bluff Lock and Dam used in LAUORB HSPF model (cfs)

Water level above regulation schedule (ft)	Jan-Feb/Nov-Dec	Mar-May	Jun-Jul	Aug-Oct
<1	30	30	30	30
<1.1	258	455	762	562
<1.2	453	455	919	885
<1.3	1280	455	1286	1041
<1.4	1695	1041	1286	1041
<1.5	1695	1650	1650	1650
>0.5	2000	2000	2000	2000

4.1.5 RATING CURVES FOR UORB FREE FLOWING CHANNELS

There are three free-flowing channels in the UORB, namely, Dead River connecting Lake Harris and Lake Eustis, Dora Canal connecting Lake Dora and Lake Eustis, and unnamed channel connecting Lake Beauclair and Lake Dora. All three channels are free flowing without manmade structures. Dead River is about 5,300-ft long with a width between 150-500 ft; Dora Canal is about 6,100-ft long and is less than 50-ft wide; and the ~~last~~ unnamed channel is only 1,500-ft long and gradually expands from 200 ft to 500 ft as the water flows from Lake Beauclair to Lake Dora.

Comment [SBU111]: Repeat of previous sentence

Comment [SBU112]: Since the other channels are named, this suggests that there is another.

There are no long-term observed flow data available for these channels. The USGS ~~had~~ attempted to measure a few points of flow data on Dead River during three separate ~~day field~~ events~~trip~~ from 1994 to 1996 (most data were rated "poor quality" by the USGS). The District ~~had~~ measured eight flows on the Dora Canal during 1998, and 2003-2004. Measuring flows in these channels has~~d~~ ~~been~~ proven~~d~~ difficult where head and tail water difference are very small, and flows can be reversed from time to time when wind and tailwater conditions change~~s~~.

Typically, in HSPF the hydraulic characterization of the channel is summarized in a piecewise-linear function table called a F-table. Although the F-table has multiple flow columns to handle different stage-discharge relationships, the table ~~it~~ is not complex enough to handle variation in the rating curves due to the tailwater influence. Neither can it handle any backflows between two connected water bodies. Hence, in this model, the rating curves for these three free-~~-~~flowing channels were represented by the~~its~~ Special Actions module. HSPF Special Actions are a means to represent processes not simulated in regular modules, which directly modifies variables at specified times during the run (Jobes 2000). Since Dead River and the unnamed channel are short and wide and based on the observation that head and tail lake stage differences are generally less than one tenth foot, an assumption was made that head and tail lake stages can be equalized during one model step (one hour). The water flow or backflow between those two lakes was calculated based on the volume of water required to equilibrate lake levels within one hour. The volume of water is subtracted from the head lake and added to the tail lake. This assumption had been proved reasonable by checking the modeled flow with a few available observed flow data.

However, ~~for Dora Canal,~~ it cannot be assumed that stages in l~~L~~akes Dora and Eustis will be equalized during one hour as the Dora Canal is narrow (less than 50-ft wide) and the observed difference of lake stages between 1995-2006 can be as high as 0.84 ft. Hence, a different approach was used to model~~handle~~ the Dora Canal flow. The equation used to calculate discharge from the Dora Canal was developed based on the Manning's Equations and the results of a HEC-RAS model. Manning's Equation:

Q = 1.486/n * area * hydraulic radius ^{A} 2/3 * slope ^{A} 1/2

The District had measured the flows in the Dora Canal in 2003 and 2004. A HEC-RAS model was developed using these measured flows. The output from the HEC-RAS model included depth, area and top width of the canal. Based on HEC-RAS modeling results, limited flow measurements, and curve fitting, the following equation was developed allowing the calculation of Dora Canal flow based on depth of water:

(1.486/0.02)*(2.5669*(((HW-54.5) + (TW-54.5))/2) ^2.5669)*((ABS (HW-TW)/6081)) A1/2

HW = Head water level of Dora Canal

TW = Tail water level of Dora Canal

Comment [SBU113]: Partially repeats previous sentence. Must keep the reference.

Comment [SBU114]: Use of tail here verges on slang. Use of “up gradient” and “down gradient” sounds more technical and is unequivocal in meaning.

Comment [SBU115]: Seems intuitive.

Comment [SBU116]: References

Comment [SBU117]: Use standard equation notation, just like you did in previous equations.

Comment [SBU118]: What about HEC-RAS cross section data? Precision, spacing, model parameters. etc.? Are these data presented in another report? If so, reference. If not, then I would develop an appendix to include these important constraints.

Comment [SBU119]: Another source of uncertainty. I fear that these efforts may be masking much uncertainty, especially since they are additive.

Comment [SBU120]: Use standard equation notation. What is goodness of fit? Residual analysis?

Given the abundance of regression and data gap filling, I suggest a data analysis report or appendix rather than incorporating in the main body of this report. The data analysis report must be cited in this report, however.

Comment [SBU121]: Assumed this is the stage at the head of the canal.

5 CALIBRATION ~~PROCESS~~ OF THE LAUORB HSPF MODEL

The calibration period selected for the LAUORB hydrologic model is from 1995 to 2006 based on the 1995 land use. This period includes a variety of hydrologic conditions including a significant high precipitation and lake level event (the 1998 El Nino peak) and a significant and sustained low period (the 1999-2002 drought). Including both extreme conditions in the calibration is~~are~~ important, especially for long-term MFLs simulation, in order to evaluate if the lakes will meet proposed MFLs under extreme conditions.

Calibration of the HSPF hydrologic model is an iterative process of changing parameters, running simulations, checking results, and repeating until an acceptable match is made between the simulated and observed data. A calibrated model is one that most closely resembles the behavior of the systems in the real world. When manually performed, model calibration can be a time consuming endeavor. For this reason, a parameter estimation optimization tool PEST was used to assist in model calibration (Doherty 2004). PEST is a nonlinear parameter estimator that will adjust model parameters to minimize the discrepancies between model-generated numbers and corresponding real-world measurements. It does this by running the model as many times as is necessary to optimize multiple objective functions. The objective functions are usually some form of weighted, squared, model-to-measurement differences. Because the problem of calibrating the HSPF hydrologic model is nonlinear, parameter estimation is an iterative process. PEST evaluates parameter changes based on the improvement to the objective functions and decides whether to undertake repeated optimization until no further improvement is achieved. The modeler must not only define the objective functions, but must also select pertinent parameters to calibrate and set the permissible parameter's upper and lower bounds for adjustment. In addition to statistical comparison, graphical comparison is used extensively by the modeler to evaluate model calibration results. The modeler selects the final best calibrated parameter sets based on his/her knowledge of basin hydrology, statistics, and visual graphical comparison.

PEST was ~~helpful~~ utilized to optimize the parameters lower zone nominal soil moisture storage (LZSN), lower zone evapotranspiration (LZEPT), index to infiltration capacity (INFILT), upper zone nominal soil moisture (UZSN), base groundwater recession (AGWRC), interflow inflow

Comment [SBU122]: I think the word process is implied here.

Comment [SBU123]: Reference or cite previous figures, which have been referenced, I hope.

Comment [SBU124]: Each paragraph should include one thought or subject. I have added paragraph breaks throughout the manuscript where I thought the subject changed. Such is the case here.

Comment [SBU125]: Meaning? How weighted?

Comment [SBU126]: This may be distracting, I presume you are talking about the root mean squared error measurement. The errors are squared and the square root of the sum is taken in order to eliminate problems with the signs of the errors. If that is what this word refers to, then delete the word as it is an incomplete description of the process. If not, to what does this refer?

(INTFW), interflow recession (IRC), fraction of groundwater inflow to deep recharge (DEEPFR) and water/wetland surface runoff FTABLE storage-runoff relationship. Relative values of

Comment [SBU127]: Again, I am concerned that these terms will not be clear to an inexperienced reader. They are not defined or referenced.

parameters were established by the modelers among land uses to produce expected relative runoff amounts. Urban land, including impervious areas, produces the most runoff, agriculture produces the next largest runoff, open land and rangeland produce less, and forest and wetlands produce the least runoff. PEST allows parameters to be "tied" to a "parent" parameter. In this way, all of the tied parameters are adjusted equally among the various land uses. In general, LZSN, LZEPT, INFILT, and UZSN parameters are tied together among land uses. The exception to this is water and wetland land use types, where water can be stored on these types of pervious land segments through the use of surface FTable. Further, water and wetland bottoms are considered connected with active groundwater, hence UZSN, IFILT and LZSN are much smaller than other land uses. For this reason, water and wetland parameter sets are not comparable to other land uses and are adjusted independently. The parameters AGWRC and DEEPFR are applied to the entire watershed. In addition, PEST allows parameters to be "fixed" and not adjusted. For example, in many cases of INTFW and lRC, these parameters usually are given a restricted range close to zero or fixed to zero or a very small number.

Comment [SBU128]: This is jargon. Can you not say "related" or some less folksy term. It is also not clear.

Comment [SBU129]: Again, unclear.

Comment [SBU130]: Use of acronyms and text construction make this somewhat confusing. At least two subjects discussed in this paragraph.

Starting with an initial set of parameters developed by the District engineers, PEST was used to help calibrate the model based on the lake levels while maintaining flow mass conservation. During the calibration, the actual observed flows at three structures were inserted into the model, and PEST adjusted parameters to match simulated lake stages with observed values. In the PEST control files, the objective functions take the form of matching simulated to gauged daily stage, monthly stage, annual stage, and stage duration curves. Gauged and simulated stages were compared within these four objective functions to address daily stage variability, seasonal variability, annual stage characteristics, and overall stage characteristics. The modeler assigns weights to each objective function based on the importance of each component that will obtain the best overall match between gauged and simulated stage.

Comment [SBU131]: Use of PEST is fine, but there should be a sensitivity analysis to demonstrate which of the PEST-controlled variables have significant effect on model results.

There should also be sensitivity analysis to show how sensitive the model results are to variations in rainfall and evaporation. This will assist in understanding the importance of uncertainties embedded in the data conditioning.

Comment [SBU132]: Will this comparison be discussed? It should be.

Comment [SBU133]: Needs amplification and discussion.

The model was~~were~~ calibrated separately at four locations, namely, Lakes Apopka, Eustis and Griffin, and Lake Yale. This is due to the facts: 1) Lake Apopka and Lake Griffin is a dual recharge/discharge lake while other lakes are recharge lakes; 2) soil compositions are different; 3) these lakes are controlled by three structures with different operation regimes **(Table 13** through **Table 15);** 4) flow data are available at these three lake outlets.

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When calibration was completed, observed flows were removed from the model and were replaced with structure discharges according to **Table 13** through **Table 15.** These stage-discharge relationships were implemented in the Special Actions module. Then, the model was~~will~~ be run one more time, and all the model calibration statistics will be based on this final model run. The model statistics on stage/flow are shown and discussed at the next section.

Comment [SBU134]: Watch tense in these sentences. Here, the action verb is in the future tense while elsewhere in the paragraph it was in the past tense.

6 CALIBRATION RESULTS AND DISCUSSION

The calibration results are shown in **Table 17 & Table 18** and **Figure 27** through **Figure 44. Table 17 & Table 18** list average observed/simulated lake water levels for each lake or average observed/simulated discharge for the three locks and dams during calibration period and their respective Nash-Sutcliffe efficiency (NSE), a common measure of the performance of a hydrologic model. NSE is defined as:

NSE = 1 - (sum((obs - sim)^2) / sum((obs - mean(obs))^2)

Nash-Sutcliffe efficiency ranges from negative infin~~m~~ity to 1:

- -Inf < NSE < 0, indicates that the observed mean is a better predictor of the dependent variable than the model;
- NSE = 0, indicates that the model predictions are as accurate as the mean of the observed data; and
- NSE = 1, corresponds to a perfect match of simulation to the observed data

Essentially, the closer the model NSE is to one, the more accurate the model is. Table 16 was adapted from Moriasi et al (2007), which indicates if NSE is greater than 0.75, the model ~~is~~ calibration is ~~ed~~ "very good~~well~~". As Table ~~16~~ 17 indicates, the average water level difference between observed and simulated is around 0.1 ft except Lake Eustis, which has actual average simulated/observed difference of 0.2 ft. The Nash-Sutcliffe coefficients, which gage how well simulated lake levels are matched with observed stages, are all above 0.75 that means all the lake stage calibration are in the "very good" category.

Comment [SBU135]: Table uses the word “good”, not “well”.

Comment [SBU136]: Table 17 needs editing. Columns 2 and 3 have the same label, yet one appears to be observed and the other calculated. Are these monthly averages? If so, say so.

Strongly suggest that table include the ranges of measured and calculated water levels. Average levels are important, but with MFLs, the extremes are critical. It is the extremes that the District regulates.

Comment [SBU137]: So does Lake Griffin

Table 16. Grading model calibration performance with the Nash—Sutcliffe efficiency (NSE)

Performance Rating	Nash—Sutcliffe (Monthly)
Very good	0.75 < NSE < 1.00
Good	0.65 < NSE < 0.75
Satisfactory	0.50 < NSE < 0.65
Unsatisfactory	< 0.50

*Adapted from (Moriasi, Arnold, Van Liew, Bigner, Harmel, & Veith, 2007)

Table 18 lists the observed flows and simulated flows at the three locks and dams that regulate water levels at Lake Apopka and Ocklawaha Lakes. The differences between average observed/simulated discharges for all structures are all less than 5% of observed flows. The Nash-Sutcliffe coefficients for the Burrell and Moss Bluff structures are 0.83, which is in the "very good" category while flows for the Apopka-Beauclair Lock & Dam simulation is in the "good" category with a Nash-Sutcliffe of 0.66.

Figures 27 through ~~**Figure**~~ **38** ~~visually~~ depict how well simulated lake levels ~~is~~ matched with corresponding observed lake levels. As the figures demonstrate, the calibrated model captures very well the peaks and troughs of the hydrographs.

Figures 39, 41 and 43 show accumulated simulated structure flows vs accumulated observed flows at AB Canal, Haines Creek, and Moss Bluff, respectively. Figures 40, 42 and 44 show simulated flows versus corresponding observed flows at the three structures. All these indicate the calibrated model reasonably simulated the human-controlled structure flows.

In conclusion, the ~~visual~~ graphs together with calibration statistics demonstrate show that HSPF adequately reproduces the observed lake levels and flow data in LAUORB. Therefore, the calibrated LAUORB HSPF model can be used to assess the MFLs as well as to evaluate the hydrologic responses of LAUORB to potential water withdrawal scenarios.

Comment [SBU138]: In general, the model does capture the Lake Apopka water levels. However, there are two episodes where the model is off by a foot or more. Why is this the case? Do these errors affect management of the lakes and/or MFLs?

Figure 28 appears to depict hysteresis or some other form of data looping. Why? Somewhere you will need to discuss the importance of uncertainties of 1 foot or more to the MFLs and ecosystems.

Lake Dora simulation appears to be good. Errors are low.

The simulations of Lakes Eustis and Harris appear to be routinely higher than the observed from 1998 through 2002. Why? What affect does this have on MFLs?

Simulation of water levels in Lake Yale are high before 2002 and low after 2003. Why? What effect does this have on the MFLs?

Simulation of Lake Griffin water levels is up to 1 foot high before mid-2002 and spot on after that. Why?

After reviewing the time series graphs comparing simulated and measured water levels, it is clear that there is a need for analysis of the residuals for each model. The Nash-Sutcliffe efficiency metric tends to hide these uncertainties and demonstrate that the ...

Comment [SBU139]: These graphs show long-term differences. Using cumulative flows is a relatively unreliable means for demonstrative goodness of fit because one or a few bad (incorrect or extreme-event) measurements throws off the lines. The slopes are parallel, but, because of a few questionable measurements, they are offset. I wouldn't use these unless there is a compelling reason.

Comment [SBU140]: As was the case with the lake-level time series, these graphs show some fairly dramatic differences between the observed and calculated flows. For example, in late 1999 the observed flow at the Apopka-Beauclair canal was around 20 cfs while the simulated was about 350 cfs. Why are these differences here? How important are they? It is not enough to just say these are reasonable when such extreme differences exist.

Comment [SBU141]: Basis? What is reasonable?

