DRAFT

Lake Apopka and the Upper Ocklawaha River Minimum Flows and Levels Hydrologic Model Sensitivity Analysis Report

By Xiaoqing "Shaw" Huang

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Introduction

Sensitivity analysis is the study of how the variation in the model output can be attibuted to different variation sources, either from data fed into the model or parameter uncertainty (Saltelli et al 2000). Sensitivity analysis will increase the confidence in the model and its predictions by providing an understanding of how the model responds to changes in the data inputs or model parameters (Mishra 2009; Saltelli et al 2000). Public workshop at the District Maitland Office during Feb 3-4, 2016 brought together the peer reviewers and stakeholders to review Lake Apopka and the Upper Ocklawaha River (LAUORB) Minimum Flows and Levels Hydrologic Model. At the workshop, the peer reviewers recommended a sensitity analysis on some important model variables as desribed in Table 1.

Table 1. Sensitivity study variables, variation amounts and general approaches recommended by peer reviewers.

Variables	Variation Amount	Approach
1. UFA POT surface	+/- 1 ft	Increase/reduce POT surface by 1 ft
2. Lake bottom seepage	+/- 10%	Increase/reduce K values by 10%
3. Runoff	+/- 10%	Increase/reduce runoff by 10%
4. Rainfall	+/- 10%	Increase/reduce rainfall by 10%
5. Rating curve discharge	+/- 10%	Increase/reduce structure rating curve discharge by 10%
6. Pumpage from NSRA	- 1 ft	Reduce NSRA pump schedule by 1 ft

Sensitivity Analysis Approach

Sensivity analysis was performed on the LAUORB calibration model with exception of the sixth sensitivity model: pumpage from NSRA, which was performed on the LAUORB baseline model. The reason is that pumpage from NSRA is a land management method in the baseline model, but not in the calibration model.

For the sensitivity analysis of variable 1 through 5, the LAUORB calibration model was run twice: one by adjusting down and the other by adjusting up the variable values by the amount specified in Table 1. When the variable values are adjusted, the same amount or percentage is applied across all the sub-basins. For example, to test the sensitivity of reducing UFA POT surface by 1 ft, all sub-basins from Lake Apopka down to Lake Griffin will be reduced by 1 ft. When the model sensitivity run were completed, the results were compared with calibration model results.

To test sensitivity of pumpage from NSRA, the LAUORB baseline model was run once by reducing water depth by 1 ft above which the NSRA pumps will turn on. Its result were compared with the LAUORB baseline model results.

Sensitivity Analysis Results and Discussions

1. UFA POT surface

The amount of seepage and its flow direction between lake bottom and the Upper Floridan Aquifer (UFA) depends on the head between lake water level and the UFA potentiometric (POT) surface. In the LAUORB hydrologic model, the seep rate was estimated by the Darcy's Equation:

$$\boldsymbol{Q = K\frac{\Delta H}{\Delta L}A} \qquad \textbf{(1)}$$

Where Q is the seepage rate, ft^3/s, which can be positive or negative depending on the head direction; 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; ΔL is the distance between lake bottom and Upper Florida Aquifer, ft; and ΔH is head between lake stage and UFA POT surface, ft. Assuming K, A and ΔL stay constant, then these three parameters can be lumped into K', where

$$K' = K\frac{A}{\Delta L}$$

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

$$Q = K'\Delta H \qquad (2)$$

$K'$was calibrated for each lake during model calibration process. Table 2 shows the calibrated $K'$for each lake.

Table 2. Calibrated K' values in LAUORB hydrologic model

Lake	K'
LK Apopka	7.376312
LK Beauclair	0.409768
LK Dora	1.841614
LK Harris	4.000000
LK Eustis	2.500000
LK Griffin	7.318310

The UFA POT surfaces under the lake bottoms are pre-computed based on observed well heads (Huang & Smith 2015), are stored in a WDM file named “input.wdm”, and are fed into the model during the model run. For this sensitivity analysis, all the UFA POT surfaces were uniformly decreased or increased by 1 ft.

Figures 1 through 5 depict how the five lakes from Lake Apopka to Lake Griffin respond to POT surface uniformly decreased or increased by 1 ft. Lakes Apopka (Figure 1) and Griffin (Figure 5) are sensitive to POT surface during the multi-year drought 2000-2003 when lake levels are lower, while there are little or no impact during the other periods. However, decreasing or reducing POT surface by 1 ft has much less impact on lake levels of Lakes Dora, Eustis and Harris even during the drought (Figures 2 to 4; Table 3). There are two reasons why Lakes Apopka and Griffin are sensitive to POT surface during drought. The first reason is that both lakes have larger K’ than other lakes (Table 2). For Lake Apopka, reducing POT surface by 1 ft will bring about 7.4 cfs recharge loss of water from lake bottom to UFA, which can significantly impact lake water budget during the multi-year drought when lake volume is smaller. The second reason is that both lakes are dual recharge/discharge lakes; reducing or increasing POT surface by 1 ft will switch some lake bottom from recharge to discharge or vice versa, which can significantly impact lake water budget during the multi-year drought.

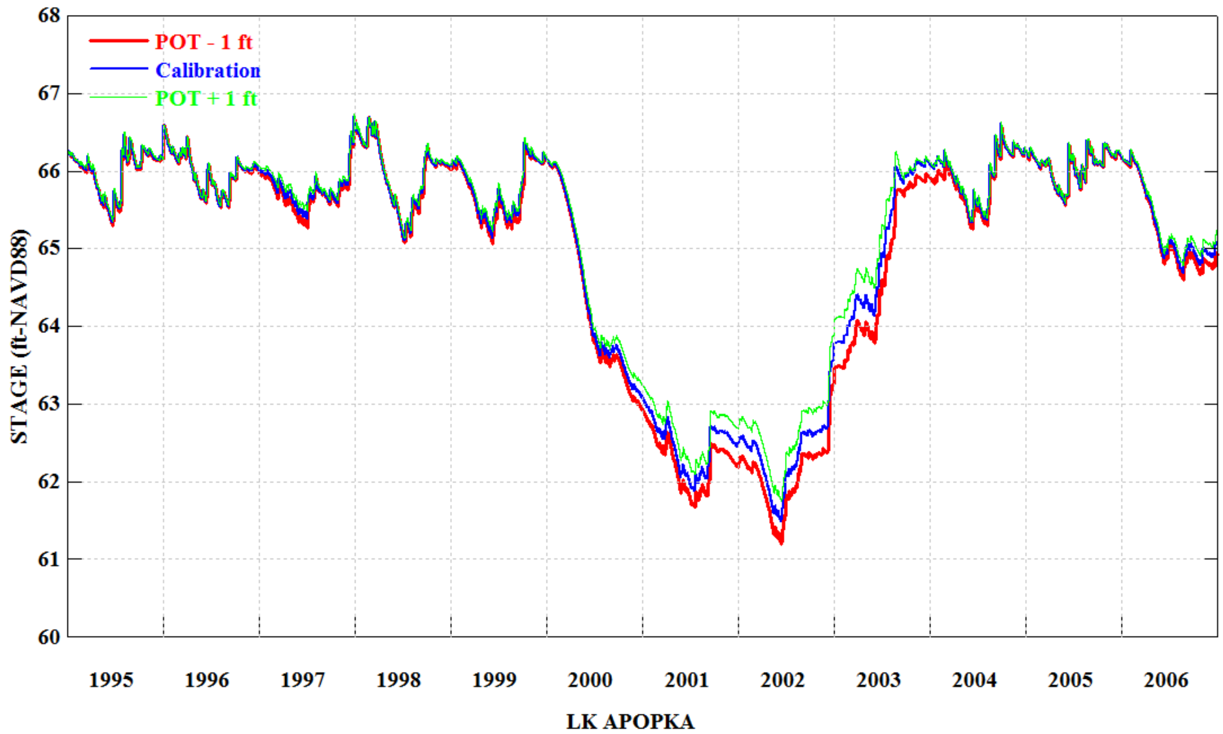

Figure 1. Lake Apopka stage responds to POT surface decline/increase by 1 ft.

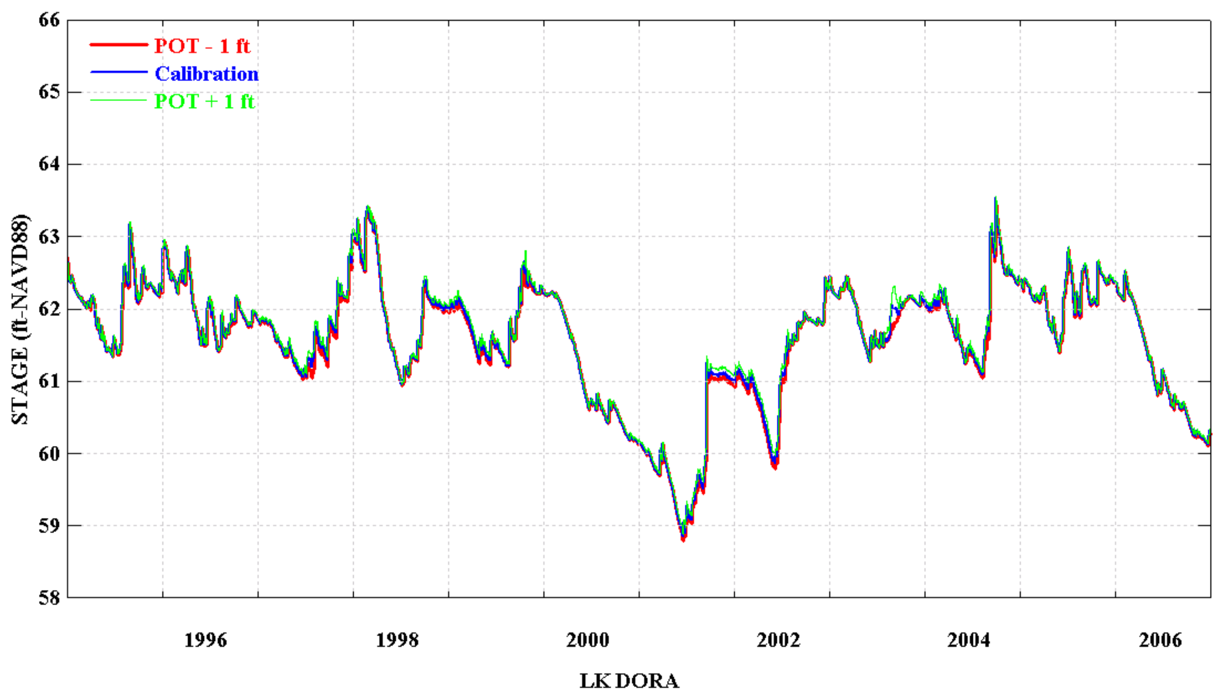

Figure 2. Lake Dora stage responds to POT surface decline/increase by 1 ft.

