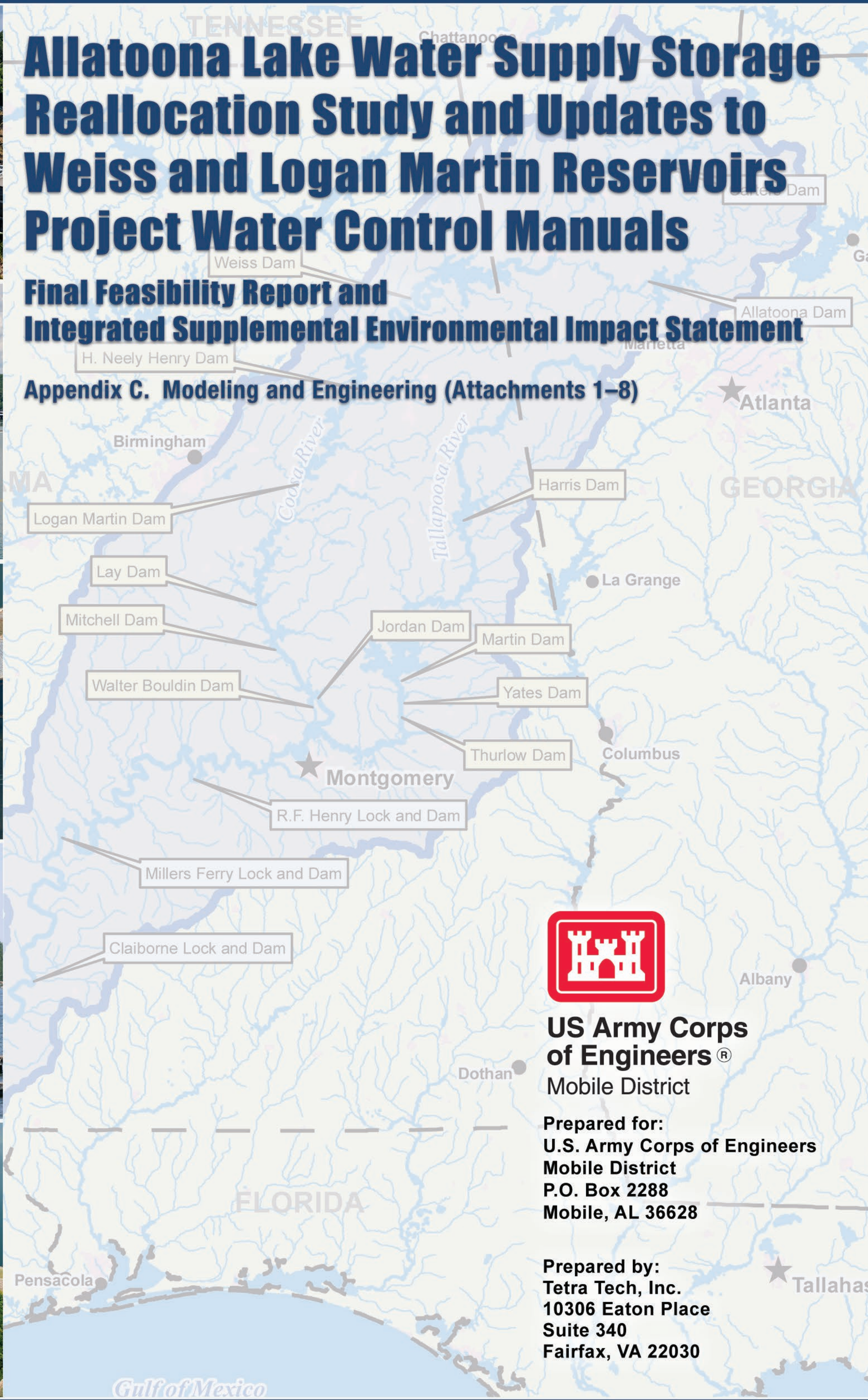
November 2020

Allatoona Lake Water Supply Storage Reallocation Study and Updates to Weiss and Logan Martin Reservoirs Project Water Control Manuals

Final Feasibility Report and Integrated Supplemental Environmental Impact Statement

Appendix C. Modeling and Engineering (Attachments 1–8)



US Army Corps of Engineers®
Mobile District

Prepared for:
U.S. Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628

Prepared by:
Tetra Tech, Inc.
10306 Eaton Place
Suite 340
Fairfax, VA 22030

APPENDIX C

MODELING AND ENGINEERING

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Attachment 1. HEC-ResSim Modeling of Reservoir Operations in Support of the Allatoona-Coosa Reallocation Study, Part 1 Daily Model Study Report

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Alabama-Coosa-Tallapoosa (ACT) Watershed

HEC-ResSim Modeling of Reservoir Operations in Support of the Allatoona-Coosa Reallocation Study

Part 1: Daily Study Model

November 2020

Prepared for:
US Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628-0001

Prepared by:
US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

(530) 756-1104
(530) 756-8250 FAX
www.hec.usace.army.mil

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I. Introduction

This report is an appendix to the "Allatoona Lake Water Supply Storage Reallocation Study and Updates to Weiss and Logan Martin Reservoirs Water Control Manuals" Preliminary Draft Feasibility Report. This supplement documents the HEC-ResSim reservoir operations models developed in support of the Allatoona-Coosa Reallocation Study. Part 1 of this report covers the daily timestep model used for general review, and Part 2 covers the hourly timestep model used to study flood conditions. A USACE Strategic Communications Plan was issued on 19 April 2018 entitled, "Allatoona Lake Water Supply Storage Reallocation Study and Updates to Weiss and Logan Martin Reservoirs Project Water Control Manuals". The following excerpt offers insight to the background of this study:

> "Eighteen major dams (six Federal and twelve non-Federal, Table 1), which form sixteen reservoirs, are located in the ACT River Basin (Figure 1). The ACT River Basin provides water resources for multiple purposes from northwestern Georgia down through central Alabama to the Gulf Coast at the mouth of Mobile Bay, extending a distance of approximately 320 miles and encompassing an area of approximately 22,800 square miles. Pursuant to Section 7 of the Flood Control Act of 1944, the USACE prescribes regulations for the operation of the USACE projects in the ACT River Basin for their authorized purposes, and for the non-federal projects that contain storage for the purposes of navigation or flood control (flood risk management), through water control plans and manuals.

Table 1. List of reservoirs or dams in the ACT basin

Reservoir or Dam	Location	Year in Service	Owner
Allatoona	Etowah River	1965	USACE
Carters	Coosawattee River	1974	USACE
Carters Reregulation	Coosawattee River	1974	USACE
Claiborne	Alabama River	1969	USACE
H. Neely Henry	Coosa River	1966	APC
Harris	Tallapoosa River	1982	APC
Hickory Log Creek	Hickory Log Creek	2008	Private
Jordan	Coosa River	1928	APC
Lay	Coosa River	1914	APC
Logan Martin	Coosa River	1964	APC
Martin	Tallapoosa River	1926	APC
Millers Ferry	Alabama River	1970	USACE
Mitchell	Coosa River	1923	APC
Robert F. Henry	Alabama River	1971	USACE
Richland Creek*	Richland Creek	2019	Private
Thurlow	Tallapoosa River	1930	APC
Walter Bouldin*	Bouldin Canal	1967	APC
Weiss	Coosa River	1961	APC
Yates	Tallapoosa River	1928	APC

- *APC is Alabama Power Company*
- *Richland Creek is currently under construction and is not included in the above paragraph.*
- *Walter Bouldin is a second dam on Jordan Lake.*

> "In May 2015, the USACE completed a long-term effort to update the Master WCM for the ACT River Basin, including updated WCMs for all five USACE projects (Allatoona Dam and Lake, Carters Dam and Lake, Robert F. Henry Lock and Dam, Millers Ferry Lock and Dam and Claiborne Lock and Dam) and two of four APC projects with navigation or flood control storage (H. Neely Henry Dam and Lake (Reservoir) and R.L. Harris Dam and Lake (Reservoir)). WCMs for the other two APC projects with navigation and flood control storage, Logan Martin Dam and Lake (Reservoir) and Weiss Dam and Lake (Reservoir), were not updated at that time. A pending request by the State of Georgia for additional water supply storage and changes to storage accounting practices at Allatoona Lake was also not included within the scope of the 2015 WCM update and EIS.
>
> "In January 2018, the U.S. District Court for the Northern District of Georgia issued a judgment in Georgia et al. v. U.S. Army Corps of Engineers, No. 14-cv-03593 (Jan. 9, 2018), holding that the USACE had unreasonably delayed action on Georgia's water supply request, and directing the USACE to take final action responding to that request by March 1, 2021. Following that court decision, the State of Georgia submitted an updated request to the USACE on March 31, 2018, and the USACE intends to evaluate actions necessary to implement Georgia's request, as well as one or more reasonable alternatives, in the proposed FR/SEIS.
>
> "The USACE did not include updates to the WCMs for the Weiss and Logan Martin projects in the 2015 ACT Basin WCM Update because further study of flood risk management issues at both projects was required. The APC proposes raising the winter conservation pool level and also lowering the upper limit of the induced surcharge operation at the Weiss Reservoir and the Logan Martin Reservoir. Current Water Control Plans for the Weiss and Logan Martin Reservoirs, originally issued in the 1960s, contain surcharge curves with elevations higher than the respective flood easements acquired by APC.
>
> "Because the USACE is simultaneously considering proposals to modify operations and update WCMs at three different ACT River Basin projects, the USACE intends to evaluate the effects of these proposals through a single EIS, which would supplement the Final EIS for the ACT Basin completed in May 2015. As part of this analysis, the USACE will consider the effects of the proposed changes on operations of the ACT system of projects for all purposes, and would revise the ACT Master WCM to incorporate the updated Allatoona Lake, Weiss Dam and Lake (Reservoir), and Logan Martin Dam and Lake (Reservoir) WCMs and to reflect changes, if any, in overall system operations."

Initial modeling goals were to establish the boundaries of reallocation from the flood and inactive pool, perform PMF routing for a dam safety check (see Appendix C, Attachment 2), and complete yield analysis to determine the initial benefit of the pool reallocation. The modeling also considers the flood pool reallocation at multiple Alabama Power Company owned projects and the update of Water Control Manuals in the ACT River Basin. The main report contains details about the planning process, including planning constraints, which are described in Section 4.1.2.3. The daily model also supports the water quality modeling with the HEC-5Q software.

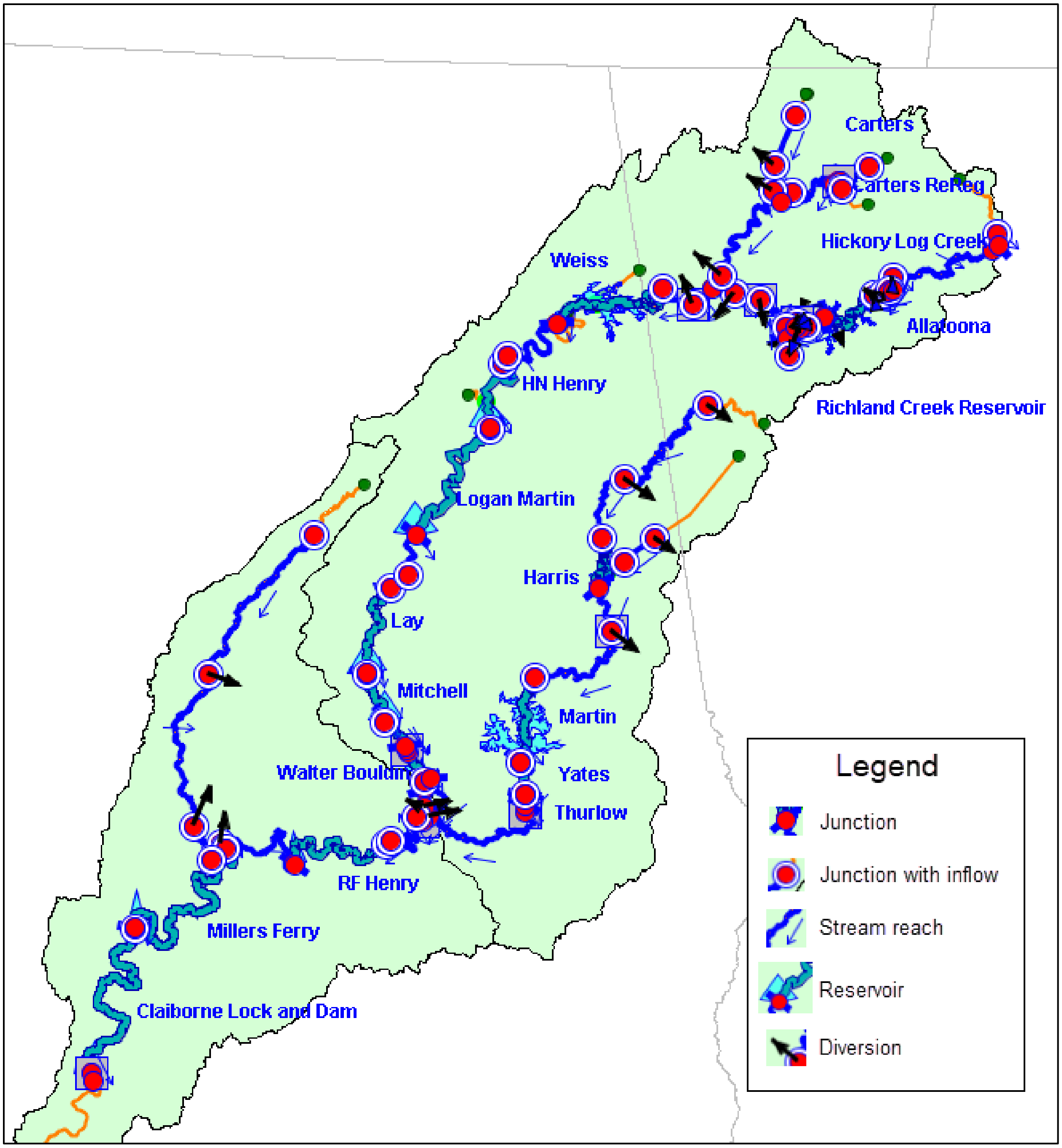


Figure 1. ACT watershed shown in the ResSim model schematic

A. ACT ResSim Modeling History

The ACT River Basin was modeled in early reservoir simulation software HEC-5. Transition from the HEC-5 model to the then new HEC-ResSim software was initiated in 2006 in preparation for the update of the basin Water Control Manuals. Since then, numerous improvements and changes have been made to the model and to the software itself. The major ACT ResSim modeling efforts are shown in Figure 2.

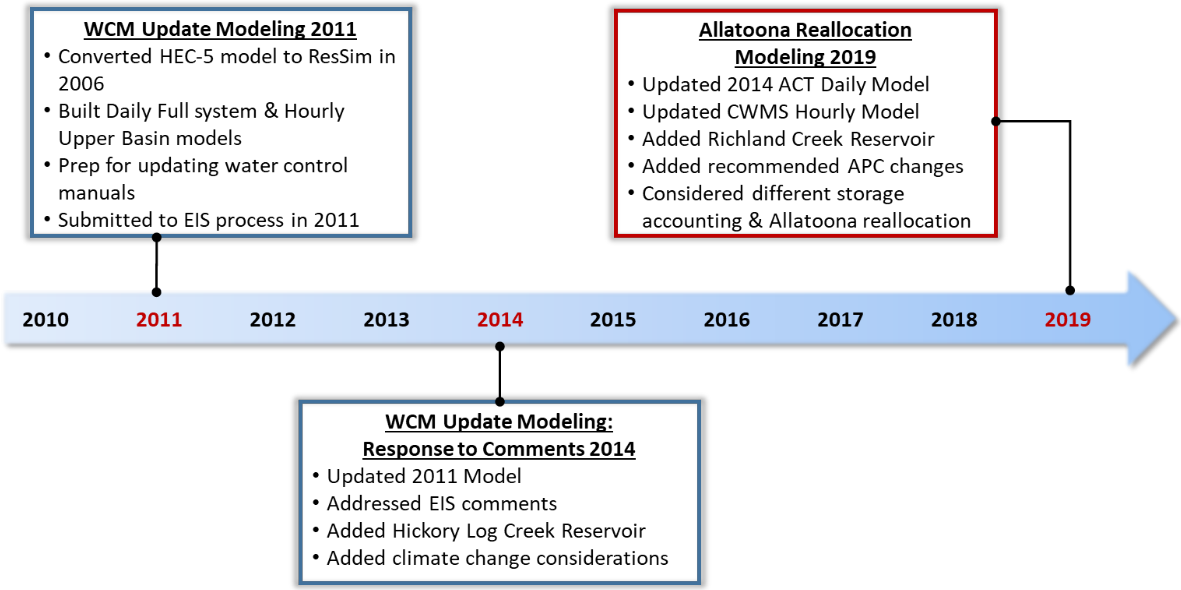


Figure 2. ACT ResSim study modeling timeline

By 2011 the Mobile District Water Control Manual Update was in the process of completing an Environmental Impact Statement. In conjunction, a report was developed to describe the modeling activities performed. The March 2011 report, "ACT HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update" details the initial design of the ACT ResSim model. An addendum to the March 2011 report was written to describe further changes to the system done during the EIS response to comments (USACE, Jul 2014). These documents are useful references that detail the assumptions and methods used to model the system and create the model that was the starting point for this work. That model, entitled "ACT-HLC_WCM_24Apr2014_HRPlansDFG", shall be referred to here as the 2014 model. It included 74 years (1939-2012) of continuously simulated, daily time step, lake levels and river flows throughout the ACT basin. The new daily model is titled "ACT-2018-daily". Part 2 of this report focuses on the model updates that were completed for the purposes of the Allatoona-Coosa Reallocation Study.

B. Overview of this Report

A number of changes were made to the 2014 model network, and a new baseline condition was developed. These changes and updates to the physical and operational properties of the reservoir are described in **Section II. Model Updates**.

Details about the operations recommended by Alabama Power Company are found in **Section III. Alabama Power Company (APC) Updates**.

The various guide curve options modeled at Allatoona are described in **Section IV. Allatoona Guide Curves** and the Allatoona water storage accounting changes are in **Section V. Allatoona Water Storage Accounting**. All of these changes necessitated the development of a new network, new model input files, and new alternatives. These updates are described throughout this report.

A listing and description of all the different alternatives modeled is in **VI. Modeled Alternatives**. The updates made to support results analysis are described in **Section VII. Sample Results and Reporting Updates**.

Details on the state variables created and updated for this work can be found in **Appendix A. State Variables & Scripted Rules**.

Appendix B. Computation of Local Flows from the Climate Change Data describes the process for developing unimpaired local flow data for climate change scenarios.

In addition to the daily timestep model, an hourly model was developed to support this study. The hourly model was used to study operations of the Upper ACT Basin under flood conditions. This work is described in **Part 2** of this report (**Appendix C, Attachment 2**).

C. HEC-ResSim Version Selection

Because the HEC-ResSim software is being continually improved, it was important to establish a specific version to be used for the Allatoona-Coosa Reallocation Study modeling. The April 2014 model results were computed using HEC-ResSim 3.2 Dev, December 2013 Build 3.2.1.22. Modeling for the Allatoona-Coosa Reallocation Study was performed in the new, developmental ResSim 3.4.1 build 32 (May 2018). Since the 3.2 version, the ResSim software has experienced changes including new features, enhancements, bug fixes, and improved algorithms. Significant advantages of the 3.4 ResSim include improved power operations, table options, and compute blocking. Most importantly, the 3.4 version was chosen to be consistent with the ResSim version currently used in the Corps Water Management Software.

Before officially moving the ACT model into the latest ResSim software, a review of changes between software versions was executed. In order to best identify and evaluate any differences in model results due to the software change, the first step was to run several alternatives using the 2013 software (build 3.2.1.22) and the 2018 software (build 3.4.1.32) and compare the results. Several alternatives were run in both ResSim versions for the full period of record. Key results time series, particularly reservoir storage and release, were identified for comparison. Over the full period of record, observed differences were minor. Some differences were seen related to the improvements to tandem operations and some related to the estimation of maximum capacity, but none had concerning impacts to results. To further satisfy the theory that software changes would be acceptable to this study, the team investigated the state variables that indicate the state of the system and can significantly impact operations. State variables related to the Drought Level Response (DLR) and navigation rules were compared. None of the differences suggested a change to the alternative rating. These results were satisfactory to the team, and modeling proceeded with ResSim build 3.4.1.32.

II. Model Updates

The modeling for the Allatoona-Coosa Reallocation Study began with the 2014 model that was used to study the system during the Water Control Manual Update. As stated earlier, documentation of that work can be found in the 2011 report and the 2014 response to review comments. The 2014 model network, titled "***2013***" was updated to create the ***2018*** network. The ***HRPlanG*** alternative, which was the prior selected alternative, was updated to create a new baseline alternative, ***Base2018***, for this phase of modeling.

The basic model updates for this study applied to the network and the baseline alternative are described in this section of the document. Other model updates that varied based on alternative are found in later sections. This section addresses the following:

A. Richland Creek Reservoir
B. Allatoona Lake
C. Elevation-Storage-Area Table for Carters Reregulation Pool
D. Pumping Hours at Carters Lake
E. Weiss Bypass Operation
F. HN Henry Updates – Gadsden Flood Operation
G. Childersburg and Gadsden Junctions
H. Harris Operation
I. Martin Lake Guide Curve
J. Millers Ferry and RF Henry Power Capacity
K. Other Model Updates

The details of the changes are described below in the separate sections.

A. Richland Creek Reservoir

Richland Creek Reservoir is a new project permitted and currently under construction in the Coosa River Basin (in the Upper ACT Basin). The overall purpose of the project is to provide a reliable source of water, capable of satisfying the projected unmet water demand of Paulding County and its water service delivery area during drought conditions through the year 2060. This reservoir is intended to replace Cobb County Marietta Water Authority (CCMWA) as the source of Paulding County's water supply. In 2006 (baseline condition), CCMWA supplied 10.6 million gallons per day (mgd) to Paulding County. This demand is expected to shift to Richland Creek. Georgia's updated water supply request has been reduced to reflect two changes – reduction in water supply to Paulding County and decreased population projection.

In 2018 the Georgia Department of Natural Resources issued permits to the Paulding County Water System for surface water withdrawal from the Etowah River and pumping into Richland Creek Reservoir (Permit # 110-1424-02) and withdrawal from the reservoir (Permit # 110-1424-01) for the purpose of municipal water supply. The State of Georgia included Richland Creek in its March 2018 ResSim model to support analysis of the 2013 requested changes to Allatoona's storage allocation (Zeng, 2018). The State of Georgia model was used as the basis for the Richland Creek modeling approach used in the study models.

General information about the Richland Creek Reservoir project can be found in the main report. To summarize, the project is a 305-acre pumped storage water supply reservoir on Richland Creek, with normal pool elevation at 910 feet above mean sea level (AMSL). The reliable yield of the proposed reservoir will be 35 MGD. A water treatment plant will be constructed adjacent to the proposed Richland Creek Reservoir and would withdraw water from the reservoir for treatment and distribution to the County's water system. Water will be pumped from the Etowah River and stored in the reservoir. The raw water intake and pump station will be located on the south side of the Etowah River, at latitude 34.1275 and longitude -84.8441, approximately 8 river miles downstream of the Lake Allatoona dam. Water would be pumped to the reservoir via a 3.7 mile long raw water pipeline. Pumping from the Etowah River can only occur if flows exceed state established minimum monthly low flows at the Etowah River pump intake. Additionally, state has established minimum monthly reservoir releases into Richland Creek equivalent to monthly 7Q10 flows.

The modeling of Richland Creek Reservoir is described in three sections: Network Updates, Physical Data, and Reservoir Operation.

1. Network Updates

Richland Creek is a tributary of the Etowah River, which is a major component of the Coosa Basin, and flows into the river downstream of Allatoona Lake. The project site is located on Richland Creek, approximately 0.4 miles upstream from the Paulding County/Bartow County line. The approximate location of the proposed dam is latitude 34.0797 and longitude -84.8567. Figure 3 shows the original network with the addition of Richland Creek to the in ResSim stream alignment. Figure 4 shows the updated 2018 network with Richland Creek Reservoir and the associated diversions, local flows, and diverted outlet in the ResSim schematic.

Adding the Richland Creek Reservoir to the model required modifications to the distribution of the local flows at some junctions around the reservoir. As shown in Figure 3, without Richland Creek, the 2014 model included only one intermediate junction (Cartersville) between Allatoona Reservoir and Kingston. A single local flow time series called "Kingston Local Flow" (DSS record = "ETOWAH/KINGSTON/FLOW_INC/") represents all incremental local inflows between Allatoona and Kingston. In the 2014 model, this time series was distributed with 44% to Cartersville and 56% to Kingston, based on their relative basin size. The distribution of local flows at these junctions is shown in Figure 5.

With addition of Richland Creek Reservoir several more junctions were added to the model below Allatoona Reservoir. Three of those new junctions were given portions of the local flow: Richland Creek_IN, Richland Creek Release, and Etowah Diversion. The distribution of local flow at these junctions and the change of distribution of local flow at Cartersville and Kingston junctions are shown in Figure 6.

The 2014 model includes routing on two of the river reaches between Allatoona_OUT and Kingston. The same approximate routing was maintained in the updated 2018 model; most of the new reaches were set to null routing. Figure 7 shows the highlighted routing reaches *Allatoona_OUT to Cartersville* and *Cartersville to Kingston* in the 2013 network without Richland Creek Reservoir. Both reaches use coefficient routing method with the same parameters, as shown in Figure 8. The same routing method and routing parameters have been applied to the highlighted reaches in the 2018 network with Richland Creek Reservoir as shown in Figure 9 and Figure 10. The other routing reaches around Richland Creek in this model are set to Null routing method.

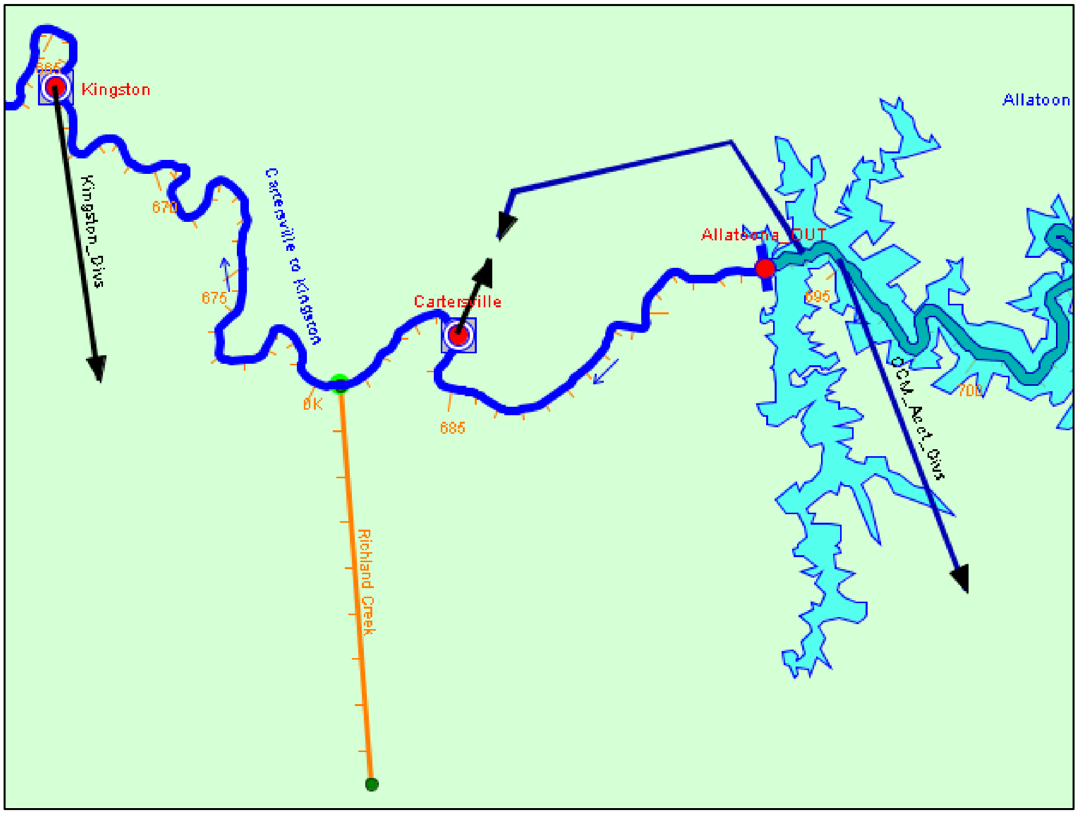


Figure 3. HEC-ResSim Network Module –Richland Creek

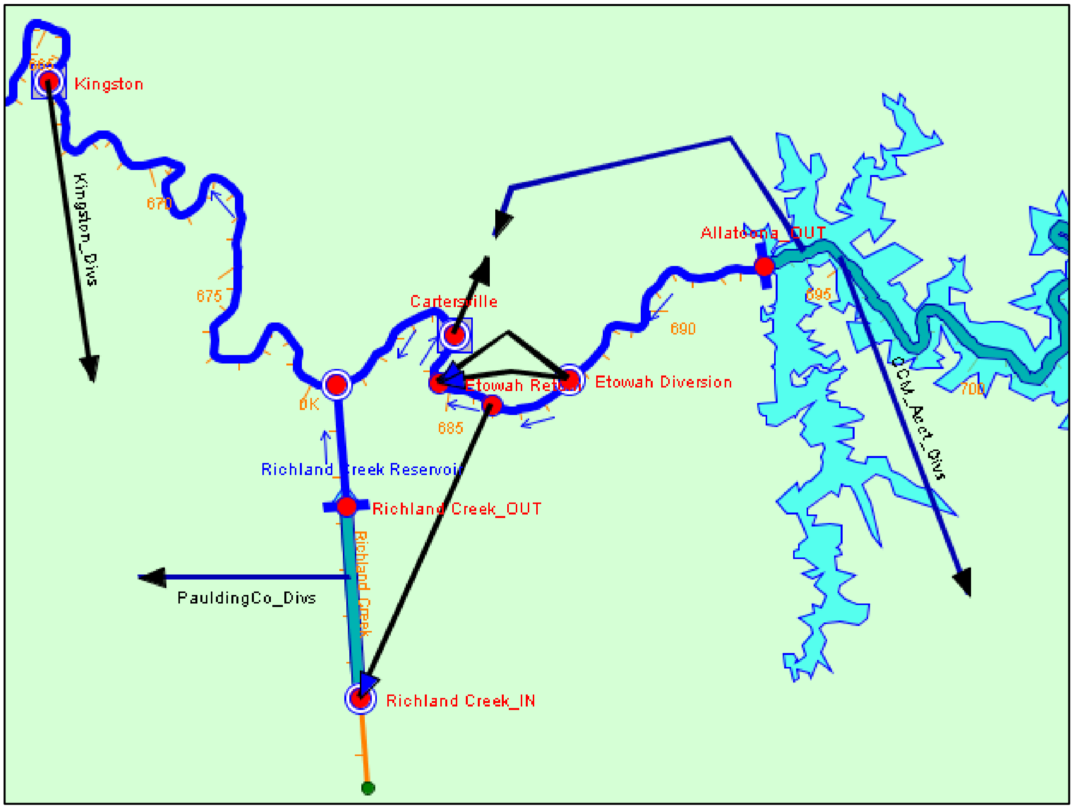
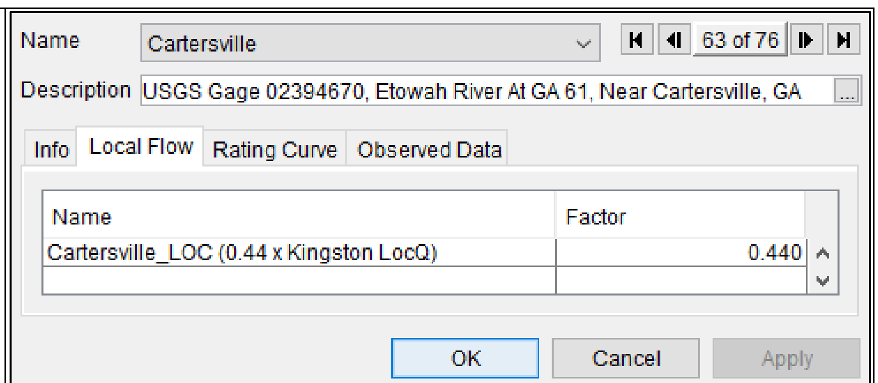


Figure 4. HEC-ResSim Network Module –Richland Creek Reservoir

In the **2014 model**, 56% of the "Kingston Local Flow" timeseries was distributed to the *Kingston* junction.



In the **2014 model**, 44% of the "Kingston Local Flow" timeseries was distributed to the Cartersville junction.

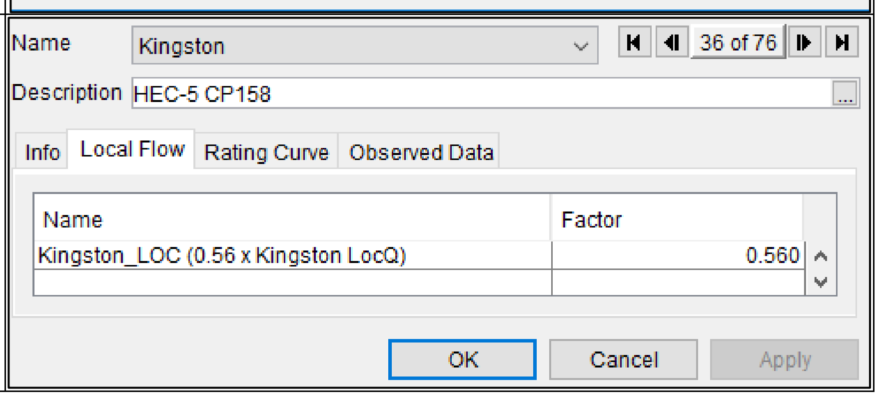
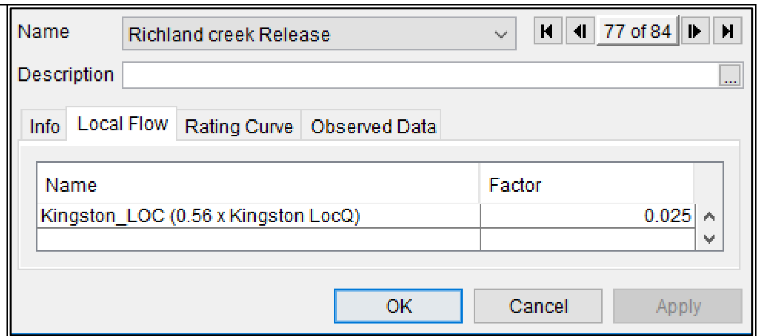


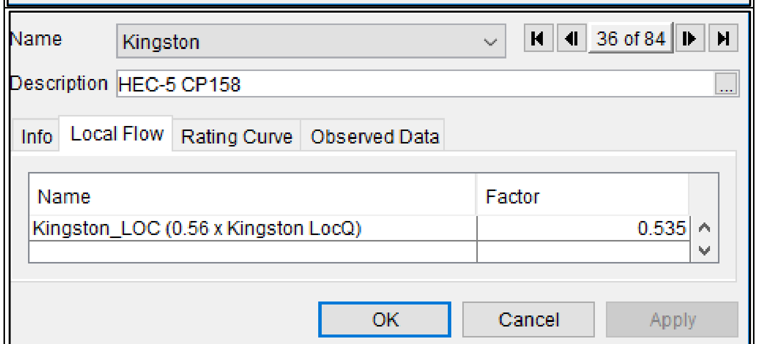
Figure 5. Local flow distribution at junctions below Allatoona without Richland Creek Reservoir

In the 2014 model, 56% of the "Kingston Local Flow" timeseries was distributed to the *Kingston* junction.

The updated **2018 model** divides that portion (56%) between *Kingston* (53.5%) and *Richland Creek Release* (2.5%).

Note that *Richland Creek Release* is the junction at the confluence of Richland Creek and the Etowah River.

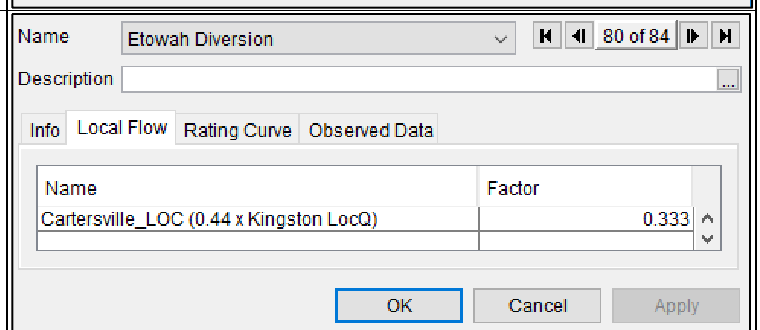


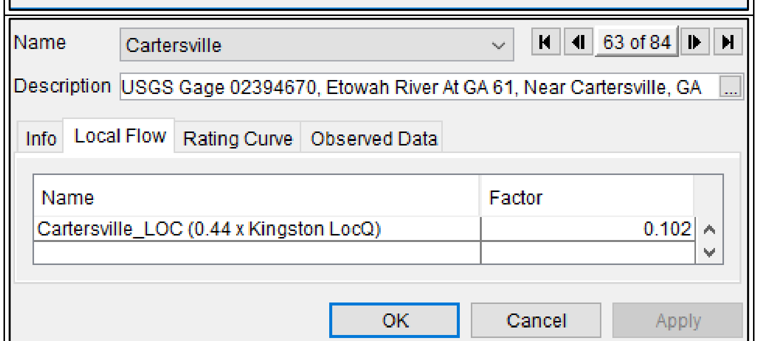


In the 2014 model, 44% of the "Kingston Local Flow" timeseries was distributed to the Cartersville junction.

The updated **2018 model** divides that portion of Kingston Local Flow (44%) between the *Etowah Diversion* junction (33.3%), *Cartersville* junction (10.2%), and *Richland_Creek_IN* junction (0.5%).

Note that *Etowah Diversion* is a junction, not a diversion.





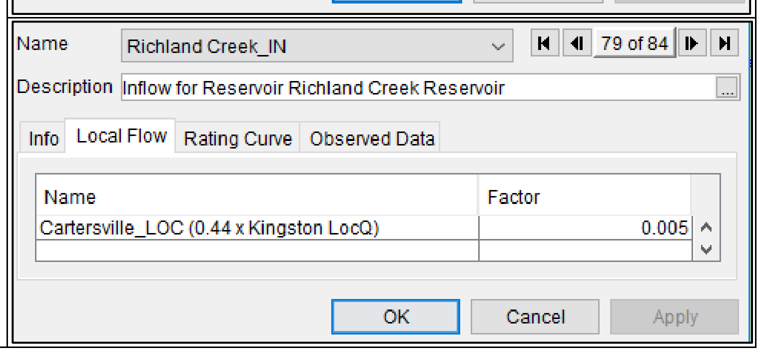


Figure 6. Local flow distribution at junctions below Allatoona with Richland Creek Reservoir

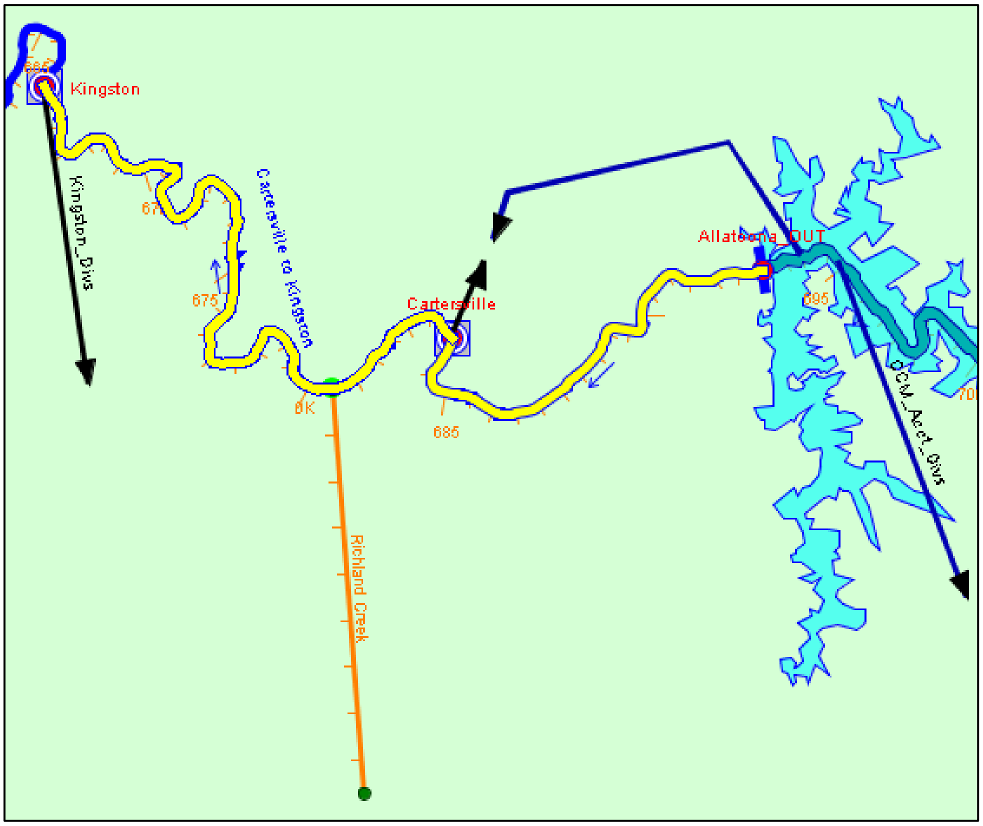


Figure 7. ***Allatoona_OUT to Cartersville*** **and** ***Cartersville to Kingston*** **reaches in the model <u>without</u> Richland Creek Reservoir**

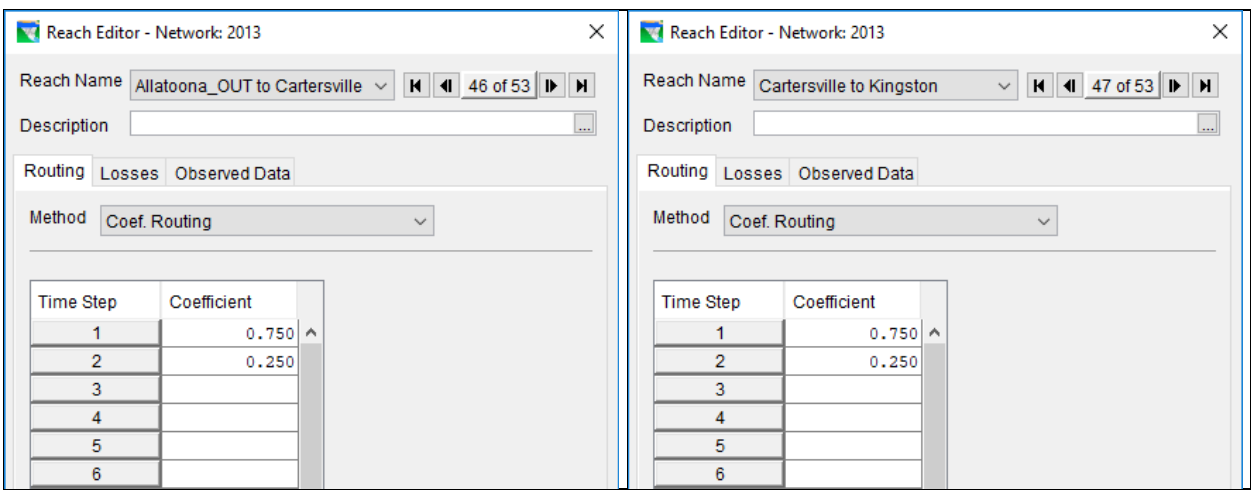


Figure 8. ***Allatoona_OUT to Cartersville*** **and** ***Cartersville to Kingston*** **routing parameters in the model <u>without</u> Richland Creek reservoir**

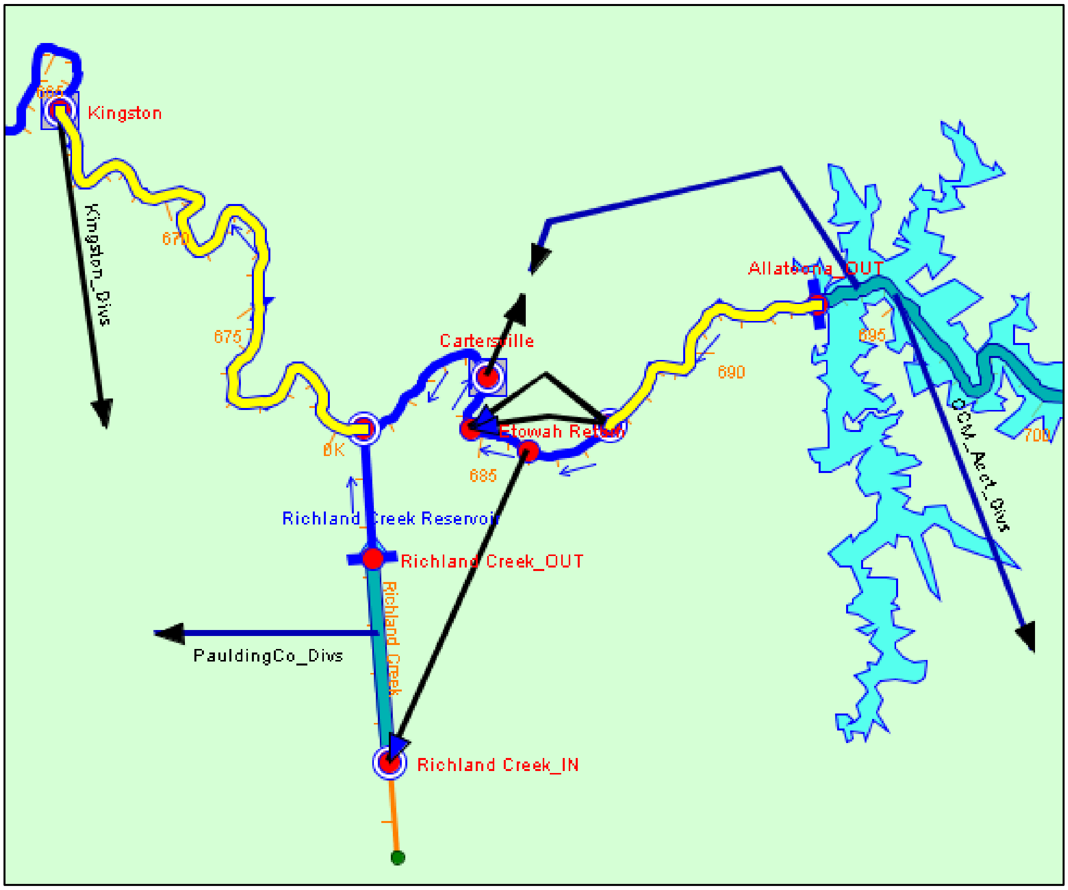


Figure 9. ***Allatoona_OUT to Etowah Diversion*** **and** ***Richland Creek Release to Kingston*** **reaches in the model** **<u>with</u>** **Richland Creek Reservoir**

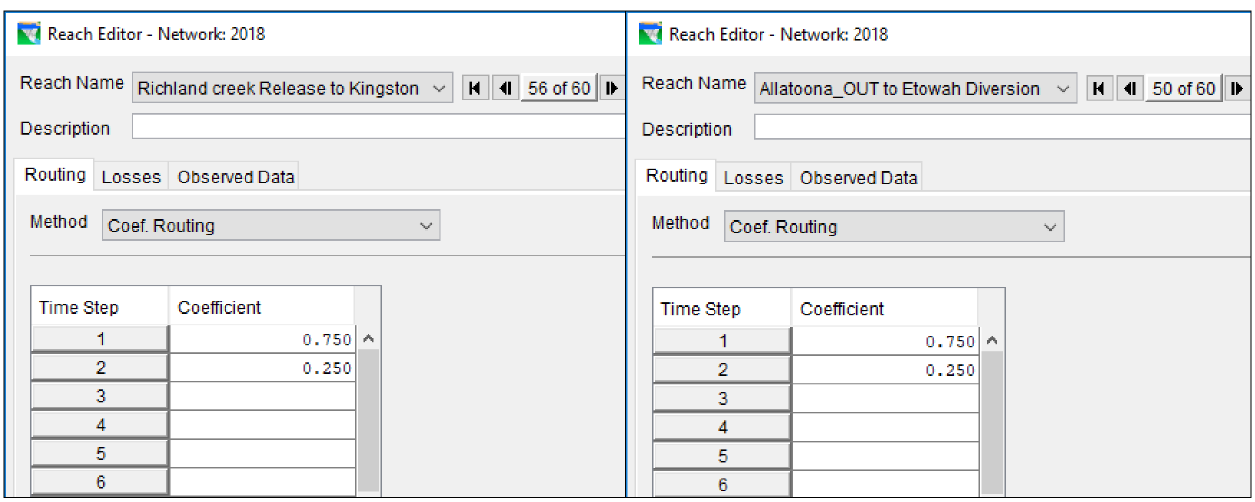


Figure 10. ***Allatoona_OUT to Etowah Diversion*** **and** ***Richland creek Release to Kingston*** **routing parameters in the model** **<u>with</u>** **Richland Creek reservoir**

2. Physical Data

The physical data for Richland Creek Reservoir used in the 2018 model originated in the State of Georgia *ACT-HLC_WCM_24Apr2014_HRPlansDFG2018GArequest4scenarios* watershed. This ResSim model was created by Georgia Department of Natural Resources, Environmental Protection Division (EPD). They included the Richland Creek Reservoir in their ResSim model to support the updated water supply request from Allatoona. It was not possible to confirm the physical details during the study effort, but they are assumed to approximate conditions sufficiently for the purpose of this work.

The physical information used to model Richland Creek Reservoir include the Elevation-Storage-Area Table, Evaporation, Outlet Capacity, Tailwater, and Diverted Outlet. The vertical datum is NGVD29, based on the Final EA.

a. Elevation-Storage-Area Table

The Elevation-Storage-Area table used for Richland Creek Reservoir is shown in Figure 11.

b. Evaporation

The evaporation rate at Richland Creek Reservoir was approximated to be the same as that at Allatoona Reservoir. As shown in Figure 12, the evaporation at Richland Creek Reservoir in the model is set to “Time Series”. This time series reflects the rate of evaporation and is modeled using the same evaporation time series as at Allatoona, as shown in Figure 13.

c. Outlet Capacity

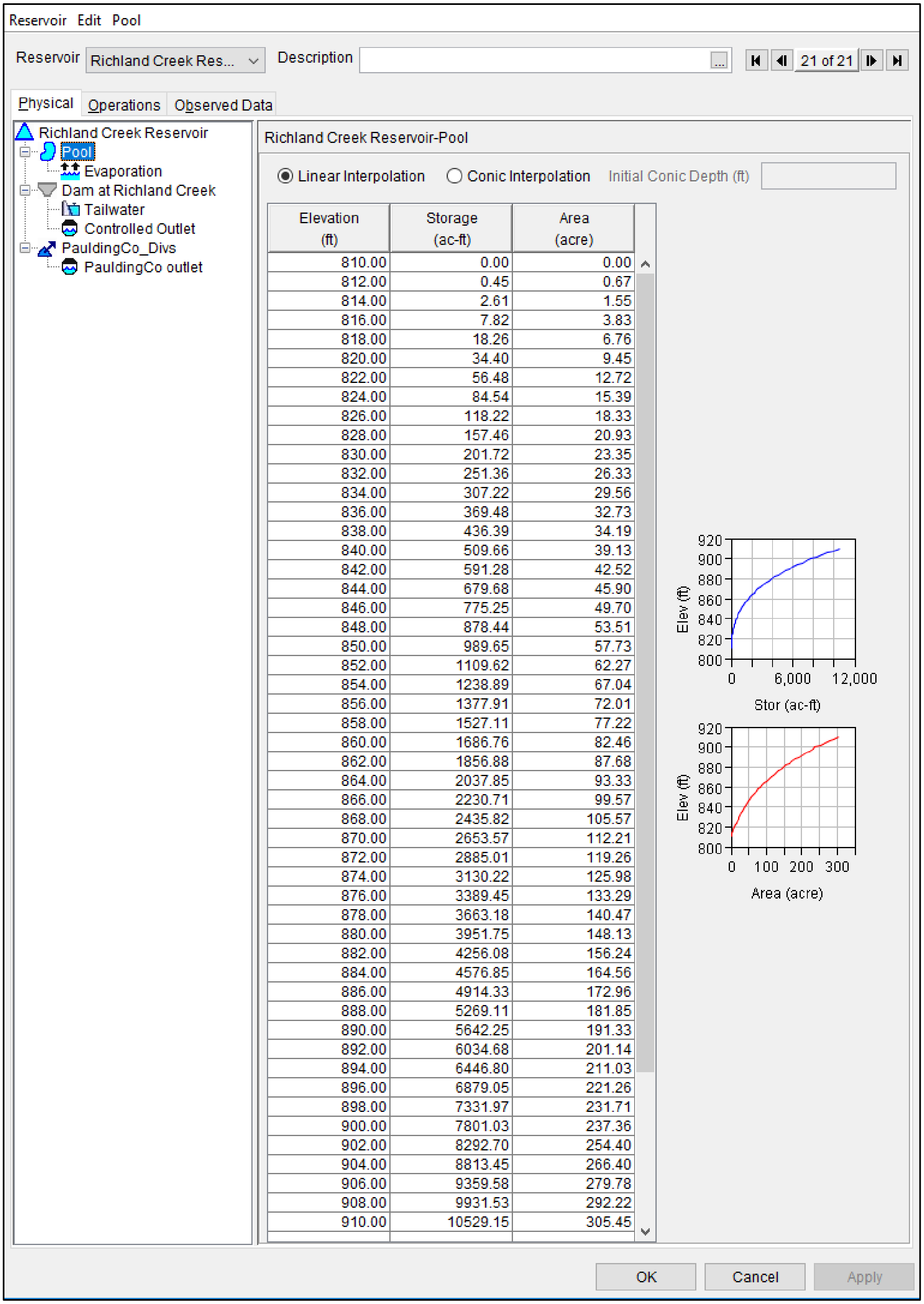
There is one controlled outlet modeled at Richland Creek Reservoir, and its capacity is shown in Figure 14.

d. Tailwater

The tailwater modeled for Richland Creek Reservoir is shown in Figure 15.

e. Diverted Outlet

Paulding County receives its water supply from the Richland Creek Reservoir diverted outlet, which is shown in Figure 16.



Elevation (ft)	Storage (ac-ft)	Area (acre)
810.00	0.00	0.00
812.00	0.45	0.67
814.00	2.61	1.55
816.00	7.82	3.83
818.00	18.26	6.76
820.00	34.40	9.45
822.00	56.48	12.72
824.00	84.54	15.39
826.00	118.22	18.33
828.00	157.46	20.93
830.00	201.72	23.35
832.00	251.36	26.33
834.00	307.22	29.56
836.00	369.48	32.73
838.00	436.39	34.19
840.00	509.66	39.13
842.00	591.28	42.52
844.00	679.68	45.90
846.00	775.25	49.70
848.00	878.44	53.51
850.00	989.65	57.73
852.00	1109.62	62.27
854.00	1238.89	67.04
856.00	1377.91	72.01
858.00	1527.11	77.22
860.00	1686.76	82.46
862.00	1856.88	87.68
864.00	2037.85	93.33
866.00	2230.71	99.57
868.00	2435.82	105.57
870.00	2653.57	112.21
872.00	2885.01	119.26
874.00	3130.22	125.98
876.00	3389.45	133.29
878.00	3663.18	140.47
880.00	3951.75	148.13
882.00	4256.08	156.24
884.00	4576.85	164.56
886.00	4914.33	172.96
888.00	5269.11	181.85
890.00	5642.25	191.33
892.00	6034.68	201.14
894.00	6446.80	211.03
896.00	6879.05	221.26
898.00	7331.97	231.71
900.00	7801.03	237.36
902.00	8292.70	254.40
904.00	8813.45	266.40
906.00	9359.58	279.78
908.00	9931.53	292.22
910.00	10529.15	305.45

Figure 11. Elevation-Storage-Area Table for Richland Creek Reservoir

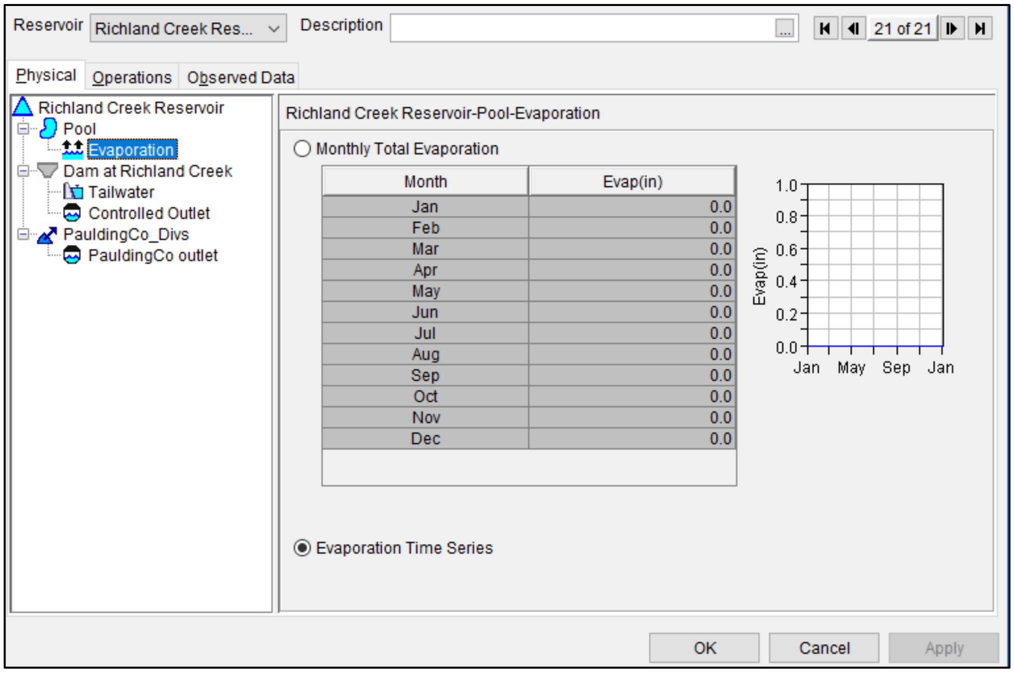


Figure 12. Evaporation at Richland Creek reservoir

CCM_QReturnTot_Divs-Cntrl	Lookback Diversion	shared/ACT_TOTALDEMANDS_04F...	ETOWAH	CCMWA_RT C...	FLOW-DIV	1DAY	TOTAL DEMA...
Cartersville_Qreturn_Divs-Cntrl	Lookback Diversion	shared/ACT_TOTALDEMANDS_04F...	ETOWAH	CARTERVILL...	FLOW-DIV	1DAY	TOTAL DEMA...
Richland Creek Reservoir-Pool	Input Evap	shared/ACTEVAP_06JAN14.DSS	ACT BASIN	ALLATOONA	EVAPNET_RATE	1DAY	EST_RATIO
Allatoona_Cartersville_Q	Lookback State Var...	shared/ACT_TOTALDEMANDS_04F...	ETOWAH	CARTERVILL...	DIV	1DAY	TOTAL DEMA...
Allatoona_CCM_Q	Lookback State Var...	shared/ACT_TOTALDEMANDS_04F...	ETOWAH	CCMWA_WD	DIV	1DAY	TOTAL DEMA...

Figure 13. Evaporation time series at Richland Creek Reservoir

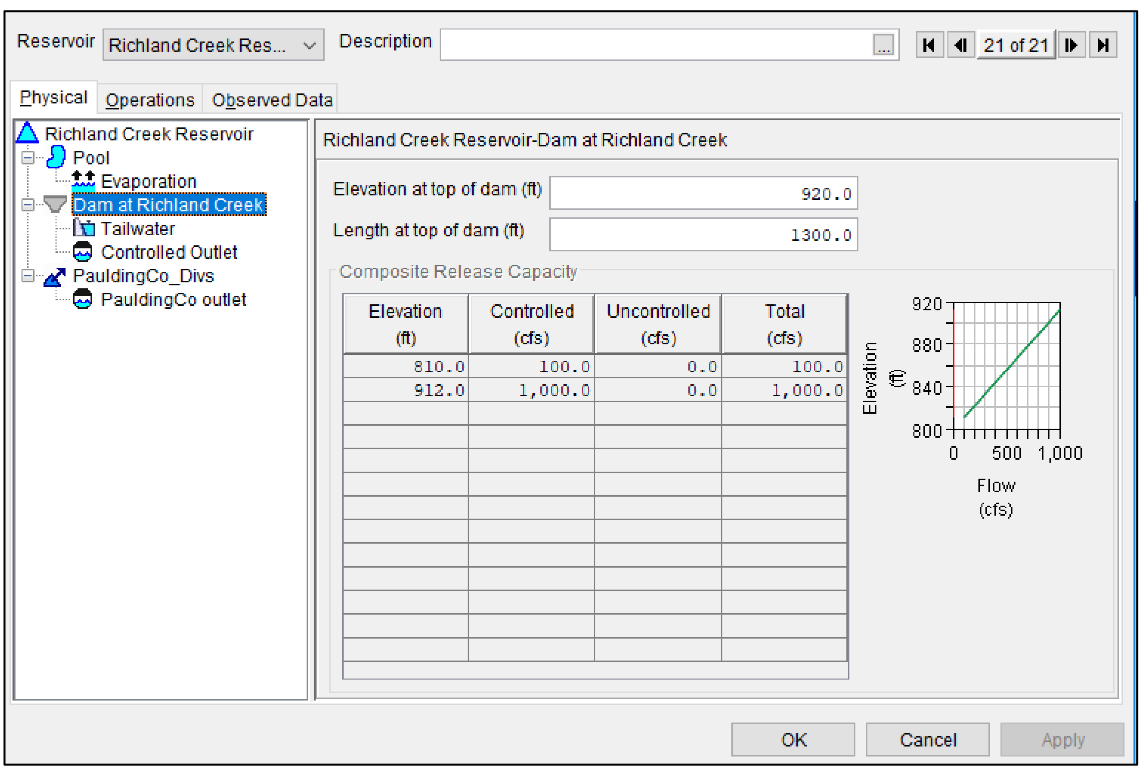


Figure 14. Outlet capacity of the Richland Creek Reservoir

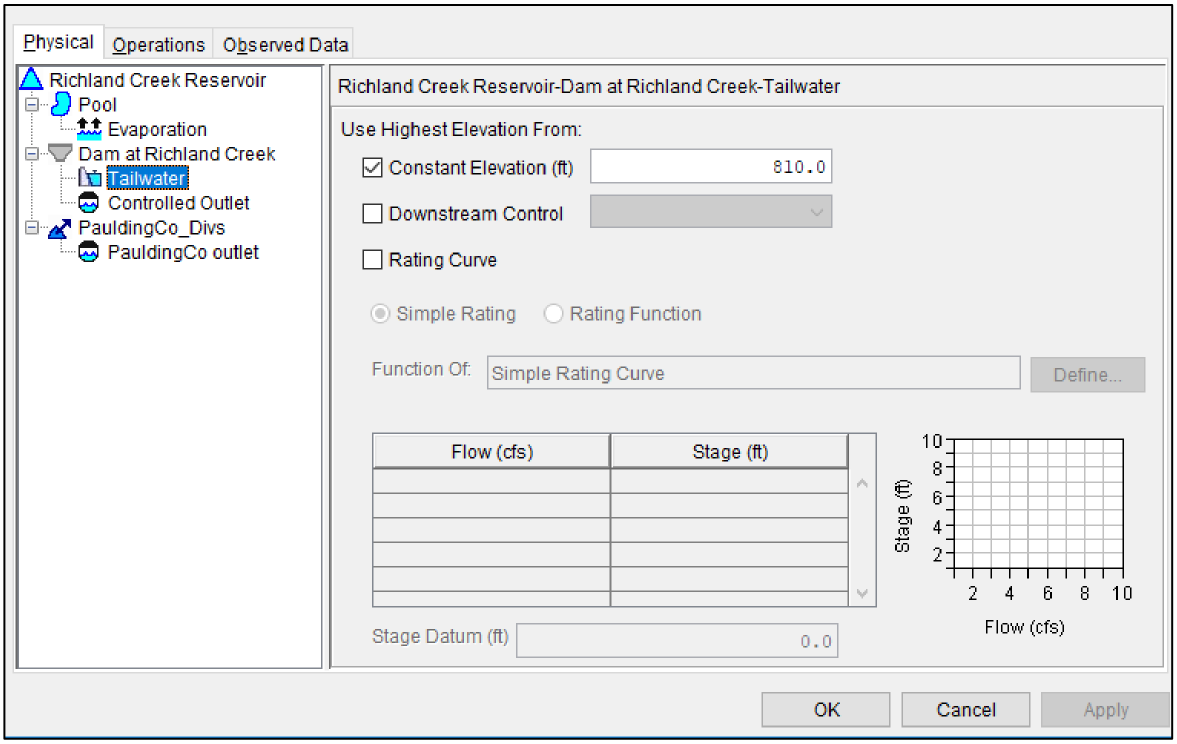


Figure 15. Tailwater of the Richland Creek Reservoir

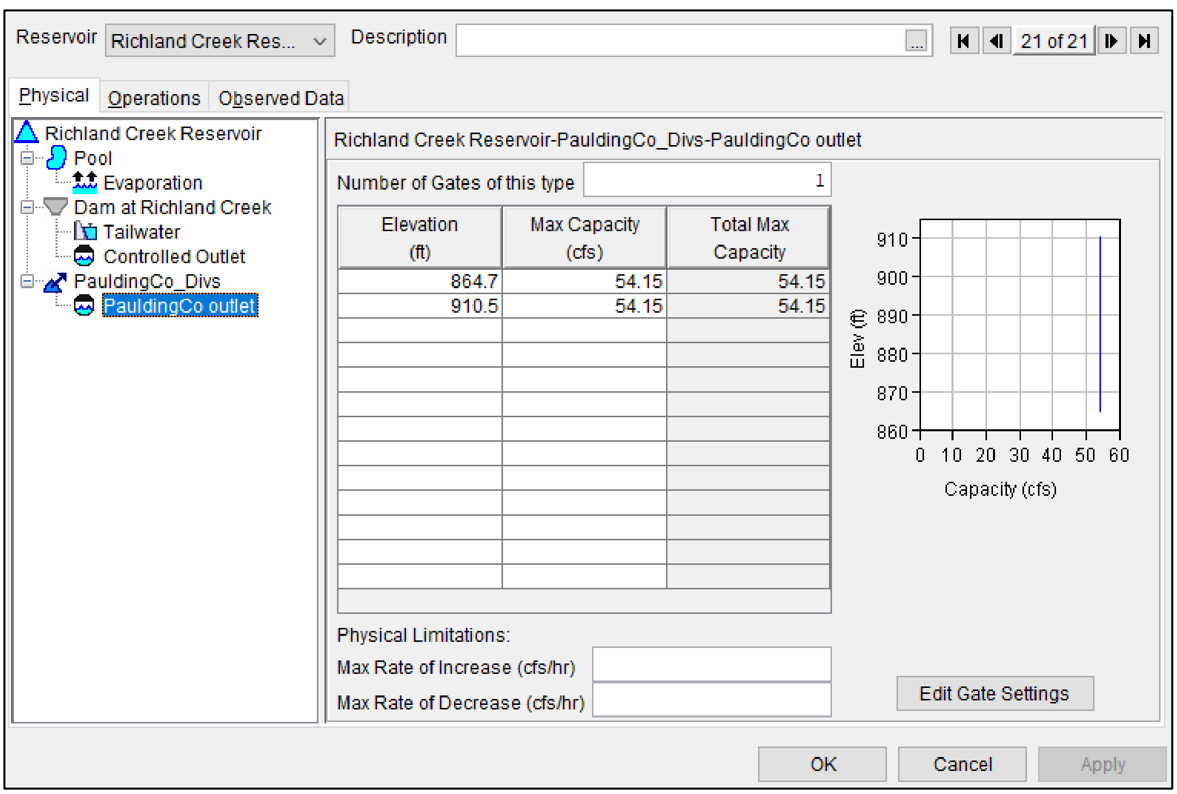


Figure 16. Diverted outlet at Richland Creek Reservoir

3. Reservoir Operations

The Georgia water withdrawal permit ("Paulding County_Richland Creek Reservoir_Final Permit_Etowah River.pdf") was issued for the withdrawal of surface water from the Etowah River and pumping to Richland Creek Reservoir for the purpose of municipal water supply. The permit provides details for the Etowah River pump intake and Richland Creek Reservoir releases. It includes a varying monthly minimum flow requirement below the river intake and varying minimum flow release from the reservoir. The modeling of the withdrawals and releases are described in this section.

a. Operating Zones

Three operation zones are defined for the Richland Creek Reservoir pool as shown in Figure 17. The *Flood Control* zone is set to 910.5 ft, the *Conservation* zone is set to 910 ft, and the *Inactive* zone is set to 864.7 ft.

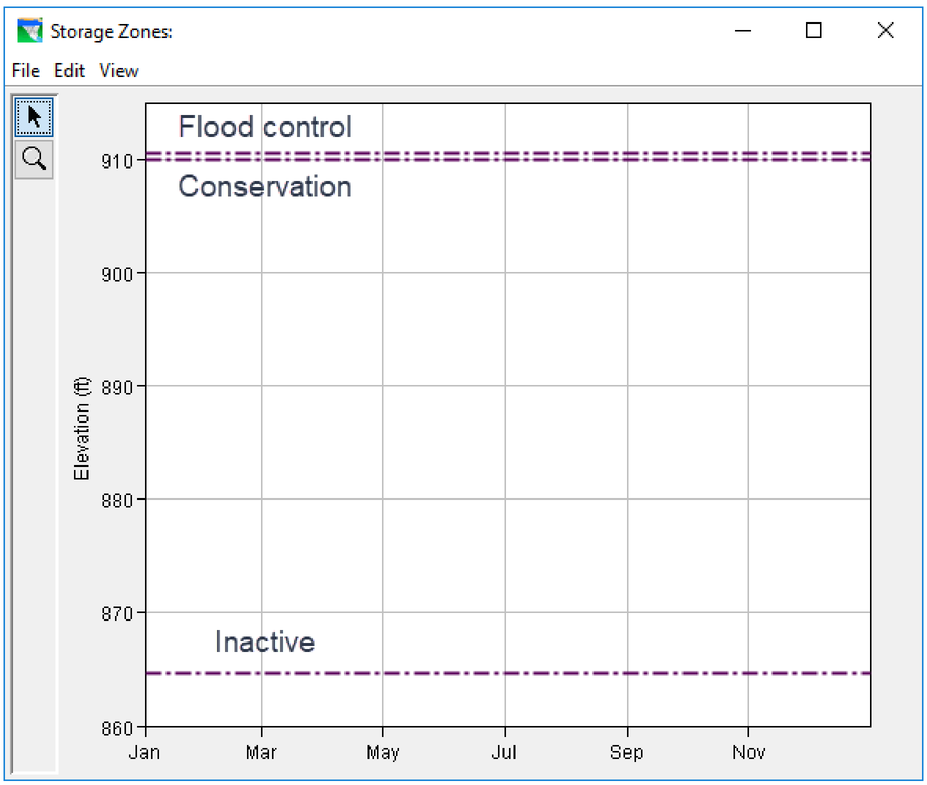


Figure 17. Operation zones at Richland Creek Reservoir

b. Min Monthly Low Flow, Etowah River

The Georgia EPD requires Minimum Monthly Low Flows (MMLF) on the Etowah River as shown in Table 2.

Table 2. Minimum Monthly Low Flows (MMLF) on the Etowah River

Month	Flow monitored at Highway 61 USGS Gage #02394670 @ Elevation of 904.1 feet	
	If reservoir is above 80% of full volume	If reservoir is below 80% of full volume
January	376	356
February	387	367
March	420	400
April	419	399
May	392	372
June	362	342
July	362	342
August	348	328
September	348	328
October	346	326
November	351	331
December	364	344

Source: Georgia EPD Permit #110-1424-02
The gage is Etowah River at GA 61, near Cartersville, GA.
The reservoir is Richland Creek Reservoir. Flows are in cfs.

The State of Georgia ResSim model used a modeling technique to handle the MMFL, which was duplicated here. This technique uses diversion model elements to pull the minimum flow out of the Etowah River upstream of the pump to Richland Creek and returns the same flow just downstream. While these diversions do not exist in reality, they are an effective and simple way of ensuring that the MMFL is met before any water is pumped to Richland Creek Reservoir. The diversions take water from Etowah Diversion junction to the Etowah Return junction, which makes it unavailable to the Richland Creek Reservoir pump station, thus preserving the instream minimum flow.

In the model, the ***Allatoona_Factored_Min*** diversion takes flow from the Etowah River based on the pool elevation (Figure 18), and the ***Two-Run 7Q10*** diversion varies by month (Figure 19). In combination they manage the MMFL. If the reservoir is above 80% of full volume (an elevation of 904 ft), then 310 cfs is diverted around the pump station via ***Allatoona _Factored_Min***, and if the reservoir is below 80% of full volume, 290 cfs is diverted through that diversion. The remaining of the required minimum flow is met through ***Two-Run 7Q10*** diversion as shown in Figure 19.

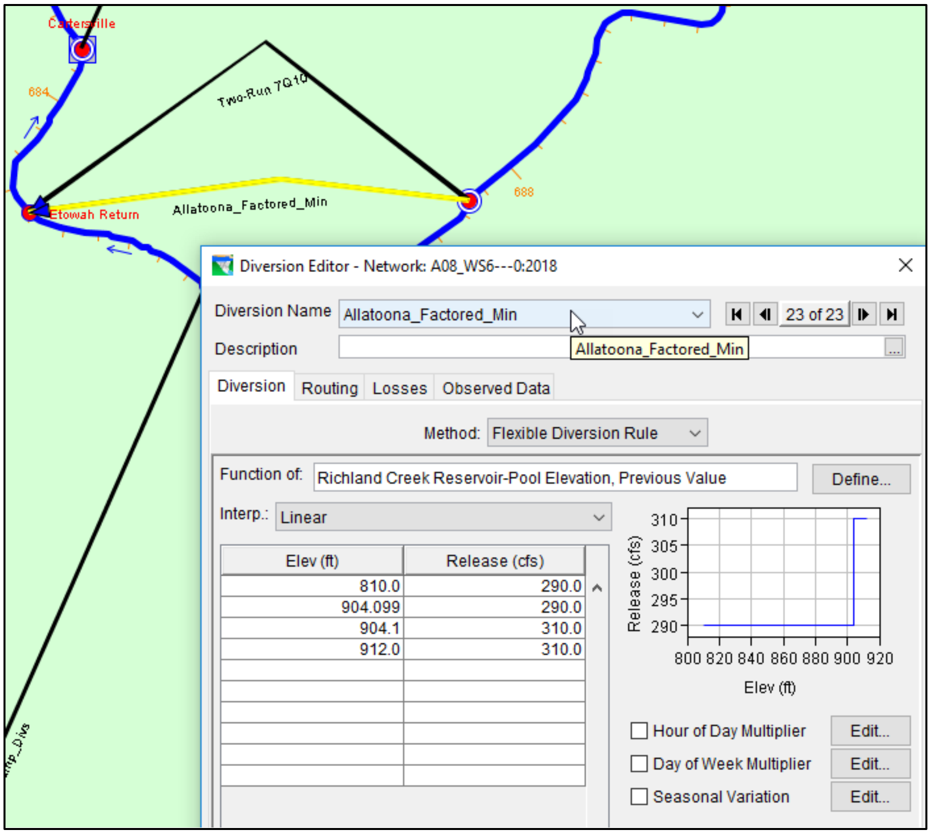


Figure 18. ***Allatoona_Factored_Min*** **diversion**

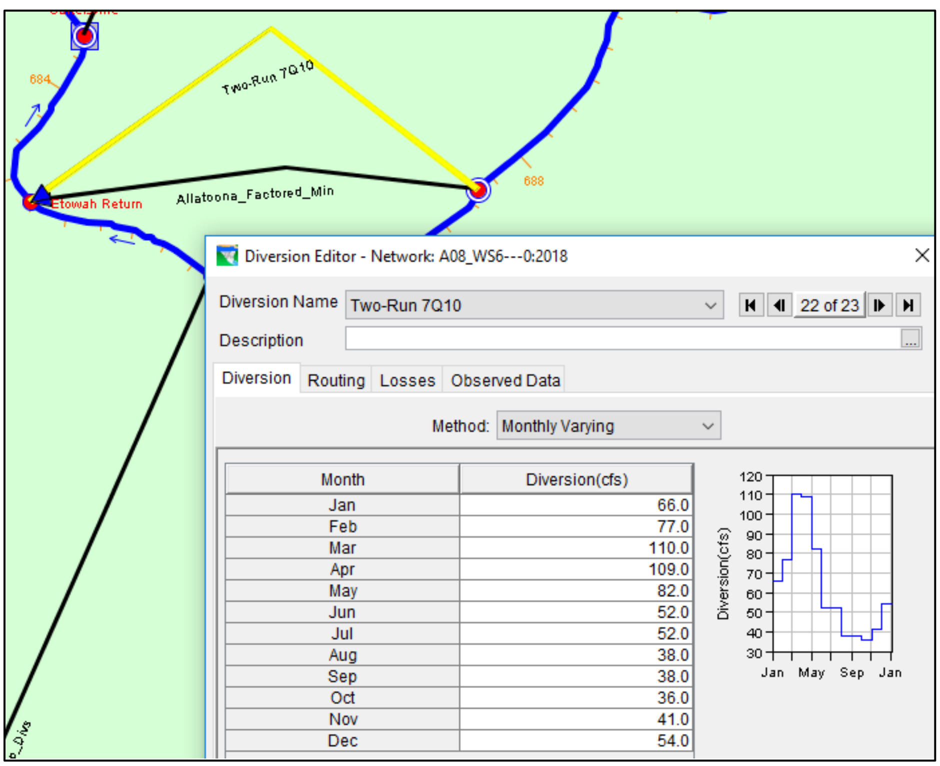


Figure 19. ***Two-Run 7Q10*** **diversion**

c. Withdrawal from Etowah River to Richland Creek Reservoir

The Richland Creek Permit allows for a maximum of 47 MGD (72.72 cfs) to be pumped from the Etowah River. In the model, water is withdrawn through ***Richland_Pump_Divs*** diversion from the Etowah River to Richland Creek Reservoir, dependent on current pool storage, as shown in Figure 20. Assuming water is available after removing the MMFL using the diversion technique, Richland Creek Reservoir will receive up to 72.72 cfs from Etowah River in order to fill to its conservation zone. When at its conservation pool or above, no pumping will occur.

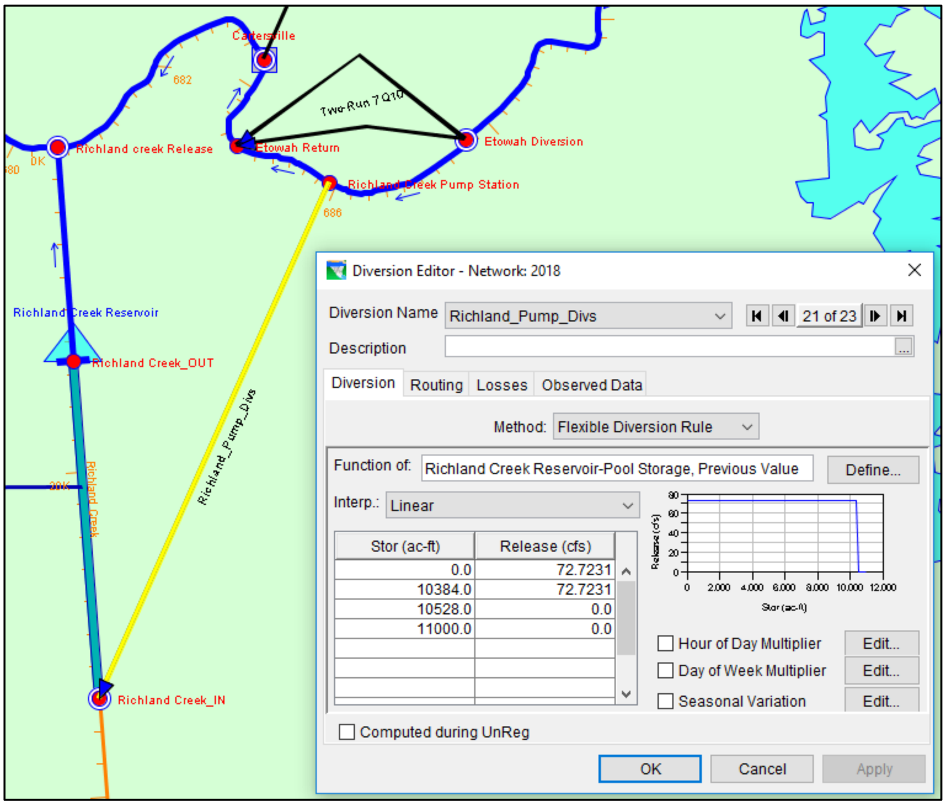


Figure 20. *Richland_Pump_Divs* diversion

d. Min_7Q10

The Georgia EPD requires a minimum flow below the Richland Creek Reservoir (minimum reservoir release) to meet the monthly 7Q10 shown in Table 3. The ***Min_7Q10*** rule shown in Figure 21 represents the required minimum release from Richland Creek reservoir.

Table 3. Minimum required release from Richland Creek Reservoir

Month	Monthly 7Q10 (cfs)
January	0.9
February	1.1
March	1.3
April	1.3
May	0.9
June	0.7
July	0.5
August	0.4
September	0.5
October	0.4
November	0.6
December	0.5

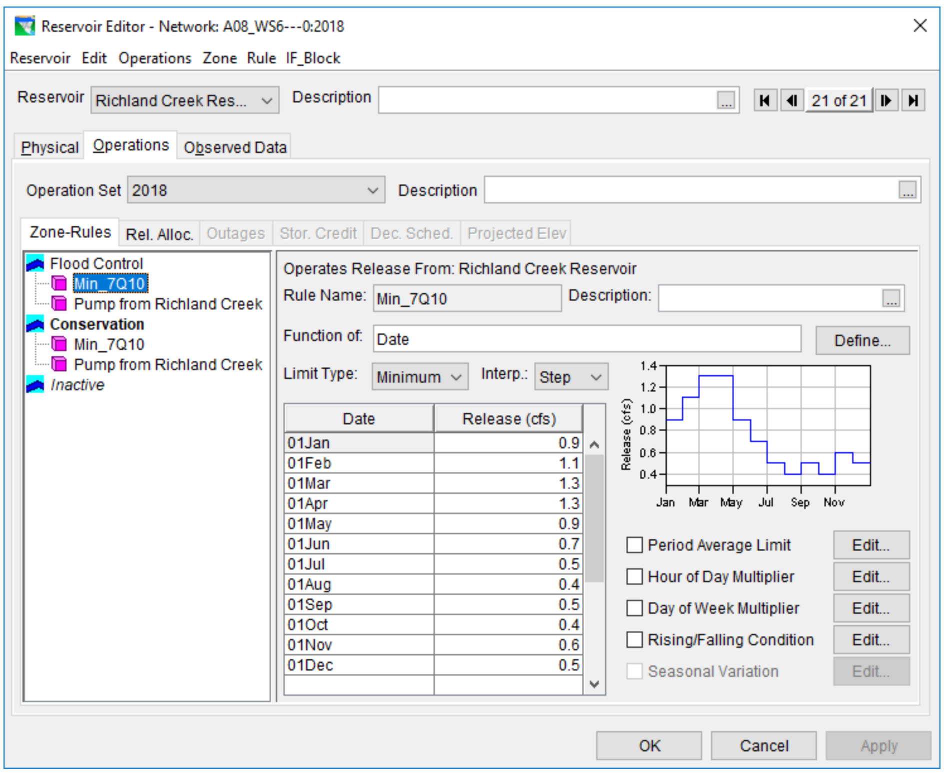


Figure 21. Min_7Q10 rule

e. Pump from Richland Creek Reservoir

According to the Richland Creek Reservoir permit application, Paulding County's need for water is expected to reach 53 million gallons per day (mgd) or 82 cfs by the year 2060. Paulding County is proposing to meet their identified need of 53 mgd by purchasing 18 mgd from Cobb County Marietta Water Authority (CCMWA) and the remaining 35 mgd (54.15 cfs) would be supplied by the proposed Richland Creek Reservoir. This amount of diversion is shown with the ***Pump from Richland Creek*** rule shown in Figure 22.

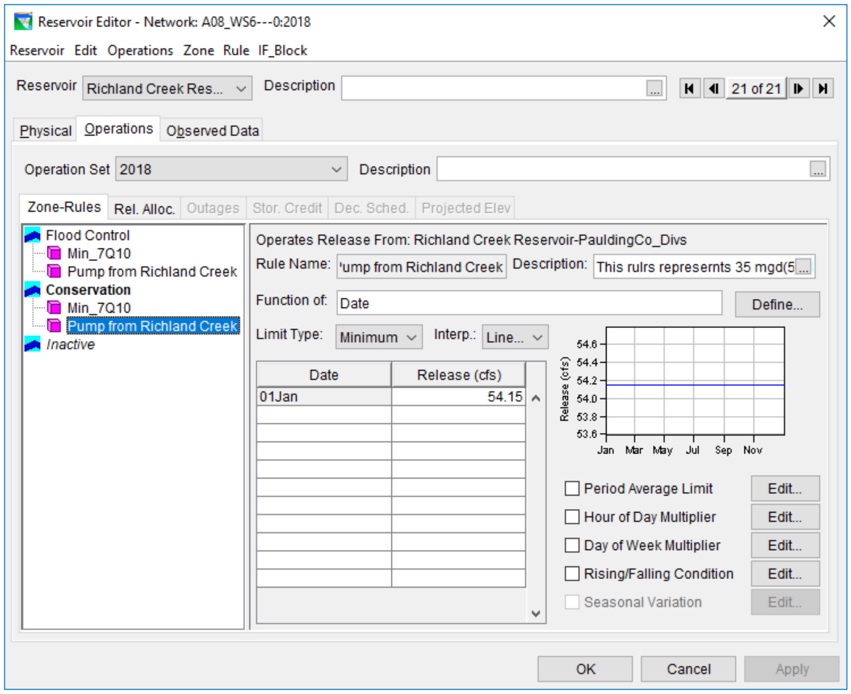


Figure 22. *Pump from Richland Creek* rule

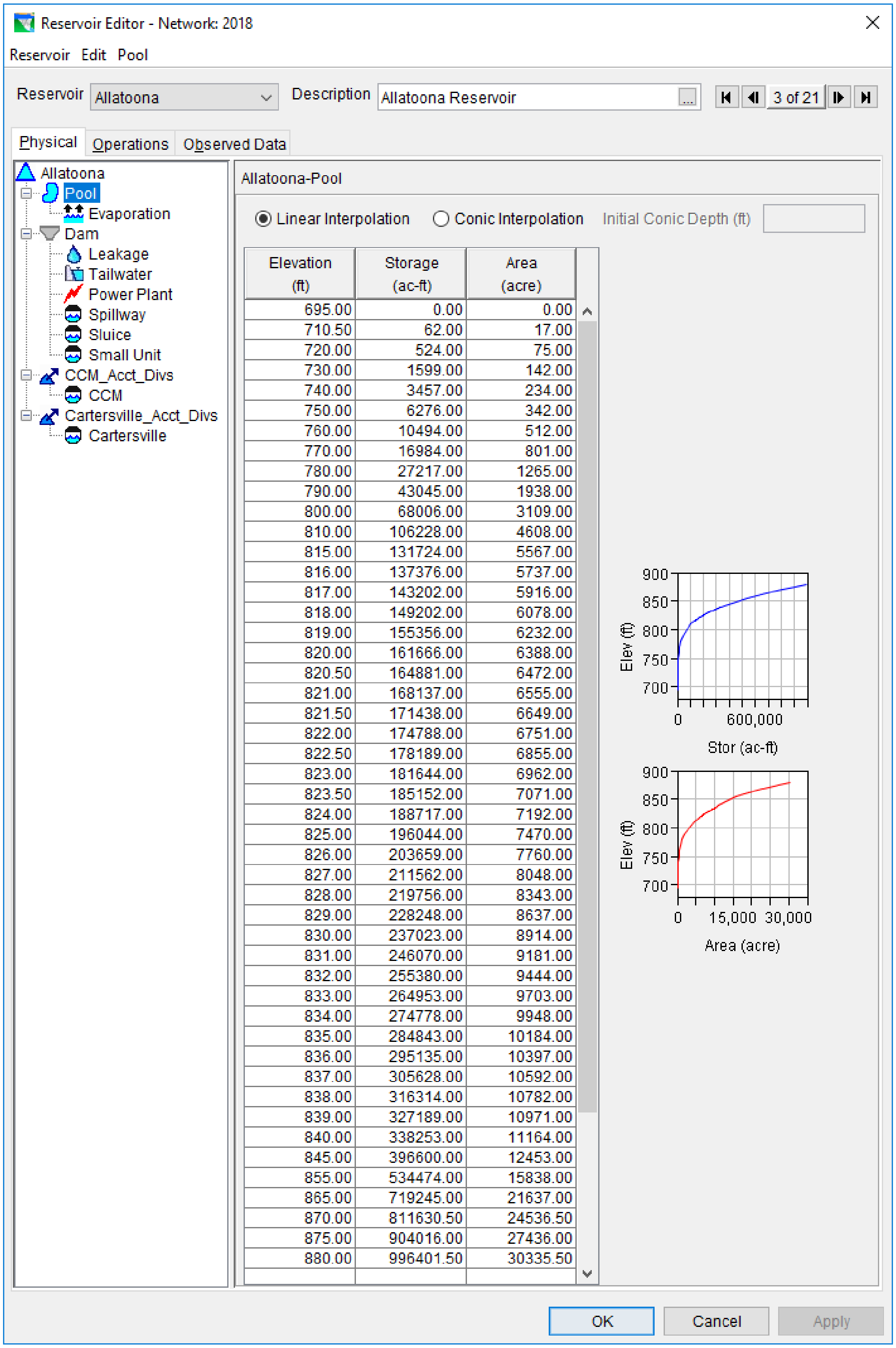
B. *Allatoona Lake*

Updates to Allatoona included a new elevation-storage-area (ESA) table, a change to the rate of leakage, and an adjustment to the gates. These changes are described below.

1. Elevation-Storage-Area Table

The USACE periodically surveys bathymetric cross-sections along established rangelines to determine changes in reservoir geometry in accordance with Engineer Manual (EM) 1110-2-4000, Sedimentation Investigations of Rivers and Reservoirs. As part of the American Recovery ACT in 2009, Mobile District performed a resurvey of all the reservoirs within the district. Sediment surveys were conducted in 2010. Tetra Tech, Inc. was retained to conduct analysis of the data and determine the extent and degree of sedimentation and erosion that has occurred in the reservoir and tributaries over the years, and where appropriate, to speculate on the causes and changes.

Hydrography and topology data at Allatoona Lake were collected using sonar and LiDAR in 2009, and Tetra Tech assembled them into a 3D model to determine new areas and volumes at each elevation increment. Their 2011 report concluded that the updated data appear to reflect sedimentation occurring around 824 ft, near the low winter conservation pool elevation, and shoreline erosion around 835 ft, near the high summer pool elevation. Accordingly the Elevation-Storage-Area table at Allatoona was updated in the ResSim model. In addition, this table was linearly extrapolated from the elevations of 870 to 880 ft in order to capture the full range of elevations up to the top of the dam, however, no model runs involved the pool reaching that range. The new ESA table is shown in Figure 23.



Elevation (ft)	Storage (ac-ft)	Area (acre)
695.00	0.00	0.00
710.50	62.00	17.00
720.00	524.00	75.00
730.00	1599.00	142.00
740.00	3457.00	234.00
750.00	6276.00	342.00
760.00	10494.00	512.00
770.00	16984.00	801.00
780.00	27217.00	1265.00
790.00	43045.00	1938.00
800.00	68006.00	3109.00
810.00	106228.00	4608.00
815.00	131724.00	5567.00
816.00	137376.00	5737.00
817.00	143202.00	5916.00
818.00	149202.00	6078.00
819.00	155356.00	6232.00
820.00	161666.00	6388.00
820.50	164881.00	6472.00
821.00	168137.00	6555.00
821.50	171438.00	6649.00
822.00	174788.00	6751.00
822.50	178189.00	6855.00
823.00	181644.00	6962.00
823.50	185152.00	7071.00
824.00	188717.00	7192.00
825.00	196044.00	7470.00
826.00	203659.00	7760.00
827.00	211562.00	8048.00
828.00	219756.00	8343.00
829.00	228248.00	8637.00
830.00	237023.00	8914.00
831.00	246070.00	9181.00
832.00	255380.00	9444.00
833.00	264953.00	9703.00
834.00	274778.00	9948.00
835.00	284843.00	10184.00
836.00	295135.00	10397.00
837.00	305628.00	10592.00
838.00	316314.00	10782.00
839.00	327189.00	10971.00
840.00	338253.00	11164.00
845.00	396600.00	12453.00
855.00	534474.00	15838.00
865.00	719245.00	21637.00
870.00	811630.50	24536.50
875.00	904016.00	27436.00
880.00	996401.50	30335.50

Figure 23. Elevation-Storage-Area table at Allatoona

2. Leakage

Allatoona leakage was updated to 150 cfs from 75 cfs. The new leakage is shown in Figure 24. This adjustment was based on estimates made by the plant operator and discussions with the modeling team (email correspondence, Bob Allen 24Aug2018). The assumption is that when the main units (1 and 2) are in shutdown status, they are each leaking 75 cfs, for a total of 150 cfs. The operator confirmed the leakage estimate of roughly 150 cfs when units 1 and 2 were in normal shutdown status by comparing unit 4 load with the downstream USGS gage measurement. Unit 4 likely has an additional leakage of around 35 cfs, however this hasn't been fully investigated. Leakage also varies dependent on which units are being used at any given time. It was decided that assuming a constant 150 cfs of leakage was reasonable for a model of this level of detail. The additional constant flow of 215 cfs from the small unit was not changed in the model.

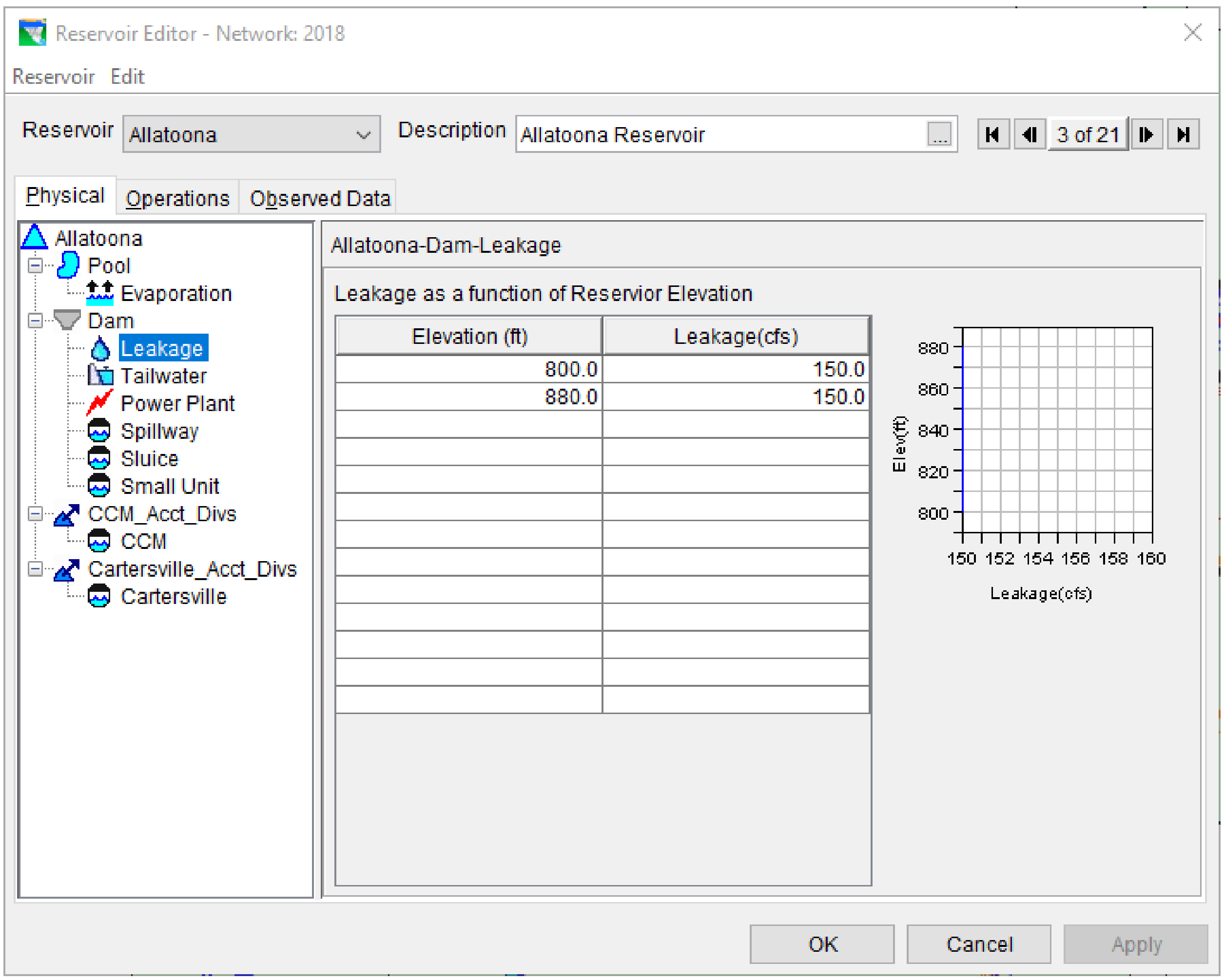
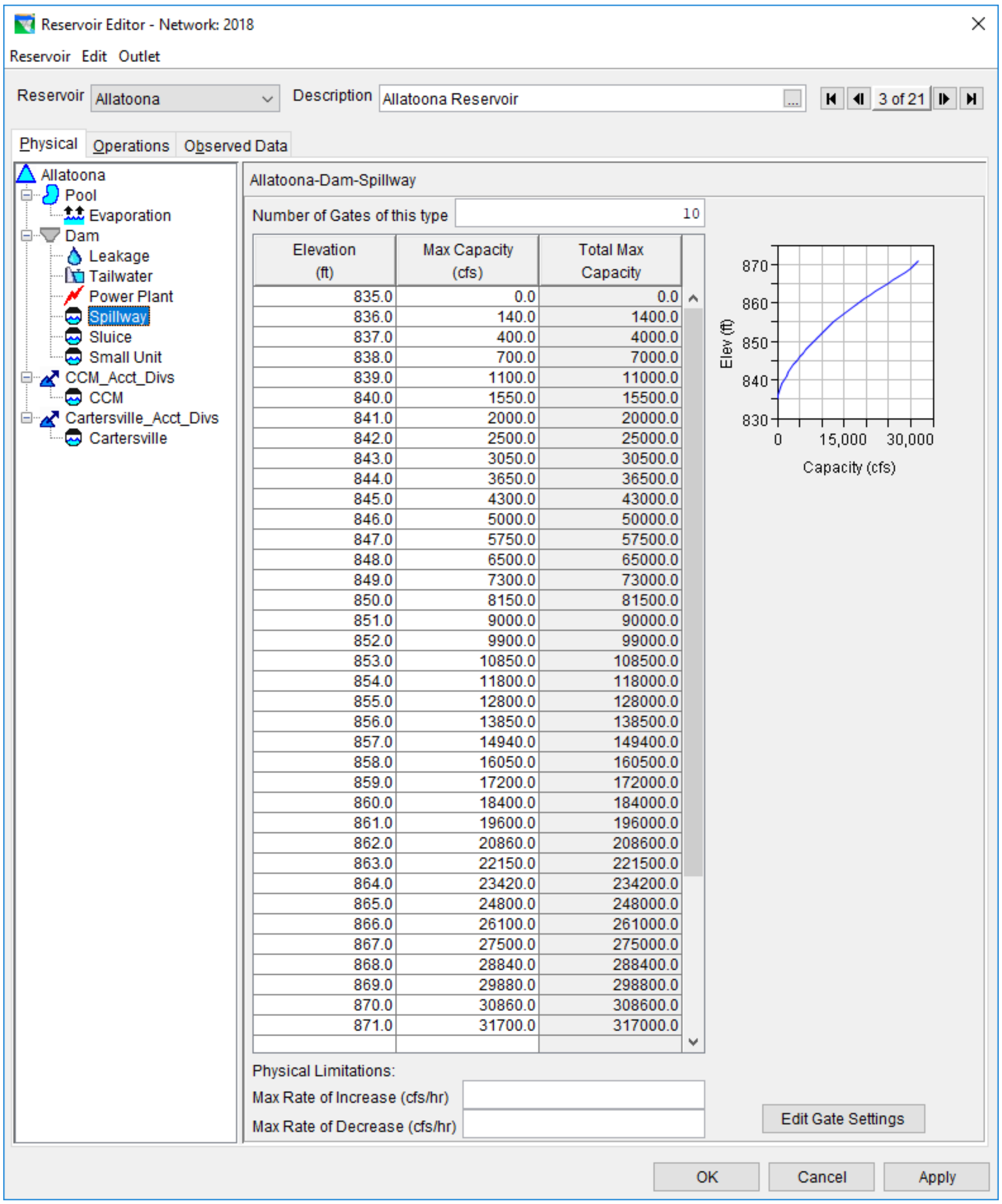


Figure 24. Leakage at Allatoona

3. Number of Gates at Allatoona

The number of spillway gates at Allatoona was changed from nine to ten gates as shown in Figure 25. This change was made to fix a data discrepancy between the original model and the Allatoona Water Control Manual (WCM). According to the WCM, the spillway consists of eleven tainter gates. Nine of the gates are 40 ft wide by 26 ft tall and the other two are 20 ft wide x 26 ft tall. The WCM does not provide a rating for the 20 ft x 26 ft gate, but the rating curve plate states that the rating is assumed to be half the rating of the larger gates. Therefore, the ten gates modeled on the Allatoona spillway represent nine large gates and the sum of two small gates.

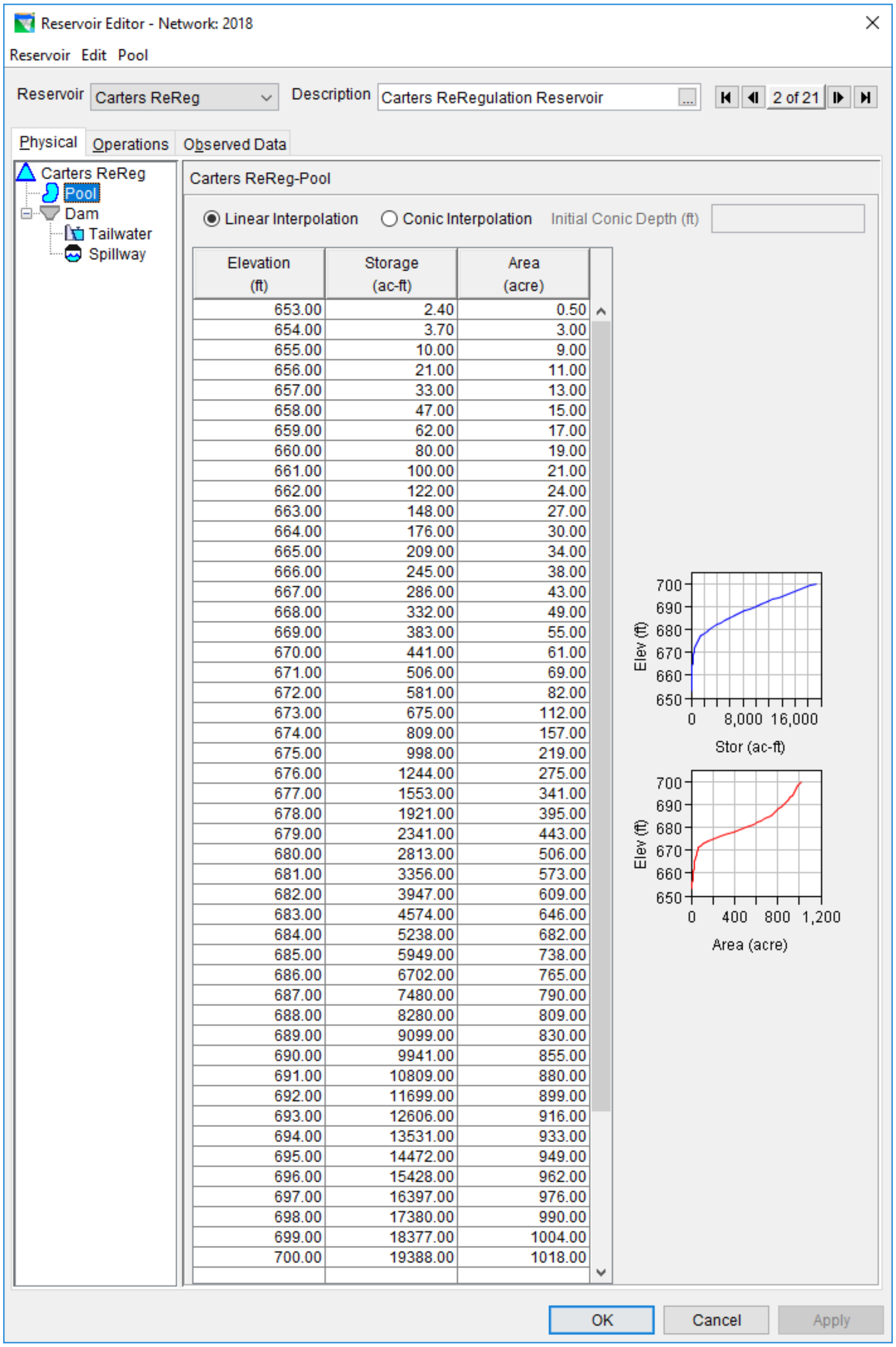


Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
835.0	0.0	0.0
836.0	140.0	1400.0
837.0	400.0	4000.0
838.0	700.0	7000.0
839.0	1100.0	11000.0
840.0	1550.0	15500.0
841.0	2000.0	20000.0
842.0	2500.0	25000.0
843.0	3050.0	30500.0
844.0	3650.0	36500.0
845.0	4300.0	43000.0
846.0	5000.0	50000.0
847.0	5750.0	57500.0
848.0	6500.0	65000.0
849.0	7300.0	73000.0
850.0	8150.0	81500.0
851.0	9000.0	90000.0
852.0	9900.0	99000.0
853.0	10850.0	108500.0
854.0	11800.0	118000.0
855.0	12800.0	128000.0
856.0	13850.0	138500.0
857.0	14940.0	149400.0
858.0	16050.0	160500.0
859.0	17200.0	172000.0
860.0	18400.0	184000.0
861.0	19600.0	196000.0
862.0	20860.0	208600.0
863.0	22150.0	221500.0
864.0	23420.0	234200.0
865.0	24800.0	248000.0
866.0	26100.0	261000.0
867.0	27500.0	275000.0
868.0	28840.0	288400.0
869.0	29880.0	298800.0
870.0	30860.0	308600.0
871.0	31700.0	317000.0

Figure 25. Number of gates at Allatoona

C. Carters ReReg Elevation-Storage-Area Table

The Elevation-Storage-Area (ESA) table at Carters ReReg has been updated with the latest (2011) survey data. The new table is shown in Figure 26.



Elevation (ft)	Storage (ac-ft)	Area (acre)
653.00	2.40	0.50
654.00	3.70	3.00
655.00	10.00	9.00
656.00	21.00	11.00
657.00	33.00	13.00
658.00	47.00	15.00
659.00	62.00	17.00
660.00	80.00	19.00
661.00	100.00	21.00
662.00	122.00	24.00
663.00	148.00	27.00
664.00	176.00	30.00
665.00	209.00	34.00
666.00	245.00	38.00
667.00	286.00	43.00
668.00	332.00	49.00
669.00	383.00	55.00
670.00	441.00	61.00
671.00	506.00	69.00
672.00	581.00	82.00
673.00	675.00	112.00
674.00	809.00	157.00
675.00	998.00	219.00
676.00	1244.00	275.00
677.00	1553.00	341.00
678.00	1921.00	395.00
679.00	2341.00	443.00
680.00	2813.00	506.00
681.00	3356.00	573.00
682.00	3947.00	609.00
683.00	4574.00	646.00
684.00	5238.00	682.00
685.00	5949.00	738.00
686.00	6702.00	765.00
687.00	7480.00	790.00
688.00	8280.00	809.00
689.00	9099.00	830.00
690.00	9941.00	855.00
691.00	10809.00	880.00
692.00	11699.00	899.00
693.00	12606.00	916.00
694.00	13531.00	933.00
695.00	14472.00	949.00
696.00	15428.00	962.00
697.00	16397.00	976.00
698.00	17380.00	990.00
699.00	18377.00	1004.00
700.00	19388.00	1018.00

Figure 26. Elevation-Storage-Area Table at Carters ReReg

D. Carters Pumping Hours

Due to the new ESA table at Carters ReReg the pumping hours at Carters needed to be updated to correct over pumping. The pump from Carters ReReg to Carters Lake can only be turned on if the ReReg is above 677 ft. The ReReg can use storage between 677-674 ft to meet minimum downstream flows. The conservation pool pumpback operation is set using an IF-block, ***Con Pumpback fn RR Pool***, and a series of pumpback rules that differ based on the number of hours to pump. The IF-block considers how high the ReReg pool is, and pumps for the number of hours comparable to the volume available.

The five pumpback rules were updated to correct the pumping based on new ESA at Carters. Figure 27 shows the pump hours in the ***Con Pumpback fn RR Pool*** IF-block in the conservation zone in Seasonal operation set as part of ***2013*** network in the old model, as compared with the updated IF block in the *Conservation* zone in the ***2018*** operation set as part of ***2018*** network. Figure 28 shows the details of the pumpback rules in 2018 operation set.

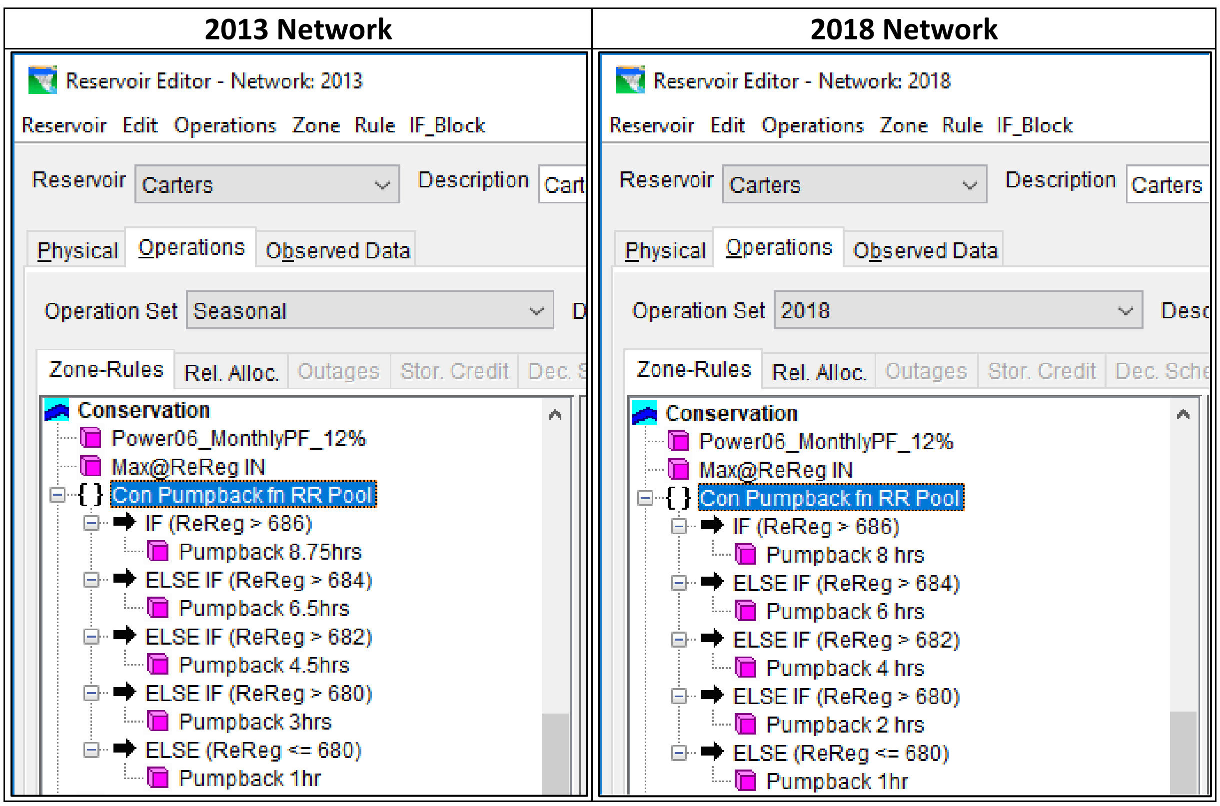


Figure 27. Pump rules at Carters in 2013 Network

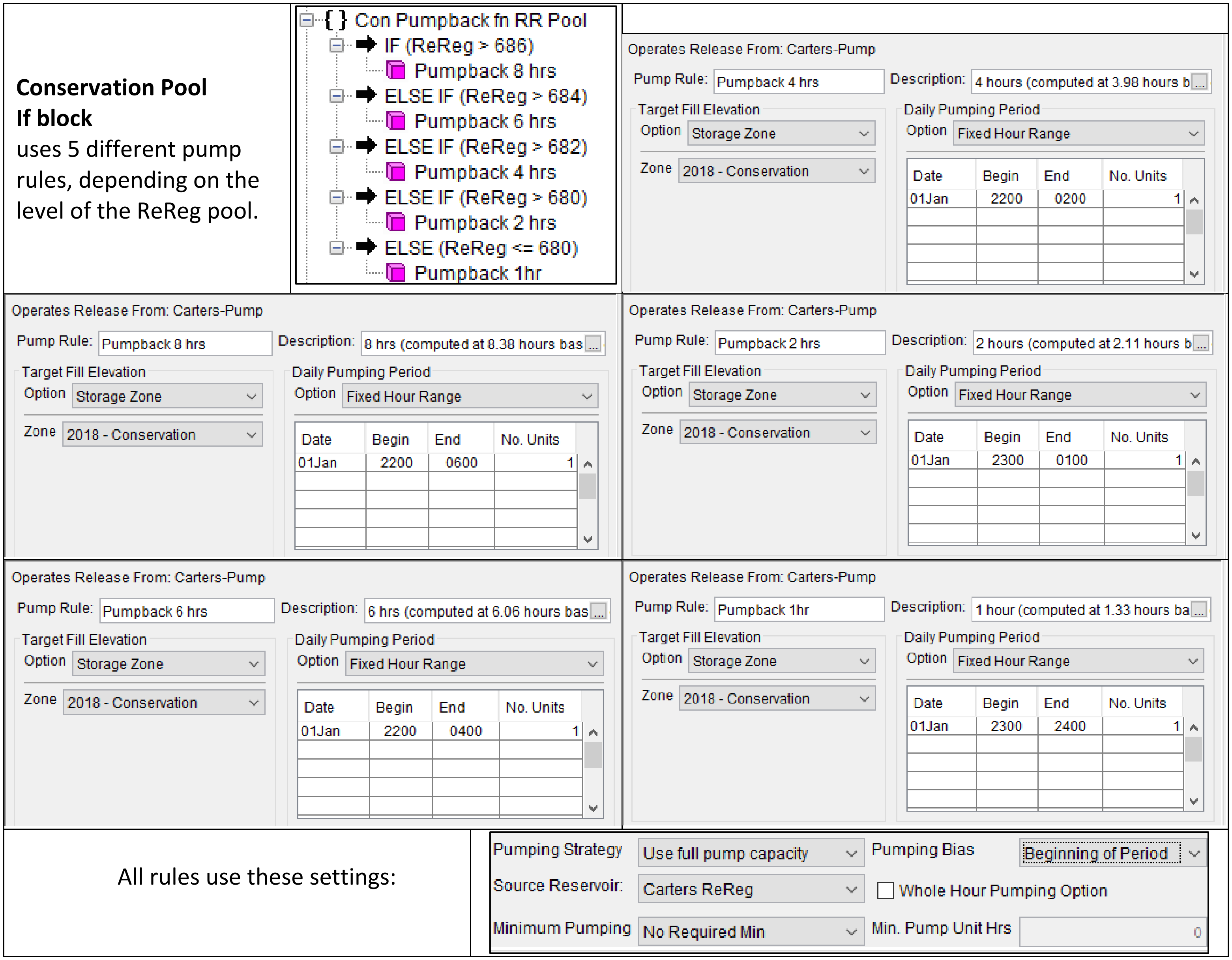


Figure 28. Carters Pumpback rules showing hours of pumping at in 2018 Network

E. Weiss Bypass Operation

The Weiss bypass operation requires a rule for the minimum flow discharge from the trash gate at the diversion dam into the spillway, which is the old river channel. The physical capacity for the gated spillways at Weiss was separated into two capacity curves for the ***2018*** network: one for the trash gate and one for the main gate. Figure 29 shows the set up for two different types of gates at Weiss. Figure 30 and Figure 31 show the capacity curves at the main gate and trash gate at Weiss respectively.

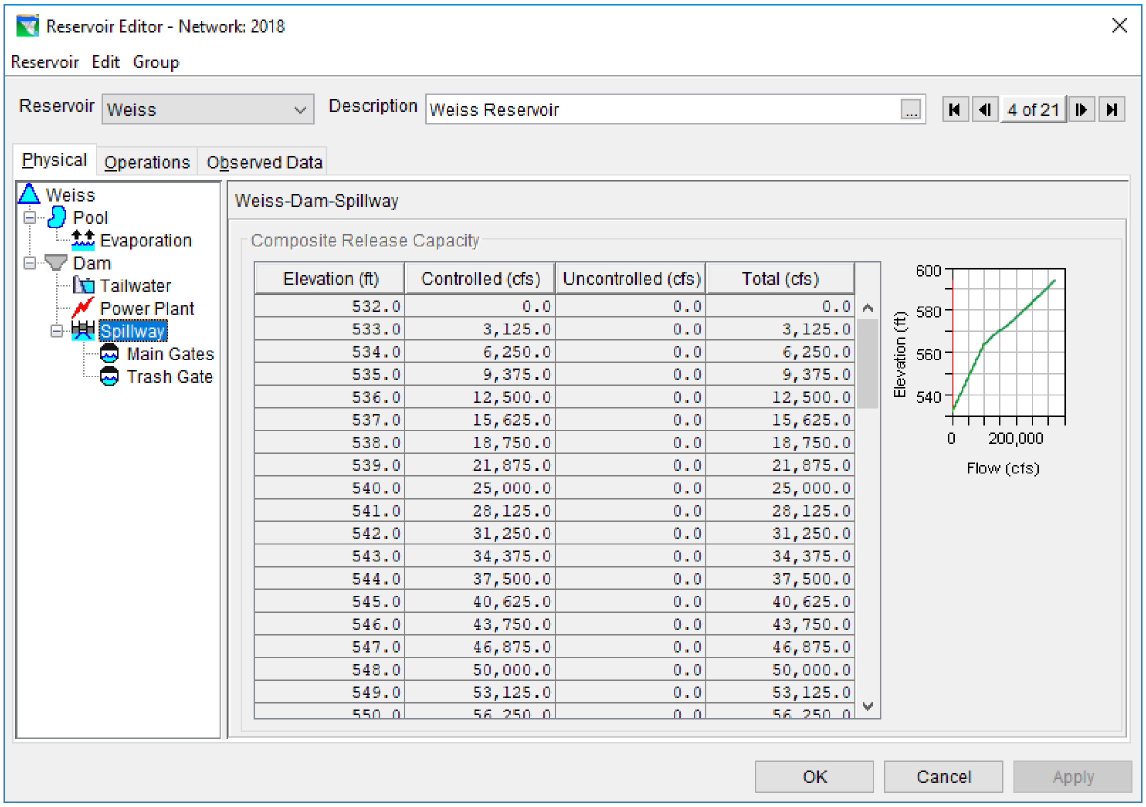
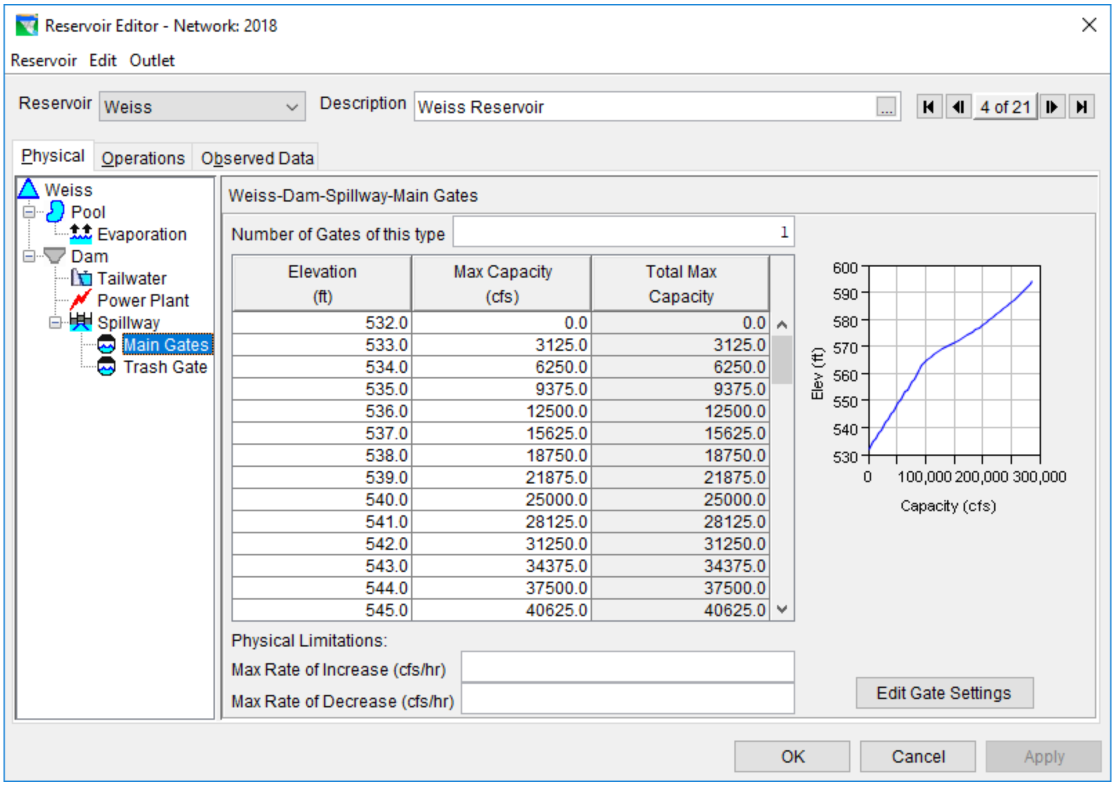
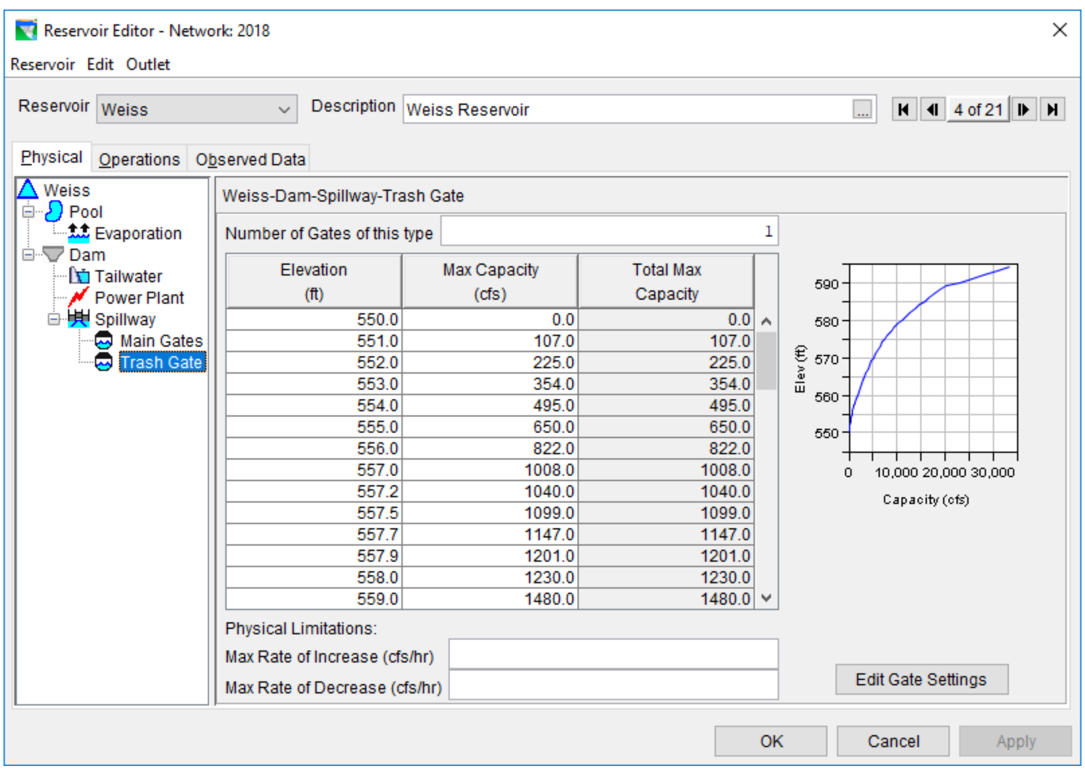


Figure 29. Spillway Capacity Curve at Weiss



Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
532.0	0.0	0.0
533.0	3125.0	3125.0
534.0	6250.0	6250.0
535.0	9375.0	9375.0
536.0	12500.0	12500.0
537.0	15625.0	15625.0
538.0	18750.0	18750.0
539.0	21875.0	21875.0
540.0	25000.0	25000.0
541.0	28125.0	28125.0
542.0	31250.0	31250.0
543.0	34375.0	34375.0
544.0	37500.0	37500.0
545.0	40625.0	40625.0

Figure 30. Main Gates Capacity Curve at Weiss



Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
550.0	0.0	0.0
551.0	107.0	107.0
552.0	225.0	225.0
553.0	354.0	354.0
554.0	495.0	495.0
555.0	650.0	650.0
556.0	822.0	822.0
557.0	1008.0	1008.0
557.2	1040.0	1040.0
557.5	1099.0	1099.0
557.7	1147.0	1147.0
557.9	1201.0	1201.0
558.0	1230.0	1230.0
559.0	1480.0	1480.0

Figure 31. Trash Gate Capacity Curve at Weiss

The flow passing from the trash gate is recalculated every Tuesday and Friday based on the flow at the USGS Mayo's Bar gage (represented by the ***Rome-Coosa*** junction in the model). The flow used in the calculation is the average of the past four days for Tuesdays and the average of the past three days for Fridays. Figure 32 shows the location of the Mayo's Bar gage, upstream of the Georgia-Alabama state line and Weiss Lake. Once this flow value has been determined, the release from the trash gate is calculated using the following table of multipliers based on the current month (Table 4).

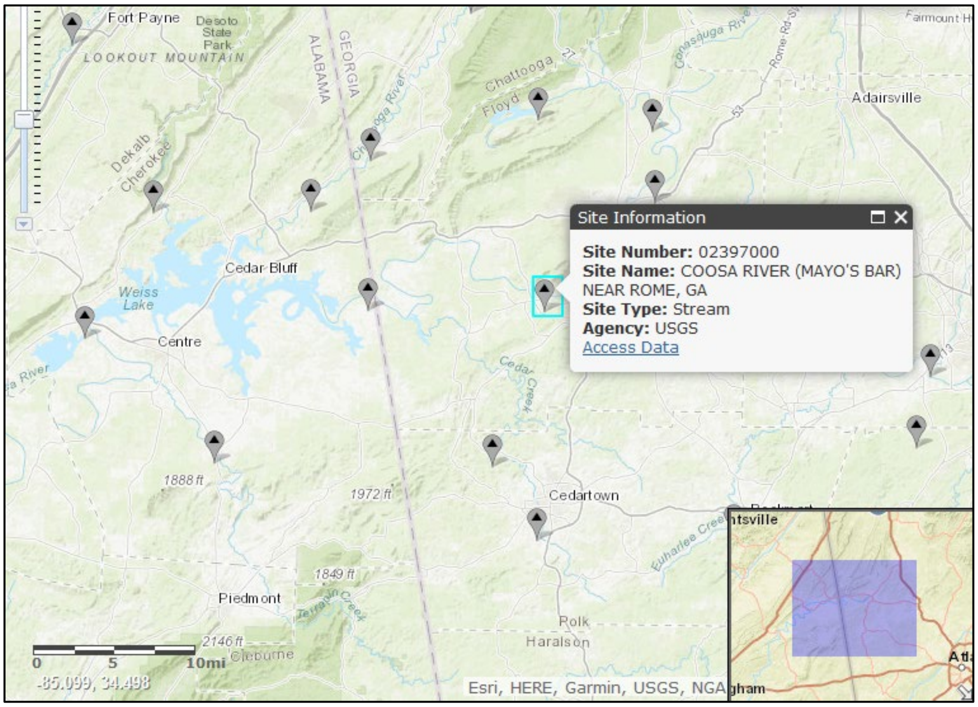


Figure 32. Location of Mayo's Bar (source: USGS)

The bypass operation at Weiss is shown in Figure 33 with the ***ByPass Flow*** rule which is a function of ***WeissByPass*** state variable in the ***2018*** operation set. The state variable is described in **Appendix A**.

Table 4. Multipliers for the release from the trash gate of Weiss Bypass

Months	Multiplier
January, September	0.06
February, March, April, May, October	0.09
June	0.05
July, August	0.04
November	0.08
December	0.07

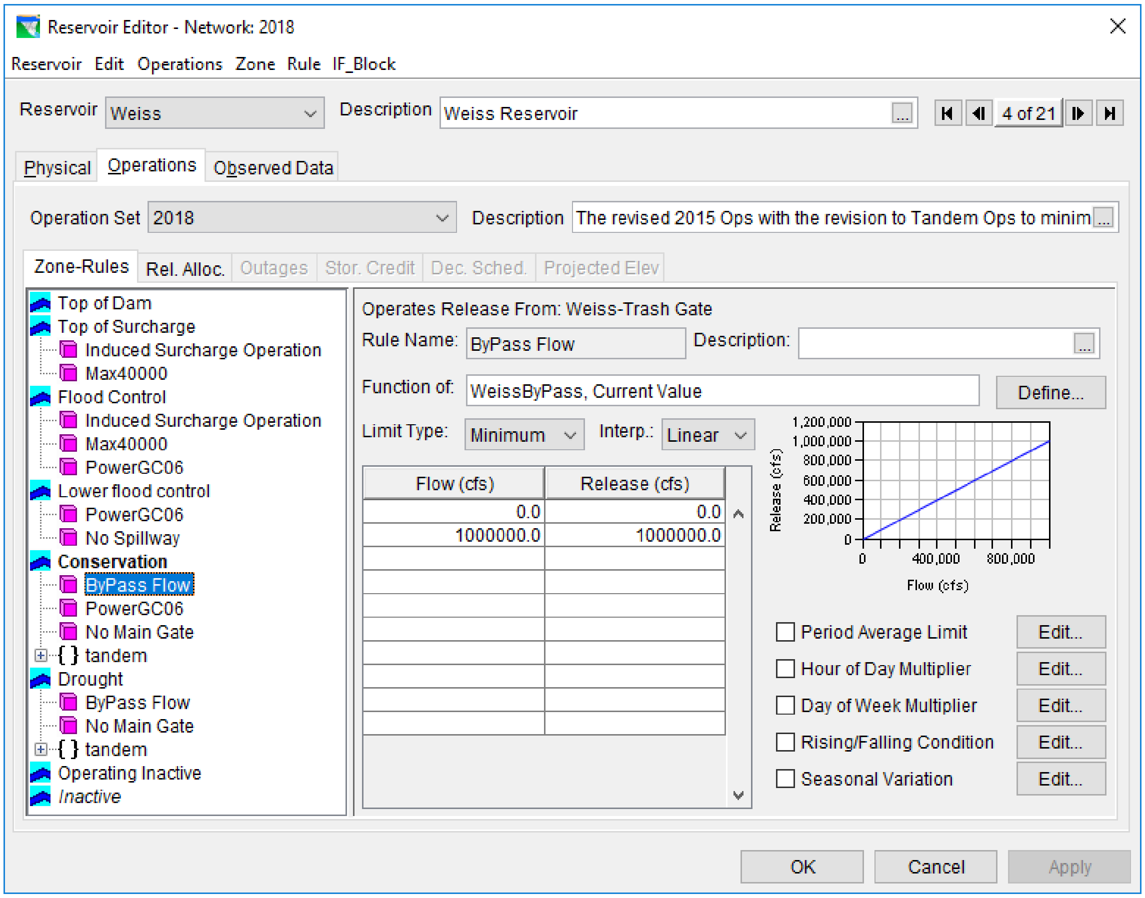


Figure 33. *ByPass Flow* rule at Weiss

The *Lower flood control* zone at the elevation of 564 ft is added to the operation set *2018* at Weiss as shown in Figure 34. The purpose of this rule is to limit the release from the spillway to zero when the pool is above conservation zone up to the *Lower flood control* zone, elevation 564 ft. This task is done by adding the ***No Spillway*** rule in the *Lower flood control* zone as shown in Figure 35.

The operation of the Weiss bypass requires that when the pool is below the Conservation zone, releases shall only be from the trash gate. This operation is applied by adding the ***ByPass Flow*** rule at the Conservation and Drought zones along with the ***No Main Gate*** rule, which limits the release from the Main Gate to zero in these operation zones. The details of the ***No Main Gate*** rule are shown in Figure 36.

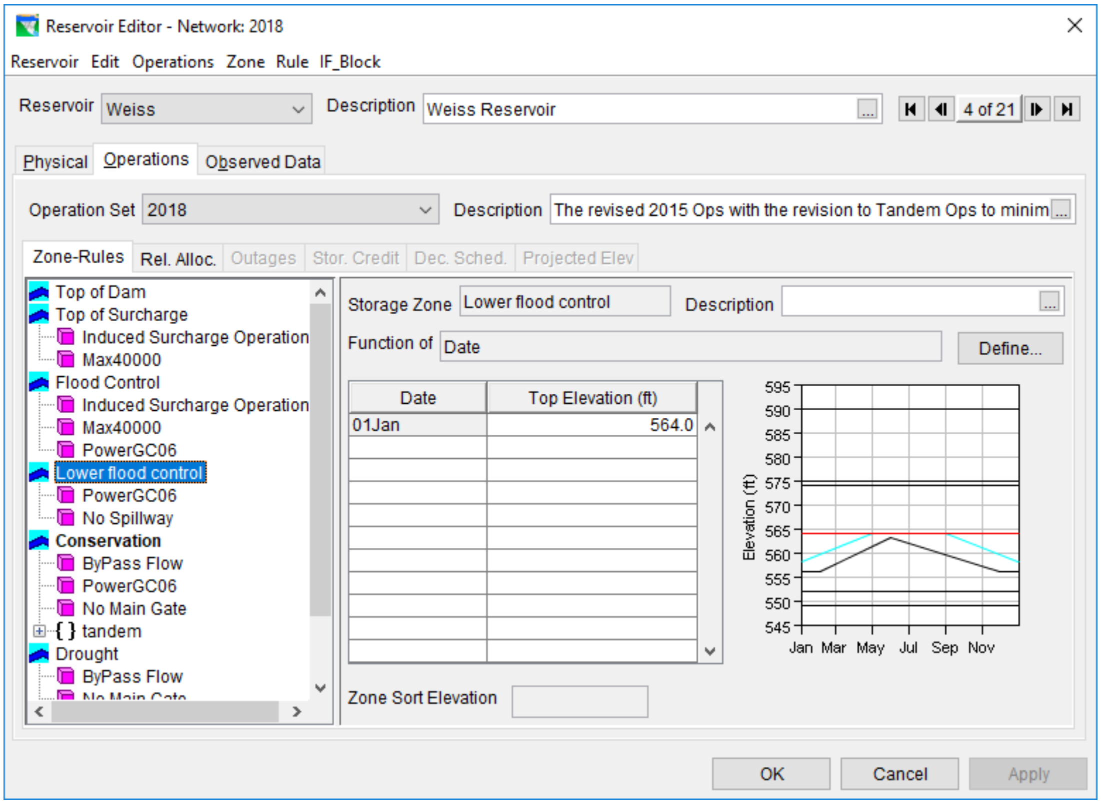


Figure 34. ***Lower Flood Control*** **operation zone at Weiss**

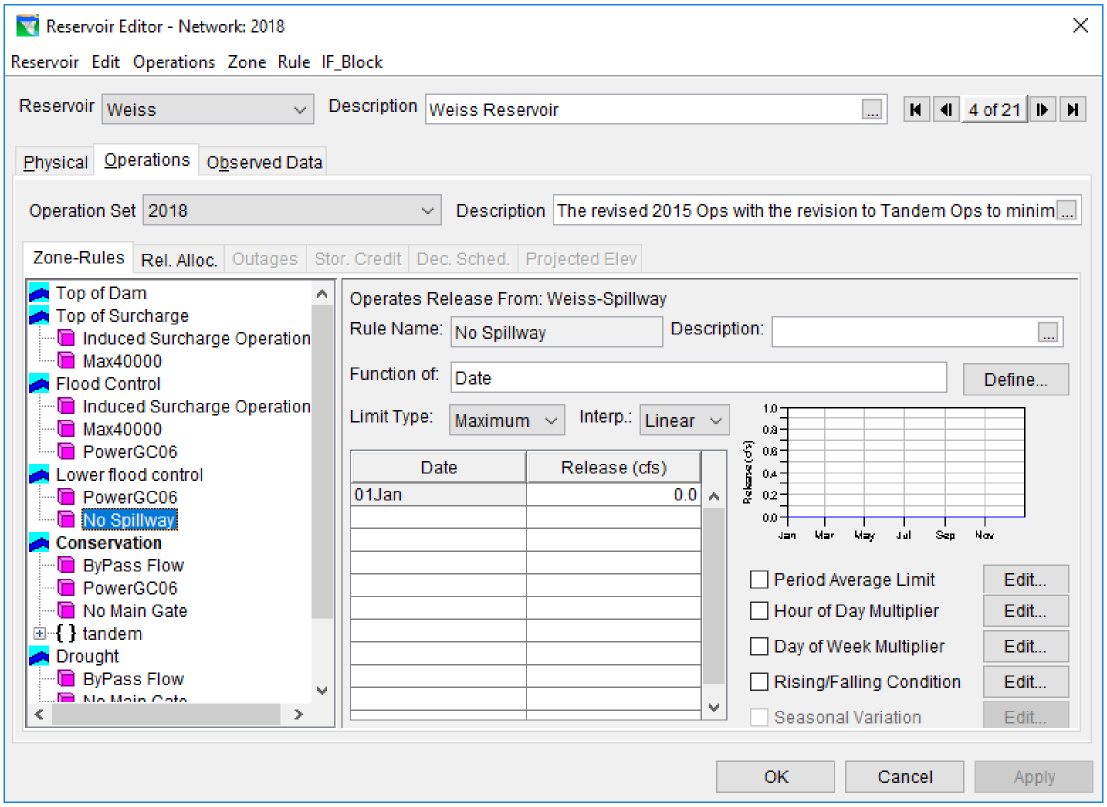


Figure 35. ***No Spillway*** **rule at Weiss**

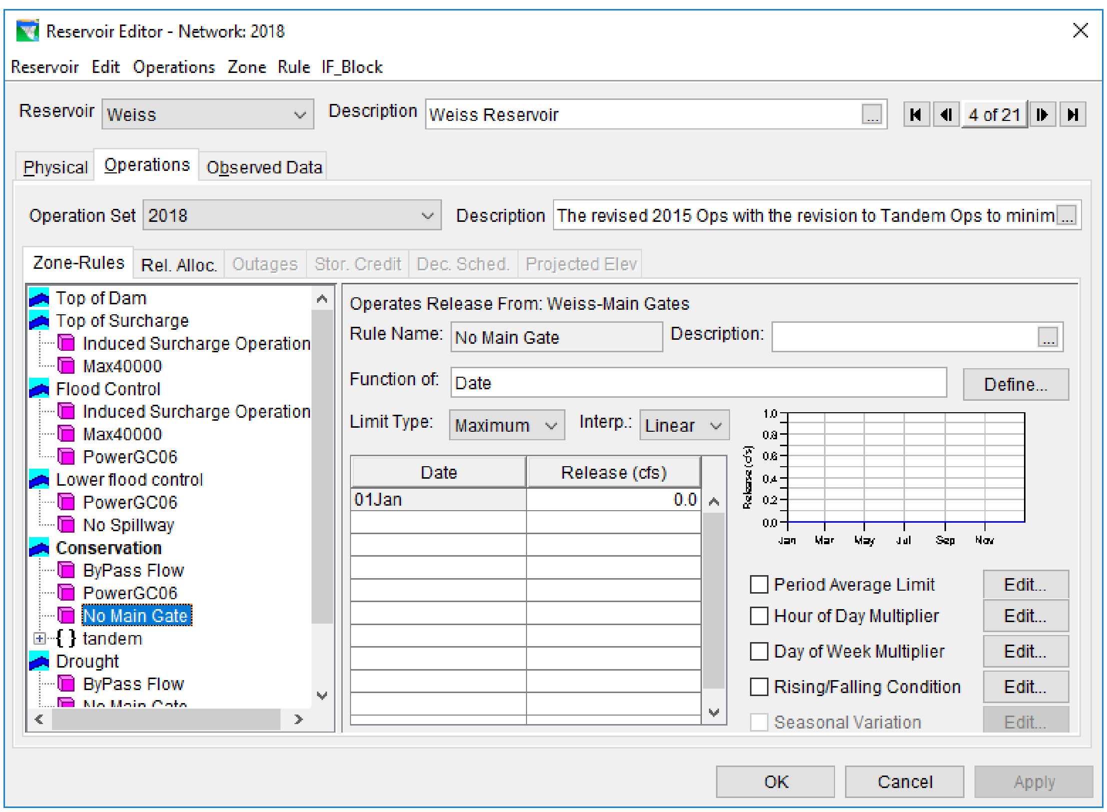


Figure 36. ***No main Gate*** **rule at Weiss**

F. HN Henry Updates –Gadsden Flood Operation

The *Gadsden_Flood_Op_APC* rule implements the HN Henry pool drawdown rules. This rule determines the appropriate HN Henry forebay elevation according to the current Gadsden stage value. Due to the path of the river downstream of Gadsden, the HN Henry flood regulations calls for lowering the HN Henry forebay elevation as the Gadsden stage rises. This is to attempt to overcome the hydraulic properties of the flow near what is referred to as Minnesota Bend just downstream of Gadsden. Refer to Figure 54 in Section G for the ResSim schematic showing the location of Gadsden with respect to HN Henry. The geography and geometry of the river at this location causes the flow to decrease significantly causing backwater effects at Gadsden. Lowering the HN Henry pool elevation creates a greater slope difference and helps to pull water through the bend. As the Gadsden stage begins to fall, the HN Henry forebay is then allowed to rise in a similar fashion. (*Modification of Flood Control Plans for Alabama Power Company Reservoirs Weiss and Logan Martin Coosa River, Alabama, Preliminary HEMP Results Technical Report December 31, 2018*). This operation is applied through *Gadsden_Flood_Op_APC* if-block, which is shown in Figure 37. The tandem rule is applied only if Gadsden stage is equal or greater than 508.5 ft or the HN Henry Pool elevation is less than or equal 507 ft. These conditions are shown in Figure 38 and Figure 39 respectively. The *GadsdenFloodOP_APC* rule is shown in Figure 40. The *GadsdenFloodOp* state variable is described in **Appendix A.4**.

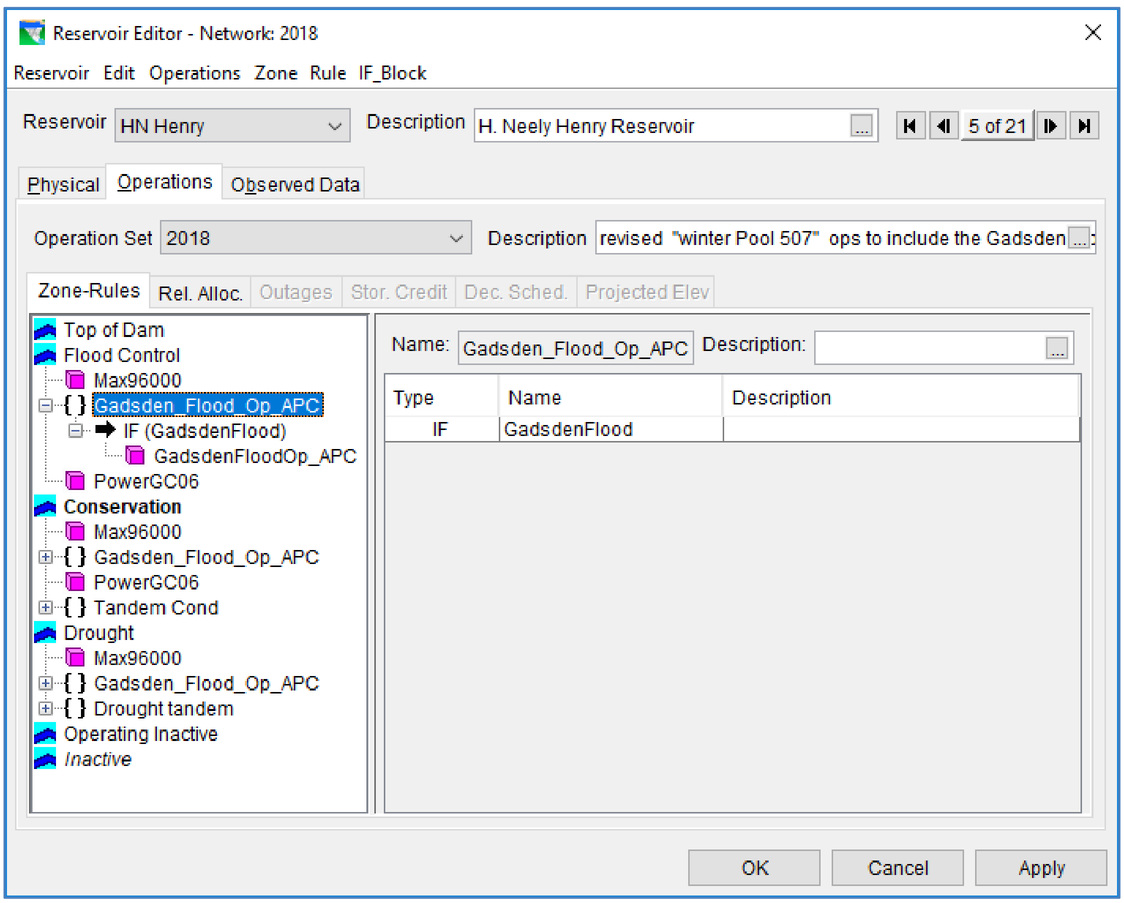


Figure 37. ***Gadsden_Flood_Op_APC*** **if-block at HN Henry**

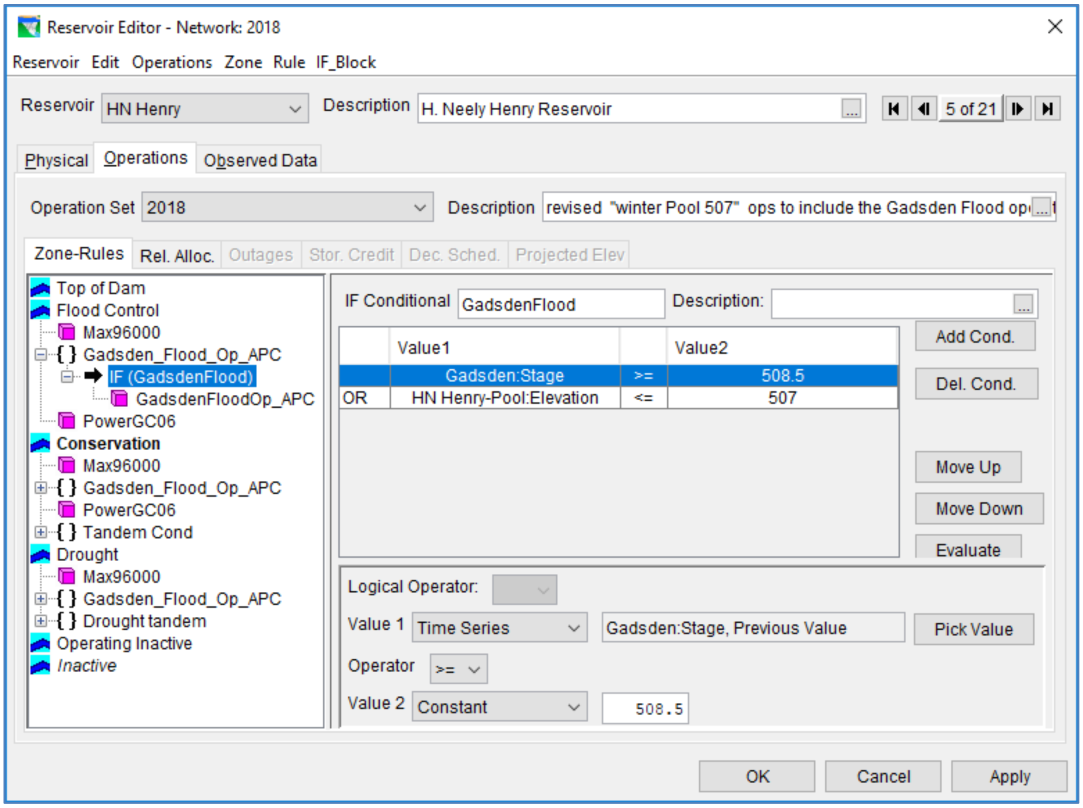


Figure 38. Gadsden stage >= 508.5 condition in *Gadsden_Flood_Op_APC* if-block

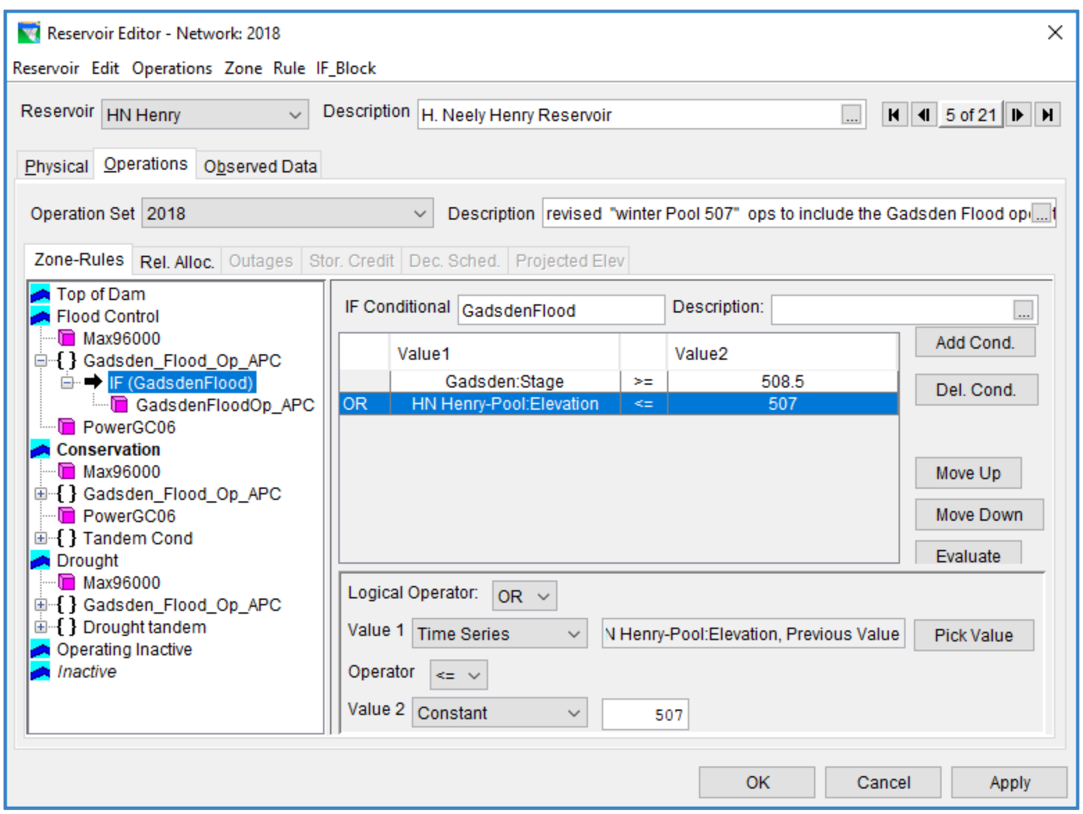


Figure 39. HN Henry pool elevation <= 507 condition in *Gadsden_Flood_Op_APC* if-block

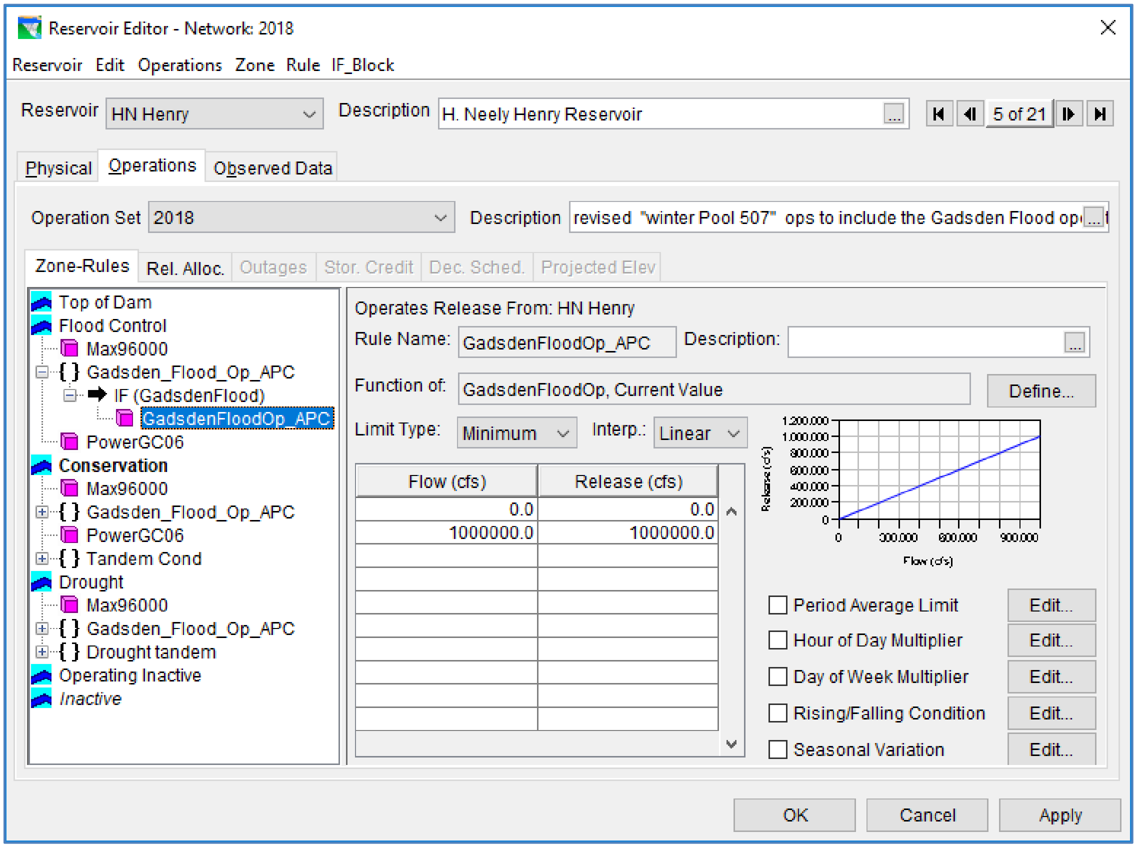


Figure 40. *GadsdenFloodOp_APC* rule

Because of this operation the tandem rule at Weiss and HN Henry needed to be revised. The reason for revision is if HN Henry is operating for Gadsden and the required flow for this operation is greater than required power flow, Weiss pool should not draw down for HN Henry and HN Henry pool should not draw down for Logan Martin. In this case the tandem rule at Weiss for HN Henry is replaced with the tandem rule for Logan Martin and the tandem rule at HN Henry is removed. Whenever Gadsden operation is not active at HN Henry, Weiss can release for HN Henry and HN Henry can release for Logan Martin through their regular Tandem Rules. Figure 41 shows the revised tandem operation at Weiss, which uses an if-block called *tandem*.

Figure 42 and Figure 43 show the conditions for *LM_Tandem* if-block at Weiss. If the result of the *GadsdenFloodOp* state variable is not equal to HN Henry pool inflow and at the same time that value is greater than required power flow at HN Henry then Weiss does not follow its regular tandem rule which is releasing for HN Henry. Instead Weiss will have *LM_Tandem* rule which releases for Logan Martin. The *LM_Tandem* rule is shown in Figure 44. If one of those conditions is not met then Weiss follow its regular tandem rule which is *HN Henry_Tandem*. The *HN Henry_Tandem* rule is shown in Figure 46. The same conditions are applied at HN Henry to set the correct tandem rule. The *Tandem Cond* if-block at HN Henry is shown in Figure 47.

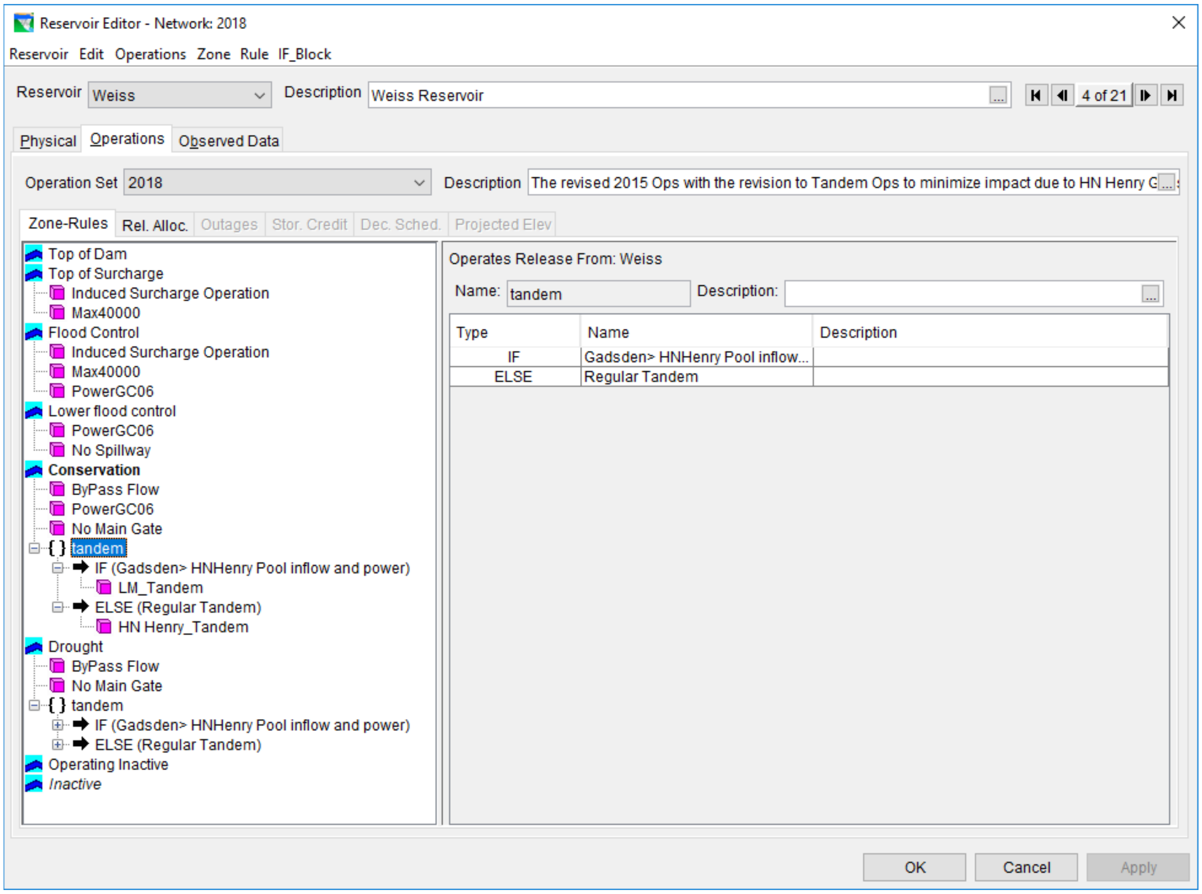


Figure 41. *tandem* if-block at Weiss

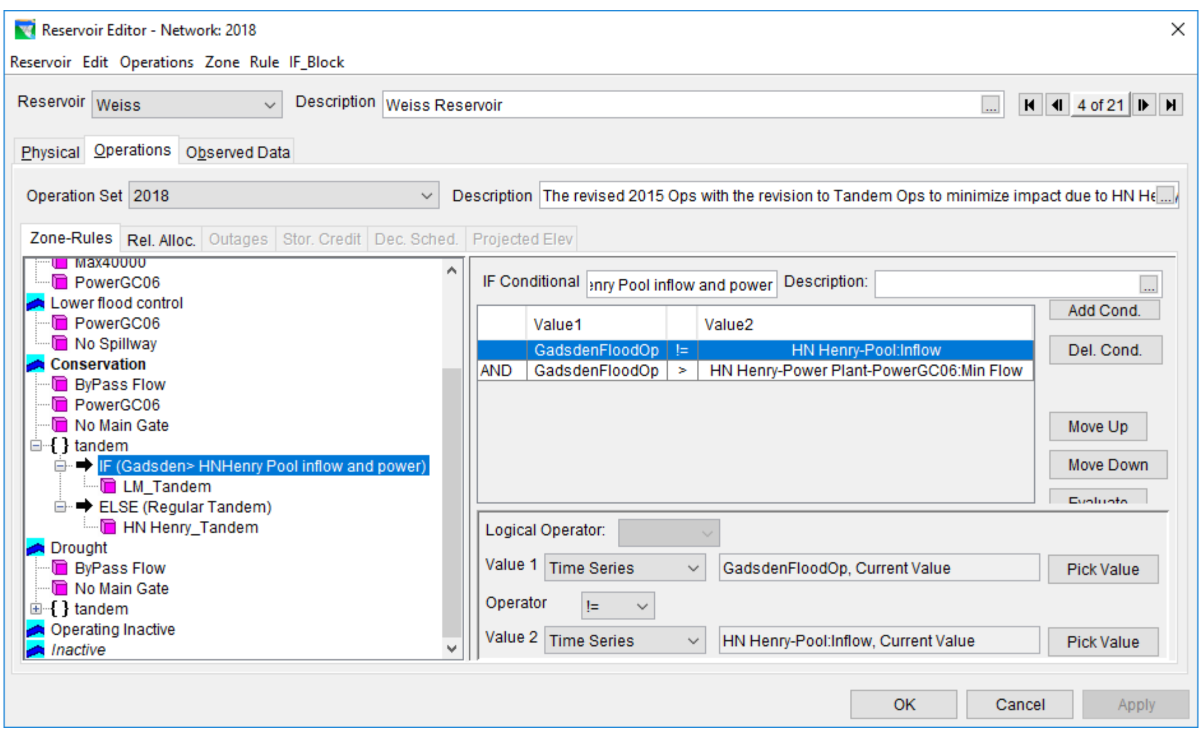


Figure 42. First condition of *tandem* if-block at Weiss

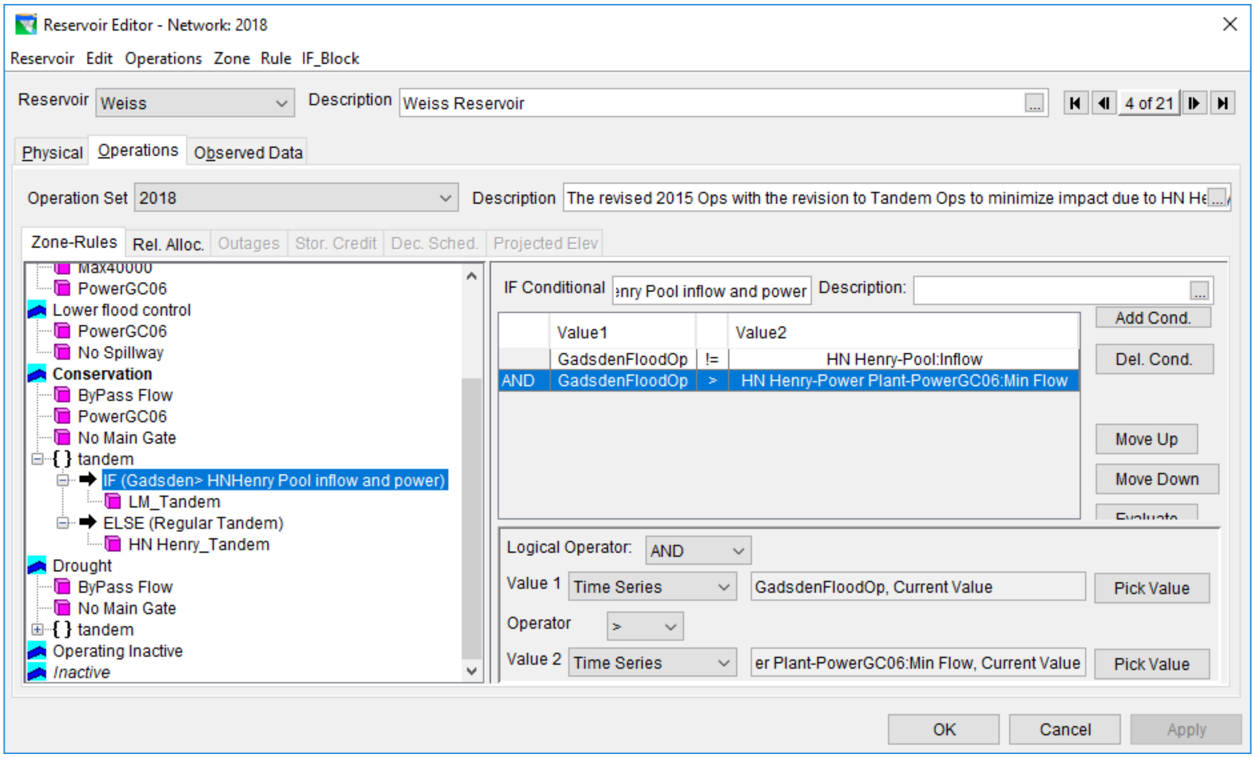


Figure 43. Second condition of *tandem* if-block at Weiss

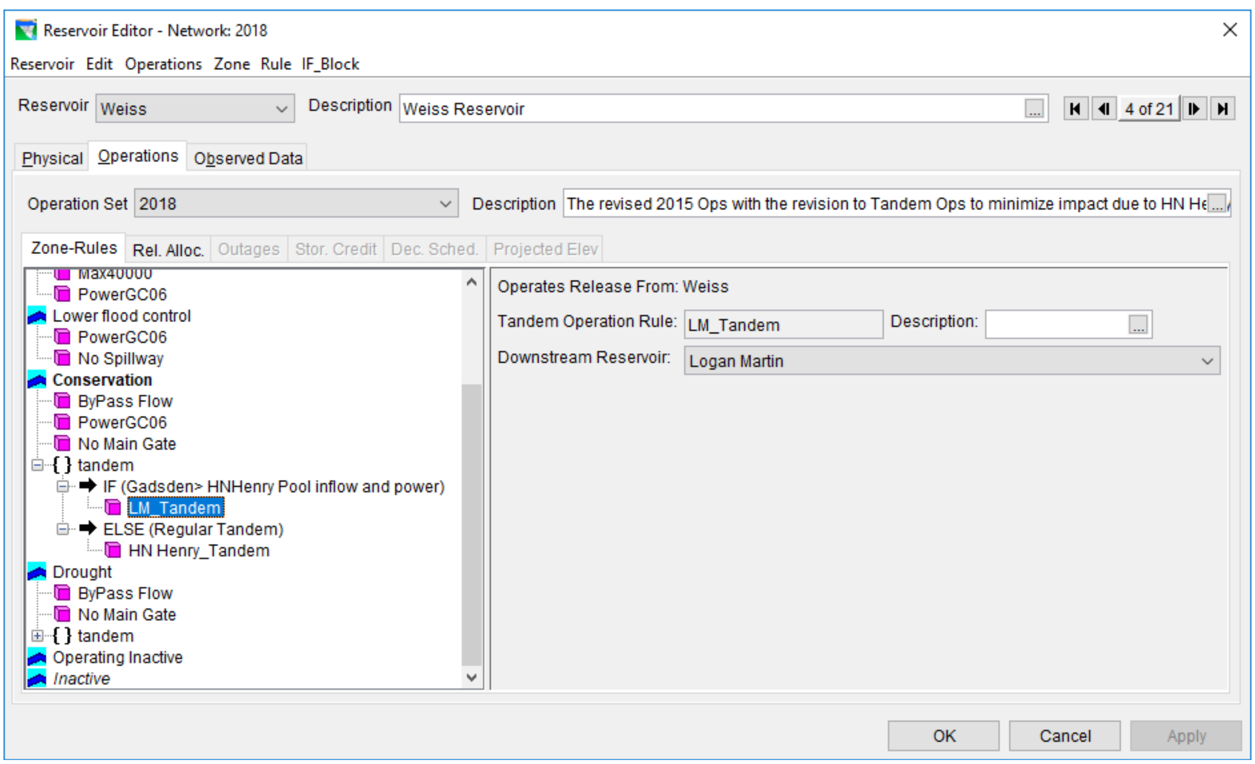


Figure 44. *LM_Tandem* rule at Weiss

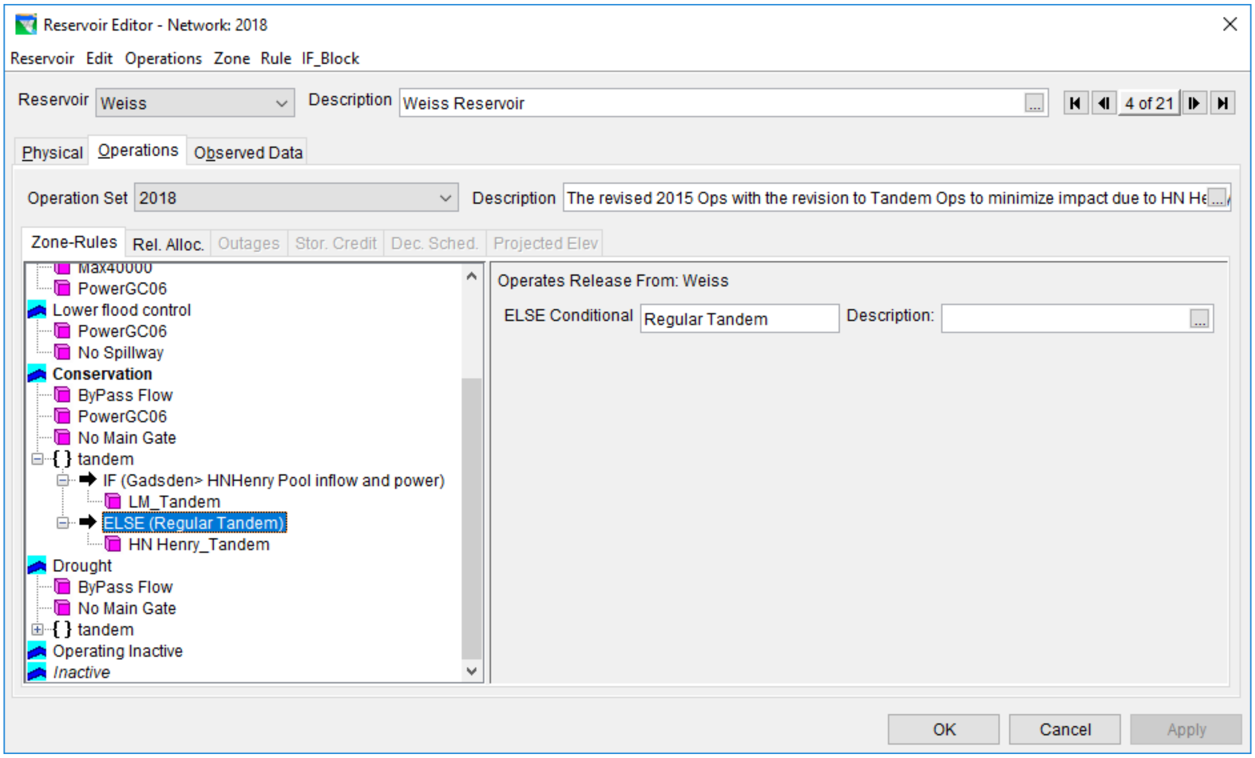


Figure 45. Else condition of *tandem* if-block at Weiss

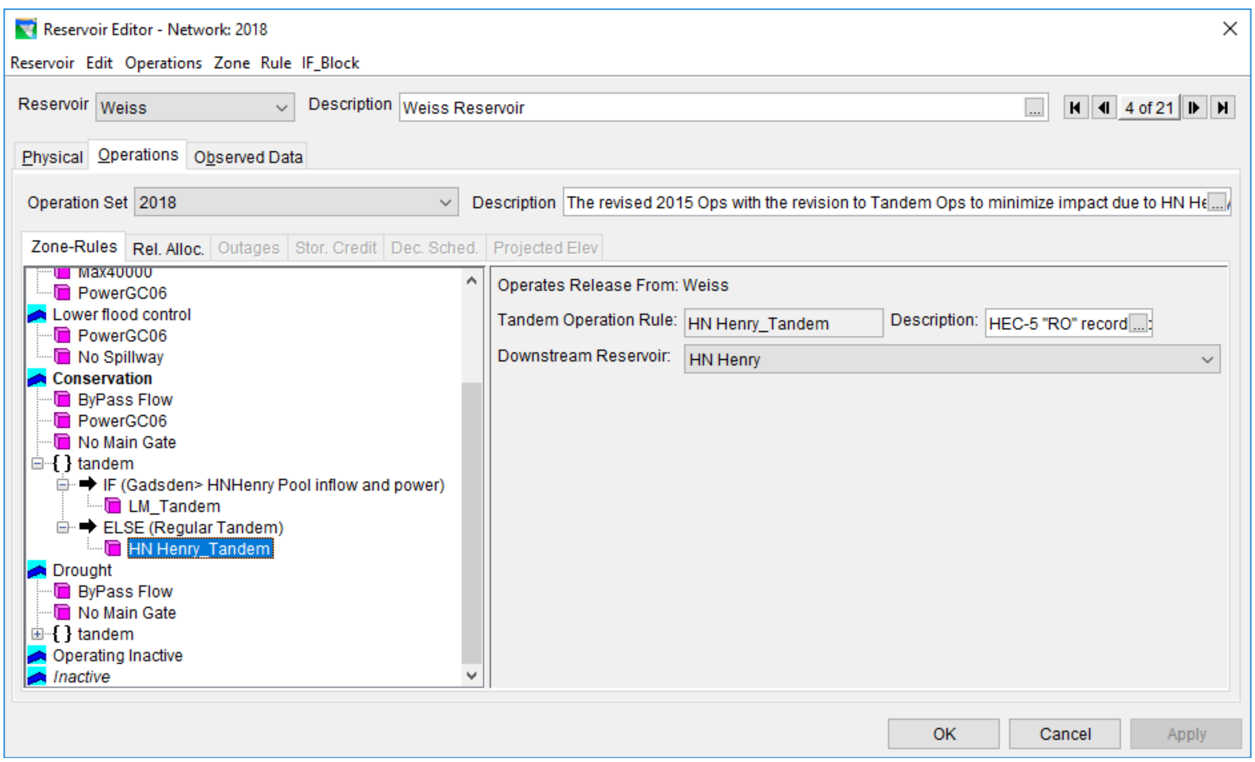


Figure 46. *HNHenry_Tandem* rule at Weiss

Figure 48 and Figure 49 show the conditions where the *Logan Martin_Tandem* rule is removed from the *2018* operation set at HN Henry. If the result of the *GadsdenFloodOp* state variable is not equal to HN Henry pool inflow and at the same time that value is greater than required power flow at HN Henry, then no tandem rule is set at HN Henry. If either of those conditions is not met then HN Henry follows its regular tandem operation, which is reflected in the *Control Tandem* if-block. The *Control Tandem* if-block is shown in Figure 51 and Figure 52, and the Logan Martin_Tandem rule is in Figure 53.

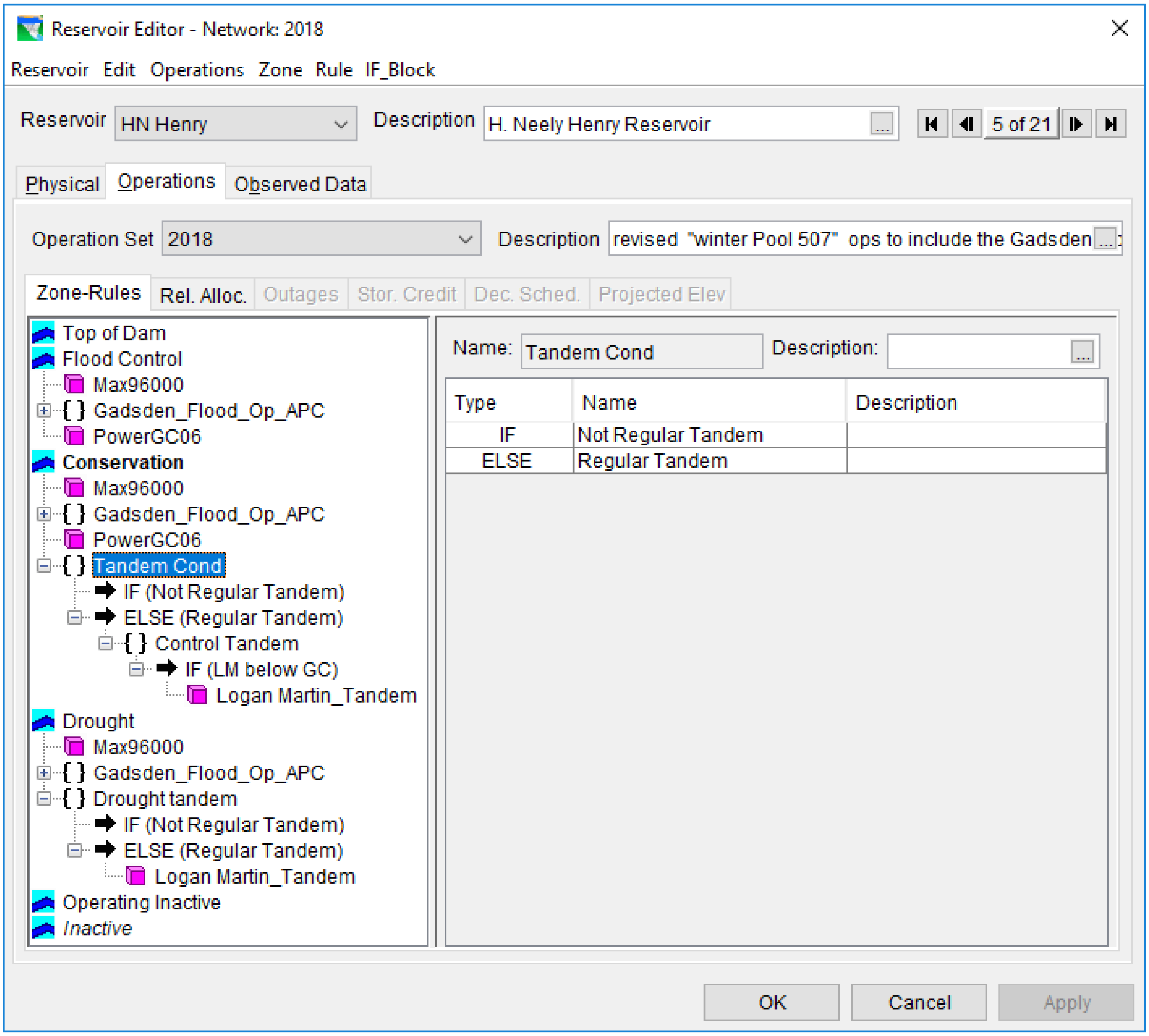


Figure 47. *Tandem Cond* if-block at HN Henry

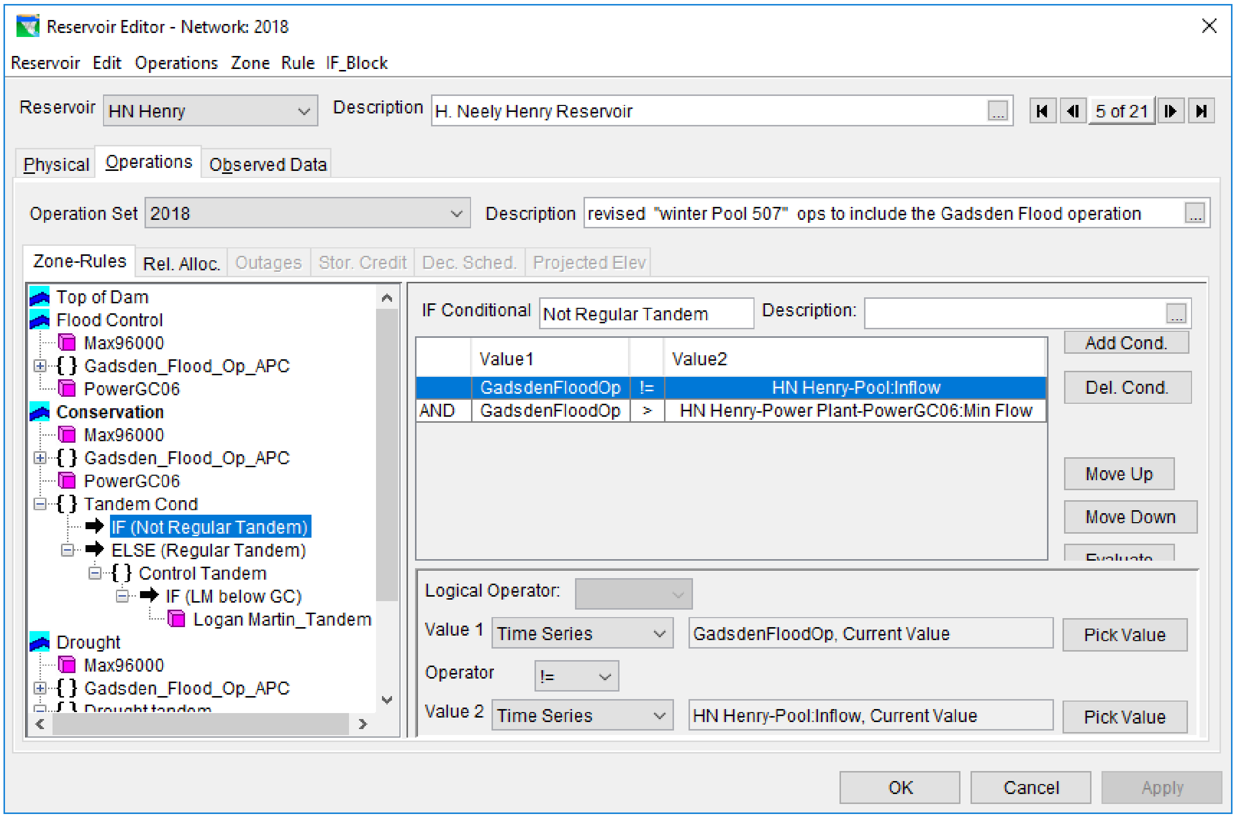


Figure 48. First condition of *Tandem Cond* if-block at HN Henry

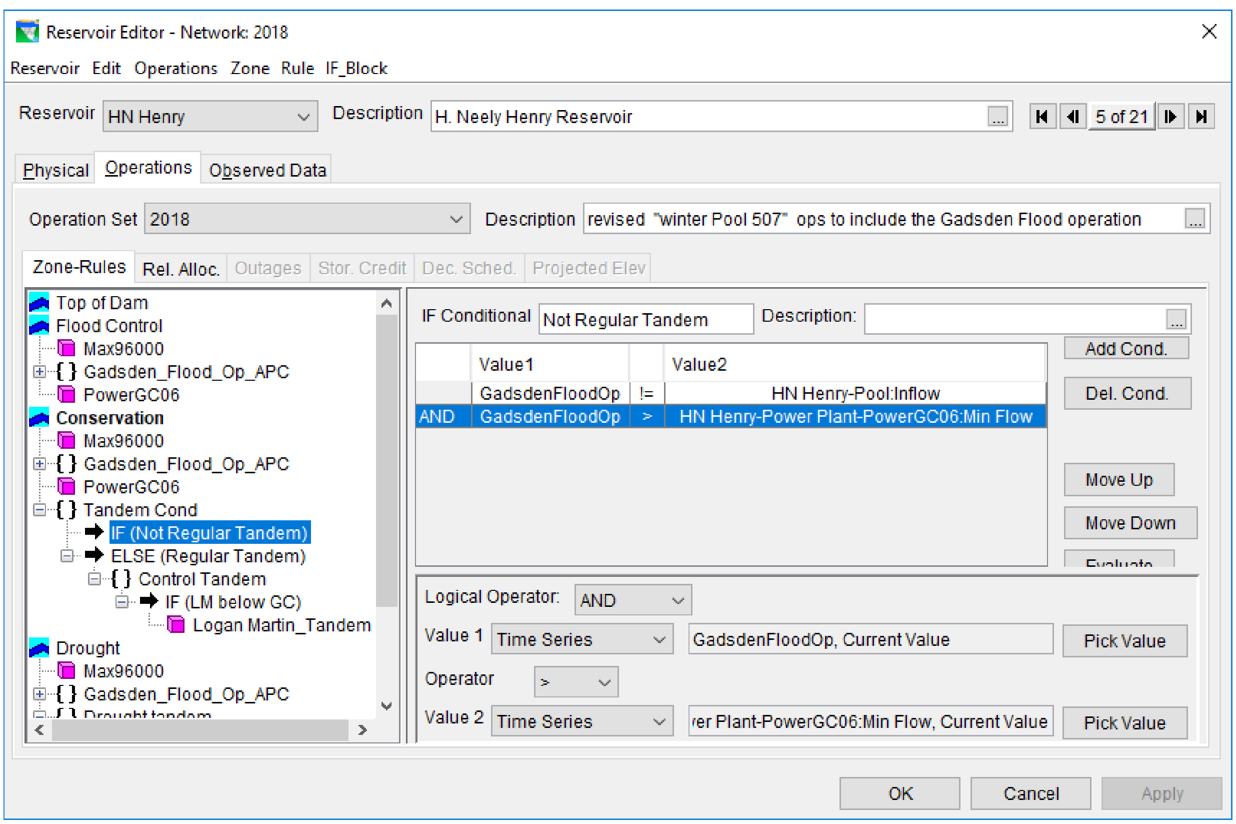


Figure 49. Second condition of *Tandem Cond* if-block at HN Henry

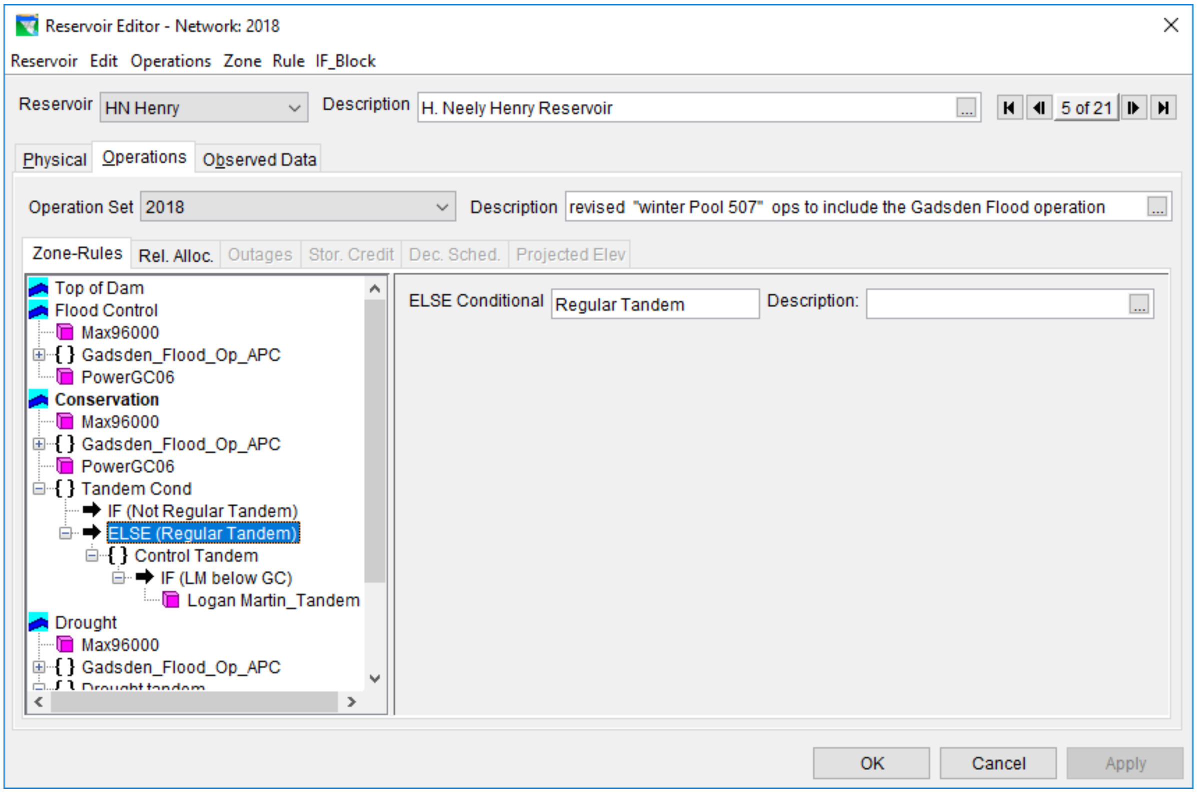


Figure 50. Else condition of *Tandem Cond* if-block at HN Henry

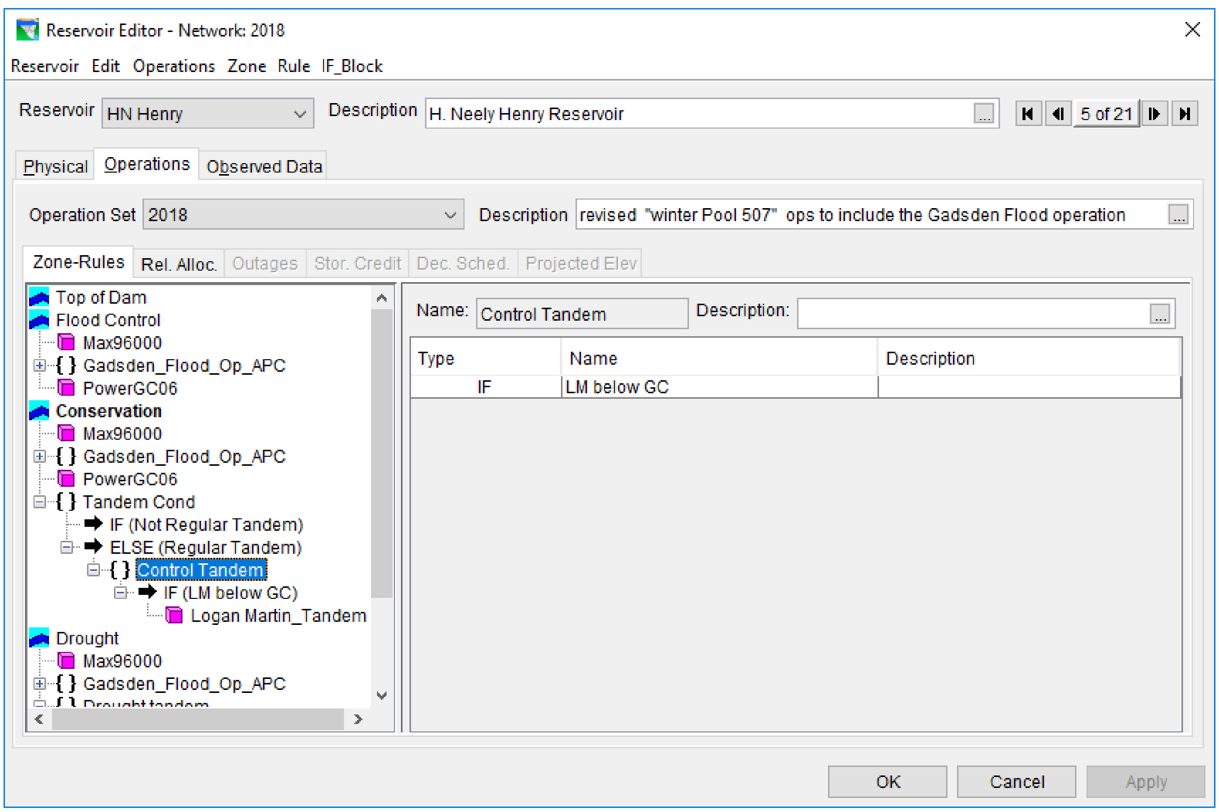


Figure 51. *Control Tandem* if-block at HN Henry

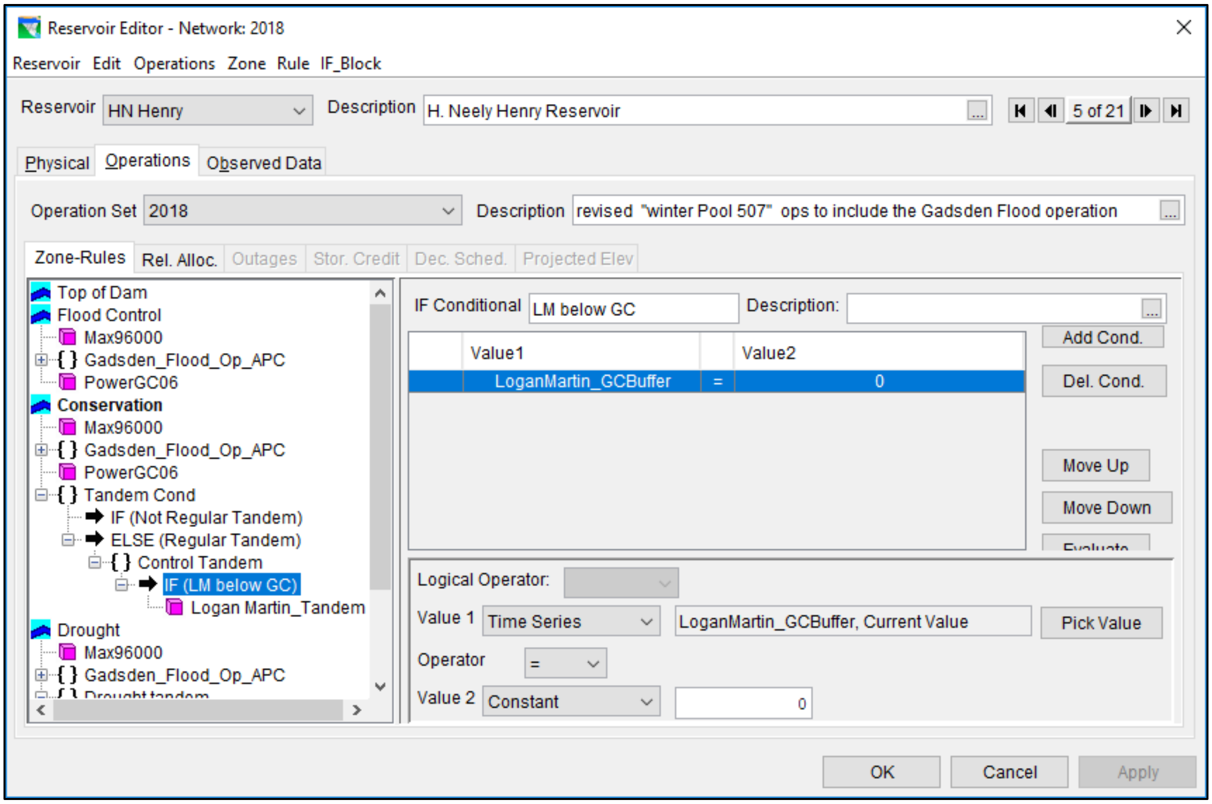


Figure 52. *LM below GC* condition at HN Henry

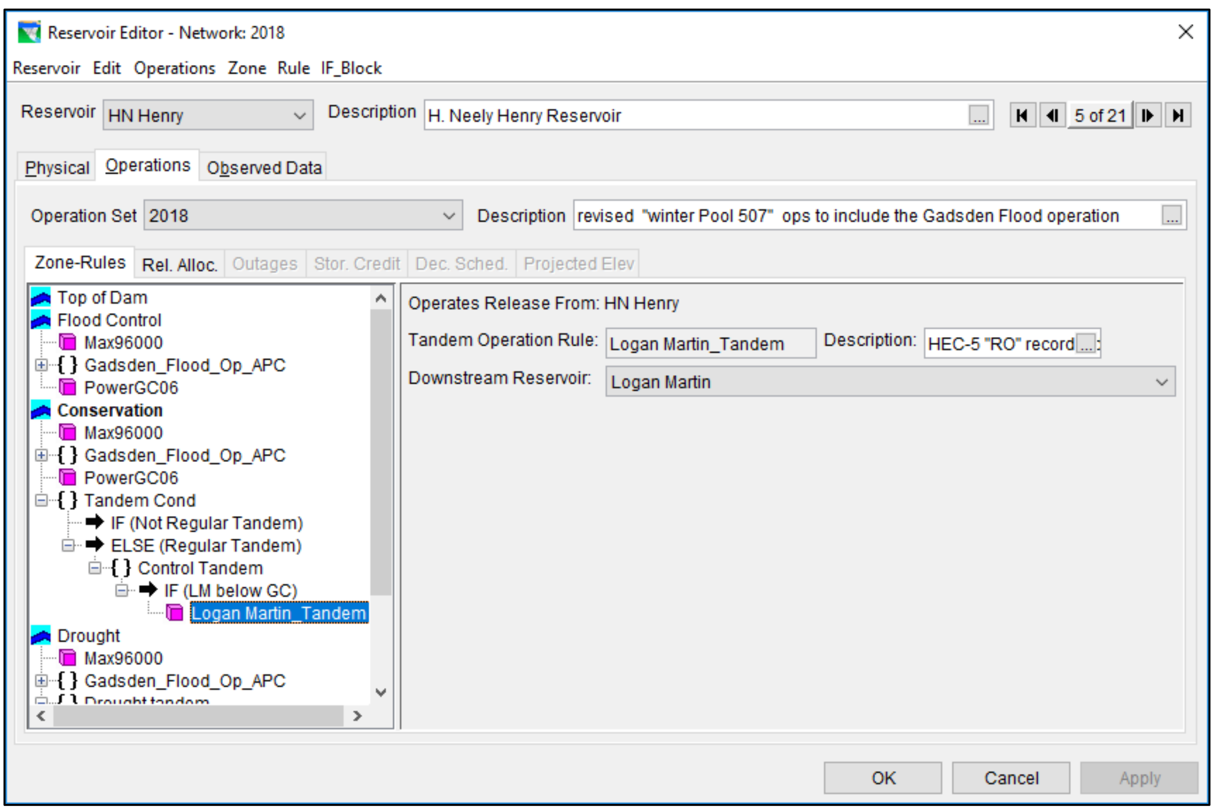


Figure 53. *Logan Martin_Tandem* rule at HN Henry

G. Childersburg and Gadsden Junctions

Gadsden and Childersburg junctions are needed to implement the *RestrictSurcharge* rule at Weiss and Logan Martin. (See the details in Section III for information on this operation.) These junctions were added in the model. The basin area-weight information have been used to approximate flow and rating curves for those locations.