Comment [SBU142]: Basis for this statement? What is considered adequate. As a modeler, I understand the uncertainties of models and their uses. However, the public will be looking at the model results and, given the sensitivity of the public to water levels in the lakes, there will be concerns. Basically, by use of terms such as "reasonable" and "adequate" without explanation is similar to sayin ...

Comment [SBU143]: Again, there is a need to (1) discuss the sensitivities of the model to data inputs and calibration variables and (2) discuss the sensitivity of the MFLs and District management decisions to the differences between modeled and measured conditions. Item 2 is what the public will want to see, I think.

Comment [SBU144]:

Table 17. Model calibration performance and average observed/simulated lake levels during calibration period (1995-2006)

Lake Name	Average Observed Lake Level (ft-NAVD88)	Average Observed Lake Level (ft-NAVD88)	Nash-Sutcliffe (monthly)
Lake Apopka	65.0	65.1	0.90
Lake Dora	61.5	61.6	0.88
Lake Eustis	61.3	61.5	0.84
Lake Harris	61.4	61.5	0.87
Lake Yale	57.8	57.8	0.79
Lake Griffin	57.3	57.5	0.81

Table 18. Model calibration performance and average observed/simulated discharge at three locks and dams in Upper Ocklawaha basin during calibration period (1995-2006)

Structure Name	Average Observed Flow (cfs)	Average Simulated Flow (cfs)	Nash-Sutcliffe (monthly)
Apopka-Beauclair Lock & Dam	66	66	0.66
Burrell Lock & Dam	198	193	0.83
Moss Bluff Lock & Dam	218	218	0.83

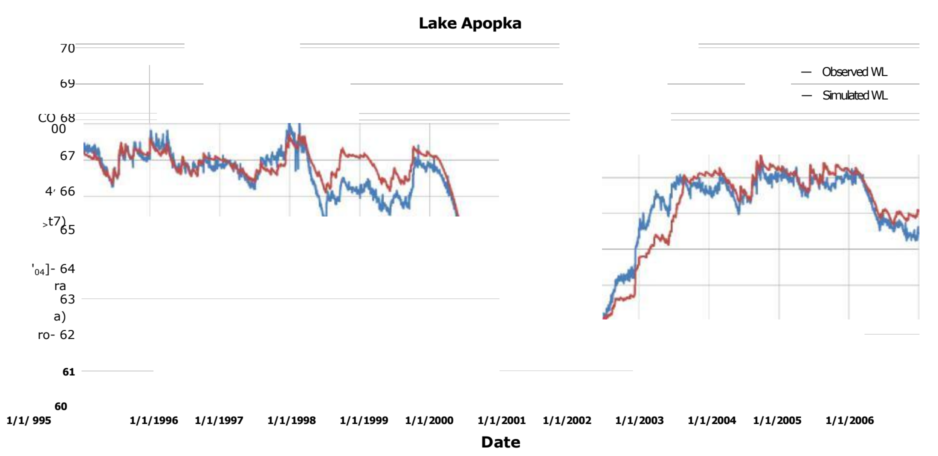


Figure 27. Lake Apopka simulated and observed daily water levels (1995-2006).

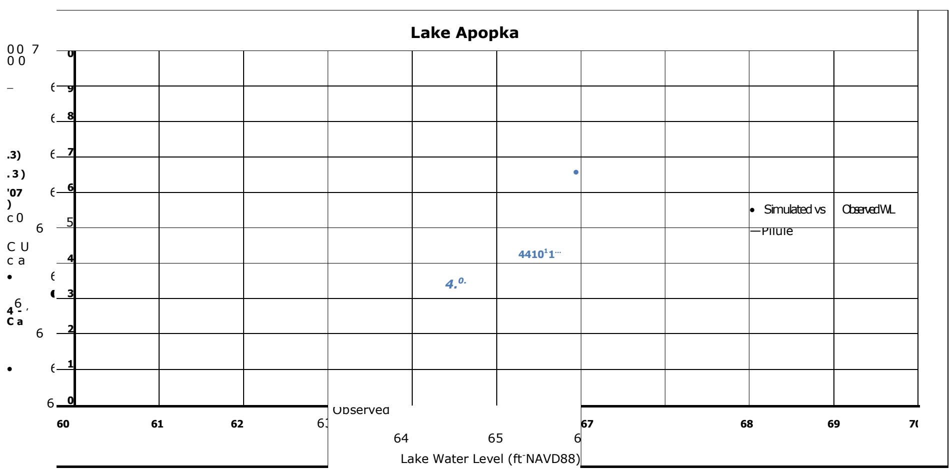


Figure 30. Scatter plot of simulated daily lake water level vs observed lake level during calibration period (1995-2006).

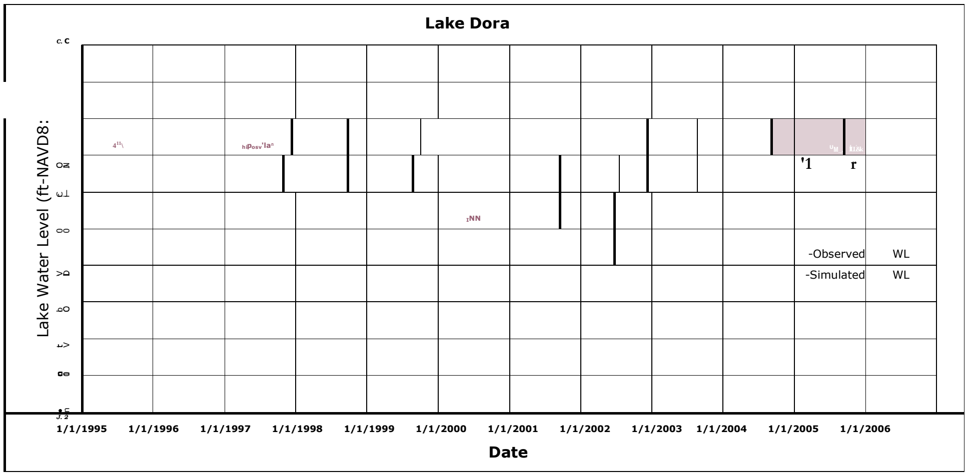


Figure 29. Lake Dora simulated and observed daily water levels during calibration period (1995-2006).

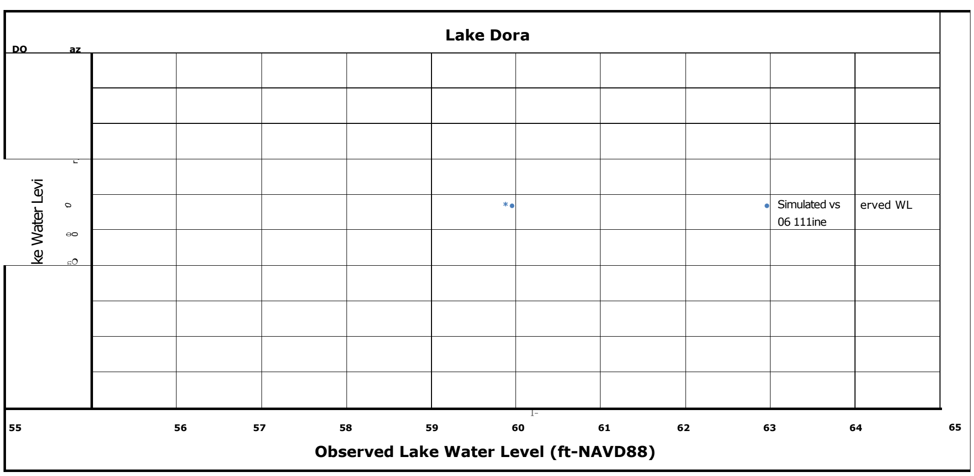


Figure 30. Scatter plot of simulated daily lake water level vs observed lake level during calibration period (1995-2006).

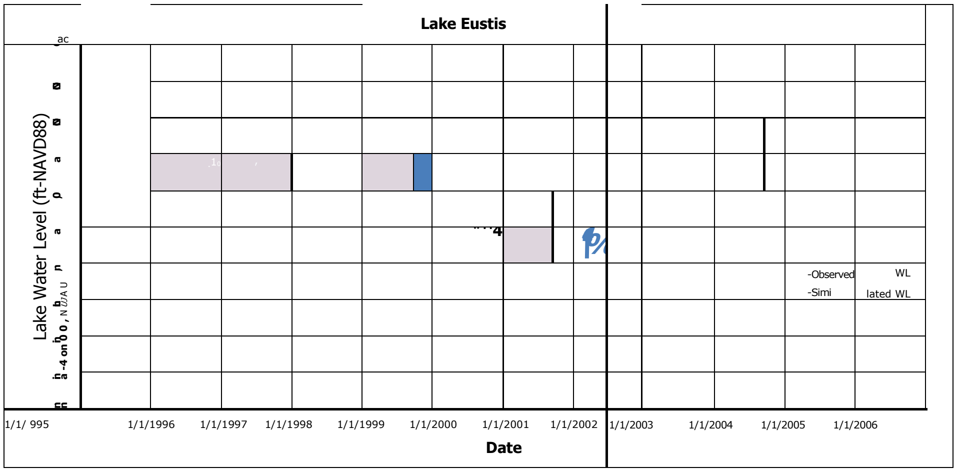


Figure 31. Lake Eustis simulated and observed daily water levels during calibration period (1995-2006).

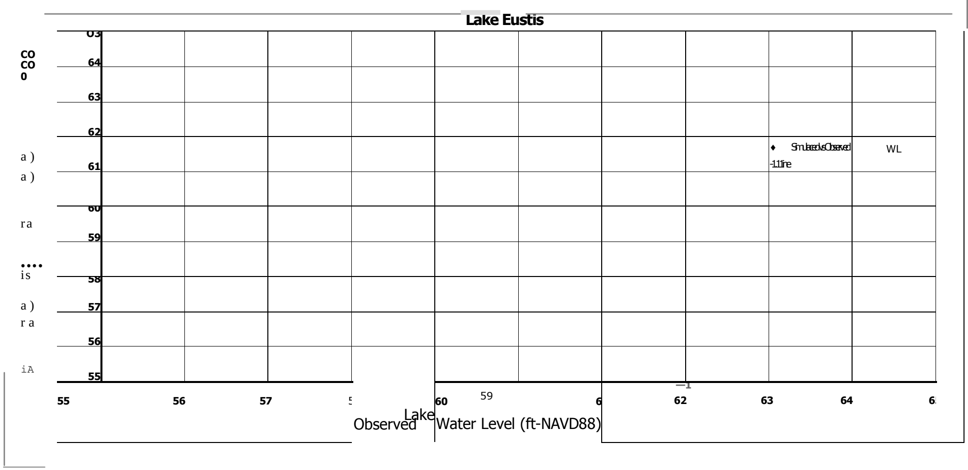


Figure 32. Scatter plot of simulated daily lake water level vs observed lake level during calibration period (1995-2006).

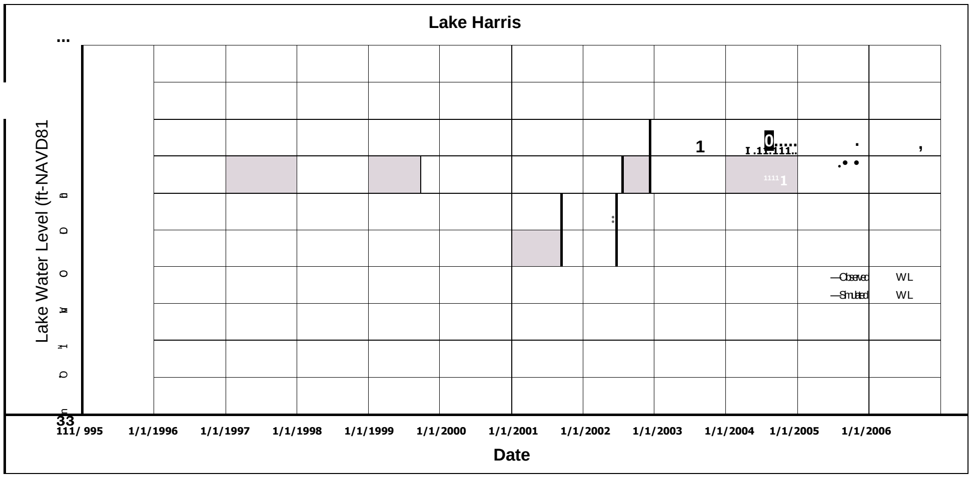


Figure 33. Lake Harris simulated and observed daily water levels during calibration period (1995-2006).

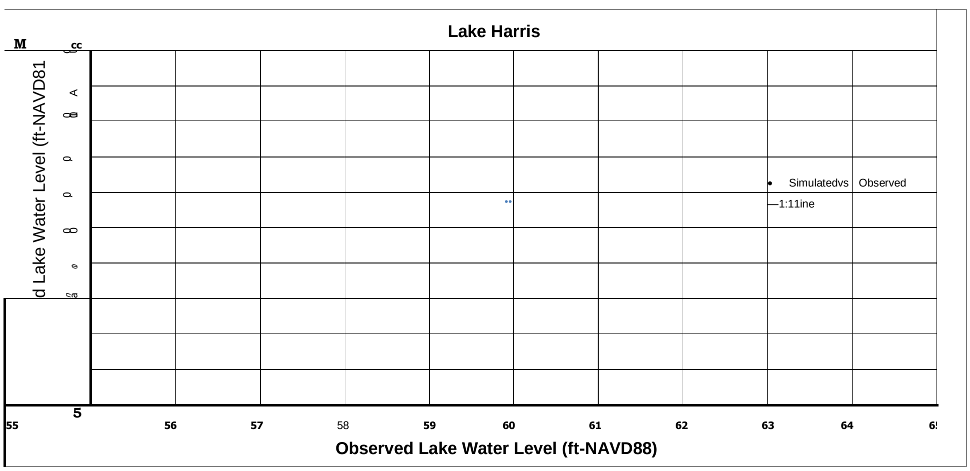


Figure 38.. Scatter plot of simulated daily lake water level vs observed lake level during calibration period (1995-2006).

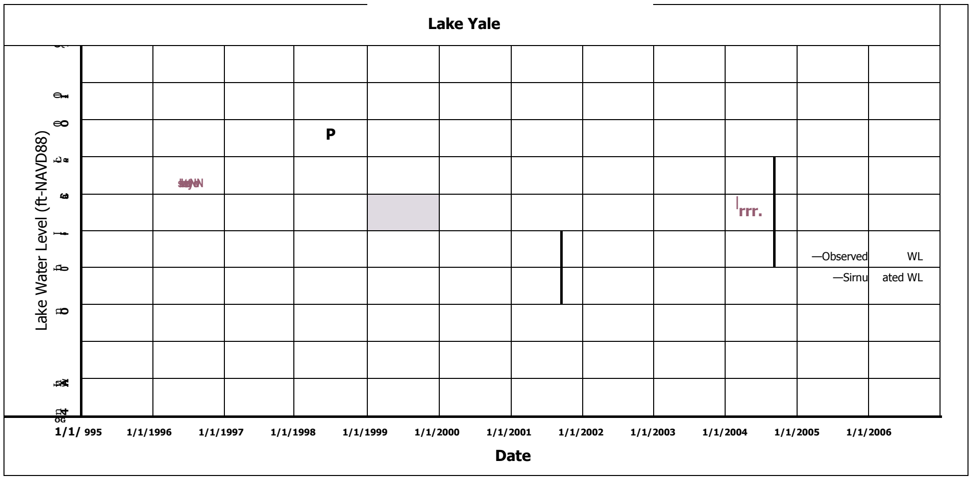


Figure 35. Lake Yale simulated and observed daily water levels during calibration period (1995-2006).