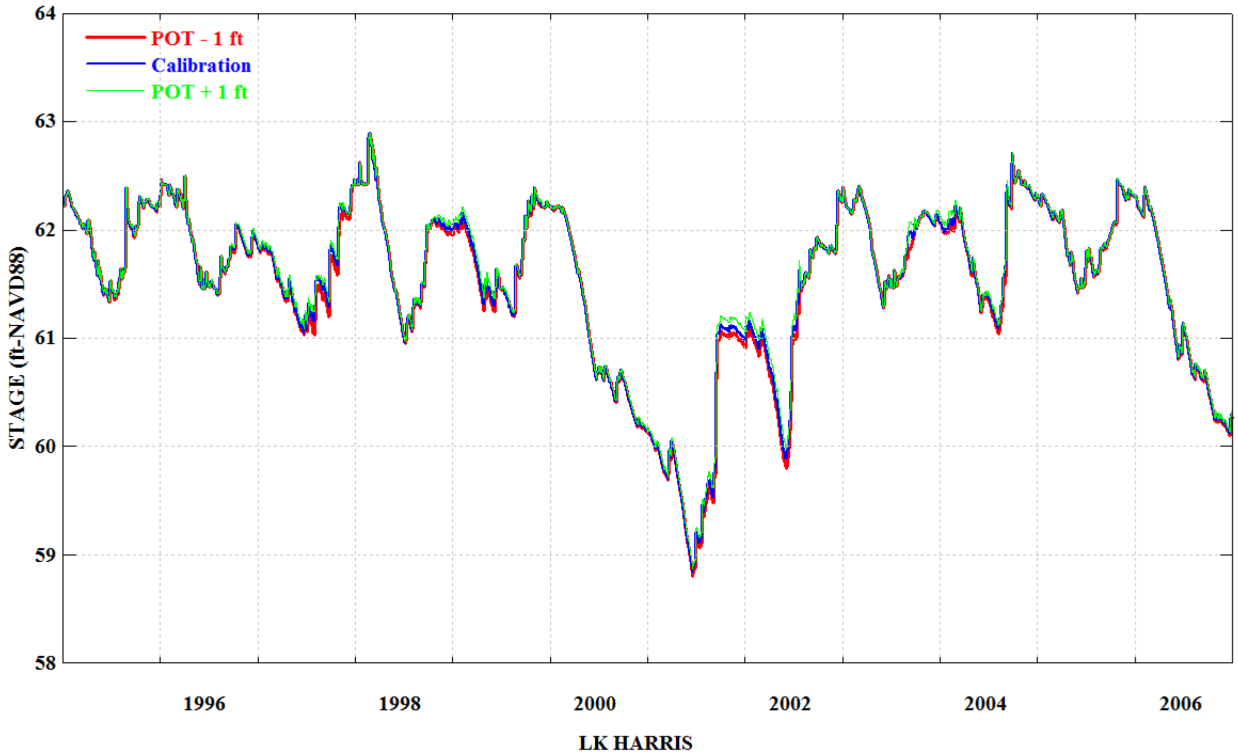

Figure 3. Lake Harris stage responds to POT surface decline/increase by 1 ft.

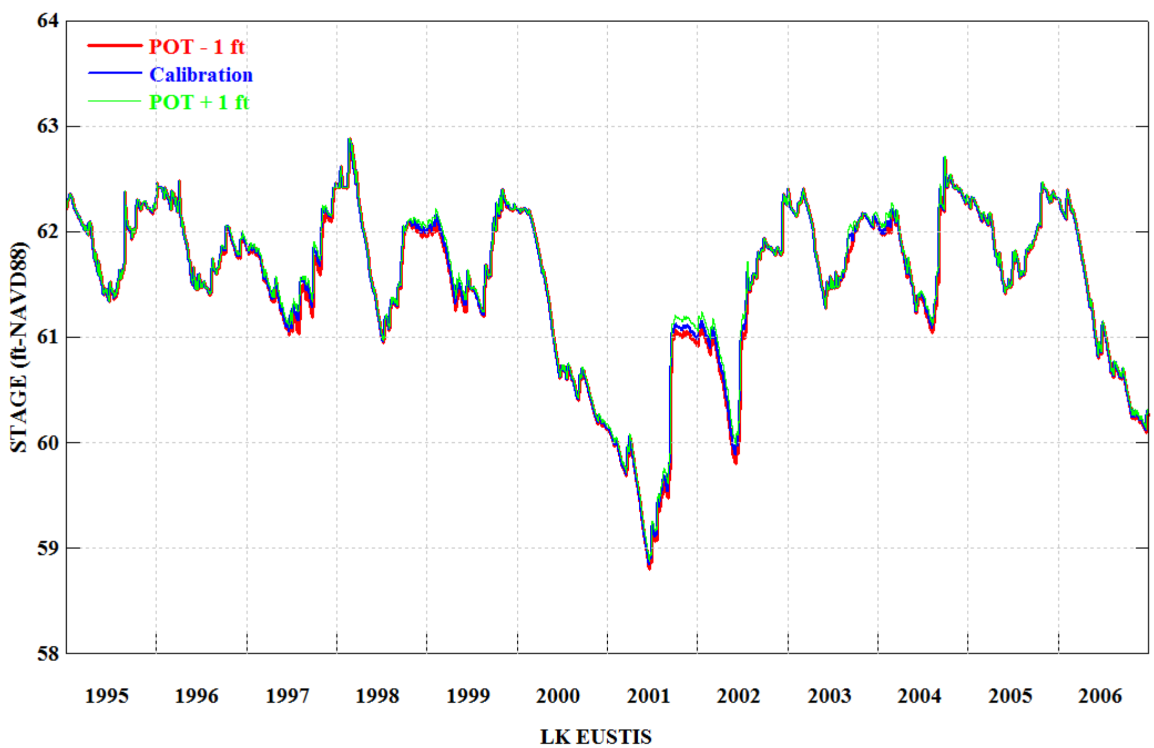

Figure 4. Lake Eustis stage responds to POT surface decline/increase by 1 ft.

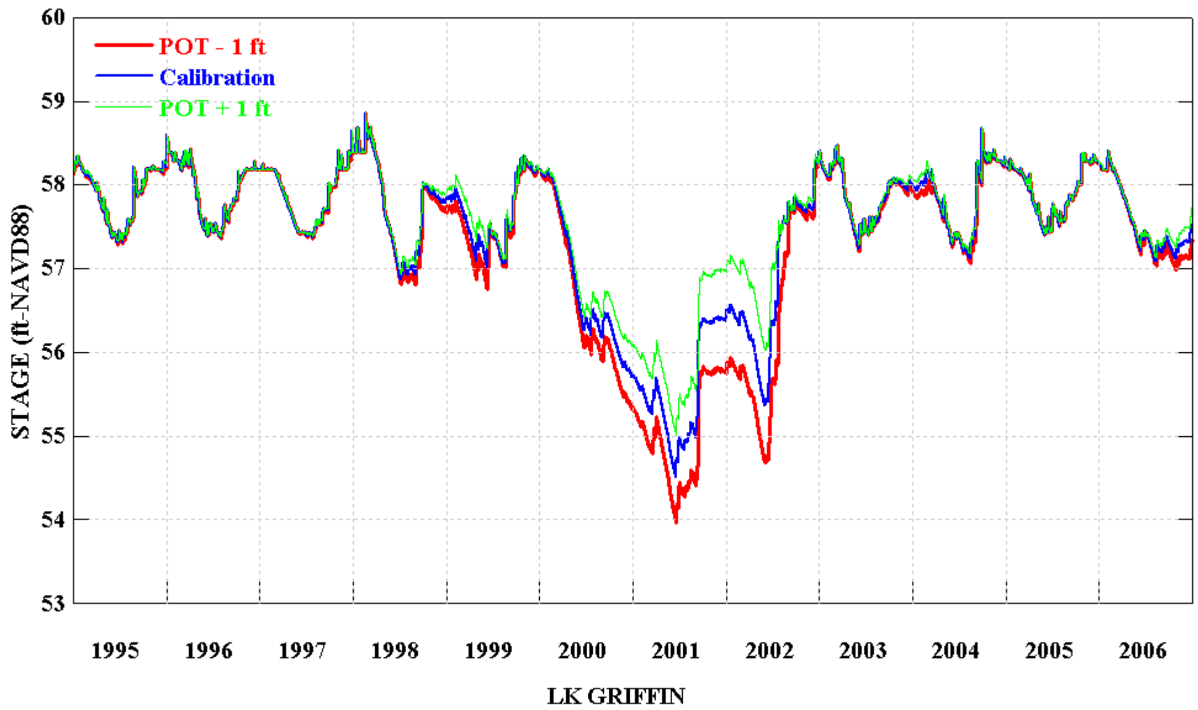

Figure 5. Lake Griffin stage responds to POT surface decline/increase by 1 ft.

Table 3. Lake stage (ft-NAVD88) statistics corresponding to calibration, POT surface decline or increase by 1 ft.

Sensitivity Scenarios	Stats	LK APOPK	LK DORA	LK HARRI	LK EUSTI	LK GRIFF
Calibration	Max	66.7	63.54	62.89	62.88	58.86
	Min	61.48	58.84	58.84	58.84	54.5
	Mean	65.1	61.61	61.54	61.53	57.47
POT- 1 ft	Max	66.68	63.49	62.89	62.88	58.86
	Min	61.19	58.79	58.8	58.8	53.96
	Mean	65	61.58	61.52	61.52	57.35
POT + 1ft	Max	66.73	63.57	62.9	62.89	58.86
	Min	61.75	58.87	58.87	58.87	55
	Mean	65.18	61.64	61.56	61.56	57.58

2. Lake bottom seepage

Table 2 lists lake bottom seepage rate (K') for all lakes. For sensitivity analysis on lake bottom seepage, all K' in Table 2 were reduced or increased by 10%.

Figures 6 through 10 demonstrate how the five lakes from Lake Apopka to Lake Griffin respond to lake seepage rates (Table 2) uniformly decreased or increased by 10%. The results show that there are slight impacts on lake levels for all five lakes during the drought of 2000-2003 while there are almost no differences in other periods. Table 4 reveals that in comparison with the calibration model results: decreasing or increasing seepage by 10% will not impact the average lake levels by more than 0.03 ft; it has almost no impact on the maximum stages; and the largest difference on the minimum stage is 0.11 ft.