Figure 54 shows the locations of Gadsden and Childersburg in the model schematic. Figure 55 shows the Gadsden rating curve, which is a function of Gadsden flow and HN Henry pool elevation. Figure 56 shows Childersburg rating curve which is a function of Childersburg flow and Lay pool elevation.

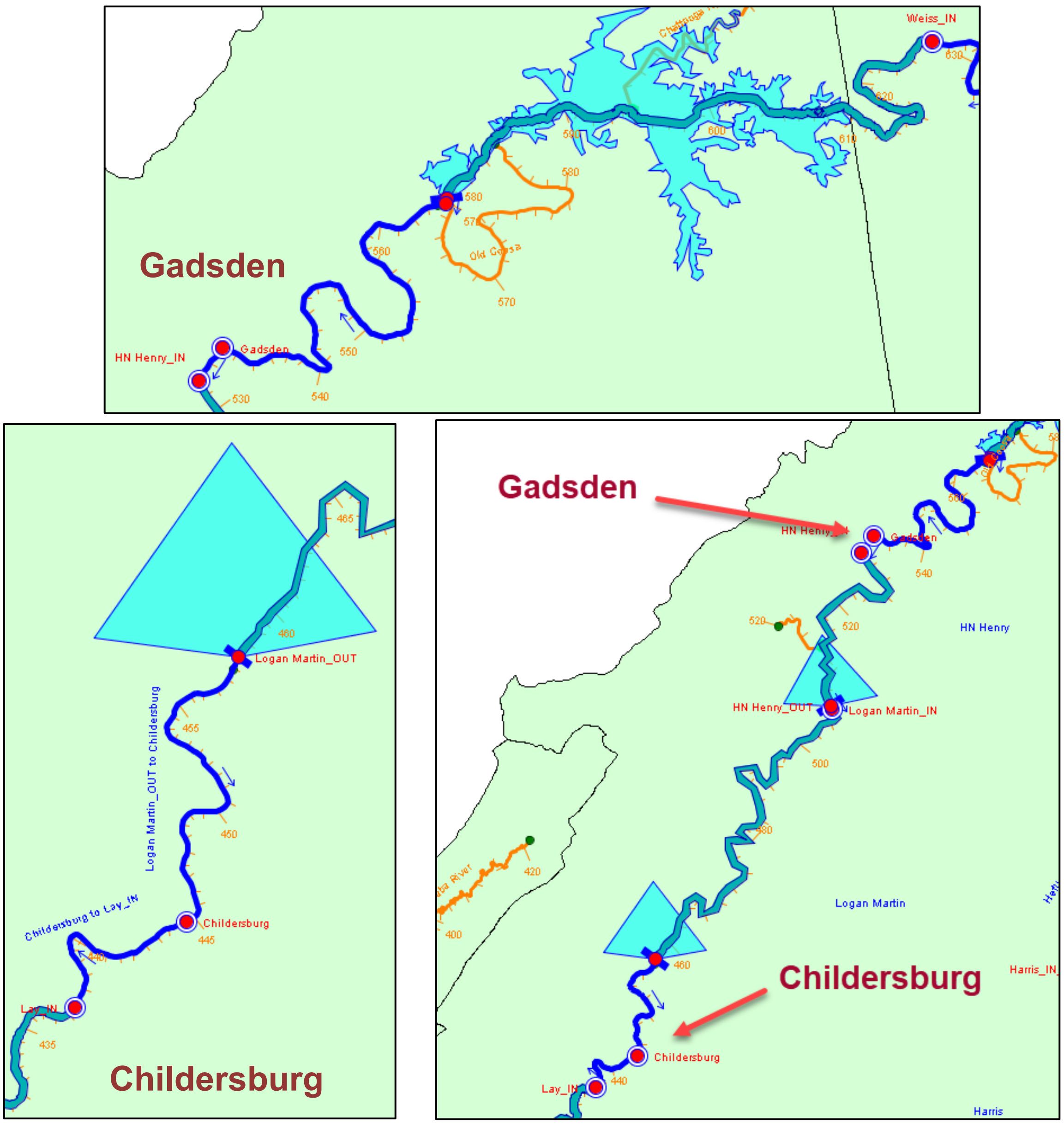
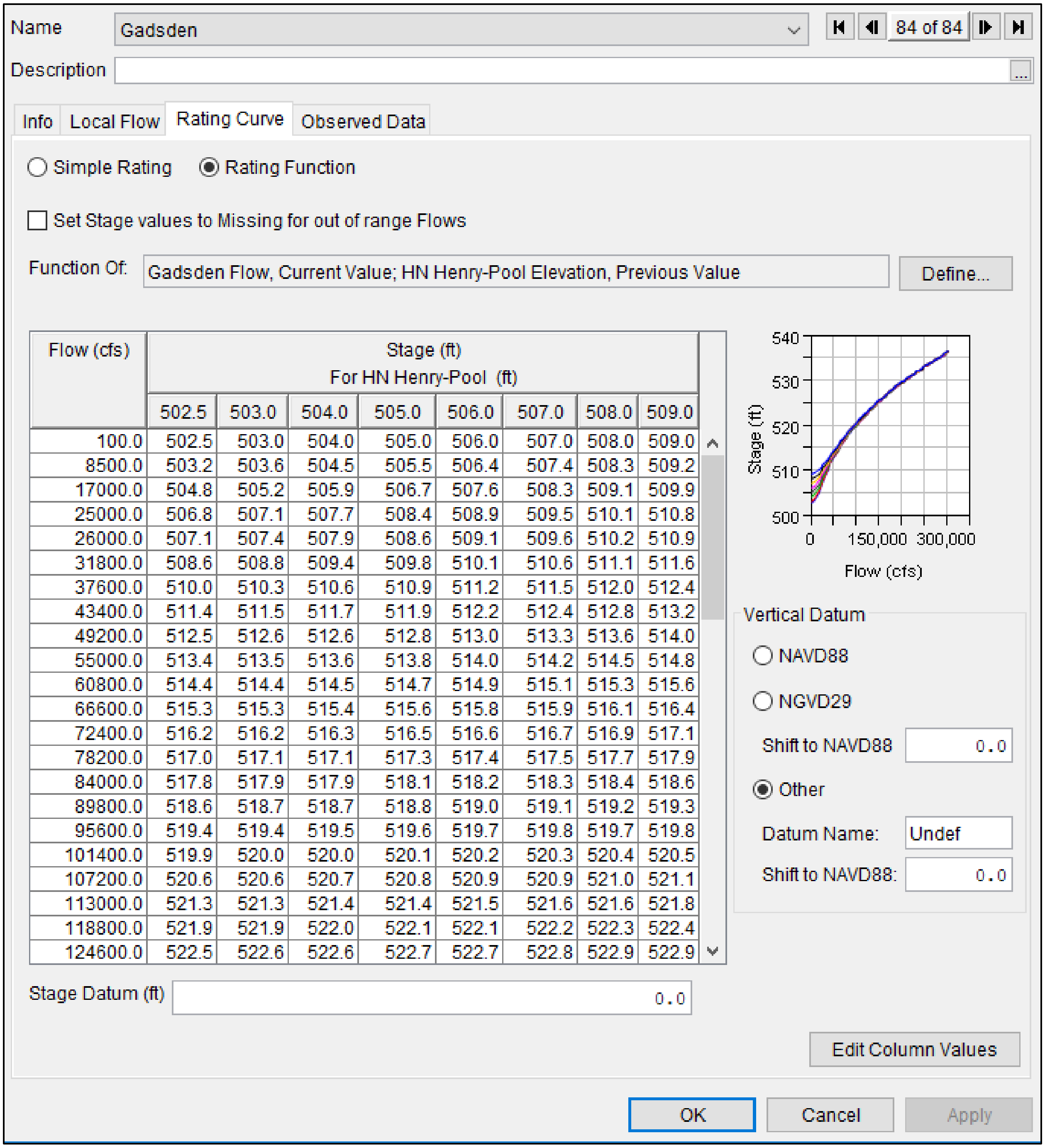
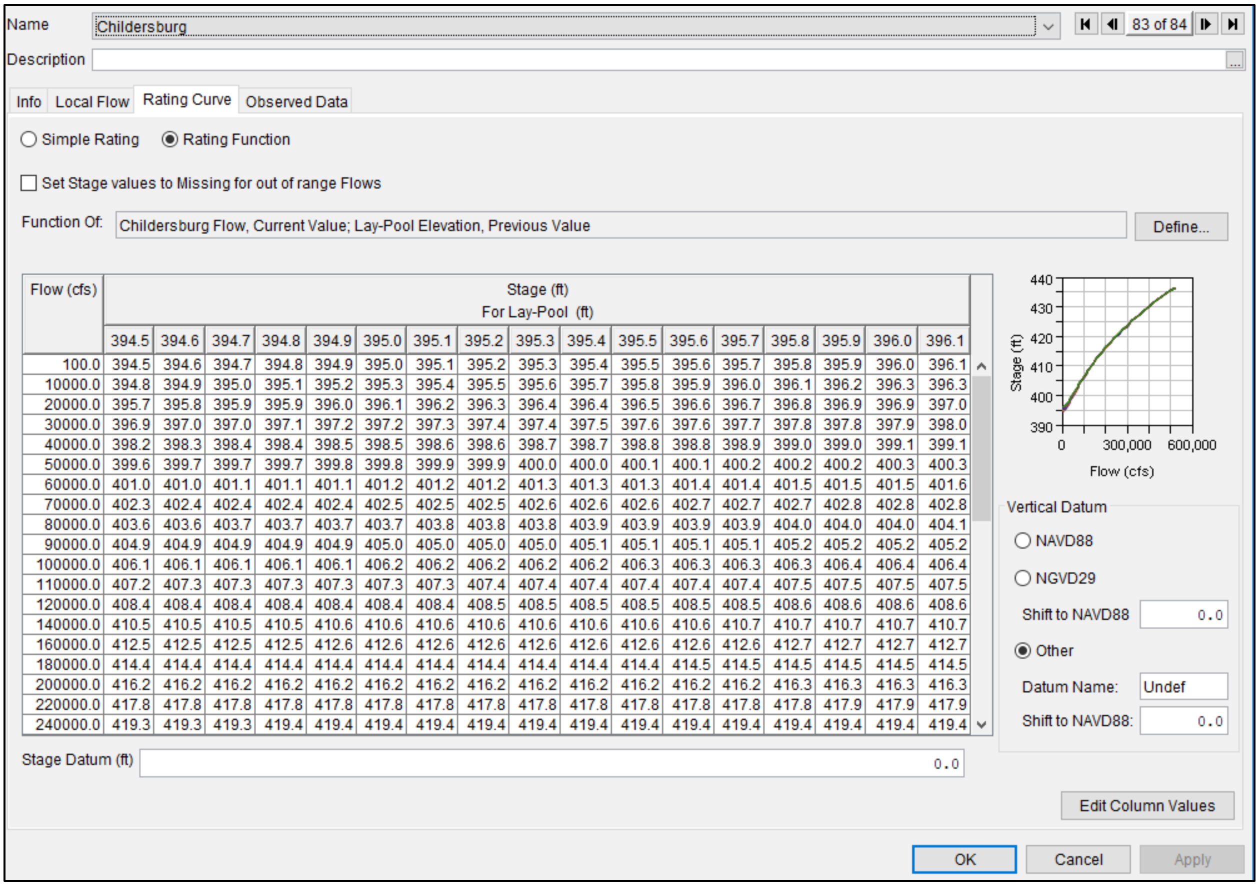


Figure 54. Gadsden and Childersburg locations in the schematic



Flow (cfs)	Stage (ft) For HN Henry-Pool (ft)							
	502.5	503.0	504.0	505.0	506.0	507.0	508.0	509.0
100.0	502.5	503.0	504.0	505.0	506.0	507.0	508.0	509.0
8500.0	503.2	503.6	504.5	505.5	506.4	507.4	508.3	509.2
17000.0	504.8	505.2	505.9	506.7	507.6	508.3	509.1	509.9
25000.0	506.8	507.1	507.7	508.4	508.9	509.5	510.1	510.8
26000.0	507.1	507.4	507.9	508.6	509.1	509.6	510.2	510.9
31800.0	508.6	508.8	509.4	509.8	510.1	510.6	511.1	511.6
37600.0	510.0	510.3	510.6	510.9	511.2	511.5	512.0	512.4
43400.0	511.4	511.5	511.7	511.9	512.2	512.4	512.8	513.2
49200.0	512.5	512.6	512.6	512.8	513.0	513.3	513.6	514.0
55000.0	513.4	513.5	513.6	513.8	514.0	514.2	514.5	514.8
60800.0	514.4	514.4	514.5	514.7	514.9	515.1	515.3	515.6
66600.0	515.3	515.3	515.4	515.6	515.8	515.9	516.1	516.4
72400.0	516.2	516.2	516.3	516.5	516.6	516.7	516.9	517.1
78200.0	517.0	517.1	517.1	517.3	517.4	517.5	517.7	517.9
84000.0	517.8	517.9	517.9	518.1	518.2	518.3	518.4	518.6
89800.0	518.6	518.7	518.7	518.8	519.0	519.1	519.2	519.3
95600.0	519.4	519.4	519.5	519.6	519.7	519.8	519.7	519.8
101400.0	519.9	520.0	520.0	520.1	520.2	520.3	520.4	520.5
107200.0	520.6	520.6	520.7	520.8	520.9	520.9	521.0	521.1
113000.0	521.3	521.3	521.4	521.4	521.5	521.6	521.6	521.8
118800.0	521.9	521.9	522.0	522.1	522.1	522.2	522.3	522.4
124600.0	522.5	522.6	522.6	522.7	522.7	522.8	522.9	522.9

Figure 55. Gadsden rating curve



Flow (cfs)	Stage (ft) For Lay-Pool (ft)																
	394.5	394.6	394.7	394.8	394.9	395.0	395.1	395.2	395.3	395.4	395.5	395.6	395.7	395.8	395.9	396.0	396.1
100.0	394.5	394.6	394.7	394.8	394.9	395.0	395.1	395.2	395.3	395.4	395.5	395.6	395.7	395.8	395.9	396.0	396.1
10000.0	394.8	394.9	395.0	395.1	395.2	395.3	395.4	395.5	395.6	395.7	395.8	395.9	396.0	396.1	396.2	396.3	396.3
20000.0	395.7	395.8	395.9	395.9	396.0	396.1	396.2	396.3	396.4	396.4	396.5	396.6	396.7	396.8	396.9	396.9	397.0
30000.0	396.9	397.0	397.0	397.1	397.2	397.2	397.3	397.4	397.4	397.5	397.6	397.6	397.7	397.8	397.8	397.9	398.0
40000.0	398.2	398.3	398.4	398.4	398.5	398.5	398.6	398.6	398.7	398.7	398.8	398.8	398.9	399.0	399.0	399.1	399.1
50000.0	399.6	399.7	399.7	399.7	399.8	399.8	399.9	399.9	400.0	400.0	400.1	400.1	400.2	400.2	400.2	400.3	400.3
60000.0	401.0	401.0	401.1	401.1	401.1	401.2	401.2	401.2	401.3	401.3	401.3	401.4	401.4	401.5	401.5	401.5	401.6
70000.0	402.3	402.4	402.4	402.4	402.4	402.5	402.5	402.5	402.6	402.6	402.6	402.7	402.7	402.7	402.8	402.8	402.8
80000.0	403.6	403.6	403.7	403.7	403.7	403.7	403.8	403.8	403.8	403.9	403.9	403.9	403.9	404.0	404.0	404.0	404.1
90000.0	404.9	404.9	404.9	404.9	404.9	405.0	405.0	405.0	405.0	405.1	405.1	405.1	405.1	405.2	405.2	405.2	405.2
100000.0	406.1	406.1	406.1	406.1	406.1	406.2	406.2	406.2	406.2	406.2	406.3	406.3	406.3	406.3	406.4	406.4	406.4
110000.0	407.2	407.3	407.3	407.3	407.3	407.3	407.3	407.4	407.4	407.4	407.4	407.4	407.4	407.5	407.5	407.5	407.5
120000.0	408.4	408.4	408.4	408.4	408.4	408.4	408.4	408.5	408.5	408.5	408.5	408.5	408.5	408.6	408.6	408.6	408.6
140000.0	410.5	410.5	410.5	410.5	410.6	410.6	410.6	410.6	410.6	410.6	410.6	410.6	410.7	410.7	410.7	410.7	410.7
160000.0	412.5	412.5	412.5	412.5	412.6	412.6	412.6	412.6	412.6	412.6	412.6	412.6	412.6	412.7	412.7	412.7	412.7
180000.0	414.4	414.4	414.4	414.4	414.4	414.4	414.4	414.4	414.4	414.4	414.4	414.5	414.5	414.5	414.5	414.5	414.5
200000.0	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.2	416.3	416.3	416.3	416.3
220000.0	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.8	417.9	417.9	417.9
240000.0	419.3	419.3	419.3	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4	419.4

Figure 56. Childersburg rating curve

H. Harris Operation

The updated operation at Harris includes operation for Wadley, a gage located roughly one routing day downstream. Figure 57 summarizes this operation. The *WadleyOps* state variable is used to implement this operation in the model. The state variable calculates the release from Harris based on three different situations. 1) Pool is at or above guide curve and less than 790, 2) pool is above guide curve and rising, 3) pool is above guide curve and falling. In the first situation Harris outflow equals the less of 13,000 cfs or an amount that will not cause the gage at Wadley to exceed 13 ft. In the second situation Harris outflow is 16,000 cfs or greater and in the third situation Harris outflow maintains the previous release.

The Operation at Wadley is applied with an If Block named *Ops for Wadley*, which is shown in Figure 58. The details of this operation are shown in Figure 59 to Figure 63.The *WadleyOps* state variable is described in **Appendix A.5**.

Figure 60 shows the *Operation For Wadley_13ft* rule. This rule calculates the amount of release based on available local flows at Wadley. The calculated release plus the available local flow will not cause the gage at Wadley to exceed 13 ft.

Rule	Condition	Harris Outflow	Operation
1	Below Power Guide Curve (PGC)		Operate power plant to satisfy system load requirements.
2	At or above PGC and below elev. 790.00	13,000 cfs or less depending on Wadley stage	Operate to discharge 13,000 cfs or an amount that will not cause the gage at Wadley to exceed 13.0 feet, unless greater discharge amounts are required by the Induced Surcharge Schedule. Discharge rates determined by the Harris real-time water control model may be substituted for those indicated by the Induced Surcharge Curves. If the model produces outflows in excess of those identified by the Induced Surcharge Schedule for six (6) consecutive periods, the operator shall notify the Water Management Section before making any further gate movements.
3	Above PGC and rising	16,000 cfs or greater	Discharge 16,000 cfs or greater if required by the Induced Surcharge Curves Releases may be made through the spillway gates or powerhouse or a combination of both. Discharge rates determined by the Harris real-time water control model may be substituted for those indicated by the Induced Surcharge Curves. If the model produces outflows in excess of those identified by the Induced Surcharge Schedule for six (6) consecutive periods, the operator shall notify the Water Management Section before making any further gate movements.
4	Above PGC and falling		When the reservoir begins to fall, maintain current gate settings and power- house discharge until the pool recedes to the PGC, then return to normal operation.

Figure 57. Harris Operation for Wadley (source: APC)

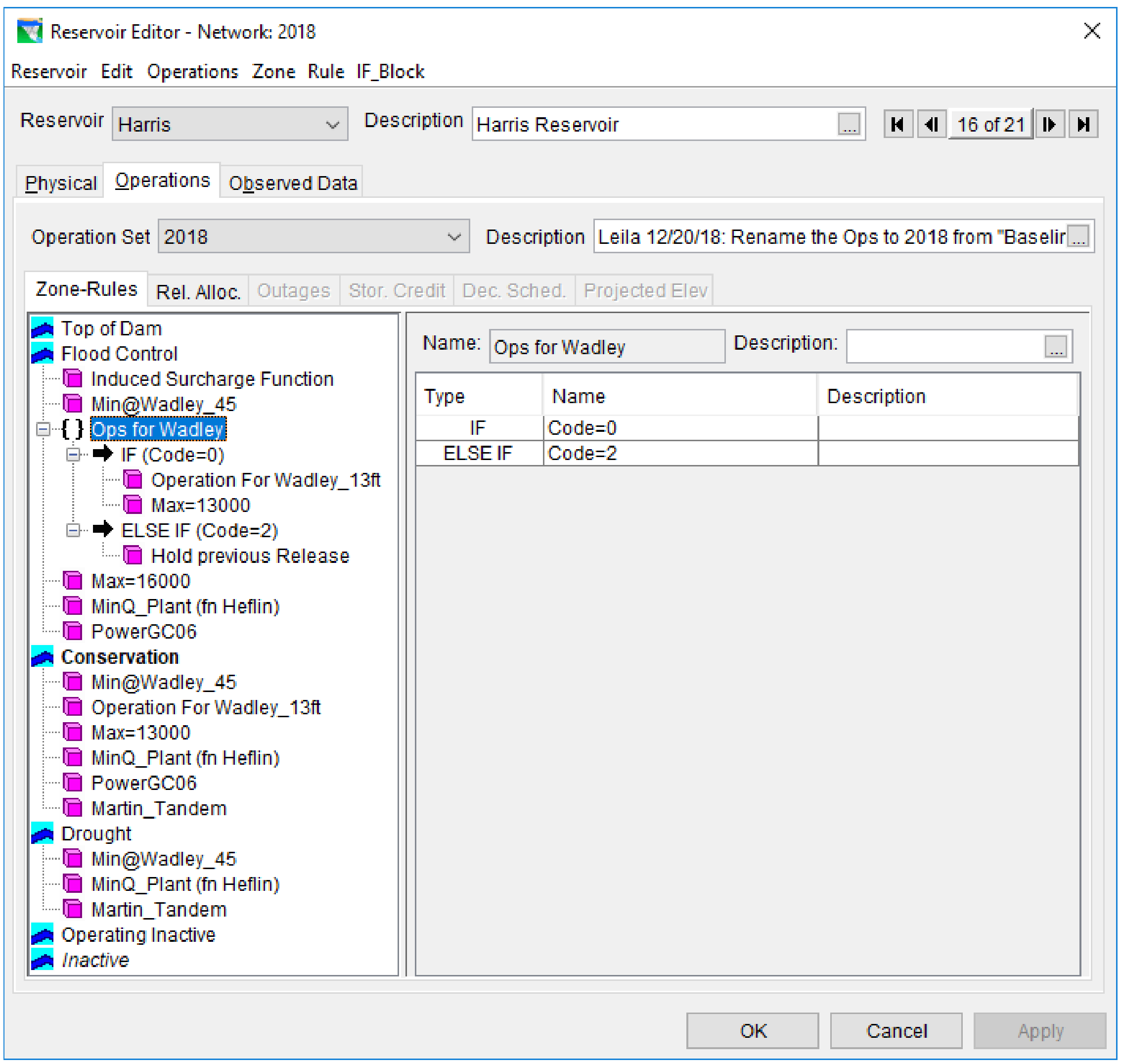


Figure 58. *Ops for Wadley* rule at Harris

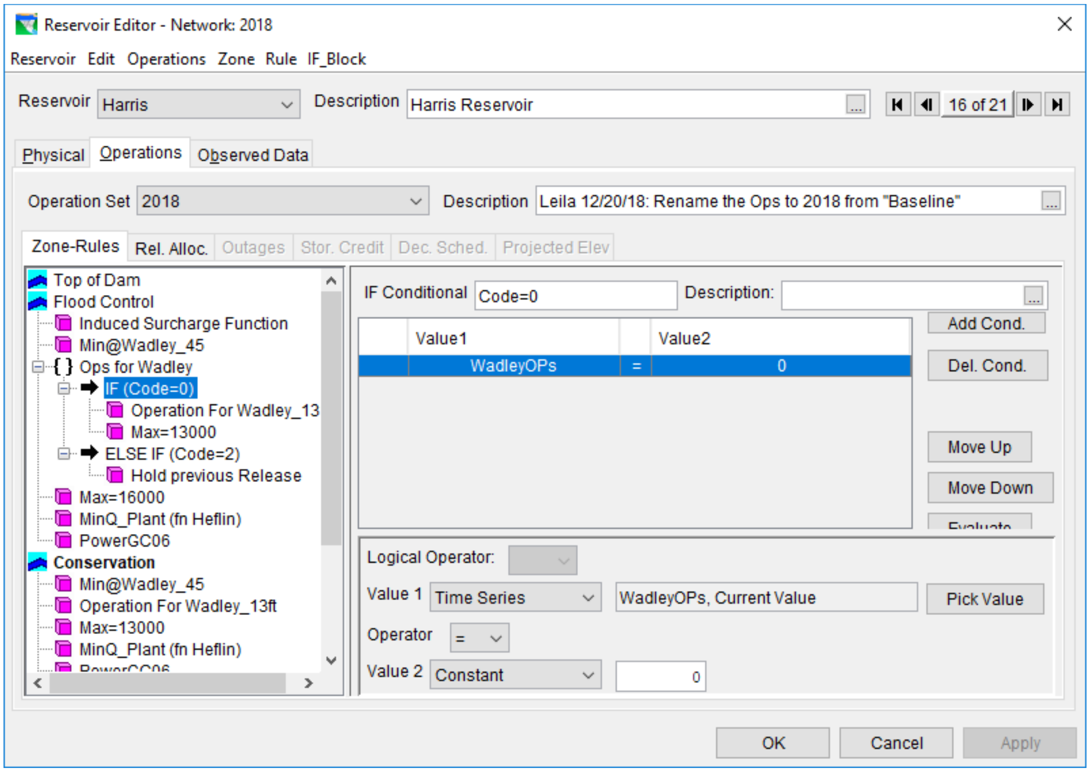


Figure 59. If *Code=0* condition at Harris

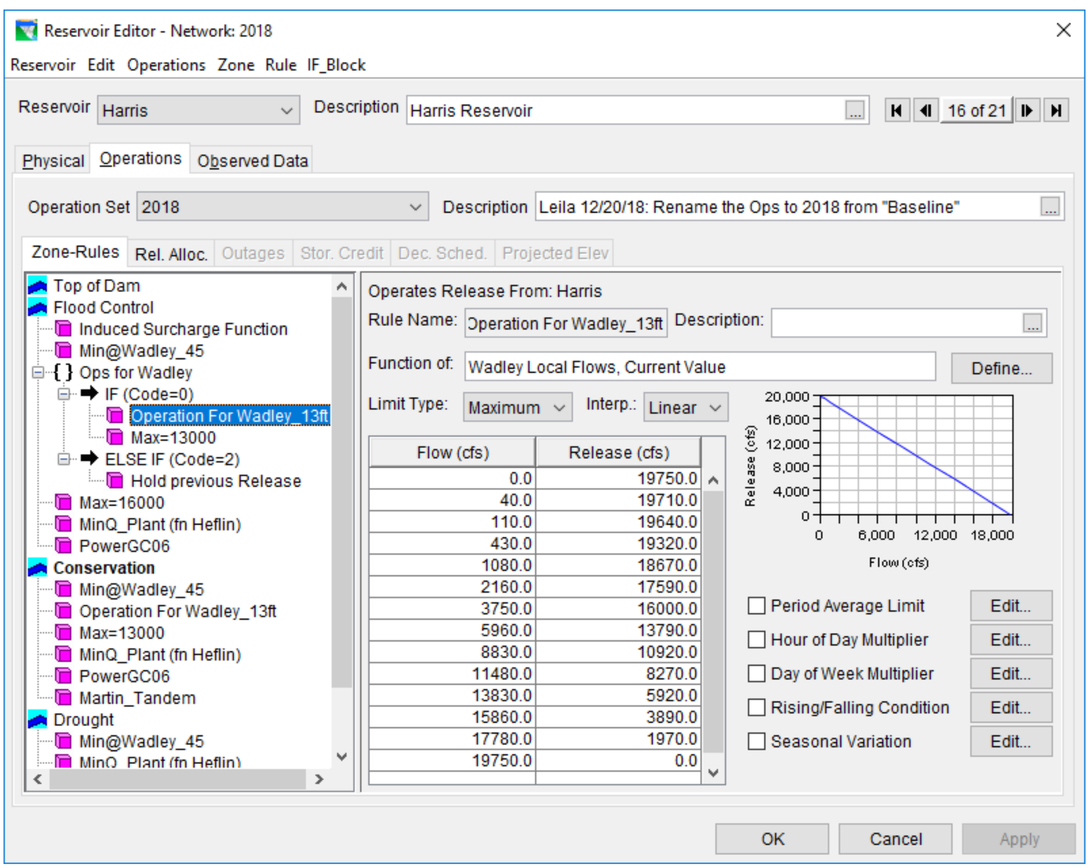


Figure 60. *Operation for wadley_13ft* rule at Harris

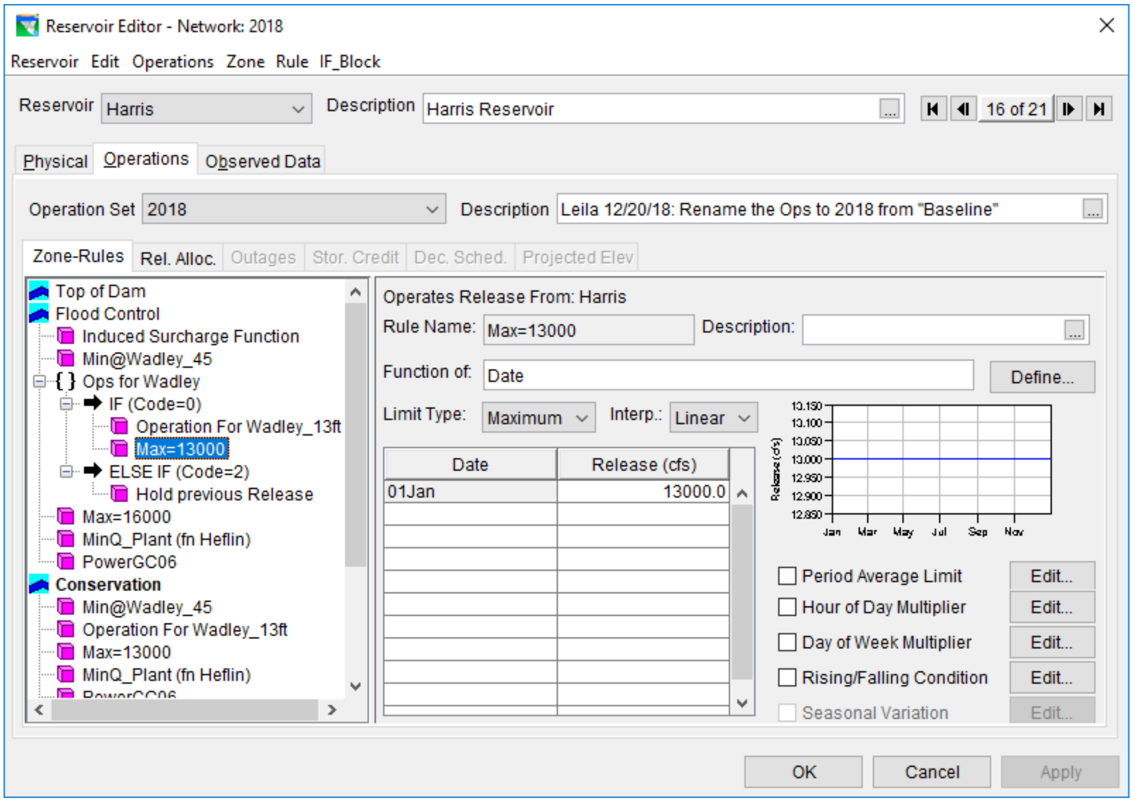


Figure 61. *Max=13000* rule at Harris

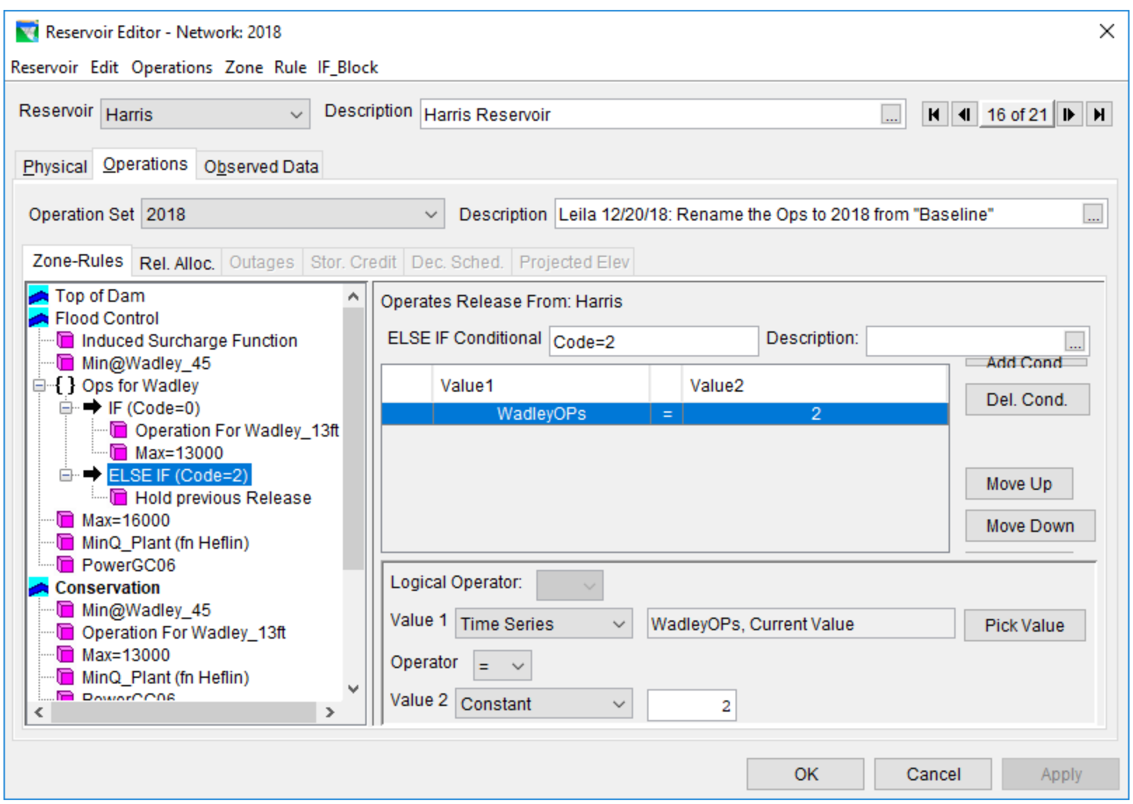


Figure 62. Else condition for *Ops for Wadley* rule at Harris

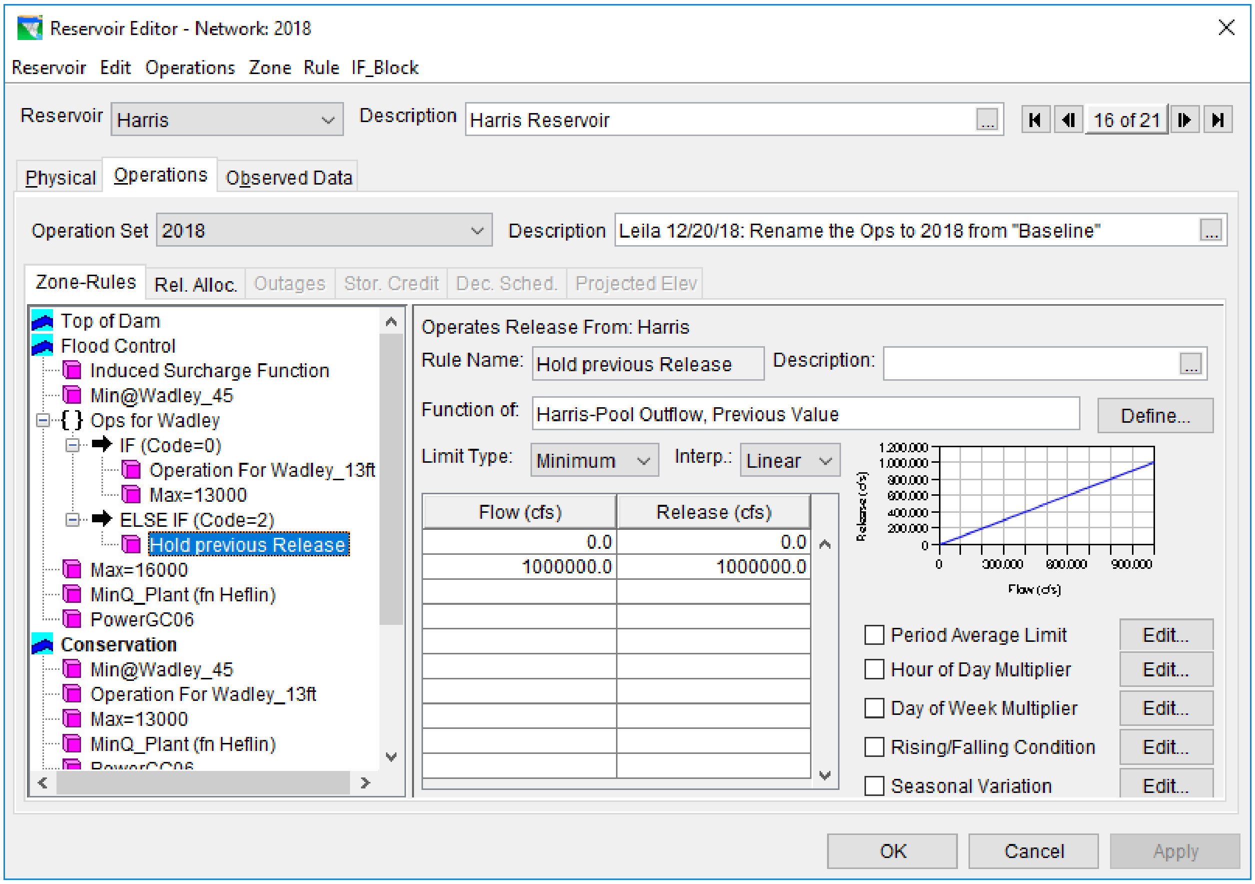


Figure 63. *Hold previous Release* rule at Harris

I. Lake Martin Guide Curve

The Lake Martin guide curve was modified in two aspects, based on the 2015 Federal Energy Regulation Committee (FERC) relicensing.

1. Increasing Winter Conservation Pool
2. Conditional Fall Extension

The details of these changes are described below.

1. Increasing Winter Conservation Pool

To enhance recreation, Alabama Power Company (APC) proposed to raise the winter guide curve for Lake Martin by 3 feet to elevation 483 ft from the third week of November to February 28. The new guide curve at Lake Martin[1] with the proposed winter pool increase is shown in Table 5.

[1] Note that the guide curve elevations are listed in Martin Datum for Martin, Yates and Thurlow. Add one (1) foot to convert from Martin Datum to NGVD29.

Table 5. APC's Proposed Guide Curve at Lake Martin

Conservation	
Date	**Elev**
1/1/2018	483
2/28/2018	483
4/1/2018	488.05
4/28/2018	490
9/2/2018	490
10/1/2018	487.99
11/1/2018	485.6
11/24/2018	483
12/31/2018	483

2. Conditional Fall Extension

To enhance late-summer and fall recreation opportunities at Lake Martin, APC proposed a modification of the flood control curve from September 1 through October 15 (Conditional Fall Extension). Under APC's proposal, the flood control curve would be maintained at 490 feet from September 1 to October 15, provided certain hydrologic and operational conditions are met. Thereafter, the flood control curve would gradually decline until it reaches elevation 483 feet by the third week in November. APC would only implement the fall extension if the following four conditions are met:

a. Lake Martin is above its operating curve during September (varies from 486 to 487.5 feet).

b. The rolling 7-day average total basin inflow on the Tallapoosa River, calculated at Thurlow Dam, is at or higher than the median historical flow.

c. The rolling 7-day average total basin inflow on the Coosa River, calculated at Jordan Dam, is at or higher than the median historical flow.

d. The elevations at the Weiss, HN Henry, and Logan Martin (developments of Project No. 2146) on the Coosa River, and the Harris Project on the Tallapoosa River, are within one foot of their respective operating curves.

In order to model this operation, an updated guide curve was developed for Lake Martin as a function of a state variable, ***Martin_GC***, and applied to the ***2018*** operation set (Figure 64). The state variable considers the four conditions to determine whether the normal guide curve or fall extension should be active, and thus calculates the appropriate elevation. The modeled top of the fall extended guide curve is 489.5 ft instead of 490 ft, which allows a buffer between the top of the guide curve and the top of flood zones. The *Martin_GC* state variable with the proposed guide curve at Lake Martin and the fall enhancement operation is described in **Appendix A**.

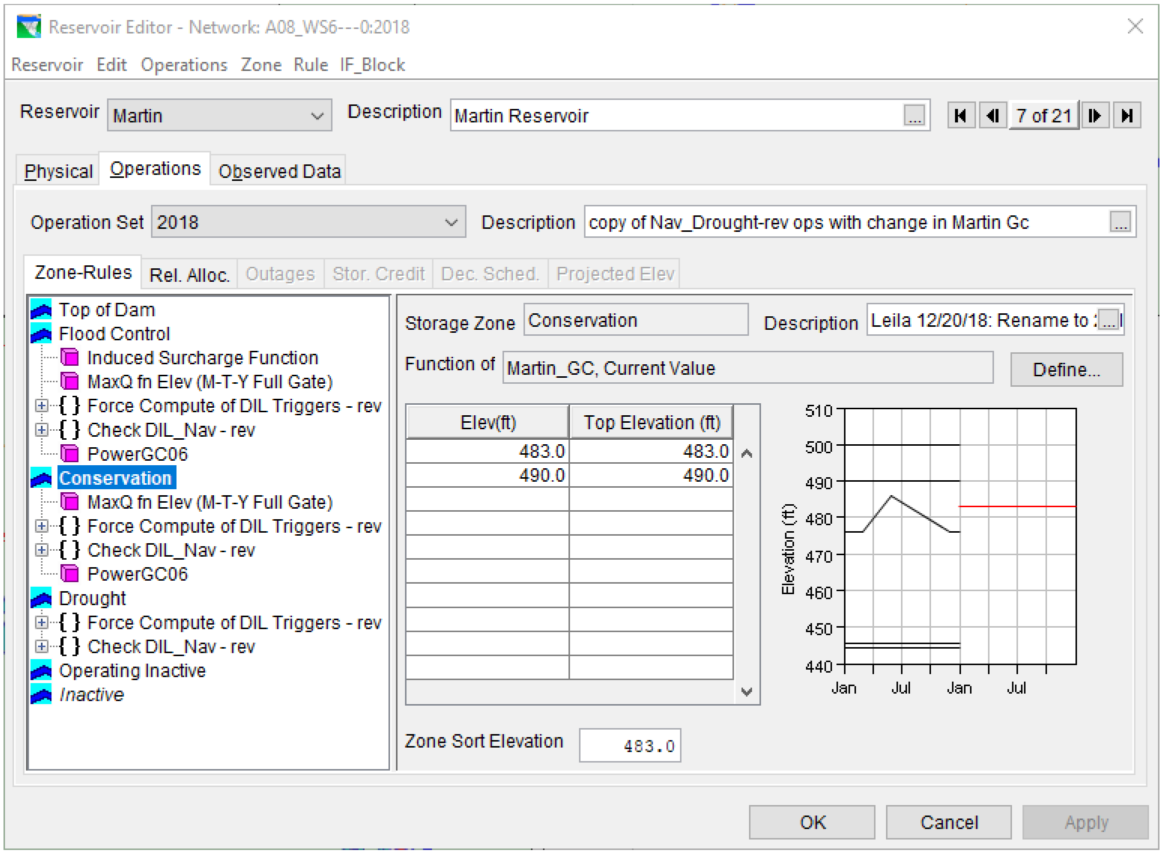


Figure 64. New Lake Martin Guide Curve

The new Lake Martin guide curve for the ***Base2018*** alternative is shown for the full POR in Figure 65. Figure 66 shows an example year (1957) where all four conditions for the fall extension are met on 30 September, which brings the guide curve back up to 489.5 ft (0.5 ft buffer zone) and maintains it at this elevation to October 15. The guide curve then declines until it reaches elevation 483 ft by the third week in November.

Figure 68 also shows the year 1958 with the normal guide curve, which starts to decline on 1 September and continues until it reaches elevation 483 ft by the third week of November.

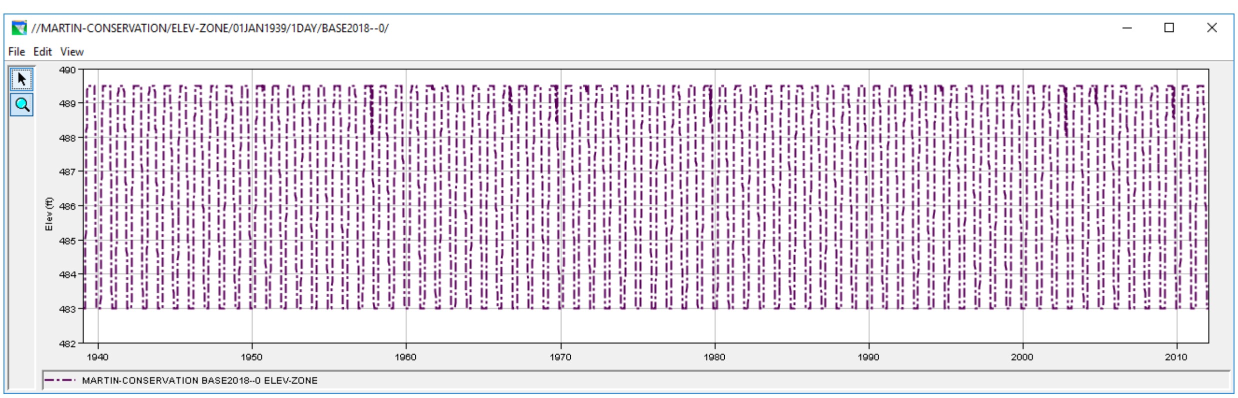


Figure 65. Martin Guide Curve for Base2018 Alternative

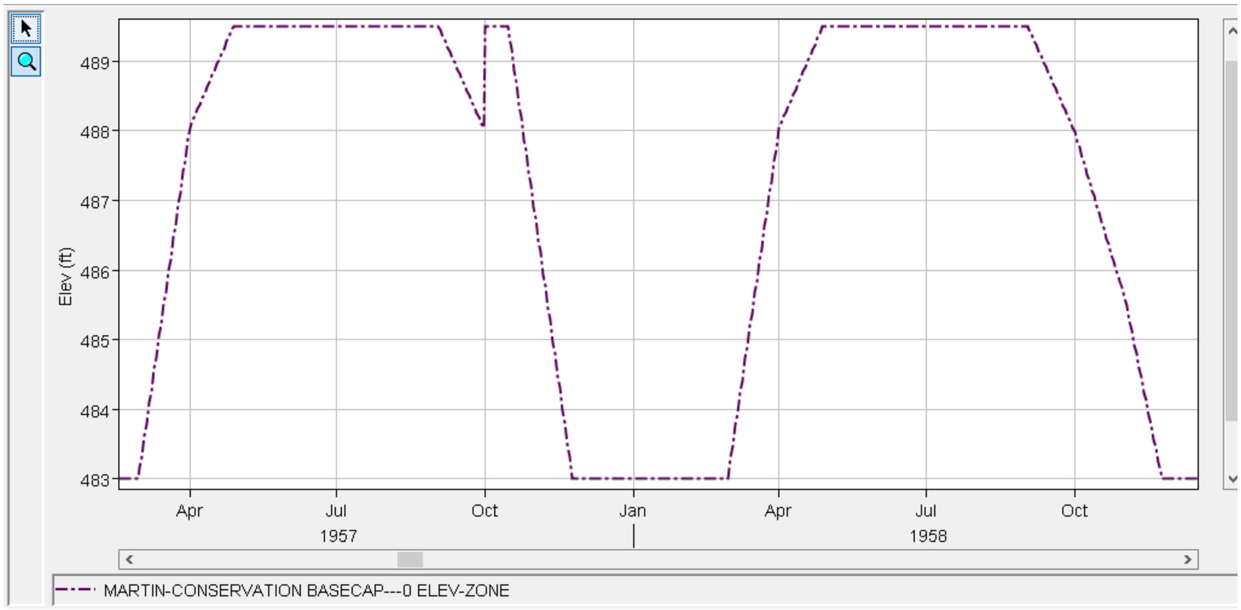
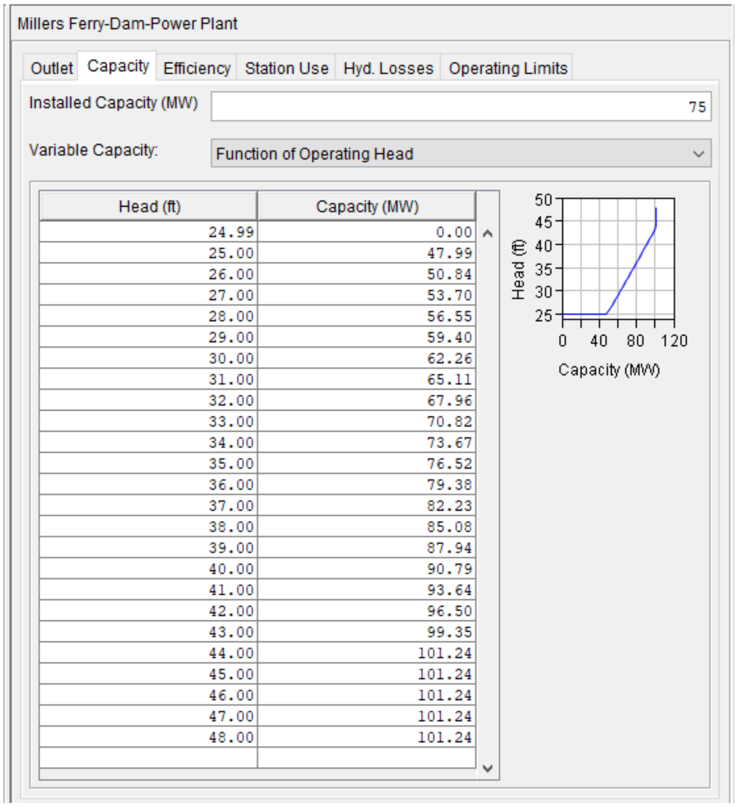


Figure 66. *Base2018* Martin Revised Guide Curve for 1957

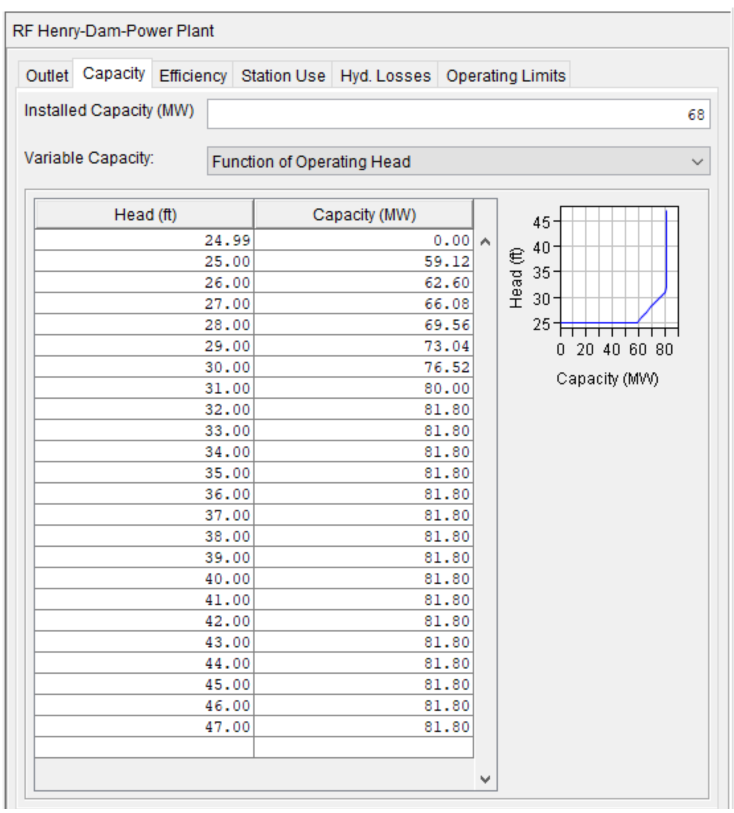
J. Millers Ferry and RF Henry Power Capacity

Operators at RF Henry and Millers Ferry do not generate power below 25 feet of head to avoid damaging equipment. So, the model was revised at RF Henry and Millers Ferry to reflect zero capacity below a head of 25 feet. Figure 67 and Figure 68 show the revised power plant capacity at Millers Ferry and RF Henry respectively. In order to ensure that the power plants are not used below their lowest efficiency, operating limits were added to the power plants for these reservoirs. An additional adjustment was made to show that the power plant should not be used below the efficiency related to a head of 25 feet. As shown in Figure 69 and Figure 71, the efficiency related to 25 ft is 64.14% for Millers Ferry and 79.85% for RF Henry. Figure 70 shows the operating limit of 64.14% for Millers Ferry. The power efficiency curve at RF Henry increases up to 86.38% at a head of 32 feet, but then it begins to decline. Its lowest operating efficiency is at 72.72% at 47 feet, which is reflected in the operating limit shown in Figure 72. Figure 73 shows an example of how the power plant operation works with respect to head for Millers Ferry. Figure 74 shows an example of the same for RF Henry.



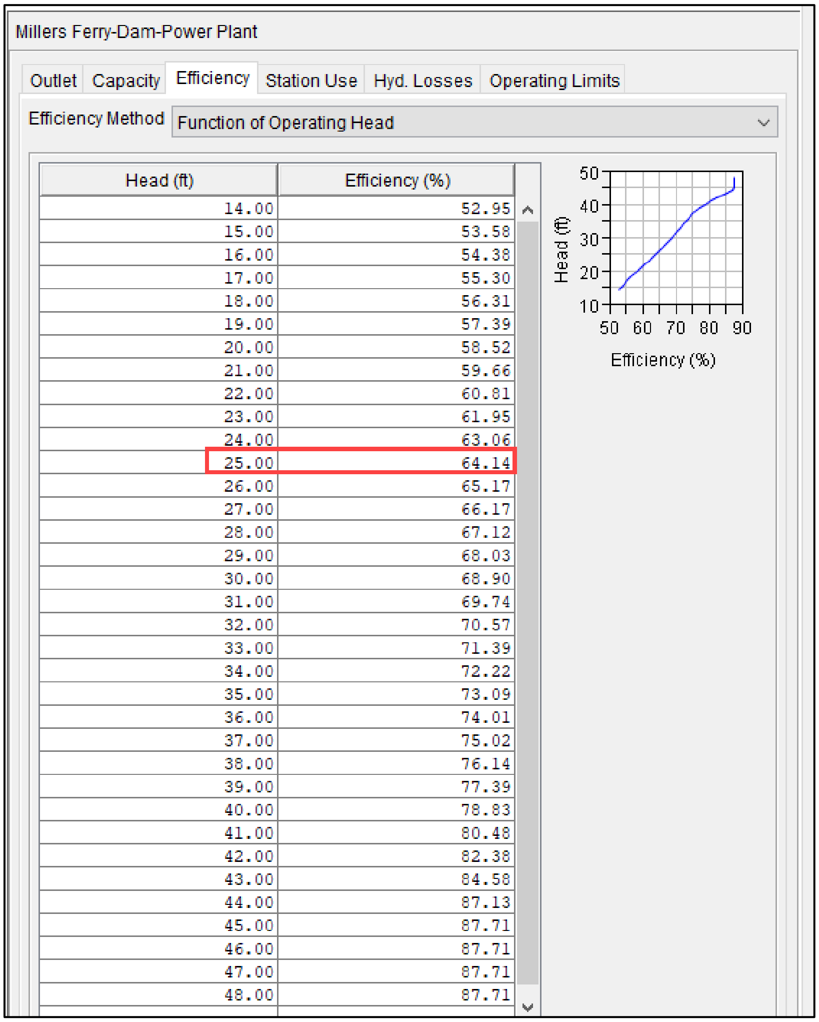
Head (ft)	Capacity (MW)
24.99	0.00
25.00	47.99
26.00	50.84
27.00	53.70
28.00	56.55
29.00	59.40
30.00	62.26
31.00	65.11
32.00	67.96
33.00	70.82
34.00	73.67
35.00	76.52
36.00	79.38
37.00	82.23
38.00	85.08
39.00	87.94
40.00	90.79
41.00	93.64
42.00	96.50
43.00	99.35
44.00	101.24
45.00	101.24
46.00	101.24
47.00	101.24
48.00	101.24

Figure 67. Power Plant Capacity at Millers Ferry



Head (ft)	Capacity (MW)
24.99	0.00
25.00	59.12
26.00	62.60
27.00	66.08
28.00	69.56
29.00	73.04
30.00	76.52
31.00	80.00
32.00	81.80
33.00	81.80
34.00	81.80
35.00	81.80
36.00	81.80
37.00	81.80
38.00	81.80
39.00	81.80
40.00	81.80
41.00	81.80
42.00	81.80
43.00	81.80
44.00	81.80
45.00	81.80
46.00	81.80
47.00	81.80

Figure 68. Power Plant Capacity at RF Henry



Head (ft)	Efficiency (%)
14.00	52.95
15.00	53.58
16.00	54.38
17.00	55.30
18.00	56.31
19.00	57.39
20.00	58.52
21.00	59.66
22.00	60.81
23.00	61.95
24.00	63.06
25.00	64.14
26.00	65.17
27.00	66.17
28.00	67.12
29.00	68.03
30.00	68.90
31.00	69.74
32.00	70.57
33.00	71.39
34.00	72.22
35.00	73.09
36.00	74.01
37.00	75.02
38.00	76.14
39.00	77.39
40.00	78.83
41.00	80.48
42.00	82.38
43.00	84.58
44.00	87.13
45.00	87.71
46.00	87.71
47.00	87.71
48.00	87.71

Figure 69. Power Plant Efficiency at Millers Ferry

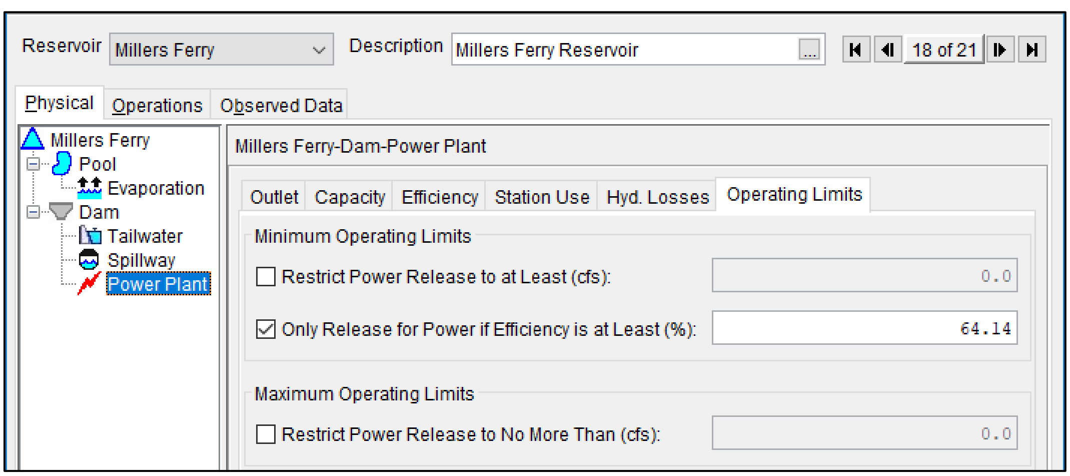
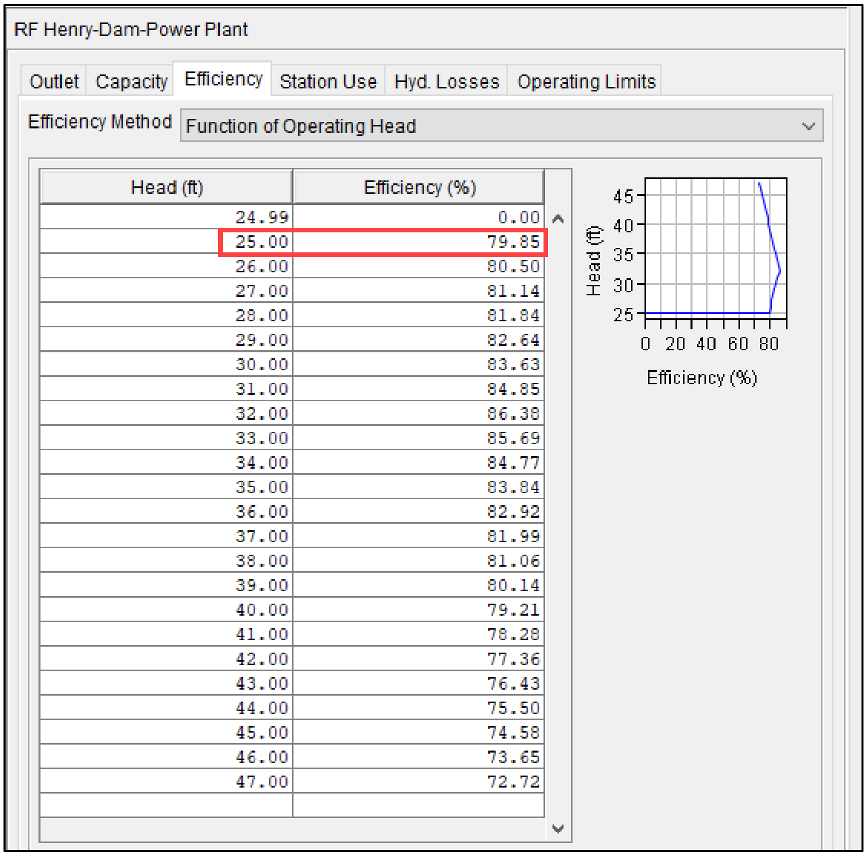


Figure 70. Power Plant Operating limits at Millers Ferry



Head (ft)	Efficiency (%)
24.99	0.00
25.00	79.85
26.00	80.50
27.00	81.14
28.00	81.84
29.00	82.64
30.00	83.63
31.00	84.85
32.00	86.38
33.00	85.69
34.00	84.77
35.00	83.84
36.00	82.92
37.00	81.99
38.00	81.06
39.00	80.14
40.00	79.21
41.00	78.28
42.00	77.36
43.00	76.43
44.00	75.50
45.00	74.58
46.00	73.65
47.00	72.72

Figure 71. Power Plant Efficiency at RF Henry

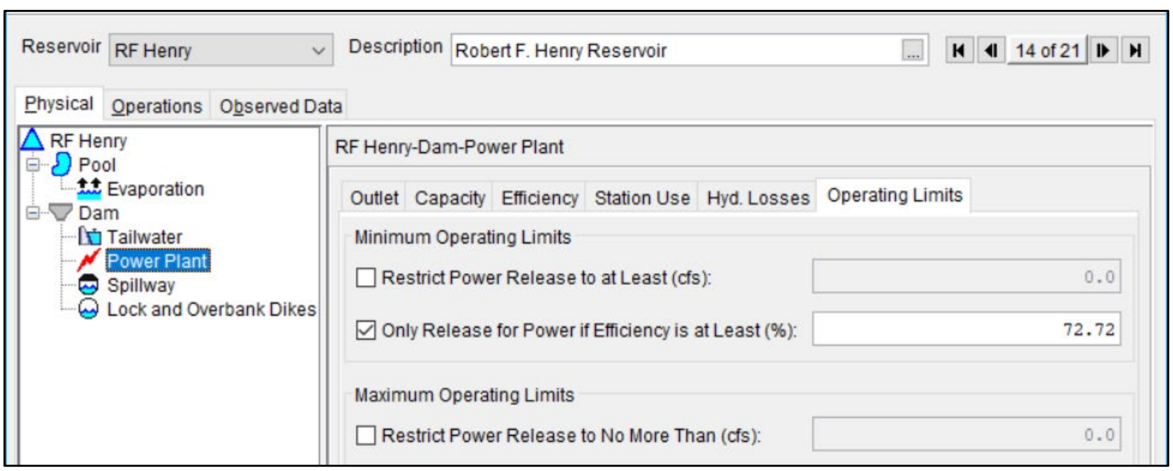


Figure 72. Power Plant Operating limits at RF Henry

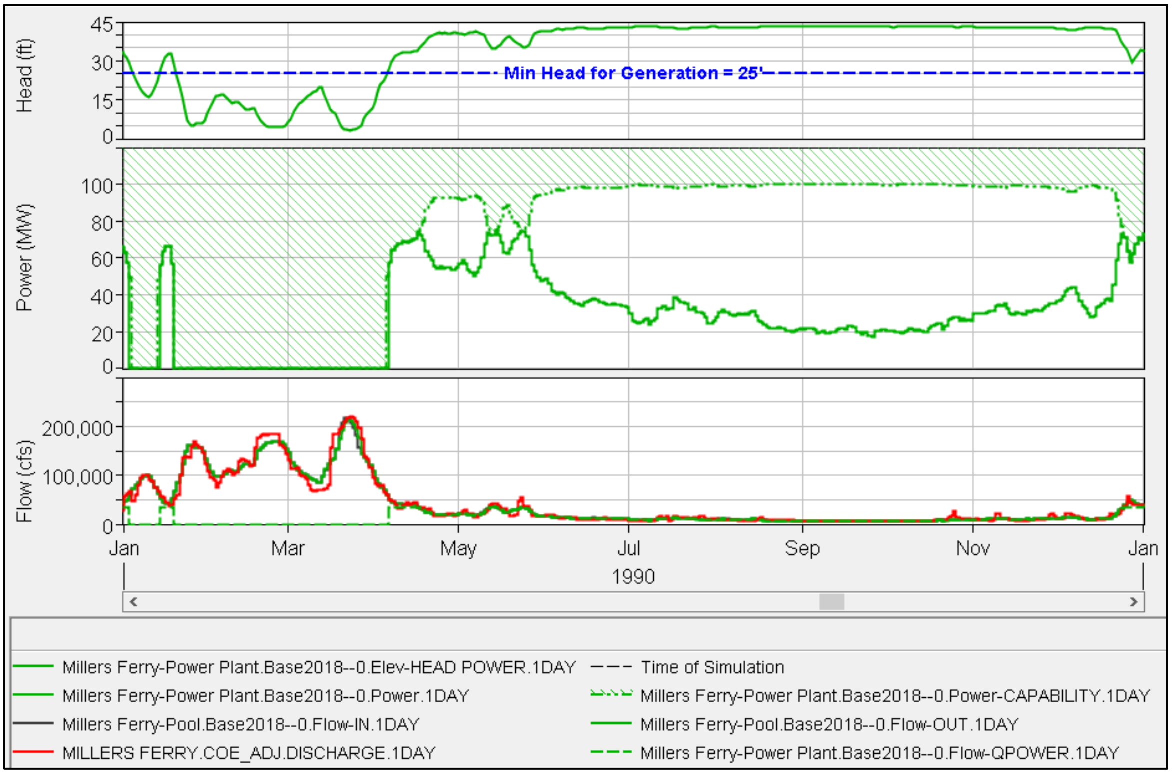


Figure 73. Millers Ferry power generation with respect to head

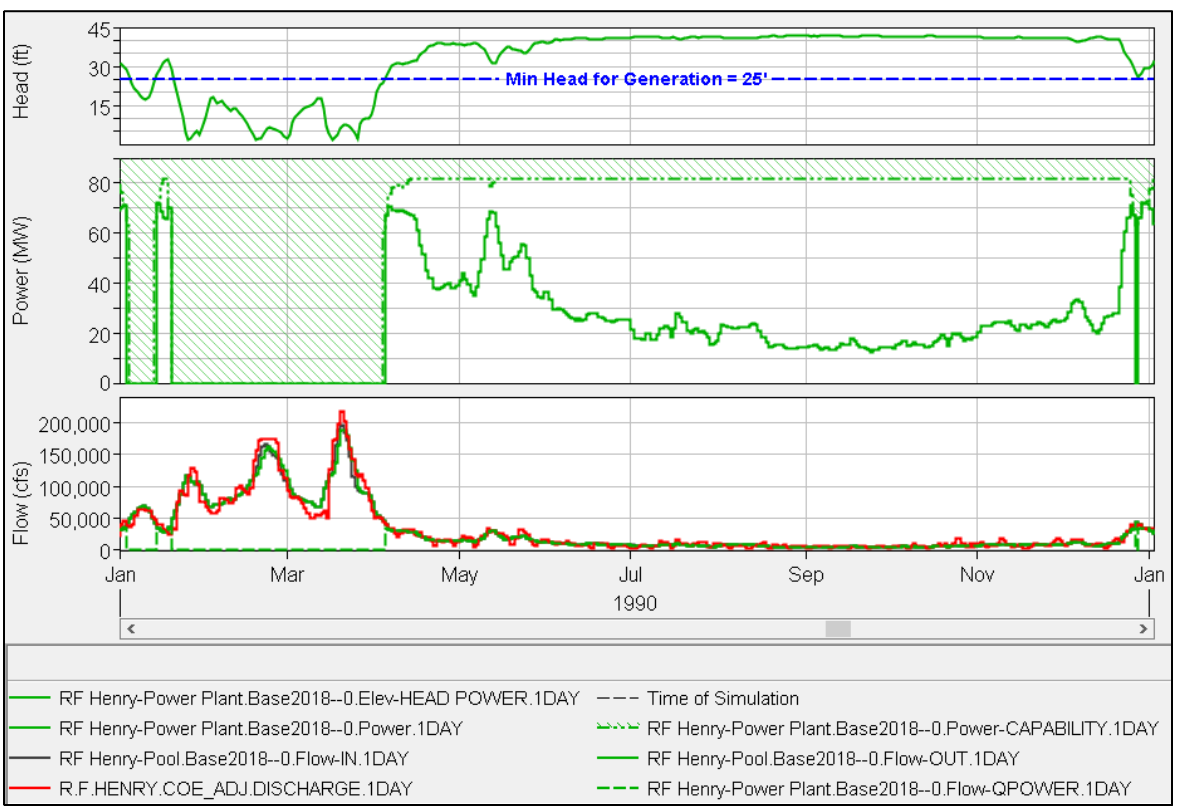


Figure 74. RF Henry power generation with respect to head

K. Basin Inflow Drought Trigger

Basin Inflow is one of the indicators used to trigger drought operations and is the total local flows (minus evaporation and diversions) above the APC projects excluding Allatoona Lake and Carters Lake.

The needed Basin Inflow is defined as the volume of water required to fill the pools to the top of the conservation guide curve plus 4,640 cfs needed for downstream navigation. The basin inflow value is computed daily and checked on the first and third Tuesday of the month. If computed basin inflow is less than the value required, the low basin inflow indicator is triggered.

The ACT Drought Response Operations Proposal (ADROP) table is used to calculate the total basin inflow needed to avoid triggering drought operations. Due to adjusted guide curves, this table has been updated since the 2013 model. The updated data is shown below in Table 6.

Table 6. Updated ADROP table for baseline operations

Month	Coosa Filling Volume	Tallapoosa Filling Volume	Total Filling Volume	Navigation	*Total Basin Inflow Needed	
January	628	0	628	4640	5268	Current ADROP table
February	626	120	747	4640	5387	
March	603	2900	3503	4640	8143	
April	1683	2585	4269	4640	8909	
May	248	0	248	4640	4888	
June	0	0	0	4640	4640	
July	0	0	0	4640	4640	
August	0	0	0	4640	4640	
September	-612	-1304	-1916	4640	2724	
October	-1371	-2132	-3503	4640	1137	
November	-920	-2186	-3106	4640	1534	
December	-821	0	-821	4640	3819	

L. Other Model Updates

Observed data at Rome-Coosa was added to the model. Figure 75 shows the check box for Rome-Coosa observed data and Figure 76 shows the time series at Rome-Coosa location.

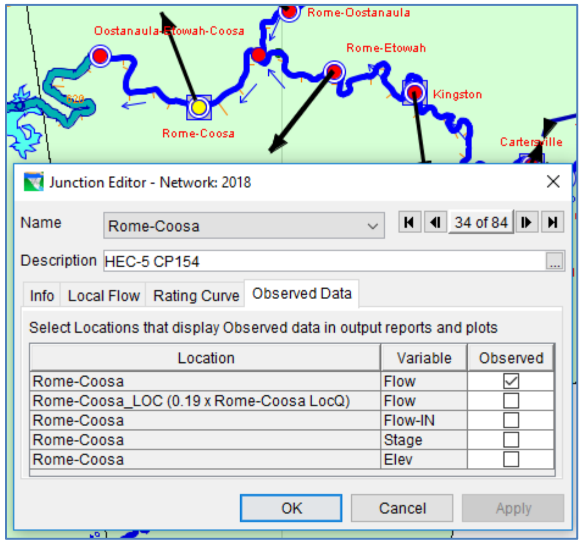


Figure 75. Rome-Coosa observed check box

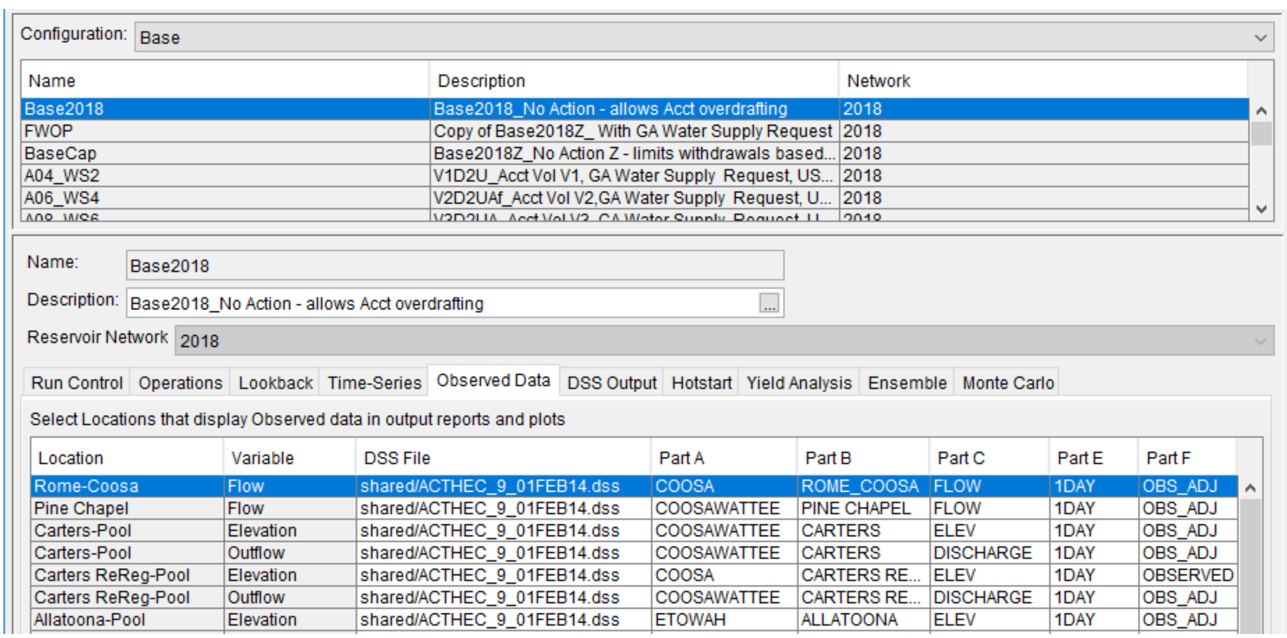


Figure 76. Alternative Editor showing Rome-Coosa observed time series

III. Alabama Power Company (APC) Updates

The model updates proposed by APC are described in this section of the document. Here is the list of updates:

- Weiss Operation
- Logan Martin Operation
- Lay Operation
- Adjustment to the Basin Inflow drought trigger

The details of the changes are described in the below sections.

A. Weiss Operation

The proposed changes by APC at Weiss are increasing the winter conservation pool, a new induced surcharge curve, and a surcharge cut back rule, which are described below.

1. Increasing Winter Conservation Pool

APC proposed a new guide curve at Weiss with a higher winter conservation pool. The guide curve is shown in Figure **77**. The baseline guide curve and the proposed guide curve at Weiss are compared in Figure 78.

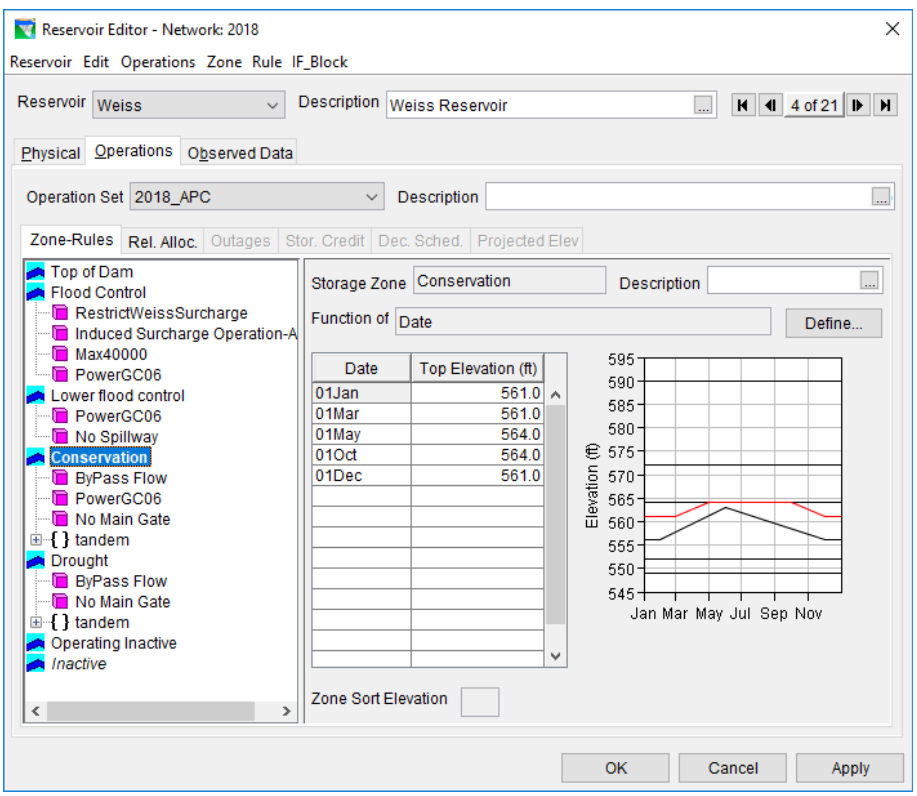


Figure 77. New Guide Curve at Weiss Proposed by APC

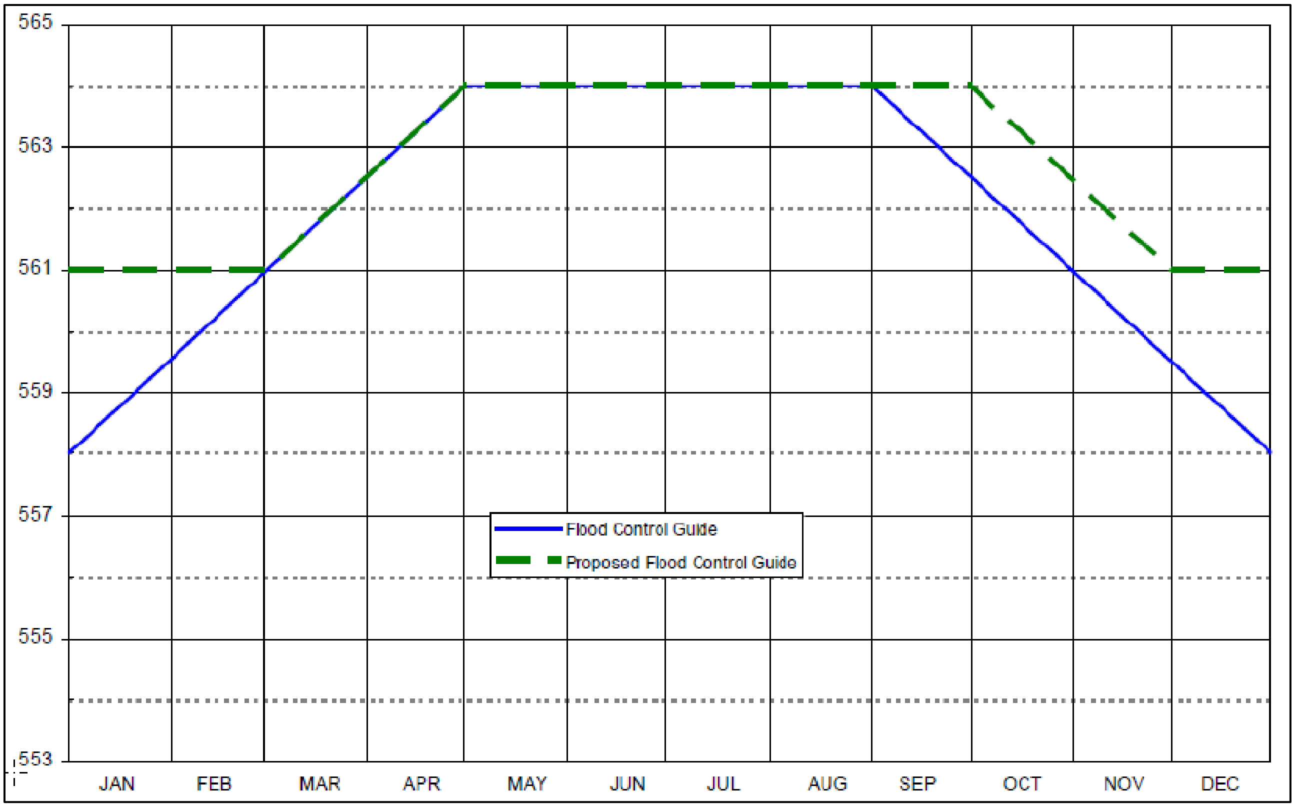


Figure 78. Weiss Baseline and new Guide Curve Proposed by APC

2. Induced Surcharge Curve

An updated induced surcharge operation at Weiss is proposed by APC. The ***Induced Surcharge Operation_APC*** rule is shown in Figure 79. The operation is specified by defining the ESRD curves. The **Falling Pool Transition Elev** shown in Figure 80 is 564 ft for Weiss. This is the pool elevation below which the induced surcharge rule will no longer operate. The **Release Options** are to designate the method for computing falling pool releases. For Weiss, the option of **Maintain Peak Gate Openings** is selected, as shown in Figure 80. The ESRD curves for the ***Induced Surcharge Operation_APC*** rule are shown in more detail in Figure 81.

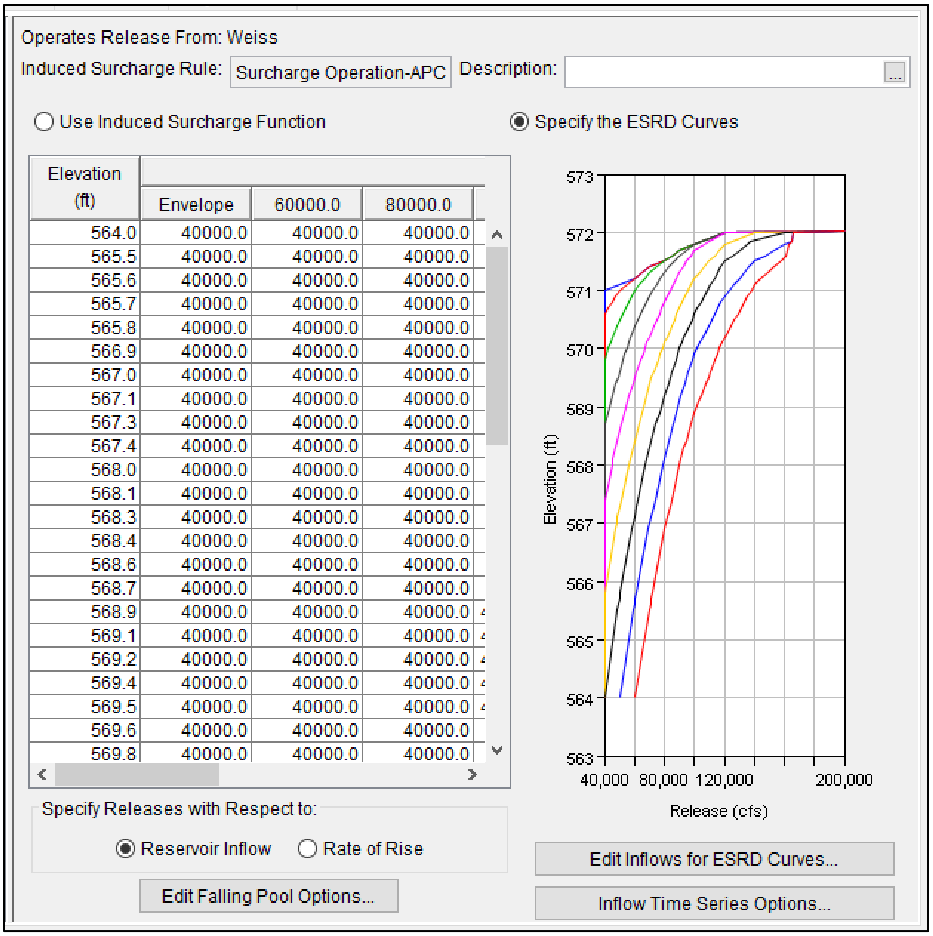


Figure 79. *Induced Surcharge Operation-APC* rule at Weiss

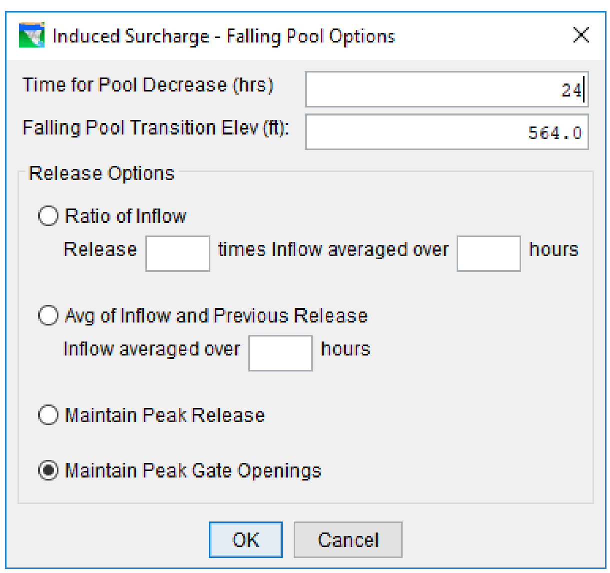


Figure 80. Induced Surcharge-Falling Pool Options at Weiss

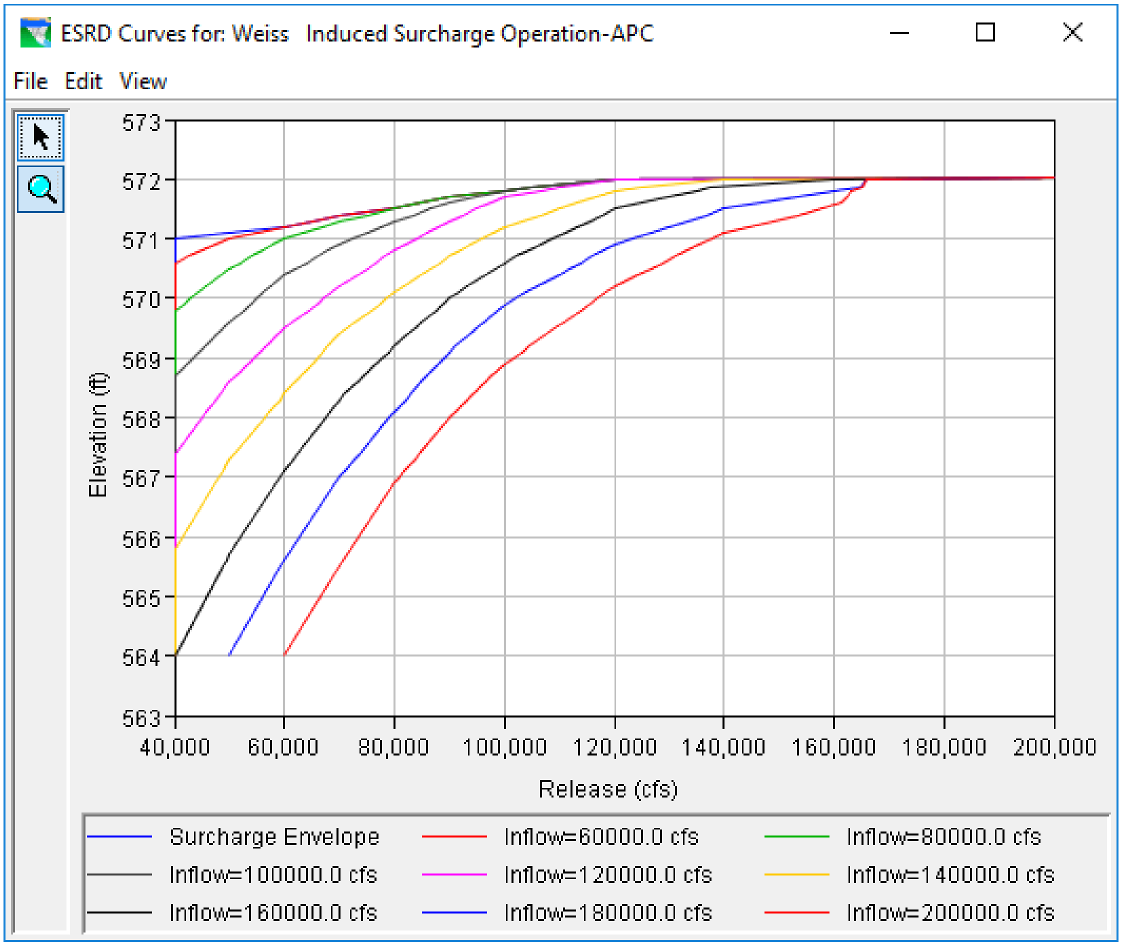


Figure 81. ESRD curves for: Weiss Induced Surcharge Operation-APC rule

3. Weiss Surcharge Cutback Rule

The APC proposed operation at Weiss includes a cutback to the surcharge releases to minimize impacts downstream of the dam. The ***RestrictWeissSurcharge*** scripted rule limits surcharge releases when the stage at Gadsden is rising over the 512 foot easement, which can occur due to a combination of discharges from Weiss and local inflow. When the rating curve at Gadsden indicates that a combination of local inflow and surcharge values from Weiss will cause the stage at Gadsden to rise over the 512 ft elevation, surcharge releases can be cut up to 50% to provide time for the local inflows to recede. The total volume of the cutback cannot exceed a volume of 22,500 cfs-days per event. The total cutback volume does not have to be used consecutively but can be implemented as multiple cutback periods during an event. Once this volume has been utilized, the project will return to the normal surcharge release schedule. The ***RestrictWeissSurcharge*** rule is shown in Figure 82 and the script is described in **Appendix A.**

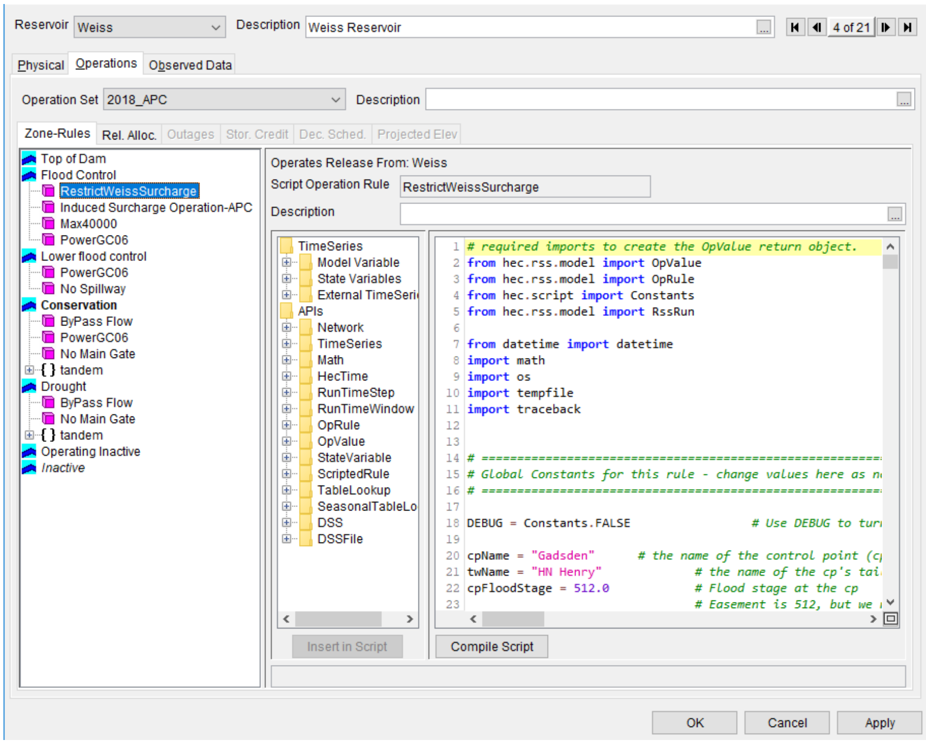


Figure 82. *RestrictWeissSurcharge* rule at Weiss

4. Flood Control Zone

APC proposed to reduce the Flood control zone from 574 ft to 572 ft as shown in Figure 83.

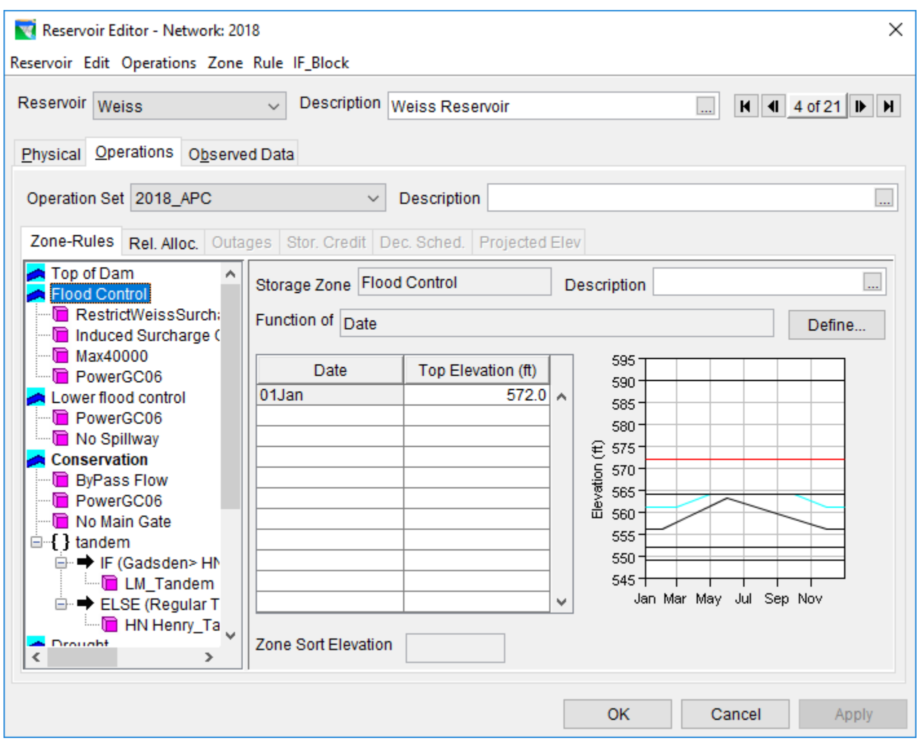


Figure 83. Flood Control Zone in 2018_APC operation set

B. Logan Martin Operation

A new operation set called ***2018_APC*** was created at Logan Martin to reflect APC proposed changes. The APC proposed changes at Logan Martin are raising the winter conservation pool, a new induced surcharge curve, and a surcharge cut back rule. Each of these changes are described below.

1. Raising the Winter Conservation Pool

APC proposed a new guide curve at Logan Martin with a higher winter conservation pool. The guide curve is shown in the Reservoir Editor in Figure 84. The baseline guide curve and the proposed guide curve at Logan Martin are compared in Figure 85.

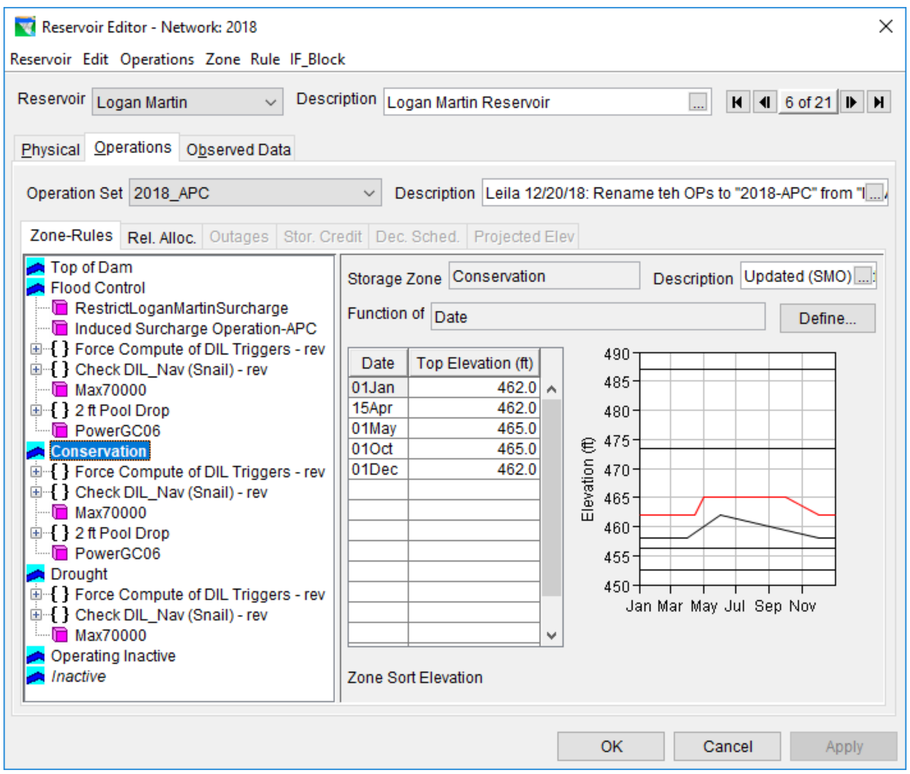


Figure 84. APC proposed Guide Curve at Logan Martin

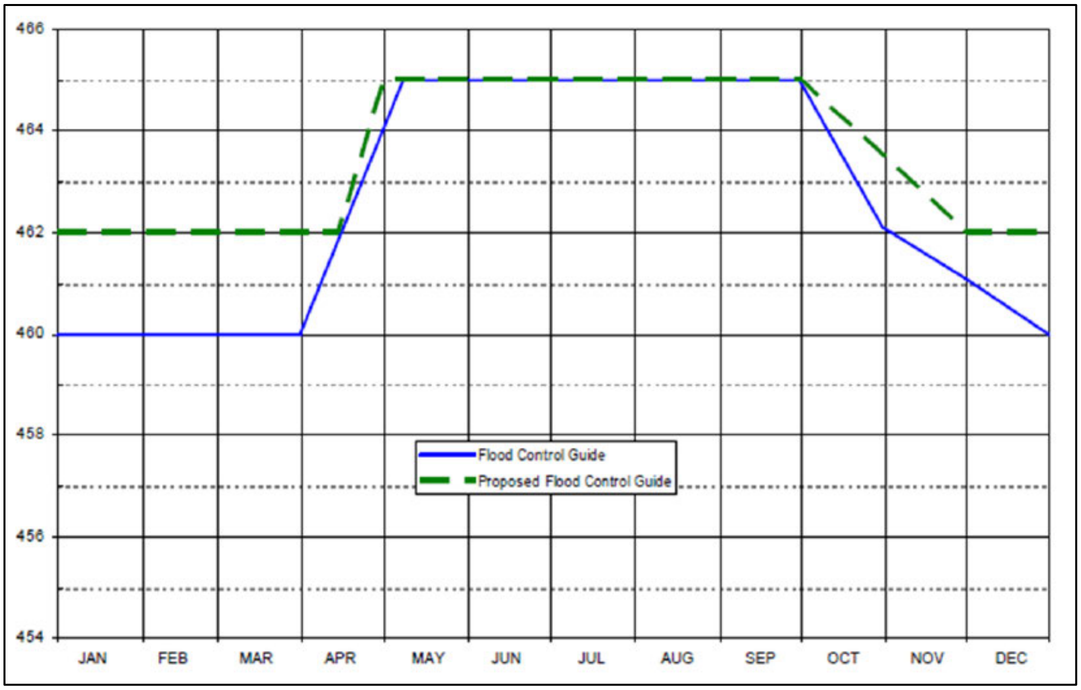


Figure 85. Baseline and new Guide Curve Proposed by APC at Weiss

2. Two Foot Pool Draw Down

APC proposed a modification of operations to coordinate flood operations with the raised guide curve. When conditions at the Logan Martin and Weiss reservoirs are in or approaching flood control triggers, Logan Martin returns to the previous winter conservation pool elevation (460 ft) from its new winter conservation pool elevation of 462 ft. This operation can be seen in the sample results shown in Figure 86.

The required conditions for this draw down operation are as follows:

1. Logan Martin is at the new winter conservation pool elevation of 462 ft.
2. Weiss is at summer pool elevation of 564 ft.
3. Logan Martin inflows are rising above plant capacity (32,989 cfs).
4. Weiss inflows are rising above plant capacity (26,021 cfs).

When all four of the triggers are met, Logan Martin will begin discharging up to the maximum flow of 70,000 cfs to draw the pool elevation down to 460 ft. Once at that elevation, it will attempt to release inflow in order to remain at that elevation until either, (a) inflows rise above 70,000 cfs, preventing it from remaining at 460 ft, or (b) the inflows drop below plant capacity. This operation is modeled using an IF_Block, *2 ft Pool Drop*, as shown in Figures 87 - 91. The *Pass Inflow+12616* rule is designed to release enough volume to draw the pool down by two feet: 12,616 cfs over the course of the daily timestep is equivalent to the pool volume between 460 and 462 ft. The details of the *2 ft Pool Drops* are shown in Figure 87 to Figure 91.

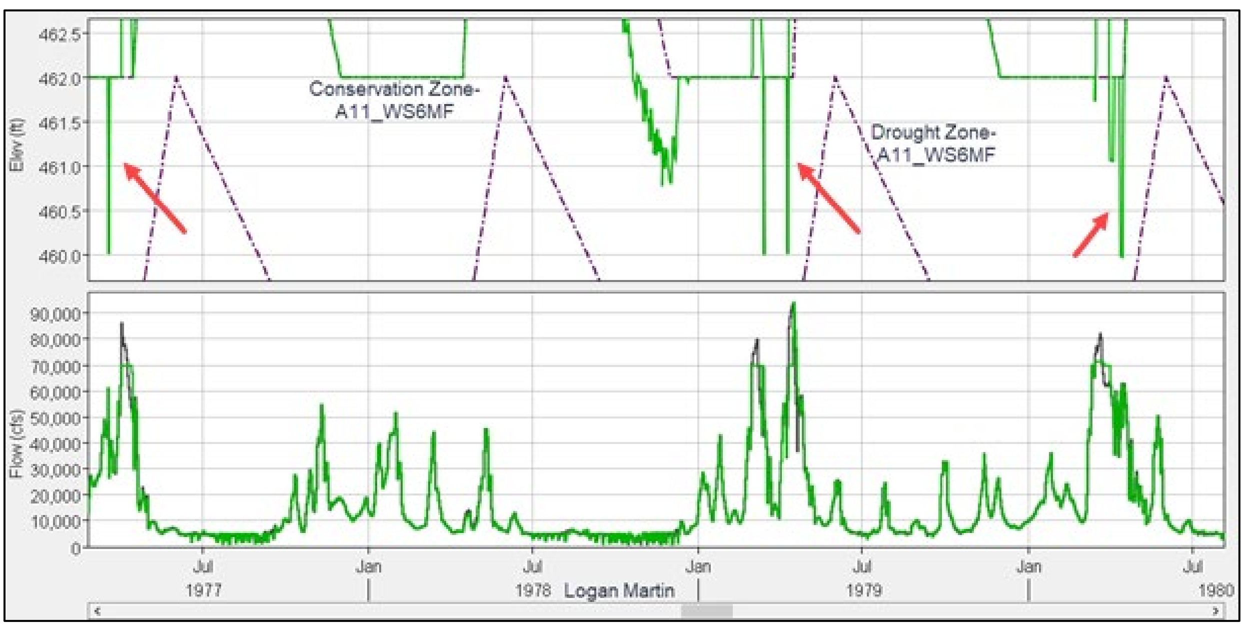


Figure 86. Logan Martin APC proposed operation showing two foot draw down during flood conditions

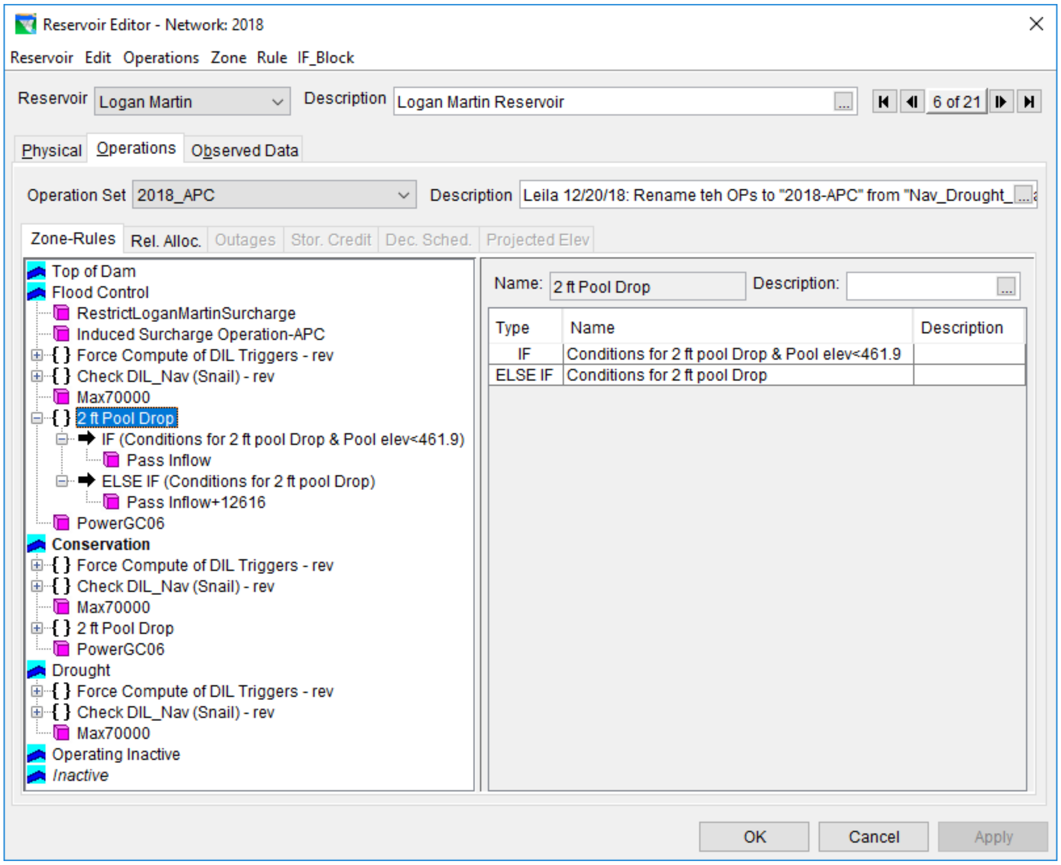


Figure 87. ***2 ft Pool Drop*** **rule at Logan Martin**

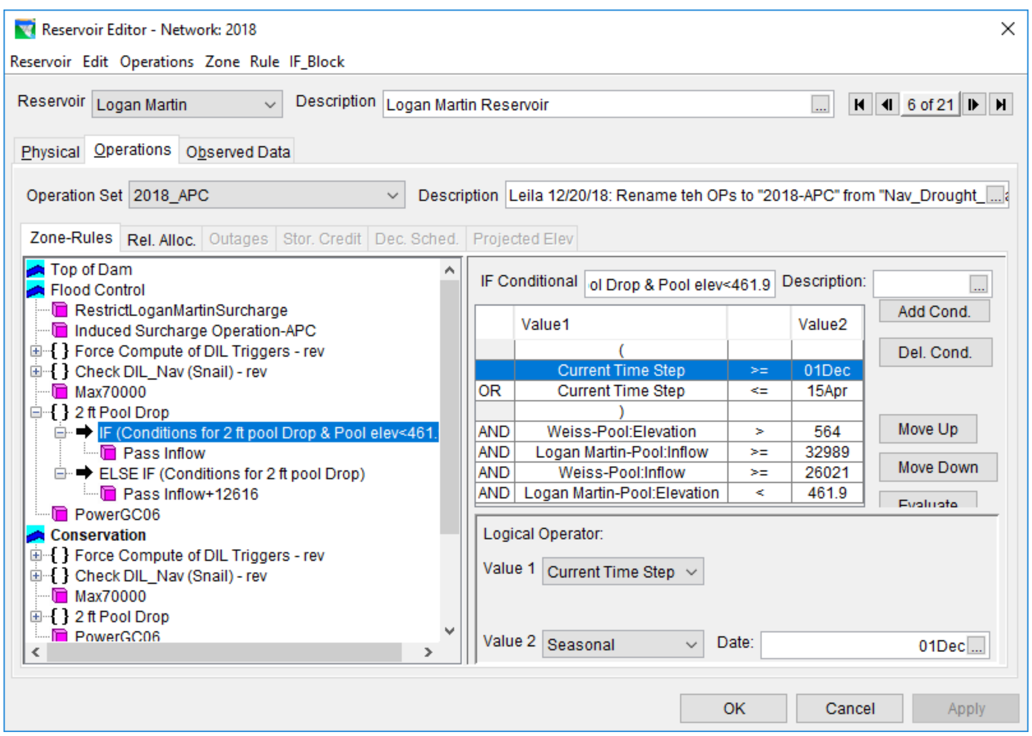


Figure 88. Conditions for ***2 ft Pool Drop*** **rule**

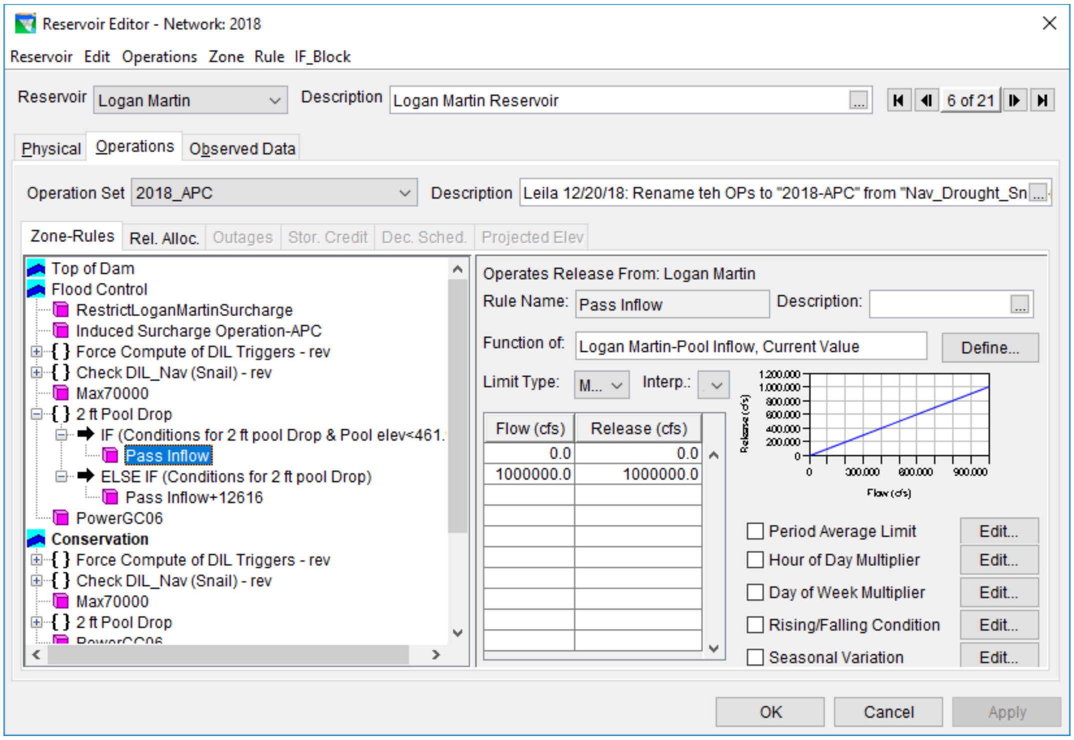


Figure 89. *Pass Inflow* rule

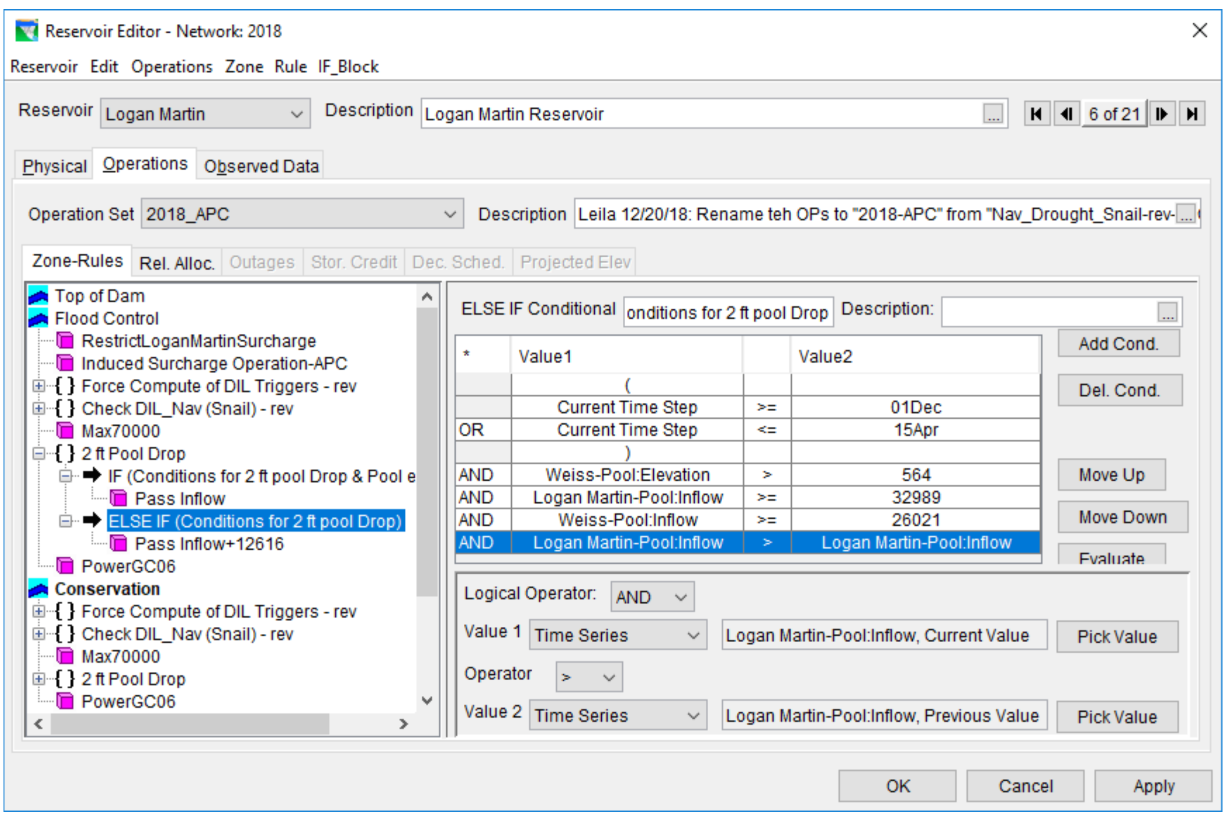


Figure 90. Else condition for 2 ft Pool Drop rule

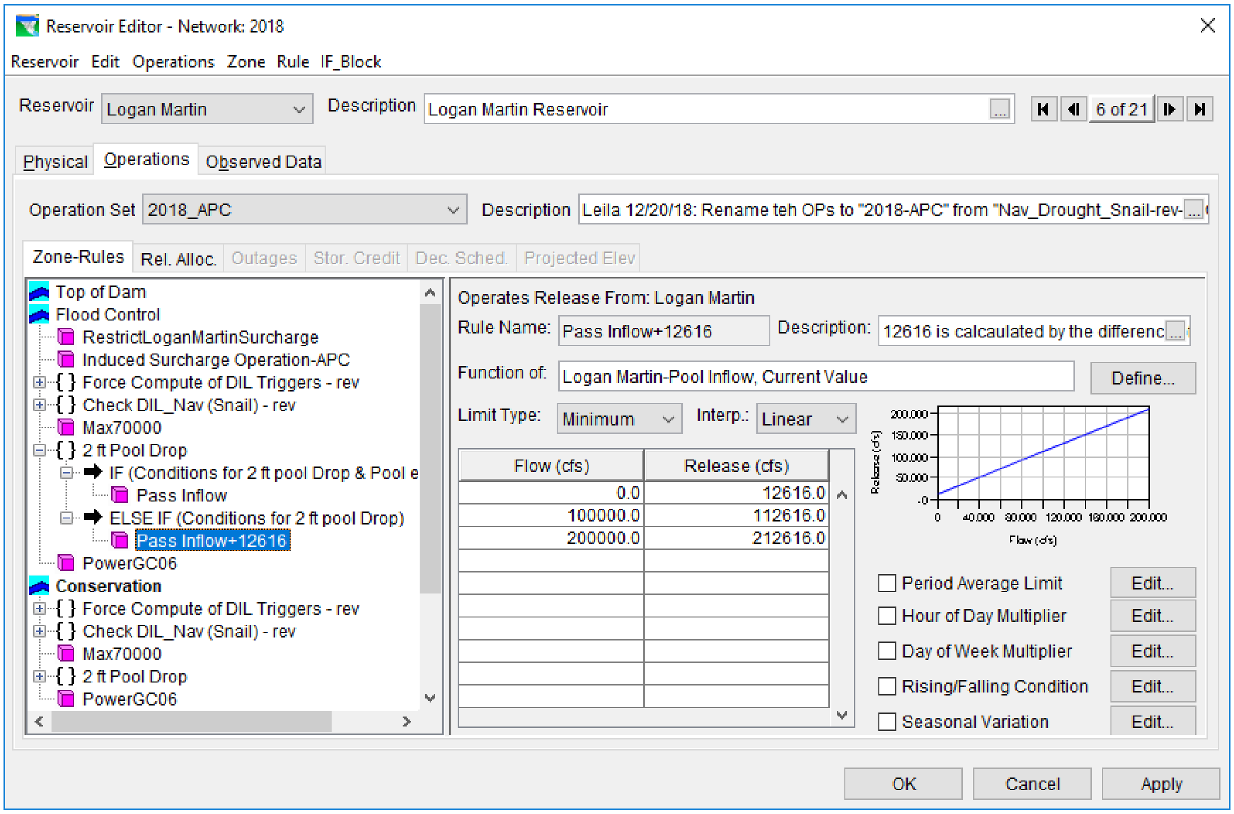


Figure 91. ***Pass Inflow+12616*** **rule**

3. Revised Maximum Release of 70,000 cfs

The Baseline 2018 operations call for a maximum channel capacity release of 50,000 cfs. The APC proposed a new maximum of 70,000 cfs. The *Max70000* rule sets the maximum release from Logan Martin to 70,000 cfs when in the Flood Control, Conservation, and Drought zones. When in the Flood Control zone, this release can be exceeded by the higher priority induced surcharge operation. The *Max70000* rule is shown in Figure 92.

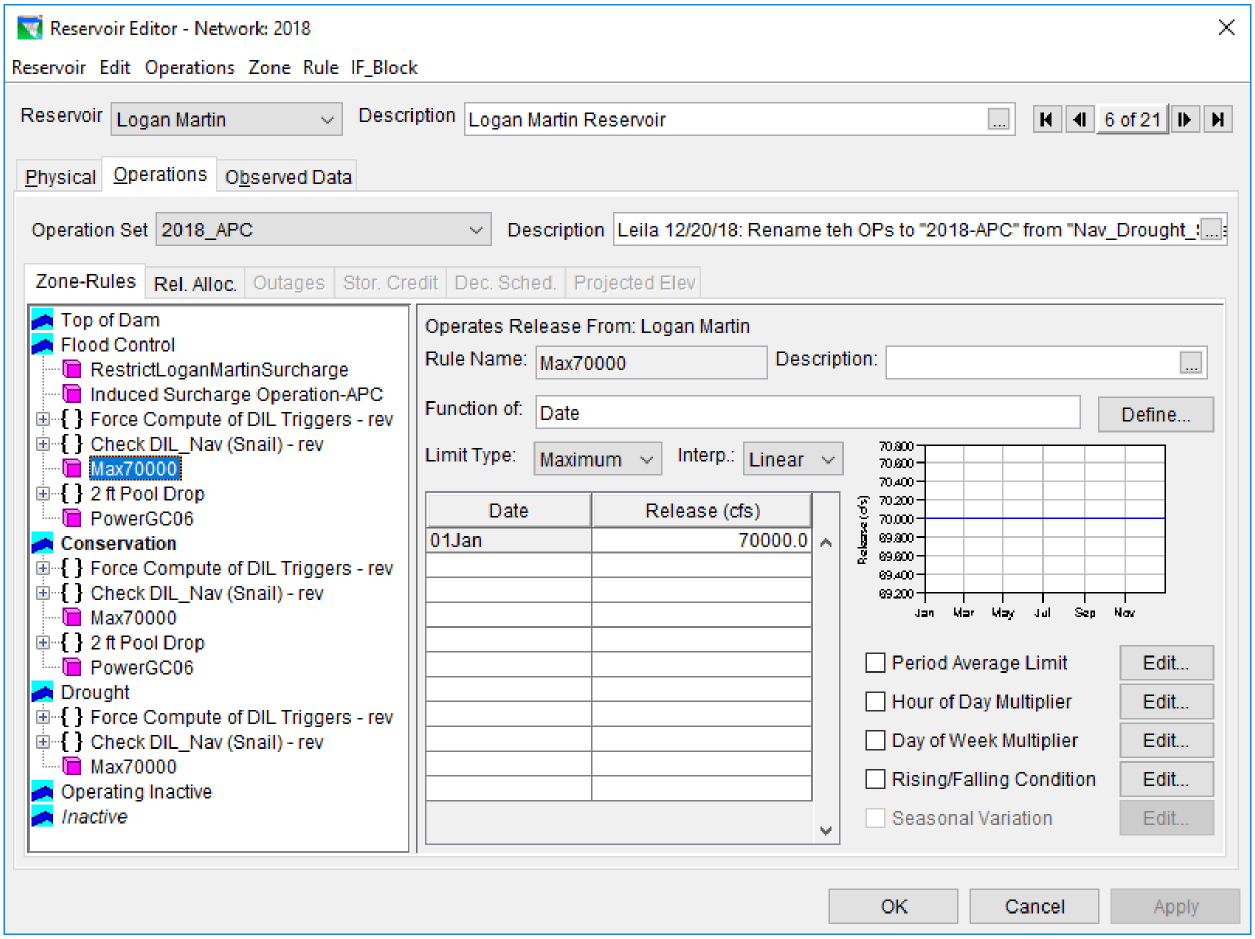


Figure 92. *Max70000* rule

4. Induced Surcharge Curve

A new Induced Surcharge curve at Logan Martin was proposed by APC. The *Induced Surcharge Operation_APC* rule is shown in Figure 93. The **Falling Pool Transition Elev** shown in Figure 80 is 460 ft for Logan Martin. This is the pool elevation below which the induced surcharge rule will no longer operate. The **Release Options** are used to designate the method for computing falling pool releases. For Logan Martin, the option of **Maintain Peak Gate Openings** is selected as shown in Figure 94.

The ESRD curves for *Induced Surcharge Operation_APC* rule at Logan Martin are shown in Figure 95.

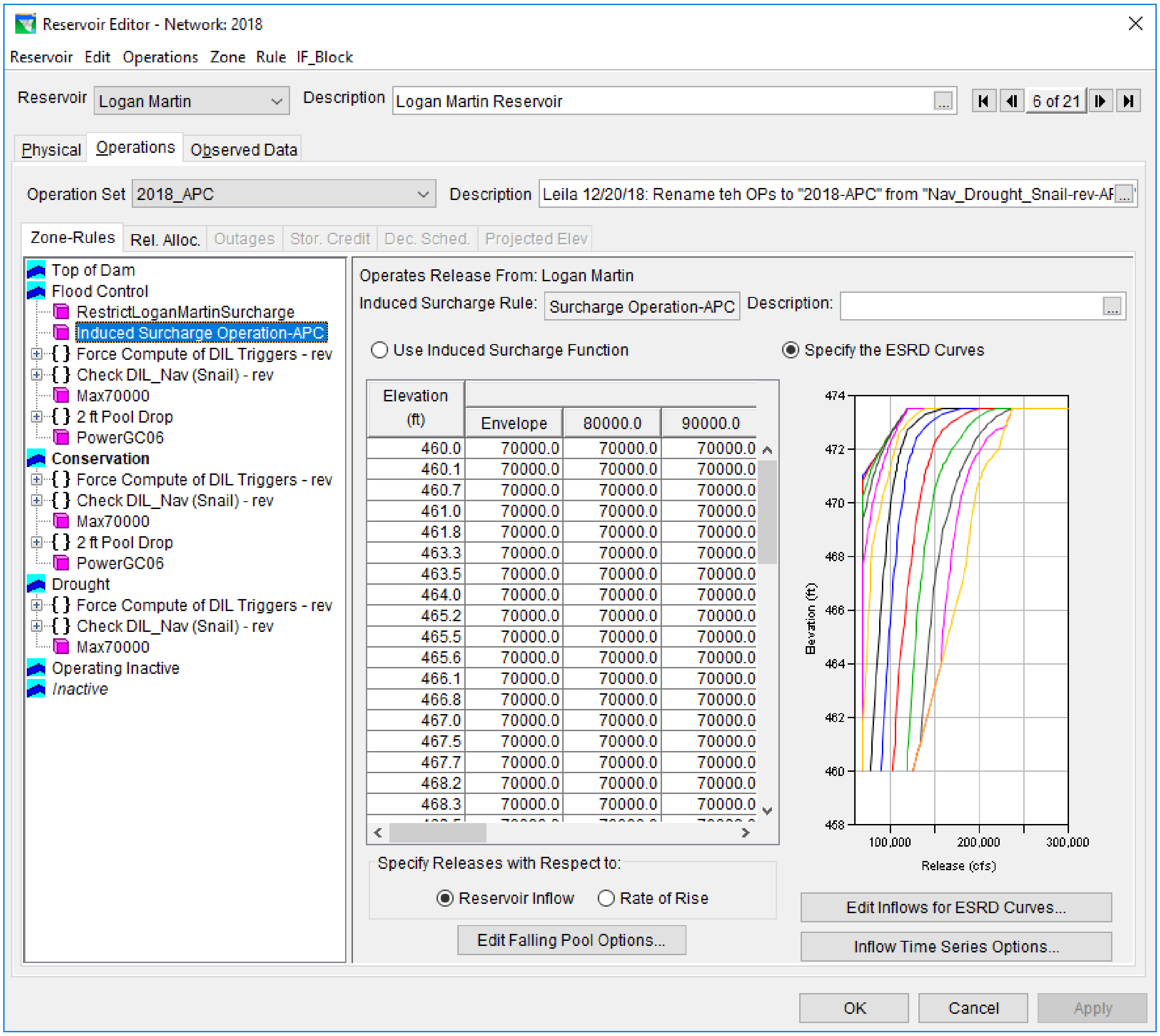


Figure 93. Induced Surcharge Operation-APC rule at Logan Martin

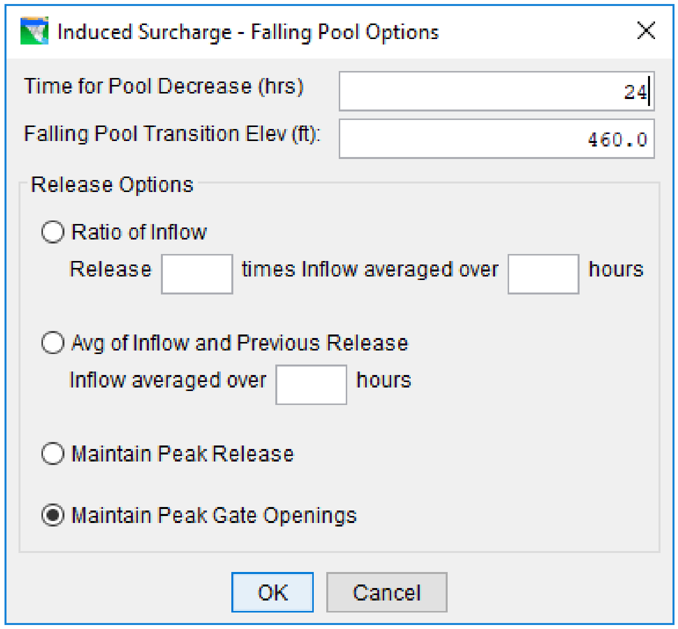


Figure 94. Induced Surcharge-Falling Pool Options at Logan Martin

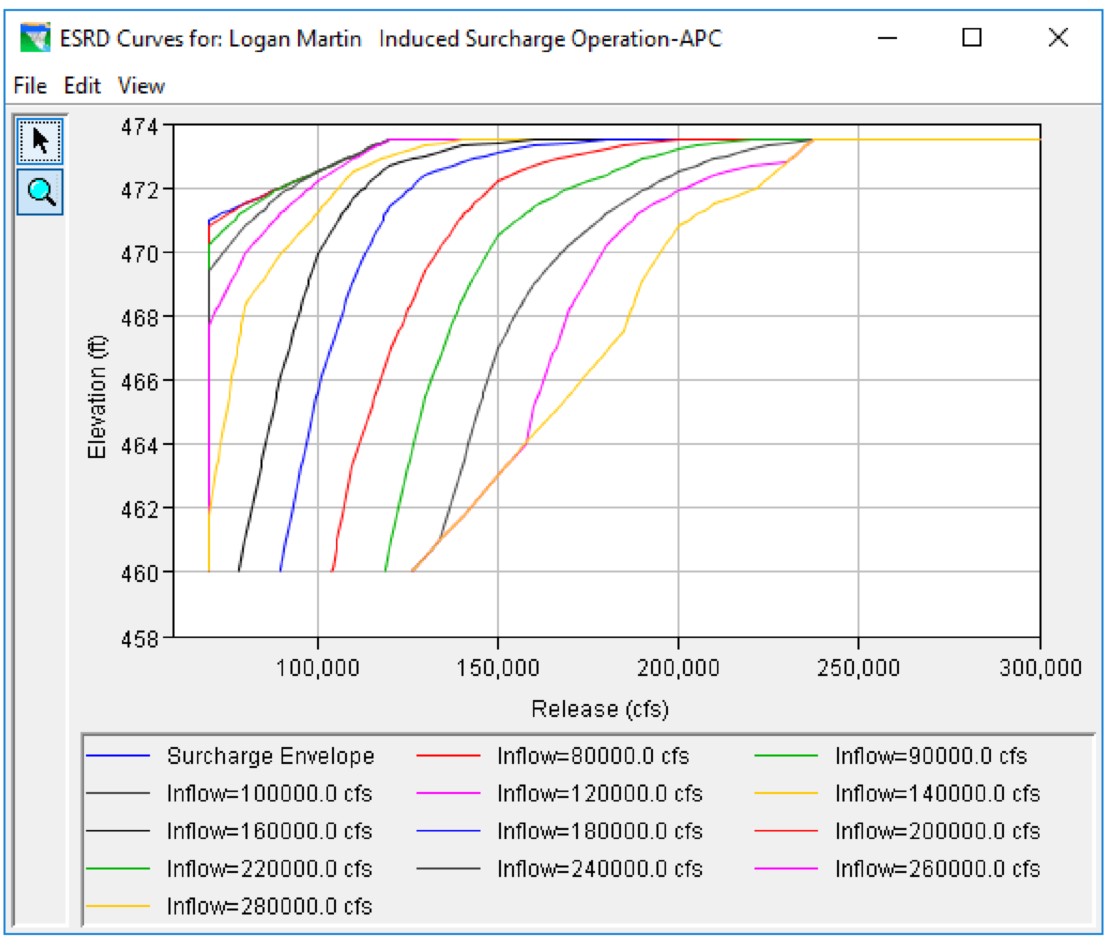


Figure 95. ESRD curves for: Logan Martin Induced Surcharge Operation-APC rule

5. Logan Martin Surcharge Cutback Rule

The *RestrictLoganMartinSurcharge* script to cut surcharge releases operates to minimize impacts downstream of the dam by limiting the surcharge when the stage at Childersburg is rising over the easement of 408 ft due to a combination of discharges from Logan Martin and local inflow. When the rating curve at Childersburg indicates that a combination of local inflow and surcharge values from Logan Martin will cause the stage at Childersburg to rise over elevation 408, surcharge releases can be cut up to 50% to provide time for the local inflows to recede. The total volume of the cutback cannot exceed 11,000 cfs-days per event. The total cutback volume does not have to be used consecutively but can be implemented as multiple cutback periods during an event. Once this volume has been utilized, the project will return to the normal surcharge release schedule. The *RestrictLoganMartinSurcharge* rule is shown in Figure 96 and the script is described in Appendix A.

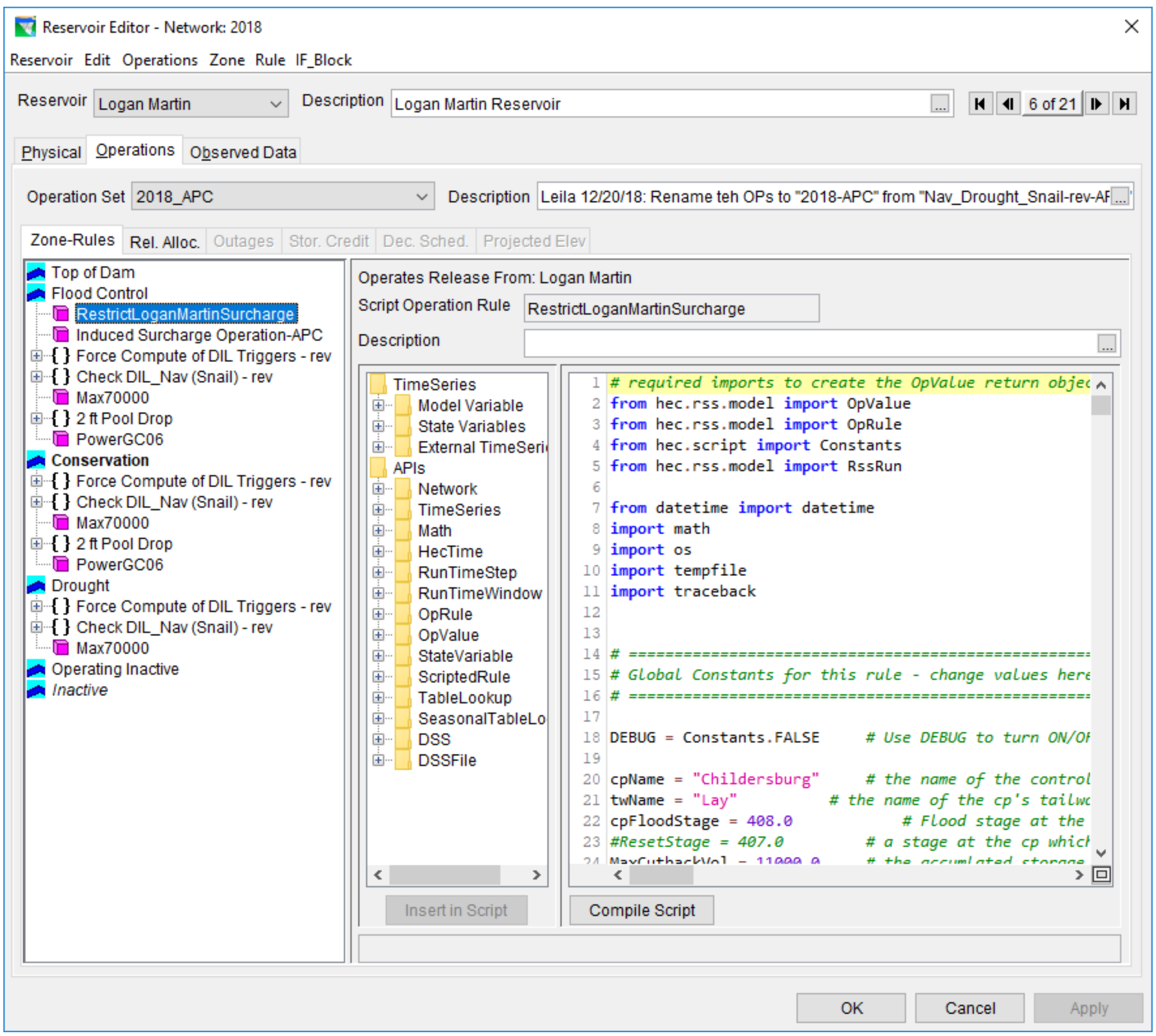


Figure 96. *RestrictLoganMartinSurcharge* rule at Logan Martin

6. Flood Control Zone

APC proposed to reduce the Flood Control zone from 476.5 ft to 473.5 ft as shown in Figure 97.

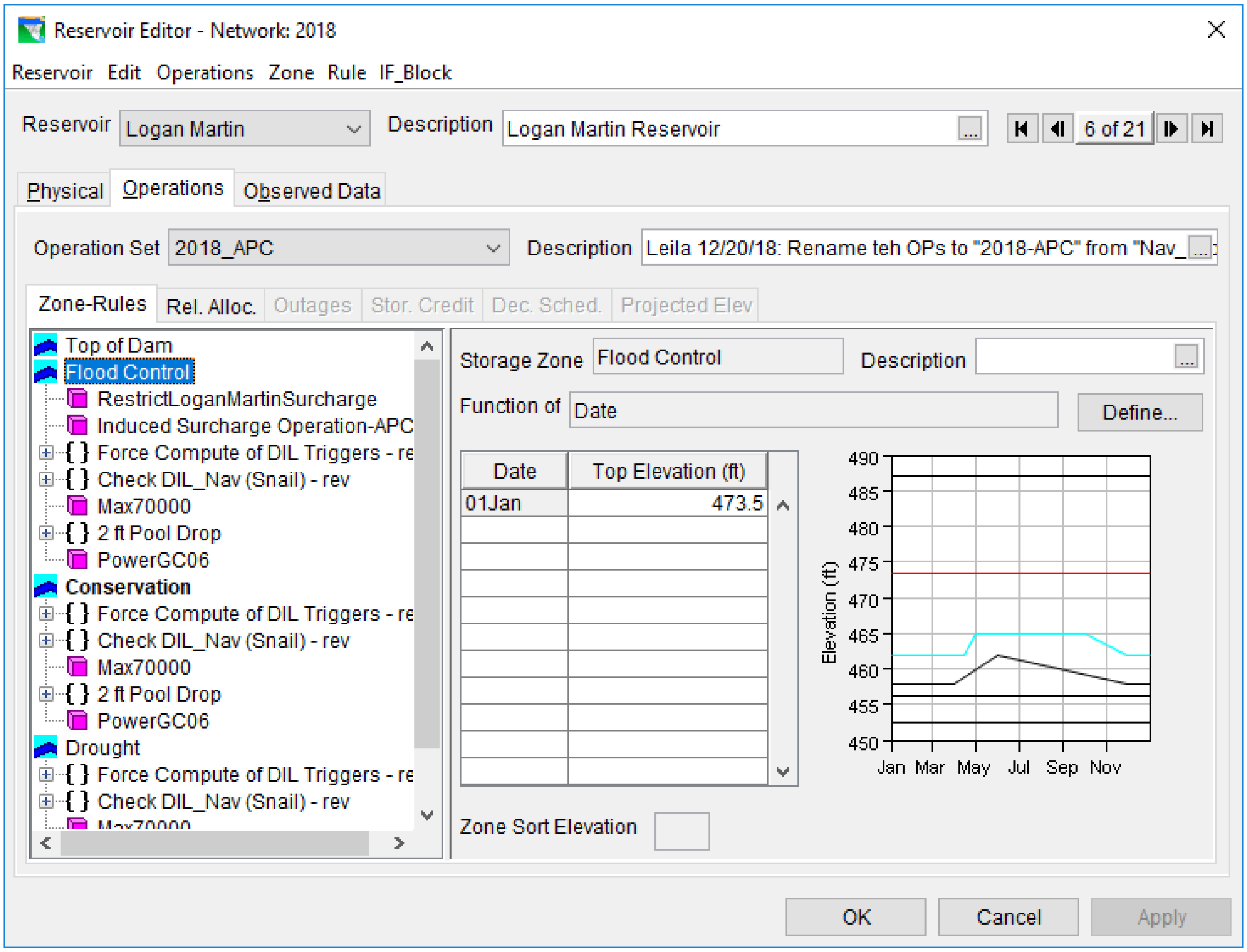


Figure 97. *Flood* control Zone in 2018_APC Operation Set

C. *Lay Operation*

When the Lay pool inflow reaches 70,000 cfs the *Pull down 1 ft* rule draws the Lay pool down to elevation 395 ft. This flexibility is helpful in preventing water from backing up to Childersburg by implementing a higher discharge before the Logan Martin releases reach the dam. When the Lay pool inflow drops back below 70,000 cfs, the Lay pool returns to elevation 396 ft. An example of this operation can be seen in Figure 98. The flow required to draw the pool down by one foot over the daily timestep is 5,852 cfs. The details of *Pull down 1 ft* rule are shown in Figures 99 - 103.

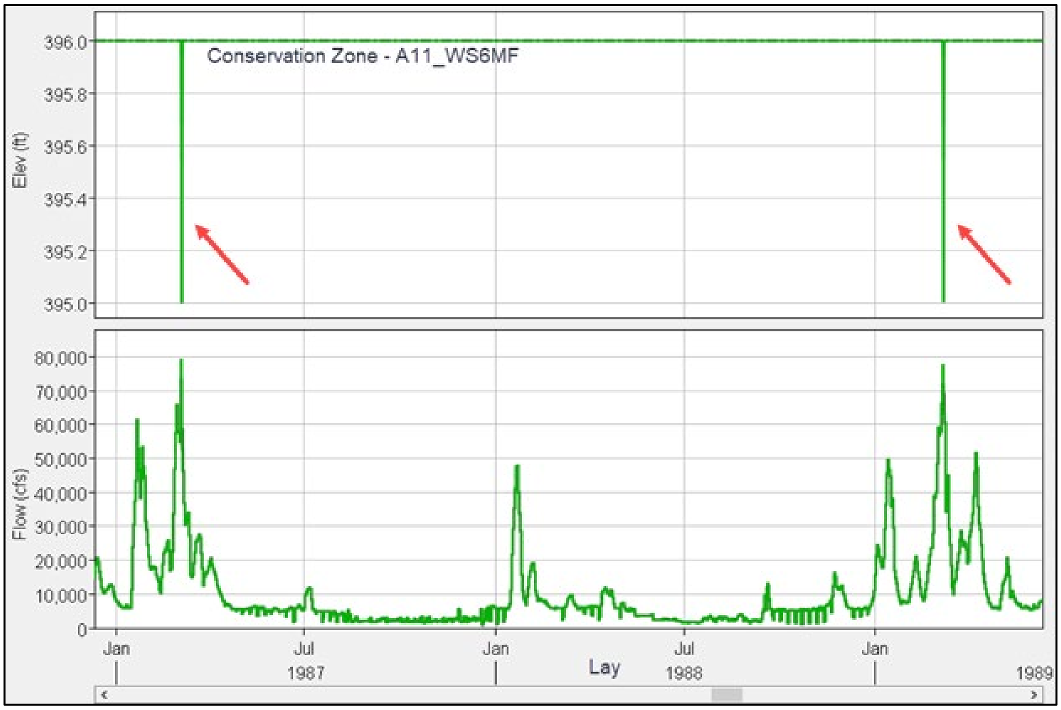


Figure 98. Lay APC proposed operation to draw the pool down by one foot when inflow is above 70 kcfs

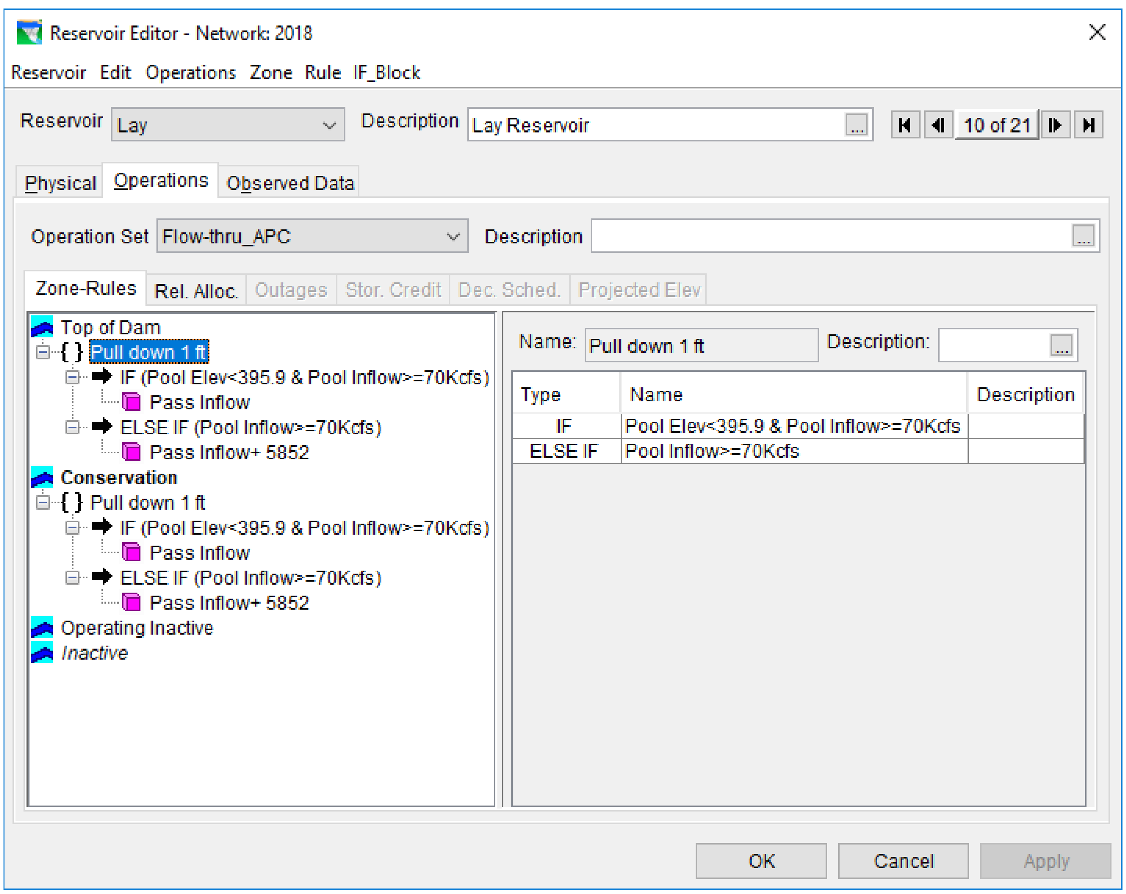


Figure 99. *Pull down 1 ft* rule at Lay

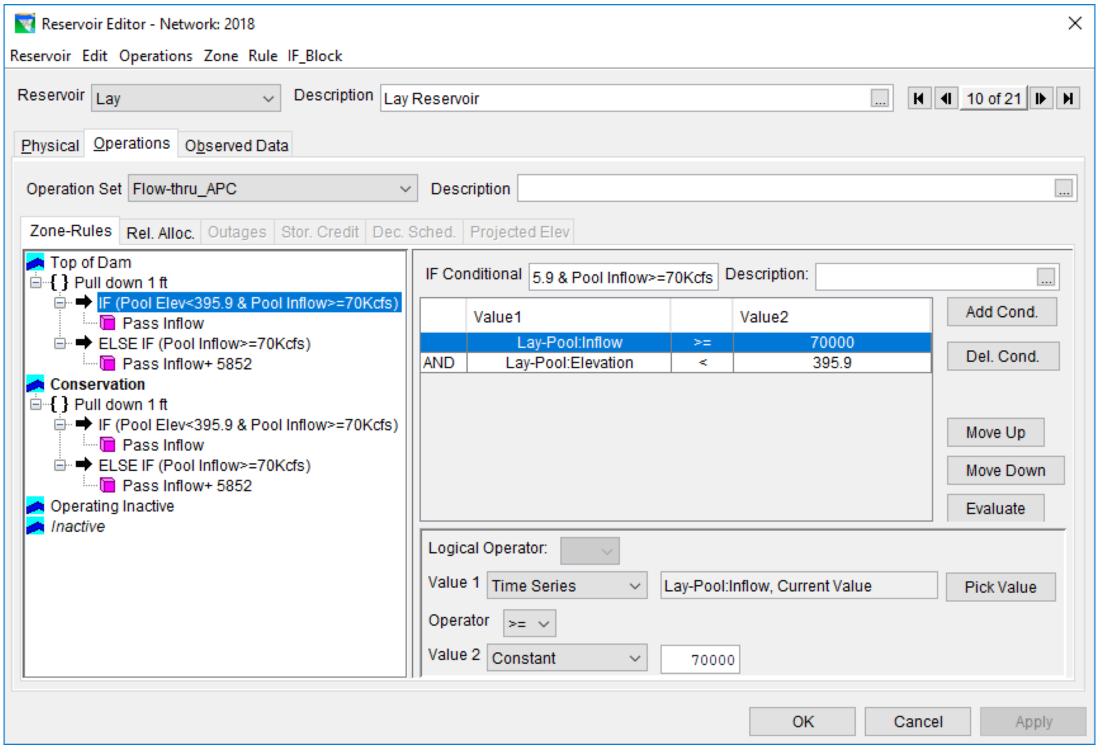


Figure 100. Condition of the the *Pull down 1 ft* rule at Lay

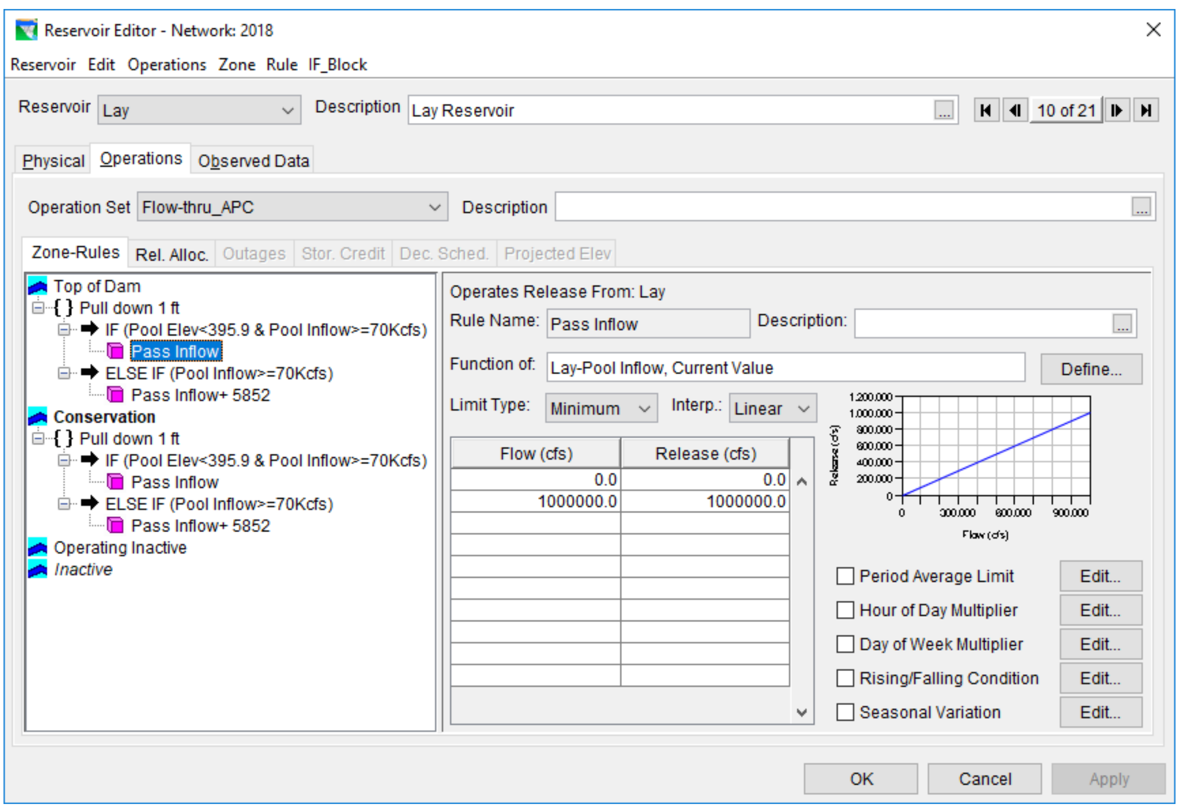


Figure 101. *Pass Inflow* rule at Lay

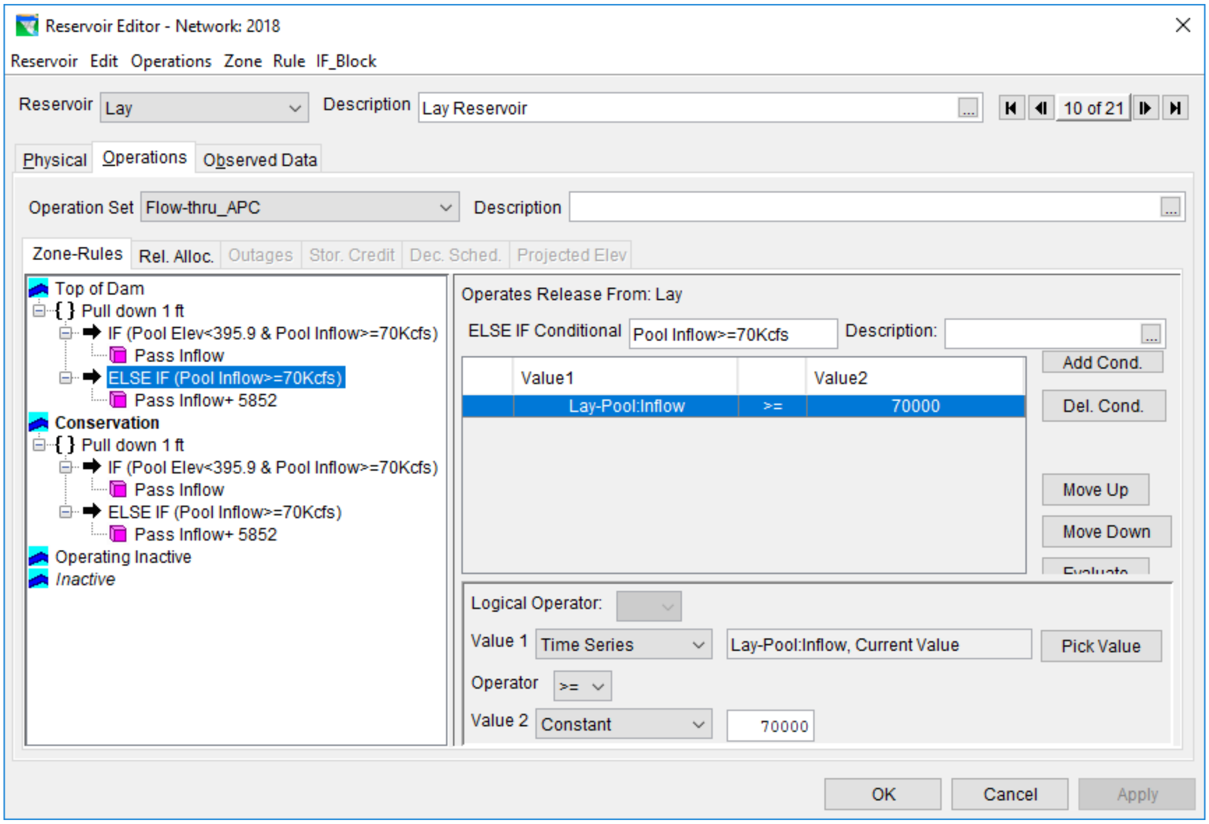


Figure 102. Else condition of the the *Pull down 1 ft* rule at Lay

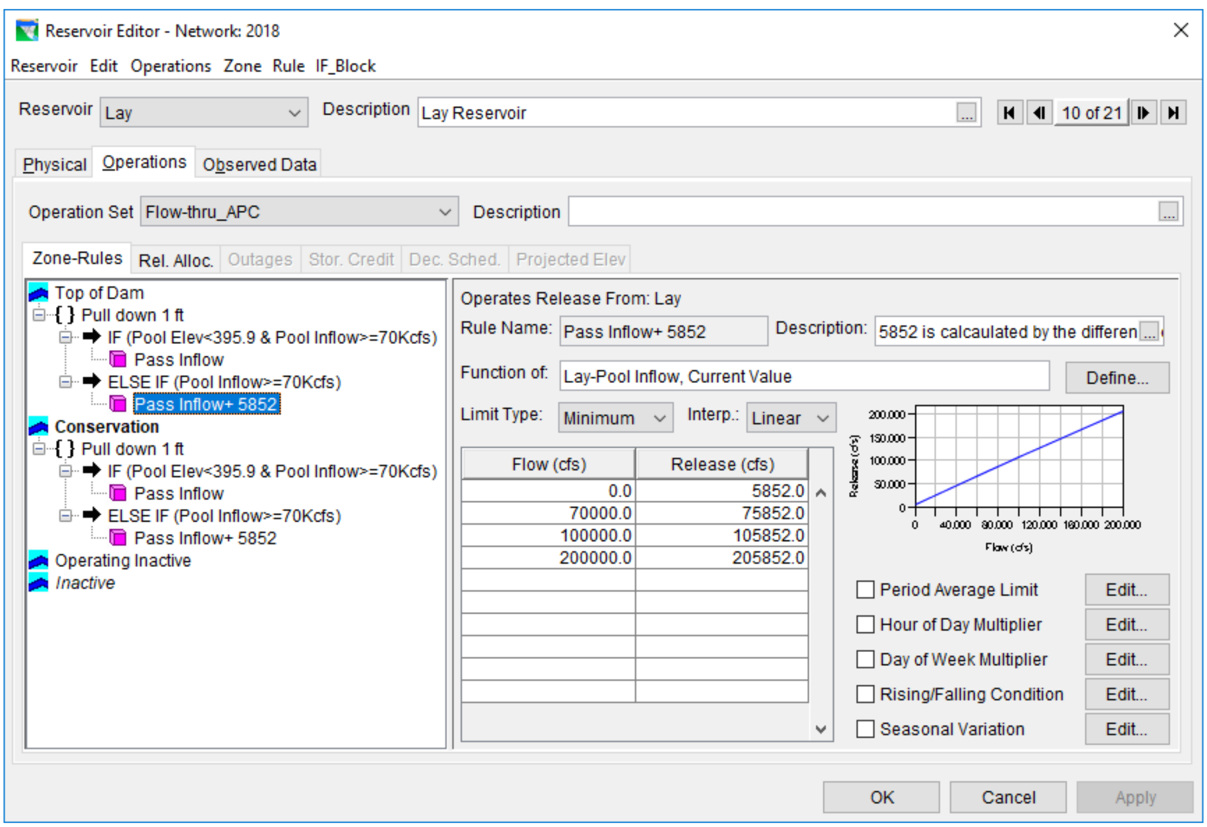


Figure 103. *Pass Inflow+5852* rule at Lay

D. APC Adjustment to Basin Inflow Drought Trigger

Basin Inflow is one of the indicators used to trigger drought operations and is the total local flows (minus evaporation and diversions) above the APC projects excluding Allatoona Lake and Carters Lake.

The needed Basin Inflow is defined as the volume of water required to fill the pools to the top of the conservation guide curve plus 4,640 cfs needed for downstream navigation. The ACT Drought Response Operations Proposal (ADROP) table is used to calculate the total basin inflow needed to avoid triggering drought operations. Since the APC has recommended adjustments to the Weiss and Logan Martin guide curves, a new ADROP table was needed to calculate filling volume. The ADROP table associated with the alterantives that use the APC recommendations is shown below in Table 7.

Table 7. New ADROP table for alternatives with APC adjustments

Month	Coosa Filling Volume	Tallapoosa Filling Volume	Total Filling Volume	Navigation	*Total Basin Inflow Needed	New ADROP table w\Weiss and Logan Rule Curve change
January	0	0	0	4640	4640	
February	0	120	120	4640	4760	
March	643	2900	3543	4640	8183	
April	1606	2585	4191	4640	8831	
May	5	0	5	4640	4645	
June	0	0	0	4640	4640	
July	0	0	0	4640	4640	
August	0	0	0	4640	4640	
September	0	-1304	-1304	4640	3336	
October	-1167	-2132	-3299	4640	1341	
November	-1067	-2186	-3253	4640	1387	
December	-3	0	-3	4640	4637	

IV. Allatoona Guide Curves

Three different guide curves are defined for Allatoona in this study. These guide curves are defined under *2018*, *2018_844.5_841.5,* and *2018_841_824.5* operations sets and are shown in Figures 104 to 106.

Pursuant to the reallocation study policy guidance, the team considered reallocating the water supply storage request amount from the Allatoona flood control pool. The first modeling attempt was to reallocate the entire additional 60 mgd request solely from the flood control pool by raising the guide curve (top of conservation) from elevation 840 to 844.5 ft in the summer and from elevation 823 to 841.5 ft in the winter. Raising the guide curve resulted in an 18% reduction of flood storage in the summer and 39% reduction during the winter drawdown period. The results showed significant flooding impacts to the reservoir, recreation areas, and boat docks, as well as increased shoreline erosion and a higher frequency of exceeding flood stages in the Rome, Georgia area. The pool increase would also put a lot of the recreation facilities under water or at risk of more frequent flooding to the point that much of it would have to be relocated. The PDT determined the significant impacts were not acceptable.

Next, the team considered a combination of reallocating from the flood control pool and the conservation pool; this reduced flood storage reallocation would have minimum impacts to downstream flooding, hydropower, and recreation. A one foot raise in summer would allow for 1.5 foot buffer before recreation areas would have to close due to high water. There is currently flexibility in Flood Zone A to keep the pool above guide curve during drought conditions. Raising the pool one foot showed minimal to negligible impacts to reservoir and downstream flooding. Therefore, the modelers raised the winter level near the equivalent of the 1 foot of storage between elevation 840 ft and 841 ft (11,670 ac-ft). Winter level increased from 823 ft to 824.5 ft (10,700 ac-ft). This allows operators to retain the winter drawdown for flood control.

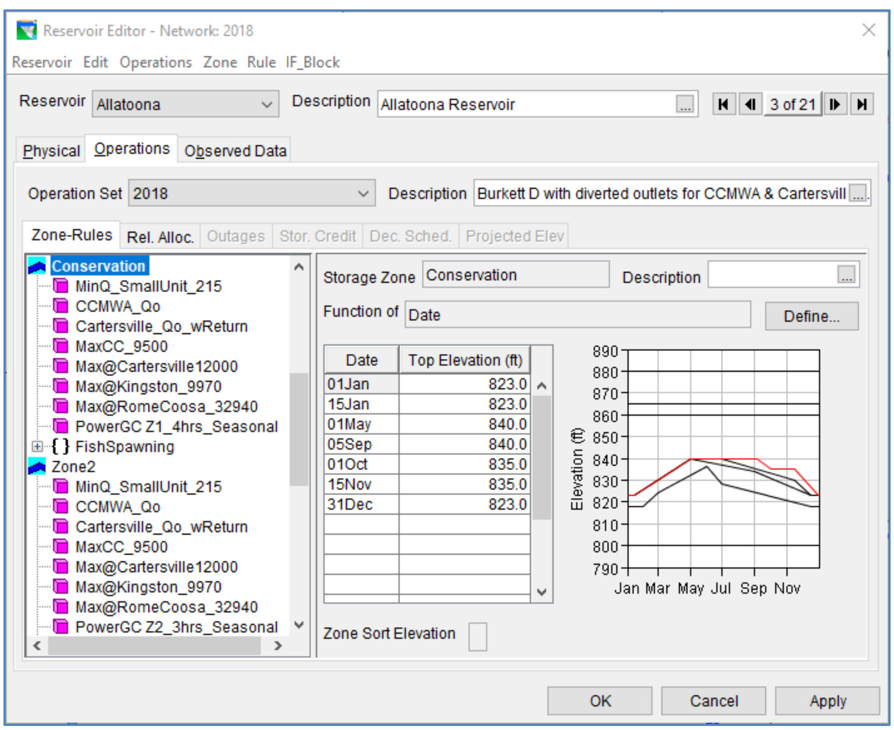


Figure 104. Allatoona Guide Curve, 2018 Operation set

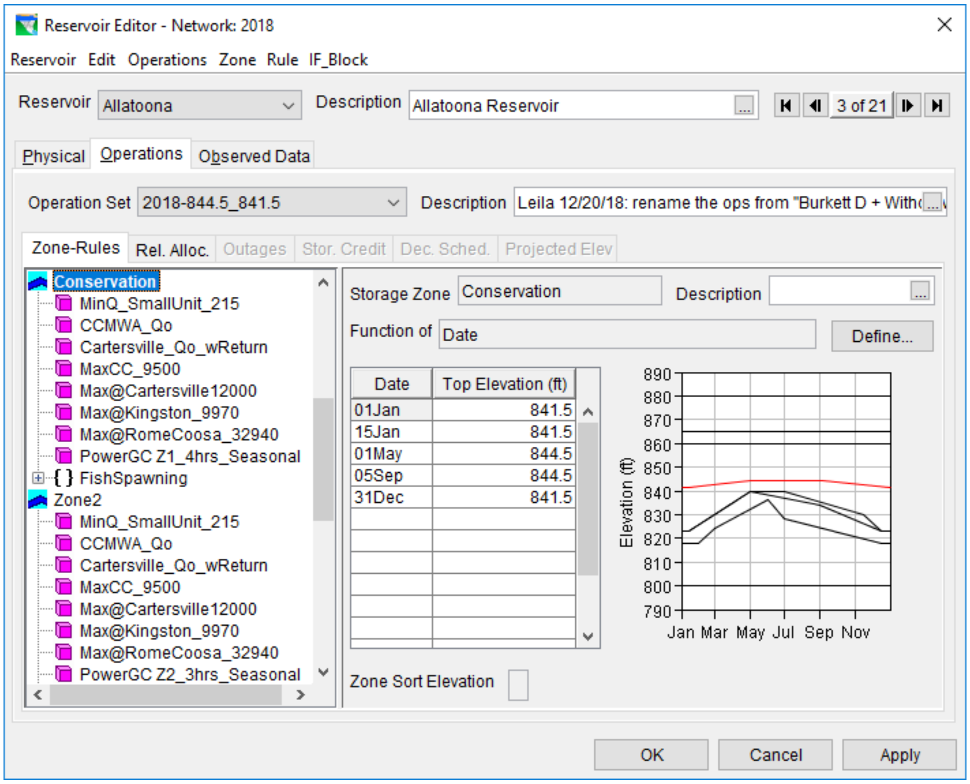


Figure 105. Allatoona Guide Curve, 2018_844.5_841.5 Operation set

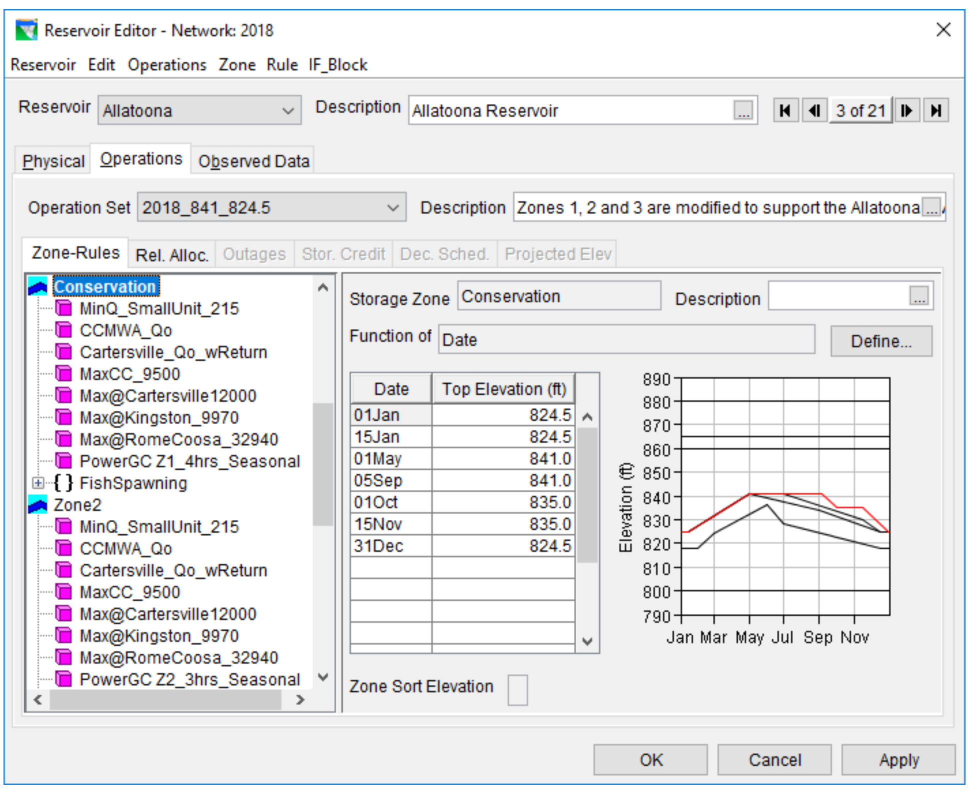


Figure 106. Allatoona Guide Curve, 2018_841_824.5 Operation set

V. Allatoona Water Storage Accounting

There are two water account holders at Allatoona Reservoir: Cobb County Marietta Water Authority (CCMWA) and the City of Cartersville. Each account holder has a portion of the conservation pool volume allocated to their use. According to their 1963 water supply storage contract, CCMWA holds 4.62% and Cartersville holds 2.24% of the conservation pool.

Changes in Allatoona's Estimated Storage

The elevation-storage relationship for Allatoona was reassessed in 2011 and the pool volume was found to have decreased. Given the reduced pool volume, the original storage account sizing does not yield as great a volume as originally calculated. Table 8 shows the original and current account storage volumes and anticipated yield.

Table 8. Allatoona Baseline water account storage volumes, as calculated before and after the updated elevation-storage-area (ESA) curves.

Account Holder	Percent of Pool	Storage Vol (ac-ft)	Anticipated Yield (mgd)	Storage Vol (ac-ft)	Anticipated Yield (mgd)
		Pre-2011 ESA		with 2011 Updated ESA	
Total		**284,589**	**747**	**270,247**	**495**
CCMWA	4.62%	13,148	34.5	12,485	22.9
Cartersville	2.24%	6,375	16.76	6,054	11.1
USACE	93.14%	265,066	--	251,708	--

Allatoona's Storage Accounting Approach

Water storage accounting at Allatoona consists of dividing the volume of the conservation pool into different subvolumes based on account size. At Allatoona, CCMWA and Cartersville hold water storage accounts of 12,485 acre-feet and 6,054 acre-feet, respectively. The remaining volume is considered to belong to USACE. When CCMWA and Cartersville withdraw water, the volume of withdrawals is deducted from their accounts. Inflows are distributed to each account based on their percentage of the total conservation volume.

Pool inflows and account water usage are calculated on a daily basis in order to track the current account storage. The approach to storage accounting for Allatoona Reservoir was established by USACE Mobile District based on the principles described in Table 9. In its reallocation request, the State of Georgia requested a different approach to accounting for water storage in Allatoona Reservoir. Both storage accounting methodologies were modeled.

The key differences between the two storage accounting approaches involve the determination of when the accounts should be considered full, the determination of the percent of inflow that should be credited to each account holder, and whether to give account holders full credit for their return flows.

Table 9. Allatoona Storage Accounting Principles

The Corps calculates the status of Allatoona storage accounts in a reservoir based on the following principles:

- The conservation storage in the reservoir is divided up among a given number of users or accounts.
- The percent of conservation storage to which usage rights are purchased is the percentage of the water supply need (anticipated yield) to the reservoir critical yield.
- That percent of conservation storage purchased (percentage of critical yield) by for each user is also represents the percentage of inflow credited to each user's storage account in a given time period.
- The percent of inflow remains constant even if the volume of with the variable conservation storage is variable.
- Reservoir drawdown according to a variable guide curve is charged to the general, multipurpose conservation storage account (or "USACE storage account"), not to water supply users. For example, at Allatoona Lake in Georgia, the Allatoona 17 foot winter drawdown from elevation 840 feet to 823 feet is considered for storage accounting purposes as a withdrawal (release) from the USACE storage account.
- Losses from evaporation and leakages are incorporated in the computation of Net Inflow.
- If one or more users have full accounts, any inflow not used by them is available to the other users with accounts less than full. That prorated inflow amount is distributed to the other users based remaining users allocated portion of conservation pool.
- Any water held above the top of conservation storage held above the 840 feet is not subject to the Corps' storage accounting. Thus, withdrawals under those circumstances are not charged to individual users' accounts, essentially free to any and all users. This applies for the entire calendar year, because the reservoir drawdown according to a variable guide curve—for example, the 17 foot winter drawdown from elevation 840 feet to 823 feet at Allatoona Lake in Georgia— is considered a withdrawal (release) from the USACE storage account.

A. Designation of Full USACE Account

Current USACE methodology considers all accounts to be full when Allatoona's elevation is at the top of the summer pool. The Georgia recommendation is to consider all accounts to be full when Allatoona is at the top of the guide curve. Since the guide curve is seasonally varying, all accounts would be considered full at a much lower level in the winter.

B. Determination of Inflow Distribution

For storage accounting, inflow is added to the accounts on a daily basis. The total inflow is calculated based on the known releases and the observed change in storage. Current USACE methodology credits inflow to account holders based on their percentage of the total conservation storage, as measured by the summer conservation pool storage. The ratio (percentage) of water supply storage to conservation storage is equivalent to the ratio (percentage) of the State's projected need to the critical yield, which is used to compute the State's storage space. For existing contracts and pool volume (baseline conditions), this is equivalent to crediting 4.62% of inflow to CCMWA and 2.24% of inflow to Cartersville. The Georgia storage accounting approach recommends that the percentage of pool volume should be calculated based on the conservation pool volume, as defined by the variable guide curve at Allatoona. Table 10 demonstrates how the percentage of inflow would vary seasonally under current conditions. For current conditions, percentage varies between 4.62-10.99% for CCMWA and 2.24-5.33% for Cartersville.

C. Return Flow Credit

CCMWA returns a percentage of its diverted flow back to Allatoona. This return flow value is lumped with the rest of Allatoona's inflow and distributed to accounts accordingly. The State of Georgia storage accounting approach proposes giving CCMWA full credit for any flow it returns to Allatoona. This approach would remove the return flow from the total inflow and credit it to CCMWA's account. The remaining inflow would be divided according to percent of pool storage.

Return flow for CCMWA is represented in the ResSim model using a negative diversion at the Allatoona inflow junction. The volume of this return flow is calculated using the ***Accounting_HLCmain*** state variable.

Table 10. Storage account percentage of summer vs. winter conservation pool for current (Baseline) conditions

			Water Accounts	
			CCMWA 12,485 ac-ft	Cartersville 6,053 ac-ft
Conservation Pool			Account Percent of Conservation Volume	
Season	Elev (ft)	Storage (ac-ft)		
Summer	840	270,247	4.62%	2.24%
Winter	823	113,638	10.99%	5.33%

VI. Modeled Alternatives

The modeling team produced two sets of alternatives for this study: the primary water supply and flood operations alternatives, and a few climate change alternatives. Each of the primary alternatives used the local inflows from the Unimpaired Flow dataset produced as part of a previous modeling effort and last updated in February 2014. The climate change alternatives began as copies of two of the primary alternatives, but the local inflows used came from the Climate Change Flows developed as part of this study. The development of the Climate Change Hydrology is described in a separate report (**Appendix C, Attachment 5**) and the subsequent computation of the local inflows from the Climate Change Hydrology is described in **Appendix B** of this report.

A. PDT Alternative Matrix

The Allatoona-Coosa Reallocation Project Delivery Team developed a list of measures and combined them to define alternatives in the interest of reducing the risk of water supply shortage for Lake Allatoona users through year 2050 and maintaining an acceptable level of flood risk at ACT projects. There were fourteen alternatives (including *No Action*, *Baseline*, and *Future Without Project* conditions) developed by the PDT that were relevant to the ResSim modeling (Table 11). Although PDT Alternatives 6 and 7 were screened-out early in the alternative selection process, Alternative 6 was still included in the ResSim modeling effort. Thus, thirteen of the original fourteen PDT alternatives were modeled.

Table 11. PDT alternatives relevant to ResSim modeling

PDT Alt #	Alternatives	Meets GA 2050 Demands 94MGD	Storage Accounting Method		Reallocation			APC Requested Changes
			USACE	GA	Inactive Pool	Con Pool	Flood Pool	
0	No Action		✓					
1	Baseline Capped		✓					
2	Future Without Project		✓					
3	Water Supply 1	✓		✓		✓		
4	Water Supply 2	✓	✓			✓		
5	Water Supply 3	✓		✓		✓	✓	
6	Water Supply 4	✓	✓				✓	
7	Water Supply 5				✓			
8	Water Supply 6	✓	✓			✓	✓	
9	Modified Flood Operation 1		✓					✓
10	Water Supply 2 + Modified Flood Operation 1	✓	✓			✓		✓
11	Water Supply 6 + Modified Flood Operation 1	✓	✓			✓	✓	✓
12	Water Supply 1 + Modified Flood Operation 1	✓		✓		✓		✓
13	Water Supply 3 + Modified Flood Operation 1	✓		✓		✓	✓	✓

B. Modeling the PDT Alternatives with ResSim

In order to develop alternatives in ResSim, the measures described by the PDT matrix were further broken down based on the adjustments that were needed in the ResSim model. The model adjustment categories were:

- Storage Account Volumes (further described below)
- Demand Timeseries (current or 2050)
- Storage Accounting Approach (as described in the previous section)
- Allatoona Reallocation (described in section IV)
- APC Modified Flood Operations (described in Section III).

1. Yield for different Pool Reallocation Options

For the alternatives modeled, there are three different Allatoona conservation pool sizes: the current pool and two variations with a raised guide curve. Alternatives that used the current pool definition meet higher account holder demands by reallocating water strictly from the USACE conservation pool. The other two reallocation scenarios take additional storage from either the flood pool only, or a combination of the flood and conservation pools (Table 12).

Yield modeling was performed for each reallocation scenario to determine Allatoona's firm yield, given the different conservation pool definitions. Note as well that the changes to Allatoona's estimated storage based on the updated survey also affected the yield calculations.

Table 12. Allatoona Conservation Pool Yield for different Reallocation Scenarios

Pool Reallocation	Guide Curve summer/winter elev (ft)	Summer Conservation Storage (ac-ft)	Anticipated Yield (mgd)
From Conservation only (current guide curve)	840 / 823	270,247	494.7
from Flood & Conservation	841 / 824.5	281,917	505.6
from Flood only	844.5 / 841.5	323,022	556.7

2. Calculating CMWA and Cartersville Water Account Volumes

Sizing the Allatoona water storage accounts is a multistep process and is dependent on the definition of the conservation pool, the associated firm yield, and the demand to be met. Therefore, even when two alternatives share the same conservation pool volume, their storage account sizes can differ. Four basic volume scenarios were necessary:

- **V0** represents the original account sizes, calculated as a percentage of the pool's yield. Note that because of the Allatoona's pool volume decrease, those original account sizes are smaller than originally intended.
- **V1** represents the account sizes necessary to meet the 2050 demand given either the Corps storage accounting approach (V1 (USACE)) or the Georgia accounting approach (V1 (GA)).

- **V2** represents the accounts sizes necessary to meet the 2050 demand if all the reallocated storage comes from the flood pool.
- **V3** represents the accounts sizes necessary to meet the 2050 demand if the reallocated storage comes from both the flood and the conservation pool. Depending on the accounting approach, there is a V3 (USACE) and V3 (GA) version.

The storage account values are listed in Table 13.

Table 13. CCMWA and Cartersville water account sizes

Account Sizing	No Action	GA accounts sized to meet demands of 94 mgd				
Reallocation Scenario	No Reallocation			Flood Pool Only	Flood & Con Pools	
Accounting Scenario	USACE	USACE	GA	USACE	USACE	GA
Volume Scenario	**V0**	**V1 (USACE)**	**V1 (GA)**	**V2**	**V3 (USACE)**	**V3 (GA)**
Storage Account	**Volume (ac-ft)**					
USACE	251,708	218,896	237,549	268,475	229,506	248,802
CCM	12,485	31,138	12,485	33,076	31,781	12,485
Cartv	6,054	20,213	20,213	21,471	20,630	20,630
Total	270,247	270,247	270,247	323,022	281,917	281,917

C. Primary ResSim Alternatives

The primary ResSim alternatives in the daily model consist of the baseline condition alterantives and the future condition alternatives. Table 14 shows the detailed ResSim alternative matrix with descriptions of the the variations.

1. The Baseline Alternatives

Two different variations on baseline conditions were considered: *No Action* and *Baseline Capped*. The *No Action* alternative depicts no change to current operations. However, current operations are not consistent with the defined operations in the WCMs or in USACE guidance. Allatoona water account holders have been allowed to withdraw water, even when their accounts empty. The *Baseline Capped* alternative is like the *No Action*, but it does not allow Allatoona account holders to withdraw more than the water available in their storage account. Having these two versions of baseline conditions allows for a comparison between current operation and operation based on the WCM guidance.

2. The Future Condition Alternatives

The future condition alternatives all use demand timeseries that reflect estimated demands for the year 2050. The *Future Without Project* (“FWOP”) alternative demonstrates operations under the current WCM guidance, equivalent to the *No Action* alternative, but with future demands instead of current. *Alternative 09*

("A09_FWOPMF") is the same as the *Future Without Project* alternative, except that it includes the recommended changes at the APC projects.

For *Alternative 03* ("A03_WS1") the storage accounting was done using the Georgia approach, and the Cartersville storage account was resized to meet the increased 2050 demand. *Alternative 10* ("A10_WS1MF") is the same as *Alternative 03*, except except that it includes the recommended changes at the APC projects.

For *Alternative 04* ("A04_WS2") the storage accounting was done using the Corps approach, and the CCMWA and Cartersville storage accounts were resized to meet the increased 2050 demand. *Alternative 12* ("A12_WS2MF") is the same as *Alternative 04*, except except that it includes the recommended changes at the APC projects.

For *Alternative 05* ("A05_WS3") the storage accounting was done using the Georgia approach, and the pool was reallocated using some flood storage and some conservation storage. The Cartersville storage account was resized to meet the increased 2050 demand, but the Georgia storage accounting approach, including return flow credit, allowed the CCMWA account to be unchanged. *Alternative 13* ("A13_WS3MF") is the same as *Alternative 05*, except except that it includes the recommended changes at the APC projects.

For *Alternative 06* ("A06_WS4") the storage accounting was done using the Corps approach, Allatoona reallocation came entirely from the flood pool, and the CCMWA and Cartersville storage accounts were resized to meet the increased 2050 demand. *Alternative 11* ("A11_WS4MF") is the same as *Alternative 06*, except except that it includes the recommended changes at the APC projects.

For *Alternative 08* ("A08_WS6") the storage accounting was done using the Corps approach, Allatoona reallocation came from the flood and conservation pools, and the CCMWA and Cartersville storage accounts were resized to meet the increased 2050 demand.

Table 14. ResSim Alternative Matrix

ResSim Alternative Name	PDT Alt #	Georgia Account Volume				Demand Time Series		Storage Accounting				Allatoona Reallocation		APC Changes
		V0	V1	V2	V3	D1	D2	U	G	H	O	Af	A	P
Base2018	0	✓				✓		✓			✓			
BaseCap	1	✓				✓		✓						
FWOP	2	✓					✓	✓						
A03_WS1	3		✓				✓		✓	✓				
A04_WS2	4		✓				✓	✓						
A05_WS3	5				✓		✓		✓	✓			✓	
A06_WS4	6			✓			✓	✓				✓		
A08_WS6	8				✓		✓	✓					✓	
A09_FWOPMF	9	✓					✓	✓						✓
A10_WS2MF	10		✓				✓	✓						✓
A11_WS6MF	11				✓		✓	✓					✓	✓
A12_WS1MF	12		✓				✓		✓	✓				✓
A13_WS3MF	13				✓		✓		✓	✓			✓	✓

Key: code descriptions

Georgia Account Volume (Allatoona's CCM and Cartersville Storage Accounts)	
V0	Accounts are sized based on the current contract (19,523 AF)
V1	Accounts are sized to meet the Georgia requested volume (94 MGD). Note that account values under the V1 condition vary between alternatives dependent on the storage accounting methodology used.
V2	Accounts are sized to meet the Georgia requested volume (94 MGD), assuming that the additional volume comes entirely from reallocating the flood pool storage to conservation storage.
V3	Accounts are sized to meet the Georgia requested volume (94 MGD), assuming that the additional volume comes from a combination of flood pool and current conservation pool. Note that account values under the V3 condition vary between alternatives dependent on the storage accounting methodology used.
Demand Time Series	
D1	Current 2006 demands.
D2	Future 2050 demands. CCMWA and Cartersville demands have been updated using the 2006 pattern, but the 94 mgd volume. All other demand time series were unchanged.
Storage Accounting	
U	USACE Storage Accounting Approach
G	State of Georgia Storage Accounting Approach
H	Storage Accounting includes use of Hickory Log Creek to meet CCMWA demands. It assumes that releases from Hickory Log Creek Reservoir can be passed through Allatoona Reservoir.
O	Allow account overdrafts. Allatoona water account holders, CCMWA and Cartersville, are able to keep withdrawing to meet their demand, even if their storage account is empty.
Allatoona Reallocation	
Af	Allatoona's Guide Curve is raised, reallocating flood pool volume to the conservation pool to meet the 2050 demands.
A	Allatoona's Guide Curve is raised, reallocating flood pool volume to the conservation pool to meet the 2050 demands, and reallocating some USACE conservation storage to the water account holders.
APC Changes	
P	Operation sets were updated to include the changes recommended by Alabama Power Company.

D. Climate Change Alternatives

The PDT requested that two of the primary modeling alternatives be computed using inflows from three of the four climate change scenarios for the time window 01Jan 2044-31Dec2095. This represents a 50 year simulation centered around 50 years into the future from year 2020. (The time window for all the primary alternatives discussed in the previous section is 01Jan1939-31Dec2011.) The two alternatives selected were:

- Alternative 2, Future Without Project (FWOP)
- Alternative 11, Water Supply 6 + Modified Flood Operation 1 (A11_WS6MF).

The three climate change scenarios to be used were:

- Average Volume
- Highest Volume 1
- Lowest Volume

Development of the climate change hydrology is detailed in **Appendix C, Attachment 5. Climate Change Hydrology Development in Support of the Allatoona Coosa Reallocation Study**. The statistical adjustment program, STADJ, is used to adjust hydrologic model outputs so that they can be used to get quantitative impacts of future climate on stream flows. Global Climate Models, GCMs, provide hindcast and projected climate data that can drive hydrologic modeling. As their title indicates, GCMs model the entire globe and are not intended to be accurate or detailed enough for regional scale climate studies. The GCM results are therefore adjusted and spatially downscaled by various methods to make their results applicable for project scale hydrologic modeling. The Corps requires climate change studies to use a range of GCM models and Representative Concentration Pathways, RCPs, and the Corps supports a database of adjusted GCM results that include results from about 100 combinations of GCM and RCP. Study hydrologic models need to be run for numerous GCM/RCPs for both hindcast and projected periods. The Corps supported data base contains daily climate data for 1950-2099. The large number of GCM/RCP combinations and the long time period of daily flows results in hydrologic models that can rarely be detailed or calibrated enough to exactly match observed flows for the hindcast period. The model projected period flow results are therefore hard to quantitatively compare to actual observed flows. The STADJ program performs the same function for model flows that the climate bias and downscaling methods do for GCM results: The hydrologic model flows for the selected hindcast period are adjusted to match observed flows and these same adjustments are applied to the hydrologic model projected period flows. The adjusted projected period flows can then be directly compared to observed flows to quantify the impact of future climate projections and uncertainty

Appendix C, Attachment 5. Appendix 4 Selecting Representative GCM/RCPs Three climate change models were utilized to represent wet, normal and dry scenarios. The scenarios were labeled as following normal-average volume, wet-highest volume 1 and dry-lowest volume. A daily time series for all 36 ResSim locations was developed for each scenario for the time period 2013 to 2099. The following three GCM/RCP models selected to represent average annual, wettest part of year and driest portion of the year are:

Highest volumes: CESM1-CAM5 RCP 6.0

Average volumes: HadGEM2-AO RCP 4.5

Lowest volumes: MIROC-ESM-CHEM RCP 4.5

Appendix B of this report details the local flow computation for the Climate Change alternatives.

In addition, since evaporation was not estimated through 2099 as part of the climate change hydrology, the PDT asked that the six alternatives described above be run without evaporation. To reflect this, a zero evaporation rate time series was used for each reservoir's input evaporation.

The PDT also asked that the existing evaporation time series be extended by copying the evaporation from 1944-1995 to the period 2044-2095 and applying the extended evaporation to Alternative 11 using the Average climate change inflows. The modeling team actually copied a somewhat bigger time window to allow for a reasonable lookback window. Sentivity analysis of appling the evaporation rate show the greatest impact to Coosa River storage reservoirs Weiss and Logan Martin during extreme low periods for the months August and September. Downstream flow values are not impacted, however there is a slight reduction in reservoir storage during these periods.