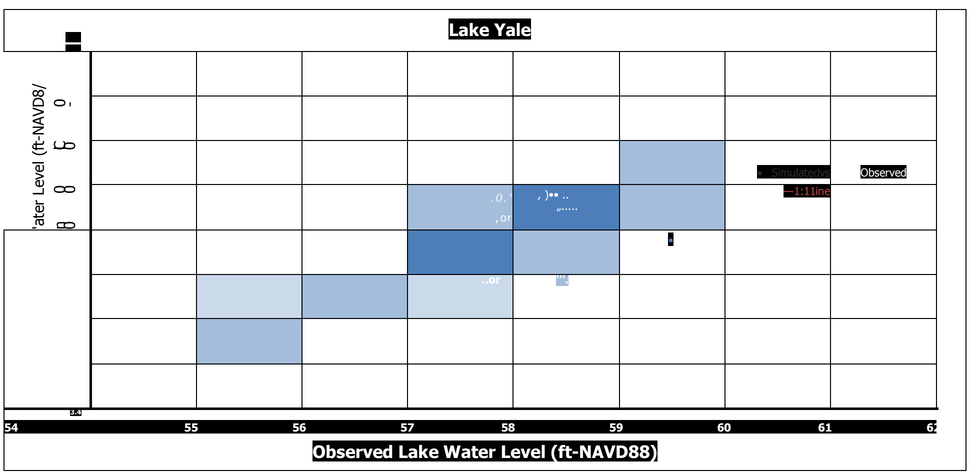


Figure 38.. Scatter plot of simulated daily lake water level vs observed lake level during calibration period (1995-2006).

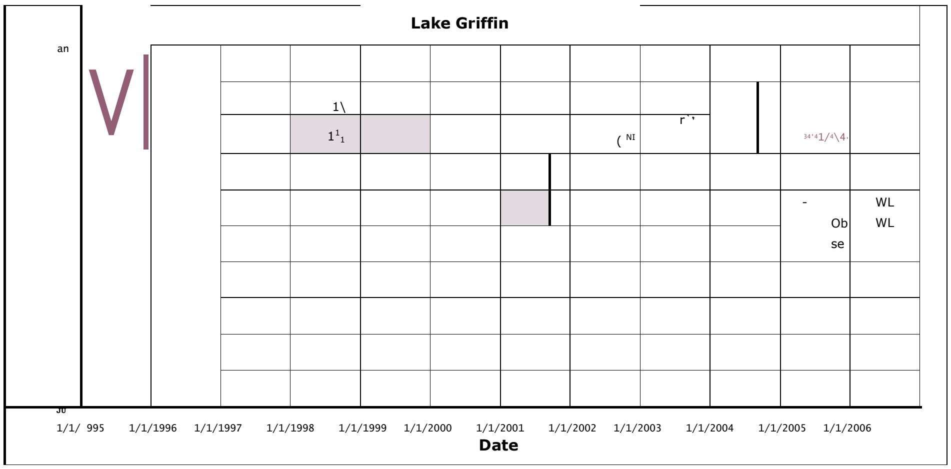


Figure 37. Lake Griffin simulated and observed daily water levels during calibration period (1995-2006).

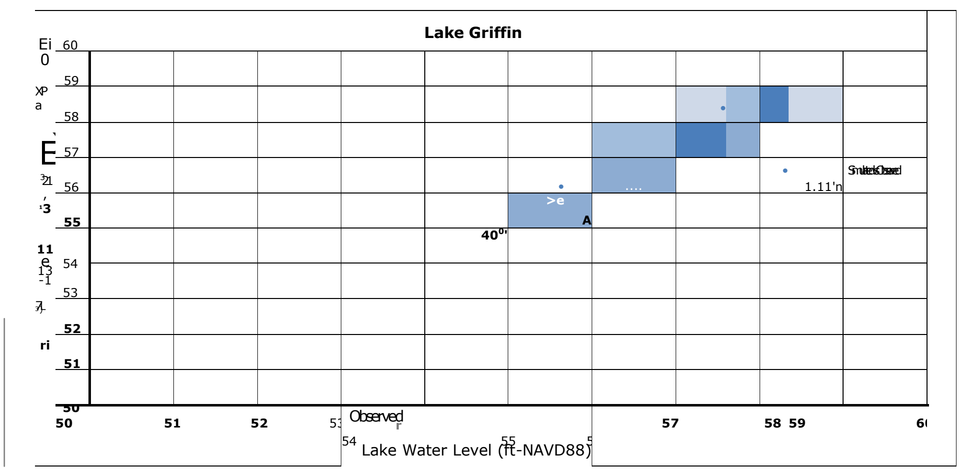


Figure 38.. Scatter plot of simulated daily lake water level vs observed lake level during calibration period (1995-2006).

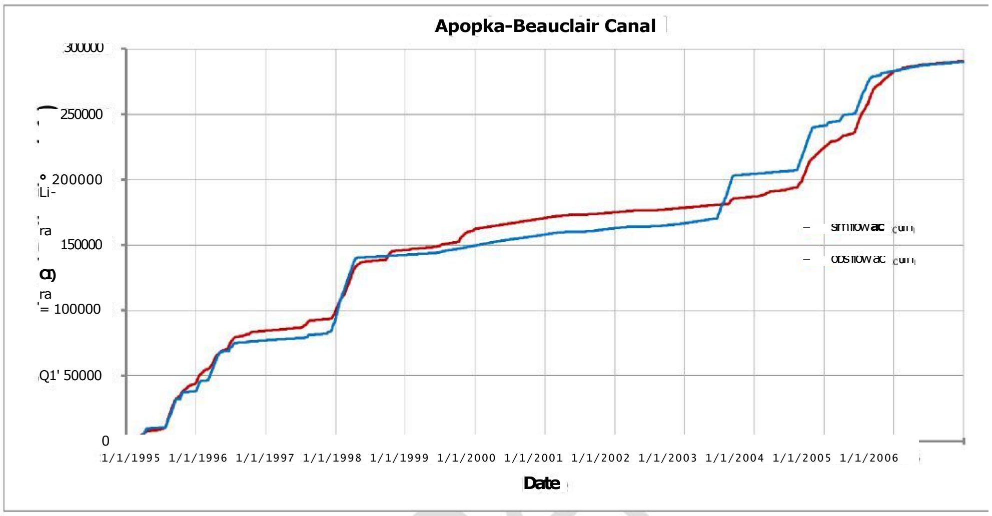


Figure 39. Accumulated simulated and observed daily flows (cfs) at Apopka-Becauclair Canal (1995-2006)

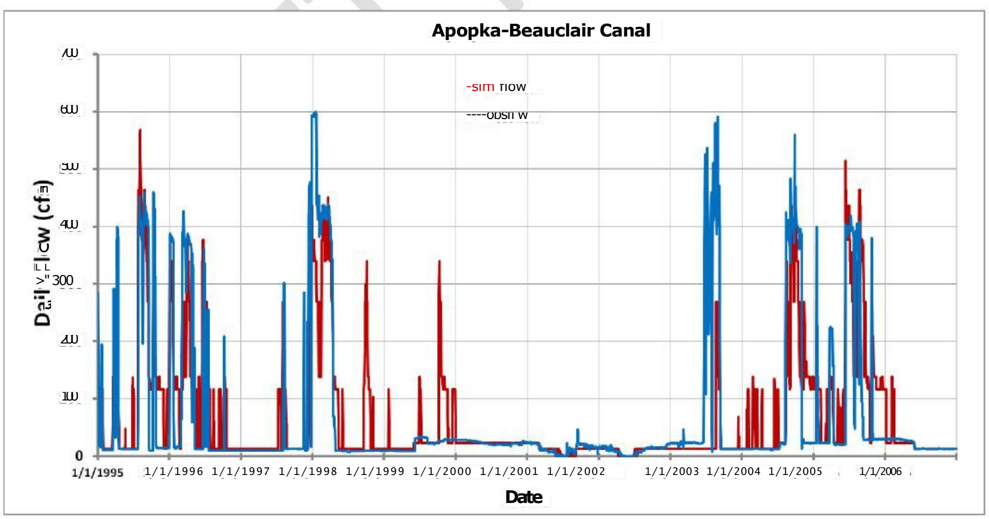


Figure 40. Simulated and observed daily flows (cfs) at Apopka-Becauclair Canal (1995-2006)

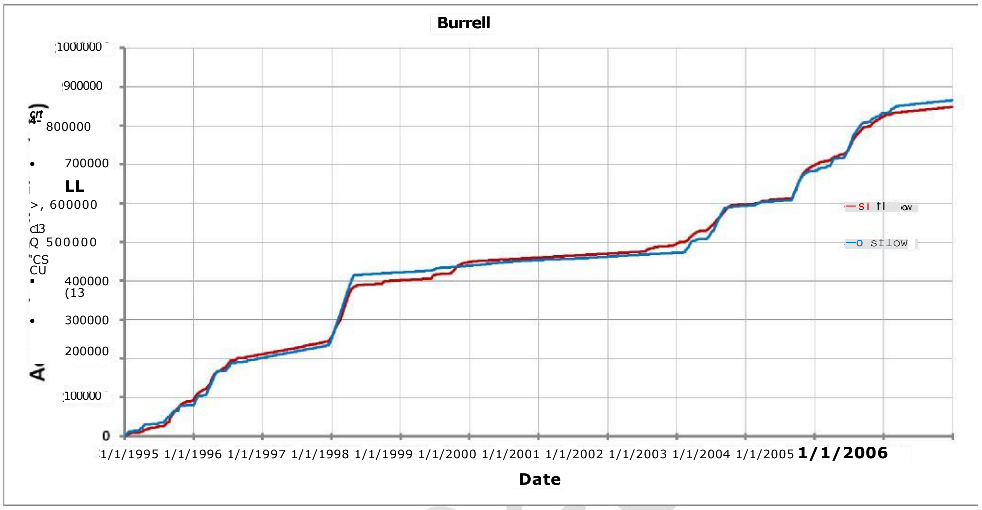


Figure 41. Accumulated simulated and observed daily flows (cfs) at Haines Creek, which connects Lakes Eustis and Griffin (1995-2006)

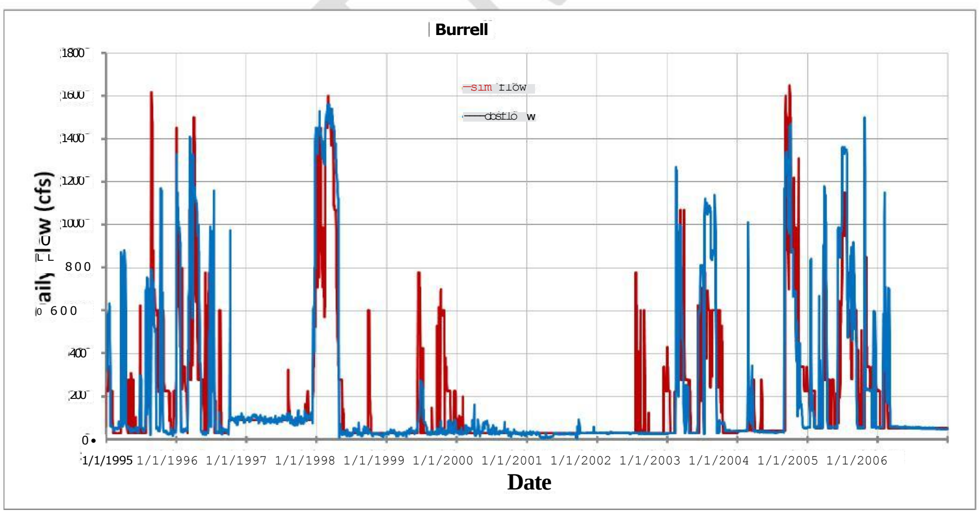


Figure 42. Simulated and observed daily flows (cfs) at Haines Creek, which connects Lakes Eustis and Griffin (1995-2006)

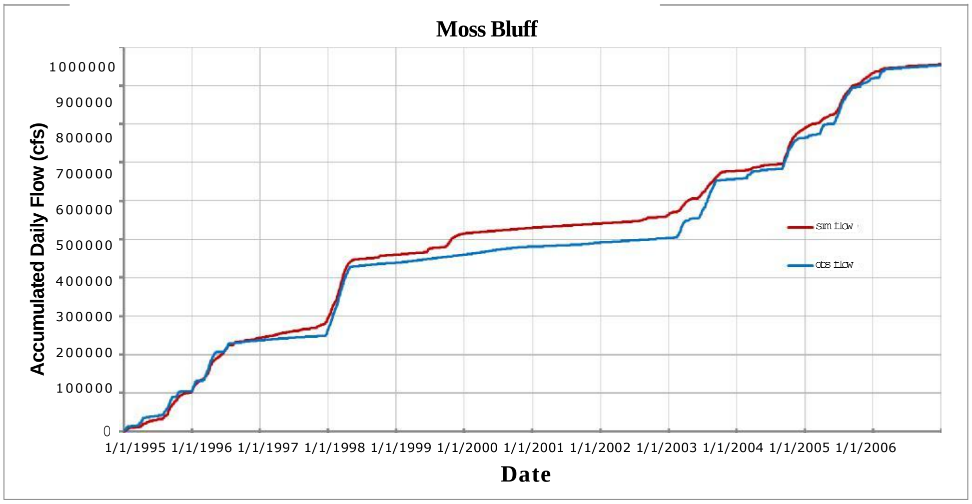


Figure 43. Accumulated simulated and observed daily flows (cfs) at Moss Bluff Lock and Dam, which is the final outlet of the Upper Ocklawaha River Basin (1995-2006)

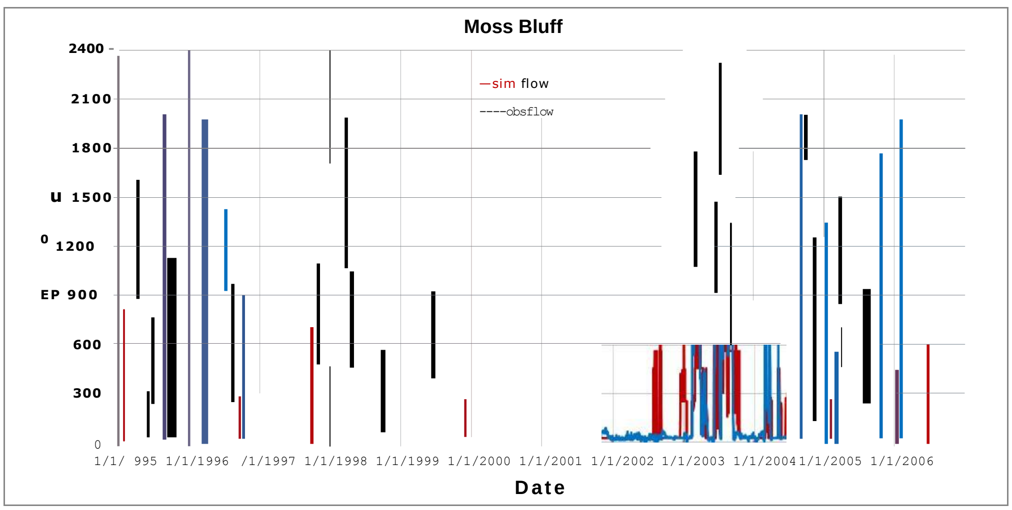


Figure 44. Simulated and observed daily flows (cfs) at Moss Bluff Lock and Dam, which is the final outlet of the Upper Ocklawaha River Basin (1995-2006)

7 LAKE WATER BUDGET ANALYSES

Water budgets were developed for Lake Apopka and the Ocklawaha Lakes using the LAUORB HSPF calibrated model results from 1995 to 2006. For each lake, a yearly average water budget ~~was~~ is shown in Figures 45, 47, 49, 51, and 53. Lake water budgets for a dry (Year 2000) and wet year (Year 2005) were shown in Figures 46, 48, 50, 52, and 54 to evaluate any hydrologic changes under dramatically different climate conditions. The actual yearly water budget data ~~were~~ are listed in~~at~~ Appended tables. *.1*

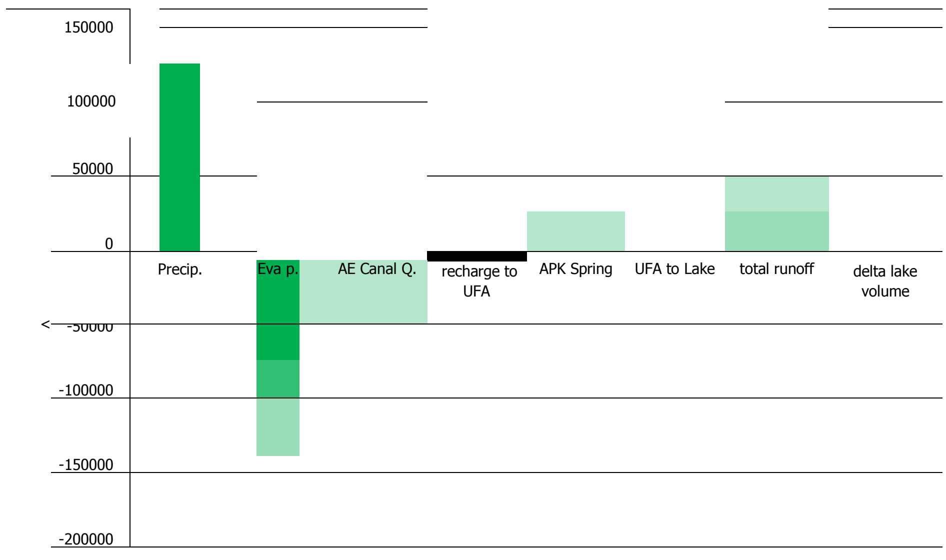
Generally speaking, recharge or discharge to or ~~/~~from the upper Floridan aquifer (UFA) are a small portion of water budget for all the lakes. However, in extreme drought, recharge can be a significant portion of the water budget. For example, in 2000 the amount of water Lake Apopka recharged to the UFA was greater~~higher~~ than the discharge through the Apopka-Beauclair Lock and Dam. However, in a wet year, recharge is not significant.