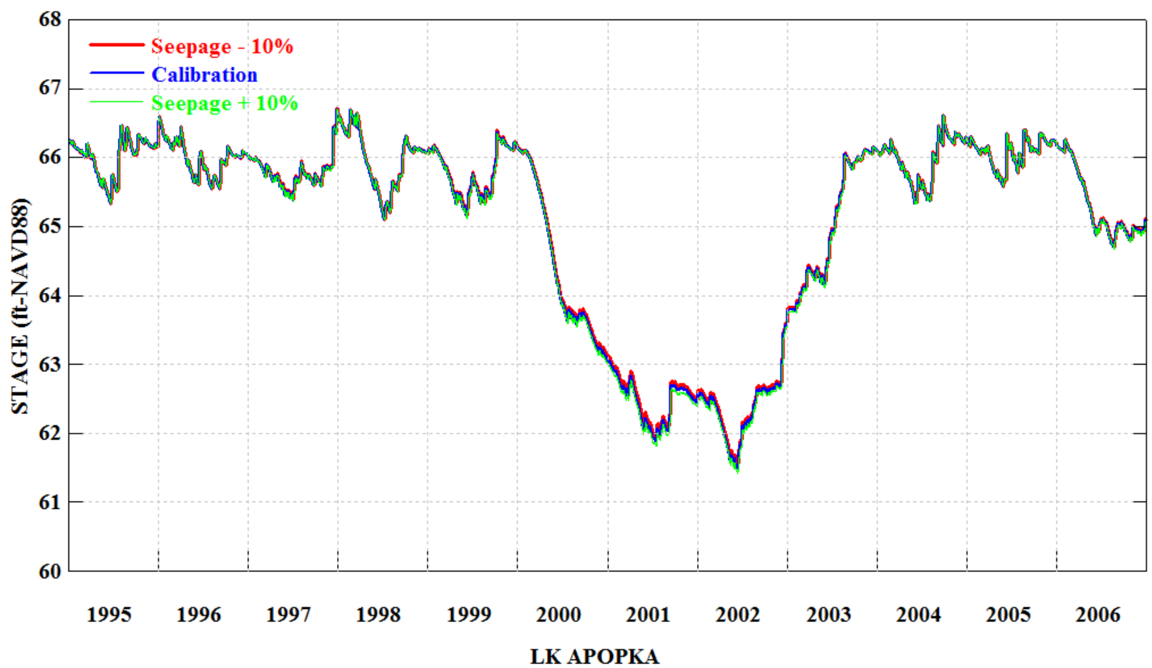

Figure 6. Lake Apopka stage responds to seepage rate reduced/increased by 10%.

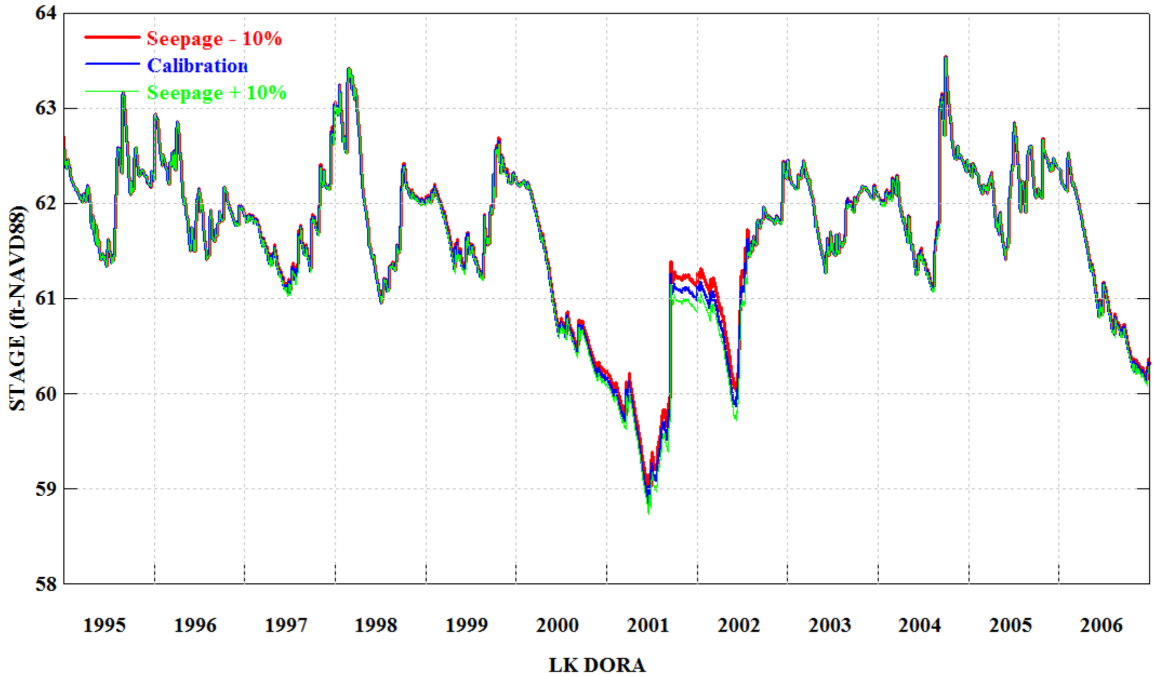

Figure 7. Lake Dora stage responds to seepage rate reduced/increased by 10%.

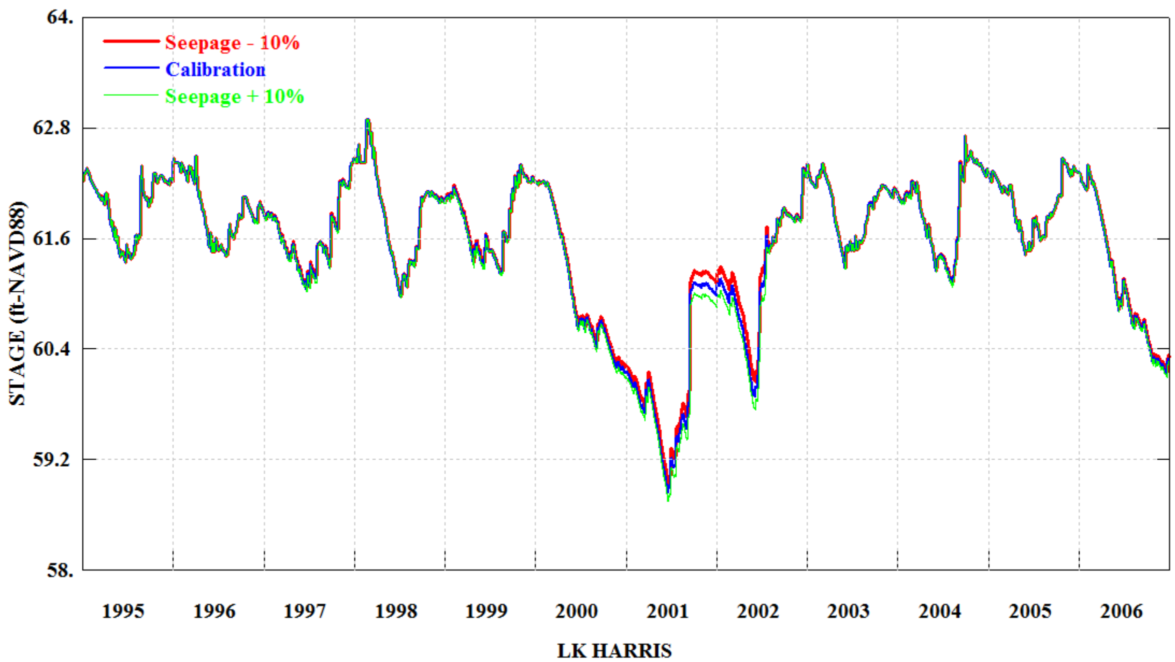

Figure 8. Lake Harris stage responds to seepage rate reduced/increased by 10%.

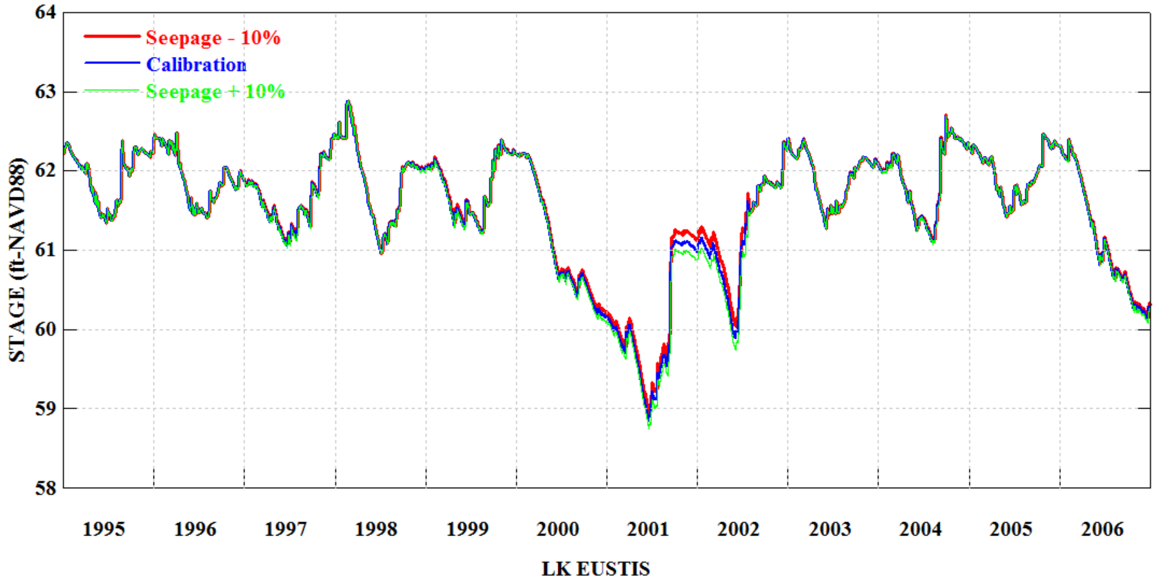

Figure 9. Lake Eustis stage responds to seepage rate reduced/increased by 10%.