The above produced seven climate change alternatives as outlined in Table 15:

Table 15. Climate Change Alternatives

	Future Without Project			Water Supply 6 + Modified Flood 1		
	Low	Average	High	Low	Average	High
No Evap	FWOP_CCLO	FWOP_CCAVG	FWOP_CCHI	A11_CCLO	A11_CCAVG	FWOP_CCHI
Extended Evap					A11_CCAVGE	

The simulation in which the alternatives listed in Table 15 were computed was named Climate Change and had the following time window specifications:

Lookback : 17Dec2043 2400
Start : 01Jan2044 2400
End : 31Dec2095 2400

VII. Sample Results and Reporting Updates

Each simulated alternative produces daily results including reservoir release (distributed by outlet) and storage, and streamflow at all junctions throughout the model. To assist with the analysis of so many results, scripted plot templates and report generation templates were created to provide on-demand illustrations of the state of various reservoir systems operations. Figure 113 shows the list of custom scripts used for plotting results, and Figure 114 shows the list of custom scripts used for building reports.

This section describes updates made related to the storing and processing of results. Model time series outputs were reduced to reduce the output file size. Updates were made to the post processing reports.

A. DSS Outputs

To reduce the file size of the each simulation's DSS output and the final ResSim watershed, the reach flow time series are left out of the results file. *HLC_DivOut to Canton* is the only reach that saves the flow data as shown in Figure 105. This reach was included because it is used for a calculation in a post-processing script.

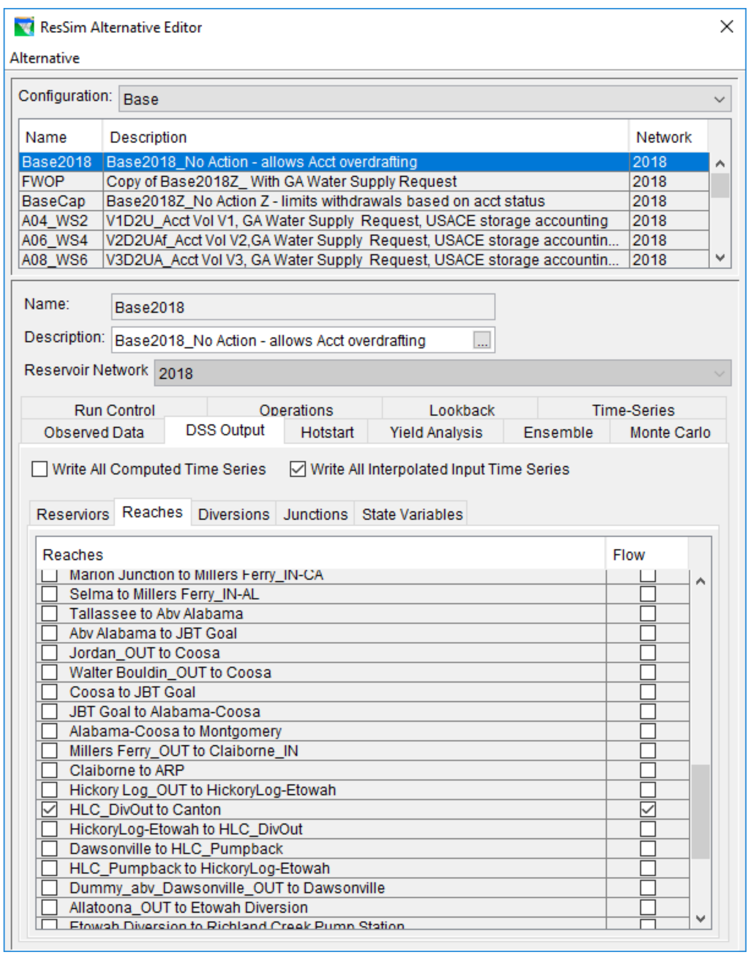


Figure 107. ***Reaches*** **tab under** ***DSS Output*** **tab of the ResSim Alternative Editor**

B. Release Decision Report

Figure 108 shows the release decision report for Allatoona from 26Oct2006 to 18Nov2006. The report shows the pool level is changing from Zone 2 to Conservation and then Flood Control zones. It also shows the net inflow, the active rule and the release from each outlet at each time step. This report type is available for each reservoir.

Release Decision Report: Allatoona

File Options

Alternative: Base2018--0:Base2018
Run: Base2018--0

Lookback: 06 Jan 1939, 0000
Start Time: 20 Jan 1939, 0000
End Time: 01 Jan 2012, 0000
Rule Key: GC=Guide Curve, RO=Release Override, EO=Elevation Override, ZB=Zone Boundary

Date-Time	Allatoona												
	Active Zone Elev (ft)	Net Inflow (cfs)	Allatoona Active Rule Flow (cfs)	-Dam Active Rule Flow (cfs)	-Dam L&O Uncontrolled Flow (cfs)	-Power Plant Active Rule Flow (cfs)	-Spillway Active Rule Flow (cfs)	-Sluice Active Rule Flow (cfs)	-Small Unit Active Rule Flow (cfs)	-CCM_Acct_Divs Active Rule Flow (cfs)	-CCM Active Rule Flow (cfs)	-Cartersville_Acc... Active Rule Flow (cfs)	-Cartersville Active Rule Flow (cfs)
26Oct2006, 24:00	829.72	1,203.23	1,092.28	996.11	150.00	631.11	0.00	0.00	215.00	74.70	74.70	21.47	21.47
	Zone2		MinRelease	MinRelease	Unctrl	PowerGC Z2 3hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
27Oct2006, 24:00	829.89	1,815.43	1,092.58	996.40	150.00	631.40	0.00	0.00	215.00	74.70	74.70	21.47	21.47
	Zone2		MinRelease	MinRelease	Unctrl	MinRelease	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
28Oct2006, 24:00	830.57	3,556.23	461.17	365.00	150.00	0.00	0.00	0.00	215.00	74.70	74.70	21.47	21.47
	Zone2		MinRelease	MinRelease	Unctrl	MinRelease	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
29Oct2006, 24:00	830.99	2,368.02	461.17	365.00	150.00	0.00	0.00	0.00	215.00	74.70	74.70	21.47	21.47
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
30Oct2006, 24:00	831.01	1,378.07	1,295.98	1,199.80	150.00	834.80	0.00	0.00	215.00	74.70	74.70	21.47	21.47
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
31Oct2006, 24:00	830.93	953.52	1,296.36	1,200.19	150.00	835.19	0.00	0.00	215.00	74.70	74.70	21.47	21.47
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
01Nov2006, 24:00	830.82	770.80	1,284.19	1,201.41	150.00	836.41	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
02Nov2006, 24:00	830.70	739.99	1,280.18	1,197.40	150.00	832.40	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z2 3hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
03Nov2006, 24:00	830.61	673.38	1,073.17	990.39	150.00	625.39	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	MinRelease	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
04Nov2006, 24:00	830.64	579.57	447.78	365.00	150.00	0.00	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	MinRelease	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
05Nov2006, 24:00	830.68	605.81	447.78	365.00	150.00	0.00	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
06Nov2006, 24:00	830.52	598.61	1,287.77	1,204.99	150.00	839.99	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
07Nov2006, 24:00	830.39	673.38	1,289.67	1,206.89	150.00	841.89	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
08Nov2006, 24:00	830.29	851.18	1,290.32	1,207.54	150.00	842.54	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
09Nov2006, 24:00	830.22	952.76	1,289.96	1,207.19	150.00	842.19	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
10Nov2006, 24:00	830.11	774.52	1,289.58	1,206.80	150.00	841.80	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	MinRelease	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
11Nov2006, 24:00	830.16	711.72	447.78	365.00	150.00	0.00	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	MinRelease	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
12Nov2006, 24:00	830.22	684.77	447.78	365.00	150.00	0.00	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
13Nov2006, 24:00	830.30	1,656.13	1,289.96	1,207.19	150.00	842.19	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
14Nov2006, 24:00	830.56	2,499.12	1,290.04	1,207.26	150.00	842.26	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
15Nov2006, 24:00	831.19	4,156.75	1,284.19	1,201.41	150.00	836.41	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		MinRelease	MinRelease	Unctrl	PowerGC Z1 4hrs Seasonal	MinRelease:Phys...	MinRelease	MinQ SmallUnit 215	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
16Nov2006, 24:00	833.34	11,598.33	1,268.18	1,185.41	150.00	820.41	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Conservation		GC	GC	Unctrl	GC	GC:PhysMaxCap	GC	GC:PhysMaxCap	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
17Nov2006, 24:00	834.22	6,161.56	1,788.59	1,705.81	150.00	1,340.81	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Flood Control		GC	GC	Unctrl	GC	GC:PhysMaxCap	GC	GC:PhysMaxCap	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...
18Nov2006, 24:00	833.96	3,428.49	4,746.99	4,664.22	150.00	4,299.22	0.00	0.00	215.00	62.42	62.42	20.36	20.36
	Flood Control		GC	GC	Unctrl	GC	GC:PhysMaxCap	GC	GC:PhysMaxCap	MinRelease	CCMWA Qo	MinRelease	Cartersville Qo...

Figure 108. Allatoona Reservoir Release Decision Report

C. ResSim Default Plots

ResSim allows easy viewing via built in plot types that can be opened directly from the simulation module. Below are default reservoir plots for Allatoona (Figure 109), Weiss (Figure 110), and Logan Martin (Figure 111). Results from the Base2018 alternative (green) and the A11_WS6MF alternative (blue) are shown in each plot, along with observed data (red). Likewise the default junction plot is shown in Figure 112 with the same alternatives and observed data timeseries. This plot is important for determining how changed operations may change the state line flow near Rome Coosa. In the sample plot, the A11 alternative plots on top of the Base 2018 alternative, indicating that the state line flow is changed very little.

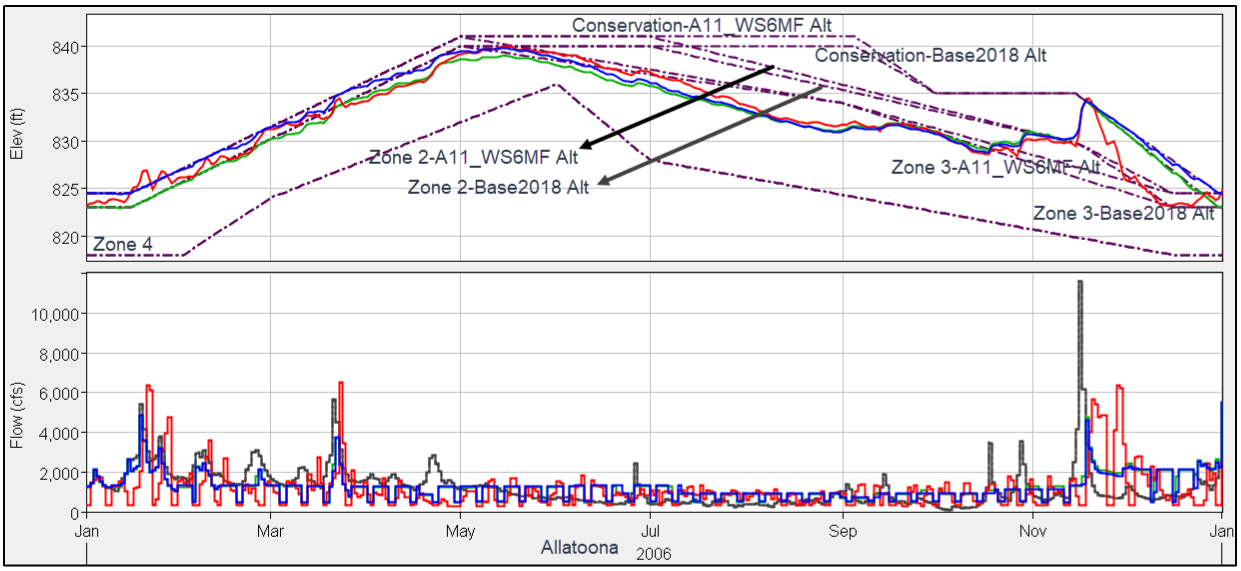


Figure 109. Allatoona Reservoir plot

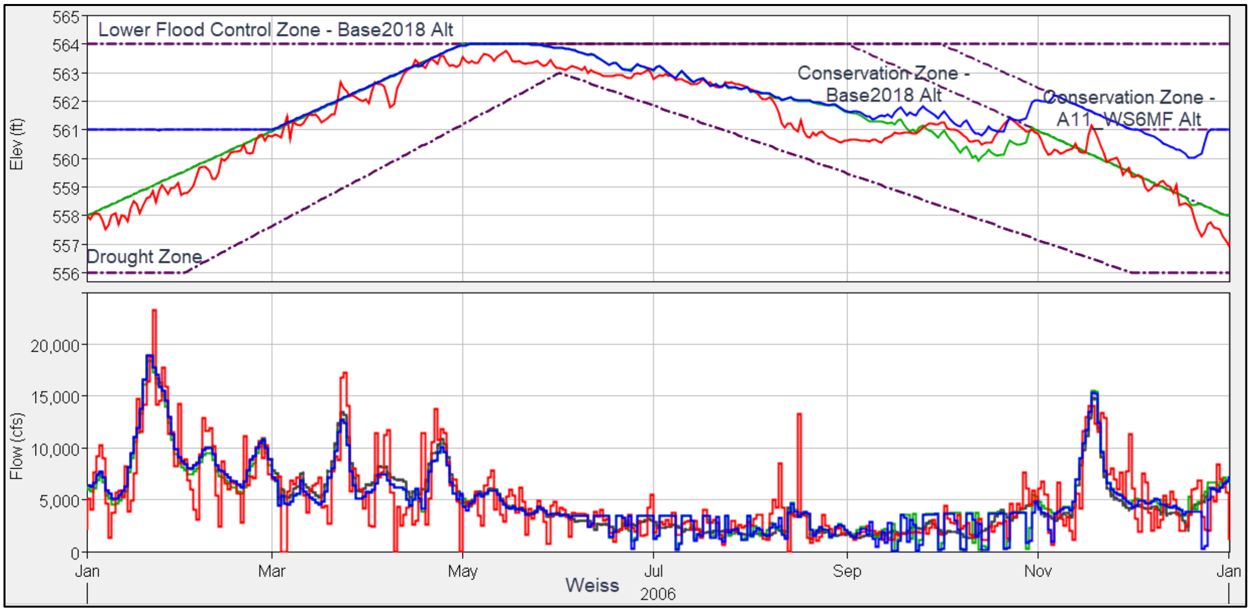


Figure 110. Weiss Reservoir plot

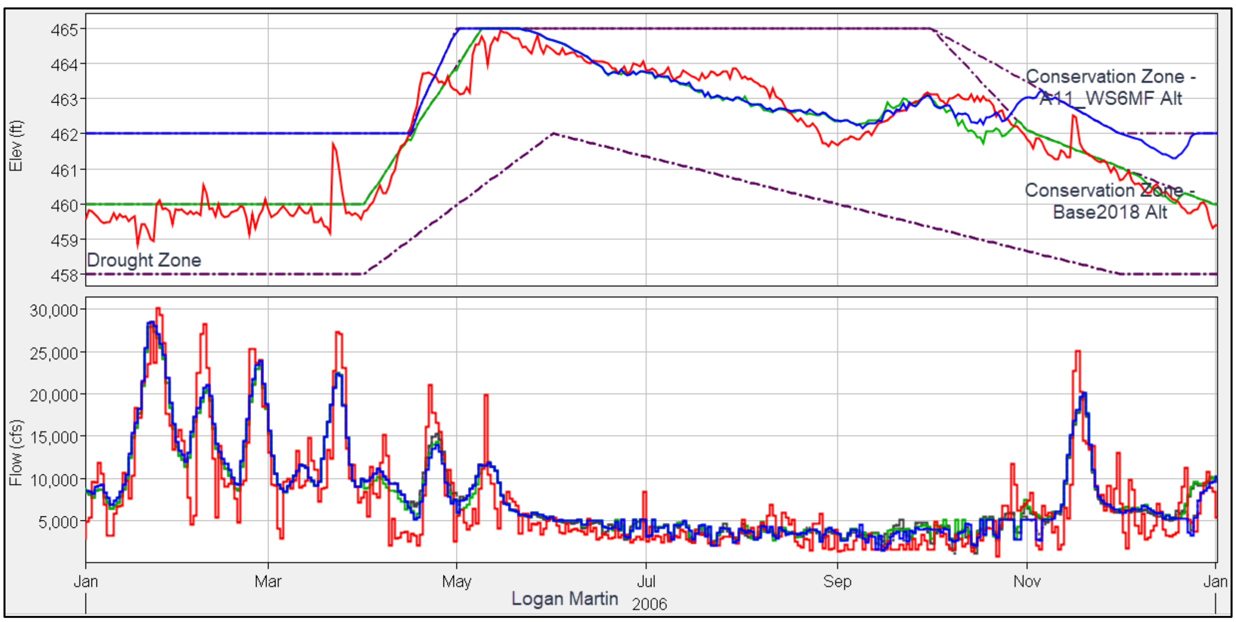


Figure 111. Logan Martin Reservoir plot

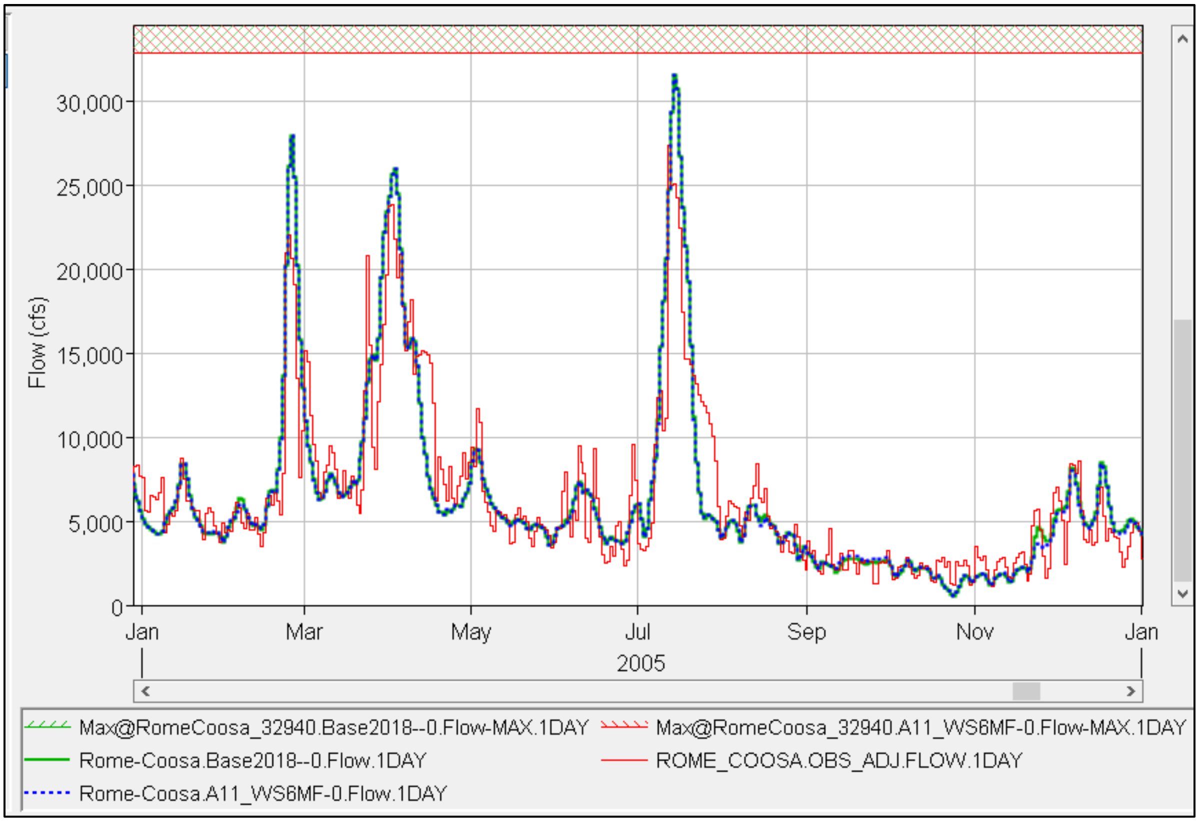


Figure 112. Rome Coosa junction plot

D. jeh Report

The "jeh Report" is a ResSim results report that is generated for alternatives in batch using the "jeh_reports_2018" post-processing script contained in the watershed. The report includes time series results that were requested by James Hathorn (jeh) to more easily conduct his results analysis. Here is the list of updates to jeh Report that were made for this study:

1. The report is updated to show Power Capacity instead of Capability. Capacity is the parameter that is of more importance to hydropower analysis.

2. Richland Creek Reservoir is added to the list of the reservoirs to save its elevation (ELEV) and outflow (FLOW-OUT) data.

3. The report is updated to show Allatoona-Dam Tailwater/FLOW instead of Allatoona_OUT/FLOW. This change should have no impact. Unlike the other reservoirs, which use their Pool/FLOW-OUT time series, Allatoona's flow was taken from its out node. This ensured the diverted outlet flows were not included. Switching to take the flow from the Dam Tailwater/FLOW will have the same effect.

E. Other Post Processing Scripts

Figure 113 shows the list of custom scripts used for plotting results, and Figure 114 shows the list of custom scripts used for building reports. Sample plots are shown in the following section.

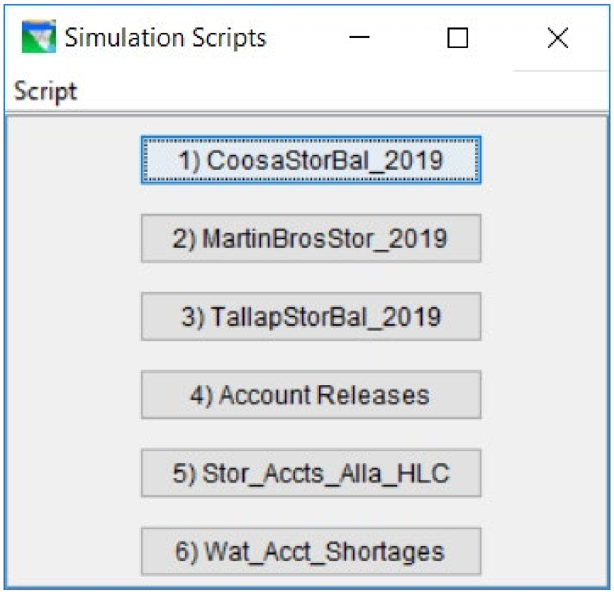


Figure 113. Simulation Scripts for Generating Plots

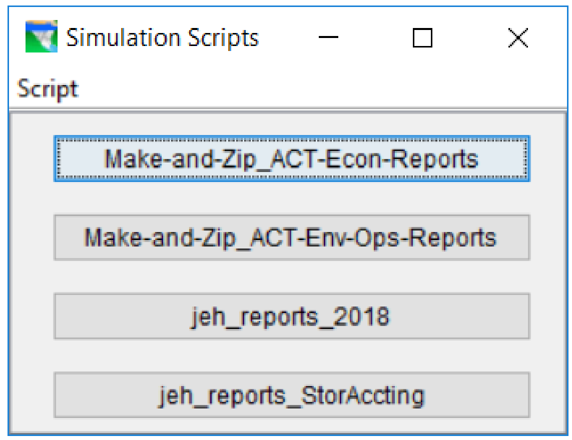


Figure 114. Simulation Scripts for Generating Reports

1. Coosa Storage Balance

The reservoirs on the Coosa River - Weiss, HN Henry, and Logan Martin - are operated together with the help of tandem rules. Weiss has a rule to operate in tandem with HN Henry, which in turn, has a tandem rule for Logan Martin. In order to maintain an even balance based on zone, an explicit balance was specified for the system of reservoirs, as shown in Figure 115. Each zone type is set up to balance at 100%, in the same manner that is shown for the Top of Dam zones.

The **CoosaStorBal2019** script plots the time series relevant to the balance of storage between the reservoirs. Table 16 lists the time series used in the plot, and Figure 116 depicts the resulting plot for the Coosa system for Alternative 11.

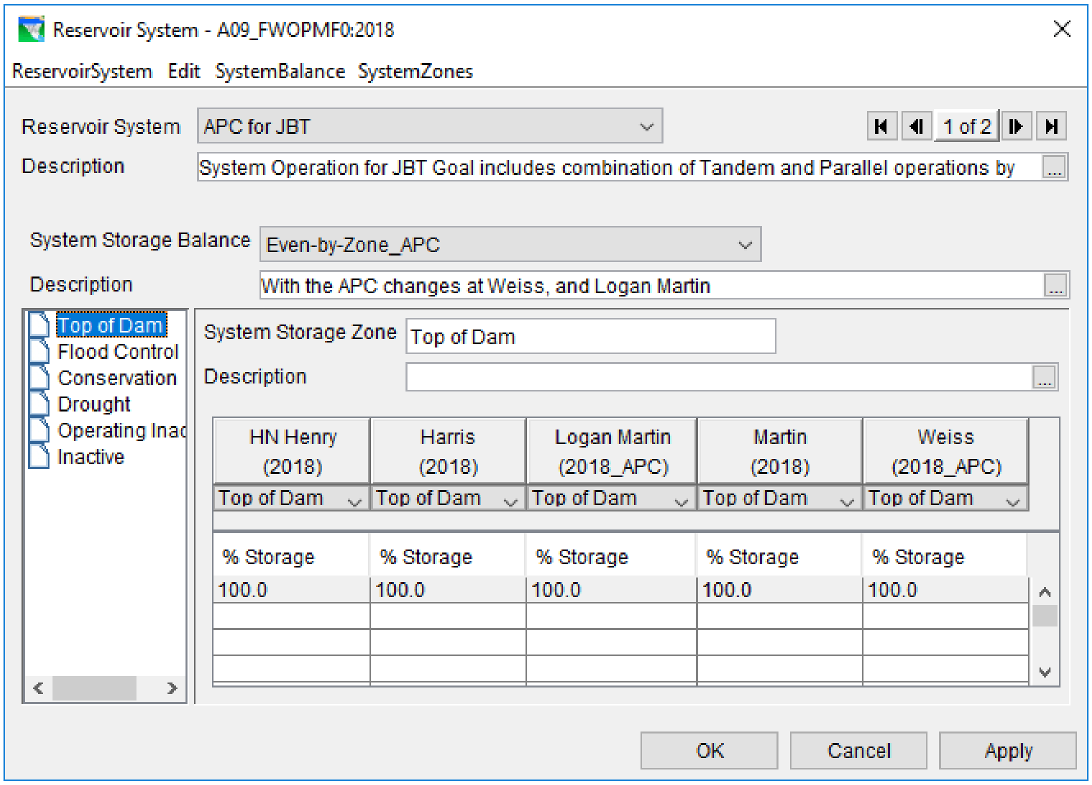


Figure 115. Alabama Power Company reservoir system balance

Table 16. Coosa Storage Balance Plot time series

Time Series	Description
DLR_DROUGHT_INTENSITY_LEVEL_rev	Revised Drought Intensity Level index. This measurement of the relative drought level impacts how restrictive operations will be.
Weiss PERCENT OF ZONE HN Henry PERCENT OF ZONE Logan Martin PERCENT OF ZONE	Percent full, per current zone. 0-100: drought zone 100-200: conservation zone 200-300: flood zone
J.D.MINIMUM	Flow at downstream location
MIN@JDMin	Minimum flow objective at downstream location
JBT GOAL	Flow at downstream location
MIN@JBTGoal	Minimum flow objective at downstream location

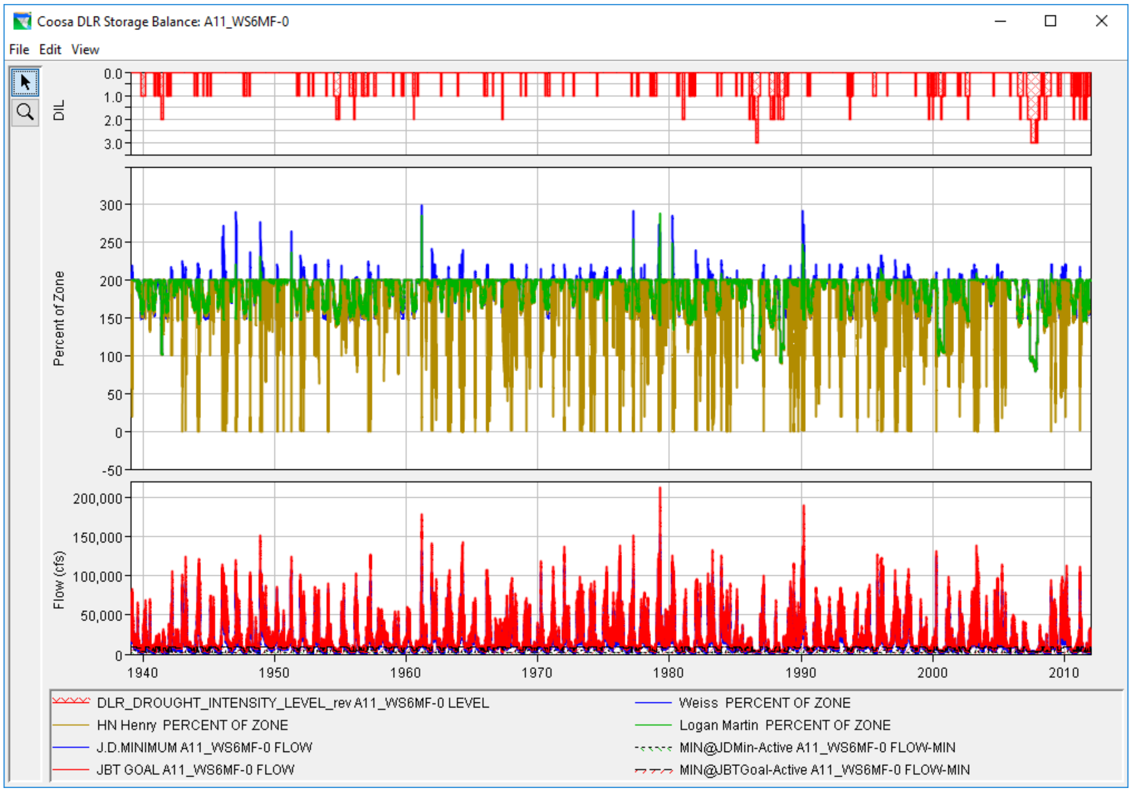


Figure 116. Coosa Balance scripted plot

2. Tallapoosa System Storage Balance

The reservoirs on the Tallapoosa River – Harris and Martin – are operated together with the help of tandem rules. Harris has a rule to operate in tandem with Martin. In order to maintain an even balance based on zone, an explicit balance was specified for the system of reservoirs, similar to the one for the Coosa system shown in Figure 115.

The **TallaStorBal_2019** script plots time series relevant to the storage balance of Harris and Martin. Table 17 lists the time series used in the plot, and Figure 117 depicts the resulting plot for the Tallapoosa system for Alternative 11.

Table 17. Tallapoosa Storage Balance Plot time series

Time Series	Description
DLR_DROUGHT_INTENSITY_LEVEL_rev	Revised Drought Intensity Level index. This measurement of the relative drought level impacts how restrictive operations will be.
Harris PERCENT OF ZONE	Percent full, per current zone. 0-100: drought zone 100-200: conservation zone 200-300: flood zone
Martin PERCENT OF ZONE	
J.D.MINIMUM	Flow at downstream location
MIN@JDMin	Minimum flow objective at downstream location
JBT GOAL	Flow at downstream location
MIN@JBTGoal	Minimum flow objective at downstream location

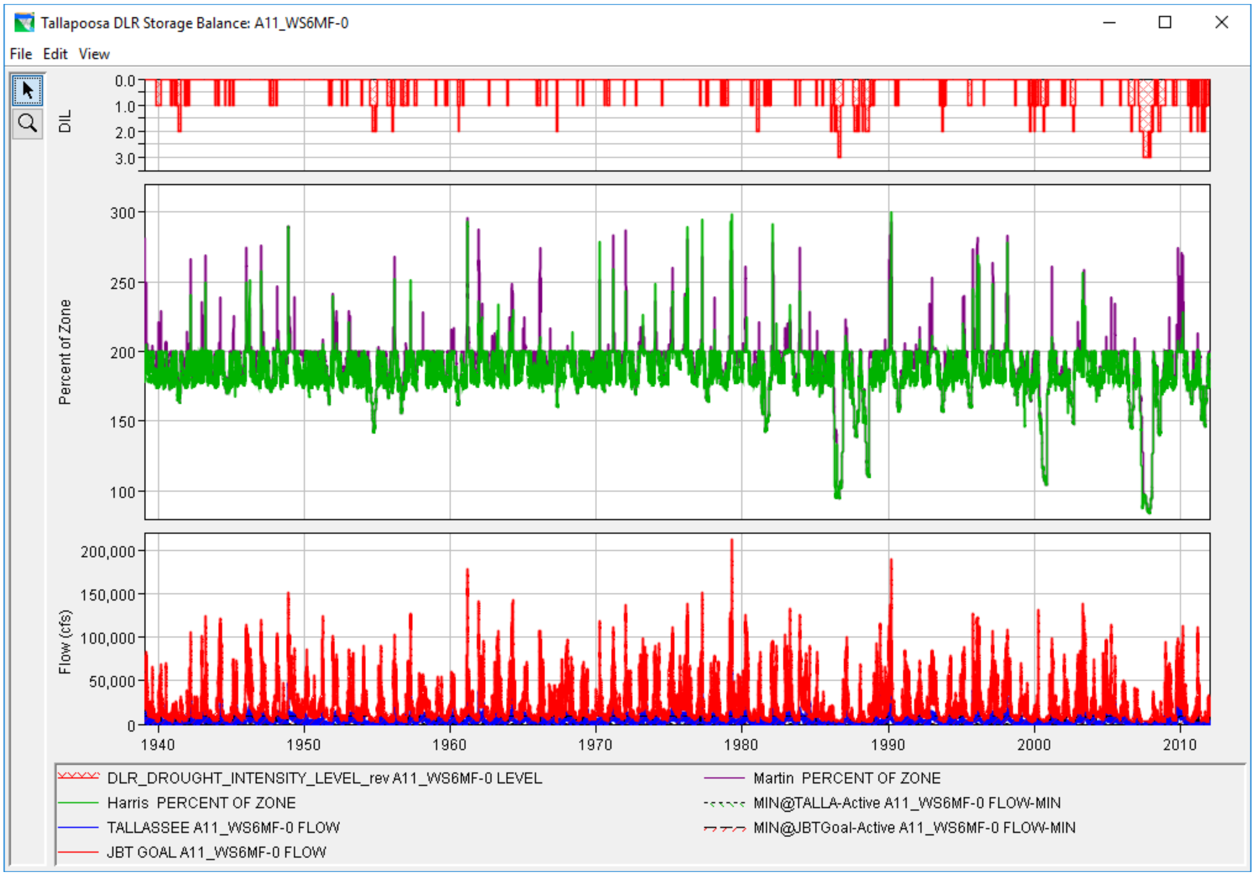


Figure 117. Tallapoosa Balance scripted plot

3. Logan Martin and Martin System Storage Balance

The **MartinBrosStor_2019** script plots time series relevant to the parallel system balance between Logan Martin and Martin Reservoirs. The zone-by-zone balance between Martin and Logan Martin is defined as part of the explicit balance that covers all five APC projects. Table 18 describes the time series used in the plots, and Figure 118 depicts the resulting plot for Alternative 11.

Table 18. Logan Martin and Martin Storage Balance Plot time series

Time Series	Description
DLR_DROUGHT_INTENSITY_LEVEL_rev	Revised Drought Intensity Level index. This measurement of the relative drought level impacts how restrictive operations will be.
Martin PERCENT OF ZONE	Percent full, per current zone. 0-100: drought zone 100-200: conservation zone 200-300: flood zone
Logan Martin PERCENT OF ZONE	
J.D.MINIMUM	Flow at downstream location
MIN@JDMin	Minimum flow objective at downstream location
JBT GOAL	Flow at downstream location
MIN@JBTGoal	Minimum flow objective at downstream location

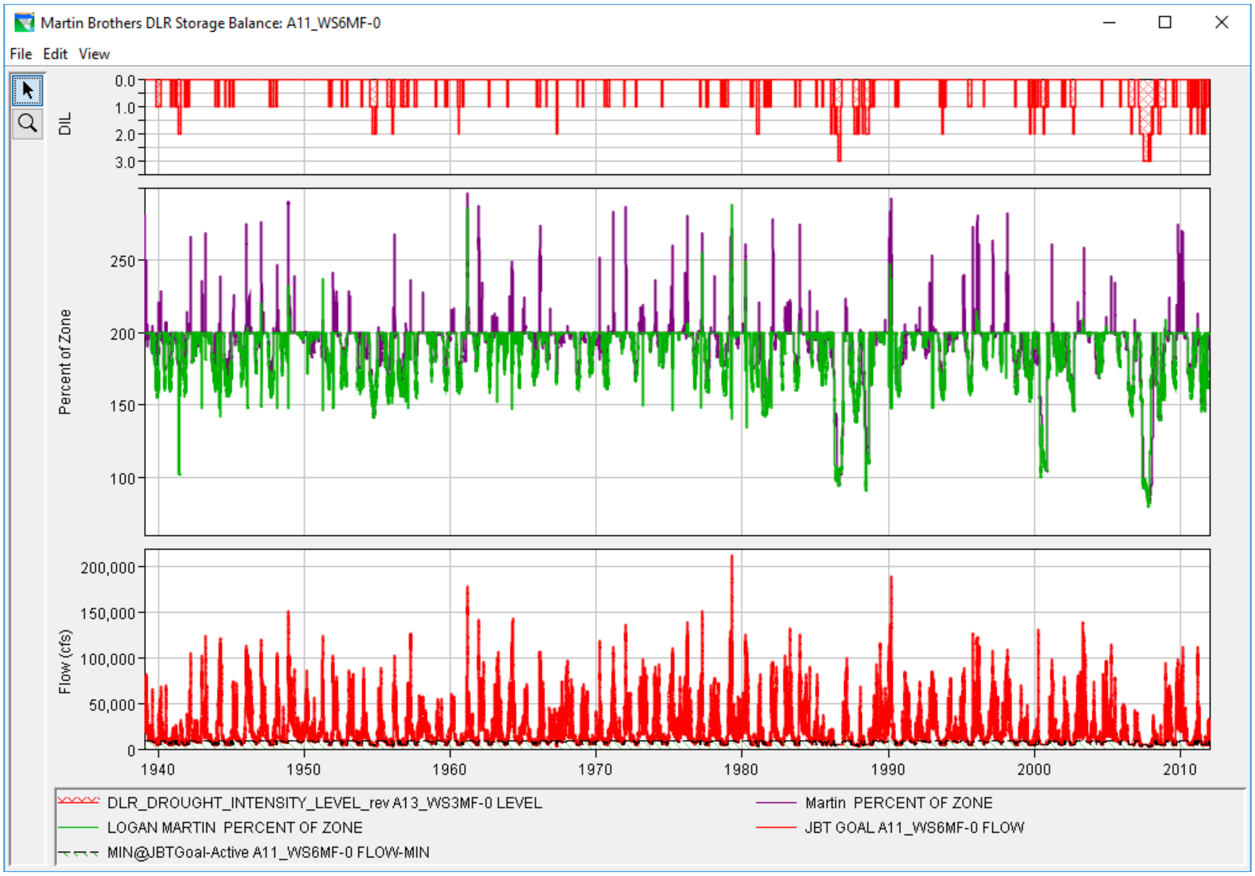


Figure 118. Martin and Logan Martin Storage Balance scripted plot

4. Account Releases

The **Account Releases** script creates two time series plots: The Allatoona account storage and release for CCMWA and Cartersville, and the Hickory Log Creek account storage and release for CCMWA. Table 19 lists the time series used, while Figures 119 and 120 show samples of the resulting plots.

Table 19. Allatoona and HLC Account Releases Plot time series

Time Series	Description
ALLATOONA_CCM_acct	Volume of water stored in CCMWA's account at Allatoona (AF)
ALLATOONA_Cartersville_acct	Volume of water stored in Cartersville's account at Allatoona (AF)
Total CCM Withdrawal	Total release for CCMWA (cfs)
ALLATOONA_Cartersville	Release from Allatoona for Cartersville (cfs)
HLC_CCM_acct	Volume of water stored in CCMWA's account at Allatoona (AF)
HLC_CCM_Q	Releases from HLC for CCMWA (cfs)
Etowah_Qin_to Canton	Flow in Etowah (cfs), which dictates how much water HLC can pump out of the river.

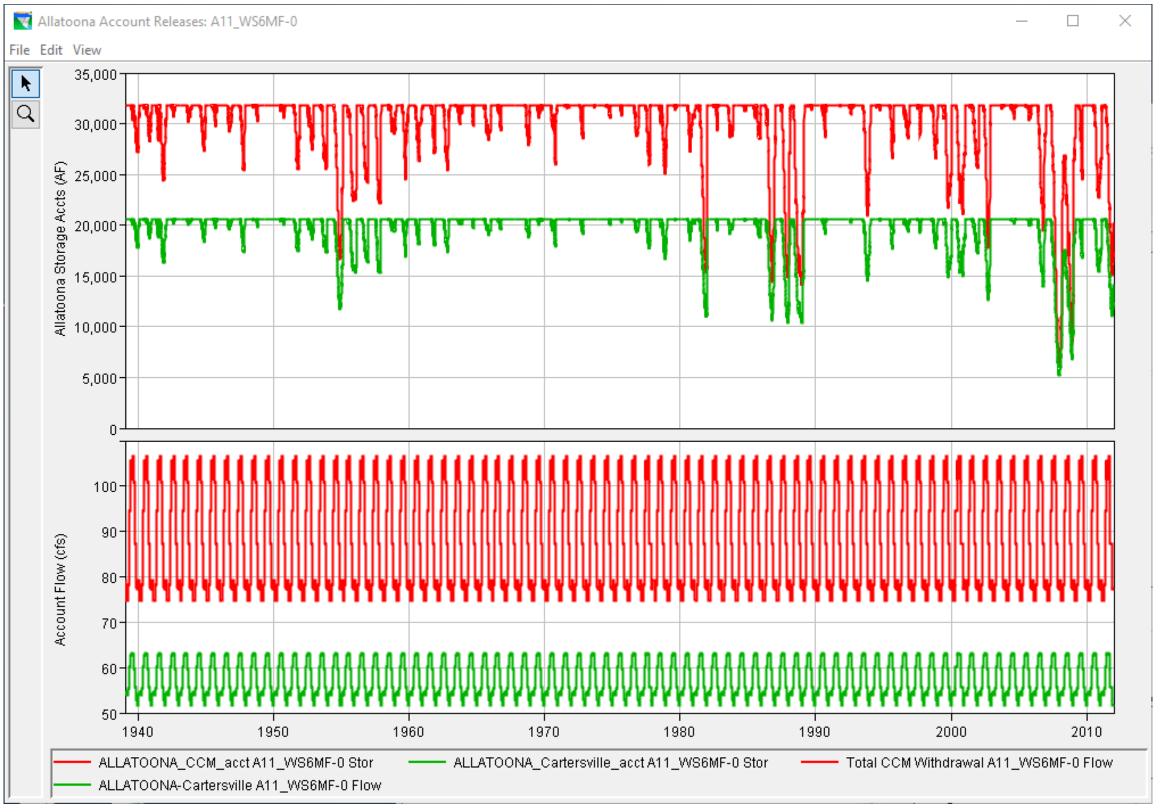


Figure 119. Allatoona account releases scripted plot

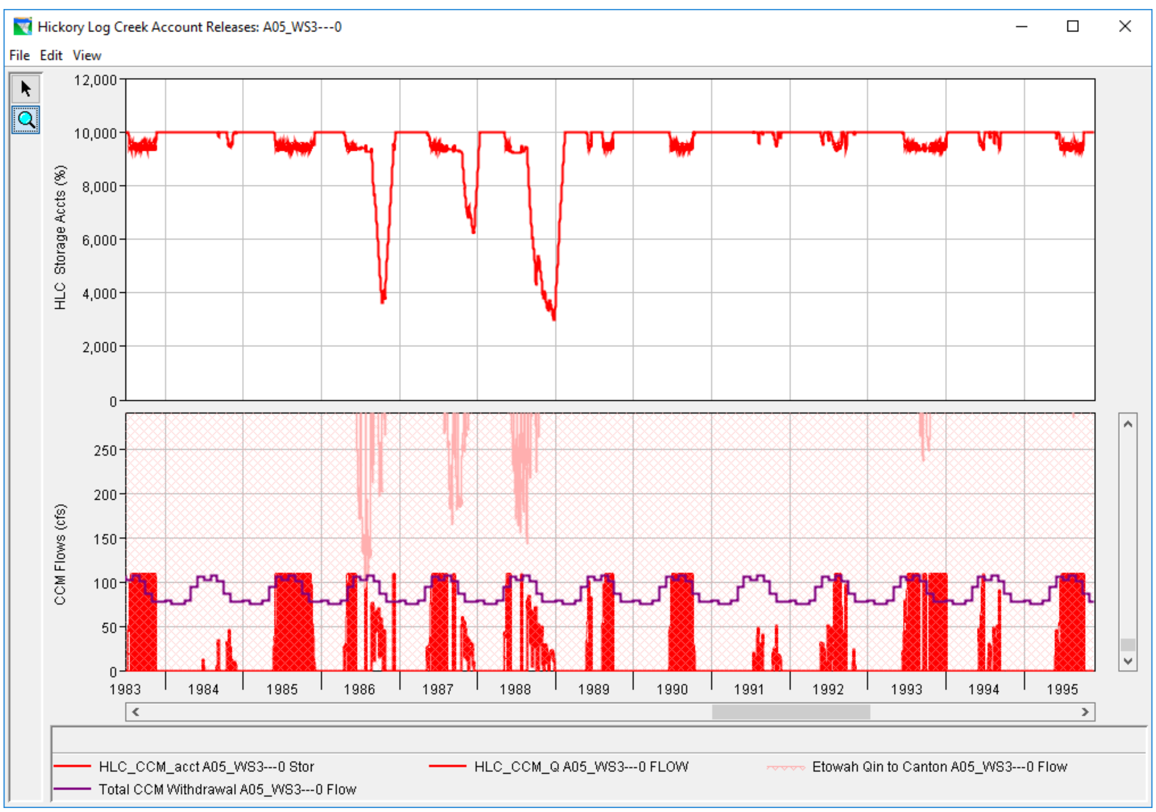


Figure 120. Hickory Log Creek account releases scripted plot

5. Additional Storage Accounting Scripts

The **Stor_Accts_Alla_HLC** script creates several additional plots relating to the water storage accounting at Allatoona and Hickory Log Creek. These can be helpful for close inspection of the storage accounting, but are not described in this report.

6. Water Account Holder Shortages

The **Wat_Acct_Shortages** script plots the time series of unmet demand for each of the water account holders at Allatoona and Hickory Log Creek. Table 20 lists the three time series used in the plot, and Figure 121 shows the Account Shortages plot for the Future Without Project alternative. Most of the alternatives modeled had no shortages.

Table 20. Shortages Plot time series

Time Series	Description
CCM Shortage	Total demanded daily flow NOT met in each timestep.
Canton Shortage	
Cartersville Shortage	

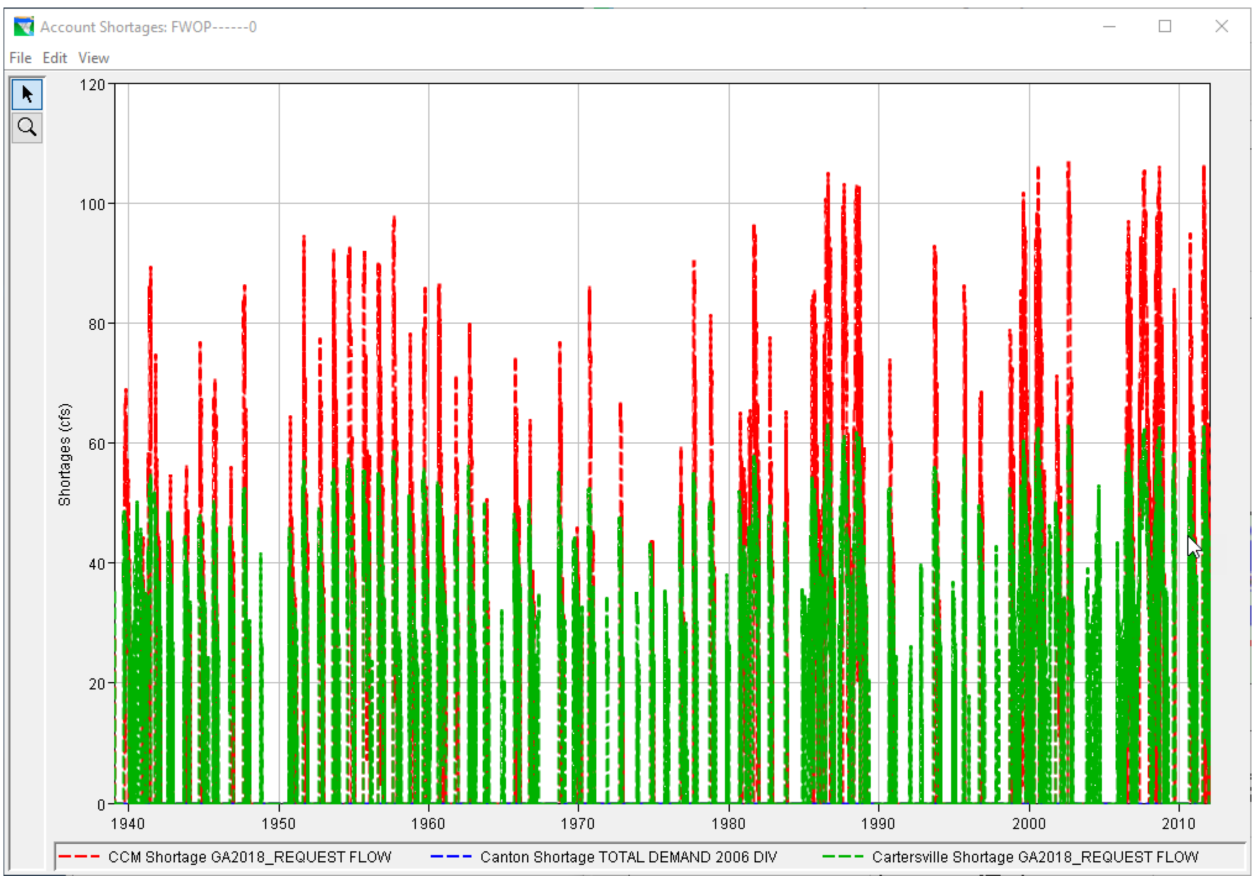


Figure 121. Account Shortages sample plot

VIII. References and Supporting Materials

Oke, A. Letter to Gene Hobgood, Mayor, City of Canton. 12 Sep. 2008. Re: *Surface Water Withdrawal Permits #028-1491-04 (Modified), #028-1491-05 (New)*. from the Georgia Department of Natural Resources.

- Describes modified permit for the withdrawal of water from the Etowah River at Canton (*#028-1491-04)* and the new permit to pump water from the Etowah River into Hickory Log Creek Reservoir (*#028-1491-05).*

Page, G.M. Letter to Col. Steven J. Roemhildt. 26 Aug. 2010. Re: *Hickory Log Creek Reservoir – Special Condition #15*. from the Cobb County-Marietta Water Authority.

- Details the proposed operation of Hickory Log Creek Reservoir.

Roemhildt, Col. S.J. Letter to Glen M. Page. 11 Sep. 2012. Re: June 22, 2012 *letter regarding whether CCMWA will be able to comply with Allatoona Water Storage Contract.* From the USACE, Mobile District.

- Discusses Allatoona storage contract and Hickory Log Creek. Notes CCMWA's desire for a reallocation study, but the Water Control Manual Update will be completed first.

Turner, J.H. Letter to Jo Ellen Darcy, Asst. Sec. of the Army for C.W. 24 Jan. 2013. Re: *Lake – Allatoona – Request for Final Agency Action*. From the Office of the Governor of the State of Georgia.

- Request to allow Hickory Log Creek releases for to be routed through Allatoona.

USACE, Mobile District. *Alabama-Coosa-Tallapoosa (ACT) Watershed. HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update. (Draft)* Mar. 2011.

- Documentation of the 2011 ACT ResSim model, in support of draft EIS.

USACE, Mobile District. *Alabama-Coosa-Tallapoosa (ACT) Watershed. HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update. Response to Comments.* Jul. 2014.

- Documentation of the 2014 ACT ResSim model – response to comments.

USACE, Mobile District. *Municipal, Industrial, Power and Agricultural Water Use Inventory. Comprehensive Study for the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa Basins. Vol. II: Surface Water Withdrawal Inventory.* Nov. 1994. p. 51

- Shows CCMWA's permit to withdraw from Allatoona reservoir.

USACE, Mobile District. Power point presentation. *Hickory Log Creek Dam Site Visit with Corrections*. 25 Jul. 2012.

- Gives physical descriptions of HLCR, outlet capacities, etc.

USACE, Mobile District. Section 134 – *Information Report. Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River Basins*. Sep. 2008. p. 28

- Gives a table of annual projected demands through the year 2031.

Zeng, W. Georgia EPD. Memo to the Director of Georgia EPD. Mar. 2018. Re: *Technical Analysis of Georgia's updated Water Supply Request in Allatoona Lake on the Coosa River Basin.*

Shabaan, W. Memo to Paulding County Board of Commissioners. May. 2018. Re: *New Surface Water Withdrawal Application #110-1424-01 (Modified), #028-1491-05 (New)*. From the Georgia Department of Natural Resources, Environmental Protection Division.

Modification of Flood Control Plans for Alabama Power Company Reservoirs Weiss and Logan Martin Coosa River, Alabama, Preliminary HEMP Results Technical Report December 31, 2018.

Paulding County_Richland Creek Reservoir_Final Permit_Etowah River.pdf

Appendix A. State Variables & Scripted Rules

Some state variables were updated or added for this study. Below is a list of those changed or new state variables (Table 21). In addition, there are special state variables that have been added for the purpose of creating an easy way to change compute options. These state variables are not computed as scripts. Instead they serve merely to add easily adjustable inputs to the Lookback tab of the ResSim Alternative Editor. These special state variables are listed in Table 22 and described more in the description of the water supply storage accounting script, which follows.

Table 21. New or updated state variables and scripted rules

Name	Units	Description
	State Variables	
WeissByPass	Flow (cfs)	Calculates minimum flow through Weiss trash gate
Martin_GC	Elev (ft)	Calculates the variable guide curve for Martin
Allatoona_USACE_Q	Volume (ac-ft)	End of previous period's release from Allatoona USACE's acct
Allatoona_USACE_acct	Volume (AF)	End of previous period's Storage in USACE's Allatoona account
GadsdenFloodOp	Flow (cfs)	Determines drawdown of HN Henry needed to relieve flooding at Gadsden
WadleyOPs	Flow (cfs)	Calculates a condition release at Harris
	Scripted Rules	
RestrictWeissSurcharge	Flow (cfs)	Calculates reduced surcharge releases at Weiss in response to conditions at Gadsden
RestrictLoganMartinSurcharge	Flow (cfs)	Calculates reduced surcharge releases at Logan Martin in response to conditions at Childersburg

Table 22. State variables used to set compute options using the Lookback setting

State Variable	Value	Description
_Alla_USACE_acct_size	-	volume of USACE account in AF
_Alla_CCM_acct_size	-	volume of CCM account in AF
_Alla_Cartv_acct_size	-	volume of Cartersville account in AF
_AllowOD	0	withdrawals are limited to the amount available in the account
	1	allow the accounts to be overdrafted.
_HLCops	0	"pure Amenity" = Pump/release to keep HLC full. Release minimum instream flow for creek
	1	operate only for Canton
	2	operate for Canton and CCMWA, using Allatoona as a flow through
_AcctingSettings	0	USACE accounting
	1	GA accounting
	2	USACE with variation - full credit for return flows
	3	GA with variation - do not vary account inflow based on % of current pool

A.1 Water Supply Storage Accounting

Water accounting for Allatoona is computed in the state variable **Accounting_HLCmain**. This state variable also manages the storage account diversions and returns and accounting for Hickory Log Creek Reservoir (HLCR) and the calculation of the pumped amount into HLCR. The **Accouting_HLCmain** master state variable determines the values for the following slave state variables:

State Variable	Units	Description
Allatoona_CCM_acct	Volume (AF)	End of previous period's Storage in CCM's Allatoona account
Allatoona_CCM_acct_int	Volume (AF)	Interim Storage in CCM's Allatoona account (withdrawals have been taken but inflows are not yet accounted for)
Allatoona_Cartersville_acct	Volume (AF)	End of previous period's Storage in Carterville's Allatoona account
Allatoona_Cartversville_ acct_int	Volume (AF)	Interim Storage in Cartersville's Allatoona account (withdrawals have been taken but inflows are not yet accounted for)
Allatoona_USACE_acct	Volume (AF)	End of previous period's Storage in USACE's Allatoona account
HLC_CCM_stor	Volume (AF)	End of previous period's Storage in CCM's HLC account
HLC_CCM_stor_int	Volume (AF)	Interim Storage in CCM's HLC account (withdrawals have been taken but inflows are not yet accounted for)
HLC_Canton_acct	Volume (AF)	End of previous period's Storage in Canton's HLC account
HLC_Canton_acct_int	Volume (AF)	Interim Storage in Canton's HLC account (withdrawals have been taken but inflows are not yet accounted for)
Allatoona_CCM_Q	Flow (cfs)	Release from CCM's Allatoona account
Allatoona_Cartersville_Q	Flow (cfs)	Release from Cartersville's Allatoona account
Allatoona_USACE_Q	Flow (cfs)	Release from Allatoona that is not being made for CCM or Cartersville.
HLC_CCM_Q	Flow (cfs)	Release from CCM's HLC account
HLC_Canton_Q	Flow (cfs)	Release from Canton's HLC account
Allatoona_CCM_Qreturn	Flow (cfs)	CCM's return flow to the Allatoona_IN junction (=31% total CCM withdrawals from all locations)
Cartersville_Cartv_Qreturn	Flow (cfs)	Cartersville's return flow to the Cartersville junction (=64% total Cartersville withdrawals from Allatoona)
HLC_Acct_OUT	Flow (cfs)	Total HLC release for CCM and Canton
HLC_PumpIN	Flow (cfs)	Pumped value from Etowah river into HLC
Canton_Etowah_WD	Flow (cfs)	Canton Total withdrawal from the Etowah at Canton (includes any release from Canton's HLC account)
CCM_Etowah_WD	Flow (cfs)	CCM Total withdrawal from the Etowah at Canton (includes any release from CCM's HLC account)

The Accounting_HLCmain state variable script existed in the 2012 study model, but several changes were made for the purposes of this work.

- A USACE storage account was added.

  Previously, only the CCM and Cartersville storage accounts were tracked, and all other releases were assumed to belong to USACE. This change should have little to no impact to the simulations. It would make a difference if the water account holders were low in their account storage, but otherwise USACE had a fully pool – in that case, all of inflow would be credited to the account holders.

- Added the option to change the storage accounting approach.
- Makes use of lookback values to set key variables instead of hardcoding them.

  In the earlier version of this script, settings were changed by creating alternative groups, and each new alternative had to be hardcoded into the script by adding it to an alternative group. An improved approach to toggling different settings for the script was to make use of the ability to set unique lookback values for each alternative.

- Since different alternatives have different sized conservation pool and storage accounts, the ability to change them has been placed as a setting in the Lookback tab of the Alternative Editor.

The following text steps through the Main part of the Accounting_HLCmain state variable script, describing the logic:

<u>ASSUMPTIONS</u>

- The approximation of natural flow in the Etowah may be off if HLCR stores inflow, but inflow is such a small value, this is not likely to make a difference.
- The system will be operated such that if there is limited water in the Etowah, Canton's demand is a higher priority than the demand to pump into HLCR. In the script, what is available to pump into HLCR is dependent on how much Canton takes downstream.
- If the demand at Canton were increased beyond the Etowah's ability to supply it, withdrawals would be made from HLCR for Canton.
- There is no routing between HLCR and Allatoona, and there is no lag in return flow for Canton, CCWMA, or Cartersville.
- If CCMWA had infrastructure to withdraw water from the Etowah, an assumed priority for meeting demand would need to be established. The script currently assumes that all demands would be met at Allatoona until the account reached "nearly" empty before withdrawals would be taken from the Etowah or HLCR.

<u>USE LOOKBACK VALUES to SET SOME KEY VARIABLES:</u>

Before making any calculations, some key settings are established using the lookback values of six special state variables. These values toggle different script behavior related to storage account sizes, storage accounting approach, and operations.

_Alla_USACE_acct_size

_Alla_CCM_acct_size

_Alla_Cartv_acct_size

_AllowOD – ***whether or not to allow account holders to overdraft accounts***

0 = limit withdrawals to the amount currently available in the account
1 = allow accounts to be overdrafted

_HLCops – how to operate Hickory Log Creek

0 = pure Amenity. Pump to stay full, releases for min instream Q
1 = only operating for Canton
2 = operation for Canton and CCMWA using Allatoona as a flow-through

_AcctingSettings – how to calculate the Allatoona storage accounting

0 = USACE accting
1 = GA accting
2 = USACE with variation
3 = GA accting with variation

The looback value of the **_AcctingSettings** state variable is then used to set three script variables in the Accounting_HLCmain script.

fullReturnCredit – whether to add all of returned flow to CCM's account or include it in inflow

0 = return flows are distributed as part of total inflow
1 = CCM gets full credit to its account for return flow

AcctVarInf - how to determine % of inflow to credit to the accounts

0 = Allatoona inflow % to accounts constant based on SUMMER Con pool volume
1 = Allatoona inflow % to accounts varies according to seasonally varying Con pool volume

ResetCon - when to assume all accounts are full

1 = Allatoona storage accounts are set to full when pool is at top of Con
0 = accounts are set to full when pool is at SUMMER top of Con

_AcctingSettings state variable		**Accounting_HLCmain** script's internal variables		
lookback value	Description of accounting approach	fullReturnCredit	AcctVarInf	ResetCon
0	pure USACE accounting (U)	0	0	0
1	pure GA accounting (G)	1	1	1
2	USACE with variation - full credit for return flows	1	0	0
3	GA with variation - do not vary account inflow based on % of current pool	1	0	1

If HLCR is operated as an Amenity Lake, it does not release to provide water for account holders. It pumps water from the Etowah only to make up for evaporation. While all alternatives allow Canton to use its account at HLCR, Canton's demand is never high enough to require releases from HLCR. Because Canton's demand is never greater than what can be met from the river naturally, HLCR never has to release water for Canton. Therefore, HLCR is effectively operated as an amenity flow-through reservoir for all alternatives. However, if the Canton demand were increased, this script would allow Canton to draw from its account at HLCR. For some alternatives, HLCR is also operated to meet CCMWA's demand. In those alternatives, HLCR releases for CCMWA are added to Allatoona's CCMWA account, so HLCR operates to support Allatoona.

The script was set up to make calculations based on one of two options: 1) either the Mobile District's storage accounting methodology, or 2) the State of Georgia storage accounting methodology. The _AllowOD allows no limit on CCMWA or Cartersville withdrawals from Allatoona. If _AllowOD = 1, CCMWA and Cartersville continue to draw water from Allatoona even when their storage accounts are empty, according to the Mobile District's storage accounting methodology.

SCRIPT LOGIC

The Accounting_HLCmain state variable script is commented using section numbers that allow the following description to pair easily with the script text and logic.

0. GET LOOKBACK SETTINGS

a. Allatoona ACCOUNTING Approach Settings

The lookback value of the ***_AcctingSettings*** state variable determines how to set the values of the internal accounting settings variables, each of which toggle different elements of the accounting calculations.

For all study alternatives, the accounting style is either purely USACE accounting, or purely the State of Georgia recommendation on accounting. However, it is possible to create alternatives that use variations on these approaches by setting the _AcctingSettings lookback to a value other than 0 (USACE) or 1 (Georgia).

*if (**_AcctingSettings == 0**) :* USACE accounting. Set these variables:

***fullReturnCredit* = 0 –** return flows are distributed as part of total inflow
AcctVarInf* = 0 – *Allatoona inflow % to accounts constant based on SUMMER Con pool volume
ResetCon* = 0 – *accounts are full when pool is at SUMMER top of Con

*if (**_AcctingSettings = 1**) :* Georgia accounting. Set these variables:

fullReturnCredit* = 1** – CCM gets full credit to its account for return flow***
AcctVarInf = 1 – Allatoona inflow % to accounts varies according to seasonally varying Con pool volume
ResetCon = 1 – accounts are full when pool is at top of Con

b. Get Storage ACCOUNT SIZES

The lookback values of these three state variables are the summer full volume of the accounts in acre-feet. The sum of these three is the total summer pool volume, which is dependent on the definition of the guide curve. The allocation of the pool to the different accounts varies depending on the level of demand being met and the type of storage accounting being used. These parameters are all determined up front for each alternative.

AllaUSACEsize = _Alla_USACE_acct_size
AllaCCMsize = _Alla_CCM_acct_size
AllaCartvsize = _Alla_Cartv_acct_size

c. Get OVERDRAFT Settings

Get the lookback value of the special state variable in order to determine whether or not to allow overdrafting from storage accounts.

_AllowOD

d. Get HLC Operation Settings

Get the lookback value of the special state variable in order to determine how to operate Hickory Log Creek Reservoir.

_HLCOps

1. INTIALIZATION - Initialize and Set Up Variables

a. Constants

Full summer pool storage values in acre-feet. For Allatoona, the account size values are used to set these.

Alla_USACE_acctFULL
Alla_CCM_acctFULL
Alla_Cartv_acctFULL
AllaTotAcctVol = ***AllaUSACEsize + AllaCCMsize + AllaCartvsize***
HLC_CCM_acctFULL = 9980.87 AF – 75% of HLC's Conservation Pool
HLC_Cant_acctFULL = 3326.96 AF – 25% of HLC's Conservation Pool

Hickory Log Creek Reservoir (HLCR) total volume when at Top of Conservation Pool (including inactive storage):

HLCTotVol = 17701.75 AF

Fraction of Storage belonging to each account holder

USACEa = ***AllaUSACEsize/AllaTotAcctVol***
CCMa = ***AllaCCMsize/AllaTotAcctVol***
CARTVa = ***AllaCartvsize/AllaTotAcctVol***
CCMh = 0.75

CANTh = 0.25

Conversion factor cfs-days to AF

cfs2AF = 1.9835

b. Inflows, Outflows, Return flows

QCantonLOC_cur – current Canton local
QCantonLOC_prev – previous Canton local
QHLC_in_cur – current HLCR local inflow (0.016xCantonLOC)
QHLC_in_prev – previous HLCR local inflow (0.016xCantonLOC)

QRT_Cartv_cur – current Cartersville return flow
QRT_CCM_cur – current CCM return flow

QAlla_in_prev – previous Allatoona inflow
QAlla_out_prev – previous Allatoona total release

QHLC_dam_prev – previous Hickory Log Creek release from Dam
QHLC_PumpINprev – previous Hickory Log Creek pump inflow

c. Elevation, Storage

Alla_elev_prev – previous Allatoona elevation
HLC_stor_prev – previous Hickory Log Creek Reservoir storage

d. Evaporation

Evaporation is stored as a negative when precipitation exceeds evaporation.

QAlla_evap_prev – previous Allatoona evaporation
QHLC_evap_cur – current HLCR evaporation
QHLC_evap_prev – previous HLCR evaporation

e. Demands

QCCMdemand **–** current Cobb County-Marietta Water Authority (CCMWA) demand
QAlla_Cartvdemand – current Cartersville demand (always withdrawn from Allatoona)
QCantondemand **–** current City of Canton demand

f. Initialize Storage Accounts

Allatoona has two water supply storage accounts, CCMWA and Cartersville. The rest of the volume of conservation storage is used by the Corps to fulfill multiple authorized purposes, excluding the CCMWA and Cartersville accounts. This model's version of the script was updated to explicitly track the Corps' account.

Alla_CCM_acct_prev – previous CCMWA storage in account at Allatoona
Alla_Cartv_acct_prev – previous Cartersville storage in account at Allatoona
Alla_USACE_acct_prev – previous USACE storage in account at Allatoona

Hickory Log Creek Reservoir has two water supply storage accounts, CCMWA and Canton. The conservation pool is divided between these two accounts, even in alternatives in which they are not actively being drawn upon.

HLC_CCM_acct_prev – previous CCMWA storage in account at HLCR
HLC_Cant_acct_prev – previous Canton storage in account at HLCR

These account balances are interim values written out by the script in the previous timestep and do not yet include the inflow for the last time period.

Although a reasonable approximation of the current timestep's inflow can be obtained, it is not known with certainty until the end of the timestep. Therefore, the final value calculated by the state variable isn't always the same as the value that is calculated when the relevant compute block is finished. When the relevant compute block (the one that includes Allatoona and HLC) finishes, the diversion values and the pumpback values are set in the model, but the final values written to DSS may differ, and in fact, do differ in some circumstances.

Therefore the interim storage values from the last time step are retrieved, and then in Step 2, they are adjusted to set the final value that reflects the inflow.

Alla_CCM_acct_int – interim CCMWA storage in account at Allatoona
Alla_Cartv_acct_int – interim Cartersville storage in account at Allatoona
HLC_CCM_acct_int – interim CCMWA storage in account at HLCR
HLC_Canton_acct_int – interim Canton storage in account at HLCR

g. Update USACE Storage Account

USACE storage account it is not known until the next timestep, after release decisions have been made.

QAlla_CCM_prev – previous CCMWA release from its account at Allatoona
QAlla_Cartv_prev – previous Cartersville release from its account at Allatoona
QAlla_USACE_prev – previous USACE release from Allatoona is determined by taking the total previous release and subtracting the release for CCMWA and Cartersville.

2. STORAGE ACCOUNTING – BEGINNING OF TIMESTEP - Determine the storage in the accounts at the end of previous time-step based on refill values.

HLC inflow can be known or reasonably approximated, but current inflow to Allatoona is unknown. Only the previous value is known with certainty. Additionally, sometimes the actual HLC pump value is different than what was calculated in the last compute of the state variable.

So, today's release is based on yesterday's ending storage, not including today's inflow.

The current inflow is added at the beginning of the next timestep and the resulting storage is saved for the end of the previous timestep.

a. Calculate the HLC storage at the end of the previous time step

Refill from previous timestep = inflow - evap - main gate releases + pumped inflow. (Anything withdrawn from the storage accounts in this timestep is managed at the end of the script.)

HLC_acct_refill = (HLC_Qin_prev - QHLC_evap_prev - QHLC_dam_prev + QHLC_PumpINprev)

HLC has two accounts, CCMWA and Canton. Distribute the inflow to the accounts in a 25/75 split.

HLC_CCM_refill = 0.75*HLC_acct_refill
HLC_Cant_refill = 0.25*HLC_acct_refill

If there is more inflow than needed for one account, the other account gets the excess added to their proportion of the inflow.

*if 0.75*HLC_acct_refill > (HLC_CCM_acctFULL- HLC_CCM_acct_prev) :*
    HLC_CCM_refill *= (HLC_CCM_acctFULL - HLC_CCM_acct_prev)*
    HLC_Cant_refill *= HLC_acct_refill - HLC_CCM_refill*

*if 0.25*HLC_acct_refill > (HLC_Cant_acctFULL - HLC_Cant_acct_prev) :*
    HLC_Cant_refill *= (HLC_Cant_acctFULL - HLC_Cant_acct_prev)*
    HLC_CCM_refill *= HLC_acct_refill - HLC_Cant_refill*

Prevent accounts from going negative. (probably unnecessary.)

CCM acct is greater of 0 and previous balance + 75% refill.

HLC_CCM_acct = max(0, (HLC_CCM_acct_prev + HLC_CCM_refill))

Canton acct is greater of 0 and previous account + 25% refill.
HLC_Cant_acct = max(0, (HLC_Cant_acct_prev + HLC_Cant_refill))

Prevent accounts from overtopping FULL.
HLC_Cant_acct = min(HLC_Cant_acctFULL, HLC_Cant_acct)
HLC_CCM_acct = min(HLC_CCM_acctFULL, HLC_CCM_acct)

b. Store HLC account values for previous timestep

HLC_CCM_acct_SV = network.getStateVariable("HLC_CCM_acct")
HLC_CCM_acct_SV.setValue(prevRTS, HLC_CCM_acct)
HLC_Cant_acct_SV = network.getStateVariable("HLC_Canton_acct")
HLC_Cant_acct_SV.setValue(prevRTS, HLC_Cant_acct)

c. Calculate Allatoona account storage at the end of the previous time step

Evaporation is taken out of inflow and must be divvied up to the accounts. (Note, negative evaporation represents precipitation.)

Alla_acct_refill = (QAlla_in_prev - QAlla_evap_prev)*cfs2AF

Return flow credit is handled differently depending on the fullReturnCredit setting. If CCMWA should get full credit for its return flow, add the value of its return flow directly to its account and subtract that value from the total inflow being used to refill the accounts.

if fullReturnCredit == 1:
  Alla_CCM_acct_prev = *Alla_CCM_acct_prev +*
    *QAlla_CCM_Qreturn_prev*cfs2AF*
  Alla_acct_refill = *Alla_acct_refill - QAlla_CCM_Qreturn_prev*cfs2AF*

Inflow is distributed based on proportion of storage belonging to each account holder. If there is more inflow than needed for one account, the other user account and the Corps share it (proportional to their pool %). The script was updated to use a function in order to take the inflow value and distribute it proportionally, then check to see if any accounts were overfilled, and if so take that excess and iterate until all inflow has been distributed. This refill function envisions and refers to the accounts as "buckets" of water.

The Allatoona refill function takes four input variables:

INvol - the total inflow volume
STORaccts - array of the previous storage in each of the three accounts
MAXaccts - array of the maximum storage in each of the accounts
dists - array of the fraction of total storage belonging to each of the accounts

```
def refill_Alla(INvol, STORaccts, MAXaccts, dists):
 while True:

   # Lower any over-full buckets to their full amount, and put the excess into
   # the input amount.  Furthermore, if an acct is full, zero out its
   # distribution fraction since it shouldn't receive any more input.
   full_count = 0
   for i, qty in enumerate(STORaccts):
    if qty >= MAXaccts[i]:
     full_count += 1
     dists[i] = 0
     INvol += qty - MAXaccts[i]
     STORaccts[i] = MAXaccts[i]

   # If all the accounts are full, or if there is nothing to input to them, then we are done.
   if (full_count == len(STORaccts)) or (INvol == 0):
    # We finished distributing the inputs to the buckets.  finally put rest in USACE
    STORaccts[0] = STORaccts[0] + INvol
    break

   # Distribute the input amount to the buckets based on their distribution fractions.
   dists_sum = sum(dists)
   for i, dist in enumerate(dists):
    STORaccts[i] += INvol * (dist / dists_sum)

   # We finished distributing the inputs to the buckets.
   INvol = 0

 # Return the new bucket quantities, and any excess input.
 return STORaccts #, INvol
```

The Allatoona refill function returns an array of the accounts' storages after refill.

When using Georgia's approach to storage accounting, the inflow distribution varies with the top of the guide curve. For USACE storage accounting, this value does not vary. Therefore the fractions for each account are recomputed at every timestep if the varying inflow is toggled on.

if AcctVarInf == 1 :
Fraction of Storage belonging to each account holder changes with changing guide curve.
varAllaTotAcctVol = AllaTopCon_stor_prev - AllaTopInactive_stor_prev
varAllaUSACEsize = varAllaTotAcctVol - AllaCCMsize - AllaCartvsize
USACEa = varAllaUSACEsize/varAllaTotAcctVol
CCMa = AllaCCMsize/varAllaTotAcctVol
CARTVa = AllaCartvsize/varAllaTotAcctVol

RefilledStorAccts – array of the new storages in each of the accounts.
RefilledStorAccts = refill*_Alla(Alla_acct_refill,*
[Alla_USACE_acct_prev,Alla_CCM_acct_prev,Alla_Cartv_acct_prev],
[Alla_USACE_acctFULL,Alla_CCM_acctFULL,Alla_Cartv_acctFULL],
[USACEa,CCMa,CARTVa])

Check the state of the pool to determine whether or not accounts should be reset to the full level.

if ResetCon == 0 :
*A*ccounts are to be set to full when Allatoona is at the top of the summer pool.
Alla_Con_Max = maximum value of the top of con pool (summer level)
if Alla_elev_prev >= Alla_Con_Max :
Alla_CCM_acct = Alla_CCM_acctFULL
Alla_Cartv_acct = Alla_Cartv_acctFULL
Alla_USACE_acct – make this whatever is left over.

if ResetCon == 1 :
Accounts are to be set to full when Allatoona is at the top of the guide curve.
Alla_Con_prev = previous value of the top of con pool
if Alla_elev_prev >= Alla_Con_prev :
Alla_CCM_acct = Alla_CCM_acctFULL
Alla_Cartv_acct = Alla_Cartv_acctFULL
Alla_USACE_acct – make this whatever is left over.

d. Store Allatoona account values for previous timestep

```
Alla_CCM_acct_SV = network.getStateVariable("Allatoona_CCM_acct")
Alla_CCM_acct_SV.setValue(prevRTS, Alla_CCM_acct)
Alla_Cartv_acct_SV =
    network.getStateVariable("Allatoona_Cartersville_acct")
Alla_Cartv_acct_SV.setValue(prevRTS, Alla_Cartv_acct)
Alla_USACE_acct_SV =
    network.getStateVariable("Allatoona_USACE_acct")
Alla_USACE_acct_SV.setValue(prevRTS, Alla_USACE_acct)
```

3. ETOWAH FLOW - Determine the flow coming into the HLC Pump location and Canton, which are required to pass the minimum of natural flow or 7Q10

An estimate of the current flow in the Etowah River at the HLC Pump and at Canton can be determined (Figure A.122). This will allow for the determination of how much flow is available to be taken from the Etowah at Canton to meet Canton and CCM demands, and how much can be pumped out of the Etowah for the purpose of filling HLC. Each location is required to pass the lesser of natural flow or 7Q10 flow.

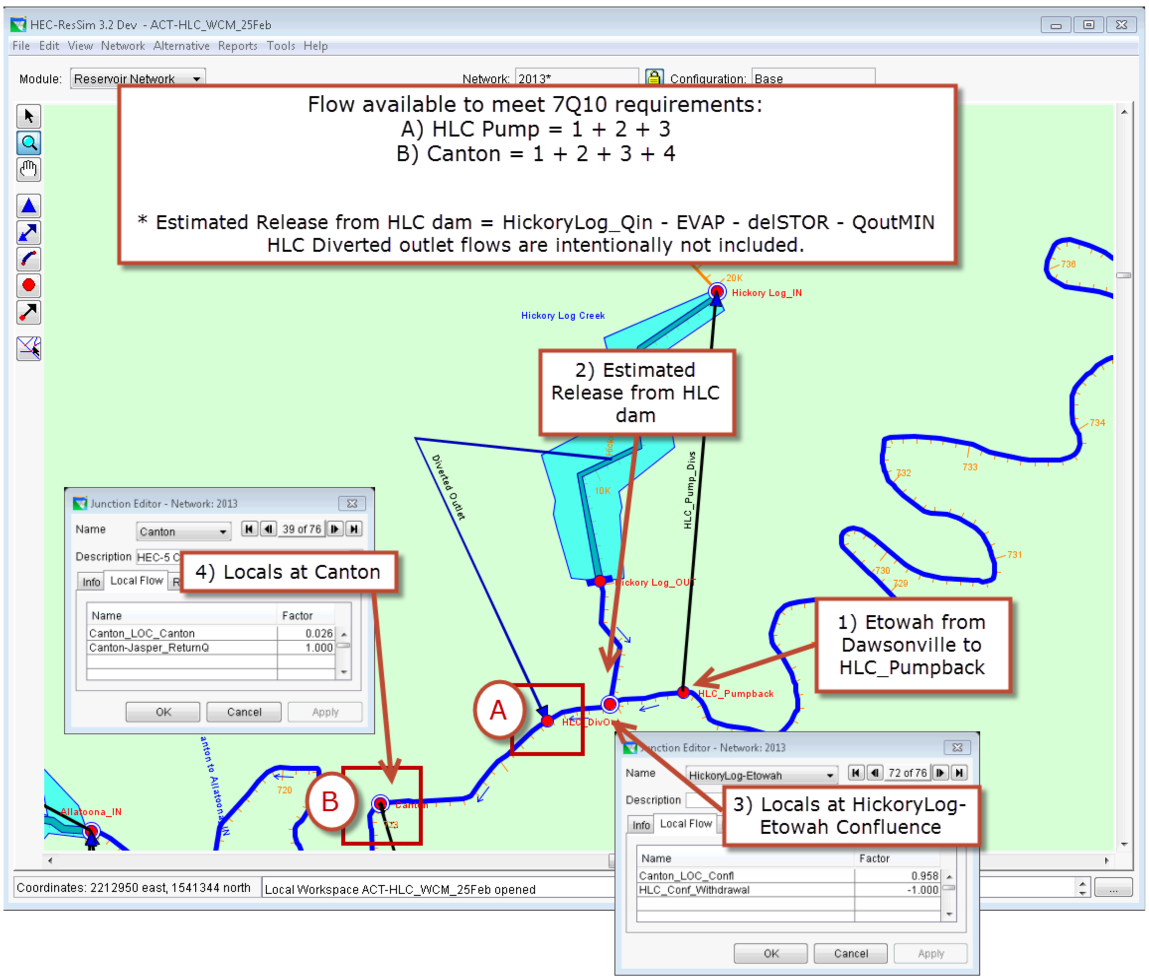


Figure A.122. Network showing HLC calculations

a. Get known components of Etowah flow in the HLC area.

HLCFillvol_cur - volume needed to fill HLCR

Yesterday's HLCR storage will determine if any of today's inflow will be needed to fill.

HLCFillvol_cur = HLCTotVol - HLC_stor_prev
QHLC_out_REQ*- minimum required release from HLCR*

HLC must release the lesser of inflow or the instream 7Q10 of 3.5 cfs.

QHLC_out_REQ = min(3.5,QHLC_in_cur)

***QHLC_out_est* -** Estimated current release from HLCR

The initial estimated outflow from HLCR is the local inflow – evaporation – Δ storage – minimum out, where

Δstorage = Full volume – prev volume

Estimated outflow is then the maximum of the initial estimated outflow and the minimum required outflow:

QHLC_out_est = max[(QHLC_in_cur - QHLC_evap_cur - HLCFillvol_cur/cfs2AF), (QHLC_out_REQ)]

QEtowahfromDawsonv_cur – current Etowah flow from Dawsonville to confluence

QHLCConfWD_cur – current withdrawal from confluence

QJasperRQ_cur – current Jasper return flow at confluence

QHLCConfLOC_cur – current local inflow at confluence inflow (0.958xCantonLOC)

QCantonLOC_Canton_cur – current local inflow at Canton inflow (0.026xCantonLOC)

b. Estimate flow that will be available to pump from the Etowah while passing the 7Q10.

Etowah Qin @ Pump is what is coming from the Etowah at Dawsonville + what is being released from HLC + local and diversion at the confluence. Although the Pump is being *modeled* upstream of the HLC-Etowah confluence, the pump is actually downstream. So we are looking at the flows at the diverted outlet junction.

QEtowah2PumpIN_cur = *QEtowahfromDawsonv_cur* + *QHLC_out_est* + *QHLCConfLOC_cur* - *QHLCConfWD_cur*

Canton is required to pass the lesser of inflow & 300 cfs (7Q10)

QHLCpumpIN_passbyREQ = min(300, QEtowah2PumpIN_cur)

So what is available to the pump is what is left over after the required amount is passed.

QHLCpumpIN_AVAIL = QEtowah2PumpIN_cur - QHLCpumpIN_passbyREQ

c. Estimate flow that will be available to withdraw at Canton while passing the 7Q10.

Etowah inflow at Canton is what is coming from the Etowah at Dawsonville + what is being released from HLC + local inflows, return flows, and diversions.

Any flows released from HLC's accounts will not be counted, because they will be taken directly out at Canton.

QEto*wah2CantonIN_cur = QEtowahfromDawsonv_cur + QHLC_out_est + QHLCConfLOC_cur - QHLCConfWD_cur + QCantonLOC_Canton_cur + QJasperRQ_cur*

Canton is required to pass the lesser of inflow & 250 cfs (7Q10)

QCanton_passbyREQ = min(250, *QEtowah2CantonIN_cur*)

So what is available to withdraw at Canton is what is left over after the required amount is passed.

QEtowah2CantonIN_AVAIL *= QEtowah2CantonIN_cur - QCanton_passbyREQ*

d. CITY OF CANTON - withdrawal from the Etowah @ Canton

Calculate how much the City of Canton will take from the Etowah. Withdrawal occurs even if HLCR has no Canton acct.

The City of Canton is permitted to take up to 28.9 cfs, as long as the 7Q10 flow (250 cfs) is passed downstream, and it is permitted to take 8.4 cfs, regardless of what is passed downstream. Therefore, in order to withdraw in excess of 8.4 cfs, the flow leaving Canton must be no less than (250 - 8.4 cfs). Demand that cannot be met with what is left in the river will be drawn from the Canton HLCR account.

QEtowah_Canton- how much Canton can withdraw from the river not including HLCR's release.
QEtowah_Canton = min(*QCantondemand, QEtowah2CantonIN_AVAIL* + 8.4)
QHLC_Cantondemand = max(0, QCantondemand - QEtowah_Canton)

If HLCR operates an Amenity Lake, it does not release for any account holders (else it will be operating for Canton only OR for CCMWA and Canton), so set Canton's demand from HLCR to zero.

if HLCops == 0 :
QHLC_Cantondemand = 0

Initial calculation of flow for CCMWA from Etowah (not including release from HLC). CCMWA can meet some of its demand at Canton only if it builds an intake. Since no intake exists, all CCMWA withdrawal from the Etowah is zero for all alternatives.

QEtowah_CCM = 0

When some of the Etowah's flow is being taken out at Canton, this could impact how much is available to be pumped out upstream. Adjust the "pump Available" amount accordingly. Although the pump is upstream of Canton, and therefore theoretically would have the first claim on the water flowing in the Etowah, we are calculating the withdrawal at Canton before the amount pumped into HLCR, because it is more efficient for water users to take the water directly out of the Etowah at Canton than it is to pump the water into HLCR.

QHLCpumpIN_AVAIL *= min(QHLCpumpIN_AVAIL, QEtowah2CantonIN_AVAIL - QEtowah_Canton - QEtowah_CCM)*
QHLCpumpIN_AVAIL *= max(QHLCpumpIN_AVAIL, 0)*

Calculate how much CCMWA demand is left. Allatoona will try to meet that next. Since CCMWA cannot take any water from the Etowah or HLCR for any alternatives, this value is the full demand amount. (Recall that *QEtowah_CCM* is 0 for all study alternatives.)

QAlla_CCMdemand *= max(0,QCCMdemand - QEtowah_CCM)*

4. ALLATOONA RELEASES - Calculate withdrawals from Allatoona storage accounts

Calculate withdrawals from Allatoona storage accounts

a. Allatoona's release for CCMWA

Allatoona's release for CCMWA is the lesser of the demand or the flow the CCMWA account can provide.

QAlla_CCM *= min(QAlla_CCMdemand, Alla_CCM_acct/cfs2AF)*

b. Allatoona's release for Cartersville

Allatoona's release for Cartersville is the lesser of the demand or the flow the Cartersville account can provide.
QAlla_Cartv *= min(QAlla_Cartvdemand, Alla_Cartv_acct/cfs2AF)*

5. HLCR RELEASES - Calculate withdrawals from HLCR storage accounts

a. HLCR's release for City of Canton

HLC release for Canton is the lesser of the account and the demand.

QHLC_Canton *= min(QHLC_Canton_demand, HLC_Canton_acct)*

The total Canton diversion is the sum of allowed withdrawal from the natural Etowah flow plus any releases from HLCR Canton account.

QCanton_CantonTot - Total flow diverted at Canton for the City of Canton
QCanton_CantonTot *= QEtowah_Canton + QHLC_Canton*

b. HLCR's release for CCMWA = 0

The total CCMWA diversion at Canton is ZERO for all alternatives. Otherwise, it would be the sum of the allowed withdrawal from the natural Etowah flow plus any releases from HLCR CCMWA account.

However, for this version of the script, if HLCR operates to supply water for CCM, it is passed through Allatoona. So, HLCR releases for CCM are used to supplement the CCM account at Allatoona and keep it full. As long as HLCR's CCM account is at least 95% full, it will release water to attempt to keep Allatoona's CCM account to 95% full. When HLCR's CCM account is less than 95% full, it releases water to keep Allatoona's CCM account with enough water for three days' worth of demand. If there is more than three days' worth of storage in the Allatoona CCM account, HLC will release nothing.

***QHLC_CCMdemand* –** Release demanded from HLCR's CCM account

if HLCops == 2 : then HLCR operates for CCMWA (and Canton).
if (HLC_CCM_acct >= HLC_CCM_acct95) :
Release to keep CCM's Allatoona acct at 95%.
QHLC_CCMdemand = *max(0, (Alla_CCM_acct95 - Alla_CCM_acct)/cfs2AF + QAlla_CCM)*
else :
Release to keep 3 days of storage in CCM's Allatoona acct
QHLC_CCMdemand = *max(0, 3*QAlla_CCMdemand - Alla_CCM_acct/cfs2AF + QAlla_CCM)*

else : ***QHLC_CCMdemand = 0***

QHLC_CCM = *min(HLC_CCM_acct/cfs2AF, QHLC_CCMdemand)*
QCanton_CCMTot *- Total flow diverted at Canton for the CCMWA (0)*

c. Calculate total release from HLC's accounts

Limit the total release to 70MGD (108.3 cfs)

Assume Canton takes its demand first, then CCMWA can take its demand up to what is left in their account and limited by the (total release - QCanton)

QHLC_MAX = 108.3
QHLC_CCM_MAX = *QHLC_MAX - QHLC_Canton*
QHLC_CCM = *max(0,min(QHLC_CCM_MAX, QHLC_CCM))*

The final value being released for both HLC accounts:

QHLCacctOUT = *QHLC_CCM + QHLC_Canton*

6. HLCR PUMP - Calculate HLC Pump value

Now that all of the withdrawals have been calculated, determine how much to pump from the Etowah into HLCR.

If there is demand for water at HLCR, it is likely that water levels are too low to allow for HLC to pump. Regardless, if water is being withdrawn from the HLCR accounts, no pumping may occur in the same timestep.

Pumping Objectives and Constraints

- HLCpumpIN_MAX capacity= 60.33 cfs
- Pump to keep reservoir at 1060 feet
- Must leave the Etowah with 7Q10 of 300 cfs (if not enough flow, pump = 0)
- If any water is released for the storage accounts today, do not pump

The lesser of natural flow or the 7Q10 of 300cfs must be passed down the Etowah, and what flow exceeds 300 cfs is available to be pumped. The pump's actual location is below the junction of the Etowah and Hickory Log Creek.

QHLCpumpIN_AVAIL was calculated in step 4.

The maximum value that can be pumped:

QHLCpumpIN_MAX *= min(60.33, QHLCpumpIN_AVAIL)*

Next, determine HLC storage volume deficit, or the demand to the pump.

Pump demand is the HLC full volume – previous storage – current inflow + previous evaporation.
QHLCpumpIN_demand *= max(0,(HLCTotVol - HLC_stor_prev)/cfs2AF - QHLC_in_cur + QHLC_evap_prev)*
Total pump-in is the demand or the max limit, whichever is smaller.
QHLCpumpIN *= min(QHLCpumpIN_MAX, QHLCpumpIN_demand)*

The pump will not be operated during the same (daily) timestep when water is being released from HLC accounts.

if QHLCacctOUT > 0 then QHLCpumpIN = 0

7. OVERDRAFT - Storage Account Overdraft at Allatoona

Track the account overdrafts (if allowed). If the alternative is one in which the accounts are allowed to be overdrawn, set the release values to the total demand.

if AllaOD == 1 :

QAlla_CCM *= QAlla_CCMdemand*
QAlla_Cartv *= QAlla_Cartvdemand*

The overdrafts are negative numbers.

Alla_CCM_overdraw *= Alla_CCM_acct - QAlla_CCM*cfs2AF*
Alla_Cartv_overdraw *= Alla_Cartv_acct - QAlla_Cartv*cfs2AF*

8. RETURN FLOWS

Cartersville return flows are modeled as 64% of their withdrawals. CCM return flows are different depending on whether current or future conditions are being modeled. An external time series of the assumed return flows was brought into the model with a dummy variable. Those return flows are multiplied by the percent of demand met in each timestep, such that if CCM's demand is shorted by 10%, the return flow is also shorted by 10%.

QCCMfrac is the fraction of demand that was met.

(Again, QEtowah_CCM = 0.)
QCCMfrac *= (QAlla_CCM + QEtowah_CCM)/QCCMdemand*
QAlla_CCM_Qreturn *= -QCCMfrac*QRT_CCM_cur*

Calculate Cartersville's return flow to Cartersville as 64% of total Cartv withdrawals

QAlla_Cartv_Qreturn *= 0.64*QAlla_Cartv*

9. INTERIM STORAGE ACCOUNTING

Calculate interim storage in accounts, based on what is known at end of this time period (includes current releases, but not yet counting current inflows. Those are added at the beginning of the next time step.)

HLC_Cant_acct_int *= HLC_Cant_acct - QHLC_Canton*cfs2AF*
HLC_CCM_acct_int *= HLC_CCM_acct - QHLC_CCM*cfs2AF*
Alla_CCM_acct_int *= Alla_CCM_acct - QAlla_CCM*cfs2AF*
Alla_Cartv_acct_int *= Alla_Cartv_acct - QAlla_Cartv*cfs2AF*

10. STORE ALL COMPUTED VARIABLES

Store data to each slave state variable calculated by this state variable. Most of the slave states variables are needed to control one or more rules or diversions in the model. The time-series of values of all state variables will be written to the simulation.dss file at the end of the compute.

<u>Interim storage accounts</u>

Alla_CCM_accti_SV.setValue(currentRuntimestep, Alla_CCM_acct_int)
Alla_Cartv_accti_SV.setValue(currentRuntimestep, Alla_Cartv_acct_int)
HLC_CCM_accti_SV.setValue(currentRuntimestep, HLC_CCM_acct_int)
HLC_Cant_accti_SV.setValue(currentRuntimestep, HLC_Cant_acct_int)

<u>Total Canton withdrawal from the Etowah River at Canton</u>

QCanton_tot_SV = network.getStateVariable("Canton_Etowah_WD")
QCanton_tot_SV.setValue(currentRuntimestep, QCanton_CantonTot)

<u>Total CCM withdrawal from the Etowah River at Canton</u>

Set timeseries of withdrawals based on whether they are coming from Allatoona or the Etowah near Canton.

QEtowah_CCM_SV = network.getStateVariable("CCM_Etowah_WD")
ZeroFlow = 0 (set a constant)

If HLCR does not operate for CCM, there are no withdrawals for CCM at Canton.

if HLCops != 2 :
QEtowah_CCM_SV.setValue(currentRuntimestep, ZeroFlow)

Otherwise set the CCMWA withdrawal from the Etowah. (But it is always zero because these even if an alternative is operating HLC for CCMWA, it passes through Allatoona)

else :
QEtowah_CCM_SV.setValue(currentRuntimestep, QCanton_CCMTot)

<u>Allatoona account withdrawals</u>

QAlla_CCM_SV = network.getStateVariable("Allatoona_CCM_Q")
QAlla_CCM_SV.setValue(currentRuntimestep, QAlla_CCM)
QAlla_Cartv_SV = network.getStateVariable("Allatoona_Cartersville_Q")
QAlla_Cartv_SV.setValue(currentRuntimestep, QAlla_Cartv)

<u>Total CCM return flow at Allatoona_IN</u>

QAlla_CCM_return_SV = network.getStateVariable("Allatoona_CCM_Qreturn")
QAlla_CCM_return_SV.setValue(currentRuntimestep, QAlla_CCM_Qreturn)
QAlla_Cartv_return_SV = network.getStateVariable("Cartersville_Cartv_Qreturn")
QAlla_Cartv_return_SV.setValue(currentRuntimestep,QAlla_Cartv_Qreturn)

<u>HLC account withdrawals</u>
QHLC_CCM_SV = network.getStateVariable("HLC_CCM_Q")
QHLC_CCM_SV.setValue(currentRuntimestep, QHLC_CCM)
QHLC_Canton_SV = network.getStateVariable("HLC_Canton_Q")
QHLC_Canton_SV.setValue(currentRuntimestep, QHLC_Canton)

<u>Total HLC account releases & pump in</u>
HLC_PumpOUT_SV = network.getStateVariable("HLC_Acct_OUT")
HLC_PumpOUT_SV.setValue(currentRuntimestep, QHLCacctOUT)
HLCpumpIN_SV = network.getStateVariable("HLC_PumpIN")
HLCpumpIN_SV.setValue(currentRuntimestep, QHLCpumpIN)

placeholder_var = 0

For all alternatives, set this variable, which is a dummy variable - never actually used, except to calculate other variables.

currentVariable.setValue(currentRuntimestep, placeholder_var)

A.2 WeissByPass State Variable

The WeissByPass State Variable calculates the minimum flow required through the Weiss trash gate. The real time trash gate operation is based on a monthly varying percentage of the recent flow volume at the Mayo's Bar USGS gage. Minimum flow is calculated twice a week - on Tuesdays, based on the previous four days flow at Mayo's Bar, and Fridays, based on the previous three days flow at Mayo's Bar. For the modeled state variable, the flow at Rome-Coosa is used in place of Mayo's Bar, which is a reasonable, and available substitute in the model.

```
#This state variable calculates the minimum flow through the Weiss trash gate (L.O. 7/6/2018)
#      Flows are adjusted on Tuesday and Friday of each week
#      The Tuesday adjustment will be based on the average flow from the previous 4 days at the
#           Mayo's Bar USGS gage(Rome Coosa) (Friday, Saturday, Sunday, Monday)
#      The Friday adjustment will be based on the average flow from the previous 3 days at the
#           Mayo's Bar USGS gage (rome Coosa) (Tuesday, Wednesday, Thursday)
#      Calculation of the target flow – To get the target flow for Tuesday or Friday, you just multiply the average flow
#            by the monthly percentage from the table below.
#      This number will be your target flow.
#      Jan 6% ,Feb 9% ,Mar 9% ,Apr 9% ,May 9%,June 5% , Jul 4%, Aug 4%, Sep 6%, Oct 9%, Nov 8%, Dec 7%

#Set the day of the week (0=Sun; 1=Mon; 2=Tue; 3=Wed; 4=Thu; 5=Fri; 6=Sat)
curDay = currentRuntimestep.getDayOfWeek()
#set the monthe of the year(1=Jan, 2=Feb, ...)
curMonth = currentRuntimestep.month()

RomeCoosaFlow=network.getTimeSeries("Junction","Rome-Coosa", "", "Flow").getCurrentValue(currentRuntimestep)

if curDay==2:
      Release=network.getTimeSeries("Junction","Rome-Coosa", "", "Flow").getPeriodAverage(currentRuntimestep, 4, 1)
      RomeCoosa_FlowAvg=currentVariable.localTimeSeriesGet("RomeCoosa_FlowAvg")
      RomeCoosa_FlowAvg.setCurrentValue(currentRuntimestep, Release)
elif (curDay==3) or (curDay==4):
      Release_TS=currentVariable.localTimeSeriesGet("RomeCoosa_FlowAvg")
      Release=Release_TS.getPreviousValue(currentRuntimestep)
      Release_TS.setCurrentValue(currentRuntimestep, Release)
elif curDay==5:
      Release=network.getTimeSeries("Junction","Rome-Coosa", "", "Flow").getPeriodAverage(currentRuntimestep, 3, 1)
      RomeCoosa_FlowAvg=currentVariable.localTimeSeriesGet("RomeCoosa_FlowAvg")
      RomeCoosa_FlowAvg.setCurrentValue(currentRuntimestep, Release)
else:
      Release_TS=currentVariable.localTimeSeriesGet("RomeCoosa_FlowAvg")
      Release=Release_TS.getPreviousValue(currentRuntimestep)
      Release_TS.setCurrentValue(currentRuntimestep, Release)

if (curMonth==1) or (curMonth==9):
      Release= Release * 0.06
elif (curMonth==2) or (curMonth==3) or (curMonth==4) or (curMonth==5) or (curMonth==10):
      Release= Release * 0.09
elif curMonth==6:
      Release= Release * 0.05
elif (curMonth==7) or (curMonth==8):
      Release= Release * 0.04
elif curMonth==11:
      Release= Release * 0.08
else:
      Release= Release * 0.07
currentVariable.setValue(currentRuntimestep, Release)
```

A.3 Martin_GC State Variable

The Martin_GC state variable calculates the guide curve at Martin with the modifications related to conditional fall extension. The new guide curve at Martin considering the winter conservation pool increase proposed by APC is used as the original Martin guide curve in this state variable. The Martin operating curve in September changes between 486 and 487.5 ft.

To enhance late-summer and fall recreation opportunities at Lake Martin, APC proposed a modification of the guide curve from September 1 through October 15 (Conditional fall extension). Under APC's proposal, the guide curve would be maintained at 490 feet (which is modeled as 489.5 ft to have 0.5 ft as buffer zone) from September 1 to October 15, provided certain hydrologic and operational conditions are met. Thereafter, the flood control curve would gradually decline until it reaches elevation 483 feet by the third week in November. APC would only implement the conditional fall extension if the four conditions mentioned in Section II.B.2 of this document are met.

```
from hec.script import Constants
from hec.model import  SeasonalRecord

def initStateVariable(currentVariable, network):

#	Martin Operating Curve in September changes between 488.5 and 487
#	t_OC[]=[01 Sep, 30 sep]
#	t_OC=[244,273]	Days
	t_OC=[351360, 393120]#Minutes
	Elev_OC=[487.5, 486]
	SR_OC=SeasonalRecord()
	SR_OC.setArrays(t_OC, Elev_OC)
	currentVariable.varPut("OC_Elev", SR_OC)
	currentVariable.localTimeSeriesNew("Martin_OperatingCurve")

#	t_GC[]=[01 Jan,28 Feb,01 Apr,28 Apr,02 Sep,01 Oct,01 Nov,24 Nov,31 Dec]
#	t_GC=[1,59,91,118,245,274,305,328,365]	Days
	t_GC=[0, 84960, 131040, 169920, 352800, 394560, 439200, 472320, 525600]   #Minutes
	Elev_GC=[483, 483, 488.05, 489.5, 489.5, 487.99, 485.6, 483, 483]
	SR_GC=SeasonalRecord()
	SR_GC.setArrays(t_GC, Elev_GC)
	currentVariable.varPut("GC_Elev", SR_GC)
	currentVariable.localTimeSeriesNew("Martin_OriginalGC")

#	t_FE[]=[01 Sep, 15 Oct, 24 Nov, 31 dec]
#	t_FE=[244, 288,328,365]	Days
	t_FE=[351360, 414720, 472320, 525600]	#Minutes
	Elev_FE=[489.5, 489.5, 483, 483]
	SR_FE=SeasonalRecord()
	SR_FE.setArrays(t_FE, Elev_FE)
	currentVariable.varPut("FE_Elev", SR_FE)
	currentVariable.localTimeSeriesNew("Martin_FallEnhancement")

#	Median Historical Flow on Coosa and Tallapoosa
	Coosa_Median=[3995,4132,4031,4086,3566,3846,3967,3920,4115,4085,4062,4060,4005,4227,4530,4253,4099,4015,4152
	,4119,3944,3741,3538,3895,3928,3922,4102,4346,4198,4465]
	Tallapoosa_Median=[1003,1002,1290,1308,1111,1182,1278,1308,1152,969,978,1085,990,985,874,939,805,821,1081,117
	7,1162,1022,1101,924,977,1334,1292,1228,1293,1194]

	currentVariable.varPut("Coosa_Median", Coosa_Median)
	currentVariable.varPut("Tallapoosa_Median", Tallapoosa_Median)
```

```
    currentVariable.localTimeSeriesNew("code")
    currentVariable.localTimeSeriesNew("Tcode")
    currentVariable.localTimeSeriesNew("day")
    currentVariable.localTimeSeriesNew("BI_Coosa")
    currentVariable.localTimeSeriesNew("BI_Tallapoosa")

    currentVariable.localTimeSeriesNew("Weiss_diff")
    currentVariable.localTimeSeriesNew("HNHenry_diff")
    currentVariable.localTimeSeriesNew("LoganMartin_diff")
    currentVariable.localTimeSeriesNew("Harris_diff")
    currentVariable.localTimeSeriesNew("Tallapoosa_Median_TS")
    currentVariable.localTimeSeriesNew("Coosa_Median_TS")

    return Constants.TRUE
```

```
# Martin Variable Guide Curve
# L.O. 7/10/2018

# Linear interpolation of Martin Guide Curve between inflection points
Martin_GC_Elev=currentVariable.varGet("GC_Elev")
Martin_GC=Martin_GC_Elev.interpolate(currentRuntimestep)
Martin_GC_TS=currentVariable.localTimeSeriesGet("Martin_OriginalGC")
Martin_GC_TS.setCurrentValue(currentRuntimestep, Martin_GC)

# Linear interpolation of Martin Operating Curve between 488.5-487 in september
Martin_OC_Elev=currentVariable.varGet("OC_Elev")
Martin_OC=Martin_OC_Elev.interpolate(currentRuntimestep)
Martin_OC_TS=currentVariable.localTimeSeriesGet("Martin_OperatingCurve")
Martin_OC_TS.setCurrentValue(currentRuntimestep, Martin_OC)

# Linear interpolation of Martin Fall enhancemnet curve between 490 (10/15)-483(11/24)
Martin_FE_Elev=currentVariable.varGet("FE_Elev")
Martin_FE=Martin_FE_Elev.interpolate(currentRuntimestep)
Martin_FE_TS=currentVariable.localTimeSeriesGet("Martin_FallEnhancement")
Martin_FE_TS.setCurrentValue(currentRuntimestep, Martin_FE)

curMonth = currentRuntimestep.month()
day=currentRuntimestep.getHecTime().day()-1

day_TS=currentVariable.localTimeSeriesGet("day")
day_TS.setCurrentValue(currentRuntimestep, day)

Martin_Elev= network.getTimeSeries("Reservoir","Martin", "Pool", "Elev").getPreviousValue(currentRuntimestep)

# Calculating 7-day average total basin inflow on the Tallapoosa River, calculated at Thurlow Dam
Harris_Flow= network.getTimeSeries("Reservoir","Harris", "Pool", "Flow-IN").getPeriodAverage(currentRuntimestep, 7)
Wadley_Local=network.getTimeSeries("Junction","Wadley", "", "Flow-Local").getPeriodAverage(currentRuntimestep, 7)
Martin_Local=network.getTimeSeries("Junction","Martin_IN", "", "Flow-Local").getPeriodAverage(currentRuntimestep, 7)
Yates_local=network.getTimeSeries("Junction","Yates_IN", "", "Flow-Local").getPeriodAverage(currentRuntimestep, 7)
Thurlow_local=network.getTimeSeries("Junction","Thurlow_IN", "", "Flow-Local").getPeriodAverage(currentRuntimestep, 7)
BI_Tallapoosa= Harris_Flow + Wadley_Local + Martin_Local + Yates_local + Thurlow_local

BI_Tallapoosa_TS=currentVariable.localTimeSeriesGet("BI_Tallapoosa")
BI_Tallapoosa_TS.setCurrentValue(currentRuntimestep, BI_Tallapoosa)

# Calculating 7-day average total basin inflow on the Coosa River, calculated at Jordan Dam
Weiss_Flow= network.getTimeSeries("Reservoir","Weiss", "Pool", "Flow-IN").getPeriodAverage(currentRuntimestep, 7)
HNHenry_Local= network.getTimeSeries("Junction","HN Henry_IN", "", "Flow-
    Local").getPeriodAverage(currentRuntimestep, 7)
```

```
LoganMartin_local= network.getTimeSeries("Junction","Logan Martin_IN", "", "Flow-
    Local").getPeriodAverage(currentRuntimestep, 7)
Lay_Local= network.getTimeSeries("Junction","Lay_IN", "", "Flow-Local").getPeriodAverage(currentRuntimestep, 7)
Mitchell_Local= network.getTimeSeries("Junction","Mitchell_IN", "", "Flow-Local").getPeriodAverage(currentRuntimestep, 7)
Jordan_Local= network.getTimeSeries("Junction","Jordan Lake Losses_IN", "", "Flow-
    Local").getPeriodAverage(currentRuntimestep, 7)
BI_Coosa= Weiss_Flow + HNHenry_Local + LoganMartin_local + Lay_Local + Mitchell_Local + Jordan_Local

BI_Coosa_TS=currentVariable.localTimeSeriesGet("BI_Coosa")
BI_Coosa_TS.setCurrentValue(currentRuntimestep, BI_Coosa)

# Getting the Median Hostorical Flow
Coosa_Median_Table = currentVariable.varGet("Coosa_Median")
Tallapoosa_Median_Table = currentVariable.varGet("Tallapoosa_Median")

Weiss_Elev=network.getTimeSeries("Reservoir","Weiss", "Pool", "Elev").getPreviousValue(currentRuntimestep)
HNHenry_Elev=network.getTimeSeries("Reservoir","HN Henry", "Pool", "Elev").getPreviousValue(currentRuntimestep)
LoganMartin_Elev=network.getTimeSeries("Reservoir","Logan Martin", "Pool",
    "Elev").getPreviousValue(currentRuntimestep)
Harris_Elev=network.getTimeSeries("Reservoir","Harris", "Pool", "Elev").getPreviousValue(currentRuntimestep)

Weiss_Con=network.getTimeSeries("Reservoir","Weiss", "Conservation", "Elev-
    ZONE").getCurrentValue(currentRuntimestep)
HNHenry_Con=network.getTimeSeries("Reservoir","HN Henry", "Conservation", "Elev-
    ZONE").getCurrentValue(currentRuntimestep)
LoganMartin_Con=network.getTimeSeries("Reservoir","Logan Martin", "Conservation", "Elev-
    ZONE").getCurrentValue(currentRuntimestep)
Harris_Con=network.getTimeSeries("Reservoir","Harris", "Conservation", "Elev-
    ZONE").getCurrentValue(currentRuntimestep)

Weiss_diff=Weiss_Elev-Weiss_Con
HNHenry_diff=HNHenry_Elev-HNHenry_Con
LoganMartin_diff=LoganMartin_Elev-LoganMartin_Con
Harris_diff=Harris_Elev-Harris_Con

# For QC
Weiss_diff_TS=currentVariable.localTimeSeriesGet("Weiss_diff")
Weiss_diff_TS.setCurrentValue(currentRuntimestep, Weiss_diff)
HNHenry_diff_TS=currentVariable.localTimeSeriesGet("HNHenry_diff")
HNHenry_diff_TS.setCurrentValue(currentRuntimestep, HNHenry_diff)
LoganMartin_diff_TS=currentVariable.localTimeSeriesGet("LoganMartin_diff")
LoganMartin_diff_TS.setCurrentValue(currentRuntimestep, LoganMartin_diff)
Harris_diff_TS=currentVariable.localTimeSeriesGet("Harris_diff")
Harris_diff_TS.setCurrentValue(currentRuntimestep, Harris_diff)

# If in September and the four conditions mentioned above are met operator hold the guide curve elevation flat,otherwise
    drawdown the pool
if curMonth==9:
    if Martin_Elev >= Martin_OC :
        Tallapoosa_Median=Tallapoosa_Median_Table[day-1]
        # For QC
        Tallapoosa_Median_TS=currentVariable.localTimeSeriesGet("Tallapoosa_Median_TS")
        Tallapoosa_Median_TS.setCurrentValue(currentRuntimestep, Tallapoosa_Median)
        if BI_Tallapoosa>= Tallapoosa_Median :
            Coosa_Median= Coosa_Median_Table[day-1]
            #For QC
            Coosa_Median_TS=currentVariable.localTimeSeriesGet("Coosa_Median_TS")
            Coosa_Median_TS.setCurrentValue(currentRuntimestep, Coosa_Median)
            if BI_Coosa>=Coosa_Median :
                if (Weiss_diff>= -1) and (HNHenry_diff>= -1) and (LoganMartin_diff>= -1) and (Harris_diff>= -1):
                    code=1
                else:
```

```
                    code=0
else:
    code=0

# Code=1 means all four conditions are met, Code=0 means at least one conditions is not met, code=2 means the pool holds the
    elevation, Code_1 is the previous value of Code
code_TS=currentVariable.localTimeSeriesGet("code")
code_TS.setCurrentValue(currentRuntimestep, code)
code_1=code_TS.getPreviousValue(currentRuntimestep)

# Tcode shows the number of times that all conditions are met(Save this TS for our knowledge)
Tcode=code
Tcode_TS=currentVariable.localTimeSeriesGet("Tcode")
Tcode_TS.setCurrentValue(currentRuntimestep, Tcode)

# Applying Fall enhancement curve
if (curMonth==9):
    if (code_1==2):
        GC_Elev=Martin_FE_TS.getCurrentValue(currentRuntimestep)
        code_TS.setCurrentValue(currentRuntimestep, 2)
    else:
        if (code==0):
            GC_Elev=Martin_GC_TS.getCurrentValue(currentRuntimestep)
        else:
            GC_Elev=Martin_FE_TS.getCurrentValue(currentRuntimestep)
            code_TS.setCurrentValue(currentRuntimestep, 2)
elif (curMonth==10 and 0<day<15):
    if (code_1==2):
        GC_Elev=Martin_FE_TS.getCurrentValue(currentRuntimestep)
        code_TS.setCurrentValue(currentRuntimestep, 2)
    else:
        GC_Elev=Martin_GC_TS.getCurrentValue(currentRuntimestep)
else:
    if (code_1==2):
        GC_Elev=Martin_FE_TS.getCurrentValue(currentRuntimestep)
        # day==0 covers 31 oct
        if ((curMonth==10) and (day==0 or day>=15)) or (curMonth==11 and day<24) :
            code_TS.setCurrentValue(currentRuntimestep, 2)
        else:
            code_TS.setCurrentValue(currentRuntimestep, 0)
    else:
        GC_Elev=Martin_GC_TS.getCurrentValue(currentRuntimestep)


currentVariable.setValue(currentRuntimestep, GC_Elev)
```

```
#Clean up
from hec.script import Constants

currentVariable.localTimeSeriesWriteAll()
```

A.4 GadsdenFloodOp State Variable

The *GadsdenFloodOp* state variable calculates the flow required to drawdown the HN Henry pool. This state variable determines the appropriate HN Henry forebay elevation according to the current Gadsden stage value. Due to the path of the river downstream of Gadsden, the Henry flood regulations call for lowering the Henry forebay elevation as the Gadsden stage rises. This is to attempt to overcome the hydraulic properties of the flow near what is referred to as Minnesota Bend just downstream of Gadsden. The geography and geometry of the river at this location causes the flow to decrease significantly causing backwater effects at Gadsden. Lowering the Henry pool elevation creates a greater slope difference and helps to pull water through the bend.

```
#Initialization
from hec.script import Constants
from datetime import datetime

def initStateVariable(currentVariable, network):
    # return Constants.TRUE if the initialization is successful and Constants.FALSE if it failed.
    # Returning Constants.FALSE will halt the compute.

    # set a debug variable
#   currentVariable.varPut('DEBUG', Constants.TRUE)         # Use DEBUG to turn ON/OFF the debug print
    statements.

    # set variables to hold actual elevations
    currentVariable.localTimeSeriesNew("ElevGadsden")
    currentVariable.localTimeSeriesNew("ElevHenry")

    # set a variable for the drawdown state
    currentVariable.localTimeSeriesNew("Drawdown")

    # set variables for target elevations
    currentVariable.localTimeSeriesNew("TgtGadsden")
    currentVariable.localTimeSeriesNew("TgtHenry")

    # set target volume for henry
    currentVariable.localTimeSeriesNew("TgtVolHenry")

    # set a variable for filling
    currentVariable.localTimeSeriesNew("Filling")

    # set a variable to track the 12 hourly steps
    currentVariable.localTimeSeriesNew("Step")

    # set variables for inflow and discharge
    currentVariable.localTimeSeriesNew("Inflow")
    currentVariable.localTimeSeriesNew("Discharge")

    return Constants.TRUE
```

```
#Main
    from hec.script import Constants
import time
```

```
# standard python imports
from datetime import datetime
import os
import tempfile
import time
import traceback

# global variables for this script
DrawdownSteps = 1                    # number of hours(12) to complete a drawdown step
RefillSteps = 2                    # number of hours(48) to complete a refill step
RisingBuffer = 0.1                    # elevation buffer over trigger to insure pool is rising
FallingBuffer = 0.25                    # elevation buffer below trigger to insure pool is falling

# variable format function
def formatValue(val, fmt):
	if val == None:
		return "NULL"
	else:
		return fmt % val

# get the EVA storage function
henry = network.findReservoir('HN Henry')
resStorFunction = henry.getStorageFunction() # lookup storage from elevation:

# Get HN Henry Pool Elevation
poolelHNHts = network.getTimeSeries("Reservoir","HN Henry","Pool", "Elev")
poolelHNH = poolelHNHts.getCurrentValue(currentRuntimestep)
poolelHNHprev = poolelHNHts.getPreviousValue(currentRuntimestep)
volumeHNHts = network.getTimeSeries("Reservoir","HN Henry","Pool", "Stor")
volumeHNH = volumeHNHts.getPreviousValue(currentRuntimestep)
#newvolumeHNH = volumeHNH / 1.9835 # convert acre-ft to DSF

# Get the guide curve elevation and volume
poolelHNHGCts = network.getTimeSeries("Reservoir","HN Henry", "Conservation", "Elev-ZONE")
pooleelHNHGC = poolelHNHGCts.getCurrentValue(currentRuntimestep)
volumeHNHGCts = network.getTimeSeries("Reservoir","HN Henry", "Conservation", "Stor-ZONE")
volumeHNHGC = volumeHNHGCts.getCurrentValue(currentRuntimestep) / 1.9835 # convert acre-ft to DSF
newvolumeHNH = volumeHNHGC # convert acre-ft to DSF

# Get the flow at Gadsden and Inflow to HN Henry
HNHenryints = network.getTimeSeries("Reservoir","HN Henry", "Pool", "Flow-IN")
HNHenryin = HNHenryints.getCurrentValue(currentRuntimestep)
gadsdenelevprevts= network.getTimeSeries("Junction","Gadsden", "", "Elev")
gadsdenelevprev = gadsdenelevprevts.getPreviousValue(currentRuntimestep)
gadsdenelevts= network.getTimeSeries("Junction","Gadsden", "", "Elev")
gadsdenelev = gadsdenelevts.getCurrentValue(currentRuntimestep)

HNHenryPrevIn = HNHenryints.getPreviousValue(currentRuntimestep)
HNHenryoutts = network.getTimeSeries("Reservoir","HN Henry", "Pool", "Flow-OUT")
HNHenryPrevOut = HNHenryoutts.getPreviousValue(currentRuntimestep)

HNHenryExtra=0

ElevGadsden_TS = currentVariable.localTimeSeriesGet("ElevGadsden")
ElevGadsden=ElevGadsden_TS.getCurrentValue(currentRuntimestep)
```

```
ElevHenry_TS = currentVariable.localTimeSeriesGet("ElevHenry")
Drawdown_TS = currentVariable.localTimeSeriesGet("Drawdown")
TgtGadsden_TS = currentVariable.localTimeSeriesGet("TgtGadsden")
TgtHenry_TS = currentVariable.localTimeSeriesGet("TgtHenry")
TgtVolHenry_TS = currentVariable.localTimeSeriesGet("TgtVolHenry")
Filling_TS = currentVariable.localTimeSeriesGet("Filling")
Step_TS = currentVariable.localTimeSeriesGet("Step")
Inflow_TS = currentVariable.localTimeSeriesGet("Inflow")
Discharge_TS = currentVariable.localTimeSeriesGet("Discharge")
#previousRuntimestep_TS = currentVariable.localTimeSeriesGet("previousRuntimestep")

# check for releases to pull to 502.5
if gadsdenelevprev >= 511+ RisingBuffer and poolelHNHprev >= 502.5: # and currentVariable.varGet('TgtHenry')
    != 502.5:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(502.5) / 1.9835
    #currentVariable.varPut('TgtVolHenry', newvolumeHNH)
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    # are we already in this drawdown?
    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 502.5 or Drawdown==1:

        # trigger flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 1)
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 511)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 502.5)
        # set the step counter
        Step_TS.setCurrentValue(currentRuntimestep, 0)

# check for holding at 502.5
elif gadsdenelevprev >= 511 and poolelHNHprev <= 502.5:

    # hold current state
    HNHenryout = HNHenryin

# check for releases to pull to 503.18
elif gadsdenelevprev >= 510.5+ RisingBuffer and poolelHNHprev >= 503: # and
    currentVariable.varGet('TgtHenry') != 503:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(503) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)
    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 503 or Drawdown==1:

        # trigger flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 1)
```

```
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 510.5)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 503)
        # set the step counter
        Step_TS.setCurrentValue(currentRuntimestep, 0)

# check for holding at 503
elif gadsdenelevprev >= 510.5 and gadsdenelevprev < 511 and poolelHNHprev  <= 503:

    # hold current state
    HNHenryout = HNHenryin

# check for coming out of flood control
elif gadsdenelevprev >= 510.5 - FallingBuffer and gadsdenelevprev < 511  and poolelHNHprev < 502.5:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(503) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 503:

        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 510.5)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 503)
        # reset flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 1)
        # trigger filling
        Step_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 0)

# check for releases to pull to 504.18
elif gadsdenelevprev >= 510+ RisingBuffer and poolelHNHprev >= 504: # and currentVariable.varGet('TgtHenry')
    != 504:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(504) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 504 or Drawdown==1:

        # trigger flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 1)
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 510)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 504)
        # set the step counter
        Step_TS.setCurrentValue(currentRuntimestep, 0)

# check for holding at or rising to 504.18
```

```
elif gadsdenelevprev>=510 and gadsdenelevprev < 510.5 and poolelHNHprev <= 504:

    # hold current state
    HNHenryout = HNHenryin

# check for coming out of flood control
elif gadsdenelevprev >= 510 - FallingBuffer and gadsdenelevprev < 510.5  and poolelHNHprev < 503:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(504) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 504:
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 510)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 504)
        # reset flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 1)
        # trigger filling
        Step_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 0)

# check for releases to pull to 505
elif gadsdenelevprev >= 509.5+ RisingBuffer and poolelHNHprev >= 505: # and
    currentVariable.varGet('TgtHenry') != 505.18:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(505) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 505 or Drawdown==1:

        # trigger flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 1)
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 509.5)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 505)
        # set the step counter
        Step_TS.setCurrentValue(currentRuntimestep, 0)

# check for holding at or rising to 505
elif gadsdenelevprev >= 509.5 and gadsdenelevprev < 510 and poolelHNH <= 505: # and poolelHNH >= 504.18
    and poolelHNH <= 505.18:

    # hold current state
    HNHenryout = HNHenryin

# check for coming out of flood control
elif gadsdenelevprev >= 509.5 - FallingBuffer and gadsdenelevprev < 510  and poolelHNHprev < 504:
```

```
    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(505) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 505:

        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 509.5)
        # set Henry target
        currentVariable.varPut('TgtHenry', 505)
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 505)
        # reset flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 1)
        # trigger filling
        Step_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 0)

# check for releases to pull to 506
elif gadsdenelevprev>=509+ RisingBuffer and poolelHNHprev>=506: # and currentVariable.varGet('TgtHenry') !=
    506:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(506) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    #if currentVariable.varGet('TgtHenry') != 506 or not currentVariable.varGet('Drawdown'):
    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 506 or Drawdown==1:

        # trigger flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 1)
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 509)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 506)
        # set the step counter
        Step_TS.setCurrentValue(currentRuntimestep, 0)

# check for holding at 506
elif gadsdenelevprev >= 509 and gadsdenelevprev < 509.5 and  poolelHNHprev <= 506:

    # hold current state
    HNHenryout = HNHenryin

# check for coming out of flood control
elif gadsdenelevprev >= 509 - FallingBuffer and gadsdenelevprev < 509.5  and poolelHNHprev < 505:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(506) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 506:
```

```
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 509)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 506)
        # reset flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 1)

        # trigger filling
        Step_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 0)

# check for releases to pull to 507
elif gadsdenelevprev >= 508.5+ RisingBuffer and poolelHNHprev >= 507: # and
    currentVariable.varGet('TgtHenry') != 507:

    # set the new volume target
    newvolumeHNH = resStorFunction.elevationToStorage(507) / 1.9835
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, newvolumeHNH)

    #if currentVariable.varGet('TgtHenry') != 507 or not currentVariable.varGet('Drawdown'):
    TgtHenry=TgtHenry_TS.getCurrentValue(currentRuntimestep)
    Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
    if TgtHenry != 507 or Drawdown==1:

        # trigger flood control
        Drawdown_TS.setCurrentValue(currentRuntimestep, 0)
        Filling_TS.setCurrentValue(currentRuntimestep, 1)
        # set Gadsden target
        TgtGadsden_TS.setCurrentValue(currentRuntimestep, 508.5)
        # set Henry target
        TgtHenry_TS.setCurrentValue(currentRuntimestep, 507)
        # set the step counter
        Step_TS.setCurrentValue(currentRuntimestep, 0)

# check for holding at 507
elif gadsdenelevprev >= 508.5 and gadsdenelevprev < 509 and poolelHNHprev <= 507:

    # hold current state
    HNHenryout = HNHenryin

# check for coming out of flood control

elif gadsdenelevprev <= 508.5 - FallingBuffer and poolelHNHprev < 506: # and abs(gadsdenelevprev -
    currentVariable.varGet('ElevGadsden')) < 0.5:

    # set the target elevation and volume to guide curve
    TgtHenry_TS.setCurrentValue(currentRuntimestep, pooleelHNHGC)
    TgtVolHenry_TS.setCurrentValue(currentRuntimestep, volumeHNHGC)

    # reset flood control
    Drawdown_TS.setCurrentValue(currentRuntimestep, 1)

    # trigger filling
    Step_TS.setCurrentValue(currentRuntimestep, 0)
    Filling_TS.setCurrentValue(currentRuntimestep, 0)
```

```
# reset fillingn counter
Filling=Filling_TS.getCurrentValue(currentRuntimestep)
Drawdown=Drawdown_TS.getCurrentValue(currentRuntimestep)
Step=Step_TS.getCurrentValue(currentRuntimestep)
TgtVolHenry=TgtVolHenry_TS.getCurrentValue(currentRuntimestep)

if (Filling==0 or Drawdown==0) and Step > (DrawdownSteps if Drawdown==0 else RefillSteps) - 1 and
    abs((volumeHNH/1.9835) - TgtVolHenry) > 250:
    Step_TS.setCurrentValue(currentRuntimestep, 0)

# calculate extra flow to reach target
HNHenryExtra = ((volumeHNH/1.9835) - TgtVolHenry)  / ((DrawdownSteps if Drawdown==0 else RefillSteps) -
    Step) if Step < (DrawdownSteps if Drawdown==0 else RefillSteps) else 0

# calculate total discharge (extra + inflow)
HNHenryout = HNHenryExtra + HNHenryin

# update local variables
Discharge_TS.setCurrentValue(currentRuntimestep, HNHenryout)
Inflow_TS.setCurrentValue(currentRuntimestep, HNHenryin)
ElevGadsden_TS.setCurrentValue(currentRuntimestep, gadsdenelev)
ElevHenry_TS.setCurrentValue(currentRuntimestep, poolelHNH)

# check for negative discharge
if HNHenryout <0:
    HNHenryout=0

# set the discharge value
currentVariable.setValue(currentRuntimestep, HNHenryout)
```

```
#Clean up
from hec.script import Constants
#
# add your code here...
```

A.5 WadleyOps State Variable

The *WadleyOps* state variable calculates the release from Harris based on three different situations. 1) Pool is at or above guide curve and less than 790, 2) pool is above guide curve and rising, 3) pool is above guide curve and falling. In the first situation Harris outflow equals the less of 13,000 cfs or an amount that will not cause the gage at Wadley to exceed 13 ft. In the second situation Harris outflow is 16,000 cfs or greater and in the third situation Harris outflow maintains the previous release.

```
#Initialization
from hec.script import Constants
#
def initStateVariable(currentVariable, network):

	currentVariable.localTimeSeriesNew("Harris_Falling")
	currentVariable.localTimeSeriesNew("Code_TS")
	currentVariable.localTimeSeriesNew("Harris_Elev_Avg")

	# return Constants.TRUE if the initialization is successful and Constants.FALSE if it failed.
	# Returning Constants.FALSE will halt the compute.
	return Constants.TRUE
```

```
#Main
# no return values are used by the compute from this script.
#
# Code=0 Pool_Elev <790
# Code=1 Pool_Elev>790 and pool is rising
# Code=2 Pool_Elev>790 and pool is falling

Harris_Elev_TS=network.getTimeSeries("Reservoir","Harris", "Pool", "Elev")
Harris_Elev_prev=Harris_Elev_TS.getPreviousValue(currentRuntimestep)
Harris_Elev_Avg=Harris_Elev_TS.getPeriodAverage(currentRuntimestep, 2, 1)

Harris_Elev_prevprev_TS = currentVariable.localTimeSeriesGet("Harris_Elev_Avg")
Harris_Elev_prevprev_TS.setCurrentValue(currentRuntimestep, Harris_Elev_Avg)

Harris_Falling_TS = currentVariable.localTimeSeriesGet("Harris_Falling")
Harris_Falling_prev=Harris_Falling_TS.getPreviousValue(currentRuntimestep)

Code_TS = currentVariable.localTimeSeriesGet("Code_TS")
Code_prev=Code_TS.getPreviousValue(currentRuntimestep)


Harris_GC=network.getTimeSeries("Reservoir","Harris", "Conservation", "Elev-
	ZONE").getCurrentValue(currentRuntimestep)
#Harris_GC_prev=network.getTimeSeries("Reservoir","Harris", "Conservation", "Elev-
	ZONE").getPreviousValue(currentRuntimestep)

if Harris_Elev_prev < Harris_GC:
	Code=0
else:
	if Harris_Elev_prev < 790:
		#if pool just reaches below 790 and in the previous time step, when pool was above 790 it was falling then
	continue to hold the
		#previous release untill return to normal opertaion
```

```
        if Code_prev<2:
            Code=0
        else:
            Code=2
    else:
        # if Rising
        if  Harris_Elev_prev >= Harris_Elev_Avg:
            Harris_Falling=0
            Harris_Falling_TS.setCurrentValue(currentRuntimestep, Harris_Falling)
            Code=1
        else:
            Harris_Falling=1
            Harris_Falling_TS.setCurrentValue(currentRuntimestep, Harris_Falling)
            Code=2

Code_TS.setCurrentValue(currentRuntimestep, Code)
currentVariable.setValue(currentRuntimestep, Code)
```

```
#Clean Up

from hec.script import Constants

currentVariable.localTimeSeriesWriteAll()
```

A.6 RestrictWeissSurcharge Script

The scripted rule, ***RestrictWeissSurcharge***, is used to minimize impacts downstream of the dam by limiting the surcharge releases. The rule applies when the stage at Gadsden is rising over the 512 foot easement of due to a combination of discharges from Weiss and local inflow. When the rating curve at Gadsden indicates that a combination of local inflow and surcharge values from Weiss will cause the stage at Gadsden to rise over elevation 512 ft, surcharge releases can be cut up to 50% to provide time for the local inflows to recede. The total volume of the cutback cannot exceed 22,500 cfs-days per event. The total cutback volume does not have to be used consecutively but can be implemented as multiple cutback periods during an event. Once this volume has been utilized, the project will return to the normal surcharge release schedule.

```
# required imports to create the OpValue return object.
from hec.rss.model import OpValue
from hec.rss.model import OpRule
from hec.script import Constants
from hec.rss.model import RssRun

from datetime import datetime
import math
import os
import tempfile
import traceback

# ======================================================================
# Global Constants for this rule - change values here as needed to control the operations
# ======================================================================

DEBUG = Constants.FALSE			# Use DEBUG to turn ON/OFF the debug print statements.

cpName = "Gadsden"	# the name of the control point (cp) for this reservoir
twName = "HN Henry"			# the name of the cp's tailwater reservoir
cpFloodStage = 512.0		# Flood stage at the cp
			# Easement is 512, but we need to catch this earlier due to
			# routing and travel time
MaxCutbackVol = 22500.0		# the accumlated storage limit that will stop the cutback operation
			# note, the units are cfs-days. The timestep is hourly.
			# To get cfs-hours into cfs-days, divide by 24 (hours per day).

TopOfFloodZone = 572		# The top of the flood control zone for this reservoir
ISRuleName = "Induced Surcharge Operation-APC"  # The name of the this rservoir's induced surcharge rule
ISTransitionElev = 564		# The IS rule's transition elevation
ISTransitionHours = 6			# The IS rule's transition hours
			# must be falling for this many consecutive hours to eliminate fluctuations
ChannelCapacity = 40000.0	# This reservoir's channel capacity (local max release)
MinSurchargeRelease = 40000	# Minimum to which surcharge should ever be limited

NoCutback = Constants.UNDEFINED	#399999.00		# a value larger than this reservoir's
    maximum release capacity

decisionInterval = 6
logFilePath = tempfile.gettempdir()	# location of script log files (usually
    C:\Users\(UserName)\AppData\Local\Temp)
```

```
# log function
def LogDebug(str, debugFile, reset=0):

   try:
      # open output file
      f = None
      if reset == 1:
         # overwrite previous file
         f = open(os.path.join(logFilePath, debugFile), 'w')
      else:
         # append to any existing file
         f = open(os.path.join(logFilePath, debugFile), 'a')
      f.write(str)
      f.write('\n')
      f.flush()
      f.close()

   except:

      # log error to console
      print traceback.format_exc()

# variable format function
def formatValue(val, fmt):
   if val == None:
      return "NULL"
   else:
      return fmt % val

# ==========================================================================
# initRuleScript is the initialization function.
# ==========================================================================
# Perform set up task that only need to be performed once so that they are not performed
# repeatedly during the compute.
#     Arguments:
#           currentRule is the rule that holds this script
#           network is the ResSim network
#     Returns: Constants.TRUE if the initialization is successful or Constants.FALSE if it failed.
#
def initRuleScript(currentRule, network):

   # JDK Note: a bug exists in the localTimeSeriesNew methods for initializing the TSRecord with a
   # constant. Since the localTimeSeriesNew method using a timeSeriesContainer to initialize the
   # TS is fully functional, tsc & tsc2 is being used to initialize our 2 local TSRecords.
   # Once the bug is fixed, the use of tsc & tsc2 can be removed and the two commented out
   # lines below can be used instead.

   try:
      # get the name of the reservoir
      resvName = currentRule.getReservoirElement().getName()
      # get the pool storage time series container and clone it
      tsc=network.getTimeSeries("Reservoir",resvName,"Pool","Stor").getTimeSeriesContainer().clone()
      # loop through time series values and set all to zero
      for i in range(tsc.numberValues):
         tsc.values[i]=0.0
```

```
        # set the location property as reservoir running storage
        tsc.location=resvName+"-RestrictSurcharge-runningStor"
        tsc.subLocation=""
        # create new time series in this rule from the cloned container
        runningStorTS = currentRule.localTimeSeriesNew("runningStor", tsc)
        # clone the new container
        tsc2 = tsc.clone()
        # set the location property as reservoir peak counter
        tsc2.location=resvName+"-RestrictSurcharge-peakCounter"
        # create a new time series in this rule from the cloned container
        peakCounter = currentRule.localTimeSeriesNew("peakCounter", tsc2)
        # currentRule.localTimeSeriesNew("runningStor", 0.0)
        # currentRule.localTimeSeriesNew("peakCounter", 0.0)

        # get the junction object for the control point
        JCTObj = network.findJunction(cpName).getFunction()
        # get the rating table for the junction object
        RatingTable = JCTObj.getRatingObject().getIndependentVariableRatingCurveExt()
        # store the rating table in this rule
        currentRule.varPut("RatingTable", RatingTable)

        # clone the new container
        tsc3 = tsc.clone()
        # set the location property as reservoir peak counter
        tsc3.location=resvName+"-RestrictSurcharge-maxRel"
        # create new time series in this rule from the cloned container
        maxRelTS = currentRule.localTimeSeriesNew("maxRel", tsc3)

        # clone the new container
        tsc4 = tsc.clone()
        # set the location property as reservoir peak counter
        tsc4.location=resvName+"-RestrictSurcharge-ISFlow"
        # create new time series in this rule from the cloned container
        ISFlowTS = currentRule.localTimeSeriesNew("ISFlow", tsc4)

        # store peak downstream elevation
        currentRule.varPut("peakStage", 0)

        # store current last step
        currentRule.varPut("step", 9999)

        # create debug file name for CSV file
        currentRule.varPut('debugFile', datetime.now().strftime('WeissRestrictSurProp_%Y%m%d_%H%M.csv'))

    except:
        return Constants.FALSE

    # return Constants.TRUE if the initialization is successful or Constants.FALSE if it failed.
    # Returning Constants.FALSE will halt the compute.
    return Constants.TRUE


def formatArrayValue(ts, step):
    if ts != None:
        if ts.getTSArray() != None:
            if ts.getTSArray()[step.getStep() - 1] != None:
```

```
            return "%.2f" % ts.getTSArray()[step.getStep() - 1]

    return "None"

# ===========================================================================
# runRuleScript() is the function called ResSim to evaluate the rule during the compute.
# ===========================================================================
# Compute a desired release and determine its associated limit type (MIN, MAX, SPEC)
#     Arguments:
#           currentRule is the rule that holds this script
#           network is the ResSim network
#           currentRuntimestep is the current Run Time Step
#     Returns: an OpValue object or None
#
def runRuleScript(currentRule, network, currentRuntimestep):
    '''
    RULE: RestrictSurcharge
    Author: Joan Klipsch, USACE-IWR-HECAug-Sep 2018 (aka JDK)

    This rule's objective is to cutback the Induced Surcharge releases from this reservoir up to 50%.
    When the accumulated storage due to this cutback exceeds a predefined limit, the cutback operation
    will cease.  Assumptions and constraints are described below and in the text of the script.

    To begin this operation,
    - the Induced Surcharge rule must be calling for a release greater than channel capacity AND
    - the IS release is expected to cause the water surface elevation at the control point to
       exceed flood stage.

    To reset the limiting operation, the following conditions are relevant:
    - the operation must have been "on" AND
       - the stage at the control point must have fallen below flood stage  OR
       - this reservoir must be below its Induced Surcharge Transition Elevation

    The variable runningStor (the additional accumulated storage due to the cutback called for by this
    rule) is used as the "operation has been on" flag

    Revisions added 9-17-2018 JDK
    - If the running storage has not maxed out before the inflow drops below release, then the max
       release from this operation should be held, regardless of the running storage.
    - A counter, peakCounter, has been added to keep track of the number of timesteps in which the
       inflow is less than the previous release.
    '''

    # NOTE: testing of this rule suggests that there MAY be a bug in the ESRD implementation of the
    # IS rule's falling pool option "maintain peak release".
    # Recommendation: Use "maintain peak gate" instead. - JDK

    # Retrieve the (3-variable) rating table for the control point from the vars list
    cpRatingTable = currentRule.varGet("RatingTable")

    # Retrieve the local variables stored in this script and their previous values
    runningStorTS = currentRule.localTimeSeriesGet("runningStor")
    peakCounterTS = currentRule.localTimeSeriesGet("peakCounter")
    runningStor = runningStorTS.getPreviousValue(currentRuntimestep)
    peakCounter = peakCounterTS.getPreviousValue(currentRuntimestep)
```

```
# Retrieve the model veriables needed by this script

# get the current model run
thisRun = network.getRssRun()
# get the local flow time series at the control point
cpCumlocTS = thisRun.getTSRecordByPathParts(cpName,"FLOW-CUMLOC")
# get the stage time series at the control point
cpStageTS = network.getTimeSeries("Junction",cpName, "", "Stage")

# get the pool elevation time series at the downstream control location
cpTailwaterTS = network.getTimeSeries("Reservoir", twName, "Pool", "Elev")
# get the total flow time series at the control point
#cpCumFlowTS = thisRun.getTSRecordByPathParts(cpName, "FLOW")

# get the reservoir name
resvName = currentRule.getReservoirElement().getName()
# get the pool elevation time series for reservoir
resvPoolTS = network.getTimeSeries("Reservoir",resvName, "Pool", "Elev")
# get the pool inflow time series for reservoir
resvInflowTS = network.getTimeSeries("Reservoir",resvName, "Pool", "Flow-IN NET")
# get the pool outflow time series for reservoir
resvOutflowTS = network.getTimeSeries("Reservoir",resvName, "Pool", "Flow-OUT")
# get the induced surcharge rule time series for reservoir
resvISRuleTS = network.getTimeSeries("Reservoir",resvName, ISRuleName, "Flow-MIN")

# Get the "current" values of the model variables

# get the control point stage at the end of the previous timestep
cpStage = cpStageTS.getPreviousValue(currentRuntimestep)
# get the control point local flow at the end of the previous timestep
cpCumloc = cpCumlocTS.getCurrentValue(currentRuntimestep)
# get the downstream elevation for the control point (dam forebay) at the end of the previous timestep
cpTailwater = cpTailwaterTS.getPreviousValue(currentRuntimestep)
# get the control point total flow at the end of the previous timestep
#cpCumFlow = cpCumFlowTS.getPreviousValue(currentRuntimestep)

# get the reservoir pool elevation at the end of the previous timestep
resvPool = resvPoolTS.getPreviousValue(currentRuntimestep)
# get the reservoir inflow at the end of the previous timestep
resvPrevIn = resvInflowTS.getPreviousValue(currentRuntimestep)
# get the reservoir inflow for the current timestep
resvCurIn = resvInflowTS.getCurrentValue(currentRuntimestep)
# get the reservoir discharge at the end of the previous timestep
resvPrevOut = resvOutflowTS.getPreviousValue(currentRuntimestep)

# get the induced surcharge rule value at the end of the previous timestep
ISFlowPrev = resvISRuleTS.getPreviousValue(currentRuntimestep)
# get the induced surcharge rule value for the current timestep
ISFlowCur = resvISRuleTS.getCurrentValue(currentRuntimestep)
# set the induced surcharge flow to the induced surcharge calculation for the current timestep
ISFlow = ISFlowCur

# initialize the local variables needed or computed by the cutback logic

# set the max release to zero
maxRel = 0.0
```

```
# set the estimated cutback volume to zero
estCutbackVolume = 0.0
# set the available storage to the max storage volume minus the running storage volume
availableStorage = MaxCutbackVol - runningStor

# get previous max release
maxRelTS = currentRule.localTimeSeriesGet("maxRel")
lastMaxRel = maxRelTS.getPreviousValue(currentRuntimestep)

# get previous induced surcharge value
ISFlowTS = currentRule.localTimeSeriesGet("ISFlow")
ISFlowLast = ISFlowTS.getPreviousValue(currentRuntimestep)

# start by checking to see if this hour is a multiple of the decision interval
isChangeHour = (currentRuntimestep.getHecTime().hour() % decisionInterval == 0)

# get the current step
curStep = currentRuntimestep.getStep()

# check to reset peak elevation
if curStep < currentRule.varGet("step"):
    currentRule.varPut("peakStage", 0)

# update peak stage
if currentRule.varGet("peakStage") < cpStage:
    currentRule.varPut("peakStage", cpStage)

if DEBUG:
    LogDebug("%s - %i != %i or %i == 0 or %i ???" % (resvName, math.floor(ISFlowPrev),
   math.floor(ISFlowCur), runningStor, ISFlowLast), currentRule.varGet('debugFile'))

if math.floor(ISFlowLast) != math.floor(ISFlowCur) or runningStor == 0: #if isChangeHour or ISFlowPrev !=
   ISFlowCur:

    if DEBUG:
        LogDebug("%s - Starting Restrict Surcharge, %s, Step = %3i, Pool = %.2f, Stage = %.2f, Local Flow =
   %6i, Stor Acct = %5i, Stor Avail = %5i, Last IS = %g, Curr IS = %g" % (resvName,
   currentRuntimestep.dateTimeString(), curStep, resvPool, cpStage, cpCumloc, runningStor, availableStorage,
   ISFlowPrev, ISFlowCur), currentRule.varGet('debugFile'))

    # Determine the "cutback release"
    #-----------------------------------------------------------------------------------------------------
    # The max release determination is divided into four conditional parts.
    # 1. if the cutback operation has been "maxed out" and remains "on"
    if runningStor >= MaxCutbackVol:
        # maintain status quo, don't apply any cutback to the IS operation.
        maxRel = NoCutback

        if DEBUG:
            LogDebug("\t%s - Restrict Surcharge Case 1 (Storage Full), Stor Acct = %5i, Max Release = %6i" %
   (resvName, runningStor, maxRel), currentRule.varGet('debugFile'))

    #-----------------------------------------------------------------------------------------------------
    # 2. if the cutback operation has been "on" and the release > inflow and inflow is falling
    #          -hold the peak until IS falling pool operations kick in
    #          -and watch for reset conditions
```

```
elif runningStor > 0.0 and resvPrevOut > resvPrevIn > resvCurIn :
    # release has peaked and inflow is falling.
    # hold peak release until IS falling pool rules should kick in.
    maxRel = resvPrevOut
    peakCounter = peakCounter + 1
    estCutbackVolume = (ISFlow - maxRel)

    if estCutbackVolume < 0:
        maxRel = NoCutback
    else:

        runningStor = runningStor + estCutbackVolume
        if runningStor > MaxCutbackVol or peakCounter > ISTransitionHours: # or ISFlow <= resvPrevOut:
            # stop restricting the IS operation if we've run out of storage
            # or if the IS falling pool options should start or already has started
            runningStor = MaxCutbackVol
            maxRel = NoCutback

    if DEBUG:
        LogDebug("\t%s - Restrict Surcharge Case 2 (Past Peak), Stor Acct = %5i, Max Release = %6i, Peak Cnt
= %3i, Cutback = %5i" % (resvName, runningStor, maxRel, peakCounter, estCutbackVolume),
currentRule.varGet('debugFile'))

#---------------------------------------------------------------------------------------------------
# 3. if the "current" desired Induced Surcharge release > channel capacity then
#           if the cutback operation has not reached its allowed storage then
#                  - determine if a cutback is desirable and the associated cutback release
#           else the maximum storage has been reached, so
#                  - turn off the cutback but consider the operation to still be on until "reset"
# ===============================================================================
# 2018-10-10 : SAF : The following line was changed from "=" to ">=" because surcharge operations
# actually begin at channel capacity (40,000 CFS) and may never rise above that value in a
# smaller event.
# ===============================================================================

# ===============================================================================
# 2018-12-19 : SAF : Modified to limit surcharge cutback to a specified minimum rather than half
# of the IS discharge. Several factors were involved in this including the question about cutting
# back beyond unit capacity or below the bottom of the surcharge curve.
# ===============================================================================

elif ISFlow >= ChannelCapacity:
    # Determine how much of the IS release can be held back, up to 50%.
    #       - Estimate the Gadsden stage using 100% IS release + locals
    FullFlow = ISFlow + cpCumloc
    estStageFull = cpRatingTable.interpolate(FullFlow, cpTailwater)
    estStageMinimum = 0; MinimumISFlow = 0; ratio = 0.0
    if estStageFull < cpFloodStage or resvPool >= TopOfFloodZone - 1:
        # 100% IS release will NOT flood Childersburg or we are too close to easement, no cutback is needed
        maxRel = NoCutback
    else:
        # 100% IS relese WILL flood Gadsden, will the specified minimum?
        #    - Estimate the Gadsden stage using the specified minimum IS release + locals
        MinimumISFlow = MinSurchargeRelease + cpCumloc
        estStageMinimum = cpRatingTable.interpolate(MinimumISFlow, cpTailwater)
        if estStageMinimum > cpFloodStage: # or MinimumISFlow > 130000:
```

```
            # since minimum specified IS release is still going to produce flooding...
            # try to stay below the peak stage
            distMin2PeakStg = currentRule.varGet("peakStage") - estStageMinimum
            distMin2FullStg = estStageFull - estStageMinimum
            LogDebug("%s - Case 3 - distMin2PeakStg = %.2f, peakStage = %.2f, estStageMinimum = %.2f" %
(resvName, distMin2PeakStg, currentRule.varGet("peakStage"), estStageMinimum),
currentRule.varGet('debugFile'))
            LogDebug("%s - Case 3 - distMin2FullStg = %.2f, estStageFull = %.2f, estStageMinimum = %.2f" %
(resvName, distMin2FullStg, estStageFull, estStageMinimum), currentRule.varGet('debugFile'))
            if distMin2FullStg == 0:
                maxRel = ISFlow # full flow
                LogDebug("%s - Case 3 - No Cutback" % (resvName), currentRule.varGet('debugFile'))
            elif distMin2PeakStg <= 0:
                maxRel = MinSurchargeRelease # minimum flow
                LogDebug("%s - Case 3 - Min Release = %i" % (resvName, MinSurchargeRelease),
currentRule.varGet('debugFile'))
            else:
                ratio = distMin2PeakStg / distMin2FullStg
                LogDebug("%s - Case 3 - ratio = %.2f" % (resvName, ratio), currentRule.varGet('debugFile'))
                maxRel = MinSurchargeRelease + ratio * (ISFlow - MinSurchargeRelease)

            #maxRel = MinSurchargeRelease

        else:     # estHalfGadsdenStage <= cpFloodStage
            # find a cutback release that would keep Gadsden at or below flood stage
            # use linear interpolation...
            distMin2FldStg = cpFloodStage - estStageMinimum
            distMin2FullStg = estStageFull - estStageMinimum
            ratio = distMin2FldStg/distMin2FullStg
            maxRel = MinSurchargeRelease + ratio * (ISFlow - MinSurchargeRelease)
            LogDebug("%s - Case 3 - distMin2FldStg = %.2f, cpFloodStage = %.2f, estStageMinimum = %.2f" %
(resvName, distMin2FldStg, cpFloodStage, estStageMinimum), currentRule.varGet('debugFile'))
            LogDebug("%s - Case 3 - distMin2FullStg = %.2f, estStageFull = %.2f, estStageMinimum = %.2f" %
(resvName, distMin2FullStg, estStageFull, estStageMinimum), currentRule.varGet('debugFile'))
            LogDebug("%s - Case 3 - ratio = %.2f" % (resvName, ratio), currentRule.varGet('debugFile'))

        # determine if estimated cutback volume can be stored, if not adjust maxRel.
        estCutbackVolume = (ISFlow - maxRel)
        if estCutbackVolume < 0:
            maxRel = NoCutback
        else:

            if estCutbackVolume <= availableStorage:
                runningStor = runningStor + estCutbackVolume
            else :
                # cutback is limited to remaining storage
                maxRel = ISFlow - availableStorage
                runningStor = MaxCutbackVol

    peakCounter = 0.0

    if DEBUG:
        LogDebug("\t%s - Restrict Surcharge Case 3 (Calc Cutback), Stor Acct = %5i, Max Release = %6i, Peak
Cnt = %3i, Cutback = %5i, Stor Avail = %5i" % (resvName, runningStor, maxRel, peakCounter,
estCutbackVolume, availableStorage), currentRule.varGet('debugFile'))
```

```
            LogDebug("\t\t%s - ISFlow = %6i, estStageFull = %.2f, estStageMinimum = %.2f, FullFlow = %6i,
    MinimumISFlow = %6i, ratio = %.3f" % (resvName, ISFlow, estStageFull, estStageMinimum, FullFlow,
    MinimumISFlow, ratio), currentRule.varGet('debugFile'))

    #----------------------------------------------------------------------------------------------------
    # 4. ELSE...
    #         probably in a rising pool condition but IS rule has not called for a release > channel capacity
    else:
        maxRel = NoCutback
        peakCounter = 0.0

        if DEBUG:
            LogDebug("\t%s - Restrict Surcharge Case 4 (No Cutback), Stor Acct = %5i, Max Release = %6i" %
    (resvName, runningStor, maxRel), currentRule.varGet('debugFile'))


    # now that a preliminary maxRel has been determined, check for reset conditions
    if maxRel == NoCutback and runningStor > 0.0:
        if DEBUG:
            LogDebug("\t%s - MaxRel = %6i, runningStor = %6i" % (resvName, maxRel, runningStor),
    currentRule.varGet('debugFile'))

        # not restricting release, watch for reset conditions
        if resvPool < ISTransitionElev:
            runningStor = 0.0
            if DEBUG:
                LogDebug("\t\t%s - resvPool = %.2f, ISTransitionElev = %.2f" % (resvName, resvPool,
    ISTransitionElev), currentRule.varGet('debugFile'))

        # ==========================================================================
        # 2018-10-12: SAF : The following reset checkk was removed because it was found
        # that the Gadsden stage could cause a reset when both it and the Weiss pool are still
        # rising at the beginning of a flood event. Since it appears that the cutback should
        # only be performed once during a flood event, a decision was made to only check
        # for Weiss pool dropping below 564 where it triggers out of surcharge operations.
        #
        # ==========================================================================

        #elif cpStage < cpResetStage and resvPool < TopOfFloodZone:
        #runningStor = 0.0
        #if DEBUG:
        #      print "\t\t%s - cpStage = %.2f, cpResetStage = %.2f, resvPool = %.2f, TopOfFloodZone = %.2f" %
    (resvName, cpStage, cpResetStage, resvPool, TopOfFloodZone)

        if runningStor == 0.0 :
            peakCounter = 0.0
            if DEBUG:
                LogDebug("\t%s - Restrict Surcharge (Reset Cutback Volume)" % (resvName),
    currentRule.varGet('debugFile'))

    ISFlowTS.setCurrentValue(currentRuntimestep, ISFlow)

else:
    if runningStor >= MaxCutbackVol:
        maxRel = NoCutback
        runningStor = MaxCutbackVol
```

```
        else:
            maxRel = lastMaxRel
            if maxRel > 0 and ISFlowLast > 0:
                estCutbackVolume = (ISFlow - maxRel)
                if estCutbackVolume <= availableStorage:
                    runningStor = runningStor + estCutbackVolume
                else :
                    # cutback is limited to remaining storage
                    maxRel = ISFlow - availableStorage
                    runningStor = MaxCutbackVol

#           maxRel = lastMaxRel
#           if maxRel > 0 and ISFlowLast > 0:
#               runningStor = runningStor + (ISFlowLast - maxRel)

        ISFlowTS.setCurrentValue(currentRuntimestep, ISFlowLast)

    # be sure to store the runningStor and peakCounter variables for use in the next timestep....
    runningStorTS.setCurrentValue(currentRuntimestep, runningStor)
    peakCounterTS.setCurrentValue(currentRuntimestep, peakCounter)
    maxRelTS.setCurrentValue(currentRuntimestep, maxRel)

    # update current step
    currentRule.varPut("step", curStep)

    if DEBUG:
        LogDebug("\t%s - Restrict Surcharge (End), Step = %3i, Stor Acct = %5i, Max Release = %6i, ISFlow = %6i,
       ISFlowLast = %6i" % (resvName, curStep, runningStor, maxRel, ISFlow, ISFlowLast),
       currentRule.varGet('debugFile'))

    if runningStor > 0.0 and maxRel > 0.0 :
        # create new Operation Value (OpValue) to return
        opValue = OpValue()
        # set type and value for OpValue
        #  type is one of:
        #  OpRule.RULETYPE_MAX  - maximum flow
        #  OpRule.RULETYPE_MIN  - minimum flow
        #  OpRule.RULETYPE_SPEC - specified flow
        opValue.init(OpRule.RULETYPE_MAX, maxRel)

        # return the Operation Value.
        return opValue
    else :
        # return "None" to have no effect on the compute
        #return None

        opValue = OpValue()
        opValue.init(OpRule.RULETYPE_MAX, NoCutback)
        return opValue
```

A.7 RestrictLoganMartinSurcharge Script

The *RestrictLoganMartinSurcharge* script to cut surcharge releases operates to minimize impacts downstream of the dam by limiting the surcharge when the stage at Childersburg is rising over the easement of 408 due to a combination of discharges from Logan Martin and local inflow. When the rating curve at Childersburg indicates that a combination of local inflow and surcharge values from Logan Martin will cause the stage at Childersburg to rise over elevation 408, surcharge releases can be cut up to 50% to provide time for the local inflows to recede. The total volume of the cutback cannot exceed 11,000 cfs-days per event. The total cutback volume does not have to be used consecutively but can be implemented as multiple cutback periods during an event. Once this volume has been utilized, the project will return to the normal surcharge release schedule.

```
# required imports to create the OpValue return object. from hec.rss.model import OpValue from hec.rss.model
    import OpRule from hec.script import Constants from hec.rss.model import RssRun  from datetime import
    datetime import math import os import tempfile import traceback  #
    ============================================================================= # Global
    Constants for this rule - change values here as needed to control the operations #
    =============================================================================  DEBUG =
    Constants.FALSE            # Use DEBUG to turn ON/OFF the debug print statements.  cpName =
    "Childersburg"        # the name of the control point (cp) for this reservoir twName = "Lay"                # the
    name of the cp's tailwater reservoir cpFloodStage = 408.0              # Flood stage at the cp #ResetStage = 407.0
              # a stage at the cp which will cause the rule to reset its ops MaxCutbackVol = 11000.0     # the
    accumlated storage limit that will stop the cutback operation                                  # note, the units are
    cfs-days. The timestep is hourly.                                 # To get cfs-hours into cfs-days, divide by 24
    (hours per day).                                  TopOfFloodZone = 473.5       # The top of the flood control
    zone for this reservoir ISRuleName = "Induced Surcharge Operation-APC"  # The name of the this rservoir's
    induced surcharge rule ISTransitionElev = 462     # The IS rule's transition elevation ISTransitionHours = 6
        # The IS rule's transition hours ChannelCapacity = 70000.0      # This reservoir's channel capacity (local
    max release) MinSurchargeRelease = 50000           # Minimum to which surcharge should ever be limited
    decisionInterval = 3  NoCutback = Constants.UNDEFINED        #399999.00                    # a value larger
    than this reservoir's maximum release capacity  logFilePath = tempfile.gettempdir()   # location of script log files
    (usually C:\Users\(UserName)\AppData\Local\Temp) # log function def LogDebug(str, debugFile, reset=0):
    try:       # open output file       f = None       if reset == 1:          # overwrite previous file          f =
    open(os.path.join(logFilePath, debugFile), 'w')        else:          # append to any existing file
       f = open(os.path.join(logFilePath, debugFile), 'a')
     f.write(str)
     f.write('\n')
     f.flush()
     f.close()

  except:

     # log error to console
     print traceback.format_exc()

# variable format function
def formatValue(val, fmt):
   if val == None:
      return "NULL"
   else:
      return fmt % val

# ===========================================================================
# initRuleScript is the initialization function.
```

```
# ============================================================================
# Perform set up task that only need to be performed once so that they are not performed
# repeatedly during the compute.
#     Arguments:
#           currentRule is the rule that holds this script
#           network is the ResSim network
#     Returns: Constants.TRUE if the initialization is successful or Constants.FALSE if it failed.
#
def initRuleScript(currentRule, network):

    # JDK Note: a bug exists in the localTimeSeriesNew methods for initializing the TSRecord with a
    # constant. Since the localTimeSeriesNew method using a timeSeriesContainer to initialize the
    # TS is fully functional, tsc & tsc2 is being used to initialize our 2 local TSRecords.
    # Once the bug is fixed, the use of tsc & tsc2 can be removed and the two commented out
    # lines below can be used instead.

    try:
        # get the name of the reservoir
        resvName = currentRule.getReservoirElement().getName()
        # get the pool storage time series container and clone it
        tsc=network.getTimeSeries("Reservoir",resvName,"Pool","Stor").getTimeSeriesContainer().clone()
        # loop through time series values and set all to zero
        for i in range(tsc.numberValues):
            tsc.values[i]=0.0
        # set the location property as reservoir running storage
        tsc.location=resvName+"-RestrictSurcharge-runningStor"
        tsc.subLocation=""
        # create new time series in this rule from the cloned container
        runningStorTS = currentRule.localTimeSeriesNew("runningStor", tsc)
        # clone the new container
        tsc2 = tsc.clone()
        # set the location property as reservoir peak counter
        tsc2.location=resvName+"-RestrictSurcharge-peakCounter"
        # create a new time series in this rule from the cloned container
        peakCounter = currentRule.localTimeSeriesNew("peakCounter", tsc2)
        # currentRule.localTimeSeriesNew("runningStor", 0.0)
        # currentRule.localTimeSeriesNew("peakCounter", 0.0)

        # get the junction object for the control point
        JCTObj = network.findJunction(cpName).getFunction()
        # get the rating table for the junction object
        RatingTable = JCTObj.getRatingObject().getIndependentVariableRatingCurveExt()
        # store the rating table in this rule
        currentRule.varPut("RatingTable", RatingTable)

        # clone the new container
        tsc3 = tsc.clone()
        # set the location property as reservoir peak counter
        tsc3.location=resvName+"-RestrictSurcharge-maxRel"
        # create new time series in this rule from the cloned container
        maxRelTS = currentRule.localTimeSeriesNew("maxRel", tsc3)

        # clone the new container
        tsc4 = tsc.clone()
        # set the location property as reservoir peak counter
        tsc4.location=resvName+"-RestrictSurcharge-ISFlow"
```

```
        # create new time series in this rule from the cloned container
        ISFlowTS = currentRule.localTimeSeriesNew("ISFlow", tsc4)

        # store peak downstream elevation
        currentRule.varPut("peakStage", 0)

        # store current last step
        currentRule.varPut("step", 9999)

        # create debug file name for CSV file
        currentRule.varPut('debugFile', datetime.now().strftime('LoganRestrictSurProp_%Y%m%d_%H%M.csv'))

    except:
        return Constants.FALSE

    # return Constants.TRUE if the initialization is successful or Constants.FALSE if it failed.
    # Returning Constants.FALSE will halt the compute.
    return Constants.TRUE

def formatArrayValue(ts, step):
    if ts != None:
        if ts.getTSArray() != None:
            if ts.getTSArray()[step.getStep() - 1] != None:
                return "%.2f" % ts.getTSArray()[step.getStep() - 1]
    return "None"

# ==========================================================================
# runRuleScript() is the function called ResSim to evaluate the rule during the compute.
# ==========================================================================
# Compute a desired release and determine its associated limit type (MIN, MAX, SPEC)
#     Arguments:
#         currentRule is the rule that holds this script
#         network is the ResSim network
#         currentRuntimestep is the current Run Time Step
#     Returns: an OpValue object or None
#
def runRuleScript(currentRule, network, currentRuntimestep):
    '''
    RULE: RestrictSurcharge
    Author: Joan Klipsch, USACE-IWR-HECAug-Sep 2018 (aka JDK)

    This rule's objective is to cutback the Induced Surcharge releases from this reservoir up to 50%.
    When the accumulated storage due to this cutback exceeds a predefined limit, the cutback operation
    will cease.  Assumptions and constraints are described below and in the text of the script.

    To begin this operation,
    - the Induced Surcharge rule must be calling for a release greater than channel capacity AND
    - the IS release is expected to cause the water surface elevation at the control point to
        exceed flood stage.

    To reset the limiting operation, the following conditions are relevant:
    - the operation must have been "on" AND
        - the stage at the control point must have fallen below flood stage  OR
        - this reservoir must be below its Induced Surcharge Transition Elevation

    The variable runningStor (the additional accumulated storage due to the cutback called for by this
```

```
rule) is used as the "operation has been on" flag

Revisions added 9-17-2018 JDK
- If the running storage has not maxed out before the inflow drops below release, then the max
   release from this operation should be held, regardless of the running storage.
- A counter, peakCounter, has been added to keep track of the number of timesteps in which the
   inflow is less than the previous release.
'''

# NOTE: testing of this rule suggests that there MAY be a bug in the ESRD implementation of the
# IS rule's falling pool option "maintain peak release".
# Recommendation: Use "maintain peak gate" instead. - JDK

# Retrieve the (3-variable) rating table for the control point from the vars list
cpRatingTable = currentRule.varGet("RatingTable")

# Retrieve the local variables stored in this script and their previous values
runningStorTS = currentRule.localTimeSeriesGet("runningStor")
peakCounterTS = currentRule.localTimeSeriesGet("peakCounter")
runningStor = runningStorTS.getPreviousValue(currentRuntimestep)
peakCounter = peakCounterTS.getPreviousValue(currentRuntimestep)

# Retrieve the model veriables needed by this script

# get the current model run
thisRun = network.getRssRun()
# get the local flow time series at the control point
cpCumlocTS = thisRun.getTSRecordByPathParts(cpName,"FLOW-CUMLOC")
# get the stage time series at the control point
cpStageTS = network.getTimeSeries("Junction",cpName, "", "Stage")

# get the pool elevation time series at the downstream control location
cpTailwaterTS = network.getTimeSeries("Reservoir", twName, "Pool", "Elev")
# get the total flow time series at the control point
#cpCumFlowTS = thisRun.getTSRecordByPathParts(cpName, "FLOW")

# get the reservoir name
resvName = currentRule.getReservoirElement().getName()
# get the pool elevation time series for reservoir
resvPoolTS = network.getTimeSeries("Reservoir",resvName, "Pool", "Elev")
# get the pool inflow time series for reservoir
resvInflowTS = network.getTimeSeries("Reservoir",resvName, "Pool", "Flow-IN NET")
# get the pool outflow time series for reservoir
resvOutflowTS = network.getTimeSeries("Reservoir",resvName, "Pool", "Flow-OUT")
# get the induced surcharge rule time series for reservoir
resvISRuleTS = network.getTimeSeries("Reservoir",resvName, ISRuleName, "Flow-MIN")

# Get the "current" values of the model variables

# get the control point stage at the end of the previous timestep
cpStage = cpStageTS.getPreviousValue(currentRuntimestep)
# get the control point local flow at the end of the previous timestep
cpCumloc = cpCumlocTS.getCurrentValue(currentRuntimestep)
# get the downstream elevation for the control point (dam forebay) at the end of the previous timestep
cpTailwater = cpTailwaterTS.getPreviousValue(currentRuntimestep)
# get the control point total flow at the end of the previous timestep
```

```
#cpCumFlow = cpCumFlowTS.getPreviousValue(currentRuntimestep)

# get the reservoir pool elevation at the end of the previous timestep
resvPool = resvPoolTS.getPreviousValue(currentRuntimestep)
# get the reservoir inflow at the end of the previous timestep
resvPrevIn = resvInflowTS.getPreviousValue(currentRuntimestep)
# get the reservoir inflow for the current timestep
resvCurIn = resvInflowTS.getCurrentValue(currentRuntimestep)
# get the reservoir discharge at the end of the previous timestep
resvPrevOut = resvOutflowTS.getPreviousValue(currentRuntimestep)

# get the induced surcharge rule value at the end of the previous timestep
ISFlowPrev = resvISRuleTS.getPreviousValue(currentRuntimestep)
# get the induced surcharge rule value for the current timestep
ISFlowCur = resvISRuleTS.getCurrentValue(currentRuntimestep)
# set the induced surcharge flow to the induced surcharge calculation for the current timestep
ISFlow = ISFlowCur

# initialize the local variables needed or computed by the cutback logic

# set the max release to zero
maxRel = 0.0
# set the estimated cutback volume to zero
estCutbackVolume = 0.0
# set the available storage to the max storage volume minus the running storage volume
availableStorage = MaxCutbackVol - runningStor

# get previous max release
maxRelTS = currentRule.localTimeSeriesGet("maxRel")
lastMaxRel = maxRelTS.getPreviousValue(currentRuntimestep)

# get previous induced surcharge value
ISFlowTS = currentRule.localTimeSeriesGet("ISFlow")
ISFlowLast = ISFlowTS.getPreviousValue(currentRuntimestep)

# start by checking to see if this hour is a multiple of the decision interval
isChangeHour = (currentRuntimestep.getHecTime().hour() % decisionInterval == 0)

# get the current step
curStep = currentRuntimestep.getStep()

# check to reset peak elevation
if curStep < currentRule.varGet("step"):
    currentRule.varPut("peakStage", 0)

# update peak stage
if currentRule.varGet("peakStage") < cpStage:
    currentRule.varPut("peakStage", cpStage)

if DEBUG:
    LogDebug("%s - %i != %i or %i == 0 or %i ???" % (resvName, math.floor(ISFlowPrev),
   math.floor(ISFlowCur), runningStor, ISFlowLast), currentRule.varGet('debugFile'))

if math.floor(ISFlowLast) != math.floor(ISFlowCur) or runningStor == 0: #if isChangeHour or ISFlowPrev !=
   ISFlowCur:
```

```
 if DEBUG:
    LogDebug("%s - Starting Restrict Surcharge, %s, Step = %3i, Pool = %.2f, Stage = %.2f, Local Flow = %6i,
Stor Acct = %5i, Stor Avail = %5i, Last IS = %g, Curr IS = %g" % (resvName,
currentRuntimestep.dateTimeString(), curStep, resvPool, cpStage, cpCumloc, runningStor, availableStorage,
ISFlowPrev, ISFlowCur), currentRule.varGet('debugFile'))


 # Determine the "cutback release"
 #---------------------------------------------------------------------------------------------------
 # The max release determination is divided into four conditional parts.
 # 1. if the cutback operation has been "maxed out" and remains "on"
 if runningStor >= MaxCutbackVol:
    # maintain status quo, don't apply any cutback to the IS operation.
    maxRel = NoCutback

    if DEBUG:
       LogDebug("\t%s - Restrict Surcharge Case 1 (Storage Full), Stor Acct = %5i, Max Release = %6i" %
(resvName, runningStor, maxRel), currentRule.varGet('debugFile'))


 #---------------------------------------------------------------------------------------------------
 # 2. if the cutback operation has been "on" and the release > inflow and inflow is falling
 #          -hold the peak until IS falling pool operations kick in
 #          -and watch for reset conditions
 elif runningStor > 0.0 and resvPrevOut > resvPrevIn > resvCurIn :
    # release has peaked and inflow is falling.
    # hold peak release until IS falling pool rules should kick in.
    maxRel = resvPrevOut
    peakCounter = peakCounter + 1
    estCutbackVolume = (ISFlow - maxRel)

    if estCutbackVolume < 0:
       maxRel = NoCutback
    else:

       runningStor = runningStor + estCutbackVolume
       if runningStor > MaxCutbackVol or peakCounter > ISTransitionHours: # or ISFlow <= resvPrevOut:
          # stop restricting the IS operation if we've run out of storage
          # or if the IS falling pool options should start or already has started
          runningStor = MaxCutbackVol
          maxRel = NoCutback

    if DEBUG:
       LogDebug("\t%s - Restrict Surcharge Case 2 (Past Peak), Stor Acct = %5i, Max Release = %6i, Peak Cnt =
%3i, Cutback = %5i" % (resvName, runningStor, maxRel, peakCounter, estCutbackVolume),
currentRule.varGet('debugFile'))


 #---------------------------------------------------------------------------------------------------
 # 3. if the "current" desired Induced Surcharge release > channel capacity then
 #          if the cutback operation has not reached its allowed storage then
 #                - determine if a cutback is desirable and the associated cutback release
 #          else the maximum storage has been reached, so
 #                - turn off the cutback but consider the operation to still be on until "reset"

 # ==========================================================================
```

```
    # 2018-10-10 : SAF : The following line was changed from "=" to ">=" because surcharge operations
    # actually begin at channel capacity (40,000 CFS) and may never rise above that value in a
    # smaller event.
    # ==========================================================================

    # ==========================================================================
    # 2018-12-19 : SAF : Modified to limit surcharge cutback to a specified minimum rather than half
    # of the IS discharge. Several factors were involved in this including the question about cutting
    # back beyond unit capacity or below the bottom of the surcharge curve.
    # ==========================================================================

    elif ISFlow >= ChannelCapacity:
        # Determine how much of the IS release can be held back, up to 50%.
        #       - Estimate the Gadsden stage using 100% IS release + locals
        FullFlow = ISFlow + cpCumloc
        estStageFull = cpRatingTable.interpolate(FullFlow, cpTailwater)
        estStageMinimum = 0; MinimumISFlow = 0; ratio = 0.0
        if estStageFull < cpFloodStage or resvPool >= TopOfFloodZone - 1:
            # 100% IS release will NOT flood Childersburg or we are too close to easement, no cutback is needed
            maxRel = NoCutback
        else:
            # 100% IS relese WILL flood Gadsden, will the specified minimum?
            #   - Estimate the Gadsden stage using the specified minimum IS release + locals
            MinimumISFlow = MinSurchargeRelease + cpCumloc
            estStageMinimum = cpRatingTable.interpolate(MinimumISFlow, cpTailwater)
            if estStageMinimum > cpFloodStage: # or MinimumISFlow > 130000:
                # since minimum specified IS release is still going to produce flooding...
                # try to stay below the peak stage
                distMin2PeakStg = currentRule.varGet("peakStage") - estStageMinimum
                distMin2FullStg = estStageFull - estStageMinimum
                LogDebug("%s - Case 3 - distMin2PeakStg = %.2f, peakStage = %.2f, estStageMinimum = %.2f" %
(resvName, distMin2PeakStg, currentRule.varGet("peakStage"), estStageMinimum),
currentRule.varGet('debugFile'))
                LogDebug("%s - Case 3 - distMin2FullStg = %.2f, estStageFull = %.2f, estStageMinimum = %.2f" %
(resvName, distMin2FullStg, estStageFull, estStageMinimum), currentRule.varGet('debugFile'))
                if distMin2FullStg == 0:
                    maxRel = ISFlow # full flow
                    LogDebug("%s - Case 3 - No Cutback" % (resvName), currentRule.varGet('debugFile'))
                elif distMin2PeakStg <= 0:
                    maxRel = MinSurchargeRelease # minimum flow
                    LogDebug("%s - Case 3 - Min Release = %i" % (resvName, MinSurchargeRelease),
currentRule.varGet('debugFile'))
                else:
                    ratio = distMin2PeakStg / distMin2FullStg
                    LogDebug("%s - Case 3 - ratio = %.2f" % (resvName, ratio), currentRule.varGet('debugFile'))
                    maxRel = MinSurchargeRelease + ratio * (ISFlow - MinSurchargeRelease)

                #maxRel = MinSurchargeRelease

            else:     # estHalfGadsdenStage <= cpFloodStage
                # find a cutback release that would keep Gadsden at or below flood stage
                # use linear interpolation...
                distMin2FldStg = cpFloodStage - estStageMinimum
                distMin2FullStg = estStageFull - estStageMinimum
                ratio = distMin2FldStg/distMin2FullStg
                maxRel = MinSurchargeRelease + ratio * (ISFlow - MinSurchargeRelease)
```

```
            LogDebug("%s - Case 3 - distMin2FldStg = %.2f, cpFloodStage = %.2f, estStageMinimum = %.2f" % (resvName, distMin2FldStg, cpFloodStage, estStageMinimum), currentRule.varGet('debugFile'))
            LogDebug("%s - Case 3 - distMin2FullStg = %.2f, estStageFull = %.2f, estStageMinimum = %.2f" % (resvName, distMin2FullStg, estStageFull, estStageMinimum), currentRule.varGet('debugFile'))
            LogDebug("%s - Case 3 - ratio = %.2f" % (resvName, ratio), currentRule.varGet('debugFile'))

        # determine if estimated cutback volume can be stored, if not adjust maxRel.
        estCutbackVolume = (ISFlow - maxRel)
        if estCutbackVolume < 0:
            maxRel = NoCutback
        else:

            if estCutbackVolume <= availableStorage:
                runningStor = runningStor + estCutbackVolume
            else :
                # cutback is limited to remaining storage
                maxRel = ISFlow - availableStorage
                runningStor = MaxCutbackVol

    peakCounter = 0.0

    if DEBUG:
        LogDebug("\t%s - Restrict Surcharge Case 3 (Calc Cutback), Stor Acct = %5i, Max Release = %6i, Peak Cnt = %3i, Cutback = %5i, Stor Avail = %5i" % (resvName, runningStor, maxRel, peakCounter, estCutbackVolume, availableStorage), currentRule.varGet('debugFile'))
        LogDebug("\t\t%s - ISFlow = %6i, estStageFull = %.2f, estStageMinimum = %.2f, FullFlow = %6i, MinimumISFlow = %6i, ratio = %.3f" % (resvName, ISFlow, estStageFull, estStageMinimum, FullFlow, MinimumISFlow, ratio), currentRule.varGet('debugFile'))

#-----------------------------------------------------------------------------------------------------
# 4. ELSE...
#          probably in a rising pool condition but IS rule has not called for a release > channel capacity
else:
    maxRel = NoCutback
    peakCounter = 0.0

    if DEBUG:
        LogDebug("\t%s - Restrict Surcharge Case 4 (No Cutback), Stor Acct = %5i, Max Release = %6i" % (resvName, runningStor, maxRel), currentRule.varGet('debugFile'))


# now that a preliminary maxRel has been determined, check for reset conditions
if maxRel == NoCutback and runningStor > 0.0:
    if DEBUG:
        LogDebug("\t%s - MaxRel = %6i, runningStor = %6i" % (resvName, maxRel, runningStor), currentRule.varGet('debugFile'))

    # not restricting release, watch for reset conditions
    if resvPool < ISTransitionElev:
        runningStor = 0.0
        if DEBUG:
            LogDebug("\t\t%s - resvPool = %.2f, ISTransitionElev = %.2f" % (resvName, resvPool, ISTransitionElev), currentRule.varGet('debugFile'))

    # =============================================================================
    # 2018-10-12: SAF : The following reset checkk was removed because it was found
```

```
        # that the Gadsden stage could cause a reset when both it and the Weiss pool are still
        # rising at the beginning of a flood event. Since it appears that the cutback should
        # only be performed once during a flood event, a decision was made to only check
        # for Weiss pool dropping below 564 where it triggers out of surcharge operations.
        # ===========================================================================

        #elif cpStage < cpResetStage and resvPool < TopOfFloodZone:
        #runningStor = 0.0
        #if DEBUG:
        #       print "\t\t%s - cpStage = %.2f, cpResetStage = %.2f, resvPool = %.2f, TopOfFloodZone = %.2f" %
  (resvName, cpStage, cpResetStage, resvPool, TopOfFloodZone)

        if runningStor == 0.0 :
            peakCounter = 0.0
            if DEBUG:
                LogDebug("\t%s - Restrict Surcharge (Reset Cutback Volume)" % (resvName),
  currentRule.varGet('debugFile'))

      ISFlowTS.setCurrentValue(currentRuntimestep, ISFlow)

    else:

      if runningStor >= MaxCutbackVol:

        maxRel = NoCutback
        runningStor = MaxCutbackVol

      else:

        maxRel = lastMaxRel
        if maxRel > 0 and ISFlowLast > 0:
            estCutbackVolume = (ISFlow - maxRel)
            if estCutbackVolume <= availableStorage:
                runningStor = runningStor + estCutbackVolume
            else :
                # cutback is limited to remaining storage
                maxRel = ISFlow - availableStorage
                runningStor = MaxCutbackVol

#           maxRel = lastMaxRel
#           if maxRel > 0 and ISFlowLast > 0:
#               runningStor = runningStor + (ISFlowLast - maxRel)

      ISFlowTS.setCurrentValue(currentRuntimestep, ISFlowLast)

    # be sure to store the runningStor and peakCounter variables for use in the next timestep....
    runningStorTS.setCurrentValue(currentRuntimestep, runningStor)
    peakCounterTS.setCurrentValue(currentRuntimestep, peakCounter)
    maxRelTS.setCurrentValue(currentRuntimestep, maxRel)

    # update current step
    currentRule.varPut("step", curStep)

    if DEBUG:
```

```
    LogDebug("\t%s - Restrict Surcharge (End), Step = %3i, Stor Acct = %5i, Max Release = %6i, ISFlow = %6i,
   ISFlowLast = %6i" % (resvName, curStep, runningStor, maxRel, ISFlow, ISFlowLast),
   currentRule.varGet('debugFile'))

 if runningStor > 0.0 and maxRel > 0.0 :

    # create new Operation Value (OpValue) to return
    opValue = OpValue()
    # set type and value for OpValue
    #  type is one of:
    #  OpRule.RULETYPE_MAX  - maximum flow
    #  OpRule.RULETYPE_MIN  - minimum flow
    #  OpRule.RULETYPE_SPEC - specified flow
    opValue.init(OpRule.RULETYPE_MAX, maxRel)

    # return the Operation Value.
    return opValue

 else :
    # return "None" to have no effect on the compute
    #return None

    opValue = OpValue()
    opValue.init(OpRule.RULETYPE_MAX, NoCutback)
    return opValue
```

Appendix B. Computation of Local Flows from the Climate Change Data

The Climate Change team developed four sets of total flow hydrographs that represent the hypothetical "unimpaired" flows that might be "observed" in the ACT basin for four climate change scenarios. The Climate Change flows mimic the Unimpaired Flows that are currently used in the daily model. The Unimpaired Flows were developed from the period of record of observed flows in the river system with the objective of removing man's influence on the hydrology. Thus, all diversions and lake evaporation losses are considered to be "added back in" to so that the reservoir operation, evaporation, and diversions can be modeled in each study alternative. Development of the climate change hydrology is detailed in **Appendix C, Attachment 5. Climate Change Hydrology Development in Support of the Allatoona Coosa Reallocation Study**.

In order to utilize the data developed by the climate change team in the daily ACT ResSim model, incremental local flow hydrographs needed to be derived from the total flow hydrographs. This document describes how those incremental local flow hydrographs were computed.

B.1 The Approach

The standard process for computing incremental local flows from observed (total) flows between two gages on a river is as follows:

$L_2 = O_2 - RO_1$

Where:

L_2 = *the incremental local flow hydrograph at the downstream gage (Gage 2)*

O_2 = *the observed flow hydrograph at the downstream gage*

O_1 = *the observed flow hydrograph at the upstream gage (Gage 1)*

RO_1 = *O_1 routed to the downstream gage location.*

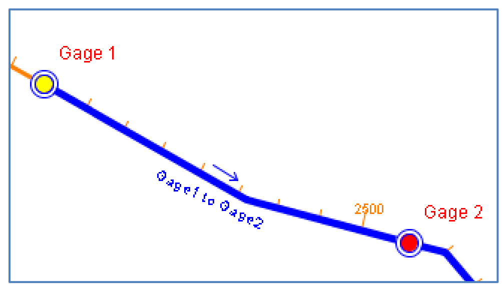


Figure B.123. Two Gages on a Stream

This basic concept for computing incremental local flows has been included as an option in a new ResSim feature called the **Operations Support Interface (OSI)**. With a *carefully configured network and alternative* and a properly configured OSI, a user can compute the incremental local flows from total observed flows at one or more locations throughout their model.

B.1.1 The OSI's Computation of Local Inflows

The OSI's compute option for calculating local inflows involves the very careful and deliberate use of the *observed* time series data specified in an alternative as well as the time series datasets representing the local inflows or "known flows".

B.1.1.1 Known Flows

In a normal or standard compute, local inflows, or "known flows", are treated as point sources of flow into the reservoir network. In a reservoir network, only junction elements can receive local inflows. Each junction adds its local inflows to the flows from its "upstream" element(s) and passes the total to its "downstream" element. The *original* time-series datasets identified in the alternative editor for each "known flow" entry (which represents a local inflow) are copied into the simulation.dss file (for the simulation time window). These datasets are normally left untouched by ResSim; any changes ResSim makes to the input data, such as interpolating to the current time step, are written as output to the simulation.dss file with a modified F-part.

However, at the end of the OSI's "Calculate Locals" compute, the input time series for the local inflows in the simulation.dss file are **overwritten** with the computed locals. This allows a subsequent standard compute of the same alternative to be launched that will then use these newly computed local inflows in its computations. Because of this, each "known flow" entry that represents a local inflow that will be calculated by the OSI must have a different pathname than any other "known flow" entry of that alternative. NOTE: A "Save to Base" action will not copy any DSS data from the simulation.dss file of the simulation back into the dss files from which the input data originated. To retain the computed local inflow time series for use in other alternatives, simulations, or watersheds, the user must manually copy the records out of the simulation.dss file to a new or existing file dss file outside of the simulation.

B.1.1.2 Observed Flows

Normally, ResSim only uses the time series data that a user identifies on the Observed Data tab of the Alternative Editor for a given alternative for plotting with the computed results of that alternative; in other words, observed data is NOT used during the computations.

However, during the OSI's "Calculate Locals" simulation, ResSim uses the Observed time series data as follows:

- At junctions where a local flow *is not computed* but an observed total flow is provided, such as at headwater junctions or reservoir outflow junctions, the *observed* total flow replaces the *computed* total flow for the junction. So, if the next element is a reach, the **observed** total flow is routed to the next junction, **not** the **computed** total flow.
- At junctions where a local flow *is* to be computed, an observed total flow *must* be provided. To calculate the local flow, the sum of the flows *routed* to the junction is subtracted from the *observed* total flow. The observed total flow is then passed to the next element; so, if the next element is a reach, the observed total flow is routed to the next junction.
- At junctions where observed total flow was *not* specified, the local flow computations simply sum up the flows routed to the junction plus any local inflows that are NOT included in the OSI as a "local inflow" OSI variable and pass the total on to the next element.

Since the Climate Change hydrographs represent *total flows that might be seen* at the various gages throughout the basin, they could be treated as "observed" flows. By recognizing this, the modeling team was able to assemble a special version of the study network and created some associated alternatives so that the OSI could be used to compute the incremental local flows from the Climate Change flows.

B.2 Time Series Data Development

Before proceeding with developing the necessary network and alternative(s), some input time series work was needed. This involved the following activities:

- *Imported the Climate Change Hydrology into HEC-DSS.* ResSim requires all its time series input to be provided in HEC-DSS format. However, the Climate Change hydrology was provided in a set of *.csv* files, one file for each "gage location" where a total flow was computed. Other than the header row, each row in the *.csv* files contained a date and 5 flow values, one labeled hindcast and 1 for each of the four climate change scenarios.

	A	B	C	D	E	F
1	date	hindcast	cesm1-cam5_rcp60_r1i1p1	csiro-mk3-6-0_rcp26_r1i1p1	hadgem2-ao_rcp45_r1i1p1	miroc-esm-chem_rcp45_r1i1p1
2	10/1/1950	444.1502075	618.0365559	372.5329137	359.8375244	255.3939886
3	10/2/1950	434.8389893	571.0886522	328.2508663	331.4654926	227.7793666
4	10/3/1950	425.4772034	547.8474467	317.1064172	321.6880028	218.5194485
5	10/4/1950	425.4772034	536.4537354	332.3020125	339.0442556	308.0260621
6	10/5/1950	425.4772034	526.608696	324.3154602	335.0281067	311.8221436
7	10/6/1950	416.0631409	516.0090686	309.4915518	318.4242628	250.2224476
8	10/7/1950	407.188446	504.2283359	305.0531175	313.0017055	303.5310948

Figure B.124. Example data from one of the Climate Change .csv files

The data in each *.csv* file was imported into an HEC-DSS database and assigned a DSS pathname using the following naming convention:

/*River Name*/*Location Name*/FLOW//1DAY/*Climate Change Scenario*/

The River and Location names were determined from the *Gage_info_summary.xlsx* file that accompanied the *.csv* files.

The labels assigned to each column of data provided in the .csv files were:

HINDCAST
AVERAGE VOLUME
HIGHEST VOLUME 1
HIGHEST VOLUME 2
LOWEST VOLUME

The filename of the dssfile (database) in which the climate change hydrology was stored is ACT_Climate_Change_Hydrology.dss.

- *Created Local Inflow Time-Series records*. When the OSI computes local inflows, it writes them into the time series records in that are attached to the local inflows for each junction. Since ResSim won't compute if it thinks its alternative is not complete or has missing data, each local inflow must be mapped to a DSS dataset that is complete for the simulation window. It may seem logical that since the local inflow is to be computed, a generic zero flow time series can be assigned to each local inflow. However, since the objective is to retain the computed local inflows for use in other alternatives, each local inflow needs a unique time series dataset for the OSI to write into.

To meet this need, a generic zero flow time series spanning the time window of the climate change data (1Oct1950-30Sep2099) was created. Then a copy of this dataset was made for each local inflow to be computed. The naming convention used matched the climate change data:

/*River Name*/*Location Name* Local/FLOW-LOC//1DAY/*Climate Change Scenario*/

Where:

Local was appended to the *Location Name* (or Lake Local for the reservoir inflow junctions)

-LOC was appended to the Parameter name, FLOW

The local flow records (containing zero flows were stored in the ACT_Climate_Change_Hydrology.DSS file along with the total flow Climate Change data that was provided.

- *Created a generic "headwater inflow" time series.* The zero flow time series was renamed to "Headwater Inflow". This time-series could be used wherever a headwater inflow was required but where the climate change modeling did not produce a total flow – for example, the inflow to Walter Bouldin reservoir.
- *Created a generic zero EVAPNET_RATE time series*. This zero evap time series would be used for each reservoir's input evaporation.
- *Developed a guide curve time series for Martin reservoir.* In the study model, Martin's guide curve is computed by a state variable. Since the simplified network is not intended to perform the standard operations, a guide curve time series was developed: The computed guide curve was copied from the *Base2018* alternative results. It was then extended through 30Sep2099. The extension was created by copying the data from 01Oct1951-30Sep1991 to 01Oct2011-30Sep2051 and from 01Oct1951-30Sep1999 to 01Oct2050-30Sep2099. This process retained the originally computed guide curve through 30Sep2011 and the copy windows and target dates avoided problems with leap years. The dataset was saved to the lookback dss file.
- *The lookback elevation data for all the reservoirs was extended* to cover the full time window of the Climate Change data using almost the same method as for the Martin Guide Curve. Since the guide curve for all other reservoirs is not a computed quantity, the copying of the lookback data simply had to keep the leap years aligned.

B.3 Creating the *Carefully Configured* Watershed

Although the OSI feature for computing local inflows was designed to be used "in-situ" – i.e., as part of a standard operational alternative, it can be challenging to verify that the results are not influenced by the operations of the model. With this in mind, the modeling team chose to create a simplified version of the ACT network as the basis for the alternatives used to compute the local inflows. Once computed, the local inflows time series were gathered into a separate DSS file for use with the study model alternatives.

The requirements for a *carefully configured network* that could be used to compute the incremental locals include:

Each Reservoir should have only 1 inflow junction. Since a reservoir usually has only 1 observed or computed inflow to the lake, then only 1 local can be computed from that inflow.

No distributed locals. A single inflow hydrograph should not be used at multiple locations and distributed using a basin weighting factor.

Only one local inflow can be computed per gage location. Although ResSim allows multiple local inflows to be applied at junction, only one incremental local inflow can be computed by the OSI per junction element.

An Observed Flow is required wherever a local flow is to be computed. If an observed flow is not available for a given location, a local inflow cannot be computed at that location. In addition, *an observed flow is required at the next gage upstream of where the local is to be computed* – this means that an observed flow must be identified at each headwater junction and at the outflow junctions of each reservoir – if a local is to be computed be computed below the reservoir.

Diversions and losses must be considered carefully. If using actual observed flows, observed diversions and/or losses should be included in the model if their effects are not to be included in the computed locals.

After careful review of the watershed, the modeling team decided that to adequately address the above requirements the following changes were needed in order to simplify the network that would be used to compute the locals:

1. All distributed locals had to be removed (or recombined).
2. The diversions throughout the model could be removed. Since the network's purpose is to compute the locals from the "unimpaired" Climate Change flows, the diversions should not be included, nor should the evaporation losses.

   Figure B.125 shows the ***original*** specification for the local inflows at one of the two inflow junctions for Harris reservoir. The first local flow entry is an example of a "distributed local" as evidenced by the factor of 0.5. The second entry is an example of a lake withdrawal (diversion) modeled as a negative inflow.

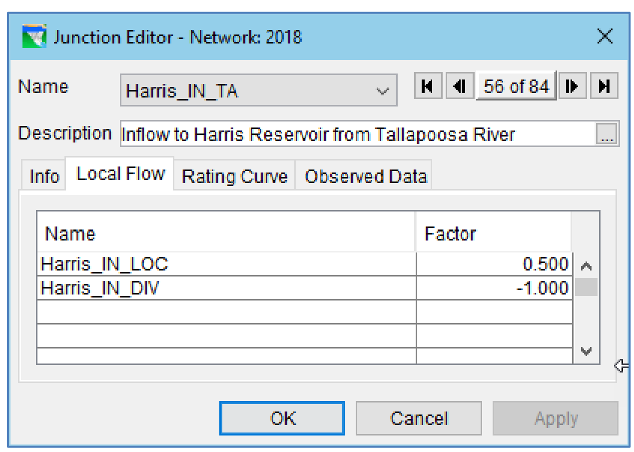


Figure B.125. Original Inflow Specification at one of Harris' Inflow Junctions

3. Harris and Millers Ferry reservoirs must be redrawn so that they only have a single inflow junction. These reservoirs were originally defined with two inflow junctions each and their single local inflow hydrograph was distributed to the two junctions.
4. Hickory Log Creek and Richland Creek reservoirs could be removed from the network[2]. Both the original basin hydrology, as well as the Climate Change data, lumped the flow provided by these small tributaries into a local inflow along the Etowah – Hickory Log Creek was part of the local at Canton and Richland Creek was part of the local at Kingston. In the base model, basin weighting was used to distribute the two downstream local inflows so that the reservoirs and control points had inflow. Since these reservoirs were not used when preparing the climate change hydrology, they were not needed for the computation of the incremental locals.
5. Dummy above Dawsonville reservoir could be removed from the network. This reservoirs is used as "modeling technique" to manage the operations of the system and is not needed for the computation of local inflows.
6. Since the alternatives to be used to compute the locals were not intended to be used as standard alternatives, the operation set needed for each reservoir is the "guide curve only" or "flow through" operation sets. These operation sets define the reservoir zones and the guide curve but do not include any rules. If a reservoir in the network did not have an operation of this type, one was created.

B.3.1 Creating a New Configuration

The modeling team decided that some of the changes that would be needed in the network called for changes to the watershed configuration that the network was based on. Rather than alter the original *Base* configuration, a new *Locals* configuration was created as a copy of the *Base* configuration and the following changes were made:

- Harris and Millers Ferry reservoirs were removed. A new version of these reservoirs was not added in the configuration; that was left to be done in the new network.
- Hickory Log Creek and Richland Creek reservoirs were removed.

B.3.2 Developing the Network

The activities for creating the "carefully configured network" then proceeded as follows:

- A new network, *CC_Locals*, was created using the new *Locals* configuration as a template.

[2] In order to remove the distributed locals on the two added creeks, the headwater inflows to the two creeks was set to zero. Thus, it was irrelevant whether the reservoirs were removed or not. In fact, since this network was used only to compute local inflows and for no operational purpose, none of the reservoirs were needed. *All* the reservoirs could have been replaced with Null routing reaches and the resulting locals would have been the same – as long as each junction was defined correctly with its assigned local inflow and observed total flow.

- A new inflow junction was drawn at the confluence of the two streams that flow into Harris and Millers Ferry reservoirs.
- Harris and Millers Ferry reservoirs were drawn from the new inflow junction to the original outflow junction.
- Routing reaches were added to the new network connecting all the junctions throughout the network.
- Schematic elements that were NOT added to the new network included all the diversions and the dummy reservoir on the Etowah used in the 2018 network.