The dry/wet year water budgets demonstrate that as the headwaters of the Upper Ocklawaha River, Lake Apopka is different from the Ocklawaha Lakes with upstream water flows. For Lake Apopka, the rainfall shortage and spring flow reduction in dry year was mostly offset ~~in~~ by reduced lake water storage and ~~(~~declin~~e~~inge water levels~~)~~. ~~;~~ For the Ocklawaha Lakes, the rainfall shortage in dry years is offset by both reduced downstream flow as well as lake storage. This difference ~~Hence, this~~ partly explains why Lake Apopka water levels decline~~s~~ faster during~~in~~ dry years than in downstream lakes.

Comment [SBU145]: In the water-budget figures, define the abbreviated terms. I would start this section with the water-budget equation to define the terms used in the graphs.

I like these figures.

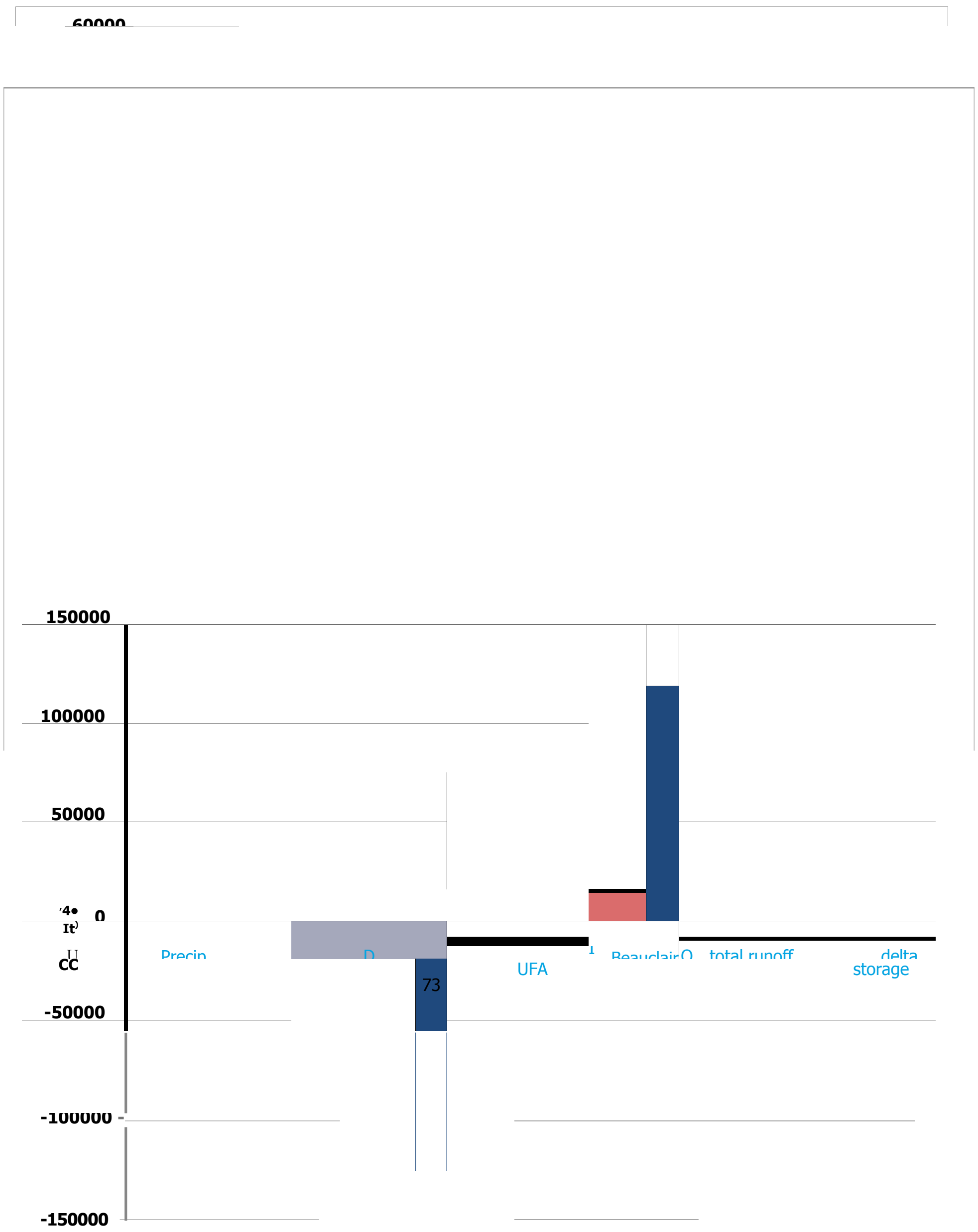
Comment [SBU146]: It appears that the appendices need to be numbered and cited by number.


150000
100000
50000
0
-50000
-100000
-150000
-200000
Precip.
Eva p.
AE Canal Q.
recharge to UFA
APK Spring
UFA to Lake
total runoff
delta lake volume


200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
Dry Year (2000, precip.:22.3 inches)
Wet Year (2005, precip.: 57.9 inches)
Precip.
A
rrge to UFA
APK Spring
UFA to Lake
total runoff
lake age

Figure 45. Lake Apopka average yearly water budget (1995 — 2006)

Figure 46. Lake Apopka water budget for dry/wet years


150000
100000
50000
0
-50000
-100000
-150000
73
UFA
storage

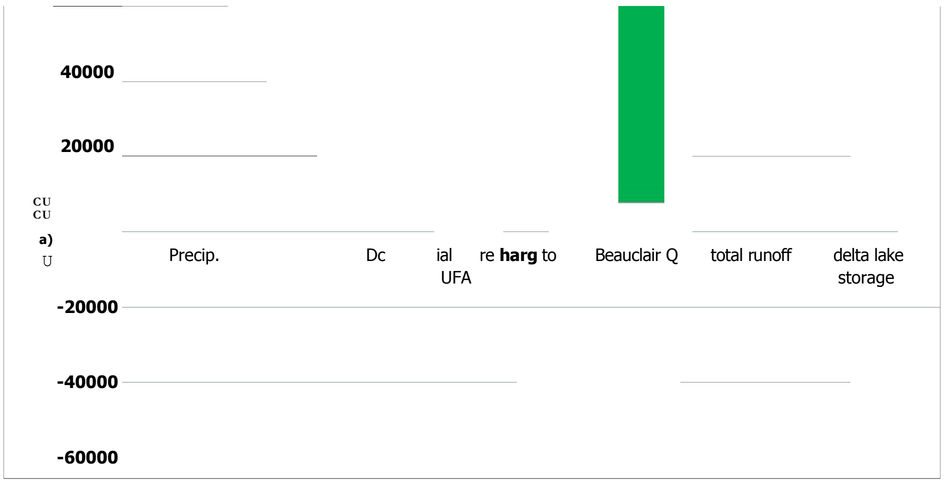


Figure 47. Lake Dora average yearly water budget (1995 — 2006)

Figure 48. Lake Dora water budget for dry/wet year.

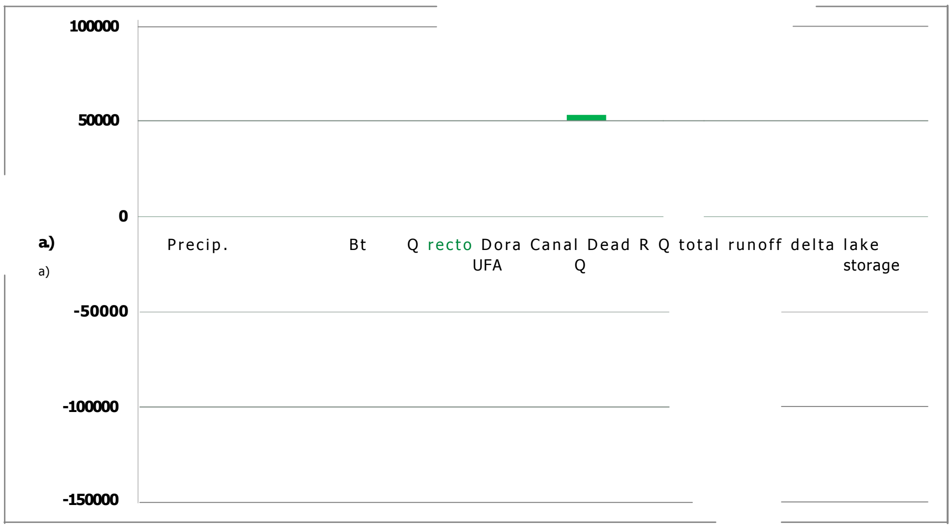


Figure 49. Lake Eustis average yearly water budget (1995 — 2006)

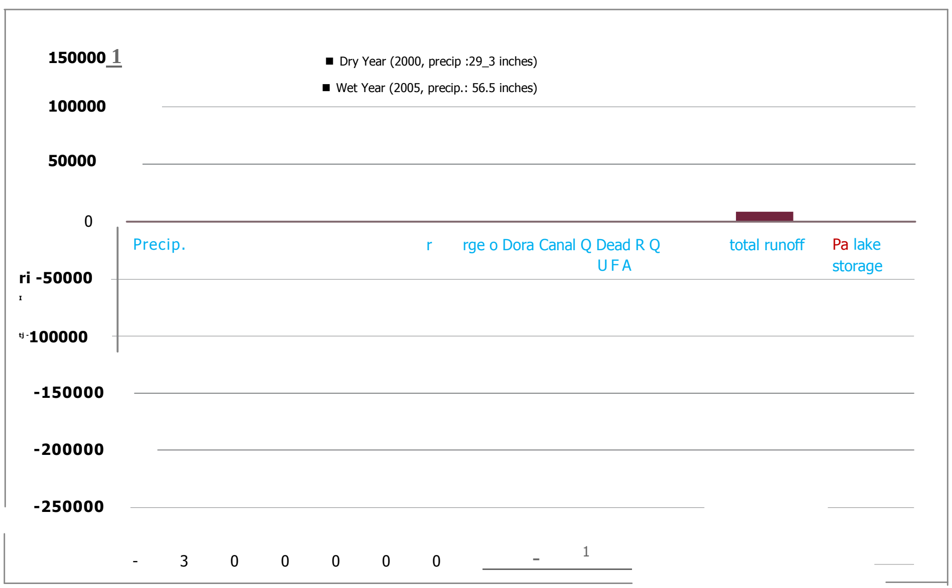


Figure 50. Lake Eustis water budget for dry/wet years

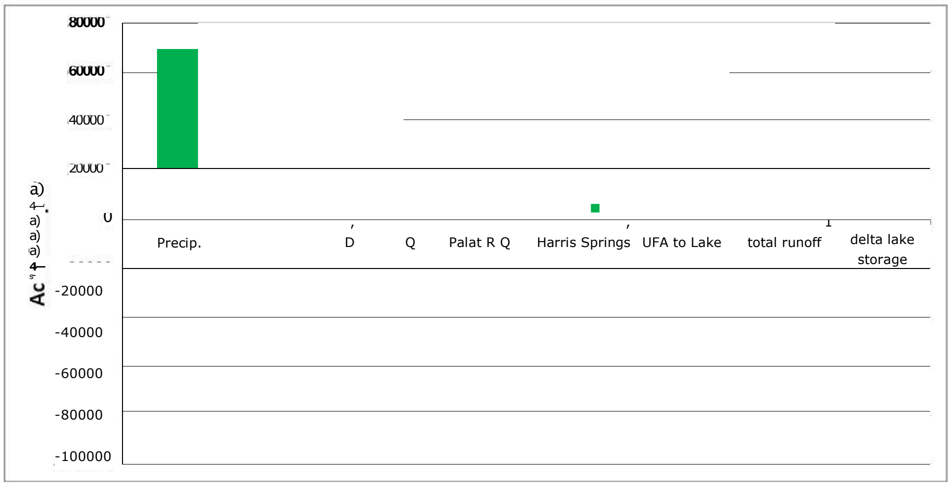


Figure 51. Lake Harris average yearly water budget (1995 — 2006)

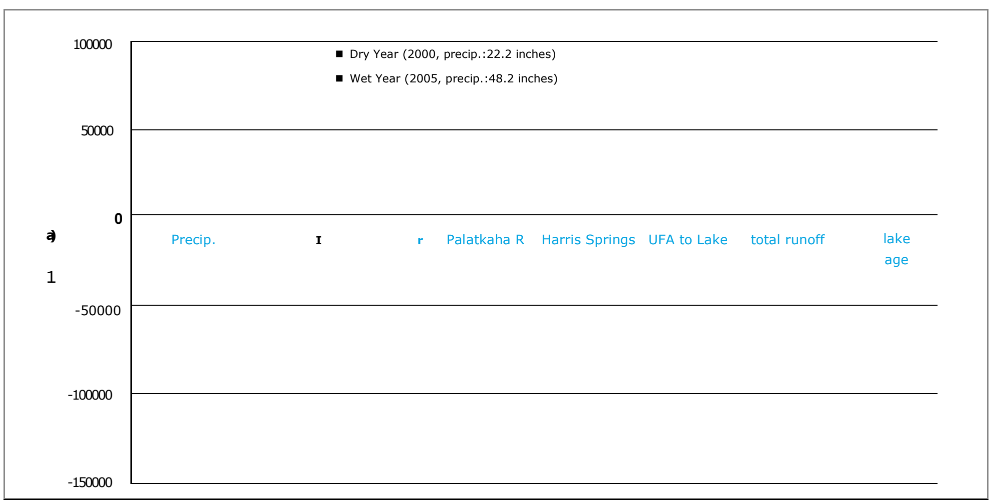


Figure 52. Lake Harris water budget for dry/wet years

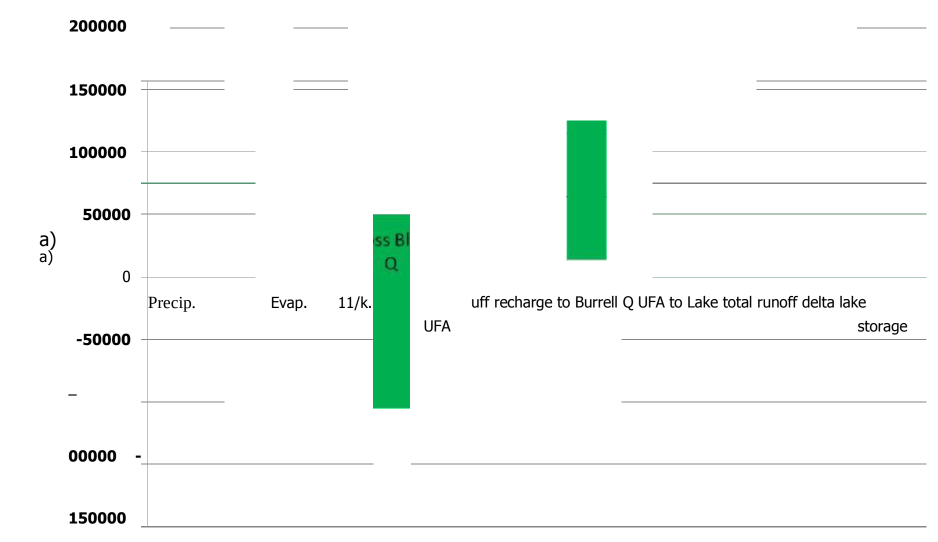


Figure 53. Lake Griffin average yearly water budget (1995 — 2006)