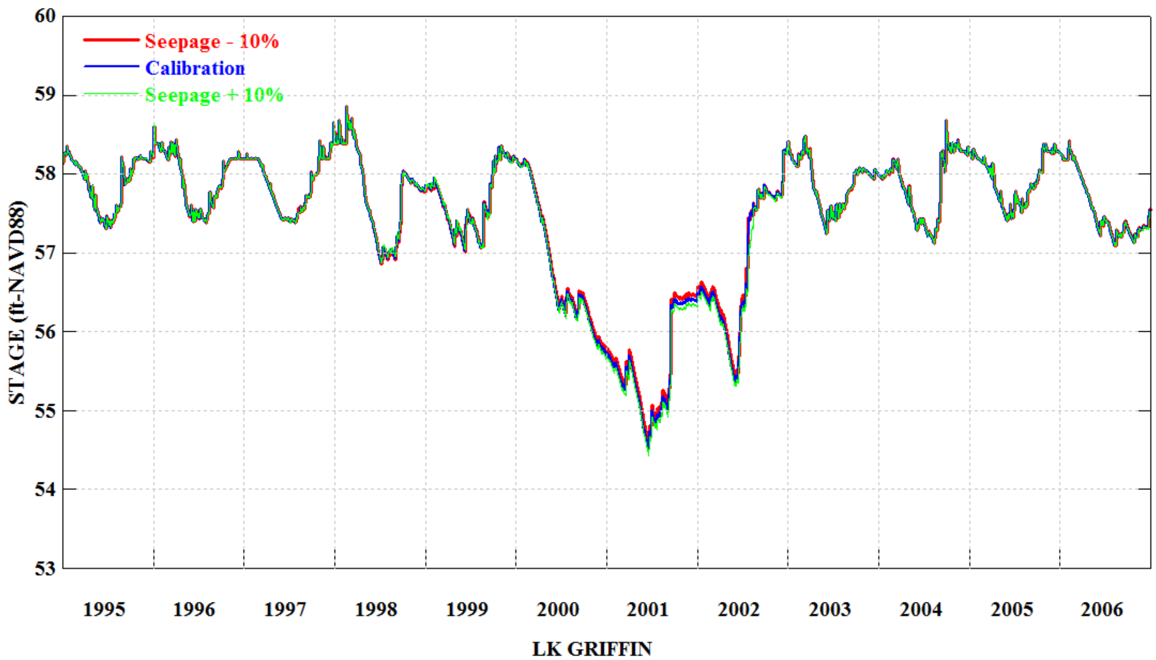

Figure 10. Lake Griffin stage responds to seepage rate reduced/increased by 10%.

Table 4. Lake stage (ft-NAVD88) statistics corresponding to calibration, seepage rate reduced or increased by 10%.

Sensitivity Scenarios	Stats	LK APOPK	LK DORA	LK HARRI	LK EUSTI	LK GRIFF
Calibration	Max	66.7	63.54	62.89	62.88	58.86
	Min	61.48	58.84	58.84	58.84	54.5
	Mean	65.1	61.61	61.54	61.53	57.47
Seepage - 10%	Max	66.71	63.55	62.89	62.88	58.86
	Min	61.53	58.95	58.94	58.94	54.58
	Mean	65.11	61.64	61.56	61.56	57.48
Seepage + 10%	Max	66.7	63.53	62.89	62.88	58.86
	Min	61.4	58.73	58.74	58.74	54.43
	Mean	65.1	61.59	61.52	61.51	57.46

3. Runoff

In this sensitivity analysis, runoff includes both direct surface runoff and base flow. Decreasing or increasing runoff by 10% is achieved through adjusting corresponding "multiplication factor" in the MASS-LINK of the LAUORB model.

Figures 11 through 15 depict how the five lakes from upstream Lake Apopka to downstream Lake Griffin respond to runoff decreased or increased by 10%. The results show that there are small impacts on lake levels for all five lakes during the droughts or periods of lower lake stages. The average lake level difference for each lake is no larger than 0.05 ft (Table 5).

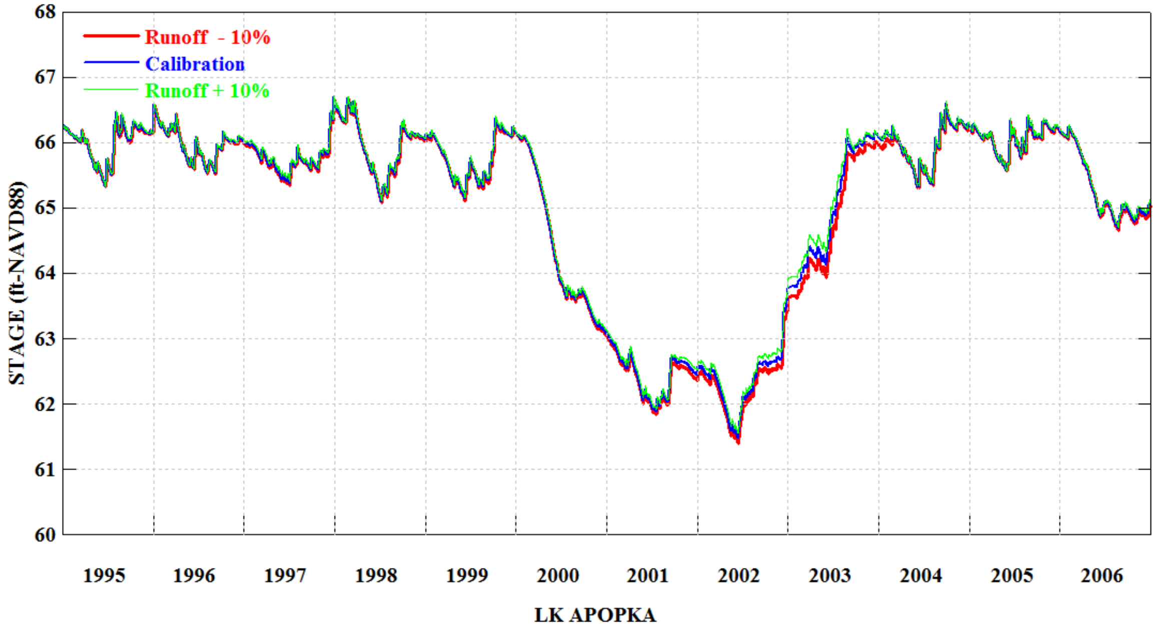

Figure 11. Lake Apopka stage responds to runoff reduced/increased by 10%.

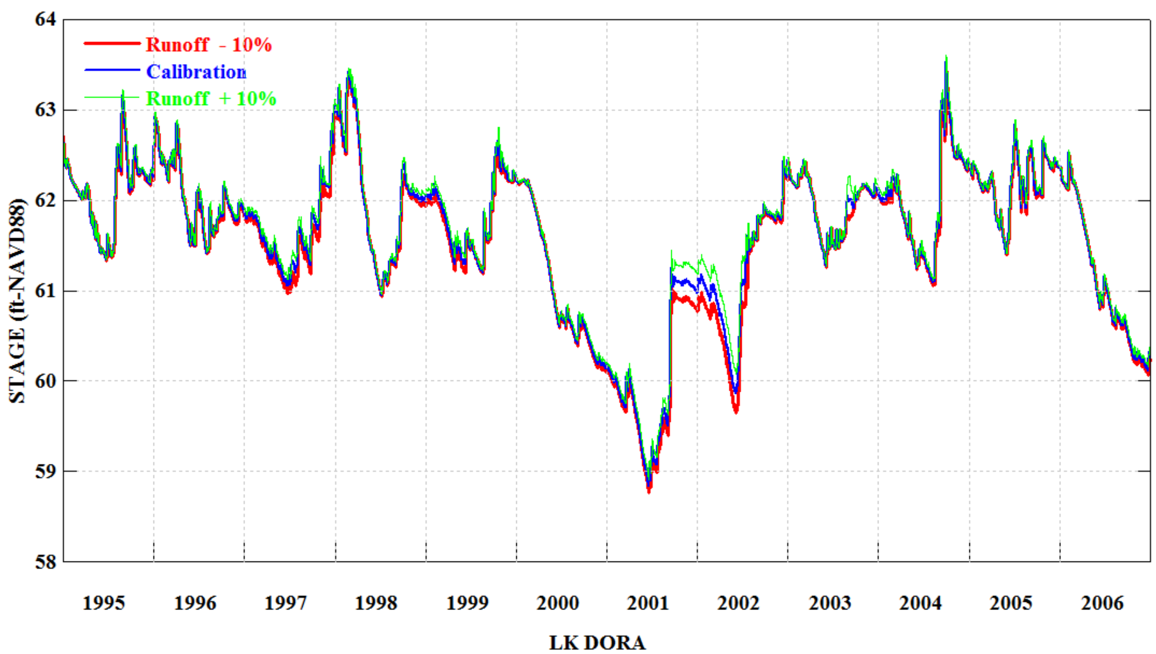

Figure 12. Lake Dora stage responds to runoff reduced/increased by 10%.

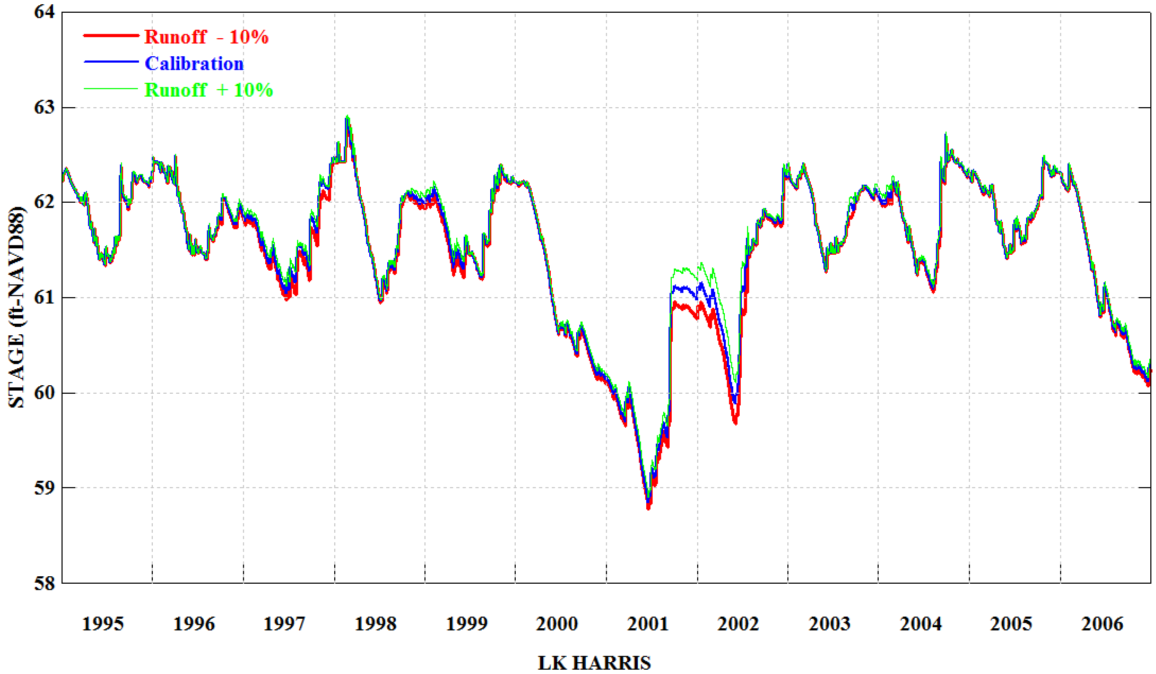

Figure 13. Lake Harris stage responds to runoff reduced/increased by 10%.