  Figure B.126 shows the newly drawn Harris reservoir with the reaches included between all the junctions. For consistency, the two original Harris inflow junctions were left in place but null routing was used to translate the flow at these junctions to the confluence. This section of the network will be used to illustrate the various settings that were required in order to "carefully configure" the network for computing local flows.

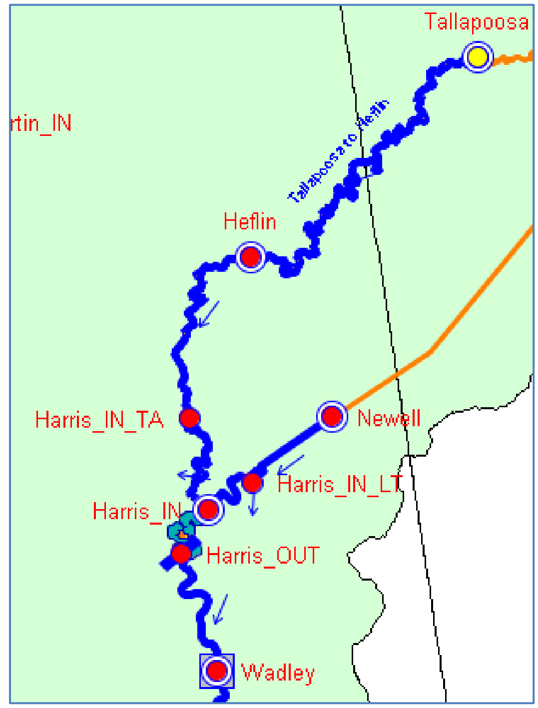


Figure B.126. Upper Tallapoosa around Harris

- The data from the 2018 network was **imported** into the new network for all the remaining reservoirs, junctions, and reaches. To the extent possible, rule connectivity was completed for the rules that the Importer identified, however this was not necessary since the rules would not be used in this network to compute the local flows.
- The imported routing methods and parameters were carefully reviewed be sure they matched the routing used in the development of the Unimpaired local inflows as listed in the report documenting the development of the Unimpaired Flows.
- All distributed local inflows were removed by identifying the (gage) location where the incremental local should be computed and deleting the distributed inflows identified at other (non-gage) locations. And, all headwater junctions that used a distributed locals were assigned a factor of 0.0 (and a zero inflow time series was mapped to them in the alternative); these included the inflow junctions for Hickory Log Creek, Richland Creek, and Walter Bouldin reservoirs.
- The negative inflows at the junctions representing lake withdrawals (diversions) were deleted.
- On the Observed tab of the following junctions:
  - headwater junctions,

- reservoir outflow junctions,
- whereever local inflow was to be computed, including the reservoir inflow junctions,

a checkmark was placed in the checkbox for ariable that represented the total outflow of the junction:Any other pre-existing checkmark was removed from these and all other junctions. The checkmark next to a variable on the Observed tab will cause an entry for the associated location and variable to be included on the Observed Data tab of the Alternative Editor for each alternative that uses this network. Figure B.127 provides an illustration of how the local flow tab and the observed tab was defined for each type of junction.

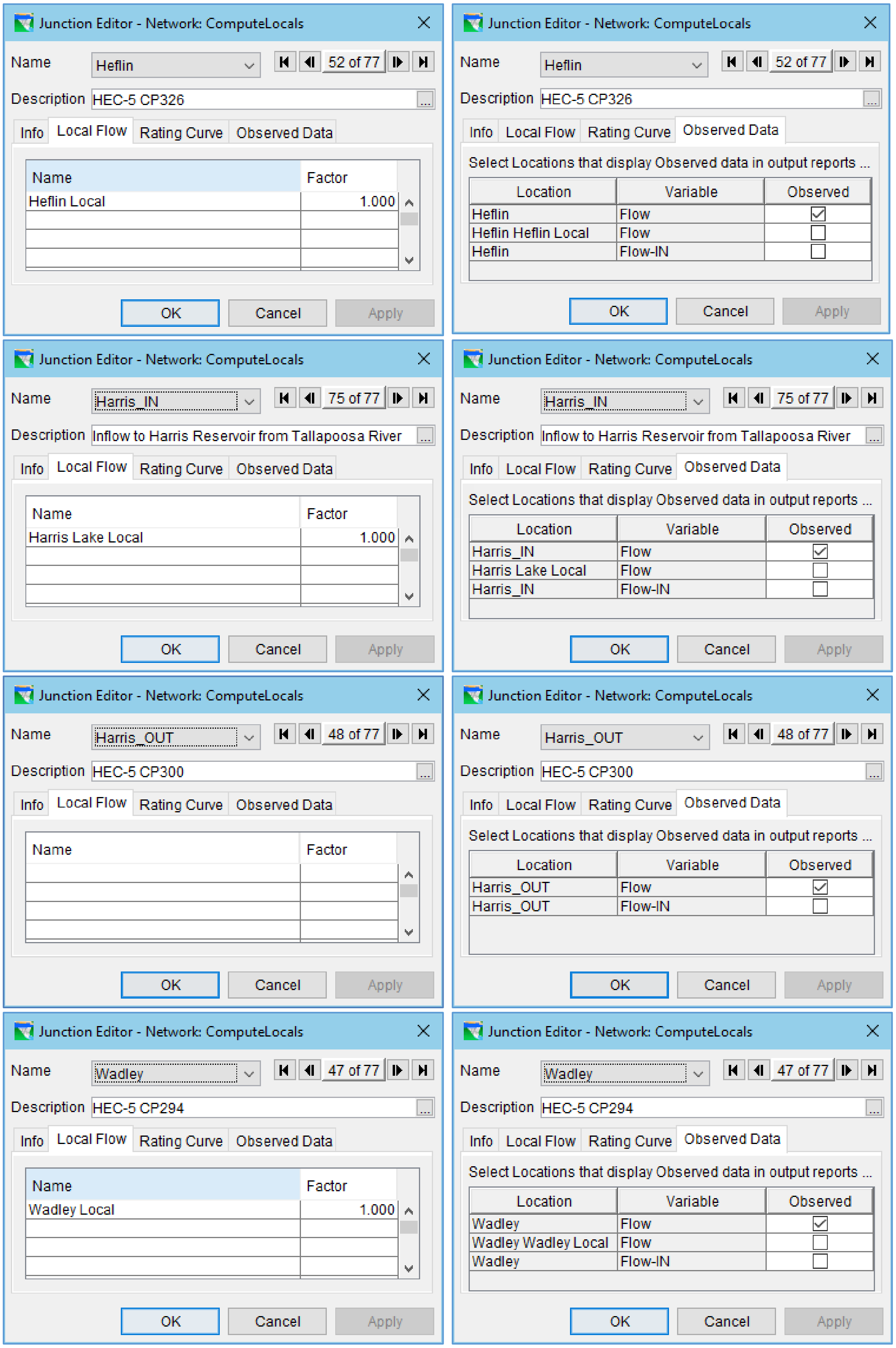


Figure B.127. Local Inflow and Observed Data Specification for Upper Tallapoosa Junctions

- The operation sets for each reservoir were reviewed to be sure that each reservoir included a "guide curve only" (or equivalent) operation set – an operation set with zones but no rules. By using this operation set for each reservoir and setting the starting pool elevation to the guide curve, the reservoirs will effectively pass inflow (as long as release capacity exceeds inflow) for the entire run.

B.3.3 Creating the Alternatives

An alternative, *CC_loc_Avg*, was created for the"Average Volume" Climate Change scenario using the *CC_Locals* network. The other three alternatives, *CC_loc_HV1*, *CC_loc_HV2*, *and CC_loc_LV*, were created later as copies of the first alternative and the pathname on the Time Series and Observed Data tabs were revised–to reflect the relevant Climate Change scenario. The reason for creating the alternatives in this way is explained in the next section, The Operations Support Interface.

The alternative settings for the alternative(s) were:

- Run Control – 1 Day Timestep; Period Average Compute Type, Standard Alternative type.
- Operations – GC Only or Flow Thru for each reservoir.
- Lookback – Elevation and one outlet's Release were set to Time-Series. All other outlet releases were set to 0.0. All remaining state variables were also initialized to 0.0 except Martin_GC which was set to time series.
- Time-Series:
    - All known flow locations were set to the individual zero flow time series created and stored in the Climate Change Hydrology file for each location for the associated scenario.
    - All Input Evap entries were mapped to the zero EVAPNET-RATE time series.
    - All Reservoir Lookback Elevation entries were set to the relevant GUIDECURVES time-series.
    - All Reservoir Lookback Release entries were set to the Climate Change Total Flow time series for each reservoir for the associated scenario.
- Observed Data - The observed total flow at each junction listed was set to the associated gage's total flow from the Climate Change hydrology for the associated scenario.

  The list of locations and variables are a function of the checkmarks specified on the Observed Tab of the element editor for each element in the network. As indicated in the Reservoir Network section above, an entry should appear for each:

    - Headwater junction
    - Inflow and Outflow junction of a reservoir
    - Each junction where a local inflow is to be computed.
    - All other observed data entries were not required for computing the local inflows and were left blank.

Note – the Climate Change Hydrology provided only one total flow time series for each reservoir. Since this flow reflects an "unregulated" condition for the river system, it can be treated both the inflow to and outflow from the reservoir for the purpose of the incremental local flow computations and therefore was used as the "observed" total flow at both the inflow and outflow junctions of the reservoir.

B.4 The Operations Support Interface – OSI

The OSI is a fully customizable tool designed for two primary purposes – 1) to facilitate the development of a real-time release schedule through the use of release overrides and 2) to compute incremental local flows from observed data. The OSI configuration described below was, of course, designed purely for computing the incremental local flows from the Climate Change total flows.

The OSI can only be configured and run from the Simulation module in ResSim, however the configuration is saved as part of the alternative. So, once the first alternative's OSI was configured and shown to be working correctly, the alternative was "Saved to Base" and then the alternatives for the remaining 3 scenarios were created using Save As… in the Alternative Editor. By creating the alternatives in this way, the OSI only had to be configured only once, not four times.

A fully configured OSI is organized by tabs and columns of data on each tab. Each column on a tab represents a variable in the model. The tabs and the variables they contain are added and defined by the user who configures the OSI.

To configure the OSI for the first alternative, the following steps were performed:

- A simulation was created covering the period of record of the climate change data 01Oct1950 – 30Sep2099 and the first scenario's alternative was included. A 7 day lookback window was used, although the length of the lookback was irrelevant. As long as the observed data is available, the OSI will compute the local inflows for the entire simulation time window.
- The alternative was computed. (The OSI won't open for an alternative that has not been computed yet.)
- The OSI was opened – by selecting **Operations Support Interface** from the bottom of the **Simulation** menu. A blank OSI window appeared as illustrated in Figure B.128.

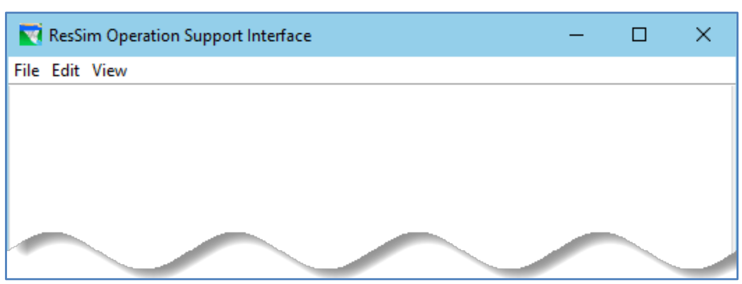


Figure B.128. An Unconfigured OSI

- The modeling team decidied to add five tabs to the OSI, one for each major river in the ACT basin: Oostanaula, Etowha, Coosa, Tallapoosa, and Alabama. Figure B.129 shows the OSI with four tabs already added, the OSI's **Edit** menu, and the **Enter a name…** dialog as it appeared while the fifth tab was added.

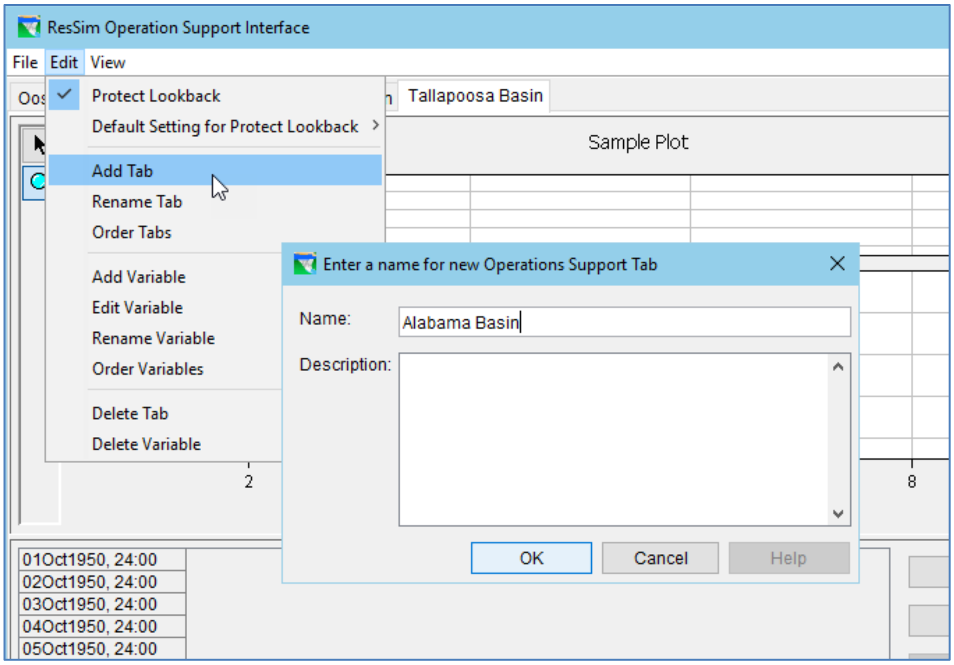


Figure B.129. Adding Tabs to the OSI

- On each tab, an OSI variable was added for each junction in the basin for which an inflow was to be computed and/or for which a total observed flow was provided. The option for **Add Variable** is also in the **Edit** menu of the OSI and, when selected, a **New Operations Support Variable** (Name…) dialog opens (Figure B.130). After giving the new variable a name, the **OSI Variable Editor** opens to allow the variable to be configured. The two examples below describe the two types of OSI variables that were created.

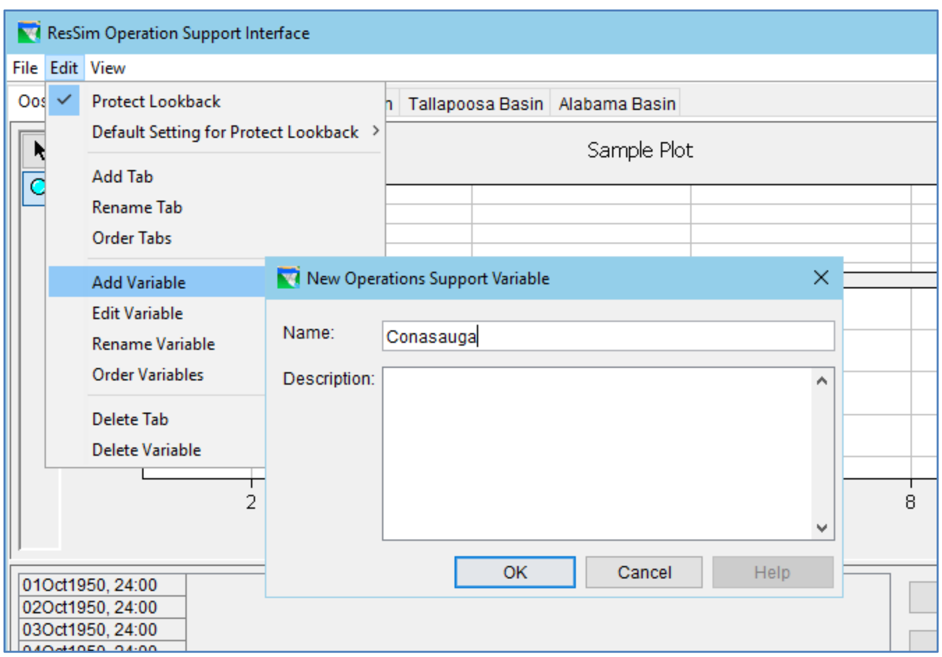


Figure B.130. Adding Varibles to the OSI

B.4.1 Example 1 – Headwater Inflow:

Some of the variables added to the OSI were for headwater junctions or reservoir outflow junctions. Since no local inflow was computed at these locations, these OSI variables were not required for the computation of the local inflows but were included for reference. This Example illustrates how a headwater inflow variable was configured in the OSI.

- The key fields for defining an OSI variable are **Element Type**, **Element**, and **Type.** Once these three fields are specified, a set of attributes will appear below the **Type** field based on the selections. For a headwater or reservoir outflow junction's total flow the settings should be:
- **Element Type**: ***Junction*** – selected from the dropdown list that includes:
    - Junction
    - Reservoir
    - Reach
    - Diversion
- **Element**: for this example, ***Conasauga***. The **Element** dropdown list populates after the **Element Type** is selected; in this case, it contained all the junctions in the network associated with the active alternative.
- **Type**: for this example, ***Computed Parameter***. The **Type** dropdown list also populates after the **Element Type** is selected. For **Junction** Elements, two options are available: *Local Inflow* and *Computed Parameter*.
- The only parameter field that appears for ***Computed Parameter*** is **Computed Time Series**. The Select button is used to open the Independent Variable Defintion editor to select the computed time series.

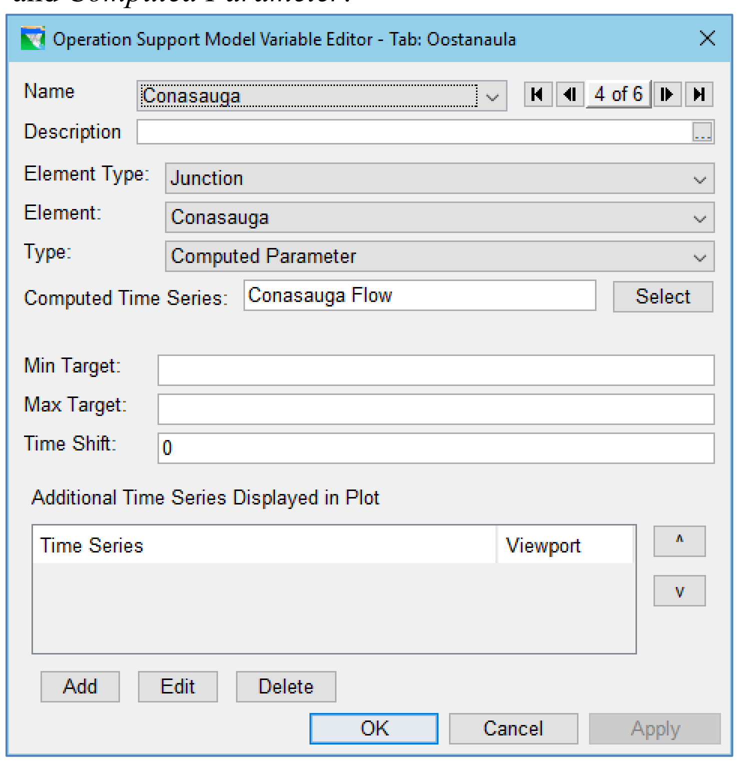


Figure B.131. An OSI Computed Parameter Variable – Added For Reference

B.4.2 Example 2 – Local Inflow

Most of the variables added to the OSI were for interior junctions where the incremental local inflow was to be computed. This example illustrates how each incremental local inflow OSI variable was configured.

- For an OSI variable for which local inflow should be calculated, the settings should be:
    - **Element Type**: ***Junction***
    - **Element**: for this example, ***Tilton***. An interior junction and gage location.
    - **Type**: ***Local Inflow***
- When a *Junction* and *Local Inflow* are selected, the attributes that appear below **Type** include the selection of the specific **Local Flow** at the selected junction and several fields related to the optional use of a **Recession Equation** to be used to estimate the local flow when the observed data runs out. Since this model has "observed" data for the full time window of the simulation, the recession equation parameters are not needed and were left blank.
- At the bottom of the **OSI Variable Editor** is a table of **Additional Time Series Displayed in Plot**. The time series that are added to this table are displayed along with the OSI variable's data but do not have any direct impact on the computations. The time series selected to be included in the plot with each local inflow variable is the *total* flow at the junction; this should reflect the observed flow at the junction after the computation of the incremental local flow.

Once the OSI configuration was complete and each tab included a variable for each local inflow in its basin, the **Calculate All Locals** button was used to run the special compute option in ResSim that routed each observed flow at a junction to the next local inflow location and subtracted the routed observed hydrograph from the total observed hydrograph at the local inflow location.

At the end of the compute, ResSim wrote the resulting *computed local inflows* to the simulation.dss file – but not as an *output* dataset; instead, the *input* dataset (time series) associated with each OSI *Local Inflow* variable was ***overwritten*** with the computed local flow data. Each local flow (input) dataset is identified on the **Time Series** tab of the Alternative Editor; these are the *Known Flow* variables.

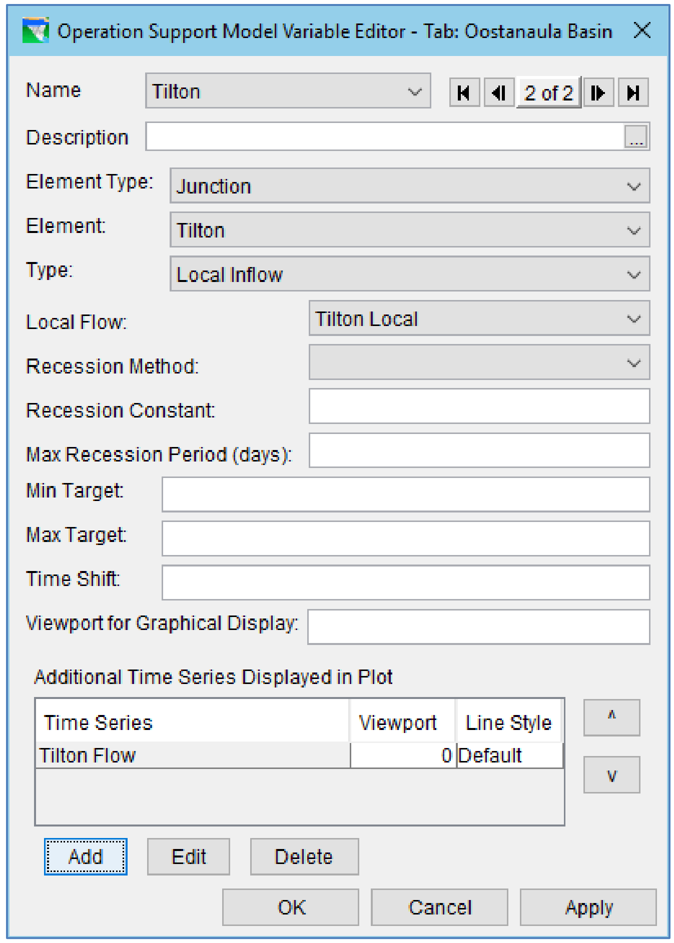


Figure B.132. An OSI Local Inflow Variable – For Computing Local Inflows

B.4.3 Viewing Results

After the **Calculate All Locals** compute completes, the OSI tables update with the results of the compute. When a user clicks in the column of a specific OSI variable in the Table section of a tab; the OSI variable and its **Additional Time Series…** will be displayed in the Plot section of the tab.

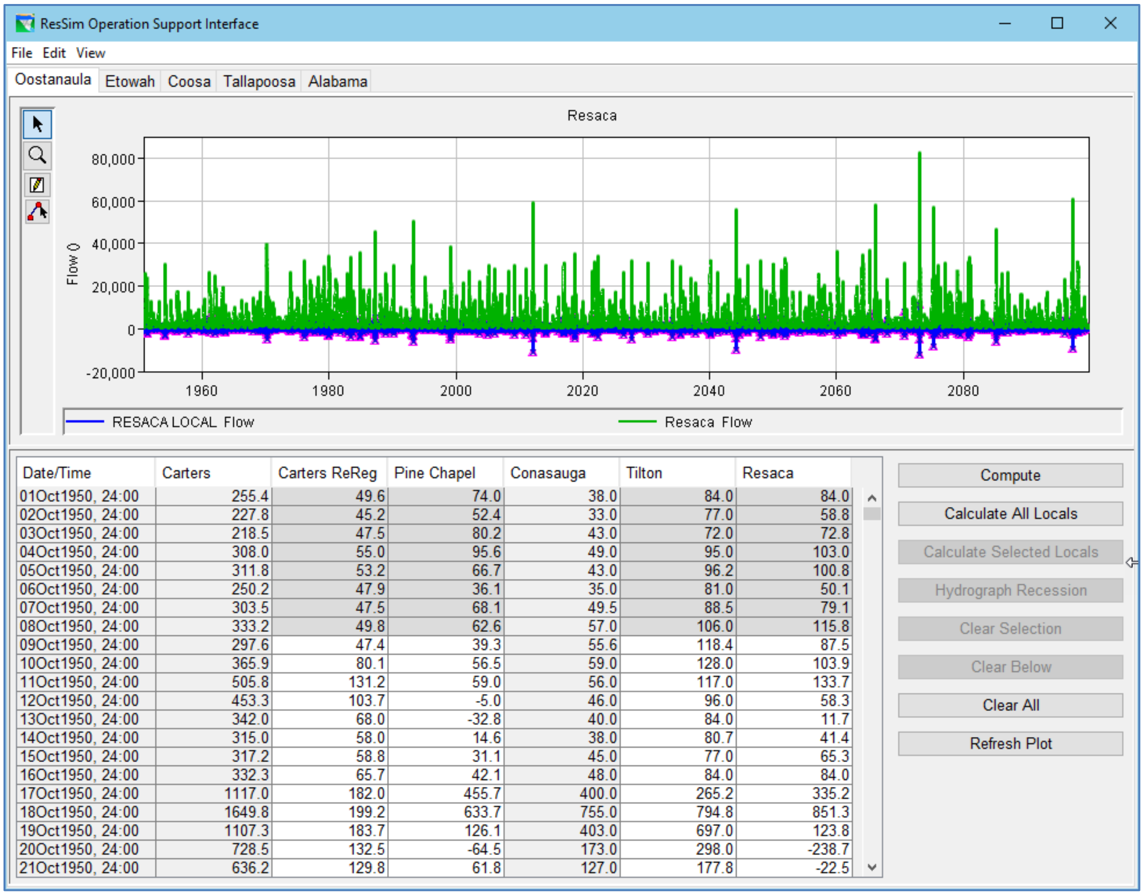


Figure B.133. An OSI Local Inflow Variable – For Computing Local Inflows

B.5 Verification & Validation

A variety of methods were used to verify that the network, alternative, and OSI were properly configured to produce valid results at the various local inflow locations. These methods included:

- Viewing and Tabulating the input and output.
- Using DSSVue Math Functions to perform the routing for a reach and the subtraction of the routed time series from the observed.
- Creating a separate watershed in which three of the most challenging subsections of the ACT basin were re-created and the OSI configured to compute the locals.

B.5.1 Viewing and Tabulating the Input and Output

The OSI plots (and the accompanying table data) for Local Inflow OSI variables can be very useful for understanding the local flow data. The modeler simply needs to review the OSI displays carefully both before and after the locals have been calculated.

For example, Figure B.134 shows two views of the OSI with the variable Wadley selected. The first view is how the OSI appears when first opened. It is important to understand that the OSI will not open until after an alternative has been computed. This view should be considered the "before" condition since it is clear that all the local inflows except the headwater flows are zero and thus is "before the locals inflows have been computed.

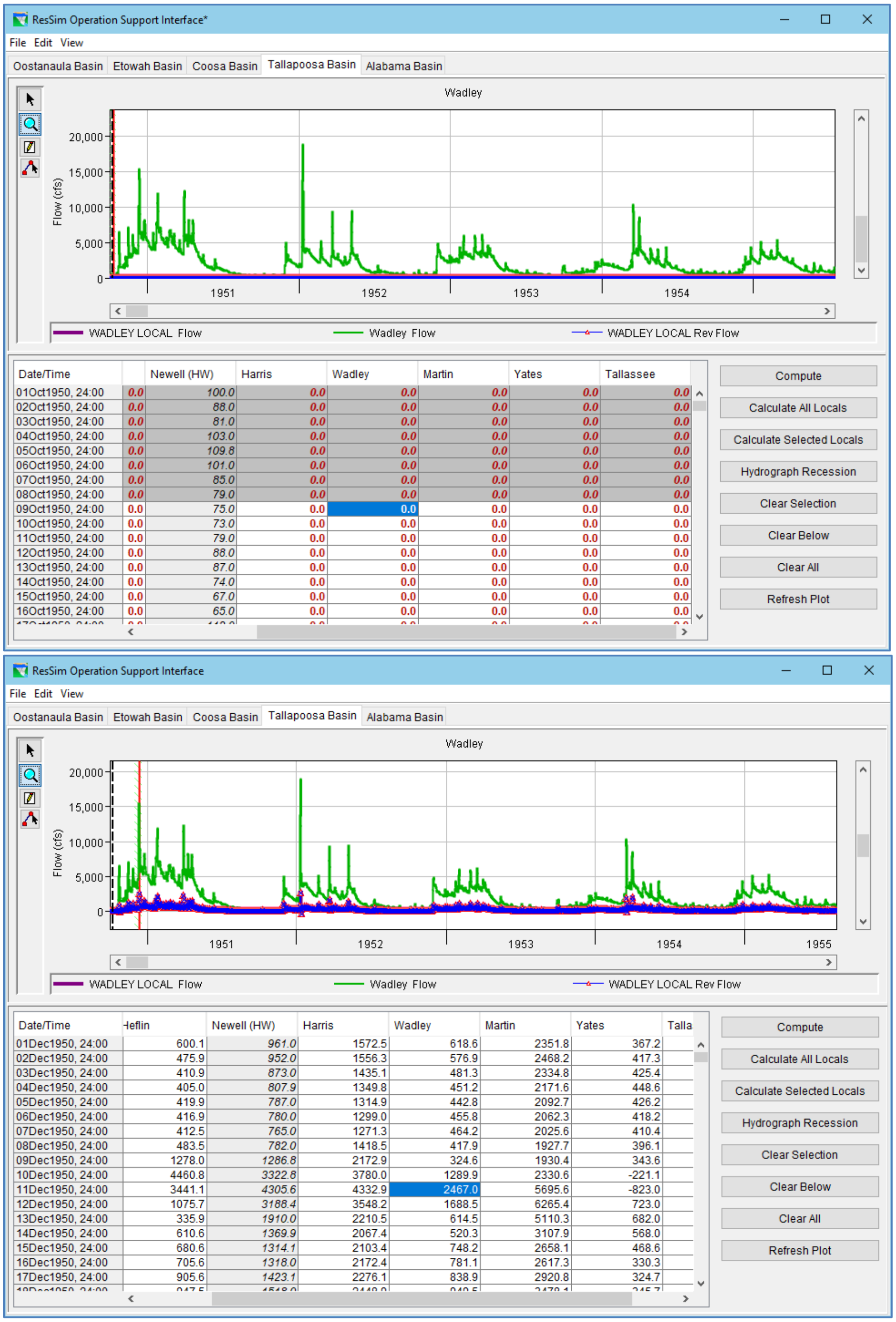


Figure B.134. OSI Plot and Table at Wadley – Before and After

The second view is the "after" condition, after the local inflows have been computed. The green curve in each plot is the "additional time series" that represents the total computed flow at the junction. The purple curve is the local inflow, the OSI variable itself.

In the before view, the purple curve and the table show the local inflow to be zero. In the after view, the purple curve and the table contain the computed locals. So, this figure illustrates that something happened, and, when you look carefully at the total flow at each junction as you move down the river, it looks like the local flow is accumulating properly. However, looks can be deceiving, so further verification was needed.

B.5.2 Using HEC-DSSVue's Math Functions

The **Hydrologic** tab of HEC-DSSVue's **Math Functions** editor includes an option for routing a hydrograph using the Muskingum routing method. To take advantage of this, a couple of locations in the basin were identified where the upstream observed flow was routed using Muskingum routing to a location where the local inflow was being computed. The selected locations were Dawsonville to Canton and Centreville to Marion Junction.

The Muskingum routing parameters (K=24, X=0.5, n=1) for the reach above Canton equated to a one day lag. After routing the observed flow at Dawsonville to Canton with the **Muskingum Routing** function and then using the **Subtract** function to subtract the routed hydrograph from the observed at Canton, the resulting local flow hydrograph was stored back to DSS. DSSVue's Compare tool was then used to compare the DSSVue-computed local hydrograph for Canton to the OSI-computed local hydrograph; the records were identical.

The Muskingum routing parameters for the reach above Marion Junction (K=36, X=0.2, n=2) were not quite as simplistic as those for Canton. When the same steps were performed to compute the local at Marion Junction with DSSVue, the resulting comparison found the two records to be identical within 6-7 digits of accuracy.

The most probable explanation for why the comparison would show *any difference at all* is the difference in digits of accuracy that can be expected from floating point storage and computations versus double precision. Double precision floating point mathematics should maintain up to 15 digits of accuracy while single precision should maintain up to 7 digits of accuracy. ResSim performs all its computations and writes all its output to DSS in double precision floating point. On the other hand, DSSVue's Math functions perform their computations in the precision of the dataset. If a dataset was stored in single precision, computations performed on that dataset will be in single precision. If multiple datasets were used in the computations, the computations would be performed in the highest precision of the datasets.

After reviewing the supplementation data for the datasets involved in the various computations, it was found that both the "observed" total flow data and the starting local flow dataset were stored in DSS in DSS's standard, single precision floating point. The local flow dataset that ResSim computed, although stored internally and computed in ResSim as double precision, was actually stored in DSS as single precision because that was the format of the original input record. During the conversion from double precision to single precision, some precision of the data could have been lost. The datasets that were involved in the DSSVue computation of the local flow were all stored in single precision, so those computations therefore would have been performed in single precision and the resulting time series stored to DSS would have been single precision. The comparison of the two computed datasets was within the accuracy of single precision floating point so the two records can be considered identical.

B.5.3 Creating a New Watershed

To verify that the network, alternative, and OSI were properly configured to produce valid results at the various local inflow locations, a separate watershed, named *Compute_Locals*, was constructed. In this watershed, three networks and their assocated alternatives were created to represent three subsections of the ACT model. The relevant reservoir and routing data was imported from the study model. For each subsection, alternatives were created using the same data used in the main model. The three subsections included the Upper Tallapoosa through Harris to Martin's inflow, the Upper Oostanaula from Carters and the Oostanaula headwater junction down to Resaca, and the Alabama River from Montgomery through RF Henry, Millers Ferry, and Claiborne Dams. These subsections were chosen because they each had issues that had to be "handled" to enable the OSI to compute locals through the region; the Oostanaula had a tributary flow entering between Carters and Carters ReReg and the other two subsections each had a reservoir that had originally been modeled with two inflow junctions. By remodeling these subsections of the basin from scratch, the expectation was that any errors in the original implementation would come to light and be able to be addressed. This expectation was realized and well worth the effort; these smaller subsection models illustrated discrepancies and errors in the original implementation and were very helpful in getting the main model's network and OSI properly configured. When finished, the local inflows computed by the OSI for each of these subsections exactly matched the results generated for the same locations in the main model. This test watershed was supplied along with the main watershed used to compute the locals in the whole basin.

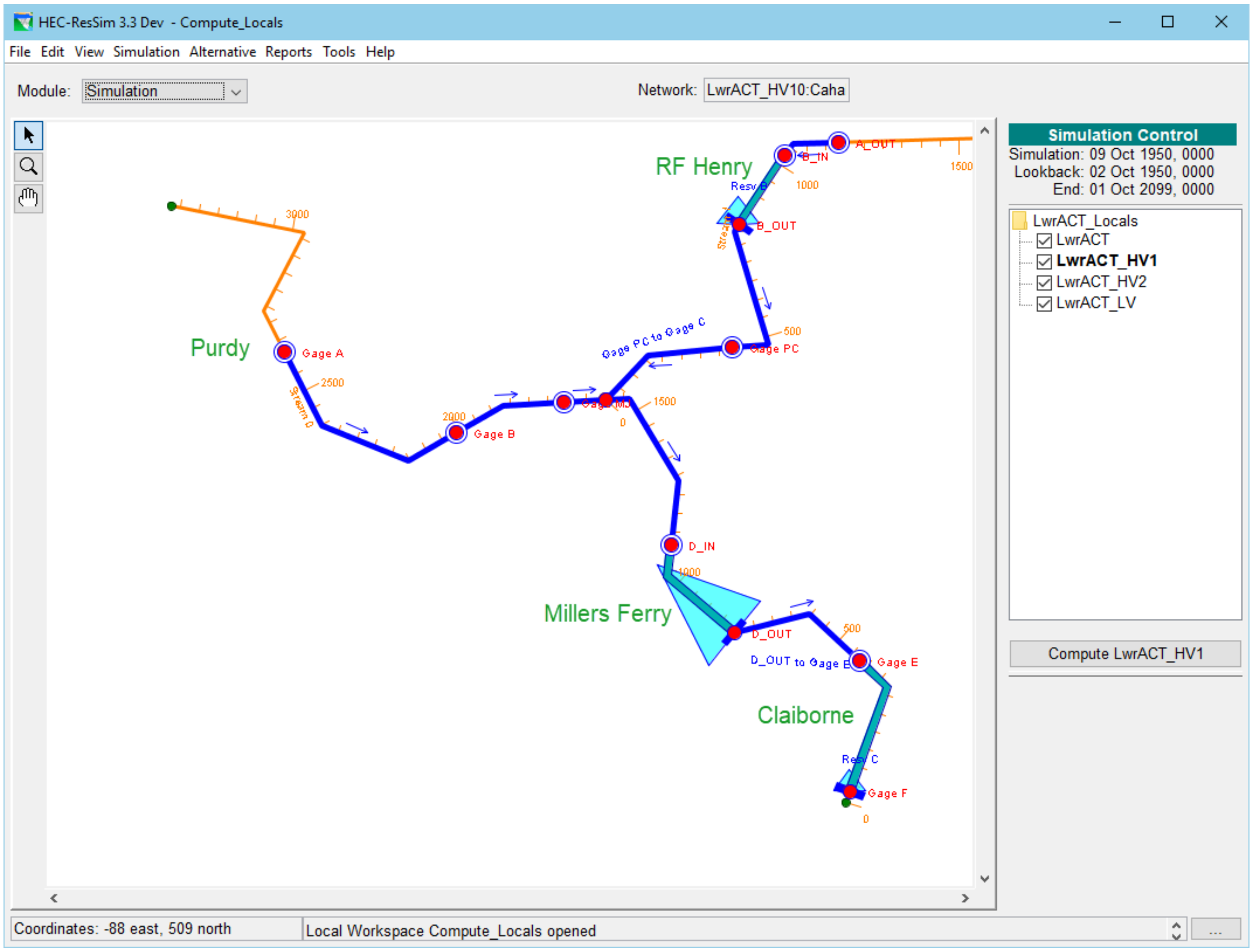


Figure B.135. The Compute_Locals test watershed, showing the re-implemented Alabama subsection of the ACT basin

B.6 Smoothing the Computed Local Inflows

In reviewing the computed local inflow time series data, it is was noticed that negative values appeared occasionally. The three primary reasons this can occur are:

- The routing method used for a reach does not perfectly reflect the natural routing of the river. A natural river typically responds differently depending on the magnitude of the flows but the routing methods used in this study was all linear mehtod and therefor do not vary with flow.
- Natural rivers have losses due to evaporation, seepage, and other natural uses of the water.
- The impact of “natural” routing through the reservoirs was not reflected in the model.

To minimize the the size of the negative flows and sometimes even eliminate them, a data smoothing technique called “centered moving average” was used. The benefit of this method is that it does not impose a loss of volume and maintains the general shape and timing of the hydrographs.

Since smooting of the computed local inflows was performed when the Modified Flow dataset was developed, the same method and period was used for the same inflow locations on the computed climate change locals. Table 23 lists the inflows that were smoothed and the period used.

Table 23. Smoothing Period Used by Location

Locations		
No Smoothing	**5-Day**	**7-Day**
CONASAUGA	CARTERS REREG	RESACA
TILTON	PINE CHAPEL	KINGSTON
CARTERS	ALLATOONA	ROME ETOWAH
ETOWAH	HARRIS	ROME COOSA
CANTON	WADLEY	WEISS
TALLAPOOSA	MARION JUNCTION	H.N.HENRY
HEFLIN		LOGAN MARTIN
NEWELL		LAY
COOSA		MITCHELL
PURDY		JORDAN
CENTREVILLE		MARTIN
		YATES
		THURLOW
		TALLASSEE
		MONTGOMERY
		R.F.HENRY
		SELMA
		MILLERS FERRY
		CLAIBORNE

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Attachment 2. HEC-ResSim Modeling of Reservoir Operations in Support of Allatoona Reallocation Study, Part 2: Hourly Model – Upper Basin Flood Modeling Report

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Alabama-Coosa-Tallapoosa (ACT) Watershed

HEC-ResSim Modeling of Reservoir Operations in Support of Allatoona Reallocation Study

Part 2: Hourly Model – Upper Basin Flood Modeling

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Prepared for:
US Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628-0001

Prepared by:
US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

(530) 756-1104
(530) 756-8250 FAX
www.hec.usace.army.mil

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I. Introduction

This report documents the ResSim models developed in support of the Allatoona Coosa Reallocation Study. Part 1 of this report covers the daily timestep model used for general review and Part 2 covers the hourly timestep model used to study flood conditions. A USACE Strategic Communications Plan was issued 19Apr2018 entitled, "Allatoona Lake Water Supply Storage Reallocation Study and Updates to Weiss and Logan Martin Reservoirs Project Water Control Manuals". The following excerpt offers insight to the background of this study:

> "Eighteen major dams (six Federal and twelve non-Federal), which form sixteen reservoirs, are located in the ACT River Basin. The ACT River Basin provides water resources for multiple purposes from northwestern Georgia down through central Alabama to the Gulf Coast at the mouth of Mobile Bay, extending a distance of approximately 320 miles and encompassing an area of approximately 22,800 square miles. Pursuant to Section 7 of the Flood Control Act of 1944, the USACE prescribes regulations for the operation of the USACE projects in the ACT River Basin for their authorized purposes, and for the non-federal projects that contain storage for the purposes of navigation or flood control (flood risk management), through water control plans and manuals.
>
> "In May 2015, the USACE completed a long-term effort to update the Master WCM for the ACT River Basin, including updated WCMs for all five USACE projects (Allatoona Dam and Lake, Carters Dam and Lake, Robert F. Henry Lock and Dam, Millers Ferry Lock and Dam and Claiborne Lock and Dam) and two of four APC projects with navigation or flood control storage (H. Neely Henry Dam and Lake (Reservoir) and R.L. Harris Dam and Lake (Reservoir)). WCMs for the other two APC projects with navigation and flood control storage, Logan Martin Dam and Lake (Reservoir) and Weiss Dam and Lake (Reservoir), were not updated at that time. A pending request by the State of Georgia for additional water supply storage and changes to storage accounting practices at Allatoona Lake was also not included within the scope of the 2015 WCM update and EIS.
>
> "In January 2018, the U.S. District Court for the Northern District of Georgia issued a judgment in Georgia et al. v. U.S. Army Corps of Engineers, No. 14-cv-03593 (Jan. 9, 2018), holding that the USACE had unreasonably delayed action on Georgia's water supply request, and directing the USACE to take final action responding to that request by March 1, 2021. Following that court decision, the State of Georgia submitted an updated request to the USACE on March 31, 2018, and the USACE intends to evaluate actions necessary to implement Georgia's request, as well as one or more reasonable alternatives, in the proposed FR/SEIS.
>
> "The USACE did not include updates to the WCMs for the Weiss and Logan Martin projects in the 2015 ACT Basin WCM Update because further study of flood risk management issues at both projects was required. The APC proposes raising the winter level and also lowering the upper limit of the induced surcharge operation at the Weiss Reservoir and the Logan Martin Reservoir. Current Water Control Plans for the Weiss and Logan Martin Reservoirs, originally issued in the 1960s, contain surcharge curves with elevations higher than the respective flood easements acquired by APC.

> "Because the USACE is simultaneously considering proposals to modify operations and update WCMs at three different ACT River Basin projects, the USACE intends to evaluate the effects of these proposals through a single EIS, which would supplement the Final EIS for the ACT Basin completed in May 2015. As part of this analysis, the USACE will consider the effects of the proposed changes on operations of the ACT system of projects for all purposes, and would revise the ACT Master WCM to incorporate the updated Allatoona Lake, Weiss Dam and Lake (Reservoir), and Logan Martin Dam and Lake (Reservoir) WCMs and to reflect changes, if any, in overall system operations."

Initial modeling goals were to establish the boundaries of reallocation from the flood and inactive pool, perform PMF routing for a dam safety check, and complete yield analysis to determine the initial benefit of the pool reallocation. The modeling also considers the flood pool reallocation at multiple Alabama Power Company owned projects and the update of Water Control Manuals in the ACT River Basin. The daily model also supports the water quality modeling with the HEC-5Q software.

A. ACT ResSim Modeling History

The Alabama-Coosa-Tallapoosa (ACT) River Basin was modeled in early reservoir simulation software HEC-5. Transition from the HEC-5 model to the then new ResSim software was initiated in 2006 in preparation for the update of the basin Water Control Manuals. Since then, numerous improvements and changes have been made to the model and to the software itself. The major ACT ResSim modeling efforts are shown in Figure 1.

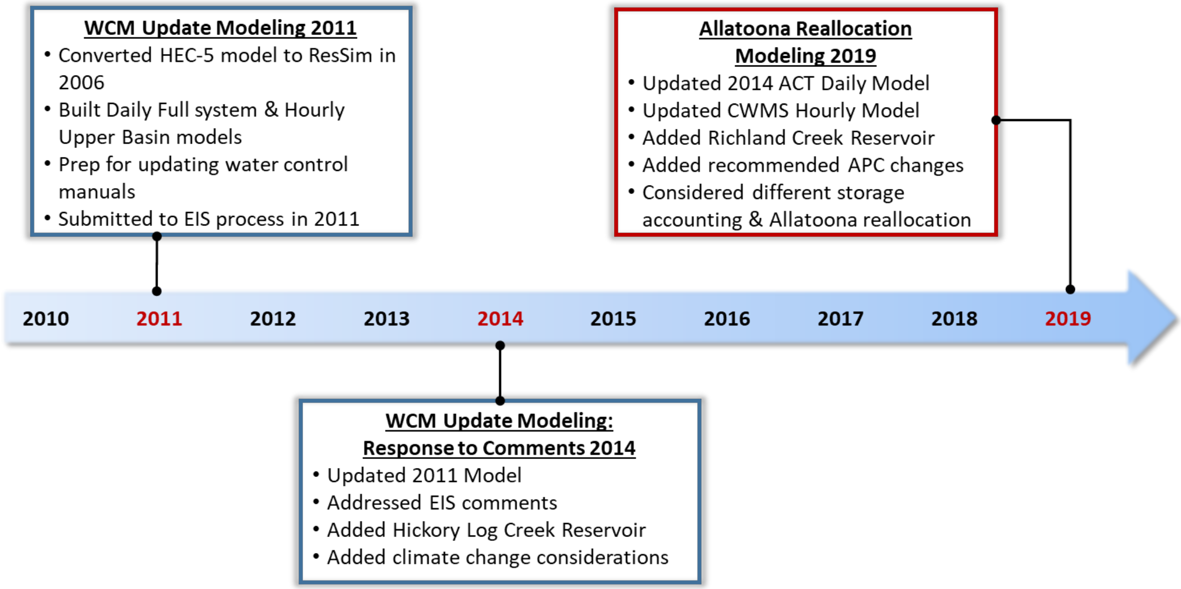

Figure 1. ACT ResSim study modeling timeline

By 2011 the Mobile District Water Control Manual Update was in the process of completing an Environmental Impact Statement. In conjunction, a report was developed to describe the modeling activities performed. The March 2011 report, "ACT HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update" details the initial design of the ACT ResSim model. An addendum to the March 2011 report was written to describe further changes to the system done during the EIS response to comments, July 2014. These documents are useful references that detail the assumptions and methods used to model the system and create the model that was the starting point for this work. That model, entitled "ACT-HLC_WCM_24Apr2014_HRPlansDFG", shall be referred to here as the 2014 model. It included 74 years (1939-2012) of continuously simulated, daily time step, lake levels and river flows throughout the ACT basin. The new daily model is titled "ACT-2018-daily". Part 2 of this report focuses on the model updates that were completed for the purposes of the Allatoona Reallocation Study.

B. Overview of this Report

This HEC-ResSim Modeling of Reservoir Operations in Support of Allatoona Reallocation Study Report, Part 2 is divided into six sections:

Section I. Introduction

Section II. Upper ACT Basin Flood Operations Modeling Approach provides some background on and decisions that affected the flood modeling of the Upper ACT Basin.

Section III. Model Updates describes the updates that were made to the CWMS model in order to develop the study flood model.

Section IV. Alternative List describes the model alternatives and simulations.

Section V. Allatoona Probable Maximum Flood provides details on the extreme event modeling for the probable maximum flood (PMF).

Section VI. Analysis of Results shows some sample results.

Appendix A. Appendix A. State Variables contains the full text of all state variable scripts.

Appendix B. Time Series Data Management offers details about how the data was managed for building the different alternatives and simulations.

C. HEC-ResSim Version Selection

Because the HEC-ResSim software is being continually improved, it was important to establish a specific version to be used for the Allatoona Reallocation Study modeling. The April 2014 model results were computed using HEC-ResSim 3.2 Dev, December 2013 Build 3.2.1.22. Modeling for the Allatoona Reallocation Study was performed in the new, developmental ResSim 3.4.1 build 32 (May 2018). Since the 3.2 version, the ResSim software has experienced changes including new features, enhancements, bug fixes, and improved algorithms. Significant advantages of the 3.4 ResSim include improved power operations, table options, and compute blocking. Most importantly, the 3.4 version was chosen to be consistent with the ResSim version currently used in the Corps Water Management Software.

II. Upper ACT Basin Flood Operations Modeling Approach

Flood risk management is one of the most important purposes for which USACE operates reservoirs, so any proposal to reallocate storage in a USACE reservoir must be evaluated to measure the impact on flood risk for the region served by the reservoir. In order to do so, modeling of reservoir operations under a variety of high flow conditions is needed.
In general, proposed alternatives in which storage reallocation is confined within the conservation pool of a reservoir have little to no probability of appreciably increasing flood risk. However, the probability of negative impacts on flood risk increases when storage is reallocated from flood control to conservation; these are the alternatives that must be addressed by a flood operations model.

The region served by Allatoona Reservoir to minimize flood risk includes the area surrounding the Lake Allatoona and the communities along the Etowah and Coosa Rivers below Allatoona Dam down to and including the city of Rome, GA. Operations to minimize flood risk at Rome are shared with the Carters Reservoir System (Carters and Carters ReRegulation Reservoirs) located on the Coosawattee River in the headwaters of the Oostanaula River. This region is referred to as the Upper ACT (Alabama-Coosa-Tallapoosa) Basin[1] in this report and is the area covered by the Upper ACT Basin flood operations model described herein. The Upper ACT Basin was modeled from the headwaters of the Coosa River to the Georgia-Alabama state line. Figure 2 shows the region of the upper basin modeling with respect to the full ACT watershed and the "ACT_Upper" ResSim network that was used for this modeling.

While a daily time step model was used to evaluate changes from many different perspectives, an hourly time step model was considered necessary to evaluate flood impacts. The factors that contributed to this decision include: the size of the Coosa watershed above Rome, the time it takes water to move through the basin, and the relatively short time of concentration and duration of flood events in the region. Therefore proposed guide curve changes were modeled in an hourly study flood model of the upper Alabama-Coosa-Tallapoosa (ACT) basin.

The flood operations modeling to support the Allatoona Reservoir Reallocation study focused on two objectives: 1) produce a "baseline" model that correctly represents current operations of Allatoona and Carters reservoirs during high flow events, and 2) create an alternative of the "baseline" model in which the proposed storage reallocation at Allatoona has been applied and compare the results of the two models to determine if the proposed storage reallocation negatively impacts flood risk in the region.

The magnitude of flood discharge along the lower Etowah and the upper Coosa Rivers is primarily influenced by the magnitude of the rainfall events, but it is also affected by flood operations at Allatoona, Carters and Carters ReReg Reservoirs. In the 2015 ACT Water Control Manual Update, the combined regulated flood frequency relationship was determined and used to produce a set of hypothetical inflow hydrographs at all gage sites and other key locations throughout the Upper ACT Basin. The inflow data set provides inflow hydrographs for 5

[1] The study region for the hourly model may be more accurately referred to as the Upper Coosa Basin, but since this work is paired with the daily model of the full Alabama-Coosa-Tallapoosa Basin, the watershed is named "Upper ACT Basin", relatively speaking.

exceedance probabilities, for 3 storm shapes (based on historical events), and for the storm occurring in each month of the year. That inflow data set was used for the current study. Four of the available twelve months were chosen to represent a range of initial conditions January, April, June, and October. In addition, the inflow hydrographs for all three storm shapes and all five recurrence intervals were used with the baseline and reallocation operational alternatives.

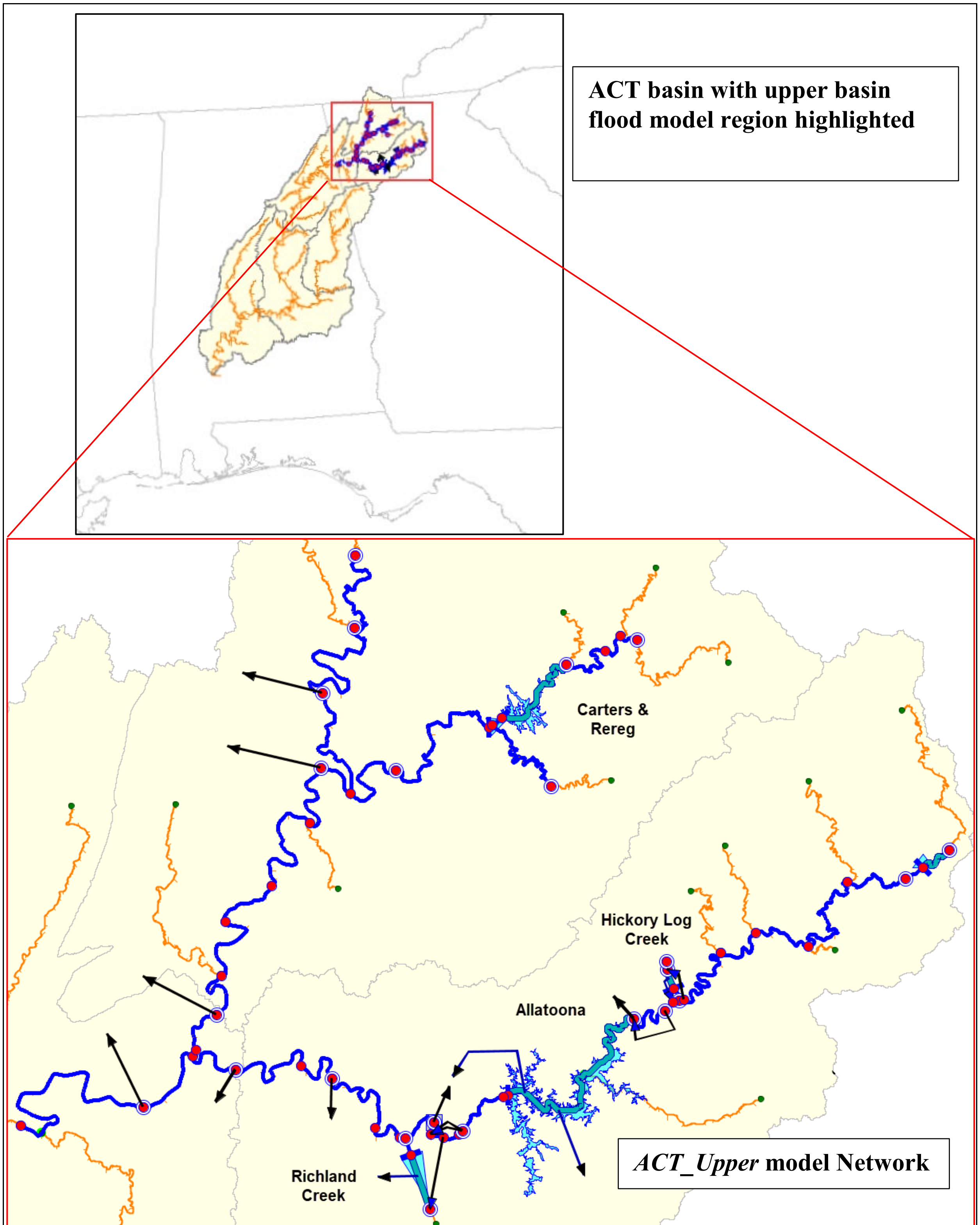

Figure 2. ACT Upper Basin as modeled in study flood model

III. Model Updates

The first step in developing the flood model for the Reallocation Study was to select a starting watershed to update. Several different ACT upper basin flood models exist as a result of earlier studies. Since the most up to date existing flood model was the Corps Water Management System (CWMS) model, which is used for real-time operation and management of the whole ACT system, the modeling team decided to use the CWMS model as a starting point from which to develop the study flood model. Since the CWMS modeling environment is designed for real-time operation and analysis, several changes were necessary to bring the real-time model to a state that is suited to a planning study model. And, because this flood modeling was closely tied to the daily study model, the flood watershed also needed to correspond well to the daily model.

Thus, the flood model for the Allatoona Reallocation study began as a copy of the CWMS ResSim watershed. The watershed contained two reservoir networks – one that covered the full ACT basin, and one that represented only the upper ACT basin; the latter network was appropriate for this flood study (Figure 2) so all work for this study focused on that network. Updates were made to the physical properties of the reaches and reservoirs, identification of inflow time series, and operations to correspond to the daily study model. For example, a number of junctions were added to the CWMS model to correspond to the local inflows produced by the CWMS HMS model of the watershed. However, since the local flows for the synthetic storm events to be used by the study model were not generated by the CWMS HMS model, inflow time-series were unavailable for the new locations and references to their local inflows had to be removed from the flood model. The following sections describe the updates made to the copy of the CWMS model to create the flood study model.

A. Vertical Datum Change

The CWMS model, designed for real-time operations, uses NAVD88 (The North American Vertical Datum of 1988). The daily study model uses datum specific to each project or NGVD29 (The National Geodetic Vertical Datum of 1929). For consistency with the daily model, the flood model was converted from NAVD88 to NGVD29. This involved the changes listed in Table 1.

Table 1. Elevation adjustments made to conform with NGVD29

Carters (+0.01 feet)	**Carters ReReg (+0.02 feet)**
• The Pool’s storage capacity table • Top of dam • Power plant & tailwater capacity table • Pump capacity table • Emergency Gated Spillway capacity table • Zone Elevations • Emergency spillway rule definition; falling pool options • Target elevation for “FC Pumpback” rule	• The Pool’s storage capacity table • Top of dam • Spillway capacity table • Zone Elevations
Hickory Log Creek (-0.1 feet)	**Allatoona elevations (-0.09 feet)**
• The Pool’s storage capacity table • Top of dam • Gated Spillway capacity table • Sluice Gate capacity table • Fixed Spillway capacity table • 7Q10 outlet capacity table • Controlled Outlet capacity table • Zone Elevation	• The Pool’s storage capacity table • Top of dam • Leakage • Tailwater Stage • Power Plant capacity table • Spillway capacity table • Sluice • Small Unit • CCM Diverted Outlet • Cartersville Diverted Outlet • Zone Elevations • Emergency spillway rule definition; falling pool options

B. Richland Creek Reservoir

Richland Creek Reservoir is a new reservoir being built to provide water for Paulding County. It is slated to be completed in 2019, and therefore was included in this modeling effort. The reservoir was added to the network using the information from the daily study model. Note: the properties and operations of Richland Creek Reservoir are not yet confirmed and final, but they suffice for the purposes of this modeling effort. The details related to the modeling approach for this new reservoir can be found in the daily model description.

Changes to the hourly model included:

Watershed Setup:

Added to the Stream Alignment:
- *Richland Creek*

Added to the Configuration:
- *Richland Creek* reservoir
- *Richland Creek_IN, Richland Creek_OUT*, *Richland Creek Release*, and *Richland Creek Pump Station* computation points
- *Richland_Pump_Divs* diversion

Reservoir Network:

Added to the ACT_Upper network:
- The configuration elements above plus…
- *Etowah Diversion* and *Etowah Return* junctions
- *PauldingCo_Divs*, *Two-Run 7Q10*, and *Allatoona Factored Min* diversions

These network changes are highlighted in Figure 3. The physical properties of the reservoir and its outlets were all taken from the daily study model. A list of the Richland Creek Reservoir operational rules and their purposes can be found in Table 2.

Table 2. Richland Creek Reservoir operation rules

Rule Name	Function
Min_7Q10	Minimum instream flow
Water Supply Withdrawal	This rule represents 35 mgd (54.15 cfs) pumped from Richland Creek Reservoir

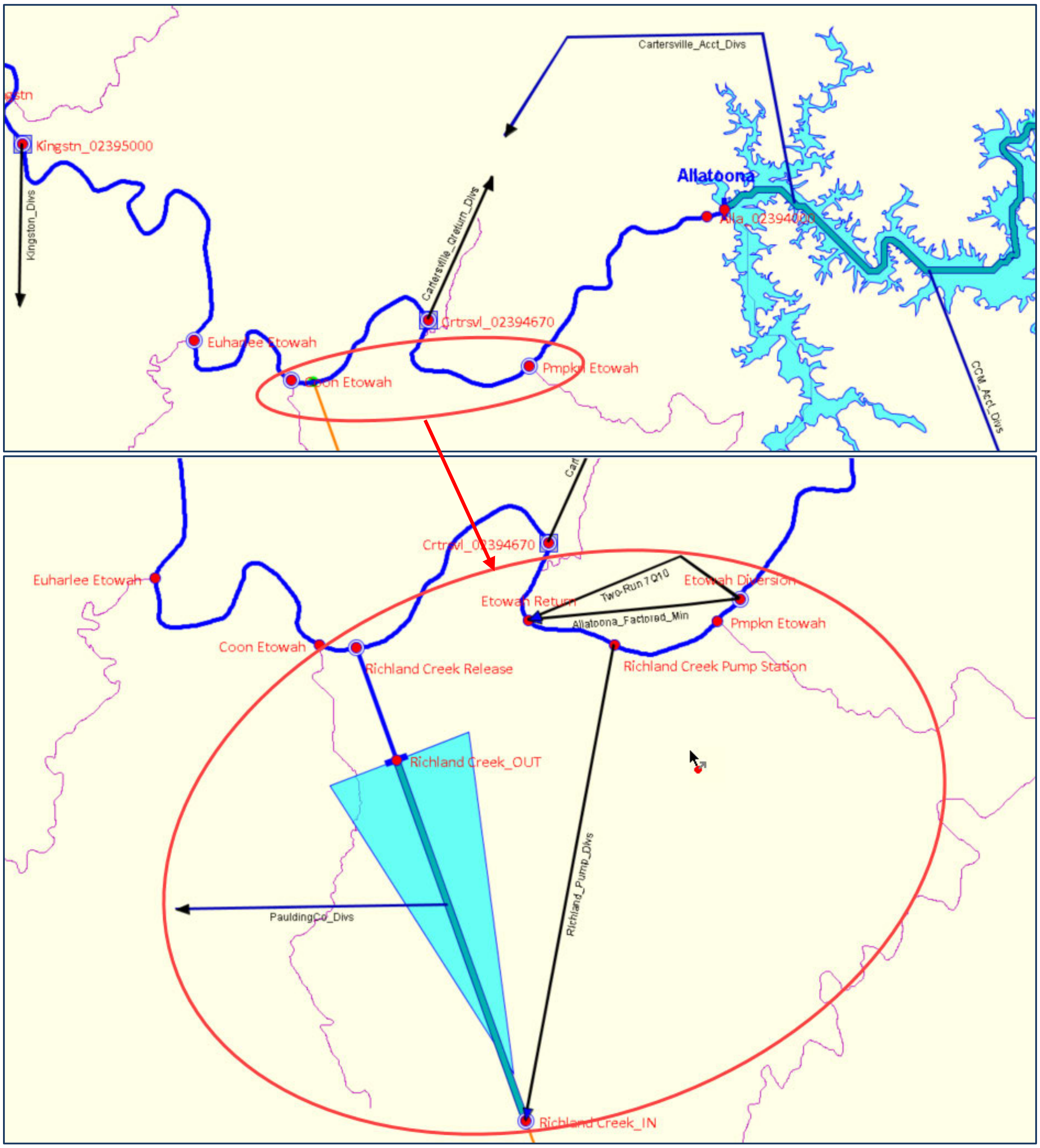

Figure 3. Updates to network related to Richland Creek Reservoir

C. Diversion Changes

A diversion can be represented in a ResSim model in three different ways:

1. as a diversion element
2. as a negative inflow
3. as a diverted outlet from a reservoir.

All three approaches were used in the flood model, depending on the specific modeling need or the precedent set by the daily model.
Some diversions return a percentage of the diverted flow back into the basin downstream. These were modeled by either (a) connecting the diversion to a downstream junction and applying a return ratio, or (b) adding another diversion element at the return location with a negative 1.0 multiplier in order to represent the return flow. The negative diversion approach allows the modeler to use a Flexible Diversion Rule (FDR) on the diversion element, which can be a function of a time series.

Changes were made to some of the diversions in the flood model for consistency with the daily study model. These changes include:

- The negative inflow (representing a diversion) at Carters_IN, *Carters_DIV*, was renamed *Carters_IN_DIV* to match the daily model.
- Four diversions were added to reflect the operations of Richland Creek:
  - A diversion from the Etowah River was added to represent the pumping of water into Richland Creek reservoir.
  - A diverted outlet was added to Richland Creek reservoir to represent the Paulding County water supply withdrawal.
  - Two new diversion elements, *Two-Run 7Q10* and *Allatoona_Factored_Min*, were added to manage the quantity of water that could be pumped from the Etowah River. These two diversions do not represent actual withdrawals from the river; instead, they are a modeling technique developed for maintaining a required minimum instream flow beyond the diversion to Richland Creek. See the daily model description, Part 1 of this report, for more details. A complete list of diversions and diversion elements is shown in Table 3.

Table 3. List of all diversions in flood model

Diversion Name	Description
Diversions modeled as Negative Inflows	
Carters_IN_DIV	Both of these locations are mapped to time series from the daily study model and use a -1.0 multiplier to represent a withdrawal rather than an inflow. They are modeled as negative inflows so that they are never shorted.
HLC_Conf_Withdrawal	
Diversions modeled as standard Diversion Elements using Time Series	
Tilton_Divs	All of these locations are mapped to time series that originated in the daily study model.
Resaca_Divs	
Rome_Oostanaula_Divs	
Rome_Coosa_Divs	
Kingston_Divs	

Rome_Etowah_Divs	
Return flows modeled as Negative Diversions	
CCM_QReturnTot_Divs	Set to a constant zero.
Cartersville_Qreturn_Divs	FDR – function of Cartersville_Qdemand time series. Set to return 64%.
Diversions used to pump into off-channel storage reservoirs	
HLC_Pump_Divs	FDR – function of Hickory Log Creek storage.
Richland_Pump_Divs	FDR – function of Richland Creek storage.
Diversions modeled to Divert and Return flow downstream	
Allatoona_Factored_Min	FDR – function of Richland Creek elevation.
Two-Run 7Q10	Monthly Varying.
Canton_Divs	FDR - function of Canton_Qdemand. Returns 64% of Canton's demand downstream
Diversions modeled as Diverted Outlets from Reservoirs	
Allatoona-Cartersville_Acct_Divs	The Cartersville_Q rule is a function of the external timeseries of demand for Cartersville. (Demand is 2006. Should be updated.)
Allatoona-CCM_Acct_Divs	The CCMWA_Q rule is a function of the external timeseries of demand for CCMWA. (Demand is 2006. Should be updated.)
Richland Creek Reservoir-PauldingCo_Divs	The Water Supply Withdrawal rule is used release a constant 54.15 cfs demand for Paulding County.

D. Junction Rating Curves

In order to better evaluate flood stage, rating curves were added to the junctions representing the NWS Flood Forecast locations listed in Table 4. The locations are marked with green circles in Figure 4. Rating curves for these gages were obtained from a variety of sources, as shown in the table. RomeOo_02388525, also known as Rome-Oostanaula, is *the* primary flood risk management location for Allatoona and Carters reservoirs. This important gage is located on the Oostanaula River, just above where the Oostanaula and the Etowah Rivers join to form the Coosa River. Being so near the confluence, the stage at Rome-Oostanaula is strongly influence by backwater effects during high flow on the Oostanaula and/or Etowah Rivers, and therefore, a simple rating curve was inadequate to relate flow to stage at this gage. To address this issue, the USACE Mobile District H&H modeling team assisted by developing a family of stage-discharge curves for the Oostanaula Rome US 27 location, which relate stage to flows on both rivers.

Table 4. Junctions with rating curves

River Location	Junction Name	Source of Rating Curve
Etowah	Crtsvl_02394670	USGS
	Kingstn_02395000	USGS
	RomeEt_02395980	2011 ResSim daily planning model (slightly higher than USGS)
Oostanaula	PineChp_02383500	2011 ResSim daily planning model (slightly higher than USGS)
	Resaca_02387500	USGS
Coosa	RomeOo_02388500	CWMS model
	RomeOo_02388525	HEC-RAS model
	RomeCo_02397000	2011 ResSim daily planning model

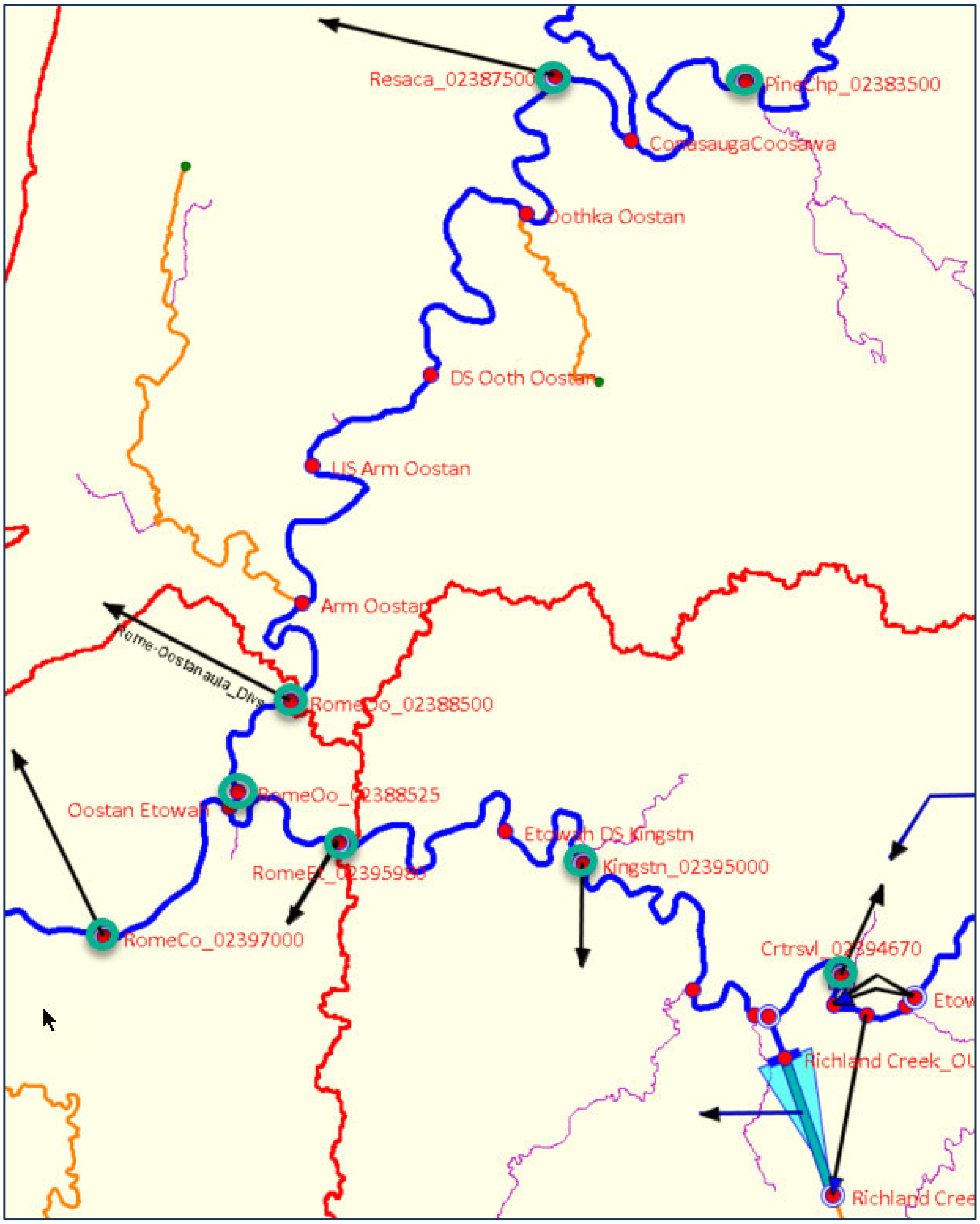

Figure 4. Important model locations with rating curves

In order to develop this family of curves, the H&H team created an updated HEC-RAS model for the region. They started with the CWMS ACT RAS model, then clipped it to extend from USGS 02395980 and USGS 02388500 on the Etowah and Oostanaula, respectively, to USGS 02397000 on the Coosa. Then the model was updated with newly surveyed bridge data and bathymetric cross sections in the study area. A new channel DEM was produced from the obtained cross sections, which compared extremely well with the cross section invert elevations from the existing ACT RAS model. For this reason, the more detailed channel data from this model were used in combination with the surveyed data. The rating curve at 02397000 was used as the downstream boundary condition for all simulations. Individual reaches of the model were calibrated to their available ratings curves (02395980 and 02388500), and the "total" model was calibrated to four events: December 2015, January 2017, April 2017, and September 2017.

The Oostanaula stage was correlated to the GA Loop gage on the Etowah River to approximate the backwater effects. The rating curves were computed by varying Oostanaula flows with constant Etowah flows. Each curve represents a constant Etowah flow, and provides the stage flow relationship at USGS 02388525 for the series of modeled Oostanaula flows. In the upper extents of the curves an intersection takes place (e.g., at 90,000 cfs for the 40,000 cfs-curve). This is caused by levee overtopping for computed water surface profiles higher than this combination of flows. The model showed that 40,000 cfs on the Etowah, combined with 90,000 cfs on the Oostanaula, produces the highest water surface elevation prior to overtopping any portion of the levee downstream of USGS 02388525.

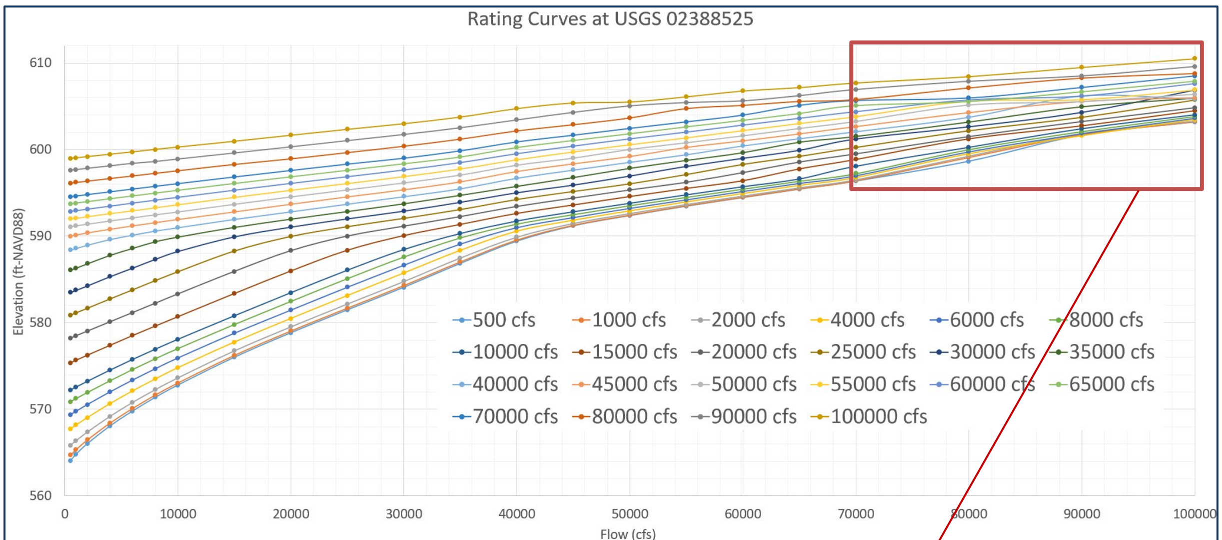

Figure 5. Family of rating curves at USGS 02388525

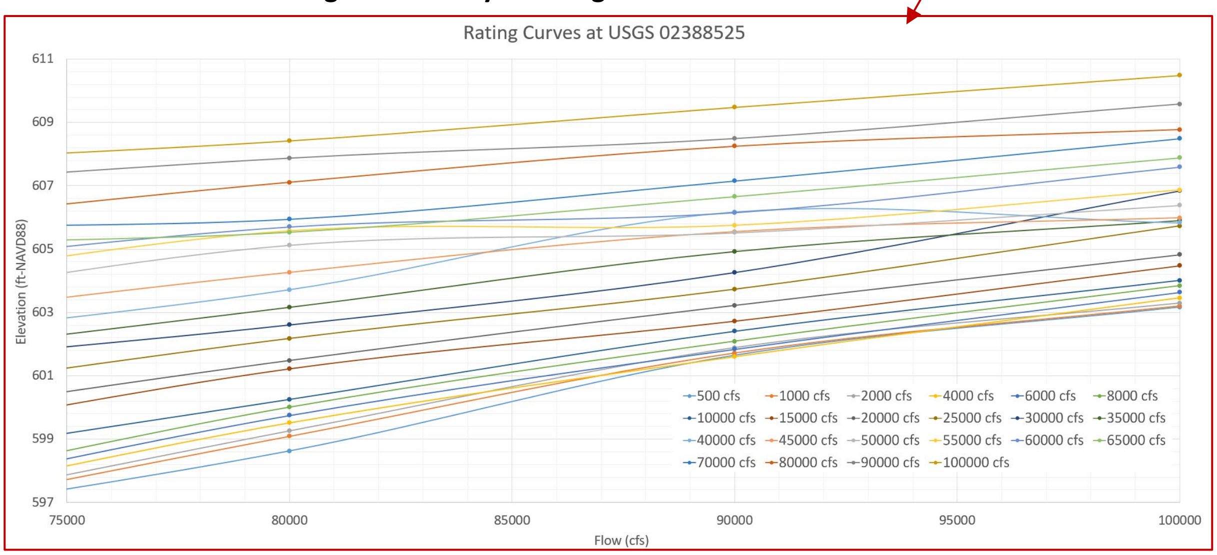

Figure 6. Upper flow levels of family of rating curves at USGS 02388525

E. Local Flow Updates

The CWMS ResSim model is linked to inflows computed by an HEC-HMS (rainfall-runoff) model. For this study, the inflows represent synthetic storm events and were generated as part of the Water Control Manual Update study. In addition, the synthetic inflow data set was created to provide inflows at the same locations as the unimpaired flow data set, which is used in the daily model. In order to maintain consistency between the daily and hourly models in this study, some changes were made to the identification, naming, and mapping of the local inflows. Table 5 shows a complete listing of local flows in the CWMS model as compared to those in the flood model and indicates the changes made.

Table 5. Local Flow Comparison Chart – CWMS model vs Flood Model

Junction	CWMS Local Flow Name	Flood Model's Local Flow Name	Factor	Operation
Allatoona_IN	Allatoona_hmslocal_Flow	Allatoona_IN_LOC		Renamed
	Woodstk_02392780_Flow			Deleted
Amica Etowah	Amicalo-Amica Etowah Flow			Deleted
Arm Oostan	Armuche-Arm Ostan_Flow			Deleted
Canton_02392000	Canton_02392000_Flow LOC	Canton_02392000_Flow LOC	0.026	
		Canton-Jasper_ReturnQ		Added
Cartecay_02379500	Cartecay_02379500_Flow	Cartecay_02379500_Flow		Mapped to Zero Flow
Carters_In	Carters_hmslocal_Flow	Carters_IN_LOC		Renamed
	Carters_DIV	Carters_IN_DIV [-1.000]	-1.0	Renamed
	MountCR-MountCr_Ellijay_Flow			Deleted
Carters ReReg_IN	Carters Rereg_hmslocal_Flow			Deleted
Coahulla Conasauga	Dalton-Coahula Conasauga_Flow	Dalton-Coahula Conasauga_Flow		Mapped to Zero Flow
Coon Etowah	Coon Etowah_Flow LOC			Deleted
Crtrsvl_02394670	Crtrsvl_02394670_Flow LOC	Kingston_LOC (0.56 x Kingston LocQ) [.102]	0.102	Renamed
DS Ooth Oostan	DS Ooth Oostan_Flow LOC			Deleted
Dummy_abv_ Dawsonville_IN	SUB Tallaps	Dawsonville_LOC		Renamed; Mapped to Zero Flow
Dwsnvl_02389150_ Flow LOC	Dwsnvl_02389150_Flow LOC	Dwsnvl_02389150_Flow LOC		
Ellijay_02380500	Ellijay_02380500_Flow LOC			Deleted
Eton_02384500	Eton_02384500_Flow	Eton_02384500_Flow		
Etowah Diversion		Cartersville_LOC (0.44 x Kingston LocQ) [.333]	0.333	Added
Etowah DS Kingstn	Etowah DS Kingstn_Flow LOC			Deleted
Euharlee Etowah	Euharlee Etowah_Flow LOC			Deleted
Hickory Log US end	Dummy Inflow Hickory Log	HLC HW (Canton_02392000_Flow LOC x 0.016)	0.016	
Hickory Log-Etowah		HLC_Conf_Withdrawal	-1.0	Added
		Canton_LOC_Conf	0.958	Added
Hinton_02382200	Hinton_02382200_Flow	Hinton_02382200_Flow		
Kingstn_02395000	Kingstn_02395000_Flow LOC	Kingston_LOC (0.56 x Kingston LocQ)	0.535	Renamed
Nelson Etowah	Nelson-Nelson Etowah Flow			Deleted
Oostan Etowah	Oostan Etowah_Flow LOC			Deleted
Oothka Oostan	Calhoun-Ooth Oostan_Flow			Deleted

PineChp_02383500	PineChp_02383500_Flow LOC	PineChp_02383500_Flow LOC		
Pmpkn Etowah	Pmpkn Etowah_Flow LOC			Deleted
Resaca_02387500	Resaca_02387500_Flow LOC	Resaca_02387500_Flow LOC		
Richland Creek_IN		Cartersville_LOC (0.44 x Kingston LocQ)	0.005	Added
Richland Creek Release		Kingston_LOC (0.56 x Kingston LocQ)	0.025	Added
RomeCo_02397000	RomeCo_02397000_Flow_LOC	RomeOo_02387000_Flow_LOC (0.19 x Rome-Coosa LocQ)	0.190	Renamed
RomeEt_02395980	RomeEt_02395980_Flow_LOC	RomeEt_02395980_Flow_LOC		Renamed
RomeOo_02388500	RomeOo_02388500_Flow_LOC	RomeOo_02388500_Flow_LOC (0.81 x Rome-Coosa LocQ)	0.810	Renamed
Setdwn Etowah	BallGro-Setdwn Etowah Flow			Deleted
Sharp Etowah	SharpCr-Sharp Etowah Flow			Deleted
StateLn_02397530	StateLn-02397530_Flow LOC			Deleted
	Cedar Coosa-StateLn_Flow			Deleted
Tilton_02387000	Tilton_02387000_Flow LOC	Tilton_02387000_Flow LOC		
US Arm Oostan	US Arm Oostan_Flow LOC			Deleted

F. Allatoona Reservoir Updates

Updates to the flood model at Allatoona Reservoir included changes to the physical data and revisions to the operation plan defined by the operating zones and rules.

1. Physical Updates

The changes made to the physical data at Allatoona matched those made in the daily study model and included the following:

- **Storage** - Updated the elevation-storage-area relationship with 2011 data and extrapolated data between the elevations of 870 and 880 ft.
- **Leakage** - Changed leakage from 75 cfs to 150 cfs
- **Spillway** - Changed number of spillway gates from 9 to 10

The details and reasoning behind these adjustments can be found in the daily study model description.

2. Operational Changes – Revisions to Existing Rules

a. Small Unit Rule

The *Allatoona MinQ_SmallUnit_215* rule was changed (recreated) so that it controlled the release from the Powerhouse Small Unit (outlet) instead of applying to the total release from the reservoir.

b. Kingston and Cartersville Downstream Control Rules

In the CWMS model, the flow limits at Kingston and Cartersville were 9,970 cfs and 12,000 cfs respectively. It was noted that although Kingston is downstream of Cartersville, its limit was smaller and, in fact, only slightly more than channel capacity at the dam. Because the Kingston constraint seemed excessively restrictive, modelers researched the origin of those limits to better understand the system. No justification for the 9,970 limit at Kingston was found. Instead, the current National Weather Service (NWS) flood "Action Stage" for the *Etowah River near Kingston* gage (18 ft) was used in coordination with the USGS rating curve to yield a 21,300 cfs flow limit. Similarly, the current Cartersville flow limit was found to be approximately 13,000 cfs. As a result, the Kingston constraint was removed from the model and the Cartersville constraint was revised.

c. Induced Surcharge Rule

The Induced Surcharge Falling Pool Transition elevation was changed from 859.5 ft to 859.4' in order to improve surcharge operations and more closely reflect the real-time operation.

d. Power Rules

Per guidance from SAM, the power guide curve rules in each reservoir zone were updated. It was noted that while the CWMS model used much the same approach as the daily model for power guide curves, this type of rule should be defined differently, depending on the computer interval or timestep.

Figure 7 illustrates how the same power operation requirement should be represented for a daily timestep vs. an hourly timestep. The operation shown in this figure calls for weekday operation at full power capacity for zero to two hours, depending on the level of the pool in Zone 3. In order to capture just a few hours of generation on a **daily** timestep, a fraction of generation time was determined by dividing the hours of generation by the 24 hours in a timestep. This fraction was multiplied by the plant factor to reduce the level of generation accordingly. The generation pattern is set to 1.0 for all weekdays and 0 for all weekends.

In contrast, the same operation is somewhat simpler to represent in the **hourly** model. The generation pattern is set to 1.0 for two hours on weekdays and 0 at all other times. The plant factor is set to 100% when two hours should be generated, 50% when one hour should be generated, and 0 otherwise.

The revised power rules in the flood model reflect the daily model's number of hours to generate per day per zone (FC and Z1= 4 hours, Z2= 3 hours, Z3= 0-2 hours, Z4= 0 hours). However, they maintained the seasonal power generation pattern and, to some extent, the hourly distribution from the CWMS model. The revised power guide curve rules demand 100% plant factor at all levels of storage above zone 3 and are limited to specific hours of generation based on the (seasonally varying) power generation pattern.

Once the revisions to the seasonal power guide curve rules were complete, a second version of each zone's rule was made without the seasonal variation in the generation pattern. The final operation set used the set of rules that do vary seasonally, however the non-seasonal rules still exist in the network. The rules were updated and renamed as shown in Table 6.

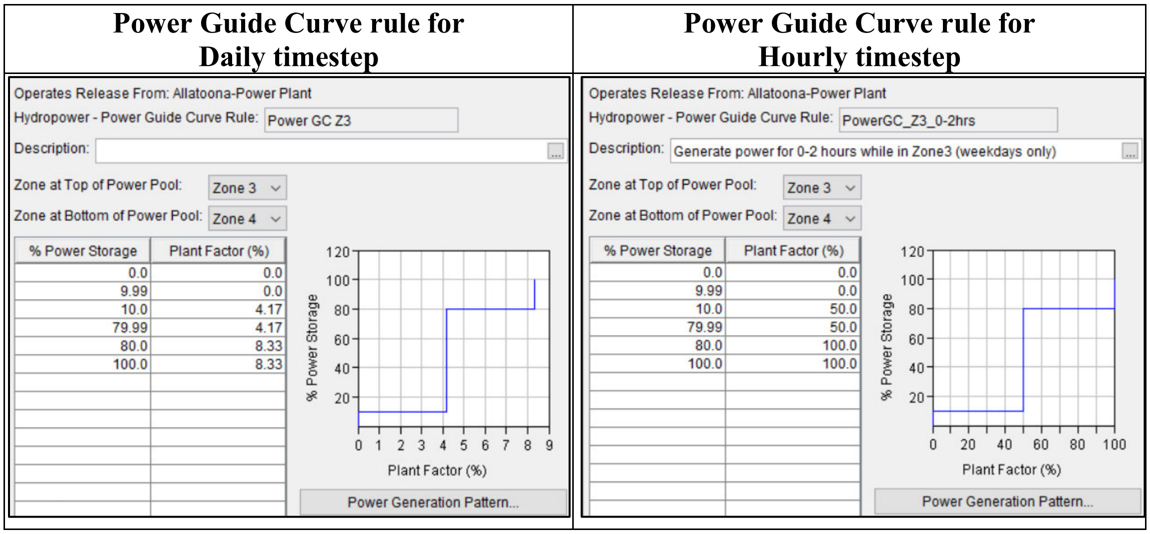

Figure 7. Hydropower operation represented for a daily vs. hourly timestep

Table 6. Power Guide Curve rule

CWMS Original Rule	Updated Seasonal Rule	Updated NonSeasonal Rule
power requirement varies seasonally		*power requirement consistent all year*
PowerGC FC	PowerGC_FC_Peaking_Seasonal	PowerGC_FC_4hrs
PowerGC_Z1	PowerGC_Z1_4hrs_Seasonal	PowerGC_Z1_4hrs
PowerGC_Z2	PowerGC_Z2_3hrs_Seasonal	PowerGC_Z2_3hrs
PowerGC_Z3	PowerGC_Z3_0-2hrs_Seasonal	PowerGC_Z3_0-2hrs

The Allatoona operation sets “WCM2015” and “flow thru” were deleted, as they were not needed for this modeling effort. "PreWCM2015” and “WCM2015_Revised” were left in the model at the request of SAM.

3. Operational Changes – Revisions to Flood Zone Operations

a. Flood Zones - Added

As part of updating the flood model to accurately reflect the flood operations described in the Allatoona Water Control Manual, it became necessary to revise the operating rules for the Allatoona flood pool. Originally, the flood pool was divided into three zones: Flood Control, Top of Surcharge, and Top of Dam. In following the operations for downstream locations specified by the Water Control Manual, five additional zones, labelled Zone A-E, were added between Conservation and Flood Control. These Flood Zones are illustrated in Figure 8.

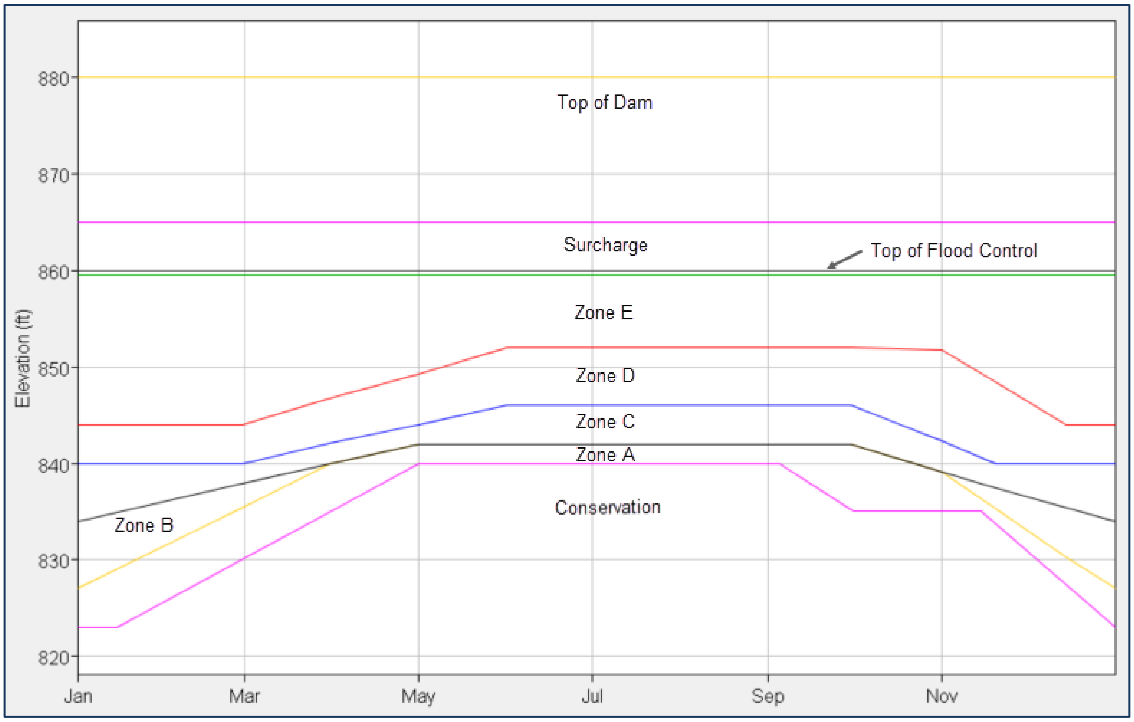

Figure 8. Allatoona Flood Pool Zones – *2018 Operations*

b. Conditional Rules

The operating objectives described in the WCM included minimum and maximum release limits that were applied conditionally based on conditions at Rome Oostanaula, inflow, and current pool elevation. To the extent possible, these conditions and their relevant operating rules were represented with IF_Blocks in the various flood zones. However, the constraints described in the WCM occasionally specified the use of forecasted conditions (e.g. "expected to rise above", "predicted to exceed"). Since modeling of forecasted conditions is very limited with this model, those portions of the operating instructions were not included.

c. Control for Rome

The operating objectives for Rome-Oostanaula are complex, shared with Carter reservoir, and do not fit the normal downstream control rule operation available in ResSim. To best model the operation for Rome, a rule guided by a scripted state variable was used. The rule limits releases from Allatoona (and Carters) based on the results computed by the state variable. The state variable script accounts for all the complex constraints that are involved in minimizing flood risk at Rome. Although the state variable and rule existed as part of the CWMS model, a variety of revisions and enhancements were made to the script in an effort to improve the operation for Rome. The script updates are described in **Appendix A.**

d. Induced Surcharge

Additionally, a problem with induced surcharge operations was noticed. When the Allatoona pool elevation dropped below 859.5 ft, the reservoir halted all but the minimum releases for one time step before rising above the 859.5 ft threshold and resuming those operations. This operation kept the pool elevation high and caused the pool elevation to repeatedly rise, resulting in an unnecessary extension of induced surcharge operations. The "Manage IS Falling" IF Block was added to allow the reservoir to maintain its previous release in that situation and gradually reduce releases after reaching the falling limb of the inflow in accordance with Table 7-5 of the WCM. This was also intended to prevent the oscillating behavior that was experienced before this rule had been implemented. The rule did alleviate those unintentional release reductions, preventing the pool elevation from oscillating.

4. Final Operation Rules and Plans

The *2018 Operations* operation set represents the baseline operations for the flood model developed for this study. The *2018 Operations (Revised GC)* operation set is a duplicate of the *2018 Operations* operation set with only one small, but very important, change – the guide curve has been revised to reflect the proposed reallocation of storage from flood control to conservation. The original and proposed guide curves are illustrated in Figure 9.

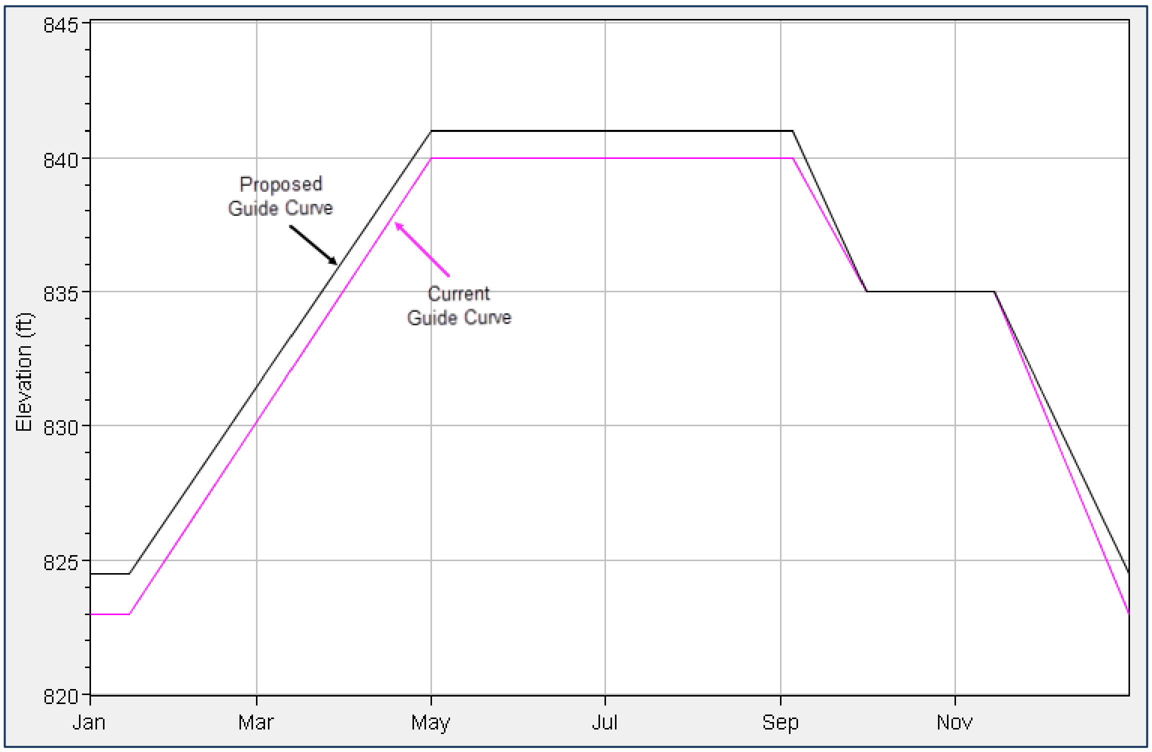

Figure 9. Allatoona Original and Proposed Guide Curve

Figure 10 illustrates Allatoona's conservation zones – with the original and proposed guide curve. Since the beginning and end of the top of Zones 2 and 3 coincide with the guide curve, these zone curves were adjusted with the revised guide curve in the *2018 Operations (Revised GC)* operation set.

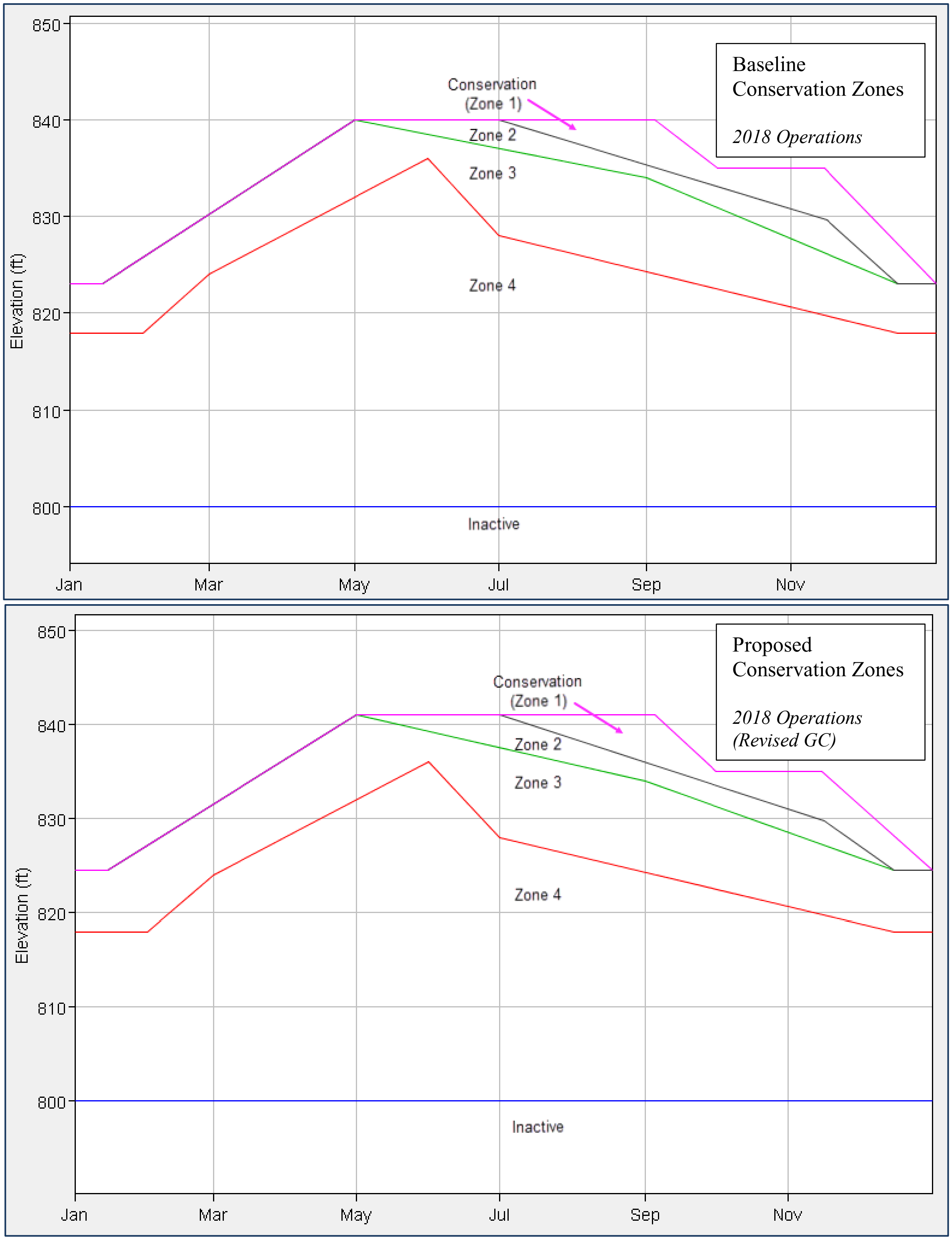

Figure 10. Allatoona Conservation Operating Zones for Baseline vs. Revised

The final set of rules used in the *2018 Operations* and *2018 Operations (Revised GC)* operation sets used by the flood model alternatives are listed in Table 7.

Table 7. Allatoona Reservoir operational rule descriptions

Rule Name	Function
Cartersville_Q	Meet the Cartersville water supply demand.
CCMWA_Q	Meet the CCMWA water supply demand. *This rule actually releases only 69% of the specified demand in order to reflect the 31% return flow that makes its way back as inflow to Allatoona.*
Control for Rome	Close or open gates based on stage at Rome. This maximum rule is a step function of the state variable *GateCloseState_Allatoona*.
DrawdownLimit1 - DrawdownLimit6	Rate of change of pool elevation limits for fish spawning support.
InducedSurchargeOps	Induced surcharge operation
MaxCC_9500	Maximum release limit for channel capacity: 9500 cfs
Max_Smallunit_zero	Shutdown the small unit.
MinQ_SmallUnit_215	Minimum small unit flow of 215 cfs. *Note: The maximum capacity of the small unit is 215 cfs.*
Release Inflow	Release the 3hour center-moving-average of inflow.
Min_PH_Cap	Release minimum 6500 cfs
PowerGC_FC_Peaking_Seasonal	Generate power for 4 hours while in FC
Max@Cartersville_13000	Maximum flow at Cartersville set to 13 kcfs
Max_PH_Cap_6500	Release maximum 6500 cfs
PowerGC_Z1_4hrs_Seasonal	Generate power for 4 hours in Zone 1 (weekdays only)
PowerGC_Z2_3hrs_Seasonal	Generate power on weekdays for 3 hours while in Zone 2
PowerGC_Z3_0-2hrs_Seasonal	Generate power on weekdays for 0-2 hours while in Zone 3
Watch Carters Dummy	Make sure that Allatoona and Carters are in the same ResSim compute block.

5. *2018 Operations* by Zone

The rules for Allatoona Reservoir are described in this section included in each operating zone at Allatoona Reservoir.

The rules “Cartersville_Q” and “CCMWA_Q” control the water supply diversions for Cartersville and CCMWA. These rules are active in each operating zone of the reservoir to ensure water supply continues during flood operation.

The “Max@Cartersville_13000” is in all middle range zones, from Zone 3 to Flood Zone E. The rule sets a downstream maximum flow of 13,000 cfs at Cartersville and reflects an adjustment to the original CWMS model rules.

a. Top of Dam

The Top of Dam zone is set at a constant elevation of 880 ft and contains only three rules, “Cartersville_Q”, “CCMWA_Q”, and “Watch Carters Dummy” (Figure 11). The third rule has no operational impact; it is simply a modeling technique that ensures that Allatoona is within the same compute block as Carters.

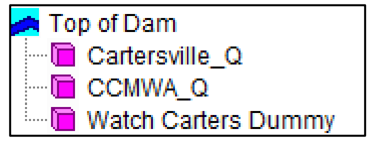

Figure 11. Allatoona’s Top of Dam Rules

b. Top of Surcharge

The Top of Surcharge zone is set to a constant elevation of 865 ft and contains the water withdrawals for CCMWA and Cartersville, the Induced Surcharge rule, the maximum channel capacity rule, and a rule to shut the small unit gates.

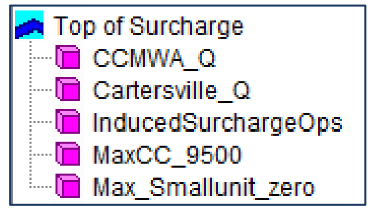

Figure 12. Allatoona’s Top of Surcharge Rules

c. Flood Control

Zone E was previously labelled as Flood Control and was set at elevation of 860 ft, as specified in the Water Control Manual (WCM). However, above 859.5 ft, the reservoir should only be concerned with induced surcharge operations. In order to simplify the operations between 859.5 and 860 ft, Zone E was created and its top of zone was set at 859.5 ft. This revised Flood Control zone includes only the required water withdrawals for CCMWA and Cartersville, the required Small Unit flow, the Induced Surcharge rule, and a maximum channel capacity rule.

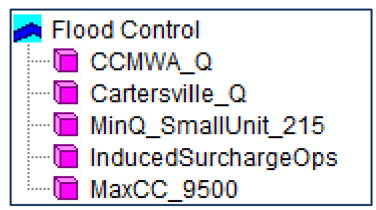

Figure 13. Allatoona’s Flood Control Rules

d. Zone E

This zone, set at 859.5 ft, is intended to act as the topmost portion of the "normal" flood control zone, meaning that **above** this zone, Induced Surcharge operations will take priority and downstream considerations are ignored.

The Flood Regulations described in the Allatoona WCM state:

> **Zone E** - Only minimum continuous release will ordinarily be made while Rome stage (USGS gauge 02388525) is above or expected to rise above 28 ft (moderate flood stage). *However, if inflows are predicted to exceed flood control space before Rome has crested, powerhouse releases which are less than inflow may be made until either the stage at Rome has peaked or greater (surcharge) releases are required.* Assuming that surcharge releases do not govern, after Rome has crested, peaking power will be made if the releases do not reverse the falling trend at Rome. Increasing releases will be made as the stage at Rome drops below 28 ft. Releases of channel capacity (about 9,500 cfs) will be made whenever such a release does not reverse the falling trend at Rome. Surcharge Releases: Infrequently inflows into Allatoona will be of such magnitude that the stage at Rome does not govern the operation of Allatoona but rather the structural stability of the dam will govern. Whenever this happens, surcharge releases will be made.

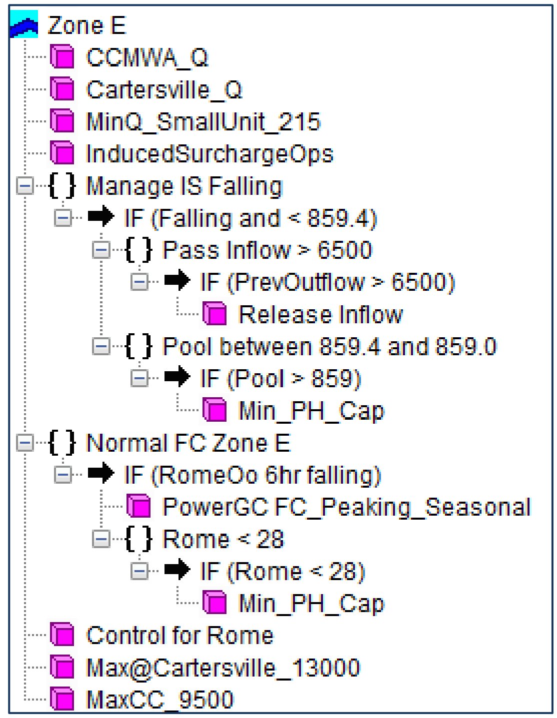

Figure 14. Allatoona's Zone E Rules

Since the conditions that use the phrases "expected to" or "predicted to" do not include any specifics on how to evaluate them, these conditions were not explicitly modeled. The rest of the instructions were interpreted as follows, by order of priority:

- Make the minimum continuous releases. These include the water supply withdrawals and the minimum Small Unit flow.
- Follow Induced Surcharge operation if necessary.
- Control for Rome-Oostanaula:
    - if Rome is above 28 ft and rising
        - make no spillway or powerhouse releases
    - if Rome is above 28 ft and falling

    - make peaking power releases as long as the power releases do not cause Rome to rise.
  - If Rome is below 28 ft
    - releases up to channel capacity (9,500 cfs) may be made, as long as they do not cause Rome to rise.

Two IF blocks were developed in a reasonably successful attempt to represent the conditions described in the WCM and to manage the undesirable behaviors that arose under those conditions not accounted for in the manual.

The purpose of the first IF block, *Manage IS Falling*, is to manage the transition between surcharge operation and the current flood control zone's normal flood operations. The *InducedSurchargeOps* rule that precedes the IF_Block uses a falling pool transition elevation of 859.4 ft. That means that if Induced Surcharge had been controlling the releases and the pool is falling and has receded below 859.4, then the release from the prior timestep would be greater than or equal to inflow and greater than channel capacity. Under these conditions, normal flood operations are likely to be very restrictive and may cause abrupt changes in the release that could force the pool and releases to oscillate which is not an release behavior you are likely to see in real-time.

The *Manage IS Falling* IF_Block works as follows: it determines whether the pool is currently below 859.4 ft and falling by checking the previous pool elevation against the pool elevation from 3 hours earlier. If the conditions are true, it passes inflow that is greater than 6,500 cfs (the operational limit for the powerhouse) as long as the previous outflow was also greater than 6,500 cfs. Since only surcharge operations would allow releases greater than 6,500 cfs at this elevation, this pass inflow rule would only be triggered if surcharge operations were previously active. If the pool elevation is between 859 ft and 859.4 ft, the release is set to a minimum of 6,500 cfs to ensure that the pool can continue to recede.

The second IF_Block, *Normal FC Zone E*, reflects the conditions that dictate the minimum releases under normal flood operations. This IF_Block first checks that the state variable *Rome_Oostanaula_Rising* is false and that the Kingston and Cartersville local flows are low enough to ensure that they will not combine with power released to change the falling trend. Sensitivity testing suggested that flows on the Etowah in excess of about 8,000 cfs could reverse the falling trend at Rome when stage is about 28 ft. Thus, the Kingston local limit was estimated at 1,500 cfs. The Cartersville limit is less restrictive at 4,500 cfs but may be effective if applied when the stage at Rome is below 28 ft. The check on the local flows at Kingston and Cartersville are being used as an indicator that powerhouse releases will not reverse the falling trend at Rome. If those conditions are true, peaking power releases are allowed. Additionally, if the stage at Rome Oostanaula 02388525 is below 28 ft, a minimum continuous release of 6,500 cfs from the powerhouse will be made from Allatoona.

Following the second IF_Block are the remaining normal flood control rules. The Control for Rome rule provides the final logic that checks the stage at Rome Oostanaula to determine whether the gates at Allatoona should be opened or closed.

The downstream control rule for Cartersville may constrain releases even if the conditions at Rome do not. And, finally the channel capacity is included at the bottom of the zone to allow Allatoona to drawdown when all other constraints are false.

e. Zone D

The Flood Regulations described in the Allatoona WCM state:

> Zone D - Only minimum continuous release will ordinarily be made while Rome stage is above or expected to rise above 28 ft. *However, if inflows…or surcharge releases are required.* Once Rome has fallen below 28 ft, up to full channel capacity (about 9,500 cfs) will be discharged. The release of powerhouse capabilities (about 6,500 cfs) may follow if consideration of downstream conditions and expected weather conditions make this prudent.

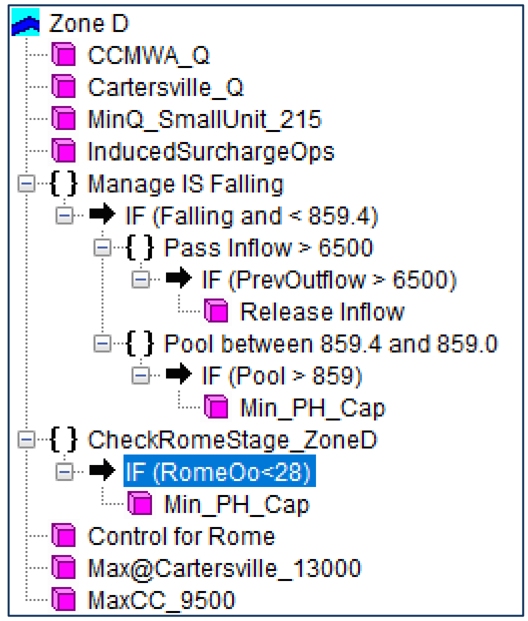

Figure 15. Allatoona's Zone D Rules

Although the manual uses fewer words to describe the operation in Zone D, these instructions were interpreted to mean that the operations of Zone E should be followed with one small difference – normal flood control releases will not be increased above minimums until the stage at Rome is below 28 ft. This difference is reflected in the *CheckRomeStage_ZoneD* IF_Block which checks if the stage at Rome-Oostanaula is below 28 ft and is not rising; when true, a minimum release of 6,500 cfs is required. All other operations are identical to those in Zone E.

f. Zone C

The Flood Regulations described in the Allatoona WCM state:

> Zone C - Only minimum continuous release will ordinarily be made while Rome stage is above or expected to rise above 28 ft. *However, if inflows…or surcharge releases are required.* After Rome has receded below 25 ft (flood stage), releases will be up to channel capacity (about 9,500 cfs). Generally, releases will be at turbine capacity (about 6,500 cfs). Scheduled peak power releases of less than 6,500 cfs/day may be used if the scheduled releases sufficiently lower the pool in light of expected weather conditions.

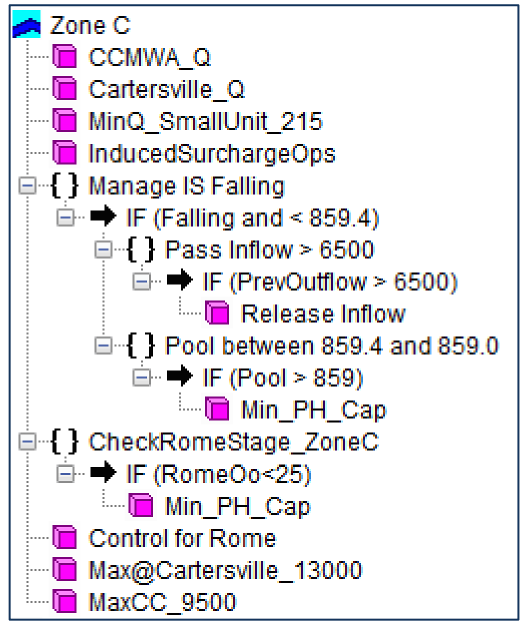

Figure 16. Allatoona Zone C Rules

These instructions were interpreted to mean that Zone C operations are identical to Zone D with the exception that the falling stage threshold at Rome-Oostanaula is lowered from 28 ft to 25 ft. This exception is reflected in the *CheckRomeStage_ZoneC* IF_Block which checks if the stage at Rome-Oostanaula is below 25 ft and is not rising; when true, a minimum release of 6,500 cfs is required. The state variable script that determines *GateCloseState_Allatoona* manages the rest of the logic related to when to "close the gates" and when to open them back up and influences the operation through the *Control for Rome* rule.

g. Zone B

The Flood Regulations described in the Allatoona WCM state:

> Zone B - Only minimum continuous release will ordinarily be made while Rome stage is above or expected to rise above 25 ft. *However, if inflows…or surcharge releases are required.* Floodwaters will be evacuated by regular scheduled hydropower releases which do not violate bankfull flows. Normally, the schedule will be to remove the floodwater within two weeks. A faster evacuation may be scheduled if additional rainfall is expected in the next several days.

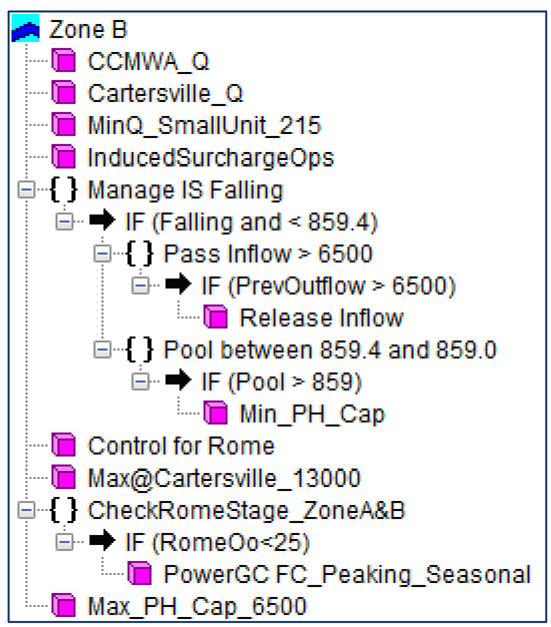

Figure 17. Allatoona Zone B Rules

These instructions were interpreted to mean that the operations for Zone B are very similar to those for Zone C but the limiting stage at Rome-Oostanaula (both rising and falling) is 25 ft. This constraint is fully represented by the state variable script that determines *GateCloseState_Allatoona* and specifies the operation in the Control for Rome rule, so no IF_Block is needed in Zone B to force Allatoona to open up even if the Control for Rome rule wants to keep the gates closed. Thus, unlike the higher zones, the *Control for Rome* rule immediately follows surcharge operations. And, like the other zones, *Control for Rome* is followed by the downstream control rule for Cartersville. However, below the downstream control rule, a new IF block called *CheckRomeStage_ZoneA&B* was added that double-checks the stage at Rome-Oostanaula – if it is below 25 ft; peaking power releases are allowed. The last rule in the zone is the Max_PH_Cap_6500 rule which limits the releases to 6500 cfs instead of the channel capacity.

h. Zone A

The Flood Regulations described in the Allatoona WCM state:

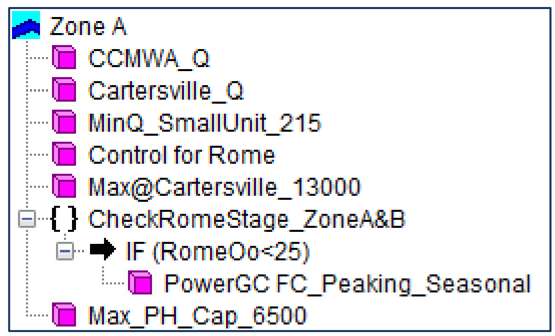

Figure 18. Allatoona Zone A Rules

> Zone A - This zone has the least urgency for being evacuated. During the winter/spring refill and summer months the pool may be allowed to rise to the top of Zone A on the weekends without releases above the minimum 240 cfs. During the fall step down period the pool may be held at the top of Zone A indefinitely if all project purposes are being met. Only minimum continuous releases will ordinarily be made while Rome stage is above or expected to rise above 25 feet.

Although the wording of these instructions sounds quite different than the instructions for Zone B, they were interpreted to mean that the operations for Zone A are very similar to Zone B except for one major difference – surcharge operations are not called for in Zone A. Thus, Zone A includes the same set of rules and IF_Blocks from Zone B except that the *InducedSurchargeOps* rule and the *Manage IS Falling* IF_Block have been removed.

Figure 19 combines Figure 14 through Figure 18 into a single figure to illustrate the relative differences between the operations for Zones A-E in the flood pool at Allatoona.

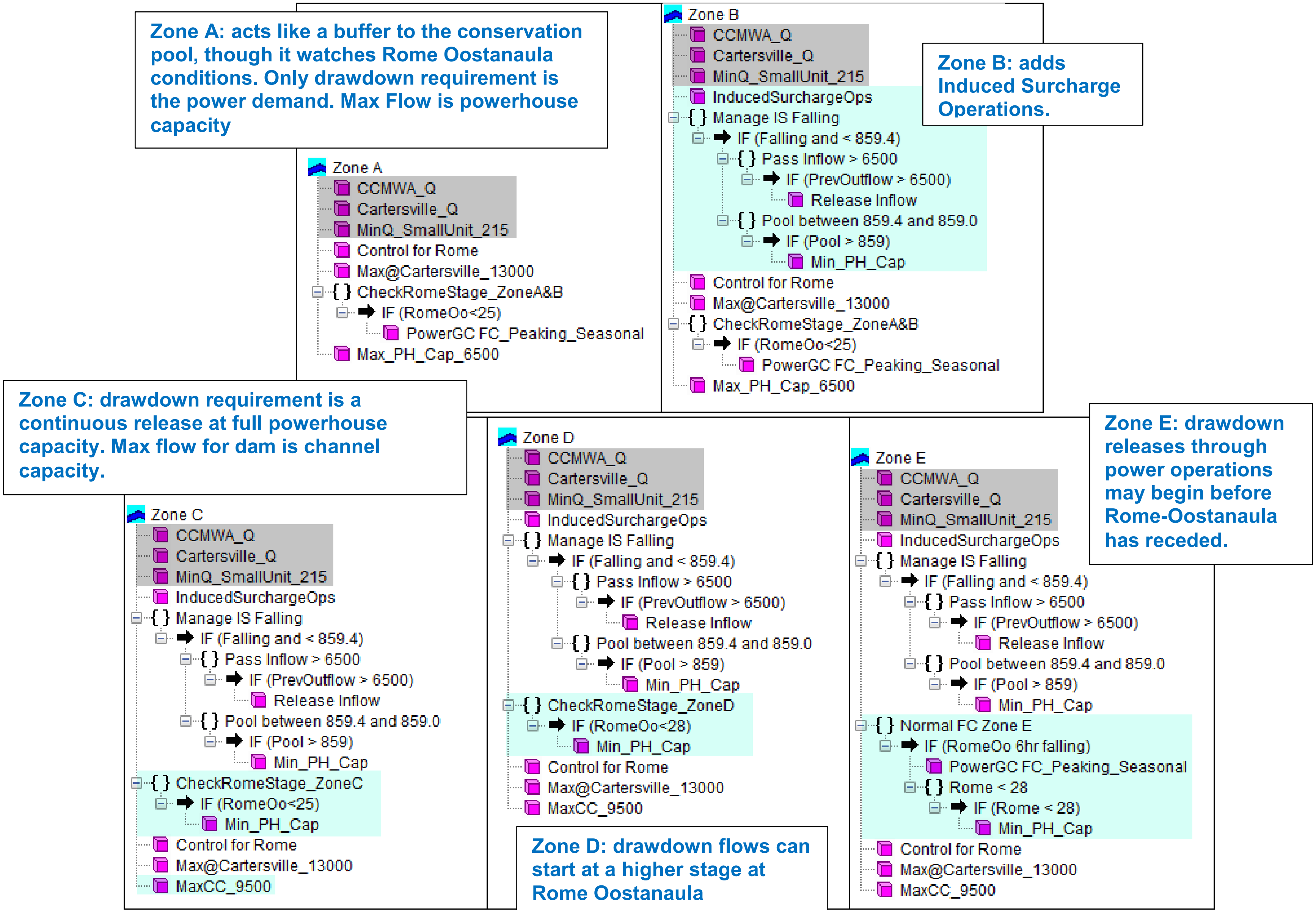

Figure 19. Rules in Allatoona Flood Zones A-E.

Highlights show a change relative to the zone below.

G. Carters and Carters ReReg Reservoir Updates

1. Physical Updates

A number of physical changes were made to Carters Reservoir and its reregulation dam, Carters ReReg. These changes were made to the hourly model to match conditions within the more recent daily model and included:

- Addition of the Carters Sluice Gate
- Revisions to Carter's Gated Spillway curve
- The length of the dam at Carters was increased from 2,053 ft to 2,753 ft.
- The length of the reregulation dam was increased from 208 ft to 3,350 ft
- Evaporation data was removed from Carters ReReg.

2. Operational Updates and Rule Descriptions

In addition to changes to the physical data of the reservoirs in the Carters system, several updates were made to the operations at Carters and Carters ReReg to match the operations in the daily model and to better reflect the flood risk management operation in the upper ACT basin as described in the Carters Water Control Manual. The changes included:

- the GC Buffer zone was given a seasonal variation so that it reflected the shape of the guide curve at Carters.
- The rule to control compute blocking, *Dummy fn of Rome*, was removed from Carters and a replacement was added to Allatoona.
- The dummy rule to force execution of the *Peak* state variable was removed. Peak is computed by the master state variable GateCloseState_Carters.
- The *Control for Rome & Resaca* rule was added to Carters
- The Carters flood control pump-back operation was revised to better handle protecting Carters ReReg without endangering Carters itself. These changes are described in Section a. below.

Table 8 lists the rules used in the 2018 Operations operation set at Carters and describes the objective of each rule.

Table 8. Carters Reservoir Operation Rules

Rule Name	Function
InducedSurch_EmergReg	Induced surcharge operation
Max Rel fn of TRC	Sets the maximum release from Carters to a function of the flow coming in from Talking Rock Creek. This rule replaced the Max_5000@ReReg_IN, a downstream control rule to limit inflow to Carters ReReg to a maximum of 5000 cfs

Pwr Generation	A power guide curve rule that calls for 4-5 hours of weekday generation at full capacity. The power generation pattern varies seasonally and specifies the hours for generation.
Control for Rome & Resaca	Close or open gates based on stages at Rome and Resaca. Specified as a function of the state variable *GateCloseState_Carters*
FC Pumpback – 24hrs	Pumpback rule for the flood pool — uses a target elevation of 1090.0'. Used to protect Carters ReReg when Talking Rock Creek inflows are very high or the Carter system is reducing releases to minimize flood risk downstream.
10HR pumping_Buffer	Pump up to 10-12 hours a night, seasonally, as needed to get to the GC Buffer. This is to maintain Power Generation across the guide curve. Note, whole hour pumping allows the pumpback to exceed the target.
MinQ_Seas_Release	Looks at the 7-day adjusted average inflow to Carters ReReg (Talking Rock Creek + Carters Inflow) to determine the minimum flow that Carters should release to support the ReReg in meeting the seasonal minimum.
Max release = Inflow	Max Rel = 105% of inflow up to 5000

Table 9. Carters ReReg Reservoir operational rule descriptions

Rule Name	**Function**
Min Release to River	Minimum release specified by the state variable *CarersReReg_MinimumRelease* which is computed by the master state variable Carters_Seasonal_Min. The master state variable accounts for the Carters system's storage state and inflow.
Control for Rome & Resaca	Close or open gates based on stages at Rome and Resaca. A function of the state variable *GateCloseState_Carters*
Channel Capacity_5000	Maximum release limit of 5000 cfs.

a. Carters Flood Control Pump-back Operation

The flood control pumping operation at Carters was adjusted by replacing the original "FC Pumpback" rule with a conditional statement using two new pumping rules. If Carters ReReg pool elevation is above 695 ft or Talking Rock Creek flow is greater than 5000 cfs, the "FC Pumpback – 24hrs" rule will operate on a fixed hour range between 20:00 and 10:00 hours, otherwise the "10HR pumping_Buffer" rule will operate on a seasonally varying fixed hour range. For both of these new rules, the number of units was increased from 1 to 2 (Figure 20).

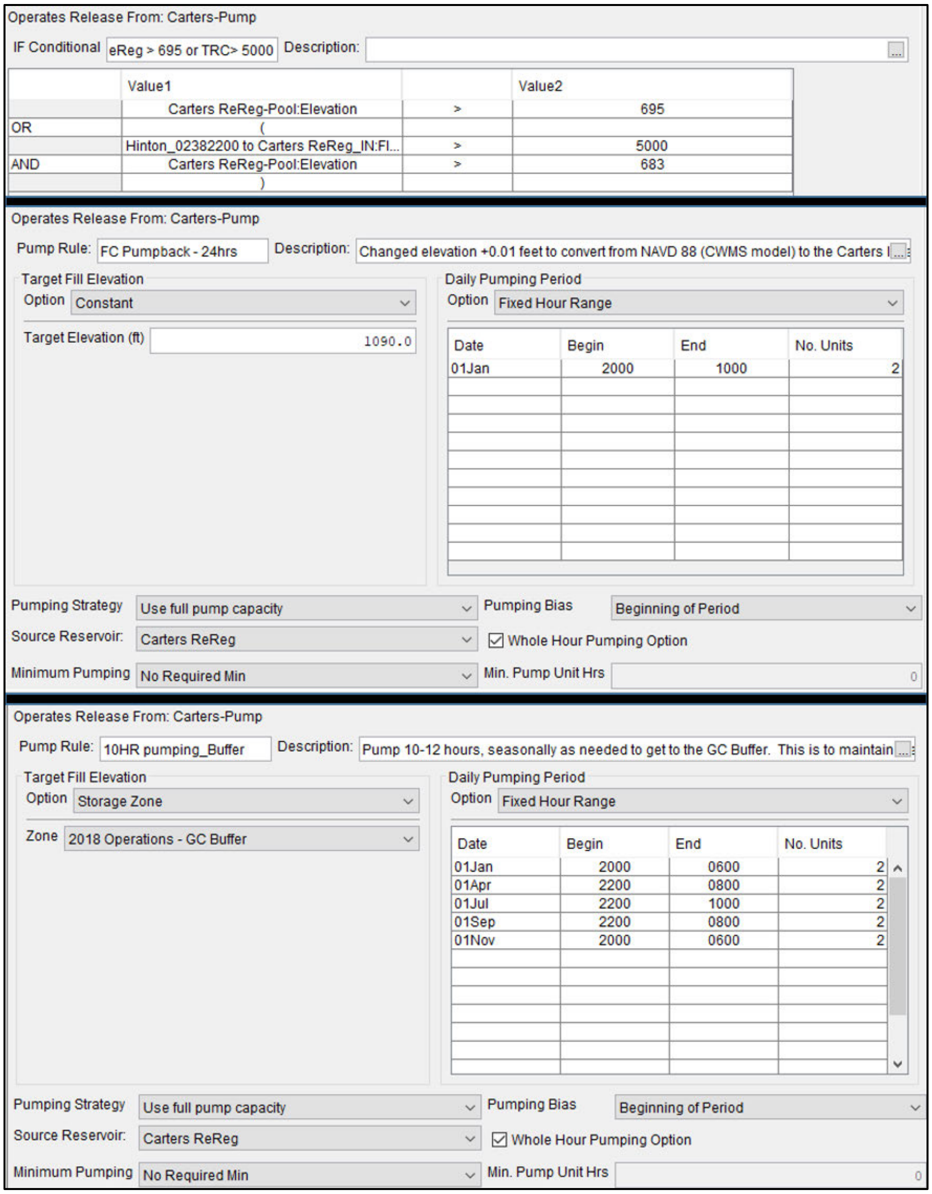

Figure 20. Carters Dam pumping rules

3. Alternative Updates

Since there was no lookback data available for the Carters ReReg pool elevation and release, the Lookback Elevation and Releases for Carters ReReg were changed from Time Series to Constants and assigned values of 687 ft and 240 cfs, respectively.

H. Hickory Log Creek Reservoir Updates

The operation of Hickory Log Creek Reservoir for the flood modeling has little consequence to the analysis. The intent is to operate purely as an "Amenity Lake", meaning that water is pumped from the Etowah River in order to keep the reservoir fully, but water is released only to maintain the minimum instream flow below the dam. No water accounting is done for the flood modeling, and no releases are made to water account holders. The operation set used for these scenarios is titled “Amenity Lake”. (The “Flow Thru” operation set was deleted.)

Table 10 shows the operational rules used for the Amenity Lake operation set at Hickory Log Creek. The MinQ_instream rule mandates a minimum flow that is a function of the inflow to Hickory Log Creek. However, in the delivered version of the model, a dummy inflow attached to a time series of zero flow is used in the rule. This is a relic of the original CWMS model, which was not altered during this flood modeling study. It makes the Amenity Lake operation actually act as a flow-through operation. Figure 21 shows the Hickory Log Creek operation for one of the flood events modeled. Overall, since the flood model is focused on large events and not on water storage balance, there is no concern that the flow-through operation will impact analysis.

Table 10. Hickory Log Creek Reservoir operational rule descriptions

Rule Name	Function
MinQ_instream	Minimum 7Q10 release of 3.5 cfs or natural flow, whichever is less.
No_HLC_div	Don't use the water account diversion, because HLC is strictly an Amenity Lake

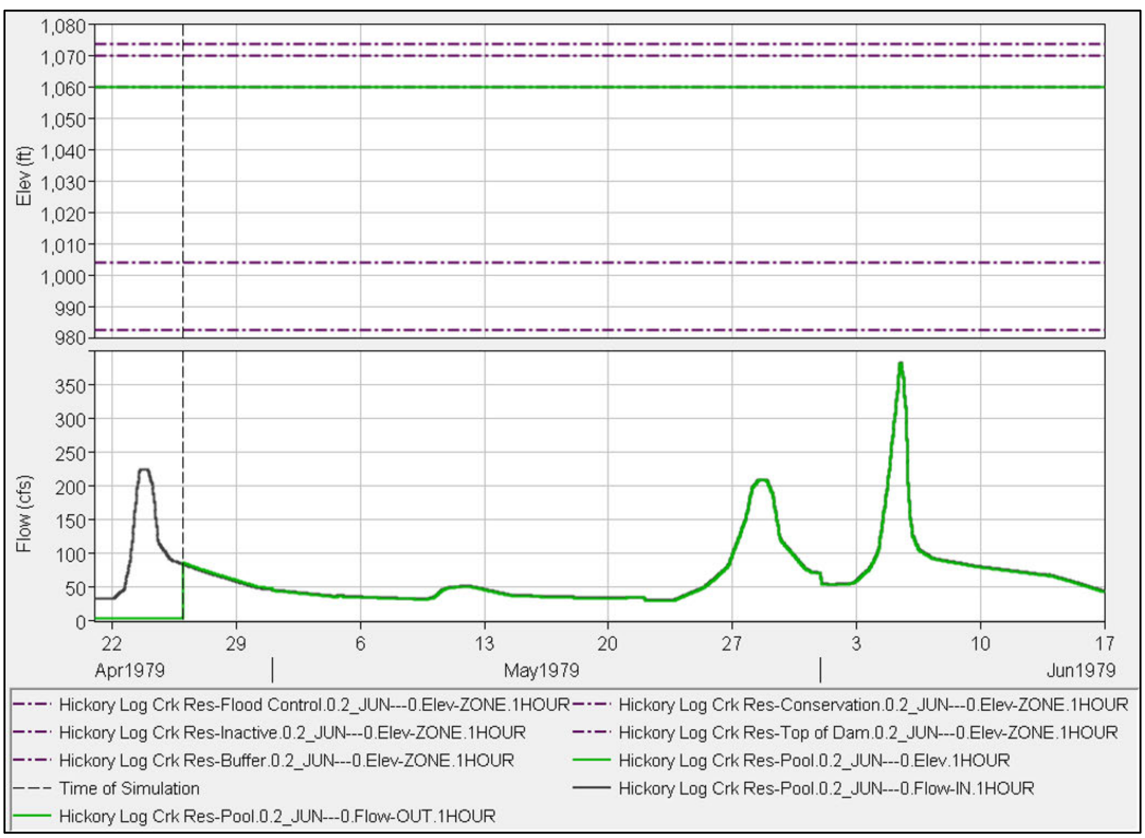

Figure 21. Plot of Hickory Log Creek

I. State Variable Scripts

The CWMS ACT model included 110 state variables, most of which were not needed for the flood study model and were ultimately removed. For the flood model, only four state variables and four slave[2] state variables are needed. These state variables are described below.

Note: There are fewer local inflow locations used in the flood model versus the CWMS model so all scripts that computed a sum of multiple local inflows were revised to reflect the new set of local inflows. Specifically, the Carters ReReg lake local identified in the CWMS model is included in the Talking Rock Creek flow in the study model and is not called out separately.

1. Allatoona_ElevState

The *Allatoona_ElevState* state variable evaluates the current condition of Allatoona's pool with respect to some seasonal conditions (shown below) and stores a code that is used by Allatoona's "Fish Spawning Season" IF-Block to determine rate of change constraints on the pool.
This state variable script acts as a master by computing the values for two slave state variables:

- *Allatoona_BaseElev* and
- *Allatoona_FSCompliance*.

The *Allatoona_ElevState* state variable script has not been revised as part of this study effort. The beginning comments of the script can be seen in Figure 22.

```
# 7/02/2010 smo.
# Create a code to track the lake state due to rising/falling during the fish spawning period for Allatoona
# 15March - 15May = 1 Spawning
# Other times = 2  Non-Spawning

# State variable: Allatoona_Elev_State
#  Code =0: Pool is rising
#          =1: The first day of the fish spawning
#          =2: The pool has dropped within 0.3 ft from the base elevation
#          =3: The pool has dropped within 0.3-0.4 ft from the base elevation
#          =4: The pool has dropped within 0.4-0.45 ft from the base elevation
#          =5: The pool has dropped within 0.45-0.49 ft from the base elevation
#          =6: The pool has dropped within 0.49-0.50 ft from the base elevation
#          =7: The pool has dropped more than 0.50 ft from the base elevation
```

Figure 22. Descriptive comments at beginning of *Allatoona_ElevState* state variable script

[2] Slave state variables are state variables that are computed by another state variable script (called a master). The slave variable is often computed as a byproduct of the computations performed by the master in order to determine its own value. For efficiency, ResSim has a switch in the state variable editor to identify a state variable as a slave so that it does not execute a script to evaluate itself during the ResSim compute. However, like all state variables, slave state variables are typically used somewhere in the operation set of one or more reservoirs or diversions to define or limit their releases.

2. Carters_Seasonal_Min

The *Carters_Seasonal_Min* state variable determines the value of the current month's required minimum release from Carters reservoir and from the Carters system (*CartersReReg_Seasonal_Min*) as prescribed in the Carters WCM.

The logic for this state variables is very straightforward. The Carters system has a seasonal minimum release requirement; 240 cfs of that requirement is expected to be met by storage in Carters ReReg. Carters itself need only release the seasonal minimum requirement minus 240 cfs and whatever local inflow might be coming in from Talking Rock Creek. *Carters_Seasonal_Min* is used by Carters' *MinQ_Seas_Release* rule.

3. CartersReReg_MinimumRelease

Previously named *ReregMin*, this state variable determines the minimum release required from Carters ReReg and is used by the *Min Release to River* rule in Carters ReReg's *2018 Operations* operation set. Several revisions were made to this state variable's script to reflect objectives and constraints described in the current Carters System Water Control Manual (WCM).

This state variables uses:

- *CartersReReg_Seasonal_Min* – a slave state variable (computed by the *Carters_Seasonal_Min* state variable script) that contains the value of the current month's minimum release from the Carters system as prescribed in the Carters WCM.

The basic logic in the original version of this state variable is illustrated in Figure 23.

```
systemInflow=CartersIn+Carters_ReReg_Local+Hinton_to_Carters_ReReg_IN

if carters_elev > Carters_Con:
    minRel= max(Min_seasonal , systemInflow)
elif carters_elev > Carters_CompositeZone2:
    minRel= max(Min_seasonal , 0.9* (Hinton_to_Carters_ReReg_IN+Carters_ReReg_Local))
else:
    minRel= 240

minRel= min(5000, minRel)
```

Figure 23. Portion of original CartersReReg_MinimumRelease state variable script logic

The revised state variable retained the same basic logic but several refinements were added, including accounting for:

- Adjustments for the rise and fall of Carters' guide curve in April and November.
- Downstream constraints computed by the *GateCloseState_Carters* state variable
- The current storage at Carters ReReg.
- The timestep of the model – a 24 hour average of future inflow was set aside in favor of a centered 6 hour average of previous and future inflow. There are fewer local inflows used in this study model versus the CWMS model so all scripts that computed a sum of multiple local inflows were revised to reflect the new set of local inflows.

4. CartersReReg_CompositeZone

The *CartersReRegCompositeZone* state variable determines the state of the composite storage in the Carters system (Carters and Carters ReReg Reservoirs); it returns a value of 1 for Normal and 2 for Low. The line that defines the border between Normal and Low varies seasonally, so for convenience, it is stored in Carters as an operating zone called CompositeZone2.

This state variable script acts as a master by computing the value for a slave state variable called *CartersReReg_CompStor* – which holds the total sum of Carters current storage plus the active storage at Carters ReReg.

5. GateCloseState_Carters

The *GateCloseState_Carters* state variable determines when Carters (and Carters ReReg) and Allatoona should cutback to minimum releases in order to protect the downstream system; the downstream control points include Resaca and Rome at Oostanaula.

The *GateCloseState_Carters* state variable script acts as a master by computing the values for three slave state variables:

- *GateCloseState_Allatoona*
- *Rome_Oostanaula_Rising*, and
- *Peak*.

GateCloseState_Allatoona is computed by this script because it was more efficient to compute it as part of determining *GateCloseState_Carters*; not only did it mean executing one script instead of two during the computations, but it makes model maintenance simpler by limiting where to look for potential errors. *Peak* and *Rome_Oostanaula_Rising* are computed as part of the process in determining the values of *GateCoseState_Allatoona* and *GateCloseState_Carters*.

The *GateCloseState_Carters* state variable was revised to reflect the full set of downstream flood constraints described in the current Carters and Allatoona water control manuals (WCMs). The revisions included:

- Operating limit variables were added to the top of the script for easy revision by Mobile District modelers. These variables include:
  - *Resaca_stage_GateClosing*
  - *Rome_stage_GateClosing*
  - *Rome_stage_GateClosingHI*
- The tests on the flooding state at Rome-Oostanaula and Resaca were rearranged to check the conditions at Rome first. The WCMs indicated that operations for Rome are primary for both Carters and Allatoona. In addition, Allatoona should not be affected by the flood state at Resaca.
- Tests were added for the current (flood) zones at Allatoona. This accounts for the fact that the Allatoona's maximum release varies with Allatoona's flood zones and the stage at Rome.
- Since the WCMs do not describe how to manage the reservoirs when conditions at the control points flutter around the operating constraints, additional logic was

developed to manage the flood releases at Allatoona (and Carters) so that they do not fluctuate wildly. This logic uses the following variables to minimize release oscillations:

- Resaca_stage_GateOpening
- Resaca_flow_tollerance
- Resaca_AllisWell_Stage
- Rome_stage_GateOpening
- Rome_stage_GateOpeningHI
- Rome_flow_tollerance
- Rome_AllisWell_Stage
- AllisWellatResaca
- AllisWellatRome

The current values of these variables have been shown to perform as intended for the flow regimes used in this study. However, they are included with the others Operating Limit variables at the top of the script and may be adjusted to fine-tune the operation for real-time use.

- Several variable names were revised to make the script more readable and self-documenting.
- Several local time series variables were added to keep track of the state of some internal variables with the objective of facilitating debugging and analysis of results. These variables are written to the simulation.dss file by the "cleanup" section of the state variable script.
- Comments were added to the script to describe the purpose of each section and/or conditional expression.

IV. Alternative List

Study alternative were developed using historical and synthetic storm data. In order to develop the synthetic storms, three historic storm events were identified from the daily average unimpaired data set: Nov-Dec 1961, Jan-Mar 1979, and Feb-Apr 1990. These storms were selected from the period of record because of their high 45-day volume, and their high peaks. A frequency analysis of the historical data was used to establish a peak-frequency relationship (documented in Appendix C – Modeling and Engineering, Attachment 8 – Flood Frequency Hydrology Development). The associated return period for an event is the inverse probability of an event being equaled or exceeded in any given year, e.g., the 100-yr event has a return period of 100 years and a frequency of 1.0%. The synthetic storms were developed using the shapes of the historical events, and peaks were based on selected event frequencies. Several different timings of the synthetic storms were considered, since reservoir conditions vary seasonally.

Results were generated for a total of 40 alternatives that used synthetic storms and two that used the 2009 historical event. These alternatives are listed in Table 11. The alternatives varied based on the event timing and return period, as well as which guide curve was used at Allatoona. The alternatives are divided into 5 distinct groups: April, Jan, Jun, Oct synthetic events, each including frequency intervals ranging from 5.0% to 0.2%, and a 2009 event using observed data. Each of the time periods represents a different initial condition for the reservoir, Jan winter level, April spring refill from winter to summer level, Jun full summer level, and Oct drawdown period from summer to winter levels. Alternative names appended with "_RG" represent a revised Allatoona guide curve elevation of 841 ft for the summer pool elevation, 835 ft for the fall drawdown, and 824.5 ft winter pool elevation.

Table 11. List of alternatives used in flood model

Return Period (Event Frequency)	Synthetic Event Timing				Historical Events
	April	January	June	October	
Alternatives using current Allatoona Guide Curve					
500-yr (0.2%)	0.2_APR	0.2_JAN	0.2_JUN	0.2_OCT	2009
200-yr (0.5%)	0.5_APR	0.5_JAN	0.5_JUN	0.5_OCT	
100-yr (1%)	1.0_APR	1.0_JAN	1.0_JUN	1.0_OCT	
50-yr (2%)	2.0_APR	2.0_JAN	2.0_JUN	2.0_OCT	
20-yr (5%)	5.0_APR	5.0_JAN	5.0_JUN	5.0_OCT	
Alternatives using Revised Allatoona Guide Curve (RG)					
500-yr (0.2%)	0.2_APR_RG	0.2_JAN_RG	0.2_JUN_RG	0.2_OCT_RG	2009_RG
200-yr (0.5%)	0.5_APR_RG	0.5_JAN_RG	0.5_JUN_RG	0.5_OCT_RG	
100-yr (1%)	1.0_APR_RG	1.0_JAN_RG	1.0_JUN_RG	1.0_OCT_RG	
50-yr (2%)	2.0_APR_RG	2.0_JAN_RG	2.0_JUN_RG	2.0_OCT_RG	
20-yr (5%)	5.0_APR_RG	5.0_JAN_RG	5.0_JUN_RG	5.0_OCT_RG	

V. Allatoona Probable Maximum Flood

The objective of the PMF alternatives in the flood model was to a) verify that the PMF event can be routed through Allatoona and b) that no increased risk was incurred with the proposed guide curve versus the current guide curve. To produce the alternatives necessary to perform this analysis, a single PMF inflow hydrograph to Allatoona was provided.

A. Development of Inflows

To analyze the potential impacts of the PMF inflow on the operations of Allatoona, it was decided that Allatoona should be modeled in-situ, i.e., not independently but as part of the upper ACT basin. This meant that inflows were needed for all locations throughout the upper basin to represent an extreme event in the basin that could be expected with a PMF inflow into Allatoona. The synthetic dataset representing the 0.2% chance exceedance inflow volume for the 1979 event year shape was selected for use as the inflows throughout the basin. For the Allatoona inflow, however, a set of hydrographs using the PMF inflow was developed using all three event year shapes . The hydrographs were grouped into a DSS "collection" in order to minimize the number of alternatives needed while still making it relatively easy to review and compare results.

In this context, a "collection" refers to a special grouping of DSS time-series records. The records in a DSS collection apply to a given location, have the same parameter and timestep, and span a common time window; thus, the members of a collection share the same A-E parts of the DSS pathname. Collection member are uniquely identified by an F-part naming convention consisting of a collection ID string prepended to a common version label.

For simplicity and ease of comparison, the computed Allatoona inflow hydrographs for the three event year shapes were normalized to the same time window: 21Apr1979 00:00 – 18Jun1979 24:00. This time window coincides with the June placement of the synthetic 0.2% chance exceedance inflow volume for the 1979 event year shape which is the dataset used as inflows throughout the rest of the basin. The May/June time period was selected as the most challenged period for Allatoona's flood operations since the Allatoona guide curve reaches full summer level on 01June and that the high summer guide curve elevation results in the smallest overall flood pool for the year.

Next, the PMF hydrograph was "placed" into each of the Allatoona 0.2% inflow hydrographs. For each event year shape, three different placements of the PMF hydrograph were made:

1. the first placement centers the peak of the PMF over the peak of the original synthetic event for the given year
2. the second placement also puts the PMF centered over the original event but includes a preceding event of 50% of the PMF that peaks 5 days prior to the start of the larger PMF event, and
3. the third placement overwrites the original tail (recession) of the synthetic event with the PMF nflow.

Some of the PMF events would have peaked too near to the end of the selected simulation window. To accomodate those instances, the recession period of the assembled Allatoona PMF inflow hydrographs was extended. In other words, one or more of the event shapes did not have a long enough recesssion period to accommodate one or more of the 3 PMF placements. Rather than "making up" data to extend the time window, data from the recesssion period of the 0.2% 1961 event shape was used since the recession limb of the PMF event merged smoothly into the longest and most realistic base flow provided in the three event year shapes.

The collection IDs for each member of the Allatoona inflow collection were assembled in the following pattern: "0", followed by the event year, followed by 1, 2, or 3 to indicate the PMF placement described above. Table 12 lists the nine member IDs, identifies the event year shape, and idicates the placement of the PMF in each member.

Table 12. Allatoona PMF Inflow Collection Member IDs

Allatoona Probable Maximum Flood Ensemble		PMF Placement		
		(1) Replace 0.2% event with PMF	(2) Replace 0.2% peak with PMF and precede with 50% PMF	(3) Follow 0.2% peak with PMF
Ensemble Member ID	019611	✓		
	019612		✓	
	019613			✓
	019791	✓		
	019792		✓	
	019793			✓
	019901	✓		
	019902		✓	
	019903			✓

The collection holding the Allatoona inflow hydrographs along with the inflow hydrographs for all other inflow locations throughout the basin used in the PMF alternatives are stored in the *PMF_Ensemble.dss* file in the shared folder of the watershed.

B. Creating and Reviewing the Alternatives

Two PMF alternatives were created: *PMF_Base* and *PMF_RG*. Each alternative uses the 1979 0.2% inflow data described in the previous section for the inflows throughout the basin and the collection (ensemble) of PMF event hydrographs created for the inflow to Allatoona. The hydrographs were grouped into a DSS "collection" in order to minimize the number of alternatives needed while still making it relatively easy to review and compare results.

Since the PMF inflow hydrographs to Allatoona were assembled using the process described above, all of the local inflow hydrographs expected *upstream* of Allatoona were assigned a zero flow time-series to prevent alternation of the inflow hydrographs during the compute of the alternatives.

The *PMF_Base* alternative used the *2018 Operations* operation set (with the current guide curve) and the *PMF_RG* alternative used the *2018 Operations (Revised GC)* operation set with the proposed guide curve. While there were noticable elevation differences in the results at lower flows, the magnitude of the PMF event unsurprisingly resulted in either minor or nonexistant differences in maximum pool elevations between the two guide curves. Table 13 lists the peak pool elevation reached for each inflow for each alternative. Figure 24 shows the ensemble results for the Allatoona PMF using the base guide curve, and Figures 25 - 33 show the individual alternative results independently.

Table 13. Comparison of maximum pool elevations using base and revised guide curves

Collection Member	Maximum Elevation with Base GC (ft.)	Maximum Elevation with Revised GC (ft.)	Maximum Elevation Change with Revised GC (ft. (*inches*))
019611	868.010	868.095	+0.085 (*1.02*)
019612	869.572	869.571	-0.001 (*-0.012*)
019613	868.945	869.022	+0.077 (*0.93*)
019791	868.860	868.945	+0.085 (*1.02*)
019792	869.510	869.512	+0.002 (*0.02*)
019793	***869.583**	***869.583**	**No Change**
019901	868.270	868.367	+0.097 (*1.16*)
019902	869.581	869.581	No Change
019903	869.417	869.475	+0.058 (*0.70*)

*Maximum pool elevation

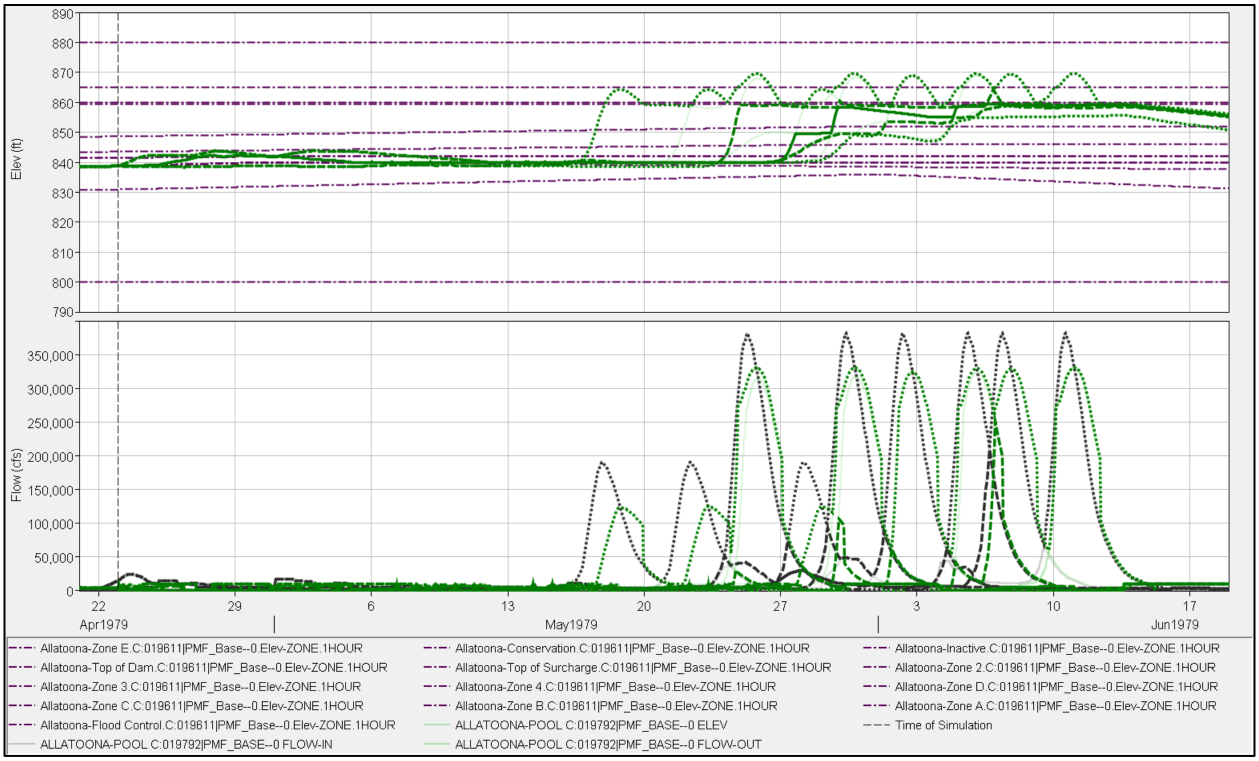

Figure 24. Allatoona PMF ensemble

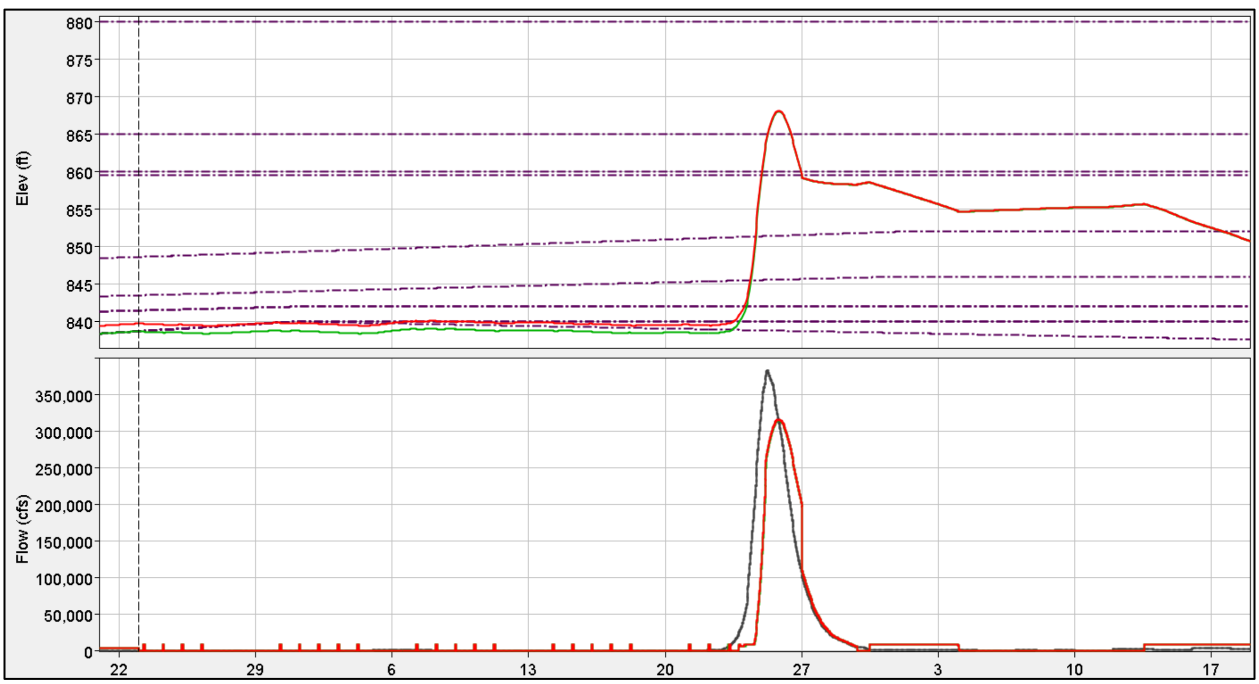

Figure 25. Collection member 019611 using current GC (green) and revised GC (red)

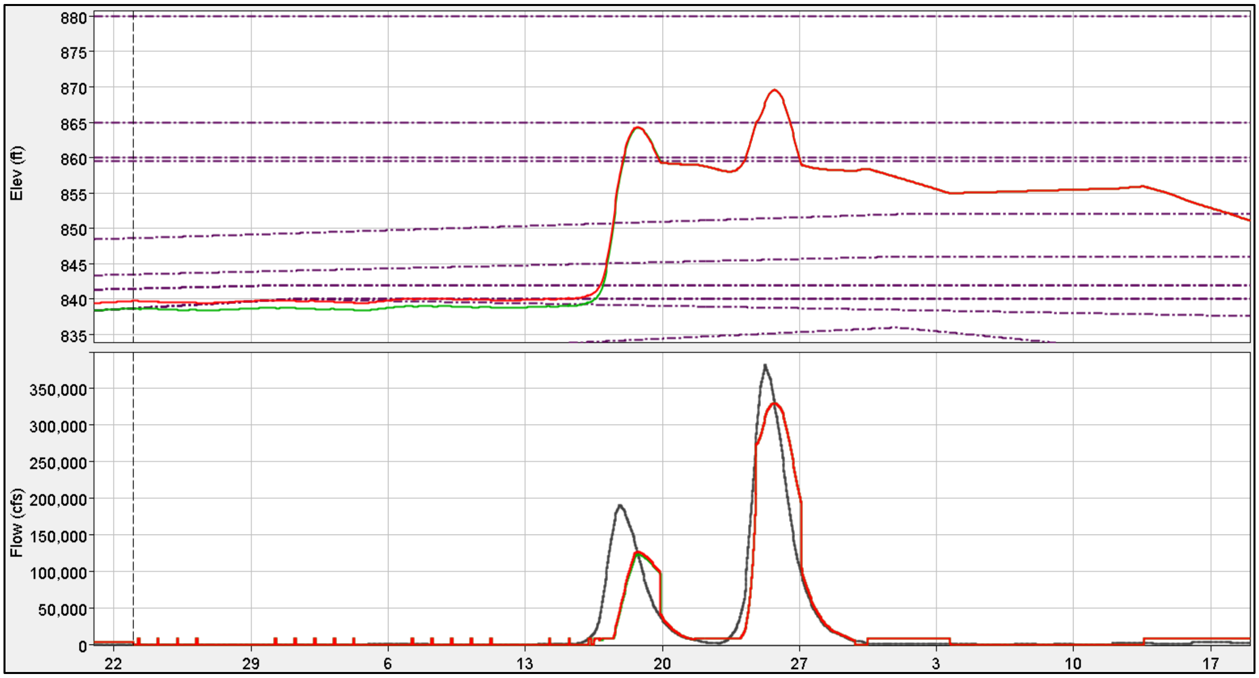

Figure 26. Collection member 019612 using current GC (green) and revised GC (red)

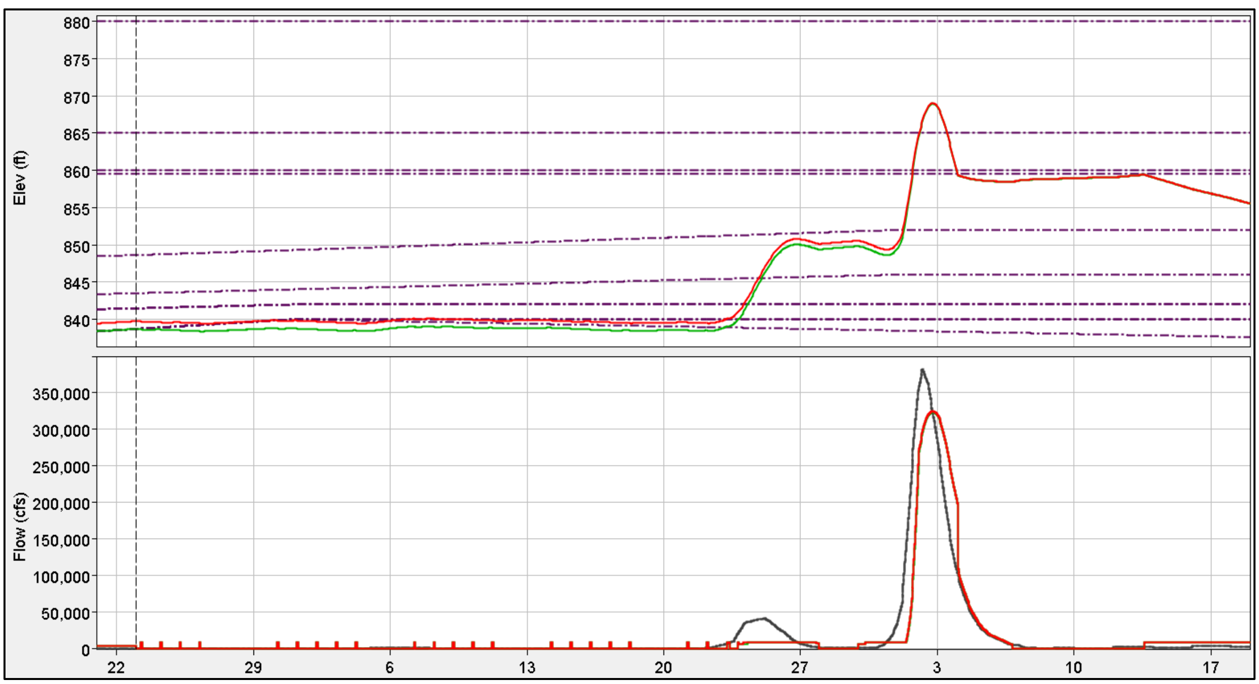

Figure 27. Collection member 019613 using current GC (green) and revised GC (red)

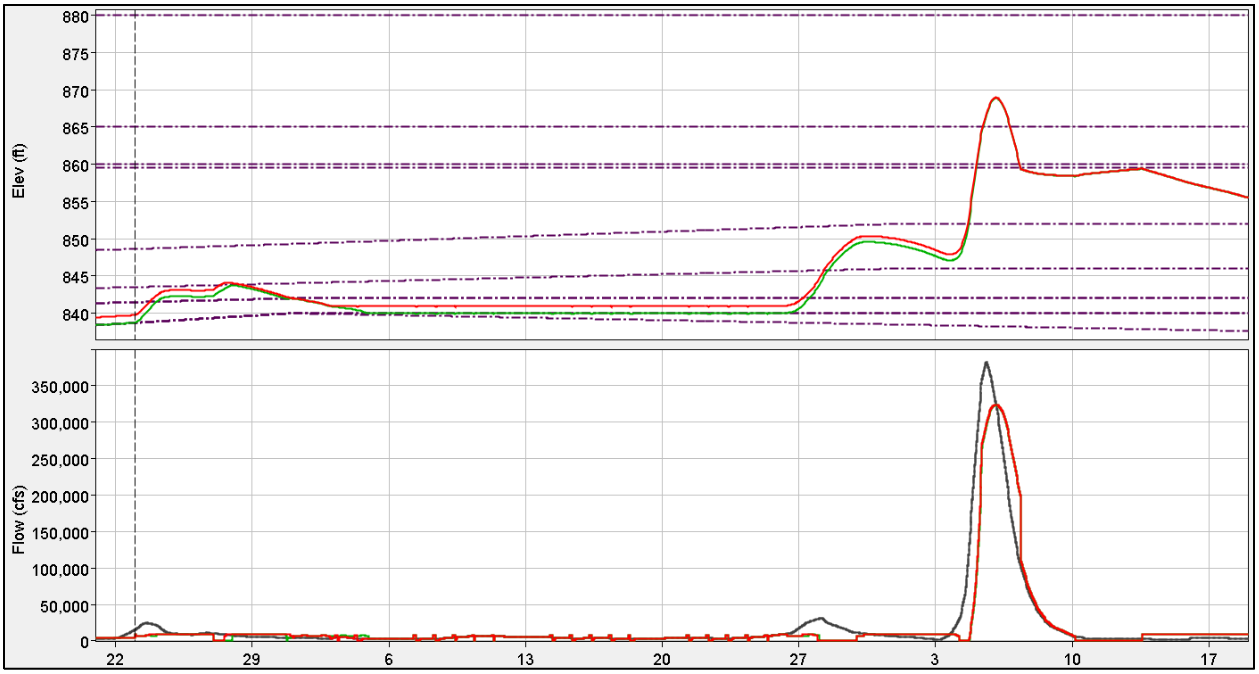

Figure 28. Collection member 019791 using current GC (green) and revised GC (red)

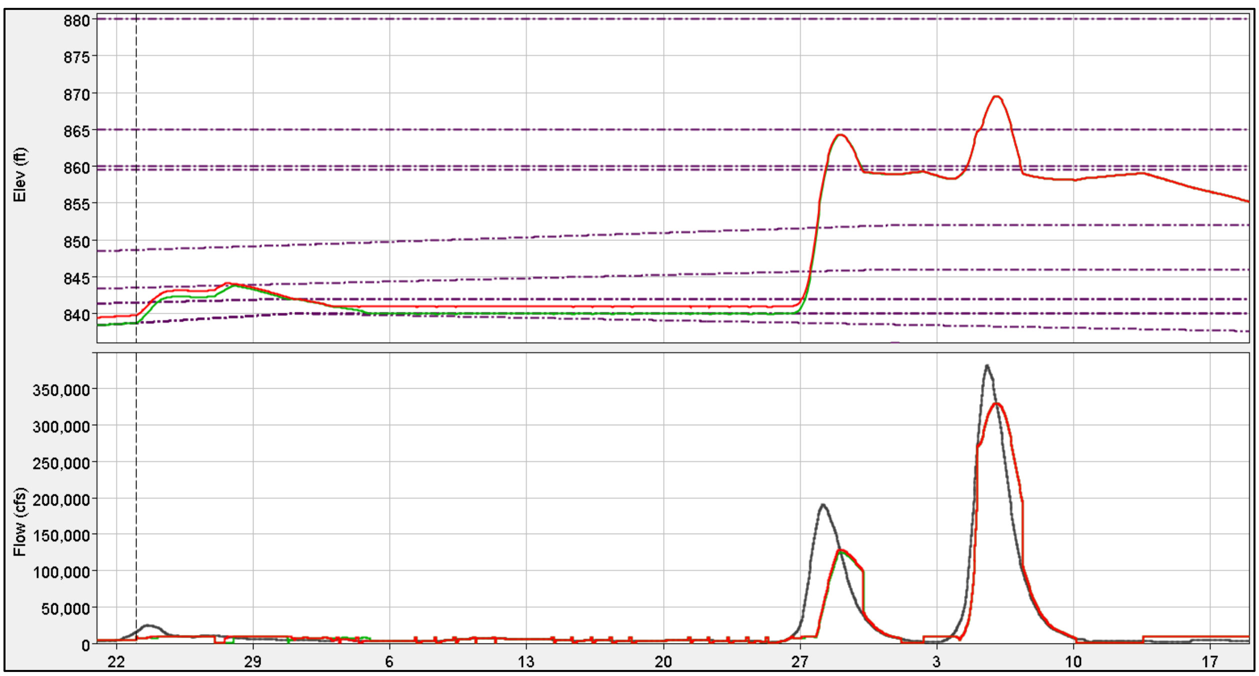

Figure 29. Collection member 019792 using current GC (green) and revised GC (red)

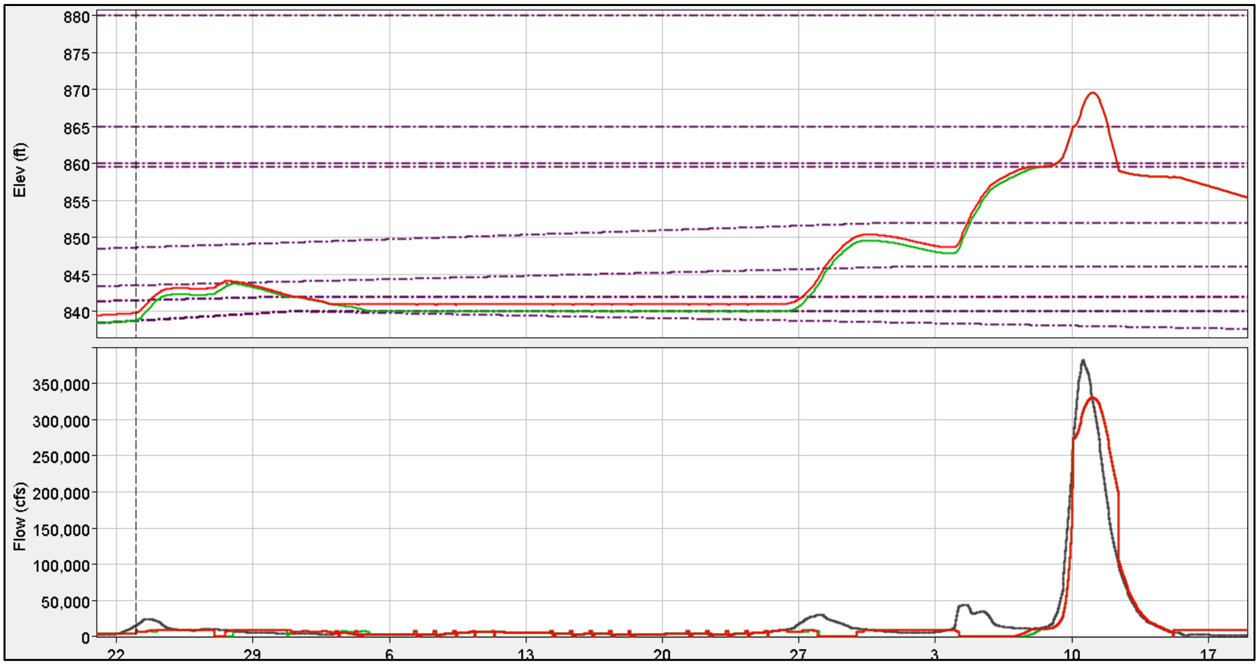

Figure 30. Collection member 019793 using current GC (green) and revised GC (red)

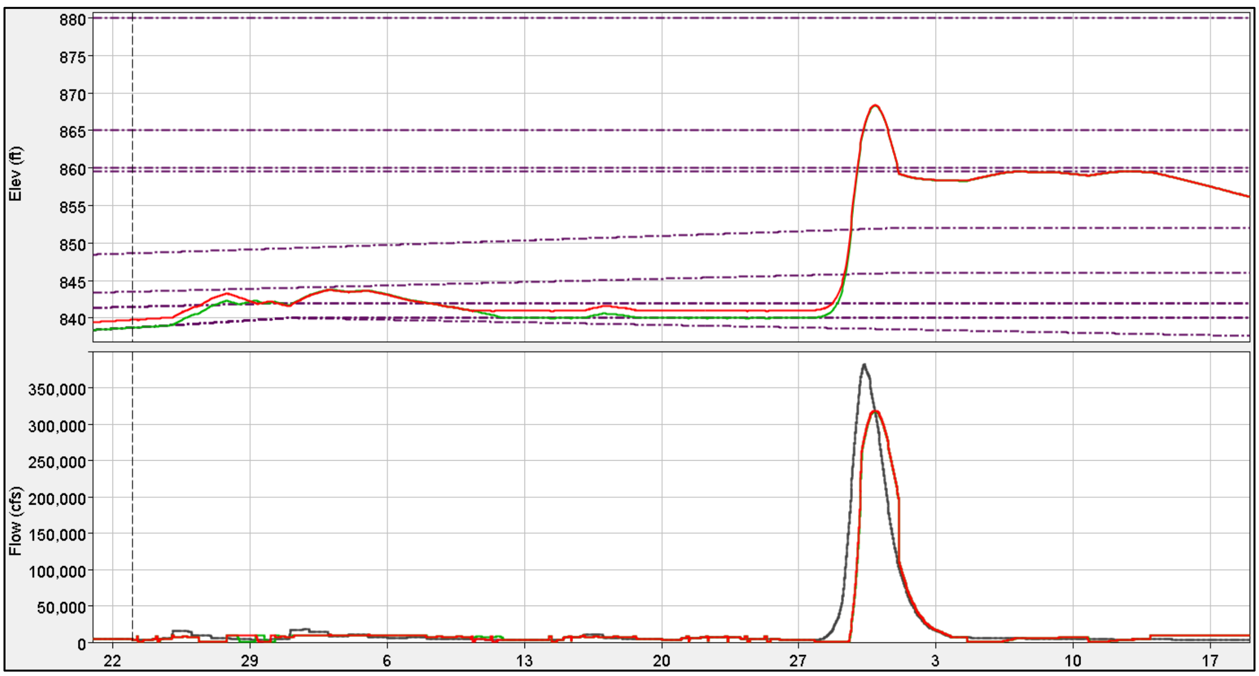

Figure 31. Collection member 019901 using current GC (green) and revised GC (red)

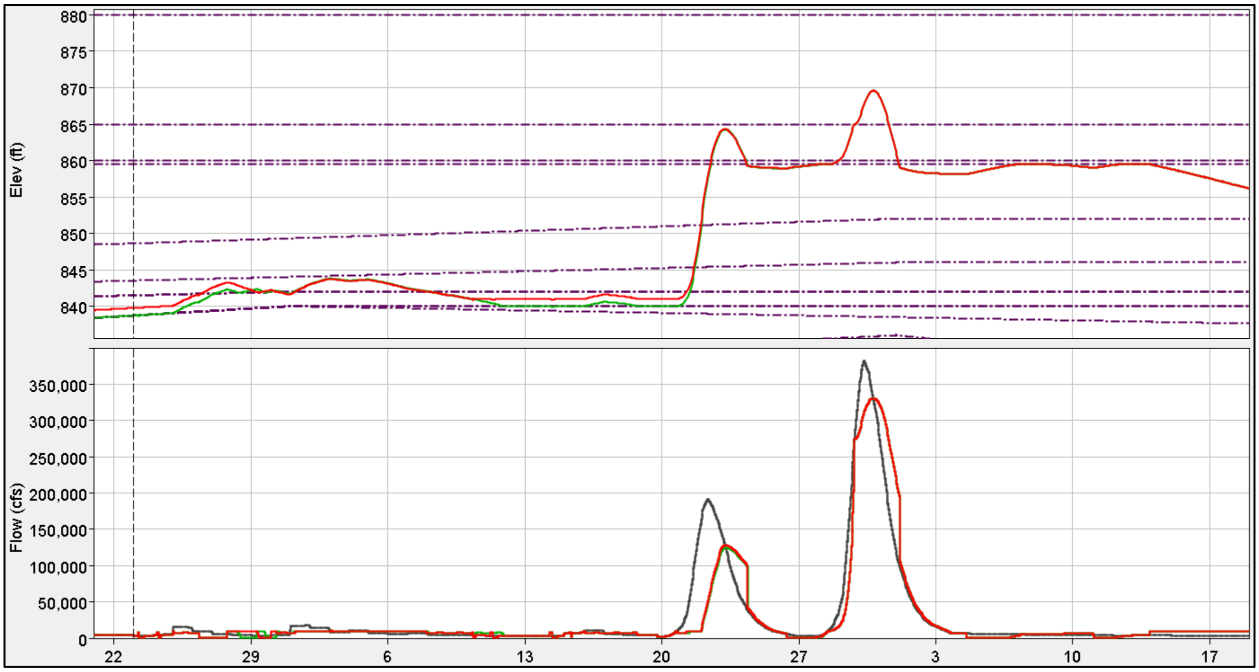

Figure 32. Collection member 019902 using current GC (green) and revised GC (red)

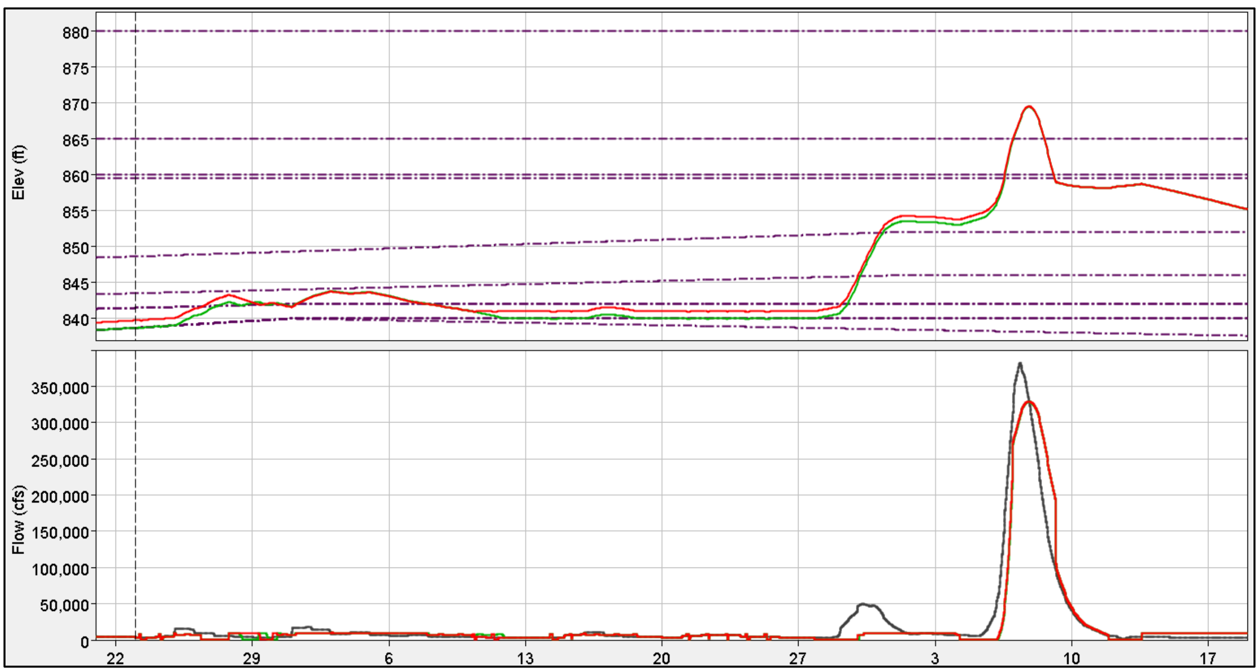

Figure 33. Collection member 019903 using current GC (green) and revised GC (red)

Figure 34 is an image of the Allatoona pool elevation plot from HEC-DSSVue (//ALLATOONA-POOL/ELEV/01Apr1979/1HOUR/C:019611|PMF_BASE—0) showing the pool elevations across all nine variations of events using the base guide curve.

Interestingly, the highest peak elevation—by ~ 0.001 ft—occurred during the 1979 event with the PMF placed after the 0.2-percent event (Figure 35). This was surprising since the 0.2-percent event was substantially smaller than the 50% PMF, so it was unexpected that the peak elevation for this event was higher than the peak produce by those events that used the 50% PMF in advance of the PMF. We believe this is the result of the downstream operation for the rest of the system extending downstream to Rome, GA, but have not had the opportunity to investigate further.

One minor concern in the greater context of the watershed is that the rating curves within the model are unable to fully represent flows at the magnitude of the PMF. While the rating at Rome-Ooostanaula could accomodate all but the largest of the flows (Figure 36), the rating at Rome-Coosa fared much worse, being overwhelmed during the entire simulation (Figure 37).

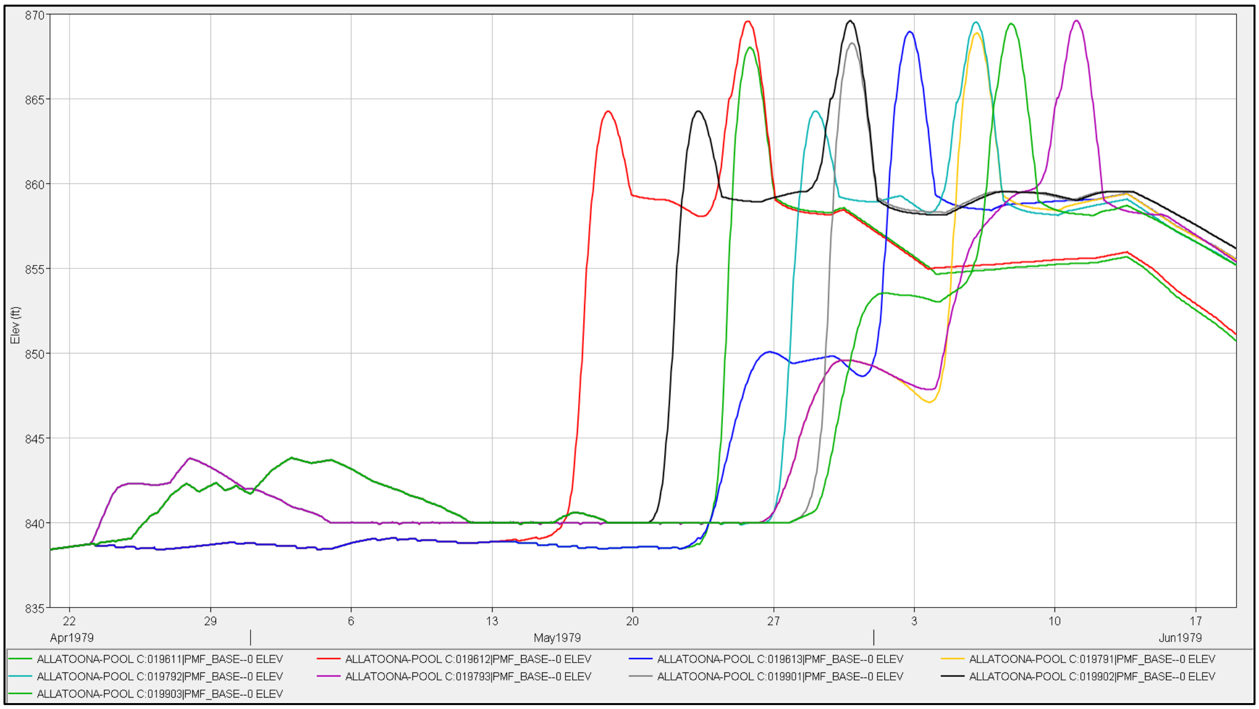

Figure 34. Allatoona elevation plot for all PMF iterations using base guide curve

Figure 35. Allatoona PMF maximum elevation peaks

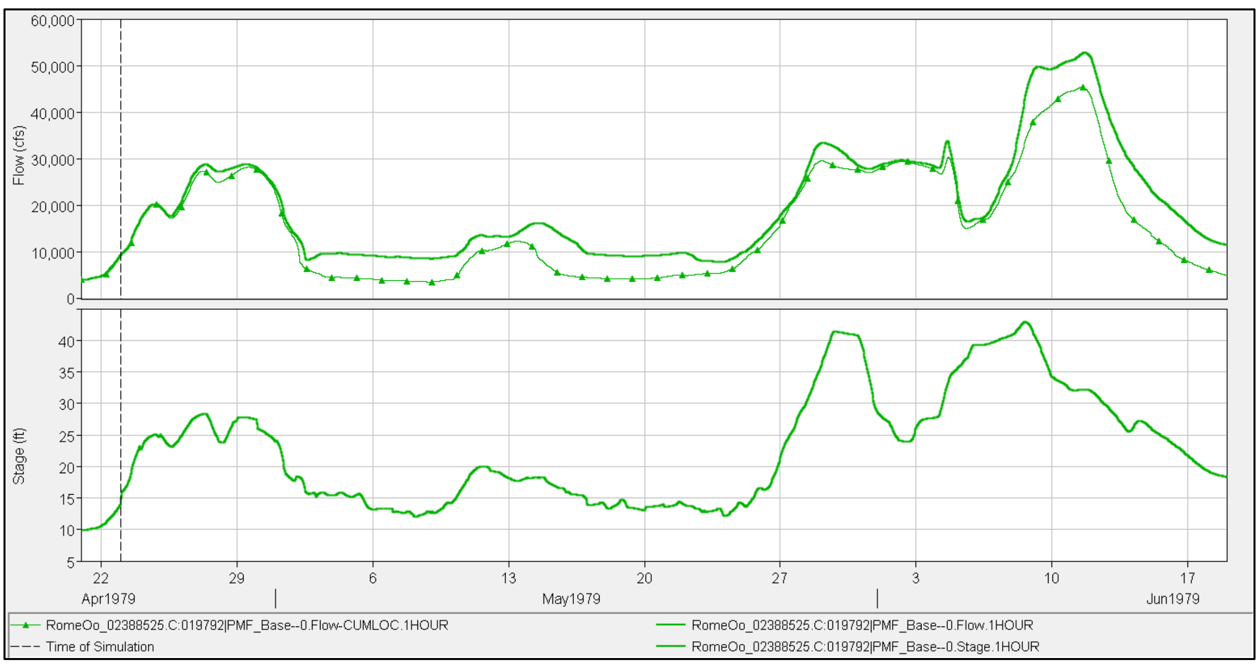

Figure 36. Rome-Oostanaula 019792 event

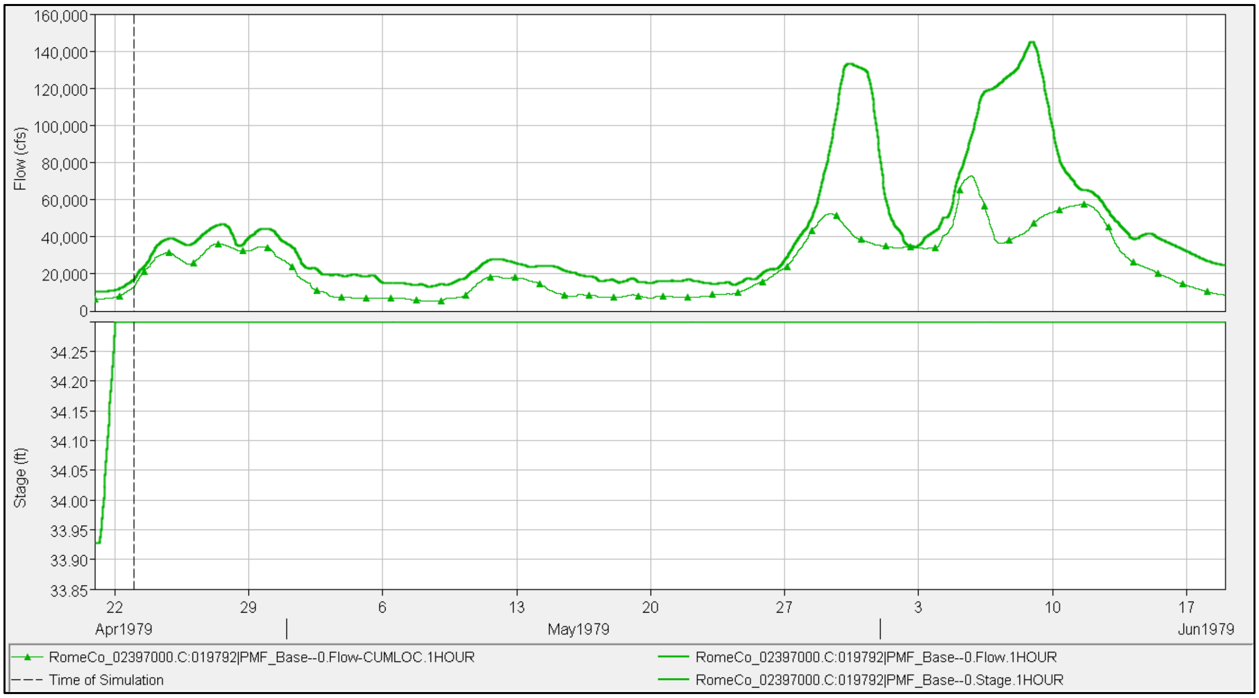

Figure 37. Rome-Coosa 019792 event

VI. Analysis of Results

Two guide curve alternatives for Allatoona were evaluated (Figure 38). The original guide curve begins at 823.0’ on January 1st and remains there until January 15th, when it begins to rise. On May 1st, it reaches its summer elevation of 840.0’, where it remains until the beginning of the phased drawdown period on September 5th. It then drops to 835.0’ from October 1st and remains there until November 15th when it begins dropping to 823.0’.

The revised guide curve begins at 824.5’ on January 1st and remains there until January 15th, when it begins to rise. On May 1st, it reaches its summer elevation of 841.0’, where it remains until the beginning of the phased drawdown period on September 5th. It then drops to 835.0’ from October 1st and remains there until November 15th when it begins dropping to 824.5’ by January 1st.

One of the goals of the hourly flood model was to determine the effects, if any, of the raised guide curve on flood operations at both Allatoona Dam and its downstream locations. Three locations were control points for Allatoona: Cartersville and Kingston on the Etowah River, and Rome, located at the confluence of the Etowah and Oostanaula Rivers. Of these locations, Rome was the more complicated location to evaluate due to upstream releases from Carters Dam on the Oostanaula and a backwater effect on the Oostanaula just upstream of its confluence with the Etowah.

Three event years were evaluated: 1961, 1979, and 1990. Four simulation time windows were chosen for each year, corresponding to January, April, June, and October. Synthetic event frequencies of 5.0-, 2.0-, 1.0-, 0.5-, and 0.2-percent were then placed in each simulation using each guide curve as a starting elevation. Due to the seasonal guide curve variation, the summer pool provides a smaller flood pool than winter months, so the summer placement of the synthetic events were of particular interest.

Table 14. 1961 Event Simulations

Simulation	1961 January	1961 April	1961 June	1961 October
Start	11 Dec 1960, 0000	15 Mar 1961, 0000	15 May 1961, 0000	10 Sep 1961, 0000
Lookback	6 Dec 1960, 0000	10 Mar 1961, 0000	10 May 1961, 0000	05 Sep 1961, 0000
End	31 Jan 1961, 0000	28 Apr 1961, 0000	01 Jul 1961, 0000	31 Oct 1961, 0000
Alternatives	0.2_JAN	0.2_APR	0.2_JUN	0.2_OCT
	0.5_JAN	0.5_APR	0.5_JUN	0.5_OCT
	1.0_JAN	1.0_APR	1.0_JUN	1.0_OCT
	2.0_JAN	2.0_APR	2.0_JUN	2.0_OCT
	5.0_JAN	5.0_APR	5.0_JUN	5.0_OCT
	0.2_JAN_RG	0.2_APR_RG	0.2_JUN_RG	0.2_OCT_RG
	0.5_JAN_RG	0.5_APR_RG	0.5_JUN_RG	0.5_OCT_RG
	1.0_JAN_RG	1.0_APR_RG	1.0_JUN_RG	1.0_OCT_RG
	2.0_JAN_RG	2.0_APR_RG	2.0_JUN_RG	2.0_OCT_RG
	5.0_JAN_RG	5.0_APR_RG	5.0_JUN_RG	5.0_OCT_RG

Table 15. 1979 Event Simulations

Simulation	1979 January	1979 April	1979 June	1979 October
Start	22 Nov 1979, 0000	26 Feb 1979, 0000	26 Apr 1979, 0000	22 Aug 1979, 0000
Lookback	17 Nov 1979, 0000	21 Feb 1979, 0000	21 Apr 1979, 0000	17 Aug 1979, 0000
End	18 Jan 1979, 0000	18 Apr 1979, 0000	17 Jun 1979, 0000	17 Oct 1979, 0000
Alternatives	0.2_JAN	0.2_APR	0.2_JUN	0.2_OCT
	0.5_JAN	0.5_APR	0.5_JUN	0.5_OCT
	1.0_JAN	1.0_APR	1.0_JUN	1.0_OCT
	2.0_JAN	2.0_APR	2.0_JUN	2.0_OCT
	5.0_JAN	5.0_APR	5.0_JUN	5.0_OCT
	0.2_JAN_RG	0.2_APR_RG	0.2_JUN_RG	0.2_OCT_RG
	0.5_JAN_RG	0.5_APR_RG	0.5_JUN_RG	0.5_OCT_RG
	1.0_JAN_RG	1.0_APR_RG	1.0_JUN_RG	1.0_OCT_RG
	2.0_JAN_RG	2.0_APR_RG	2.0_JUN_RG	2.0_OCT_RG
	5.0_JAN_RG	5.0_APR_RG	5.0_JUN_RG	5.0_OCT_RG

Table 16. 1990 Event Simulations

Simulation	1990 January	1990 April	1990 June	1990 October
Start	10 Dec 1989, 0000	14 Mar 1990, 0000	14 May 1990, 0000	09 Sep 1990, 0000
Lookback	05 Dec 1989, 0000	09 Mar 1990, 0000	09 May 1990, 0000	04 Sep 1990, 0000
End	03 Mar 1990, 0000	01 Jun 1990, 0000	01 Aug 1990, 0000	01 Dec 1990, 0000
Alternatives	0.2_JAN	0.2_APR	0.2_JUN	0.2_OCT
	0.5_JAN	0.5_APR	0.5_JUN	0.5_OCT
	1.0_JAN	1.0_APR	1.0_JUN	1.0_OCT
	2.0_JAN	2.0_APR	2.0_JUN	2.0_OCT
	5.0_JAN	5.0_APR	5.0_JUN	5.0_OCT
	0.2_JAN_RG	0.2_APR_RG	0.2_JUN_RG	0.2_OCT_RG
	0.5_JAN_RG	0.5_APR_RG	0.5_JUN_RG	0.5_OCT_RG
	1.0_JAN_RG	1.0_APR_RG	1.0_JUN_RG	1.0_OCT_RG
	2.0_JAN_RG	2.0_APR_RG	2.0_JUN_RG	2.0_OCT_RG
	5.0_JAN_RG	5.0_APR_RG	5.0_JUN_RG	5.0_OCT_RG

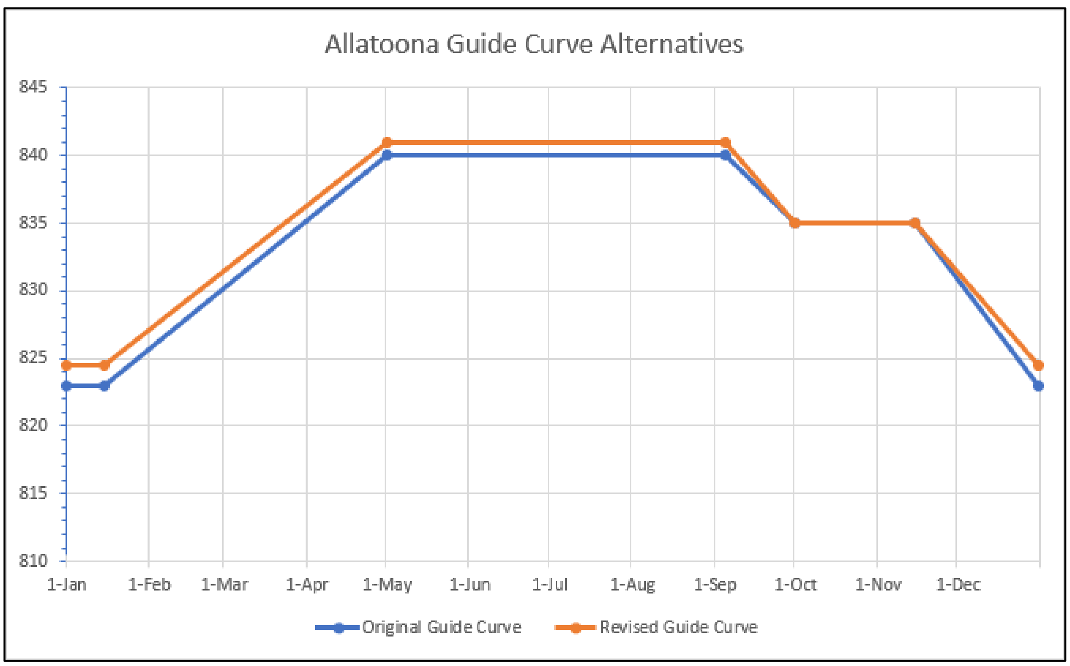

Figure 38. Allatoona guide curve alternatives

A. Allatoona Downstream Control Operation: Kingston & Cartersville

The analysis of results was focused on the operations at Allatoona Dam and the two downstream control points of Rome-Oostanaula and Kingston as stages at those locations were the primary constraining factors for Allatoona releases. It was determined that the Cartersville control point had little to no impact on operations at Allatoona.