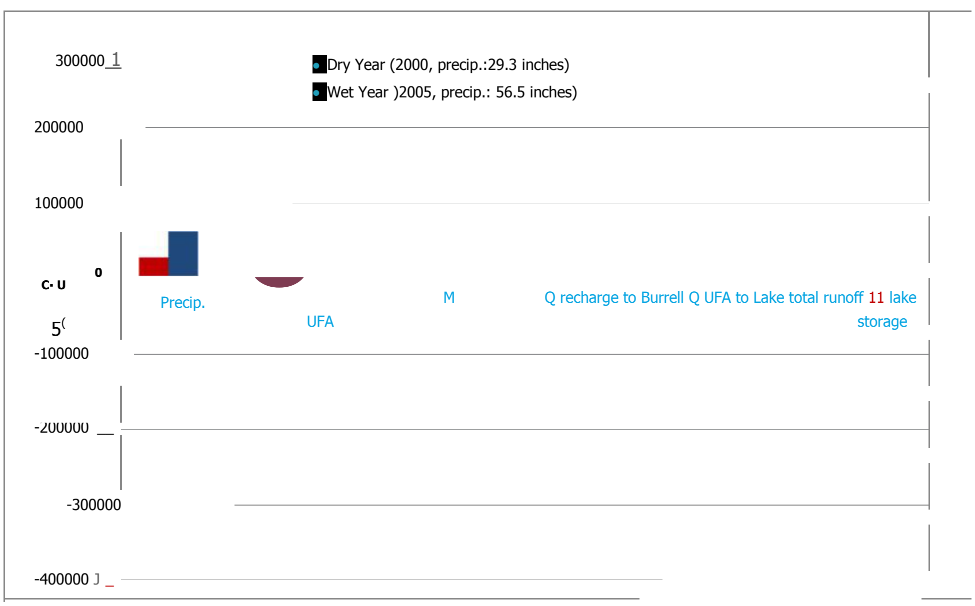


Figure 54. Lake Griffin water budget for dry/wet years

8 ASSESSMENT OF BASELINE HYDROLOGIC CONDITIONS FOR LAKE APOPKA AND THE UPPER OCKLAWAHA RIVER BASIN IN THE CONTEXT OF MFLs

8.1 INTRODUCTION

The SJRWMD MFLs program relies on results of long-term hydrologic simulations to determine if MFLs are being met based on current hydrologic watershed conditions. Once a hydrologic model is calibrated, the model is modified to simulate 30 to 50 years into the future. In this study, the LAUORB HSPF model is modified to simulate 48 years into the future staring from 2009. In the long-term simulation, the LAUORB HSPF calibration model is modified to reflect the baseline hydrologic conditions, such as most recent land use data, permitted consumptive uses, restoration, etc, while calibrated parameters remain the same as in the calibration model and input time series are extended for 48 years using historical rainfall and evaporation data. This long-term simulation provides the District a useful tool to evaluate if there are any hydrologic changes under the baseline conditions.

Simulated lake water levels are statistically analyzed to determine if the proposed MFLs ~~levels~~ are being met. It should be noted that a few assumptions are made in the model extension. These assumptions are: 1) anthropogenic changes will not significantly modify baseline conditions during the 48-year simulation period; 2) hydrologic characteristics of the basin will not change significantly during the simulation period; 3) input time series of historic data used in the extended model are~~is~~ ~~a~~ statistically realistic representations of the future hydrology and meteorology.

This section will document the assessment of the baseline hydrologic conditions for Lake Apopka and the Ocklawaha Lakes in the context of MFLs through long-term simulation. The following issues will be addressed:

- Extension of UORB HSPF model,
- Baseline hydrologic conditions for UORB in the context of MFLs, and
- Simulated lake stages under the baseline conditions.

8.2 EXTENSION OF UORB HSPF MODEL

Comment [SBU147]: You need to explain how historic rainfall data are projected into the future. Normally, this is done stochastically or by use of scenario modeling. It appears that you are simply running the historical data in a model calibrated to current conditions. This is not, in my opinion, forecasting; you are not projecting into the future. You are simply looking at the predicted historic flow or level regime given current hydrologic conditions.

Comment [SBU148]: Explain what this is. Do you insert planned restoration efforts?

Comment [SBU149]: I trust you will be explaining how this is done.

Comment [SBU150]: Repeat of L in MFL

Comment [SBU151]: Data is a plural word.

Comment [SBU152]: See comment above. Given what we know about climate change, AMOs, etc. there is no way that the historic data predict the future. This is dangerous. For example, Figure predicts a severe drought in 2033 and in 2052. Really?

You really need to develop a better explanation for use of historical data for MFLs and quit using the terms “future”, “extended”. etc. These terms are very misleading and far from correct.

Comment [SBU153]: To what? Into the future?

Extension of UORB hydrologic simulations from the calibration years (1995-2006) to long-term simulation (48 years) requires extension of many time series of input data: hourly rainfall and evaporation, daily spring flows for lake Apopka ~~Springs~~ and Harris s~~S~~prings, and lake bottom average UFA potentiometric surface levels. Extension of rainfall, evaporation, and spring flows are readily available within the District. The lake bottom average UFA potentiometric surface levels were estimated from nearby well data through MOVE-3 statistic method as described in the previous chapter.

Comment [SBU154]: Use of the word extension gives me significant heartburn. You do not have forecasts for these variables into the future. You are using historical data under the assumption that the same regimes will be repeated with the same frequencies in the future, if you are truly extending into the future. It appears to me that you are simply developing a simulated regime based on historical climatic data and current physical hydrologic conditions.

Unless you are truly forecasting conditions, you should not use the words extension or future.

8.3 LAND USE CHANGE

The calibrated UORB HSPF model is based on 1995 land use since the calibration period is from 1995 to 2006. The extended long-term model needs to use the most recent land use data that ~~is~~ are available for the UORB, which is 2009 land use.

Comment [SBU155]: See previous comments

Harris Bayou was constructed by the District in 2008 to directly connect Lake Harris with Lake Griffin for additional discharge capacity to Lake Griffin when Haines Creek ~~is~~ reaches~~ing~~ its flow capacity. The completion of Harris Bayou changed the hydrology of the Lake Harris and Lake Griffin basins, i.e., Harris Bayou sub-basin was part of Lake Harris basin in the calibration model while in the long-term MFLs model the 1914 acres of the Harris Bayou sub-basin became part of the Lake Griffin basin. Hence, this sub-basin was subtracted from the Lake Harris basin and was added to the Lake Griffin~~m~~ basin in the UORB MFLs HSPF model. Since Harris Bayou was completed in 2008, it has not been operational except under experimental conditions~~operation~~ due to: 1)~~.~~ w~~W~~ater quality issues inside the bayou, especially high sediment phosphorus concentrations~~ in the sediment~~, and ~~;~~ 2)~~.~~ s~~S~~o far there has been no need to discharge through Harris Bayou. Given that the District has not started to operate the bayou and will not routinely operate it, it wa~~i~~s decided that the bayou would ~~is~~ not be operated in the baseline condition model.

Comment [SBU156]: The more I think about it, the long-term model is a better term than extended long-term. If you explain how the long-term model differs from the calibrated model through incorporation of historical data to generate a flow and/or level regime over a longer period of time in order to capture extreme events, etc., this discussion will make more sense.

In my mind, use of the long-term historical data allows for incorporation of extreme events, AMO cycles, etc. into a flow/stage regime. These data do not predict the future, they only offer the possible range and frequency of events assuming that there are no changes in climate.

Comment [SBU157]: Again, do not assume that the reader will understand this terminology. Explain the baseline model and scenarios to be run for permitting and outcomes evaluations.

8.4 LAKE APOPKA NORTH SHORE RESTORATION AREA

In the calibration model the North Shore Restoration Area of Apopka (NSRA; Figure 55) was modeled as an upland watershed, and flow was routed to the lake. In the baseline conditions, the NSRA~~orth shore~~ is represented as a managed shallow marsh using pumps to remove excess water to Lake Apopka when necessary. The watershed north of the NSRA is routed into the managed marsh. The City of Apopka will also withdraw surface water from the ~~North~~ NSRA~~Shore~~.

The NSRA has been under dynamic and active management since the District obtaine ownership of the ~~bought out~~ muck farms during the 1990s. As of 2014, all phases in NSRA have been approved for being flooded and

Comment [SBU158]: Explain, areas?

restored as wetlands. However, details of managing water levels within each phase and among phases to meet wetland criteria have not been finalized by District's environmental scientists. Hence, detailed the NSRA configuration is simplified into one big storage area~~box~~ by leveling and combining Phases 1 through 8. The stage-area-storage relation is shown in **Table 19.** Under baseline conditions simulation, when water depth in this box exceeds 2 ft, Unit 1 Pump with 33 cfs capacity will pump water to Lake Apopka; when water depth exceeds 3 ft, additional Unit 2 Pump will kick in to pump water to Lake Apopka which brings total pumpage to 133 cfs. This setup will allow NSRA to keep some water for wetland vegetation establishment while pumping water back to Lake Apopka when NSRA water depth is more than 2-3 ft high.

Comment [SBU159]: I hope the box stays dry. Reports are hard to read when they are wet. Use a better word, such as "in the NSRA"

Duda block (Figure 55) is simulated separately from NSRA. When its water level exceeds 62 ft, a 55-cfs pump will pump water to Lake Apopka so that its water level will never exceed~~top~~ 64 ft for levee safety as well as for wetland vegetation establishment.

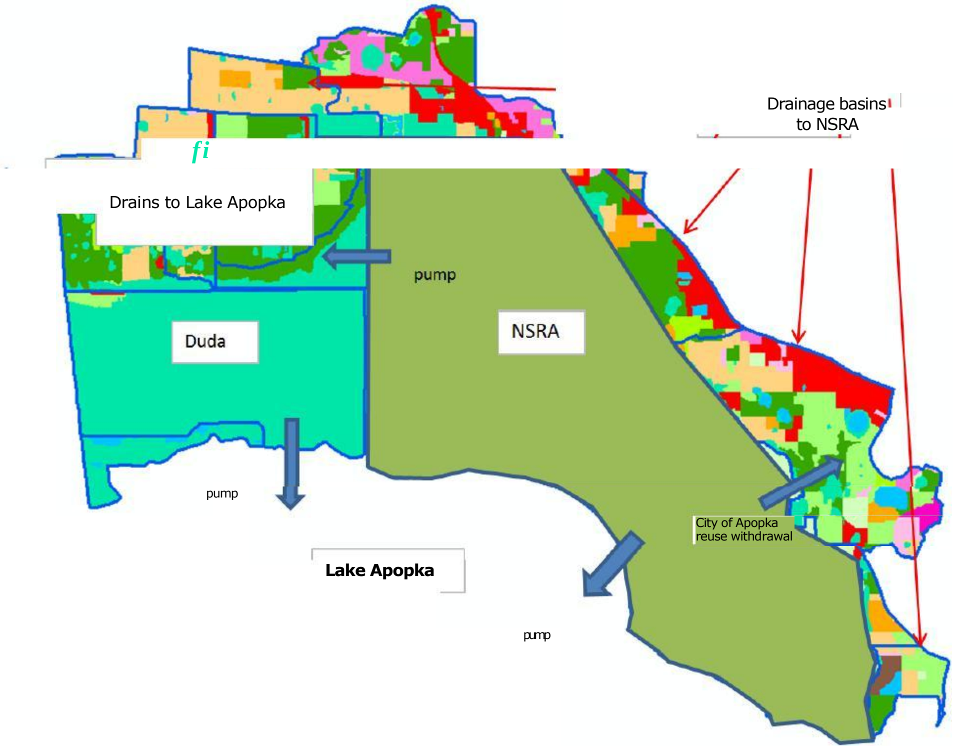


Figure 55. NSRA configuration under baseline conditions

Table 19. Stage-are.-storage relationship for simplified NSRA configuration under baseline conditions. Phases 1- 8 are rnrnhirmd into one storage box by leveling all phases.

Stage (ft)	acres	acre-feet
0	0	0
0.5	195.9	44.1
1.0	1472.4	461.2
1.5	3327.9	1661.3
2.0	4562.5	3633.9
2.5	5608.2	6176.5
3.0	6562.8	9219.3
3.5	7075.3	12628.8
4.0	7508.9	16274.9
4.5	7792.2	20100.1
5.0	8011.8	24051.1
5.5	8140.9	28089.3
9.0	8754	57655.4

8.5 SURFACE WATER CONSUMPTIVE USE

There are many surface water consumptive use permits~~,~~ which allow ~~directly~~ withdrawal of water directly from lakes or canals connected with lakes (**Table** 20). In the baseline conditions simulation, the current average reported water uses for 1999-2013 were used (**Table** 21). However, permit 102497, which permits the City of Apopka to withdraw up to 5 MGD (daily average) water from the Lust/Pole Road canal in the NSRA for supplemental residential use, is simulated in baseline conditions since the infrastructure to pump up to 5MGD NSRA water is under active construction and expected to be finished by the end of this year. The withdrawal of 5 MGD water is simulated when Lake Apopka level is above 65.15 ft-NAVD88.

Comment [SBU160]: Important to state that the model is based on permitted withdrawal amounts, not actual use amounts. Withdrawals are typically seasonal or driven by needs. You need to explain how/why the temporal variations were not included in the model and how use of average withdrawals affects the model results. Point out that this is a worst-case model when the maximum permitted amounts are used. Again, incorporation of a sensitivity analysis based on variations of the withdrawal amounts used in the model will be important.

Table 20.Surface water Consumptive use withdrawals from water bodies

Water Body	Permit Number	Surface water Source	End-of-permit (MGD)
Lake Apopka			
	3291	Lake Apopka	0.038
Lake Beauclair/Dora			
	65573	Apopka Beauclair Canal	0.115
	2484	Canal (connected to Apopka Beauclair)	0.108
	71411	Canal (connected to Lake Beauclair)	0.030
	6320	Lake Dora	0.345
	85182	Lake Dora	0.049
Lake Eustis			
	91079	Lake Eustis	0.004
Lake Griffin			
	279	Lake Griffin	0
	2894	Lake Griffin	0.020
	124036	Lake Griffin	0.408
Lake Harris			
	2664	Lake Harris	0.235
	2665	Lake Harris	0.092
	2843	Lake Harris	0.225
	50243	Lake Harris	0.169
	135453	Little Lake Harris	0.109
Lake Yale			
	2508	Lake Yale	0.142
	2620	Lake Yale	0.065
Holly/Ella			
	2988	Holly Lake	0.022
	3006	Ella Lake	0.068
NSRA			
	102497	North Shore Restoration Area Unit 2	5

Table 21. Average surface water consumptive use withdrawals from each lake, reported for 1999-2013 in cubic feet per second; and End-of-permit capacity

Water Bodies	Average current water withdrawals (1999-2013, cfs)	End-of-Permit surface water withdrawal (cfs)
Lake Apopka	0	0.06
City of Apopka Withdrawal from NSRA	0	7.75
Lake Beauclair/Dora	0.67	0.96
Lake Eustis	0.04	0.01
Lake Harris	0.55	1.29
Lake Griffin	0.71	0.85
Lake Yale	0.16	0.32
Lake Ella/Holly	0.02	0.14

8.6 SIMULATION RESULTS UNDER BASELINE CONDITIONS

The baseline conditions are simulated for 48 years into the future. The simulated hydrographs of lake levels for Lakes Apopka, Eustis and Griffin are shown in **Figure 56.** The lake stage duration curves are shown in **Figure 57 through Figure 59.** These results will be processed by a MFL statistic program developed by the SJRWMD MFL program to assess if the proposed MFLs are met under the existing conditions. A separate study/report will document assessment results for the proposed LAUORB MFLs, freeboard analyses, and prevention or recovery strategies if there are needed.