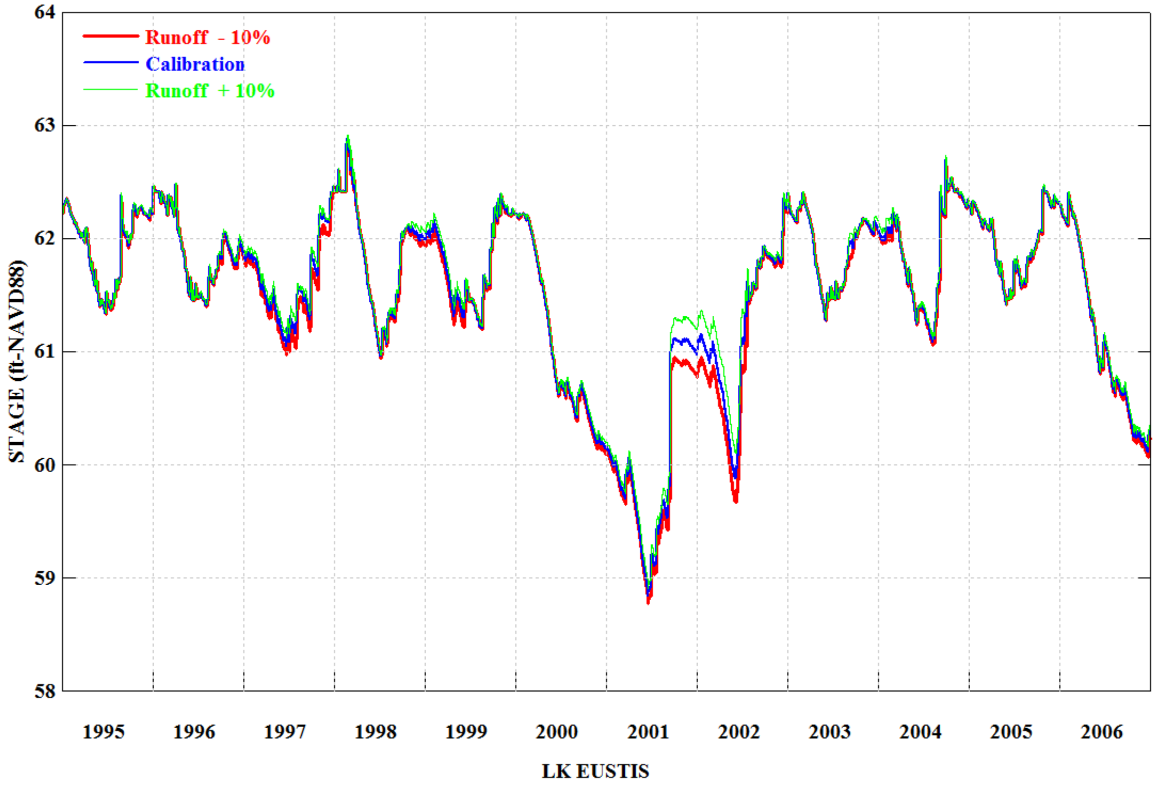

Figure 14. Lake Eustis stage responds to runoff reduced/increased by 10%.

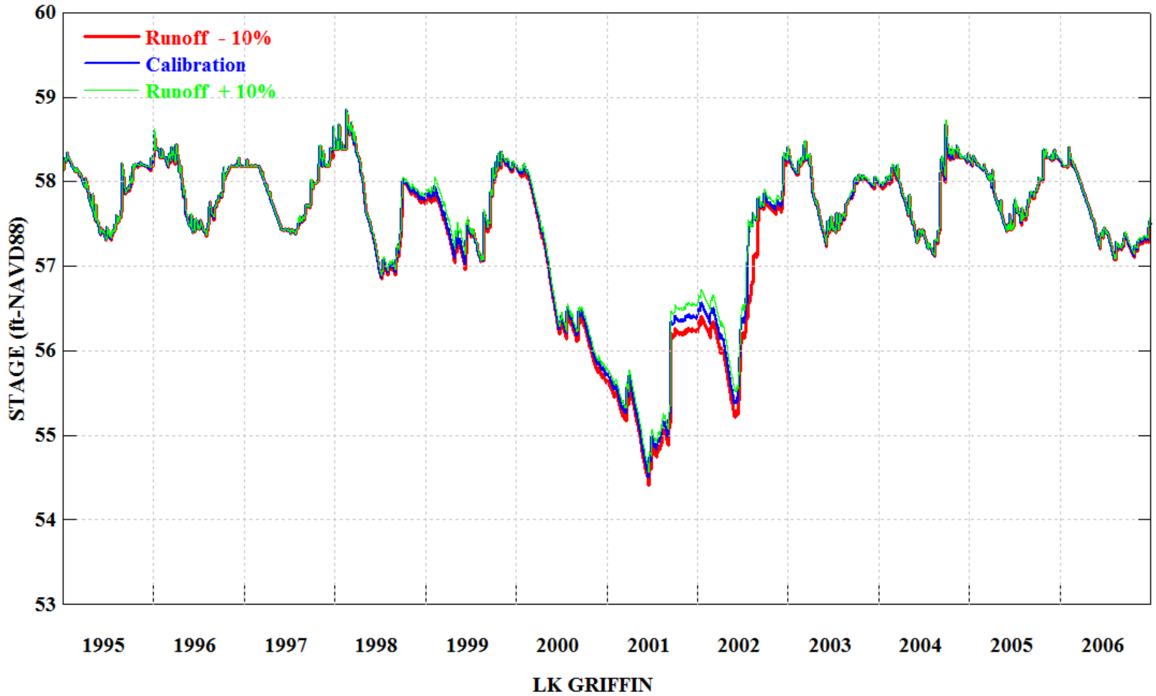

Figure 15. Lake Griffin stage responds to runoff reduced/increased by 10%.

Table 5. Lake stage (ft-NAVD88) statistics corresponding to calibration, runoff reduced or increased by 10%.

Sensitivity Scenarios	Stats	LK APOPK	LK DORA	LK HARRI	LK EUSTI	LK GRIFF
Calibration	Max	66.7	63.54	62.89	62.88	58.86
	Min	61.48	58.84	58.84	58.84	54.5
	Mean	65.1	61.61	61.54	61.53	57.47
Runoff - 10%	Max	66.68	63.45	62.87	62.86	58.85
	Min	61.4	58.77	58.78	58.78	54.41
	Mean	65.05	61.56	61.5	61.49	57.43
Runoff + 10%	Max	66.73	63.61	62.92	62.91	58.87
	Min	61.55	58.91	58.91	58.91	54.57
	Mean	65.13	61.66	61.58	61.57	57.5

4. Rainfall

The rainfalls are observed data, are stored in a WDM file named "RainModel20130613.wdm" and are fed into the model during the model run. For this sensitivity analysis, all the hourly precipitations are uniformly decreased or increased by 10% through adjusting corresponding "multiplication factor" in the EXT SOURCES of the LAUORB model.

Figures 16 through 20 depict all five lakes are very sensitive to rainfall decreased or increased by 10%. The LAUORB model is more sensitive to rainfall reduced by 10% than increased by 10% especially during the droughts or the periods of lower lake stages. Compared with calibration model results, the sensitivity scenarios can reduce or increase lake levels by over 1 ft (Figures 16 through 20). On average, reducing rainfall by 10% will lower lake levels by 0.4, 0.35, 0.28, 0.31 and 0.28 ft while increasing rainfall by 10% will increase lake levels by 0.24, 0.24, 0.3, 0.18, and 0.18 ft, respectively for Lakes Apopka, Dora, Harris, Eustis, and Griffin (Table 6).

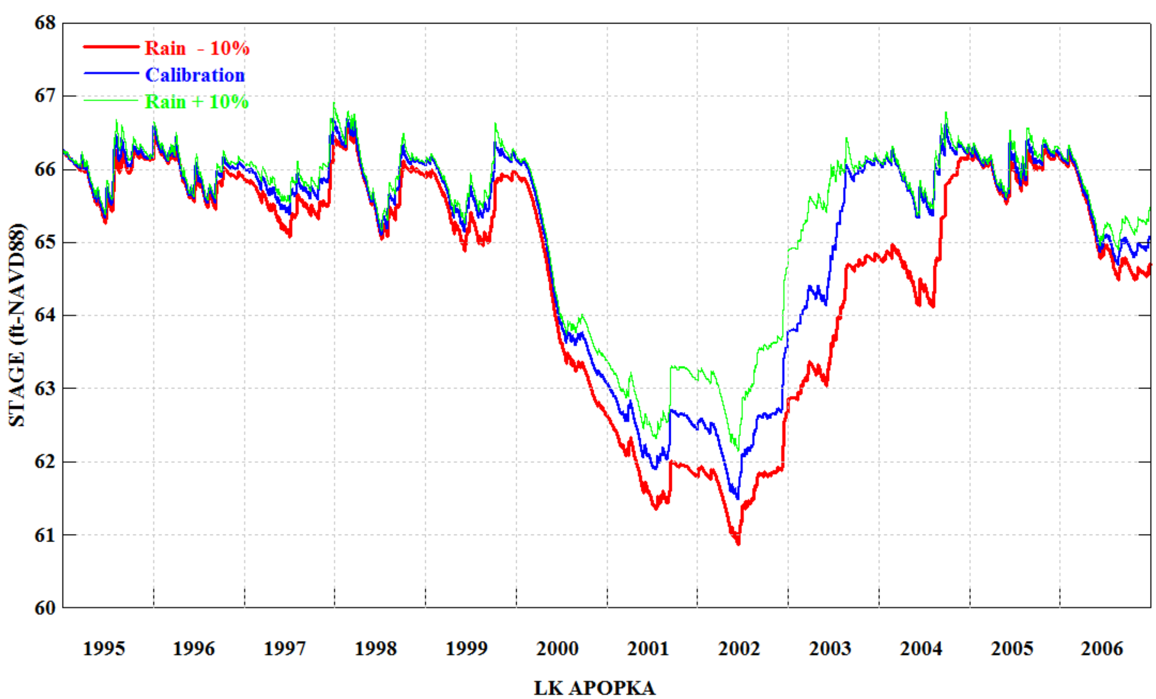

Figure 16. Lake Apopka stage responds to rainfall reduced/increased by 10%.