At the lower flows of the smaller synthetic events (5.0-, 2.0-, and 1.0-percent), operational differences for the two guide curves was more noticeable (Figure 39). During the larger events, the downstream system tended to become overwhelmed before the peak of the event. The state of the downstream system placed release constraints on Allatoona that lead to nearly identical releases and maximum pool elevations regardless of the guide curve elevation (Figure 40).

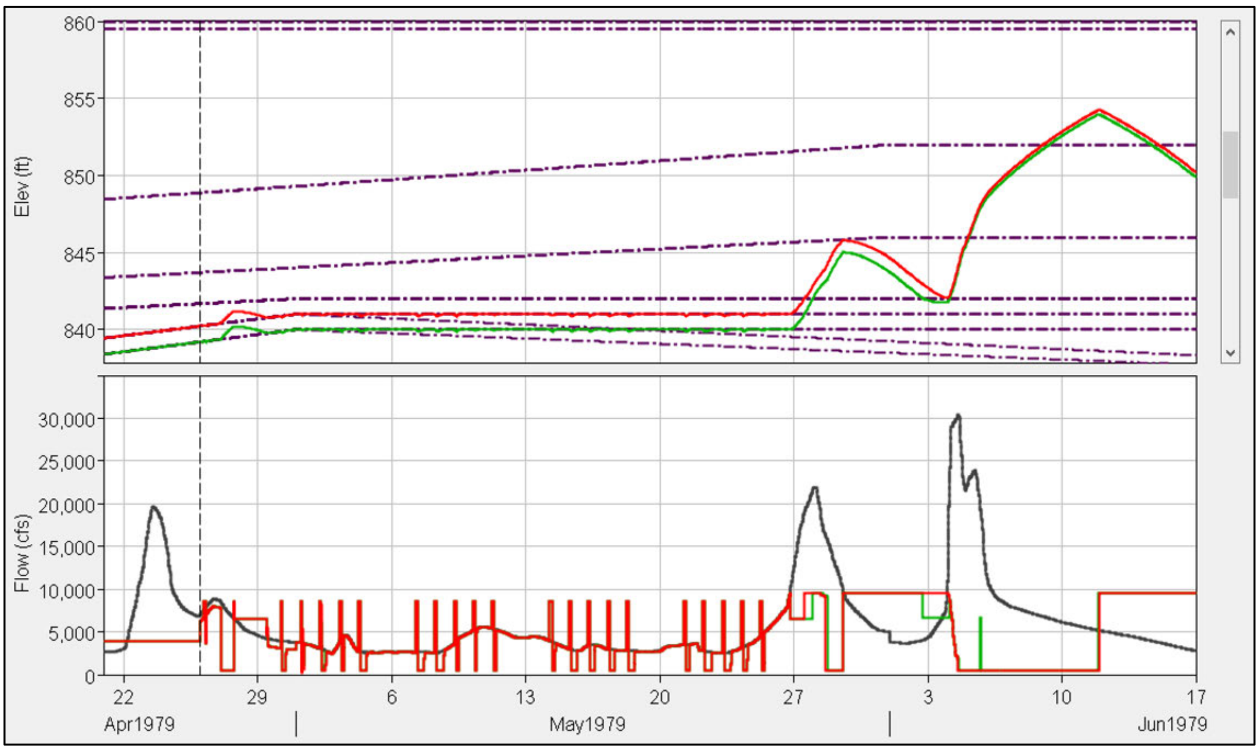

Figure 39. Allatoona June 1979 5.0 event original GC (green) and revised GC (red)

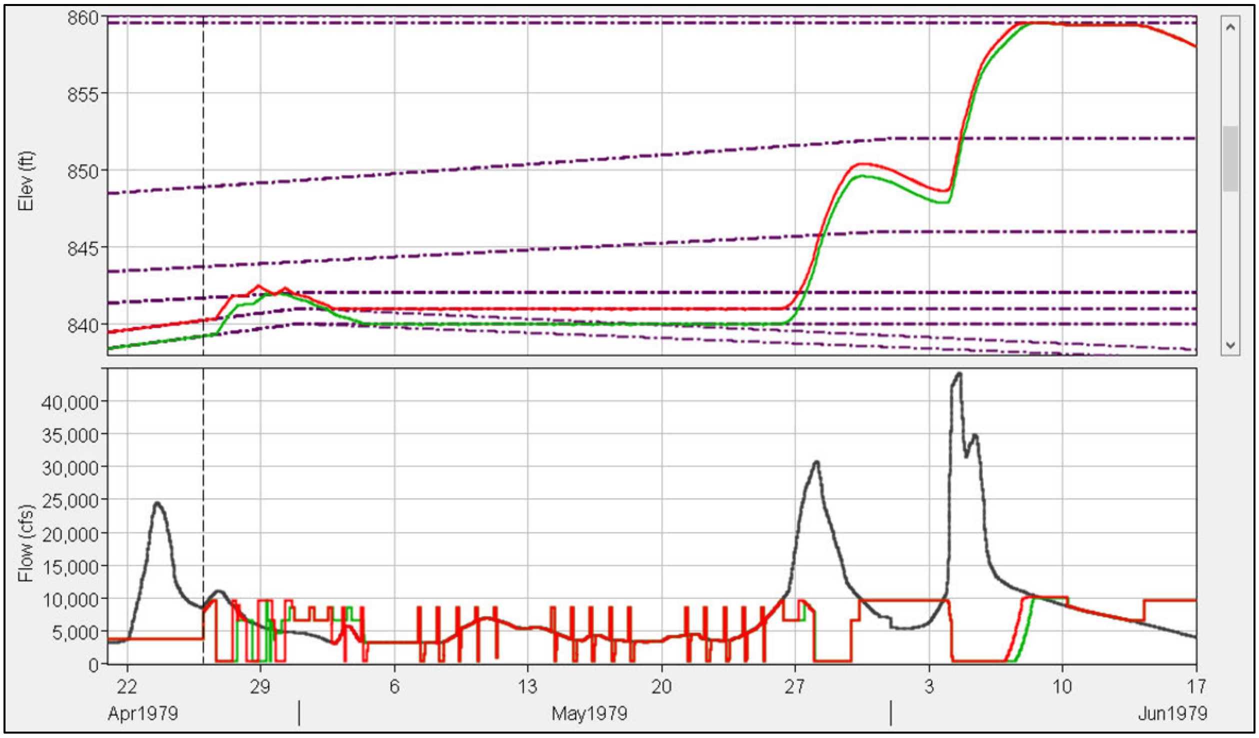

Figure 40. Allatoona 0.2 June 1979 event original GC (green) and revised GC (red)

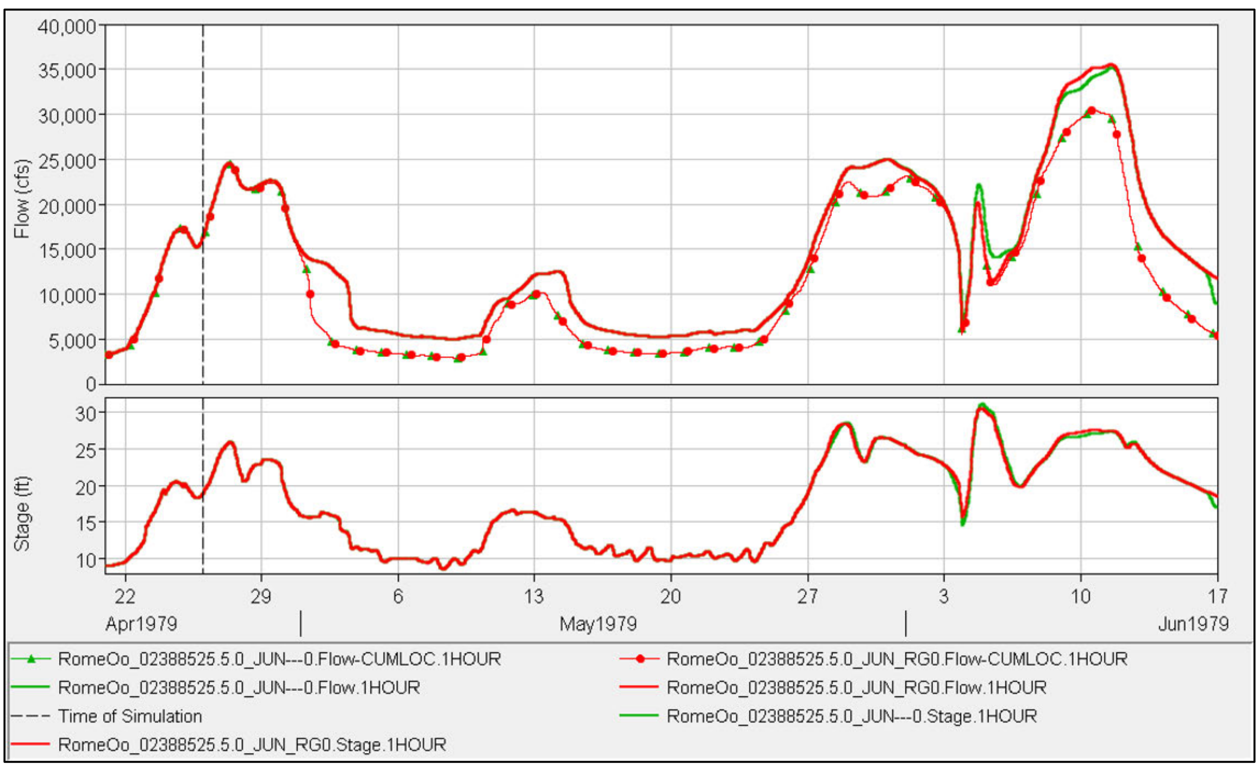

Figure 41. Rome Oostanaula 5.0 June 1979 event original GC (green) and revised GC (red)

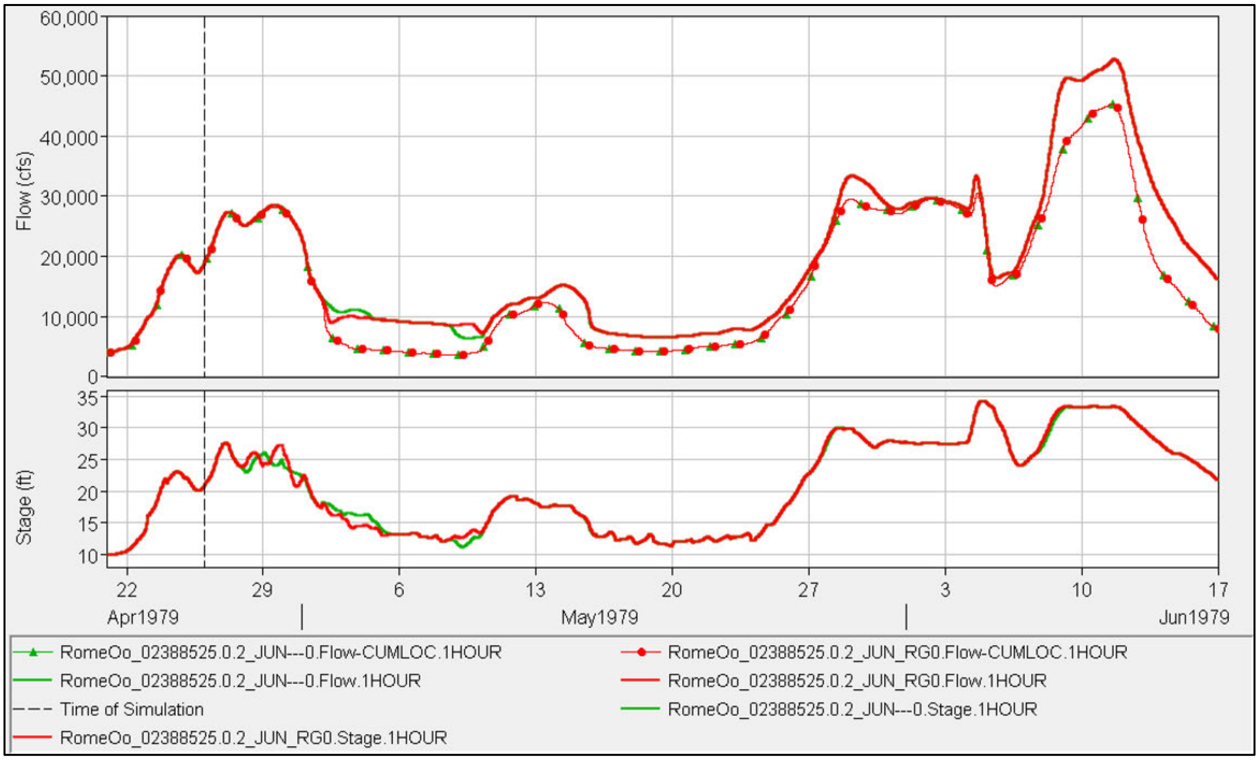

Figure 42. Rome Oostanaula 0.2 June 1979 event original GC (green) and revised GC (red)

During the initial analysis of results, it was determined that, while not the primary constraining factors on releases from Allatoona, the downstream control rule that operated for a maximum flow of 9,970 cfs at gage 02395000 near Kingston and, to a far lesser extent, the maximum channel capacity of 12,000 cfs at the 02394670 gage near Cartersville were causing additional delays in evacuation of the pool. This limitation seemed inaccurate due to the higher channel capacity of 12,000 cfs near Cartersville versus the lower channel capacity of 9,970 cfs at the more downstream gage near Kingston. Upon further investigation of USGS rating tables and NWS flood stage categories, it was determined that the channel capacity at the Kingston gage would be revised to 21,300 cfs, resulting in the downstream control rule at Kingston being unnecessary and subsequently removed, and the channel capacity at Cartersville would be revised to 13,000 cfs. The tighter channel capacity restriction at Kingston served as a proxy for the operations at Rome. Operation for Kingston is included only in the "Standing Instructions for the Damtender for Water Control" appendix of the water control manual. The operator will not likely have access to the same forecast tools as the basin manager.

During the June 1979 0.2-percent synthetic event, these operational rule changes resulted in a noticeable increase in flows at Kingston (Figure 43) and Cartersville (Figure 44) that remained within acceptable stage tolerances while lowering the peak stage and flow at each location. At Allatoona (Figure 45), the changes resulted in noticeably lower elevations before the peak of the event, a slightly lower maximum elevation (~0.5'), and a faster elevation drawdown. At Rome Oostanaula (Figure 46), these changes did not have an effect on stage that significantly impacted the reservoir operations for that location, and for one period the stage was lowered enough to allow for greater releases than would have previously been possible.

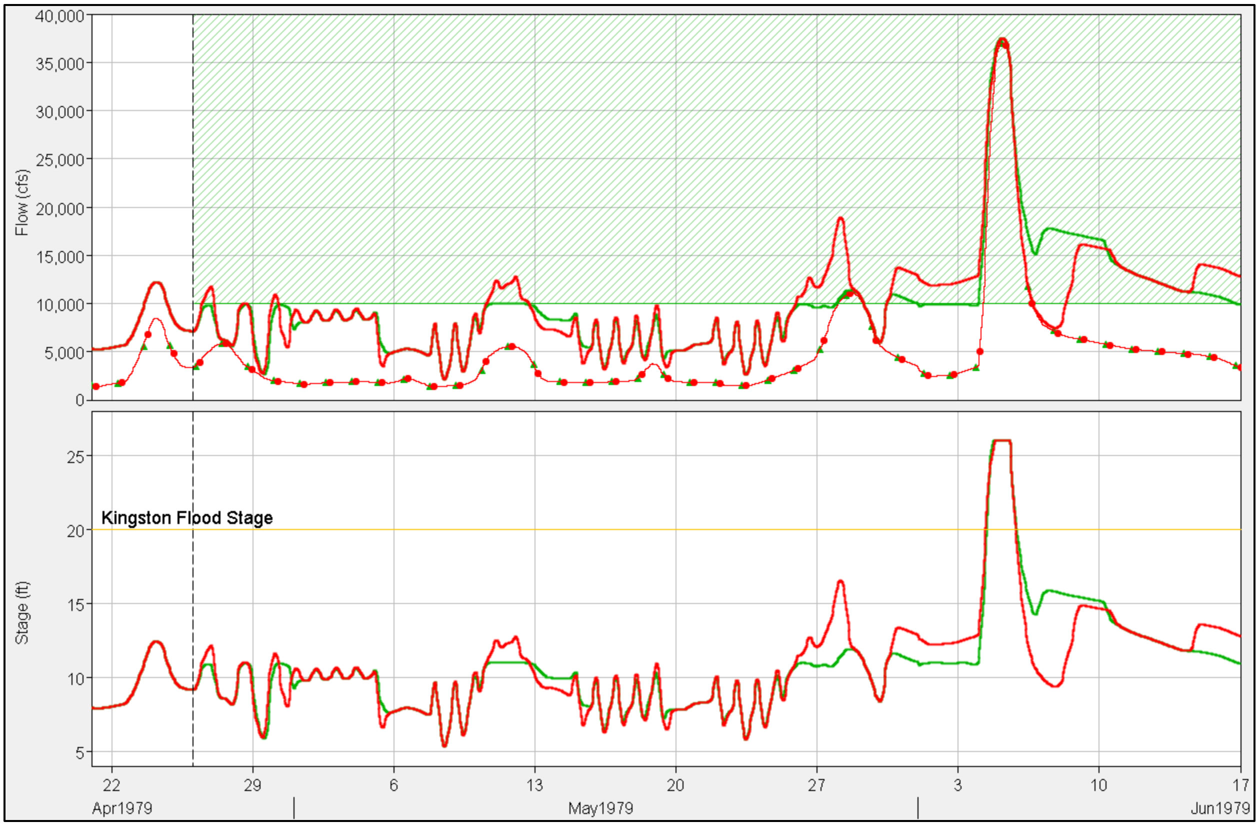

Figure 43. Kingston flow and stage before (green) and after (red) channel capacity changes

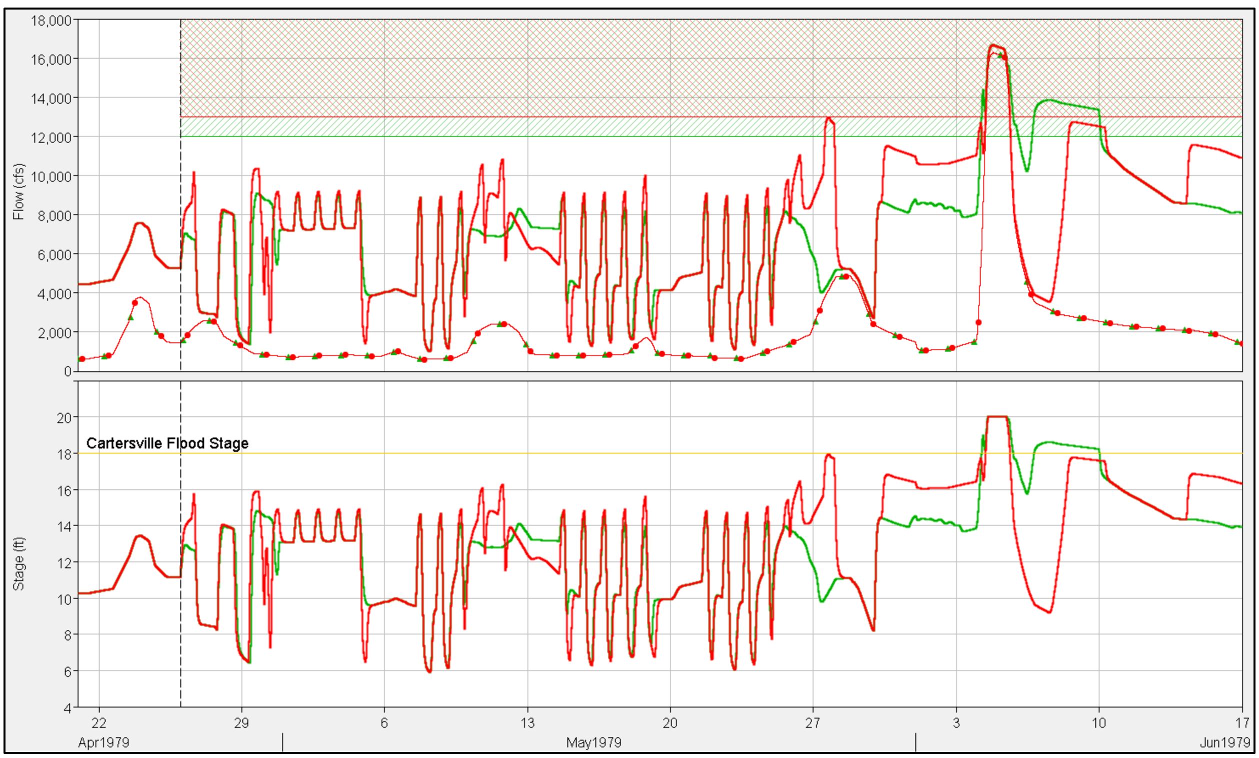

Figure 44. Cartersville flow and stage before (green) and after (red) channel capacity changes

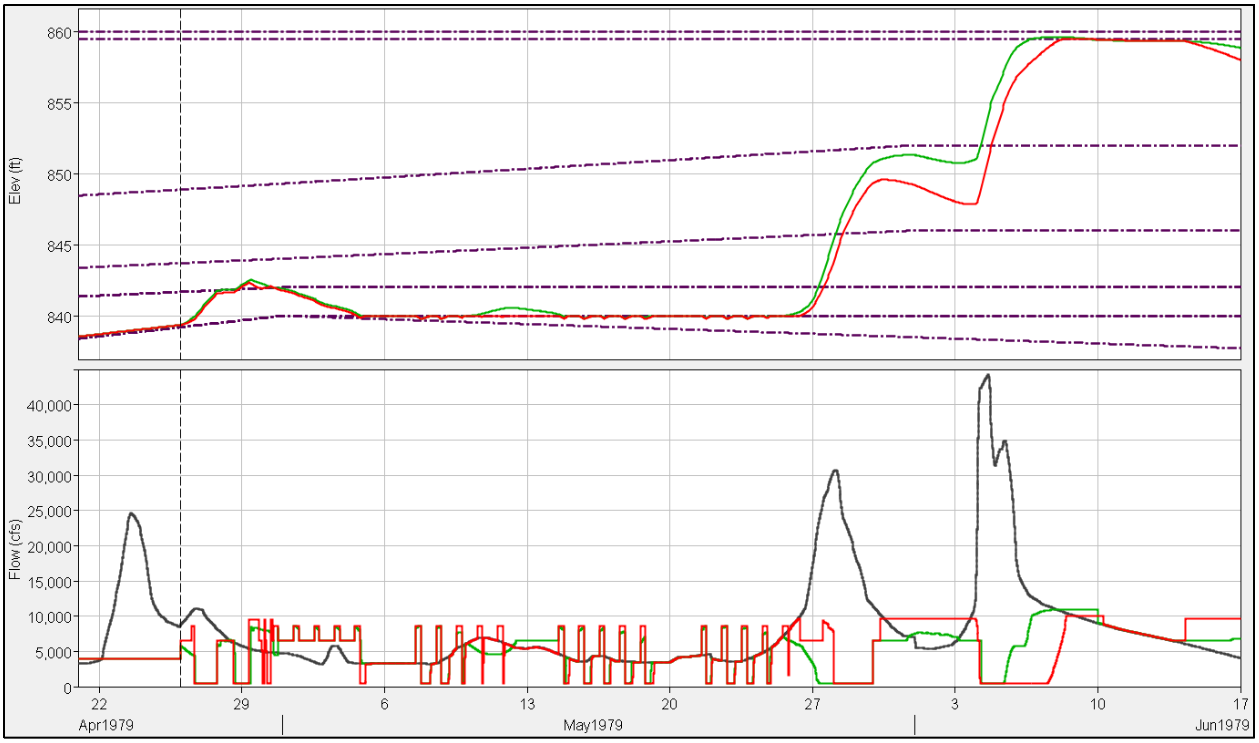

Figure 45. Allatoona releases before (green) and after (red) channel capacity changes

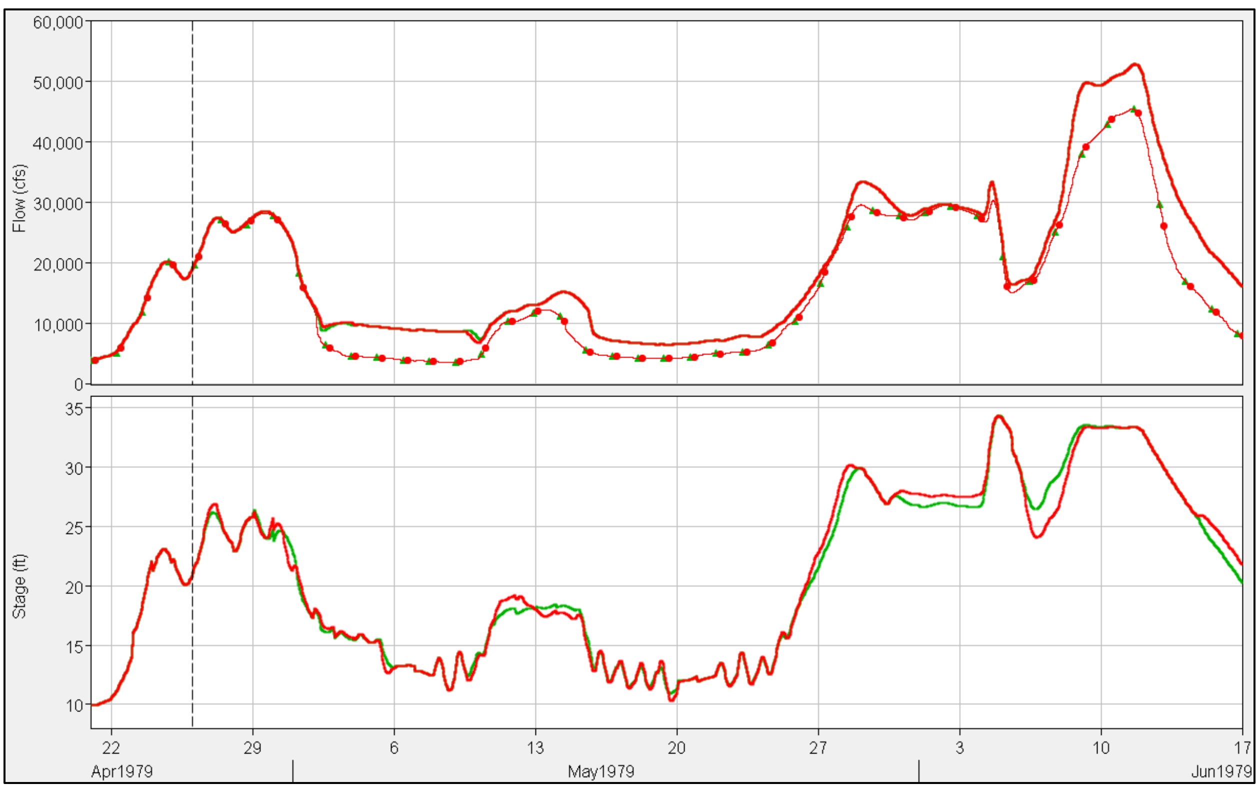

Figure 46. Rome Oostanaula before (green) and after (red) channel capacity changes

B. Allatoona Downstream Control Operation: Rome Oostanaula

The primary release constraint during the larger events is the stage at the Rome Oostanaula 02388500 gage. A state variable is used to trigger closing of the Allatoona gates when Rome Oostanaula experiences stages of 25' and 28', with the lower trigger stage being used when the Allatoona pool is below the top of flood pool Zone C and the higher stage being used when the pool is in Zone D or higher. As illustrated in Figure 47, during the larger synthetic events caused the stage at Rome Oostanaula to exceed both of its trigger elevations at the beginning of the simulation, while greatly exceeding those trigger stages during the peak of the event, while remaining above the trigger level for more than a week.

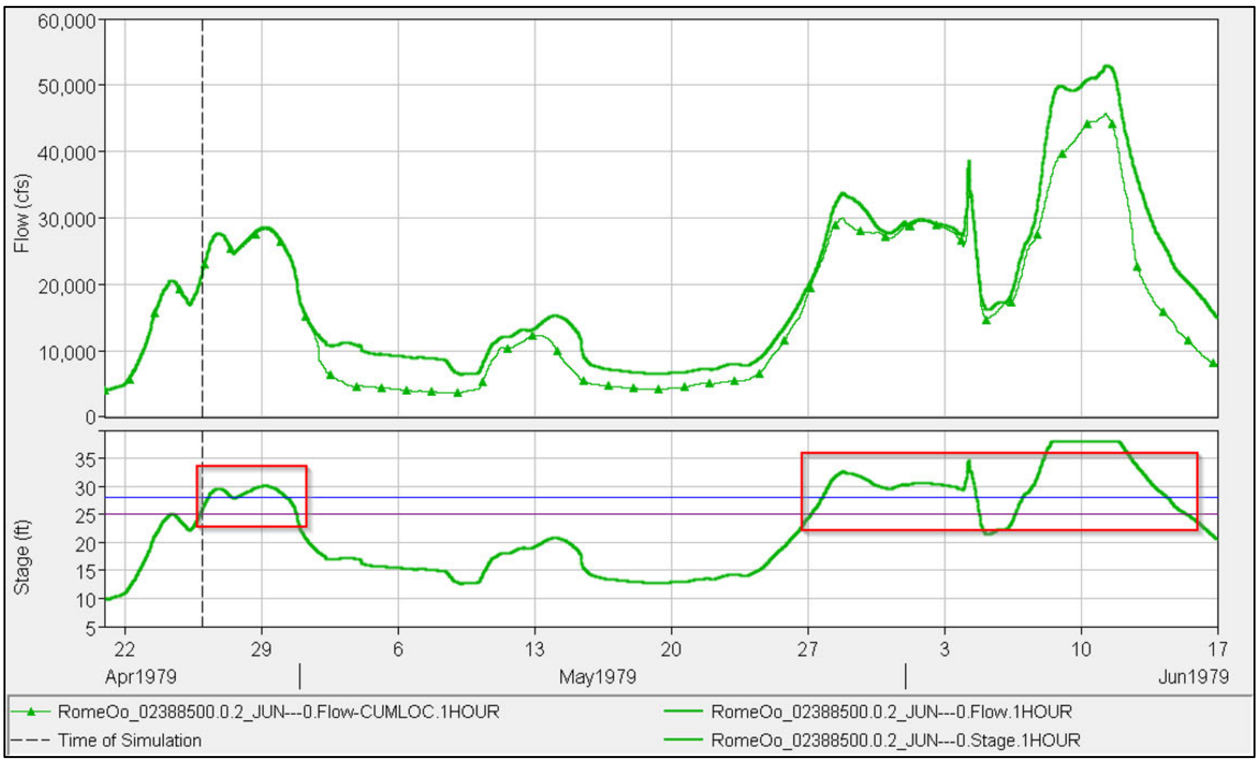

Figure 47. Rome Oostanaula plot of June 1979 0.2 event (blue line = 28', purple line = 25')

As illustrated in Figure 48, operating for the stage at Rome Oostanaula is the single greatest factor in causing the flood pool to rise while also preventing the evacuation of the Allatoona flood pool until reaching an elevation great enough to trigger induced surcharge operations.

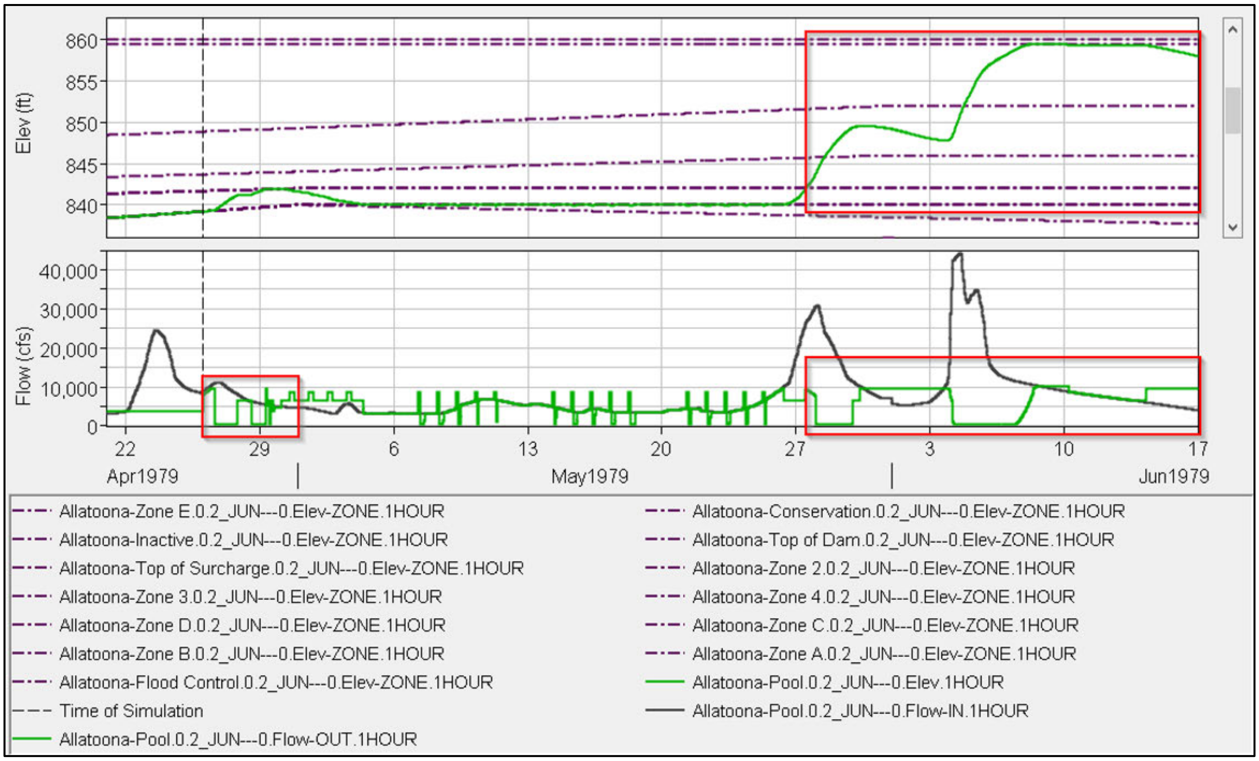

Figure 48. Allatoona reservoir reacting to trigger stages at Rome Oostanaula

Appendix A. State Variables

This appendix contains information about all the state variables in the model, listed in alphabetic order. For each state variable defined by a Jython script, the text of the three script sections is provided as well as a list of where the variable is used. If the state variable is a slave, then the master of the slave is identified in place of the script text.

A.1 Independent and Master State Variable Scripts

State Variable scripts have three parts, an initialization function, a main, and a cleanup function, so each part of each state variable is listed, even if it effectively empty.

1. Allatoona_BaseElev

This slave state variable holds a running value of the base elevation for which Allatoona must not drop by more than one half foot during spawning season. Once determined, this value should remain constant during the season unless conditions changes that might cause it to reset.
It is computed by: *Allatoona_ElevState* and is not used by an operational element in the model. It was stored to a state variable so that it would be written as model data and used during analysis of results.

2. Allatoona_ElevState

This state variable is used by the *Fish Spawning Season* If-Block in Allatoona's *2018 Operations* operation set to determine the drawdown rate, if any, that is allowed at Allatoona during the fish spawning season. The logic in this state variable determines how far from the base elevation Allatoona's pool has fallen and restricts releases so that the pool does not fall more than one half foot from the base elevation.

Initialization Function

Below is the template provided for the initialization function of each state variable. Although the template is effectively empty of functional code, it is included here, this once, so that it need not be repeated for other state variables that also have "empty" initialization functions.

```
from hec.script import Constants
#
# initialization function. optional.
# set up tables and other things that only need to be performed once at the start of the compute.
#
# variables that are passed to this script during the compute initialization:
#	currentVariable - the StateVariable that holds this script
#	network - the ResSim network
#
# throw a hec.rss.lang.StopComputeException from anywhere in the script to
# have ResSim stop the compute.
# from hec.rss.lang import StopComputeException
# raise StopComputeException("the reason to stop the compute")
#
def initStateVariable(currentVariable, network):
	# return Constants.TRUE if the initialization is successful and Constants.FALSE if it failed.
	# Returning Constants.FALSE will halt the compute.
	return Constants.TRUE
```

Main

```
# 7/02/2010 smo.  Based on the WalterFGeorge script in ACF model
# Create a code to track the lake state due to rising/falling during the fish spawning period for Allatoona
# 15March - 15May = 1 Spawning
# Other times = 2  Non-Spawning

# State variable: Allatoona_Elev_State
#  Code =0: Pool is rising
#	=1: The first day of the fish spawning
#	=2: The pool has dropped within 0.3 ft from the base elevation
#	=3: The pool has dropped within 0.3-0.4 ft from the base elevation
#	=4: The pool has dropped within 0.4-0.45 ft from the base elevation
#	=5: The pool has dropped within 0.45-0.49 ft from the base elevation
#	=6: The pool has dropped within 0.49-0.50 ft from the base elevation
#	=7: The pool has dropped more than 0.50 ft from the base elevation

from hec.model import RunTimeStep

curMon = currentRuntimestep.getHecTime().month()
curDay = currentRuntimestep.getHecTime().day()
curHour = currentRuntimestep.getHecTime().hour()

curStep = currentRuntimestep.getStep()
tw=network.getRssRun().getCurrentComputeBlockRunTimeWindow()
firstStep = tw.getNumLookbackSteps()

# Set the base lake elevation at the beginning of the fish spawning period - March 15
# defined as "BaseElev"

if ((curMon==3) and (curDay == 15) and (curHour == 01)) or (curStep == firstStep+1) :
		ELEV_TS = network.getTimeSeries("Reservoir","Allatoona", "Pool", "Elev")
```

```
            ELEV = ELEV_TS.getPreviousValue(currentRuntimestep)
            BaseElev = ELEV
            Code =1
            BaseELEV_StVar=network.getStateVariable("Allatoona_BaseElev")
            BaseELEV_StVar.setValue(currentRuntimestep,BaseElev)
            currentVariable.setValue(currentRuntimestep,Code)

# Count the number of days that the fish spawning requirements are met.
            Days_StVar= network.getStateVariable("Allatoona_FSCompliance")
            Num=1 # first day is automatically compliant
            Days_StVar.setValue(currentRuntimestep,Num)

# Starting on the second day of the spawning period (Mar 16) and going until May 15th
if (curMon==3 and curDay>15) or (curMon==4) or (curMon==5 and curDay <=15) or (curStep == firstStep+1):
      ELEV_TS = network.getTimeSeries("Reservoir","Allatoona", "Pool", "Elev")
      ELEV = ELEV_TS.getPreviousValue(currentRuntimestep)
      BaseELEV_StVar=network.getStateVariable("Allatoona_BaseElev")
      BaseELEV_StVar_TS=BaseELEV_StVar.getTimeSeries()
      # get previous value of the base elevation which will be the minimum elev.
      BaseELEV_Pre=BaseELEV_StVar_TS.getPreviousValue(currentRuntimestep)

      # if the elev for the current timestep is higher than the previous base elevation, reset the base.
      if BaseELEV_Pre < ELEV:
            BaseELEV_Cur=ELEV
            Code=0

      else :
            BaseELEV_Cur=BaseELEV_Pre

            Diff=BaseELEV_Pre - ELEV
            if Diff <=0.3:
                  Code=2
            elif Diff >0.3 and Diff<=0.4:
                  Code=3
            elif Diff >0.4 and Diff<=0.45:
                  Code=4
            elif Diff >0.45 and Diff<=0.49:
                  Code=5
            elif Diff >0.49 and Diff<=0.50:
                  Code=6
            else:
                  Code=7

      Days_StVar= network.getStateVariable("Allatoona_FSCompliance")
      Days_StVar_TS= Days_StVar.getTimeSeries()
      Count_Pre=Days_StVar_TS.getPreviousValue(currentRuntimestep)
      if Code <=6:
            Count_Cur=Count_Pre+1
      else:
            Count_Cur=Count_Pre
      Days_StVar.setValue(currentRuntimestep,Count_Cur)

      currentVariable.setValue(currentRuntimestep,Code)

      BaseELEV_StVar.setValue(currentRuntimestep, BaseELEV_Cur)
```

CleanUp Function

Below is the template provided for the CleanUp function of each state variable. Although the template is effectively empty of functional code, it is included here, this once, so that it need not be repeated for other state variables that also have "empty" CleanUp functions.

```
from hec.script import Constants
#
# script to be run only once, at the end of the compute. optional.

# variables that are available to this script during the compute:
#      currentVariable - the StateVariable that holds this script
#      network - the ResSim network

# The following represents an undefined value in a time series:
#      Constants.UNDEFINED
#
# throw a hec.rss.lang.StopComputeException from anywhere in the script to
# have ResSim stop the compute.
# from hec.rss.lang import StopComputeException
# raise StopComputeException("the reason to stop the compute")

# add your code here...
```

3. Allatoona_FSCompliance

This slave state variable holds a running value of the number of days that Allatoona has been compliant with the fish spawning guidance.
It is computed by: *Allatoona_ElevState* and is not used by an operational element in the model. It was stored to a state variable so that it would be written as model data and used during analysis of results.

4. CartersReRegCompositeZone

This state variable determines the state of the available storage in the Carters System. It is used by the *Check Composite Storage* If-block in Carters' *2018 Operations* operation set to determine if Carters is responsible for meeting minimum seasonal releases.

Main

```
f # This script calculates whether the composite storage in Carters and Carters Rereg is Zone1 or Zone2
# It uses a Composite Zone defined at Carters # quoth RAA:
#    "It includes the storage in rereg between elev. 677-696 (or current definition of Buffer-ToC)
#    but not more than would fill the main dam above its seasonal level (1072/1074)"
# SMO 06/26/2009
# updated 07/01/2009
# revised 09/24/18 jdk

# This state is currently only computed every Sunday (TriggerDay=0)
# Set TriggerDay to be the day you would like the Composite Zone decision to be made.
# 0=Sun; 1=Mon; 2=Tue; 3=Wed; 4=Thu; 5=Fri; 6=Sat
TriggerDay = 0
#--------------------------------------------------------------------------------------------------------------------------------

dayOfWeek = currentRuntimestep.getDayOfWeek()
hourOfDay = currentRuntimestep.getHecTime().hour()

TotalCompStorSV = network.getStateVariable("CartersReReg_CompStor")
```

```
# ------------------------------------------------------------------------------------------------------------------------------------
# If the current day and hour are "right", set the Composite Storage Zone.
# ------------------------------------------------------------------------------------------------------------------------------------
if dayOfWeek == TriggerDay and hourOfDay == 01 :
	# Get the current value of Storage in Carters and the ReReg
	Carter_Stor = network.getTimeSeries("Reservoir","Carters", "Pool", "Stor").getPreviousValue(currentRuntimestep)
	ReReg_Stor = network.getTimeSeries("Reservoir","Carters ReReg", "Pool", "Stor").getPreviousValue(currentRuntimestep)

	# Get the current value of Storage for the ReReg's Buffer and Top of Conservation zones
	ReRegBuff_Stor = network.getTimeSeries("Reservoir","Carters ReReg", "Buffer", "Stor-
ZONE").getCurrentValue(currentRuntimestep)
	ReRegToC_Stor = network.getTimeSeries("Reservoir","Carters ReReg", "Conservation", "Stor-
ZONE").getCurrentValue(currentRuntimestep)

	# ------------------------------------------------------------------------------------------------------------------------------------
	# Only the Volume in the ReReg Con pool is included in the composite storage.
	# ------------------------------------------------------------------------------------------------------------------------------------
	if ReReg_Stor > ReRegToC_Stor :
		# ReReg is above Con, use Con Storage Only
	    ReReg_Stor = ReRegToC_Stor
	elif ReReg_Stor < ReRegBuff_Stor :
		# ReReg is in Buffer, no contributing volume.
		ReReg_Stor = ReRegBuff_Stor
	ReReg_Vol = ReReg_Stor - ReRegBuff_Stor

	TotalCompStor = Carter_Stor + ReReg_Vol
	# ------------------------------------------------------------------------------------------------------------------------------------
	# Get the previous value of Storage for Top of Composite Zone 2
	# ------------------------------------------------------------------------------------------------------------------------------------
	TopZone2 = network.getTimeSeries("Reservoir","Carters", "CompositeZone2", "Stor-
ZONE").getCurrentValue(currentRuntimestep)

	# Composite Storage must fall above Zone2 Storage in Carters
	# --------------------------------------------------------------------------------------
	if TotalCompStor > TopZone2 :
		systemZone = 1.0
	else :
		systemZone = 2.0
else :
	# it is not the chosen day of the week for making the comp zone decision.
	# so, set the Comp Zone to be the same value as yesterday (the previous timestep).
	systemZone = currentVariable.getPreviousValue(currentRuntimestep)
	TotalCompStor = TotalCompStorSV.getPreviousValue(currentRuntimestep)

# ------------------------------------------------------------------------------------------------------------------------------------
# Store the value of Composite Storage to another State variable
# ------------------------------------------------------------------------------------------------------------------------------------
currentVariable.setValue(currentRuntimestep, systemZone)
TotalCompStorSV.setValue(currentRuntimestep, TotalCompStor)

# print currentRuntimestep.dateTimeString(), TotalCompStor, currentVariable.getValue(currentRuntimestep)
```

5. CartersReReg_CompStor

This state variable is computed by: CartersReRegCompositeZone
This state variable is not used by an operational element in the model. It was stored to a state variable so that it would be written as model data and used during analysis of results.

6. CartersReReg_MinimumRelease

This state variable is used by the operating rule *Control for Rome & Resaca in* Carters' and Carter ReReg's *2018 Operations* operation sets to determine if the Carters system must hold back releases to minimize flooding at Rome and/or Resaca.

Main

```
# This script calculates whether the composite storage in Carters and Carters Rereg is Zone1 or Zone2
# It uses a Composite Zone defined at Carters # quoth RAA:
#     "It includes the storage in rereg between elev. 677-696 (or current definition of Buffer-ToC)
#     but not more than would fill the main dam above its seasonal level (1072/1074)"
# SMO 06/26/2009
# updated 07/01/2009
# revised 09/24/18 jdk

# This state is currently only computed every Sunday (TriggerDay=0)
# Set TriggerDay to be the day you would like the Composite Zone decision to be made.
# 0=Sun; 1=Mon; 2=Tue; 3=Wed; 4=Thu; 5=Fri; 6=Sat
TriggerDay = 0
#----------------------------------------------------------------------------------------------------------------------------------

dayOfWeek = currentRuntimestep.getDayOfWeek()
hourOfDay = currentRuntimestep.getHecTime().hour()

TotalCompStorSV = network.getStateVariable("CartersReReg_CompStor")

# ---------------------------------------------------------------------------------------------------------------------------------
# If the current day and hour are "right", set the Composite Storage Zone.
# ---------------------------------------------------------------------------------------------------------------------------------
if dayOfWeek == TriggerDay and hourOfDay == 01 :
        # Get the current value of Storage in Carters and the ReReg
        Carter_Stor = network.getTimeSeries("Reservoir","Carters", "Pool", "Stor").getPreviousValue(currentRuntimestep)
        ReReg_Stor = network.getTimeSeries("Reservoir","Carters ReReg", "Pool", "Stor").getPreviousValue(currentRuntimestep)

        # Get the current value of Storage for the ReReg's Buffer and Top of Conservation zones
        ReRegBuff_Stor = network.getTimeSeries("Reservoir","Carters ReReg", "Buffer", "Stor-
ZONE").getCurrentValue(currentRuntimestep)
        ReRegToC_Stor = network.getTimeSeries("Reservoir","Carters ReReg", "Conservation", "Stor-
ZONE").getCurrentValue(currentRuntimestep)

        # ---------------------------------------------------------------------------------------------------------------------
        # Only the Volume in the ReReg Con pool is included in the composite storage.
        # ---------------------------------------------------------------------------------------------------------------------
        if ReReg_Stor > ReRegToC_Stor :
                # ReReg is above Con, use Con Storage Only
            ReReg_Stor = ReRegToC_Stor
        elif ReReg_Stor < ReRegBuff_Stor :
                # ReReg is in Buffer, no contributing volume.
                ReReg_Stor = ReRegBuff_Stor
        ReReg_Vol = ReReg_Stor - ReRegBuff_Stor

        TotalCompStor = Carter_Stor + ReReg_Vol
        # ---------------------------------------------------------------------------------------------------------------------
        # Get the previous value of Storage for Top of Composite Zone 2
        # ---------------------------------------------------------------------------------------------------------------------
        TopZone2 = network.getTimeSeries("Reservoir","Carters", "CompositeZone2", "Stor-
ZONE").getCurrentValue(currentRuntimestep)

        # Composite Storage must fall above Zone2 Storage in Carters
        # ---------------------------------------------------------------------------------
```

```
        if TotalCompStor > TopZone2 :
                systemZone = 1.0
        else :
                systemZone = 2.0
else :
        # it is not the chosen day of the week for making the comp zone decision.
        # so, set the Comp Zone to be the same value as yesterday (the previous timestep).
        systemZone = currentVariable.getPreviousValue(currentRuntimestep)
        TotalCompStor = TotalCompStorSV.getPreviousValue(currentRuntimestep)

# ------------------------------------------------------------------------------------------------------------------------------------
# Store the value of Composite Storage to another State variable
# ------------------------------------------------------------------------------------------------------------------------------------
currentVariable.setValue(currentRuntimestep, systemZone)
TotalCompStorSV.setValue(currentRuntimestep, TotalCompStor)

# print currentRuntimestep.dateTimeString(), TotalCompStor, currentVariable.getValue(currentRuntimestep)
```

7. CartersReReg_SeasonalMin

This holds the seasonal minimum requirement that must be released from the Carters system.
It is computed by the state variable: *Carters_Seasonal_Min*
And, it is used by the state variable: *CartersReReg_MinimumRelease.*

8. Carters_Seasonal_Min

This master state variable determines the minimum release requirement from Carters reservoir. It also determines the minimum release requirement (*CartersReReg_Seasonal Min*) for the Carters System which will be met by Carters ReReg reservoir.
It is used by the operating rule *MinQ_Seas_Release* in Carters' *2018 Operations* operation set.

Initialization Function

```
from hec.script import Constants
#
# initialization function. optional.
# set up tables and other things that only need to be performed once at the start of the compute.
#
# variables that are passed to this script during the compute initialization:
#       currentVariable - the StateVariable that holds this script
#       network - the ResSim network
#
def initStateVariable(currentVariable, network):
        # return Constants.TRUE if the initialization is successful and Constants.FALSE if it failed.
        # Returning Constants.FALSE will halt the compute.

        #   These 12 values are the corresponding 7Q10 FLOWS (from Table 5, DLR document).
        #    The -1 is a placeholder for the "zeroeth" month so month numbers can be used to index the tuple table.
        #       Jan, Feb, Mar, Apr, May,  Jun, Jul,  Aug, Sep, Oct,  Nov, Dec
        mo_min = (-1,    660, 790, 865, 770, 620, 475, 400, 325, 250, 275, 350, 465)

        currentVariable.varPut("MonthlyMin", mo_min)

        currentVariable.localTimeSeriesNew("trcFlow")
        return Constants.TRUE
```

Main

```
# determine the minimum flow that Carters should release to support the rereg in meeting the seasonal minimum.
# this value should consider the inflow from Talking Rock Creek.
# Note - The ReReg is responsible for 240 cfs of the minimum release from the system.

month = currentRuntimestep.month()
mo_min=currentVariable.varGet("MonthlyMin")
SystemMin=mo_min[month]

TRCflow = network.getTimeSeries("Reach","Hinton_02382200 to Carters ReReg_In", "",
"Flow").getCurrentValue(currentRuntimestep)

CartersMin = max(0.0, (SystemMin - TRCflow - 240.0)) # no negative values

network.getStateVariable("CartersReReg_Seasonal_Min").setValue(currentRuntimestep, SystemMin)
currentVariable.setValue(currentRuntimestep, CartersMin)
```

CleanUp Function

```
from hec.script import Constants
#
# script to be run only once, at the end of the compute. optional.

# variables that are available to this script during the compute:
#       currentVariable - the StateVariable that holds this script
#       network - the ResSim network

currentVariable.localTimeSeriesWriteAll()
```

9. GateCloseState_Allatoona

This slave state variable holds a boolean value to indicate whether Allatoona must hold back releases to minimize flooding at Rome. A value of 0 means False, Allatoona need not hold back for Rome; a value of 1 means True, Allatoona should hold back releases.
It is computed by the state variable: *GateCloseState_Carters*
And, it is used by the operating rule: *Control for Rome*
in Allatoona's *2018 Operations* operation set.

10. GateCloseState_Carters

This master state variable holds a Boolean value to indicate whether Carters and Carters ReReg must hold back releases to minimize flooding at Rome or Resaca. A value of 0 means False, Carters need not hold back for Rome; a value of 1 means True, Carters should hold back releases. It is used by the operating rules named *Control for Rome & Resaca* in Carters' and Carter ReReg's *2018 Operations* operation sets.
This state variable computes three slave state variables: *GateCloseState_Allatoona*, *Peak*, and *Rome_Ooostanaula_Rising.*

Initialization Function

```
from hec.script import Constants
#
# initialization function. optional.
# set up tables and other things that only need to be performed once at the start of the compute.
```

```
#
# variables that are passed to this script during the compute initialization:
#       currentVariable - the StateVariable that holds this script
#       network - the ResSim network
#
def initStateVariable(currentVariable, network):
        # return Constants.TRUE if the initialization is successful and Constants.FALSE if it failed.
        # Returning Constants.FALSE will halt the compute.

        #   These 12 values are the corresponding 7Q10 FLOWS (from Table 5, DLR document).
        #    The -1 is a placeholder for the "zeroeth" month so month numbers can be used to index the tuple table.
        #       Jan, Feb, Mar, Apr, May,  Jun, Jul,  Aug, Sep, Oct,  Nov, Dec
        mo_min = (-1,    660, 790, 865, 770, 620, 475, 400, 325, 250, 275, 350, 465)

        currentVariable.varPut("MonthlyMin", mo_min)

        currentVariable.localTimeSeriesNew("trcFlow")
        return Constants.TRUE
```

Main

```
# This script determines if the Carters and Allatoona reservoirs should open or close their gates
# based on the stage at the Rome-Oostananula and Reseca gages.
# values
#       0/FALSE = open gates
#       1/TRUE  = close gates
#
# substantially revised 9-24-18 jdk -
#       If Resaca was the control, not Rome, then Allatoona should not be affected
#       AND Carters should open back up on independently of Allatoona.
#       Also, added Allatoon's upper flood pool constraints for Rome.
# more revisions - 10-25-18 jdk -
#       - primary issue was the order of determination of Carter closing - Rome should be checked first, not Resaca.
#       - also, the flow tollerance should be an OR condition, not an AND.  This condition allows the reservoirs to open up in the
#       falling limb of the event. By doing so, the flood lasts a bit longer but is not made higher (worse) by the releases and the
#       reservoirs get the chance to evacuate sooner, to reduce risk of being too high if another event comes along.
#       - and, I added logic for an "All is Well" condition at Rome and Resaca to enable opening of Carters and/or Allatoona
#       even if the other is "in trouble". “All is Well Stages" were selected to allow enough space for Carters and Allatoona channel
#       capacity releases (allowing for attentuation).  This logic is currently very simplistic and counts on the rating curves to be valid.
#       When the rating curves are more better represented, this logic will need to be revised, or maybe just the AllisWell stages.

from hec.script import Constants
#------------------------------------------------------------------------
# Script Global Constants that control the operation are HERE:
#------------------------------------------------------------------------
Resaca_stage_GateClosing = 22        # Flood stage at Resaca is 22'
Resaca_stage_GateOpening = 20
Resaca_flow_tollerance = 3000

Rome_stage_GateClosingHI = 28
Rome_stage_GateOpeningHI = 27

Rome_stage_GateClosing = 25          # Flood stage at Rome-Oostanaula is 25'
Rome_stage_GateOpening = 24
Rome_flow_tollerance = 8000

Resaca_AllisWell_Stage = 18
Rome_AllisWell_Stage = 17

AllisWellatResaca = Constants.TRUE
AllisWellatRome = Constants.TRUE
```

```
#-----------------------------------------------------------------------
#-----------------------------------------------------------------------

#-----------------------------------------------------------------------
#-----------------------------------------------------------------------
#       Determine Rising/Falling at Rome-Oostanaula and look for peak
#-----------------------------------------------------------------------
#-----------------------------------------------------------------------
# Get running variables, stage, and Flow TS for Rome-Oostanaula
Rome_Rising_SV = network.getStateVariable("Rome_Oostanaula_Rising")
Rome_Rising_prev = Rome_Rising_SV.getPreviousValue(currentRuntimestep)
Peak_SV = network.getStateVariable("Peak")
Peak = Peak_SV.getPreviousValue(currentRuntimestep)

Rome_Flow_TS=network.getTimeSeries("Junction","RomeOo_02388525", "", "Flow")
Rome_Flow_cur=Rome_Flow_TS.getPreviousValue(currentRuntimestep)
Rome_Flow2hr=Rome_Flow_TS.getPeriodAverage(currentRuntimestep, 2)
Rome_Flow6hr=Rome_Flow_TS.getPeriodAverage(currentRuntimestep, 6)
Rome_Stage_TS=network.getTimeSeries("Junction","RomeOo_02388525", "", "Stage")
Rome_Stage_cur=Rome_Stage_TS.getPreviousValue(currentRuntimestep)

if (Rome_Flow2hr > Rome_Flow6hr):
        # Flow @ Rome is rising
        Rome_Rising_cur = Constants.TRUE
else:
        # Flow @ Rome is falling
        Rome_Rising_cur = Constants.FALSE

# has the peak at Rome been reached?
if (Rome_Rising_prev) and (not Rome_Rising_cur):
        Peak = max(Peak, Rome_Flow_cur)

#-----------------------------------------------------------------------
# Is Rome above flood stage?
#               Should Carters and Allatoona(below top of FC Zone B) control for Rome?
#-----------------------------------------------------------------------
close4RomeTS = currentVariable.localTimeSeriesGet("Close4Rome")
close4Rome = close4RomeTS.getPreviousValue(currentRuntimestep)
close4RomePrev = close4Rome

close4RomeHITS = currentVariable.localTimeSeriesGet("Close4RomeHI")
close4RomeHI = close4RomeHITS.getPreviousValue(currentRuntimestep)
close4RomeHIPrev = close4RomeHI

if Rome_Stage_cur < Rome_AllisWell_Stage:
        # Rome is not currently at risk of flooding
        AllisWellatRome = Constants.TRUE
        close4Rome = Constants.FALSE
        close4RomeHI = Constants.FALSE
else:
        # the flood risk at Rome is not clear, check conditions more carefully
        AllisWellatRome = Constants.FALSE
        if close4Rome:
                # Rome was in flood risk (above flood stage), is it still?
                if ( not Rome_Rising_cur and (Rome_Stage_cur < Rome_stage_GateOpening or Rome_Flow_cur < (Peak - 
Rome_flow_tollerance) ) ):
                        close4Rome = Constants.FALSE
                        Peak = 0.0 # we are past the event, reset the running peak.
        else: #Rome was NOT in flood, is it now?
                if ( Rome_Rising_cur and Rome_Stage_cur >= Rome_stage_GateClosing):   # Rome is now in flood risk
                        close4Rome = Constants.TRUE
```

```
    #-----------------------------------------------------------------------
    # Is Rome above higher (moderate) flood stage?
    #           Should Allatoona(above FC Zone B) control for Rome?
    #-----------------------------------------------------------------------

    if close4RomeHI:
        # Rome was in high flood risk, is it still?
        if ( not Rome_Rising_cur and (Rome_Stage_cur < Rome_stage_GateOpeningHI or Rome_Flow_cur < (Peak -
Rome_flow_tollerance) ) ):
            close4RomeHI = Constants.FALSE
    else:
        #Rome was NOT in high flood risk, is it now?
        if ( Rome_Rising_cur and Rome_Stage_cur >= Rome_stage_GateClosingHI ):
            # Rome is now in high flood risk
            close4RomeHI = Constants.TRUE

# store the running values for Rome flood operation
Rome_Rising_SV.setValue(currentRuntimestep, Rome_Rising_cur)
Peak_SV.setValue(currentRuntimestep, Peak)
close4RomeTS.setCurrentValue(currentRuntimestep, close4Rome)
close4RomeHITS.setCurrentValue(currentRuntimestep, close4RomeHI)

#-----------------------------------------------------------------------
#-----------------------------------------------------------------------
#    Determine Rising/Falling at Resaca and look for peak
#-----------------------------------------------------------------------
#-----------------------------------------------------------------------
# Get running variables, stage, and Flow TS for Resaca
Resaca_Rising_TS = currentVariable.localTimeSeriesGet("Resaca_Rising")
Resaca_Rising_prev = Resaca_Rising_TS.getPreviousValue(currentRuntimestep)
Resaca_Peak_TS = currentVariable.localTimeSeriesGet("Resaca_Peak")
Resaca_Peak = Resaca_Peak_TS.getPreviousValue(currentRuntimestep)

Resaca_Flow_TS = network.getTimeSeries("Junction","Resaca_02387500", "", "Flow")
Resaca_Flow_cur = max(0.0, Resaca_Flow_TS.getCurrentValue(currentRuntimestep))
Resaca_Flow2hr = Resaca_Flow_TS.getPeriodAverage(currentRuntimestep, 2)
Resaca_Flow6hr = Resaca_Flow_TS.getPeriodAverage(currentRuntimestep, 6)
Resaca_Stage_TS = network.getTimeSeries("Junction","Resaca_02387500", "", "Stage")
Resaca_Stage_cur = Resaca_Stage_TS.getCurrentValue(currentRuntimestep)

# is the flow at Resaca rising ?
if (Resaca_Flow2hr > Resaca_Flow6hr):
    # Flow @ Resaca is rising
    Resaca_Rising_cur = Constants.TRUE
else:
    # Flow @ Resaca is falling
    Resaca_Rising_cur = Constants.FALSE

# has the peak at Resaca been reached?
if (Resaca_Rising_prev) and (not Resaca_Rising_cur):
    Resaca_Peak = max(Resaca_Peak, Resaca_Flow_cur)

#-----------------------------------------------------------------------
# Is Resaca above flood stage?
#-----------------------------------------------------------------------
close4ResacaTS = currentVariable.localTimeSeriesGet("Close4Resaca")
close4Resaca = close4ResacaTS.getPreviousValue(currentRuntimestep)
close4ResacaPrev = close4Resaca

if Resaca_Stage_cur < Resaca_AllisWell_Stage:
    # Resaca is not currently at risk of flooding
```

```
        AllisWellatResaca = Constants.TRUE
        close4Resaca = Constants.FALSE
else:
        # the flood risk at Resaca is not clear, check conditions more carefully
        AllisWellatResaca = Constants.FALSE
        if close4Resaca:
                # Resaca has been above flood stage (gate closing stage), is it still at risk?
                if ( not Resaca_Rising_cur and (Resaca_Stage_cur < Resaca_stage_GateOpening or Resaca_Flow_cur <
(Resaca_Peak - Resaca_flow_tollerance) ) ):
                        close4Resaca = Constants.FALSE
                        Resaca_Peak = 0.0    # we are past the event, reset the running peak.
        else:
                # Resaca has not been above flood stage, is it now?
                if (Resaca_Stage_cur >= Resaca_stage_GateClosing):
                        # Resaca is now in flood risk
                        close4Resaca = Constants.TRUE

# store the running values for Resaca flood operation
Resaca_Rising_TS.setCurrentValue(currentRuntimestep, Resaca_Rising_cur)
Resaca_Peak_TS.setCurrentValue(currentRuntimestep, Resaca_Peak)
close4ResacaTS.setCurrentValue(currentRuntimestep, close4Resaca)

#-----------------------------------------------------------------------
#-----------------------------------------------------------------------
#       Determine GateCloseStates for Carters and Allatoona
#-----------------------------------------------------------------------
#-----------------------------------------------------------------------

closegates_Carters =currentVariable.getPreviousValue(currentRuntimestep)
GateCloseState_Allatoona_SV = network.getStateVariable("GateCloseState_Allatoona")
closegates_Allatoona = GateCloseState_Allatoona_SV.getPreviousValue(currentRuntimestep)
AllatoonaPool = network.getTimeSeries("Reservoir","Allatoona", "Pool", "Elev").getPreviousValue(currentRuntimestep)
AllFCzoneBtop = network.getTimeSeries("Reservoir","Allatoona", "Zone B", "Elev-ZONE").getCurrentValue(currentRuntimestep)
AllFCzoneCtop = network.getTimeSeries("Reservoir","Allatoona", "Zone C", "Elev-ZONE").getCurrentValue(currentRuntimestep)

# Set Gate Operation for Allatoona
if AllisWellatRome :
        # JDK.. I added logic here for "all is well" to enable opening of Carters and/or Allatoon even if the other is "in trouble".
        closegates_Allatoona = Constants.FALSE
else:
        # check the tighter conditions for open/close states
        if close4RomeHI:
                closegates_Allatoona = Constants.TRUE
        elif close4Rome :
                if AllatoonaPool <= AllFCzoneBtop :
                        # Allatoona is in Zones A or B. Rome is at Risk, close the gates at Allatoona
                        closegates_Allatoona = Constants.TRUE
                elif AllatoonaPool <= AllFCzoneCtop and Rome_Stage_cur > 25.0 and closegates_Allatoona == Constants.TRUE  :
                        # Rome above opening stage and Allatoona is in Zone C. Rome is at Risk, close the gates at Allatoona
                        closegates_Allatoona = Constants.TRUE
                else:
                        closegates_Allatoona = Constants.FALSE
        else: # Rome is NOT at risk, open the gates at Allatoona
                closegates_Allatoona = Constants.FALSE

# Set Gate Operation for Carters
if AllisWellatRome and AllisWellatResaca :
                closegates_Carters = Constants.FALSE
else:
        # check the tighter conditions for open/close states
        if close4Rome:
                # Rome is at Risk, close the gates at Carters
```

```
            closegates_Carters = Constants.TRUE
        elif close4Resaca:
            # Resaca is at Risk (even though Rome is not), close the gates at Carters
            closegates_Carters = Constants.TRUE
        elif closegates_Carters :
            # Carters has been closed but now there's no flood risk.
            if close4RomePrev and AllatoonaPool > AllFCzoneBtop:
                # However Allatoona is above Zone B. Keep Carters Closed.
                # This test gives Allatoona priority to release over Carters - if Allatoona is high
                closegates_Carters = Constants.TRUE
                close4Rome = Constants.TRUE
                close4RomeTS.setCurrentValue(currentRuntimestep, close4Rome)
            else:
                # Allatoona is not in trouble... Open Carters
                closegates_Carters = Constants.FALSE
        else:
            # this is the "otherwise" - so that the state variable always has a value.
            # this is the case of "no flood risk" and Carters has been open, so stay open.
            closegates_Carters = Constants.FALSE

#--------------------------------------------------------------------------
# store the gate close states in Allatoona's and Carters' state variables.
GateCloseState_Allatoona_SV.setValue(currentRuntimestep, closegates_Allatoona)
currentVariable.setValue(currentRuntimestep, closegates_Carters)
```

CleanUp Function

```
from hec.script import Constants
#
# script to be run only once, at the end of the compute. optional.

# variables that are available to this script during the compute:
#     currentVariable - the StateVariable that holds this script
#     network - the ResSim network

# The following represents an undefined value in a time series:
#     Constants.UNDEFINED

currentVariable.localTimeSeriesWriteAll()
```

11. Peak

This slave state variable holds a running value for the flow associated with the peak stage at Rome Oostanaula. This variable is zeroed-out when Rome-Oostanaula falls below flood stage.
This state variable is computed and used by the state variable: *GateCloseState_Carters*

12. Rome_Oostanaula_Rising

This slave state variable holds a Boolean value to indicate if the stage at Rome-Oostanaula is rising. A value of 0 means False, the stage at is falling or constant; a value of 1 means True, the stage is rising.
This state variable is computed and used by the state variable: *GateCloseState_Carters.*
It is also used in the *Normal FC Zone E* If-block in *Zone E* of the *2018 Operations* operation set in Allatoona to determine if conditions in the system would allow power releases from Allatoona.

Appendix B. Time Series Data Management

The study team was provided with a significant number of DSS files containing the time series data to be used in the model. Some of the files provided led to confusion and the creation of an excessive number of alternatives in the initial versions of the model. In order to better manage the DSS data, it was consolidated into a single DSS file wherever it made the most sense. The data files associated with the watershed are all contained in the watershed "/shared/" subdirectory. The original files were maintained as a record and placed in a "/shared/Archive/" subdirectory. The actions taken to clean up and consolidate the file systems are described below.

B.1 Consolidation of Inflows

The first set of files that were consolidated contained the local inflows computed for the 5 exceedance probability intervals [0.2%, 0.5%, 1.0%, 2.0%, 5.0%] based on the three historic events [1961, 1979, 1990]. The files were organized and named by the three historic event years. These files are:

- ACT-SUBDAILY_1961-Revised.dss
- ACT-SUBDAILY_1979.dss
- ACT-SUBDAILY_1990.dss

After a quick review of the data, it was determined that the pathnames in each file were unique (by F-part) so the contents were merged into a single file without the records overwriting one another. The consolidated file was named: ***ACT-Upper-HOURLY-SyntheticEvents.dss***.

Establishing and Applying a Naming Convention to the Inflows

<u>Identified Problems:</u>

After reviewing the pathnames in the consolidated file of inflows, it was discovered that the names of the data locations and parameters were not consistent. This was unexpected but was likely the result of three different modelers producing the five synthetic events, each working with one of the three historic events.

The discovered inconsistencies were in the A-, B-, and C-parts of the DSS pathnames. The most challenging of these inconsistencies is illustrated in the example below, showing four DSS pathname styles for flows at the Rome Coosa location.

//**COOSAROMEJUNCTION_LOCAL/FLOW**//1HOUR/0.2%_1961_14APR/
/**12/ROME_COOSA/FLOW_INC**//1HOUR/0.2%_1979_05APR/
/**13/ROME_COOSA/FLOW**//1HOUR/0.2%_1979_05APR/
/**COOSA/ROME_COOSA/FLOW_INC_ADJ**//1HOUR/0.2%_1990_17APR/

The pathname inconsistencies were parsed out from the above example and organized by pathname part in the following table:

Pathname Part	DSS Naming Convention	Entries
A	Watershed or River Name	blank, 12, 13, and COOSA
B	Location Name	COOSAROMEJUNCTION_LOCAL and ROME_COOSA
C	parameter or kind of data, e.g., FLOW, ELEV, STAGE	FLOW, FLOW_INC, and FLOW_INC_ADJ.

A summary of the A-, B-, and C-part inconsistencies found in and between the three datasets (files) is shown in the table below. With the combination of inconsistencies in the B and C-parts of the pathnames within *and* across the three datasets, identifying the data stored in each record was much more challenging that it should have been and could potentially lead to incorrect usage in the model.

Table 17. List of time series naming inconsistencies

Naming Inconsistencies	**1961**	**1979**	**1990**
A-part	Blanks	Numeric	River names
B-part	Different Names from other datasets	Names *mostly* similar to 1990 dataset	Names *mostly* similar to 1979 dataset
	Used no delimiters	Used no delimiters	
	Used blank and dash (-) as delimiters	Used blank and underscore (_) as delimiters	Used blank and underscore (_) as delimiters
	Used modifier _LOCAL in only one location name		
C-part	Used FLOW only with no modifiers	Used only FLOW or FLOW_INC per location, with only one exception ROME_COOSA. See figure below.	Used only FLOW_ADJ or FLOW_INC_ADJ per location.
		Underscore not recognized by DSS as a valid delimiter for a parameter modifier	Underscore not recognized by DSS as a valid delimiter for a parameter modifier
			Significance of _ADJ is unknown

FLOW vs FLOW_INC

The data in the 1979 dataset was used for ROME-COOSA, the only location in any of the three files that had both FLOW and FLOW_INC records, to justify the assumption that **FLOW** was meant to represent *total flow* at a location while **FLOW_INC** was intended to represent *incremental local flow*. This is illustrated in Figure 49 below where the red curve is FLOW with a peak of 120,000 cfs and the green curve is FLOW_INC with a peak of 35,000 cfs.
The 1961 data (in which all the data is identified with a C-part of FLOW) is illustrated for Rome in the plot with the blue curve. This record has a peak of 50,000 cfs. The fact that this peak is closer to the FLOW_INC peaks of the other two datasets (1979 and 1990) and as well as the use of _LOCAL in the B-part of the pathname imply that the selected record represents a local flow at ROME.

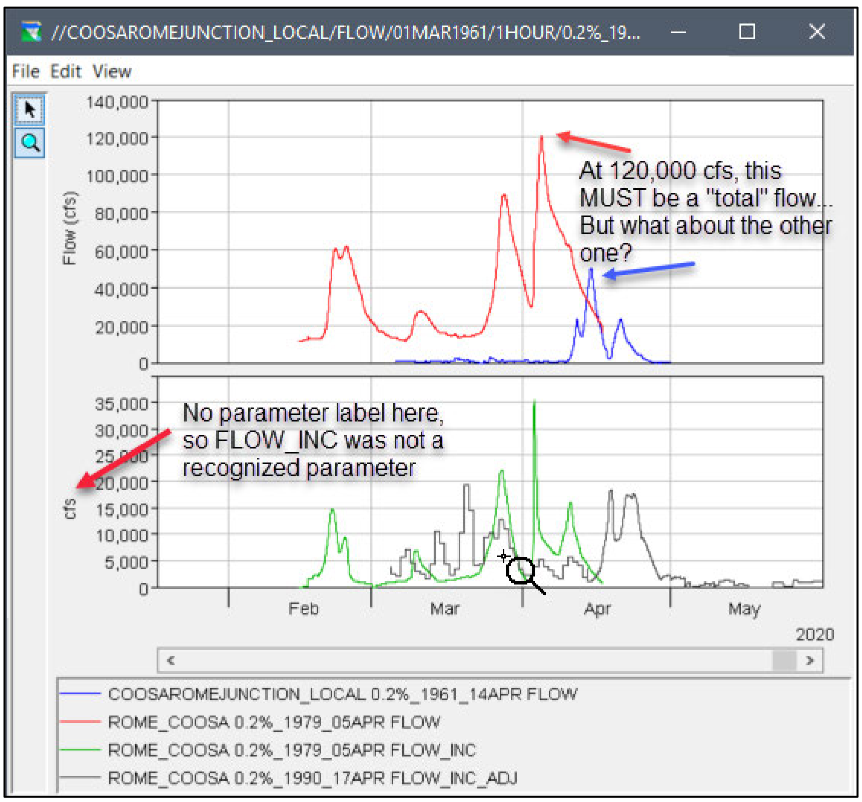

Figure 49. FLOW versus FLOW INC

Solutions:
To address the identified problems in the naming of the data, it was decided to apply a consistent set of names to the data locations for each of the events. DSS standards were followed, assigning river names to the A-parts, location names to the B-parts, and parameters to the C-parts. In the C-parts, the DSS standard of using a hyphen to separate the parameter from its modifier was followed. This was done so that FLOW and FLOW-INC would both be recognized as FLOW and would plot together. These decisions resulted in the following changes:

A-parts

- Blanks and numbers became Conasauga, Coosa, Coosawattee, Etowah, or Oostanaula as appropriate to the associated locations.

B-parts

- The table below lists the original location names and their new names. Not all location names required revision. For example, Tilton (a perfectly fine name) was Tilton in all three event datasets, so it remained Tilton.

Table 18. Renamed time series B-part locations

Original B-part	New B-part
ALLATOONAJUNCTION	ALLATOONA_IN*
ALLATOONA	ALLATOONA_IN*
CARTERS	CARTERS_IN*
CARTERS-INFLOW	CARTERS_IN*
CARTERSREREG	CARTERS REREG**
CONASAUGA	ETON
CONASAUGAETON	ETON
COOSAROMEJUNCTION_LOCAL	ROME_COOSA
ETOWAH ROME	ROME_ETOWAH
ETOWAH_DAWSON	DAWSONVILLE
ETOWAHDAWSONVILLE	DAWSONVILLE
PINECHAPEL	PINE CHAPEL
RESACA PLUS CONAS BLW TILTON	RESACA
* Since inflows are applied to stream locations in the model and not to reservoirs, the stream location names were used for the model's reservoir inflow junction names (which include the modifier _IN) to identify the reservoir inflow locations in the dataset ** To be consistent, CARTERS REREG should have been renamed to CARTERS REREG_IN. The reason it wasn't renamed is that there was not a good indication of what the data represented and it was decided to leave the naming of the data alone until it was determined what the data represents. If the record contains the cumulative local inflow into Carters ReReg (i.e., it does not include Carters outflow), then the C-part (parameter name) should also be changed to FLOW-INC or the location name should be changed to HINTON or TALKING ROCK CREEK.	

The table below lists the original and revised parameter names as well as the interpretation applied to those parameter names.

Table 19. List of renamed C-parts

Original C-part	New C-part	Interpretation
FLOW	FLOW	Total Flow
FLOW_ADJ	FLOW	Total Flow
FLOW (some 1961 data)*	FLOW-INC	Incremental Local Inflow
FLOW_INC	FLOW-INC	Incremental Local inflow
FLOW_INC_ADJ	FLOW-INC	Incremental Local inflow
* see description of inference		

Even though the 1979 ROME_COOSA data supported the assumption that the parameter FLOW represents total flow and the parameter FLOW_INC represents local inflow in the 1979 & 1990 datasets, there was no obvious way to tell which kind of flow the data the 1961 dataset represents – other than comparison of peak magnitudes. So, an **inference** was made:

- If a location had only local inflow (FLOW_INC) data in the 1979 and 1990 datasets, then the data for that location in the 1961 dataset must represent local inflow as well.
- Similarly, if a location had only total flow (FLOW) data in the 1979 and 1990 datasets, then the data for that location in the 1961 dataset must be total flow.

The magnitude of the data for each location and its hydrologic neighbors was reviewed to verify the FLOW or FLOW-INC selection at each location.

F-parts

- Although no concerns about the F-parts were described in the "Problems" section above, a revised naming convention was applied to the F-parts to produce more consolidation of the data:
  - **Remove Event Year** - Since the data for each event year did not overlap one another, the use of the event year in the F-part was not strictly needed and a single dataset could hold all three event shapes.
  - **Remove Date of Event Peak** - The day of the month when the event peaked was not considered to be necessary information either.

Thus, 0.2%_1990_17APR became 0.2% APR.

It was not possible to also eliminate month (placement) identifiers because the data for each event spans more than one month and the data for one month's event overlaps that for the next and/or previous month making the time window of the data inadequate to identify "placement".

NOTE - By making the changes described above to the pathnames of the inflow data, we were able to create **just 5** alternatives **<u>per "Month" placement</u>** for the 5 exceedance probabilities **instead of the 15** alternatives that the original data naming required. The name (and time window) of the simulations now indicates the event year.

B.2 Consolidation of Diversions

The second set of files targeted for consolidation contained the diversion data. The reach gains and losses, specified as stream and reservoir withdrawals, covered the period of record and were contained in the following files:

- ACT_TOTALDEMANDS.DSS
- ACT_TOTALDEMANDS_04Feb2014.dss
- ACT_Contract-DIV.dss
-

After reviewing the first two files carefully, it was determined that the data in the **ACT_TOTALDEMANDS _04Feb2014.dss** file spans 1939-2011 while the **ACT_TOTALDEMANDS.DSS** file only spans 1939-2008. In addition, where they overlap, the data in the two files is not the same; the differences probably represent updates or revisions made when the additional years were added. Since the longer period of record data is being used in our daily model and updated data is usually preferred, it was concluded that the data in the **ACT_TOTALDEMANDS _04Feb2014.dss** file was more appropriate for use in the hourly model than the **ACT_TOTALDEMANDS.DSS** file. Therefore the mapping of the diversion data in our alternatives was revised to ensure that all model locations were mapped to the more recent **ACT_TOTALDEMANDS _04Feb2014.dss** file.

The third file, **ACT_Contract-DIV.dss**, contains only one dataset, the diversion from Allatoona representing the maximum contracted yield of 79.3 cfs. This record could easily be included in the DEMANDS file(s) and need not be stored separately.

So, a single file for use in this study was created and named ***ACT-Upper_TOTALDEMANDS_04Feb2014.dss***. The *daily* data was copied into it from the **ACT_TOTALDEMANDS _04Feb2014.dss** and **ACT_Contract-DIV.dss** files.
Next, the pathnames of the data in the ***ACT-Upper_TOTALDEMANDS_04Feb2014.dss*** was reviewed. Most records had a river name in the A-part but the names of the B-parts were mystifying –almost all location names followed the naming pattern: REACH_NNN, where NNN was a number. The mist cleared when it was later learned that REACH_NNN came from the naming convention used in the HEC-5 ACT model developed and used in the mid 1990's. After reviewing the mapping of the diversions in 2014 modeling report, it was possible to identify those REACH_NNNs that were associated with the diversion locations in our Upper ACT model. To facilitate future alternative mapping, the relevant location names were prepended into the B-parts of the pathnames and the REACH_NNN pattern was shortened to RNNN. Then, all unneeded records for locations not in the upper ACT model were deleted.

It was also noticed that the only parameter (C-part) used for the diversion data was **DIV**. While this parameter appropriately describes the data, **DIV** is not a recognized parameter in DSS. So, all C-parts of **DIV** were replaced with **FLOW-DIV**.

B.3 A complete list of the revised B-parts is shown in Consolidation of Starting Conditions

Time series of guide curves are used for starting pool elevations for Allatoona and Carters. These time series were stored in the following files:

- ConPool_1961.dss
- ConPool_1979.dss
- ConPool_1990.dss

Although the pathnames in each file are the same, the data does not overlap so all the records were copied into a single file named **ACT-Upper-HOURLY-StartingConditions.dss**. None of the records inside the new file were renamed.

Table 20.

B.4 Consolidation of Starting Conditions

Time series of guide curves are used for starting pool elevations for Allatoona and Carters. These time series were stored in the following files:

- ConPool_1961.dss
- ConPool_1979.dss
- ConPool_1990.dss

Although the pathnames in each file are the same, the data does not overlap so all the records were copied into a single file named **ACT-Upper-HOURLY-StartingConditions.dss**. None of the records inside the new file were renamed.

Table 20. List of revised B-parts

A-part	Original B-part	New B-part
CONASAUGA	REACH_386	TILTON_R386
COOSAWATTEE	REACH_189	CARTERS_IN_R180
OOSTANAULA	REACH_R170	RESACA_R170
ETOWAH	CANTON_WD	
ETOWAH	CANTON_PERMIT_WD*	
ETOWAH	CANTON_RT	CANTON_RETURN (or JASPER_RETURN)
ETOWAH	REACH_160	ALLATOONA_IN_R160* (once used for Allatoona DIV)
ETOWAH	ALLATOONA (REACH 160)	ALLATOONA_LAKE_WD_R160*
ETOWAH	CCMWA_ WD	CCMWA_LAKE_WD
ETOWAH	CCMWA_RT	CCMWA_RETURN
ETOWAH	CARTERVILLE_WD	CARTERSVILLE_LAKE_WD
ETOWAH	- Not in original file -	CARTERSVILLE_RETURN_64% (= 64% of CARTERSVILLE_LAKE_WD)
ETOWAH	HLC_CONFLUENCE_WD	
ETOWAH	REACH_158	KINGSTON_R158*
ETOWAH	REACH_158 MINUS CARTERSVILLE RT	KINGSTON_R158 MINUS CARTERSVILLE RT
ETOWAH	REACH_156	ROME_ETOWAH_R156†
COOSA	REACH_154	ROME_COOSA_TOTAL_R154*† (= ROME_OOSTAN + ROME_ETOWAH)
ETOWAH	REACH_154E	ROME_COOSA_R154E†
OOSTANAULA	REACH_154O	ROME_OOSTAN_R154O†
ZERO	- Not in original file -	DUMMY DIVERSION

* Not currently used in the hourly model. If needed, DUMMY DIVERSION of zero was used instead.

† The diversion time-series used in the model to represent the diversions at ROME may look confusing but are actually quite reasonable. The data in REACH_154 equals the ***sum*** of REACH_154O and REACH_154E. So REACH_154O was applied at ROME_OOSTANAULA and REACH_154E (the additional, incremental diversion) was applied at ROME_COOSA. [Optionally, the total diversion at Rome could have been applied at ROME_COOSA without a diversion being applied at ROME_OOSTANAULA but the original modeling team chose this setup so that the flow at ROME_OOSTANUALA was as accurate as possible for flood operations.] Additionally, the reach below Kingston, REACH_156, was applied at ROME_ETOWAH.

B.5 Consolidation of the 2009 event data

Two files were being used to hold the inflows and starting conditions for the 2009 historic event data. These file are:

- 2009 ACT FLOWS.dss
- sep2009_Carters_Allatoona_dams.dss

Since the data in these files did not overlap, most of their contents were combined into a single file named **ACT-Upper-2009-Event.dss**. In the new file, a single DUMMY INFLOW record containing a zero flow time series was created and all the records containing a zero flow time series for specifically named locations were deleted. No other records that came from the **FLOWS** file were altered. The records that were copied from the **sep2009_Carters_Allatoona_dams** file included flows at Hinton on Talking Rock Creek as well as observed data for Carters and Allatoona.

Unfortunately, the Carters and Allatoona data had location names (B-parts) that reflected their SHEF IDs rather than a descriptive names. The elevation records were plotted and it was determined which name was associated with which reservoir. With the elevation records done, the location and parameter names were changed for the other data provided for the two reservoirs. Table 21 lists the original and new pathname parts for the 2009 event data.

Table 21. Revised pathname parts for 2009 event data

Original A, B, & C-parts	New A, B, & C-parts
/COE/CRTG1/DISCHARGE/	/COOSAWATTEE RIVER/CARTERS DISCHARGE/FLOW/ or //COOSAWATTEE RIVER/CARTERS POOL/FLOW-OUT/
/COE/CRTG1/INFLOW/	/COOSAWATTEE RIVER/CARTERS INFLOW/FLOW/ or /COOSAWATTEE RIVER/CARTERS POOL/FLOW-IN/
/COE/CRTG1/ELEV/	/COOSAWATTEE RIVER/CARTERS POOL/ELEV/
/COE/CRTG1/ELTW/*	/COOSAWATTEE RIVER/CARTERS REREG POOL/ELEV/
/COE/CVLG1/DISCHARGE/	/ETOWAH RIVER/ALLATOONA DISCHARGE/FLOW/ or /ETOWAH RIVER/ALLATOONA POOL/FLOW-OUT/
/COE/CVLG1/INFLOW/	/ETOWAH RIVER/ALLATOONA INFLOW/FLOW or /ETOWAH RIVER/ALLATOONA POOL/FLOW-IN/
/COE/CVLG1/ELEV/	/ETOWAH RIVER/ALLATOONA POOL/ELEV/
* It was assumed ELTW represented tailwater elevation so that data was applied to Carters ReReg's pool elevation.	

B.6 Evaporation Data

Only one other DSS file is used by the current alternatives – the file containing the monthly/daily estimated evaporation rates for each reservoir in the ACT basin:

- ACT-EVAP_06JAN14.DSS

This is the evaporation data file used in the daily model, and it has been expanded to extend to the whole period of study: 1939-2012. The original file, ACT-EVAP.DSS, remains in the watershed, although it is not used since it only covers the 1939-2008 time period.

B.7 Cleanup of other DSS Files

Finally, three other DSS files were included in the watershed. They are not currently used in any alternatives. These files include:

- **Hackneyville.dss** - The gage record(s) for Hackneyville used by an operation for Harris and Martin.
- **Hourly Data.dss** - The original "unregulated" data used by the folks who developed the 5 exceedance probability events (I think).
- **simulation.dss** – an output file from an unknown simulation that covers a time window from 8 Sep 2009 to 7 Oct 2009.

These and all other DSS files that are no longer used by any alternatives in the model have been moved to the subfolder /**Archive** under the /**shared** folder of the watershed.

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Attachment 3. HEC-ResSim and HEC-5Q Report Simulation of Water Quality in the ACT River Basin

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FINAL REPORT

HEC-RESSIM AND HEC-5Q SIMULATION OF WATER QUALITY IN THE ALABAMA-COOSA-TALLAPOOSA RIVER BASIN

Todd E. Steissberg, Ph.D., P.E.
Water Quality and Contaminant Modeling Branch
Environmental Laboratory
U.S. Army Engineer Research and Development Center (ERDC)
707 Fourth Street, Suite 100
Davis, California 95616

Donald J. Smith, P.E.
Resource Management Associates (RMA)
1756 Picasso Avenue, Suite G
Davis, California 95618

Prepared for

U.S. Army Corps of Engineers, Mobile District

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1. INTRODUCTION

An HEC-5Q model was developed for the Alabama-Coosa-Tallapoosa (ACT) Basin in support of the Environmental Impact Statement (EIS) for the Lake Allatoona Water Supply Storage Reallocation Study and Updates to the Weiss and Logan Martin Reservoir Project Water Control Manuals. It was developed to evaluate the impacts of proposed alternative water reallocation options on long-term, system-wide, stream and reservoir water quality.

The water quality model was created to serve as a defensible screening tool to make relative comparisons of the impacts among various water management alternatives. The central focus of this effort was to enable the EIS Project Delivery Team (PDT) to evaluate the differences in water quality between alternatives over the algal growing season (spring, summer, and fall). The decision to model 70 years of record allows insight regarding the frequency and duration of water quality situations resulting from water management operations. The model was evaluated for the 2001–2008 period to best capture the effects of recent population, water usage, and land use on pollution levels. The model does not capture the total maximum daily loads (TMDLs) of pollutants and nutrients published for the Coosa River by the Alabama Department of Environmental Management in 2008. The evaluation also ensured that the model exhibited the tendencies seen in the observed data and that it was sufficient to provide reasonable long-term estimates of water quality through the ACT system. The 2001–2008 modeling period encompassed years where hydrologic conditions were representative of "normal" in-stream flows, as well as years with high flow ("wet") or drought ("dry") conditions. Point source (wastewater) and non-point source (tributary streams) inflow water quality was developed from database information compiled during this analysis.

HEC-5Q was selected for the water quality model because it is compatible with HEC-ResSim and has been used for previous analyses of the ACT system. The HEC-5Q model was developed to work seamlessly with the HEC-ResSim model used to evaluate the water management alternatives.

HEC-5Q uses well-known algorithms to compute key water quality variables including temperature, nutrients (nitrate [NO_3], ammonia [NH_3], and orthophosphate [PO_4]), phytoplankton, and dissolved oxygen (DO). The connection to HEC-ResSim makes possible relative comparisons of the water quality impacts of water management alternatives broadly across the basin.

The 1999 Comprehensive Study used HEC-5 to generate the flows that were then used as input for the HEC-5Q model (HEC 1999). These were used to model water quality of the streams in the ACT basin, using a daily time step. During the 2014 analysis, the HEC-5Q model was linked to HEC-ResSim to provide flows and other operational information.

The HEC-5Q model used for the 1999 EIS was updated to implement a 6-hour time step to capture diurnal variations, which are often important. Then the ACT model was extended to include modeling of the reservoirs themselves, adjusted to approximate the 2001–2008 observed data, and verified with additional observations in key locations.

The revised HEC-5Q model was used to make preliminary observations using present-day water quality loading parameters applied to water levels and flows for six proposed water management alternatives, including a No Action Alternative. This work was performed in close coordination with water quality and water management technical staff members from U.S. Army Corps of Engineers (USACE) Mobile District, USACE Hydrologic Engineering Center (HEC), Resource Management Associates (RMA), and Tetra Tech.

Below is a summary of the various model specifics for the current water quality modeling study.

1.1 HEC-5Q Model Assumptions and Limitations

The HEC-5Q water quality model that was initially developed (RMA 1999) and subsequently updated (RMA 2014) has been extended and updated. The major updates implemented for the current study goals were:

- Modify the model representation to include Hickory Log Creek and Richland Creek reservoirs
- Increase the spatial resolution by limiting the stream element length to approximately one mile
- Adjust the reservoir and stream limits to more closely align with HEC-ResSim
- Develop meteorological inputs based on actual 1-hour resolution data
- Use a 1-hour time step for comparison of alternatives

The HEC-5Q model was adjusted to produce reasonable results for the whole watershed under a range of conditions that were experienced over the 2001–2008 modeling period. A single set of model parameters was used for the entire period and for each model alternative to ensure consistency. The “BASE2018” HEC-ResSim results were used during this process.

The modeled flows computed by HEC-ResSim reasonably approximated the observed flows over the analysis period. However, there were periods where modeled flows did not match observed flows. This difference is due to required exceptions to normal operations in the field, such as temporary maintenance operations. This analysis did not require that these special operations or conditions be approximated by the HEC-ResSim or HEC-5Q models.

Water quality, both modeled and observed, is sensitive to the amount of flow. The hydrology of the HEC-ResSim model for the No Action (BASE2018) conditions was used in the model performance demonstration. The No Action flows are not historical discharges, and in situations where they differ substantially, it becomes very difficult to make calibration assessments. Furthermore, since the flows associated with observed concentrations do not always closely match the No Action flows, careful apportioning of the modeled flows is required to avoid unreasonable mass loadings. Because historical data were not used, this effort does not represent a true calibration. Rather, it is an attempt to represent the current operations strategies and reproduce the global response.

The daily time step HEC-ResSim model output was input to the HEC-5Q model. The HEC-5Q model for the ACT Basin does not account for the anoxic leakage around Logan Martin Dam. This flow of up to 750 cubic feet per second (cfs) of anoxic water from leakage around the dam is concerning as there are periods of low flow through Logan Martin Dam into Lay Lake. This model does not capture the impacts of this low quality flow to downstream reaches of the system. The observed water quality data for reservoirs represent the average over the euphotic zone, while the modeled data represent the surface layer. Rather than focusing on replicating super-saturated values, the adjustment of the model was conservative, focusing on minimum DO values. Differences may also be due to vertical location of the computed and observed values or the time of day measurements are taken (during peak algal production). The HEC-5Q model coefficients and parameters are within acceptable ranges, as reported in the literature. None of the model coefficients were skewed only to fit the data. Comparison with the observed data indicates that the model does a reasonable job of predicting temperature, DO, and chlorophyll *a* trends as indicated by the data, as shown in Figure 3.2 through Figure 3.11 in Chapter 3.

No special adjustments were made to the HEC-5Q model for low flow conditions. However, non-point source loadings were computed for all flows using the U.S. Environmental Protection (USEPA) Better Assessment Science Integrating Point and Non-point Sources (BASINS) model, and measured point source loadings were used, where available. One of the three hydrologic periods modeled in this analysis was a low flow period. The BASINS model provided 102 non-point tributary inflows and loadings for biochemical oxygen demand (BOD), total nitrogen (TN), and total phosphorous (TP). The BASINS model computes tributary inflows and loadings for a wide range of flows, including low flows. Point source inflows represent non-tributary inflows and include municipal and industrial discharges and cooling water returns. Agricultural returns and groundwater inflows were not considered as point sources. Monthly average flow and water quality characteristics were defined as the average of all the available measurements without regard to the time of month. If insufficient data were available, default values or relationships between parameters were used. The initial conditions of each reservoir were defined using the available data and the tendencies seen in the data. An initial stream quality was not defined but was computed from the reservoir releases after the first time step. Reservoir releases serve as the boundary condition for computing the initial water quality for the downstream reach, since reservoir residence times are significantly longer than the stream travel time. Each HEC-5Q model run was started on January 1, 2000 to provide a 1-year model initialization time. The results from year 2000 were not included in the evaluations summarized in this report.

1.2 MODEL LOADS

The non-point source water quality inputs to the HEC-ResSim and HEC-5Q models were developed from observed data in conjunction with BASINS model loads that were developed during previous ACT basin modeling efforts (USACE 1998; HEC 2014). The BASINS model computes flow and water quality (BOD, TN, and TP) as a function of precipitation, land use, antecedent conditions, and other factors. BASINS model outputs were produced for three conditions: 1995 land uses, anticipated 2020, and anticipated 2050. Each of these conditions was calculated using the 1984–1989 precipitation record. The 2020 BASINS model output was used to develop extrapolation functions that relate hydrograph dynamics and HEC-ResSim incremental local flows to concentration. The 2020 BASINS model was selected since its time period is currently the closest of the three periods to present day conditions. The extrapolation functions were then applied to the 2001–2008 HEC-ResSim flows to generate the non-point source loadings for input to the HEC-5Q model. It should be noted that the 2000 model initialization period used input data that were developed using the same procedures outlined for the 2001–2008 period. The 2020 BASINS model was not updated from the study described by HEC 2014. The PDT evaluated using updated BASINS models. However, the time periods of the BASINS models from Alabama and Georgia did not line up with the time period of the HEC-5Q model used for this study. However, the 2020 BASINS model was applied identically and consistently to all alternatives.

Default loading values were assumed, as outlined in Section 1.3 where these were not available from municipal or industrial dischargers. When point source data were available, these consisted of one value per month. These monthly data provided a seasonal pattern to the inflow quality, but day-to-day variations are not captured. Since constant loading values were used instead of time series of the actual values and modeled instead of observed flows were used as inputs, the HEC-5Q model was not expected or required to replicate individual historic concentration values. Adjusting the model to replicate individual extreme values and particular times and locations can compromise the ability of the model to provide reasonable estimates for the majority of time periods throughout the system. Therefore, the focus of this analysis was to achieve reasonable responses over the system for the entire analysis period, using a consistent set of model coefficients.

1.3 ALTERNATIVE REALLOCATION OPTIONS

To analyze the range of potential impacts of water reallocation, six potential project alternatives were evaluated in the HEC-5Q model:

- Alternative 0 (BASE2018) – This is the No Action alternative, which represents a set of assumptions and conditions that would occur absent any additional action by USACE. The No Action Alternative assumes water withdrawals in the ACT River Basin at year 2006 levels, the year of highest water withdrawals in the basin, and applies the USACE storage accounting methodology.

- Alternative 2 (A02-FWOP) – This is the Future Without Project alternative, which represents a set of assumptions and conditions that would occur in the future absent any action by USACE. This includes no additional reallocation of storage at Allatoona Lake but does include increased water supply demands through year 2050. Systemwide operations are those that were approved in the 2015 ACT River Basin Water Control Manual (WCM) update.

- Alternative 3 (A03-WS1) – This alternative includes a storage reallocation from Allatoona Lake for up to 94 million gallons per day (MGD) from conservation storage and applies the storage accounting methodology proposed by the State of Georgia. Systemwide operations are those that were approved in the 2015 Alabama-Coosa-Tallapoosa (ACT) River Basin WCM update.

- Alternative 9 (A09-FWOPMF) – This alternative represents a set of assumptions and conditions that would occur in the future, including satisfying the requested modifications to Weiss and Logan Martin project flood operations. Systemwide operations are those that were approved in the 2015 ACT River Basin WCM update. The alternative does not include the proposed storage reallocation at Allatoona Lake and continues to apply the current USACE storage accounting methodology to existing water supply storage agreements at Allatoona Lake.

- Alternative 10 (A10-WS2MF) – This alternative represents a set of assumptions and conditions that would occur in the future including satisfying the requested modifications to Weiss and Logan Martin projects flood operations as well as meeting the full need from the State of Georgia request out of Allatoona Lake. The full need would be met out of the conservation pool. It also applies the USACE storage accounting methodology.

- Alternative 11 (A11-WS6MF) – This alternative is the Tentatively Selected Plan (TSP), which represents a set of assumptions and conditions that would occur in the future including satisfying the requested modifications to Weiss and Logan Martin projects flood operations as well as meeting the full need from the State of Georgia request out of Allatoona Lake. The full need would be met out of a combination reallocation from the conservation and flood pools. It also applies the USACE storage accounting methodology.

1.4 HYDROLOGIC CONDITIONS

To evaluate the effects of the six alternatives on the water quality of the ACT system, three different hydrologic conditions were selected for analysis. The year 2002 was selected to represent normal hydrologic conditions, 2003 was selected to represent flood (“wet”) conditions, and 2007 was selected to represent drought (“dry”) conditions. These selections were based on an analysis of 2001–2008 flow data recorded on the Coosa River at the Alabama-Georgia state line, the Tallapoosa River at Jordan-Bouldin-Thurlow (JBT) projects goal, and at the Alabama River and Pulp Mill (ARP). The year 2002 corresponded to the median flow levels, while 2003 and 2007 corresponded to the highest and lowest flow levels, respectively, during the 2001–2008 model period. In addition, the 2001–2008 model period was summarized, plotting “composite” longitudinal river profiles of each water quality parameter. The tabular comparisons of alternatives considered the entire 2001–2008 period to ensure that critical periods in the remaining years were not missed. The analysis periods are shown in Table 1.1.

Table 1.1. Hydrologic conditions and associated analysis years.

Hydrologic Conditions	Representative Year
Normal	2002
Flood (“Wet”)	2003
Drought (“Dry”)	2007
Composite	2001–2008

Each of these options was evaluated using the HEC-5Q water quality model. The evaluation used non-point source pollutant loads developed from observed data in conjunction with BASINS model loadings that were developed during the 1998 and 2014 ACT studies (RMA 1998, HEC 2014).

1.5 PROJECT OBJECTIVES

The purpose of this analysis was to evaluate the impacts of the proposed alternatives on long-term, system-wide, stream and reservoir water quality of the ACT system. The focus of this effort was to enable the EIS PDT to evaluate the differences in water quality between alternatives over the phytoplankton growing season. The principal water quality constituents simulated were temperature, NH_3, NO_3, PO_4, phytoplankton (reported as chlorophyll *a*), DO, and 5-day Uninhibited BOD (BOD5U). In addition, the percentage of flow consisting of municipal or industrial wastewater was modeled.

1.6 REPORT ORGANIZATION

Modifications made in the previous version of HEC-5Q model are described in this report. A description of the model is presented in Chapter 2 including a discussion of representation of the physical system with the model, input provided to the model, and water quality constituents simulated. A demonstration of model performance results is presented in Chapter 3. Results of the water quality model runs are presented in Chapter 4. The results of the water quality parameter sensitivity analysis are summarized in Chapter 5. The climate change sensitivity results are included in Chapter 6.

2. MODEL DESCRIPTION

The HEC-5Q model was developed so that temperature and selected conservative and non-conservative constituents could be included as a consideration in system planning and management. Using computed reservoir operations and system flows generated by the HEC-ResSim model, the HEC-5Q model computes the distribution of temperature and other constituents in the reservoirs and in the associated downstream reaches. For those constituents modeled, the water quality model can be used in conjunction with the HEC-ResSim model to determine concentrations resulting from operation of the reservoir system for flow and storage considerations, or alternately, flow rates necessary to meet water quality objectives.

The HEC-5Q model can be used to evaluate options for coordinating reservoir releases among projects to examine the effects on flow and water quality at specified locations. Examples of applications of the flow simulation model include examination of reservoir capacities for flood control, hydropower, and reservoir release requirements to meet water supply and irrigation diversions. The model may be used to evaluate in-stream temperatures and constituent concentrations at critical locations in the system or examine the potential effects of changing reservoir operations or water use patterns on temperature or water quality constituent concentrations. Reservoirs equipped with selective withdrawal structures may be simulated using the HEC-5Q model to determine operations necessary to meet water quality objectives downstream. The HEC-5Q model can be used to simulate concentrations of various combinations of a wide range of water quality constituents. For the ACT analysis, the following parameters were modeled.

- Temperature
- Point source tracer
- DO
- NH_3 – Nitrogen
- NO_3 – Nitrogen
- PO_4 – Phosphorus
- Phytoplankton – Chlorophyll *a*
- Point source dissolved organics as BOD
- Non-point source dissolved organics as BOD
- Particulate organic matter (POM) as Total Suspended Solids (TSS)

These parameters are assumed to be passively transported by advection and diffusion. All rate coefficients regulating the parameter kinetics are temperature dependent. A brief description of the processes affecting each of these parameters is provided below. Additional documentation of hydrodynamics, transport and water quality kinetics are presented in various reports (HEC 1999).

2.1 TEMPERATURE

The external heat sources and sinks that are considered in the HEC-5Q model are assumed to occur at the air-water interface and with the riverbed. The exchange with the bed through conductance moderates diurnal temperatures variations. The bed heat capacity is expressed as an equivalent water thickness. The method used to evaluate the net rate of heat transfer uses the concepts of equilibrium temperature and coefficient of surface heat exchange. The equilibrium temperature is defined as the water temperature at which the net rate of heat exchange between the water surface and the overlying atmosphere is zero. The coefficient of surface heat exchange is the rate at which the heat transfer process proceeds. All heat transfer mechanisms, except short-wave solar radiation, are applied at the water surface. Short-wave radiation penetrates the water surface and may affect water temperatures several meters below the surface. The depth of penetration is a function of adsorption and scattering properties of the water.

2.2 Point Source Tracer

The point source tracer is a tag assigned to all point discharges. A value of 100 is assigned so that the concentration of the tracer translates to the percentage of point discharge water at any location. For this analysis, no distinction is made between the types of point discharges.

2.3 Ammonia - Nitrogen

NH_3 is a plant nutrient and is consumed with phytoplankton growth. The remaining ammonia sink is decay. Sources of ammonia include phytoplankton respiration, TSS and dissolved organic matter (DOM) decay, and aerobic and anaerobic release from bottom sediments.

2.4 Nitrate - Nitrogen

NO_3 is a plant nutrient and is consumed with phytoplankton growth. The remaining NO_3 sink is denitrification associated with suboxic processes. Decay of ammonia provides a source of NO_3 (nitrite [NO_2] formation phase is ignored). It should be noted that much of the sampling data are reported as total NO_2NO_3-N.

2.5 Orthophosphate - Phosphorus

Phosphorus is the third plant nutrient considered in the model and is consumed with phytoplankton growth. PO_4 tends to sorb to suspended solids and is subject to loss by settling. Sources of phosphorus include phytoplankton respiration, TSS and DOM decay, and aerobic release from bottom sediments.

2.6 Phytoplankton - Chlorophyll *a*

Photosynthesis acts as a phytoplankton source that is dependent on PO_4, NH_3, and NO_3. Carbon limitation was not considered. Photosynthesis is therefore a sink for these nutrients. Conversely, phytoplankton respiration releases PO_4 and NH_3. Phytoplankton is an oxygen source during photosynthesis and an oxygen sink during respiration. Phytoplankton growth rates are a function of the limiting nutrient (or light) as determined by the Michaelis-Menten formulation. Respiration, settling and mortality are phytoplankton sinks.

The HEC-5Q model uses phytoplankton as a state variable. The relationship between phytoplankton biomass and chlorophyll *a* is variable by speciation, available light, and other environmental factors. The model does not include assumptions of algal speciation. All tabular and plot references to phytoplankton or chlorophyll *a* assume a ratio of 10 µg/L chlorophyll *a* to 1 mg/L phytoplankton biomass (dry weight). This 1:100 ratio corresponds to a chlorophyll *a* to carbon ratio of 1:45 assuming a 45% carbon ratio for phytoplankton. Nutrient interactions with phytoplankton assume a chemical composition of 0.01 and 0.08 for phosphorus and nitrogen, respectively, or chlorophyll *a* to phosphorus and chlorophyll *a* to nitrogen ratios of 1 and 8 respectively. These values are in line with CE-QUAL-R1 (USACE Waterways Experiment Station 1986) guidelines.

2.7 DISSOLVED OXYGEN

Exchange of DO at the water surface is a function of the surface exchange (reaeration) rate that is determined by wind speed in reservoirs and hydraulic characteristics in streams. Reaeration below hydropower facilities is represented by a source proportional to the oxygen deficit. For selected APC reservoirs, a 4 mg/L minimum is imposed to account for forced aeration facilities. Phytoplankton photosynthesis is a source of DO. Sinks for DO include DOM, TSS and NH_3 decay, phytoplankton respiration, and benthic uptake. The total oxygen consumption potential is computed as BOD5U as a model output.

2.8 DISSOLVED ORGANICS (BOD)

DOM represents all materials that exert an oxygen demand (BOD) during decay and transformation to their chemical components. Thus, they contribute to dissolved nitrogen and phosphorus. The dissolved material is subdivided into point and non-point origin to add flexibility in assigning decay rates. It is also a measure of point source influence that considers decay and source quality.

2.9 ORGANIC PARTICULATE (TSS)

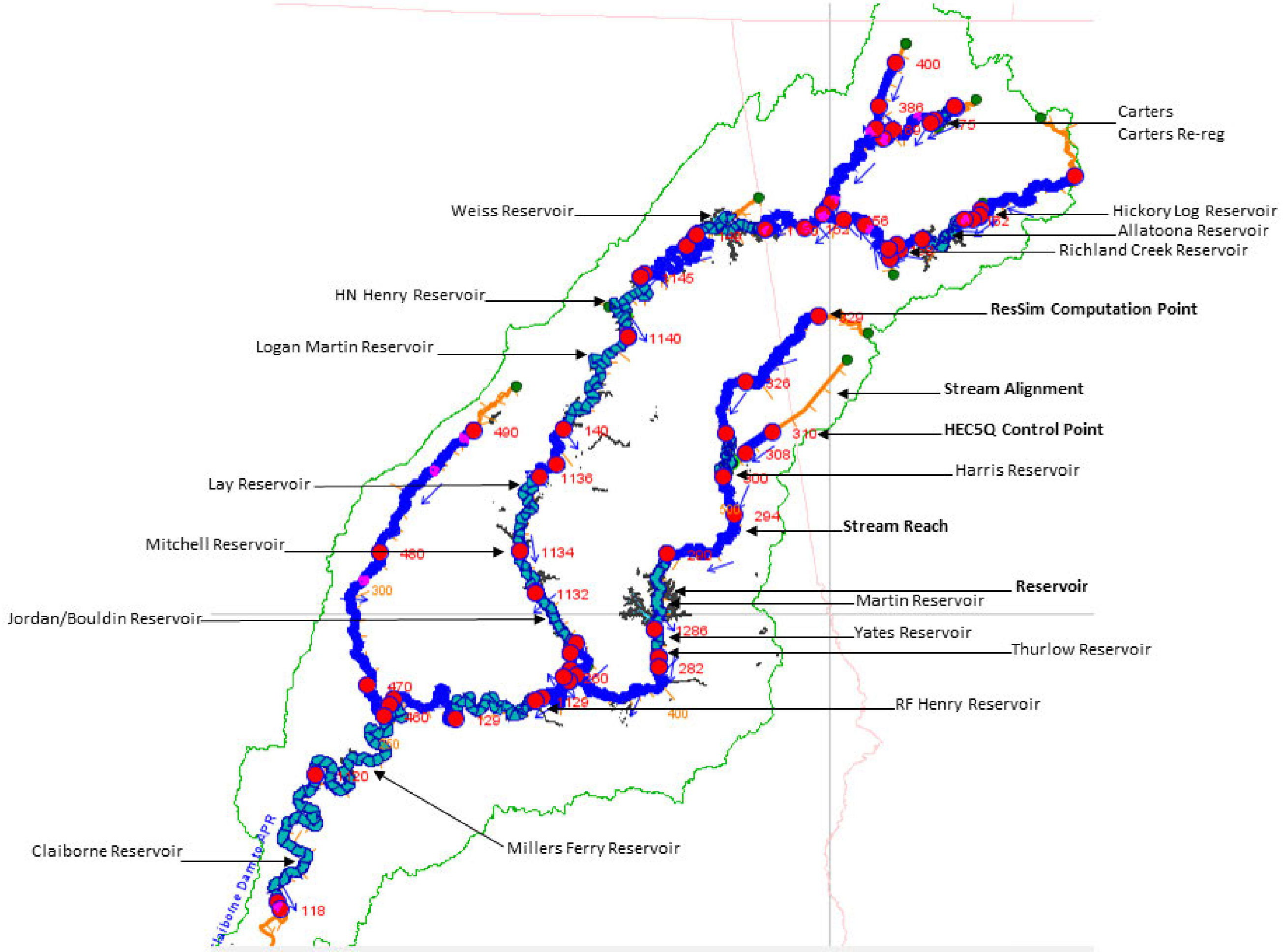
Sources of TSS include a component of phytoplankton mortality. TSS also exerts an oxygen demand (BOD) during decay and transformation to its chemical components. TSS sinks include decomposition to phosphate and ammonia. TSS is also subject to settling. Oxygen uptake associated with TSS decay is represented by BOD.

TSS levels recorded at major discharge locations were predominantly POM. A strong relationship was found between TSS and BOD. All major discharge sites measured BOD. There were nine dischargers with flows greater than 5 MGD and six dischargers with flows greater than 10 MGD. For flows greater than 5 MGD, 82% of reported measurements (255 out of 311) contained BOD. For flows greater than 10 MGD, 93% of reported measurements (216 out of 232) had BOD. The remainder of these measurements contained TSS only. Therefore, the TSS to BOD relationship was primarily applied to small discharge sites (flows less than 5 MGD), which have a minor impact on the system.

2.10 MODEL REPRESENTATION OF THE PHYSICAL SYSTEM

Reservoirs and rivers comprising the ACT system were represented as a network of reservoirs and streams and discretized into sections, as shown in Figure 2.1 and Figure 2.2.

Flow and water quality were simulated by HEC-ResSim and HEC-5Q models, respectively. In the HEC-5Q model, stream elements are assumed to be well mixed. Stream reaches are typically partitioned into computational elements of approximately one mile or less in length. Because of the simplified geometry, lateral cross-stream variations cannot be evaluated, and longitudinal variations are limited to the element length. Likewise, the reservoir elements are assumed laterally mixed so that isolated water quality at the distal ends of arms of the lake is not represented. Area-capacity curves come from the HEC-ResSim model output. Other geometry (outlets, etc.) were taken from the 1998 HEC-5 model.



Note: The red numbers and markers are control points of the HEC-5Q model, not river miles.

Figure 2.1. HEC-5 and HEC-5Q model schematic of the ACT basin showing reservoirs.

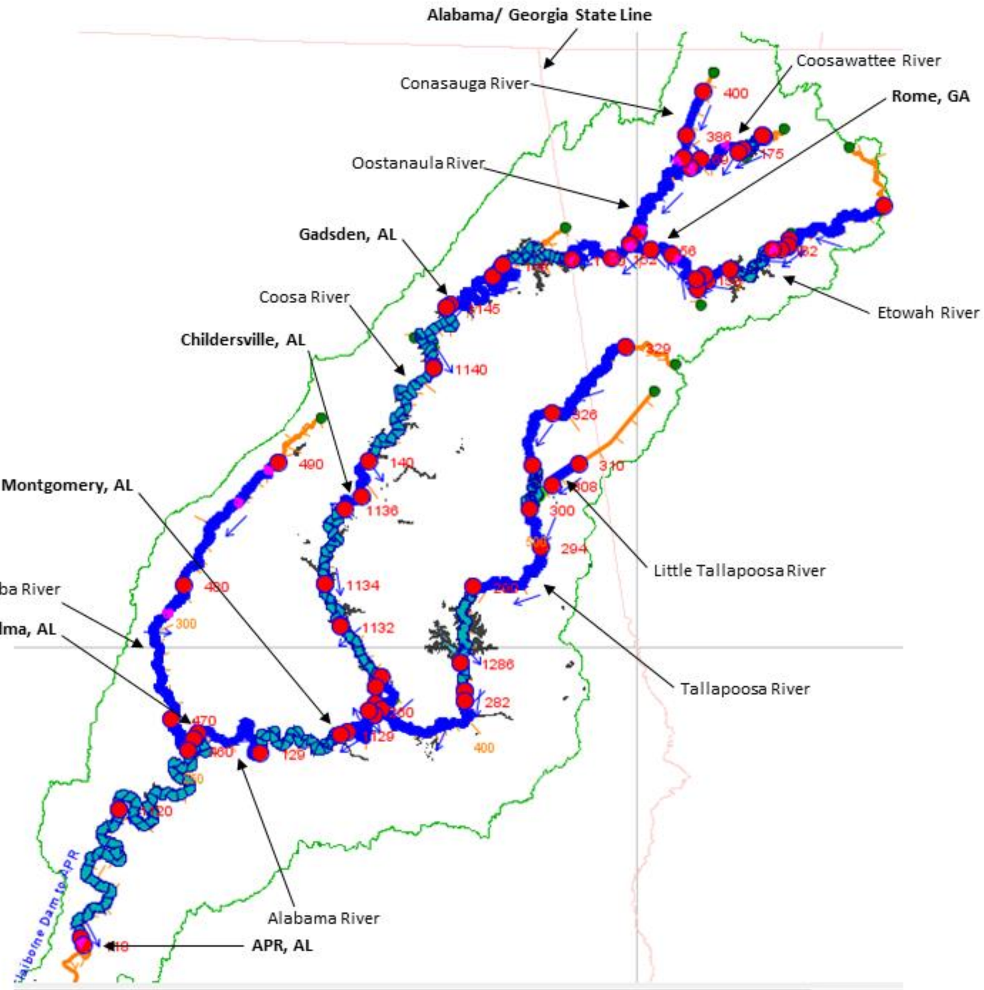


Figure 2.2. HEC-5 and HEC-5Q model schematic of ACT basin showing rivers and prominent locations.

2.10.1 MODEL REPRESENTATION OF RESERVOIRS

For water quality simulations, each reservoir was geometrically discretized and represented as either vertically segmented and laterally averaged or longitudinally segmented and vertically layered. Four ACT reservoirs (Lake Allatoona, Carters Lake, R. L. Harris Lake, and Martin Lake) are represented as vertically segmented and laterally averaged. These reservoirs are characterized by stronger thermal stratification and longer hydrologic residence times. All other reservoirs are longitudinally segmented and are characterized by weaker thermal stratification and shorter residence time (run of river reservoirs). A description of the different types of reservoir representation follows. A list of all reservoirs and their geometric representations are shown in Table 2.1. Inflows and tributaries are presented in Appendix A. The equations used by the HEC-5Q model for each configuration are listed in HEC 1986.

2.10.1.1 Vertically Segmented Reservoirs

Vertically stratified reservoirs are represented conceptually by a series of one-dimensional horizontal slices or layered volume elements, each characterized by an area, thickness, and volume. In the aggregate the assemblage of layered volume elements is a geometrically discretized representation of the prototype reservoir. Within each horizontal layer of a vertically segmented reservoir, or layered volume element, the water is assumed to be fully mixed with all isopleths parallel to the water surface both laterally and longitudinally. External inflows and withdrawals occur as sources or sinks within each element and are instantaneously dispersed and homogeneously mixed throughout the layer from the headwaters of the impoundment to the dam. Consequently, simulation results are most representative of conditions in the main reservoir body and may not accurately describe flow or quality characteristics in shallow regions or near reservoir banks. It is not possible to model longitudinal variations in water quality constituents using the vertically segmented configuration.

Vertical advection is one of two transport mechanisms used in the HEC-5Q model to simulate transport of water quality constituents between elements in a vertically segmented reservoir. Vertical transport is defined as the inter-element flow that results in flow continuity and is calculated as the algebraic sum of inflows to and outflows from each layer beginning with the lowest layer in the reservoir. Any flow imbalance is accounted for by vertical advection into or out of the layer above, a process that is repeated for all layers in the reservoir. At the surface layer, an increase or decrease in reservoir volume accounts for any resulting flow imbalance.

An additional transport mechanism used to distribute water quality constituents between elements is effective diffusion, representing the combined effects of molecular and turbulent diffusion, and convective mixing or the physical movement of water due to density instability. Wind and flow-induced turbulent diffusion and convective mixing are the dominant components of effective diffusion in the epilimnion of most reservoirs.

The outflow component of the model incorporates the selective withdrawal techniques developed by Bohan and Grace (1973) for withdrawal through a dam outlet or other submerged orifice, or for flow over a weir. The relationships developed for the 'WES Withdrawal Allocation Method' describe the vertical limits of the withdrawal zone and the vertical velocity distribution throughout the water column. The withdrawal zone limits and the corresponding velocity profile are calculated as a function of the water temperature distribution with depth in a stratified reservoir. In the HEC-5Q model, the approach velocity profile is approximated as an average velocity in each layer just upstream of a submerged weir or a dam with a submerged orifice. The computed velocity distribution is then used to allocate withdrawals from each layer. Detailed descriptions of the WES Withdrawal Allocation Method and weir formulation are provided in the HEC-5 Appendix on Water Quality (HEC 1998). Carters Lake, Lake Allatoona, R. L. Harris Lake, and Lake Martin are examples of vertically segmented reservoirs in the ACT model (Figure 2.3).

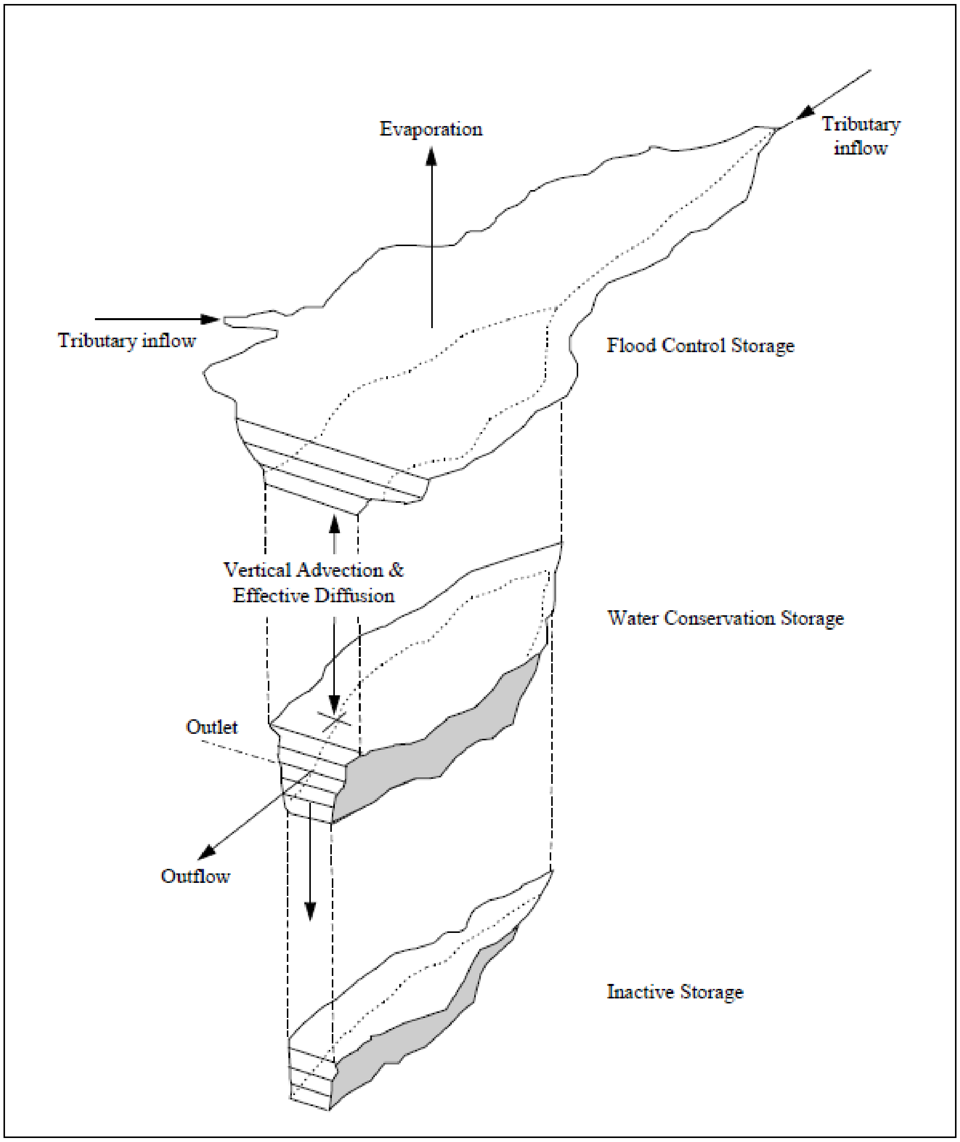


Figure 2.3. Schematic representation of a vertically segmented reservoir (HEC 1986).

2.10.1.2 Vertically and Longitudinally Segmented Reservoirs

Longitudinally segmented reservoirs are represented conceptually as a linear network of a specified number of segments or volume elements. Length and the relationship between width and elevation characterize the geometry of each reservoir segment. The surface areas, volumes and cross-sections are computed from the width relationship.

Longitudinally segmented reservoirs may be subdivided into vertical elements with each element assumed fully mixed in the vertical and lateral directions. Branching of reservoirs is allowed. For reservoirs represented as layered and longitudinally segmented, all cross-sections contain the same number of layers and each layer is assigned the same fraction of the reservoir cross-sectional area. The model performs a backwater computation to define the water surface profile as a function of the hydraulic gradient based on flow and Manning's equation.

External flows such as withdrawals and tributary inflows occur as sinks or sources. Inflows to the upstream ends of reservoir branches are allocated to individual elements in proportion to the fraction of the cross-section assigned to each layer. Other inflows to the reservoir are distributed in proportion to the local reservoir flow distribution. External flows may be allocated along the length of the reservoir to represent dispersed, or non-point, source inflows including agricultural drainage or groundwater accretions.

The longitudinally segmented reservoirs of the ACT system contain up to eight layers (Figure 2.4). The layered representation was used for all reservoirs that had the potential for both horizontal and vertical gradients in flow, temperature and water quality.

Vertical variations in constituent concentrations are computed for each cell of the layered and longitudinally segmented reservoir model. Mass transport between vertical layers is represented by net flow determined by mass balance and by diffusion.

Vertical flow distributions at dams are based on weir or orifice withdrawal. The velocity distribution within the water column is calculated as a function of the water density and depth using the WES weir withdrawal or orifice withdrawal allocation method (Bohan and Grace 1973). The HEC-5Q model uses an elemental average of the approach velocity for each layer in the reservoir.

A uniform vertical flow distribution is specified at the upstream end of each reservoir and at any intermediate location. Linear interpolation of flow is performed for reservoir segments without specifically defined flow fields (e.g., interpolation between flows at the dam face and the defined intermediate location). Table 2.1 summarizes the discretization of all reservoirs in the ACT model, listing the number of segments and layers in each longitudinally segmented reservoir and the layer thickness of each vertically segmented reservoir.

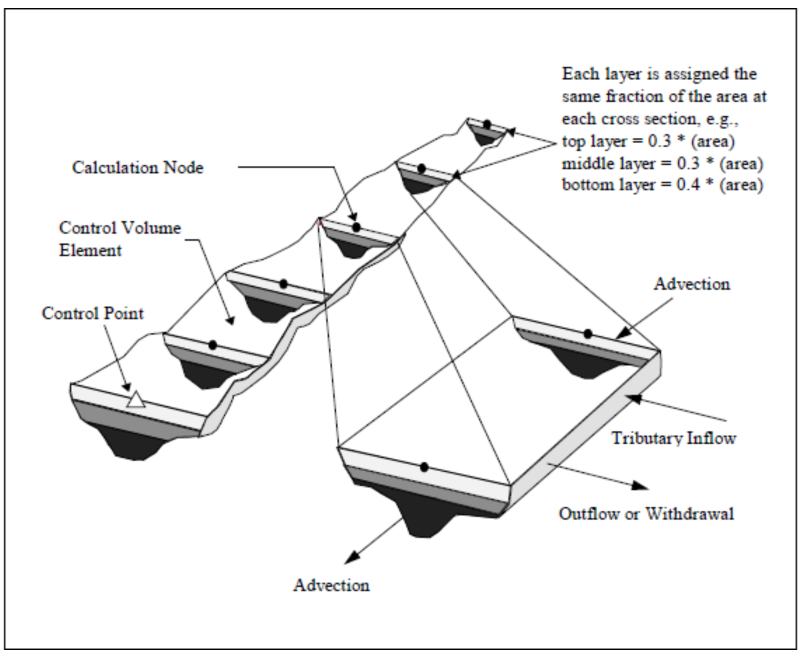


Figure 2.4. Schematic representation of a layered and longitudinally segmented reservoir (HEC 1986).

Table 2.1 Summary of reservoir discretization.

River/ Reservoir	Reservoir Type	# of Segments/ Layer Thickness (ft)	# of Layers
Etowah River			
Allatoona	Vertical	3	Varies with lake level
Hickory Log Creek	Vertical	3	Varies with lake level
Richland Creek	Vertical	3	Varies with lake level
Coosawattee River			
Carters	Vertical	3	Varies with lake level
Carters re-reg	Longitudinal	6	1
Coosa River			
Weiss	Branched Longitudinal	19	8
H.N. Henry	Branched Longitudinal	17	5
Logan Martin	Longitudinal	21	5
Lay	Longitudinal	14	5
Mitchell	Longitudinal	7	5
Jordan/Bouldin	Longitudinal	10	5
Tallapoosa River			
R. L. Harris	Vertical	3	Varies with lake level
Martin	Vertical	3	Varies with lake level
Yates	Longitudinal	4	4
Thurlow	Longitudinal	2	4
Alabama River			
R.F. Henry	Longitudinal	20	5
Millers Ferry	Branched Longitudinal	29	5
Claiborne	Longitudinal	19	5

2.10.2 MODEL REPRESENTATION OF STREAMS

In the HEC-5Q model, a reach of a river or stream is represented conceptually as a linear network of segments or layered volume elements. Each element is characterized by its length, depth, width, and cross-sectional area. The depth is defined as a function of flow, and the cross-section areas and widths are subsequently defined as a function of the depth. Stream flow, diversion, and incremental inflow rates are provided by the HEC-ResSim model at stream control points. The total incremental local inflow is divided into components and placed at the actual inflow locations of the non-point source inflow. The diversion defined by the HEC-ResSim model represents the net point source inflow above the control point. The individual point source inflows and withdrawals are assigned to the location of the discharge or diversion. A flow balance is used to determine the flow rate at element boundaries. Once inter-element flows are established, the water depth, surface width, and cross-sectional area is defined at each element boundary as a function of the user specified flow-depth relationship. A list of all stream reaches and point and non-point source inflows and water quality is provided in Appendix A.

2.11 Water Quality Boundary Conditions and Input Data

The HEC-5Q model requires that in-stream flows, tributary flows and water quality, withdrawals, reservoir operations, and other point and non-point source flows and water quality loads to the system be specified for simulation of water quality.

The HEC-ResSim model incremental inflows are determined by difference from available and/or synthesized river flows, reservoir operation, and point source inflows. This process may result in computed inflows that are negative. This approach assumes that the observed/synthesized flows are the best depiction of historical inflow conditions. Negative inflows do not present a problem for the HEC-ResSim model.

Negative inflows are a problem, however, from a water quality perspective in that the inflow quality must be defined while the negative inflow removes ambient water quality. As an example, if a -100 cfs is followed by a +100 cfs to represent an inflow of near zero, an artificial tributary load is introduced on the +100 cfs day. To mitigate this effect, the water quality load is computed from an inflow rate that is constrained as positive. An example of 7-day average (with negative flows) and constrained Weiss reservoir inflows is provided in Figure 2.5, with a detail view of 2001 in Figure 2.6. In some instances, the constrained inflow is developed by aggregating two or more sets of HEC-ResSim model incremental inflows. The rate of decrease is further limited to 67% of the previous day’s flow. Residual negative inflows are allocated to future positive inflow. Aggregation occurs when adjacent control points have erratic local flows or when one of the local flows has extensive negative inflows. An example of this approach is shown in Figure 2.7 where the inflow to H. Neely Henry (H.N. Henry) Lake has extensive negative inflow periods. The inflows to H.N. Henry and Logan Martin Lakes are combined and then constrained to the 67% decrease. The scaled flows are then allocated to individual tributaries proportional to tributary inflow as computed by BASINS.

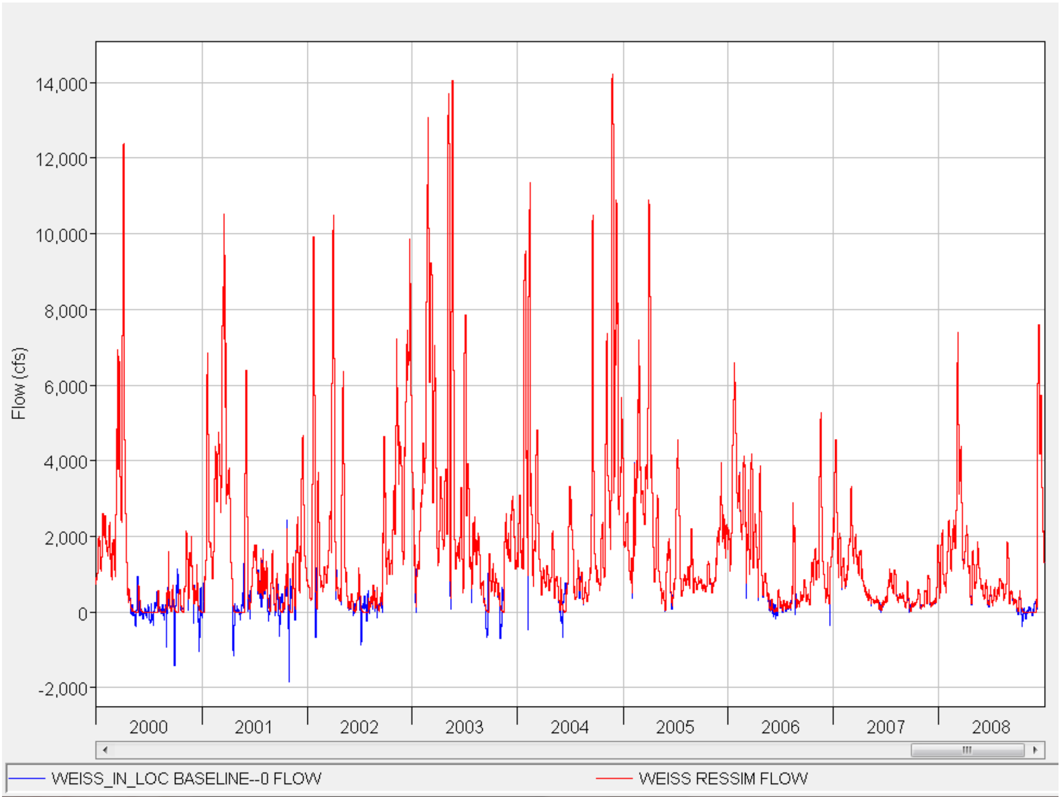


Figure 2.5. Comparison of the 7-day averages of unconstrained (blue line) and constrained (red line) inflows to Weiss Reservoir. The constrained inflows eliminate negative values.

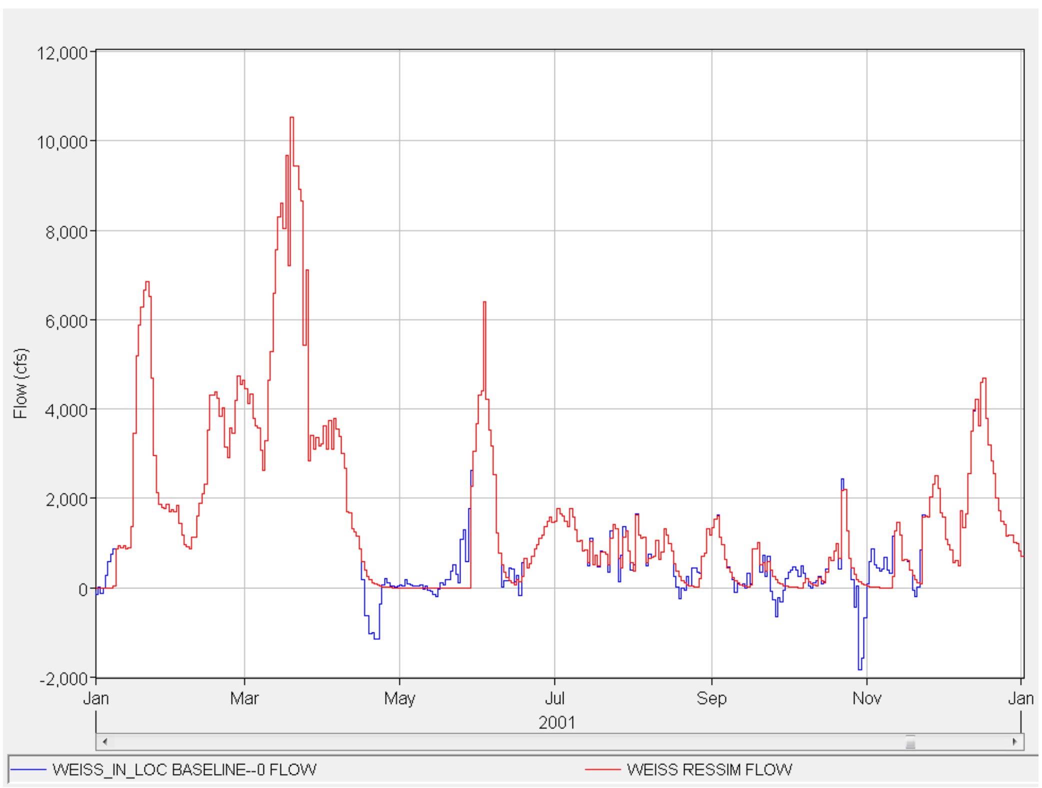


Figure 2.6. Inflow comparison from Figure 2-5, showing detail for the year 2001.

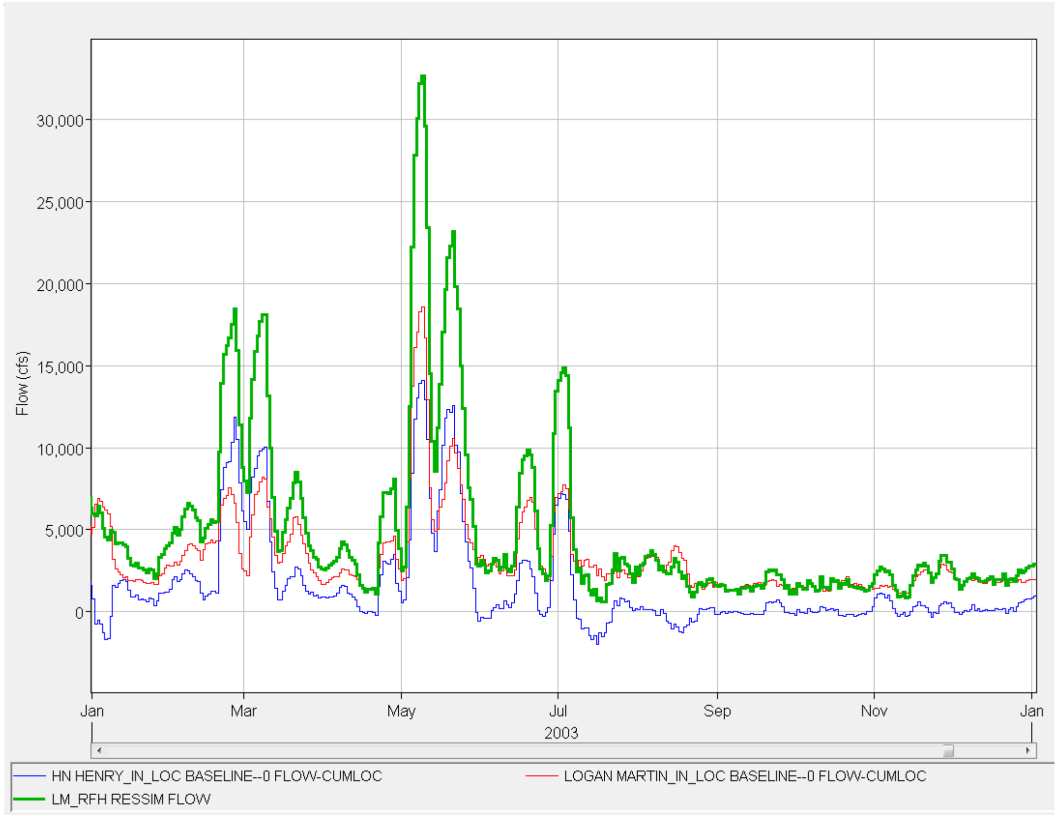


Figure 2.7. Inflows to H.N. Henry Lake (blue) and Logan Martin Lake (red) and combined and constrained H.N. Henry and Logan Martin ResSim flows (green).

2.11.1 Non-point Source Flow and Water Quality Data

As noted in the introduction to this section, the 2020 BASINS model was selected since its time period is currently the closest to present day conditions. The extrapolation functions were applied to the 2001–2008 HEC-ResSim model flows to generate the non-point source loadings for input to the HEC-5Q model. Output for 200 ACT BASINS watersheds was available. These watersheds were consolidated to define 102 non-point source inflows for the current HEC-5Q modeling effort. The watersheds/stream names and corresponding stream/ inflow locations can be found in Appendix A.

The HEC-5Q model of the ACT was designed to use flows computed by the HEC-ResSim model for the 1939–2008 period of record. The tributary flows and water quality computed by BASINS for the 1984–1989 period served as a basis for estimating the response of water quality parameters to tributary stream flow dynamics and for extrapolating a comparable record for the 1939–2008 HEC-ResSim model simulation period. However, all the HEC-5Q model simulations were performed for the 2000–2008 period with the results for 2000 considered as model initialization.

The intent of the extrapolation was to establish the shape of the water quality response to flow. The extrapolation assumed that the inflowing concentration is influenced by the rate of change in flow. On the rising hydrograph, the concentration was computed as:

$$C = C_o + K_1 * (\log Q_t - \log Q_{t-1})$$

Where: C = Concentration
C_o = Minimum concentration
K_1 = Scaling factor
Q_t = Flow for current day
Q_{t-1} = Flow for previous day

On the falling hydrograph, the concentration was computed as a fraction of the previous day's concentration. For example:

$$C = C_o + K_2 * (C_{t-1} - C_o)$$

Where: C = Concentration
C_o = Minimum concentration
K_2 = Scaling factor
C_{t-1} = Concentration for previous day

The extrapolated water quality was computed as a function of HEC-ResSim model-based flows to align the inflow concentration with the HEC-ResSim model inflow hydrographs. The C and K values were selected such that the concentration range, magnitude, and response to flow dynamics were in line with those predicted by the BASINS model.

Water quality field data for eight tributaries to the upper ACT basin rivers were compared with the BASINS-based water quality for the 2001–2008 period. The fraction of TN allocated to NO_3 and NH_4 was based on these observations.

Tributaries to the upper ACT:

1. Mountaintown Creek (15) [1]
2. Armuchee Creek (25)
3. Shoal Creek (6)
4. Little River (8)
5. Raccoon Creek (11)
6. Euharlee Creek (12)
7. Beech Creek (27)
8. Chattooga River (30)

The observed data for these tributaries include the following water quality parameters:

1. BOD5U
2. DO

[1] The numbers in parentheses correspond to the tributary numbers within the HEC-5Q data set.

3. NH_3
4. NO_2NO_3
5. TOTALP
6. SOLIDTSS
7. TEMP
8. Chlorophyll *a* [2]

Table 2.2 provides a summary of available observed data, including number of samples and average, maximum, minimum, and median values for the above listed tributaries and parameters. The ratio of average to the median value is also included to identify those parameters where the average is overly weighted by a few extreme measurements. Parameters such as TP and TSS are examples of parameters where the average concentration is elevated relative to the median value. The sample weighted averages for the eight tributaries is also included.

Average non-point source inputs to the model are provided in Table 2.3. Full tables of maximum, minimum, and average values can be found in Appendix A.

[2] All references to chlorophyll *a* assume a ratio of 10 ug/L chlorophyll *a* to 1 mg/L phytoplankton biomass (dry weight).

Table 2.2. Summary of available observed data for non-point source inflow water quality for the 2000–2008 period.

	BOD5U (mg/L)	OXYGEN (mg/L)	NH3-N (mg/L)	NO2+NO3-N (mg/L)	Total P (mg/L)	TSS (mg/L)	Temp. (C)	Chlorophyll a (ug/L)
Mountaintown Creek at State Road 282 (US Hwy 76) near Ellijay, Ga.								
Samples	94	147	79	91	89	65	147	18
Avg	1.50	10.14	0.033	0.110	0.052	16.00	14.44	2.63
Min	0.10	7.64	0.010	0.040	0.012	1.00	2.40	0.80
Max	2.85	14.32	0.100	0.260	0.720	506.00	25.99	9.70
Median	2.00	9.88	0.030	0.101	0.020	6.00	15.08	2.10
Avg/Median	1.33	0.98	0.919	0.921	0.381	0.38	1.05	0.80
Armuchee Creek at Old Dalton Road near Rome, Ga.								
Samples	43	62	35	35	35	37	62	15
Avg	1.18	8.18	0.035	0.253	0.031	15.47	19.81	3.41
Min	0.00	6.06	0.010	0.050	0.020	1.00	4.80	1.00
Max	7.38	24.57	0.120	0.980	0.185	130.00	27.10	21.10
Median	0.83	7.56	0.030	0.240	0.020	11.50	21.86	1.90
Avg/Median	0.70	0.92	0.853	0.947	0.645	0.74	1.10	0.56
Shoal Creek at State Road 108 (Fincher Rd.) near Waleska, Ga.								
Samples	91	156	76	88	87	59	156	18
Avg	1.41	9.37	0.036	0.154	0.043	13.91	14.79	2.52
Min	0.10	5.67	0.010	0.020	0.015	1.00	2.02	0.70
Max	3.50	13.60	0.100	0.320	0.700	362.00	25.54	5.60
Median	1.45	9.21	0.030	0.170	0.020	5.00	15.10	2.20
Avg/Median	1.03	0.98	0.823	1.105	0.462	0.36	1.02	0.87
Little River at Georgia Highway 5 near Woodstock, Ga.								
Samples	91	156	76	88	86	91	156	18
Avg	1.65	8.88	0.113	0.843	0.080	25.83	15.73	3.59
Min	0.10	5.50	0.020	0.100	0.020	1.00	1.90	1.30
Max	6.30	13.20	0.530	6.800	0.660	240.00	25.90	11.90
Median	1.85	8.70	0.076	0.430	0.060	14.00	16.40	2.80
Avg/Median	1.12	0.98	0.672	0.510	0.750	0.54	1.04	0.78
Raccoon Creek at State Road 113 near Stilesboro, Ga.								
Samples	12	45	12	12	12	12	45	1
Avg	0.53	7.92	0.025	0.415	0.026	14.50	18.49	2.00
Min	0.20	5.40	0.010	0.160	0.020	1.00	4.10	2.00
Max	1.20	12.10	0.030	0.540	0.080	100.00	25.93	2.00
Median	0.40	7.54	0.030	0.450	0.020	7.00	19.52	2.00
Avg/Median	0.75	0.95	1.200	1.084	0.774	0.48	1.06	1.00
Euharlee Creek at County Road 32 near Stilesboro, Ga.								
Samples	42	35	36	36	36	37	35	14
Avg	1.09	8.14	0.038	0.690	0.116	24.38	18.28	2.41
Min	0.30	6.70	0.010	0.236	0.020	3.00	8.10	0.70
Max	2.85	10.30	0.160	1.440	0.410	112.00	24.14	11.30
Median	0.98	7.90	0.030	0.660	0.100	15.50	19.72	1.50
Avg/Median	0.90	0.97	0.794	0.957	0.859	0.64	1.08	0.62
Beech Creek at Mays Bridge Road SW near Rome, Ga.								
Samples	64	68	48	56	57	58	68	12
Avg	1.48	5.44	0.043	0.150	0.037	9.85	18.47	3.36
Min	0.00	2.14	0.018	0.020	0.019	1.00	7.80	1.10
Max	5.14	10.20	0.110	0.303	0.120	36.00	25.13	6.90
Median	1.29	5.20	0.032	0.150	0.028	9.50	19.62	2.50
Avg/Median	0.87	0.96	0.746	1.003	0.756	0.97	1.06	0.74

Table 2.2 (continued). Summary of available observed data for non-point source inflow water quality for the 2000–2008 period.

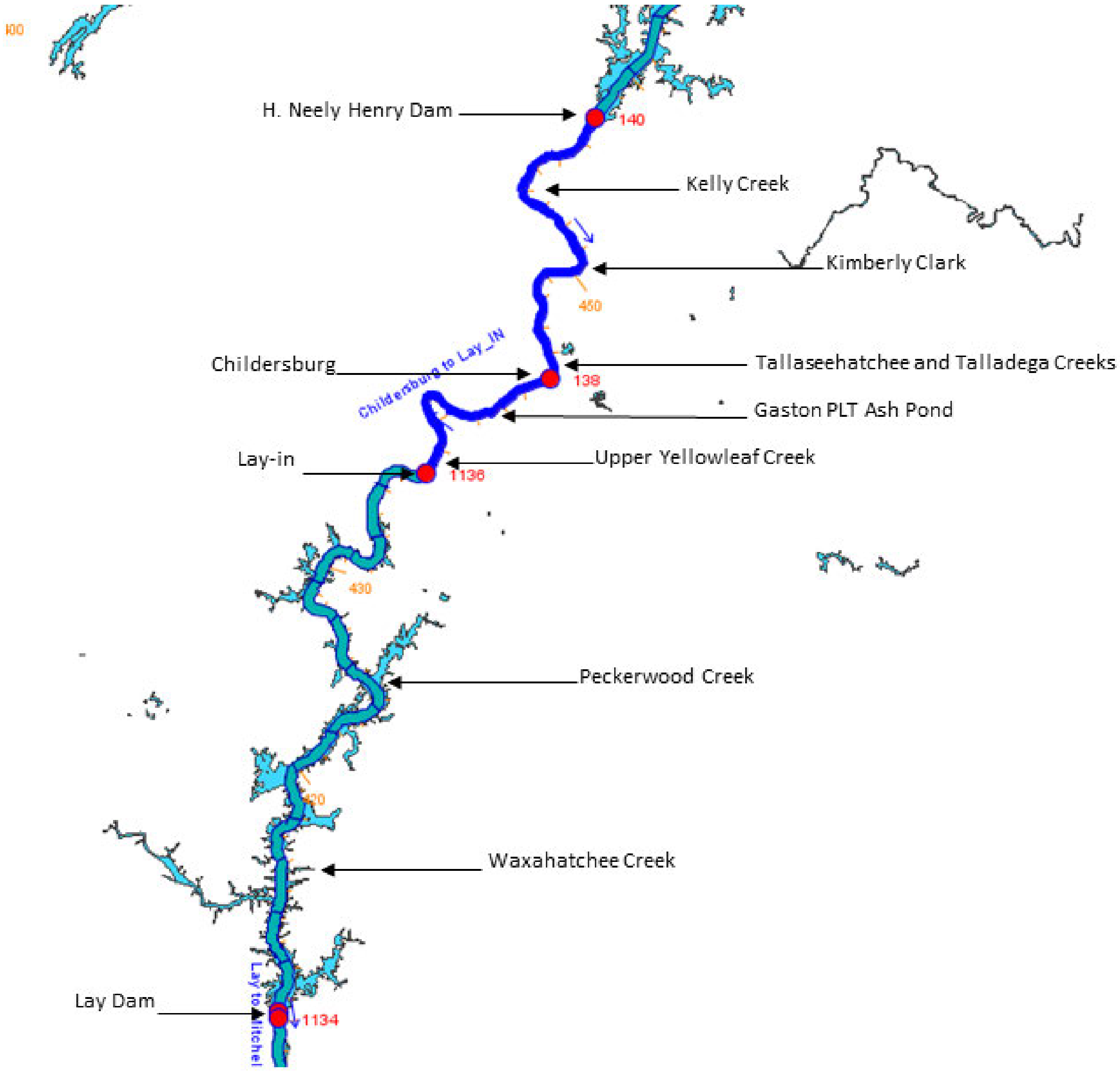
	BOD5U (mg/L)	OXYGEN (mg/L)	NH3-N (mg/L)	NO2+NO3-N (mg/L)	Total P (mg/L)	TSS (mg/L)	Temp. (C)	Chlorophyll a (ug/L)
Chattooga River at Holland-Chattoogaville Road (FAS1363) near Lyerly,								
Samples	90	156	76	90	88	91	157	24
Avg	1.78	8.60	0.065	0.421	0.266	16.77	17.23	3.49
Min	0.36	4.40	0.020	0.050	0.020	2.50	3.90	0.70
Max	3.91	15.85	0.370	1.160	0.950	94.00	29.59	11.10
Median	2.00	8.34	0.050	0.410	0.210	12.50	18.00	2.60
Avg/Median	1.13	0.97	0.775	0.974	0.790	0.75	1.05	0.75
Sample Weighted (Average of all tributaries)								
Samples	527	825	438	496	490	450	826	120
Avg	0.02	0.08	0.001	0.006	0.001	0.30	0.17	0.20
Min	0.00	0.05	0.000	0.001	0.000	0.03	0.04	0.07
Max	0.06	0.14	0.003	0.024	0.008	3.51	0.25	0.66
Median	0.02	0.08	0.001	0.005	0.001	0.18	0.18	0.15
Avg/Median	0.01	0.01	0.015	0.015	0.011	0.01	0.01	0.05

Table 2.3. Summary of average non-point source inflow and water quality for tributaries for the 2000–2008 period.

Location	Flow (cfs)	Temp (C)	NO3-N (mg/L)	PO4-P (mg/L)	Chlorophyll *a* (ug/L)	NH3-N (mg/L)	DO (mg/L)	Diss. Org. (mg/L)	Org. Solids (mg/L)
upstream Etowah R.	98.0	17.6	0.189	0.017	0.000	0.018	8.44	2.01	1.18
Amicaloa Cr.	96.0	17.6	0.200	0.017	0.000	0.019	8.43	2.02	1.27
Settingdown Cr.	173.7	17.6	0.232	0.018	0.000	0.022	8.43	2.02	1.27
Long Swamp Cr.	263.7	17.6	0.227	0.018	0.000	0.021	8.43	2.02	1.25
Mountain Cr.	372.7	17.6	0.236	0.019	0.000	0.022	8.43	2.03	1.32
Shoal Cr.	30.2	17.6	0.202	0.018	0.000	0.019	8.38	2.04	1.35
Noonday & Allatonna Cr.	147.0	17.6	0.283	0.025	0.000	0.025	8.38	2.23	1.80
Little R.	231.0	17.6	0.282	0.026	0.000	0.025	8.38	2.23	1.80
Pumpkinvine Cr.	107.4	17.6	0.330	0.017	0.000	0.019	8.43	2.02	1.28
Pettit Cr.	188.4	17.6	0.440	0.019	0.000	0.024	8.43	2.03	1.36
Raccoon Cr.	226.1	17.6	0.435	0.019	0.000	0.023	8.43	2.03	1.37
Euharlee Cr.	366.5	17.6	0.438	0.018	0.000	0.023	8.43	2.02	1.32
Two Run Cr.	77.0	17.6	0.437	0.018	0.000	0.023	8.43	2.01	1.24
Dikes Cr.	133.7	17.6	0.446	0.018	0.000	0.024	8.43	2.01	1.23
Coosawattee R.	616.2	17.6	0.182	0.016	0.000	0.018	8.43	2.01	1.23
Talking Rock Cr.	195.9	17.6	0.250	0.021	0.000	0.023	8.43	2.06	1.48
Salacoa Cr.	296.3	17.6	0.257	0.052	0.000	0.024	8.43	2.06	1.34
Conasauga R	255.6	17.6	0.258	0.024	0.000	0.024	8.43	2.04	1.28
Coahulla R.	265.8	17.6	0.346	0.037	0.000	0.030	8.43	2.20	1.61
Holly Cr.	468.5	17.6	0.319	0.035	0.000	0.028	8.43	2.24	1.68
Polecat Cr.	47.4	17.6	0.248	0.020	0.000	0.023	8.43	2.10	1.43
Oostanaula Tribs.	97.1	17.6	0.275	0.020	0.000	0.025	8.43	2.09	1.40
Oothkalooga Cr.	70.7	17.6	0.302	0.021	0.000	0.027	8.43	2.09	1.59
Johns Cr.	66.3	17.6	0.278	0.019	0.000	0.025	8.43	2.04	1.43
Armuchee Cr.	205.2	17.6	0.254	0.018	0.000	0.023	8.43	2.03	1.34
Silver Cr.	221.5	17.6	0.440	0.019	0.000	0.024	8.43	2.03	1.38
Coosa R. Tribs	16.0	17.6	0.274	0.020	0.000	0.025	8.43	2.11	1.59
Big Cedar Cr.	178.6	17.6	0.253	0.017	0.000	0.023	8.43	2.07	1.35
Spring Cr.	267.9	17.6	0.257	0.017	0.000	0.023	8.43	2.07	1.36
Chattooga R.	520.2	17.6	0.247	0.017	0.000	0.023	8.43	2.06	1.33
Weiss Lake	702.3	17.6	0.241	0.017	0.000	0.022	8.43	2.05	1.29
Terrapin Cr.	177.8	17.6	0.242	0.016	0.000	0.022	8.43	2.01	1.33
Big Willis Cr.	350.0	17.6	0.243	0.016	0.000	0.022	8.43	2.01	1.36
Big Canoe Cr.	516.3	17.6	0.237	0.015	0.000	0.022	8.43	2.00	1.31
Beaver Cr.	554.7	17.6	0.235	0.015	0.000	0.022	8.43	2.00	1.30
Ohatchee Cr.	174.5	17.6	0.183	0.015	0.000	0.018	8.43	2.00	1.17
Cane Cr.	251.4	17.6	0.182	0.015	0.000	0.018	8.43	2.00	1.19
Broken Arrow Cr.	366.4	17.6	0.175	0.015	0.000	0.017	8.43	2.00	1.17
Choccolocco Cr.	895.5	17.6	0.181	0.015	0.000	0.018	8.43	2.00	1.19
Kelley Cr.	85.7	17.6	0.225	0.017	0.000	0.021	8.43	2.06	1.31
Talladega Cr.	204.9	17.6	0.236	0.017	0.000	0.022	8.43	2.07	1.38
Upper Yellowleaf Cr.	284.3	17.6	0.230	0.017	0.000	0.021	8.43	2.07	1.34
Peckerwood Cr.	331.4	17.6	0.235	0.017	0.000	0.022	8.43	2.07	1.35
Waxahatchee Cr.	414.3	17.6	0.229	0.017	0.000	0.021	8.43	2.07	1.36
Lower Yellowleaf Cr.	59.1	17.6	0.170	0.016	0.000	0.017	8.43	2.03	1.19
Walnut Cr.	509.3	17.6	0.172	0.016	0.000	0.017	8.43	2.04	1.21
Chestnut Cr.	154.9	17.6	0.186	0.015	0.000	0.018	8.43	2.02	1.13
Weoka Cr.	398.4	17.6	0.176	0.015	0.000	0.018	8.43	2.02	1.12
Tallapoosa R.	162.6	17.6	0.245	0.019	0.000	0.023	8.43	2.03	1.39
Little Cr.	38.9	17.6	0.262	0.020	0.000	0.024	8.43	2.04	1.41
Muscadine Cr.	71.5	17.6	0.248	0.019	0.000	0.023	8.43	2.02	1.35
Kelley + Norman Cr.	97.6	17.6	0.255	0.020	0.000	0.023	8.43	2.03	1.38

Table 2.3 (continued). Summary of average non-point source inflow and water quality for tributaries for the 2000–2008 period.

Location	Flow (cfs)	Temp (C)	NO3-N (mg/L)	PO4-P (mg/L)	Chlorophyll *a* (ug/L)	NH3-N (mg/L)	DO (mg/L)	DOM (mg/L)	TSS (mg/L)
Silas Cr.	138.3	17.6	0.262	0.020	0.000	0.024	8.43	2.03	1.38
Cane Cr.	56.5	17.6	0.187	0.017	0.000	0.018	8.43	2.02	1.31
Dyne Cr.	102.6	17.6	0.198	0.017	0.000	0.019	8.43	2.01	1.29
Ketchepedrakee Cr.	151.1	17.6	0.194	0.016	0.000	0.019	8.43	2.01	1.25
Little Tallapoosa R.	244.7	17.6	0.330	0.024	0.000	0.029	8.43	2.07	1.52
Cohobadiah Cr.	83.6	17.6	0.287	0.019	0.000	0.026	8.43	2.00	1.20
Tallapoosa R. Tribs	157.6	17.6	0.245	0.018	0.000	0.023	8.43	2.01	1.24
Crooked Cr.	83.5	17.6	0.225	0.016	0.000	0.021	8.43	2.02	1.26
Cornhouse Cr.	178.9	17.6	0.218	0.016	0.000	0.021	8.43	2.02	1.23
High Pine Cr.	50.3	17.6	0.206	0.016	0.000	0.020	8.43	2.03	1.33
Chikasanoxee Cr.	146.7	17.6	0.201	0.016	0.000	0.019	8.43	2.02	1.24
Chatahospee Cr.	275.1	17.6	0.210	0.016	0.000	0.020	8.43	2.02	1.23
Hillabee Cr.	565.5	17.6	0.202	0.016	0.000	0.019	8.43	2.02	1.24
Martin Lake Tribs	367.1	17.8	0.206	0.016	0.000	0.020	8.34	2.02	1.30
Channahatchee Cr.	31.4	17.6	0.234	0.022	0.000	0.022	8.43	2.23	1.56
Tallapoosa R. Tribs	3.7	17.6	0.344	0.025	0.000	0.030	8.43	2.32	1.70
Upahee Cr.	29.3	17.6	0.321	0.033	0.000	0.028	8.43	2.47	1.91
Calebee Cr.	48.0	17.6	0.335	0.034	0.000	0.029	8.43	2.45	1.88
Cubahatchee Cr.	56.8	17.6	0.327	0.033	0.000	0.029	8.43	2.44	1.87
Line Cr.	86.1	17.6	0.349	0.033	0.000	0.030	8.43	2.38	1.79
Chubbehatchee Cr.	93.3	17.6	0.343	0.033	0.000	0.030	8.43	2.36	1.76
Tallapoosa R. Tribs	104.5	17.6	0.361	0.035	0.000	0.031	8.43	2.38	1.79
Coosa R. Tribs	9.9	17.6	0.473	0.048	0.000	0.040	8.43	2.36	1.76
Autauga Cr.	530.1	17.6	0.354	0.025	0.000	0.031	8.43	2.26	1.72
Pintalla Cr.	798.2	17.6	0.350	0.024	0.000	0.030	8.43	2.19	1.59
Swift Cr.	991.5	17.6	0.338	0.023	0.000	0.030	8.43	2.15	1.52
Purdy Lake Tribs	23.5	17.6	0.238	0.021	0.000	0.022	8.43	2.14	1.47
Cahaba R.	65.7	17.6	0.220	0.023	0.000	0.021	8.43	2.14	1.46
Little Shades Cr.	101.4	17.6	0.282	0.031	0.000	0.025	8.43	2.33	1.78
Buck Cr.	155.0	17.6	0.275	0.029	0.000	0.025	8.43	2.28	1.70
Pineywood Cr.	231.8	17.6	0.272	0.029	0.000	0.025	8.43	2.28	1.70
Little Cahaba R.	391.1	17.6	0.292	0.029	0.000	0.026	8.43	2.23	1.63
Shultz Cr.	438.2	17.6	0.284	0.028	0.000	0.026	8.43	2.21	1.59
Affohee+Hayson+Blue Cr.	110.1	17.6	0.209	0.015	0.000	0.020	8.43	2.01	1.27
Old Town + Wallace Cr.	193.4	17.6	0.210	0.016	0.000	0.020	8.43	2.01	1.29
Waters Cr.	246.7	17.6	0.214	0.016	0.000	0.020	8.43	2.01	1.29
Oakmulgee Cr.	414.4	17.6	0.213	0.015	0.000	0.020	8.43	2.01	1.27
Cahaba R. Tribs	25.2	17.6	0.437	0.026	0.000	0.037	8.43	2.01	1.23
Big Swamp Cr.	115.9	17.6	0.390	0.034	0.000	0.033	8.43	2.18	1.54
Mulberry Cr.	327.3	17.6	0.343	0.030	0.000	0.030	8.43	2.13	1.44
Beach Cr.	375.6	17.6	0.344	0.030	0.000	0.030	8.43	2.15	1.49
Cedar Cr.	575.7	17.6	0.332	0.030	0.000	0.029	8.43	2.17	1.52
Bogue Chitto Cr.	685.6	17.6	0.339	0.029	0.000	0.030	8.43	2.16	1.50
Chilatchee Cr.	849.1	17.6	0.328	0.029	0.000	0.029	8.43	2.16	1.52
Beaver Cr.	48.6	17.6	0.251	0.025	0.000	0.023	8.43	2.32	1.80
Pursley Cr.	63.6	17.6	0.252	0.025	0.000	0.023	8.43	2.35	1.85
Bear Cr.	78.9	17.6	0.250	0.025	0.000	0.023	8.43	2.35	1.84
Tallahatchee Cr.	94.9	17.6	0.253	0.025	0.000	0.023	8.43	2.35	1.85
Cane Cr.	113.9	17.6	0.249	0.025	0.000	0.023	8.43	2.33	1.82



Note: Non-point source flow allocation percentages and point source discharge rates are indicated.

Figure 2.8. HEC-5 and HEC-5Q model schematic of Lay Lake with inflows.

2.11.2 Point Source Flow and Water Quality Data

Point source inflows represent non-tributary inflows and include municipal and industrial discharges and cooling water returns. Agricultural returns and groundwater inflows were not considered. Discharge rate and water quality were defined seasonally for each discharge where sufficient data were available. The seasonal discharge rates and quality were based on point source discharge data provided by Tetra Tech for the 2000–2008 period. Monthly average flow and quality characteristics were defined as the average of all the available measurements without regard to the time of month. If insufficient data were available, default values or relationships between parameters were used. The following assumptions were used for those discharges and parameters that could not be defined monthly.

- Temperature – Available observed water temperature data were used to develop a relationship with equilibrium temperature that defined daily average inflow temperature. This followed the standard procedure for model calibration.

- DO – A uniform percent saturation was defined, based on a linear relationship with BOD (55% for BOD at 10 mg/L and 22% for BOD at 50 mg/L). These percentages were developed from discharge data for facilities that had both DO and BOD data. Defining the percent saturation results in a variable inflow concentration in response to inflow temperature. The sensitivity of the model to point source DO was tested by decreasing the inflow concentration to less than 1% saturation for each discharger for which DO was not reported. The resulting decrease in DO was checked at several locations and found to either be negligible (less than 0.001) or a very slight decrease.

- Nitrogen (municipal) – A uniform NO_3-N concentration of 10 mg/L was specified for advanced treatment facilities. Smaller NO_3-N and larger NH_3-N concentrations were assumed for plants without nitrification. This was based on observed data and the sensitivity analysis in Chapter 5.

- Nitrogen (Industrial) – Uniform NO_3-N and NH_3-N concentrations were assigned based on the industry. Of special interest is the NH_3-N concentration of 4 mg/L assigned for pulp mills. This value is considered conservative and results in elevated ammonia levels in the model predictions. Sensitivity to pulp mill NH_3 is evaluated in Chapter 5.

- Phosphorus – A uniform concentration of 0.7 mg/L was assigned to Georgia dischargers and discharger specific concentrations were assigned for Alabama dischargers. This was based on observed data and the sensitivity analysis in Chapter 5.

For DOM, either BOD or TSS were generally available and so DOM was calculated from BOD5U as (BOD*2.5). The scaling factor was based on an assumed BOD decay rate, as well as a decay rate and chemical composition of DOM as defined by the input data and model relationships between DO and DOM. For municipal dischargers, BOD was estimated as the equivalent of TSS. For industrial loads, the TSS to BOD ratio is 2 to 1. This ratio was based on correlations developed from discharge data where both parameters were available.

Average point source inputs are summarized in Table 2.4. Full tables of maximum, minimum and average values can be found in Appendix A.

Table 2.4. Summary of average point source inflow and quality for municipal and industrial discharges for the 2000–2008 period. This table contains both observed and assumed values.

Location	Flow (cfs)	Temp (C)	NO3-N (mg/L)	PO4-P (mg/L)	Chlorophyll *a* (ug/L)	NH3-N (mg/L)	DO (mg/L)	Diss. Org (mg/L)	Org. Solids (mg/L)
Cartersville WPCP	13.0	21.6	10.000	3.720	0.000	1.336	3.92	17.16	9.55
Calhoun WPCP	11.5	21.6	10.000	3.720	0.000	0.566	4.66	26.36	16.58
City of Chatsworth	2.2	21.6	10.000	3.720	0.000	0.312	6.37	7.20	4.27
Cobb County Noonday Cree	15.1	21.6	10.000	0.264	0.000	0.155	6.43	3.75	1.39
Canton WPCP	2.4	21.6	10.000	4.605	0.000	2.426	4.37	16.25	11.13
Cherokee County Rose Cre	5.9	21.6	10.000	0.175	0.000	0.381	5.75	6.25	2.07
Cobb County Northwest WP	10.7	21.6	10.000	0.102	0.000	0.106	6.52	2.50	1.06
Inland Paperboard	35.1	21.6	1.000	0.300	0.000	4.000	3.90	41.33	94.05
Etowah River mile 675 NO3-N Source	0.1855	-	750 lb/day	-	-	-	-	-	-
Georgia Power Company	1.5	21.6	0.600	0.100	0.000	0.300	0.12	7.50	3.00
Rome WPCP	16.9	21.6	10.000	2.085	0.000	0.439	4.69	14.35	7.03
Rome - Coosa WPCP	1.3	21.6	10.000	1.524	0.000	0.204	5.45	2.68	3.51
Gadsden East WWTP	4.9	21.6	2.945	2.220	0.000	8.863	3.90	41.42	17.76
Gadsden West WWTP	8.3	21.6	4.303	1.942	0.000	6.921	4.01	21.70	10.62
Attalla Lagoon	3.3	21.6	0.686	1.048	0.000	3.657	3.59	53.71	43.38
Tyson Foods	1.6	21.6	10.000	6.500	0.000	1.000	6.24	22.63	11.31
Goodyear Tire and Rubber	12.8	24.4	1.000	0.300	0.000	4.000	3.73	35.00	13.77
Pell City Dye Creek WWTP	2.5	21.6	4.758	1.500	0.000	0.159	8.22	16.53	2.74
Kimberley-Clark Corporat	37.1	21.6	1.000	0.300	0.000	4.000	3.90	50.06	25.07
APCO Gaston PLT ash pond	38.5	21.6	0.220	0.060	0.000	0.050	6.24	9.00	3.60
Tallassee Lagoon	1.0	21.6	10.000	2.374	0.000	1.834	3.90	26.95	22.57
Tuskegee South WWTP (Cal	1.6	21.6	10.000	0.700	0.000	1.074	6.47	20.00	9.32
Tuskegee North WWTP	2.2	21.6	10.000	0.700	0.000	1.551	5.46	5.84	5.74
Alexander City Coley Cre	12.4	21.6	8.449	1.051	0.000	0.314	7.11	5.48	4.83
Wetumka City of Water Wo	3.2	21.6	10.000	2.700	0.000	0.250	6.24	6.25	6.22
International Paper Comp	44.5	21.6	1.000	0.300	0.000	4.000	0.86	88.42	45.69
International Paper	41.5	21.6	1.000	0.300	0.000	4.000	0.86	83.34	62.00
General Electric WWTP	4.1	21.6	0.100	0.300	0.000	0.100	5.85	17.45	10.65
Prattville Pine Creek	3.2	21.6	10.000	0.800	0.000	6.000	5.85	12.75	12.10
Montgomery Econchate	26.3	20.3	2.500	1.000	0.000	7.399	3.44	56.25	16.50
Montgomery Towassa	3.9	20.3	2.500	1.000	0.000	7.399	3.44	56.25	16.50
Catoma Creek WWTPg	25.4	21.6	10.000	0.700	0.000	0.200	5.19	6.40	2.89
Macmillan Bloedel Packin	27.8	21.6	1.000	1.200	0.000	1.400	2.34	104.79	62.13
Alabama River Pulp Compa	35.8	20.3	1.000	0.300	0.000	4.000	0.86	148.26	77.00
Selma Valley Creek WWTP	5.6	21.6	10.000	0.700	0.000	5.386	3.90	59.23	16.52
Leeds	1.7	22.0	14.250	5.000	0.000	1.000	5.93	37.50	6.70
Birminghan Area discharges	3.7	20.3	12.000	5.000	0.000	3.000	5.16	22.50	8.40
Jefferson Co. + Hoover RC	7.3	20.3	13.897	5.000	0.000	1.106	6.15	8.27	3.85
Pelham	1.5	19.0	14.000	5.000	0.000	1.000	6.34	30.00	11.20
* 0.1855 cfs at 750 mg/L = 750 pounds/day									

2.11.3 WATER QUALITY MONITORING

Water quality in the ACT basin is monitored by a number of federal, state, and local agencies as well as by industries for compliance with standards. Table 2.5 summarizes water quality conditions along the main-stem rivers in the ACT basin using data collected by states as part of their monitoring efforts. States use their monitoring data to make decisions about violations of water quality standards. These data were used in this EIS to develop the HEC-5Q water quality model of the ACT basin.

Table 2.5. Summary of monitoring data collected by Alabama and Georgia fully encompassing the 2001–2008 modeling period in the main-stem rivers of the ACT basin.

Note: As denoted by the time period for each parameter and station, data were not available for all parameters at all stations for the full 2001–2008 period.

	BOD_5U (mg/L)	Oxygen (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	TSS (mg/L)	Temp. (C)	Chlorophyll *a* (µg/L)
Coosawattee River at Carters								
No. of Samples	61	53	47	47	49	55	53	10
Avg	1.54	8.94	0.04	0.14	0.03	8.06	20	7.56
Min	0.4	7.09	0.02	0.05	0.02	3	5.8	3.6
Max	5.14	12.8	0.15	0.25	0.09	19	24.77	16.4
Median	1.3	8.61	0.03	0.13	0.02	7.5	21.75	4.1
Period of Record	Jan 2001-Oct 2006							Jun – Oct 2005
Coosawattee River at Calhoun								
No. of Samples	69	92	62	63	64	63	94	15
Avg	1.57	8.7	0.04	0.26	0.04	19.66	17.94	4.88
Min	0.5	5.42	0.01	0.13	0.02	4	4.9	2.6
Max	5.37	12.6	0.22	0.43	0.15	66	25.47	11.5
Median	1.52	8.2	0.03	0.26	0.03	15	19.92	4.2
Period of Record	Jan 2001 - Oct 2006							Jun 2005 – Oct 2006
Etowah River at Lake Allatoona								
No. of Samples	0	56	56	56	49	56	56	56
Avg	NA	8.44	0.15	0.27	0.04	5.49	37.96	11.63
Min	NA	6.75	0.03	0.03	0.04	3	16.65	4.51
Max	NA	10.7	6.02	1.08	0.23	14.12	88.44	22.98
Median	NA	8.36	0.03	0.25	0.04	5	27.69	11.09
Period of Record	Apr 2000 – Oct 2007							
Etowah River at Euharlee								
No. of Samples	101	162	86	99	97	96	162	31
Avg	1.58	9.08	0.07	0.54	0.09	23.17	16.72	6.94
Min	0.34	5.9	0.01	0.11	0.02	1	4.9	0.6
Max	3.59	13.77	0.23	1.18	0.55	480	28	115
Median	2	8.87	0.05	0.5	0.06	7	16.7	2.1
Period of Record	Jan 2000 – Aug 2008							Jun 2005 – Oct 2006

Table 2.5 (continued). Summary of monitoring data collected by Alabama and Georgia fully encompassing the 2001–2008 modeling period in the main-stem rivers of the ACT basin.

	BOD_5U (mg/L)	Oxygen (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	TSS (mg/L)	Temp. (C)	Chlorophyll *a* (µg/L)
Etowah River at Canton								
No. of Samples	91	156	76	89	87	59	156	24
Avg	1.4	9.2	0.05	0.26	0.05	34.96	15.74	4.4
Min	0.1	5.8	0.01	0.05	0.02	1	2.46	1.3
Max	3.92	13.5	0.28	0.88	0.72	675	27.17	17.9
Median	1.4	8.95	0.03	0.25	0.02	8	15.6	2.2
Period of Record	Jan 2000 – Jun 2008					Jan 2000 – Dec 2007	Jan 2000 – Jun 2008	Feb - Dec 2006
Oostanaula River at Resaca								
No. of Samples	69	100	62	63	63	62	102	15
Avg	1.64	8.28	0.04	0.3	0.08	24.94	18.32	8.01
Min	0.2	4.62	0.01	0.04	0.02	2	3.9	1.9
Max	5.31	12.75	0.12	0.6	0.26	95	26.69	37
Median	1.66	7.76	0.03	0.29	0.07	21.5	19.9	4.7
Period of Record	Jan 2001 – Oct 2006							Jun – Oct 2005
Coosa River near Rome								
No. of Samples	0	595	0	0	0	0	3292	545
Avg	NA	8.94	NA	NA	NA	NA	17.37	6.04
Min	NA	5.4	NA	NA	NA	NA	4	1.48
Max	NA	12.4	NA	NA	NA	NA	29	31.8
Median	NA	8.7	NA	NA	NA	NA	18	4.28
Period of Record	NA	Mar 2005 – Dec 2006	NA	NA	NA	NA	Jan 2000 – Nov 2009	Mar 2005 – Sep 2006
Coosa River at State Line								
No. of Samples	130	3106	110	122	123	123	3352	678
Avg	2	8.82	0.04	0.4	0.1	17.68	19.82	7.04
Min	0.57	3.8	0.01	0.05	0.02	3	6	1.71
Max	9	15.3	0.18	0.61	0.5	229.09	34	36.2
Median	2	8.7	0.03	0.41	0.1	14	20	4.85
Period of Record	Jan 2000 – Aug 2008							Jun 2005 – Sep 2006
Coosa River at Weiss								
No. of Samples	0	118	118	118	118	0	118	118
Avg	NA	8.31	0.03	0.24	0.09	NA	23.67	19.67
Min	NA	4.04	0.02	0	0	NA	8.63	0.1
Max	NA	12.17	0.15	0.63	0.29	NA	33.42	51.4
Median	NA	8.3	0.02	0.22	0.08	NA	24.41	19.8
Period of Record	Apr 2002 – Nov 2008							Apr 2002 – Nov 2008
Coosa River at H.N. Henry								
No. of Samples	0	27	27	27	27	0	27	27
Avg	NA	8.07	0.02	0.06	0.06	NA	27.12	27.15
Min	NA	4.13	0.02	0	0	NA	20.43	2.14
Max	NA	12.93	0.07	0.66	0.14	NA	32.4	40.58
Median	NA	7.66	0.02	0.01	0.06	NA	27.99	26.7
Period of Record	Aug 2002 – Oct 2008							

Table 2.5 (continued). Summary of monitoring data collected by Alabama and Georgia fully encompassing the 2001–2008 modeling period in the main-stem rivers of the ACT basin.

	BOD_5U (mg/L)	Oxygen (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	TSS (mg/L)	Temp. (C)	Chlorophyll *a* (µg/L)
Coosa River at Logan Martin								
No. of Samples	0	38	39	39	39	0	38	39
Avg	NA	8.33	0.02	0.04	0.06	NA	27.09	20.22
Min	NA	5.26	0.02	0	0	NA	17.85	0.8
Max	NA	12.39	0.06	0.18	0.09	NA	32.56	34.89
Median	NA	8.04	0.02	0.01	0.06	NA	28.06	19.76
Period of Record	Aug 2002 – Sep 2005							
Coosa River at Lay								
No. of Samples	0	51	51	51	51	0	51	51
Avg	NA	8.46	0.03	0.09	0.05	NA	28.08	18.48
Min	NA	5.12	0.01	0	0	NA	17.84	0.36
Max	NA	12.96	0.17	0.6	0.1	NA	33.4	35.78
Median	NA	8.26	0.02	0.02	0.05	NA	28.8	17.89
Period of Record	Aug 2002 – Oct 2008							
Coosa River at Mitchell								
No. of Samples	0	53	53	53	53	0	53	53
Avg	NA	8.7	0.02	0.05	0.05	NA	27.2	18.01
Min	NA	4.56	0.02	0	0	NA	20.02	0.71
Max	NA	12.22	0.07	0.25	0.09	NA	33.66	60.18
Median	NA	8.78	0.02	0.02	0.06	NA	27.73	16.55
Period of Record	Aug 2002 – Oct 2008							
Coosa River at Jordan								
No. of Samples	0	30	30	30	30	0	30	30
Avg	NA	8.66	0.02	0.05	0.04	NA	27.21	14.32
Min	NA	3.55	0.02	0	0	NA	19.45	2.67
Max	NA	13.47	0.13	0.24	0.08	NA	32.37	24.03
Median	NA	8.65	0.02	0.02	0.04	NA	27.99	14.15
Period of Record	Aug 2002 – Oct 2008							
Tallapoosa River at Harris Lake								
No. of Samples	0	101	101	101	101	0	101	101
Avg	NA	8.54	0.03	0.07	0.04	NA	25.87	12.12
Min	NA	4.14	0.02	0	0	NA	19.29	2.14
Max	NA	12.06	0.26	0.31	0.09	NA	31.53	67.8
Median	NA	8.42	0.02	0.05	0.03	NA	26.2	8.9
Period of Record	Apr 2002 – Oct 2008							
Tallapoosa River at Lake Martin								
No. of Samples	0	129	129	129	129	0	129	129
Avg	NA	8.18	0.02	0.05	0.04	NA	26.68	4.48
Min	NA	6.28	0.02	0	0	NA	18.92	0.53
Max	NA	10.72	0.14	0.35	0.1	NA	32.55	13.62
Median	NA	8.12	0.02	0.03	0.03	NA	26.99	3.47
Period of Record	Apr 2002 – Oct 2008							

Table 2.5 (continued). Summary of monitoring data collected by Alabama and Georgia fully encompassing the 2001–2008 modeling period in the main-stem rivers of the ACT basin.

	BOD_5U (mg/L)	Oxygen (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	TSS (mg/L)	Temp. (C)	Chlorophyll *a* (µg/L)
Tallapoosa River at Yates								
No. of Samples	0	23	23	23	23	0	23	23
Avg	NA	8.32	0.04	0.13	0.03	NA	24.28	4.94
Min	NA	6.44	0.02	0.01	0.01	NA	17.94	1
Max	NA	10.26	0.19	0.21	0.07	NA	30.69	18.69
Median	NA	8.24	0.02	0.12	0.03	NA	24.15	3.74
Period of Record	Apr 2002 – Oct 2008							
Tallapoosa River at Thurlow								
No. of Samples	0	23	23	22	23	0	23	23
Avg	NA	8.18	0.03	0.14	0.03	NA	22.76	2.82
Min	NA	6.6	0.02	0	0	NA	18	0.8
Max	NA	11.27	0.15	0.22	0.06	NA	29.3	5.97
Median	NA	7.98	0.02	0.14	0.02	NA	22.86	2.4
Period of Record	Apr 2002 – Oct 2008							
Alabama River at R.F. Henry								
No. of Samples	0	50	50	50	50	0	50	50
Avg	NA	8.53	0.02	0.13	0.04	NA	27.15	16.09
Min	NA	5.4	0.02	0	0	NA	18.76	3.56
Max	NA	11.77	0.16	0.33	0.08	NA	33.4	33.11
Median	NA	8.51	0.02	0.11	0.04	NA	28.53	15.49
Period of Record	Aug 2002 – Oct 2008							

2.11.4 HISTORICAL METEOROLOGICAL DATA AND TRIBUTARY WATER TEMPERATURES

Meteorological data were developed for a 6-year period (1984–1989) during the initial ACT River Basin modeling effort using 3-hour observations of wind speed, cloud cover, air temperature, and dew point (or wet bulb) temperature. Daily average equilibrium temperature, heat exchange rate, wind speed, and solar radiation were computed as inputs to a 24-hour time step HEC-5/HEC-5Q model. In 2014, the 24-hour time step was considered inadequate since diurnal effects could not be represented. Diurnal variations in temperature were approximated with a 6-hour time step model where the daily minimum occurs at 06:00 and maximum at 18:00. The 2014 report (RMA 2014) describes the downscaling approach in detail. Both the raw meteorological data limitation (downscaling procedure) and 6-hour computational time step were identified as a model limitation at that time.

The current model application uses a 1-hour time step based on 1-hour meteorology (i.e., solar radiation, air temperature, wind speed, and relative humidity). The surface heat exchange is computed using the equilibrium temperature approach where the surface heat exchange is computed as:

$$H = Ke * (Te - Tw)$$

Where: H = heat flux.
Te = equilibrium temperature
Ke = heat exchange rate
Tw = surface water temperature

The raw 1-hour data are processed externally to define the Ke and Te. For layered reservoirs, solar radiation that is attenuated at depth is subtracted from the surface heat transfer to conserve the total heat transfer. The wind speed is also used for reservoir wind mixing.

One or more meteorological data sets are required. The data are adjusted to specific model locations with scaling factors and offsets of equilibrium temperature and exchange rates.

e.g., EQTL = EQTK1 (EQT – EQTK2)

where: EQTL = local equilibrium temperature
EQTK1 = scaling factor
EQT = input equilibrium temperature
EQTK2 = offset

Note that these adjustments are necessary regardless of the number of data sets and are determined during model calibration.

Two comprehensive data files that were developed for the Georgia State Water Plan (Tetra Tech 2014, 2017a, and 2017b) were used as a basis for the meteorological data used in the HEC-5Q model. Data for the “Ringgold” and “Taylorsville” stations had 1-hour data throughout the 2000–2008 period. The Ringgold air and dewpoint temperature, cloud cover, and solar radiation data were from Lowell Field Airport located approximately 10 miles north of Ringgold (70 miles north of Rome). The Ringgold wind speed was from the Richard B Russel Airport located 60 miles south of Ringgold (10 miles north of Rome). The Taylorsville air and dewpoint temperature, cloud cover and solar radiation data were from Hartsfield Jackson International Airport in Atlanta located approximately 50 miles south east of Taylorsville (30 miles south of Lake Allatoona). The wind speed data were also from the Richard B Russel Airport.

To check the veracity of the data, the computed temperature of a 5-foot pool of water was evaluated. The pool water temperature was computed using the same heat exchange rates and equilibrium temperatures used in the HEC-5Q model. Figure 2.8 shows the computed water temperature for the two data sets. The Ringgold station data (located farther north) calculated a temperature that is slightly cooler than the temperature calculated by the Taylorsville data. The Ringgold station data were used for the most northerly portion of the model that included the Coosawattee and Conasauga Rivers and Carters Lake. Had the Taylorsville data been used for this section also, the offsets and scaling factors would have been slightly different but would have resulted in essentially the same model results (model calibration). Taylorsville data were used for the remainder of the model. The Taylorsville station is located between Lake Allatoona and Weiss Lake.

A second data source was provided by APC that provided hourly air temperatures at numerous locations within the ACT basin. The stations were identified by name; however, specific locations were not provided. Therefore, a Google map reconnaissance was relied upon to identify the general location of the most data rich stations. Table 2.6 lists the locations with at least 60,000 hourly values. These data were transferred to HEC-DSS (Data Storage System) files (AlabamaPower_air.temp.dss) to facilitate comparison between stations. This HEC-DSS file contains the daily average, maximum, and minimum temperatures to the hourly data provided by APC. A review of these air temperature data indicated that in-basin temperature variations were not extreme. Figure 2.9 and Figure 2.10 show the daily and monthly observed average air temperatures at four locations within the Tallapoosa and Alabama-Coosa watershed, respectively. The plots show 2005 only so that the daily variation can be seen in detail. It is clear that the daily trends are consistent for all locations and the monthly average offset is generally a few degrees Fahrenheit between locations (generally less than 2 °F).

Figure 2.11 shows the maximum and minimum observed air temperatures for Ellisville south of Claiborne Dam near Mobile and at Mayo's Bar Lock and Dam on the Coosa River near Rome. This comparison shows that the daily temperature extremes are similar at widely separated locations.

A final comparison is provided in Figure 2.12 where the Taylorsville daily temperature is compared with four APC data stations. The two regression equations (one forced through zero) indicate a nearly 1:1 relationship. Note that the Newell plot has considerable scatter caused by the data problems indicated by the time series plot insert. Several of the data stations have this type of issue where the hourly temperatures are limited to an apparent arbitrary temperature.

Table 2.6. Approximate location of temperature records provided by APC.

Alabama Power ID	observations	Average temperature (F)	River	Approximate location
Alpine	65961	60.78	Coosa	10 miles NE of Childersburg
Ashville	65639	59.3	Coosa	10 miles west of Logan Martin
BluePond	62490	61.89	Coosa	near Weiss
Childersburg	68795	63.44	Coosa	above Lay Reservoir
Childersburg2	66499	65.31	Coosa	above Lay Reservoir
Collinsville	68443	61.33	Coosa	8 miles west of Weiss
Crudup	67265	61.43	Coosa	North of Gadsden
Dearmanville	70939	62.29	Tallapoosa	8 miles west of Hefflin
Ellisville	63176	60.62	Alabama	River Near Mobile
FortPayne	65782	60.13	Oostanaula	15 miles of North of Weiss
Gadsden2	69817	64.22	coosa	North end of Logan Martin Lake
Gaylesville	65834	61.04	Chatooga	North of Weiss on Chatooga River
Hackneyville	68389	61.72	mid way between Coosa and Tallapoosa	
Heflin	67346	58.53	Tallapoosa	20 miles north of Harris Lake
HorseshoeBend	64491	62.26	Tallapoosa	5 miles above Lake Martin
JacksonShoals	68834	64.15	Coosa	Choccolocco Creek - Logan Martin
MayosBar	67783	59.76	Coosa	7 miles south of Rome
Newell	68370	59.81	Little Tallapoosa	12 miles above Harris Lake
Rockford	68531	60.93	mid way between Lake Martin and Coosa River	
Rockrun	70074	59.36	Coosa	8 miles south of State Line near Weiss
Vincent	65768	62.21	Coosa	8 miles north of Childersville
Wadley	69323	62.83	Tallapoosa	12 miles south of Harris Dam

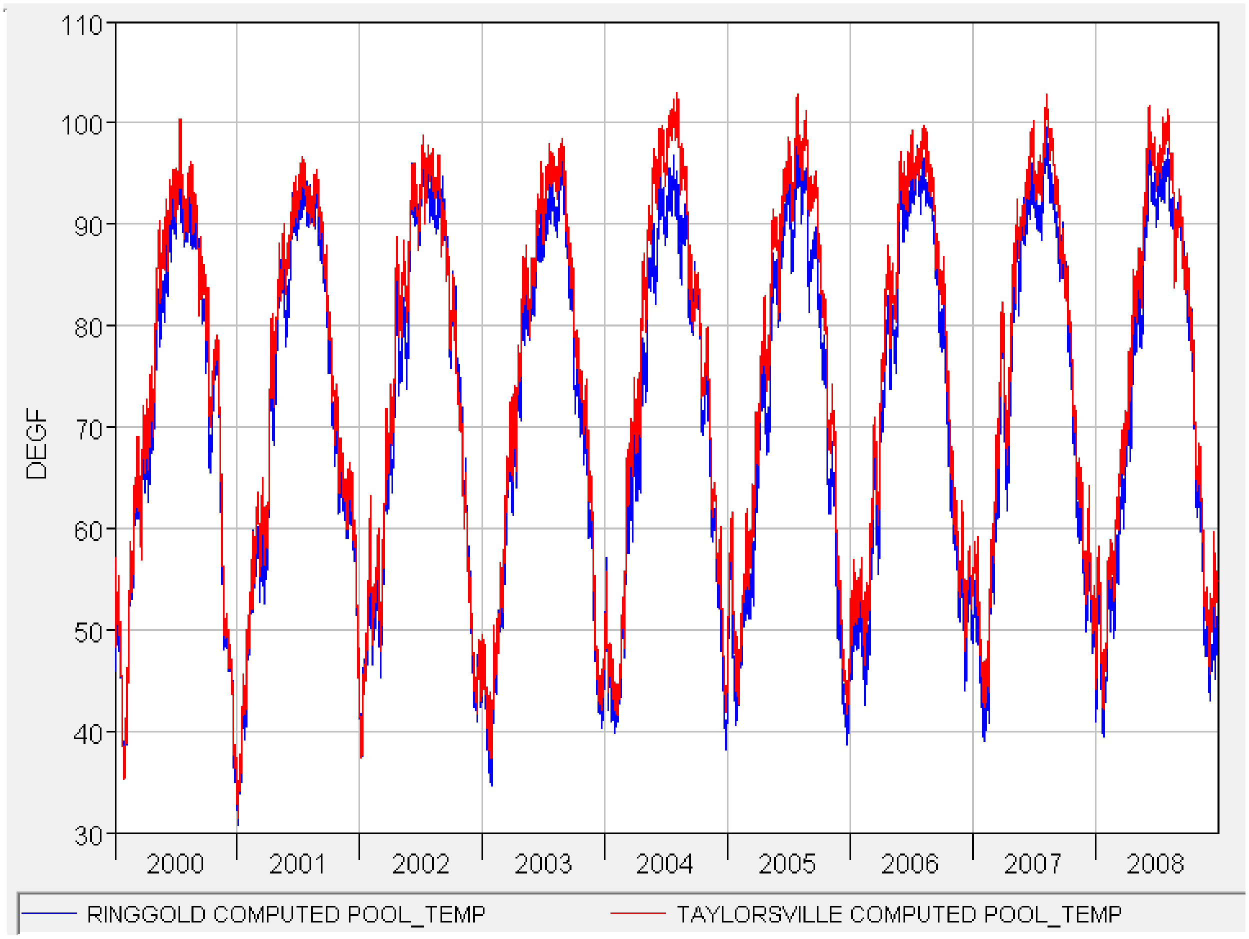


Figure 2.8. Computed pool temperature for Ringgold and Taylorsville.