Comment [SBU161]: This concept gives me much angst. You are not really forecasting into the future, you are recreating the past water levels and flows assuming current conditions and maximum permitted withdrawals. As such, the following flow/stage duration curves are not projections, they reflect the modeled historical lake behaviors assuming current physical conditions and worst-case withdrawals.

The minute rainfall or some other input variable differs from the historical pattern, those who want to dispute the MFLs will have an argument if the results are cast in terms of the future.

Comment [SBU162]: Are there only going to be MFLs for the three lakes shown here?

Comment [SBU163]: Is there a reference for this? I realize that this will be covered in a separate report.

Comment [SBU164]: This is a style comment, but the report just stops here. I feel that there should be some elaboration on the next steps in MFL development (the process of setting the MFLs) and a concluding statement.

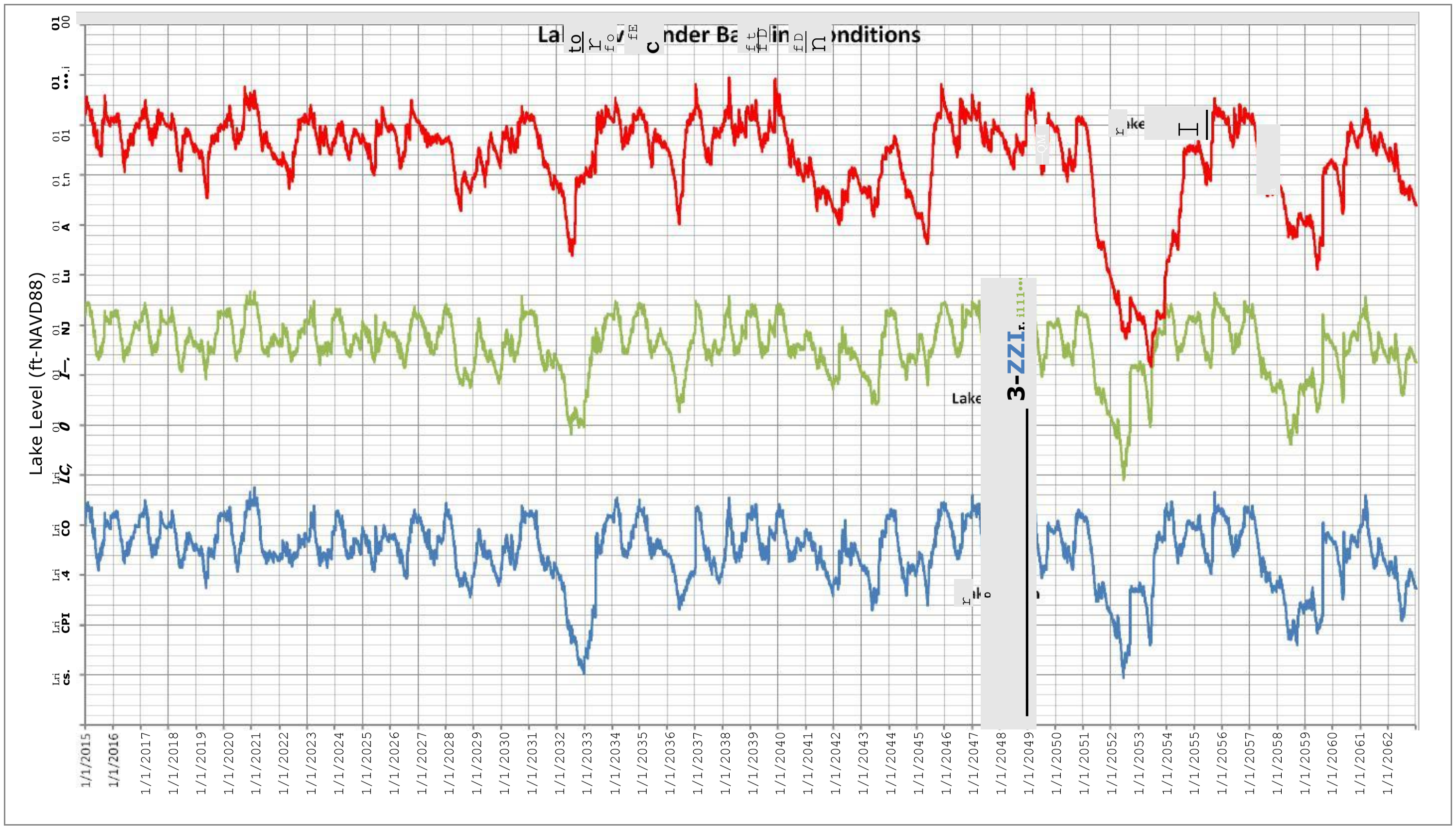


Figure 56. Long-term lake level simulation of Lakes Apopka, Eustis and Griffin under baseline conditions for 48 years Into future.

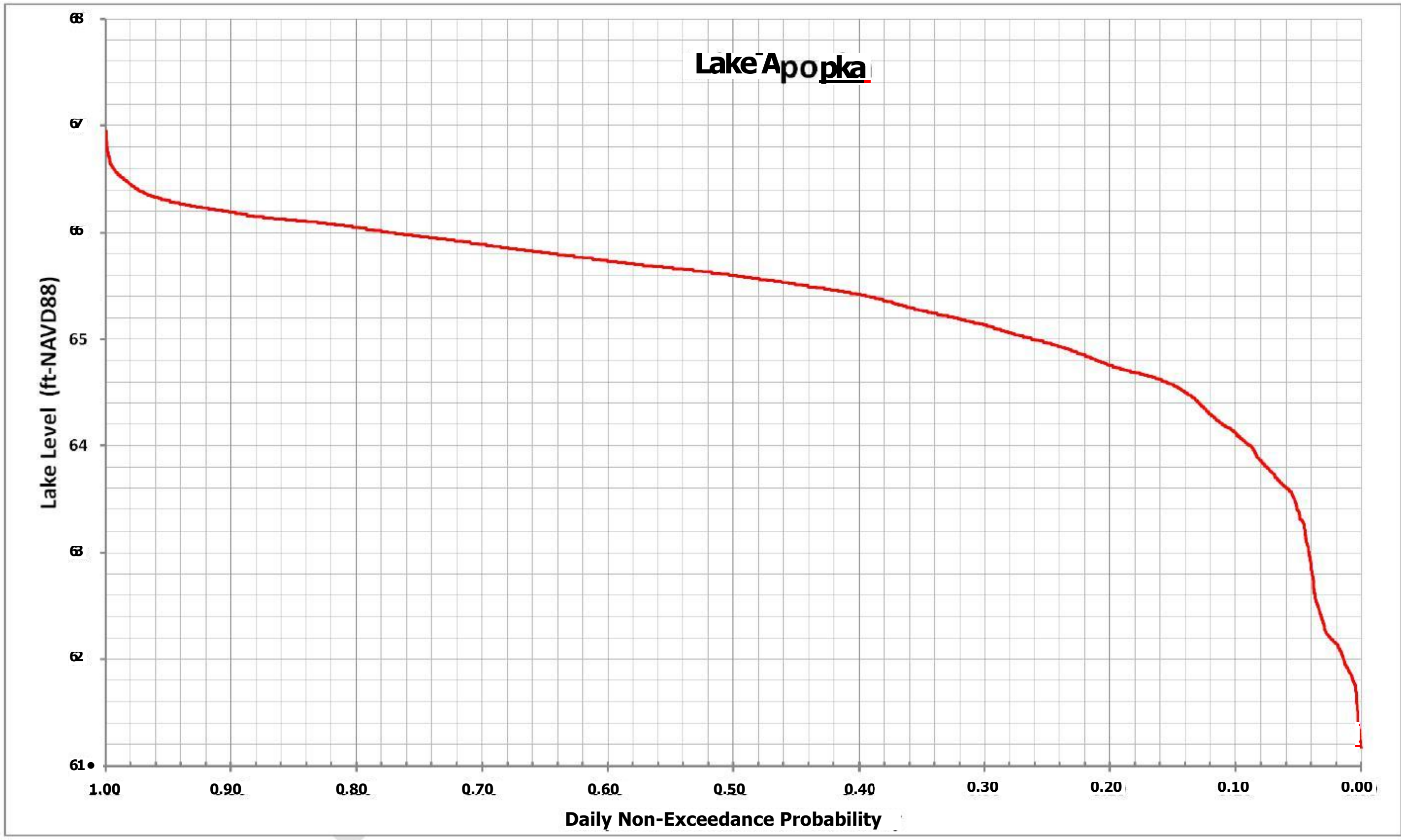


Figure 57. Simulated daily Apopka lake level frequency curves under baseline conditions

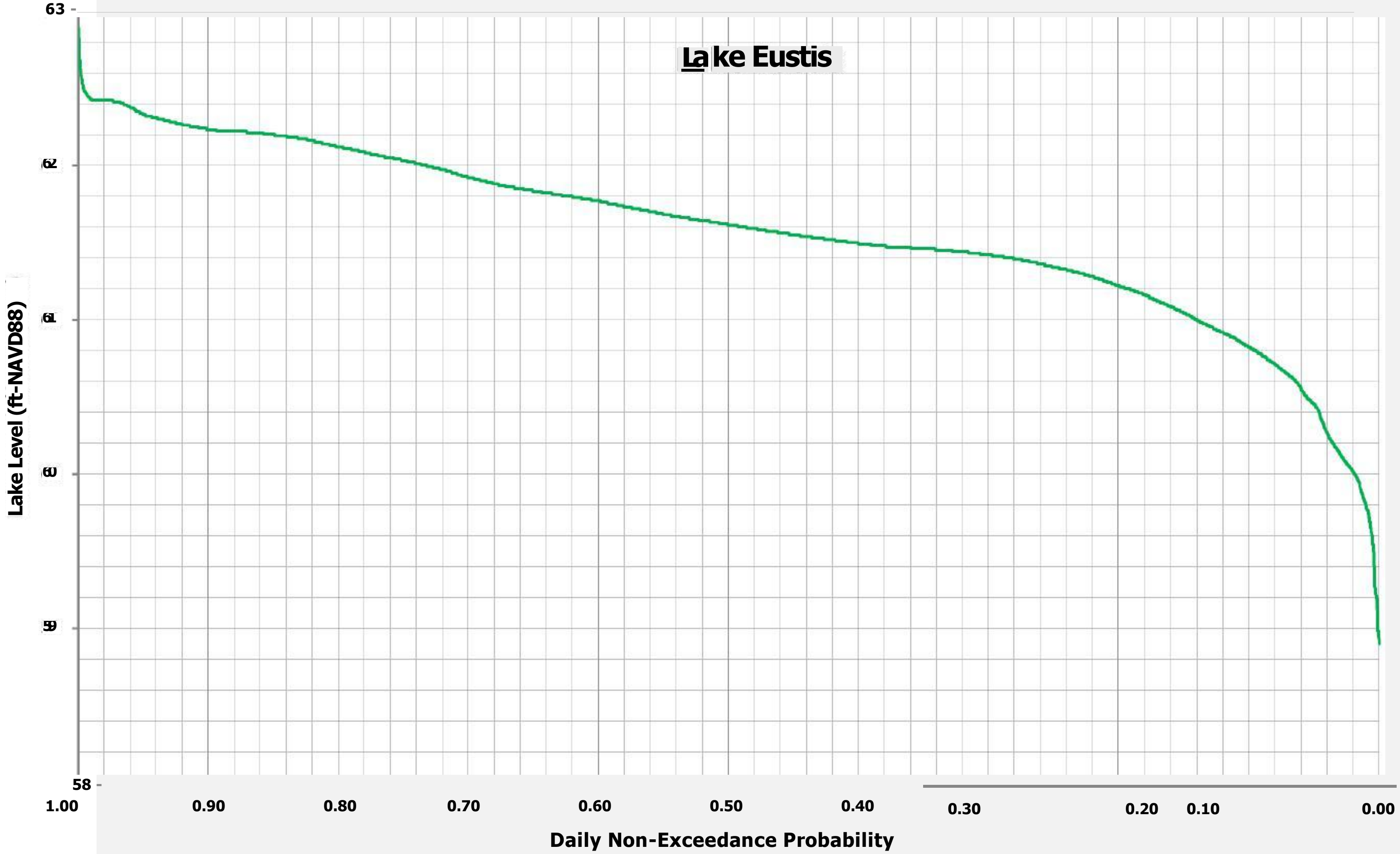


Figure 58. Simulated daily Eustis lake level frequency curves for Lake Eustis under baseline conditions

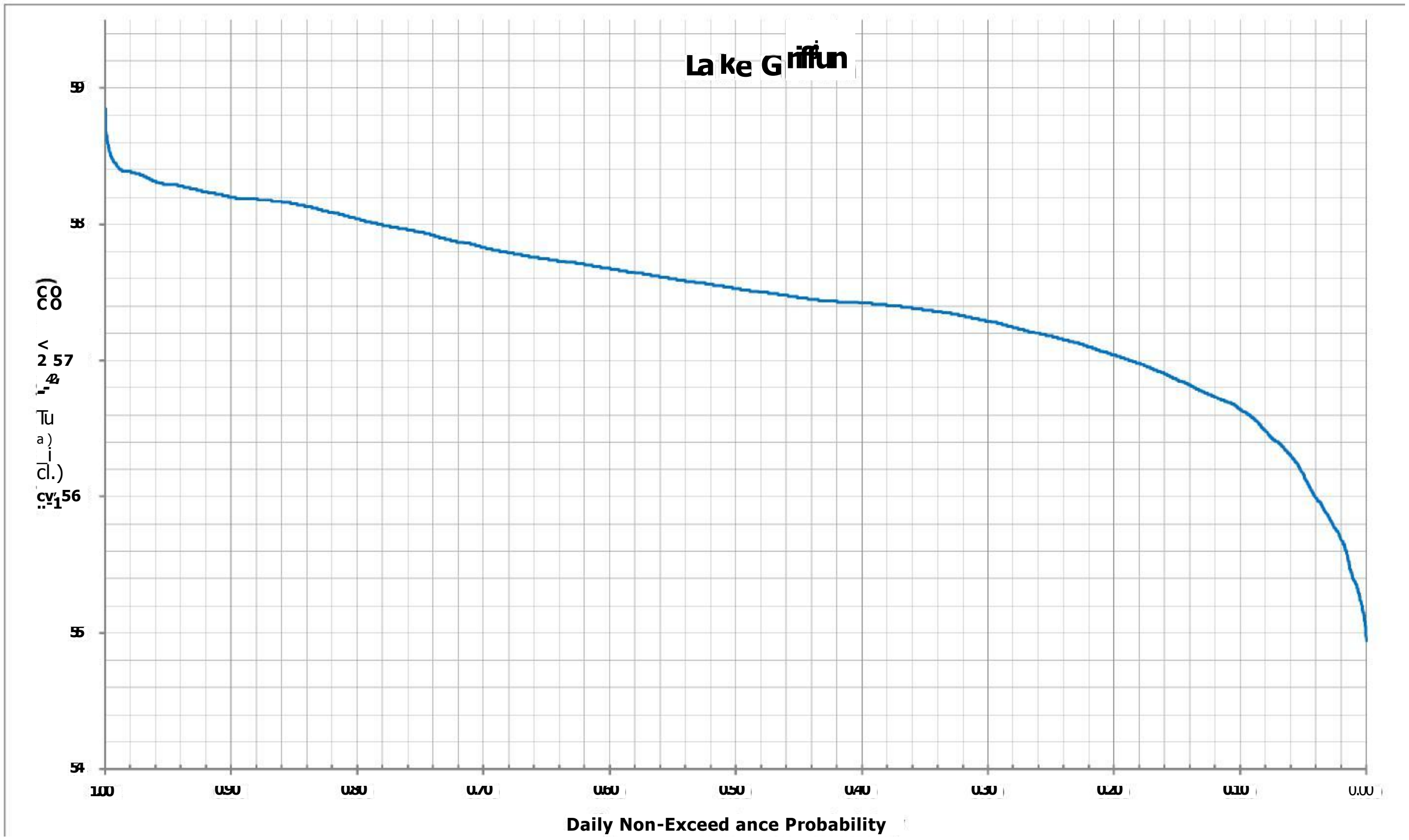


Figure 59. Simulated daily Griffin lake level frequency curves for Lake Griffin under baseline conditions

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Comment [SBU165]: Reference citations need formatting and some, like this one, are incomplete.