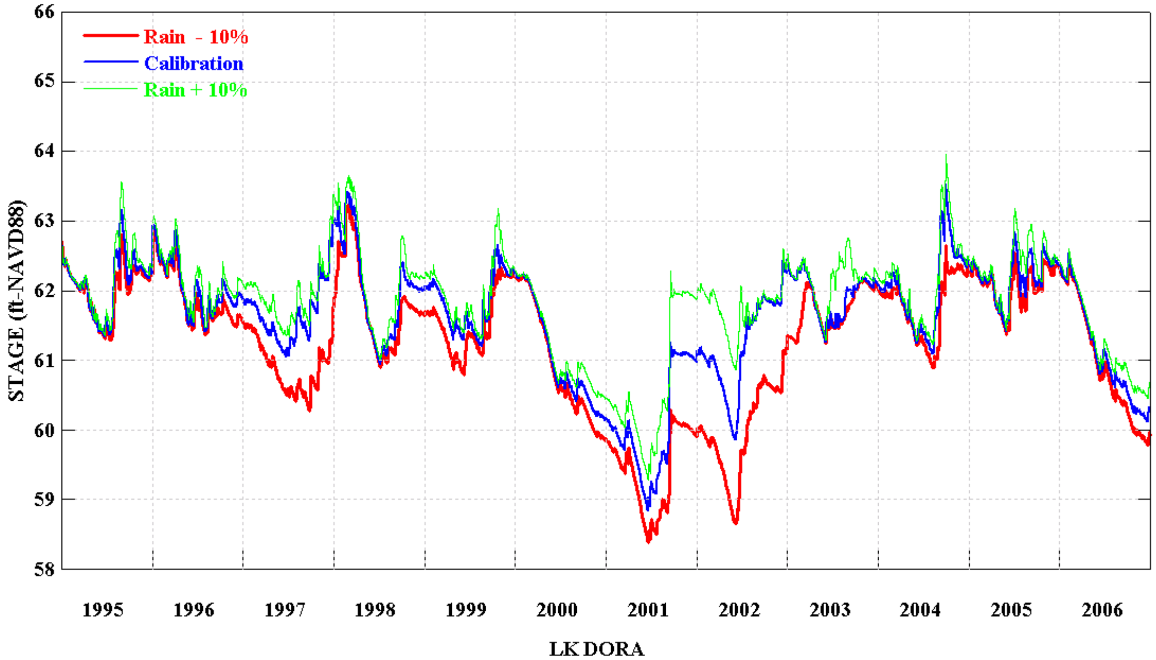

Figure 17. Lake Dora stage responds to rainfall reduced/increased by 10%.

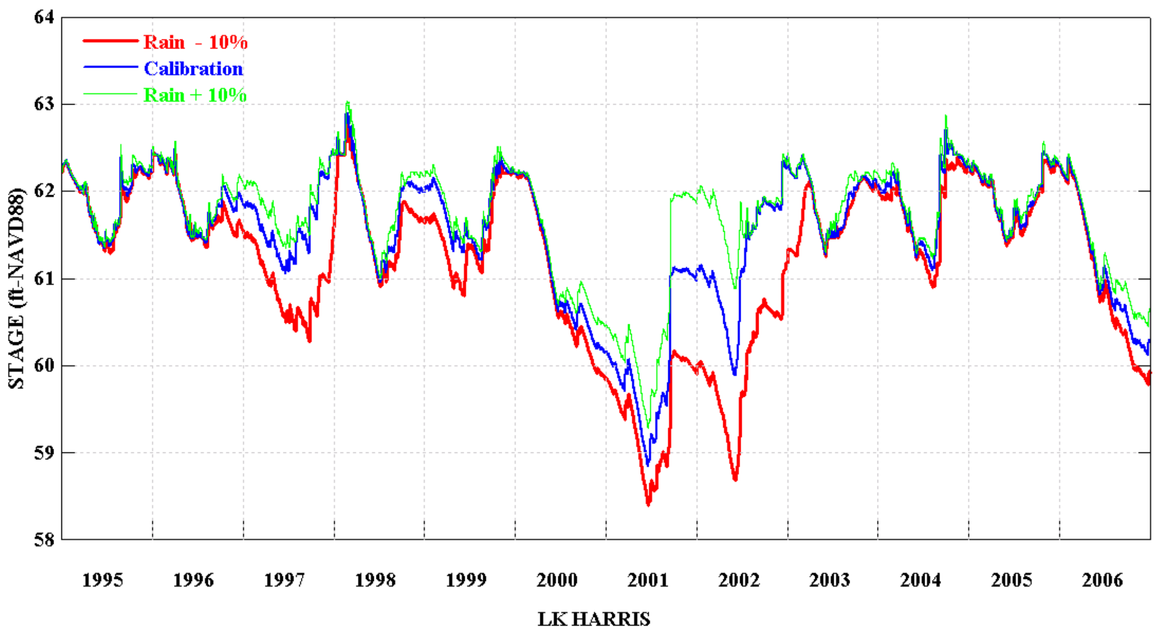

Figure 18. Lake Harris stage responds to rainfall reduced/increased by 10%.

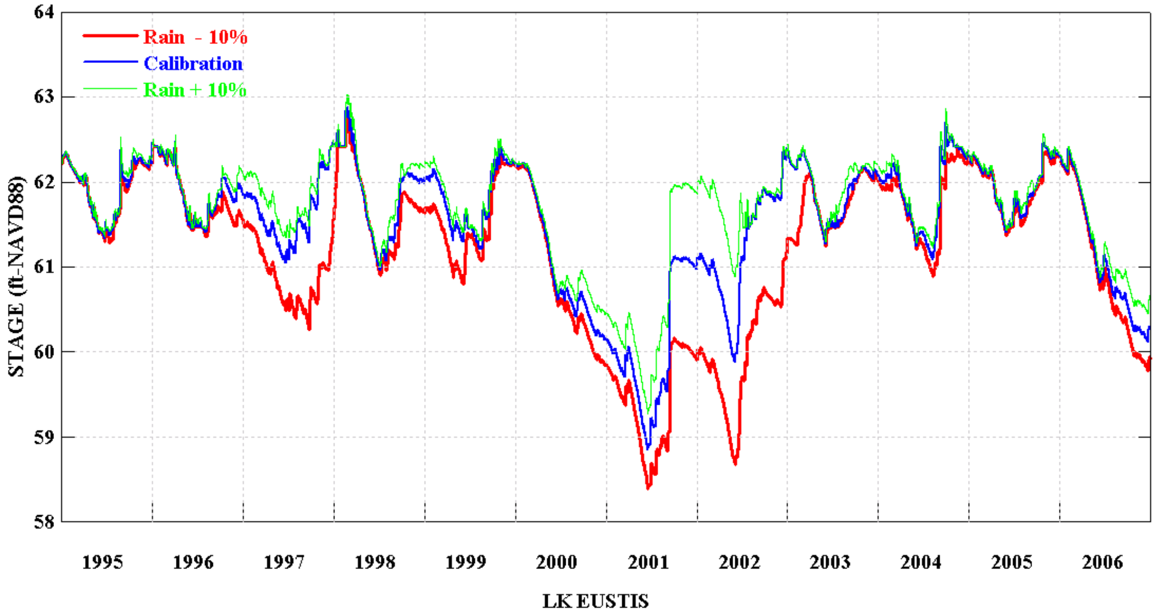

Figure 19. Lake Eustis stage responds to rainfall reduced/increased by 10%.

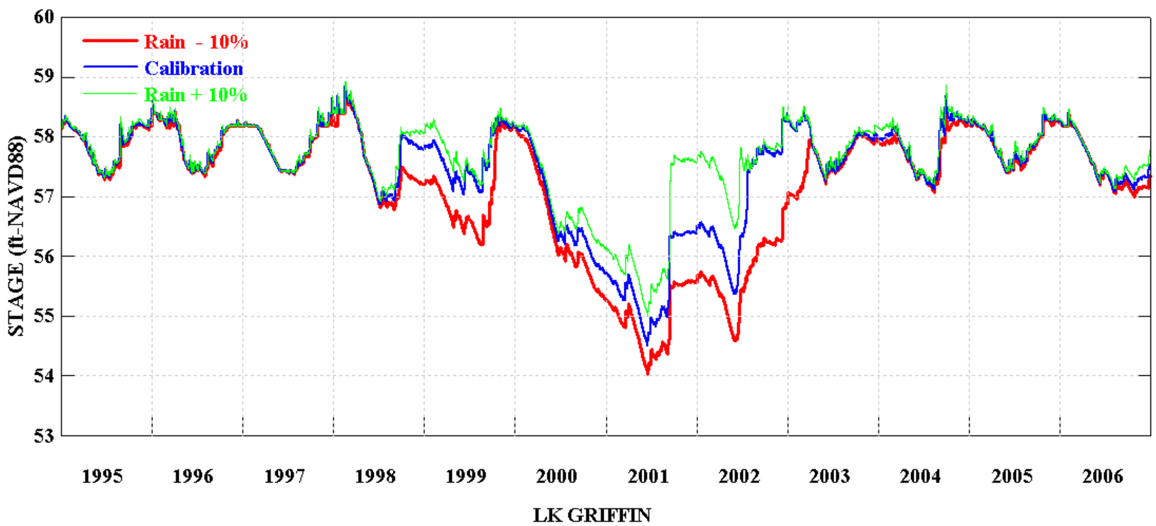

Figure 20. Lake Griffin stage responds to rainfall reduced/increased by 10%.

Table 6. Lake stage (ft-NAVD88) statistics corresponding to calibration, rainfall reduced or increased by 10%.

Sensitivity Scenarios	Stats	LK APOPK	LK DORA	LK HARRI	LK EUSTI	LK GRIFF
Calibration	Max	66.70	63.54	62.89	62.88	58.86
	Min	61.48	58.84	58.84	58.84	54.50
	Mean	65.10	61.61	61.54	61.53	57.47
Rain - 10%	Max	66.60	63.27	63.23	62.78	58.79
	Min	60.87	58.38	58.38	58.39	54.02
	Mean	64.70	61.26	61.26	61.22	57.19
Rain + 10%	Max	66.92	64.00	63.95	63.02	58.93
	Min	62.15	59.28	59.28	59.27	54.99
	Mean	65.34	61.85	61.84	61.71	57.65

5. Rating curve discharge

Tables 7 through 9 list rating curve discharges used in the LAUORB model for Apopka-Beauclair Lock and Dam, Burrell Lock and Dam, and Moss Bluff Lock and Dam. For sensitivity analysis of structure rating curves, all discharges in Tables 7 through 9 were reduced or increased by 10%.

Figures 21 through 25 and Table 10 display how the five lakes from upstream Lake Apopka to downstream Lake Griffin respond to rating curve discharges decreased or increased by 10%. The results show that there are minimal impacts on lake levels for all five lakes. Table 10 shows that decreasing or increasing rating curve discharge by 10% will not impact the average lake levels by more than 0.03 ft in comparison with the calibration model results.