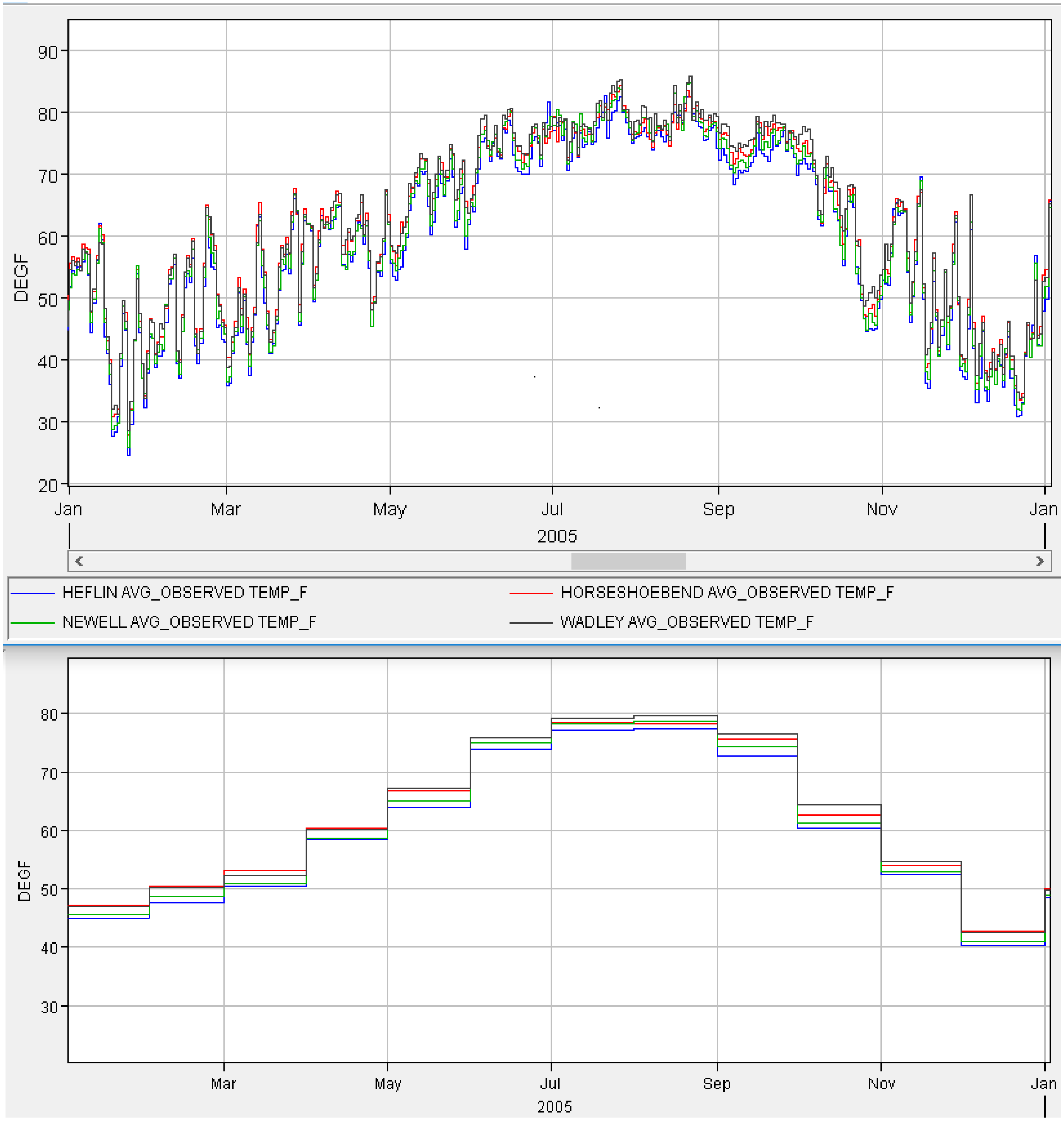


Figure 2.9. Daily (top panel) and monthly (bottom panel) average air temperature at four locations in the Tallapoosa River watershed.

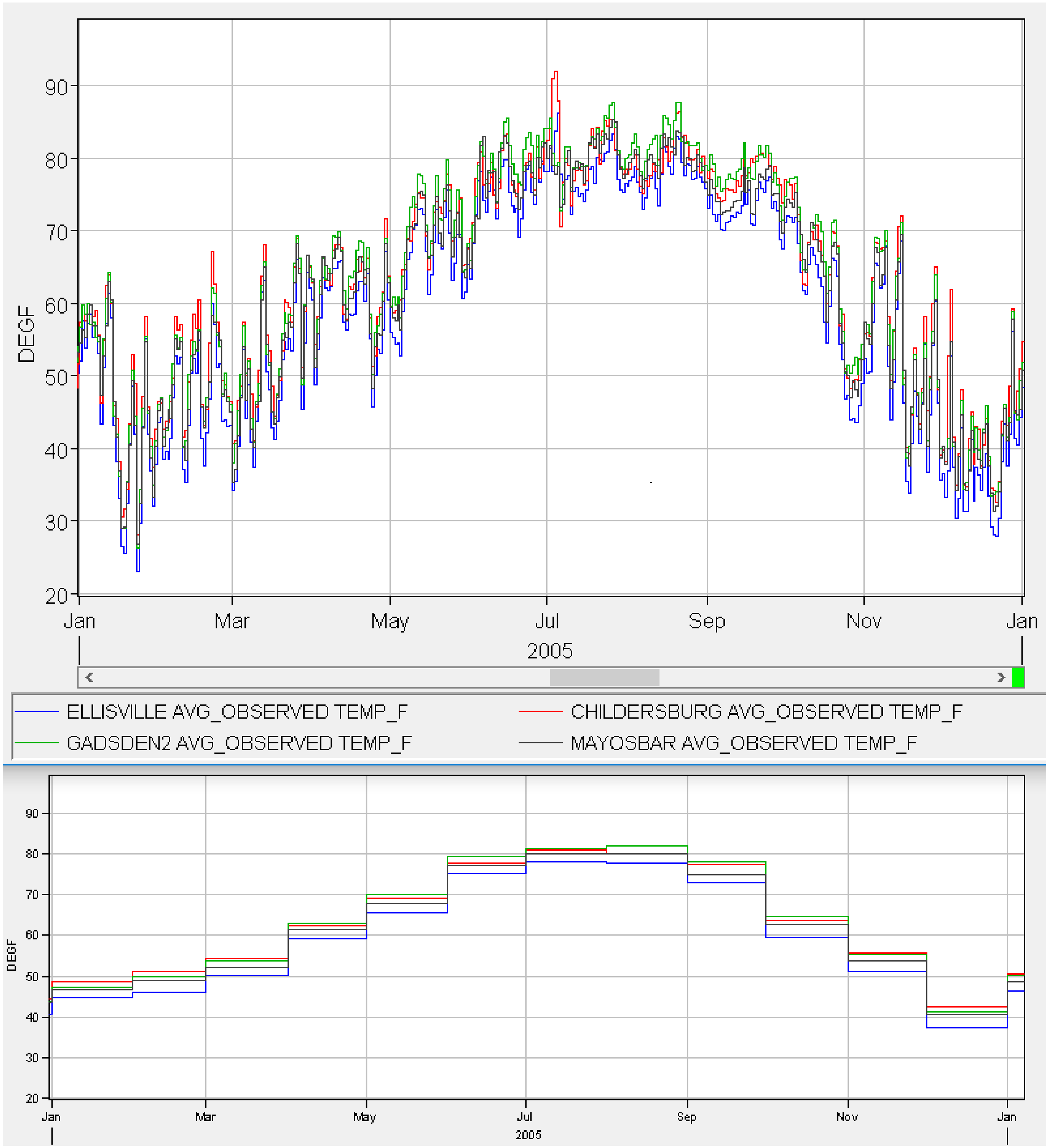


Figure 2.10. Daily (top panel) and monthly (bottom panel) average air temperature at four locations in the Alabama and Coosa River watersheds.

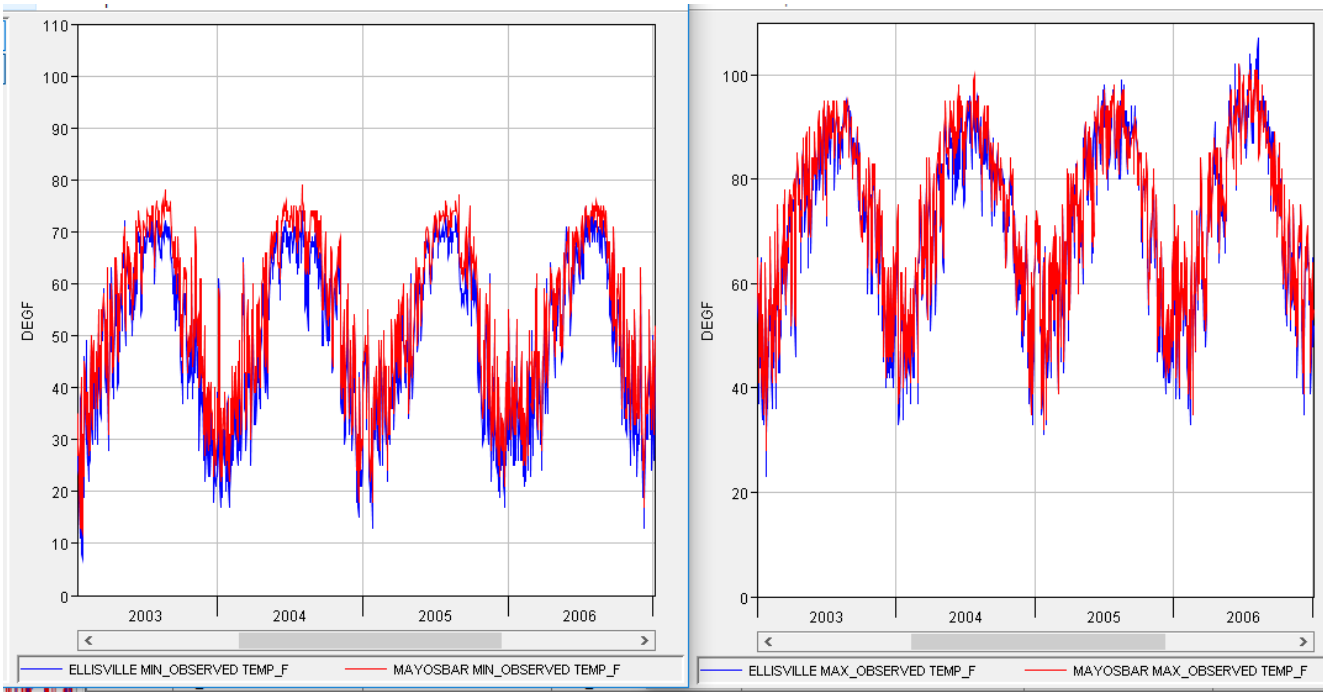
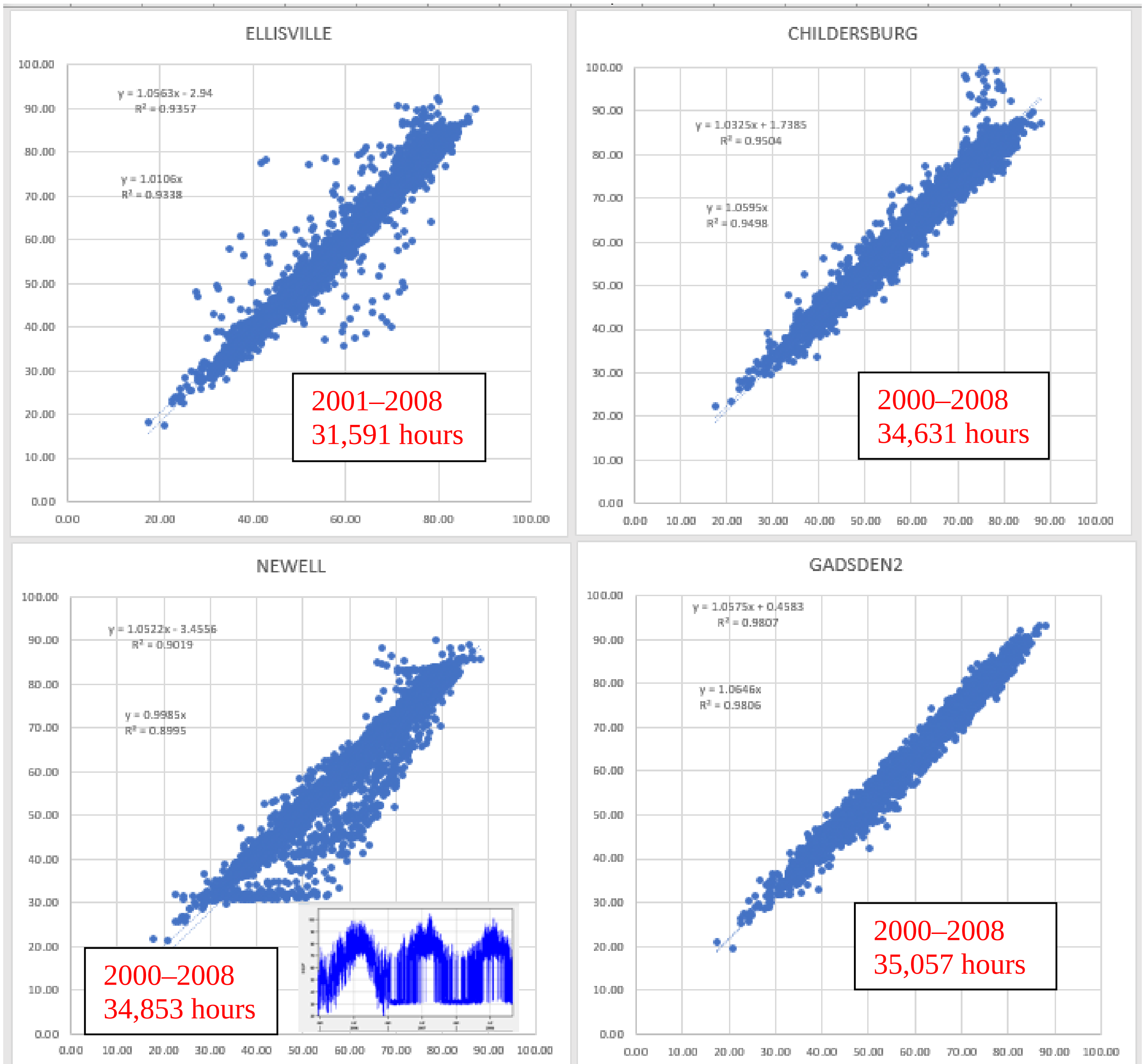


Figure 2.11. Maximum and minimum observed air temperature at Ellisville and Mayo's Bar (Lock and Dam site).



Note: The insert plot shows the 0 °F values (bad data) in the observed data set supplied by APC. This is typical of many of the stations. The bad data results in the off-diagonal points in the scatter plot.

Figure 2.12. Relationship between Taylorsville daily average temperature (°F) (Y-axis) and four APC temperature-monitoring stations' temperature data (°F) (X-axis).

The uniformity of the APC air temperature data and the relationship with the Taylorsville data serve as a justification for the use of a single meteorological data set for much of the model.

The scaling factors were determined through calibration to observed ambient water temperatures. The scaling factors and offsets ranged from -0.05 to 4.0 and 0.75 to 0.92, respectively, and are defined on a reach by reach and reservoir by reservoir basis. These factors resulted in a downward adjustment of the equilibrium temperature of approximately 2 to 3 °C for a Taylorsville equilibrium temperature of 25 °C. The justification for the reductions is increased wind speeds over open water and riparian shading and reduced wind speeds in sheltered stream channels.

To put the effort for developing the new meteorology in perspective, an example of the model performance using the old and new data sets is provided. Figure 2.13 shows the 2014 model computed and observed water temperature at Mayo's Bar Lock and Dam (U.S. Geological Survey [USGS] gauge) located on the Coosa River 7.5 miles below the Etowah River confluence. Figure 2.14 shows the results for the 2019 model and the Taylorsville data. Each of these results are for a 6-hour time step and baseline operation which do have minor differences in operation assumptions. There is clearly less scatter between the computed and observed with the 2019 model. The reason for difference in the scatter is shown in Figure 2.15 where a more detailed time series plot clearly shows that the temporal representation is improved when the model is driven by real data.

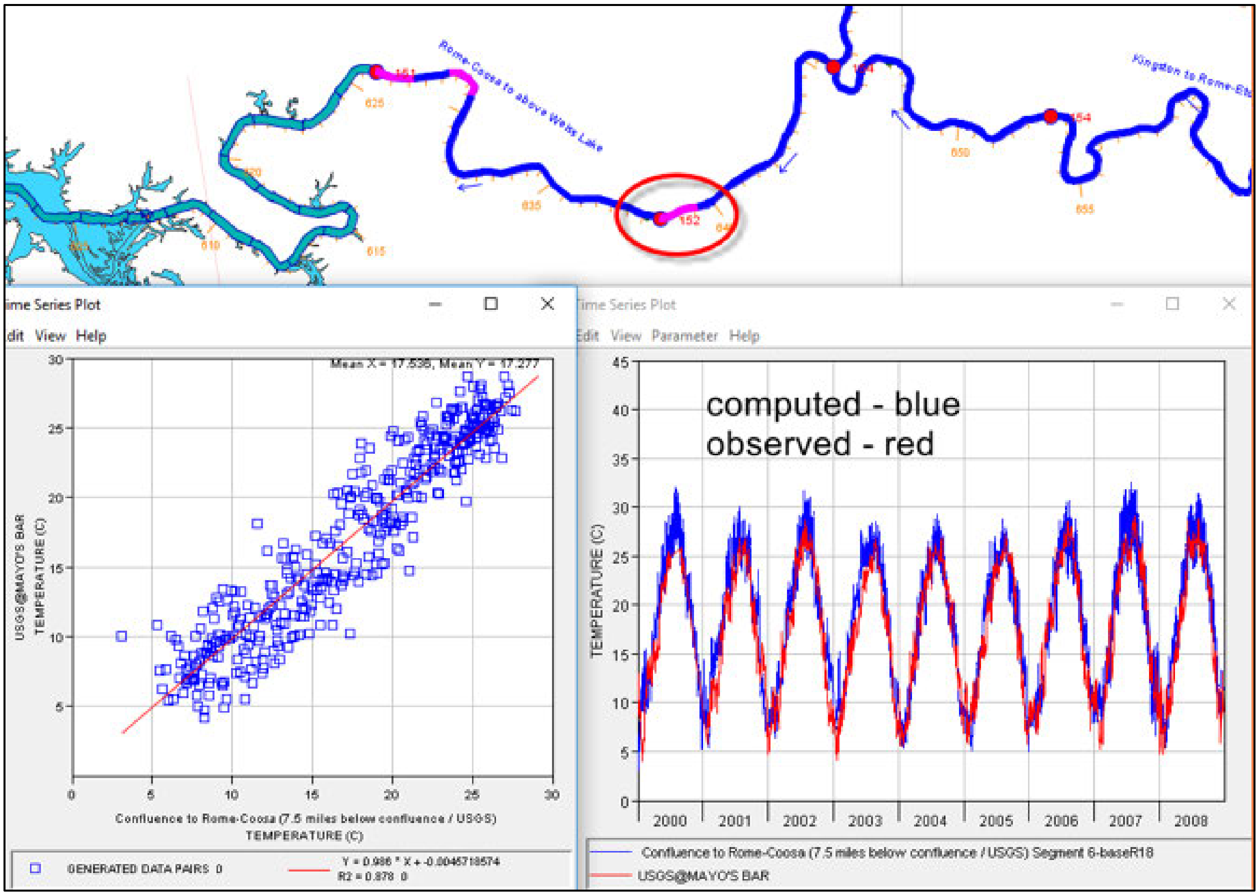
The second issue raised during the 2014 project was the computational time step. The Taylorsville data were processed for both 6-hour and 1-hour model time steps. To quantify the differences, Table 2.7 provides statistics by month, growing season, peak algal production months (May–July) and year. The statistics are for the entire 2001–2008 simulation period. The statistics include mean absolute error, root mean square (RMS) error, average computed and observed, and bias including percent bias. These statistics show a slightly better fit with the 6-hour time step. However, the observed data at the state line monitoring site was emphasized during calibration. Table 2.8 contains the statistics for both locations using the 1-hour time step and shows a better fit at the state line location.

Table 2.7. Computed versus observed temperature statistics in the Coosa River at the USGS gauge at Mayo's Bar Lock and Dam for the 2001–2008 modeling period.

	2014 model, extrapolated meteorology, 6-hour time step																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	2960	762	1734	1967	1477	221	248	278	257	261	263	238	227	250	238	233	246
Mean absolute error	1.81	1.49	1.63	1.69	1.56	1.74	2.07	1.99	2.03	1.87	1.48	1.09	1.28	1.55	2.06	2.08	2.44
RMS error	2.31	1.93	2.10	2.16	2.01	2.18	2.61	2.50	2.52	2.30	1.98	1.35	1.71	1.96	2.52	2.59	2.98
Average - observed	17.37	22.93	22.07	21.12	23.08	8.06	8.92	12.61	16.31	20.19	23.76	25.02	26.20	24.09	19.51	14.03	9.66
Average - computed	17.64	23.39	22.14	21.26	23.00	8.26	9.57	13.09	17.21	21.08	24.05	25.21	25.37	23.32	19.15	14.68	10.38
Bias (comp-obs)	0.27	0.47	0.07	0.14	-0.08	0.20	0.65	0.48	0.90	0.89	0.29	0.19	-0.83	-0.77	-0.36	0.65	0.72
Bias (%)	0.8	1.0	0.2	0.3	-0.2	1.2	3.5	1.9	2.7	2.2	0.6	0.4	-1.6	-1.6	-0.9	2.3	3.6
	2019 model, Hourly data based meteorology, 6-hour time step																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	2961	762	1734	1967	1477	221	248	278	257	261	263	238	227	250	238	233	247
Mean absolute error	0.83	1.05	0.93	0.90	0.95	0.57	0.66	0.73	0.84	0.94	1.03	1.21	1.11	0.79	0.62	0.66	0.75
RMS error	1.04	1.30	1.16	1.13	1.19	0.71	0.82	0.90	1.02	1.22	1.28	1.41	1.30	1.00	0.80	0.85	0.92
Average - observed	17.37	22.93	22.07	21.12	23.08	8.06	8.92	12.61	16.31	20.19	23.76	25.02	26.20	24.09	19.51	14.03	9.66
Average - computed	17.33	22.94	21.95	21.06	22.88	8.22	8.74	12.59	16.60	20.61	23.49	24.89	25.54	23.57	19.42	14.42	9.82
Bias (comp-obs)	-0.04	0.01	-0.13	-0.06	-0.20	0.16	-0.18	-0.02	0.28	0.43	-0.27	-0.13	-0.66	-0.52	-0.08	0.39	0.16
Bias (%)	-0.1	0.0	-0.3	-0.2	-0.4	1.0	-1.0	-0.1	0.9	1.0	-0.6	-0.3	-1.3	-1.1	-0.2	1.4	0.8
	2019 model, Hourly data based meteorology, 1-hour time step																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	2961	762	1734	1967	1477	221	248	278	257	261	263	238	227	250	238	233	247
Mean absolute error	1.13	1.48	1.27	1.24	1.23	0.80	0.85	1.06	1.47	1.76	1.24	1.44	1.18	0.87	0.85	1.06	0.90
RMS error	1.43	1.83	1.59	1.55	1.55	0.98	1.02	1.34	1.81	2.04	1.59	1.83	1.41	1.05	1.05	1.25	1.09
Average - observed	17.37	22.93	22.07	21.12	23.08	8.06	8.92	12.61	16.31	20.19	23.76	25.02	26.20	24.09	19.51	14.03	9.66
Average - computed	18.12	23.90	22.83	21.90	23.71	8.73	9.39	13.52	17.75	21.75	24.37	25.73	26.29	24.25	20.07	15.02	10.29
Bias (comp-obs)	0.75	0.97	0.75	0.78	0.63	0.67	0.47	0.91	1.43	1.57	0.62	0.71	0.09	0.17	0.57	0.99	0.63
Bias (%)	2.1	2.1	1.7	1.8	1.4	4.0	2.5	3.5	4.2	3.7	1.3	1.4	0.2	0.3	1.4	3.4	3.2

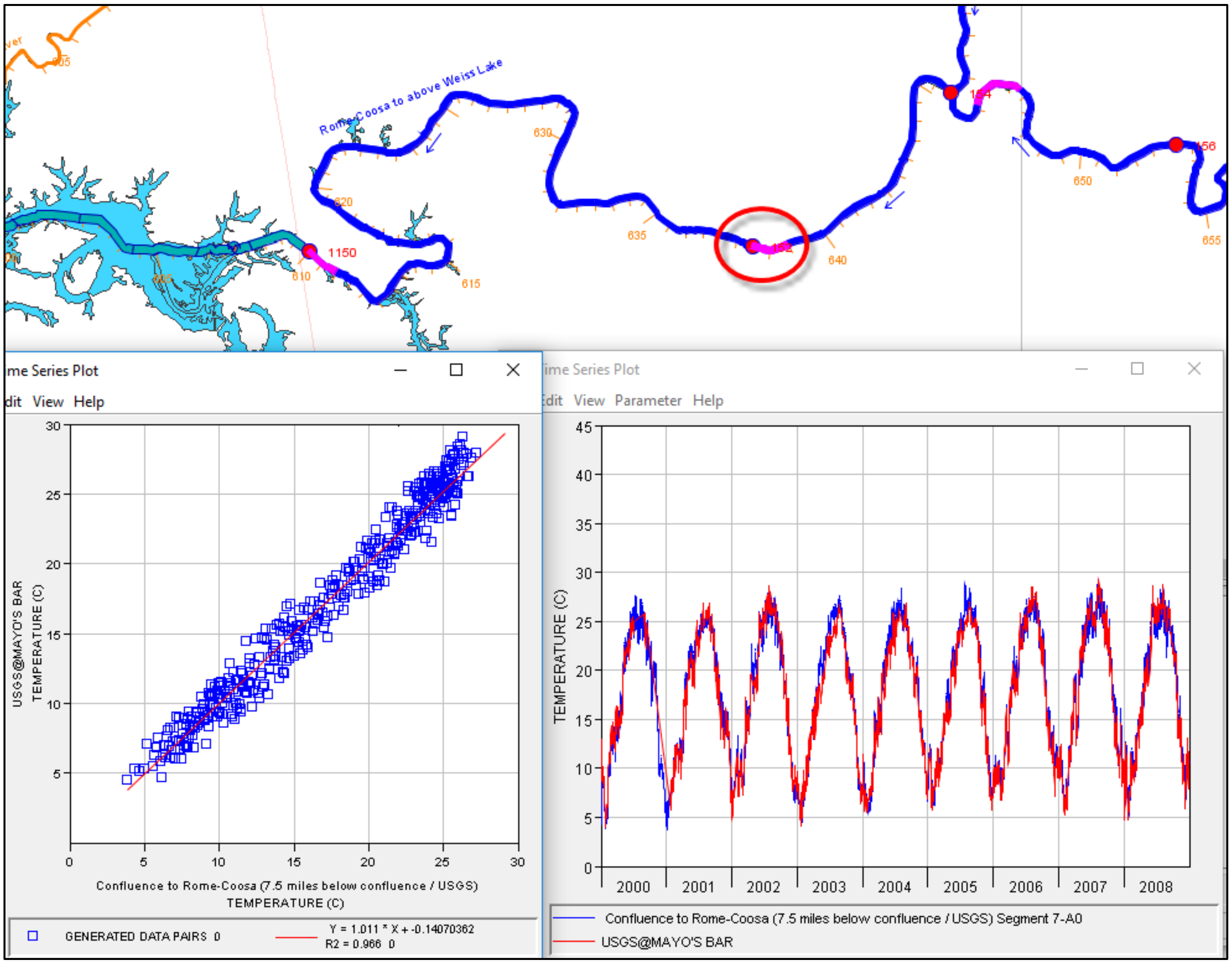
Table 2.8. Computed versus observed temperature statistics in the Coosa River at Mayo's Bar Lock and Dam and the state line for the 2001–2008 modeling period.

	Coosa River at the USGS gauge at Mayo's Lock and Dam (site)																
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	2961	762	1734	1967	1477	221	248	278	257	261	263	238	227	250	238	233	247
Mean absolute error	1.13	1.48	1.27	1.24	1.23	0.80	0.85	1.06	1.47	1.76	1.24	1.44	1.18	0.87	0.85	1.06	0.90
RMS error	1.43	1.83	1.59	1.55	1.55	0.98	1.02	1.34	1.81	2.04	1.59	1.83	1.41	1.05	1.05	1.25	1.09
Average - observed	17.37	22.93	22.07	21.12	23.08	8.06	8.92	12.61	16.31	20.19	23.76	25.02	26.20	24.09	19.51	14.03	9.66
Average - computed	18.12	23.90	22.83	21.90	23.71	8.73	9.39	13.52	17.75	21.75	24.37	25.73	26.29	24.25	20.07	15.02	10.29
Bias (comp-obs)	0.75	0.97	0.75	0.78	0.63	0.67	0.47	0.91	1.43	1.57	0.62	0.71	0.09	0.17	0.57	0.99	0.63
Bias (%)	2.1	2.1	1.7	1.8	1.4	4.0	2.5	3.5	4.2	3.7	1.3	1.4	0.2	0.3	1.4	3.4	3.2
	Coosa River at the Georgia Alabama State Line																
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	9075	2198	5303	6113	4613	711	737	755	690	730	744	724	818	787	810	810	759
Mean absolute error	1.32	1.58	1.43	1.38	1.42	1.28	1.20	1.10	1.46	1.63	1.47	1.63	1.48	1.25	1.10	1.07	1.23
RMS error	1.70	1.92	1.77	1.73	1.76	1.69	1.58	1.36	1.84	1.94	1.84	2.00	1.81	1.56	1.36	1.48	1.81
Average - observed	19.91	26.16	25.32	24.07	26.41	9.68	10.59	13.62	18.00	22.71	27.32	28.45	30.01	27.46	22.44	15.92	11.34
Average - computed	19.74	26.83	25.40	24.07	26.32	8.69	9.70	14.23	19.30	23.97	27.71	28.82	29.32	26.52	21.68	15.37	10.47
Bias (comp-obs)	-0.17	0.67	0.09	0.00	-0.09	-0.99	-0.88	0.61	1.30	1.27	0.39	0.36	-0.68	-0.93	-0.76	-0.55	-0.87
Bias (%)	-0.4	1.3	0.2	0.0	-0.2	-5.4	-4.3	2.2	3.5	2.7	0.7	0.6	-1.1	-1.7	-1.7	-1.8	-4.0



Note: The scatter plot in the left panel covers the same time period as the time series plot in the right panel.

Figure 2.13. Computed and observed water temperature at Mayo's Bar Lock and Dam using the 2014 model and extrapolated meteorological inputs.



Note: The scatter plot in the left panel covers the same time period as the time series plot in the right panel.

Figure 2.14. Computed and observed water temperature at Mayo's Bar Lock and Dam using the 2019 model and meteorological inputs based on Taylorsville data.

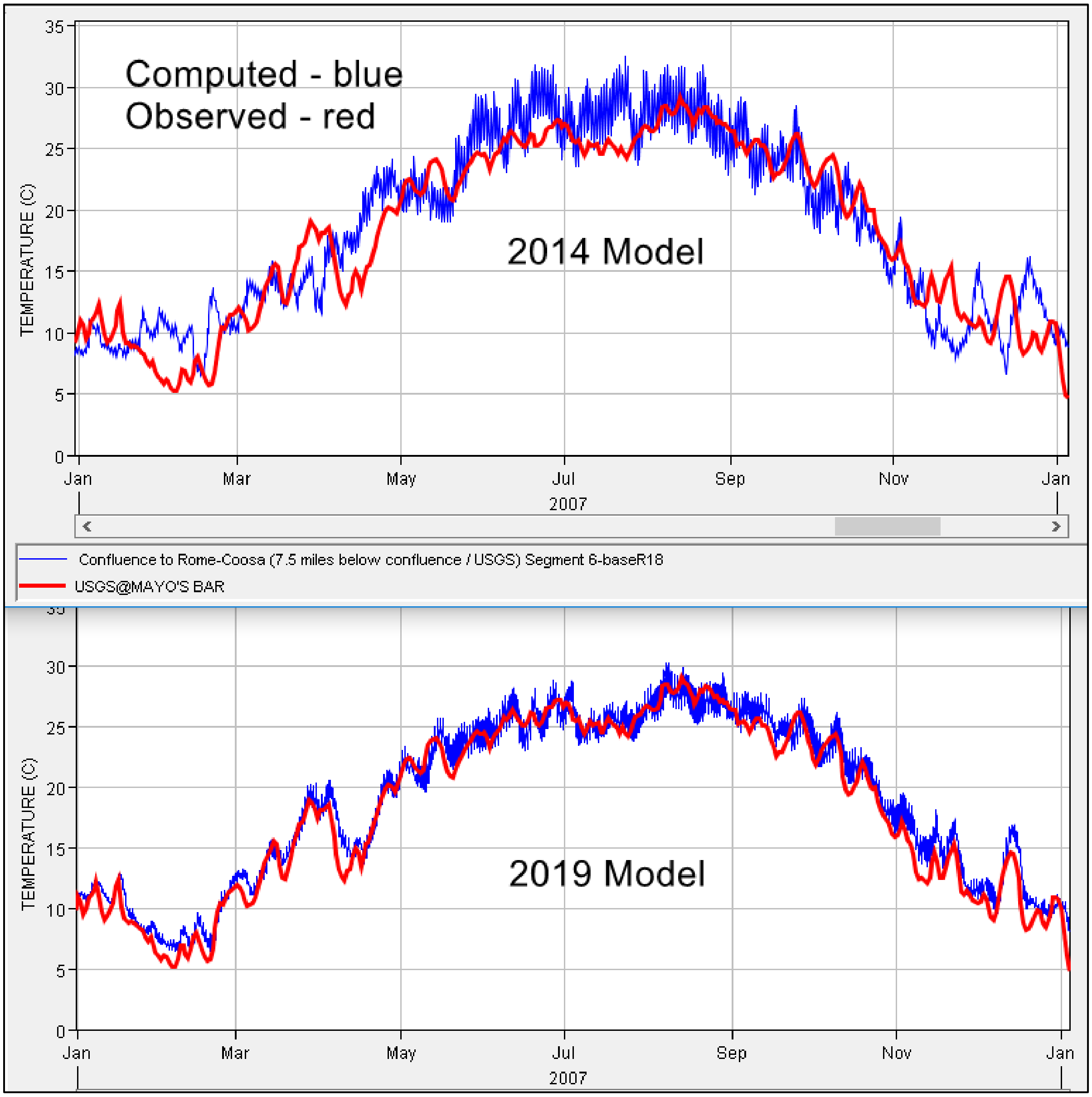


Figure 2.15. Computed and observed water temperature at Mayo's Bar Lock and Dam for the 2014 and 2019 models and corresponding meteorological inputs.

3. DEMONSTRATION OF MODEL PERFORMANCE

Extensive comparison of modeled and observed time series (streams) and profiles (reservoirs) was performed on the HEC-5Q ACT model. Since the HEC-ResSim model flows differ from actual historical flows, this comparison is not referred to as model validation, but it represents a similar process. In addition, a model sensitivity analysis was performed, as detailed in Appendix B. For model performance demonstration, the point source and non-point source water quality described in Section 2.11 was assumed. Constituents chosen for presentation of model demonstration results include temperature, DO, NO_3, NH_3, PO_4, and chlorophyll *a*. Nutrient and chlorophyll *a* data are typically available at monthly intervals during the spring, summer and fall months (growing season) and represent conditions in the photic zone.

Water temperature ramifications of the 1-hour based meteorological data developed during this effort are discussed in Chapter 2. That discussion focused on the Coosa River above Weiss Lake. As such, that discussion serves as part of the temperature model demonstration.

Additionally, the USGS monitored temperature in the Etowah River below Allatoona Dam during 2005 and 2006. Figure 3.1 shows the computed and observed temperatures at the following locations (note that the location names reflect the USGS gauge names):

- Allatoona Dam – ½ mile below the dam
- GA61.Cartersville – 9 miles below the dam
- Kingston – 27 miles below the dam and
- GA1.loop near Rome – 47 miles below dam

The minimum observed temperature is shown in Figure 3.1. The actual USGS data also include the maximum temperature. However, the maximum temperature occurs during non-power periods when the quiescent water warms due to the meteorological condition. The model assumes a uniform release rate (daily average flow throughout) so the model results are comparable to the minimum (power cycle) observed temperatures. Since the model results always reflect the average condition, the model results should be interpreted as the daily minimum. This also applies to DO.

A review of Figure 3.1 indicates that the model produces reasonable approximation of the observed data. The diurnal variation at Cartersville and Kingston is larger for the observed so that the maximum temperature is often 1 °C greater than the computed. Table 3.1 provides statistics for these four locations. The bias (computed-observed) is generally less than 1 °C at all locations and time periods.

The reservoir temperature profiles presented below augment the Chapter 2 discussion and further demonstrate the veracity of the new meteorological inputs.

Figure 3.2 through Figure 3.6 show typical computed and observed temperature profiles in various reservoirs. The locations of all reservoirs are shown in Figure 2.2. Figure 3.2 and Figure 3.3 are for Lake Allatoona and Lake Martin, respectively. These lakes are represented in the model as laterally mixed and vertically segmented reservoirs. Each of the profile plots have multiple observed profiles representing various spatial locations within each lake. The goal of the calibration was to focus on the profiles near the dam (deepest profile) so that the dam outflow to the river would be emphasized. Several of the plots have shallow profiles that cannot be represented with the laterally mixed assumption model but appear on the plot to provide an indication of the lateral variability. R. L. Harris Lake (Tallapoosa River) and Carters Lake (Coosawattee River) are also represented as laterally mixed and vertically segmented reservoirs.

Figure 3.4 through Figure 3.6 are for longitudinally segmented reservoirs. These reservoirs are represented as a series of segments whereas the vertically segmented reservoirs have no segment lines.

Figure 3.4 and Figure 3.5 are for Lake Weiss and Millers Ferry Lake, respectively. These profile plots have a background map indicating the reservoir segments that are represented by the computed temperature profiles. The exact locations of observed temperature profiles are unknown; however, the deeper profile tend to be near the dam. All the reservoirs represented this way are weakly stratified with very little thermal stratification. A review of these figures shows that the surface temperatures and degree of stratification are well represented in the model. The weak thermal stratification is due to relative high flow through rate (low residence times) and the near equilibrium temperatures of the inflows temperatures.

Yates Lake, below Martin Dam, exhibits the slightly greatest degree of stratification due to the cooler inflow originating from the Lake Martin hypolimnion. Typical profiles for Yates Lake are shown in Figure 3.6. The observed profiles of August 13, 2007, June 17, 2008, and July 22, 2008 show the largest degree of thermal stratification. The average observed bottom and surface temperatures on these three dates are 16 ˚C and 29 ˚C, respectively. The average observed surface temperature of Lake Martin is approximately 32 ˚C and the computed Martin Dam release temperature is approximately 16 ˚C. The Lake Martin surface temperature is near equilibrium due to the long residence time of the surface layer. The heat flux to Yates Lake (more rapid surface heating) is larger due the bigger difference between the surface temperature and equilibrium temperature. A comparison of Figure 3.5 and Figure 3.6 indicates that the hypolimnion temperatures are approximate 20 °C and 29 °C for Yates and Millers Ferry, respectively, in July 2005. The warmer Millers Ferry hypolimnion indicates that Tallapoosa River temperature has approached equilibrium prior to reaching the Alabama River. The Yates hypolimnion temperature is well represented so that the discharge to the Tallapoosa River is also well represented.

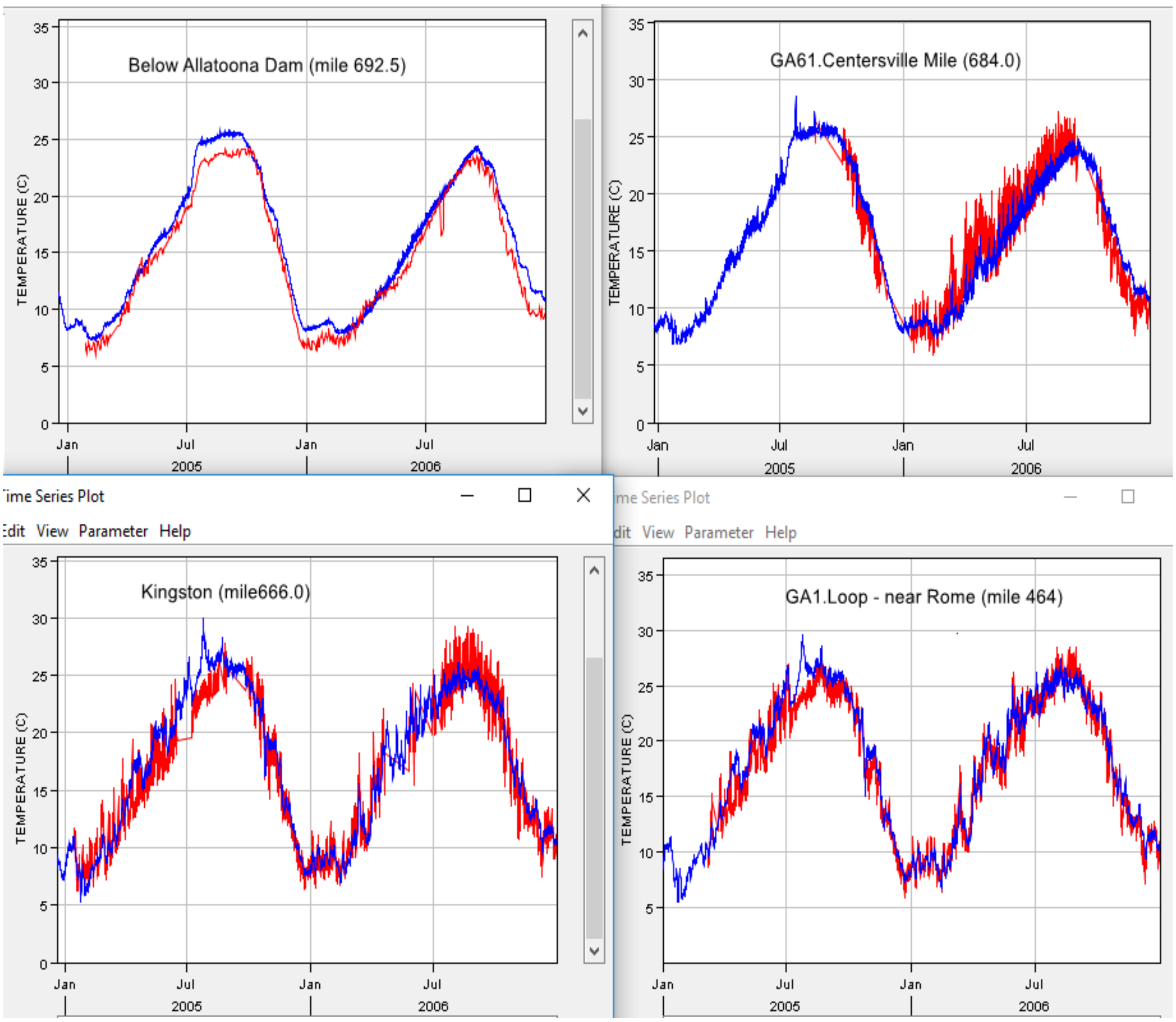


Figure 3.1. Computed (blue) and observed (red) temperatures in the Etowah River downstream of Allatoona Dam.

Table 3.1. Statistical comparison between computed and observed temperatures in the Etowah River downstream of Allatoona Dam for the 2001–2008 modeling period.

Computed and Observed temperature (Celsius)																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Etowah River below Allatoona Dam (USGS-Allatoona Dam)																	
total # points	694	184	428	488	368	36	56	52	60	62	60	62	62	60	62	60	62
Mean absolute error	1.24	1.38	1.14	1.22	1.24	1.47	1.04	0.75	0.50	1.20	1.28	1.66	1.06	1.31	0.96	1.83	1.81
RMS error	1.41	1.52	1.33	1.41	1.41	1.50	1.10	0.87	0.64	1.25	1.33	1.88	1.29	1.42	1.14	1.93	1.89
Average - observed	15.01	16.53	18.35	17.90	19.43	7.02	7.13	8.69	11.70	13.56	16.29	19.74	22.60	23.35	21.06	14.70	9.32
Average - computed	16.22	17.91	19.45	19.09	20.66	8.49	8.16	9.32	12.03	14.76	17.56	21.40	23.66	24.66	21.95	16.53	11.13
Bias (comp-obs)	-1.21	-1.38	-1.10	-1.19	-1.23	-1.47	-1.04	-0.64	-0.33	-1.20	-1.28	-1.66	-1.05	-1.31	-0.88	-1.83	-1.81
Bias (%)	-3.9	-4	-2.9	-3.2	-3.1	-9.5	-6.8	-3.5	-1.4	-4.2	-3.8	-4	-2.3	-2.7	-2.1	-5.8	-8.9
Etowah River near Cartersville (USGS-GA61; 9 miles below Allatoona Dam)																	
total # points	1158	273	648	825	558	60	84	93	90	93	87	93	96	39	150	177	96
Mean absolute error	1.50	1.60	1.57	1.58	1.41	0.96	0.94	1.62	2.59	1.72	1.59	1.50	1.17	1.05	1.29	1.60	1.50
RMS error	1.93	2.05	2.07	2.03	1.83	1.12	1.13	2.08	3.15	2.29	2.02	1.81	1.67	1.34	1.61	1.90	1.76
Average - observed	16.11	18.66	19.76	18.68	20.44	8.56	8.37	11.15	15.56	16.21	18.64	21.13	23.83	24.08	20.57	14.70	10.37
Average - computed	16.06	18.06	19.19	18.56	20.18	8.78	8.49	9.79	13.04	15.25	18.15	20.79	22.92	23.96	21.30	16.26	11.82
Bias (comp-obs)	0.05	0.60	0.57	0.12	0.26	-0.22	-0.13	1.37	2.51	0.96	0.49	0.34	0.91	0.12	-0.73	-1.55	-1.44
Bias (%)	0.2	1.6	1.5	0.3	0.6	-1.3	-0.7	6.5	8.8	3.1	1.3	0.8	1.9	0.3	-1.8	-5	-6.5
Etowah River at Kingston (USGS -Kingston; 27 miles below Allatoona Dam)																	
total # points	1749	308	888	1068	741	143	166	186	147	99	64	145	144	103	186	180	186
Mean absolute error	1.37	2.10	1.73	1.62	1.73	0.85	1.04	1.12	1.74	2.01	1.92	2.25	1.65	1.37	1.36	1.10	0.86
RMS error	1.75	2.48	2.12	2.01	2.11	1.01	1.31	1.40	2.16	2.35	2.30	2.63	2.04	1.67	1.68	1.38	1.06
Average - observed	16.05	20.76	20.95	19.90	22.07	8.72	9.31	11.67	15.30	17.87	19.62	23.24	25.35	24.08	20.60	14.71	9.99
Average - computed	16.44	22.21	21.64	20.58	22.71	8.71	8.65	11.51	16.23	19.34	20.64	24.87	25.38	23.96	20.79	15.36	10.48
Bias (comp-obs)	-0.39	-1.45	-0.69	-0.68	-0.64	0.01	0.66	0.15	-0.94	-1.48	-1.02	-1.63	-0.03	0.13	-0.19	-0.66	-0.49
Bias (%)	-1.2	-3.4	-1.6	-1.7	-1.4	0.1	3.7	0.7	-3	-4	-2.5	-3.4	-0.1	0.3	-0.5	-2.2	-2.4
Etowah River at above Rome (USGS -GA1.Loop; 47 miles below Allatoona Dam)																	
total # points	1953	552	1279	1459	1102	93	84	131	177	186	180	186	186	178	186	180	186
Mean absolute error	1.19	1.67	1.40	1.34	1.37	0.61	0.67	0.99	1.58	1.67	1.59	1.74	1.20	0.97	1.03	0.89	0.69
RMS error	1.52	2.01	1.74	1.67	1.70	0.74	0.82	1.23	1.95	1.93	1.94	2.15	1.44	1.18	1.28	1.13	0.89
Average - observed	18.07	21.51	21.60	20.72	22.44	9.10	8.93	12.42	16.39	18.86	21.77	23.93	25.84	24.20	20.08	14.46	9.90
Average - computed	18.78	22.88	22.56	21.63	23.36	9.18	8.72	12.36	17.59	20.29	22.91	25.44	26.26	24.79	20.53	15.02	10.24
Bias (comp-obs)	-0.71	-1.37	-0.96	-0.91	-0.93	-0.08	0.21	0.05	-1.19	-1.43	-1.14	-1.52	-0.43	-0.59	-0.45	-0.56	-0.34
Bias (%)	-1.9	-3.1	-2.2	-2.2	-2	-0.4	1.2	0.2	-3.5	-3.7	-2.6	-3.1	-0.8	-1.2	-1.1	-1.9	-1.7

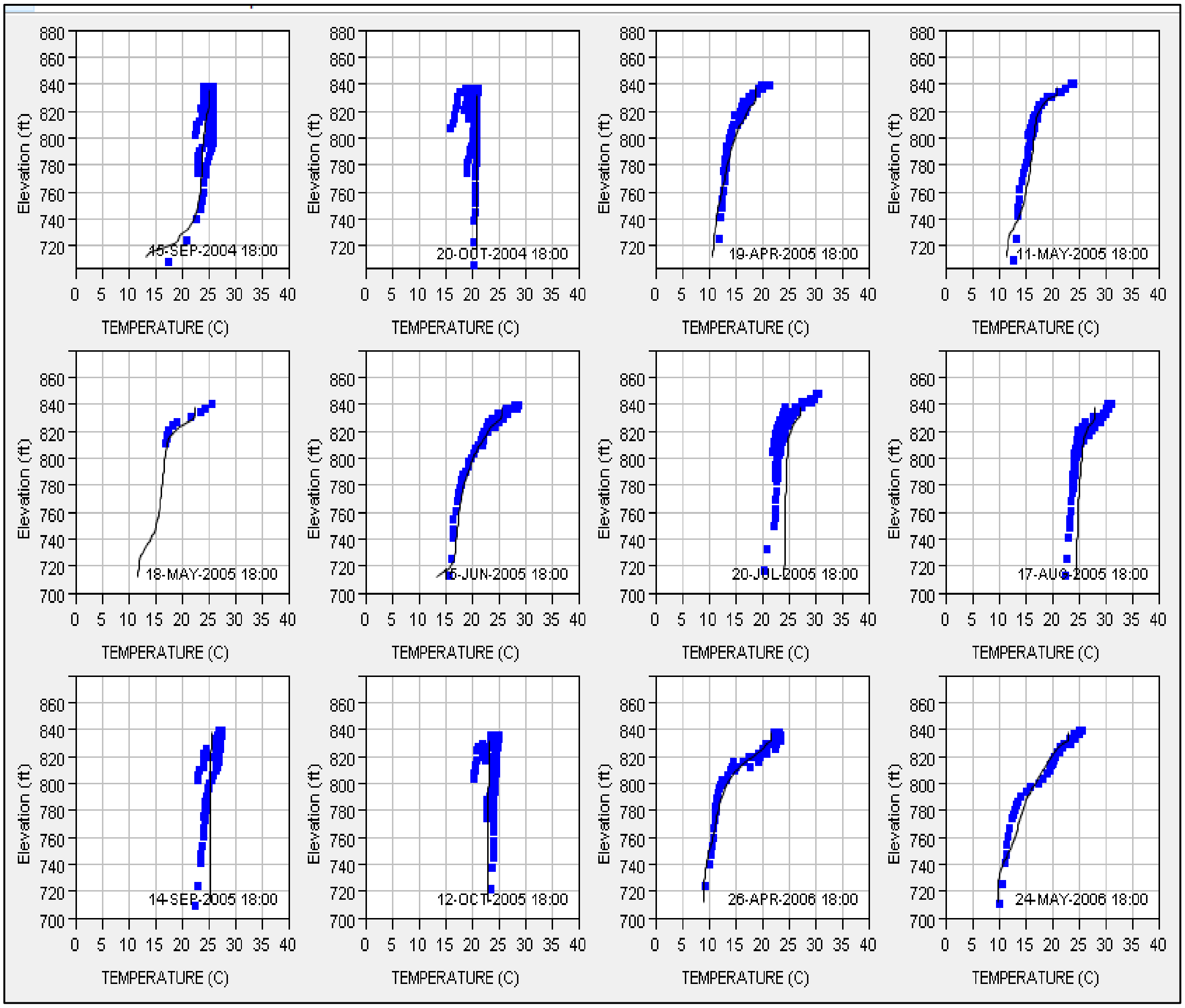


Figure 3.2. Typical computed (black lines) and observed (blue markers) temperature profiles in Lake Allatoona – Etowah River.

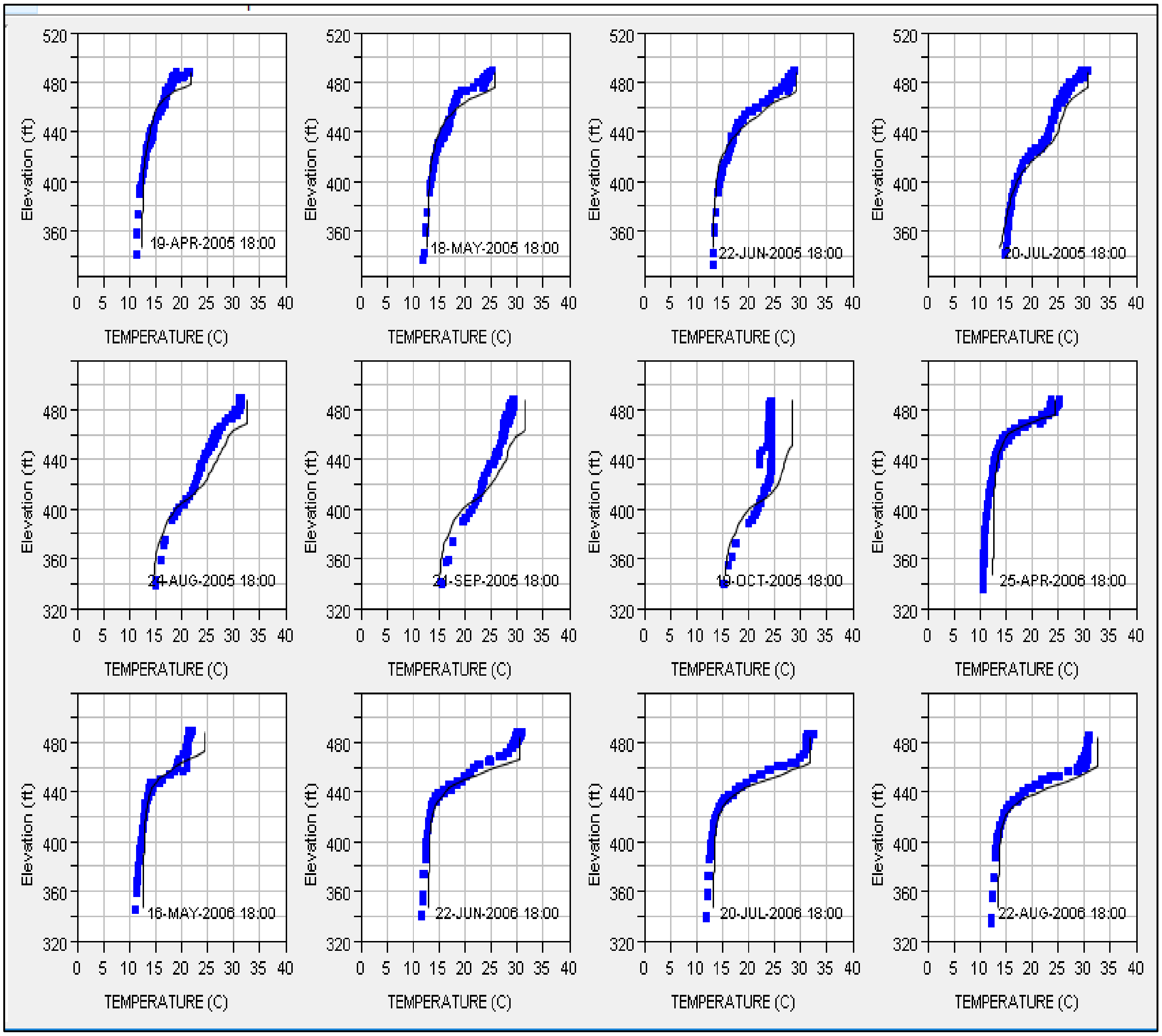


Figure 3.3. Typical computed (black lines) and observed (blue markers) temperature profiles in Lake Martin – Tallapoosa River.

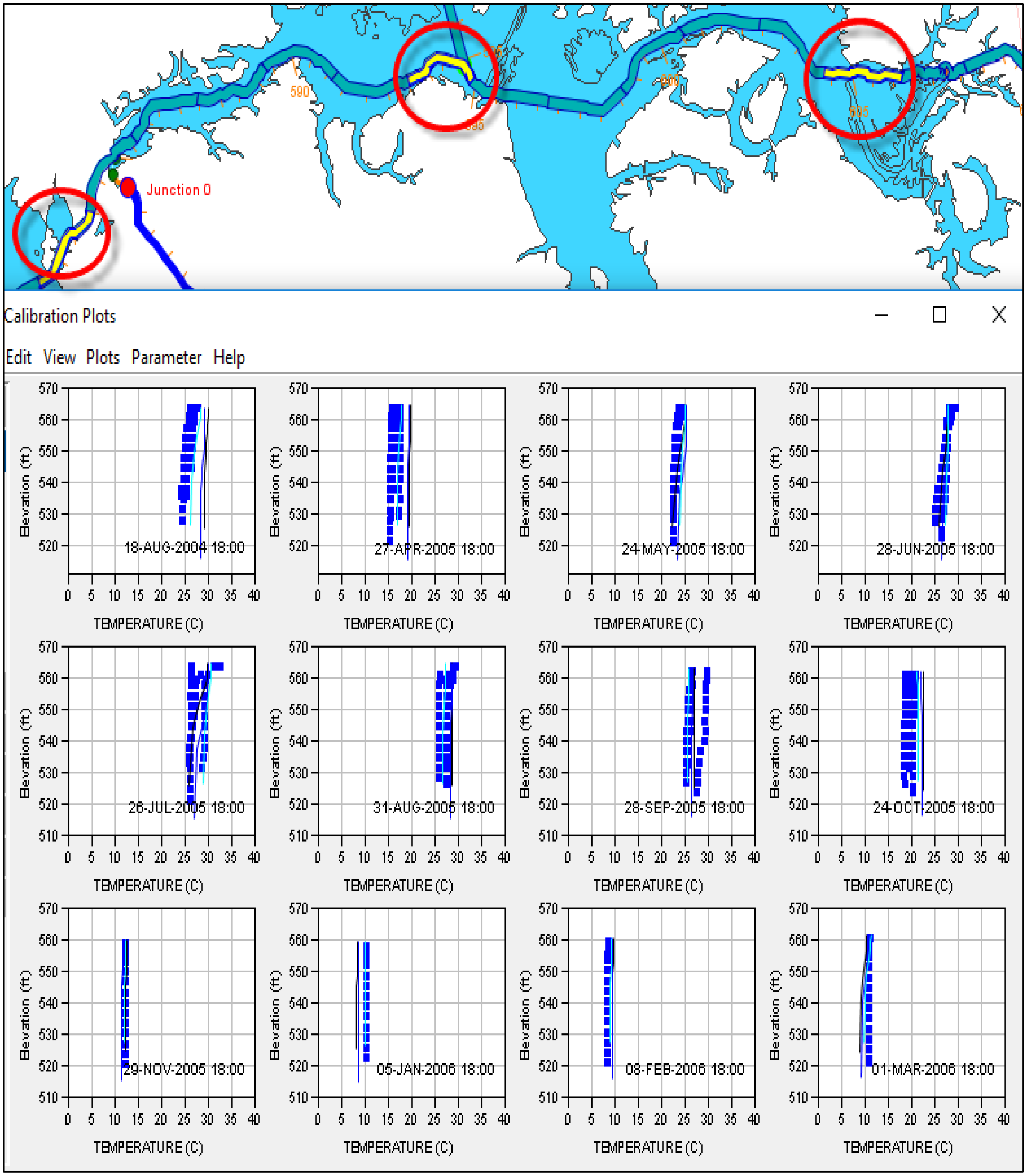


Figure 3.4. Typical computed (black and cyan lines) and observed (blue markers) temperature profiles in Lake Weiss – Coosa River. The deeper profiles are near the dam.

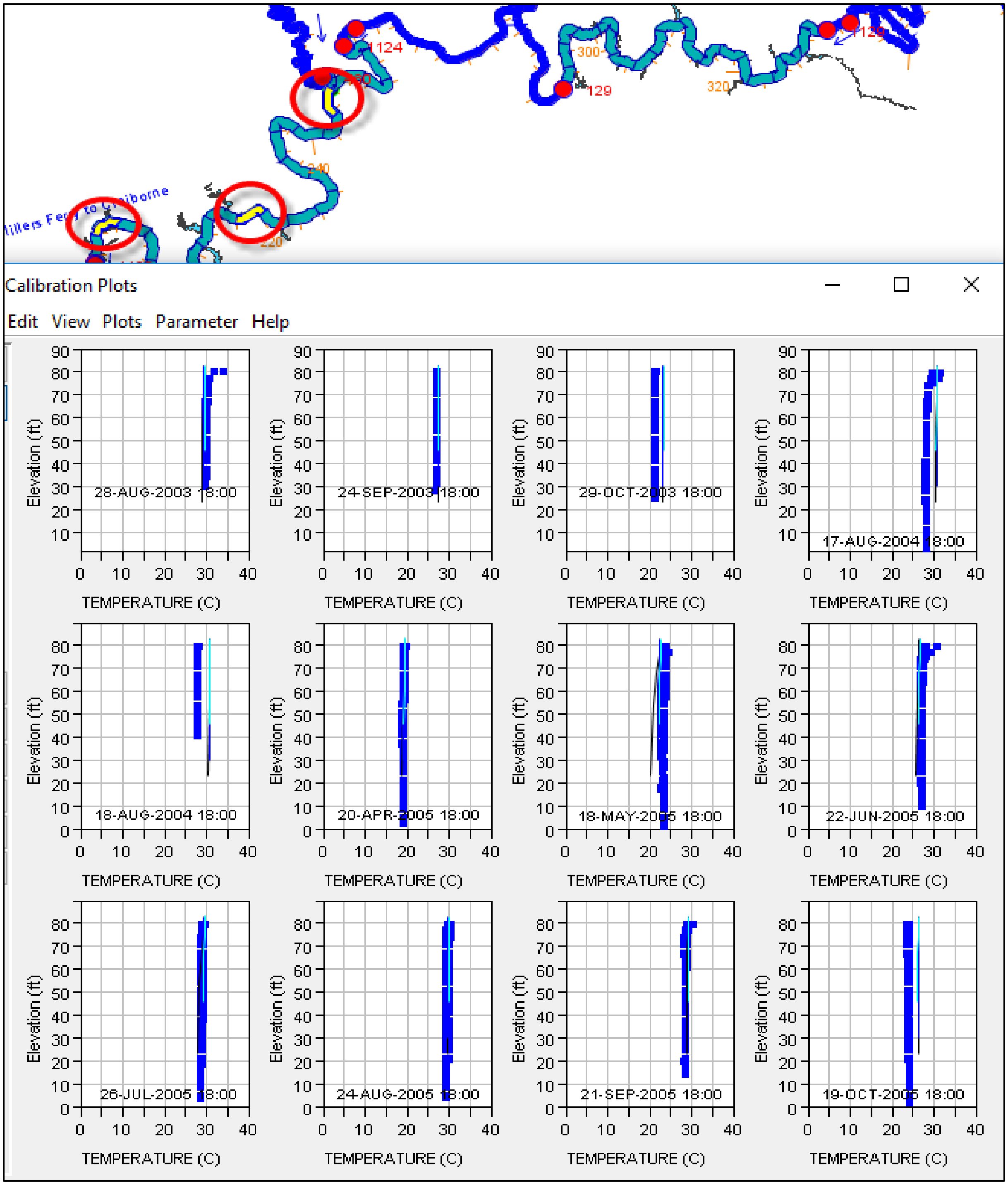


Figure 3.5. Typical computed (black and cyan lines) and observed (blue markers) temperature profiles in Millers Ferry – Alabama River. The deeper profiles are near the dam.

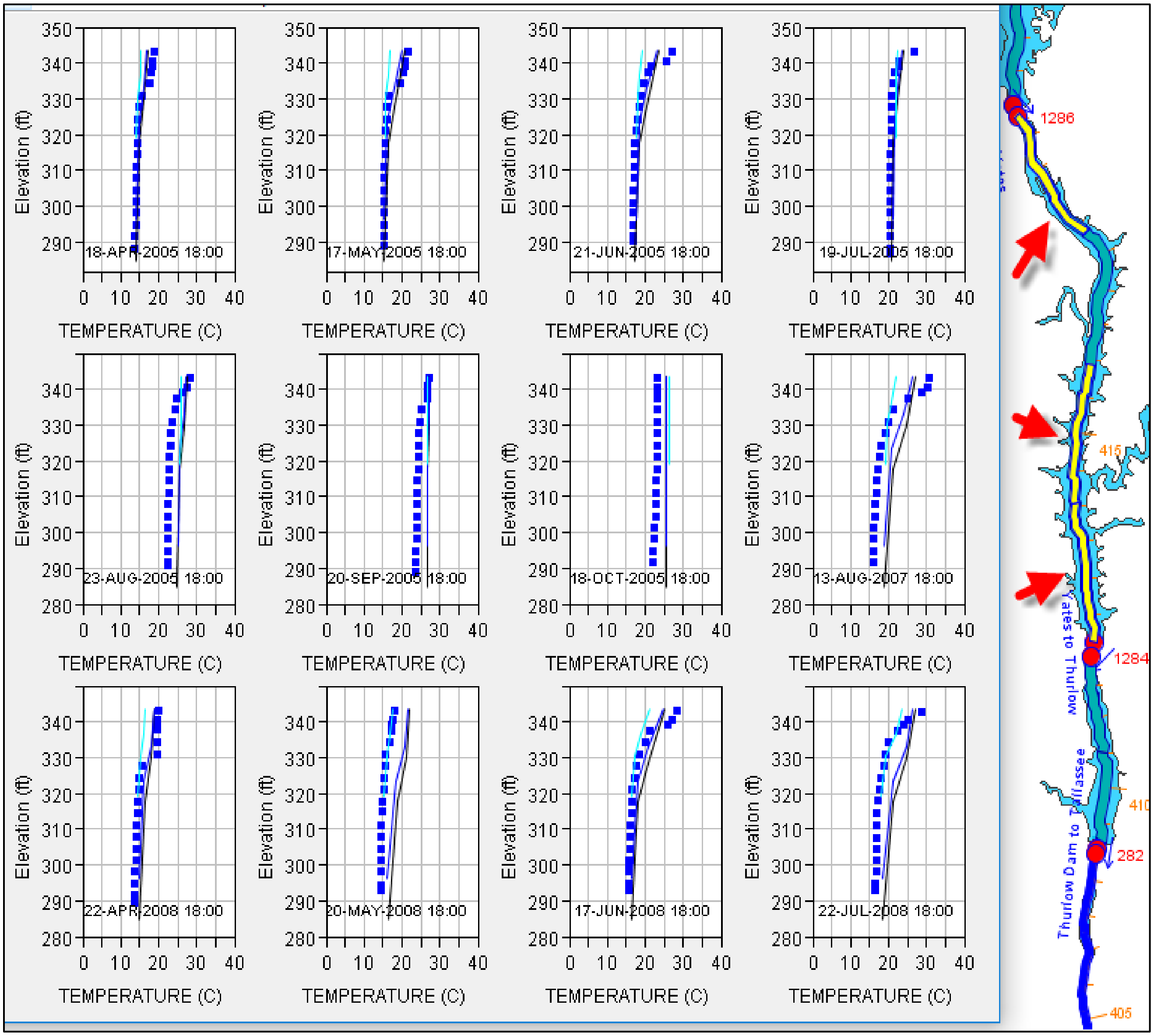


Figure 3.6. Typical computed (black and cyan lines) and observed (blue markers) temperature profiles in Yates Lake – Tallapoosa River. The deeper profiles are near the dam.

3.1 WATER QUALITY DEMONSTRATION

The point (municipal and industrial discharges) and non-point (streams) inflow data were unchanged from the 2014 modeling effort (HEC 2014), since the selected modeling period (2001–2008) was not changed. The net point and non-point flows were defined explicitly in the HEC-ResSim model hydrology. The associated non-point water quality was based on output from an USEPA BASINS model. The point source data were defined by discharger data compiled by USACE from the Georgia Environmental Protection Division, Alabama Department of Environmental Management, and federal USEPA databases. The BASINS processing and point source data are described in detail and are included by reference (RMA 2014) herein. All facets of the earlier study were subject to internal and external review.

However, some changes were made to the model in the current study including the meteorology and computational time step. Therefore, the model demonstration was refreshed for the current HEC-5Q model based on the updated meteorology and 1-hour time step. The 2014 report contains numerous time series and profile plots without supporting statistics. In this report, typical plots are included with supporting statistics to quantify model accuracy.

3.1.1 LAKE DISSOLVED OXYGEN

Typical computed and observed DO profiles in various reservoirs are presented to quantify the model's accuracy for both vertically segmented and layered longitudinally segmented reservoirs. Figure 3.7 and Figure 3.8 are for Lake Allatoona and Lake Martin, respectively. Both of these lakes are represented in the model as laterally mixed and vertically segmented. Each of the profile plots have multiple observed profiles representing various spatial locations within each lake. The goal of the calibration was to emphasize the profiles near the dam (deepest profile) so that the dam outflow to the river is represented. Additionally, the surface oxygen concentration was emphasized as well as the variation with depth. On one occasion, both the computed and observed surface DO falls below 5 mg/L in Lake Allatoona (October 20, 2004). The surface DO concentration exceeds 6 mg/L at all plot times at both reservoirs. R. L. Harris Lake (Tallapoosa River) and Carters Lake (Coosawattee River) are also represented as laterally mixed and vertically segmented reservoirs.

Figure 3.9 and Figure 3.10 are for Lake Weiss and Millers Ferry Lake, respectively. They are both represented in the model as longitudinally segmented and layered reservoirs. These profile plots have a background map indicating the reservoir segments that are represented by the computed temperature profiles. The exact locations of observed temperature profiles are unknown; however, the deeper profile tend to be near the dam. The reservoirs represented this way are weakly stratified with very little thermal stratification. However, DO (chemical stratification) can be large due to the warm temperatures, oxygen consuming matter (BOD) and photosynthesis. A review of these figures shows that the surface DO never drops below 6 mg/L at both lakes on the sampling dates. The degree of stratification is well represented. The degree of stratification is less in Millers Ferry caused in part by the extremely weak thermal stratification (Figure 3.5) and possibly a lesser amount of oxygen consuming material depleted within the reservoirs upstream.

Figure 3.11 shows typical computed and observed oxygen profiles in Logan Martin Lake. This figure is included to demonstrate how thermal destratification impacts DO. On July 20, 2004, the computed and observed profiles are very similar. The August 19, 2004 profiles are quite different in that the observed data show stratification while the model is more vertically mixed with a low surface concentration approximately 4 mg/L less than observed. The low concentration results from oxygenated surface waters mixing with anoxic water at depth (July 20, 2004). On September 22, 2004, both the computed and observed profiles are vertically mixed (overturn). Note that the model surface concentration is nearly 2 mg/L greater than the observed due to the mixing of the water column. This sequence of plots illustrated that surface oxygen dips at overturn as the low concentration hypolimnion water mix with the oxygenated surface waters. Both the data and model show this effect although the model overturns prior to what the data indicates. On October 20, 2004, both the model and data are in sync. While the model timing of overturn is approximate, the impacts on surface concentration appear reasonably well represented. The overturn results in concentrations below the DO standard of 5.0 mg/L.

The model assumption used during this study is that the oxygen injection systems added on the Logan Martin, Weiss, and H. Neely Henry Dams by APC were operational with the requirement that a minimum dissolved oxygen of 4 mg/L at the compliance point for each dam is being achieved. Figure 3.12 compares the 2008 computed DO concentration below Logan Martin Dam with observed data from 2018. This figure demonstrates that the computed DO does not drop below 4 mg/L even though Figure 3.11 clearly shows anoxic conditions in the lake hypolimnion. However, there is considerable variation in the observed data that cannot be replicated in the model. The scatter results from dam underflow during off-peak power generation periods. This underflow originates upstream of the dam and is often anoxic. The underflow rate is approximately 750 cfs. The model uses a daily average flow that are an average of the peak and off-peak generation rates. The daily average flow almost always exceeds 750 cfs.

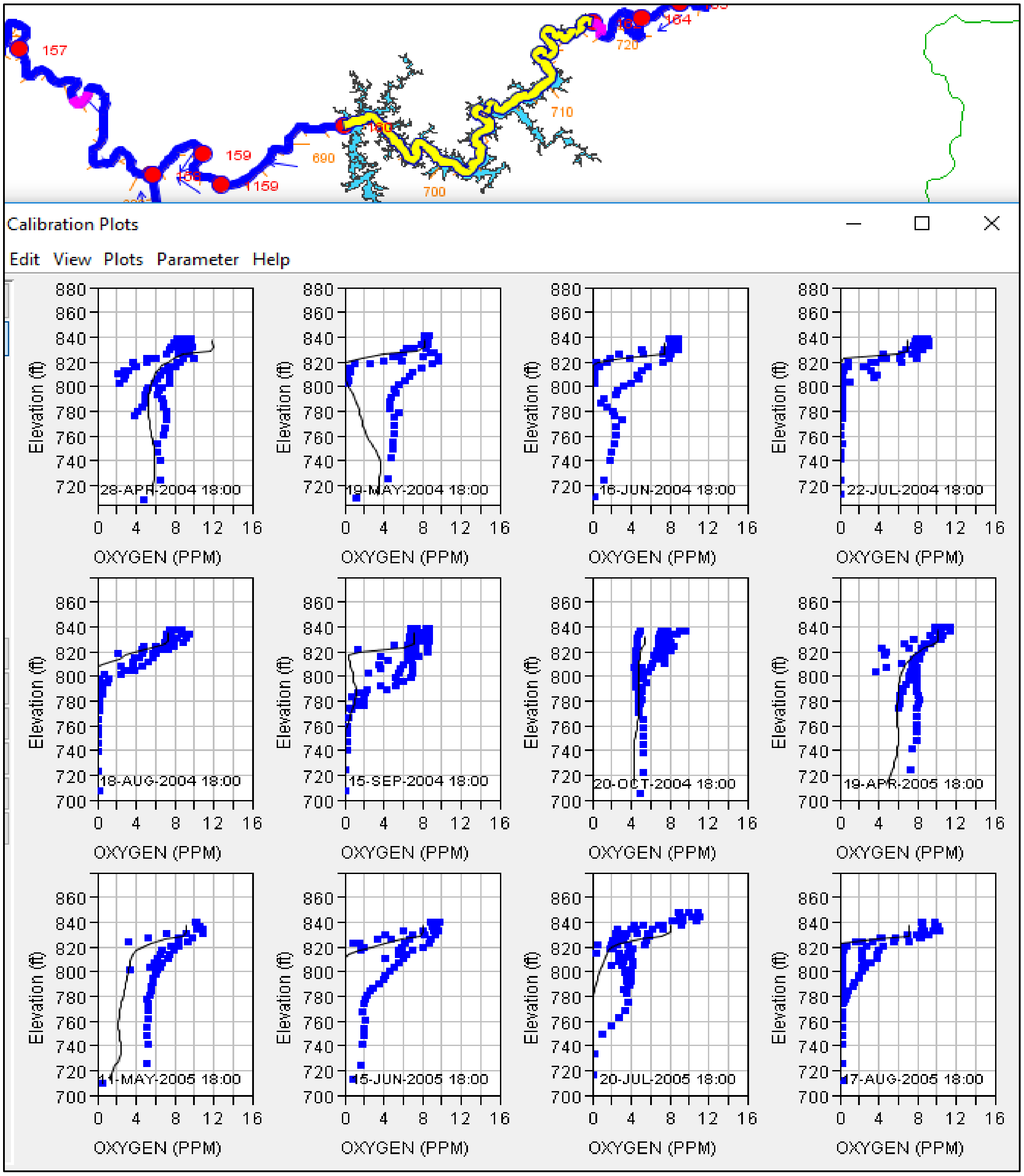


Figure 3.7. Typical computed (black lines) and observed (blue markers) oxygen profiles in Lake Allatoona – Etowah River. The blue dots show the observed values from multiple locations along the reservoir. Lake Allatoona. The deeper profiles are near the dam.

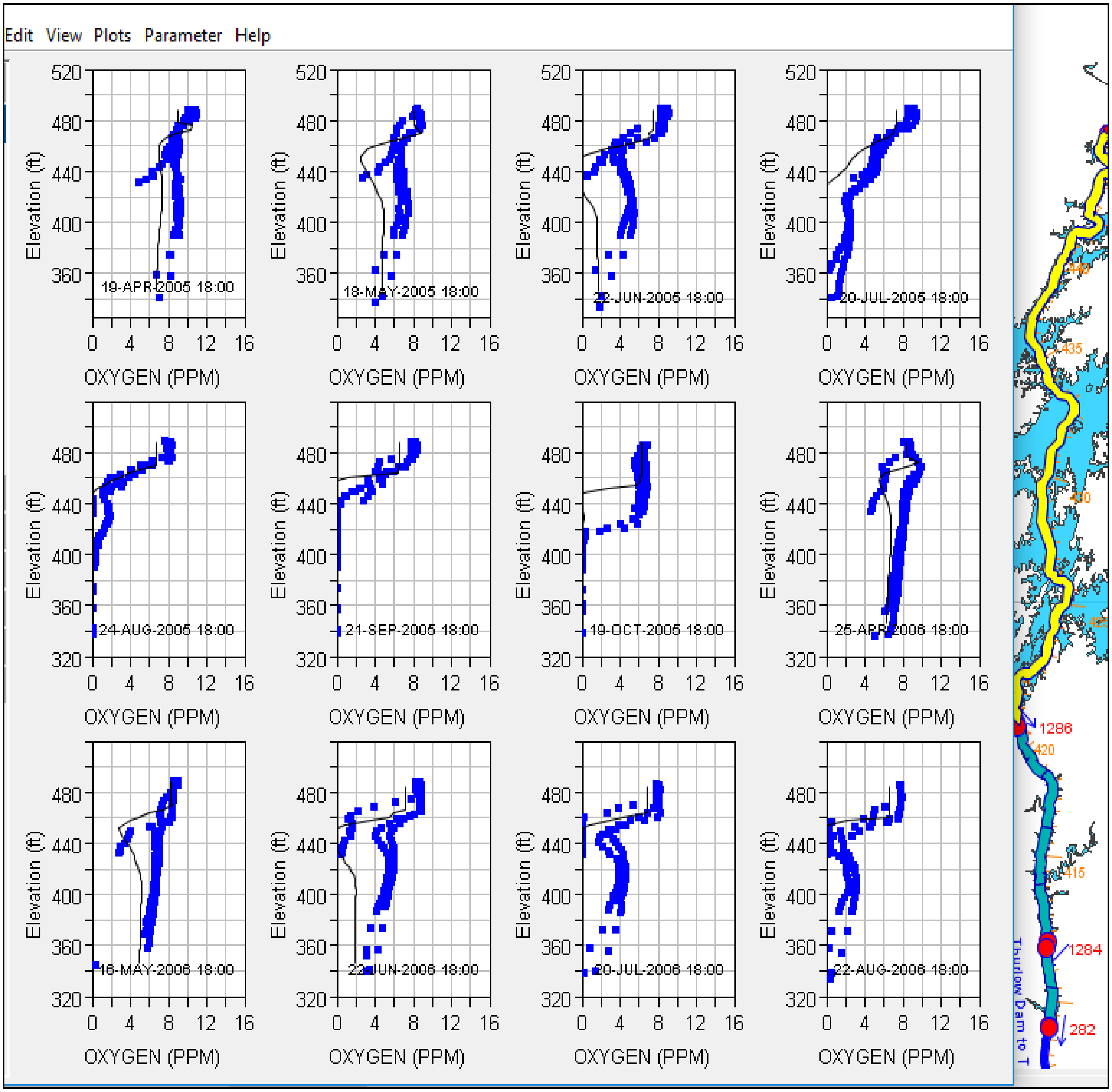


Figure 3.8. Typical computed (black lines) and observed (blue markers) oxygen profiles in Lake Martin – Tallapoosa River. The deeper profiles are near the dam.

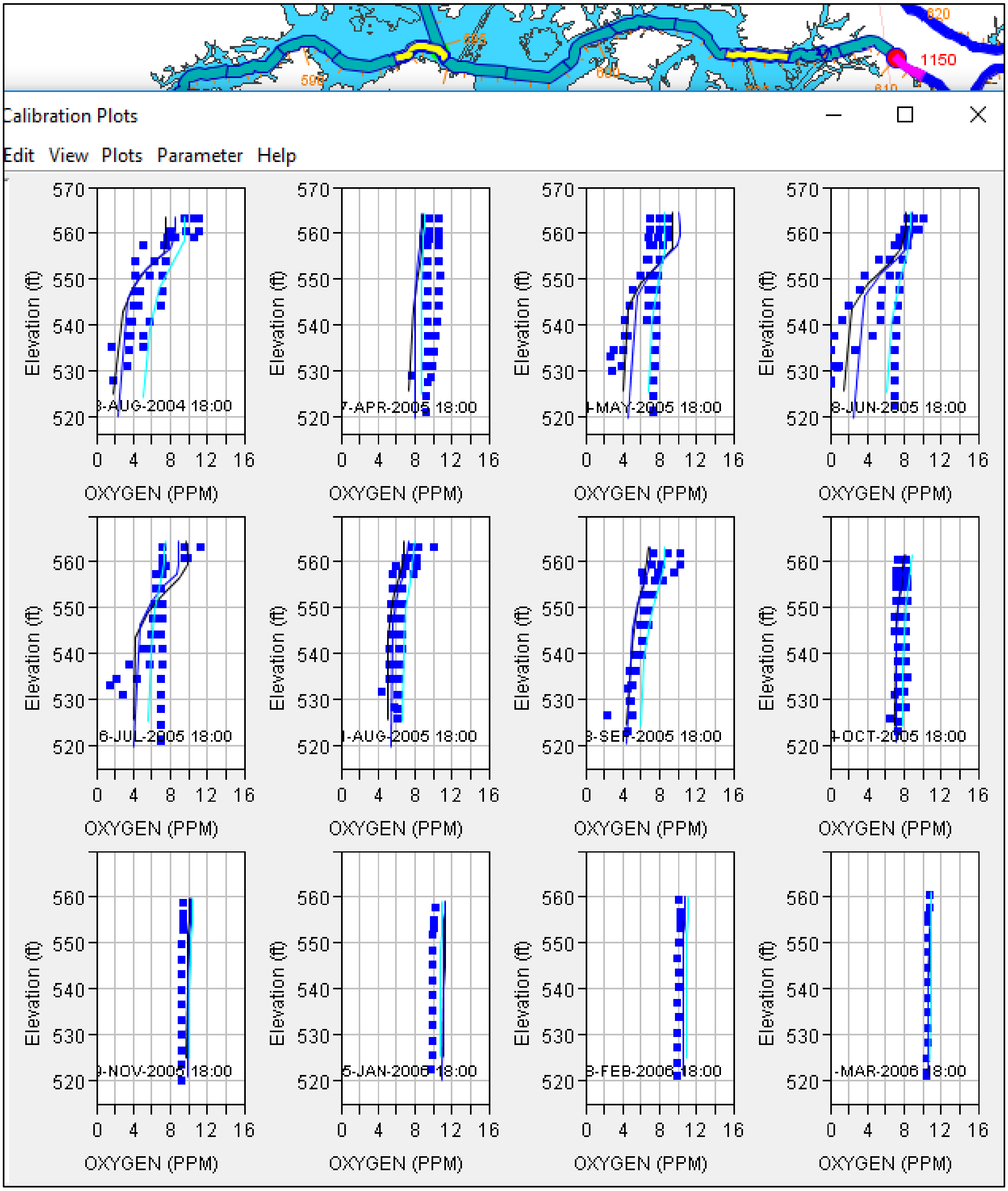


Figure 3.9. Typical computed (black and cyan lines) and observed (blue markers) oxygen profiles in Weiss Lake – Coosa River. The deeper profiles are near the dam.

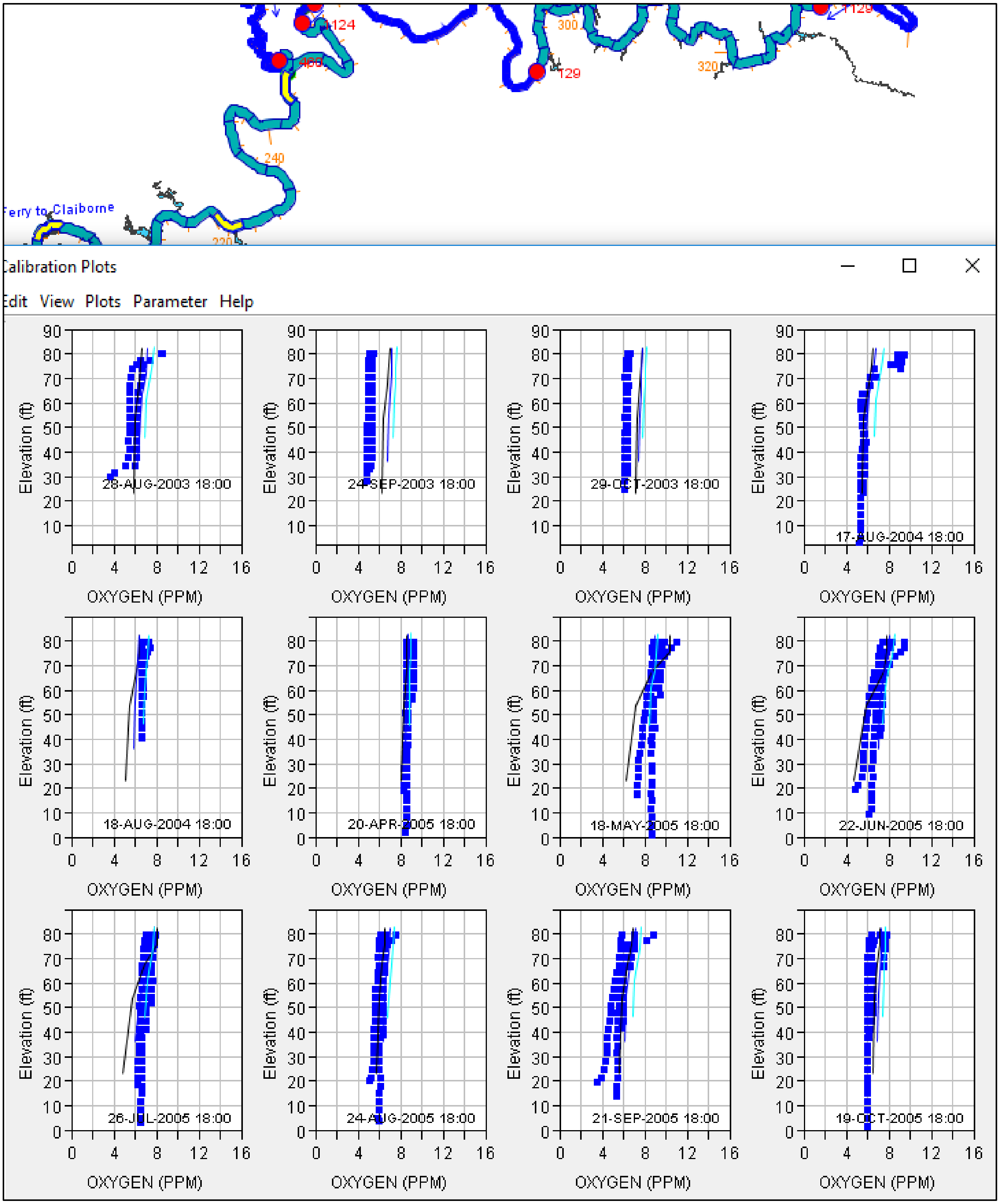


Figure 3.10. Typical computed (black and cyan lines) and observed (blue markers) oxygen profiles in Millers Ferry – Alabama River. The deeper profiles are near the dam.

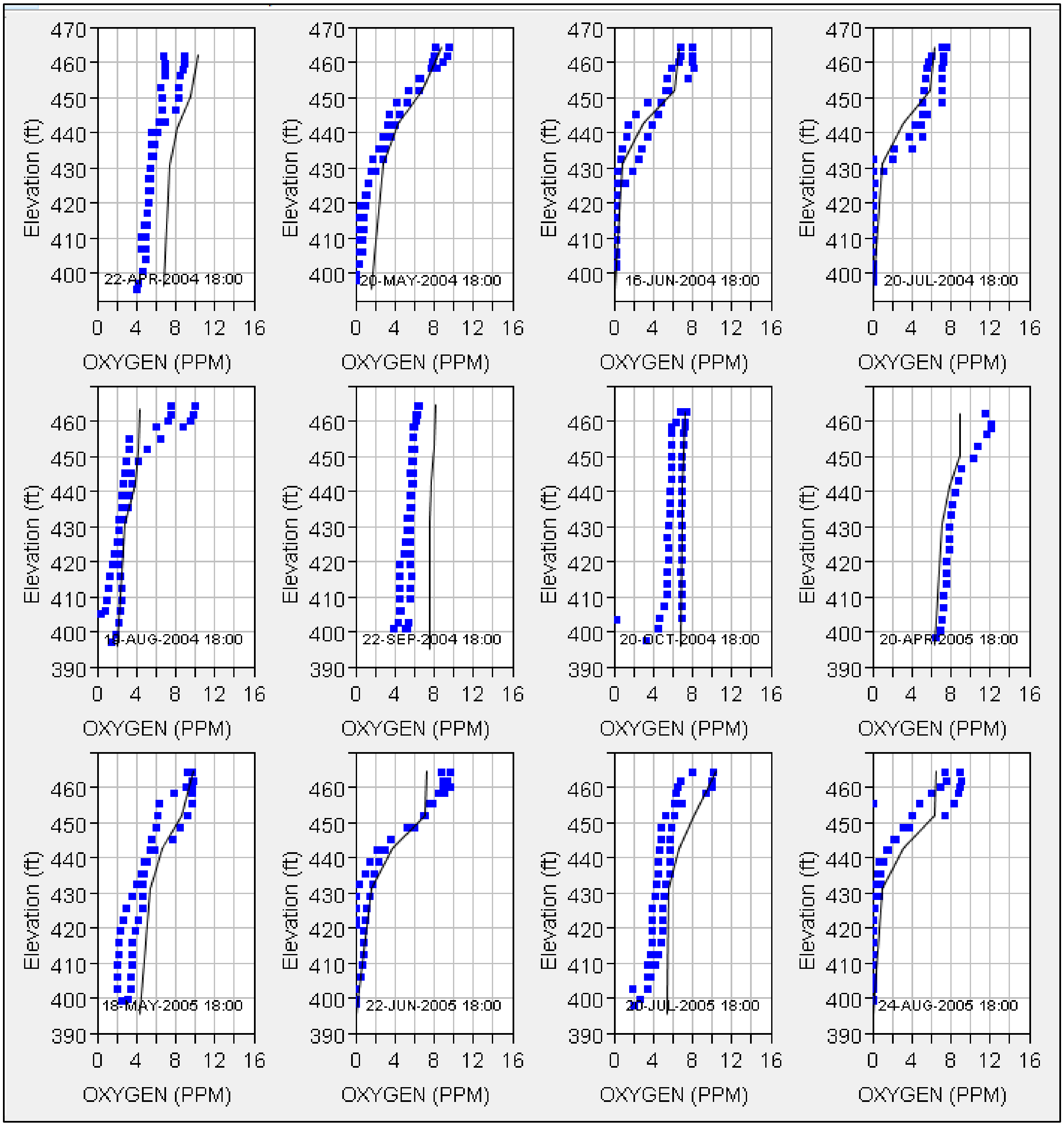


Figure 3.11. Typical computed (black lines) and observed (blue markers) oxygen profiles in Logan Martin – Coosa River. The deeper profiles are near the dam.

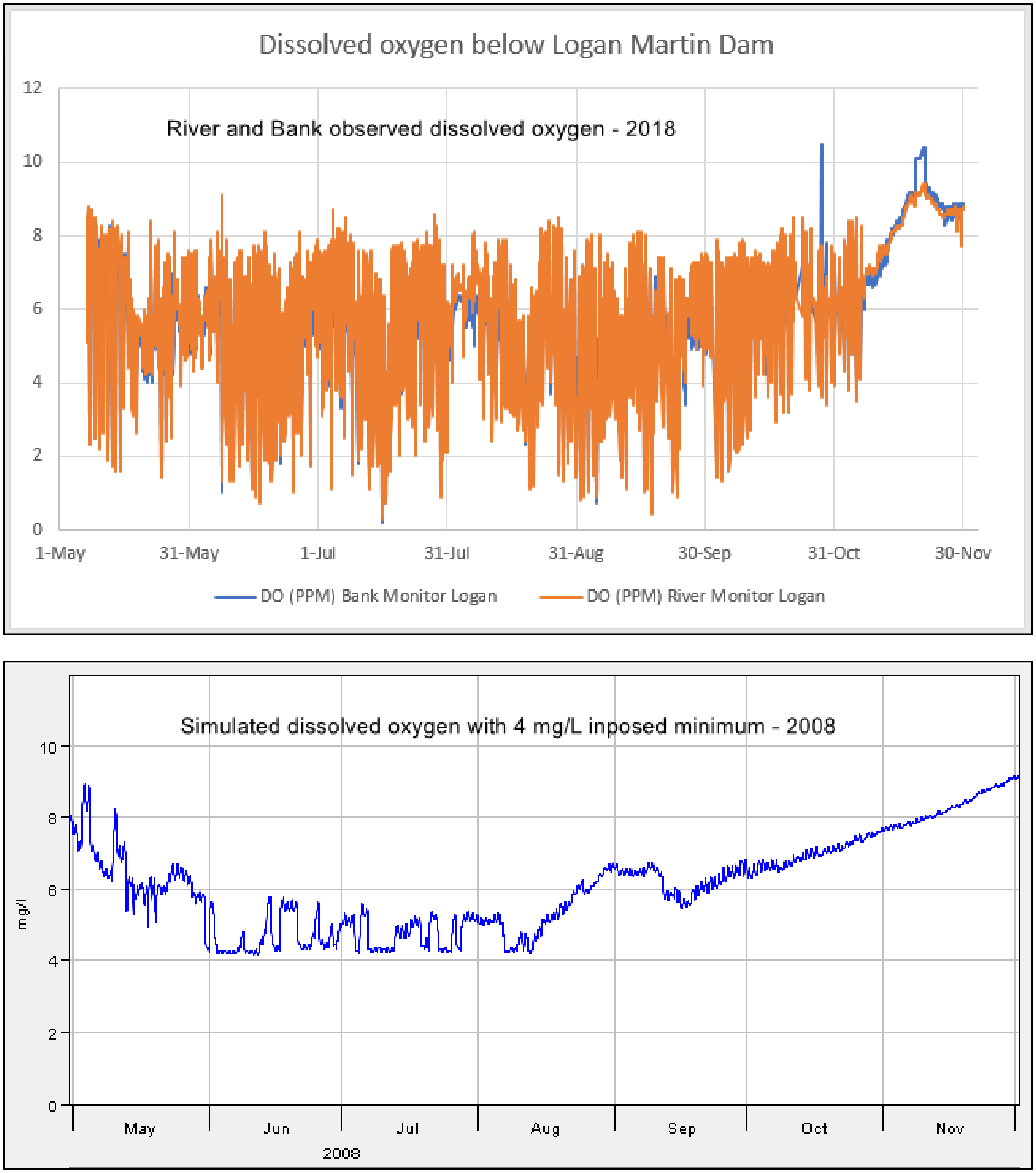


Figure 3.12. Impacts of oxygen injection designed to limit DO above 4 mg/L at Logan Martin Lake (2018 observed values [mg/L] shown in top panel; 2008 computed value shown in bottom panel).

3.1.2 LAKE CHLOROPHYLL *A* AND OTHER WATER QUALITY PARAMETERS

Chlorophyll *a* data are available during the growing season at most of the ACT system reservoirs. It is assumed that these measurements are taken near the surface since there appear to be no vertical profiles. The 2014 report contains numerous longitudinal profiles from Claiborne Lake to Weiss Lake. These longitudinal profiles compare concentrations ranges with model results presented as 5%, 25%, 50%, 75%, and 95% occurrences. These profiles are representative of the current calibration. To augment the 2014 results, several time series plots of chlorophyll *a* are presented below as well as tables that attempt to quantify the model accuracy. Figure 3.13 through Figure 3.15 show the computed and observed near surface chlorophyll *a* concentration over the 2000–2008 simulation period. Four reservoirs plots are on each figure and all plots have the same vertical scale.

Figure 3.13 presents results for the four vertically segmented reservoirs. There is reasonable agreement in the magnitude and timing of phytoplankton (chlorophyll *a*) activity. The model underpredicts the observed chlorophyll *a* during 2003 (high flow year) in Lake Allatoona; however, both the observed and computed are the lowest during that year. The model under predicts the observed chlorophyll *a* at both R. L. Harris Lake and Lake Martin. It is important to recognize that the vertically segmented reservoir representation assumes complete lateral mixing. Therefore, chlorophyll *a* levels at the distal ends of the arms of the reservoir may be substantially higher than that computed by the model. Nutrients, also assumed to be laterally mixed, are often highest in the arms at the stream inflow point. The computed Carters Lake chlorophyll *a* levels are approximately the same as those of R. L. Harris Lake. In the absence of observed data for Carters Lake, the observed R. L. Harris Lake chlorophyll *a* may be comparable to the Carters Lake levels. The decrease in chlorophyll *a* between R. L. Harris Lake and Lake Martin is due to uptake of available nutrients in R. L. Harris Lake. In general, nutrients that stimulate algal growth decrease in downstream reservoirs due to uptake in upstream reservoirs.

Figure 3.14 presents results for four longitudinally segmented reservoirs in the north – central Coosa River. The magnitude and seasonal distribution are well represented. As is the case in the vertically segmented reservoirs, the model under predicts 2003 levels but both the model and data are lowest during the high runoff year. The computed and observed decrease in the downstream reservoirs due to nutrient uptake in the upstream reservoirs.

Figure 3.15 shows the chlorophyll *a* in Mitchell and Jordan Lakes in the lower Coosa River and R.E. “Bob” Woodruff Lake and William “Bill” Dannelly Reservoir (R.F. Henry Lock and Dam and Millers Ferry Lock and Dam) in the Alabama River. The magnitude and seasonal distribution are well represented including 2003 in Millers Ferry.

Figure 3.16, Figure 3.17, and Figure 3.18 show the computed and observed NH_3, NO_3, and phosphorus, respectively, in Lake Allatoona, Lake Martin, Weiss Lake, and Millers Ferry Lock and Dam. Many of the observations are near non-detect levels. These reservoirs bracket the range in concentration seen in the data and model results. The Lake Allatoona and Lake Martin plots indicate that in mid-summer, all nutrients are depleted by photosynthesis. Weiss and Millers are likewise nutrient limited; however, Weiss generally has period of ample nutrients due to the inflow contributions for the upper watershed. Note that the model is often nitrogen limited, however, the model has fixed nutrient fractions of phytoplankton biomass. Typically, the nitrogen component of phytoplankton can vary with availability so that phosphorus limitation also impacts chlorophyll *a* levels.

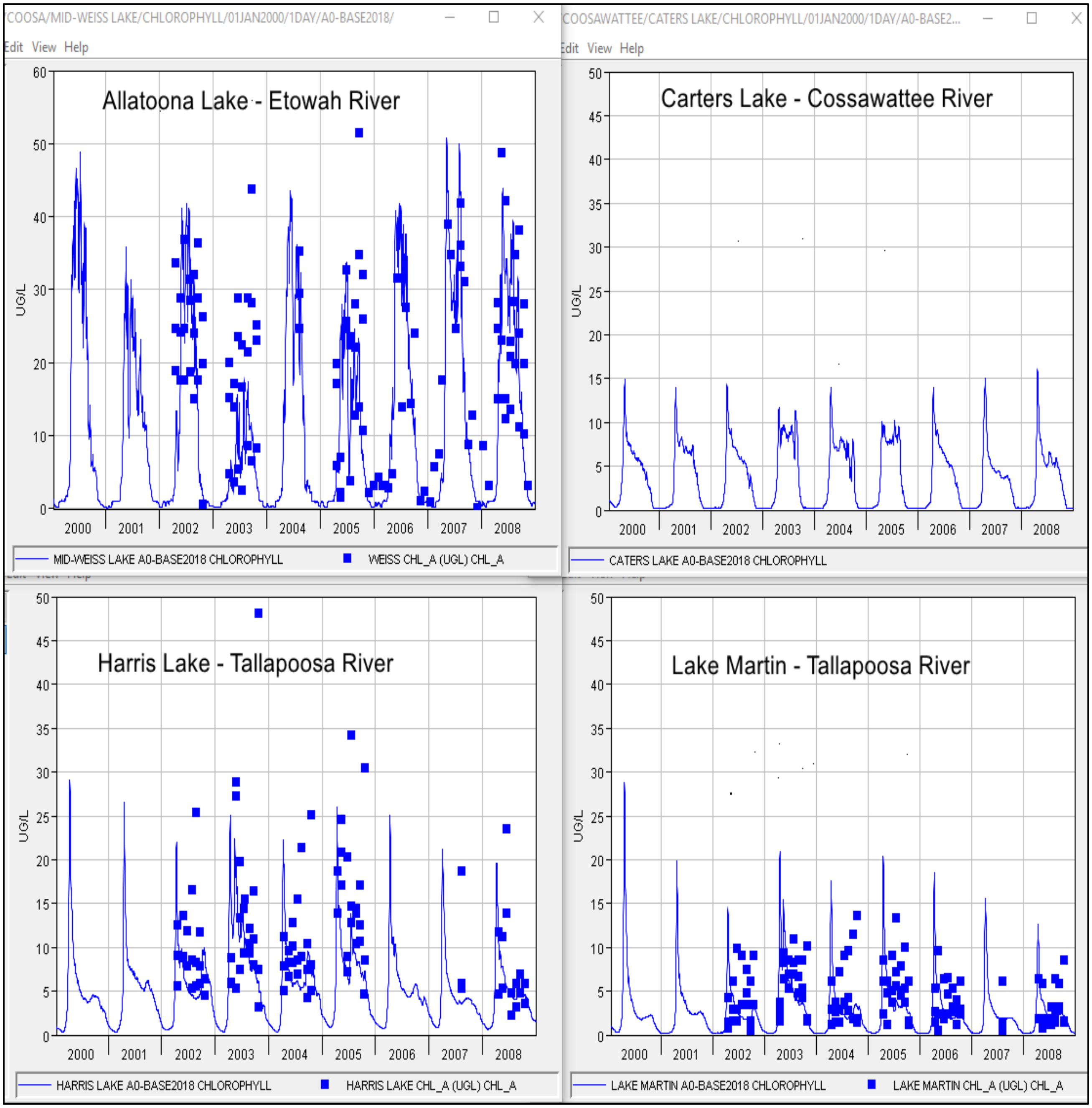


Figure 3.13. Computed (lines) and observed (square markers) lake surface chlorophyll *a* in vertically segmented reservoirs.

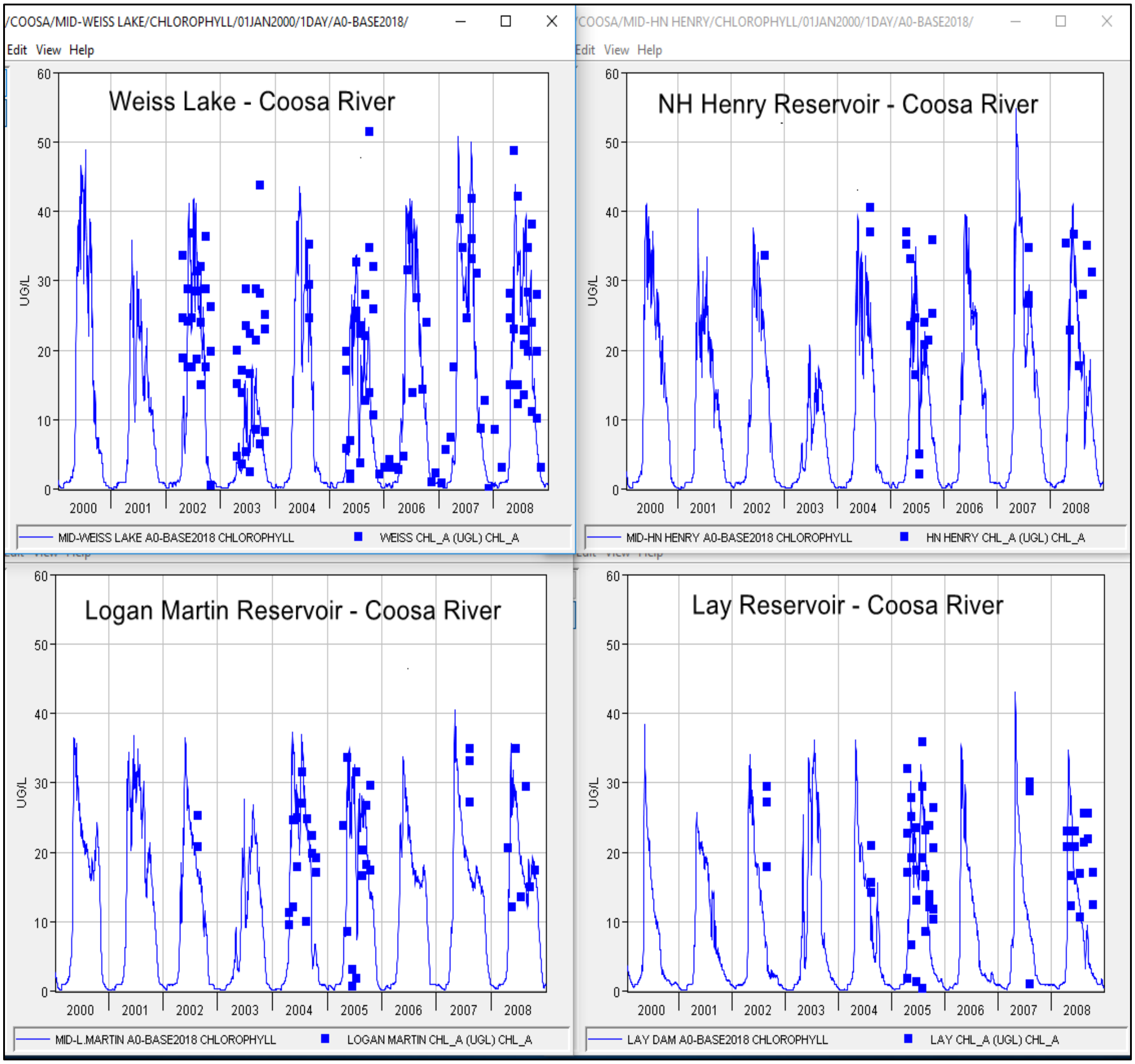


Figure 3.14. Computed (lines) and observed (square markers) lake surface chlorophyll *a* in longitudinally segmented reservoirs – north and central Coosa River.

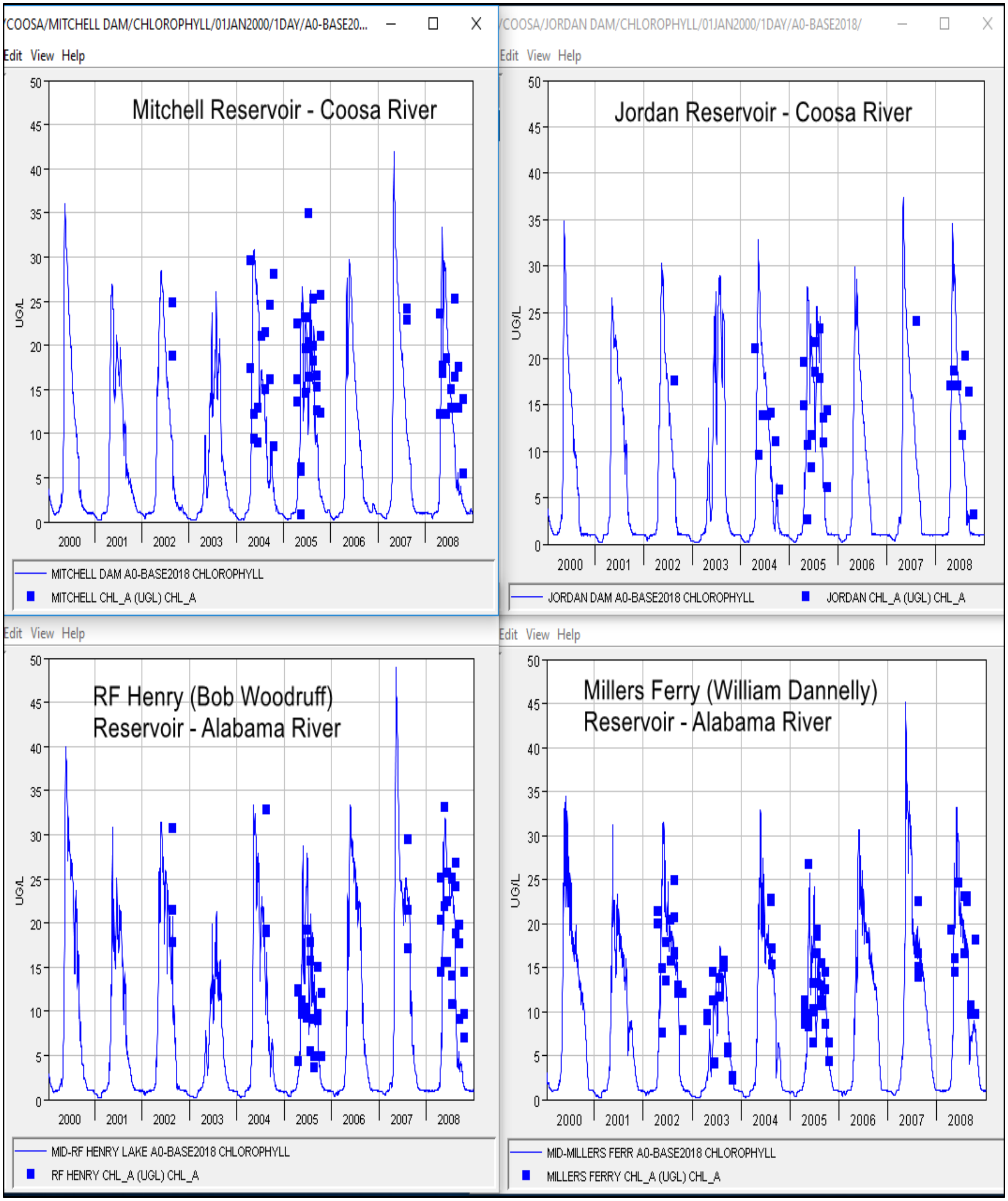


Figure 3.15. Computed (lines) and observed (square markers) lake surface chlorophyll *a* in longitudinally segmented reservoirs – south Coosa and Alabama Rivers.

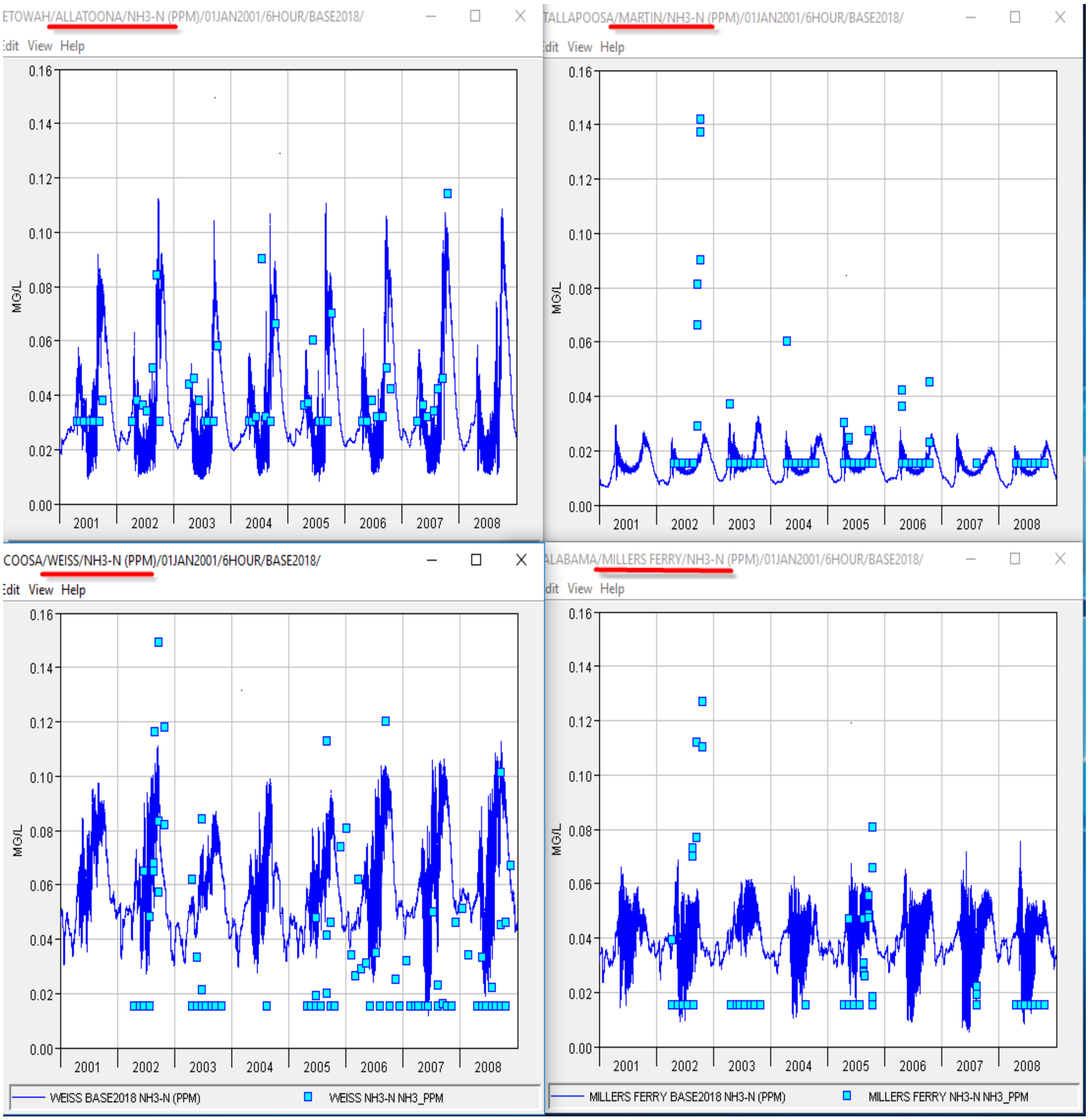


Figure 3.16. Computed (lines) and observed (square markers) lake surface NH_3 in Lake Allatoona, Lake Martin, Weiss Reservoir and Millers Ferry.

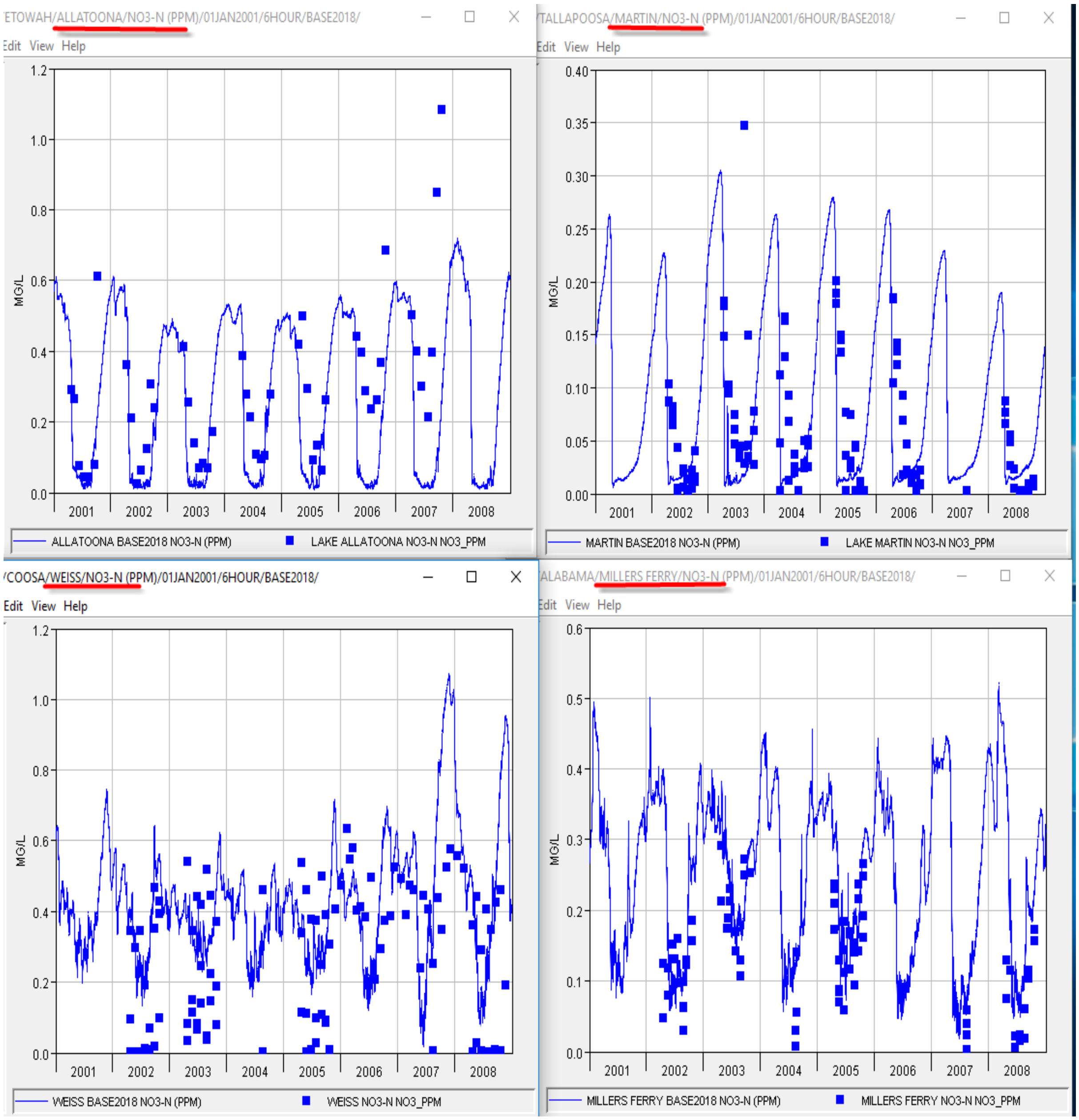


Figure 3.17. Computed (lines) and observed (square markers) lake surface NO_3 in Lake Allatoona, Lake Martin, Weiss Reservoir and Millers Ferry.

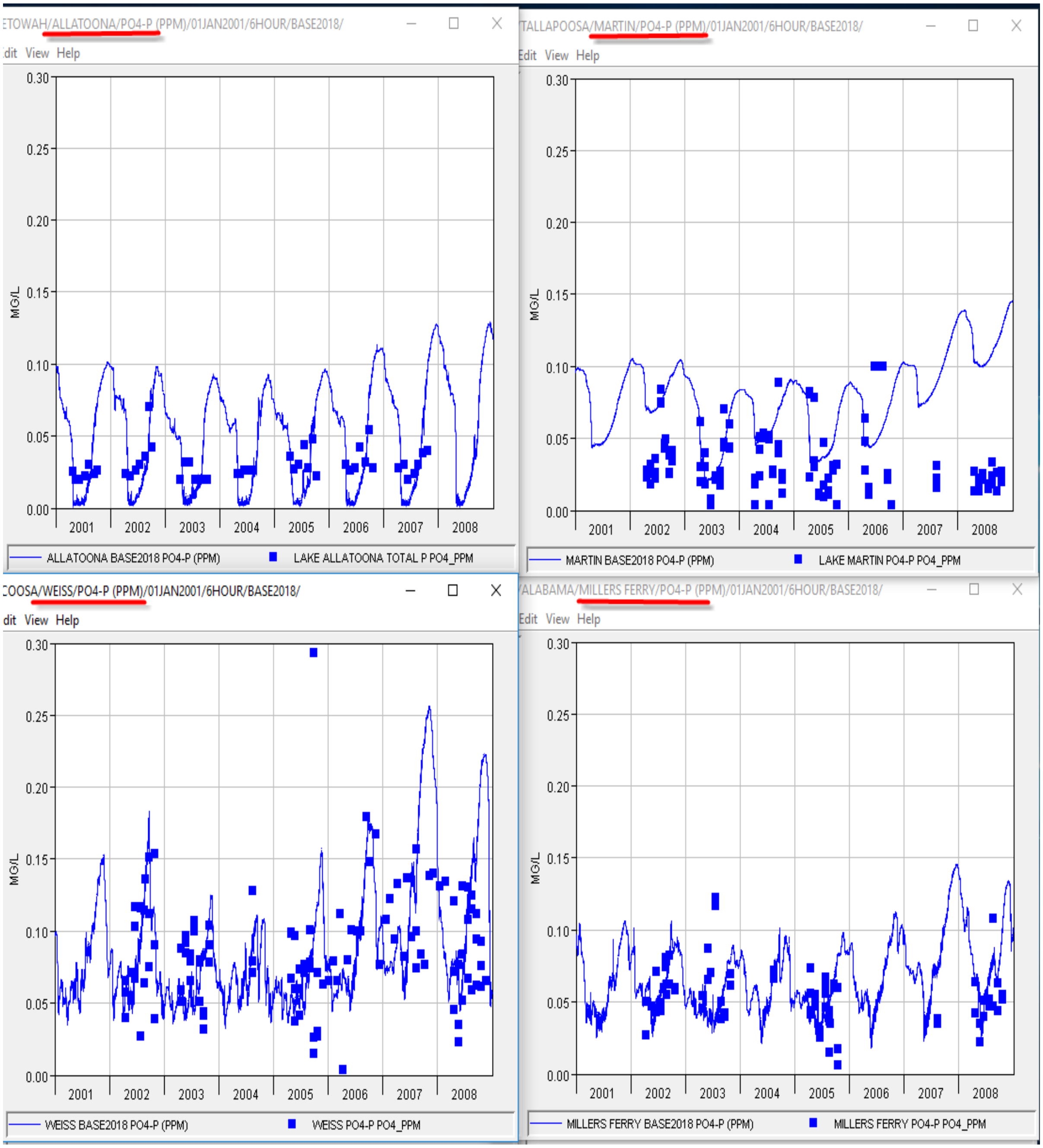


Figure 3.18. Computed (lines) and observed (square markers) lake surface phosphorus in Lake Allatoona, Lake Martin, Weiss Reservoir and Millers Ferry.

3.2 Water Quality Statistical Assessment

The visual results indicate that seasonal magnitude and distribution are represented but assessing model accuracy with visual plots is difficult. To quantify model accuracy, a statistical analysis was performed. The statistics include mean absolute error, RMS error, average computed and observed values, and bias including percent bias. The observed surface temperatures and water quality were compared with simulated daily average values at 13 reservoirs. The daily comparisons were then grouped into two time periods. The May–July period was intended to evaluate model accuracy during initial algal buildup. The other period is the Alabama Department of Environmental Management growing season of April – November. Note that the yearly and growing period statistics were nearly identical except for Weiss where 11 of the 58 samples were collected during the winter months. The results of this analysis are tabulated in Table 3.2 through Table 3.5.

Table 3.5 includes three sets of average values for 13 reservoirs, the three vertically segmented with data and the 10 laterally segmented and layered reservoirs. A review of the averaged statistics leads to the following observations.

1) Temperature: The percent bias between the average computed and observed is less than 2.5% for the vertically segmented reservoirs. The percent bias for the 10 longitudinally segmented reservoirs is less than 0.5%. A positive bias indicates that the computed exceeds the observed. The mean absolute error and RMS error are approximately 2 °C indicating good agreement throughout the sampling period.
2) DO: The percent bias between the average computed and observed is less than 7.5% for the vertically segmented reservoirs. The percent bias for the 10 longitudinally segmented reservoirs is less than 3.5%. The mean absolute error and RMS error are approximately 1.5 mg/L indicating reasonable agreement throughout the sampling period. The observed average concentration exceeds the computed; therefore, the model results can be considered conservative.
3) Chlorophyll *a*: The average computed exceeds the average observed by 6% to 11% for the vertically segmented reservoirs. The difference for the 10 longitudinally segmented reservoirs ranges from 8% to 14%. The difference between the May–July and growing season average indicated more rapid growth in the model during the early summer. The mean absolute error and RMS error are approximately half of the averages indicating more variation throughout the year.
4) NH_3: The average computed is less than the average observed by as much as 0.006 mg/L (less than 12% of observed) for the three vertically segmented reservoirs. For the 10 longitudinally segmented reservoirs, the average computed exceeds the observed by 0.013 mg/L (greater than 20% of observed). The mean absolute error and RMS error are approximately equal to the averages and observed and computed indicating variations in concentration of the same magnitude as the averages.
5) NO_3: The average computed and observed differ by as much as 0.08 mg/L and 0.05 mg/L for the three vertically and 10 longitudinally segmented reservoirs respectively. The computed nitrated is much lower in the vertically segmented suggesting that algal growth is more limited by nitrogen in the model. The mean absolute error and RMS error are approximately equal to the averages and observed and computed indicating variations in concentration between the computed and observed of the same magnitude as the averages.
6) PO_4: The average computed and observed differ by as much as 0.08 mg/L and 0.05 mg/L for the three vertically and 10 longitudinally segmented reservoirs respectively. The mean absolute error and RMS error are approximately two-thirds of the averages and observed and computed indicating variations in concentration between the computed and observed of the nearly the same magnitude as the averages.

Table 3.2. Computed versus observed statistics for Lake Allatoona, Lake Weiss, H. Neely Henry Lake, and Logan Martin Lake for the 2001–2008 modeling period. May–July indicates the summer period and AL: Apr–Nov indicates the Alabama growing season.

LAKE ALLATOONA

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	24	56	24	56	24	56	24	56	24	56	24	54
Mean absolute error	1.69	1.52	1.03	1.26	5.39	5.98	0.0150	0.0170	0.1600	0.1690	0.0140	0.0320
RMS error	1.88	1.80	1.16	1.45	6.57	7.91	0.0200	0.0230	0.2030	0.2360	0.0150	0.0390
Average - observed	26.98	25.01	8.70	8.44	11.54	11.63	0.0370	0.0410	0.1900	0.2670	0.0270	0.0300
Average - computed	25.36	24.21	7.77	7.41	16.53	14.43	0.0250	0.0420	0.0300	0.1220	0.0410	0.0610
Bias (comp-obs)	-1.62	-0.80	-0.93	-1.03	5.00	2.81	-0.01	0.00	-0.16	-0.15	0.01	0.03
Bias (%)	-3.1	-1.6	-5.6	-6.5	17.8	10.8	-19.9	1.6	-72.5	-37.4	20.3	35.0

WEISS

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	18	47	18	47	18	47	18	47	18	47	18	43
Mean absolute error	1.35	1.27	1.45	1.27	8.54	8.66	0.0190	0.0350	0.1630	0.1920	0.0330	0.0380
RMS error	1.58	1.62	1.71	1.59	11.18	11.21	0.0230	0.0430	0.2150	0.2430	0.0400	0.0470
Average - observed	26.78	24.40	8.17	8.01	21.79	20.98	0.0210	0.0300	0.1550	0.1630	0.0730	0.0700
Average - computed	27.09	24.91	7.88	7.86	24.51	17.02	0.0390	0.0560	0.0970	0.2440	0.0470	0.0740
Bias (comp-obs)	0.31	0.51	-0.28	-0.15	2.72	-3.96	0.02	0.03	-0.06	0.08	-0.03	0.00
Bias (%)	0.6	1.0	-1.8	-0.9	5.9	-10.4	30.6	29.2	-22.7	20.0	-21.3	2.9

HN HENRY

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	6	17	6	17	6	17	6	17	6	17	6	17
Mean absolute error	3.23	4.18	1.10	1.94	8.41	13.34	0.0120	0.0220	0.0790	0.1430	0.0160	0.0250
RMS error	3.89	5.15	1.39	2.27	9.77	15.92	0.0160	0.0270	0.1240	0.2190	0.0230	0.0340
Average - observed	24.18	26.65	8.85	7.70	21.49	27.98	0.0150	0.0200	0.0200	0.0650	0.0500	0.0630
Average - computed	27.40	27.10	8.46	7.57	27.65	19.86	0.0270	0.0410	0.0770	0.1230	0.0350	0.0600
Bias (comp-obs)	3.23	0.45	-0.38	-0.13	6.16	-8.11	0.01	0.02	0.06	0.06	-0.02	0.00
Bias (%)	6.3	0.8	-2.2	-0.8	12.5	-17.0	27.9	35.6	58.3	31.2	-17.4	-2.7

LOGAN MARTIN

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	9	23	9	23	9	23	9	23	9	23	9	23
Mean absolute error	1.07	1.23	1.45	1.75	11.91	11.93	0.008	0.019	0.039	0.085	0.030	0.025
RMS error	1.34	1.55	1.75	2.06	14.45	13.66	0.011	0.023	0.060	0.119	0.039	0.033
Average - observed	27.92	26.82	8.63	8.23	17.60	18.41	0.016	0.017	0.010	0.040	0.054	0.053
Average - computed	27.21	26.33	7.70	7.14	23.38	14.51	0.024	0.035	0.049	0.123	0.028	0.047
Bias (comp-obs)	-0.71	-0.49	-0.93	-1.09	5.78	-3.89	0.01	0.02	0.04	0.08	-0.03	-0.01
Bias (%)	-1.3	-0.9	-5.7	-7.1	14.1	-11.8	18.8	34.6	66.3	50.7	-31.8	-6.1

Table 3.3. Computed versus observed statistics for Lay Lake, Mitchell Lake, Jordan Lake, and Woodruff Lake (R.F. Henry Lock and Dam) for the 2001–2008 modeling period. May–July indicates the summer period and AL: Apr–Nov indicates the Alabama growing season.

LAY

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	5	17	5	17	5	17	5	17	5	17	5	17
Mean absolute error	1.09	1.24	2.94	1.96	7.80	10.07	0.012	0.014	0.011	0.059	0.026	0.022
RMS error	1.19	1.60	3.60	2.59	8.83	11.60	0.025	0.020	0.011	0.095	0.032	0.028
Average - observed	28.41	28.04	10.37	8.65	16.91	18.89	0.026	0.019	0.006	0.025	0.043	0.046
Average - computed	27.57	27.98	7.96	6.92	19.77	12.58	0.015	0.025	0.017	0.085	0.019	0.043
Bias (comp-obs)	-0.84	-0.07	-2.41	-1.73	2.86	-6.31	-0.01	0.01	0.01	0.06	-0.02	0.00
Bias (%)	-1.5	-0.1	-13.1	-11.1	7.8	-20.1	-26.9	15.1	49.3	53.9	-39.7	-3.2

MITCHELL

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	9	23	9	23	9	23	9	23	9	23	9	23
Mean absolute error	1.26	1.34	2.48	2.05	15.21	11.90	0.012	0.014	0.052	0.086	0.023	0.023
RMS error	1.53	1.61	2.78	2.40	19.82	15.09	0.018	0.019	0.070	0.126	0.029	0.029
Average - observed	28.31	27.14	9.91	8.94	20.08	17.95	0.020	0.022	0.013	0.037	0.049	0.051
Average - computed	27.06	26.94	7.96	7.29	20.96	12.53	0.023	0.027	0.065	0.123	0.027	0.047
Bias (comp-obs)	-1.26	-0.20	-1.95	-1.65	0.88	-5.42	0.00	0.01	0.05	0.09	-0.02	0.00
Bias (%)	-2.3	-0.4	-10.9	-10.2	2.1	-17.8	7.4	11.3	66.5	53.4	-28.4	-3.8

JORDAN

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	9	23	9	23	9	23	9	23	9	23	9	23
Mean absolute error	0.73	1.20	1.81	1.87	7.31	8.41	0.004	0.013	0.023	0.068	0.029	0.026
RMS error	0.91	1.56	2.40	2.28	9.72	9.97	0.008	0.027	0.028	0.110	0.038	0.032
Average - observed	28.03	27.03	9.27	8.49	13.98	14.19	0.015	0.021	0.017	0.053	0.049	0.045
Average - computed	27.74	27.54	8.02	7.28	20.37	11.65	0.018	0.022	0.036	0.112	0.021	0.043
Bias (comp-obs)	-0.29	0.50	-1.25	-1.20	6.39	-2.54	0.00	0.00	0.02	0.06	-0.03	0.00
Bias (%)	-0.5	0.9	-7.2	-7.6	18.6	-9.8	8.9	3.0	36.5	35.5	-40.7	-2.2

RF HENRY

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	7	19	7	19	7	19	7	19	7	19	7	19
Mean absolute error	0.54	0.98	1.67	1.10	9.24	7.81	0.006	0.014	0.045	0.058	0.006	0.022
RMS error	0.62	1.19	1.87	1.35	10.48	8.92	0.009	0.017	0.051	0.088	0.008	0.032
Average - observed	26.77	26.40	7.66	7.71	15.84	14.33	0.015	0.019	0.096	0.13	0.037	0.041
Average - computed	27.11	27.02	9.31	8.41	25.01	14.70	0.021	0.031	0.062	0.15	0.035	0.056
Bias (comp-obs)	0.34	0.62	1.66	0.71	9.17	0.38	0.01	0.01	-0.03	0.02	0.00	0.02
Bias (%)	0.6	1.2	9.8	4.4	22.4	1.3	16.1	23.5	-21.4	7.1	-2.4	15.7

Table 3.4. Computed versus observed statistics for the reservoirs at Millers Ferry, Claiborne, R. L. Harris, and Martin dams for the 2001–2008 modeling period. May–July indicates the summer period and AL: Apr–Nov indicates the Alabama growing season.

MILLERS FERRY

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	12	31	12	31	12	31	12	31	12	31	12	31
Mean absolute error	1.14	1.46	0.98	1.00	5.91	5.38	0.031	0.029	0.045	0.076	0.026	0.022
RMS error	1.38	1.89	1.13	1.21	7.44	7.22	0.032	0.033	0.055	0.109	0.034	0.03
Average - observed	27.58	27.13	7.23	7.27	13.46	13.55	0.015	0.025	0.102	0.112	0.057	0.057
Average - computed	26.81	26.67	7.86	7.48	17.77	12.56	0.046	0.046	0.137	0.177	0.042	0.057
Bias (comp-obs)	-0.77	-0.47	0.63	0.20	4.31	-0.99	0.03	0.02	0.04	0.07	-0.02	0.00
Bias (%)	-1.4	-0.9	4.2	1.4	13.8	-3.8	50.9	29.5	14.7	22.6	-15.2	0.3

CLAIBORNE

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	11	30	11	30	11	30	11	30	11	30	11	29
Mean absolute error	1.68	1.42	0.89	0.81	8.04	6.73	0.027	0.029	0.06	0.094	0.024	0.026
RMS error	2.03	1.67	1.06	1.02	8.76	8.42	0.03	0.031	0.083	0.136	0.028	0.032
Average - observed	27.65	26.98	7.45	7.12	10.65	11.05	0.027	0.024	0.159	0.145	0.054	0.054
Average - computed	26.45	26.13	7.51	7.18	16.39	11.25	0.044	0.046	0.116	0.159	0.037	0.054
Bias (comp-obs)	-1.19	-0.85	0.07	0.05	5.74	0.20	0.02	0.02	-0.04	0.01	-0.02	0.00
Bias (%)	-2.2	-1.6	0.4	0.4	21.2	0.9	23.2	31.9	-15.5	4.8	-18.9	-0.2

HARRIS LAKE

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	15	36	15	36	15	36	15	36	15	36	15	36
Mean absolute error	2.20	2.75	1.66	1.52	3.97	3.50	0.004	0.015	0.027	0.047	0.021	0.025
RMS error	2.39	2.98	1.73	1.65	5.33	4.55	0.015	0.041	0.039	0.072	0.026	0.030
Average - observed	27.37	25.76	8.52	8.13	10.59	8.35	0.019	0.027	0.034	0.053	0.035	0.030
Average - computed	29.57	28.51	6.86	6.72	8.04	7.86	0.016	0.020	0.010	0.018	0.025	0.037
Bias (comp-obs)	2.20	2.75	-1.66	-1.42	-2.55	-0.50	0.00	-0.01	-0.02	-0.04	-0.01	0.01
Bias (%)	3.9	5.1	-10.8	-9.5	-13.7	-3.1	-9.4	-14.3	-55.7	-49.2	-18.0	10.1

LAKE MARTIN

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	18	43	18	43	18	43	18	43	18	43	18	43
Mean absolute error	1.23	1.92	0.81	0.78	1.70	2.69	0.002	0.009	0.051	0.049	0.034	0.042
RMS error	1.52	2.23	0.92	0.92	2.14	4.75	0.003	0.022	0.067	0.069	0.044	0.051
Average - observed	27.61	26.33	8.22	8.09	3.11	2.72	0.015	0.022	0.063	0.051	0.033	0.032
Average - computed	28.79	28.23	7.41	7.32	4.01	4.56	0.014	0.016	0.015	0.022	0.055	0.064
Bias (comp-obs)	1.18	1.90	-0.81	-0.77	0.91	1.84	0.00	-0.01	-0.05	-0.03	0.02	0.03
Bias (%)	2.1	3.5	-5.2	-5.0	12.7	25.3	-6.0	-16.0	-62.0	-39.6	24.9	33.5

Table 3.5. Computed versus observed statistics for Yates Lake and averages for all 13 reservoirs for the 2001–2008 modeling period. May–July indicates the summer period and AL: Apr–Nov indicates the Alabama growing season.

YATES

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	9	22	9	22	9	22	9	22	9	22	9	22
Mean absolute error	2.42	2.71	0.84	0.99	6.81	4.25	0.008	0.024	0.078	0.074	0.049	0.072
RMS error	3.00	3.70	0.98	1.15	8.01	5.61	0.015	0.045	0.084	0.084	0.057	0.079
Average - observed	23.48	24.51	8.54	8.36	6.09	5.00	0.018	0.037	0.147	0.131	0.039	0.032
Average - computed	23.07	23.00	8.53	7.91	9.56	5.93	0.022	0.028	0.086	0.093	0.087	0.103
Bias (comp-obs)	-0.41	-1.51	-0.01	-0.45	3.47	0.93	0.00	-0.01	-0.06	-0.04	0.05	0.07
Bias (%)	-0.9	-3.2	0.0	-2.8	22.1	8.5	9.8	-14.4	-26.4	-16.8	38.0	52.8

Average of all 13 reservoirs

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	152	387	152	387	152	387	152	387	152	387	152	380
Mean absolute error	1.51	1.79	1.47	1.41	7.71	7.74	0.012	0.020	0.064	0.092	0.025	0.031
RMS error	1.79	2.20	1.73	1.69	9.42	9.60	0.017	0.029	0.084	0.131	0.032	0.038
Average - observed	27.01	26.32	8.58	8.09	14.09	14.23	0.020	0.025	0.078	0.098	0.046	0.046
Average - computed	27.02	26.50	7.94	7.42	18.00	12.26	0.026	0.033	0.061	0.119	0.038	0.057
Bias (comp-obs)	0.01	0.18	-0.63	-0.67	3.91	-1.97	0.01	0.01	-0.02	0.02	-0.01	0.01
Bias (%)	0.0	0.3	-3.7	-4.3	12.1	-3.6	10.1	13.1	1.2	10.5	-11.6	10.2

3 Vertically segmented reservoir averages

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	57	135	57	135	57	135	57	135	57	135	57	133
Mean absolute error	1.71	2.06	1.17	1.19	3.69	4.06	0.007	0.014	0.079	0.088	0.023	0.033
RMS error	1.93	2.34	1.27	1.34	4.68	5.74	0.013	0.029	0.103	0.126	0.028	0.040
Average - observed	27.32	25.70	8.48	8.22	8.41	7.57	0.024	0.030	0.096	0.124	0.032	0.031
Average - computed	27.91	26.98	7.35	7.15	9.53	8.95	0.018	0.026	0.018	0.054	0.040	0.054
Bias (comp-obs)	0.59	1.28	-1.13	-1.07	1.12	1.38	-0.01	0.00	-0.08	-0.07	0.01	0.02
Bias (%)	1.0	2.3	-7.2	-7.0	5.6	11.0	-11.8	-9.6	-63.4	-42.1	9.1	26.2

10 Longitudinally segmented and layered Reservoir averages

	Temperature (C)		Oxygen (MG/L)		Chlorophyll a (ug/L)		NH3-N (mg/L)		NO3-N (mg/L)		PO4-P (mg/L)	
	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov	May-July	AL: Apr-Nov
total # points	95	252	95	252	95	252	95	252	95	252	95	247
Mean absolute error	1.45	1.70	1.56	1.47	8.92	8.85	0.014	0.021	0.060	0.094	0.026	0.030
RMS error	1.74	2.15	1.87	1.79	10.85	10.76	0.019	0.029	0.078	0.133	0.033	0.038
Average - observed	26.91	26.51	8.61	8.05	15.79	16.23	0.019	0.023	0.073	0.090	0.051	0.051
Average - computed	26.75	26.36	8.12	7.50	20.54	13.26	0.028	0.036	0.074	0.139	0.038	0.058
Bias (comp-obs)	-0.16	-0.15	-0.49	-0.55	4.75	-2.97	0.01	0.01	0.00	0.05	-0.01	0.01
Bias (%)	-0.3	-0.3	-2.7	-3.4	14.1	-8.0	16.7	19.9	20.6	26.2	-17.8	5.4

3.2.1 STREAM WATER QUALITY STATISTICS

Stream water quality data are concentrated in the headwater streams above the Coosa River. During years 2005 and 2006, two stations were maintained in the Etowah River below the Allatoona Dam and near Rome. Figure 3.19 shows the computed and observed DO at these two locations. The figure also includes statistics that help interpret the model accuracy. It is clear that the decline in concentration below the dam occurs earlier than the observed data indicates. In 2005, the duration of the sub–4 mg/L period remained the same, but that period was offset by a month. In 2006, the decline occurs earlier but the recovery time and rate are well represented. The observed DO is the reported daily minimum since it best represents the daily average model assumption. The 4 mg/L is also the standard for the daily minimum. The phasing of the depressed oxygen is an indication of how rapidly the oxygen is depleted in Lake Allatoona. The sensitivity analysis that evaluates the impact of the sediment oxygen demand (SOD) addresses the rate at Lake Allatoona approaches anoxic conditions. The computed and observed DO near Rome indicates that the low concentration below the dam does not impact the Coosa River. The diurnal variation is less in the model suggesting that primary productivity is lower in the model.

The Etowah River and other streams contribute nutrients to the Coosa River and influence water quality in the Coosa River reservoirs. Plots of computed and observed data at the Rome Water intake on the Oostanaula River above the Etowah – Coosa confluence are shown in Figure 3.20. These plots show sparse observed data and this station is the most data rich station on the rivers above the Coosa River (other than the 2005–2006 USGS data). These plots are virtually unchanged from those reported in the 2014 report. A statistical evaluation of the computed and observed is provided to assess the accuracy of the model results beyond that gleaned from a visual inspection of plots.

Table 3.6 and Table 3.7 provide statistics by month, three growing seasons, peak algal production months (May–July), and year for the combined data from Weiss Lake. The growing seasons are defined by the Georgia Environmental Protection Division (April–October), Alabama Department of Environmental Management (April–November), and U.S. Fish and Wildlife Service (USFWS) (May–October). The statistics are for the entire 2001–2008 simulation period. The total number of observations and statistics that include mean absolute error, RMS error, average computed and observed, and bias including percent bias are listed.

The first set of statistics of Table 3.6 is for temperature. The differences in the seasonal averages are approximately 3% and the mean absolute and RMS errors are approximately 2 °C. Larger differences are computed during the winter months but the differences during the June through September period are smaller, which indicates that the maximum temperatures are well represented.

The next two sets of statistics of Table 3.6 are for DO. The first set includes the DO data in the Coosa River at the state line. The percent bias between the average computed and observed is less than 0.5 mg/L. The mean absolute and RMS errors are less than 1 mg/L for all months and averaging periods. The minimum average concentration during the July through September period is approximately 7.2 mg/L and 6.8 mg/L for the observed and computed, respectively. The model concentrations are lower and therefore conservative from a minimum oxygen perspective. The second set of DO statistics excludes the state line data. The statistics with and without the state line data are similar and indicate the model's accuracy is comparable throughout the ACT system above Weiss Lake.

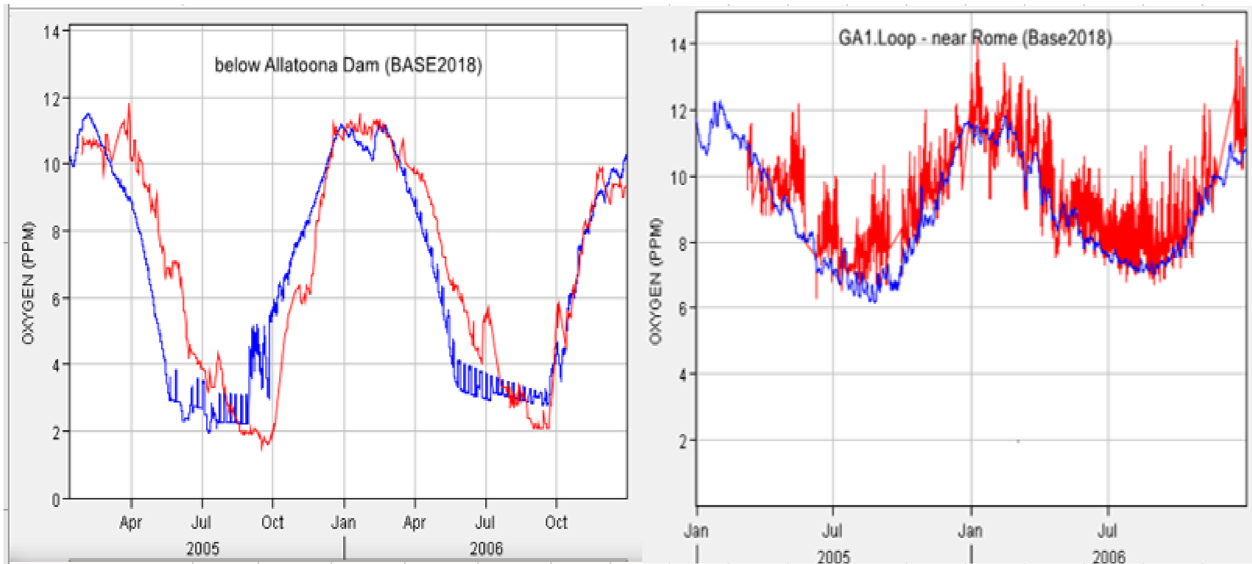
The fourth set of statistics of Table 3.6 are for chlorophyll *a* and include the state line data. The model consistently under predicts the observed levels. The mean absolute errors are large, and the RMS errors are often higher than the computed and observed. The chlorophyll *a* plot is typical of many of the other locations and explains the large RMS error. The under prediction of chlorophyll *a* at the state line is addressed in the sensitivity analysis section. At the other locations, the RMS error is dominated by a few extreme chlorophyll *a* measurements. For example, there are 24 chlorophyll *a* measurements at Canton on the Etowah River. The average of the three largest measurements is 17.1 µg/L while the average of the smallest 21 is only 2.6 µg/L. At Euharlee, there are 31 measurements. The average of the smallest 27 is

2.0 µg/L while the average of the four is 40 µg/L. The model results are in line with approximately 90% of the observations.

Table 3.7 lists the statistics for nutrients. The first set of statistics is for NH_3. The computed concentration is generally larger than the observed concentration, but the difference is always less than 0.02 mg/L. The mean absolute and RMS error are generally less than the computed and observed. These concentrations are relatively low and some of the measured data are likely non-detects. The low NH_3 levels also suggest a nitrogen limiting system.

The second set of statistics are for NO_3. The observed data include NO_2, which is normally a small nitrogen component. The model does not make a distinction between the NO_3 and NO_2 ions. The computed concentration is generally larger than the observed concentration, but the difference is always less than 25% of the computed concentration. The mean absolute and RMS errors are generally less than half the computed value.

The final set of statistics are for phosphorus. The observed data are for TP while the computed is PO_4; therefore, the model results should be less than the observed. Both the computed and observed phosphorus is up to twice the NH_3 concentration and indicated a nitrogen limited environment. The mean absolute and RMS errors are always less than the computed and observed.



Computed and Observed Dissolved Oxygen (mg/L)																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Etowah River below Allatoona Dam (USGS-Allatoona Dam)																	
total # points	619	169	384	443	324	36	55	36	60	62	60	47	59	56	40	59	49
Mean absolute error	1.11	1.88	1.41	1.35	1.38	0.41	0.41	0.91	1.62	2.49	1.89	1.06	0.37	1.18	0.99	0.93	0.35
RMS error	1.44	2.15	1.72	1.65	1.73	0.46	0.50	1.17	1.69	2.63	2.12	1.30	0.47	1.40	1.26	1.06	0.44
Average - observed	6.92	5.41	5.16	5.51	4.37	11.01	10.80	10.57	9.40	7.04	4.91	3.88	2.59	2.29	5.57	7.78	9.67
Average - computed	6.39	3.53	4.28	4.79	3.63	10.80	10.97	9.81	7.78	4.55	3.02	2.84	2.76	3.33	5.75	8.11	9.92
Bias (comp-obs)	0.54	1.88	0.88	0.72	0.74	0.21	-0.17	0.76	1.62	2.49	1.89	1.05	-0.17	-1.05	-0.19	-0.33	-0.25
Bias (%)	4	21	9.3	7	9.3	1	-0.8	3.7	9.4	21.5	23.9	15.6	-3.2	-18.6	-1.6	-2.1	-1.3
Etowah River at above Rome (USGS -GA1.Loop; 47 miles below Allatoona Dam)																	
total # points	1756	502	1186	1339	1009	93	84	129	177	160	159	183	186	135	186	153	111
Mean absolute error	0.81	0.88	0.87	0.85	0.91	0.67	0.47	0.71	0.69	1.08	0.85	0.73	1.17	0.82	0.77	0.67	0.74
RMS error	1.06	1.14	1.14	1.11	1.18	0.88	0.59	0.91	0.90	1.40	1.06	0.93	1.45	1.11	1.01	0.87	1.05
Average - observed	9.36	8.53	8.61	8.76	8.45	11.56	11.65	10.77	9.54	9.45	8.41	7.83	8.06	8.08	8.90	9.91	11.32
Average - computed	8.72	7.77	7.89	8.06	7.66	11.23	11.35	10.40	9.17	8.49	7.61	7.30	6.93	7.35	8.31	9.41	10.70
Bias (comp-obs)	0.63	0.76	0.73	0.70	0.79	0.33	0.30	0.37	0.37	0.96	0.80	0.53	1.14	0.73	0.58	0.50	0.62
Bias (%)	3.5	4.6	4.4	4.2	4.9	1.4	1.3	1.8	2	5.4	5	3.5	7.6	4.7	3.4	2.6	2.8

Figure 3.19. Computed (blue lines) and observed (red lines) DO in the Etowah River downstream of Lake Allatoona.

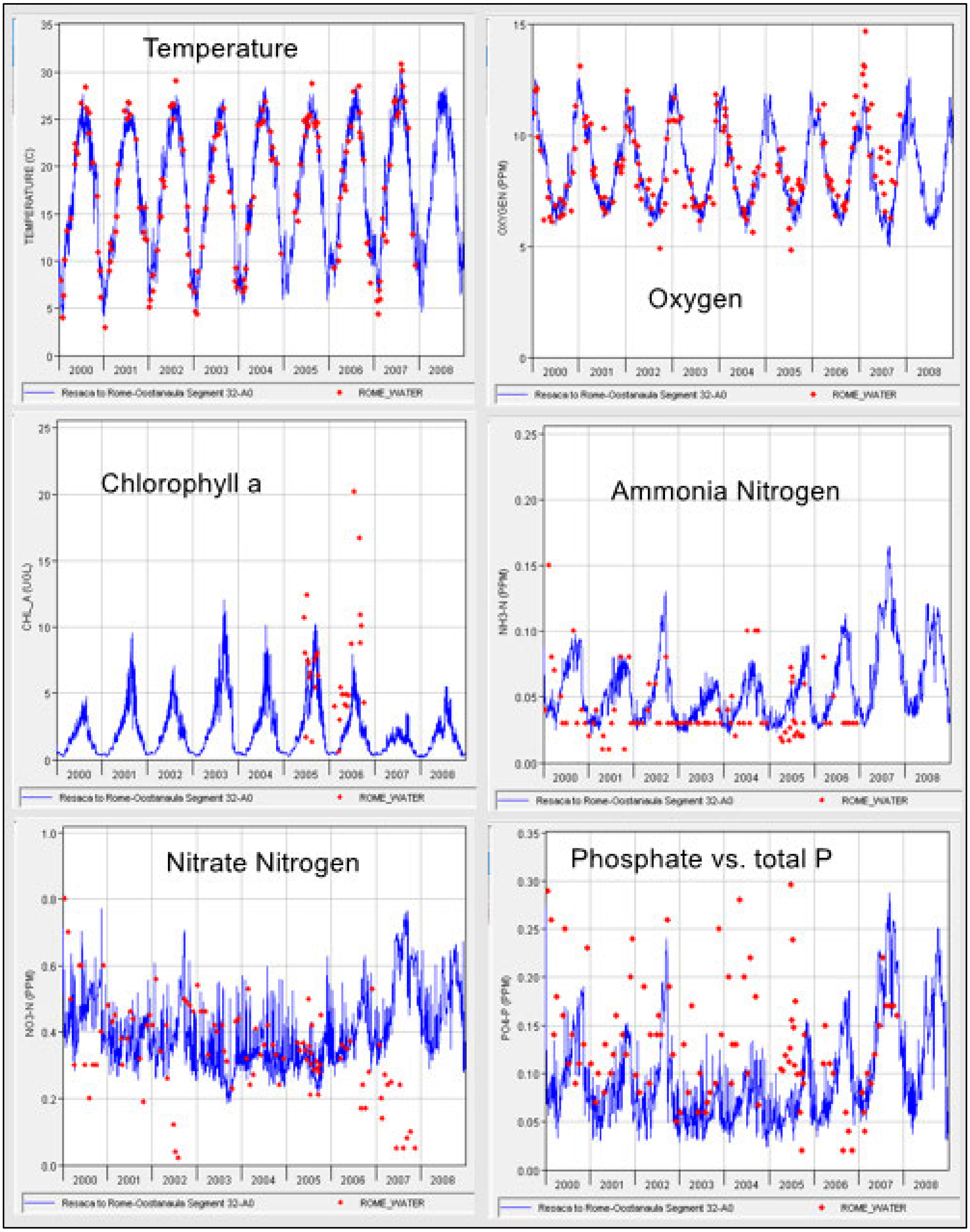


Figure 3.20. Computed (blue lines) and observed (red markers) temperature, DO, chlorophyll *a*, and nutrients in the Oostanaula River at the Rome water intake.

Table 3.6. Computed versus observed statistics for the combined temperature, DO, and chlorophyll *a* data from monitoring stations upstream of Weiss Lake.

average Temperature (C) at all locations																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	732	212	489	538	426	29	61	56	63	50	73	89	76	81	57	49	48
Mean absolute error	1.74	1.83	1.74	1.73	1.72	2.85	1.65	1.84	2.06	2.48	1.84	1.48	1.63	1.32	1.80	2.38	2.05
RMS error	2.12	2.23	2.10	2.11	2.09	3.00	1.81	2.05	2.31	2.81	2.08	1.84	1.91	1.59	1.99	2.58	2.25
Average - observed	17.75	21.41	21.13	20.55	21.97	5.62	8.32	11.27	14.34	17.28	21.84	23.20	24.55	22.95	19.12	13.97	9.74
Average - computec	18.82	22.43	22.07	21.51	22.84	8.30	9.80	12.91	16.23	19.41	22.29	24.05	24.62	23.39	20.75	16.29	11.68
Bias (comp-obs)	1.07	1.02	0.93	0.96	0.87	2.67	1.48	1.64	1.89	2.13	0.45	0.85	0.06	0.44	1.63	2.32	1.94
Bias (%)	3.0	2.2	2.2	2.3	1.9	18.1	8.0	7.0	6.4	5.7	0.9	1.7	0.1	0.9	4.3	7.5	8.9
average Dissolved Oxygen (mg/L) at all locations (including State Line on the Coosa River																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	3472	863	2050	2367	1763	236	280	299	287	273	296	294	300	287	313	317	290
Mean absolute error	0.81	0.94	0.83	0.83	0.86	0.95	0.83	0.69	0.64	0.83	1.01	1.00	0.91	0.78	0.61	0.88	0.68
RMS error	1.01	1.20	1.09	1.09	1.12	1.20	1.09	0.87	0.86	1.01	1.27	1.26	1.19	0.96	0.75	1.06	0.83
Average - observed	7.49	7.87	7.85	7.97	7.63	11.59	11.17	10.33	9.19	8.59	8.00	7.38	7.13	7.14	8.02	9.16	10.66
Average - computec	7.24	7.26	7.41	7.60	7.18	11.46	11.00	9.80	8.89	8.03	7.24	6.82	6.63	7.01	7.81	9.08	10.57
Bias (comp-obs)	-0.41	-0.61	-0.43	-0.37	-0.45	-0.12	-0.17	-0.53	-0.30	-0.56	-0.77	-0.57	-0.50	-0.13	-0.21	-0.09	-0.09
Bias (%)	-1.7	-4.1	-2.9	-2.5	-3.2	-0.6	-0.8	-2.7	-1.7	-3.3	-5.1	-4.1	-3.8	-1.0	-1.5	-0.6	-0.5
average Dissolved Oxygen (mg/L) at all locations (excluding State Line on the Coosa River)																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	675	195	441	489	379	28	60	51	62	47	68	80	65	70	49	48	47
Mean absolute error	0.78	0.89	0.80	0.80	0.82	0.98	0.82	0.69	0.64	0.78	0.93	0.96	0.88	0.73	0.59	0.88	0.63
RMS error	0.97	1.11	1.04	1.04	1.06	1.23	1.07	0.86	0.86	0.93	1.13	1.19	1.16	0.90	0.72	1.06	0.77
Average - observed	7.23	7.83	7.84	7.96	7.61	11.74	11.16	10.37	9.26	8.67	7.92	7.34	7.08	7.18	8.07	9.26	10.82
Average - computec	6.93	7.23	7.37	7.54	7.12	11.49	10.98	9.80	8.94	8.06	7.22	6.78	6.58	6.95	7.72	9.00	10.54
Bias (comp-obs)	-0.49	-0.60	-0.47	-0.42	-0.49	-0.24	-0.18	-0.56	-0.32	-0.61	-0.70	-0.56	-0.50	-0.22	-0.35	-0.27	-0.28
Bias (%)	-2.0	-4.1	-3.1	-2.8	-3.5	-1.1	-0.8	-2.8	-1.8	-3.6	-4.7	-4.1	-3.8	-1.7	-2.3	-1.6	-1.4
average Chlorophyll a (ug/L) at all locations																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	May-Oct	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	791	225	514	582	449	56	30	58	65	71	76	78	75	82	67	68	65
Mean absolute error	4.26	5.49	4.47	4.48	4.60	3.87	2.80	2.65	3.04	1.80	7.37	5.37	5.01	3.53	2.11	3.98	2.39
RMS error	8.39	10.69	9.02	8.88	9.29	4.01	2.82	3.19	3.13	2.31	12.89	7.05	6.78	3.96	2.39	4.89	2.41
Average - observed	6.26	8.40	6.86	6.73	7.06	4.17	3.18	3.24	4.49	4.07	10.01	8.68	7.68	5.30	3.96	4.58	2.72
Average - computec	2.91	3.11	3.38	3.20	3.49	0.30	0.38	0.63	1.45	2.27	3.11	3.37	3.21	4.51	2.81	0.60	0.33
Bias (comp-obs)	-3.35	-5.29	-3.49	-3.53	-3.58	-3.87	-2.80	-2.61	-3.04	-1.80	-6.91	-5.31	-4.47	-0.80	-1.15	-3.98	-2.39
Bias (%)	-39.7	-42.2	-36.0	-38.3	-35.6	-86.6	-77.9	-63.7	-48.9	-25.6	-38.2	-36.9	-38.7	-10.1	-21.1	-74.8	-76.2

Table 3.7. Computed versus observed statistics for the combined nutrient data from monitoring stations upstream of Weiss Lake.

average NH3-N (mg/L)at all locations																	
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	525	146	375	406	334	21	32	31	41	42	52	52	64	71	53	31	35
Mean absolute error	0.027	0.028	0.031	0.030	0.033	0.016	0.018	0.018	0.017	0.020	0.034	0.030	0.050	0.033	0.027	0.025	0.015
RMS error	0.044	0.037	0.047	0.048	0.050	0.017	0.024	0.027	0.022	0.023	0.043	0.036	0.074	0.040	0.029	0.033	0.018
Average - observed	0.045	0.044	0.046	0.046	0.047	0.035	0.042	0.043	0.034	0.038	0.044	0.050	0.057	0.053	0.040	0.052	0.034
Average - computec	0.051	0.052	0.059	0.058	0.062	0.033	0.029	0.033	0.032	0.038	0.056	0.060	0.078	0.070	0.060	0.044	0.032
Bias (comp-obs)	0.007	0.008	0.013	0.011	0.015	-0.002	-0.013	-0.010	-0.002	0.000	0.012	0.009	0.020	0.018	0.019	-0.008	-0.002
Bias (%)	3.6	3.0	8.4	6.9	9.1	-8.7	-22.5	-14.0	-7.3	-2.0	6.2	2.7	10.7	12.8	17.9	-8.0	-6.1
average NO3-N (mg/L) at all locations			(Model NO3-N versus observed NO2NO3)														
	year	May-Jul	A: Apr-O	: Apr-N	WL: May	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	577	159	405	440	359	25	38	35	46	46	57	56	68	75	57	35	39
Mean absolute error	0.129	0.098	0.129	0.132	0.134	0.097	0.107	0.093	0.078	0.095	0.118	0.091	0.176	0.149	0.169	0.168	0.149
RMS error	0.174	0.131	0.177	0.179	0.179	0.113	0.119	0.106	0.104	0.112	0.158	0.119	0.224	0.185	0.209	0.204	0.197
Average - observed	0.321	0.341	0.307	0.304	0.300	0.413	0.405	0.397	0.365	0.357	0.342	0.322	0.269	0.276	0.250	0.275	0.333
Average - computec	0.384	0.371	0.383	0.385	0.386	0.399	0.376	0.397	0.369	0.378	0.394	0.351	0.403	0.393	0.407	0.421	0.377
Bias (comp-obs)	0.062	0.030	0.075	0.081	0.086	-0.014	-0.029	0.000	0.003	0.021	0.051	0.029	0.134	0.117	0.157	0.146	0.044
Bias (%)	8.4	5.2	10.7	11.4	12.2	-2.3	-4.3	-1.4	-0.3	3.6	10.4	4.6	17.5	15.8	23.0	20.6	4.9
average PO4-P (mg/L) at all locations			Model PO4-P versus observed Total P)														
	year	May-July	GA: Apr-Oct	AL: Apr-Nov	USFWL: May-	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
total # points	575	165	411	442	365	25	38	35	46	46	60	59	68	75	57	31	35
Mean absolute error	0.045	0.041	0.045	0.046	0.047	0.033	0.035	0.029	0.027	0.033	0.044	0.044	0.050	0.053	0.050	0.057	0.083
RMS error	0.071	0.066	0.064	0.065	0.067	0.041	0.045	0.036	0.032	0.041	0.068	0.061	0.061	0.065	0.059	0.067	0.140
Average - observed	0.076	0.087	0.073	0.075	0.075	0.061	0.065	0.079	0.062	0.070	0.095	0.090	0.068	0.065	0.056	0.094	0.119
Average - computec	0.076	0.068	0.080	0.081	0.084	0.064	0.053	0.058	0.054	0.060	0.077	0.068	0.095	0.095	0.102	0.089	0.068
Bias (comp-obs)	0.000	-0.019	0.007	0.006	0.009	0.003	-0.011	-0.021	-0.008	-0.010	-0.018	-0.022	0.027	0.030	0.045	-0.005	-0.051
Bias (%)	1.1	-11.2	4.6	4.1	5.7	10.6	1.6	-14.0	-0.8	-3.1	-8.4	-11.8	16.9	16.7	28.6	1.9	-14.5

4. RESULTS

The HEC-5Q model was used to simulate water quality in the ACT basin under six alternative reallocation scenarios. These results consist of time series, cumulative occurrence profiles, and longitudinal river profiles of occurrence of each water quality parameter. The details of these results are outlined below, and representative plots are shown. All plots are available on the companion DVD to this report, along with HEC-DSS files used to create the plots. The model output in the DSS files may be viewed in tabular form or plotted using HEC-DSSVue.

The simulation results for stream sections represent the average concentration of each water quality parameter at each river mile. In the reservoirs, the simulation results represent the average concentration in the approximate euphotic zone (top 5 to 10 feet) of each reservoir.

Time series were output for several model locations along the Alabama, Coosa, Tallapoosa, Etowah, and Coosawattee Rivers. These locations are shown in Table 4.1. The time series were used to compute the cumulative occurrence of each water quality parameter. Then occurrence was computed for several annual, seasonal, and weekly periods and plotted by river mile to create longitudinal occurrence profiles for each parameter. The definition of each plot type and the various computation intervals applied to derive each set of plots are detailed in the following sections.

Table 4.1. Time Series Output Locations (Upstream to Downstream).

River Mile	River	River Profile	Time Series Location
730.85	Coosawattee	Coosawattee to Weiss	Carters - Pumpback
720.00	Coosawattee	Coosawattee to Weiss	Carters - Lake
719.05	Coosawattee	Coosawattee to Weiss	Carters
718.51	Coosawattee	Coosawattee to Weiss	Carters Rereg
701.51	Coosawattee	Coosawattee to Weiss	Pine Chapel
695.87	Coosawattee	Coosawattee to Weiss	Oostanaula
688.80	Oostanaula	Coosawattee to Weiss	Resaca
668.87	Oostanaula	Coosawattee to Weiss	Oostanaula - River Mile 669
651.02	Oostanaula	Coosawattee to Weiss	Rome-Oostanaula
776.5	Etowah	Etowah to Weiss	Dawsonville
723.5	Etowah	Etowah to Weiss	Canton
717.5	Etowah	Etowah to Weiss	Above Allatoona
694.0	Etowah	Etowah to Weiss	Allatoona - Lake
692.5	Etowah	Etowah to Weiss	Allatoona - Outflow
684.0	Etowah	Etowah to Weiss	Cartersville
672.0	Etowah	Etowah to Weiss	Euharlee
666.0	Etowah	Etowah to Weiss	Kingston
653. 0	Etowah	Etowah to Weiss	Rome
646.5	Etowah	Etowah to Weiss	Oostanaula
639.04	Oostanaula	Etowah to Weiss	Rome-Coosa
645.46	Coosa	Coosa to Montgomery	Oostanaula-Etowah-Coosa
625.59	Coosa	Coosa to Montgomery	Weiss - Inflow
603.26	Coosa	Coosa to Montgomery	Weiss - Mid-lake
580.93	Coosa	Coosa to Montgomery	Weiss - Dam
584.25	Coosa	Coosa to Montgomery	Weiss - Spillway
533.69	Coosa	Coosa to Montgomery	H.N. Henry - Mid-lake

River Mile	River	River Profile	Time Series Location
507.35	Coosa	Coosa to Montgomery	H.N. Henry - Dam
481.95	Coosa	Coosa to Montgomery	Logan Martin - Mid-lake
459.00	Coosa	Coosa to Montgomery	Logan Martin - Dam
434.05	Coosa	Coosa to Montgomery	Lay - Mid-lake
411.38	Coosa	Coosa to Montgomery	Lay - Dam
403.20	Coosa	Coosa to Montgomery	Mitchell - Mid-lake
397.16	Coosa	Coosa to Montgomery	Mitchell - Dam
386.85	Coosa	Coosa to Montgomery	Jordan - Mid-lake
378.96	Coosa	Coosa to Montgomery	Jordan - Dam
355.44	Coosa	Coosa to Montgomery	Coosa
522.60	Tallapoosa	Tallapoosa to Montgomery	Above Harris
498.00	Tallapoosa	Tallapoosa to Montgomery	Harris - Lake
497.83	Tallapoosa	Tallapoosa to Montgomery	Harris - Outflow
484.15	Tallapoosa	Tallapoosa to Montgomery	Wadley
465.40	Tallapoosa	Tallapoosa to Montgomery	Tallapoosa - River Mile 465
445.55	Tallapoosa	Tallapoosa to Montgomery	Above Martin
498.00	Tallapoosa	Tallapoosa to Montgomery	Martin - Lake
419.95	Tallapoosa	Tallapoosa to Montgomery	Martin - Outflow
413.03	Tallapoosa	Tallapoosa to Montgomery	Yates - Dam
409.51	Tallapoosa	Tallapoosa to Montgomery	Thurlow - Dam

The water quality parameters simulated by the HEC-5Q model include:

- Water temperature
- DO
- BOD5U
- NO_3-N
- NH_3-N
- PO_4-P
- Phytoplankton (algae), reported as chlorophyll *a*
- Municipal and industrial wastewater as percent of flow (the percentage is either 100 for point sources or 0 for non-point inflows; this is the tracer for computing the percentage component of wastewater origin throughout the river system)

Three categories of plots were created from the HEC-5Q model output to summarize the results: time series, cumulative occurrence, and river profiles. These are described in the following sections.

4.1 TIME SERIES

A time series plot was created for each water quality parameter at each location (Table 4.1) along the Alabama, Coosa, Tallapoosa, Etowah, Oostanaula, and Coosawattee Rivers for the 2001–2008 model period. Representative plots of chlorophyll *a* are shown in Figure 4.1 at two stations on the Coosa River: Weiss – State Line and Jordan Dam.

In addition to the plots presented in this section, "delta" plots were created, which show the difference of each alternative from the No Action alternative. For every plot of actual values, there is a corresponding delta plot.

Model output and post-processed results were saved to HEC-DSS files. These plots and files were provided electronically to USACE Mobile District and were used by the EIS PDT to analyze the water quality differences between alternatives. The DSS results were used to produce tables in the EIS.

4.2 CUMULATIVE OCCURRENCE

The cumulative percentage of occurrence of each water quality parameter was computed for the 2001–2008 modeling period using the time series from each time series location shown in Table 4.1 along the Alabama, Coosa, Tallapoosa, Etowah, and Coosawattee Rivers. The cumulative occurrence plots show the percentage of time each parameter was lower than a certain concentration level. For example, if a DO plot shows a 5% occurrence level at 6 mg/L, then 5% of the observations were lower than this level. An occurrence level of 95% at 12 mg/L shows that 95% of model values fell below 12 mg/L. Conversely, this would indicate that 5% of the model values were higher than 12 mg/L. The 0% and 100% levels represent the theoretical minimum and maximum values, respectively, of a parameter. These proxies for the minimum and maximum values eliminated reporting of water quality spikes, due to “negative” inflows and other factors. In the longitudinal river profiles shown below, the 5%, 50%, and 95% occurrence levels are plotted to show the lower, median, and upper range of concentration values. Representative plots of chlorophyll *a* are shown in Figure 4.2 at two stations on the Coosa River.

Model output and post-processed results were saved to HEC-DSS files. These plots and files were provided electronically to USACE Mobile District and were used by the EIS PDT to analyze the water quality differences between alternatives. The DSS results were used to produce tables in the EIS.

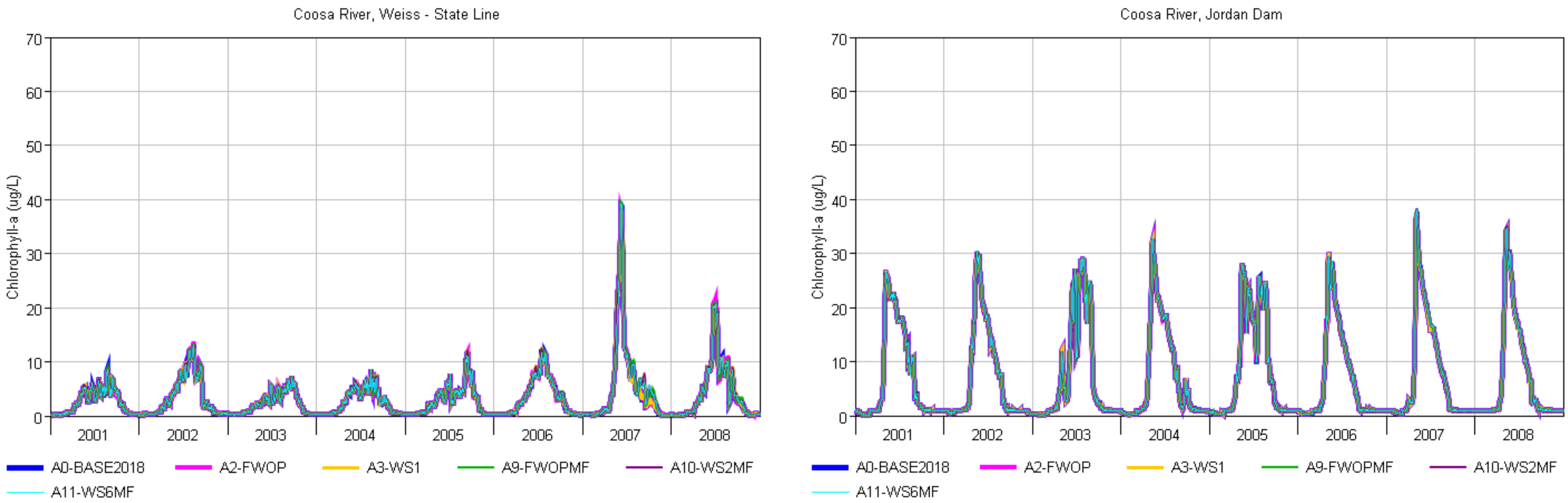
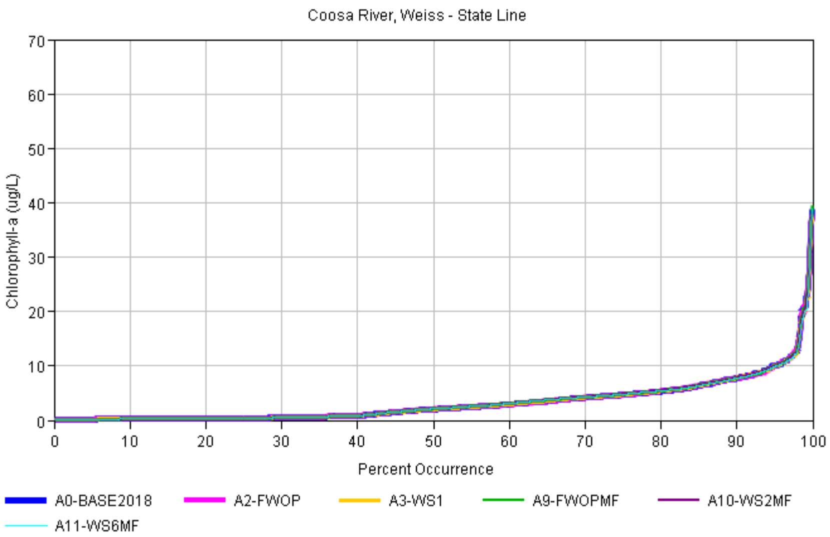


Figure 4.1. Time series of chlorophyll *a*, computed for the Coosa River at two stations, Weiss – State Line and Jordan Dam, during the 2001–2008 modeling period.



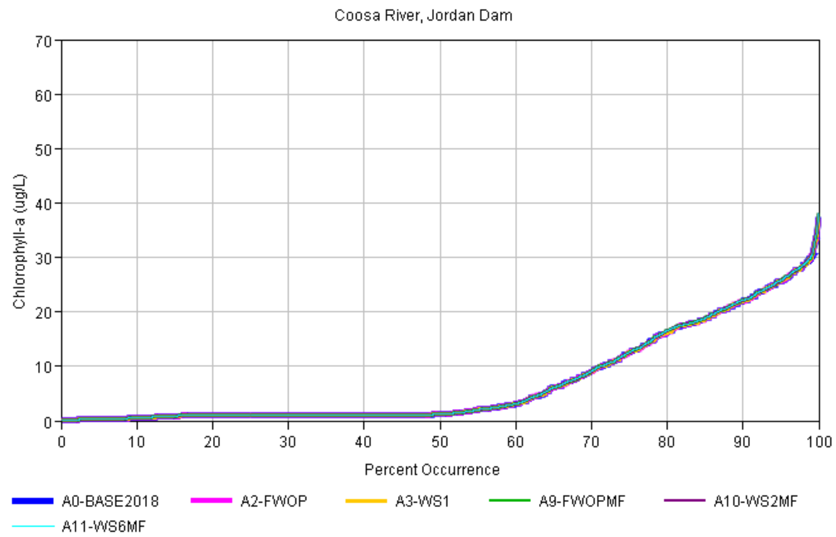


Figure 4.2. Cumulative occurrence of chlorophyll *a*, computed for the Coosa River at two stations, Weiss – State Line and Jordan Dam, during the 2001–2008 modeling period.

4.3 River Profiles

Cumulative occurrence levels of each water quality parameter were computed for each river mile along the rivers of the ACT basin for the No Action alternative and each of the six alternatives. The occurrence levels were plotted by river mile to show longitudinal profiles of occurrence for each parameter. Occurrence profiles were plotted to show how water quality varies along each reach, and how it may be affected by dams, other structures, or discharges (point source and non-point source). Peak values may shift longitudinally during a dry year versus a wet year. Therefore, these can serve as validation of the model accuracy. The 50% occurrence level shows the median concentration of each parameter. The 5% and 95% occurrence were selected as proxies of the minimum and maximum values, respectively. A minimum/maximum value computed by the model may not be representative of the true minimum/maximum, but instead may be a function of minor model error due to missing data or other factors. The 5% and 95% occurrence levels are expected to be better representations of the lower and upper bounds of concentration in the ACT basin.

4.3.1 Computation

A post-processing program was used to compute the percentage exceedance of each parameter at multiple exceedance levels. The exceedance shows the percentage of time a parameter exceeded a particular concentration. To avoid confusion with the water quality definition of exceedance as a violation of a standard, the percentage of occurrence is shown instead. This was computed by subtracting the exceedance level from 100%. Therefore, low occurrence levels are analogous to low values of a given parameter, while high occurrence levels are analogous to high values.

4.3.2 Computation Periods

While cumulative occurrence was computed for the entire model period in Section 4.2, several weekly, seasonal, and annual model periods were computed and shown as longitudinal occurrence profiles.

To show how the ACT system functions during different annual hydrologic conditions, three years were selected to represent normal (2002), wet (2003), and dry (2007) conditions. These are plotted along with profiles of the composite of the 2001–2008 modeling period.

In addition to showing the annual percentage of occurrence of each parameter, the ACT system function is particularly important during the growing season, which is defined as the period between April and November each year. Occurrence profiles were computed for this growing season for each representative hydrologic period and for the 2001–2008 model period.

Occurrence profiles were computed for every combination of the annual and seasonal periods outlined above. In addition to the plots presented in this section, "delta" plots were created, which show the difference of each alternative from the No Action alternative. For every plot of actual values, there is a corresponding delta plot. Model output and post-processed results were saved to HEC-DSS files. These plots and files were provided electronically to USACE Mobile District and were used by the EIS PDT to analyze the water quality differences between alternatives. The DSS results were used to produce tables in the EIS.

4.3.3 Reach Geometry for the Occurrence Profiles

Several stream alignments were selected from the HEC-ResSim and HEC-5Q models to compute and display the longitudinal river occurrence profiles. Figure 4.3 shows the three stream alignments used for the longitudinal occurrence profiles for the Etowah and Coosawattee Rivers and the Georgia portion of the Coosa River.

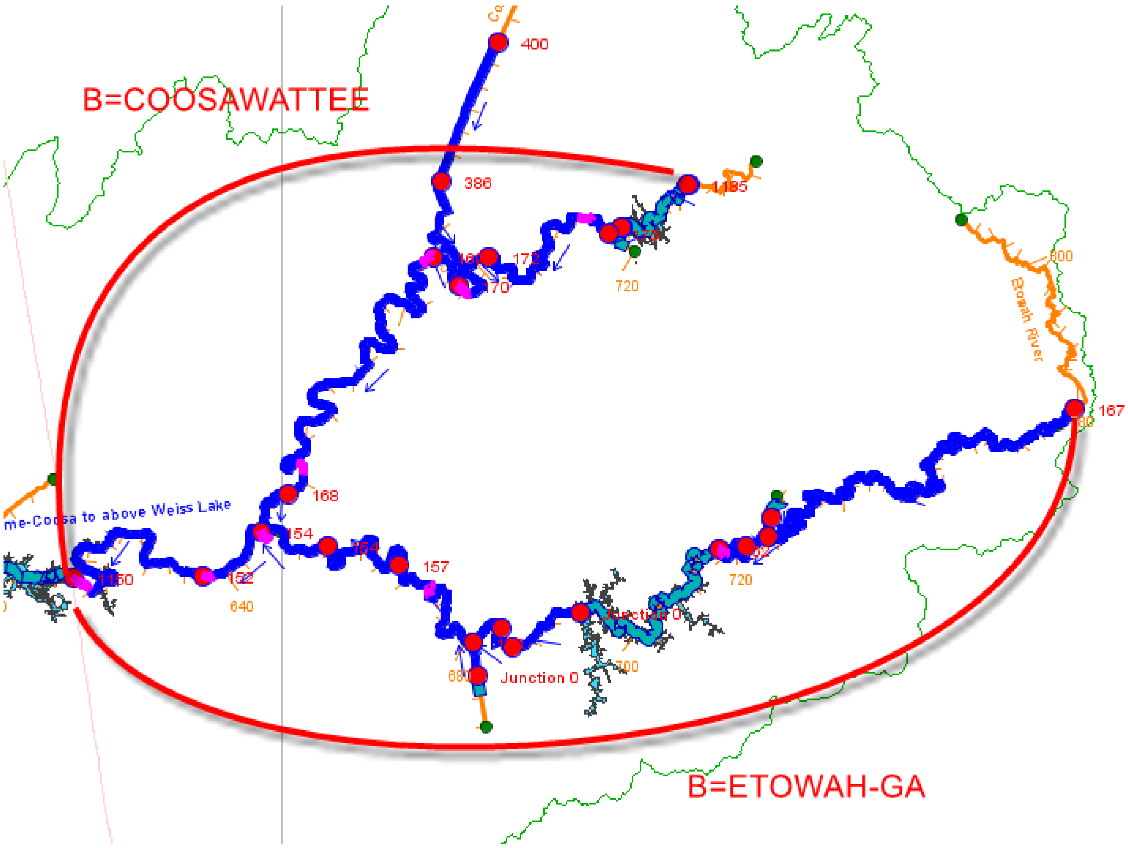


Figure 4.3. Etowah and Coosawattee rivers and the Georgia portion of the Coosa River, April through November growing season.

Figure 4.4 shows the stream alignment for the Coosa River plots. The old Coosa channel is represented in the model between 5 miles below the spillway to the Weiss Dam tailrace with 1-mile long stream elements. Due to the overlap of river miles, the profiles include all of Weiss Lake surface quality and then the old Coosa channel beginning at mile 580 (Terrapin Creek) to mile 564.5 (tailrace). For this portion of the system, the following assumptions apply:

- The HEC-ResSim model flow is often zero, and the HEC-5Q model assumes a 5 cfs minimum flow above Terrapin Creek.
- All the spill is assumed removed from the Weiss Lake surface element including the low flow bypass that does not appear to be represented in the HEC-ResSim model.
- Terrapin Creek quality is based on BASINS model, and the creek chlorophyll *a* concentration may not be realistic.

This profile includes the Coosa River between Jordan Dam and JBT Goal (Coosa – Tallapoosa – Alabama River confluence) but does not include Bouldin Lake or the Bouldin Dam Tailrace channel.

Figure 4.5 shows a detailed segment from Lay Dam to JBT Goal. Figure 4.6 shows the Tallapoosa River from Heflin to JBT Goal (at the confluence of the Alabama, Coosa, and Tallapoosa Rivers). Figure 4.7 shows the Alabama River reach from JBT Goal to ARP, below Claiborne Dam. Figure 4.8 shows the extended steam alignment used for the sensitivity analysis. This alignment extends from the Etowah River to the Alabama River.

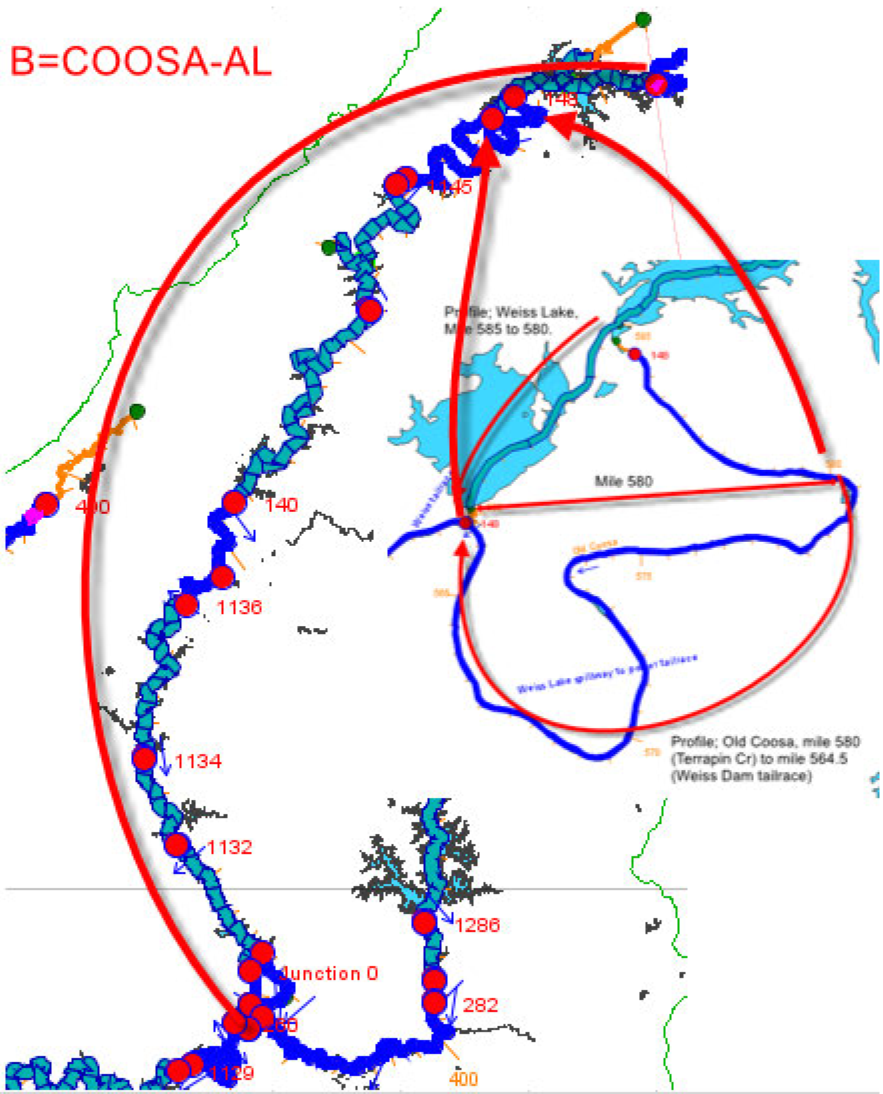


Figure 4.4. Coosa River below State Line, April through November growing season.

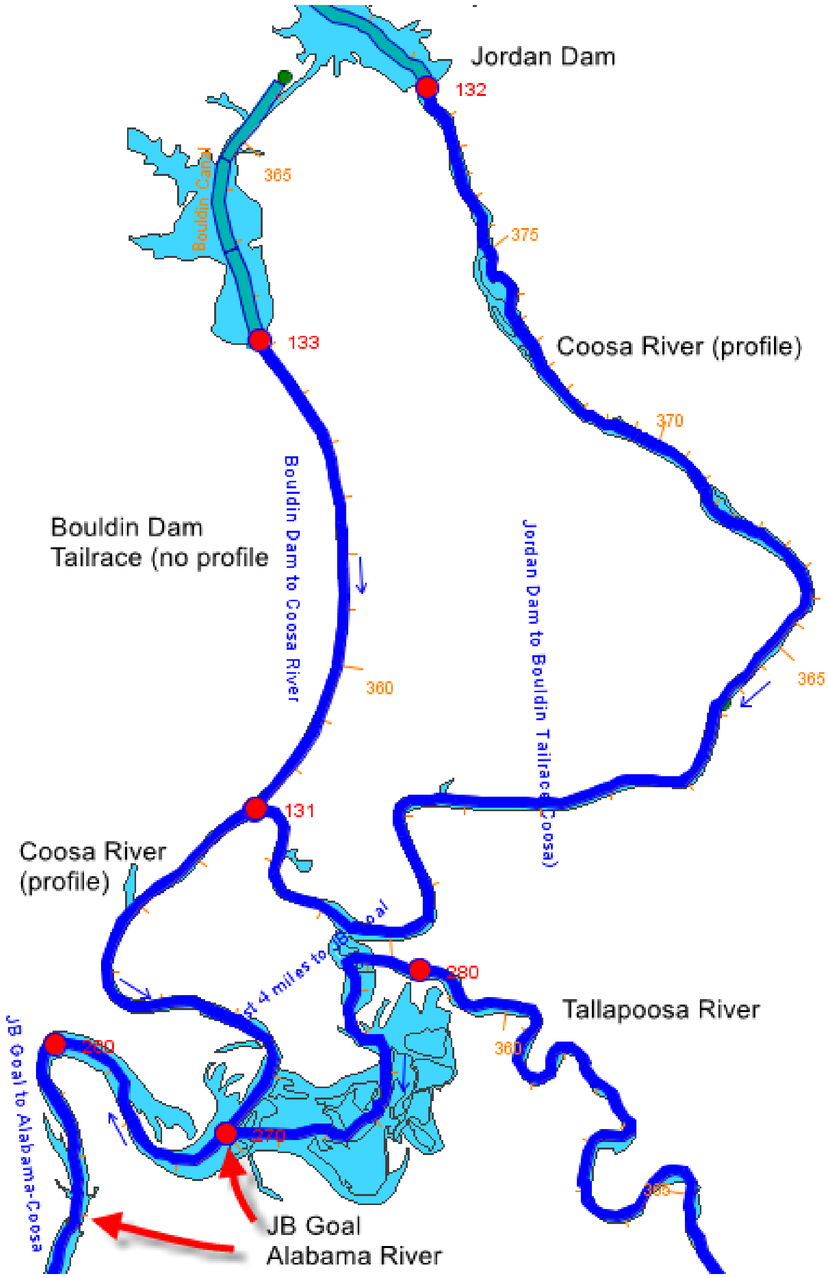


Figure 4.5. Lay Dam to JBT Goal.