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10 APPENDICES

Table 22. Listings of annual mean spring flows (cfs)

Comment [SBU166]: The text simply says that these tables are in the appendix. I would either give each table a separate appendix number or letter or cite the table numbers used herein. In the text, the references to the appendices should be specific.

Year	Apopka Spring	Harris Springs
1964	29.6	18.4
1965	29.5	18.4
1966	29.7	18.4
1967	29.3	18.4
1968	28.3	18.4
1969	29	18.4
1970	31.2	18.4
1971	30.5	18.4
1972	28.9	18.4
1973	29.2	18.4
1974	29.5	18.4
1975	29.3	18.4
1976	29.4	18.4
1977	29.1	18.4
1978	28.8	18.4
1979	28.5	18.4
1980	28.7	18.4
1981	27.5	18.4
1982	27.9	18.4
1983	30.3	18.4
1984	30.5	18.4
1985	28.7	18.4
1986	29.3	18.4
1987	30.1	18.4
1988	30.4	18.4

1989	29.8	18.4
1990	29	18.4
1991	28.8	19.9
1992	28	15.6
1993	29	16.5
1994	28.8	17.6
1995	31.2	21.2
1996	32.1	23.2
1997	29.4	18.1
1998	32.2	22.7
1999	28.4	17
2000	26.5	14.1
2001	23.9	13.9
2002	25.4	16.7
2003	27.7	22.1
2004	27.5	21.4
2005	28.1	22.5
2006	26.9	18.7
2007	25	15.7
2008	25.1	17.9
2009	25.7	17.9
2010	25.6	18.4
2011	23.8	15.5
Mean	28.6	18.4

Table 23. Listings of annual rainfall and ET used in the model

Year	Leesburg Annual Rainfall	Lisbon Annual Rainfall	Isleworth Annual Rainfall	Clermont Annual PET	Lisbon Annual PET
1964	54.2	51	56.5	51.4	53.2
1965	44.5	49.7	46.3	51.7	54.0
1966	49.3	50.6	58.8	49.7	52.2
1967	37.3	40.6	42.9	52.7	55.3
1968	53.3	51.7	45.5	51.3	54.3
1969	59.7	53.1	67.1	48.8	52.2
1970	39.9	36.3	41.7	51.8	53.5
1971	46	42.5	52.5	52.0	55.3
1972	50.2	46.2	49.5	51.5	54.7
1973	59.7	52	46.1	50.7	53.4
1974	45.5	44.1	54.1	51.5	54.8
1975	54.9	45.4	54.2	52.1	55.2
1976	63.8	48.6	43.9	51.2	53.9
1977	37.8	40	38.5	52.1	55.6
1978	42	46.6	47.9	51.1	55.9
1979	60.1	57.5	58.7	50.5	54.0
1980	40.2	42.6	35.5	51.5	53.8
1981	42.3	34.4	50	53.4	55.7
1982	67.2	62.7	67.5	50.8	52.9
1983	61.2	53.2	60	48.5	51.3
1984	36.8	45	41.8	54.1	52.9
1985	43.9	39.7	54.2	53.9	53.8
1986	49.3	43.8	51.3	51.8	54.3
1987	50.3	47.2	67.1	50.6	52.6
1988	48	51.6	62.1	50.6	52.9
1989	47.6	47.5	38.9	52.3	55.4
1990	36.2	41.9	39.5	53.0	57.5
1991	49.3	66.3	46.1	50.8	58.4

1992	46.6	55.9	50.5	50.3	51.0
1993	40.1	44.3	31.9	52.4	50.9
1994	53.4	66.9	73.1	51.2	51.5
1995	44.4	52.1	53.6	51.1	48.9
1996	51.8	57.9	49.8	49.3	48.8
1997	52.3	56.1	52.8	49.6	48.9
1998	46.2	42.6	47.2	50.8	49.7
1999	52.1	54.1	49.3	52.0	48.8
2000	22.2	29.3	22.3	57.4	50.5
2001	44.4	47.3	39.1	54.5	48.6
2002	59.9	57.2	52.8	53.9	51.4
2003	42.6	49.8	55.5	52.6	50.3
2004	44.7	56.2	54.1	52.2	50.6
2005	48.2	56.5	57.9	50.5	50.1
2006	31.4	32.6	33.6	52.6	53.4
2007	43.8	41.9	39.8	51.1	51.7
2008	46.3	52.4	51.5	51.8	51.1
2009	51.5	47.7	49.6	52.3	52.2
2010	46.5	43	45.6	51.2	50.8
2011	41.6	48.4	39.5	53.2	54.5
Max	67.2	66.9	73.1	57.4	58.4
Min	22.2	29.3	22.3	48.5	48.6
Mean	47.5	48.4	49.3	51.7	52.8

10.1 CALIBRATED LAKE WATER BUDGET

Table 24. Lake Apopka annual water budget (1995-200o , unit: acre-feet

Year	Lake Volume	Precip.	Evap.	AB Canal Flow	Recharge to UFA	Surface Withdra -wal	Apopka Spring	UFA to Lake	Total Runoff	Delta Lake Volume	Total Inflow	Total Outflow	Error	Error%
1995	192456	143881	-137001	-87991	-724	-7	22589	6943	48772	-3552	222185	-225723	14	0.01%
1996	187724	133780	-132272	-79416	-362	-7	23240	4148	46193	-4732	207362	-212057	36	0.02%
1997	208177	141251	-132644	-29878	-10715	-7	21286	22	31159	20453	193719	-173237	29	0.01%
1998	188950	126764	-136223	-92617	-5575	-7	23313	2346	62749	-19227	215172	-234414	-15	-0.01%
1999	191982	131579	-138927	-31958	-15131	-7	20562	0	36906	3032	189046	-186015	-1	0.00%
2000	95550	57570	-149899	-16697	-19258	-7	19186	0	12657	-96432	89413	-185854	-9	-0.01%
2001	76225	97384	-136060	-8566	-10208	-7	17304	59	20726	-19325	135472	-154834	-37	-0.03%
2002	115464	130893	-133034	-7065	-4344	-7	18390	2642	31740	39240	183664	-144443	-18	-0.01%
2003	190446	146448	-139015	-16862	-652	-7	20055	2773	62277	74982	231553	-156528	43	0.02%
2004	195794	145185	-139973	-74444	-5357	-7	19910	3663	56374	5348	225132	-219774	9	0.00%
2005	193466	155398	-135559	-115094	-869	-7	20344	3613	69835	-2328	249190	-251522	-4	0.00%
2006	157383	89017	-139591	-16079	-7529	-7	19476	55	18525	-36084	127073	-163199	-42	-0.03%
mea n	166135	124929	-137516	-48056	-6727	-7	20471	2189	41493	-3219	189082	-192300	0	0.00%

Table 25. Lake Dora annual water budget (1995-2006), unit: acre-ft

Year	Lake Vol.	Precip.	Evap.	Dora Canal flow	recharge to UFA	surface withdrawal	Beaucl. flow	total runoff	delta ake lstorage	total inflow	total outflow	error	error%
1995	43923	19065	-17868	-94840	-6766	-550	92451	6195	-2188	117710	-120024	-125	-0.11%
1996	42183	21118	-17754	-92668	-6410	-552	86225	8178	-1740	115521	-117384	-124	-0.11%
1997	47479	20248	-17505	-27076	-8573	-550	32217	6547	5296	59012	-53705	10	0.02%
1998	42731	15645	-18048	-102804	-6783	-550	99329	8067	-4748	123041	-128186	-397	-0.32%
1999	43867	19570	-17602	-34968	-9156	-550	36343	7483	1136	63395	-62276	-16	-0.03%
2000	34980	10255	-17818	-9774	-10781	-552	16651	3104	-8887	30010	-38924	-28	-0.09%
2001	38363	16084	-16550	-2751	-10650	-550	10787	7009	3383	33880	-30500	-3	-0.01%
2002	43840	20291	-18162	-4561	-9768	-550	10425	7772	5477	38487	-33041	-31	-0.08%
2003	43108	18046	-18247	-21719	-6834	-550	21574	7049	-731	46670	-47350	51	0.11%
2004	44527	20574	-18377	-80361	-7613	-552	79420	8131	1419	108125	-106902	-197	-0.18%
2005	44359	20746	-18383	-123075	-6695	-550	120469	7359	-169	148574	-148703	39	0.03%
2006	35417	11493	-18889	-12452	-8278	-550	16579	3187	-8942	31259	-40169	31	0.10%
mean	42065	17761	-17934	-50587	-8192	-551	51872	6673	-891	76307	-77264	-66	-0.09%

Table 26. Lake Harris annual water budget (1995-2006) , unit: acre-ft

. Year	Lake Vol	Precip.	Evap.	Dead River Q	surface withdrawal	Palat River Q	Harris Springs	UFA to Lake	total runoff	delta lake storage	total inflow	total outflow	error	error%
1995	226838	68676	-75760	-81812	-289.6	43368	15349	10860	19462	164	157714	-157862	-312	-0.20%
1996	220054	80507	-75414	-121632	-290.4	57196	16797	11367	24848	-6784	190714	-197337	161	0.08%
1997	230598	79942	-74810	-55676	-289.6	11367	13104	8326	28612	10544	141351	-130775	33	0.02%
1998	222406	71890	-76777	-175932	-289.6	121632	16435	10932	23553	-8192	244442	-252999	-364	-0.15%
1999	226676	80153	-75136	-50463	-289.6	2317	12308	7312	28081	4270	130171	-125889	12	0.01%
2000	189039	33523	-76377	-16797	-290.4	507	10208	5647	5950	-37637	55836	-93465	9	0.02%
2001	203723	65115	-71591	-20851	-289.6	290	10064	6733	25232	14684	107433	-92732	17	0.02%
2002	229113	91040	-77841	-44598	-289.6	1086	12091	6878	37016	25390	148110	-122729	-9	-0.01%
2003	224012	65804	-77891	-170140	-289.6	128872	16000	10498	21833	-5101	243008	-248321	-213	-0.09%
2004	228351	69343	-78253	-108600	-290.4	77468	15494	9629	19623	4339	191557	-187144	74	0.04%
2005	228499	74581	-77653	-112220	-289.6	67332	16290	11077	20909	148	190189	-190163	-122	-0.06%
2006	191051	47331	-80951	-36924	-289.6	2317	13539	9195	8347	-37448	80728	-118165	11	0.01%
mean	218363	68992	-76538	-82970	-290	42813	13973	9038	21955	-2969	156771	-159798	-58	-0.04%

Table 27. Lake Eustis annual water budget (1995-2006) , unit: acre-ft

Year	Lake vol	Precip.	Evap.	Burrell Q	recharge to UFA	surface withdrawal	Dora Canal	Dead R Q	total runoff	delta lake storag	total inflow	total outflow	error	error%
1995	89428	33675	-31631	-184043	-9388	-87	94840	81809	15903	616	226226	-225149	462	0.20%
1996	86609	37497	-31483	-235447	-8993	-87	92668	121627	21119	-2819	272911	-275923	-193	-0.07%
1997	90991	36150	-31349	-88131	-11741	-87	27076	55673	16799	4382	135698	-131222	94	0.07%
1998	87588	27831	-32103	-288784	-9383	-87	102804	175925	21128	-3403	327688	-330270	821	0.25%
1999	89368	34908	-31424	-94605	-12473	-87	34968	50461	20028	1781	140365	-138502	82	0.06%
2000	73547	18578	-32153	-21849	-14375	-87	9774	16796	7469	-15821	52617	-68377	61	0.12%
2001	79757	29604	-30421	-20271	-14038	-87	2751	20850	17824	6210	71030	-64730	90	0.13%
2002	90284	36542	-32741	-49263	-13171	-87	4561	44597	20108	10527	105808	-95176	105	0.10%
2003	88259	32210	-32521	-201302	-9704	-87	21719	170133	17710	-2025	241772	-243527	269	0.11%
2004	90059	36496	-32707	-201727	-10488	-87	80361	108596	21295	1800	246747	-244922	26	0.01%
2005	90114	36529	-32405	-248795	-9213	-87	123075	112215	18800	54	290619	-290413	152	0.05%
2006	74398	20781	-34059	-48072	-11329	-87	12452	36922	7633	-15716	77788	-93459	44	0.06%
mean	85867	31733	-32083	-140191	-11191	-87	50587	82967	17151	-1201	182439	-183472	168	0.09%

Table 28. Lake Griffin annual water budget (1995-2006), unit: acre-feet

Year	Lake Volume	Precip.	Evap.	Moss Bluff Flow	Recharge to UFA	Surface Withdr -awal	Burrell Flow	UFA to Lake	Total Runoff	Delta Lake Volume	Total Inflow	Total Outflow	Error	Error%
1995	83914	56074	-52721	-204416	-247	-601	184043	1738	17411	1280	259265	-257985	0	0.00%
1996	83458	64503	-53603	-278058	-2	-603	235455	4655	27197	-456	331810	-332267	0	0.00%
1997	86416	62461	-52244	-102776	-6671	-601	88154	0	14634	2958	165249	-162292	0	0.00%
1998	78203	47838	-52687	-326637	-151	-601	288725	6747	28552	-8213	371862	-380076	-1	0.00%
1999	83389	56254	-50111	-109608	-2702	-601	94637	605	16712	5187	168208	-163021	0	0.00%
2000	55573	26464	-47285	-29236	-7914	-603	21849	0	8908	-27817	57221	-85038	0	0.00%
2001	62165	39103	-40371	-21719	-4450	-601	20271	36	14323	6592	73733	-67141	0	0.00%
2002	84279	54399	-48091	-45938	-4370	-601	49261	0	17453	22114	121113	-98999	0	0.00%
2003	80763	54156	-54186	-225362	-1312	-601	201335	2469	19985	-3516	277945	-281460	0	0.00%
2004	84695	61378	-54364	-222209	-1493	-603	201691	1774	17758	3932	282600	-278669	-1	0.00%
2005	84521	61070	-54326	-283571	0	-601	248810	6545	21898	-174	338323	-338497	0	0.00%
2006	74936	33235	-54480	-45090	-1408	-601	48063	1252	9443	-9585	91993	-101579	0	0.00%
mean	78526	51411	-51206	-157885	-2560	-602	140191	2152	17856	-642	211610	-212252	0	0.00%

Table 29. Lake Yale water budget (1995-2006), unit: acre-feet

Year	Lake Vol.	Precip.	Evap.	Yale-Griffin Canal Q	recharge to UFA	withdrawal	Yale to Ella Q	surface total total runoff	delta lake storage	inflow	total outflow	error	error%
1995	52688	17594	-16535	-1213	-2824	-116	-956	3363	-685	20957	-21642	0	0.00%
1996	53368	20957	-17747	-5907	-2657	-116	1187	4956	680	25913	-25239	-7	-0.03%
1997	54207	18838	-16398	-647	-3911	-116	-223	3295	839	22133	-21294	0	0.00%
1998	50818	15983	-18096	-5606	-2290	-116	1050	5685	-3389	21668	-25058	0	0.00%
1999	52327	18066	-16291	-364	-3226	-116	-272	3711	1509	21777	-20268	0	0.00%
2000	42960	9531	-16552	-122	-4307	-116	-14	2213	-9367	11744	-21111	0	0.00%
2001	41929	14828	-15272	0	-3696	-116	0	3225	-1031	18053	-19084	0	0.00%
2002	44890	18072	-16221	0	-2726	-116	0	3952	2961	22024	-19063	0	0.00%
2003	47272	16342	-16556	0	-1995	-116	-97	4804	2383	21146	-18764	0	0.00%
2004	50570	18434	-16583	0	-2202	-116	-325	4092	3298	22526	-19227	1	0.00%
2005	53844	19184	-17022	-1718	-1994	-116	263	4679	3275	23863	-20588	0	0.00%
2006	45383	10842	-17801	-832	-2814	-116	85	2174	-8462	13016	-21478	0	0.00%
mean	49188	16556	-16756	-1367	-2887	-116	58	3846	-666	20402	-21126	0	0.00%