Table 7. Rating curve discharge schedule at Apopka-Beauclair Lock and Dam used in the LAUORB HSPF model (cfs)

Water level above regulation schedule (ft)	A-B Canal Q (cfs)
<=0	23
<=0.1	116
<=0.2	138
<=0.3	269
<=0.4	340
<=0.5	377
<=0.6	437
<=0.7	464
<=0.8	540
<=0.9	600
>0.9	600

Table 8. Rating curve discharge 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
<=0	28	28	28	28
<=0.1	225	277	624	600
<=0.2	338	277	777	600
<=0.3	1450	1067	948	700
<=0.4	1450	1370	1154	880
<=0.5	1450	1500	1500	1500
<=0.6	1450	1500	1500	1500
<=0.7	1450	1600	1600	1600
<=0.8	1450	1650	1650	1650
>0.8	1650	1650	1650	1650

Table 9. Rating curve discharge 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
<=0	30	30	30	30
<=0.1	258	455	762	562
<=0.2	453	455	919	885
<=0.3	1280	455	1286	1041
<=0.4	1695	1041	1286	1041
<=0.5	1695	1650	1650	1650
>0.5	2000	2000	2000	2000

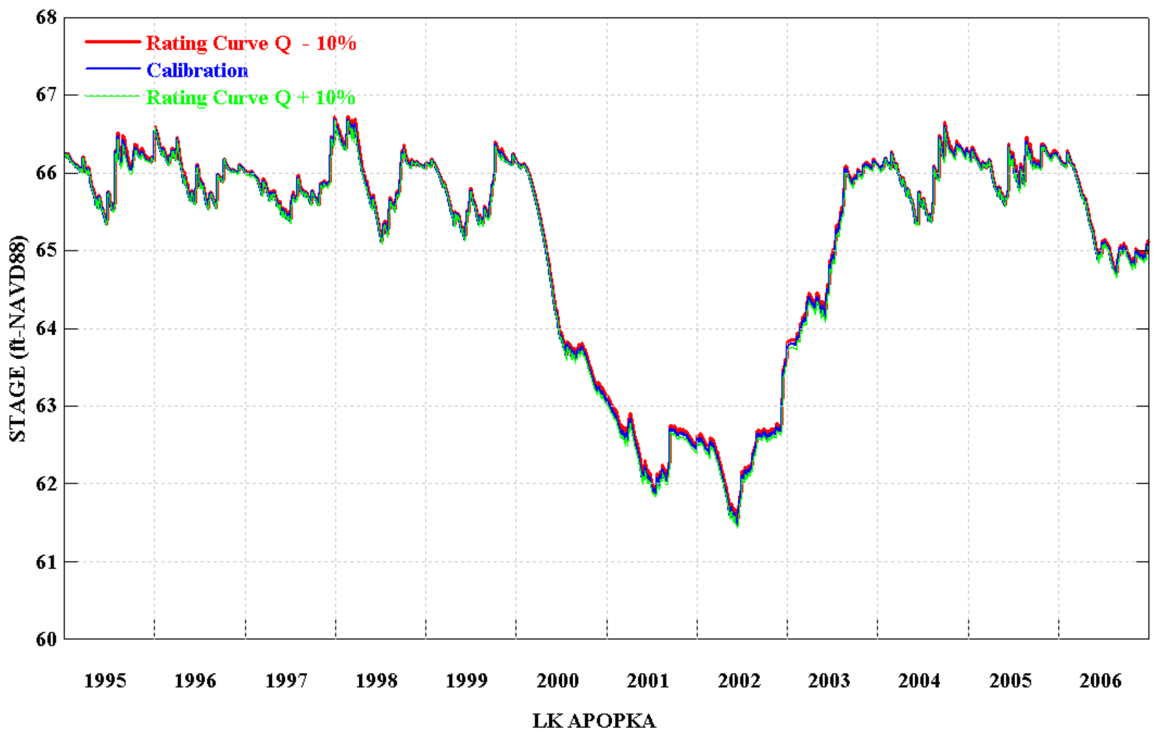

Figure 21. Lake Apopka stage responds to structures (A-B Canal, Burrell, and Moss Bluff) rating curve discharge rate reduced or increased by 10%.

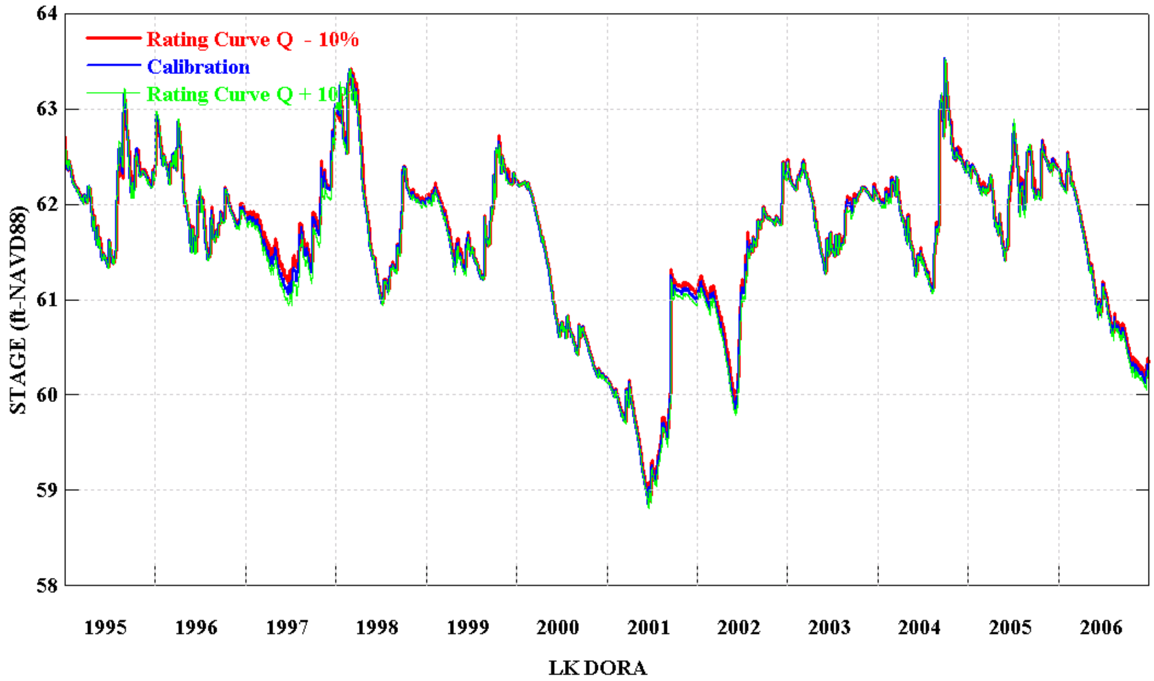

Figure 22. Lake Dora stage responds to structures (A-B Canal, Burrell, and Moss Bluff) rating curve discharge rate reduced or increased by 10%.

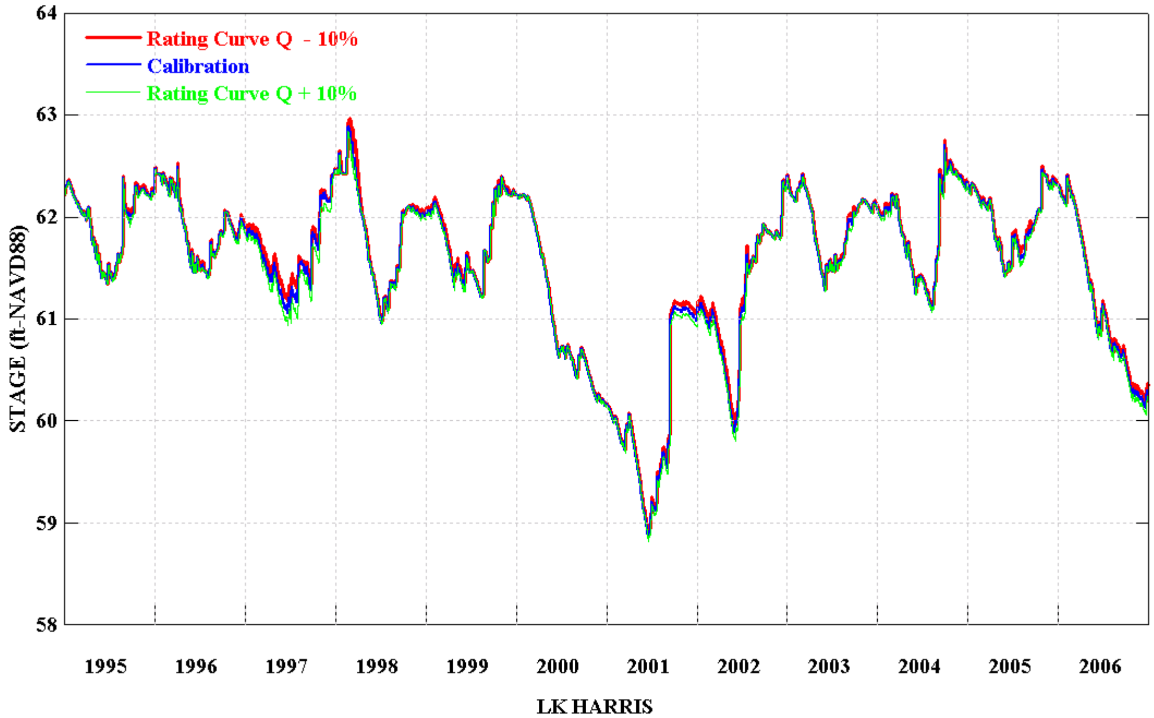

Figure 23. Lake Harris stage responds to structures (A-B Canal, Burrell, and Moss Bluff) rating curve discharge rate reduced or increased by 10%.