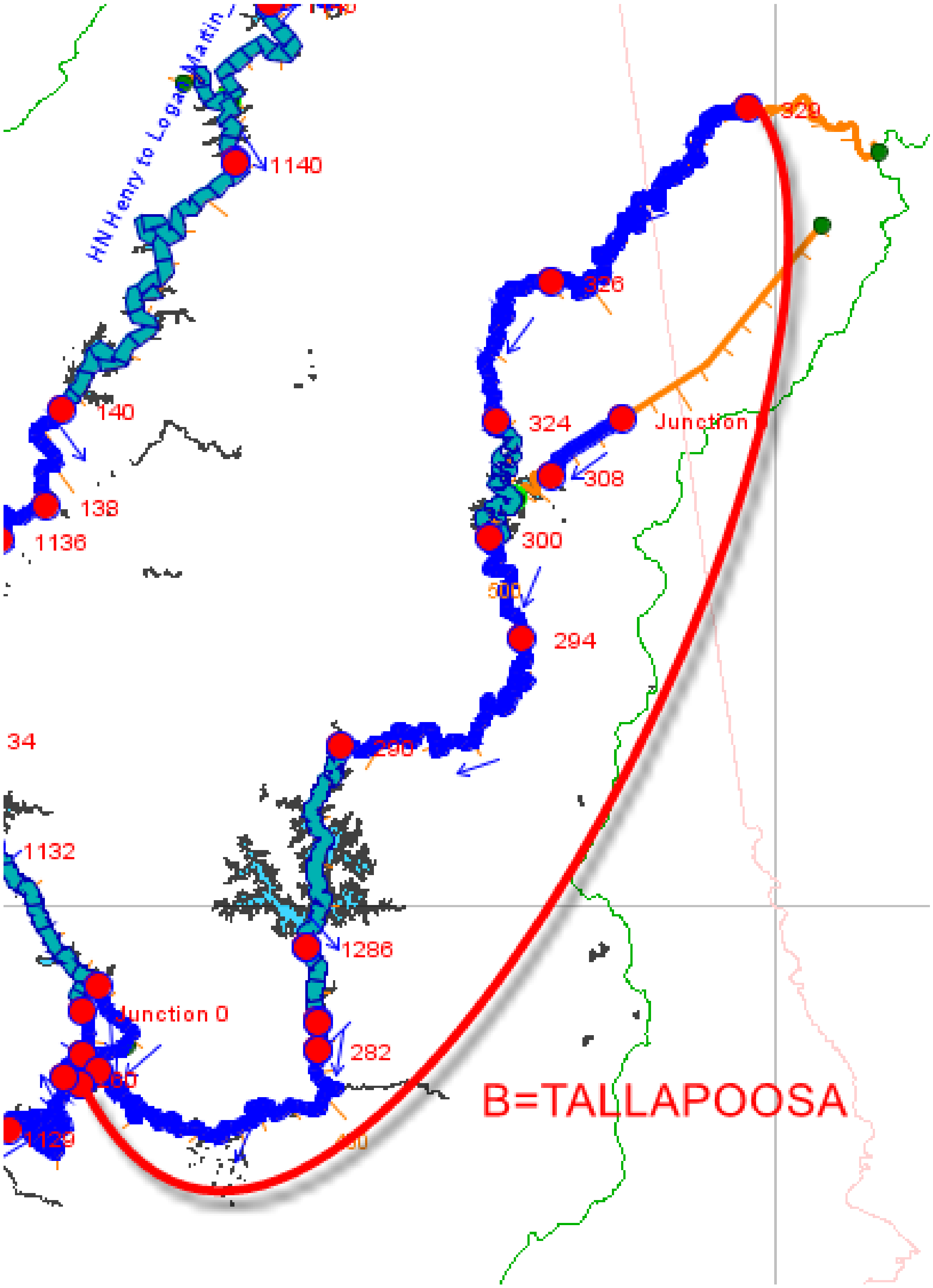


Figure 4.6. Tallapoosa River, Heflin to JBT Goal (at the Alabama–Coosa–Tallapoosa River confluence).

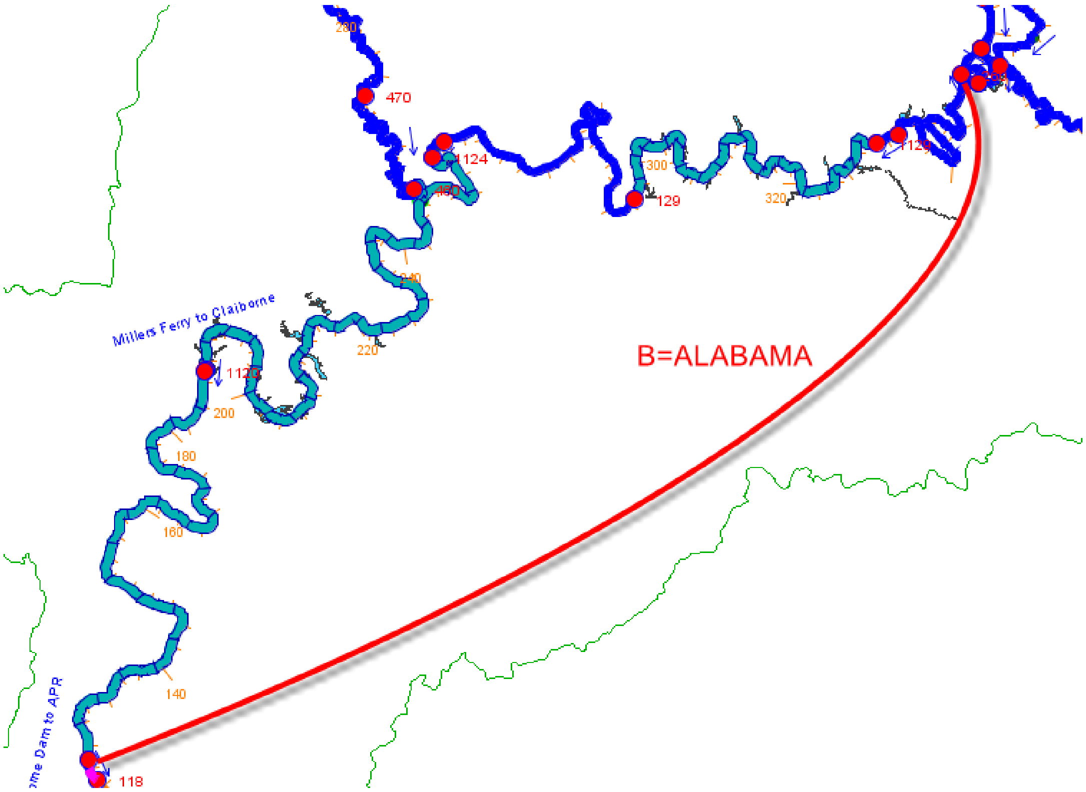


Figure 4.7. Alabama River - JBT Goal to ARP (below Claiborne Dam).

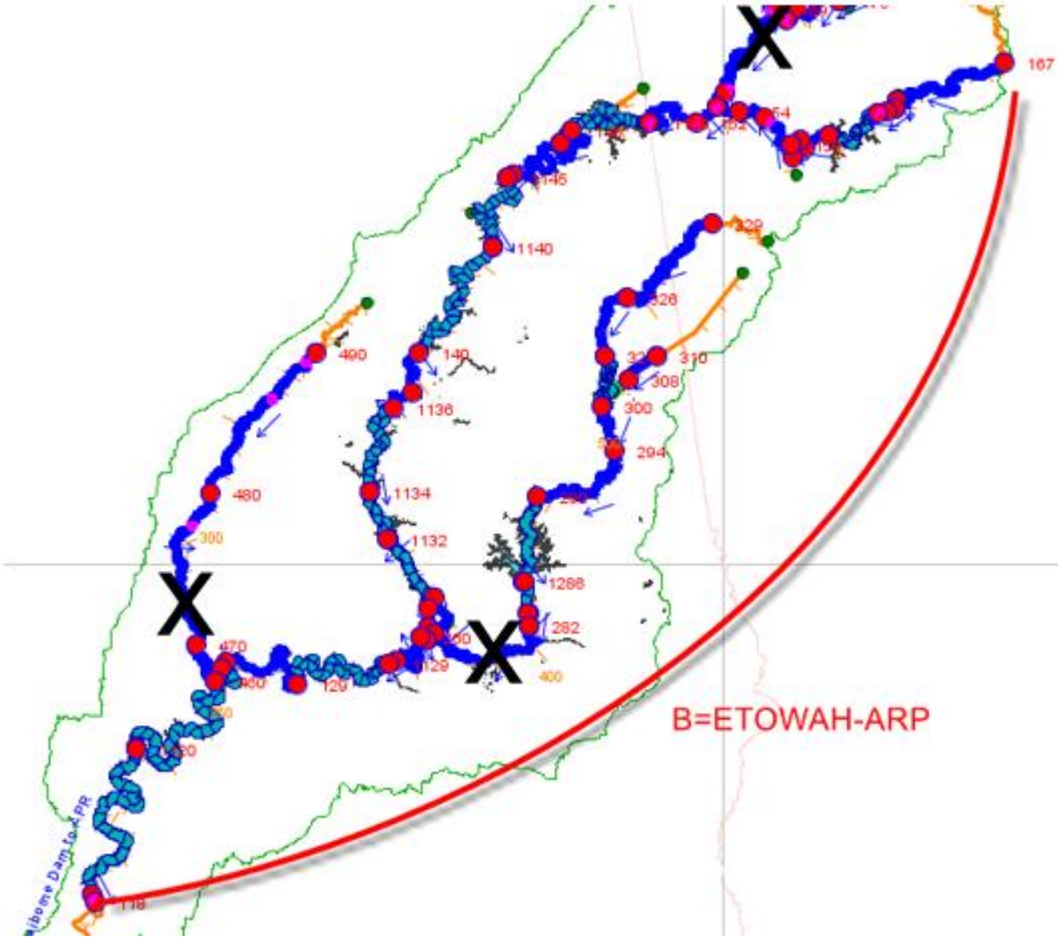
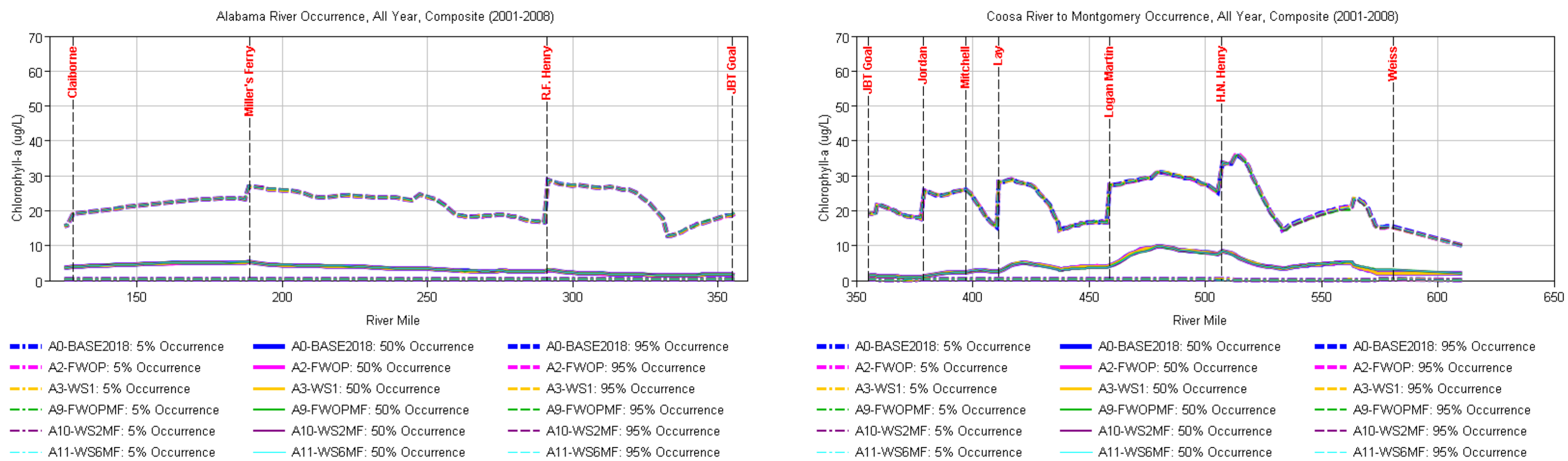


Figure 4.8. Alignment for the USFWS growing season plot of chlorophyll *a* for the sensitivity analysis (not including the Coosawattee, Tallapoosa, and Cahaba rivers).

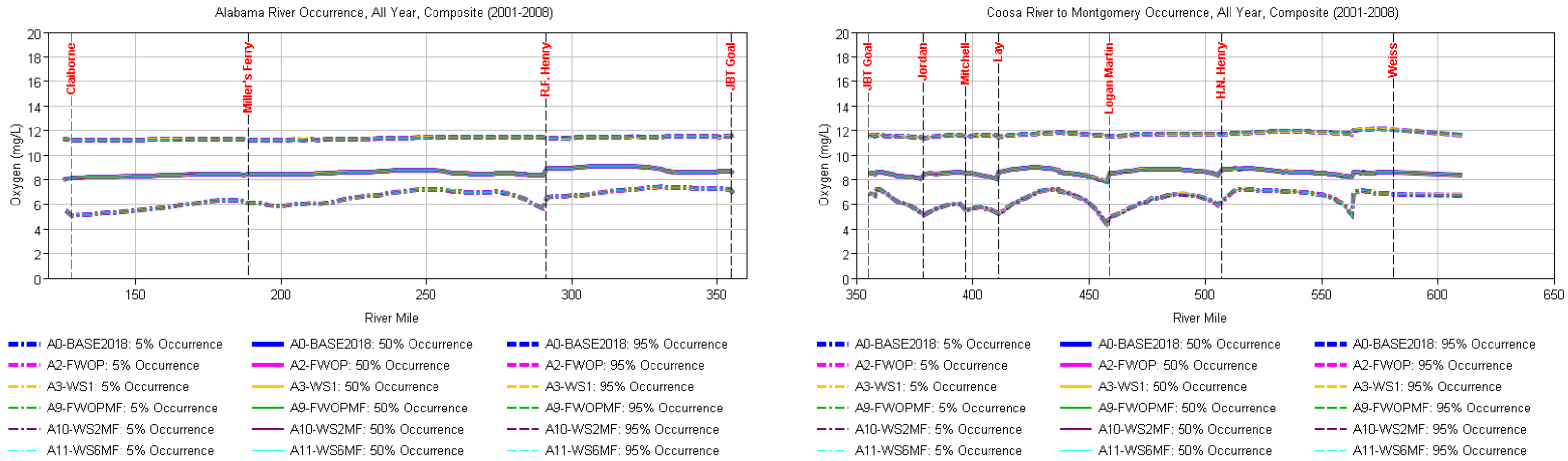
4.3.3.1 Composite Period

Longitudinal occurrence profile plots were created for nine parameters: chlorophyll *a*, DO, wastewater percent of flow, BOD5U, NH_3-N, NO_3-N, TN, PO_4, and TP for the composite 2001–2008 modeling period. Representative plots are shown in Figure 4.9 through Figure 4.17.



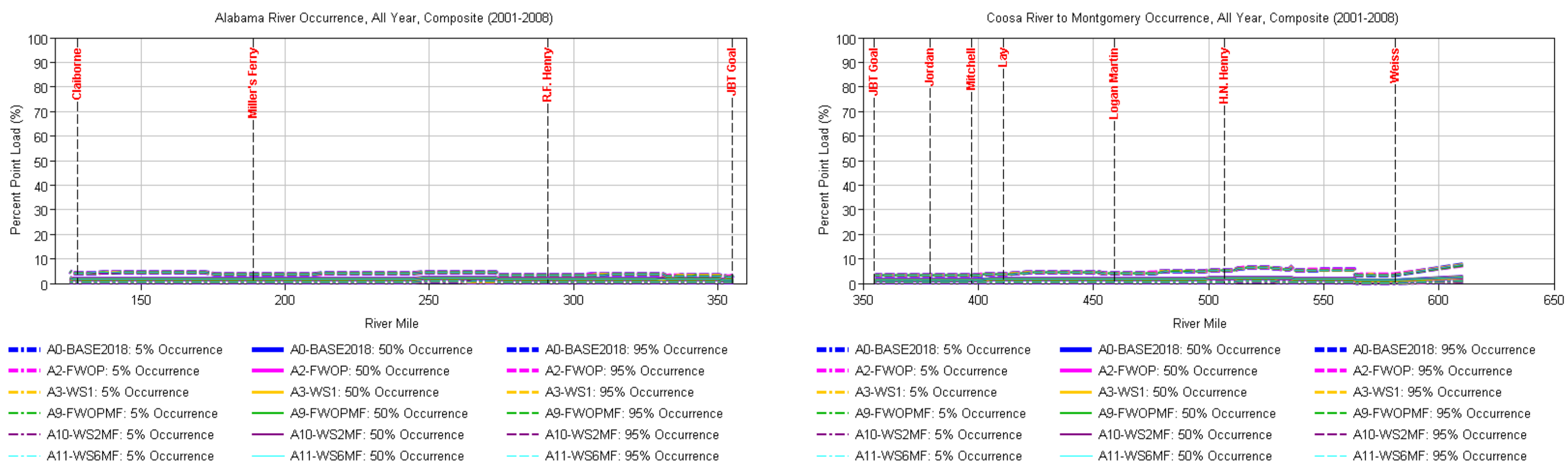
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.9. Longitudinal occurrence profiles of chlorophyll *a* computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



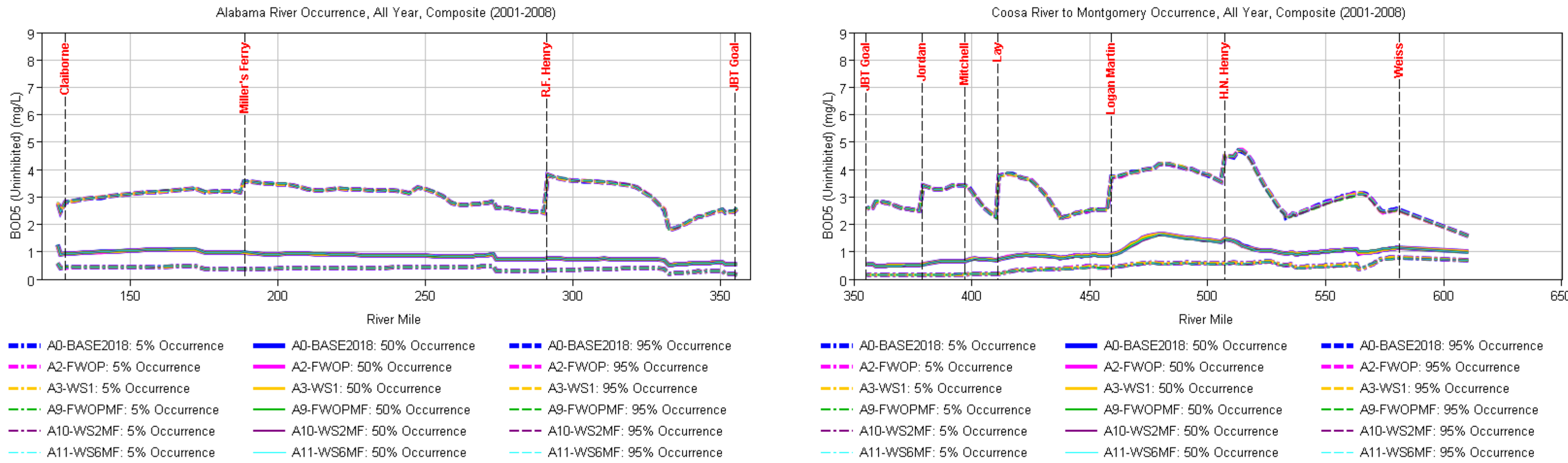
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.10. Longitudinal occurrence profiles of DO computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



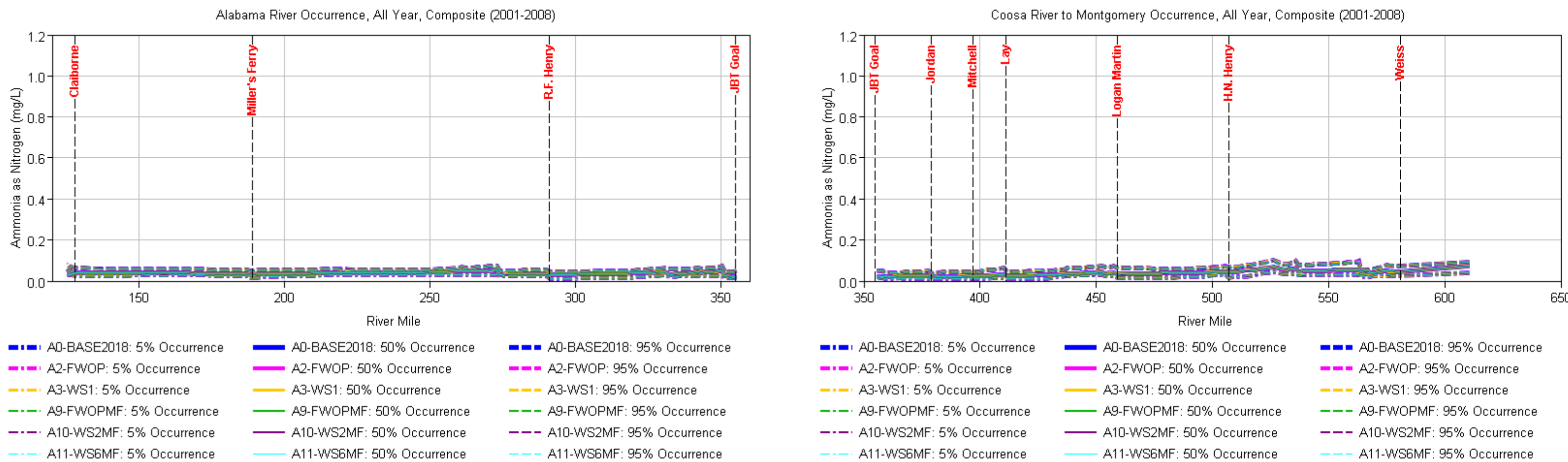
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.11. Longitudinal occurrence profiles of wastewater computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



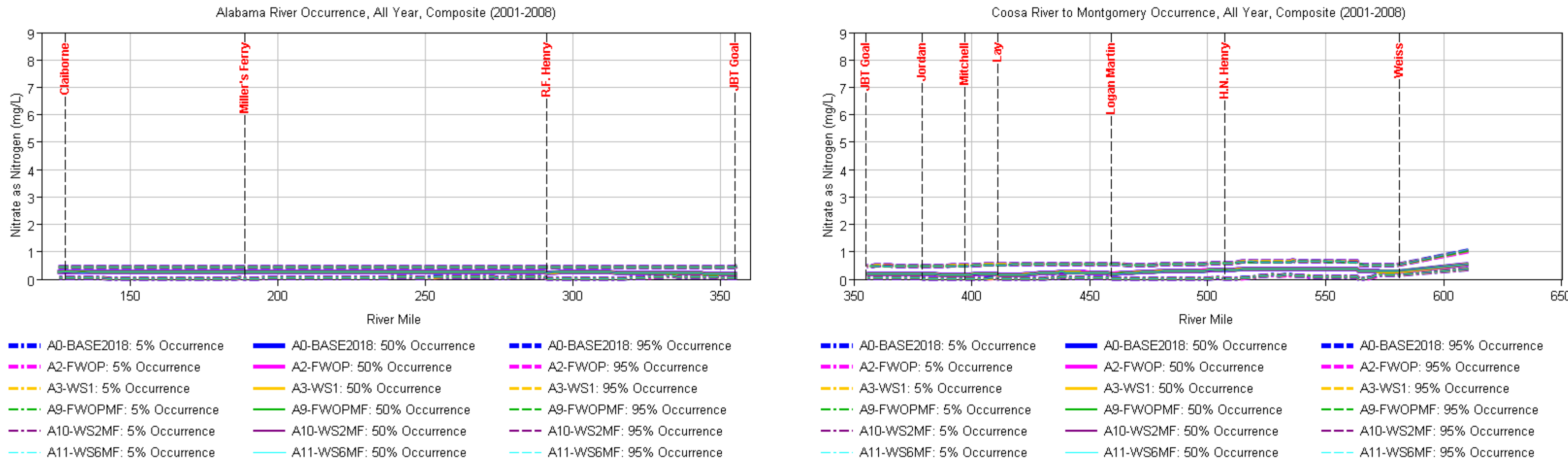
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.12. Longitudinal occurrence profiles of BOD5U computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



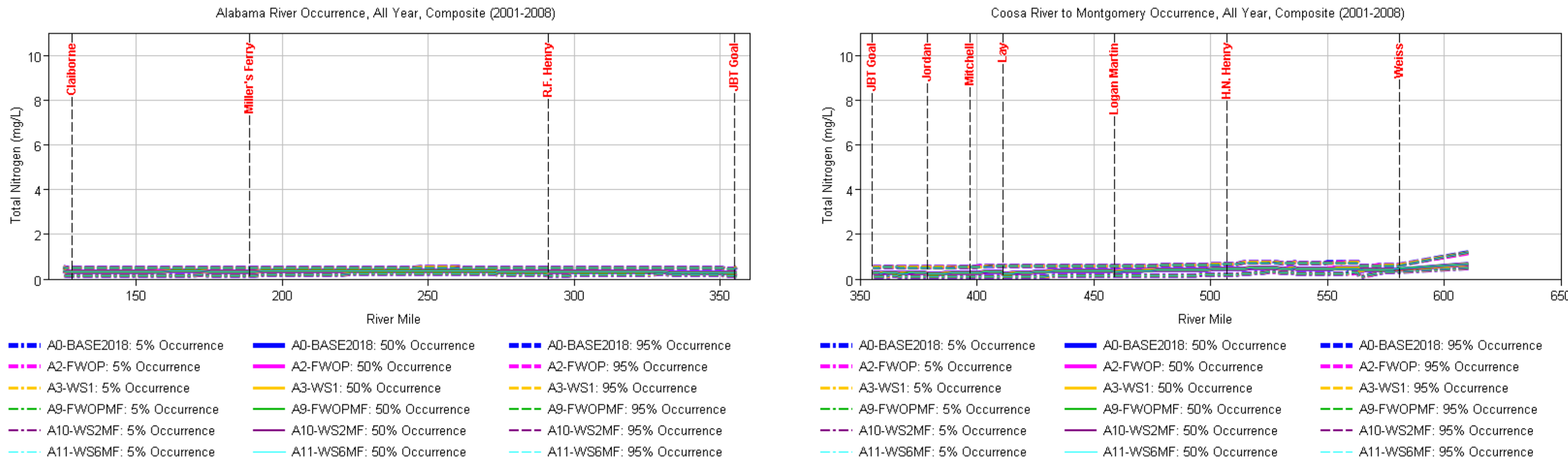
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.13. Longitudinal occurrence profiles of NH_3-N computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



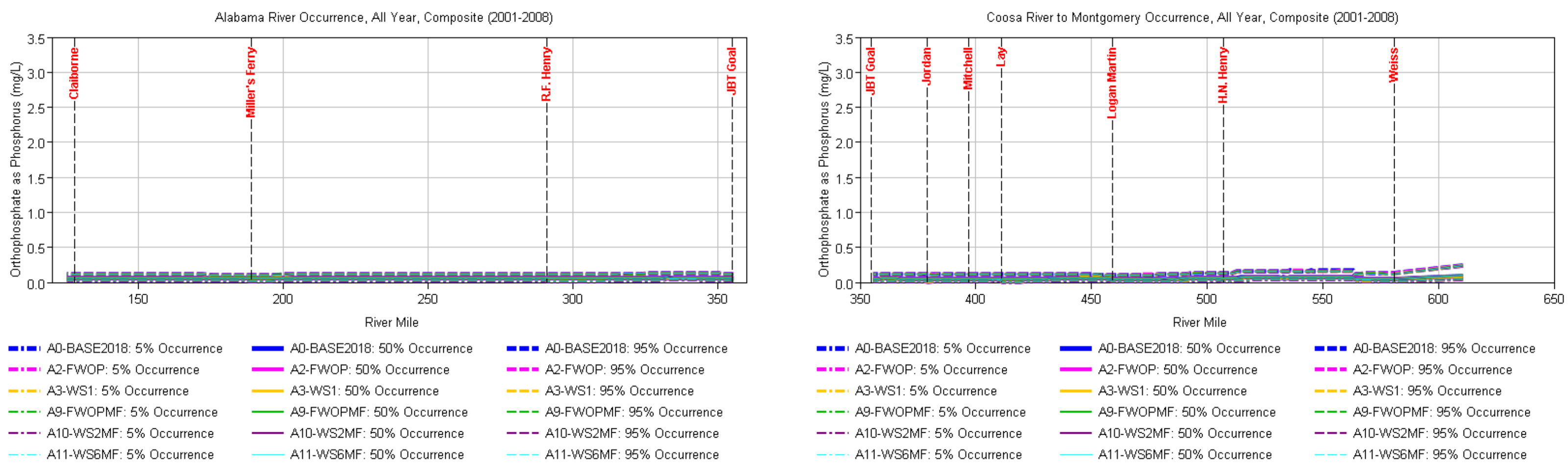
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.14. Longitudinal occurrence profiles of NO_3-N computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



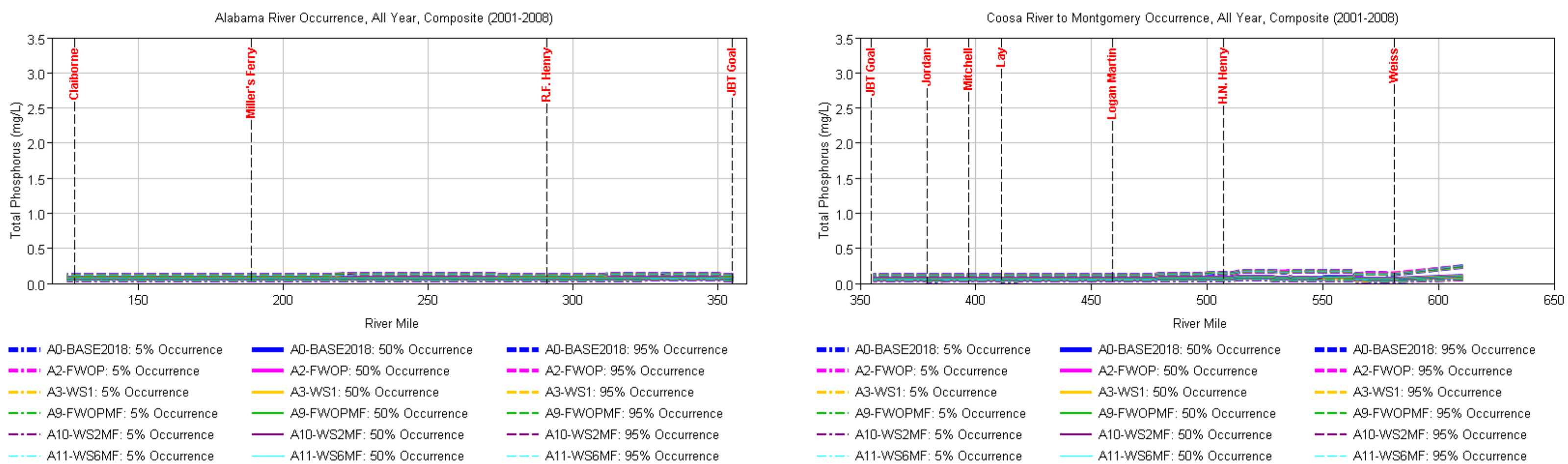
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.15. Longitudinal occurrence profiles of TN computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.



Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.16. Longitudinal occurrence profiles of PO_4-P computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.

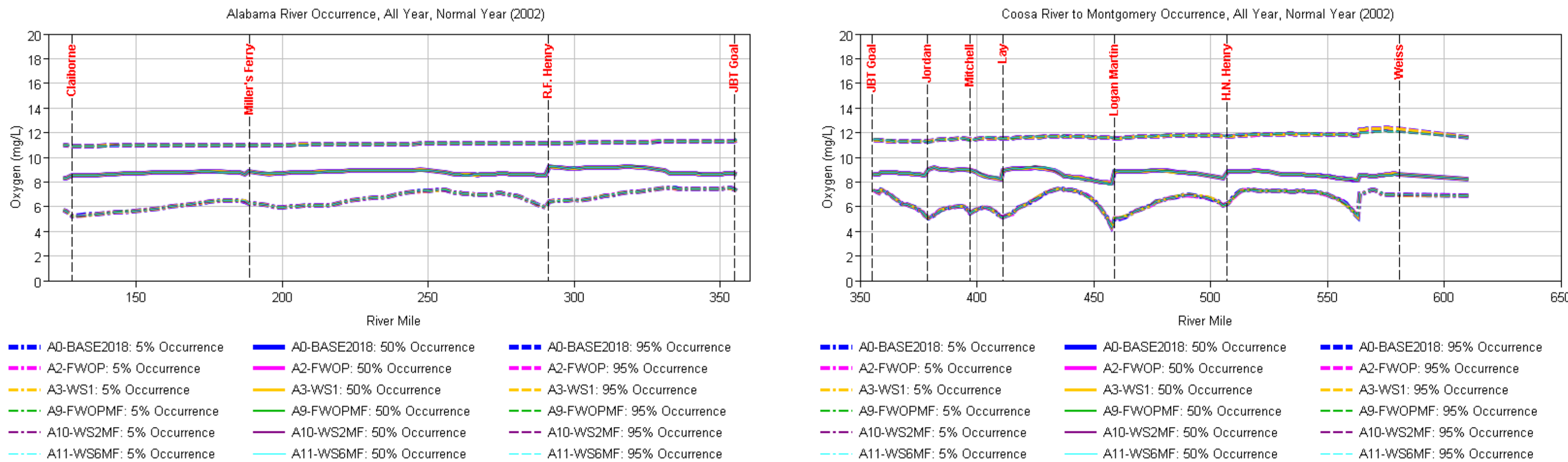


Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.17. Longitudinal occurrence profiles of TP computed along the Alabama and Coosa rivers during the 2001–2008 modeling period.

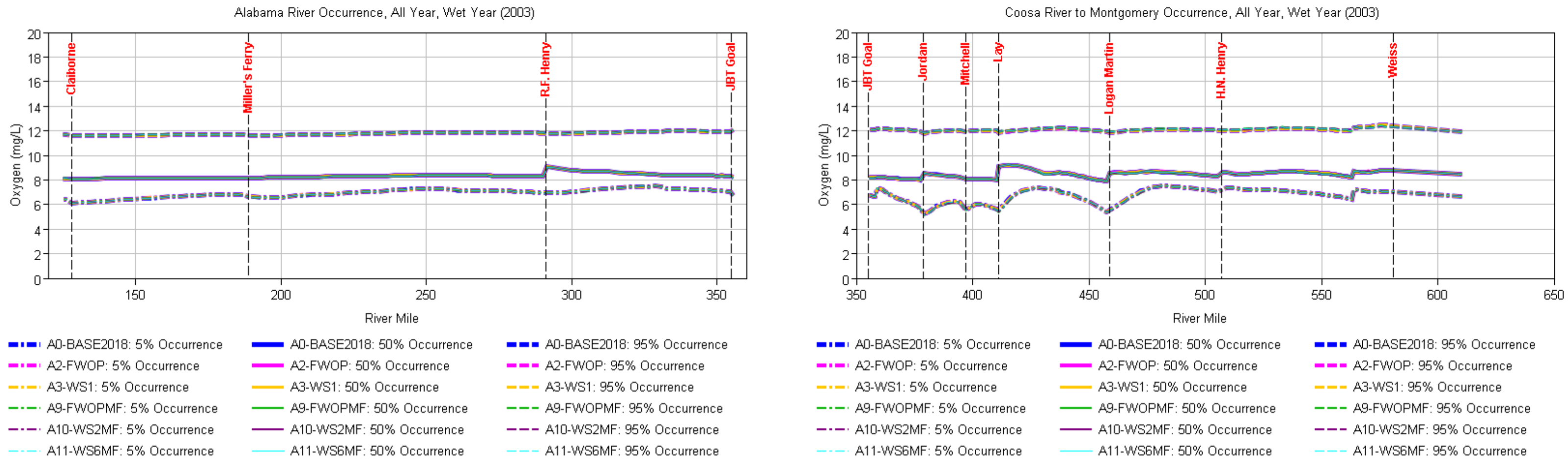
4.3.3.2 *Annual Hydrologic Periods*

Longitudinal occurrence profile plots were created for nine parameters: chlorophyll *a*, DO, wastewater percent of flow, BOD5U, NH_3-N, NO_3-N, TN, PO_4, and TP for each hydrologic period: wet (2003), normal (2002), and dry (2007). Representative plots are shown in Figure 4.18 through Figure 4.20. DO was selected to highlight these representative years in these plots.



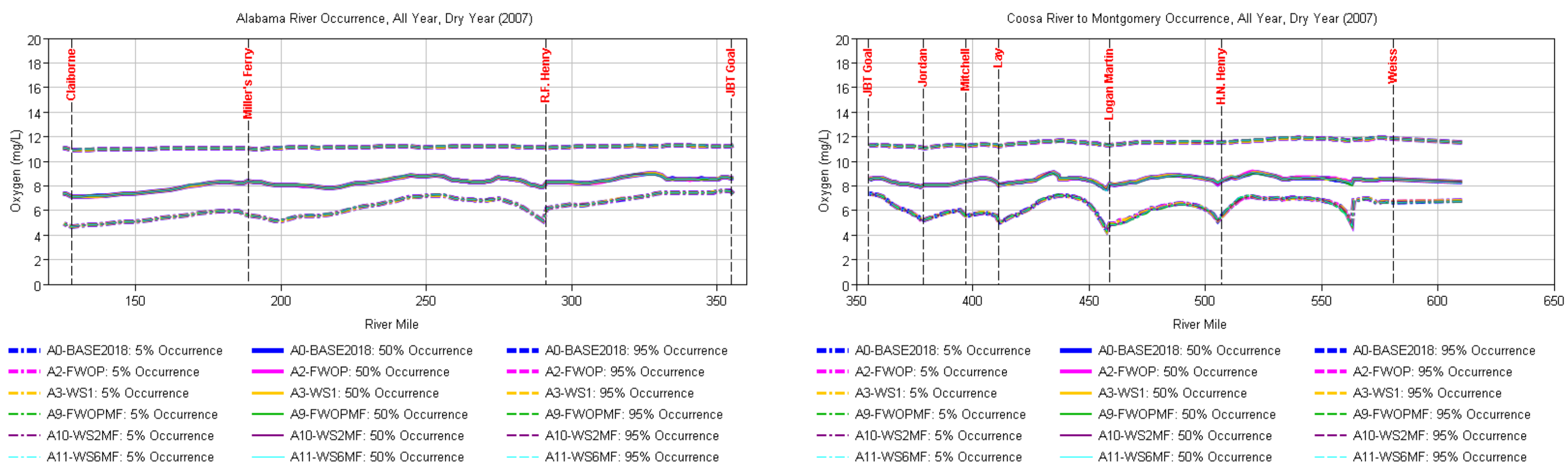
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.18. Longitudinal occurrence profiles of DO computed along the Alabama and Coosa Rivers during a “normal” year (2002).



Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.19. Longitudinal occurrence profiles of DO computed along the Alabama and Coosa rivers during a “wet” year (2003).



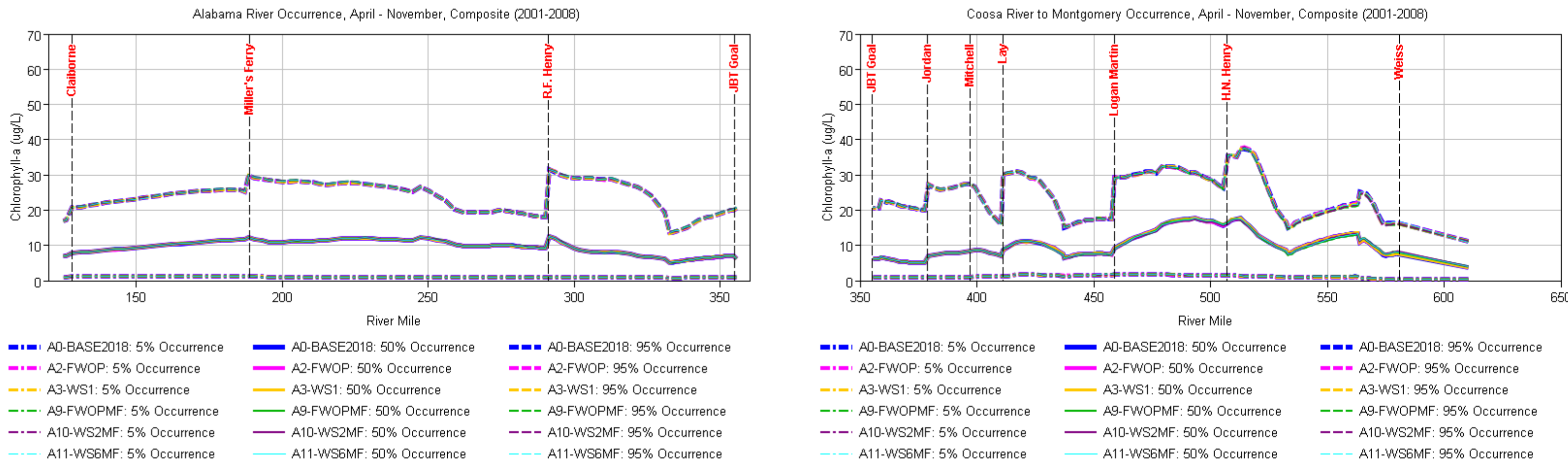
Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.20. Longitudinal occurrence profiles of DO computed along the Alabama and Coosa rivers during a “dry” year (2007).

4.3.3.3 Growing Seasons

Longitudinal occurrence profile plots were created for each growing season for nine parameters: chlorophyll *a*, DO, wastewater percent of flow, BOD5U, NH_3-N, NO_3-N, TN, PO_4, and TP for each hydrologic period: wet (2003), normal (2002), and dry (2007), and for the 2001–2008 modeling period. Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.21 shows a representative plot.



Note: The 95%, 50%, and 5% occurrence levels are shown for the six project alternatives.

Figure 4.21. Chlorophyll *a* was computed for the months of April–November along the Alabama and Coosa Rivers during the 2001–2008 modeling period.

4.3.4 TABULATED RESULTS

Tabulated results were computed to assist the EIS PDT with the water quality analysis. Examples of these are shown in Table 4.2 through Table 4.10. Table 4.2 lists 49 locations where tabular data are provided. The first 16 locations are reservoirs and the tabular data are an average of more than one computational element. For those reservoirs with “top 3” in the “# elements mile” column, the water quality of the top three layers of the four vertically segmented reservoirs are averaged. The top three elements represent the upper nine feet of the lake. For the remaining reservoirs, this column indicates the number of surface elements that are averaged for the longitudinally segmented and layered reservoirs. As an example, tabular data for Weiss Lake are computed as an average of eight surface elements. Figure 4.22 shows the Weiss Lake example. The next 14 locations are below dam locations and the remainder are name recognizable locations. The last three columns are the temperature and water quality standards.

Table 4.3 is an example of a report that identifies five levels of percent exceedance and the percentage of time the standard is exceeded for all 49 locations identified in Table 4.2. This table was prepared for temperature, DO, and chlorophyll *a* for the No Action (Base2018) alternative and the other five alternatives.

Table 4.4 is an example of the report that describes the seasonal distribution of temperature, DO, and chlorophyll *a*. The daily average, daily average maximum, and hourly 95% exceedance (daily minimum and 5% for DO minimum) are listed for the entire year, each month, and various growing seasons. To the right of the chlorophyll *a* table are flags that identify differences greater than 1%, 2%, or 5%.

Table 4.7 lists the percent of time the chlorophyll *a* standard is exceeded for the No Action alternative and each of the other five alternatives, and the difference in percent between the No Action alterative and each alternative. Table 4.8 is another example of alternatives compared with the No Action alternative that shows how compliance with the DO standards varies with the 5 mg/L daily average and the 4 mg/L daily minimum.

Table 4.6 is an example of the yearly and growing season summary of chlorophyll *a* by reservoir category. It provides a comparison between the average, maximum and 95% level for the baseline and alternative. The difference and percent difference between the baseline and each alternative show the small differences between alternatives.

Table 4.9 provides an example of alternatives compared with the No Action alternative. The table lists changes in DO standards compliance (4 mg/L daily minimum and 5 mg/L daily average). There is a large difference at the reservoirs with the 4 mg/L limit imposed in the model. Table 4.10 lists the incremental changes in compliance between alternatives.

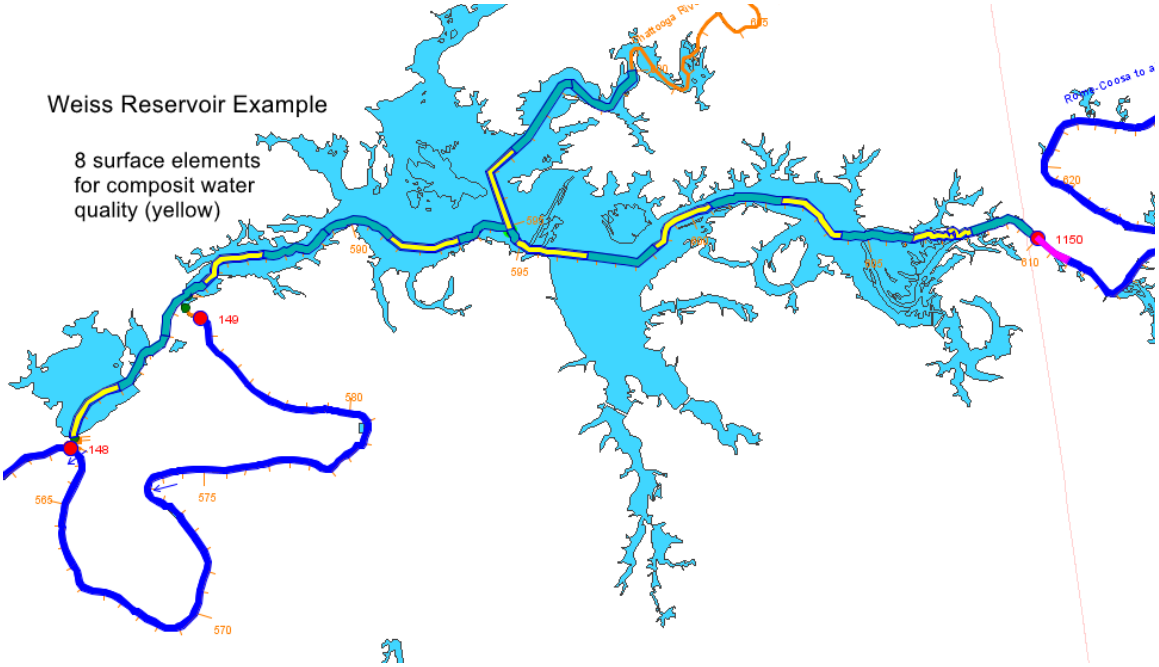


Figure 4.22. Example of reservoir surface elements for computing composite water quality.

Table 4.2. Water quality standards and locations for time series plots and tables (aggregated reservoir surface elements or river miles; maximum daily average for temperature and chlorophyll *a*; daily average and minimum for DO)

Plot time series and results tables				Standards	
		# elements		DO	
Reservoirs		mile	Temp	Min/Avg	Chl-a
Etowah	Allatoona	top 3	32.22	5	12
Coosawattee	Carters	top 3	32.22	5	10
Coosawattee	Carters Rereg	3	32.22	5	10
Coosa	Weiss	8	32.22	5	20
Coosa	HN Henry	8	32.22	5	18
Coosa	Logan Martin	8	32.22	5	17
Coosa	Lay	7	32.22	5	17
Coosa	Mitchell	7	32.22	5	17
Coosa	Jordan	7	32.22	5	14
Coosa	Bouldin	3	32.22	5	14
Tallapoosa	Harris	top 3	32.22	5	10
Tallapoosa	Martin	top 3	32.22	5	5
Tallapoosa	Yates+Thurlow	5	30.00	5	5
Alabama	RF Henry	7	32.22	5	17
Alabama	Millers Ferry	7	32.22	5	17
Alabama	Claiborne	7	32.22	5	15
Below Dams					
Etowah	Allatoona-TW	693	32.22	4/5	10
Coosawattee	CartersRereg-TW	717	32.22	4/5	10
Coosa	Weiss Power-TW	581	32.22	4/5	14
Coosa	Weiss Spill-TW	585	32.22	4/5	14
Coosa	HN Henry-TW	506	32.22	4/5	14
Coosa	Logan Martin-TW	458	32.22	4/5	14
Coosa	Lay-TW	410	32.22	4/5	14
Coosa	Mitchell-TW	396	32.22	4/5	14
Coosa	Jordan-TW	378	32.22	4/5	14
Coosa	Bouldin-TW	263	32.22	4/5	14
Tallapoosa	Harris-TW	498	30.00	4/5	10
Tallapoosa	Martin-TW	420	30.00	4/5	10
Alabama	RF Henry-TW	290	32.22	4/5	15
Alabama	Millers Ferry-TW	187	32.22	4/5	15
Other River locations					
Etowah	Canton	723	32.22	5	10
Etowah	Cartersville	684	32.22	5	10
Etowah	Kingston	667	32.22	5	10
Etowah	Rome	653	32.22	5	10
Coosawattee	Pine Chapel	701	32.22	5	10
Oostanaula	Rome	651	32.22	5	10
Coosa	Rome	646	32.22	5	14
Coosa	State Line	610	32.22	5	14
Coosa	Gadsden	535	32.22	5	14
Coosa	Childersburg	445	32.22	5	14
Coosa	JB Goal	355	32.22	5	14
Tallapoosa	Wadley	485	30.00	5	10
Tallapoosa	Tallassee	407	30.00	5	5
Tallapoosa	JB Goal	355	30.00	5	5
Alabama	JB Goal	355	32.22	5	15
Alabama	Montgomery	333	32.22	5	15
Alabama	Selma	260	32.22	5	15
Cahaba	Marion Junction	265	30.00	5	5
Alabama	ARP	125	32.22	5	15

Table 4.3. Example showing the 5%, 25%, 50%, 75%, and 95% exceedance of DO and the percent of time the standard is exceeded (daily minimum of 4 mg/L below dams and 5 mg/L daily average elsewhere).

OXYGEN (PPM), Base2018		5%	25%	50%	75%	95%	%<Standard	Standard
Etowah	Allatoona	4.9308	6.2868	6.9645	7.6841	8.7372	5.9783	5
Coosawattee	Carters	5.9498	6.9949	7.3760	7.8544	8.7542	1.0870	5
Coosawattee	Carters Rereg	6.3793	7.4664	7.9846	8.5191	9.3259	-	5
Coosa	Weiss	6.9166	7.4181	7.8268	8.3018	8.9523	-	5
Coosa	H. N. Henry	6.8638	7.3669	7.7846	8.3385	9.2559	-	5
Coosa	Logan Martin	5.9654	6.6116	7.3121	7.9501	9.1874	-	5
Coosa	Lay	6.1316	6.9326	7.5436	8.2630	9.4840	-	5
Coosa	Mitchell	5.3369	6.1971	6.8453	7.5672	8.9106	1.4266	5
Coosa	Jordan	5.3767	6.4324	7.0439	7.9280	9.5382	1.6984	5
Coosa	Bouldin	5.2501	6.1478	6.7806	7.5549	9.3091	1.5625	5
Tallapoosa	Harris	5.5257	5.9878	6.3127	6.9130	7.8950	0.0679	5
Tallapoosa	Martin	6.3047	6.7300	6.9438	7.3648	8.1340	-	5
Tallapoosa	Yates & Thurlow	5.0043	6.1110	7.2550	8.2437	9.2648	4.8234	5
Alabama	R. F. Henry	6.7826	7.3346	7.9507	8.7437	9.7894	-	5
Alabama	Millers Ferry	6.4338	6.8675	7.2657	7.9830	9.0997	-	5
Alabama	Claiborne	5.4420	6.0615	6.7329	7.5349	8.8972	0.2038	5
Etowah	Allatoona Tailwater	2.2319	2.8474	3.1711	4.3943	6.5273	70.5163	4
Coosawattee	CartersRereg Tailwater	6.8154	7.7491	8.1739	8.6709	9.4366	-	4
Coosa	Weiss Power Tailwater	4.0473	5.4050	6.4566	7.3462	8.1313	-	4
Coosa	Weiss Spill Tailwater	6.5851	6.9207	7.2837	7.8480	8.7391	-	4
Coosa	H. N. Henry Tailwater	5.0371	5.9687	6.7905	7.4891	8.2367	-	4
Coosa	Logan Martin Tailwater	4.1716	4.6807	5.7509	6.7433	7.7507	-	4
Coosa	Lay Tailwater	4.6388	5.1897	6.0137	6.9280	7.8277	-	4
Coosa	Mitchell Tailwater	5.3104	6.2806	6.8900	7.6042	8.9333	0.2038	4
Coosa	Jordan Tailwater	5.0654	5.6155	6.2518	7.1537	8.7209	-	4
Coosa	Bouldin Tailwater	4.9749	5.6510	6.4364	7.3300	8.3832	0.2717	4
Tallapoosa	Harris Tailwater	3.0404	3.3070	3.5791	4.3710	5.5974	68.2065	4
Tallapoosa	Martin Tailwater	1.8290	1.9618	2.4922	4.1555	7.0361	73.5734	4
Alabama	R. F. Henry Tailwater	5.3787	6.3408	6.9791	7.5859	8.6370	-	4
Alabama	Millers Ferry Tailwater	5.8517	6.3944	6.8490	7.5302	8.5377	-	4
Etowah	Canton	7.4814	7.7194	7.9827	8.4693	9.4385	-	5
Etowah	Cartersville	3.7584	5.3228	6.0998	6.9805	8.2605	19.7011	5
Etowah	Kingston	5.4787	6.3870	6.8989	7.5351	8.3144	0.2038	5
Etowah	Rome	6.0956	6.8762	7.3577	7.9074	8.5470	-	5
Coosawattee	Pine Chapel	6.7328	7.3396	7.6423	8.0505	8.8164	-	5
Oostanaula	Rome	5.2341	5.9247	6.4945	7.1391	7.9611	3.1250	5
Coosa	Rome	6.4596	6.9857	7.3083	7.7646	8.5224	-	5
Coosa	State Line	6.6151	6.9532	7.2745	7.7837	8.5175	-	5
Coosa	Gadsden	6.9622	7.2074	7.5041	7.9891	8.6232	-	5
Coosa	Childersburg	6.3532	6.9457	7.2227	7.7879	8.3603	-	5
Coosa	JB Goal	6.7263	7.1813	7.5240	7.8857	8.7075	-	5
Tallapoosa	Wadley	5.9522	6.8176	7.2895	7.6554	8.3973	0.8832	5
Tallapoosa	Tallassee	5.5542	6.0085	6.6542	7.5417	8.6819	-	5
Tallapoosa	JB Goal	7.6462	8.0495	8.3604	8.7056	9.0941	-	5
Alabama	JB Goal	7.1211	7.4592	7.7870	8.1786	8.8318	-	5
Alabama	Montgomery	7.3242	7.5015	7.7495	8.1689	8.6762	-	5
Alabama	Selma	6.9561	7.2285	7.4650	7.9520	8.6450	-	5
Cahaba	Marion Junction	5.6584	6.2929	6.7966	7.4401	8.6028	0.6793	5
Alabama	ARP	5.4210	5.8746	6.4939	7.2910	8.1779	0.9511	5

Table 4.4. Seasonal distribution (month, growing season, and year) of temperature at one of the 49 reservoirs and stream locations. This example table shows the distribution for Lake Allatoona.

Etowah Allatoona TEMPERATURE (C)										
Period	Values	average-Base2018	average-A02_FWOP	difference (avg)	maximum-Base2018	maximum-A02_FWOP	difference (max)	95%-Base2018	95%-A02_FWOP	difference (95%)
year	2922	19.116	19.123	0.007	19.324	19.331	0.006	27.870	27.869	-0.001
Jan	745	8.742	8.757	0.014	8.923	8.937	0.014	11.220	11.245	0.025
Feb	679	8.736	8.740	0.004	8.959	8.963	0.004	11.191	11.194	0.003
Mar	745	12.739	12.740	0.001	13.023	13.024	0.001	15.660	15.665	0.005
Apr	721	17.728	17.729	0.001	18.029	18.030	0.001	20.912	20.911	-0.001
May	745	22.316	22.316	-0.001	22.620	22.619	-0.001	24.781	24.781	0.000
Jun	721	25.895	25.895	0.000	26.138	26.138	0.000	27.598	27.597	-0.001
Jul	745	27.422	27.422	0.000	27.639	27.638	-0.001	28.266	28.265	-0.001
Aug	745	27.587	27.587	0.000	27.785	27.784	-0.001	28.748	28.742	-0.006
Sep	721	25.886	25.891	0.005	26.050	26.054	0.004	27.491	27.492	0.001
Oct	745	22.501	22.514	0.013	22.637	22.650	0.013	24.784	24.801	0.017
Nov	721	17.456	17.479	0.023	17.578	17.600	0.022	20.352	20.368	0.016
Dec	745	11.800	11.821	0.021	11.930	11.950	0.020	15.106	15.180	0.074
Winter:Dec-Mar	2890	10.522	10.532	0.010	10.567	10.577	0.010	14.855	14.872	0.016
GA: Apr-Oct	5101	23.986	23.988	0.003	23.982	23.984	0.002	28.075	28.075	0.001
AL: Apr-Nov	5846	23.098	23.103	0.005	23.065	23.071	0.005	28.024	28.027	0.002
USFWL: May-Oct	4356	25.113	25.116	0.003	25.124	25.127	0.003	28.162	28.167	0.005

Table 4.5. Seasonal distribution (month, growing season and year) of DO at Lake Allatoona.

Etowah Allatoona OXYGEN (PPM)										
Period	Values	average-Base2018	average-A02_FWOP	difference (avg)	minimum-Base2018	minimum-A02_FWOP	difference (min)	5%-Base2018	5%-A02_FWOP	difference (5%)
Year	2922	8.479	8.477	(0.002)	8.291	8.290	(0.001)	5.348	5.338	(0.010)
Jan	248	11.066	11.060	(0.006)	11.017	11.011	(0.006)	10.263	10.253	(0.010)
Feb	226	11.258	11.256	(0.002)	11.219	11.218	(0.002)	10.564	10.563	-
Mar	248	10.296	10.296	-	10.258	10.258	-	9.643	9.643	-
Apr	240	9.854	9.853	(0.001)	9.674	9.673	(0.001)	9.263	9.264	0.001
May	248	8.652	8.653	0.001	8.398	8.401	0.002	7.822	7.826	0.004
Jun	240	7.628	7.627	(0.001)	7.421	7.420	(0.002)	6.978	6.969	(0.008)
Jul	248	7.130	7.127	(0.003)	6.874	6.873	(0.001)	6.498	6.510	0.012
Aug	248	6.638	6.636	(0.002)	6.302	6.302	-	5.843	5.842	(0.002)
Sep	240	5.692	5.686	(0.007)	5.238	5.236	(0.002)	4.364	4.344	(0.020)
Oct	248	6.026	6.020	(0.006)	5.758	5.756	(0.003)	4.744	4.706	(0.039)
Nov	240	7.816	7.817	0.001	7.713	7.715	0.002	6.603	6.645	0.042
Dec	248	9.843	9.839	(0.004)	9.778	9.774	(0.004)	8.793	8.795	0.002
Winter:Dec-Mar	970	10.601	10.598	(0.003)	10.553	10.550	(0.003)	9.136	9.134	(0.002)
GA: Apr-Oct	1712	7.370	7.367	(0.003)	7.090	7.089	(0.001)	4.969	4.947	(0.021)
AL: Apr-Nov	1952	7.424	7.422	(0.002)	7.167	7.166	-	5.064	5.058	(0.007)
USFWS: May-Oct	1472	6.964	6.961	(0.003)	6.669	6.668	(0.001)	4.883	4.859	(0.023)

Table 4.6. Seasonal distribution (month, growing season, and year) of chlorophyll *a* at Lake Allatoona.

Etowah	Allatoona	CHLOROPHYLL_A (UGL)											
Period	Values	average-Base2018	average-A02_FWOP	difference (avg)	maximum-Base2018	maximum-A02_FWOP	difference (max)	95%-Base2018	95%-A02_FWOP	difference (95%)	>avg	>max	>&
year	2922	8.567	8.521	-0.046	9.394	9.341	-0.053	21.168	21.137	-0.032			
Jan	745	0.202	0.201	-0.001	0.206	0.205	-0.001	0.266	0.262	-0.004			1
Feb	679	0.185	0.185	0	0.191	0.191	0	0.254	0.254	0			
Mar	745	0.472	0.472	0	0.503	0.503	0	0.857	0.857	0			
Apr	721	10.617	10.618	0.001	12.03	12.031	0.001	33.697	33.687	-0.011			
May	745	20.357	20.335	-0.022	21.685	21.66	-0.025	31.207	31.349	0.141			
Jun	721	15.542	15.532	-0.01	16.619	16.609	-0.01	18.334	18.36	0.025			
Jul	745	16.143	16.085	-0.058	17.391	17.326	-0.066	19.547	19.548	0.001			
Aug	745	16.33	16.24	-0.09	17.902	17.799	-0.102	19.553	19.523	-0.031			
Sep	721	13.625	13.473	-0.152	15.649	15.471	-0.178	20.176	19.655	-0.522	1	1	2
Oct	745	6.48	6.307	-0.172	7.467	7.266	-0.201	13.996	13.462	-0.534	2	2	2
Nov	721	1.893	1.857	-0.036	2.084	2.045	-0.039	3.936	3.829	-0.106	1	1	2
Dec	745	0.458	0.449	-0.01	0.474	0.464	-0.01	1.116	1.055	-0.061	2	2	5
Winter:Dec-Mar	2890	0.327	0.324	-0.003	0.336	0.333	-0.003	0.796	0.786	-0.01			1
GA: Apr-Oct	5101	13.943	13.87	-0.073	14.044	13.968	-0.076	23.91	23.81	-0.101			
AL: Apr-Nov	5846	12.425	12.357	-0.068	12.47	12.4	-0.07	23.119	23.038	-0.082			
USFWL: May-Oct	4356	14.852	14.769	-0.083	14.707	14.626	-0.082	22.564	22.419	-0.145			

Table 4.7. Percent of time the chlorophyll *a* standard is exceeded for the No Action Alternative and each alternative and the percent difference between the No Action Alternative and each alternative.

Chlorophyll-a, daily average (ug/L)						Percent of time standard is exceeded					Change in the percent of time standard is exceeded		
			Base2018	A02_FWOP	A03_WS1	A09_FWOPMF	A10_WS2M	A11_WS6MF	A02_FWOP	A03_WS1	A09_FWOPMF	A10_WS2M	A11_WS6MF
Chlorophyl_a (UGL)		Standard	%>Standard	%>Standard	%>Standard	%>Standard	%>Standard	%>Standard	Base-Alternative	Base-Alternative	Base-Alternative	Base-Alternative	Base-Alternative
Etowah	Alatoona	12	78.9402	78.6005	79.3478	78.7364	79.2799	79.2799	0.3397	(0.4076)	0.2038	(0.3397)	(0.3397)
Coosawattee	Carters	10	2.5136	2.5136	2.5136	2.5136	2.5136	2.5136	-	-	-	-	-
Coosawattee	Carters Rereg	10	2.4457	2.4457	2.4457	2.4457	2.4457	2.4457	-	-	-	-	-
Coosa	Weiss	20	41.9158	42.3913	42.2554	42.9348	42.7310	42.7989	(0.4755)	(0.3397)	(1.0190)	(0.8152)	(0.8832)
Coosa	HN Henry	18	48.3696	48.0299	48.5054	48.1658	48.3016	48.7772	0.3397	(0.1359)	0.2038	0.0679	(0.4076)
Coosa	Logan Martin	17	51.6304	51.7663	51.4946	50.8832	51.4946	51.4266	(0.1359)	0.1359	0.7473	0.1359	0.2038
Coosa	Lay	17	40.2174	40.5571	40.3533	40.4212	40.4212	40.3533	(0.3397)	(0.1359)	(0.2038)	(0.2038)	(0.1359)
Coosa	Mitchell	17	22.6223	22.5543	22.5543	22.6223	22.6902	22.4864	0.0679	0.0679	-	(0.0679)	0.1359
Coosa	Jordan	14	44.4973	44.4973	44.5652	44.6332	44.7011	44.7011	-	(0.0679)	(0.1359)	(0.2038)	(0.2038)
Coosa	Bouldin	14	37.0924	37.2283	37.1603	37.8397	37.8397	38.0435	(0.1359)	(0.0679)	(0.7473)	(0.7473)	(0.9511)
Tallapoosa	Harris	10	9.3750	9.3750	9.3750	9.3750	9.3750	9.3750	-	-	-	-	-
Tallapoosa	Martin	5	11.0734	11.0734	11.0734	11.0734	11.0734	11.0734	-	-	-	-	-
Tallapoosa	Yates & Thurlow	5	48.7772	48.4375	48.5734	48.5734	48.3016	48.4375	0.3397	0.2038	0.2038	0.4755	0.3397
Alabama	RF Henry	17	43.7500	43.6821	43.7500	43.8859	43.8179	43.8179	0.0679	-	(0.1359)	(0.0679)	(0.0679)
Alabama	Millers Ferry	17	27.7853	27.8533	27.7853	27.9891	27.9212	27.9212	(0.0679)	-	(0.2038)	(0.1359)	(0.1359)
Alabama	Claiborne	15	29.8913	29.9592	29.8913	30.2310	30.2310	30.2310	(0.0679)	-	(0.3397)	(0.3397)	(0.3397)
Etowah	Allatoona Tailwater	10	-	-	-	-	-	-	-	-	-	-	-
Coosawattee	CartersRereg Tailwater	10	3.5326	3.5326	3.5326	3.5326	3.5326	3.5326	-	-	-	-	-
Coosa	Weiss Power Tailwater	14	63.3152	62.9076	63.4511	60.8016	63.1114	61.6848	0.4076	(0.1359)	2.5136	0.2038	1.6304
Coosa	Weiss Spill Tailwater	14	15.2853	14.8098	14.6739	14.7418	15.1495	15.4891	0.4755	0.6114	0.5435	0.1359	(0.2038)
Coosa	HN Henry Tailwater	14	74.0489	74.1168	74.3886	72.4864	71.5353	72.1467	(0.0679)	(0.3397)	1.5625	2.5136	1.9022
Coosa	Logan Martin Tailwater	14	24.7962	24.5924	24.8641	25.0679	24.7962	24.8641	0.2038	(0.0679)	(0.2717)	-	(0.0679)
Coosa	Lay Tailwater	14	24.8641	24.7962	25.0679	25.3397	25.3397	25.1359	0.0679	(0.2038)	(0.4755)	(0.4755)	(0.2717)
Coosa	Mitchell Tailwater	14	43.0707	43.2065	43.1386	43.5462	43.6821	43.8179	(0.1359)	(0.0679)	(0.4755)	(0.6114)	(0.7473)
Coosa	Jordan Tailwater	14	20.9918	21.0598	20.7880	22.1467	22.2826	22.2826	(0.0679)	0.2038	(1.1549)	(1.2908)	(1.2908)
Coosa	Bouldin Tailwater	14	9.3071	9.3071	9.3071	9.3071	9.3071	9.2391	-	-	-	-	0.0679
Tallapoosa	Harris Tailwater	10	-	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Martin Tailwater	10	-	-	-	-	-	-	-	-	-	-	-
Alabama	RF Henry Tailwater	15	21.3995	21.3995	21.4674	21.3995	21.6033	21.4674	-	(0.0679)	-	(0.2038)	(0.0679)
Alabama	Millers Ferry Tailwater	15	39.2663	39.4022	39.3342	39.5380	39.6060	39.3342	(0.1359)	(0.0679)	(0.2717)	(0.3397)	(0.0679)
Etowah	Canton	10	-	-	-	-	-	-	-	-	-	-	-
Etowah	Cartersville	10	-	-	-	-	-	-	-	-	-	-	-
Etowah	Kingston	10	-	-	-	-	-	-	-	-	-	-	-
Etowah	Rome	10	-	-	-	-	-	-	-	-	-	-	-
Coosawattee	Pine Chapel	10	0.0679	0.0679	0.0679	0.0679	0.0679	0.0679	-	-	-	-	-
Oostanaula	Rome	10	-	-	-	-	-	-	-	-	-	-	-
Coosa	Rome	14	-	-	-	-	-	-	-	-	-	-	-
Coosa	State Line	14	3.7364	3.8043	3.7364	3.8043	3.7364	3.6005	(0.0679)	-	(0.0679)	-	0.1359
Coosa	Gadsden	14	16.5761	15.5571	15.5571	14.4022	14.9457	16.5082	1.0190	1.0190	2.1739	1.6304	0.0679
Coosa	Childersburg	14	22.4185	22.4185	22.5543	22.5543	22.6223	22.6223	-	(0.1359)	(0.1359)	(0.2038)	(0.2038)
Coosa	JB	14	26.5625	26.5625	26.4266	26.9701	26.8342	27.0380	-	0.1359	(0.4076)	(0.2717)	(0.4755)
Tallapoosa	Wadley	10	-	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Tallassee	5	33.8315	33.6277	33.6957	33.8315	33.5598	33.5598	0.2038	0.1359	-	0.2717	0.2717
Tallapoosa	JB Goal	5	64.8098	65.3533	64.8777	63.7228	63.5190	63.5190	(0.5435)	(0.0679)	1.0870	1.2908	1.2908
Alabama	JB Goal	15	23.3016	23.7092	23.4375	23.5734	23.5734	23.5734	(0.4076)	(0.1359)	(0.2717)	(0.2717)	(0.2717)
Alabama	Montgomery	15	2.7853	2.9212	2.8533	3.2609	3.2609	3.2609	(0.1359)	(0.0679)	(0.4755)	(0.4755)	(0.4755)
Alabama	Selma	15	36.8886	36.8207	36.8886	36.9565	36.9565	36.9565	0.0679	-	(0.0679)	(0.0679)	(0.0679)
Cahaba	Marion Junction	5	-	-	-	-	-	-	-	-	-	-	-
Alabama	ARP	15	13.2473	13.4511	13.3152	13.4511	13.5190	13.5190	(0.2038)	(0.0679)	(0.2038)	(0.2717)	(0.2717)
								Max decrease	0.5435	0.4076	1.1549	1.2908	1.2908
								Max increase	1.0190	1.0190	2.5136	2.5136	1.9022
								Avg change	0.0170	(0.0000)	0.0495	(0.0085)	(0.0340)

Table 4.8. Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

All Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.665	6.662	-0.003	(0.051)	7.474	7.470	-0.004	(0.050)	20.420	20.416	-0.004	(0.019)
	GA: Apr-Oct	10.665	10.661	-0.005	(0.043)	11.985	11.980	-0.005	(0.042)	22.608	22.610	0.003	0.012
	AL: Apr-Nov	9.596	9.591	-0.005	(0.049)	10.780	10.775	-0.005	(0.049)	22.061	22.058	-0.003	(0.011)
Above Weiss Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.865	4.850	-0.015	(0.316)	5.342	5.324	-0.018	(0.331)	12.890	12.879	-0.011	(0.083)
	GA: Apr-Oct	7.846	7.822	-0.024	(0.306)	8.621	8.593	-0.028	(0.321)	14.552	14.532	-0.019	(0.133)
	AL: Apr-Nov	7.024	7.002	-0.023	(0.323)	7.719	7.694	-0.026	(0.337)	14.135	14.115	-0.020	(0.144)
Six Coosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	8.275	8.274	-0.001	(0.007)	9.300	9.300	0.000	(0.002)	26.011	26.003	-0.008	(0.032)
	GA: Apr-Oct	13.374	13.375	0.001	0.004	15.064	15.065	0.001	0.007	28.172	28.184	0.013	0.045
	AL: Apr-Nov	12.009	12.009	0.000	-	13.520	13.520	0.000	0.002	27.652	27.652	0.001	0.002
Tallapoosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.833	3.833	-0.001	(0.017)	4.157	4.156	-0.001	(0.024)	11.426	11.425	-0.001	(0.009)
	GA: Apr-Oct	5.683	5.682	-0.002	(0.029)	6.161	6.159	-0.002	(0.027)	13.843	13.838	-0.004	(0.029)
	AL: Apr-Nov	5.254	5.253	-0.001	(0.025)	5.701	5.700	-0.001	(0.023)	13.211	13.210	-0.001	(0.005)
Alabama River Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	7.540	7.539	-0.001	(0.009)	8.661	8.661	-0.001	(0.012)	23.896	23.906	0.010	0.043
	GA: Apr-Oct	12.145	12.146	0.000	-	13.992	13.992	0.000	-	26.446	26.454	0.008	0.030
	AL: Apr-Nov	10.878	10.878	-0.001	(0.009)	12.525	12.524	-0.001	(0.011)	25.790	25.796	0.006	0.025
All Reservoir tailwaters													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.112	5.106	-0.006	(0.115)	5.577	5.570	-0.007	(0.132)	15.091	15.062	-0.029	(0.191)
	GA: Apr-Oct	8.054	8.046	-0.009	(0.110)	8.812	8.801	-0.012	(0.131)	16.459	16.420	-0.039	(0.234)
	AL: Apr-Nov	7.302	7.293	-0.008	(0.115)	7.983	7.973	-0.011	(0.135)	16.130	16.086	-0.044	(0.273)
Allatoona and Carters tailwater													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.657	1.654	-0.003	(0.151)	1.814	1.813	-0.002	(0.110)	5.720	5.739	0.019	0.323
	GA: Apr-Oct	2.318	2.316	-0.003	(0.129)	2.557	2.556	-0.002	(0.059)	6.645	6.694	0.050	0.742
	AL: Apr-Nov	2.195	2.192	-0.003	(0.137)	2.416	2.414	-0.002	(0.083)	6.420	6.449	0.029	0.443
Coosa Reservoir tailwaters (including Weiss spill to the old Coosa channel													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.395	6.386	-0.009	(0.141)	6.971	6.959	-0.012	(0.169)	19.086	19.032	-0.054	(0.282)
	GA: Apr-Oct	10.205	10.190	-0.014	(0.141)	11.151	11.132	-0.019	(0.171)	20.655	20.574	-0.080	(0.389)
	AL: Apr-Nov	9.215	9.202	-0.013	(0.144)	10.063	10.046	-0.017	(0.172)	20.295	20.211	-0.084	(0.416)
Tallapoosa reservoir tailwaters (including Tallassee)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.419	1.419	-0.001	(0.070)	1.520	1.519	-0.001	(0.066)	3.105	3.105	-0.001	(0.016)
	GA: Apr-Oct	1.838	1.837	-0.001	(0.054)	1.980	1.978	-0.002	(0.101)	3.423	3.424	0.002	0.044
	AL: Apr-Nov	1.805	1.804	-0.001	(0.055)	1.943	1.941	-0.002	(0.103)	3.352	3.351	-0.001	(0.030)
Alabama reservoir tailwaters (includes APR)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.595	6.594	-0.001	(0.020)	7.181	7.179	-0.001	(0.019)	18.939	18.936	-0.003	(0.016)
	GA: Apr-Oct	10.501	10.500	-0.001	(0.006)	11.459	11.458	-0.001	(0.009)	20.823	20.820	-0.003	(0.016)
	AL: Apr-Nov	9.461	9.459	-0.002	(0.018)	10.321	10.319	-0.002	(0.023)	20.322	20.326	0.005	0.023
Average of all river locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.273	3.273	0.000	(0.000)	3.516	3.516	0.000	0.004	9.829	9.822	-0.007	(0.071)
	GA: Apr-Oct	5.099	5.098	-0.001	(0.025)	5.491	5.490	-0.001	(0.024)	10.799	10.822	0.023	0.216
	AL: Apr-Nov	4.608	4.608	0.000	(0.001)	4.961	4.962	0.000	0.005	10.575	10.595	0.020	0.189

Table 4.8 (continued). Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

Average of all above Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.255	1.257	0.003	0.199	1.381	1.383	0.003	0.205	3.451	3.478	0.027	0.789
	GA: Apr-Oct	1.784	1.787	0.003	0.149	1.980	1.983	0.003	0.135	4.039	4.098	0.059	1.446
	AL: Apr-Nov	1.661	1.665	0.004	0.231	1.842	1.846	0.004	0.235	3.901	3.957	0.056	1.425
Average of all Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.283	4.285	0.001	0.033	4.622	4.624	0.002	0.043	12.646	12.609	-0.038	(0.298)
	GA: Apr-Oct	6.800	6.800	0.000	(0.006)	7.358	7.358	0.000	-	13.948	13.975	0.027	0.196
	AL: Apr-Nov	6.130	6.132	0.002	0.033	6.629	6.631	0.003	0.039	13.646	13.667	0.020	0.148
Average of all Tallapoosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.482	3.476	-0.006	(0.182)	3.731	3.724	-0.007	(0.188)	11.409	11.387	-0.023	(0.199)
	GA: Apr-Oct	5.278	5.266	-0.011	(0.215)	5.663	5.650	-0.013	(0.224)	12.183	12.161	-0.023	(0.186)
	AL: Apr-Nov	4.795	4.785	-0.010	(0.202)	5.149	5.139	-0.010	(0.194)	11.997	11.977	-0.020	(0.164)
Average of all Alabama River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.554	5.554	-0.001	(0.014)	5.890	5.889	-0.001	(0.013)	16.637	16.627	-0.010	(0.060)
	GA: Apr-Oct	8.877	8.876	-0.001	(0.011)	9.428	9.428	-0.001	(0.008)	18.045	18.050	0.005	0.029
	AL: Apr-Nov	7.951	7.949	-0.001	(0.016)	8.443	8.442	-0.001	(0.012)	17.732	17.733	0.001	0.003
All Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.665	6.668	0.004	0.055	7.474	7.478	0.004	0.056	20.420	20.420	0.001	0.004
	GA: Apr-Oct	10.665	10.671	0.006	0.056	11.985	11.992	0.007	0.056	22.608	22.599	-0.009	(0.041)
	AL: Apr-Nov	9.596	9.601	0.005	0.057	10.780	10.786	0.006	0.057	22.061	22.037	-0.024	(0.108)
Above Weiss Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.865	4.875	0.010	0.198	5.342	5.353	0.011	0.199	12.890	12.866	-0.024	(0.186)
	GA: Apr-Oct	7.846	7.860	0.014	0.174	8.621	8.636	0.016	0.182	14.552	14.437	-0.115	(0.793)
	AL: Apr-Nov	7.024	7.038	0.014	0.199	7.719	7.735	0.016	0.203	14.135	14.005	-0.130	(0.926)
Six Coosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	8.275	8.278	0.004	0.048	9.300	9.305	0.005	0.051	26.011	26.023	0.012	0.047
	GA: Apr-Oct	13.374	13.382	0.008	0.059	15.064	15.073	0.009	0.059	28.172	28.186	0.014	0.050
	AL: Apr-Nov	12.009	12.015	0.006	0.052	13.520	13.527	0.007	0.054	27.652	27.650	-0.002	(0.007)
Tallapoosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.833	3.833	0.000	-	4.157	4.157	0.000	-	11.426	11.422	-0.004	(0.032)
	GA: Apr-Oct	5.683	5.682	-0.001	(0.012)	6.161	6.160	-0.001	(0.016)	13.843	13.856	0.013	0.094
	AL: Apr-Nov	5.254	5.253	-0.001	(0.013)	5.701	5.700	-0.001	(0.012)	13.211	13.211	0.000	-
Alabama River Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	7.540	7.541	0.001	0.009	8.661	8.662	0.001	0.008	23.896	23.899	0.003	0.014
	GA: Apr-Oct	12.145	12.146	0.001	0.005	13.992	13.993	0.001	0.005	26.446	26.465	0.019	0.073
	AL: Apr-Nov	10.878	10.879	0.001	0.009	12.525	12.526	0.001	0.008	25.790	25.797	0.008	0.030
All Reservoir tailwaters													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.112	5.109	-0.003	(0.066)	5.577	5.572	-0.005	(0.086)	15.091	15.046	-0.044	(0.293)
	GA: Apr-Oct	8.054	8.049	-0.005	(0.067)	8.812	8.804	-0.008	(0.088)	16.459	16.386	-0.073	(0.444)
	AL: Apr-Nov	7.302	7.297	-0.005	(0.067)	7.983	7.976	-0.007	(0.090)	16.130	16.066	-0.064	(0.398)
Allatoona and Carters tailwater													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.657	1.653	-0.004	(0.212)	1.814	1.810	-0.005	(0.248)	5.720	5.651	-0.070	(1.231)
	GA: Apr-Oct	2.318	2.311	-0.007	(0.302)	2.557	2.549	-0.009	(0.333)	6.645	6.617	-0.028	(0.422)
	AL: Apr-Nov	2.195	2.190	-0.006	(0.274)	2.416	2.409	-0.007	(0.290)	6.420	6.378	-0.043	(0.664)

Table 4.8 (continued). Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

Coosa Reservoir tailwaters (including Weiss spill to the old Coosa channel													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.395	6.390	-0.005	(0.082)	6.971	6.964	-0.008	(0.108)	19.086	19.029	-0.057	(0.300)
	GA: Apr-Oct	10.205	10.197	-0.008	(0.076)	11.151	11.139	-0.012	(0.104)	20.655	20.534	-0.121	(0.585)
	AL: Apr-Nov	9.215	9.208	-0.007	(0.079)	10.063	10.052	-0.011	(0.108)	20.295	20.193	-0.102	(0.504)
Tallapoosa reservoir tailwaters (including Tallassee)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.419	1.420	0.001	0.035	1.520	1.520	0.000	-	3.105	3.099	-0.006	(0.193)
	GA: Apr-Oct	1.838	1.837	-0.001	(0.027)	1.980	1.979	-0.001	(0.025)	3.423	3.422	-0.001	(0.015)
	AL: Apr-Nov	1.805	1.806	0.000	-	1.943	1.943	-0.001	(0.026)	3.352	3.349	-0.003	(0.075)
Alabama reservoir tailwaters (includes APR)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.595	6.595	0.000	0.005	7.181	7.181	0.001	0.009	18.939	18.936	-0.003	(0.016)
	GA: Apr-Oct	10.501	10.502	0.000	-	11.459	11.459	0.000	0.003	20.823	20.823	0.000	0.002
	AL: Apr-Nov	9.461	9.462	0.001	0.007	10.321	10.322	0.001	0.006	20.322	20.326	0.004	0.021
Average of all river locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.273	3.272	-0.001	(0.024)	3.516	3.515	-0.001	(0.028)	9.829	9.810	-0.018	(0.188)
	GA: Apr-Oct	5.099	5.097	-0.002	(0.034)	5.491	5.489	-0.002	(0.037)	10.799	10.774	-0.024	(0.223)
	AL: Apr-Nov	4.608	4.607	-0.001	(0.029)	4.961	4.960	-0.002	(0.035)	10.575	10.547	-0.028	(0.265)
Average of all above Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.255	1.255	0.000	0.013	1.381	1.380	0.000	(0.024)	3.451	3.425	-0.026	(0.766)
	GA: Apr-Oct	1.784	1.783	-0.001	(0.047)	1.980	1.979	-0.002	(0.076)	4.039	4.004	-0.035	(0.862)
	AL: Apr-Nov	1.661	1.661	-0.001	(0.030)	1.842	1.840	-0.001	(0.063)	3.901	3.861	-0.040	(1.027)
Average of all Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.283	4.281	-0.002	(0.056)	4.622	4.619	-0.002	(0.048)	12.646	12.627	-0.019	(0.149)
	GA: Apr-Oct	6.800	6.796	-0.004	(0.056)	7.358	7.354	-0.004	(0.054)	13.948	13.932	-0.016	(0.112)
	AL: Apr-Nov	6.130	6.126	-0.003	(0.055)	6.629	6.625	-0.004	(0.054)	13.646	13.608	-0.038	(0.280)
Average of all Tallapoosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.482	3.482	-0.001	(0.029)	3.731	3.729	-0.002	(0.045)	11.409	11.390	-0.019	(0.167)
	GA: Apr-Oct	5.278	5.276	-0.002	(0.044)	5.663	5.660	-0.003	(0.047)	12.183	12.137	-0.046	(0.381)
	AL: Apr-Nov	4.795	4.794	-0.001	(0.028)	5.149	5.147	-0.002	(0.045)	11.997	11.976	-0.021	(0.172)
Average of all Alabama River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.554	5.554	0.000	(0.005)	5.890	5.889	0.000	(0.004)	16.637	16.626	-0.011	(0.063)
	GA: Apr-Oct	8.877	8.877	-0.001	(0.006)	9.428	9.428	-0.001	(0.005)	18.045	18.036	-0.008	(0.046)
	AL: Apr-Nov	7.951	7.950	0.000	(0.003)	8.443	8.443	0.000	(0.003)	17.732	17.722	-0.010	(0.056)
All Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.665	6.674	0.009	0.127	7.474	7.484	0.010	0.130	20.420	20.442	0.022	0.109
	GA: Apr-Oct	10.665	10.682	0.016	0.154	11.985	12.004	0.019	0.155	22.608	22.642	0.034	0.151
	AL: Apr-Nov	9.596	9.610	0.014	0.143	10.780	10.795	0.016	0.145	22.061	22.096	0.035	0.160
Above Weiss Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.865	4.856	-0.009	(0.192)	5.342	5.332	-0.011	(0.200)	12.890	12.889	-0.001	(0.010)
	GA: Apr-Oct	7.846	7.832	-0.014	(0.183)	8.621	8.604	-0.017	(0.194)	14.552	14.550	-0.002	(0.014)
	AL: Apr-Nov	7.024	7.011	-0.014	(0.195)	7.719	7.704	-0.016	(0.203)	14.135	14.135	0.000	-
six Coosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	8.275	8.289	0.014	0.169	9.300	9.316	0.016	0.173	26.011	26.024	0.013	0.051
	GA: Apr-Oct	13.374	13.404	0.030	0.225	15.064	15.098	0.034	0.228	28.172	28.199	0.027	0.095
	AL: Apr-Nov	12.009	12.033	0.023	0.195	13.520	13.547	0.027	0.198	27.652	27.692	0.041	0.147

Table 4.8 (continued). Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

Tallapoosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.833	3.832	-0.001	(0.035)	4.157	4.156	-0.002	(0.040)	11.426	11.423	-0.004	(0.032)
	GA: Apr-Oct	5.683	5.678	-0.005	(0.082)	6.161	6.155	-0.005	(0.087)	13.843	13.847	0.004	0.031
	AL: Apr-Nov	5.254	5.251	-0.003	(0.057)	5.701	5.698	-0.003	(0.053)	13.211	13.203	-0.008	(0.058)
Alabama River Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	7.540	7.563	0.023	0.309	8.661	8.688	0.026	0.304	23.896	23.989	0.093	0.387
	GA: Apr-Oct	12.145	12.182	0.036	0.299	13.992	14.033	0.041	0.293	26.446	26.563	0.118	0.444
	AL: Apr-Nov	10.878	10.914	0.035	0.324	12.525	12.565	0.039	0.314	25.790	25.891	0.101	0.392
All Reservoir tailwaters													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.112	5.102	-0.010	(0.199)	5.577	5.564	-0.013	(0.235)	15.091	15.021	-0.070	(0.466)
	GA: Apr-Oct	8.054	8.040	-0.014	(0.179)	8.812	8.792	-0.020	(0.223)	16.459	16.367	-0.091	(0.556)
	AL: Apr-Nov	7.302	7.288	-0.014	(0.195)	7.983	7.964	-0.019	(0.236)	16.130	16.044	-0.086	(0.531)
Allatoona and Carters tailwater													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.657	1.659	0.002	0.090	1.814	1.817	0.002	0.110	5.720	5.748	0.028	0.480
	GA: Apr-Oct	2.318	2.322	0.004	0.172	2.557	2.562	0.005	0.176	6.645	6.691	0.046	0.690
	AL: Apr-Nov	2.195	2.198	0.003	0.137	2.416	2.420	0.004	0.145	6.420	6.456	0.036	0.551
Coosa Reservoir tailwaters (including Weiss spill to the old Coosa channel													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.395	6.370	-0.025	(0.396)	6.971	6.941	-0.031	(0.440)	19.086	18.937	-0.149	(0.784)
	GA: Apr-Oct	10.205	10.168	-0.036	(0.355)	11.151	11.105	-0.046	(0.412)	20.655	20.467	-0.187	(0.911)
	AL: Apr-Nov	9.215	9.179	-0.036	(0.394)	10.063	10.019	-0.045	(0.444)	20.295	20.117	-0.178	(0.881)
Tallapoosa reservoir tailwaters (including Tallassee)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.419	1.425	0.006	0.387	1.520	1.525	0.005	0.296	3.105	3.101	-0.005	(0.145)
	GA: Apr-Oct	1.838	1.844	0.006	0.326	1.980	1.985	0.006	0.277	3.423	3.431	0.008	0.233
	AL: Apr-Nov	1.805	1.813	0.008	0.442	1.943	1.950	0.007	0.334	3.352	3.354	0.003	0.075
Alabama reservoir tailwaters (includes APR)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.595	6.615	0.020	0.298	7.181	7.202	0.021	0.292	18.939	19.005	0.066	0.350
	GA: Apr-Oct	10.501	10.530	0.029	0.273	11.459	11.490	0.031	0.270	20.823	20.868	0.044	0.213
	AL: Apr-Nov	9.461	9.490	0.030	0.313	10.321	10.353	0.031	0.303	20.322	20.392	0.071	0.347
Average of all river locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.273	3.270	-0.004	(0.108)	3.516	3.512	-0.004	(0.108)	9.829	9.849	0.020	0.206
	GA: Apr-Oct	5.099	5.094	-0.005	(0.095)	5.491	5.486	-0.005	(0.097)	10.799	10.830	0.032	0.296
	AL: Apr-Nov	4.608	4.604	-0.004	(0.089)	4.961	4.957	-0.004	(0.090)	10.575	10.608	0.033	0.311
Average of all above Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.255	1.259	0.004	0.292	1.381	1.385	0.005	0.325	3.451	3.486	0.035	1.004
	GA: Apr-Oct	1.784	1.789	0.005	0.299	1.980	1.987	0.006	0.311	4.039	4.101	0.062	1.524
	AL: Apr-Nov	1.661	1.667	0.005	0.321	1.842	1.848	0.007	0.352	3.901	3.954	0.054	1.366
Average of all Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.283	4.260	-0.023	(0.543)	4.622	4.599	-0.023	(0.508)	12.646	12.641	-0.005	(0.040)
	GA: Apr-Oct	6.800	6.768	-0.032	(0.475)	7.358	7.325	-0.032	(0.441)	13.948	13.923	-0.024	(0.172)
	AL: Apr-Nov	6.130	6.099	-0.031	(0.507)	6.629	6.597	-0.031	(0.466)	13.646	13.652	0.005	0.040
Average of all Tallapoosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.482	3.472	-0.010	(0.297)	3.731	3.718	-0.012	(0.331)	11.409	11.369	-0.040	(0.354)
	GA: Apr-Oct	5.278	5.257	-0.021	(0.392)	5.663	5.639	-0.024	(0.425)	12.183	12.154	-0.029	(0.236)
	AL: Apr-Nov	4.795	4.779	-0.015	(0.320)	5.149	5.130	-0.019	(0.370)	11.997	11.972	-0.025	(0.209)

Table 4.8 (continued). Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

Average of all Alabama River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.554	5.569	0.015	0.261	5.890	5.903	0.014	0.233	16.637	16.717	0.081	0.483
	GA: Apr-Oct	8.877	8.903	0.025	0.278	9.428	9.452	0.024	0.254	18.045	18.156	0.111	0.612
	AL: Apr-Nov	7.951	7.973	0.023	0.286	8.443	8.465	0.022	0.257	17.732	17.820	0.088	0.495
All Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.665	6.677	0.012	0.186	7.474	7.488	0.014	0.185	20.420	20.456	0.036	0.177
	GA: Apr-Oct	10.665	10.687	0.022	0.208	11.985	12.010	0.025	0.205	22.608	22.655	0.048	0.211
	AL: Apr-Nov	9.596	9.615	0.019	0.202	10.780	10.801	0.021	0.198	22.061	22.121	0.060	0.271
Above Weiss Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.865	4.879	0.014	0.287	5.342	5.358	0.016	0.293	12.890	12.897	0.007	0.054
	GA: Apr-Oct	7.846	7.867	0.021	0.263	8.621	8.644	0.024	0.274	14.552	14.543	-0.009	(0.062)
	AL: Apr-Nov	7.024	7.045	0.020	0.289	7.719	7.742	0.023	0.298	14.135	14.157	0.022	0.156
six Coosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	8.275	8.286	0.012	0.140	9.300	9.313	0.013	0.135	26.011	26.044	0.032	0.124
	GA: Apr-Oct	13.374	13.400	0.026	0.197	15.064	15.092	0.029	0.190	28.172	28.231	0.059	0.210
	AL: Apr-Nov	12.009	12.029	0.020	0.165	13.520	13.541	0.021	0.156	27.652	27.732	0.080	0.288
Tallapoosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.833	3.832	-0.001	(0.035)	4.157	4.156	-0.002	(0.040)	11.426	11.425	-0.001	(0.009)
	GA: Apr-Oct	5.683	5.678	-0.005	(0.082)	6.161	6.155	-0.006	(0.092)	13.843	13.861	0.019	0.137
	AL: Apr-Nov	5.254	5.251	-0.003	(0.063)	5.701	5.698	-0.004	(0.064)	13.211	13.200	-0.012	(0.091)
Alabama River Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	7.540	7.567	0.027	0.353	8.661	8.692	0.030	0.350	23.896	24.007	0.112	0.468
	GA: Apr-Oct	12.145	12.186	0.041	0.337	13.992	14.038	0.046	0.331	26.446	26.552	0.107	0.403
	AL: Apr-Nov	10.878	10.919	0.040	0.367	12.525	12.571	0.045	0.361	25.790	25.912	0.123	0.475
All Reservoir tailwaters													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.112	5.110	-0.002	(0.036)	5.577	5.575	-0.001	(0.023)	15.091	15.051	-0.040	(0.266)
	GA: Apr-Oct	8.054	8.052	-0.002	(0.027)	8.812	8.810	-0.002	(0.027)	16.459	16.390	-0.069	(0.420)
	AL: Apr-Nov	7.302	7.299	-0.003	(0.034)	7.983	7.981	-0.002	(0.029)	16.130	16.057	-0.073	(0.451)
Allatoona and Carters tailwater													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.657	1.657	0.001	0.030	1.814	1.815	0.001	0.028	5.720	5.713	-0.008	(0.131)
	GA: Apr-Oct	2.318	2.316	-0.002	(0.086)	2.557	2.555	-0.002	(0.078)	6.645	6.655	0.010	0.150
	AL: Apr-Nov	2.195	2.196	0.001	0.023	2.416	2.417	0.001	0.021	6.420	6.414	-0.007	(0.101)
Coosa Reservoir tailwaters (including Weiss spill to the old Coosa channel													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.395	6.383	-0.012	(0.190)	6.971	6.960	-0.011	(0.160)	19.086	18.998	-0.088	(0.461)
	GA: Apr-Oct	10.205	10.189	-0.015	(0.150)	11.151	11.135	-0.016	(0.141)	20.655	20.515	-0.140	(0.681)
	AL: Apr-Nov	9.215	9.198	-0.017	(0.187)	10.063	10.046	-0.017	(0.168)	20.295	20.148	-0.147	(0.726)
Tallapoosa reservoir tailwaters (including Tallassee)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.419	1.428	0.008	0.562	1.520	1.526	0.006	0.394	3.105	3.099	-0.006	(0.177)
	GA: Apr-Oct	1.838	1.847	0.009	0.489	1.980	1.987	0.007	0.353	3.423	3.430	0.008	0.219
	AL: Apr-Nov	1.805	1.816	0.011	0.608	1.943	1.952	0.009	0.436	3.352	3.358	0.006	0.164
Alabama reservoir tailwaters (includes APR)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.595	6.617	0.022	0.338	7.181	7.205	0.024	0.338	18.939	19.010	0.071	0.376
	GA: Apr-Oct	10.501	10.534	0.032	0.304	11.459	11.494	0.034	0.299	20.823	20.877	0.053	0.256
	AL: Apr-Nov	9.461	9.494	0.033	0.352	10.321	10.357	0.036	0.345	20.322	20.395	0.073	0.359

Table 4.8 (continued). Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

Average of all river locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.273	3.271	-0.003	(0.079)	3.516	3.513	-0.003	(0.076)	9.829	9.846	0.018	0.181
	GA: Apr-Oct	5.099	5.096	-0.003	(0.059)	5.491	5.488	-0.003	(0.059)	10.799	10.815	0.016	0.150
	AL: Apr-Nov	4.608	4.605	-0.003	(0.057)	4.961	4.958	-0.003	(0.058)	10.575	10.590	0.015	0.141
Average of all above Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.255	1.255	0.000	-	1.381	1.380	0.000	(0.012)	3.451	3.445	-0.006	(0.169)
	GA: Apr-Oct	1.784	1.783	-0.001	(0.075)	1.980	1.979	-0.002	(0.076)	4.039	4.040	0.001	0.017
	AL: Apr-Nov	1.661	1.661	0.000	-	1.842	1.841	0.000	(0.018)	3.901	3.899	-0.002	(0.038)
Average of all Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.283	4.267	-0.016	(0.374)	4.622	4.607	-0.015	(0.325)	12.646	12.686	0.039	0.309
	GA: Apr-Oct	6.800	6.782	-0.019	(0.277)	7.358	7.341	-0.017	(0.229)	13.948	13.951	0.003	0.023
	AL: Apr-Nov	6.130	6.110	-0.020	(0.330)	6.629	6.610	-0.018	(0.278)	13.646	13.666	0.020	0.146
Average of all Tallapoosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.482	3.473	-0.010	(0.297)	3.731	3.718	-0.013	(0.340)	11.409	11.355	-0.054	(0.474)
	GA: Apr-Oct	5.278	5.257	-0.021	(0.399)	5.663	5.638	-0.025	(0.437)	12.183	12.119	-0.065	(0.532)
	AL: Apr-Nov	4.795	4.779	-0.016	(0.327)	5.149	5.130	-0.020	(0.383)	11.997	11.942	-0.055	(0.457)
Average of all Alabama River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.554	5.570	0.016	0.279	5.890	5.905	0.016	0.267	16.637	16.721	0.085	0.508
	GA: Apr-Oct	8.877	8.905	0.027	0.304	9.428	9.455	0.026	0.278	18.045	18.166	0.121	0.667
	AL: Apr-Nov	7.951	7.975	0.025	0.308	8.443	8.468	0.025	0.290	17.732	17.821	0.089	0.502
All Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.665	6.678	0.013	0.191	7.474	7.488	0.014	0.192	20.420	20.456	0.037	0.179
	GA: Apr-Oct	10.665	10.688	0.023	0.212	11.985	12.011	0.026	0.213	22.608	22.635	0.028	0.122
	AL: Apr-Nov	9.596	9.616	0.020	0.204	10.780	10.802	0.022	0.206	22.061	22.119	0.058	0.262
Above Weiss Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.865	4.860	-0.005	(0.103)	5.342	5.336	-0.006	(0.112)	12.890	12.860	-0.030	(0.233)
	GA: Apr-Oct	7.846	7.837	-0.009	(0.119)	8.621	8.610	-0.011	(0.128)	14.552	14.526	-0.026	(0.177)
	AL: Apr-Nov	7.024	7.017	-0.007	(0.104)	7.719	7.711	-0.009	(0.112)	14.135	14.122	-0.013	(0.094)
six Coosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	8.275	8.297	0.022	0.267	9.300	9.325	0.025	0.270	26.011	26.070	0.059	0.225
	GA: Apr-Oct	13.374	13.417	0.043	0.323	15.064	15.113	0.049	0.326	28.172	28.206	0.034	0.122
	AL: Apr-Nov	12.009	12.044	0.035	0.292	13.520	13.560	0.040	0.293	27.652	27.755	0.104	0.374
Tallapoosa Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.833	3.831	-0.002	(0.052)	4.157	4.155	-0.002	(0.056)	11.426	11.426	0.000	-
	GA: Apr-Oct	5.683	5.677	-0.006	(0.100)	6.161	6.154	-0.006	(0.103)	13.843	13.836	-0.007	(0.053)
	AL: Apr-Nov	5.254	5.250	-0.004	(0.083)	5.701	5.696	-0.004	(0.076)	13.211	13.200	-0.012	(0.091)
Alabama River Reservoirs													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	7.540	7.563	0.023	0.309	8.661	8.688	0.026	0.304	23.896	23.984	0.088	0.368
	GA: Apr-Oct	12.145	12.180	0.035	0.285	13.992	14.031	0.039	0.278	26.446	26.546	0.100	0.379
	AL: Apr-Nov	10.878	10.913	0.034	0.315	12.525	12.565	0.039	0.311	25.790	25.882	0.092	0.357
All Reservoir tailwaters													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.112	5.118	0.006	0.124	5.577	5.583	0.007	0.118	15.091	15.068	-0.022	(0.148)
	GA: Apr-Oct	8.054	8.067	0.012	0.152	8.812	8.824	0.012	0.141	16.459	16.438	-0.021	(0.126)
	AL: Apr-Nov	7.302	7.312	0.010	0.136	7.983	7.993	0.010	0.125	16.130	16.115	-0.014	(0.089)

Table 4.8 (continued). Yearly and growing season summary of chlorophyll *a* by reservoir category and comparison of the average, maximum and 95% level for the No Action Alternative and Future Without Project alternative.

Allatoona and Carters tailwater													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.657	1.649	-0.008	(0.454)	1.814	1.806	-0.008	(0.442)	5.720	5.701	-0.020	(0.341)
	GA: Apr-Oct	2.318	2.305	-0.013	(0.562)	2.557	2.543	-0.014	(0.549)	6.645	6.634	-0.011	(0.166)
	AL: Apr-Nov	2.195	2.185	-0.011	(0.480)	2.416	2.405	-0.012	(0.477)	6.420	6.410	-0.010	(0.156)
Coosa Reservoir tailwaters (including Weiss spill to the old Coosa channel													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.395	6.401	0.006	0.090	6.971	6.977	0.006	0.090	19.086	19.035	-0.051	(0.266)
	GA: Apr-Oct	10.205	10.220	0.015	0.148	11.151	11.166	0.016	0.139	20.655	20.608	-0.047	(0.226)
	AL: Apr-Nov	9.215	9.225	0.009	0.102	10.063	10.073	0.010	0.097	20.295	20.253	-0.042	(0.207)
Tallapoosa reservoir tailwaters (including Tallassee)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.419	1.426	0.006	0.422	1.520	1.525	0.005	0.296	3.105	3.100	-0.006	(0.177)
	GA: Apr-Oct	1.838	1.844	0.007	0.353	1.980	1.984	0.005	0.252	3.423	3.428	0.006	0.175
	AL: Apr-Nov	1.805	1.814	0.009	0.470	1.943	1.949	0.006	0.308	3.352	3.351	-0.001	(0.015)
Alabama reservoir tailwaters (includes APR)													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	6.595	6.615	0.020	0.303	7.181	7.202	0.021	0.297	18.939	18.998	0.060	0.315
	GA: Apr-Oct	10.501	10.529	0.028	0.266	11.459	11.489	0.030	0.259	20.823	20.860	0.037	0.176
	AL: Apr-Nov	9.461	9.491	0.030	0.313	10.321	10.353	0.032	0.306	20.322	20.392	0.070	0.346
Average of all river locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.273	3.267	-0.006	(0.180)	3.516	3.509	-0.007	(0.195)	9.829	9.840	0.012	0.119
	GA: Apr-Oct	5.099	5.091	-0.008	(0.164)	5.491	5.481	-0.010	(0.177)	10.799	10.805	0.006	0.057
	AL: Apr-Nov	4.608	4.600	-0.008	(0.166)	4.961	4.952	-0.009	(0.179)	10.575	10.583	0.008	0.076
Average of all above Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	1.255	1.249	-0.006	(0.466)	1.381	1.374	-0.007	(0.496)	3.451	3.437	-0.014	(0.416)
	GA: Apr-Oct	1.784	1.774	-0.010	(0.553)	1.980	1.969	-0.012	(0.582)	4.039	4.037	-0.002	(0.045)
	AL: Apr-Nov	1.661	1.653	-0.008	(0.503)	1.842	1.832	-0.010	(0.545)	3.901	3.893	-0.007	(0.188)
Average of all Coosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	4.283	4.264	-0.019	(0.454)	4.622	4.602	-0.020	(0.425)	12.646	12.680	0.034	0.267
	GA: Apr-Oct	6.800	6.776	-0.025	(0.365)	7.358	7.333	-0.025	(0.338)	13.948	13.918	-0.030	(0.214)
	AL: Apr-Nov	6.130	6.104	-0.025	(0.415)	6.629	6.603	-0.025	(0.384)	13.646	13.653	0.006	0.045
Average of all Tallapoosa River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	3.482	3.471	-0.011	(0.326)	3.731	3.717	-0.014	(0.385)	11.409	11.370	-0.039	(0.345)
	GA: Apr-Oct	5.278	5.255	-0.023	(0.443)	5.663	5.636	-0.027	(0.472)	12.183	12.153	-0.030	(0.249)
	AL: Apr-Nov	4.795	4.777	-0.018	(0.369)	5.149	5.128	-0.021	(0.415)	11.997	11.962	-0.035	(0.292)
Average of all Alabama River locations													
		average-Base2018	average-A02_FWOP	difference (avg)	% difference	maximum-Base2018	maximum-A02_FWOP	difference (max)	% difference	95%-Base2018	95%-A02_FWOP	difference (95%)	% difference
	year	5.554	5.568	0.014	0.243	5.890	5.902	0.013	0.220	16.637	16.701	0.065	0.387
	GA: Apr-Oct	8.877	8.901	0.024	0.264	9.428	9.451	0.022	0.233	18.045	18.137	0.092	0.507
	AL: Apr-Nov	7.951	7.972	0.021	0.267	8.443	8.464	0.021	0.243	17.732	17.800	0.068	0.381

Table 4.9. Alternatives compared with the No Action Alternative for changes in DO standards compliance (4 mg/L daily minimum and 5 mg/L daily average).

		Percent of Time Dissolved Oxygen is Below the Standard											
		Base2018		A02_FWOP		A03_WS1		A09_FWOPMF		A10_WS2M		A11_WS6MF	
River	Reservoirs	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard
Etowah	Allatoona	5.978	0.815	5.978	0.883	5.842	1.019	6.046	0.815	5.910	0.883	5.842	0.951
Coosawattee	Carters	1.087	-	1.087	-	1.087	-	1.087	-	1.087	-	1.087	-
Coosawattee	Carters Rereg	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Weiss	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	HN Henry	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Logan Martin	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Lay	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Mitchell	1.427	-	1.495	-	1.495	-	1.359	-	1.495	-	1.495	-
Coosa	Jordan	1.698	-	1.698	-	1.630	-	1.698	-	1.698	-	1.766	-
Coosa	Bouldin	1.563	-	1.766	-	1.630	-	1.766	-	1.970	-	1.698	-
Tallapoosa	Harris	0.068	-	0.068	-	0.068	-	0.068	-	0.068	-	0.068	-
Tallapoosa	Martin	-	-	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Yates&Thurlow	4.823	0.068	4.891	0.068	4.823	0.068	5.163	0.136	5.163	0.136	5.435	0.136
Alabama	RF Henry	-	-	-	-	-	-	-	-	-	-	-	-
Alabama	Millers Ferry	-	-	-	-	-	-	-	-	-	-	-	-
Alabama	Claiborne	0.204	-	0.204	-	0.204	-	0.204	-	0.272	-	0.272	-
	Below Dams	79.552	70.516	79.280	70.448	79.891	70.380	79.416	70.313	79.552	70.313	79.484	70.380
Etowah	Allatoona-TW	-	-	-	-	-	-	-	-	-	-	-	-
Coosawattee	CartersRereg-TW	14.266	-	14.266	-	15.217	-	15.829	-	14.470	-	15.693	-
Coosa	Weiss Power-TW	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Weiss Spill-TW	3.261	-	3.261	-	3.329	-	3.193	-	3.193	-	3.193	-
Coosa	HN Henry-TW	28.804	-	28.804	-	29.144	-	29.620	-	29.552	-	29.212	-
Coosa	Logan Martin-TW	11.005	-	11.073	-	11.141	-	10.598	-	11.073	-	10.802	-
Coosa	Lay-TW	1.155	0.204	1.155	0.204	1.155	0.204	1.223	0.204	1.223	0.204	1.291	0.204
Coosa	Mitchell-TW	2.785	-	2.785	-	2.785	-	2.921	-	2.921	-	2.853	-
Coosa	Jordan-TW	3.804	0.272	3.057	0.272	3.261	0.340	3.533	0.272	3.736	0.272	3.261	0.272
Coosa	Bouldin-TW	86.005	68.207	85.802	68.139	85.938	67.935	85.938	67.935	86.005	67.459	86.005	67.595
Tallapoosa	Harris-TW	82.133	73.573	82.133	73.573	82.133	73.573	82.133	73.030	82.133	72.826	82.065	72.894
Tallapoosa	Martin-TW	-	-	-	-	-	-	-	-	-	-	-	-
Alabama	RF Henry-TW	0.068	-	0.068	-	-	-	0.068	-	0.068	-	0.068	-
Alabama	Millers Ferry-TW	-	-	-	-	-	-	-	-	-	-	-	-
	Other River locations	19.701	11.345	19.158	10.870	19.022	10.802	19.769	11.345	18.954	10.734	19.226	11.345
Etowah	Canton	0.204	-	0.204	-	0.204	-	0.204	-	0.204	-	0.272	-
Etowah	Cartersville	-	-	-	-	-	-	-	-	-	-	-	-
Etowah	Kingston	-	-	-	-	-	-	-	-	-	-	-	-
Etowah	Rome	3.125	1.698	2.989	1.698	2.989	1.698	3.125	1.698	2.989	1.630	3.057	1.698
Coosawattee	Pine Chapel	-	-	-	-	-	-	-	-	-	-	-	-
Oostanaula	Rome	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Rome	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	State Line	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Gadsden	-	-	-	-	-	-	-	-	-	-	-	-
Coosa	Childersburg	0.883	-	0.883	-	0.883	-	0.883	-	0.883	-	0.883	-
Coosa	JB Goal	-	-	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Wadley	-	-	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Tallassee	-	-	-	-	-	-	-	-	-	-	-	-
Tallapoosa	JB Goal	-	-	-	-	-	-	-	-	-	-	-	-
Alabama	JB Goal	-	-	-	-	-	-	-	-	-	-	-	-
Alabama	Montgomery	0.679	-	0.679	-	0.679	-	0.679	-	0.679	-	0.679	-
Alabama	Selma	0.951	-	0.951	-	0.951	-	0.951	-	0.951	-	0.951	-
Cahaba	Marion Junction	0.679	-	0.679	-	0.679	-	0.679	-	0.679	-	0.679	-
Alabama	ARP	0.951	-	0.951	-	0.951	-	0.951	-	0.951	-	0.951	-

Table 4.10. Example of incremental changes in DO standards compliance (4 mg/L daily minimum and 5 mg/L daily average) between alternatives.

		A02_FWOP		A03_WS1		A09_FWOPMF		A10_WS2M		A11_WS6MF	
River	Reservoirs	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard	%<5 mg/L Standard	%<4 mg/L Standard
Etowah	Allatoona	-	0.068	(0.136)	0.204	0.068	-	(0.068)	0.068	(0.136)	0.136
Coosawattee	Carters	-	-	-	-	-	-	-	-	-	-
Coosawattee	Carters Rereg	-	-	-	-	-	-	-	-	-	-
Coosa	Weiss	-	-	-	-	-	-	-	-	-	-
Coosa	HN Henry	-	-	-	-	-	-	-	-	-	-
Coosa	Logan Martin	-	-	-	-	-	-	-	-	-	-
Coosa	Lay	-	-	-	-	-	-	-	-	-	-
Coosa	Mitchell	0.068	-	0.068	-	(0.068)	-	0.068	-	0.068	-
Coosa	Jordan	-	-	(0.068)	-	-	-	-	-	0.068	-
Coosa	Bouldin	0.204	-	0.068	-	0.204	-	0.408	-	0.136	-
Tallapoosa	Harris	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Martin	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Yates & Thurlow	0.068	-	-	-	0.340	0.068	0.340	0.068	0.611	0.068
Alabama	RF Henry	-	-	-	-	-	-	-	-	-	-
Alabama	Millers Ferry	-	-	-	-	-	-	-	-	-	-
Alabama	Claiborne	-	-	-	-	-	-	0.068	-	0.068	-
	Below Dams	(0.272)	(0.068)	0.340	(0.136)	(0.136)	(0.204)	-	(0.204)	(0.068)	(0.136)
Etowah	Allatoona Tailwater	-	-	-	-	-	-	-	-	-	-
Coosawattee	CartersRereg Tailwater	-	-	0.951	-	1.563	-	0.204	-	1.427	-
Coosa	Weiss Power Tailwater	-	-	-	-	-	-	-	-	-	-
Coosa	Weiss Spill Tailwater	-	-	0.068	-	(0.068)	-	(0.068)	-	(0.068)	-
Coosa	HN Henry Tailwater	-	-	0.340	-	0.815	-	0.747	-	0.408	-
Coosa	Logan Martin Tailwater	0.068	-	0.136	-	(0.408)	-	0.068	-	(0.204)	-
Coosa	Lay Tailwater	-	-	-	-	0.068	-	0.068	-	0.136	-
Coosa	Mitchell Tailwater	-	-	-	-	0.136	-	0.136	-	0.068	-
Coosa	Jordan Tailwater	(0.747)	-	(0.543)	0.068	(0.272)	-	(0.068)	-	(0.543)	-
Coosa	Bouldin Tailwater	(0.204)	(0.068)	(0.068)	(0.272)	(0.068)	(0.272)	-	(0.747)	-	(0.611)
Tallapoosa	Harris Tailwater	-	-	-	-	-	(0.543)	-	(0.747)	(0.068)	(0.679)
Tallapoosa	Martin Tailwater	-	-	-	-	-	-	-	-	-	-
Alabama	RF Henry Tailwater	-	-	(0.068)	-	-	-	-	-	-	-
Alabama	Millers Ferry Tailwater	-	-	-	-	-	-	-	-	-	-
	Other River locations	(0.543)	(0.476)	(0.679)	(0.543)	0.068	-	(0.747)	(0.611)	(0.476)	-
Etowah	Canton	-	-	-	-	-	-	-	-	0.068	-
Etowah	Cartersville	-	-	-	-	-	-	-	-	-	-
Etowah	Kingston	-	-	-	-	-	-	-	-	-	-
Etowah	Rome	(0.136)	-	(0.136)	-	-	-	(0.136)	(0.068)	(0.068)	-
Coosawattee	Pine Chapel	-	-	-	-	-	-	-	-	-	-
Oostanaula	Rome	-	-	-	-	-	-	-	-	-	-
Coosa	Rome	-	-	-	-	-	-	-	-	-	-
Coosa	State Line	-	-	-	-	-	-	-	-	-	-
Coosa	Gadsden	-	-	-	-	-	-	-	-	-	-
Coosa	Childersburg	-	-	-	-	-	-	-	-	-	-
Coosa	JB Goal	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Wadley	-	-	-	-	-	-	-	-	-	-
Tallapoosa	Tallassee	-	-	-	-	-	-	-	-	-	-
Tallapoosa	JB Goal	-	-	-	-	-	-	-	-	-	-
Alabama	JB Goal	-	-	-	-	-	-	-	-	-	-
Alabama	Montgomery	-	-	-	-	-	-	-	-	-	-
Alabama	Selma	-	-	-	-	-	-	-	-	-	-
Cahaba	Marion Junction	-	-	-	-	-	-	-	-	-	-
Alabama	ARP	-	-	-	-	-	-	-	-	-	-
	maximum increase (%)	0.204	0.068	0.951	0.204	1.563	0.068	0.747	0.068	1.427	0.136
	maximum increase (%)	0.747	0.476	0.679	0.543	0.408	0.543	0.747	0.747	0.543	0.679
	Average change (%)	(0.034)	-	0.041	(0.068)	0.027	(0.204)	0.095	(0.181)	(0.011)	(0.226)

5. WATER QUALITY PARAMETER SENSITIVITY ANALYSIS

Appendix B contains a summary of the model sensitivity to various model parameters and system fluxes such as point and non-point sources and bottom sources and sinks. This section summarizes sensitivity evaluations for three scenarios.

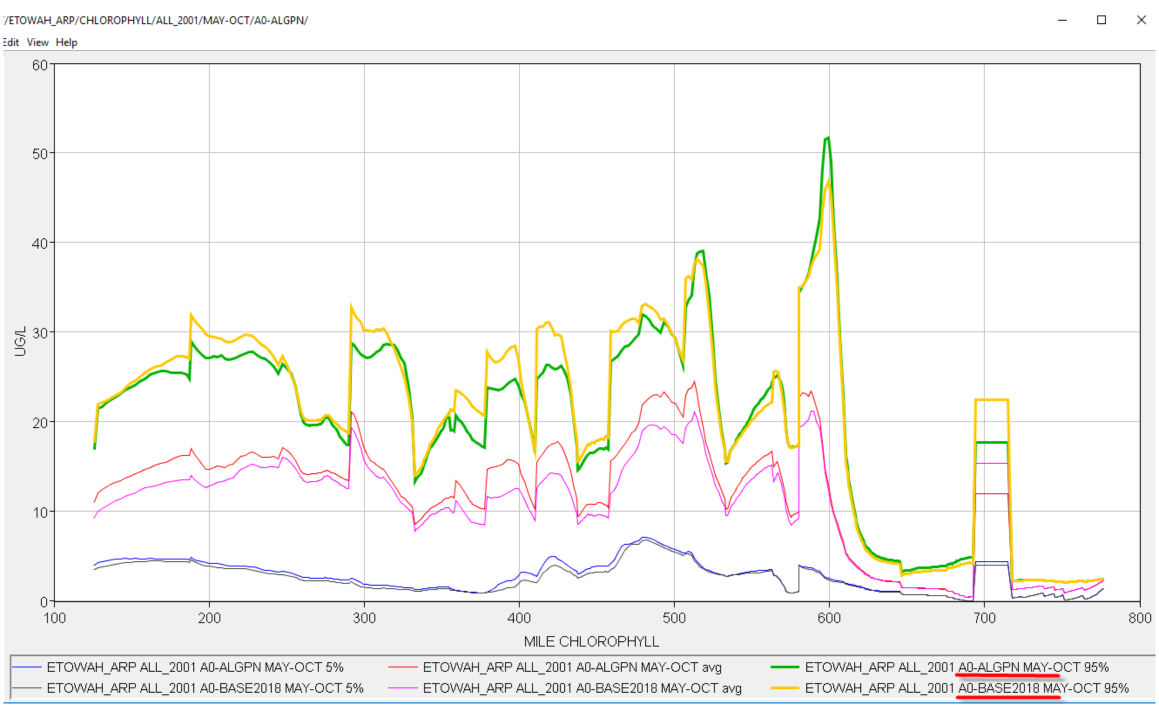
5.1 NUTRIENT FRACTION OF PHYTOPLANKTON SENSITIVITY

The model used for alternative evaluation tended to be nitrogen limiting. The data suggested that both nitrogen and phosphorus may be limited at certain times and locations. Observed mid-summer concentrations of NO_3 are often less than 0.1 mg/L and both NH_3 and phosphorus are less than 0.05 mg/L. The model assumes a constant nitrogen and phosphorus fraction of the algae biomass of 0.08 and 0.01, respectively. The sensitivity of phytoplankton growth to these ratios was tested by increasing the phosphorus fraction to 0.011 (+10%) and decreasing the nitrogen fraction to 0.072 (-10%) in order to tend towards a phosphorus limited environment.

Note: ALGPN (“algae, phosphorus, and nitrogen”) denotes the sensitivity results.

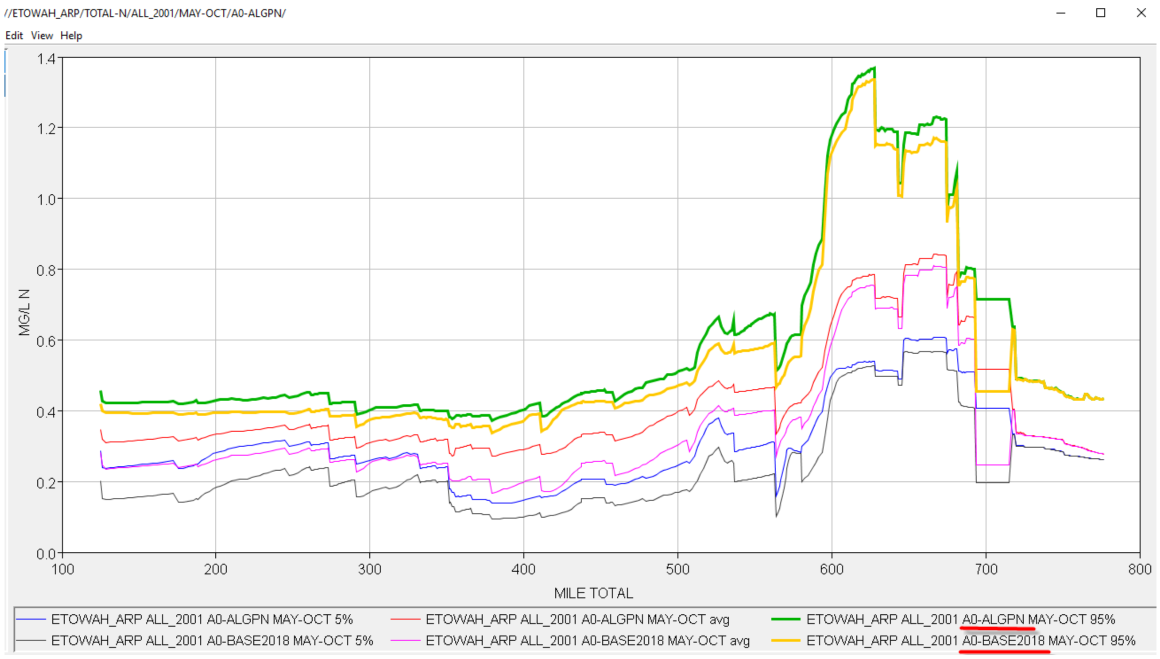
Figure 5.1Figure 5.1 shows the Etowah-Dawsonville to Alabama-ARP profile of computed chlorophyll *a* for the 95%, 50%, and 5% exceedances for both nutrient fraction assumptions for the April–November growing season. The change in the 95% level of chlorophyll *a* is generally within 10% (plus or minus). In response to the smaller nitrogen fraction, there is a slight increase in TN (generally less than 10%) as seen in Figure 5.2Note: ALGPN (“algae, phosphorus, and nitrogen”) denotes the sensitivity results.

Figure 5.2. The increased algal phosphorus fraction has a more dramatic impact on TP by decreasing the TP to 30% as seen in Figure 5.3. The relative difference in the nitrogen/phosphorus response indicates that phosphorus is becoming more limiting in the alternatives model. Regardless of the nitrogen/phosphorus assumption, the relative impacts of alternative operation would be comparable.



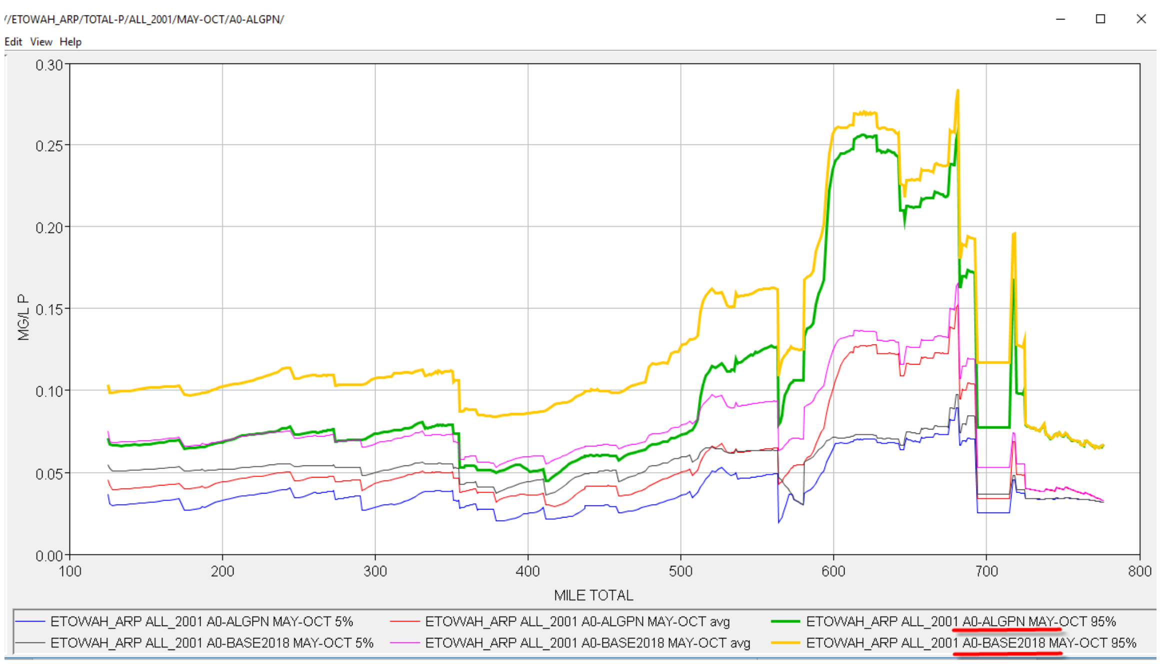
Note: ALGPN (“algae, phosphorus, and nitrogen”) denotes the sensitivity results.

Figure 5.1. Chlorophyll *a* sensitivity to nitrogen and phosphorus fraction of phytoplankton (profile, Etowah – Dawsonville to Alabama – ARP).



Note: ALGPN ("algae, phosphorus, and nitrogen") denotes the sensitivity results.

Figure 5.2. TN sensitivity to nitrogen and phosphorus fraction of phytoplankton (profile, Etowah – Dawsonville to Alabama – ARP).



Note: ALGPN ("algae, phosphorus, and nitrogen") denotes the sensitivity results.

Figure 5.3. TP sensitivity to nitrogen and phosphorus fraction of phytoplankton (profile, Etowah – Dawsonville to Alabama – ARP).

5.2 Chlorophyll *a* Levels in the Coosa River at the State Line

The model tends to underpredict the chlorophyll *a* concentration in the Coosa River between Rome and Weiss Lake. This portion of the river varies between a riverine and lake environment depending on the river flow. The model defines the beginning of Weiss Lake at the state line for consistency with the HEC-ResSim model representation.

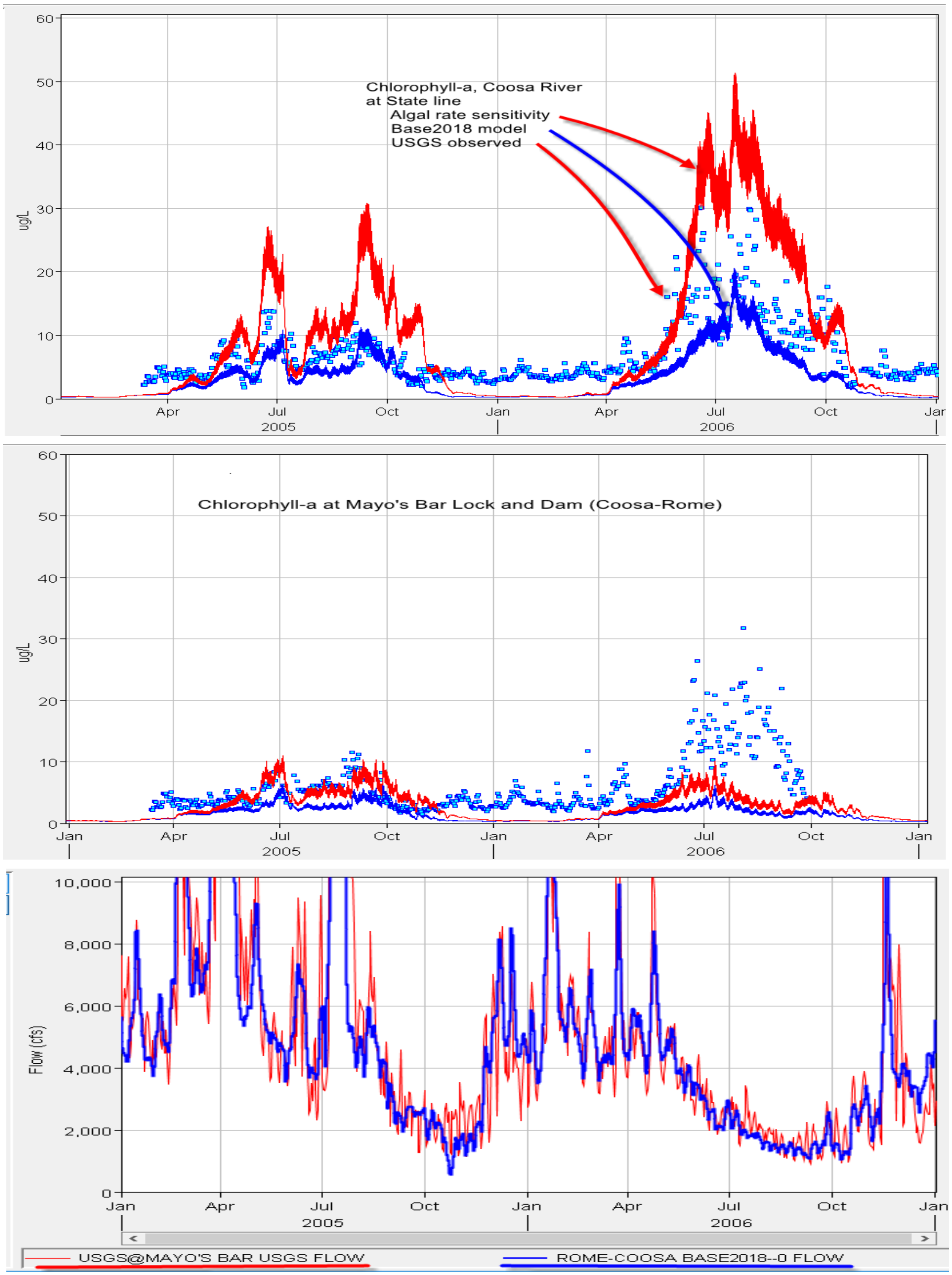
To test the response of computed chlorophyll *a* to model rates impacting algal dynamics, a sensitivity run was performed where the algal growth rate was increased by 10% and the respiration and settling rates were decreased by 10%. Figure 5.4 compares the computed chlorophyll *a* with the observed at the state line and at Mayo's Bar Lock and Dam with the USGS observed data for 2005 and 2006. The first observation is that the chlorophyll *a* levels are quite different between the two years. The two models produce results that bracket the observed data at the state line and indicate that the model could be refined to better represent chlorophyll *a* at this location. However, while the sensitivity model results are in line with the observed data at Mayo's Bar Lock and Dam in 2005, neither model predicts chlorophyll *a* concentrations at the magnitude seen in the 2006 data.

The flow plot shows that the July 2006 flows are approximately one-third of the July 2005 flows. The lack of response seen in the model is likely due to the water depth and travel time above the disabled Mayo's Bar Lock and Dam being misrepresented in the model. To put the differences in computed chlorophyll *a* in context, Figure 5.5 shows that the variations in model chlorophyll *a* above Weiss Lake do not appreciably impact the downstream river levels. This figure shows a detailed view of the river above Weiss Lake and the average observed July chlorophyll *a* for both years and locations.

5.3 Sediment Oxygen Demand Impacts on Lake Allatoona Dissolved Oxygen

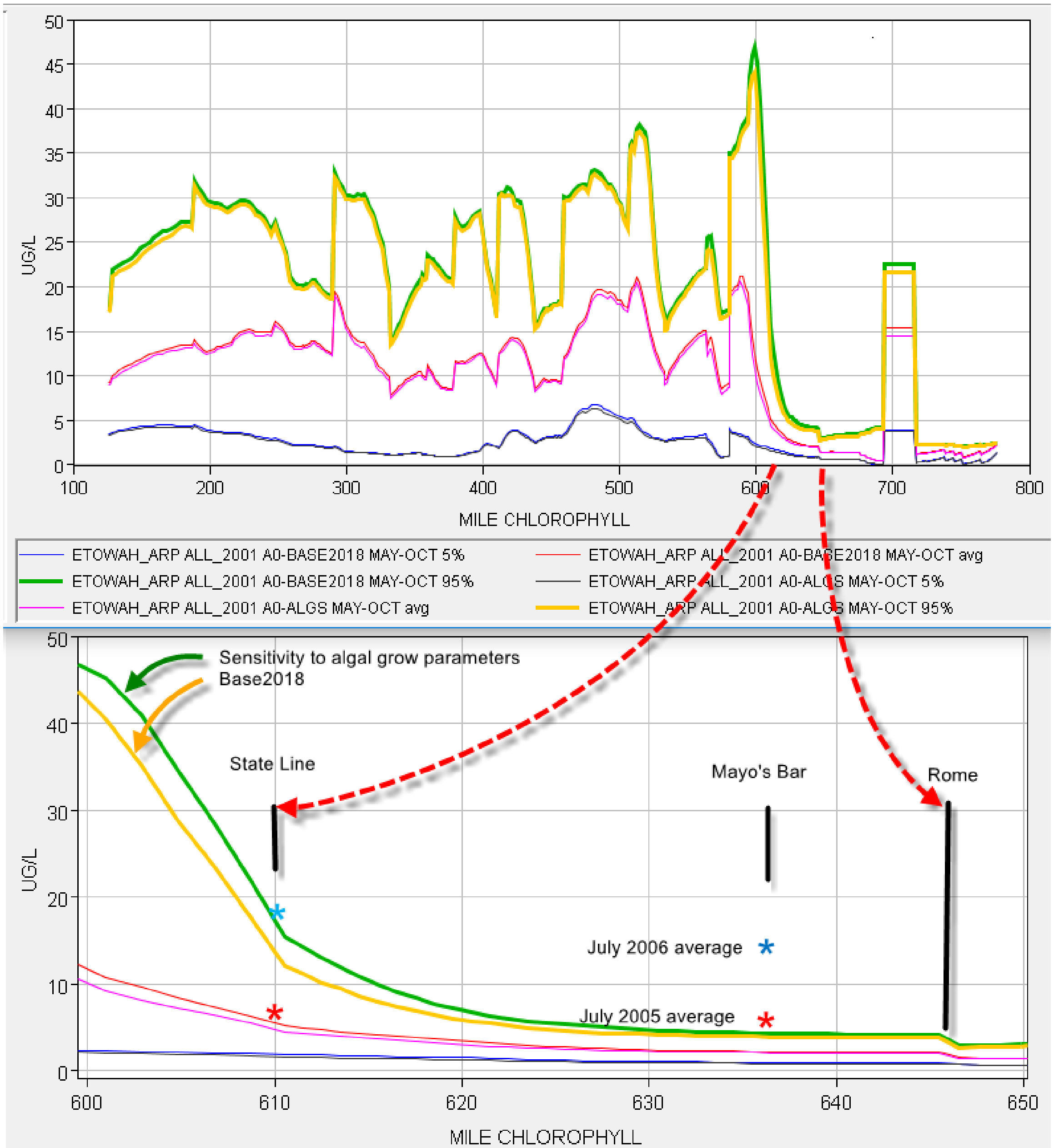
Figure 3.7 of the model demonstration section shows the computed and observed DO below Lake Allatoona. It shows that decline in concentration below the dam occurs earlier than the observed data indicates. In 2005, the total time below 4 mg/L is offset by about a month but the length below 4 mg/L (DO minimum standard) is about the same. In 2006, the decline occurs earlier but the recovery time and rate are well represented. The phasing of the depressed oxygen is an indication of how rapidly the oxygen is depleted in Lake Allatoona. One input variable that impacts reservoir dissolved oxygen is SOD. To quantify this impact, a sensitivity simulation was performed where the SOD for Lake Allatoona was reduced by approximately two-thirds. Figure 5.6 shows the effect of the reduced SOD within the lake. These profiles coincide with the observed DO profiles during the 2005–2006 period. The computed profiles show that the revised SOD model reduces that rate of decline of the hypolimnion. The May and June 2005 and April and May 2006 profiles are a better match with the observations. The data and model results indicate anoxic conditions in the hypolimnion from mid-summer to early fall.

The impacts on DO in the Etowah River below the dam and near Rome due to the revised lake SOD assumption are shown in Figure 5.7. During 2005, the timing of the dip below 4 mg/L is offset by approximately two weeks with the revised SOD model instead of one month. The 2006 timing and duration of the period below 4 mg/L is well represented. Both the No Action alternative and revised SOD model results show that the 4 mg/L standard is violated. The percentage of time the computed outflow falls below 4 mg/L during the two-year period is 37% and 28.5% for the No Action alternative and SOD models, respectively. The computed and observed DO near Rome indicates that the low concentration below the dam does not impact the Coosa River. It should be noted that the computed DO below the dam assumes a 0.2 aeration factor (20% of the deficit recovered). The small diurnal variation in the computed DO is due to reaeration in the one-mile long element.



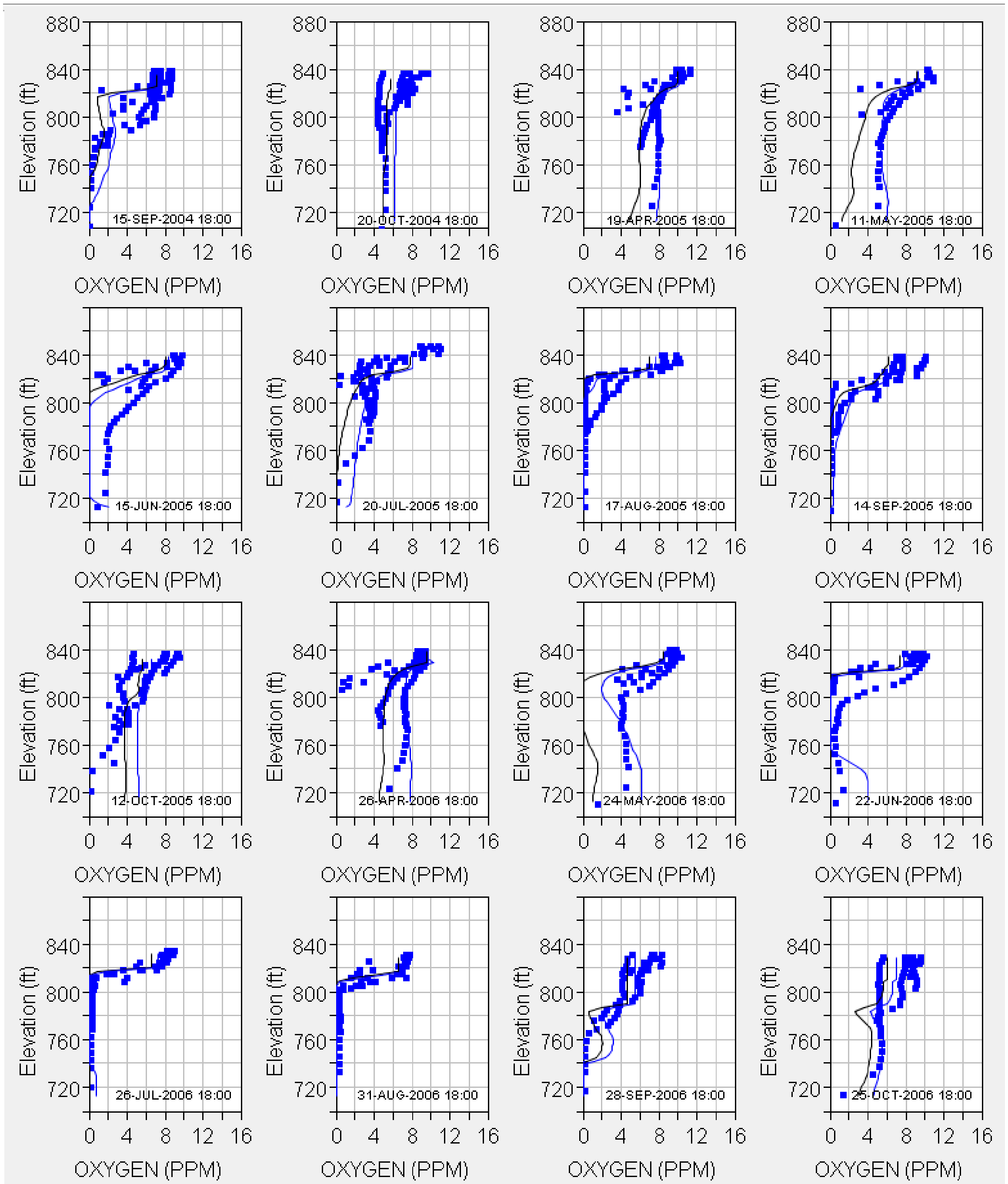
Note: The flows are scaled to show the detail for low and moderate flows, where sensitivity of chlorophyll *a* to flow is greater.

Figure 5.4. Computed and observed chlorophyll *a* in the Coosa River at the state line and Mayo's Bar Lock and Dam for the No Action Alternative and sensitivity to algal growth factors (flows at Mayo's Bar Lock and Dam).



Note: ALGS ("algae sensitivity") denotes the sensitivity results for chlorophyll *a*.

Figure 5.5. Chlorophyll *a* profile for baseline and sensitivity to various phytoplankton rates (profile, Etowah – Dawsonville to Alabama – ARP and Coosa – Rome to Weiss).



Note: The blue line shows an improved match with the observed values.

Figure 5.6. Computed (black and blue lines) and observed (blue markers)DO profiles during 2005 and 2006 in Lake Allatoona for the No Action Alternative and SOD reduced models.

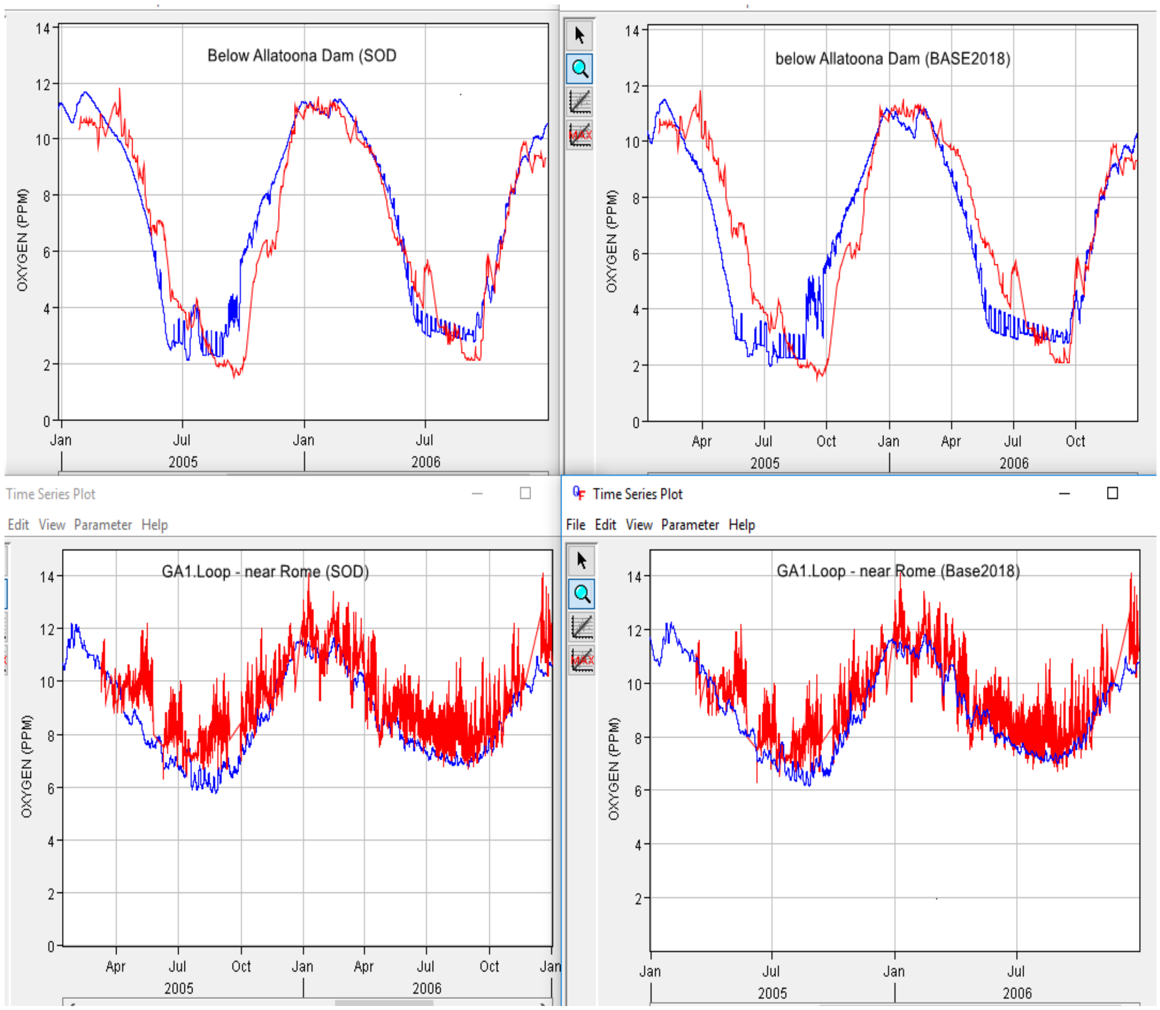


Figure 5.7. Computed (blue lines) and observed (red lines) DO below Allatoona Dam and near Rome for the No Action Alternative and SOD reduced models.

6. CLIMATE SENSITIVITY ANALYSIS

The HEC-5Q model of the ACT watershed was developed to analyze water quality for a specific time period (2001–2008). This time period was selected during the 2015 Water Control Manual update study. It was re-analyzed for the current study and was determined to still be the best representative window of time. First, this period contained the full range of hydrologic conditions from wet to dry periods. Second, observed hydrologic, meteorological, and water quality data existed to provide the boundary and initial conditions for the HEC-5Q model as well as to use to adjust the model coefficients and assess the performance of the model. The HEC-ResSim model simulated each water management alternative for this selected time period. The outflows computed by the HEC-ResSim model were then input into the HEC-5Q model. The HEC-5Q model was then run with the flows for each analyzed alternative to determine the impacts to water quality that each alternative would have when compared to the baseline condition for the 2001–2008 time period.

Forecasted water quality input data were not readily available to create a future time period that would correspond to the climate change flow output from the HEC-ResSim model. Furthermore, the combination of hydrologic and meteorological variables that affect water quality (e.g., flows, water levels, air temperature, relative humidity, and wind speed) is complex with a large amount of uncertainty. Therefore, a sensitivity analysis was selected to analyze the potential climate change impacts on water quality. A sensitivity analysis of the TSP was completed by increasing and decreasing temperatures and flows. This analysis demonstrated how much the model (and by extension the water quality of the ACT) is expected to change for the TSP, due to incremental changes of air temperature and flow. The flows were increased and decreased using flow change factors developed by creating a ratio of the hindcast cumulative volume to the future cast cumulative volume at each of the 36 gage sites that were studied in the climate change analysis, and then averaging those values. This was done for both the high volume model and the low volume model. Following this methodology, the flow change factors were 1.38 and 0.83; therefore, the flows were increased by 38% and decreased by 17%. This resulted in the following three flow conditions that represent the average annual, wettest portion of the year, and driest portion of the year:

1. A11 (TSP): Flows for the TSP alternative
2. LO (Low Flows): A11 local flows reduced by a factor of 0.83
3. HI (High Flows): A11 local flows increased by a factor of 1.38

These flows were simulated in combination with changes to air temperature forcing. The three air temperature adjustments modeled were:

1. No change in air temperatures
2. Increased air temperatures of 1 °C due to climate change
3. Decreased air temperatures of 1 °C due to climate change

A total of nine scenarios were derived by combining each flow condition with a change of air temperature by 0, +1, or -1 °C. One of these represents the TSP alternative with no climate forcing of the HEC-5Q model with air temperature and/or flow changes. Therefore, only various climate forcing scenarios are presented in this section.

The equilibrium water temperature in the HEC-5Q model was adjusted in response to the 1 °C increase or decrease in air temperatures, as described in Section 6.1. Water quality was simulated for the TSP under these conditions, and these results were compared to the TSP under existing (non-sensitivity) conditions.

These are independent scenarios with forcings of different relative magnitudes, i.e., a 1 °C temperature change should not be considered equivalent to a 15% increase or reduction of flows. Furthermore, these scenarios were simulated independently as sensitivity analyses in order to assess the response in the watershed to each condition. Therefore, the results of these analyses should not be compared with one another.

Longitudinal profiles of occurrence levels were plotted for all water quality parameters, summarizing the results for the full year and the three growing seasons for the 2001–2008 model period and each of the three hydrologic periods. The results were also written to HEC-DSS and were summarized in a series of spreadsheets and tables. Figure 6.1 shows the HEC-DSS “F” parts of the nine climate change scenarios.

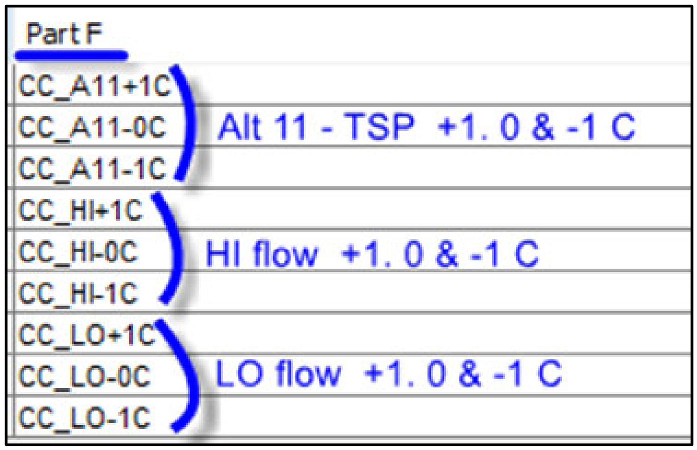


Figure 6.1. The nine scenarios that combine the six forcing factors are shown, along with the F parts of the HEC-DSS output file produced by HEC-5Q.

Figure 6.2 lists the spreadsheets that were produced to summarize the results of the climate change sensitivity analyses. The first two spreadsheets have details that support the next nine spreadsheets.

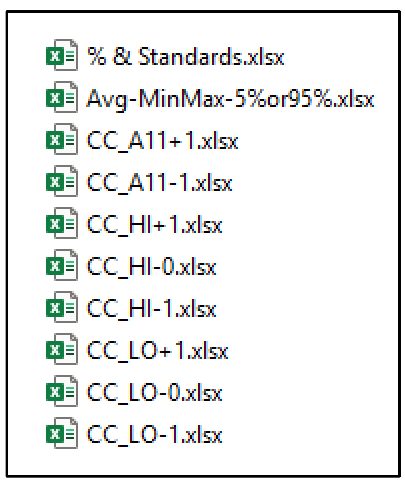


Figure 6.2. List of spreadsheets summarizing the climate sensitivity analyses.

Table 6.1 through Table 6.8 show the basin wide impacts of each variation to the TSP (A11_WS6MF). A description of these tables is provided in Appendix B.

6.1 SENSITIVITY TO 1 °C AIR TEMPERATURE INCREASE – TSP FLOWS

Table 6.1 shows incremental changes between the TSP without climate forcing and the TSP with a 1 °C air temperature increase over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively small changes in water quality. The largest response was in water temperature with an average difference of 2.27%.

Table 6.1. Incremental changes between the TSP without climate forcing and the TSP with a 1 °C air temperature increase over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
A11 + 1 Celsius	25.36653		A11 + 1 Celsius	0.19867	
difference	0.56326	2.27%	difference	-0.00327	-1.62%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
A11 + 1 Celsius	6.67638		A11 + 1 Celsius	0.05970	
difference	-0.10619	-1.57%	difference	0.00109	1.86%
	Chlorophyll *a*, ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
A11 + 1 Celsius	8.00169		A11 + 1 Celsius	0.07335	
difference	0.04795	0.60%	difference	0.00164	2.29%

6.2 SENSITIVITY TO 1 °C AIR TEMPERATURE DECREASE – TSP FLOWS

Table 6.2 shows incremental changes between the TSP without climate forcing and the TSP with a 1 °C air temperature decrease over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively small changes in water quality. The largest response was in water temperature with a difference of -2.28%.

Table 6.2. Incremental changes between the TSP and the TSP with a 1 °C air temperature decrease over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
A11 - 1 Celsius	24.23709		A11 - 1 Celsius	0.20562	
difference	-0.56619	-2.28%	difference	0.00368	1.82%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
A11 - 1 Celsius	6.91744		A11 - 1 Celsius	0.05744	
difference	0.13487	1.99%	difference	-0.00116	-1.99%
	Chlorophyll *a* , ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
A11 - 1 Celsius	7.89494		A11 - 1 Celsius	0.07016	
difference	-0.05880	-0.74%	difference	-0.00155	-2.16%

6.3 Sensitivity to 1 °C Air Temperature Increase – TSP*0.83 Flows

Table 6.3 shows incremental changes between the TSP without climate forcing and the TSP with both a 1 °C air temperature increase and a reduction of TSP flows by a factor of 0.83 over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively small changes in most of the water quality parameters, with the exception of orthophosphate as phosphorus, which showed an average concentration increase of 10.16%.

Table 6.3. Incremental changes between the TSP and the LO flow condition (all local flows scaled by 0.83) with a 1 °C air temperature increase over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
LO + 1 Celsius	25.26594		LO + 1 Celsius	0.20342	
difference	0.46267	1.87%	difference	0.00149	0.74%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
LO + 1 Celsius	6.70284		LO + 1 Celsius	0.06011	
difference	-0.07973	-1.18%	difference	0.00150	2.56%
	Chlorophyll *a* , ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
LO + 1 Celsius	8.09710		LO + 1 Celsius	0.07899	
difference	0.14337	1.80%	difference	0.00729	10.16%

6.4 Sensitivity to No Air Temperature Change – TSP*0.83 Flows

Table 6.4 shows incremental changes between the TSP without climate forcing and the TSP with a reduction of TSP flows by a factor of 0.83 but no temperature change over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively small changes in most of the water quality parameters, with the exception of orthophosphate as phosphorus, which showed an average concentration increase of 7.44%.

Table 6.4. Incremental changes between the TSP and the LO flow condition (all local flows scaled by 0.83) with a 0 °C air temperature increase over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
LO - 0 Celsius	24.69944		LO - 0 Celsius	0.20653	
difference	-0.10384	-0.42%	difference	0.00460	2.28%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
LO - 0 Celsius	6.82572		LO - 0 Celsius	0.05889	
difference	0.04314	0.64%	difference	0.00029	0.49%
	Chlorophyll *a* , ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
LO - 0 Celsius	8.08464		LO - 0 Celsius	0.07704	
difference	0.13091	1.65%	difference	0.00533	7.44%

6.5 Sensitivity to 1 °C Air Temperature Decrease – TSP*0.83 Flows

Table 6.5 shows incremental changes between the TSP without climate forcing and the TSP with both a 1 °C air temperature decrease and a reduction of TSP flows by a factor of 0.83 over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively small changes in many of the water quality parameters. Nitrate as nitrogen and orthophosphate as phosphorus exhibited average increases of 4.02% and 4.94%, respectively.

Table 6.5. Incremental changes between the TSP and the LO flow condition (all local flows scaled by 0.83) with a 1 °C air temperature decrease over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
LO - 1 Celsius	24.13217		LO - 1 Celsius	0.21004	
difference	-0.67111	-2.71%	difference	0.00811	4.02%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
LO - 1 Celsius	6.94979		LO - 1 Celsius	0.05772	
difference	0.16722	2.47%	difference	-0.00088	-1.50%
	Chlorophyll *a*, ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
LO - 1 Celsius	8.06315		LO - 1 Celsius	0.07525	
difference	0.10941	1.38%	difference	0.00354	4.94%

6.6 Sensitivity to 1 °C Air Temperature Increase – TSP*1.38 Flows

Table 6.6 shows incremental changes between the TSP without climate forcing and the TSP with both a 1 °C air temperature increase and an increase of TSP flows by a factor of 1.38 over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively small changes in chlorophyll *a* and ammonia. However, orthophosphate as phosphorus decreased on average by 8.78%, while temperature increased by 3.05% and nitrate as nitrogen decreased by 3.54%.

Table 6.6. Incremental changes between the TSP and the HI flow condition (all local flows scaled by 1.38) with a 1 °C air temperature increase over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
HI + 1 Celsius	25.55925		HI + 1 Celsius	0.19480	
difference	0.75598	3.05%	difference	-0.00714	-3.54%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
HI + 1 Celsius	6.63338		HI + 1 Celsius	0.05869	
difference	-0.14920	-2.20%	difference	0.00008	0.14%
	Chlorophyll *a*, ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
HI + 1 Celsius	7.82245		HI + 1 Celsius	0.06541	
difference	-0.13128	-1.65%	difference	-0.00630	-8.78%

6.7 Sensitivity to No Air Temperature Increase – TSP*1.38 Flows

Table 6.7 shows incremental changes between the TSP without climate forcing and the TSP with an increase of TSP flows by a factor of 1.38 but no temperature change over the 2001–2008 period during the May–October growing season. This scenario resulted in relatively modest changes in the water quality parameters, except for a fairly large average decrease in orthophosphate as phosphorus by 10.70%.

Table 6.7. Incremental changes between the TSP and the HI flow condition (all local flows scaled by 1.38) with a 0 °C air temperature increase over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
HI + 0 Celsius	25.00433		HI + 0 Celsius	0.19764	
difference	0.20106	0.81%	difference	-0.00430	-2.13%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
HI + 0 Celsius	6.74557		HI + 0 Celsius	0.05772	
difference	-0.03700	-0.55%	difference	-0.00088	-1.51%
	Chlorophyll *a* , ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
HI + 0 Celsius	7.77436		HI + 0 Celsius	0.06403	
difference	-0.17938	-2.26%	difference	-0.00767	-10.70%

6.8 Sensitivity to 1 °C Air Temperature Decrease – TSP*1.38 Flows

Table 6.8 shows incremental changes between the TSP without climate forcing and the TSP with both a 1 °C air temperature decrease and an increase of TSP flows by a factor of 1.38 over the 2001–2008 period during the May–October growing season. This scenario resulted in a large average reduction of orthophosphate as phosphorus by 12.44% but relatively minor changes in the other water quality parameters.

Table 6.8. Incremental changes between the TSP and the HI flow condition (all local flows scaled by 1.38) with a 1 °C air temperature decrease over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
	Temperautre , C			NO3-N, mg/L	
TSP (A11_WS6MF)	24.80327		TSP (A11_WS6MF)	0.20194	
HI - 1 Celsius	24.44466		HI - 1 Celsius	0.20092	
difference	-0.35861	-1.45%	difference	-0.00102	-0.50%
	Oxygen, mg/L			NH3-N, mg/L	
TSP (A11_WS6MF)	6.78257		TSP (A11_WS6MF)	0.05860	
HI - 1 Celsius	6.86282		HI - 1 Celsius	0.05673	
difference	0.08025	1.18%	difference	-0.00188	-3.20%
	Chlorophyll *a* , ug/L			PO4-P, mg/L	
TSP (A11_WS6MF)	7.95374		TSP (A11_WS6MF)	0.07171	
HI - 1 Celsius	7.70271		HI - 1 Celsius	0.06279	
difference	-0.25103	-3.16%	difference	-0.00892	-12.44%

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APPENDIX A. TRIBUTARY FLOW AND WATER QUALITY INPUTS

Table A.1. Average, maximum, and minimum tributary flow and water quality inputs.

Location/River/River Mile	Avg/ Max/Min	**Flow (cfs)**	**Temp (C)**	**NO3-N (mg/l)**	**PO4-P (mg/l)**	**Chlorophyll *a* (ug/l)**	**NH3-N (mg/l)**	**DO (mg/l)**	**diss. org (mg/l)**	**org solids (mg/l)**
upstream Etowah R.	Avg	98.0	17.6	0.189	0.017	0.155	0.018	8.44	2.01	1.18
Etowah R.	Min	0.0	6.0	0.151	0.015	0.050	0.016	5.51	2.00	1.09
Mile 774	Max	1344.1	28.1	0.687	0.144	0.250	0.055	12.35	4.17	4.04
Amicaloa Cr.	Avg	96.0	17.6	0.200	0.017	0.155	0.019	8.43	2.02	1.27
Etowah R.	Min	1.6	6.0	0.159	0.015	0.050	0.016	3.09	2.00	1.13
Mile 767	Max	1317.0	28.1	0.746	0.167	0.387	0.060	12.35	5.71	5.52
Settingdown Cr.	Avg	173.7	17.6	0.232	0.018	0.155	0.022	8.43	2.02	1.27
Etowah R.	Min	2.9	6.0	0.180	0.015	0.050	0.018	3.09	2.00	1.13
Mile 751	Max	2382.2	28.1	0.913	0.209	0.387	0.072	12.35	5.65	5.47
Long Swamp Cr.	Avg	263.7	17.6	0.227	0.018	0.155	0.021	8.43	2.02	1.25
Etowah R.	Min	4.4	6.0	0.177	0.015	0.050	0.018	3.09	2.00	1.12
Mile 745	Max	3615.9	28.1	0.889	0.199	0.387	0.070	12.35	5.36	5.18
Mountain Cr.	Avg	372.7	17.6	0.236	0.019	0.155	0.022	8.43	2.03	1.32
Etowah R.	Min	6.3	6.0	0.182	0.015	0.050	0.018	3.09	2.00	1.15
Mile 738	Max	5111.1	28.1	0.934	0.226	0.387	0.074	12.35	6.52	6.30
Shoal Cr.	Avg	30.2	17.6	0.202	0.018	0.155	0.019	8.38	2.04	1.35
Allatoona - Etowah R.	Min	0.5	8.0	0.160	0.015	0.050	0.016	2.94	2.00	1.17
Mile 715	Max	414.5	24.0	0.756	0.190	0.387	0.060	11.77	7.14	6.90
Noonday & Allatonna Cr.	Avg	147.0	17.6	0.283	0.025	0.155	0.025	8.38	2.23	1.80
Allatoona - Etowah R.	Min	2.5	8.0	0.214	0.015	0.050	0.020	2.94	2.00	1.37
Mile 708	Max	2016.2	24.0	1.189	0.401	0.387	0.093	11.77	12.00	14.31
Little R.	Avg	231.0	17.6	0.282	0.026	0.155	0.025	8.38	2.23	1.80
Allatoona - Etowah R.	Min	3.9	8.0	0.213	0.015	0.050	0.020	2.94	2.00	1.38
Mile 694	Max	3168.6	24.0	1.183	0.406	0.387	0.092	11.77	12.00	14.41
Pumpkinvine Cr.	Avg	107.4	17.6	0.330	0.017	0.155	0.019	8.43	2.02	1.28
Etowah R.	Min	0.3	6.0	0.268	0.015	0.050	0.017	3.09	2.00	1.17
Mile 686	Max	1124.5	28.1	1.403	0.178	0.387	0.059	12.35	5.65	5.47
Pettit Cr.	Avg	188.4	17.6	0.440	0.019	0.155	0.024	8.43	2.03	1.36
Etowah R.	Min	0.6	6.0	0.352	0.015	0.050	0.020	3.09	2.00	1.22
Mile 683	Max	1972.2	28.1	1.978	0.279	0.387	0.081	12.35	7.14	6.89
Raccoon Cr.	Avg	226.1	17.6	0.435	0.019	0.155	0.023	8.43	2.03	1.37
Etowah R.	Min	0.7	6.0	0.349	0.015	0.050	0.020	3.09	2.00	1.22
Mile 679	Max	2367.3	28.1	1.954	0.270	0.387	0.079	12.35	7.22	6.97
Euharlee Cr.	Avg	366.5	17.6	0.438	0.018	0.155	0.023	8.43	2.02	1.32
Etowah R.	Min	1.1	6.0	0.351	0.015	0.050	0.020	3.09	2.00	1.19
Mile 675	Max	3836.4	28.1	1.968	0.244	0.387	0.080	12.35	6.33	6.12
Two Run Cr.	Avg	77.0	17.6	0.437	0.018	0.155	0.023	8.43	2.01	1.24
Etowah R.	Min	0.2	6.0	0.349	0.015	0.050	0.020	3.09	2.00	1.15
Mile 665	Max	805.9	28.1	1.959	0.220	0.387	0.080	12.35	5.05	4.88
Dikes Cr.	Avg	133.7	17.6	0.446	0.018	0.155	0.024	8.43	2.01	1.23
Etowah R.	Min	0.4	6.0	0.357	0.015	0.050	0.021	3.09	2.00	1.14
Mile 656	Max	1399.5	28.1	2.000	0.229	0.387	0.083	12.35	4.87	4.72
Coosawattee R.	Avg	616.2	17.6	0.182	0.016	0.155	0.018	8.43	2.01	1.23
Carters - Coosawattee R.	Min	67.5	6.0	0.150	0.015	0.050	0.016	3.09	2.00	1.14
Mile 730	Max	11652.1	28.1	0.680	0.092	0.387	0.055	12.35	3.95	3.83
Talking Rock Cr.	Avg	195.9	17.6	0.250	0.021	0.155	0.023	8.43	2.06	1.48
Carters Rereg - Coosawattee R.	Min	21.5	6.0	0.198	0.015	0.050	0.019	3.09	2.00	1.29
Mile 718	Max	3703.9	28.1	1.067	0.235	0.387	0.084	12.35	7.18	6.93
Salacoa Cr.	Avg	296.3	17.6	0.257	0.052	0.155	0.024	8.43	2.06	1.34
Coosawattee R.	Min	1.0	6.0	0.181	0.015	0.050	0.018	3.09	2.00	1.13
Mile 702	Max	5714.0	28.1	0.897	0.500	0.387	0.071	12.35	7.13	6.89

Conasauga R	Avg	255.6	17.6	0.258	0.024	0.155	0.024	8.43	2.04	1.28
Conasauga R.	Min	0.9	6.0	0.182	0.015	0.050	0.018	3.09	2.00	1.10
Mile 735	Max	4930.4	28.1	0.899	0.291	0.387	0.071	12.35	6.11	5.91
Coahulla R.	Avg	265.8	17.6	0.346	0.037	0.155	0.030	8.43	2.20	1.61
Conasauga R.	Min	0.9	6.0	0.233	0.015	0.050	0.022	3.09	2.00	1.22
Mile 723	Max	5126.3	28.1	1.297	0.500	0.387	0.101	12.35	12.00	11.56
Holly Cr.	Avg	468.5	17.6	0.319	0.035	0.155	0.028	8.43	2.24	1.68
Conasauga R.	Min	1.6	6.0	0.217	0.015	0.050	0.021	3.09	2.00	1.25
Mile 716	Max	9035.9	28.1	1.173	0.500	0.387	0.091	12.35	12.00	12.84
Polecat Cr.	Avg	47.4	17.6	0.248	0.020	0.155	0.023	8.43	2.10	1.43
Conasauga R.	Min	0.2	6.0	0.176	0.015	0.050	0.017	3.09	2.00	1.16
Mile 696	Max	913.2	28.1	0.853	0.204	0.387	0.068	12.35	8.72	8.42
Oostanaula Tribs.	Avg	97.1	17.6	0.275	0.020	0.155	0.025	8.43	2.09	1.40
Oostanaula R.	Min	0.3	6.0	0.192	0.015	0.050	0.019	3.09	2.00	1.15
Mile 694	Max	1873.4	28.1	0.979	0.203	0.387	0.077	12.35	8.26	7.97
Oothkalooga Cr.	Avg	70.7	17.6	0.302	0.021	0.155	0.027	8.43	2.09	1.59
Oostanaula R.	Min	0.2	6.0	0.247	0.015	0.050	0.023	3.09	2.00	1.35
Mile 673	Max	739.8	28.1	1.259	0.350	0.387	0.098	12.35	10.89	10.49
Johns Cr.	Avg	66.3	17.6	0.278	0.019	0.155	0.025	8.43	2.04	1.43
Oostanaula R.	Min	0.2	6.0	0.229	0.015	0.050	0.021	3.09	2.00	1.26
Mile 666	Max	694.5	28.1	1.132	0.290	0.387	0.088	12.35	8.24	7.95
Armuchee Cr.	Avg	205.2	17.6	0.254	0.018	0.155	0.023	8.43	2.03	1.34
Oostanaula R.	Min	0.6	6.0	0.211	0.015	0.050	0.020	3.09	2.00	1.21
Mile 657	Max	2148.0	28.1	1.007	0.239	0.387	0.079	12.35	6.79	6.56
Silver Cr.	Avg	221.5	17.6	0.440	0.019	0.155	0.024	8.43	2.03	1.38
Etowah R.	Min	0.7	6.0	0.352	0.015	0.050	0.020	3.09	2.00	1.23
Mile 646	Max	2318.6	28.1	1.977	0.255	0.387	0.081	12.35	7.36	7.11
Coosa R. Tribs	Avg	16.0	17.6	0.274	0.020	0.155	0.025	8.43	2.11	1.59
Weiss - Coosa R.	Min	0.0	6.0	0.235	0.015	0.050	0.022	3.09	2.00	1.38
Mile 621	Max	135.1	28.1	1.140	0.463	0.387	0.089	12.35	12.00	17.74
Big Cedar Cr.	Avg	178.6	17.6	0.253	0.017	0.155	0.023	8.43	2.07	1.35
Weiss - Coosa R.	Min	0.4	6.0	0.218	0.015	0.050	0.021	3.09	2.00	1.22
Mile 617	Max	1507.2	28.1	1.028	0.270	0.387	0.081	12.35	11.37	10.96
Spring Cr.	Avg	267.9	17.6	0.257	0.017	0.155	0.023	8.43	2.07	1.36
Weiss - Coosa R.	Min	0.6	6.0	0.222	0.015	0.050	0.021	3.09	2.00	1.23
Mile 600	Max	2260.8	28.1	1.051	0.272	0.387	0.082	12.35	11.55	11.13
Chattooga R.	Avg	520.2	17.6	0.247	0.017	0.155	0.023	8.43	2.06	1.33
Weiss - Coosa R.	Min	1.3	6.0	0.213	0.015	0.050	0.020	3.09	2.00	1.21
Mile 592	Max	4389.4	28.1	0.995	0.252	0.387	0.078	12.35	10.68	10.29
Weiss Lake	Avg	702.3	17.6	0.241	0.017	0.155	0.022	8.43	2.05	1.29
Weiss - Coosa R.	Min	1.7	6.0	0.209	0.015	0.050	0.020	3.09	2.00	1.19
Mile 588	Max	5926.5	28.1	0.964	0.224	0.387	0.076	12.35	9.65	9.30
Terrapin Cr.	Avg	177.8	17.6	0.242	0.016	0.155	0.022	8.43	2.01	1.33
Old Coosa R.	Min	1.3	6.0	0.211	0.015	0.050	0.020	3.09	2.00	1.25
Mile 564	Max	2072.5	28.1	0.480	0.065	0.387	0.040	12.35	3.52	3.42
Big Willis Cr.	Avg	350.0	17.6	0.243	0.016	0.155	0.022	8.43	2.01	1.36
H.N.Henry - Coosa R.	Min	2.5	6.0	0.212	0.015	0.050	0.020	3.09	2.00	1.27
Mile 530	Max	4079.9	28.1	0.483	0.069	0.387	0.040	12.35	3.73	3.62
Big Canoe Cr.	Avg	516.3	17.6	0.237	0.015	0.155	0.022	8.43	2.00	1.31
H.N.Henry - Coosa R.	Min	3.7	6.0	0.207	0.015	0.050	0.020	3.09	2.00	1.24
Mile 514	Max	6018.4	28.1	0.468	0.064	0.387	0.039	12.35	3.38	3.29
Beaver Cr.	Avg	554.7	17.6	0.235	0.015	0.155	0.022	8.43	2.00	1.30
H.N.Henry - Coosa R.	Min	4.0	6.0	0.205	0.015	0.050	0.020	3.09	2.00	1.23
Mile 511	Max	6466.6	28.1	0.463	0.062	0.387	0.039	12.35	3.29	3.20
Ohatchee Cr.	Avg	174.5	17.6	0.183	0.015	0.155	0.018	8.43	2.00	1.17
Logan Martin - Coosa R.	Min	1.2	6.0	0.163	0.015	0.050	0.016	3.09	2.00	1.13
Mile 505	Max	2034.2	28.1	0.336	0.026	0.387	0.029	12.35	2.26	2.21

Cane Cr.	Avg	251.4	17.6	0.182	0.015	0.155	0.018	8.43	2.00	1.19
Logan Martin - Coosa R.	Min	1.8	6.0	0.162	0.015	0.050	0.016	3.09	2.00	1.15
Mile 498	Max	2930.7	28.1	0.333	0.030	0.387	0.029	12.35	2.48	2.42
Broken Arrow Cr.	Avg	366.4	17.6	0.175	0.015	0.155	0.017	8.43	2.00	1.17
Logan Martin - Coosa R.	Min	2.6	6.0	0.156	0.015	0.050	0.016	3.09	2.00	1.13
Mile 484	Max	4271.5	28.1	0.317	0.026	0.387	0.028	12.35	2.32	2.27
Choccolocco Cr.	Avg	895.5	17.6	0.181	0.015	0.155	0.018	8.43	2.00	1.19
Logan Martin - Coosa R.	Min	6.4	6.0	0.161	0.015	0.050	0.016	3.09	2.00	1.15
Mile 475	Max	10439.3	28.1	0.332	0.029	0.387	0.029	12.35	2.47	2.41
Kelley Cr.	Avg	85.7	17.6	0.225	0.017	0.155	0.021	8.43	2.06	1.31
Lay - Coosa R.	Min	0.1	6.0	0.195	0.015	0.050	0.019	3.09	2.00	1.21
Mile 456	Max	1948.5	28.1	0.998	0.275	0.387	0.078	12.35	10.87	10.47
Talladega Cr.	Avg	204.9	17.6	0.236	0.017	0.155	0.022	8.43	2.07	1.38
Lay - Coosa R.	Min	0.3	6.0	0.204	0.015	0.050	0.020	3.09	2.00	1.26
Mile 445	Max	4657.5	28.1	1.065	0.336	0.387	0.083	12.35	12.00	12.77
Upper Yellowleaf Cr.	Avg	284.3	17.6	0.230	0.017	0.155	0.021	8.43	2.07	1.34
Lay - Coosa R.	Min	0.4	6.0	0.199	0.015	0.050	0.019	3.09	2.00	1.24
Mile 436	Max	6461.7	28.1	1.028	0.312	0.387	0.081	12.35	12.00	11.63
Peckerwood Cr.	Avg	331.4	17.6	0.235	0.017	0.155	0.022	8.43	2.07	1.35
Lay - Coosa R.	Min	0.4	6.0	0.203	0.015	0.050	0.019	3.09	2.00	1.24
Mile 422	Max	7533.1	28.1	1.056	0.316	0.387	0.083	12.35	12.00	11.69
Waxahatchee Cr.	Avg	414.3	17.6	0.229	0.017	0.155	0.021	8.43	2.07	1.36
Lay - Coosa R.	Min	0.6	6.0	0.198	0.015	0.050	0.019	3.09	2.00	1.25
Mile 415	Max	9415.0	28.1	1.020	0.313	0.387	0.080	12.35	12.00	12.00
Lower Yellowleaf Cr.	Avg	59.1	17.6	0.170	0.016	0.155	0.017	8.43	2.03	1.19
Mitchell - Coosa R.	Min	0.1	6.0	0.151	0.015	0.050	0.016	3.09	2.00	1.13
Mile 410	Max	1343.4	28.1	0.661	0.135	0.387	0.053	12.35	7.21	6.96
Walnut Cr.	Avg	509.3	17.6	0.172	0.016	0.155	0.017	8.43	2.04	1.21
Mitchell - Coosa R.	Min	0.7	6.0	0.153	0.015	0.050	0.016	3.09	2.00	1.14
Mile 402	Max	11574.5	28.1	0.673	0.148	0.387	0.054	12.35	7.67	7.40
Chestnut Cr.	Avg	154.9	17.6	0.186	0.015	0.155	0.018	8.43	2.02	1.13
Jordan - Coosa R.	Min	0.2	6.0	0.164	0.015	0.050	0.017	3.09	2.00	1.09
Mile 393	Max	3519.5	28.1	0.756	0.094	0.387	0.060	12.35	5.03	4.87
Weoka Cr.	Avg	398.4	17.6	0.176	0.015	0.155	0.018	8.43	2.02	1.12
Jordan - Coosa R.	Min	0.5	6.0	0.156	0.015	0.050	0.016	3.09	2.00	1.08
Mile 382	Max	9054.2	28.1	0.698	0.091	0.387	0.056	12.35	4.69	4.55
Tallapoosa R.	Avg	162.6	17.6	0.245	0.019	0.155	0.023	8.43	2.03	1.39
Tallapoosa R.	Min	1.9	6.0	0.190	0.015	0.050	0.019	3.09	2.00	1.23
Mile 576	Max	3354.4	28.1	0.851	0.233	0.387	0.067	12.35	7.63	7.37
Little Cr.	Avg	38.9	17.6	0.262	0.020	0.155	0.024	8.43	2.04	1.41
Tallapoosa R.	Min	0.4	6.0	0.201	0.015	0.050	0.019	3.09	2.00	1.24
Mile 574	Max	802.3	28.1	0.928	0.273	0.387	0.073	12.35	7.97	7.69
Muscadine Cr.	Avg	71.5	17.6	0.248	0.019	0.155	0.023	8.43	2.02	1.35
Tallapoosa R.	Min	0.8	6.0	0.192	0.015	0.050	0.019	3.09	2.00	1.21
Mile 572	Max	1475.3	28.1	0.864	0.247	0.387	0.068	12.35	6.90	6.66
Kelley + Norman Cr.	Avg	97.6	17.6	0.255	0.020	0.155	0.023	8.43	2.03	1.38
Tallapoosa R.	Min	1.1	6.0	0.196	0.015	0.050	0.019	3.09	2.00	1.22
Mile 563	Max	2013.7	28.1	0.897	0.262	0.387	0.071	12.35	7.40	7.15
Silas Cr.	Avg	138.3	17.6	0.262	0.020	0.155	0.024	8.43	2.03	1.38
Tallapoosa R.	Min	1.6	6.0	0.202	0.015	0.050	0.019	3.09	2.00	1.23
Mile 552	Max	2853.6	28.1	0.931	0.274	0.387	0.073	12.35	7.51	7.25
Cane Cr.	Avg	56.5	17.6	0.187	0.017	0.155	0.018	8.43	2.02	1.31
Tallapoosa R.	Min	0.6	6.0	0.151	0.015	0.050	0.016	3.09	2.00	1.19
Mile 544	Max	1165.7	28.1	0.587	0.149	0.387	0.048	12.35	6.32	6.11
Dyne Cr.	Avg	102.6	17.6	0.198	0.017	0.155	0.019	8.43	2.01	1.29
Tallapoosa R.	Min	1.2	6.0	0.158	0.015	0.050	0.016	3.09	2.00	1.17
Mile 535	Max	2116.0	28.1	0.636	0.148	0.387	0.052	12.35	5.90	5.70

Ketchepedrakee Cr.	Avg	151.1	17.6	0.194	0.016	0.155	0.019	8.43	2.01	1.25
Tallapoosa R.	Min	1.7	6.0	0.155	0.015	0.050	0.016	3.09	2.00	1.15
Mile 528	Max	3117.5	28.1	0.619	0.135	0.387	0.050	12.35	5.26	5.09
Little Tallapoosa R.	Avg	244.7	17.6	0.330	0.024	0.155	0.029	8.43	2.07	1.52
Little Tallapoosa R.	Min	2.8	6.0	0.248	0.015	0.050	0.023	3.09	2.00	1.30
Mile 540	Max	5047.7	28.1	1.241	0.396	0.387	0.096	12.35	9.77	9.42
Cohobadiah Cr.	Avg	83.6	17.6	0.287	0.019	0.155	0.026	8.43	2.00	1.20
Little Tallapoosa R.	Min	1.0	6.0	0.218	0.015	0.050	0.021	3.09	2.00	1.12
Mile 536	Max	1725.6	28.1	1.044	0.236	0.387	0.082	12.35	4.47	4.33
Tallapoosa R. Tribs	Avg	157.6	17.6	0.245	0.018	0.155	0.023	8.43	2.01	1.24
Harris - Tallapoosa R.	Min	1.8	6.0	0.190	0.015	0.050	0.019	3.09	2.00	1.14
Mile 512	Max	3252.1	28.1	0.854	0.193	0.387	0.068	12.35	4.99	4.83
Crooked Cr.	Avg	83.5	17.6	0.225	0.016	0.155	0.021	8.43	2.02	1.26
Tallapoosa R.	Min	0.2	6.0	0.189	0.015	0.050	0.018	3.09	2.00	1.20
Mile 498	Max	1183.4	28.1	0.771	0.177	0.387	0.062	12.35	7.16	6.91
Cornhouse Cr.	Avg	178.9	17.6	0.218	0.016	0.155	0.021	8.43	2.02	1.23
Tallapoosa R.	Min	0.5	6.0	0.184	0.015	0.050	0.018	3.09	2.00	1.18
Mile 492	Max	2534.5	28.1	0.738	0.171	0.387	0.059	12.35	6.41	6.19
High Pine Cr.	Avg	50.3	17.6	0.206	0.016	0.155	0.020	8.43	2.03	1.33
Tallapoosa R.	Min	0.1	6.0	0.175	0.015	0.050	0.017	3.09	2.00	1.26
Mile 482	Max	713.3	28.1	0.684	0.158	0.387	0.055	12.35	8.76	8.45
Chikasanoxee Cr.	Avg	146.7	17.6	0.201	0.016	0.155	0.019	8.43	2.02	1.24
Tallapoosa R.	Min	0.4	6.0	0.171	0.015	0.050	0.017	3.09	2.00	1.19
Mile 477	Max	2078.6	28.1	0.661	0.137	0.387	0.053	12.35	6.68	6.45
Chatahospee Cr.	Avg	275.1	17.6	0.210	0.016	0.155	0.020	8.43	2.02	1.23
Tallapoosa R.	Min	0.8	6.0	0.178	0.015	0.050	0.018	3.09	2.00	1.18
Mile 465	Max	3897.3	28.1	0.700	0.146	0.387	0.056	12.35	6.33	6.12
Hillabee Cr.	Avg	565.5	17.6	0.202	0.016	0.155	0.019	8.43	2.02	1.24
Tallapoosa R.	Min	1.6	6.0	0.172	0.015	0.050	0.017	3.09	2.00	1.19
Mile 445	Max	8012.0	28.1	0.663	0.144	0.387	0.054	12.35	6.63	6.40
Martin Lake Tribs	Avg	367.1	17.8	0.206	0.016	0.155	0.020	8.34	2.02	1.30
Martin - Tallapoosa R.	Min	1.1	10.0	0.175	0.015	0.050	0.017	2.81	2.00	1.23
Mile 430	Max	5201.2	26.6	0.684	0.172	0.387	0.055	11.23	8.05	7.77
Channahatchee Cr.	Avg	31.4	17.6	0.234	0.022	0.155	0.022	8.43	2.23	1.56
Yates - Tallapoosa R.	Min	0.3	6.0	0.160	0.015	0.050	0.016	3.09	2.00	1.16
Mile 420	Max	603.6	28.1	0.673	0.101	0.387	0.054	12.35	5.29	5.11
Tallapoosa R. Tribs	Avg	3.7	17.6	0.344	0.025	0.155	0.030	8.43	2.32	1.70
Tallapoosa R.	Min	0.0	6.0	0.218	0.015	0.050	0.021	3.09	2.00	1.19
Mile 408	Max	71.1	28.1	1.085	0.131	0.387	0.085	12.35	6.31	6.10
Upahee Cr.	Avg	29.3	17.6	0.321	0.033	0.155	0.028	8.43	2.47	1.91
Tallapoosa R.	Min	0.3	6.0	0.206	0.015	0.050	0.020	3.09	2.00	1.25
Mile 403	Max	561.8	28.1	1.002	0.201	0.387	0.079	12.35	7.95	7.67
Calebee Cr.	Avg	48.0	17.6	0.335	0.034	0.155	0.029	8.43	2.45	1.88
Tallapoosa R.	Min	0.5	6.0	0.214	0.015	0.050	0.020	3.09	2.00	1.24
Mile 396	Max	921.8	28.1	1.054	0.206	0.387	0.083	12.35	7.70	7.43
Cubahatchee Cr.	Avg	56.8	17.6	0.327	0.033	0.155	0.029	8.43	2.44	1.87
Tallapoosa R.	Min	0.6	6.0	0.209	0.015	0.050	0.020	3.09	2.00	1.24
Mile 389	Max	1090.7	28.1	1.022	0.200	0.387	0.080	12.35	7.60	7.34
Line Cr.	Avg	86.1	17.6	0.349	0.033	0.155	0.030	8.43	2.38	1.79
Tallapoosa R.	Min	0.9	6.0	0.221	0.015	0.050	0.021	3.09	2.00	1.22
Mile 387	Max	1653.4	28.1	1.104	0.201	0.387	0.086	12.35	6.99	6.75
Chubbehatchee Cr.	Avg	93.3	17.6	0.343	0.033	0.155	0.030	8.43	2.36	1.76
Tallapoosa R.	Min	1.0	6.0	0.218	0.015	0.050	0.021	3.09	2.00	1.21
Mile 383	Max	1791.2	28.1	1.084	0.195	0.387	0.085	12.35	6.73	6.50
Tallapoosa R. Tribs	Avg	104.5	17.6	0.361	0.035	0.155	0.031	8.43	2.38	1.79
Tallapoosa R.	Min	1.1	6.0	0.228	0.015	0.050	0.021	3.09	2.00	1.22
Mile 365	Max	2006.3	28.1	1.151	0.216	0.387	0.090	12.35	7.00	6.76

Coosa R. Tribs	Avg	9.9	17.6	0.473	0.048	0.155	0.040	8.43	2.36	1.76
Coosa R.	Min	0.1	6.0	0.288	0.015	0.050	0.026	3.09	2.00	1.21
Mile 357	Max	190.2	28.1	1.573	0.324	0.387	0.121	12.35	6.74	6.51
Autauga Cr.	Avg	530.1	17.6	0.354	0.025	0.155	0.031	8.43	2.26	1.72
R.F.Henry - Alabama R.	Min	0.7	6.0	0.276	0.015	0.050	0.025	3.09	2.00	1.30
Mile 328	Max	12947.3	28.1	0.854	0.196	0.387	0.068	12.35	8.77	8.46
Pintalla Cr.	Avg	798.2	17.6	0.350	0.024	0.155	0.030	8.43	2.19	1.59
R.F.Henry - Alabama R.	Min	1.1	6.0	0.273	0.015	0.050	0.025	3.09	2.00	1.24
Mile 323	Max	19497.5	28.1	0.842	0.179	0.387	0.067	12.35	7.35	7.10
Swift Cr.	Avg	991.5	17.6	0.338	0.023	0.155	0.030	8.43	2.15	1.52
R.F.Henry - Alabama R.	Min	1.3	6.0	0.265	0.015	0.050	0.024	3.09	2.00	1.21
Mile 310	Max	24217.4	28.1	0.811	0.166	0.387	0.065	12.35	6.61	6.38
Purdy Lake Tribs	Avg	23.5	17.6	0.238	0.021	0.155	0.022	8.43	2.14	1.47
Cahaba R.	Min	2.2	6.0	0.172	0.015	0.050	0.017	3.09	2.00	1.16
Mile 392	Max	562.0	28.1	0.975	0.136	0.387	0.077	12.35	5.21	5.04
Cahaba R.	Avg	65.7	17.6	0.220	0.023	0.155	0.021	8.43	2.14	1.46
Cahaba R.	Min	6.1	6.0	0.161	0.015	0.050	0.016	3.09	2.00	1.16
Mile 390	Max	1571.5	28.1	0.876	0.153	0.387	0.069	12.35	5.15	4.98
Little Shades Cr.	Avg	101.4	17.6	0.282	0.031	0.155	0.025	8.43	2.33	1.78
Cahaba R.	Min	9.4	6.0	0.197	0.015	0.050	0.019	3.09	2.00	1.27
Mile 385	Max	2426.2	28.1	1.217	0.273	0.387	0.095	12.35	7.97	7.69
Buck Cr.	Avg	155.0	17.6	0.275	0.029	0.155	0.025	8.43	2.28	1.70
Cahaba R.	Min	14.3	6.0	0.193	0.015	0.050	0.019	3.09	2.00	1.24
Mile 377	Max	3708.3	28.1	1.178	0.245	0.387	0.092	12.35	7.33	7.07
Pineywood Cr.	Avg	231.8	17.6	0.272	0.029	0.155	0.025	8.43	2.28	1.70
Cahaba R.	Min	21.4	6.0	0.191	0.015	0.050	0.019	3.09	2.00	1.24
Mile 362	Max	5545.6	28.1	1.158	0.238	0.387	0.090	12.35	7.27	7.02
Little Cahaba R.	Avg	391.1	17.6	0.292	0.029	0.155	0.026	8.43	2.23	1.63
Cahaba R.	Min	36.2	6.0	0.203	0.015	0.050	0.020	3.09	2.00	1.22
Mile 334	Max	9358.3	28.1	1.272	0.246	0.387	0.099	12.35	6.62	6.40
Shultz Cr.	Avg	438.2	17.6	0.284	0.028	0.155	0.026	8.43	2.21	1.59
Cahaba R.	Min	40.5	6.0	0.199	0.015	0.050	0.019	3.09	2.00	1.20
Mile 324	Max	10485.6	28.1	1.227	0.231	0.387	0.095	12.35	6.27	6.06
Affohee+Hayson+Blue Cr.	Avg	110.1	17.6	0.209	0.015	0.155	0.020	8.43	2.01	1.27
Cahaba R.	Min	0.6	6.0	0.182	0.015	0.050	0.018	3.09	2.00	1.21
Mile 312	Max	1450.1	28.1	1.155	0.228	0.387	0.090	12.35	8.41	8.12
Old Town + Wallace Cr.	Avg	193.4	17.6	0.210	0.016	0.155	0.020	8.43	2.01	1.29
Cahaba R.	Min	1.0	6.0	0.183	0.015	0.050	0.018	3.09	2.00	1.22
Mile 294	Max	2548.0	28.1	1.162	0.241	0.387	0.091	12.35	8.71	8.40
Waters Cr.	Avg	246.7	17.6	0.214	0.016	0.155	0.020	8.43	2.01	1.29
Cahaba R.	Min	1.2	6.0	0.187	0.015	0.050	0.018	3.09	2.00	1.22
Mile 280	Max	3249.6	28.1	1.198	0.244	0.387	0.093	12.35	8.71	8.40
Oakmulgee Cr.	Avg	414.4	17.6	0.213	0.015	0.155	0.020	8.43	2.01	1.27
Cahaba R.	Min	2.1	6.0	0.186	0.015	0.050	0.018	3.09	2.00	1.20
Mile 268	Max	5458.6	28.1	1.192	0.231	0.387	0.093	12.35	8.22	7.93
Cahaba R. Tribs	Avg	25.2	17.6	0.437	0.026	0.155	0.037	8.43	2.01	1.23
Cahaba R.	Min	0.1	6.0	0.366	0.015	0.050	0.032	3.09	2.00	1.17
Mile 256	Max	332.5	28.1	2.001	0.500	0.387	0.227	12.35	7.18	6.93
Big Swamp Cr.	Avg	115.9	17.6	0.390	0.034	0.155	0.033	8.43	2.18	1.54
Millers Ferry - Alabama R.	Min	-0.2	6.0	0.268	0.015	0.050	0.024	3.09	2.00	1.22
Mile 288	Max	1972.7	28.1	1.445	0.321	0.387	0.111	12.35	7.86	7.58
Mulberry Cr.	Avg	327.3	17.6	0.343	0.030	0.155	0.030	8.43	2.13	1.44
Millers Ferry - Alabama R.	Min	-0.4	6.0	0.239	0.015	0.050	0.022	3.09	2.00	1.18
Mile 276	Max	5572.2	28.1	1.240	0.262	0.387	0.096	12.35	6.64	6.41
Beach Cr.	Avg	375.6	17.6	0.344	0.030	0.155	0.030	8.43	2.15	1.49
Millers Ferry - Alabama R.	Min	-0.5	6.0	0.240	0.015	0.050	0.022	3.09	2.00	1.20
Mile 261	Max	6394.2	28.1	1.246	0.267	0.387	0.097	12.35	7.22	6.97

Cedar Cr.	Avg	575.7	17.6	0.332	0.030	0.155	0.029	8.43	2.17	1.52
Millers Ferry - Alabama R.	Min	-0.7	6.0	0.232	0.015	0.050	0.022	3.09	2.00	1.21
Mile 227	Max	9801.0	28.1	1.190	0.258	0.387	0.093	12.35	7.66	7.40
Bogue Chitto Cr.	Avg	685.6	17.6	0.339	0.029	0.155	0.030	8.43	2.16	1.50
Millers Ferry - Alabama R.	Min	-0.9	6.0	0.237	0.015	0.050	0.022	3.09	2.00	1.20
Mile 215	Max	11671.7	28.1	1.222	0.254	0.387	0.095	12.35	7.33	7.08
Chilatchee Cr.	Avg	849.1	17.6	0.328	0.029	0.155	0.029	8.43	2.16	1.52
Millers Ferry - Alabama R.	Min	-1.1	6.0	0.230	0.015	0.050	0.022	3.09	2.00	1.21
Mile 213	Max	14454.9	28.1	1.176	0.244	0.387	0.092	12.35	7.58	7.32
Beaver Cr.	Avg	48.6	17.6	0.251	0.025	0.155	0.023	8.43	2.32	1.80
Claiborne - Alabama R.	Min	-0.1	6.0	0.183	0.015	0.050	0.018	3.09	2.00	1.32
Mile 178	Max	827.6	28.1	0.839	0.182	0.387	0.067	12.35	11.24	10.83
Pursley Cr.	Avg	63.6	17.6	0.252	0.025	0.155	0.023	8.43	2.35	1.85
Claiborne - Alabama R.	Min	-0.1	6.0	0.183	0.015	0.050	0.018	3.09	2.00	1.34
Mile 167	Max	1082.7	28.1	0.843	0.191	0.387	0.067	12.35	11.83	11.40
Bear Cr.	Avg	78.9	17.6	0.250	0.025	0.155	0.023	8.43	2.35	1.84
Claiborne - Alabama R.	Min	-0.1	6.0	0.182	0.015	0.050	0.018	3.09	2.00	1.34
Mile 155	Max	1343.5	28.1	0.833	0.189	0.387	0.066	12.35	11.74	11.31
Tallahatchee Cr.	Avg	94.9	17.6	0.253	0.025	0.155	0.023	8.43	2.35	1.85
Claiborne - Alabama R.	Min	-0.1	6.0	0.184	0.015	0.050	0.018	3.09	2.00	1.34
Mile 145	Max	1615.6	28.1	0.847	0.193	0.387	0.067	12.35	11.86	11.42
Cane Cr.	Avg	113.9	17.6	0.249	0.025	0.155	0.023	8.43	2.33	1.82
Claiborne - Alabama R.	Min	-0.1	6.0	0.182	0.015	0.050	0.018	3.09	2.00	1.33
Mile 134	Max	1938.7	28.1	0.831	0.189	0.387	0.066	12.35	11.51	11.09

Table A.2. Average, maximum, and minimum flow and water quality inputs from municipal and industrial discharges.