10.2 CALIBRATED PARAMETER SETS FOR LAKE APOPKA AND UORB HSPF MODEL

Table 30. The calibrated PWAT-PARM2 parameters for sub basins Lake Beauclair, Dora, Eustis and Harris

HSPF Supphnental Param. #	FOREST	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in)	AGWRC (1/day)
1	0	3.873	0.4667	300	0.00177	0.001	0.983
2	0	3.873	0.4667	300	0.00177	0.001	0.983
3	0	3.873	0.4667	300	0.00177	0.001	0.983
4	0	3.873	0.4667	300	0.00177	0.001	0.983
5	0	2.908	0.6667	300	0.00177	0.001	0.983
6	0	4.362	0.6667	300	0.00177	0.001	0.983
7	0	4.362	0.6667	300	0.00177	0.001	0.983
8	0	4.845	0.8000	300	0.00177	0.001	0.983
9	0	4.845	0.8000	300	0.00177	0.001	0.983
10	0	4.362	0.6667	300	0.00177	0.001	0.983
11	1	5.816	1.0000	300	0.00177	0.001	0.983
12	0	0.500	0.0219	300	0.001	0.001	0.999
13	0	0.500	0.0219	300	0.001	0.001	0.999

Table 31. The calibrated PWAT-PARM2 paraaieters for sub basin Lake Griffin

HSPF Supphnental Param. #	FOREST	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in)	AGWRC (1/day)
101	0	3.996	0.3733	300	0.00177	0.001	0.989
102	0	3.996	0.3733	300	0.00177	0.001	0.989
103	0	3.996	0.3733	300	0.00177	0.001	0.989
104	0	3.996	0.3733	300	0.00177	0.001	0.989
105	0	3.000	0.5333	300	0.00177	0.001	0.989
106	0	4.500	0.5333	300	0.00177	0.001	0.989
107	0	4.500	0.5333	300	0.00177	0.001	0.989
108	0	5.004	0.6400	300	0.00177	0.001	0.989
109	0	5.004	0.6400	300	0.00177	0.001	0.989
110	0	4.500	0.5333	300	0.00177	0.001	0.989
111	1	6.000	0.8000	300	0.00177	0.001	0.989
112	0	0.500	0.0281	300	0.001	0.001	0.999
113	0	0.500	0.0281	300	0.001	0.001	0.999

Table 32. The calibrated PWAT-PARM2 paraaieters for sub basin Lake Yale

[1]1 HSPF Supphnental Param. #	FOREST	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in)	AGWRC (1/day)
201	0	3.996	0.3733	300	0.016	0.001	0.993
202	0	3.996	0.3733	300	0.016	0.001	0.993
203	0	3.996	0.3733	300	0.016	0.001	0.993
204	0	3.996	0.3733	300	0.016	0.001	0.993
205	0	3.000	0.5333	300	0.016	0.001	0.993
206	0	4.500	0.5333	300	0.016	0.001	0.993
207	0	4.500	0.5333	300	0.016	0.001	0.993
208	0	5.004	0.6400	300	0.016	0.001	0.993
209	0	5.004	0.6400	300	0.016	0.001	0.993
210	0	4.500	0.5333	300	0.016	0.001	0.993
211	1	6.000	0.8000	300	0.016	0.001	0.993
212	0	0.500	0.0281	300	0.001	0.001	0.999
213	0	0.500	0.0281	300	0.001	0.001	0.999

Table 33. The calibrated PWAT-PARM2 paraaieters for sub basin Lake Apopka

.N. HSPF Supphnental Param. #	FOREST	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in)	AGWRC (1/day)
901	0	3.873	0.4667	300	0.00219	0.001	0.985
902	0	3.873	0.4667	300	0.00219	0.001	0.985
903	0	3.873	0.4667	300	0.00219	0.001	0.985
904	0	3.873	0.4667	300	0.00219	0.001	0.985
905	0	2.908	0.6667	300	0.00219	0.001	0.985
906	0	4.362	0.6667	300	0.00219	0.001	0.985
907	0	4.362	0.6667	300	0.00219	0.001	0.985
908	0	4.845	0.8000	300	0.00219	0.001	0.985
909	0	4.845	0.8000	300	0.00219	0.001	0.985
910	0	4.362	0.6667	300	0.00219	0.001	0.985
911	1	5.816	1.0000	300	0.00219	0.001	0.985
912	0	0.500	0.0219	300	0.001	0.001	0.999
913	0	0.500	0.0219	300	0.001	0.001	0.999

Table 34. The calibrated PWAT-PARM3 parameters for sub basins Lake Beauclair, Dora, Eustis and Harris

HSPF Supphnental Param. #	PETMAX (degree F)	PET1VIIN (degree F)	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
21	40	35	2	2	0.398	0.02	0.0
22	40	35	2	2	0.398	0.02	0.0
23	40	35	2	2	0.398	0.02	0.0
24	40	35	2	2	0.398	0.02	0.0
25	40	35	2	2	0.398	0.02	0.0
26	40	35	2	2	0.398	0.02	0.0
27	40	35	2	2	0.398	0.02	0.0
28	40	35	2	2	0.398	0.02	0.0
29	40	35	2	2	0.398	0.02	0.0
30	40	35	2	2	0.398	0.02	0.0
31	40	35	2	2	0.398	0.02	0.0
32	40	35	2	2	0.398	0.02	0.25
33	40	35	2	2	0.398	0.02	0.25

Table 35. The calibrated PWAT-PARM3 parameters for sub basin Lake Griffis

HSPF Supphnental Param. #	PETMAX (degree F)	PET1VIIN (degree F)	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
121	40	35	2	2	0.580	0.02	0.0
122	40	35	2	2	0.580	0.02	0.0
123	40	35	2	2	0.580	0.02	0.0
124	40	35	2	2	0.580	0.02	0.0
125	40	35	2	2	0.580	0.02	0.0
126	40	35	2	2	0.580	0.02	0.0
127	40	35	2	2	0.580	0.02	0.0
128	40	35	2	2	0.580	0.02	0.0
129	40	35	2	2	0.580	0.02	0.0
130	40	35	2	2	0.580	0.02	0.0
131	40	35	2	2	0.580	0.02	0.0
132	40	35	2	2	0.580	0.02	0.25
133	40	35	2	2	0.580	0.02	0.25

Table 36. The calibrated PWAT-PARM3 parameters for sub basin Lake Yale

HSPF Supphnental Param. #	PETMAX (degree F)	PET1VIIN (degree F)	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
221	40	35	2	2	0.632	0.02	0.0
222	40	35	2	2	0.632	0.02	0.0
223	40	35	2	2	0.632	0.02	0.0
224	40	35	2	2	0.632	0.02	0.0
225	40	35	2	2	0.632	0.02	0.0
226	40	35	2	2	0.632	0.02	0.0
227	40	35	2	2	0.632	0.02	0.0
228	40	35	2	2	0.632	0.02	0.0
229	40	35	2	2	0.632	0.02	0.0
230	40	35	2	2	0.632	0.02	0.0
231	40	35	2	2	0.632	0.02	0.0
232	40	35	2	2	0.632	0.02	0.25
233	40	35	2	2	0.632	0.02	0.25

Table 37. The calibrated PWAT-PARM3 parameters for sub basin Lake Apopka

HSPF Supphnental Param. #	PETMAX (degree F)	PET1VIIN (degree F)	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
921	40	35	2	2	0.300	0.02	0.0
922	40	35	2	2	0.300	0.02	0.0
923	40	35	2	2	0.300	0.02	0.0
924	40	35	2	2	0.300	0.02	0.0
925	40	35	2	2	0.300	0.02	0.0
926	40	35	2	2	0.300	0.02	0.0
927	40	35	2	2	0.300	0.02	0.0
928	40	35	2	2	0.300	0.02	0.0
929	40	35	2	2	0.300	0.02	0.0
930	40	35	2	2	0.300	0.02	0.0
931	40	35	2	2	0.300	0.02	0.0
932	40	35	2	2	0.300	0.02	0.25
933	40	35	2	2	0.300	0.02	0.25

Table 38. The calibrated PWAT-PARM4 parameters for sub basins Lake Beauclair, Dora, Eustis and Harris

HSPF Supphnental Param. #	CEPSC (in)	UZSN (in)	NSUR	INTFW	IRC (1/day)	LZETP
41	0.05	1.400	0	0.001	0.6	0.376
42	0.05	1.400	0	0.001	0.6	0.376
43	0.05	1.400	0	0.001	0.6	0.376
44	0.05	1.400	0	0.001	0.6	0.376
45	0.03	1.400	0	0.001	0.6	0.301
46	0.03	1.400	0	0.001	0.6	0.301
47	0.08	1.400	0	0.001	0.6	0.414
48	0.08	1.600	0	0.001	0.6	0.527
49	0.10	1.600	0	0.001	0.6	0.527
50	0.08	1.400	0	0.001	0.6	0.452
51	0.12	2.000	0	0.001	0.6	0.602
52	0.12	0.084	0	0	0.6	0.900
53	0.12	0.084	0	0	0.6	0.900

Table 39. The calibrated PWAT-PARM4 parameters for sub basins Lake Griffin

HSPF Supphnental Param. #	CEPSC (in)	UZSN (in)	NSUR	INTFW	IRC (1/day)	LZETP
141	0.05	1.400	0	0.001	0.6	0.376
142	0.05	1.400	0	0.001	0.6	0.376
143	0.05	1.400	0	0.001	0.6	0.376
144	0.05	1.400	0	0.001	0.6	0.376
145	0.03	1.400	0	0.001	0.6	0.301
146	0.03	1.400	0	0.001	0.6	0.301
147	0.08	1.400	0	0.001	0.6	0.414
148	0.08	1.600	0	0.001	0.6	0.527
149	0.10	1.600	0	0.001	0.6	0.527
150	0.08	1.400	0	0.001	0.6	0.452
151	0.12	2.000	0	0.001	0.6	0.602
152	0.12	0.084	0	0	0.6	0.900
153	0.12	0.084	0	0	0.6	0.900

Table 40. The calibrated PWAT-PARM4 parameters for sub basins Lake Yale

HSPF Supphnental Param. #	CEPSC (in)	UZSN (in)	NSUR	INTFW	IRC (1/day)	LZETP
241	0.05	1.400	0	0.001	0.6	0.376
242	0.05	1.400	0	0.001	0.6	0.376
243	0.05	1.400	0	0.001	0.6	0.376
244	0.05	1.400	0	0.001	0.6	0.376
245	0.03	1.400	0	0.001	0.6	0.301
246	0.03	1.400	0	0.001	0.6	0.301
247	0.08	1.400	0	0.001	0.6	0.414
248	0.08	1.600	0	0.001	0.6	0.527
249	0.10	1.600	0	0.001	0.6	0.527
250	0.08	1.400	0	0.001	0.6	0.452
251	0.12	2.000	0	0.001	0.6	0.602
252	0.12	0.084	0	0	0.6	0.900
253	0.12	0.084	0	0	0.6	0.900

Table 41. The calibrated PWAT-PARM4 parameters for sub basins Lake Apopka

HSPF Supphnental Param. #	CEPSC (in)	UZSN (in)	NSUR	INTFW	IRC (1/day)	LZETP
941	0.05	1.400	0	0.001	0.6	0.376
942	0.05	1.400	0	0.001	0.6	0.376
943	0.05	1.400	0	0.001	0.6	0.376
944	0.05	1.400	0	0.001	0.6	0.376
945	0.03	1.400	0	0.001	0.6	0.301
946	0.03	1.400	0	0.001	0.6	0.301
947	0.08	1.400	0	0.001	0.6	0.414
948	0.08	1.600	0	0.001	0.6	0.527
949	0.10	1.600	0	0.001	0.6	0.527
950	0.08	1.400	0	0.001	0.6	0.452
951	0.12	2.000	0	0.001	0.6	0.602
952	0.12	0.084	0	0	0.6	0.900
953	0.12	0.084	0	0	0.6	0.900

Table 42. The calibrated PWAT-STATE1 parameters for sub basins Lake Beauclair, Dora, Eustis and Harris

HSPF Supplmental Param. #	CEPS (in)	SURS (in)	UZS (in)	IFVVS (in)	LZS (in)	AGWS (in)	GWVS (in)
61	0	0	1.400	0	3.873	0.530	0
62	0	0	1.400	0	3.873	0.530	0
63	0	0	1.400	0	3.873	0.530	0
64	0	0	1.400	0	3.873	0.530	0
65	0	0	1.400	0	2.908	0.530	0
66	0	0	1.400	0	4.362	0.530	0
67	0	0	1.400	0	4.362	0.530	0
68	0	0	1.600	0	4.845	0.530	0
69	0	0	1.600	0	4.845	0.530	0
70	0	0	1.400	0	4.362	0.530	0
71	0	0	2.000	0	5.816	0.530	0
72	0	0	0.084	0	0.5	0.530	0
73	0	0	0.084	0	0.5	0.530	0

Table 43. The calibrated PWAT-STATE1 parameters for sub basins Lake Griffin

HSPF Supplmental Param. #	CEPS (in)	SURS (in)	UZS (in)	IFVVS (in)	LZS (in)	AGWS (in)	GWVS (in)
161	0	0	1.400	0	3.996	1.497	0
162	0	0	1.400	0	3.996	1.497	0
163	0	0	1.400	0	3.996	1.497	0
164	0	0	1.400	0	3.996	1.497	0
165	0	0	1.400	0	3.000	1.497	0
166	0	0	1.400	0	4.500	1.497	0
167	0	0	1.400	0	4.500	1.497	0
168	0	0	1.600	0	5.004	1.497	0
169	0	0	1.600	0	5.004	1.497	0
170	0	0	1.400	0	4.500	1.497	0
171	0	0	2.000	0	6.000	1.497	0
172	0	0	0.084	0	0.5	1.497	0
173	0	0	0.084	0	0.5	1.497	0

Table 44. The calibrated PWAT-STATE1 parameters for sub basins Lake Yale

HSPF Supplmental Param. #	CEPS (in)	SURS (in)	UZS (in)	IFVVS (in)	LZS (in)	AGWS (in)	GWVS (in)
261	0	0	1.400	0	3.996	1.383	0
262	0	0	1.400	0	3.996	1.383	0
263	0	0	1.400	0	3.996	1.383	0
264	0	0	1.400	0	3.996	1.383	0
265	0	0	1.400	0	3.000	1.383	0
266	0	0	1.400	0	4.500	1.383	0
267	0	0	1.400	0	4.500	1.383	0
268	0	0	1.600	0	5.004	1.383	0
269	0	0	1.600	0	5.004	1.383	0
270	0	0	1.400	0	4.500	1.383	0
271	0	0	2.000	0	6.000	1.383	0
272	0	0	0.084	0	0.5	1.383	0
273	0	0	0.084	0	0.5	1.383	0

Table 45. The calibrated PWAT-STATE1 parameters for sub basins Lake Apopka

HSPF Supplmental Param. #	CEPS (in)	SURS (in)	UZS (in)	IFVVS (in)	LZS (in)	AGWS (in)	GWVS (in)
961	0	0	1.400	0	3.873	0.500	0
962	0	0	1.400	0	3.873	0.500	0
963	0	0	1.400	0	3.873	0.500	0
964	0	0	1.400	0	3.873	0.500	0
965	0	0	1.400	0	2.908	0.500	0
966	0	0	1.400	0	4.362	0.500	0
967	0	0	1.400	0	4.362	0.500	0
968	0	0	1.600	0	4.845	0.500	0
969	0	0	1.600	0	4.845	0.500	0
970	0	0	1.400	0	4.362	0.500	0
971	0	0	2.000	0	5.816	0.500	0
972	0	0	0.084	0	0.5	0.500	0
973	0	0	0.084	0	0.5	0.500	0