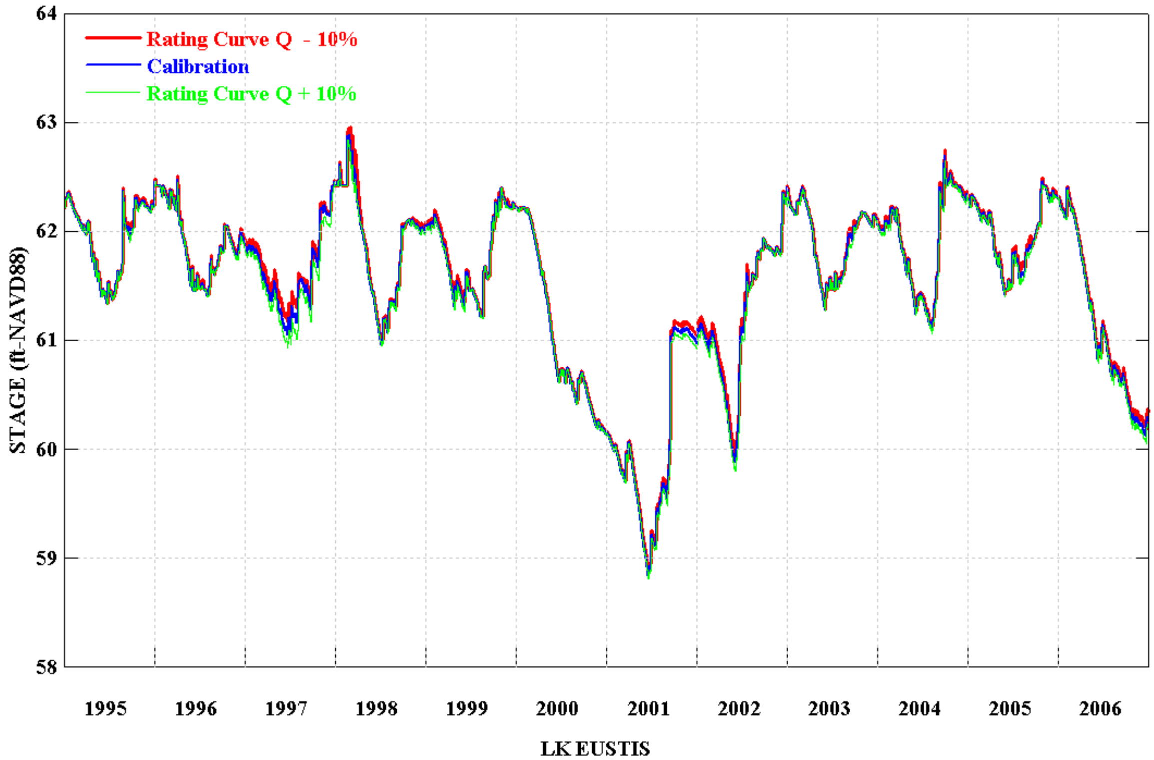

Figure 24. Lake Eustis stage responds to structures (A-B Canal, Burrell, and Moss Bluff) rating curve discharge rate reduced or increased by 10%.

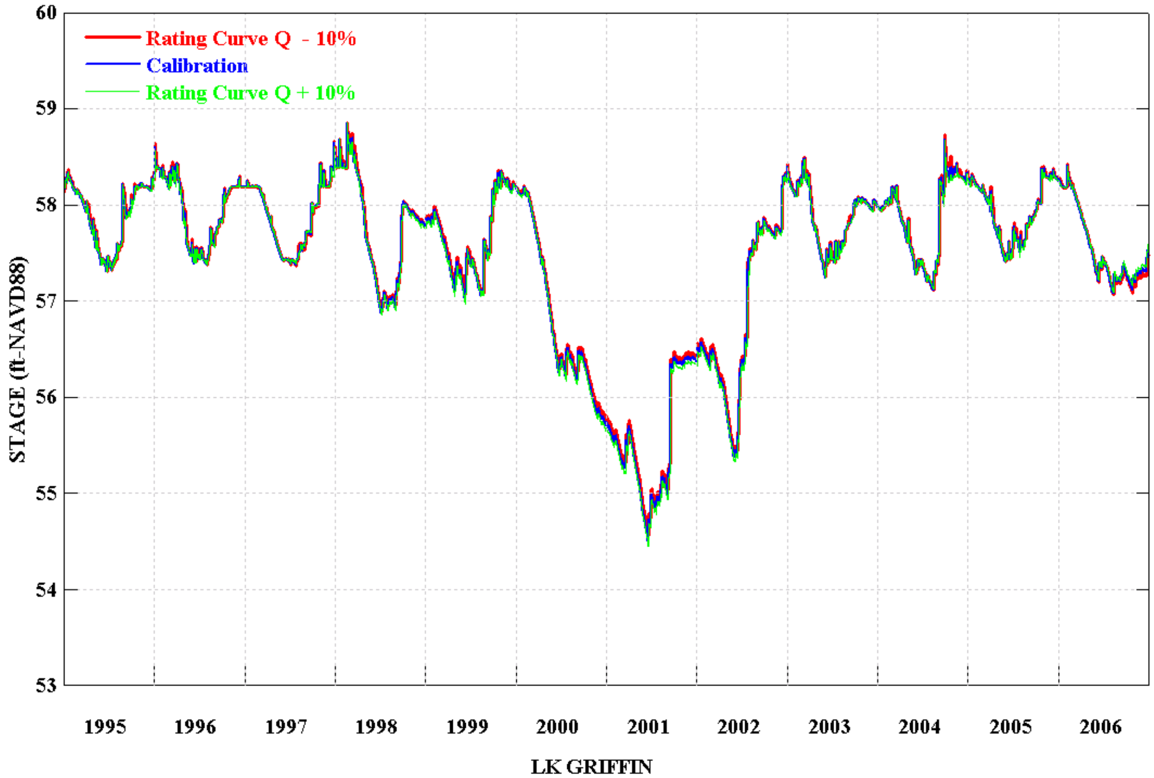

Figure 25. Lake Griffin stage responds to structures (A-B Canal, Burrell, and Moss Bluff) rating curve discharge rate reduced or increased by 10%.

Table 10. Lake stage (ft-NAVD88) statistics corresponding to calibration, structures (A-B Canal, Burrell, and Moss Bluff) rating curve discharge rate reduced or increased by 10%.

Sensitivity Scenarios	Stats	LK APOPK	LK DORA	LK HARRI	LK EUSTI	LK GRIFF
Calibration	Max	66.7	63.54	62.89	62.88	58.86
	Min	61.48	58.84	58.84	58.84	54.5
	Mean	65.1	61.61	61.54	61.53	57.47
Rating Curve Q - 10%	Max	66.72	63.52	62.97	62.96	58.86
	Min	61.53	58.87	58.87	58.87	54.56
	Mean	65.13	61.64	61.56	61.56	57.49
Rating Curve Q + 10%	Max	66.68	63.53	62.85	62.84	58.85
	Min	61.43	58.8	58.81	58.81	54.45
	Mean	65.07	61.59	61.51	61.51	57.45

6. NSRA pump schedule

There are two NSRA (Lake Apopka North Shore Restoration Area) pumps, i.e., Unit 1 and Unit 2 pumps, which pumps water from NSRA to Lake Apopka to control water levels at NSRA. Under the baseline condition, Unit 1 and 2 pumps will turn on/off when water depth is above/below 2 and 3 ft, respectively. The sensitivity analysis will test pump-triggering water depth reduced by 1 ft, i.e., the triggering water depth will be 1 and 2 ft, respectively for Unit 1 and Unit 2 pumps. Under this scenario more water will be pumped to Lake Apopka from NSRA. The results are shown in Figure 26 and Table 11. The pumpage from NSRA to Lake Apopka increases to 8.7 cfs from Baseline's 5.7 cfs. However, the impact on Lake Apopka water level is small: the average lake stage difference is only 0.03 ft, the difference on the minimum lake stage is 0.05 ft and there is no difference on the maximum lake stage (Table 11).

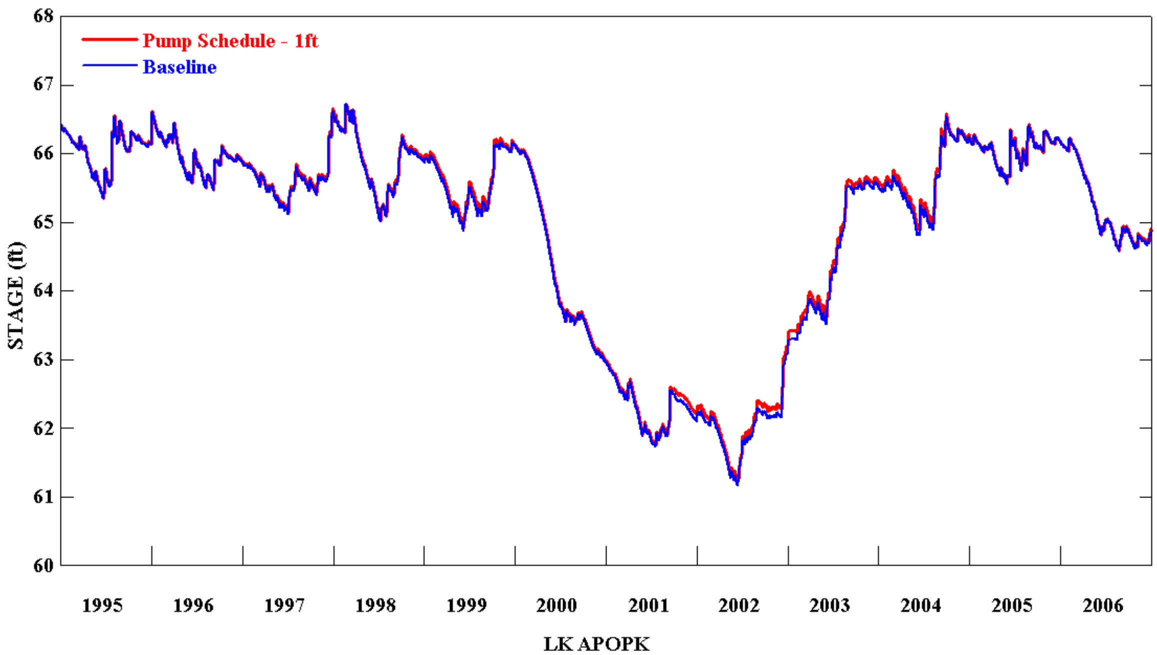

Figure 26. Lake Apopka stage responds to pump schedule reduced by 1 ft under baseline condition.

Table 11. Lake Apopka stage and NSRA statistics corresponding to pump schedule reduced by 1 ft.

Sensitivity Scenarios	Stats	LK APOPK Stage (ft-NAVD88)	NSRA Pumpage to Apopka (cfs)
Baseline	Max	66.72	33
	Min	61.17	0
	Mean	64.92	5.7
Pump Schedule - 1 ft	Max	66.72	33
	Min	61.22	0
	Mean	64.95	8.7

Conclusions

In conclusion, the LAUORB model is most sensitive to rainfall changes by +/-10%, followed by UFA POT surface changes by +/-1 ft, and then followed by runoff changes +/-10%, especially during the drought or the periods of lower lake stage. The model is not very sensitive to the three remaining variables, i.e., seepage changes by +/-10%, structure rating curve changes by +/-10%, and NSRA pump schedule reduced by 1 ft. However, even for these three variables, there are noticeable impacts on lake stages during the multi-year drought or the periods of lower lake stage.

References

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