Location/River/River Mile	Avg/ Max/Min	**Flow (cfs)**	**Temp (C)**	**NO3-N (mg/l)**	**PO4-P (mg/l)**	**Chlorophyll *a* (ug/l)**	**NH3-N (mg/l)**	**DO (mg/l)**	**diss. org (mg/l)**	**org solids (mg/l)**
Cartersville WPCP	Avg	13.0	21.6	10.000	3.720	0.000	1.336	3.92	17.16	9.55
Etowah R.	Min	11.5	12.0	10.000	2.962	0.000	0.560	2.81	10.40	4.84
Mile 681	Max	15.1	28.0	10.000	5.086	0.000	2.720	5.11	32.40	17.54
Calhoun WPCP	Avg	11.5	21.6	10.000	3.720	0.000	0.566	4.66	26.36	16.58
Coosawattee R.	Min	10.3	12.0	10.000	2.962	0.000	0.471	3.59	19.73	13.11
Mile 693	Max	13.2	28.0	10.000	5.086	0.000	0.667	5.75	32.23	20.22
City of Chatsworth O	Avg	2.2	21.6	10.000	3.720	0.000	0.312	6.37	7.20	4.27
Conasauga R.	Min	1.7	12.0	10.000	2.962	0.000	0.125	4.41	5.48	2.96
Mile 713	Max	2.7	28.0	10.000	5.086	0.000	0.556	8.60	9.50	5.30
Cobb County Noonday Cree	Avg	15.1	21.6	10.000	0.264	0.000	0.155	6.43	3.75	1.39
Allatoona - Etowah R.	Min	14.1	12.0	10.000	0.183	0.000	0.114	4.93	3.75	1.21
Mile 710	Max	16.4	28.0	10.000	0.343	0.000	0.300	8.02	3.75	1.80
Canton WPCP	Avg	2.4	21.6	10.000	4.605	0.000	2.426	4.37	16.25	11.13
Etowah R.	Min	2.3	12.0	10.000	3.275	0.000	0.500	2.67	16.25	7.54
Mile 717	Max	2.5	28.0	10.000	6.873	0.000	7.160	6.68	16.25	24.67
Cherokee County Rose Cre	Avg	5.9	21.6	10.000	0.175	0.000	0.381	5.75	6.25	2.07
Allatoona - Etowah R.	Min	4.8	12.0	10.000	0.100	0.000	0.125	4.46	6.25	1.43
Mile 705	Max	6.5	28.0	10.000	0.300	0.000	0.933	7.10	6.25	2.60
Cobb County Northwest WP	Avg	10.7	21.6	10.000	0.102	0.000	0.106	6.52	2.50	1.06
Allatoona - Etowah R.	Min	9.8	12.0	10.000	0.100	0.000	0.100	4.86	2.50	1.00
Mile 700	Max	11.5	28.0	10.000	0.120	0.000	0.170	8.08	2.50	1.40
Inland Paperboard	Avg	35.1	21.6	1.000	0.300	0.000	4.000	3.90	41.33	94.05
Coosa R.	Min	31.6	12.0	1.000	0.300	0.000	4.000	1.36	32.03	74.82
Mile 628	Max	37.4	28.0	1.000	0.300	0.000	4.000	5.42	58.80	105.14
Georgia Power Company -	Avg	1.5	1.0	90.000	0.100	0.000	0.300	0.12	7.50	3.00
Etowah R.	Min	1.5	1.0	90.000	0.100	0.000	0.300	0.04	7.50	3.00
Mile 674	Max	1.5	1.0	90.000	0.100	0.000	0.300	0.14	7.50	3.00
Rome WPCP	Avg	16.9	21.6	10.000	2.085	0.000	0.439	4.69	14.35	7.03
Coosa R.	Min	12.9	12.0	10.000	1.333	0.000	0.262	3.38	9.45	5.44
Mile 643	Max	22.1	28.0	10.000	2.712	0.000	0.725	6.30	20.30	9.12
Rome - Coosa WPCP	Avg	1.3	21.6	10.000	1.524	0.000	0.204	5.45	2.68	3.51
Coosa R.	Min	0.8	12.0	10.000	0.900	0.000	0.129	3.87	2.50	2.00
Mile 640	Max	2.0	28.0	10.000	2.167	0.000	0.400	7.22	3.43	5.75
Gadsden East WWTP	Avg	4.9	21.6	2.945	2.220	0.000	8.863	3.90	41.42	17.76
H.N.Henry - Coosa R.	Min	3.6	12.0	1.457	1.632	0.000	7.420	1.36	36.40	12.94
Mile 526	Max	6.3	28.0	4.266	5.772	0.000	9.670	5.42	50.30	23.75
Gadsden West WWTP	Avg	8.3	21.6	4.303	1.942	0.000	6.921	4.01	21.70	10.62
H.N.Henry - Coosa R.	Min	5.0	12.0	2.390	1.150	0.000	4.820	2.58	18.48	7.61
Mile 524	Max	11.4	28.0	7.795	2.403	0.000	9.400	7.11	29.33	14.20
Attalla Lagoon	Avg	3.3	21.6	0.686	1.048	0.000	3.657	3.59	53.71	43.38
H.N.Henry - Coosa R.	Min	1.7	12.0	0.277	0.810	0.000	2.270	1.44	36.00	23.73
Mile 528	Max	4.6	28.0	1.225	1.782	0.000	6.640	8.04	95.90	61.60
Tyson Foods	Avg	1.6	21.6	10.000	6.500	0.000	1.000	6.24	22.63	11.31
H.N.Henry - Coosa R.	Min	1.3	12.0	10.000	6.500	0.000	1.000	2.17	5.00	2.63
Mile 518	Max	2.0	28.0	10.000	6.500	0.000	1.000	8.67	38.35	33.46
Goodyear Tire and Rubber	Avg	12.8	24.4	1.000	0.300	0.000	4.000	3.73	35.00	13.77
H.N.Henry - Coosa R.	Min	10.5	15.2	1.000	0.300	0.000	4.000	1.26	35.00	11.10
Mile 534	Max	17.2	33.1	1.000	0.300	0.000	4.000	5.06	35.00	23.60
Pell City Dye Creek WWTP	Avg	2.5	21.6	4.758	1.500	0.000	0.159	8.22	16.53	2.74
Logan Martin - Coosa R.	Min	1.7	12.0	0.657	0.720	0.000	0.130	5.31	15.18	2.01
Mile 481	Max	3.4	28.0	9.150	3.036	0.000	0.220	11.07	18.13	3.51
Kimberley-Clark Corporat	Avg	37.1	21.6	1.000	0.300	0.000	4.000	3.90	50.06	25.07
Lay - Coosa R.	Min	31.5	12.0	1.000	0.300	0.000	4.000	1.36	30.75	19.15
Mile 454	Max	47.4	28.0	1.000	0.300	0.000	4.000	5.42	72.60	38.00

APCO Gaston PLT ash pond	Avg	38.5	21.6	0.220	0.060	0.000	0.050	6.24	9.00	3.60
Lay - Coosa R.	Min	38.5	12.0	0.220	0.060	0.000	0.050	2.17	9.00	3.60
Mile 443	Max	38.5	28.0	0.220	0.060	0.000	0.050	8.67	9.00	3.60
Tallassee Lagoon	Avg	1.0	21.6	10.000	2.374	0.000	1.834	3.90	26.95	22.57
Tallapoosa R.	Min	0.8	12.0	10.000	1.183	0.000	0.470	1.36	14.60	11.20
Mile 407	Max	1.4	28.0	10.000	4.042	0.000	3.150	5.42	37.13	30.88
Tuskegee South WWTP (Cal	Avg	1.6	21.6	10.000	0.700	0.000	1.074	6.47	20.00	9.32
Tallapoosa R.	Min	1.1	12.0	10.000	0.700	0.000	0.240	4.49	20.00	5.11
Mile 401	Max	2.3	28.0	10.000	0.700	0.000	1.790	8.72	20.00	21.33
Tuskegee North WWTP	Avg	2.2	21.6	10.000	0.700	0.000	1.551	5.46	5.84	5.74
Tallapoosa R.	Min	1.8	12.0	10.000	0.700	0.000	0.190	1.90	4.33	3.55
Mile 399	Max	3.0	28.0	10.000	0.700	0.000	4.080	7.59	8.28	8.62
Alexander City Coley Cre	Avg	12.4	21.6	8.449	1.051	0.000	0.314	7.11	5.48	4.83
Martin - Tallapoosa R.	Min	12.4	12.0	5.440	0.650	0.000	0.220	5.16	3.75	3.33
Mile 430	Max	12.4	28.0	10.663	1.340	0.000	0.450	8.90	6.68	6.75
Wetumka City of Water Wo	Avg	3.2	21.6	10.000	2.700	0.000	0.250	6.24	6.25	6.22
Coosa R.	Min	1.8	12.0	10.000	2.700	0.000	0.250	2.17	6.25	2.07
Mile 366	Max	4.2	28.0	10.000	2.700	0.000	0.250	8.67	6.25	10.88
International Paper Comp	Avg	44.5	21.6	1.000	0.300	0.000	4.000	0.86	88.42	45.69
Millers Ferry - Alabama R.	Min	39.6	12.0	1.000	0.300	0.000	4.000	0.70	55.83	38.40
Mile 273	Max	48.3	28.0	1.000	0.300	0.000	4.000	1.00	121.83	53.76
International Paper	Avg	41.5	21.6	1.000	0.300	0.000	4.000	0.86	83.34	62.00
R.F.Henry - Alabama R.	Min	30.5	12.0	1.000	0.300	0.000	4.000	0.70	55.53	62.00
Mile 330	Max	55.5	28.0	1.000	0.300	0.000	4.000	1.00	143.30	62.00
General Electric WWTP	Avg	4.1	21.6	0.100	0.300	0.000	0.100	5.85	17.45	10.65
R.F.Henry - Alabama R.	Min	2.7	12.0	0.100	0.300	0.000	0.100	2.03	11.75	1.00
Mile 325	Max	5.1	28.0	0.100	0.300	0.000	0.100	8.13	25.25	40.20
Prattville Pine Creek	Avg	3.2	21.6	10.000	0.800	0.000	6.000	5.85	12.75	12.10
R.F.Henry - Alabama R.	Min	3.2	12.0	10.000	0.800	0.000	6.000	2.03	12.75	12.10
Mile 347	Max	3.2	28.0	10.000	0.800	0.000	6.000	8.13	12.75	12.10
Montgomery Econchate	Avg	26.3	20.3	2.500	1.000	0.000	7.399	3.44	56.25	16.50
R.F.Henry - Alabama R.	Min	26.3	2.6	2.500	1.000	0.000	7.400	2.80	56.25	16.50
Mile 344	Max	26.3	32.5	2.500	1.000	0.000	7.400	4.00	56.25	16.50
Montgomery Towassa	Avg	3.9	20.3	2.500	1.000	0.000	7.399	3.44	56.25	16.50
R.F.Henry - Alabama R.	Min	3.9	2.6	2.500	1.000	0.000	7.400	2.80	56.25	16.50
Mile 339	Max	3.9	32.5	2.500	1.000	0.000	7.400	4.00	56.25	16.50
Catoma Creek WWTPg	Avg	25.4	21.6	10.000	0.700	0.000	0.200	5.19	6.40	2.89
R.F.Henry - Alabama R.	Min	21.8	12.0	10.000	0.700	0.000	0.120	3.90	5.63	2.40
Mile 332	Max	32.4	28.0	10.000	0.700	0.000	0.300	6.57	7.50	3.50
Macmillan Bloedel Packin	Avg	27.8	21.6	1.000	1.200	0.000	1.400	2.34	104.79	62.13
Claiborne - Alabama R.	Min	24.2	12.0	1.000	1.200	0.000	1.400	0.81	88.75	45.67
Mile 171	Max	32.0	28.0	1.000	1.200	0.000	1.400	3.25	123.83	80.35
Alabama River Pulp Compa	Avg	35.8	20.3	1.000	0.300	0.000	4.000	0.86	148.26	77.00
Alabama R.	Min	30.5	2.6	1.000	0.300	0.000	4.000	0.70	138.00	65.20
Mile 125	Max	38.1	32.5	1.000	0.300	0.000	4.000	1.00	150.00	100.70
Selma Valley Creek WWTP	Avg	5.6	21.6	10.000	0.700	0.000	5.386	3.90	59.23	16.52
Millers Ferry - Alabama R.	Min	4.6	12.0	10.000	0.700	0.000	4.520	1.36	51.55	12.86
Mile 258	Max	6.8	28.0	10.000	0.700	0.000	6.120	5.42	66.25	19.62
Leeds	Avg	1.7	22.0	14.250	5.000	0.000	1.000	5.93	37.50	6.70
Cahaba R.	Min	1.7	2.7	14.250	5.000	0.000	1.000	2.59	37.50	6.70
Mile 389	Max	1.7	33.9	14.250	5.000	0.000	1.000	9.97	37.50	6.70
Birminghan Area discharges	Avg	3.7	20.3	12.000	5.000	0.000	3.000	5.16	22.50	8.40
Cahaba R.	Min	3.7	2.6	12.000	5.000	0.000	3.000	4.20	22.50	8.40
Mile 387	Max	3.7	32.5	12.000	5.000	0.000	3.000	6.00	22.50	8.40
Jefferson Co. + Hoover RC	Avg	7.3	20.3	13.897	5.000	0.000	1.106	6.15	8.27	3.85
Cahaba R.	Min	5.7	2.6	12.800	5.000	0.000	0.410	2.59	7.03	3.30
Mile 384	Max	11.4	32.5	14.600	5.000	0.000	2.210	10.20	10.98	5.19
Pelham	Avg	1.5	19.0	14.000	5.000	0.000	1.000	6.34	30.00	11.20
Cahaba R.	Min	1.5	2.0	14.000	5.000	0.000	1.000	2.59	30.00	11.20
Mile 372	Max	1.5	32.5	14.000	5.000	0.000	1.000	10.37	30.00	11.20

APPENDIX B. MODEL SENSITIVITY ANALYSIS

A sensitivity analysis was performed on the HEC-5Q ACT model to quantify the relative impact of various model coefficients and sources on model predictions. The primary emphasis was the impacts on temperature, DO, phytoplankton (chlorophyll *a*) and nutrients (NO_3, NH_3, and PO_4). These parameters provide an indication of reservoir and stream environmental quality and high levels are associated with degraded water quality. Note that the impacts on temperature was limited to the effects of phytoplankton shading on light attenuation in reservoirs.

Although not an actual sensitivity run, the first condition is the sensitivity of the six alternatives relative to the Base2018 and provides a perspective on the magnitude of the incremental changes resulting from following sensitivity runs. A total of 17 sensitivity runs were performed in which the following model parameters or sources were incremented + 10%, except as noted for #5 and #17. The values within the brackets are the typical baseline ranges.

1. Alternative operation sensitivity
2. Algal growth rate, 1/day (1.6 – 2.2)
3. Algal respiration rate, 1/day (0.25 – 0.3)
4. Algal settling velocity, meters/day (0.15 – 0.5)
5. Algae growth (+10%), respiration (-10%), and settling (-10%), combined
6. Algal nitrogen and phosphorus fraction (P: 0.01 to 0.011 and N: 0.08 to 0.072)
7. Benthic oxygen uptake/demand, mg/m^2/day (500 – 1,250)
8. Benthic nitrogen source rate, mg/m^2/day (5 – 12)
9. Benthic phosphorus source rate, mg/m^2/day (2 – 4)
10. Ammonia decay rate, 1/day (0.1 - 0.2)
11. Dissolved organics decay rates, 1/day (0.06 – 0.2)
12. Non-point/tributary stream dissolved organics, mg/L (variable – BASINS based)
13. Point/municipal and industrial dissolved organics, mg/L (variable – treatment plant specific)
14. Non-point/tributary stream nitrogen (NH_3+NH_4), mg/L (variable – BASINS based)
15. Point/municipal and industrial nitrogen (NH_3+NH_4), mg/L (variable – treatment plant specific)
16. Non-point/tributary stream phosphorus (PO_4), mg/L (variable – BASINS based)
17. Point/municipal and industrial phosphorus (PO_4), mg/L (variable – treatment plant specific)
18. Tailwater oxygen reaeration (impacts of low DO remediation – aeration factor of 0.1 – fraction of the deficit reduced)

Each sensitivity run affects multiple parameters throughout the ACT river system. It is impossible to quantify the impacts at all locations and times; therefore, the impacts are summarized in tables that lists the 5, 25, 50 (average), 75, and 95 percent occurrence at 49 locations. These are the same discrete tailwater (TW) and stream locations and composite reservoirs that are described in Chapter 4, Table 4.3. Spreadsheets have been created that provide the percent occurrences for the six parameters averaged over the 2001–2008 modeling period for the May–October growing season. To further summarize model sensitivity, the impacts for the following locations are averaged.

- Georgia Reservoirs (Allatoona, Carters, and Carters Rereg.)

- Coosa Reservoirs (Weiss, H. Neely Henry, Logan Martin, Lay, Mitchel, and Bouldin)
- Tallapoosa Reservoirs (Harris, Martin, and Yates/Thurlow)
- Alabama River Reservoirs (R.R. Henry, Millers Ferry, and Claiborne)
- Tailwater and stream locations for the afore mentioned below dam/stream locations
- All 49 locations

In addition to the averages, the incremental change between the averages of the TSP (A11_WS6MF) and the sensitivity runs is summarized. In general, the sensitivity for each of the four reservoir subsets and the tailwater and stream categories were similar. Therefore, the summary tables include only the average for the forty-nine locations.

In the following sections, the impacts of the six alternative conditions relative to the sensitivity impacts is compared to put the model sensitivity in perspective.

B.1 SENSITIVITY TO THE ALTERNATIVE OPERATIONS

In Chapter 4, the impacts of the six alternative operations are described. Table B.1 shows the averaged changes using the same metrics used to quantify the impacts of the various sensitivity runs. This table also includes the absolute values of the differences since many of the +/- differences cancel. The other 17 tables do not have the absolute differences since they are typically all plus or minus.

A review of this table confirms the assessment of Chapter 4 that there are only minor differences between the six alternatives. The difference in temperature and chlorophyll *a* are less than 0.1 % and the difference in the other four parameters is less than 0.001 mg/L. The percentage change is greater for the nutrients since the concentrations are so low. However, the percentage increments are less than 1%.

Comparing the remaining sensitivity matrices with those for the six alternatives allows for an estimate of the percentage change in the model parameters equivalent to the impacts of the six operational alternatives. Note that the differences are computed as the sensitivity level less the baseline.

B.2 SENSITIVITY TO ALGAE GROWTH

A 10% higher growth rate results in larger algal concentrations, as shown in Table B.2. DO increases slightly indicating that photosynthesis exceeds the respiration and settling impacts (these rates remain unchanged). The increase in growth rate decreases the nutrient concentrations. The NO_3-nitrogen decreases more dramatically due in part to the specified phytoplankton nitrogen and phosphorus biomass fraction. These fractions are evaluated in Chapter 5. Based on a comparison of Table B.1 and Table B.2, a 1% change in growth rates result in a larger impact the alternative operation scenarios.

Note that the temperature impacts are a function of the light attenuation changes due to higher levels of phytoplankton. Temperature impacts are typical for the remaining sensitivity runs and will not be discussed further.

B.3 SENSITIVITY TO ALGAE RESPIRATION

A 10% larger respiration rate results in lower algal concentrations as shown in Table B.3. Despite the increase in respiration rate, there is a slight decrease in the dissolved oxygen concentration since the decrease phytoplankton level offsets the increased oxygen uptake by respiration. The phytoplankton concentration decreased by over 13% and the NO_3 increases by over 12%. Again, the nutrient response is consistent with lower phytoplankton levels offsetting the higher respiration rate.

B.4 SENSITIVITY TO ALGAE SETTLING

A 10% higher algal settling rate results in lower algal concentrations as shown in Table B.4. The response to settling is less than the response to changes in growth and respiration but settling does have a measurable effect on the algal levels. The net impact on DO and nutrients is less 0.01 mg/L. NH_3 decreases while NO_3 increases. This is due to the nitrogen species preference that emphasized NH_3 in algae growth.

B.5 COMBINED SENSITIVITY TO ALGAE GROWTH, RESPIRATION, AND SETTLING

A 10% increase in the algae growth rate coupled with a 10% reduction in the algae respiration and settling rate results in a dramatic model response as shown in Table B.5. These results show that very small changes can produce a range of impacts that far excel the impacts of the various alternatives.

B.6 COMBINED SENSITIVITY TO ALGAE NUTRIENT FRACTION

A 10% increase in the algae phosphorus fraction and 10% reduction in the algae nitrogen fraction results in a dramatic model response as shown in Table B.6. These results show that the limiting nutrient assessment is very dependent on these fractions. As the phosphate fraction increases, the limiting nutrient switches for nitrogen to phosphorus. With these changes, the phytoplankton levels decrease indicating that phosphorus has become more limiting within the river system. There is a relatively large increase in nitrogen and a corresponding decrease in phosphorus,

B.7 SENSITIVITY TO BENTHIC OXYGEN

A 10% increase in benthic oxygen demand results in a 1% decrease in DO as shown in Table B.7. These results, however, reflect the near surface concentration and do not reflect the impacts on oxygen within the reservoir hypolimnion. The hypolimnion impact are addressed in Chapter 3. There are small impacts on algae and nutrients since the sediment nutrient fluxes are defined as a fraction of the benthic oxygen demand.

B.8 SENSITIVITY TO BENTHIC NITROGEN SOURCE RATE

The benthic source rate for nitrogen stimulates algal growth and increases total nitrogen as shown in Table B.8. Phytoplankton and ammonia nitrogen are increased while phosphorus decreases. The nitrogen source contributes to NH_3 where impacts are the largest and subsequently decays to NO_3.

B.9 SENSITIVITY TO BENTHIC PHOSPHORUS SOURCE RATE

A 10% increase in the benthic source rate for phosphorus increases PO_4 as shown in Table B.9 but does not make an appreciable change in chlorophyll *a*, or in any other nutrients. From the model perspective, the limiting nutrient for algal growth is nitrogen. However small changes in other model parameters can results in phosphorus limitation.

B.10 Sensitivity to Ammonia Decay

A 10% higher ammonia decay rate hastens the transformation of ammonia to nitrate (NH_3 decreases while NO_3 increases) as shown in Table B.10. There is little impact on other parameters, including chlorophyll *a*, since the algae preference for ammonia appears to have a minor impact (total nitrogen is unchanged). With the exception of temperature, these impacts are greater than the impacts of alternatives analyzed.

B.11 Sensitivity to Dissolved Organic Material Decay Rate

A 10% increase in the dissolved organics decay rate has little impact on any parameter, as shown in Table B.11. The impact on any parameter is of the magnitude seen with the alternatives analysis.

B.12 Sensitivity to Non-point Source Dissolved Organic Material Concentration

A 10% change in DOM concentration of the non-point sources (tributary streams) does not have a major impact on any other parameter, as shown in Table B.12. One of the reasons for the insensitivity is the relatively low decay rate assigned to the more refractory DOM of tributary stream origin. Point source DOM is assumed to decay at a higher rate (labile dominated). The impact on any parameter are only slightly larger than those seen with the alternatives analysis.

B.13 Sensitivity to Point Source Dissolved Organic Material Concentration

A 10% change in the DOM concentration of the point sources (treatment plants) has a greater impact than non-point DOM sources. A review of Table B.12 and Table B.13 indicates that the point sources have a greater impact than non-point sources. However, the impacts remain relatively low.

B.14 Sensitivity to Non-Point Source Nitrogen

A 10% increase in non-point source nitrogen (both NH_3 and NO_3) concentration results in higher nitrogen and chlorophyll *a* as shown in Table B.14. DO is slightly lower due to the uptake by NH_3 decay. Phosphorus decreases slightly due to increased phytoplankton growth. Higher phytoplankton levels and subsequent settling results in slightly lower dissolved oxygen below several of the dams.

B.15 Sensitivity to Point Source Nitrogen

As with the 10% increase in the point source nitrogen (both NH_3 and NO_3), model results predict increased nitrogen and chlorophyll *a* by about half the rate predicted for the non-point nitrogen increase, as shown in Table B.15. There is similarly small reduction in phosphorus due to increased phytoplankton activity. The higher phytoplankton levels and subsequent settling result in slightly lower DO below several of the dams.

B.16 Sensitivity to Non-Point Source Phosphorus

A 10% increase in non-point source phosphorus results in 3.5% higher phosphorus as shown in Table B.16. Since the model is nitrogen limited, there is little impact on NO_3, NH_3, chlorophyll *a*, and DO.

B.17 SENSITIVITY TO POINT SOURCE PHOSPHORUS

A 10% increase in point source phosphorus results in 1.8% higher phosphorus and a very small increment in NO_3, NH_3, chlorophyll *a*, and DO, as shown in Table B.17. The impact of point source phosphorus inflows is approximately twice that of the non-point-source inflows.

B.18 SENSITIVITY TO TAILWATER OXYGEN REAERATION FACTORS

The sensitivity to the dam tailwater reaeration factors was evaluated by specifying a factor of 0.1 that reduces the oxygen deficit below dams by only 10%, as shown in Table B.18. The calibrated model has factors ranging from 20% to 50% and three reservoirs have forced oxygen injections systems designed to bring the DO up to 4 mg/L. DO is the only parameter that is affected by the reaeration factor in a meaningful way. Table B.18 shows the oxygen impacts for the 14 tailwater locations instead of all 49 locations. The approximately 0.3 mg/L reduction in the average concentration is for the entire growing season and does not represent the mid-summer minimums. Additionally, the deep strongly stratified reservoirs like Allatoona and Martin have small reaeration factors of 20%; therefore, the factor reduction from 20% to 10% does not contribute greatly to the reduction in the average.

Table B.1. Average of the Base2018 and five alternatives models output over the 2001–2008 period during the May–October growing season and the differences between the averaged model results.

	Averages for all 49 locations	%		Averages for all 49 locations	%
	TEMPERATURE (C)			NO3-N (PPM)	
Base2018	25.20628		Base2018	0.21341	
All alternatives	25.20379		All alternatives	0.21267	
difference	-0.00249	-0.01%	difference	-0.00074	-0.35%
abs difference	0.00345	0.01%	Abs difference	0.00093	0.44%
	OXYGEN (PPM)			NH3-N (PPM)	
Base2018	6.89682		Base2018	0.05809	
All alternatives	6.89702		All alternatives	0.05806	
difference	0.00020	0.00%	difference	-0.00003	-0.05%
abs difference	0.00039	0.01%	Abs difference	0.00003	0.05%
	Chlorophyl_a (UGL)			PO4-P (PPM)	
Base2018	8.48897		Base2018	0.07161	
All alternatives	8.49042		All alternatives	0.07152	
difference	0.00145	0.02%	difference	-0.00009	-0.13%
abs difference	0.00480	0.06%	Abs difference	0.00015	0.21%

Table B.2. Incremental changes resulting from a 10% increase in the algae growth rate over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
	TEMPERATURE (C)	Alg_G		NO3-N (PPM)	Alg_G
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Algae growth	24.89227		Algae growth	0.16531	
difference	-0.00889	-0.04%	difference	-0.03270	-16.51%
	OXYGEN (PPM)	Alg_G		NH3-N (PPM)	Alg_G
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Algae growth	6.78609		Algae growth	0.05630	
difference	0.01419	0.21%	difference	-0.00234	-3.99%
	Chlorophyl_a (UGL)	Alg_G		PO4-P (PPM)	Alg_G
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Algae growth	9.27020		Algae growth	0.06691	
difference	1.10390	13.52%	difference	-0.00471	-6.58%

Table B.3. Incremental changes resulting from a 10% increase in the algae respiration rate over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
	TEMPERATURE (C)	Alg_R		NO3-N (PPM)	Alg_R
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.20879	
Algae respiration	24.90473		Algae respiration	0.23440	
difference	0.00356	0.01%	difference	0.02561	12.27%
				NH3-N (PPM)	Alg_R
	OXYGEN (PPM)	Alg_R			
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05802	
Algae respiration	6.74638		Algae respiration	0.05964	
difference	-0.02551	-0.38%	difference	0.00162	2.79%
	Chlorophyl_a (UGL)	Alg_R		PO4-P (PPM)	Alg_R
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07163	
Algae respiration	7.07246		Algae respiration	0.07562	
difference	-1.09384	-13.39%	difference	0.00398	5.56%

Table B.4. Incremental changes resulting from a 10% increase in the algae settling rate over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
	TEMPERATURE (C)	Alg_S		NO3-N (PPM)	Alg_S
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.20879	
Algae settling	24.91798		Algae settling	0.21196	
difference	0.01682	0.07%	difference	0.00317	1.52%
	OXYGEN (PPM)	Alg_S		NH3-N (PPM)	Alg_S
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05802	
Algae settling	6.78254		Algae settling	0.05775	
difference	0.01064	0.16%	difference	-0.00027	-0.46%
	Chlorophyl_a (UGL)	Alg_S		PO4-P (PPM)	Alg_S
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07163	
Algae settling	7.88810		Algae settling	0.07180	
difference	-0.27820	-3.41%	difference	0.00017	0.23%

Table B.5. Incremental changes resulting from a 10% increase in the algae growth rate and a 10% reduction in the algae respiration and settling rate over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
TEMPERATURE (C)		ALG_GRS	NO3-N (PPM)		ALG_GRS
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Algae grow, resp & settl	24.96521		Algae grow, resp & settl	0.11237	
difference	0.06404	0.26%	difference	-0.08563	-43.25%
OXYGEN (PPM)		ALG_GRS	NH3-N (PPM)		ALG_GRS
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Algae grow, resp & settl	6.84255		Algae grow, resp & settl	0.04488	
difference	0.07065	1.04%	difference	-0.01376	-23.46%
Chlorophyl_a (UGL)		ALG_GRS	PO4-P (PPM)		ALG_GRS
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Algae grow, resp & settl	8.77085		Algae grow, resp & settl	0.06133	
difference	0.60455	7.40%	difference	-0.01029	-14.36%

Table B.6. Incremental changes resulting from a 10% increase in the algae phosphorus fraction and 10% reduction in the algae nitrogen fraction over the 2001–2008 period during the May–October growing season.

	Averages for all 49 locations	%		Averages for all 49 locations	%
TEMPERATURE (C)	Alg_PN		NO3-N (PPM)	Alg_PN	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Algae N & P fraction	24.87952		Algae N & P fraction	0.21180	
difference	-0.02164	-0.09%	difference	0.01380	6.97%
OXYGEN (PPM)	Alg_PN		NH3-N (PPM)	Alg_PN	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Algae N & P fraction	6.75510		Algae N & P fraction	0.06122	
difference	-0.01679	-0.25%	difference	0.00258	4.40%
Chlorophyl_a (UGL)	Alg_PN		PO4-P (PPM)	Alg_PN	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Algae N & P fraction	8.83303		Algae N & P fraction	0.06288	
difference	0.66674	8.16%	difference	-0.00874	-12.21%

Table B.7. Incremental changes resulting from a 10% increase in benthic oxygen demand and dependent nitrogen (NH_3) and phosphorus source rate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	Ben_O		NO3-N (PPM)	Ben_O	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Benthic Oxygen demand	24.90160		Benthic Oxygen demand	0.19683	
difference	0.00044	0.00%	difference	-0.00117	-0.59%
OXYGEN (PPM)	Ben_O		NH3-N (PPM)	Ben_O	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Benthic Oxygen demand	6.70433		Benthic Oxygen demand	0.05903	
difference	-0.06757	-1.00%	difference	0.00039	0.67%
Chlorophyl_a (UGL)	Ben_O		PO4-P (PPM)	Ben_O	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Benthic Oxygen demand	8.13804		Benthic Oxygen demand	0.07267	
difference	-0.02826	-0.35%	difference	0.00105	1.47%

Table B.8. Incremental changes resulting from a 10% increase in benthic nitrogen (NH_3) source rate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	Ben_N		NO3-N (PPM)	Ben_N	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Benthic Nitrogen source	24.89598		Benthic Nitrogen source	0.20146	
difference	-0.00519	-0.02%	difference	0.00346	1.75%
OXYGEN (PPM)	Ben_N		NH3-N (PPM)	Ben_N	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Benthic Nitrogen source	6.76587		Benthic Nitrogen source	0.06101	
difference	-0.00603	-0.09%	difference	0.00237	4.04%
Chlorophyl_a (UGL)	Ben_N		PO4-P (PPM)	Ben_N	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Benthic Nitrogen source	8.30370		Benthic Nitrogen source	0.07104	
difference	0.13740	1.68%	difference	-0.00058	-0.81%

Table B.9. Incremental changes resulting from a 10% increase in benthic phosphorus source rate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	Ben_P		NO3-N (PPM)	Ben_P	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Benthic Phosphorus source	24.90085		Benthic Phosphorus source	0.19788	
difference	-0.00031	0.00%	difference	-0.00012	-0.06%
OXYGEN (PPM)	Ben_P		NH3-N (PPM)	Ben_P	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Benthic Phosphorus source	6.77155		Benthic Phosphorus source	0.05864	
difference	-0.00035	-0.01%	difference	0.00000	0.01%
Chlorophyl_a (UGL)	Ben_P		PO4-P (PPM)	Ben_P	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Benthic Phosphorus source	8.16749		Benthic Phosphorus source	0.07659	
difference	0.00119	0.01%	difference	0.00497	6.94%

Table B.10. Incremental changes resulting from a 10% increase in ammonia decay rate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	NH3_DK		NO3-N (PPM)	NH3_DK	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Ammonia decay rate	24.90142		Ammonia decay rate	0.20006	
difference	0.00025	0.00%	difference	0.00206	1.04%
OXYGEN (PPM)	NH3_DK		NH3-N (PPM)	NH3_DK	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Ammonia decay rate	6.76673		Ammonia decay rate	0.05607	
difference	-0.00517	-0.08%	difference	-0.00257	-4.38%
Chlorophyl_a (UGL)	NH3_DK		PO4-P (PPM)	NH3_DK	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Ammonia decay rate	8.15484		Ammonia decay rate	0.07167	
difference	-0.01146	-0.14%	difference	0.00005	0.07%

Table B.11. Incremental changes resulting from a 10% increase in dissolved organic material (BOD) decay rate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	DOM_DK		NO3-N (PPM)	DOM_DK	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Dissolved organics decay	24.90024		Dissolved organics decay	0.19830	
difference	-0.00092	0.00%	difference	0.00030	0.15%
OXYGEN (PPM)	DOM_DK		NH3-N (PPM)	DOM_DK	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Dissolved organics decay	6.76697		Dissolved organics decay	0.05901	
difference	-0.00493	-0.07%	difference	0.00037	0.63%
Chlorophyl_a (UGL)	DOM_DK		PO4-P (PPM)	DOM_DK	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Dissolved organics decay	8.18764		Dissolved organics decay	0.07187	
difference	0.02134	0.26%	difference	0.00025	0.35%

Table B.12. Incremental changes resulting from a 10% increase in non-point source dissolved organic material over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	NPt_DOM		NO3-N (PPM)	NPt_DOM	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Non-point inflow DOM	24.89884		Non-point inflow DOM	0.19911	
difference	-0.00232	-0.01%	difference	0.00111	0.56%
OXYGEN (PPM)	NPt_DOM		NH3-N (PPM)	NPt_DOM	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Non-point inflow DOM	6.75448		Non-point inflow DOM	0.05943	
difference	-0.01742	-0.26%	difference	0.00079	1.34%
Chlorophyl_a (UGL)	NPt_DOM		PO4-P (PPM)	NPt_DOM	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Non-point inflow DOM	8.22428		Non-point inflow DOM	0.07252	
difference	0.05798	0.71%	difference	0.00090	1.26%

Table B.13. Incremental changes resulting from a 10% increase in point source dissolved organic material over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	Pt_DOM		NO3-N (PPM)	Pt_DOM	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Point inflow DOM	24.90105		Point inflow DOM	0.19825	
difference	-0.00011	0.00%	difference	0.00024	0.12%
OXYGEN (PPM)	Pt_DOM		NH3-N (PPM)	Pt_DOM	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Point inflow DOM	6.76754		Point inflow DOM	0.05877	
difference	-0.00436	-0.06%	difference	0.00013	0.22%
Chlorophyl_a (UGL)	Pt_DOM		PO4-P (PPM)	Pt_DOM	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Point inflow DOM	8.18175		Point inflow DOM	0.07172	
difference	0.01545	0.19%	difference	0.00010	0.13%

Table B.14. Incremental changes resulting from a 10% increase in non-point source nitrogen (NO_3 and NH_3) over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	NPt_N		NO3-N (PPM)	NPt_N	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Non-point inflow Nitrogen	24.89129		Non-point inflow Nitrogen	0.20910	
difference	-0.00987	-0.04%	difference	0.01110	5.61%
OXYGEN (PPM)	NPt_N		NH3-N (PPM)	NPt_N	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Non-point inflow Nitrogen	6.76261		Non-point inflow Nitrogen	0.06063	
difference	-0.00928	-0.14%	difference	0.00199	3.39%
Chlorophyl_a (UGL)	NPt_N		PO4-P (PPM)	NPt_N	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Non-point inflow Nitrogen	8.45765		Non-point inflow Nitrogen	0.07052	
difference	0.29135	3.57%	difference	-0.00110	-1.53%

Table B.15. Incremental changes resulting from a 10% increase in point source nitrogen (NO_3 and NH_3) over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	Pt_N		NO3-N (PPM)	Pt_N	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Point inflow Nitrogen	24.89894		Point inflow Nitrogen	0.20280	
difference	-0.00223	-0.01%	difference	0.00480	2.42%
OXYGEN (PPM)	Pt_N		NH3-N (PPM)	Pt_N	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Point inflow Nitrogen	6.76819		Point inflow Nitrogen	0.05968	
difference	-0.00371	-0.05%	difference	0.00104	1.77%
Chlorophyl_a (UGL)	Pt_N		PO4-P (PPM)	Pt_N	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Point inflow Nitrogen	8.29904		Point inflow Nitrogen	0.07112	
difference	0.13274	1.63%	difference	-0.00050	-0.70%

Table B-16. Incremental changes resulting from a 10% increase in non-point source phosphate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	NPt_P		NO3-N (PPM)	NPt_P	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Non-point inflow Phosphorus	24.90063		Non-point inflow Phosphorus	0.19779	
difference	-0.00053	0.00%	difference	-0.00021	-0.11%
OXYGEN (PPM)	NPt_P		NH3-N (PPM)	NPt_P	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Non-point inflow Phosphorus	6.77076		Non-point inflow Phosphorus	0.05863	
difference	-0.00114	-0.02%	difference	-0.00001	-0.01%
Chlorophyl_a (UGL)	NPt_P		PO4-P (PPM)	NPt_P	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Non-point inflow Phosphorus	8.17006		Non-point inflow Phosphorus	0.07413	
difference	0.00376	0.05%	difference	0.00251	3.50%

Table B.17. Incremental changes resulting from a 10% increase in point source phosphate over the 2001–2008 period during the May–October growing season.

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	Pt_P		NO3-N (PPM)	Pt_P	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Point inflow Phosphorus	24.90110		Point inflow Phosphorus	0.19795	
difference	-0.00006	0.00%	difference	-0.00005	-0.02%
OXYGEN (PPM)	Pt_P		NH3-N (PPM)	Pt_P	
TSP (A11_WS6MF)	6.77190		TSP (A11_WS6MF)	0.05864	
Point inflow Phosphorus	6.77191		Point inflow Phosphorus	0.05865	
difference	0.00001	0.00%	difference	0.00001	0.01%
Chlorophyl_a (UGL)	Pt_P		PO4-P (PPM)	Pt_P	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Point inflow Phosphorus	8.16736		Point inflow Phosphorus	0.07295	
difference	0.00106	0.01%	difference	0.00133	1.85%

Table B.18. Incremental changes resulting from reducing the tailwater reaeration factor to 0.1 of the oxygen deficit over the 2001–2008 period during the May–October growing season (DO impacts for tailwater only).

Averages for all 49 locations		%	Averages for all 49 locations		%
TEMPERATURE (C)	TW_K2		NO3-N (PPM)	TW_K2	
TSP (A11_WS6MF)	24.90116		TSP (A11_WS6MF)	0.19800	
Tail Water Reaeration	24.90114		Tail Water Reaeration	0.19779	
difference	-0.00002	0.00%	difference	-0.00021	-0.11%
OXYGEN (PPM)	**TW_K2**		NH3-N (PPM)	TW_K2	
TSP (A11_WS6MF)	**5.81676**		TSP (A11_WS6MF)	0.05864	
Tail Water Reaeration	**5.45098**		Tail Water Reaeration	0.05870	
difference	**-0.36578**	**-6.29%**	difference	0.00006	0.11%
Chlorophyl_a (UGL)	TW_K2		PO4-P (PPM)	TW_K2	
TSP (A11_WS6MF)	8.16630		TSP (A11_WS6MF)	0.07162	
Tail Water Reaeration	8.15953		Tail Water Reaeration	0.07164	
difference	-0.00677	-0.08%	difference	0.00002	0.03%
14 Tailwater locations only					

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Attachment 4. Allatoona-Coosa Reallocation Study—Flood Risk Management Impact Analysis

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APPENDIX C. ATTACHMENT 4: FLOOD RISK MANAGEMENT IMPACT ANALYSIS

CONTENTS

FIGURE

TABLES

C.1 Purpose and Need

An update of the Alabama Coosa Tallapoosa (ACT) River Basin Master Water Control Manaul (WCM) and individual project WCMs, supported by an Environmental Impact Statement (EIS), was completed in May 2015. During the WCM update process, the United States Army Corps of Engineers (USACE) deferred consideration of two specific requests pending completion of further detailed studies and analyses: (1) a January 2013 updated request from the state of Georgia to reallocate additional reservoir storage in Allatoona Lake to municipal and industrial (M&I) water supply and (2) an Alabama Power Company (APC) request for changes to flood operations at the APC Weiss and Logan Martin projects (including associated updates to the WCMs for those projects). The Feasibility Report (FR) and Integrated Supplemental EIS (SEIS), of which this report is an appendix, addresses these proposed actions that were deferred during the 2015 ACT River Basin WCM update process. A detailed discussion of the study background can be found in Section 1, labeled Purpose and Authority, of the FR/SEIS.

All proposed water reallocation alternatives were evaluated against legal, policy, public safety, economic, and environmental considerations, prior to the selection of a Tentatively Selected Plan (TSP). As a subset of the public safety consideration, it was deemed necessary to evaluate and determine what impacts the proposed TSP would have to the safety and stability of the Allatoona Lake Dam and to the downstream flood risk management (FRM) benefits currently provided by each of three projects being considered for operational changes in support of reallocation. Dam safety analysis was not completed for the two Alabama Power projects, as dam safety falls under the jurisdiction of the Federal Energy Regulatory Commission, and is covered under their relicensing process. This Appendix has been prepared to document and provide the results of the dam safety and/or flood risk management analysis completed on the Allatoona Lake, Weiss Dam and Lake, and Logan Martin Dam and Lake operational changes that are included in the TSP.

C.2 Project Background

C.2.1 Coosa River Basin Overview

The Coosa River is a part of the 22,820 square mile (sq-mi) ACT Basin, which stretches from southeast Tennessee to the Mobile River in Southern Alabama. The Coosa River Basin is a 10,200 sq-mi sub-watershed with headwaters originating in the Blue Ridge Mountains in the northwestern corner of Georgia and a small area of southeastern Tennessee. The Etowah River and the Oostanaula headwater tributaries, the Coosawattee and Conasauga Rivers, begin as small mountain springs that converge and form rivers that flow southwest along the valleys of the Blue Ridge Mountains and Cumberland Plateau. The Etowah River lies entirely within Georgia and is formed by mountain streams that rise on the southern slopes of the Blue Ridge Mountains at an elevation of about 3,250 feet. The Etowah River flows for 150 miles to Rome, Georgia, and has a drainage area of 1,860 sq-mi. The Etowah River varies in width from 100 to 300 feet, with stable banks that vary in height from 25 to 300 feet and an average fall of 17.9 feet per mile. Flows with moderately steep slopes through a hilly topography characterize the upper 21 miles of the Etowah River before the topography transitions to a flatter section for the next 85 miles of river flow. The lower reach of the river flows 44 miles through a low, flat, valley. Allatoona Dam and Lake Project is located on the Etowah River upstream of Cartersville, Georgia. The Conasauga and Coosawattee Rivers rise in the mountains to the west of the Etowah headwaters and flow to Newton Ferry, Georgia where they merge to form the Oostanaula River. The Coosawattee River is 45 miles long and has an average fall of 14.4 feet per mile; the Conasauga River is 95 miles long and has an average fall of 19.2 feet per mile. The Carters Dam and Lake Project is located on the Coosawattee River about 27 miles (mi) upstream of the confluence of the Coosawattee and Conasauga Rivers. Once formed, the Oostanaula River meanders southwesterly through a broad plateau for 47 miles, merging with the Etowah River at Rome, Georgia. The Oostanaula River has a total drainage area of 2,160 sq-mi with stable banks from 20 to 60 feet high.

The Coosa River is formed by the Etowah and Oostanaula Rivers at Rome, Georgia, and flows first westerly, then southwesterly, and finally southerly for a total of 286 miles before joining the Tallapoosa River to form the Alabama River south of Wetumpka, Alabama. The drainage area of the Coosa River is approximately 10,200 sq-mi. The riverbanks of the Coosa are stable and vary from 25 to 150 feet in height. The river width varies from 300 to 500 feet between banks. The Coosa River has a total fall of 454 feet in 286 miles, yielding an average slope of 1.59 feet per mile. The steepest slope occurs at the Fall Line in the lower reach. Alabama Power Company owns and operates three projects on the Coosa River with federal Flood Control authorizations: Weiss Dam and Lake, H. Neely Henry Dam and Lake, and Logan Martin Dam and Lake. In addition, they own and operate four additional projects: Lay, Mitchell, Jordan and Bouldin, which do not have federal water management authorizations. A map of the ACT basin can be seen in Figure 1.

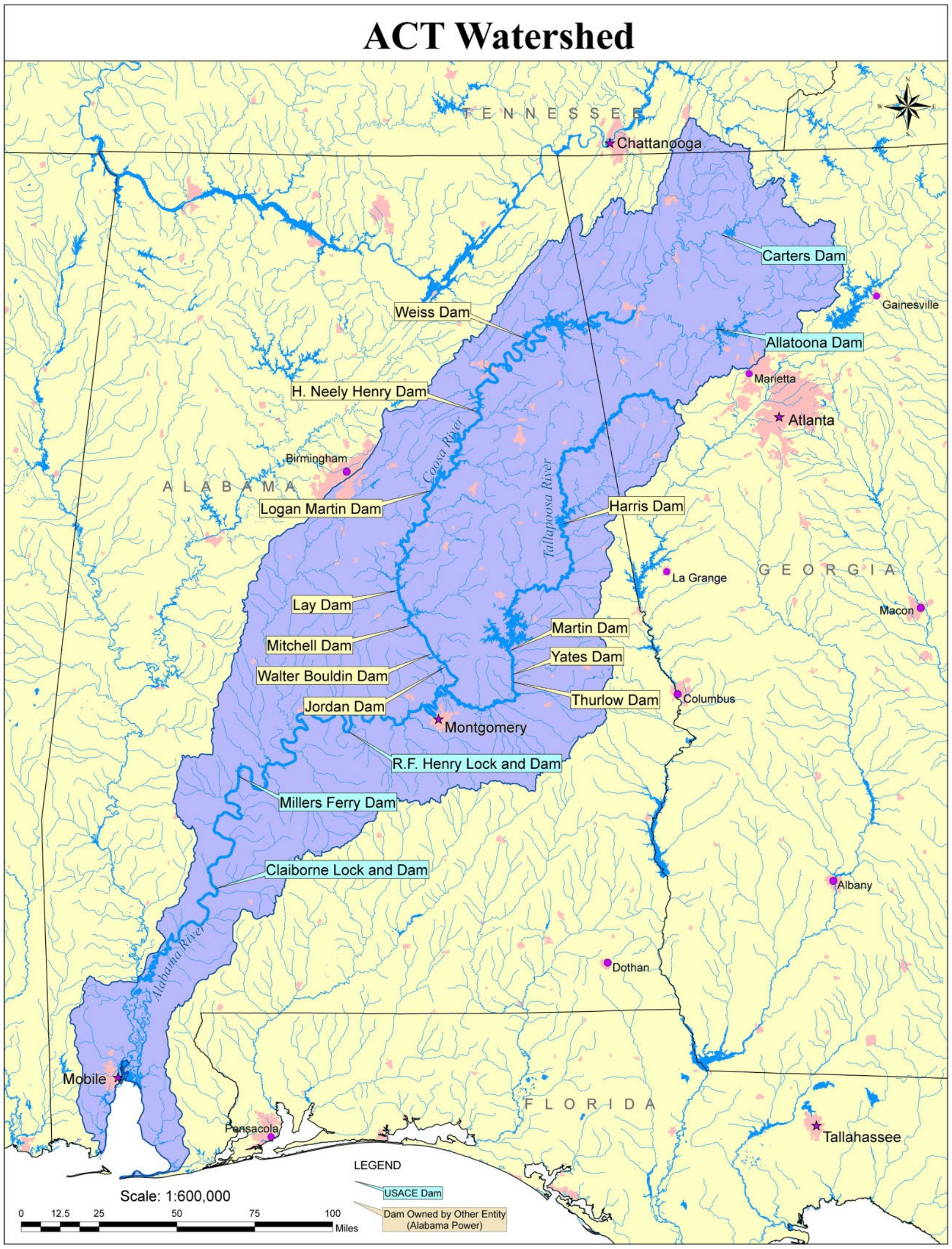

Figure 1: ACT Watershed Major Tributaries and Water Management Projects

C.2.1.1 Allatoona Dam and Lake

Authorized by the Flood Control Act of 1941 (P.L. 77-228, 55 Stat 638), Allatoona Dam and Lake is a USACE multipurpose reservoir project on the Etowah River (river mile 47.86) in northwest Georgia. The project consists of a gravity-type concrete dam 1,250 feet (ft) long having a top elevation of 880 ft. Power installation consists of two 40 megawatt (MW) generators and a 2.2 MW service unit (declared values). The lake has a surface area of 11,164 acres (ac) at normal pool elevation of 840 ft, a flood storage capacity of 288,606 acre-feet (ac-ft), and conservation storage capacity of 270,247 ac-ft. A minimum flow of about 240 cubic feet per second (cfs) is continuously released through a small service unit, which generates power while providing a constant flow to the Etowah River downstream, for water quality purposes. The major FRM areas downstream of Allatoona Dam are Cartersville, Kingston, and Rome, Georgia.

The top of the conservation pool at Allatoona Lake is at elevation 840 ft during the late spring and summer months (May through August); transitions to elevation 835 ft in the fall (October through mid-November); transitions to a winter drawdown to elevation 823 ft (1-15 January); and refills back to elevation 840 ft during the winter and spring wet season. However, the lake level may fluctuate significantly from the guide curve over time, dependent primarily upon basin inflows but also influenced by project operations, evaporation, withdrawals, and return flows. The project also has four action zones within the conservation storage that provide water control regulation guidance to meet water conservation while balancing the use of available storage to meet the project purposes. Under drier conditions when basin inflows are reduced, project operations are adjusted to conserve storage in Allatoona Lake while continuing to meet project purposes in accordance with the four action zones. Figure 2 gives the existing guide curve and top of flood control pool for Allatoona Lake.

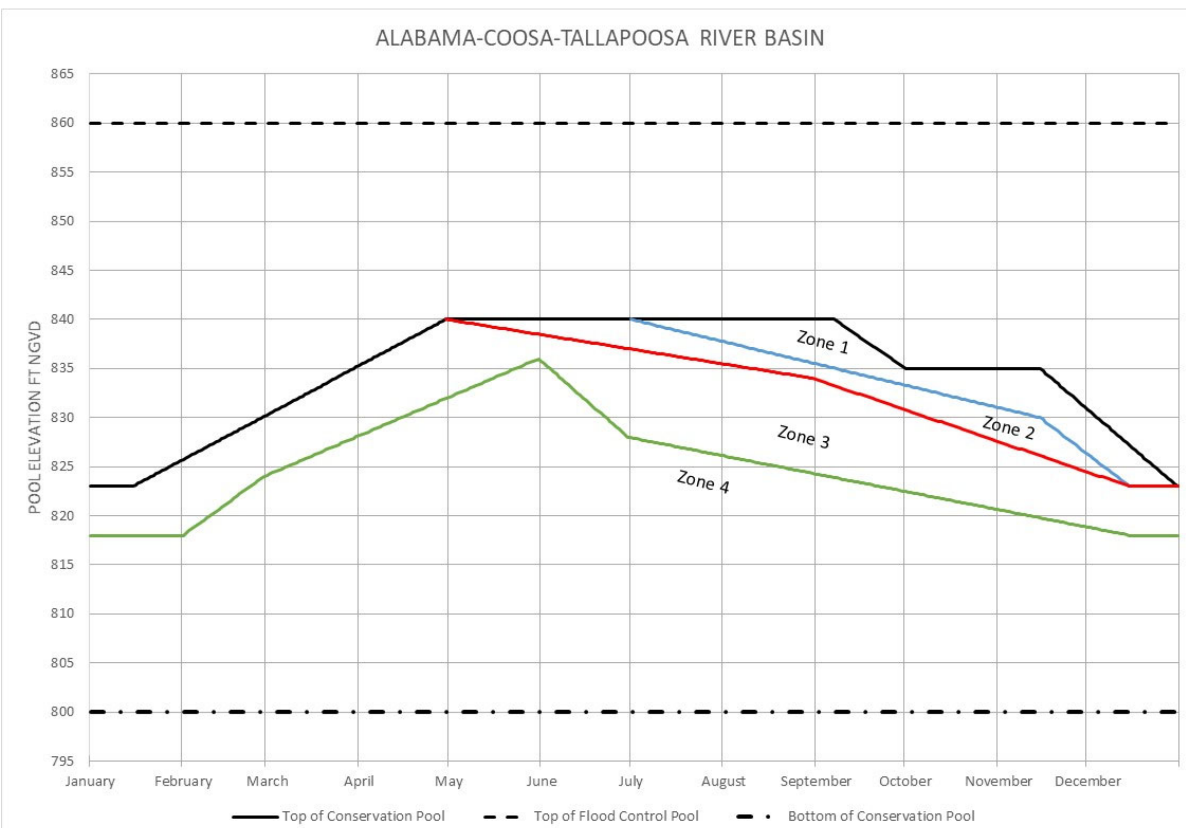

Figure 2: Allatoona Lake - Current Guide Curve and Top of Flood Control Pool.

C.2.1.2 Weiss Dam and Lake

Weiss Dam and Lake is on the Coosa River at river mile (RM) 225.7, about 50 mi upstream from Gadsden, Alabama, and about one mi southeast of the town of Leesburg, Alabama. The reservoir, extending from the dam about 52 mi upstream to Mayo's Bar, Georgia, is in Cherokee County, Alabama, and Floyd County, Georgia. Weiss Dam and Lake is a multiple purpose project and is the most upstream of seven APC reservoirs on the Coosa River. APC built it principally for hydropower production and to provide FRM and navigation benefits. The project is a source of water supply for domestic, agricultural, municipal, and industrial uses. The lake provides a large surface area, 30,027 ac, for water-based recreation, with opportunities for fishing, boating, and other water sports. The reservoir has 447 mi of shoreline and a maximum depth of 62 ft and is relatively shallow with an average depth of around 10 ft at normal pool elevation.

From May through the end of August, the reservoir is typically operated near full pool elevation of 564 ft during normal inflows and average system generating requirements. A drawdown of the reservoir begins in September and continues to the end of December when the level is lowered to elevation 558 ft. The reservoir begins refilling on January 1 and continues to refill until April 30, when full pool is normally reached. Available conservation storage is 263,417 ac-ft (USACE, Mobile District 2014a). Conservation storage is used for hydropower augmenting low inflow and seasonally for FRM capability for small flood events. The dedicated FRM pool for Weiss Lake is from 564 ft to 574 ft and provides 397,759 ac-ft of storage (FERC, 2009). Figure 3 gives the existing guide curve and maximum surcharge elevation for Weiss Dam and Lake.

The generating capacity of the project is 87.75 Mega Watts (MW). A canal about 7,000 ft long carries water from the main reservoir to the forebay at the powerhouse. Discharges through the Weiss Lake powerhouse flow into a 1,300-ft-long, man-made tailrace canal to re-enter the Coosa River at the downstream end of the bypass reach.

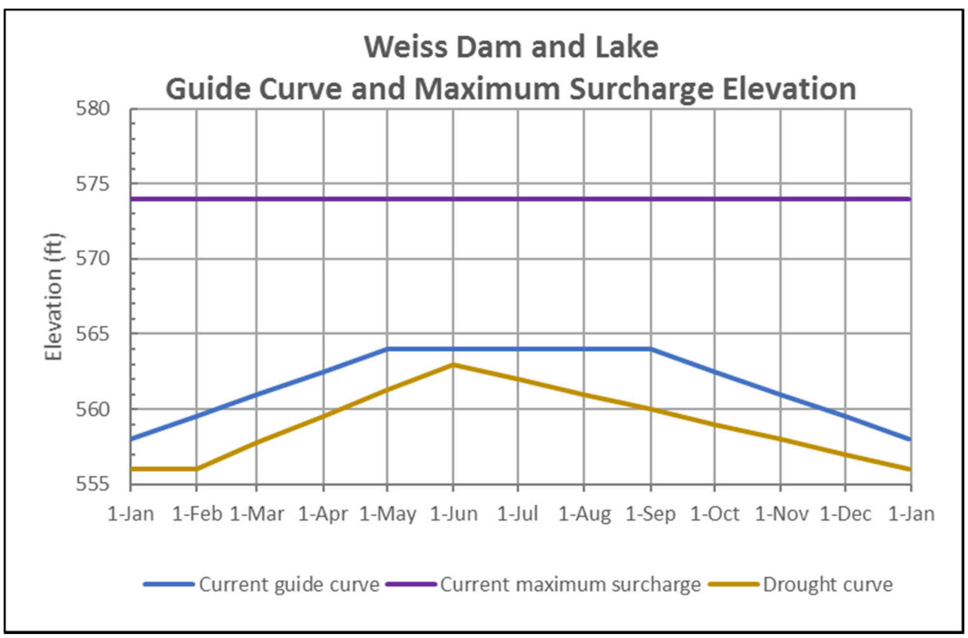

Figure 3: Weiss Dam and Lake - Current Guide Curve and Maximum Surcharge Elevation

C.2.1.3 Logan Martin Dam and Lake

Logan Martin Dam and Lake is on the Coosa River at RM 99.5, about 13 mi upstream from Childersburg, Alabama. The lake, extending upstream 48.5 mi to the H. Neely Henry Dam, is in Talladega, St. Clair and Calhoun counties.

The lake has 275 mi of shoreline and a maximum depth of 69 ft at the dam (FERC, 2009). The lake has a surface area of 15,269 ac and a total storage capacity of 273,467 ac-ft at the top of the conservation pool. Available conservation storage is 144,383 ac-ft (USACE Mobile District, 2014a). Logan Martin Dam and Lake is a multipurpose project. APC built it principally for hydropower production and to provide FRM and navigation benefits. The reservoir is a water supply for domestic, agricultural, municipal, and industrial uses. The lake provides a large surface area for water-based recreation, including opportunities for fishing, boating, and other water sports. The dedicated flood storage for Logan Martin Lake is from 465 ft to 477 ft and provides 245,673 ac-ft of storage (FERC, 2009). APC coordinates the operation of Logan Martin Lake with other projects on the Coosa River to minimize flooding. When inflow exceeds the power plant's capacity (32,700 cfs), the excess is released through the spillway.

APC normally operates the Logan Martin Lake in a peaking mode for several hours each weekday, depending on electrical power demand. Discharges from the Logan Martin Lake powerhouse enter the upper reaches of the Lay Lake immediately downstream from the Logan Martin Lake. The generating capacity of the project is 128.25 MW. From May 8 through the end of September, Logan Martin Lake is operated from the full pool elevation of 465.0 ft during normal inflows and system generating requirements. Beginning on October 1, the guide curve decreases to elevation 463.0 ft at the end of the month. Between November 1 and December 31, the water level drops to elevation 460 ft where it remains until March 30. On April 1, the water level begins rising toward the normal full pool elevation of 465.0 ft on May 8 (FERC, 2009). Figure 4 gives the existing guide curve and maximum surcharge elevation for Logan Martin Dam and Lake.

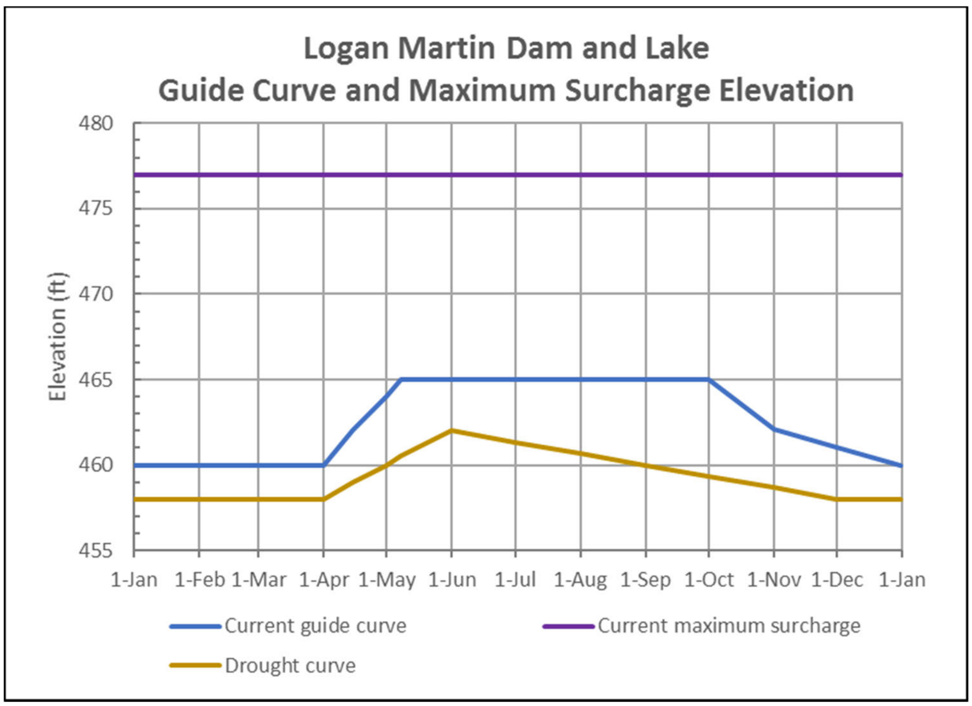

Figure 4: Logan Martin Dam and Lake - Current Guide Curve and Maximum Surcharge Elevation

C.2.2 Proposed Changes to Flood Operations

The following sections give a brief description of the proposed changes to flood operations, by project, that are being analyzed with respect to changes in downstream flood risk.

C.2.2.1 Description of the Proposed Changes to Flood Operations at Allatoona Lake

One of measures proposed as a solution to meet the Georgia water supply request was to reallocate all or part of the requested amount from the Allatoona flood pool. Initial calculations were completed that showed that a total reallocation from flood pool would result in an unacceptable decrease in available flood storage. Also, a secondary impact of a total reallocation from flood pool would be the need for significant modifications to existing recreational infrastructure to mitigate for higher pool levels. Based on this, a total reallocation from flood pool was screened without an analysis of FRM. The amount of reallocation from flood pool to be contained in the combination flood/conservation reallocation alternative was set by using the recreational infrastructure impact level as a guide in setting the maximum summer elevation. The conjugate rise in the winter drawdown was calculated by adding the volume of the proposed summer increase to the winter pool volume and obtaining the required pool elevation from the storage capacity curve. This method kept the spring refill volume approximately the same, which minimized impacts to the annual refilling of the pool. This methodology resulted in a summer increase of 1ft. and a winter increase of 1.5 ft. A graphical representation of these changes can be seen in Figure 1Figure 5. An increase in the summer and winter guide curve levels were the only proposed changes to the Allatoona flood operations. The analysis of changes in downstream FRM as a result of these proposed changes is documented in section C.3.

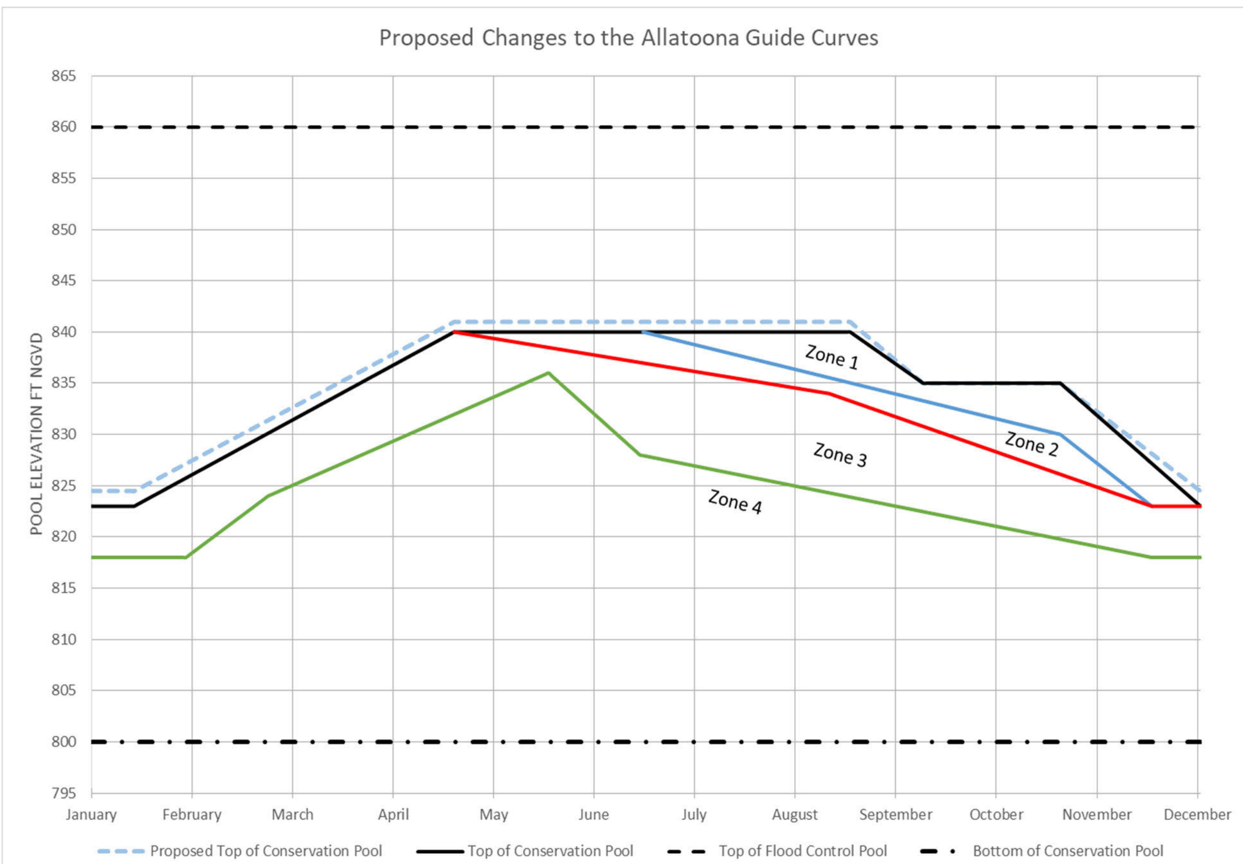

Figure 5: Proposed Changes to the Allatoona Guide Curve

C.2.2.2 Description of the Proposed Changes to Flood Operations at APC Weiss and Logan Martin Projects

APC proposes revisions to flood operation plans for the Weiss and Logan Martin projects, which include raising the winter guide curve elevation at each project, lowering the upper limit of the induced surcharge operation at each reservoir, and making some adjustments to the operating rules during flood events. Current water control plans for the Weiss and Logan Martin projects include induced surcharge curves with elevations higher than the flood easements acquired by APC at each project. APC variance requests, evaluated and approved by the USACE, have been necessary to avoid/minimize exceedances of APC flood easements at these reservoirs during major flood events.

C.2.2.2.1 Weiss Dam and Lake

APC proposes to increase the project guide curve level during the winter months (December through February) at Weiss Dam and Lake from elevation 558 ft to elevation 561 ft and to reduce the maximum surcharge elevation (top of flood pool) from elevation 574 ft to elevation 572 ft. In addition, APC has proposed to extend the summer guide curve elevation of 564 ft from September 1 to October 1. The request for a reduction in the top elevation of the induced surcharge pool is being made because APC did not obtain all of the easements required to raise the pool to elevation to 574 ft, which is the official top of the induced surcharge pool as stated in the WCM. The current maximum surcharge elevation is 2 ft higher than the APC flood easement elevation of 572 ft for Weiss Lake. The USACE was unaware until approximately 2011 that the flood easements were not all obtained prior to completion of the projects. These proposed changes would result in a 30 percent reduction in flood storage during the winter months and a 24 percent reduction in the flood storage at the project in the summer months. As a result of these proposed elevation changes, APC proposes to modify the current Flood Regulation Schedule for Weiss Dam. The proposed changes to the project guide curve and maximum surcharge elevation are depicted in Figure 6 . Figure 6 was taken from the APC report included as Attachment 7 of the Engineering Appendix C, within which a detailed description of the proposed changes to flood operations can be found. The analysis of changes in downstream FRM as a result of these proposed changes is documented in section C.3.

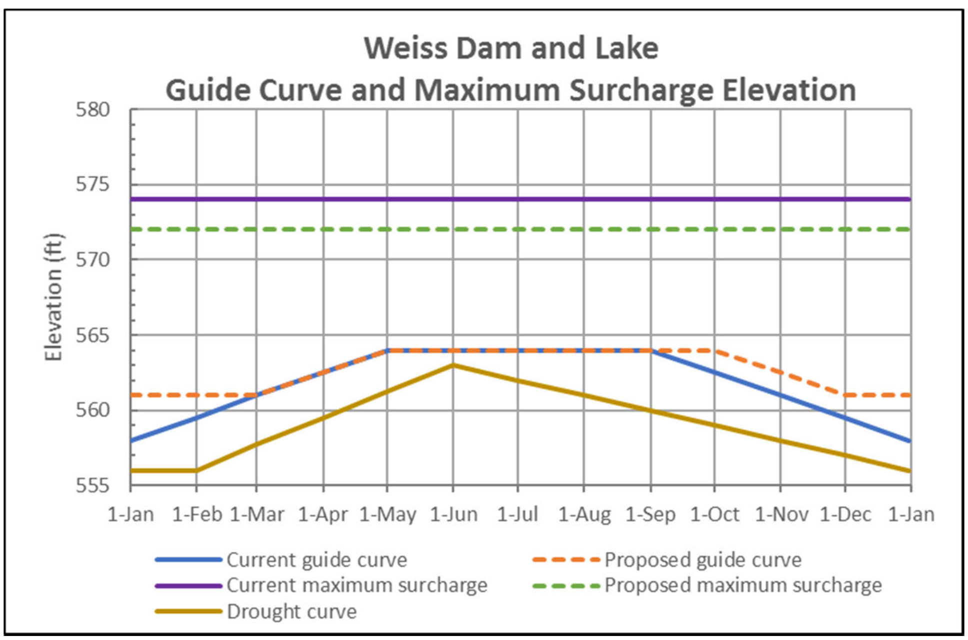

Figure 6. Weiss Dam and Lake - Proposed Changes to Guide Curve and Maximum Surcharge Elevation

C.2.3 Logan Martin Dam and Lake

APC proposes to increase the project guide curve level during the winter months (December through March) at Logan Martin Dam and Lake from elevation 460 ft to elevation 462 ft and to reduce the maximum surcharge elevation (top of flood pool) from elevation 477 ft to elevation 473.5 ft. The current maximum surcharge elevation is 3.5 ft higher than the APC flood easement elevation of 473.5 ft for Logan Martin Lake. These proposed changes would result in a 35 percent reduction in flood storage during the winter months and a 35 percent reduction in the flood storage at the project in the summer months. As a result of these proposed elevation changes, APC proposes to modify the current Flood Regulation Schedule for Logan Martin Dam. The proposed changes to the project guide curve and maximum surcharge elevation are depicted in Figure 7. Figure 7 was taken from the APC report included as Attachment 7 of the Engineering Appendix C, within which a detailed description of the proposed changes to flood operations can be found.

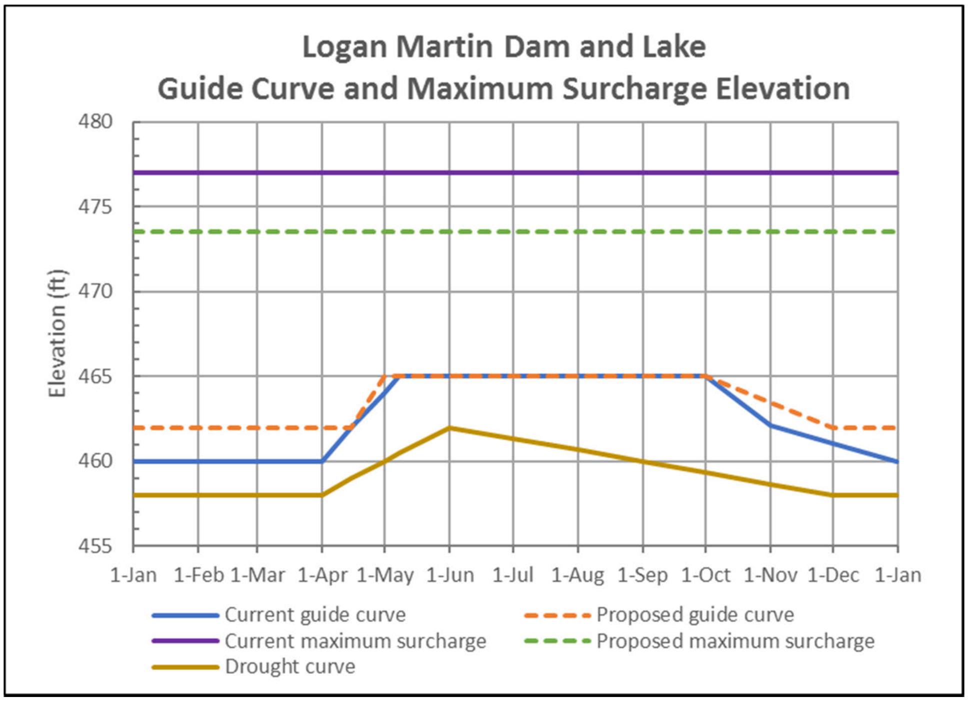

Figure 7. Logan Martin Dam and Lake - Proposed Changes to Guide Curve and Maximum Surcharge Elevation

C.3 Allatoona Impact Analysis

This section contains the methodology for and results of the analysis and consideration given to determine the impacts of the proposed flood pool changes at the Allatoona Reservoir on downstream flood risk. This includes a determination of whether the increases in normal pool elevations create or exacerbate any dam safety concerns, an analysis of downstream changes in flooding elevations, and consideration of the impacts of these changes to the Rome, GA levee safety program.

C.3.1 Dam Safety Impact Assessment

The following sections discuss the possibility that the proposed changes could impact the safety of the dam. It includes a description of the current dam safety status, a brief discussion of dam safety considerations associated with the proposed changes, and a routing comparison of the PMF based on current and proposed operations.

C.3.1.1 Current Dam Safety Status of Allatoona Dam

A dam's Hazard Classification is not based on condition, but on incremental loss of life potential in the event of project miss-operation or dam failure. Any project where the loss of one or more lives is probable due to miss-operation or failure is classified as High hazard potential. The Allatoona Dam is classified as a High hazard potential project.

Dam Safety Action Classification (DSAC) is a metric used to describe incremental loss of life risk associated with a dam project and the types of actions that are undertaken to manage that risk. The DSAC emanates from a risk assessment of the dam, which considers feature design, performance, and condition attributes in conjunction with dam failure impacts. The USACE Dam Safety Policy requires a routine risk assessment, called a Periodic Assessment, every ten years. The purpose of a Periodic Assessment is to validate or modify as necessary, a dam's DSAC.

The Allatoona Dam Project has two DSACs assigned to it; one for the main dam and one for Saddle Dike 1. The project has two DSAC's because a portion of the estimated loss of life consequences pertaining to failure of the Saddle Dike are separable from those corresponding to failure of the main dam.

The project's first Periodic Assessment occurred in October 2014, and subsequent to that assessment both the Dam and the Saddle Dike were assigned DSAC 4 ratings. DSAC 4 is characterized by low incremental risk, in that for confirmed and unconfirmed dam safety issues, the combination of life, economic, or environmental consequences with likelihood of failure is low to very low and the dam may not meet all essential USACE guidelines. The USACE considers this level of life-risk to be tolerable.

C.3.1.2 Dam Safety Assessment of the TSP

The Dam Safety Assessment for this project considers whether life safety risk attendant to the project might be changed as a result of the proposed Tentatively Selected Plan. The scope of the assessment is limited to examination and consideration of existing information and no new dam safety related risk assessments were performed.

The TSP proposes raising the pool 1.5 feet during the winter and one foot during the summer. The USACE Mobile District Hydraulics and Hydrology Section reports that there are no resultant impacts to the routed Probable Maximum Flood (PMF) maximum pool elevation, and that there are no significant downstream impacts to routed flood discharge. Thus, there are no apparent reservoir capacity or dam freeboard issues. The proposed pool raise is well with the dam design loading conditions, and there are no known flaws or features at or about the level of the proposed pool raise that are detrimentally occupied. There are no known stability issues with the reservoir rim that indicate adverse impacts resultant of the pool raise. In short, existing information gives no indication that the proposed pool raise portends an increase in the likelihood of an uncontrolled release of water from the project.

Because the fulfillment of the project purposes is dependent on maintaining the needed pool storage, it is important to note that there are no stop logs provided for the spillway gates. This means that in the event that a spillway gate fails, or cannot be closed, and the resultant discharge through the bay of the broken gate exceeds inflow, that the pool would gradually drop to the spillway crest, elevation 835.0 ft, until such time as the gate could be restored to service. This is well below the proposed full conservation pool elevation of 841.0 feet. Impacts to hydropower, recreation, and water supply may be realized in such an event.

Additionally, the project was designed and constructed to receive a third hydropower unit at some point in the future. The penstock was constructed, as was a cavity to receive a turbine and generator. The intake to this penstock is bifurcated and is occupied by two 'temporary' concrete bulkheads. This arrangement provides for no redundancy, which is undesirable. Slots for an additional set of bulkheads are provided upstream of those currently occupied by the temporary bulkheads, and it is desirable that new bulkheads be designed, constructed, and placed to fill those slots in order to provide redundancy against catastrophic failure of the temporary bulkheads.

C.3.2 Updated PMF Routing

The PMF from the WCM was routed through the reservoir, using both the existing and proposed project operations, to determine whether there would be an increase in the peak pool elevation. The starting pool elevation was chosen in accordance with the requirements set forth in ER 1110-8-2 FR, that the greater of the top of flood pool or the elevation occurring after a ½ Inflow Design Flood antecedent event should be used as the starting pool elevation. It was determined that using either of the two prescribed starting elevations would result in approximately the same starting elevation. The routing the PMF based on the current operations and the proposed operations, as shown in Figure 8, resulted in peak elevations that were nearly identical. The proposed operation produced a peak that was 0.06 ft higher than the base condition, however this difference was within the tolerances of the HEC-ResSim model being used to route the PMF hydrographs through the reservoir. Based on this analysis, there is not expected to be a change in the peak pool elevation experienced as a result of the PMF. An increase in the peak pool elevation would have resulted in a significant dam safety concern, as it could lead to the project being considered hydraulically deficient.

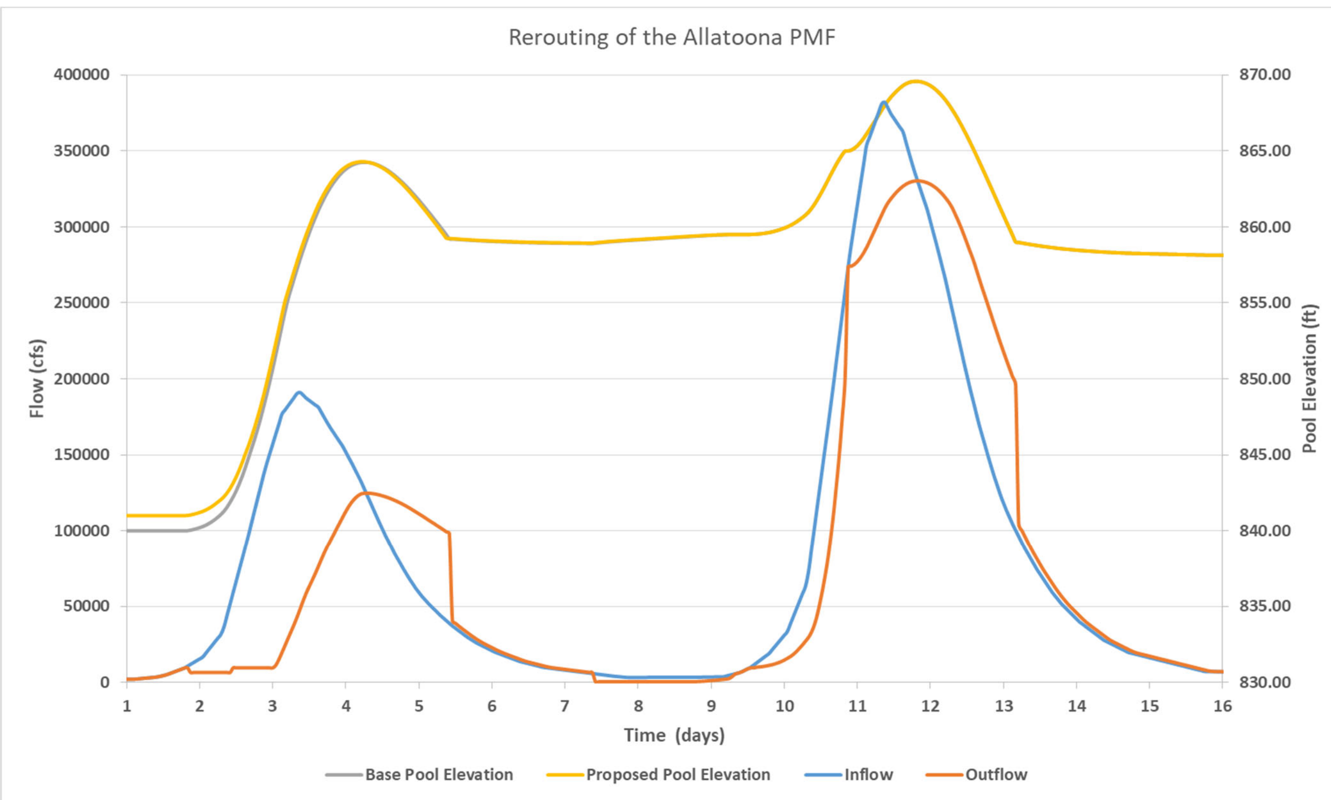

Figure 8: PMF Routing Comparison

C.3.3 Flood Risk Management Impact Analysis

The purpose of this analysis is to quantify the impacts that a flood pool reallocation would have on the current level of downstream FRM provided by the Allatoona project. These impacts were determined using a combination of reservoir simulation, hydraulic, and economic models. Scaled frequency storm hydrographs were run through a

HEC-ResSim model to obtain the Allatoona discharges for the base (existing) and proposed (with flood pool reallocation) project operations. These discharges were then input into a HEC-RAS model to calculate water surface profiles through the downstream damage reach. Depth grids resulting from each frequency event were then produced for both the base and proposed operations. These depth grids were then analyzed using HEC-FIA to determine the flood damages associated with each event. The impact of the flood pool reallocation on the current level of downstream FRM provided by the Allatoona project was then determined by comparing the base and proposed flood damages for each frequency event. A description of the HEC-FIA model and the results of the base and proposed flood damage comparisons can be found in Appendix B: Economics Appendix.

C.3.3.1 Damage Reach

The goal of the Allatoona FRM operations is to reduce flooding in the reach of the river between the dam and Rome, GA. There are three Georgia cities located on this reach of the river: Cartersville, Kingston, and Rome, with Rome being the main population center that receives FRM benefits from the Allatoona Project. The Carters Project also provides FRM benefits at Rome, Georgia. Of the 4,011 square miles of drainage area above Rome, Georgia (2,150 square miles Oostanaula River plus 1,861 square miles Etowah River), 374 square miles are controlled by Carters Dam, 146 square miles are controlled by Carters Reregulation Dam, and 1,122 square miles are controlled by Allatoona Dam. This leaves 59 percent of the drainage area at Rome, Georgia, unregulated. A federally constructed levee also helps reduce the flood risk for a portion of the city of Rome, GA. Table 1 gives the city, population, and distance below the Allatoona Dam.

Table 1: Cities within Allatoona’s Downstream Damage Reach.

City/State	Population (2016)	Miles Downstream from Dam
Cartersville, GA	20,169	4
Kingston, GA	521	28
Rome, GA	36,340	47/72*

*Miles Downstream of Allatoona/Carters

C.3.3.2 Hydrology

During the ACT Basin Water Control Manual (WCM) update, that was completed in 2015, the USACE Hydrologic Engineering Center was tasked to develop hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events on the Alabama Coosa Tallapoosa (ACT) River system basin above Rome, GA. These hydrographs were used in the current reallocation study to evaluate the impact of changes in flood control operations that would result from a reallocation from the Allatoona flood control pool. In order to determine the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events at the inflow locations and points of interest, the USACE Mobile District and the USACE Hydrologic Engineering Center (HEC) developed a 6 step process. This process consisted of (1) generating a daily vs. instantaneous peak flow relationships at various gages throughout the basin, (2) developing instantaneous, 1-, 3-, 5-, and 45-day frequency curves at Rome, (3) identification of three historic storm events, (4) converting the daily unimpaired data to hourly for these three historic storm events, (5) development and calibration of an HEC-HMS model, and (6) scaling the hourly data to produce the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events in the HEC-HMS model. A detailed report of the development of these hydrographs can be found in Engineering Appendix C Attachement 8: Development of Sub-daily Flows for the Upper Coosa.

The third step in the development of the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent chance annual exceedance events was the identification of three separate storm events. Three historic storm events were identified from the daily average unimpaired data set for use in this analysis (Nov-Dec 1961, Jan - Mar 1979, and Feb-Apr 1990). These storms were selected from the period of record because of their high 45-day volume, and their high peak flows. By developing unimpaired frequency flows at Rome, GA from three separate events, the proposed changes in Allatoona FRM operations can be tested on storm events that occured over different portions of the basin.

C.3.3.3 Reservoir Routing

The hourly hypothetical hydrographs developed in this analysis were developed for input to a reservoir system simulation (HEC-ResSim) model of the ACT River system. This hourly reservoir simulation model was developed to accurately reflect the Allatoona operations as laid out in the WCM. The scaled 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance hydrographs for each of the three historic storms were routed through the HEC-ResSim model using the operating rules for the base and proposed conditions. Furthermore, because the Allatoona operations change based on the time of year, each event was routed through the pool in January, April, June, and October to ensure that the full range of operations were tested. In all, there were 120 model simulations runs: 60 for the base operations, and 60 for the proposed operations. Because the summer operations have the least amount of available flood storage, the June simulation events were chosen to examine the downstream impacts of a flood pool reallocation. More detail on the reservoir routing can be found in the Engineering Appendix C Attachment 2: ResSim Hourly Modeling Report.

C.3.3.4 Hydraulic Modeling

This study utilized the unsteady HEC-RAS hydraulic model that is a part of the Corps Water Management System (CWMS) model of the ACT basin. A CWMS model is the combination of hydrologic, reservoir routing, hydraulic, and economic models into one system that can be used to analyze the impacts of real-time changes to project operations during flooding events. The HEC-RAS model was created for the Mobile District by West Consultants as a part of the ACT basin CWMS effort. See Enclosure 1 for an excerpt from the CWMS report that gives more information on the HEC-RAS Model development. The model was truncated adjacent to the old Mayo's Bar lock, to allow for shorter run times and to reduce the amount of required flow data. Because of the limited changes in operation being proposed at Allatoona, it was felt that truncating the model at this location would adequately capture the downstream impacts. Model results supported this initial assumption, and it was determined that modeling of the Coosa River downstream of Mayo's Bar would not be needed.

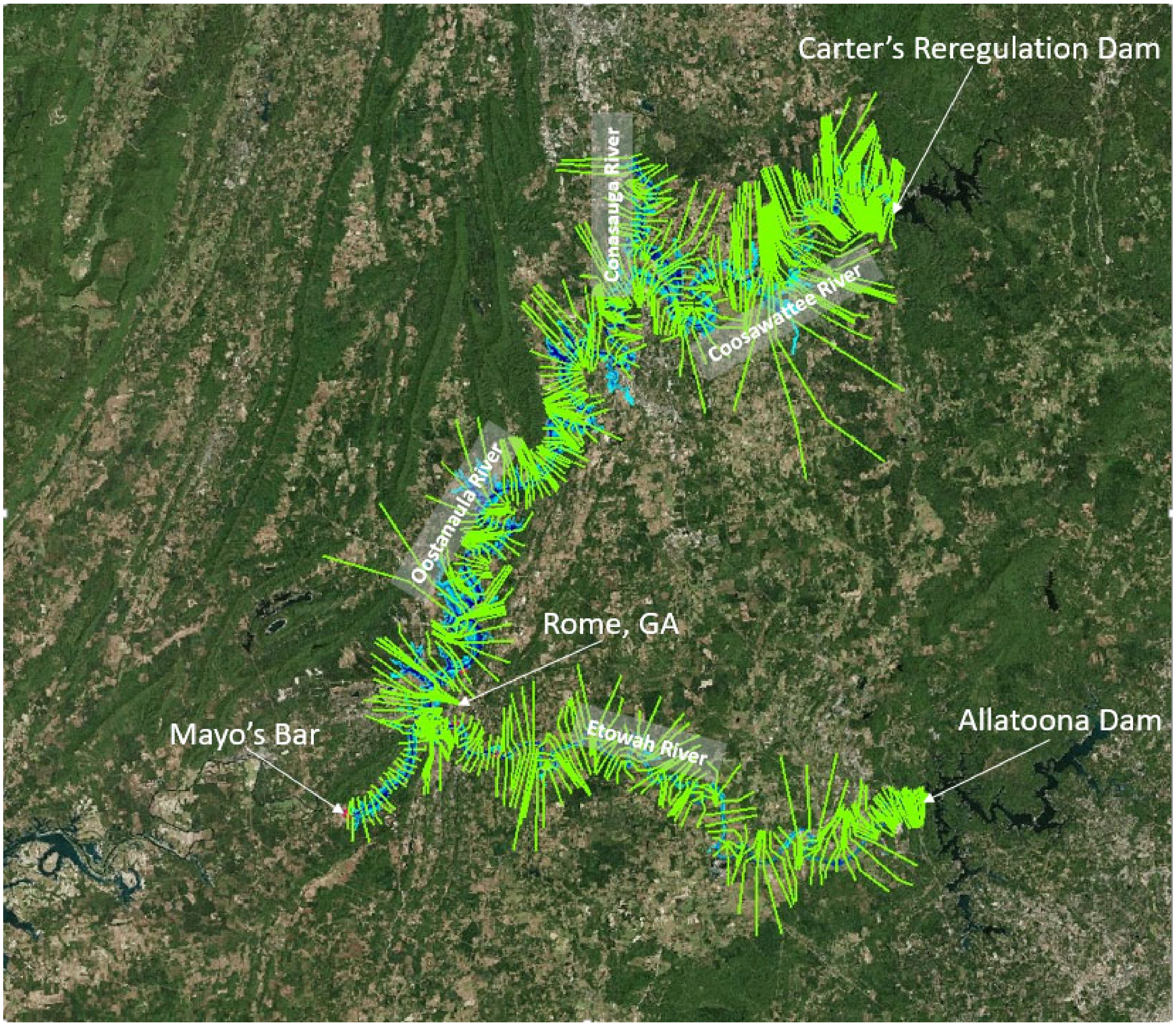

Figure 9: Truncated CWMS HEC-RAS Model

The only change to the HEC-RAS model was the updating of the model geometry in the vicinity of Rome, GA to include bridges and some adjustments of the Manning's n values in the vicinity of the bridges. The geometry of these bridges was collected in support of an effort to better define backwater impacts near the confluence of the Etowah and Oostanaula Rivers. A small HEC-RAS model, also taken from the CWMS HEC-RAS model, was updated with the field verified bridge geometries, calibrated, and then used to route a specific sequence of steady flows down the two rivers in an effort to create a better flow/stage relationship within the HEC-ResSim model. The results of this modeling effort can be found in Engineering Appendix C Attachment 2: HEC-ResSim Daily Modeling Report. The geometry from this small model was imported into the truncated CWMS HEC-RAS model in an effort to better represent the river hydraulics in the vicinity of Rome, GA.

The HEC-RAS model was then used to route the Allatoona discharges for the various events and frequencies for both the base (existing operation) and proposed (proposed operation) condition. The HEC-ResSim model also provided the discharge for the Carter's Reregulation Dam along with coincident flows for the tributaries flowing into the rivers being modeled. The Carter's Reregulation Dam discharge and the coincident flows were specific to the event and frequency, however they did not change between the base and proposed condition model runs. There were a total of 30 hydraulic model simulation runs completed in an effort to accurately characterize the changes in downstream conditions caused by the proposed operations.

C.3.3.5 Results

Table 2 through Table 5 give a comparison of the downstream peak water surface elevations, at specific locations within the downstream damage reach, that result from the base and proposed flood operations at the Allatoona Dam for each of the frequency storm events. The data output locations were chosen to represent areas of interest throughout the damage reach. The cross sections on the Oostanaula River were included to show the effects of back water near the confluence of the rivers, and, specifically, to capture any water surface changes adjacent to the Rome Levee. Table 2 below describes the locations of the sites chosen to display output data, while Figure 10 gives a visual location of the sites (the “Map Location” field of Table 2 should be used to match the location to the river mile). Appendix C, Attachment 10: Stage and Flow Hydrographs contains the associated stage/flow hydrographs, for each modeled event, at the cross sections shown in the tables below.

The results of this analysis show that the increased flooding risk in the damage reach below Allatoona dam is low, with the maximum modeled increase being 0.34 ft. The 0.34 ft of change in peak elevation adjacent to the levee occurred during a simulated 0.5% annual chance exceedance event scaled from a 1979 storm. This increase occurred at the top the Coosa and created a back water effect up both the Etowah and Oostanaula Rivers for a short distance. The change in water surface elevation was caused by a small increase in discharge from the Allatoona Dam that arrived at the confluence of the two rivers concurrently with the peak of the hydrograph on the Oostanaula. Of the three events that were scaled to a 0.5% annual chance exceedance, the 1979 event was the only event that had an increase greater than 0.01 ft adjacent to the levee. This shows that the 0.34 ft. increase is dependent on frequency flow, the temporal characteristics of the events, and the hydraulic responses of both river systems. Based on this, the actual likelihood of having an event that produces a change of this magnitude is well below the 0.5% annual chance exceedance assigned to the event.

Table 2: Description of model output locations below Allatoona Dam

Map Location	River Mile*	Location Description
Etowah River		
A	48.2	Just Downstream of Allatoona Dam
B	39.21	Near Cartersville
C	20.62	Near Kingston
D	1.7675	Upstream of Turner McCall Blvd.
E	0.325	Upstream of South Broad Street
Oostanaula River		
F	2.3384	Upstream of Veteran's Memorial Pkwy
G	0.89	Adjacent to the Upstream end of the Rome Levee
H	0.37	Downstream of 5th Ave
Coosa River		
I	271.16	Adjacent to the gated road closure in the Rome Levee
* River mile values reflect specific HEC-RAS Cross Sections		

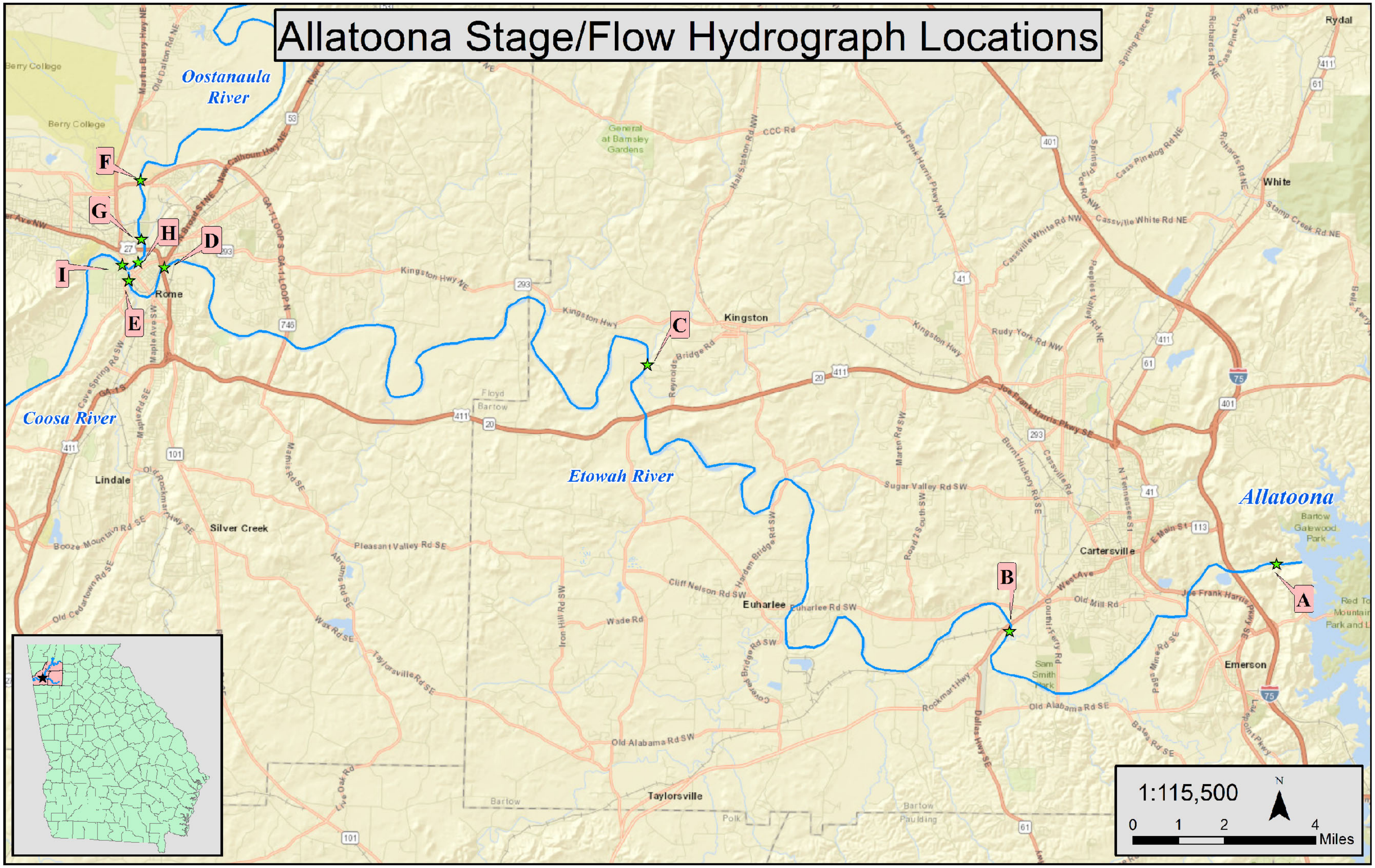

Figure 10: Allatoona Stage/Flow Hydrograph Location

Table 3: Peak Water Surface Comparison for Specific Locations on the Etowah River.

Etowah River					
River Mile	Storm	% Annual Chance Exceedance	Peak Base Elevation (ft)	Peak Proposed Elevation (ft)	Elevation Difference
48.2	1961	0.2	696.19	696.19	0
		0.5	696.19	696.19	0
		1	696.25	696.25	0
		2	696.19	696.19	0
		5	696.21	696.21	0
	1979	0.2	696.49	696.61	0.12
		0.5	696.2	696.2	0
		1	696.19	696.19	0
		2	696.19	696.19	0
		5	696.19	696.19	0
	1990	0.2	696.33	696.33	0
		0.5	696.19	696.19	0
		1	696.19	696.19	0
		2	696.19	696.19	0
		5	696.19	696.19	0
39.21	1961	0.2	665.5	665.5	0
		0.5	665.5	665.5	0
		1	665.53	665.53	0
		2	665.5	665.5	0
		5	665.51	665.51	0
	1979	0.2	665.79	665.9	0.11
		0.5	665.5	665.5	0
		1	665.5	665.5	0
		2	665.5	665.5	0
		5	665.5	665.5	0
	1990	0.2	665.56	665.56	0
		0.5	665.5	665.5	0
		1	665.5	665.5	0
		2	665.5	665.5	0
		5	665.5	665.5	0
Increased flooding					

Table 3 Continued:

Etowah River					
River Mile	Storm	% Annual Chance Exceedance	Peak Base Elevation (ft)	Peak Proposed Elevation (ft)	Elevation Difference (ft)
20.62	1961	0.2	619.4	619.4	0
		0.5	619.34	619.34	0
		1	619.29	619.29	0
		2	619.23	619.23	0
		5	619.14	619.14	0
	1979	0.2	622.08	622.08	0
		0.5	622.45	622.45	0
		1	622.2	622.2	0
		2	621.53	621.53	0
		5	620.9	621.05	0.15
	1990	0.2	620.8	620.82	0.02
		0.5	620.58	620.62	0.04
		1	620.41	620.47	0.06
		2	620.11	620.18	0.07
		5	619.76	619.91	0.15
1.7675	1961	0.2	593.74	593.74	0
		0.5	592.87	592.87	0
		1	592.74	592.74	0
		2	592.58	592.58	0
		5	586.95	586.96	0.01
	1979	0.2	593.67	593.81	0.14
		0.5	593.03	593.03	0
		1	592.25	592.25	0
		2	591.26	591.26	0
		5	590.33	590.49	0.16
	1990	0.2	592.82	592.82	0
		0.5	592.61	592.61	0
		1	591.96	591.96	0
		2	591.39	591.39	0
		5	590.58	590.59	0.01
Increased flooding					

Table 3 Continued:

Etowah River					
River Mile	Storm	% Annual Chance Exceedance	Peak Base Elevation (ft)	Peak Proposed Elevation (ft)	Elevation Difference
0.325	1961	0.2	593.71	593.72	0.01
		0.5	592.85	592.85	0
		1	592.37	592.37	0
		2	591.67	591.67	0
		5	585.96	585.97	0.01
	1979	0.2	593.49	593.62	0.13
		0.5	591.65	591.97	0.32
		1	590.62	590.62	0
		2	589.71	589.7	-0.01
		5	589.08	589.01	-0.07
	1990	0.2	592.21	592.21	0
		0.5	591.49	591.49	0
		1	590.84	590.84	0
		2	590.28	590.28	0
		5	589.46	589.47	0.01
Increased flooding					

Table 4: Peak Water Surface Comparison for a Specific Location on the Coosa River.

Oostanaula River					
River Mile	Storm	% Annual Chance Exceedance	Peak Base Elevation (ft)	Peak Proposed Elevation (ft)	Elevation Difference
2.3384	1961	0.2	595.11	595.11	0
		0.5	594.2	594.2	0
		1	593.69	593.69	0
		2	592.94	592.94	0
		5	586.9	586.91	0.01
	1979	0.2	594.57	594.72	0.15
		0.5	592.9	592.96	0.06
		1	591.79	591.79	0
		2	590.64	590.64	0
		5	589.83	589.73	-0.1
	1990	0.2	593.19	593.19	0
		0.5	592.39	592.4	0.01
		1	591.69	591.7	0.01
		2	591.09	591.09	0
		5	590.25	590.26	0.01
0.89	1961	0.2	594.24	594.24	0
		0.5	593.37	593.37	0
		1	592.88	592.88	0
		2	592.17	592.17	0
		5	586.34	586.35	0.01
	1979	0.2	593.93	594.07	0.14
		0.5	592.13	592.38	0.25
		1	591.05	591.05	0
		2	590.06	590.06	0
		5	589.41	589.38	-0.03
	1990	0.2	592.63	592.63	0
		0.5	591.89	591.89	0
		1	591.22	591.22	0
		2	590.61	590.61	0
		5	589.8	589.81	0.01
Increased flooding					

Table 4 Continued:

Oostanaula River					
River Mile	Storm	% Annual Chance Exceedance	Peak Base Elevation (ft)	Peak Proposed Elevation (ft)	Elevation Difference
0.37	1961	0.2	593.4	593.4	0
		0.5	592.58	592.58	0
		1	592.12	592.12	0
		2	591.47	591.47	0
		5	585.93	585.94	0.01
	1979	0.2	593.31	593.43	0.12
		0.5	591.55	591.84	0.29
		1	590.79	590.79	0
		2	589.86	589.86	0
		5	589.09	589.16	0.07
	1990	0.2	592.09	592.09	0
		0.5	591.41	591.41	0
		1	590.79	590.79	0
		2	590.25	590.25	0
		5	589.46	589.47	0.01
Increased flooding					

Table 5: Peak Water Surface Comparison for a Specific Location on the Coosa River.

Coosa River					
River Mile	Storm	% Annual Chance Exceedance	Peak Base Elevation (ft)	Peak Proposed Elevation (ft)	Elevation Difference
271.16	1961	0.2	593.28	593.29	0.01
		0.5	592.46	592.46	0
		1	591.99	591.99	0
		2	591.32	591.32	0
		5	585.74	585.75	0.01
	1979	0.2	593.02	593.13	0.11
		0.5	591.25	591.57	0.32
		1	590.37	590.37	0
		2	589.47	589.47	0
		5	588.81	588.79	-0.02
	1990	0.2	591.8	591.8	0
		0.5	591.11	591.11	0
		1	590.5	590.5	0
		2	589.96	589.96	0
		5	589.17	589.18	0.01

C.3.3.6 Levee Safety Impacts

The City of Rome, founded in 1834, has had a frequent history of flooding since its development. The center of the city is situated where the Etowah and Oostanaula Rivers unite to form the Coosa River. During times of flooding, the rivers would flood parts of the city, primarily the Fourth Ward, which is located to the north of the rivers' confluence. Frequent flooding prompted the USACE to construct a levee system along the banks of the Oostanaula and Coosa Rivers to reduce flood damages.

C.3.3.6.1 Project Description

The project was designed to provide protection against a flood with a magnitude similar to the 1886 flood, which reached an elevation equivalent to 602 feet NGVD29 (602.11 feet NAVD88) at the 5th Avenue gage. USGS estimates that this flood reached a peak flow of 70,000 cfs. The original project design and construction, completed in 1939, included a 1.7 mile-long, U-shaped earthen embankment, two concrete retaining walls at the 5th and 2nd Avenue bridges, two pump stations, two stoplog closures, and two culvert/gravity drains. The design crest elevation varies from 604.97 to 605.61 ft. NAVD88. After construction, the levee system was turned over to the City of Rome, who acts as the owner and operator of the levee system. Since the initial construction, the following changes have been made to the system by the City of Rome: the abandonment of both stop-log closure openings, the installation of one manual flood gate, the installation of an additional pump station, and the installation 2 culverts. During times of flooding, the City ensures the flood gate and culvert gates are closed, and the 3 pump stations are operated to remove interior drainage from the leveed area (the area that could potentially be flooded behind the levee in the event of a levee breach). The levee provides flood damage reduction for over 620 structures of public, commercial (including a hospital), private, and residential use. Population in the leveed area fluctuates between 1,700 to over 3,300 people depending on the time of day.

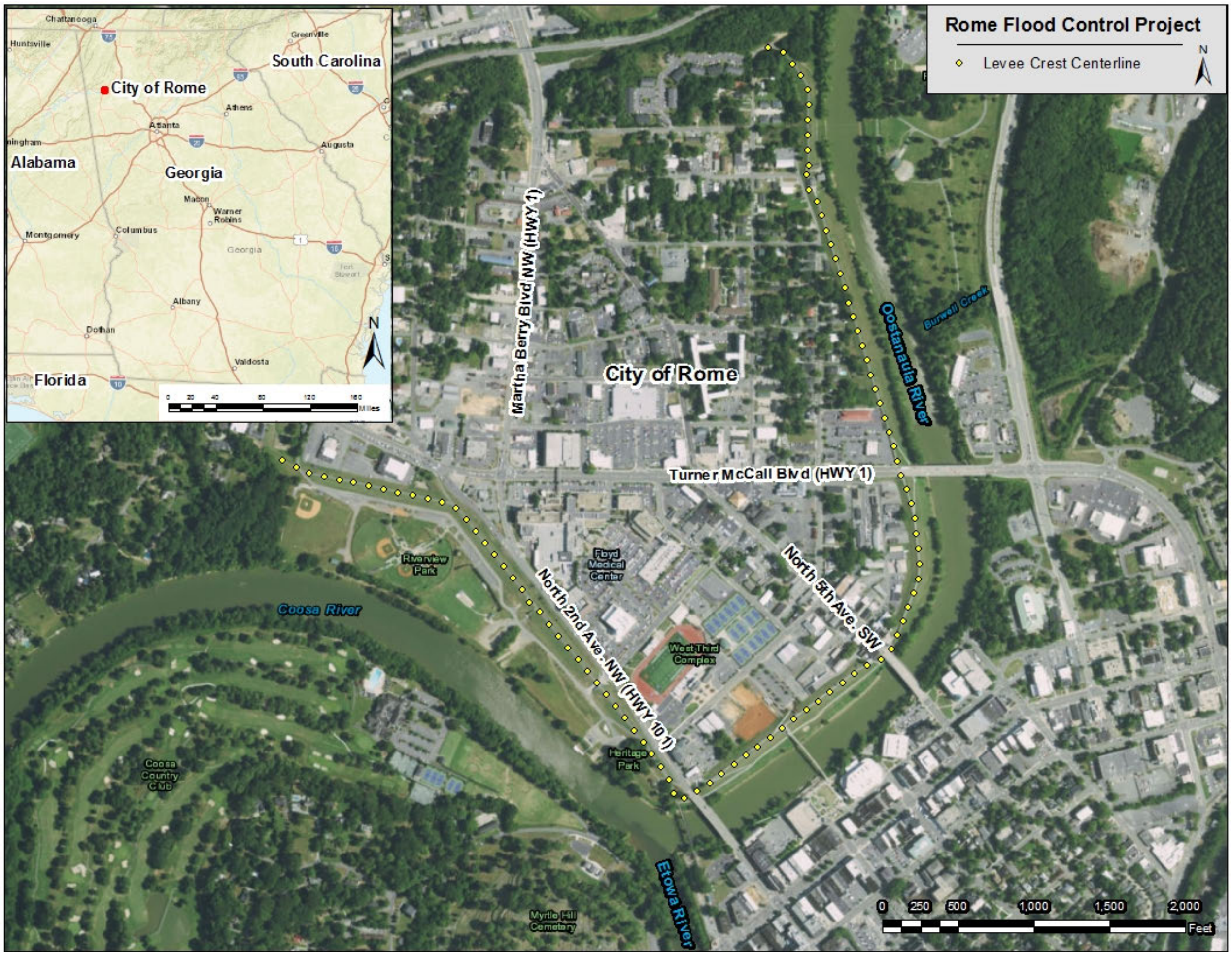

Figure 11: Location of the USACE constructed levee in Rome, GA

C.3.3.6.2 Risk Characterization of Existing Condition

The USACE completed a risk assessment of the Rome Levee in 2016. Since the construction of the levee, it has performed well, seeing multiple events that have loaded the levee to around 50% of its design height. However, there is some uncertainty associated with the levee performance should flood stage exceed 75% of the design height. Short of overtopping, seepage under and through the embankment is seen as the most significant risk for the system. Inspections of the levee show that it is well-maintained, however, there are some encroachments and isolated areas of vegetation on the embankment which could create pathways for seepage during flood events. Due to the population density in the leveed area, a breach could cause extensive damage and significant loss of life.

C.3.3.6.3 Risk Characterization of Proposed Condition

After analyzing the changes resulting from the proposed flood operations, it was determined that there would not be a measurable increase in risk to levee safety. This determination was made based on the small magnitude of the increase coupled with the small likelihood of its occurrence.

C.4 APC Modeling Results

This section summarizes the methodology for and results of the APC analysis completed to determine the impacts of the proposed flood pool changes at Weiss and Logan Martin Reservoirs on downstream flood risk. A Hydrologic Engineering Plan (HEMP), covering the analysis needed to determine the impacts of the proposed changes, was agreed to by the USACE and APC. The HEMP is included as Appendix C, Attachment 7: HEMP. All reservoir and hydraulic modeling was completed by APC, along with a modeling report that is included as Appendix C, Attachment 6: APC ResSim Modeling Report. The methodology and results contained in this section are based on the HEMP, APC report, discussions with the APC model team, and actual model output. The economic modeling and analysis referenced in this section were completed by the USACE Mobile District, and the results can be found in Appendix D: Economics.

C.4.1 Dam Safety Impact Assessment

Dam safety oversight of the APC projects is covered under the Federal Energy Regulatory Commission (FERC) license. Because the USACE does not have dam safety oversight for Weiss and Logan Martin Dams, this analysis does not cover impacts to dam safety resulting from the proposed changes. The USACE recommends that an assessment covering the impacts to dam safety from the proposed changes should be a requirement under the updated FERC License.

C.4.2 Updated PMF Routing

The rerouting of the existing WCM PMF, for each project, using the proposed FRM operation changes was the only dam safety related requirement covered by the HEMP. This requirement was included so that updated PMF routing plates could be included in the WCM updates. The PMF's were routed based on FERC requirements, which do not necessarily match USACE guidance. The following excerpt from the APC modeling report (Attachment 6 of Appendix C) gives the assumed conditions under which the PMF's were routed for each project:

> Inflow hydrographs for the Probable Maximum Flood events at Weiss and Logan Martin were determined in previous evaluations. Flows downstream of the evaluated projects were not determined in the updated PMF re-studies. Therefore, the proposed rules operating for a downstream control point were not modeled. The proposed operation to lower Logan Martin to 460' MSL was also removed. These assumptions result in a conservatively simplified model. Starting pool elevations were 564.12' MSL at Weiss and 460.09' MSL for the Base alternative and 462.09' MSL for the Proposed alternative at Logan Martin, consistent with previous PMF evaluations. Routing the PMF inflows through Weiss and Logan Martin was done at the request of the USACE and does not represent official PMF data for APC projects.

The APC rerouting of the PMF's using the proposed FRM operation changes resulted in a decrease of the peak elevation and discharge at both projects. This decrease is a result of the proposed operations calling for higher releases earlier in the event. Graphs of the updated PMF routing for both projects are shown below in Figure 12 and Figure 13.

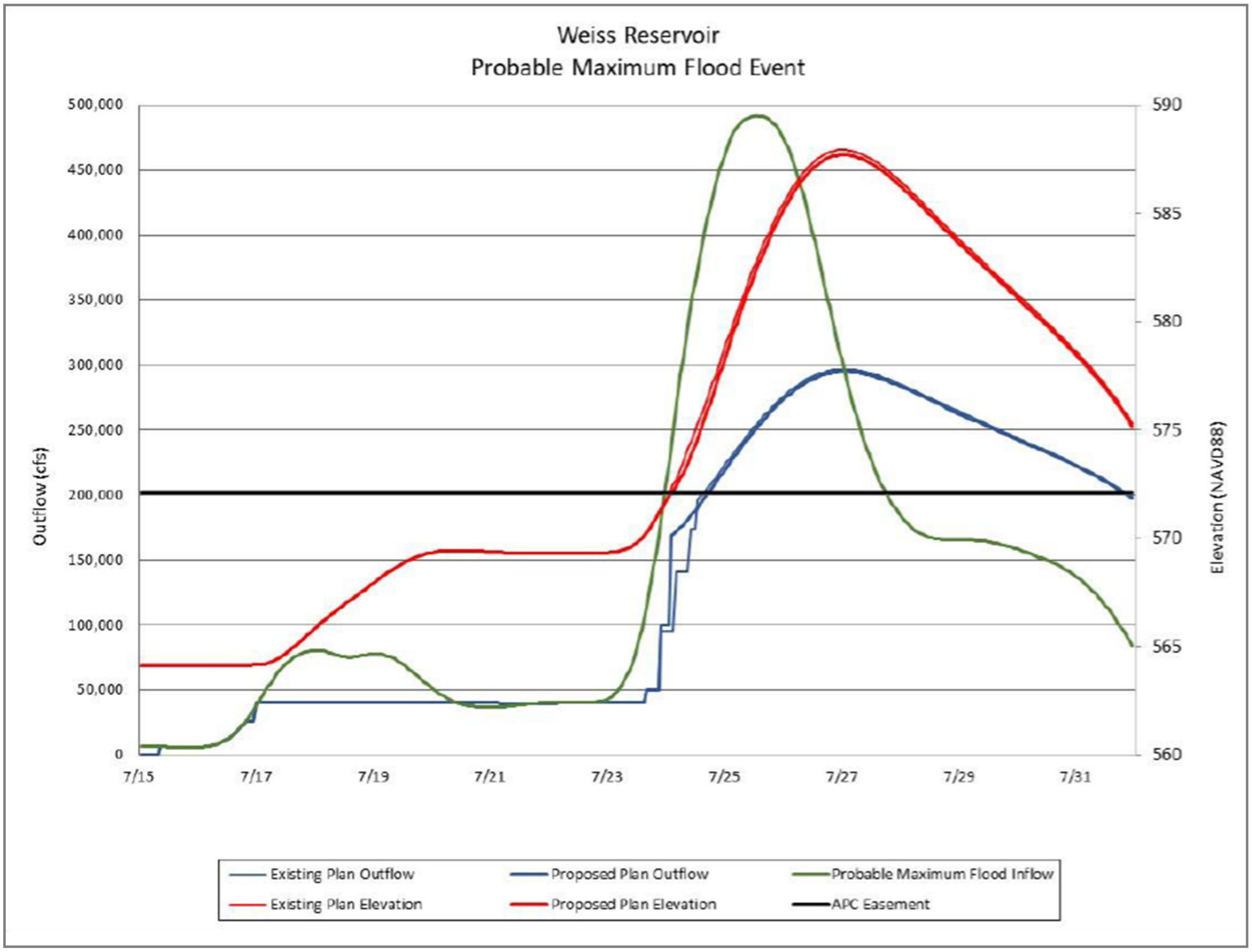

Figure 12: PMF Routing Comparison for Weiss Dam (Taken from the APC modeling Report found in Attachment 6 of Appendix C)

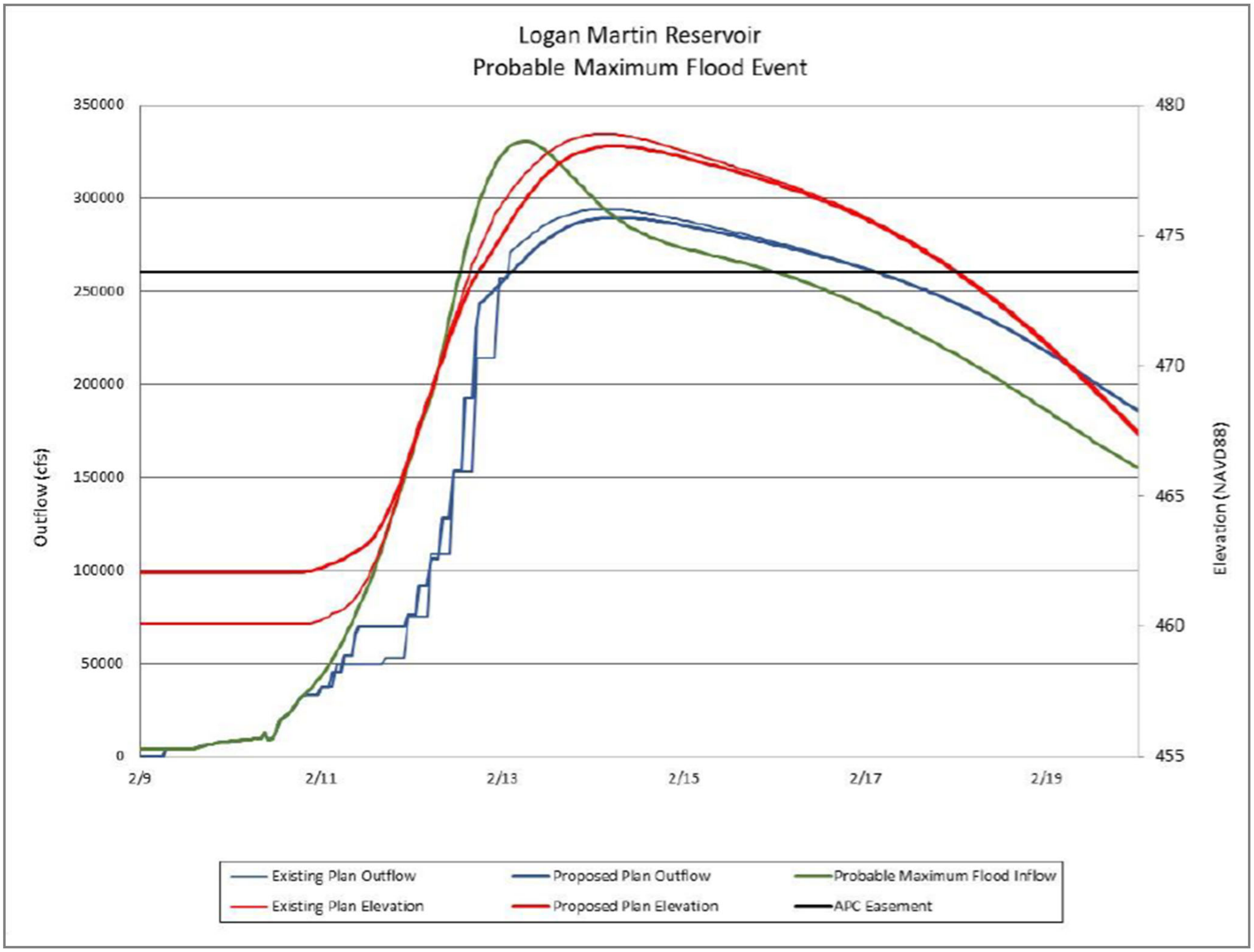

Figure 13: PMF Routing Comparison for Logan Martin Dam (Taken from the APC modeling Report found in Attachment 6 of Appendix C)

C.4.3 Flood Risk Management Impact Analysis

The purpose of this analysis is to quantify the impacts of the proposed FRM operational changes on the current level of downstream FRM provided by Weiss and Logan Martin Dams. These impacts were determined using a combination of reservoir simulation, hydraulic, and economic models. Multiple historical events and two scaled events were run through a HEC-ResSim model to obtain project discharges for the base (existing) and proposed (with FRM operational changes) project operations. These discharges were then input into a HEC-RAS model to calculate water surface profiles through the downstream damage reaches. Depth grids resulting from each event were then produced for both the base and proposed operations. These depth grids were then analyzed using HEC-FIA to determine the flood damages associated with each event. The impact of the flood pool reallocation on the current level of downstream FRM provided by the Allatoona project was then determined by comparing the base and proposed flood damages for each frequency event. A description of the HEC-FIA model and the results of the base and proposed flood damage comparisons can be found in Appendix D: Economics. The reservoir simulation and hydraulic modeling were completed by APC, while the economic modeling and analysis was completed by the USACE.

C.4.3.1 Damage Reach

The purpose of the APC FRM operations at Weiss dam is to reduce flooding in the reach of the river between the dam and Gadsden, AL. This reach of river is 30 miles long and consists primarily of farmland and small forests, with the majority of structures being located at or near Gadsden, AL. Likewise, the Logan Martin FRM operations are in place to reduce flooding in the reach of the Coosa River between the dam and Childersburg, AL. This reach of river is 13 miles long and consists primarily of forest, farm and industrial property, with the majority of structures being located at or near Childersburg, AL. Table 6 lists the city, and its population, below each project.

Table 6: Cities within APC Downstream Reaches

City/State	Population (2010)	Upstream Dam of Interest	Miles Downstream from Dam
Gadsden, AL	36,856	Weiss Dam (Powerhouse)	30
Childersburg, AL	5,175	Logan Martin Dam	13

C.4.3.2 Hydrology

APC developed a proposed design flood that replicated a 100 year, unregulated inflow hydrograph into each reservoir. The design flood was developed to evaluate the impacts of the proposed operational changes on the release hydrographs and downstream flooding compared with historical operation. Each design flood was developed by applying the 2004 Coosa River Basin Flood Frequency Analysis (HEC-FFA) to the USACE unimpaired, unsmoothed database inflows for the respective reservoirs. Three sets of frequency information were generated: (1) daily frequency volumes, (2) 3-day frequency volumes, (3) 5-day frequency volumes. The USACE database included average daily flows which reflected the appropriate volumes. These data, generated by HEC-FFA, were used to scale a historical hydrograph (February 1990 flood) to match the 1% chance exceedance volumes for 1, 3 and 5 day average volumes. The 1% chance of exceedance values were used to generate the design flood.

Based on a February 2007 technical conference between APC, FERC, USACE, and other stakeholders, it was determined that, due to issues with developing synthetic floods, multiple historical floods would be evaluated in lieu of completing the full range of frequency events. The USACE, FERC and APC agreed to evaluate the April 1979, February 1990, October 1995, and May 2003 events. The assigned frequencies these floods represent at various points along the river can be found Table 7.

Table 7: Evaluated Floods with Assigned Frequencies

Dam/event	Apr 1979	Feb 1990	Design Flood	Oct 1995	May 2003
Jordan	250-yr < X < 500-yr	25-yr	Unregulated 100-yr	5-yr	5-yr
Mitchell	250-yr < X < 500-yr	25-yr	Unregulated 100-yr	5-yr	8-yr
Childersburg		33-yr		5-yr	16-yr
Lay	250-yr	33-yr	Unregulated 100-yr	5-yr	13-yr
Logan Martin	250-yr	25-yr < X < 50-yr	Unregulated 100-yr		20-yr
Gadsden		90-yr		5-yr	10-yr
Henry	100-yr < X < 250-yr	75-yr	Unregulated 100-yr	5-yr	15-yr
Weiss	50-yr	100-yr	Unregulated 100-yr	5-yr	8-yr

In addition to the events discussed above, a synthetic event was created to simulate a back to back storm event. This event was created by taking the May 2003 event inflows at all model locations and increasing them by 30% to develop a back to back event. The resulting inflows represent an event with a frequency ranging from 15-year to greater than 150-year at different locations on the Coosa River.

C.4.3.3 Reservoir Routing

The storm hydrographs discussed above were developed for input to a reservoir system simulation (HEC-ResSim) model of the ACT River system. This hourly reservoir simulation model was developed to accurately reflect the APC project operations as laid out in the WCMs. The hydrographs for each of the storms were routed through the HEC-ResSim model using the operating rules for the base and proposed conditions. More detail on the APC reservoir routing can be found in the Engineering Appendix C, Attachment 6: APC ResSim Modeling Report.

C.4.3.4 Hydraulic Modeling

APC utilized the unsteady HEC-RAS hydraulic model that is a part of the Real Time Simulation (HEC-RTS) model of the ACT basin. HEC-RTS is the non-USACE version of CWMS, and is the combination of hydrologic, reservoir routing, hydraulic, and economic models into one system that can be used to analyze the impacts of real-time changes to project operations during flooding events. The HEC-RTS model was created around the same time as the CWMS model, and it utilized the CWMS HEC-RAS model. This HEC-RAS model was created for the Mobile District by West Consultants as a part of the overall ACT basin CWMS effort. APC completed significant improvements to the model by updating the terrain with LiDAR, adjusting poorly drawn cross sections, and updating Manning's n values. The HEC-RAS model was then used to route the APC project discharges for the various events for the base (existing), proposed, and proposed without cutbacks conditions. See Enclosure 1 for an excerpt from the CWMS report that gives more information on the HEC-RAS Model development.

C.4.3.5 Results

Table 9 gives a comparison of the downstream peak water surface elevations and flows at specific locations within the downstream damage reaches resulting from the base and proposed FRM operations at the APC projects. The data output locations were chosen to represent areas of interest throughout the damage reaches. Output data is provided for the base (existing), proposed, and proposed without cutbacks model runs of each storm event. The proposed and proposed without cutback scenarios were both provided, in an effort to show the impacts of the proposed cutback rule. The cutback rule was proposed to be used only during small events to reduce downstream impacts. A full description of this rule can be found in Engineering Appendix C, Attachment 6: APC ResSim

Modeling Report. Table 8 describes the locations of the sites chosen to display output data, while Figure 14 and Figure 15 give a visual location of the sites (the "Map Location" field of Table 8 should be used to match the location to the river mile). Appendix C, Attachment 10: Stage and Flow Hydrographs contains the associated stage/flow hydrographs, for each modeled event, at the cross sections shown in the table below.

The highlighted sections of Table 9 show the areas that have increased maximum WSE over the base condition for the analyzed events. Values highlighted with yellow show an increase if the cutback rule is not used, values highlighted with red show an increase if the cutback rule is used, and values highlighted in orange show an increase in WSE regardless of whether or not the cutback rule is used. If the cutback rule is correctly implemented, the majority of the red and yellow highlighted areas would be prevented, however the values highlighted in orange see WSE increases regardless of cutback rule implementation. The largest increase in WSE between the base and proposed condition occurs directly downstream of the Weiss spillway during the design event. River mile 213.98, below the spillway, had an approximate 4.68 ft increase in WSE using the without cutback scenario. The higher proposed WSE during the design event steadily decreased as the event moved downstream, with there being a net decrease of 0.07 ft in the maximum WSE at the I-759 Bridge (river mile 163.39) in Gadsden, AL. Based on the analyzed storm events, a correct implementation of the cutback rule would prevent any increases in WSE above 0.1 ft between Logan Martin and Lay Dams. Incorrect implementation of the cutback rule could see WSE elevations increase up to 2.54 ft above the base condition (Back to Back event at River Mile 81.51). The last significant downstream impact were seen just downstream of Lay Dam, where there was a consistent increase in WSE for smaller events. The largest increase at river mile 44.43 occurred during the Oct 1995 event and consisted of a 1.99 ft increase in WSE for the with cutback scenario. A positive benefit of the proposed FRM operational changes is that many locations along the Coosa River experienced decreased peak WSE elevations for the analyzed storm events when the proposed operational changes were implemented. The largest decrease of 3.19 ft occurred at river mile 113.63 for the October 1995 event.

Table 8: Description of model output locations below Weiss and Logan Martin Dams

Map Location	River Mile*	Location Description
Weiss		
A	213.98	Downstream of Weiss Spillway
B	195.22	Downstream of Weiss Powerhouse
C	192.04	River Adjacent to Coosa Drive
D	187.35	River Adjacent to Longview Drive
E	166.33	River Adjacent to power plant and Goodyear
F	163.39	River Upstream of the 759 Bridge
G	138.66	Downstream of Neely Henry Dam
H	113.63	River Upstream of the I-20 Bridge
Logan Martin		
I	90.65	Downstream of Logan Martin Dam
J	84.45	Adjacent to the Childersburg Industrial Complex
K	81.51	Adjacent to the Paper Mill
L	78.8	River Upstream of the 38 Bridge in Childersburg
M	69.33	Adjacent to the Power Plant
N	44.43	Downstream of Lay Dam
* River mile values reflect specific HEC-RAS Cross Sections		

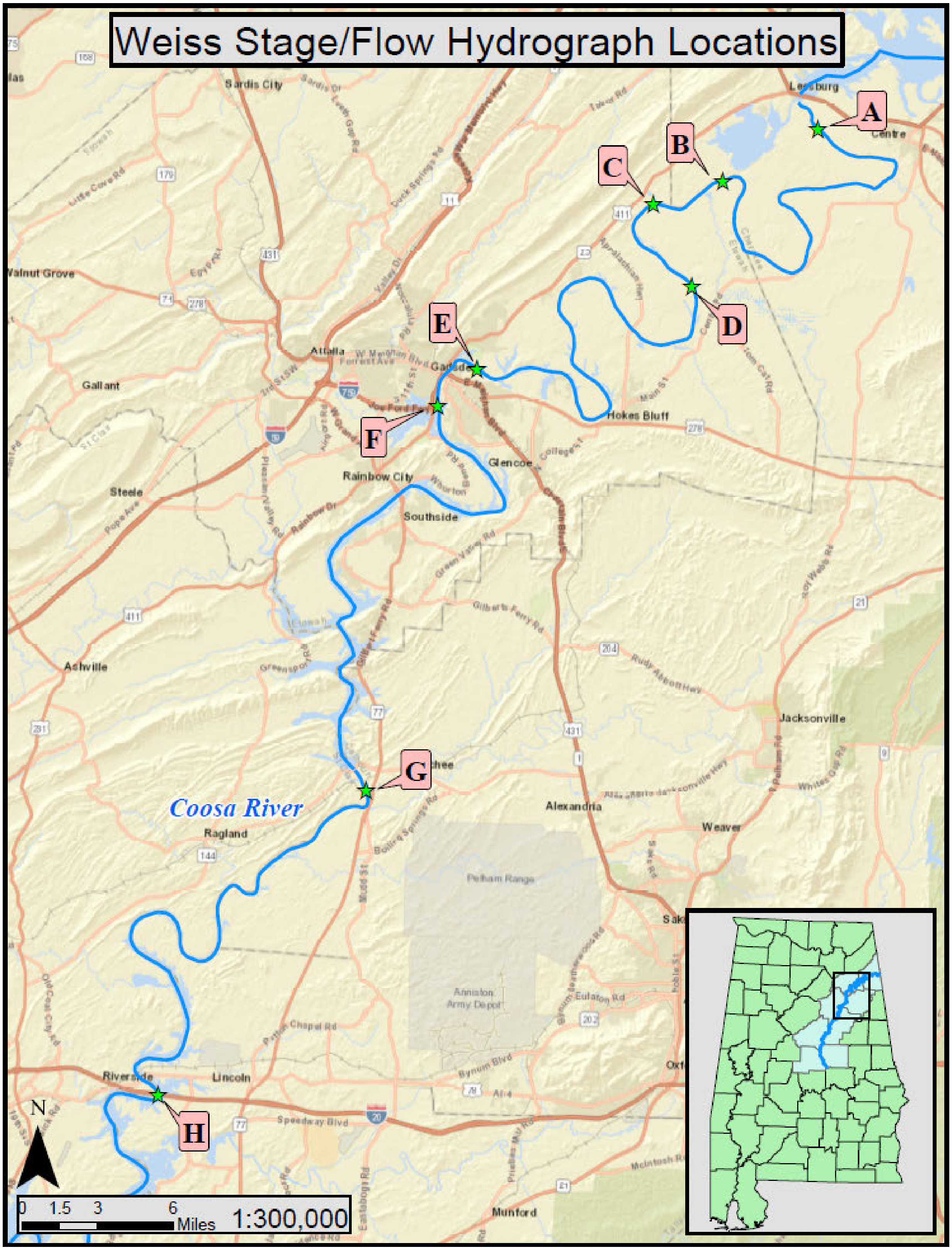

Figure 14: Weiss Stage/Flow Hydrograph Locations

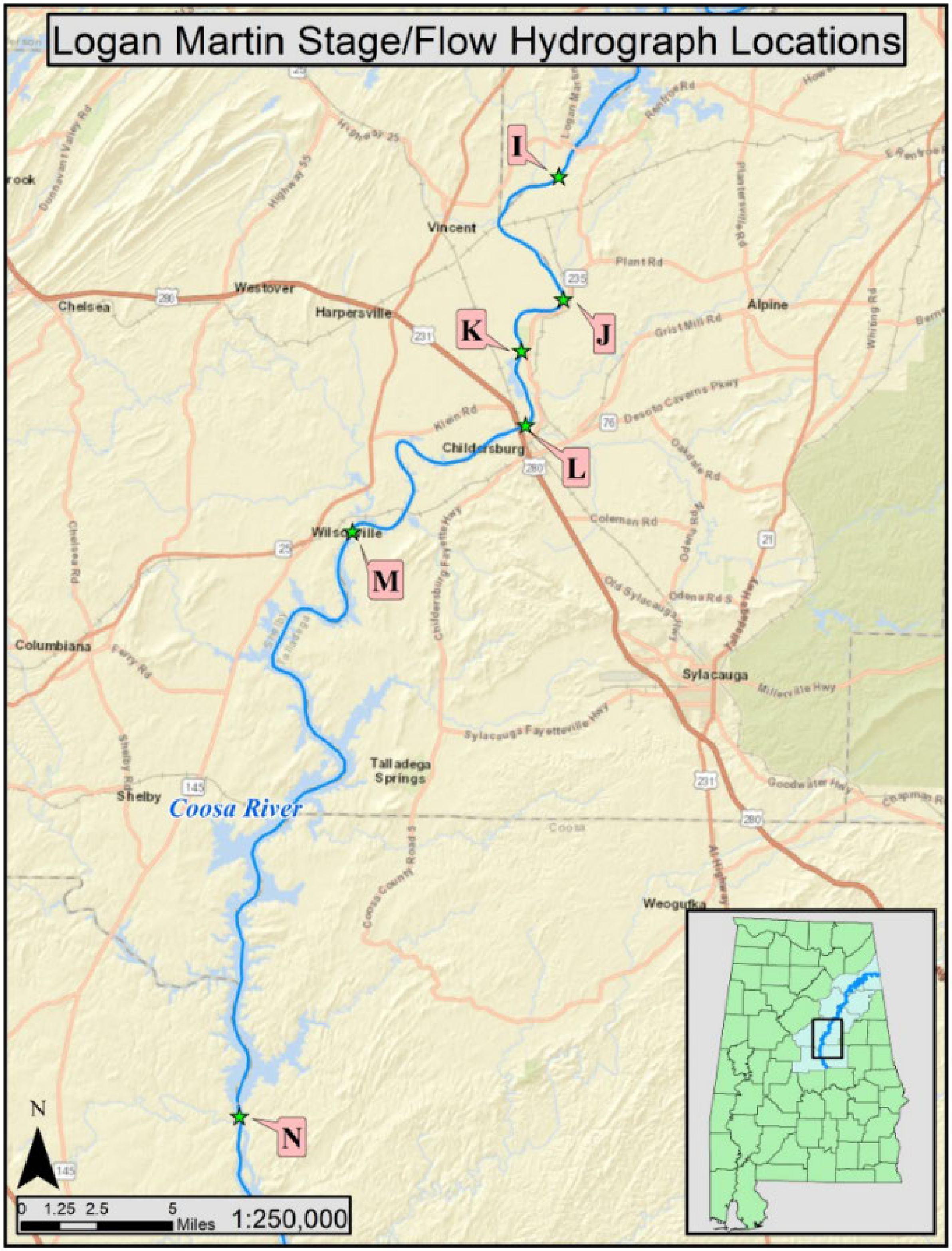

Figure 15: Logan Martin Stage/Flow Hydrograph Locations

Table 9: Peak Water Surface and Flow Comparison for Specific Locations on the Coosa River.

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
213.98	April-79	0.004-0.02	With	535.73	536.28	0.55	17,898	24,730	6,832
			Without	535.73	536.6	0.87	17,898	23,445	5,547
	Feb-90	0.01-0.011	With	540.56	538.91	-1.65	31,383	28,116	-3,267
			Without	540.56	538.43	-2.13	31,383	26,799	-4,583
	Oct-95	0.2	With	535.76	535.8	0.05	14,004	13,940	-64
			Without	535.76	535.8	0.05	14,004	13,940	-64
	May-03	0.1-0.125	With	532.16	532.16	0	14,111	14,112	0
			Without	532.16	532.16	0	14,111	14,112	0
	Back to Back	NA	With	532.55	532.48	-0.07	14,642	14,550	-92
			Without	532.55	532.48	-0.07	14,642	14,550	-92
	Design Storm	0.01 (Unregulated)	With	536.66	541.37	4.71	21,694	34,427	12,733
			Without	536.66	541.34	4.68	21,694	33,951	12,256
195.22	April-79	0.004-0.02	With	528.93	527.93	-1	50,759	49,484	-1,276
			Without	528.93	528.67	-0.26	50,759	51,185	426
	Feb-90	0.01-0.011	With	532.22	530.53	-1.69	60,734	56,450	-4,283
			Without	532.22	530.85	-1.37	60,734	55,098	-5,636
	Oct-95	0.2	With	528.52	528.61	0.09	52,701	52,258	-444
			Without	528.52	528.61	0.09	52,701	52,862	161
	May-03	0.1-0.125	With	525.82	525.82	0	42,892	42,892	0
			Without	525.82	525.91	0.09	42,892	42,901	10
	Back to Back	NA	With	526.15	526.11	-0.04	43,803	43,687	-116
			Without	526.15	526.11	-0.04	43,803	43,687	-116
	Design Storm	0.01 (Unregulated)	With	530.39	531.99	1.6	52,894	62,658	9,764
			Without	530.39	533.04	2.65	52,894	62,507	9,613
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

Table 9 Continued:

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
192.04	April-79	0.004-0.02	With	527.29	526.32	-0.97	50,540	48,683	-1,858
			Without	527.29	526.93	-0.36	50,540	51,191	651
	Feb-90	0.01-0.011	With	530.65	528.84	-1.81	61,160	56,323	-4,837
			Without	530.65	529.35	-1.3	61,160	55,259	-5,901
	Oct-95	0.2	With	526.73	526.82	0.09	51,650	51,137	-513
			Without	526.73	526.82	0.09	51,650	51,899	249
	May-03	0.1-0.125	With	524.09	524.09	0	42,671	42,671	0
			Without	524.09	524.09	0	42,671	42,671	0
	Back to Back	NA	With	524.4	524.36	-0.04	43,720	43,603	-117
			Without	524.4	524.36	-0.04	43,720	43,603	-117
	Design Storm	0.01 (Unregulated)	With	529.16	530.3	1.14	51,901	62,084	10,183
			Without	529.16	531.57	2.41	51,901	62,602	10,701
187.35	April-79	0.004-0.02	With	524.82	523.91	-0.91	50,593	48,459	-2,134
			Without	524.82	524.24	-0.58	50,593	51,309	716
	Feb-90	0.01-0.011	With	528.52	526.39	-2.13	61,575	56,452	-5,123
			Without	528.52	527.14	-1.38	61,575	55,591	-5,984
	Oct-95	0.2	With	524	524.1	0.1	51,183	50,839	-344
			Without	524	524.1	0.1	51,183	51,467	283
	May-03	0.1-0.125	With	521.41	521.41	0	42,556	42,556	0
			Without	521.41	521.41	0	42,556	42,556	0
	Back to Back	NA	With	521.68	521.65	-0.03	43,659	43,542	-118
			Without	521.68	521.65	-0.03	43,659	43,542	-118
	Design Storm	0.01 (Unregulated)	With	527.51	528.18	0.67	52,345	61,783	9,439
			Without	527.51	529.38	1.87	52,345	62,823	10,478
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

Table 9 Continued:

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
166.33	April-79	0.004-0.01	With	513.88	513.57	-0.31	53,791	50,915	-2,876
			Without	513.88	513.57	-0.31	53,791	52,672	-1,118
	Feb-90	0.011	With	515.89	514.36	-1.53	66,488	59,267	-7,221
			Without	515.89	514.76	-1.13	66,488	62,289	-4,198
	Oct-95	0.2	With	514.14	514.17	0.03	62,898	57,359	-5,539
			Without	514.14	514.17	0.03	62,898	63,053	154
	May-03	0.1	With	511.57	511.57	0	42,906	42,906	0
			Without	511.57	511.57	0	42,906	42,906	0
	Back to Back	NA	With	511.57	511.56	-0.01	43,367	43,252	-115
			Without	511.57	511.56	-0.01	43,367	43,252	-115
	Design Storm	0.01 (Unregulated)	With	515.45	515.05	-0.4	61,395	66,979	5,583
			Without	515.45	515.63	0.18	61,395	71,923	10,527
163.39	April-79	0.004-0.01	With	513.21	512.95	-0.26	54,089	51,343	-2,746
			Without	513.21	512.95	-0.26	54,089	52,708	-1,381
	Feb-90	0.011	With	515.89	513.75	-2.14	66,488	59,325	-7,162
			Without	515.89	514.09	-1.8	66,488	62,261	-4,226
	Oct-95	0.2	With	513.19	513.22	0.03	62,638	57,374	-5,264
			Without	513.19	513.22	0.03	62,638	62,808	170
	May-03	0.1	With	511.01	511.01	0	43,097	43,097	0
			Without	511.01	511.01	0	43,097	43,097	0
	Back to Back	NA	With	511.01	511	-0.01	43,553	43,438	-115
			Without	511.01	511	-0.01	43,553	43,438	-115
	Design Storm	0.01 (Unregulated)	With	514.76	514.56	-0.2	61,565	67,235	5,670
			Without	514.76	514.69	-0.07	61,565	72,207	10,642
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

Table 9 Continued:

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
138.66	April-79	0.004-0.01	With	484.79	484.4	-0.39	95,591	95,615	24
			Without	484.79	484.4	-0.39	95,591	95,616	25
	Feb-90	0.013	With	484.77	482.28	-2.49	104,835	90,554	-14,281
			Without	484.77	482.77	-2	104,835	91,330	-13,505
	Oct-95	0.2	With	480.97	481.12	0.15	87,472	94,854	7,382
			Without	480.97	481.12	0.15	87,472	79,664	-7,807
	May-03	0.067	With	481.76	481.7	-0.06	88,943	88,987	44
			Without	481.76	481.7	-0.06	88,943	88,987	44
	Back to Back	NA	With	482.83	482.61	-0.22	95,234	95,295	62
			Without	482.83	482.61	-0.22	95,234	95,295	62
	Design Storm	0.01 (Unregulated)	With	483.98	482.92	-1.06	92,989	92,875	-113
			Without	483.98	482.88	-1.1	92,989	92,916	-73
113.63	April-79	0.004	With	475	474.61	-0.39	106,907	107,521	615
			Without	475	474.45	-0.55	106,907	104,425	-2,482
	Feb-90	0.02-0.04	With	475.77	472.58	-3.19	95,724	83,417	-12,308
			Without	475.77	472.79	-2.98	95,724	86,976	-8,748
	Oct-95	0.2	With	471.45	472.46	1.03	80,122	80,620	498
			Without	471.45	472.46	1.03	80,122	76,681	-3,441
	May-03	0.05	With	473.28	472.45	-0.83	72,948	76,235	3,287
			Without	473.28	472.45	-0.83	72,948	76,235	3,287
	Back to Back	NA	With	474.5	473.74	-0.76	81,969	81,306	-662
			Without	474.5	473.52	-0.98	81,969	81,278	-691
	Design Storm	0.01 (Unregulated)	With	476.11	474.65	-1.46	87,479	88,911	1,433
			Without	476.11	474.55	-1.56	87,479	86,961	-517
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

Table 9 Continued:

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
90.65	April-79	0.004	With	422.71	423.86	1.15	116,459	130,616	14,156
			Without	422.71	422.7	-0.01	116,459	116,962	503
	Feb-90	0.03	With	415.45	414.58	-0.87	93,078	87,930	-5,148
			Without	415.45	415.06	-0.39	93,078	91,147	-1,931
	Oct-95	0.2	With	415.99	414.17	-1.81	91,946	89,786	-2,160
			Without	415.99	414.17	-1.81	91,946	86,889	-5,058
	May-03	0.063	With	415.79	415.89	0.1	84,400	85,604	1,204
			Without	415.79	415.89	0.1	84,400	85,604	1,204
	Back to Back	NA	With	419.02	418.79	-0.23	108,490	108,681	190
			Without	419.02	418.42	-0.6	108,490	104,226	-4,264
	Design Storm	0.01 (Unregulated)	With	422.25	422.83	0.58	124,370	146,340	21,971
			Without	422.25	422.03	-0.22	124,370	137,693	13,324
84.45	April-79	0.004	With	417.99	419.03	1.04	155,545	167,650	12,105
			Without	417.99	417.94	-0.05	155,545	155,945	400
	Feb-90	0.03	With	417.99	410.19	-7.8	155,545	90,410	-65,135
			Without	417.99	410.42	-7.57	155,545	93,551	-61,994
	Oct-95	0.2	With	411.51	409.85	-1.65	98,288	91,434	-6,854
			Without	411.5	409.85	-1.65	98,288	88,004	-10,283
	May-03	0.063	With	411.58	411.62	0.04	95,586	96,707	1,121
			Without	411.58	411.62	0.04	95,586	96,707	1,121
	Back to Back	NA	With	414.53	414.22	-0.31	119,229	118,239	-991
			Without	414.53	413.96	-0.57	119,229	114,865	-4,364
	Design Storm	0.01 (Unregulated)	With	417.79	418.11	0.32	147,175	154,111	6,936
			Without	417.79	417.3	-0.49	147,175	146,525	-651
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

Table 9 Continued:

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
81.51	April-79	0.004	With	414.5	415.41	0.91	154,823	166,061	11,238
			Without	414.5	414.42	-0.08	154,823	155,036	213
	Feb-90	0.03	With	410.83	407.68	-3.15	95,698	90,377	-5,321
			Without	410.83	407.69	-3.14	95,698	93,490	-2,208
	Oct-95	0.2	With	408.89	407.46	-1.43	97,873	91,386	-6,487
			Without	408.89	407.46	-1.43	97,873	87,918	-9,955
	May-03	0.063	With	409.13	409.12	-0.01	95,796	96,949	1,154
			Without	409.13	409.12	-0.01	95,796	96,949	1,154
	Back to Back	NA	With	411.68	414.22	2.54	119,534	118,239	-1,296
			Without	411.68	411.16	-0.52	119,534	115,352	-4,182
	Design Storm	0.01 (Unregulated)	With	414.66	414.73	0.07	146,474	153,820	7,346
			Without	414.66	413.99	-0.67	146,474	146,264	-210
78.8	April-79	0.004	With	411.56	412.37	0.81	153,768	164,075	10,307
			Without	411.56	411.46	-0.1	153,768	153,729	-39
	Feb-90	0.03	With	405.69	405.35	-0.34	97,162	96,097	-1,066
			Without	405.69	405.35	-0.34	97,162	96,097	-1,066
	Oct-95	0.2	With	406.49	405.2	-1.29	105,308	96,919	-8,389
			Without	406.49	405.2	-1.29	105,308	94,491	-10,816
	May-03	0.063	With	406.79	406.72	-0.07	107,531	108,404	873
			Without	406.79	406.72	-0.07	107,531	108,404	873
	Back to Back	NA	With	409.06	408.66	-0.4	129,938	126,729	-3,209
			Without	409.06	408.57	-0.49	129,938	125,514	-4,424
	Design Storm	0.01 (Unregulated)	With	411.82	411.76	-0.06	159,237	159,027	-211
			Without	411.82	411.07	-0.75	159,237	151,546	-7,692
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

Table 9 Continued:

Coosa River									
River Mile	Storm	Approximate Annual Chance Exceedance	Cutbacks	Base Peak Elevation (ft)	Proposed Peak Elevation (ft)	Stage Difference	Base Flow* (cfs)	Proposed Flow* (cfs)	Flow Difference
69.33	April-79	0.004	With	404.14	404.54	0.4	158,455	169,056	10,601
			Without	404.14	403.94	-0.2	158,455	158,674	219
	Feb-90	0.03	With	400.49	399.99	-0.5	96,739	95,326	-1,413
			Without	400.49	399.99	-0.5	96,739	95,326	-1,413
	Oct-95	0.2	With	400.92	399.91	-1.01	104,002	96,615	-7,387
			Without	400.92	399.91	-1.01	104,002	93,986	-10,015
	May-03	0.063	With	401.1	400.81	-0.29	106,936	107,739	803
			Without	401.1	400.81	-0.29	106,936	107,739	803
	Back to Back	NA	With	402.44	402.09	-0.35	129,180	125,580	-3,600
			Without	402.44	402.05	-0.39	129,180	124,749	-4,431
	Design Storm	0.01 (Unregulated)	With	404.12	403.94	-0.18	158,320	158,706	387
			Without	404.12	403.51	-0.61	158,320	151,223	-7,097
44.43	April-79	0.004	With	326.12	326.03	-0.09	178,548	189,218	10,670
			Without	326.12	326.02	-0.1	178,548	176,650	-1,898
	Feb-90	0.03	With	321.5	322.73	1.23	121,552	138,326	16,774
			Without	321.5	322.73	1.23	121,552	138,326	16,774
	Oct-95	0.2	With	320.51	320.76	0.25	109,237	135,091	25,854
			Without	320.51	320.76	0.25	109,237	112,307	3,070
	May-03	0.077	With	321.39	321.48	0.09	120,515	121,641	1,126
			Without	321.39	321.48	0.09	120,515	121,641	1,126
	Back to Back	NA	With	323.93	323.67	-0.26	156,245	152,341	-3,905
			Without	323.93	323.59	-0.34	156,245	151,268	-4,977
	Design Storm	0.01 (Unregulated)	With	324.64	324.27	-0.37	166,855	161,222	-5,633
			Without	324.64	324.24	-0.4	166,855	156,091	-10,764
Increased flooding without Cutbacks									
Increased flooding with Cutbacks									
Increased flooding with and without Cutbacks									

*The flow values correspond to the flow at the time of the peak elevation, and are not necessarily the peak flows.

C.5 Conclusions

The Flood Risk Management impact analysis summarized in this report shows that there are increases in WSE occurring below each of the evaluated projects as a result of the proposed changes. Below Allatoona Dam there was a 0.34 ft increase in peak WSE adjacent to the Rome levee during a simulated 0.5% annual chance exceedance event scaled from a 1979 storm. This increase occurred at the top the Coosa and created a back water effect up both the Etowah and Oostanaula Rivers for a short distance. The change in water surface elevation was caused by a small increase in discharge from the Allatoona Dam that arrived at the confluence of the two rivers concurrently with the peak of the hydrograph on the Oostanaula. The section of the Coosa River below the Weiss spillway experienced the largest WSE increases, with the design event producing a 4.68 ft increase. This increase in WSE was reduced by floodplain attenuation to the point that there was no increase adjacent to Gadsden, AL. Based on the analyzed storm events, a correct implementation of the cutback rule would prevent any increases in WSE above 0.1 ft between Logan Martin and Lay Dams. Incorrect implementation of the cutback rule could see WSE elevations increase up to 2.54 ft above the base condition (Back to Back event at River Mile 81.51). The last significant downstream impacts were seen just downstream of Lay Dam, where there was a consistent increase in WSE for smaller frequency events. The largest increase in WSE downstream of Lay Dam occurred during the Oct 1995 event and consisted of a 1.99 ft increase in WSE for the with cutback scenario.

C.6 References

FERC. (2009). *Final Environmental Assessment for Hydropower License, Coosa River Hydroelectric Project - FERC Project No. 2146-111.* Washington, DC: Federal Energy Regulatory Commission.

USACE Mobile District. (2014a). *Final Environmental Impact Statement Update of the Water Control Manual for the Alabama-Coosa-Tallapoosa River Basin in Georgia and Alabama.* Mobile, Alabama: U.S. Army Corps of Engineers, Mobile District.

Enclosure 1

Section 8: HEC-RAS Model Development from the *Corps Water Management System (CWMS) Final Report for the ACT Watershed*

8.0 HEC-RAS Model Development

8.1 Status of District's Existing HEC-RAS Model(s)

At the onset of the study, the Mobile District and Alabama Power Company (APC) both provided HEC-RAS models of various locations throughout the basin. Steady and Unsteady models for CWMS were developed utilizing existing MMC dam break models and APC models. The tributaries are not modeled as reaches. ResSim operation decisions will be used as boundary conditions. Calibration data for the RAS models will include USGS rating curves, streamflow and stage hydrographs at gage locations, bank-full discharges, high water marks and aerial flood photographs. For real-time simulation, reservoir outflows and pool elevations will be imported from ResSim and local inflows will be imported from HEC-HMS.

Alabama Power Company (APC) currently has HEC-RAS (version 3.1.1) models developed, calibrated and verified for the Coosa River from Carters and Allatoona discharges to Weiss, Weiss to Neely Henry, Neely Henry to Logan Martin, Logan Martin to Lay, Lay to Mitchell, Mitchell to Jordan/Bouldin and Jordan /Bouldin to R F Henry. These models use bathymetric data from a variety of sources and 30-meter quads for out of bank data. They were calibrated using the February 1990 flood. The models are not geo-referenced. On the Tallapoosa River, APC has RAS models developed, calibrated and verified from Harris discharge to Martin, and Thurlow discharge to R F Henry (on the Alabama River). The Thurlow to R F Henry model is geo-referenced and includes the Jordan/Bouldin releases as well. APC does not currently have RAS modeling above Harris Reservoir or for Yates and Thurlow reservoirs. Primary areas of interest for APC are Rome, Gadsden, Childersburg and Wadley.

Mobile District currently has RAS modeling completed for MMC Dam Break studies for Carters and Allatoona. The model for the Carters Dam Break study included the Coosawattee, below Carters Dam, to its confluence with the Conasauga River where the Oostanaula River is formed, the Conasauga River below the Tilton gage, along the entire Oostanaula River to its confluence with the Etowah where the Coosa River is formed and along the Coosa River down to Logan Martin Dam. The RAS model also included the Etowah River. The model for the Allatoona Dam Break Study included the Etowah River below Allatoona Dam and the Coosa River from formation to Wetumpka, Alabama, along with the tributary, the Oostanaula River. The geometry for the MMC Dam Break models was essentially developed using 10 meter Digital Elevation Models (DEMs). The MMC Dam Break models are geo-referenced.

In addition, the Alabama Department of Economic and Community Affairs (ADECA) developed a model that extends from the Millers Ferry Lock and Dam on the Alabama River to the Jordan Dam north of Wetumpka, AL on the Coosa River. The geometry along the reaches was taken from a combination of different sources, including LiDAR, Alabama River bathymetry, channel surveys, 10 meter DEM, and as-built bridge plans. The ADECA model was geo-referenced.

The MMC Dam Break models were created using higher resolution data in the overbanks area, but they did not have representative channel data. The APC models included channel data, but the overbank data was coarser than the MMC models. In addition, The MMC Dam Break models are geo-referenced but the APC models are not, except for the models for the Tallapoosa River. For this study, steady and unsteady flow models for CWMS were developed using a combination of the existing MMC dam break models and APC models on the Coosa River above Jordan Dam. The existing APC model on the upper Tallapoosa River and the existing ADECA on the Alabama River were used directly. In general, the layout of the cross sections and the geometry of the overbank areas in the CWMS model on the Coosa River system were taken from the MMC Dam Break models while the geometry of the channel portion was based on the APC models. This blending process resulted in the best available overbank data as well as the best available channel data. Finally, the ground elevations in all the CWMS models were converted to NAVD88 if the original existing models were not referenced to NAVD88 already.

Some cross section adjustments were made due to spacing or mapping issues, as explained later in this report, and additional storage areas were added on the Alabama and Tallapoosa Rivers. A 10-meter DEM was used for all overbank and storage area data that was added to the model. The final unsteady flow model for the ACT basin was developed in HEC-RAS 4.1. It consists of sixteen reaches described in Table 8.1. The location of all the reaches can be seen in Figure 8.1.

Table 8.1 – HEC-RAS Reach Descriptions

River	Reach	Description

River	Reach	Description
Alabama River	Main	From headwaters to RF Henry
Conasauga	Conasauga	From DS of the Tilton gage to confluence with the Coosawatee River
Coosa	Lower	From DS of Jordan to confluence with Tallapoosa River
Coosa	Below Powerhouse	From Weiss PH to Coosa River
Coosa	Bypass	From Weiss spillway to Weiss PH outflow location
Coosa	Rome Weiss	From headwaters of Coosa to Weiss
Coosa	Lay-Mitchell	From Lay to Mitchell
Coosa	Mitchell-Jordan	From Mitchell to Jordan
Coosa	Logan Martin-Lay	From Logan Martin to Lay
Coosa	HNH-Logan Martin	From HN Henry to Logan Martin
Coosa	Weiss-HNH	From Weiss to HN Henry
Coosawatee	Coosawatee	From DS of Carters Rereg to confluence with the Conasauga River
Etowah	Etowah	From DS of Allatoona to confluence with the Oostanaula River
Oostanaula	Oostanaula	Entire Oostanaula River
Tallapoosa	Lower Tallapoosa	From DS of Thurlow to confluence with the Coosa River
Tallapoosa	Martin-Harris	From DS RL Harris to Martin

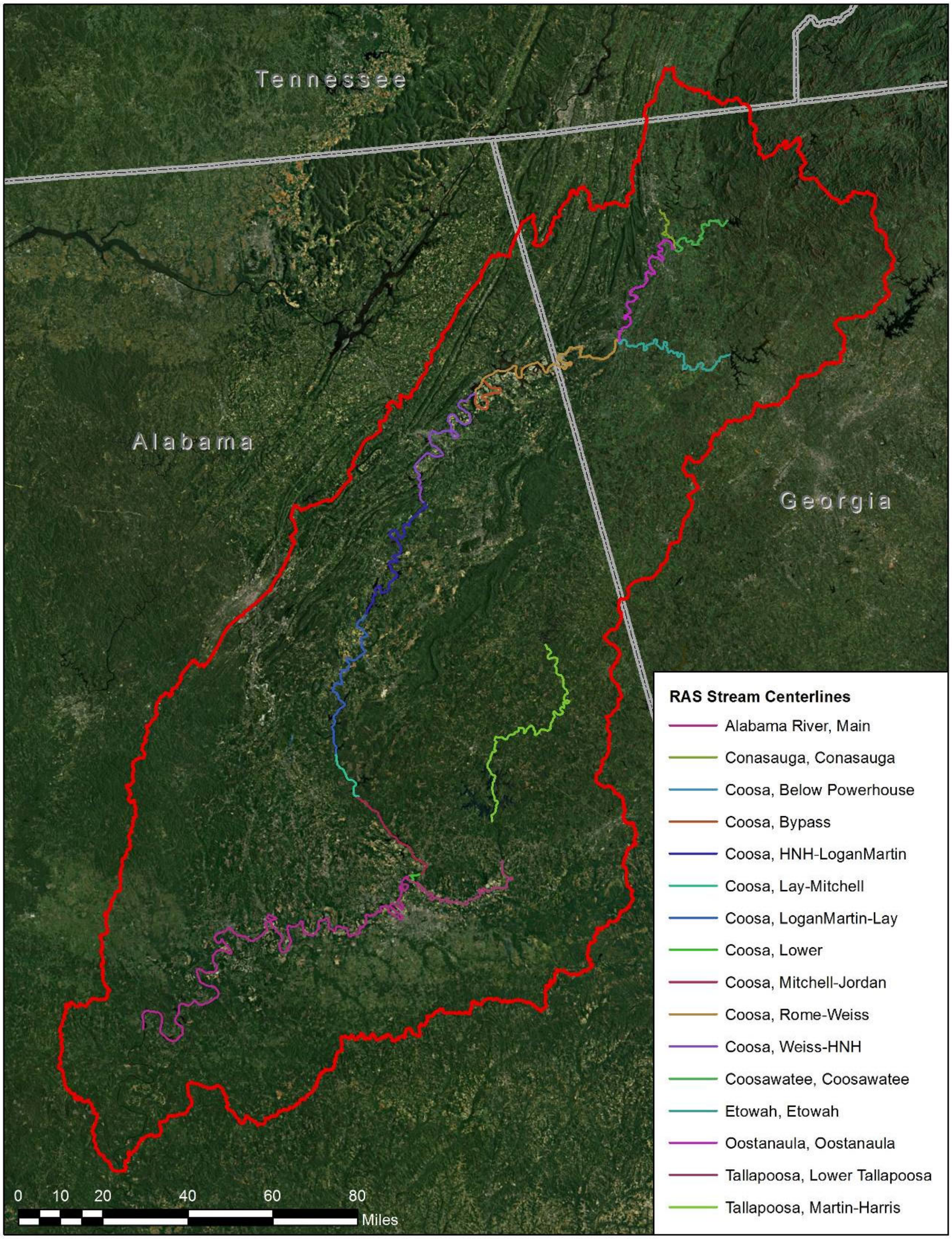

Figure 8.1 – HEC-RAS Reach Location Map

8.2 Boundary Conditions

The Steady Flow model boundary conditions were all set at 0.0001 ft/ft on the downstream end of the various reaches just to test if the model would run to completion without any major errors. The unsteady flow boundary conditions utilize inflow hydrographs at the upper end of each reach and the downstream reservoir's pool elevation as the downstream boundary condition. For reaches in between reservoirs, the inflow hydrograph is the outflow from the upstream reservoir (taken from HEC-ResSim) and the downstream boundary condition is the pool elevation of the downstream reservoir. The local inflows from subbasins entering the mainstem reaches in the RAS model are taken from the HEC-HMS model and added as lateral inflows at the cross section that corresponds to the confluence of the tributary and the mainstem. A list of all boundary condition locations, and their links to .DSS files that were used in the initial unsteady testing, is presented in Table 8.2. The actual .DSS files and pathnames varied in the calibration events, and will vary in the final model. However, the locations of the lateral inflows will not change.

Table 8.2 – Unsteady RAS Flow File Information

River	Reach	Station	Boundary Condition Type	DSS File	DSS Path
Alabama River	Main	172.37	Lateral Inflow Hydrograph	ACT_HMS.dss	//MONTGRY_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	144.01	Lateral Inflow Hydrograph	ACT_HMS.dss	//MONTGRY_HMSLOCAL_LWR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	141.09	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB AUTAUGA CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	136.32	Lateral Inflow Hydrograph	ACT_HMS.dss	//CATOMA-CATOMA BAMA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	135.26	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB PINTLALA CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	134.73	Lateral Inflow Hydrograph	ACT_HMS.dss	//RF HENRY_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	122.67	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB SWIFT CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	103.12	Lateral Inflow Hydrograph	ACT_HMS.dss	//RF HENRY_HMSLOCAL_LWR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Alabama River	Main	102.55	Stage Hydrograph	APC_Projects.dss	/ACT/RF HENRY/ELEV/01SEP2009/1HOUR//
Conasauga	Conasauga	12.01	Flow Hydrograph	ACT_HMS.dss	//TILTON_02387000/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	271.16	Lateral Inflow Hydrograph	ACT_HMS.dss	//ROMECO_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	264.2	Lateral Inflow Hydrograph	ACT_HMS.dss	//ROMECO_HMSLOCAL_LWR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	243.29	Lateral Inflow Hydrograph	ACT_HMS.dss	//JCT CEDAR COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	239.23	Lateral Inflow Hydrograph	ACT_HMS.dss	//STATELN_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	221.76	Lateral Inflow Hydrograph	ACT_HMS.dss	//GAYLESV_02398300/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	219.3	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB BLUEPND/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	215.64	Lateral Inflow Hydrograph	ACT_HMS.dss	//WEISS_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Rome-Weiss	0.07	Stage Hydrograph	APC_Projects.dss	/ACT/WEISS/ELEV/01SEP2009/1HOUR//
Coosa	Bypass	215.29	Flow Hydrograph	ACT_HMS.dss	//WEISS OUT SPWY/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Bypass	209.75	Lateral Inflow Hydrograph	ACT_HMS.dss	//ELLISVL-O COOSA TERRA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Weiss-HNH	186.73	Lateral Inflow Hydrograph	ACT_HMS.dss	//GADSDEN_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/

River	Reach	Station	Boundary Condition Type	DSS File	DSS Path
Coosa	Weiss-HNH	167.19	Lateral Inflow Hydrograph	ACT_HMS.dss	//GADSDEN_HMSLOCAL_LWR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Weiss-HNH	163.39	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB BIG WILLIS CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Weiss-HNH	162.94	Lateral Inflow Hydrograph	ACT_HMS.dss	//REECE-B WILLIS COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Weiss-HNH	163.63	Lateral Inflow Hydrograph	ACT_HMS.dss	//HN HENRY_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Weiss-HNH	145.7	Lateral Inflow Hydrograph	ACT_HMS.dss	//ASHVIL-B CANOE COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Weiss-HNH	139.78	Stage Hydrograph	APC_Projects.dss	/ACT/HN HENRY/ELEV/01SEP2009/1HOUR//
Coosa	HNH-LoganMartin	139.53	Flow Hydrograph	ACT_HMS.dss	//HN HENRY OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	HNH-LoganMartin	139.11	Lateral Inflow Hydrograph	ACT_HMS.dss	//HN HENRY_HMSLOCAL_LWR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	HNH-LoganMartin	137.92	Lateral Inflow Hydrograph	ACT_HMS.dss	//OHATCHEE-OHATCHEE COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	HNH-LoganMartin	134.04	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CANE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	HNH-LoganMartin	107.6	Lateral Inflow Hydrograph	ACT_HMS.dss	//JACKSON_02404400/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	HNH-LoganMartin	91.84	Stage Hydrograph	APC_Projects.dss	/ACT/LOGAN MARTIN/ELEV/01SEP2009/1HOUR//
Coosa	LoganMartin-Lay	91.58	Flow Hydrograph	ACT_HMS.dss	//LOGAN MARTIN OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	91.45	Lateral Inflow Hydrograph	ACT_HMS.dss	//LOGAN MARTIN_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	89.52	Lateral Inflow Hydrograph	ACT_HMS.dss	//VINCENT-KELLY COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	79.53	Lateral Inflow Hydrograph	ACT_HMS.dss	//ALPINE-TALLDGA COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	77.78	Lateral Inflow Hydrograph	ACT_HMS.dss	//CHLDRSB_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	71.76	Lateral Inflow Hydrograph	ACT_HMS.dss	//YELLOWLEAF-YELLOWLF COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	70.94	Lateral Inflow Hydrograph	ACT_HMS.dss	//YELLOWLEAF CR_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	58.99	Lateral Inflow Hydrograph	ACT_HMS.dss	//UPPER LAY_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	45.2	Lateral Inflow Hydrograph	ACT_HMS.dss	//LAY_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	LoganMartin-Lay	44.9	Stage Hydrograph	APC_Projects.dss	/ACT/LAY/ELEV/01SEP2009/1HOUR//

River	Reach	Station	Boundary Condition Type	DSS File	DSS Path
Coosa	Lay-Mitchell	44.75	Flow Hydrograph	ACT_HMS.dss	//LAY OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lay-Mitchell	43.96	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB LWR YELLOW LEAF CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lay-Mitchell	36.57	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB WALNUT CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lay-Mitchell	35.61	Lateral Inflow Hydrograph	ACT_HMS.dss	//HATCHET CR_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lay-Mitchell	35.27	Lateral Inflow Hydrograph	ACT_HMS.dss	//ROCKFRD-HATCHET COOSA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lay-Mitchell	30.98	Lateral Inflow Hydrograph	ACT_HMS.dss	//MITCHELL_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lay-Mitchell	30.94	Stage Hydrograph	APC_Projects.dss	/ACT/MITCHELL/ELEV/01SEP2009/1HOUR//
Coosa	Mitchell-Jordan	30.85	Flow Hydrograph	ACT_HMS.dss	//MITCHELL OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Mitchell-Jordan	27.33	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CRESTNUT CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Mitchell-Jordan	15.85	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB WEOKA CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Mitchell-Jordan	13.51	Lateral Inflow Hydrograph	ACT_HMS.dss	//JORDAN BOULDIN_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Mitchell-Jordan	13.1	Lateral Inflow Hydrograph	APC_Projects.dss	/ACT/JORDAN/ELEV/01SEP2009/1HOUR//
Coosa	Lower	12.59	Flow Hydrograph	ACT_HMS.dss	//JORDAN OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Lower	5.3	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB WTMPKA/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosa	Below Powerhouse	0.29	Flow Hydrograph	ACT_HMS.dss	//WEISS OUT PH/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosawattee	Coosawattee	25.18	Flow Hydrograph	ACT_HMS.dss	//CARTERS REREG OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosawattee	Coosawattee	10.52	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB SALACOA CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Coosawattee	Coosawattee	10.19	Stage Hydrograph	ACT_HMS.dss	//SUB PINECH/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Etowah	Etowah	48.68	Flow Hydrograph	ACT_HMS.dss	//ALLATOONA IN/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Etowah	Etowah	41.86	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB PUMPKINVINE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Etowah	Etowah	40.99	Lateral Inflow Hydrograph	ACT_HMS.dss	//CRTSVL_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Etowah	Etowah	34.37	Lateral Inflow Hydrograph	ACT_HMS.dss	//KINGSTN_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/

River	Reach	Station	Boundary Condition Type	DSS File	DSS Path
Etowah	Etowah	31.86	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB EUHARLEE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Etowah	Etowah	21.13	Lateral Inflow Hydrograph	ACT_HMS.dss	//KINGSTN_HMSLOCAL_LWR/FLOW/01OCT2009/1HOUR/RUN:EVENT A/
Etowah	Etowah	16.46	Lateral Inflow Hydrograph	ACT_HMS.dss	//ROMEET_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Oostanaula	Oostanaula	44.76	Lateral Inflow Hydrograph	ACT_HMS.dss	//RESACA_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Oostanaula	Oostanaula	38.14	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CALHOUN/FLOW/01OCT2009/1HOUR/RUN:EVENT A/
Oostanaula	Oostanaula	25.21	Lateral Inflow Hydrograph	ACT_HMS.dss	//ROMECO_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Oostanaula	Oostanaula	11.18	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB ARMUCHE/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	136.65	Flow Hydrograph	ACT_HMS.dss	//RL HARRIS OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	120.51	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB HIGH PINE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	116.13	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CHIKASANOXEE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	104.08	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CHATAHOSPEE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	94.44	Lateral Inflow Hydrograph	ACT_HMS.dss	//HORSESH_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	84.47	Lateral Inflow Hydrograph	ACT_HMS.dss	//JCT HILLABEE TALLAP/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	70.06	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB SANDY CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	61.11	Lateral Inflow Hydrograph	ACT_HMS.dss	//MARTIN_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Martin-Harris	60.75	Stage Hydrograph	APC_Projects.dss	/ACT/MARTIN/ELEV/01SEP2009/1HOUR//
Tallapoosa	Lower Tallapoosa	47.32	Flow Hydrograph	ACT_HMS.dss	//THURLOW OUT/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	46.91	Lateral Inflow Hydrograph	ACT_HMS.dss	//JCT SGHTCHEE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	46.47	Lateral Inflow Hydrograph	ACT_HMS.dss	//YATES_THURLOW_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	42.53	Lateral Inflow Hydrograph	ACT_HMS.dss	//UPHAPEE CR-UPHAPEE TALLAP/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	38.99	Lateral Inflow Hydrograph	ACT_HMS.dss	//MILSTD_HMSLOCAL/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	35.47	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CALEBEE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/

River	Reach	Station	Boundary Condition Type	DSS File	DSS Path
Tallapoosa	Lower Tallapoosa	28.72	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB CUBAHATCHEE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	25.42	Lateral Inflow Hydrograph	ACT_HMS.dss	//SUB LINE CR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	22.48	Lateral Inflow Hydrograph	ACT_HMS.dss	//MONTGWW_HMSLOCAL_UPR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/
Tallapoosa	Lower Tallapoosa	11.62	Lateral Inflow Hydrograph	ACT_HMS.dss	//MONTGWW_HMSLOCAL_LWR/FLOW/01SEP2009/1HOUR/RUN:EVENT A/

8.3 Model Parameters

The majority of model parameters were obtained from the models provided by the District and by APC. During the calibration process, parameters were adjusted to match observed data. Some parameters, such as Hydraulic Table (HTab) parameters, were adjusted to account for larger flows.

8.3.1 Manning's n Values

The initial Manning's n values were not adjusted until the model was calibrated. A description of the calibration process and procedure is listed in a later section. Table 8.3 presents the final (calibrated) range of Manning's n-values for each reach.

Table 8.3 – Summary of Manning's n values for RAS reaches

				Manning's n Value Ranges		
River	Reach	Length (mi.)	Ave. Reach Length (ft)	LOB	Channel	ROB
Alabama River	Main	72.8	2236	0.15-0.2	0.03-0.055	0.15-0.2
Conasauga	Conasauga	12.0	1812	0.12	0.037-0.042	0.1-0.12
Coosa	Lower	12.6	2463	0.15	0.041	0.15
Coosa	Below Powerhouse	0.28	752	0.1	0.027	0.1
Coosa	Bypass	19.4	1970	0.08	0.027	0.08
Coosa	Rome Weiss	60.1	2367	0.1-0.15	0.02-0.04	0.1-0.15
Coosa	Lay-Mitchell	13.9	2288	0.035-0.1	0.03-0.1	0.1
Coosa	Mitchell-Jordan	18.2	2086	0.1	0.035	0.1
Coosa	Logan Martin-Lay	46.7	2492	0.1-0.12	0.027-0.035	0.1-0.12
Coosa	HNH-Logan Martin	47.8	2500	0.1	0.033	0.1
Coosa	Weiss-HNH	56.2	2722	0.08	0.027	0.08
Coosawattee	Coosawattee	25.2	1564	0.1-0.12	0.04-0.045	0.1-0.12
Etowah	Etowah	48.7	1761	0.1-0.15	0.03-0.04	0.1-0.15
Oostanaula	Oostanaula	48.8	1868	0.1-0.15	0.03-0.04	0.1-0.12
Tallapoosa	Lower Tallapoosa	47.3	1893	0.1-0.2	0.04-0.05	0.1-0.2
Tallapoosa	Martin-Harris	76.0	1399	0.1-0.15	0.04-0.07	0.1-0.15

8.3.2 HTab Parameters

The HTab parameters for the cross sections were completed using a starting elevation equal to the cross section invert, and then using 100 increments, the increment size ranging from 0.5 to 2.5 feet depending on the location. The increment size was determined by the depth of flow at each cross section. The smallest increment that could capture the entire range of flows and allow room for reasonably larger flows was used.

8.3.3 Cross Sections

Cross sections taken from the MMC dam break models were cut with enough resolution that the modeling effort did not require any interpolated cross sections. The Tallapoosa reaches, which were taken from the APC models, came with extensive interpolated cross sections that were removed for the final model. New cross sections in this reach were extracted using existing 10-meter DEM's, and the existing interpolated cross sections were used to define the channel in the new cross sections. Cross section spacing was determined by CWMS Standard Operating Procedure, based on the channel slope. In other locations throughout the model, cross sections were adjusted to account for cross section overlap and river meanders. These cross sections were also cut using existing 10 meter DEMs and the existing or interpolated cross sections were used for channel data on these new cross sections.

8.3.4 Overbanks and Levees

The overbank areas are modeled using an appropriate ineffective or levee feature depending on the possibility of water spilling out into areas of the cross section that lie below the banks of the channel.

8.3.5 Lateral Structures

There are several lateral structures in the model that are used to connect cross sections to storage areas where extensive spilling and storage are expected in the model. These locations include reservoirs and tributaries where significant backwater effects are expected. The weir coefficient is set to 1 for all lateral structures in this model.

8.3.6 Bridges

All of the bridges in the model were taken from the existing ADECA model. There are 12 bridges included in the model. The location and description of each bridge is found in Table 8.4. Many of these crossings include a very large cross section where the multiple opening analysis has been implemented so the model can adequately determine how to allocate the flows through the multiple openings that exist at these crossings. Upon comparison with aerial photography, it was determined that the four bridges on the Lower Tallapoosa reach were not in the correct locations. These bridges were moved to match their actual locations, and new cross sections were added where needed to ensure accurate calculations near the bridges. These new locations are reflected in Table 8.4.

Neither the MMC Dam Break models nor the APC models for the Coosa system and the Tallapoosa River include any bridges. Requests for effective hydraulic models for Federal Emergency Management Agency (FEMA) flood insurance studies were sent to FEMA Engineering Library on May 8, 2014. The FEMA effective hydraulic models might include bridge data. As of November 19, 2014, WEST has not received any models from FEMA

Table 8.4 – Bridges Included in HEC-RAS Model

Bridge Description	River	Reach	River Station
Alabama River Parkway	Alabama River	Main	161.71
CSXT Railroad - North of Montgomery	Alabama River	Main	157.71
State Highway 152/North Boulevard	Alabama River	Main	152.86
Interstate 65	Alabama River	Main	151.55
U.S. Highway 31	Alabama River	Main	143.40
CSXT Railroad - Prattville/Montgomery	Alabama River	Main	142.84
Coosa River Parkway/Stat Highway 14	Coosa	Lower	6.68
Bibb Graves Bridge/State Highway 111	Coosa	Lower	5.60
Tuckabatchee Rd/State Highway 229	Tallapoosa	Lower Tallapoosa	38.1
Emerald Mountain Expressway	Tallapoosa	Lower Tallapoosa	16.9
North bound Hwy 231	Tallapoosa	Lower Tallapoosa	8.24
South bound Hwy 231	Tallapoosa	Lower Tallapoosa	8.21

The ineffective flows locations near bridges were set based on guidance in the HEC-RAS Hydraulic Reference Manual (USACE, 2010). The expansion and contraction coefficients and placement of ineffective flow elevations are presented in Table 8.5.

Table 8.5 – Treatment of Ineffective Flow Areas around Bridges

Parameter	Value
Upstream Contraction	0.3
Downstream Expansion	0.5
Ineffective Area Height – upstream cross sections	corresponds to top of the bridge
Ineffective Area Height – downstream cross sections	corresponds to midway between the low chord and top of road elevations

8.4 Model Calibration

The USGS gages listed below in Table 8.6 provided calibration data for the HEC-RAS model. These gages reported stage values, with some providing flow as well. All stage values were converted to elevation values, and are presented in the NAVD 88 vertical datum. These gages were chosen because they were located on the modeled river reaches, and because they recorded data during the storms of interest. There were no reported problems with the USGS gages. Several gages also had associated rating curves, which were used as the primary basis for calibration when possible.

Model calibration included adjustments to channel and overbank Manning's 'n' values as well as to ineffective flow areas. Fine-tuning of the calibration was accomplished by adjusting flow roughness factors in the plan editor. Attempts were made to match the historic observed river elevations to the calculated water surface elevations from the model. The calibration goal was generally to get the peak calculated water surface elevations to within 1 foot of the observed data, while matching the shape as well as possible. Where rating curves are available, preference was given to matching the rating curve since differences exist between the computed flows from HMS and the observed event flows.

Table 8.6 – Gage Locations Used in the Calibration of the September 2009 and April 2014 Events

Gage Location	USGS Gage Number	River	Reach	River Station	USGS Data Availability (Stage, Flow, Rating Curve)
Alabama River Near Montgomery, AL	02420000	Alabama	Main	143.45	Y, Y, N
Alabama River at Montgomery, AL	02419988	Alabama	Main	152.83	Y, N, N
Tallapoosa River Near Mont.-Mont. Water Works	02419890	Tallapoosa	Lower Tallapoosa	11.4	Y, Y, Y
Tallapoosa River at Milstead, AL	02419500	Tallapoosa	Lower Tallapoosa	38.61	Y, N, N
Tallapoosa River near New Site, AL (Horseshoe Bend)	02414715	Tallapoosa	Martin-Harris	93.99	Y, Y, Y
Tallapoosa River at Wadley, AL	02414500	Tallapoosa	Martin-Harris	122.97	Y, Y, Y
Coosa River at Wetumpka, AL	02411600	Coosa	Lower	5.59	Y, N, N
Coosa River at Gaston Steam Plant	02407526	Coosa	LoganMartin-Lay	69.46	Y, N, N
Coosa River at Childersburg, AL	02407000	Coosa	LoganMartin-Lay	78.65	Y, Y, N
Coosa River at Gadsden, AL	02400500	Coosa	Coosa Weiss-HNH	164.52	Y, N, N
Coosa River at Gadsden	02400496	Coosa	Coosa Weiss-	166.55	Y, N, N

Gage Location	USGS Gage Number	River	Reach	River Station	USGS Data Availability (Stage, Flow, Rating Curve)
Steam Plant			HNH		
Coosa River at Leesburg, AL	02399500	Coosa	Coosa Rome-Weiss	215.60	Y, N, N
Coosa River at State Line, AL/GA	02397530	Coosa	Coosa Rome-Weiss	240.67	Y, N, N
Coosa River near Rome, GA	02397000	Coosa	Coosa Rome-Weiss	264.29	Y, Y, Y
Etowah River at Coosa Valley F.G., at Rome	02395996	Etowah	Etowah	2.45	Y, N, N
Etowah River at GA 1 Loop, Near Rome, GA	02395980	Etowah	Etowah	5.66	Y, Y, Y
Etowah River Near Kingston, GA	02395000	Etowah	Etowah	21.96	Y, Y, Y
Etowah River at GA 61, Near Cartersville, GA	02394670	Etowah	Etowah	39.07	Y, N, Y
Etowah River at Allatoona Dam, ABV Cartersville, GA	02394000	Etowah	Etowah	47.99	Y, N, Y
Etowah River Allatoona Dam TW	02393501	Etowah	Etowah	48.68	Y, N, N
Oostanaula River US 27 at Rome, GA	02388525	Oostanaula	Oostanaula	0.63	Y, N, N
Oostanaula River Near Rome, GA	02388500	Oostanaula	Oostanaula	4.98	Y, Y, Y
Oostanaula River at Calhoun, GA	02387520	Oostanaula	Oostanaula	38.58	Y, N, N
Oostanaula River at Resaca, GA	02387500	Oostanaula	Oostanaula	45.11	Y, Y, Y
Conasauga River at Sloan Bridge, Below Dalton, GA	02387010	Conasauga	Conasauga	9.13	Y, N, N
Conasauga River, at Tilton, GA	02387000	Conasauga	Conasauga	12.16	Y, Y, Y
Coosawattee River at Pine Chapel, GA	02383520	Coosawattee	Coosawattee	6.57	Y, N, N
Coosawattee River near Pine Chapel, GA	02383500	Coosawattee	Coosawattee	8.82	Y, Y, Y
Coosawattee River at Carters, GA	02382500	Coosawattee	Coosawattee	25.12	Y, Y, Y

8.5 Calibration Events and Results

The September-October 2009 and March-April 2014 events were used for calibrating the HEC-RAS model. Details of the model simulation periods can be found below in Table 8.7. Both events were run in HEC-RAS with the same model geometry. Model calibration included adjustments to channel and overbank Manning's 'n' values as well as to ineffective flow areas. Resulting Manning's 'n' values lie in the range of generally accepted 'n' values reported in the literature. Fine-tuning of the calibration was accomplished by adjusting flow roughness factors in the plan editor. The general trend in the reaches was for roughness to decrease with increased flow, which is expected. This is likely related to the decreasing effect of bed roughness on flow as the water level increases and may also be related to the cultivated fields near the river, which could cause decreased roughness as distance from the main channel increased. There were also some areas that showed an increase in roughness with flow, which may be due to increased vegetation on upper reaches of the overbank area where no farmed fields are present. These flow roughness factors were kept the same in each of the calibration and validation plans.

Attempts were made to match the historic observed river elevations to the calculated water surface elevations. Where rating curves are available, preference was given to matching the rating curve because of differences that exist between the calculated flows from HMS and the observed event flows. While both events were considered in the final calibration, more weight was given to the 2014 event due to more reliable data from the HMS model for this event. A summary of calibration results for both calibration events appears in Table 8.8.

Figure 8.2 through Figure 8.64 show the HEC-RAS calibration profiles, verification profiles, and rating curve comparisons at gages within the watershed. For reaches that do not have observed rating curves, the calculated and observed stages are shown from one representative location on each reach.

Table 8.7 – Storm Events Provided for HEC-RAS Calibration

HEC-RAS Simulation Period			
Start Date	Start Time	End Date	End Time
September 5, 2009	06:00	October 5, 2009	18:00
March 24, 2014	06:00	April 24, 2014	03:00

Table 8.8 – Summary of Calibration Results for September 2009 and April 2014 Events.

Gage Location	River	Reach	Event	Model Peak WSEL (ft, NAVD88)	Observed Peak WSEL (ft, NAVD88)	Diff. Peak WSEL (ft)	Peak Stage Time Diff. (hours)
Alabama River Near Montgomery, AL	Alabama	Main	2009	131.49	131.01	0.48	3
			2014	138.75	139.48	-0.73	4.33
Alabama River Near Montgomery, AL	Alabama	Main	2009	134.93	133.6	1.33	5.33
			2014	142.82	142.77	0.05	-3
Tallapoosa River Near Mont.-Mont. Water Works	Tallapoosa	Lower Tallapoosa	2009	147.19	146.74	0.45	-15.17
			2014	159.03	160.95	-1.92	-1.83
Tallapoosa River at Milstead, AL	Tallapoosa	Lower Tallapoosa	2009	173.27	171.95	1.32	-6.33
			2014	190.79	191.43	-0.64	-1.83
Tallapoosa River near New Site, AL (Horseshoe Bend)	Tallapoosa	Martin-Harris	2009	537.58	537.39	0.19	123.17*
			2014	539	540.74	-1.74	-1.5
Tallapoosa River at Wadley, AL	Tallapoosa	Martin-Harris	2009	610.1	612.19	-2.09	49.5*
			2014	612.09	617.13	-5.04	19
Coosa River at Wetumpka, AL	Coosa	Lower	2009	142.94	142.18	0.76	5
			2014	151.81	151.82	-0.01	-1
Coosa River at Gaston Steam Plant	Coosa	LoganMartin-Lay	2009	396.8	396.98	-0.18	-0.5
			2014	398.71	398.73	-0.02	5
Coosa River at Childersburg, AL	Coosa	LoganMartin-Lay	2009	399.04	398.65	0.39	-6
			2014	403.3	403.31	-0.01	-1.5
Coosa River at Gadsden, AL	Coosa	Coosa Weiss-HNH	2009	508.86	508.46	0.4	-2.5
			2014	509.25	509.32	-0.07	-16
Coosa River at Gadsden Steam Plant	Coosa	Coosa Weiss-HNH	2009	509.3	509.04	0.26	-3
			2014	509.73	509.87	-0.14	-16.5
Coosa River at Leesburg, AL	Coosa	Coosa Rome-Weiss	2009	564.19	563.91	0.28	-2.5
			2014	564.87	564.7	0.17	-3.5

Gage Location	River	Reach	Event	Model Peak WSEL (ft, NAVD88)	Observed Peak WSEL (ft, NAVD88)	Diff. Peak WSEL (ft)	Peak Stage Time Diff. (hours)
Coosa River at State Line, AL/GA	Coosa	Coosa Rome-Weiss	2009	565.1	564.82	0.28	0.5
			2014	565.61	566.41	-0.8	-4
Coosa River near Rome, GA	Coosa	Coosa Rome-Weiss	2009	578.18	577.11	1.07	-9.5
			2014	578.09	579.84	-1.75	-6
Etowah River at Coosa Valley F.G., at Rome	Etowah	Etowah	2009	587.25	587.3	-0.05	-4.25
			2014	585.47	587.8	-2.33	-5.5
Etowah River at GA 1 Loop, Near Rome, GA	Etowah	Etowah	2009	590.86	591.65	-0.79	-2
			2014	588.69	590.93	-2.24	-12
Etowah River Near Kingston, GA	Etowah	Etowah	2009	625.7	626.74	-1.04	-1.25
			2014	623.74	624.15	-0.41	-10
Etowah River at GA 61, Near Cartersville, GA	Etowah	Etowah	2009	670.3	671.64	-1.34	0.5
			2014	666.77	666.11	0.66	0.75
Etowah River at Allatoona Dam, ABV Cartersville, GA	Etowah	Etowah	2009	694.55	694.9	-0.35	-0.75
			2014	693.52	693.63	-0.11	-3
Etowah River Allatoona Dam TW	Etowah	Etowah	2009	696.75	696.25	0.5	-1.25
			2014	695.72	695.03	0.69	24.2
Oostanaula River US 27 at Rome, GA	Oostanaula	Oostanaula	2009	584.26	583.3	0.96	-11.25
			2014	584.08	586.15	-2.07	-8.75
Oostanaula River Near Rome, GA	Oostanaula	Oostanaula	2009	585.52	584.85	0.67	-13
			2014	585.91	589.36	-3.45	-3
Oostanaula River at Calhoun, GA	Oostanaula	Oostanaula	2009	616.6	615.1	1.5	-10.75
			2014	614.9	617.43	-2.53	4.5
Oostanaula River at Resaca, GA	Oostanaula	Oostanaula	2009	624.84	622.32	2.52	-6
			2014	622.6	624.49	-1.89	6.25
Conasauga River at Sloan Bridge, Below Dalton, GA	Conasauga	Conasauga	2009	638.37	636.83	1.54	32.4
			2014	634.64	634.32	0.32	-3.5

Gage Location	River	Reach	Event	Model Peak WSEL (ft, NAVD88)	Observed Peak WSEL (ft, NAVD88)	Diff. Peak WSEL (ft)	Peak Stage Time Diff. (hours)
Conasauga River, at Tilton, GA	Conasauga	Conasauga	2009	644.11	642.53	1.58	33.1
			2014	638.29	639.04	-0.75	34.8
Coosawattee River at Pine Chapel, GA	Coosawattee	Coosawattee	2009	638.37	636.83	1.54	-3
			2014	634.64	634.32	0.32	-3.75
Coosawattee River near Pine Chapel, GA	Coosawattee	Coosawattee	2009	644.11	642.53	1.58	0.25
			2014	638.29	639.04	-0.75	-2.75
Coosawattee River at Carters, GA	Coosawattee	Coosawattee	2009	638.37	636.83	1.54	7
			2014	634.64	634.32	0.32	0.75

*Large differences in peak stage times attributed to multiple peaks in the modeling

8.6 Verification Events and Discussion

The April – May 2013 storm event was used for validating the HEC-RAS calibration and geometry. The effectiveness of the calibrated model was tested by comparing computed versus observed gage data for the event. Discharges from the 2013 event were generally greater than the 2009 event and less than the 2014 event, which indicates that the results should be similar to the calibrated events. However, on the Martin-Harris reach of the Tallapoosa, as well as on the Oostanaula and Conasauga rivers, the 2013 event was much greater than the 2014 event. On these reaches the verification results indicate how well the model might be able to predict floods that are larger than the calibrated events. Table 8.9 and Table 8.10 below show the details of the simulation period and the results of the model run, respectively.

When calibrating and validating the model, some baseflow adjustments had to be incorporated to prevent model instability. A minimum baseflow of 100 cfs was used for most reaches that required a baseflow. A minimum baseflow of 400 cfs was used on the Martin-Harris reach of the Tallapoosa River because this was the minimum observed flow of the river, and because smaller baseflows still resulted in some instabilities. The predicted values match the observed values fairly well at most locations. Most large differences between observed and predicted values occur at locations that have multiple peaks of similar magnitude. At these locations, it was usually possible to match only one but not all of the peaks, which can especially be seen in the peak stage time difference at some locations. Even with these difficulties, the rest of the model locations show reasonable predictions and indicate that the model was calibrated as well as possible. Overall, the calibration and verification runs demonstrate that the HEC-RAS model is able to predict approximate water surface elevations in ACT basin.

Figure 8.2 through Figure 8.16 show the HEC-RAS calibration profiles and verification profiles, while Figure 8.17 through Figure 8.64 show rating curve and stage comparisons at gages within the watershed. All gaged rating curves are shown. For reaches that do not have observed rating curves, the calculated and observed stages are shown from a representative location. To conserve space, the stage comparisons are only shown from one gage on each reach that does not have a rating curve.

Table 8.9 – Storm Event Provided for HEC-RAS Validation

HEC-RAS Simulation Period			
Start Date	Start Time	End Date	End Time
April 18, 2013	06:00	May 31, 2013	03:00

Table 8.10 – Summary of Verification Results

Gage Location	River	Reach	Event	Model Peak WSEL (ft, NAVD88)	Observed Peak WSEL (ft, NAVD88)	Diff. Peak WSEL (ft)	Peak Stage Time Diff. (hours)
Alabama River Near Montgomery, AL	Alabama	Main	2013	131.67	132.23	-0.56	6.83
Alabama River Near Montgomery, AL	Alabama	Main	2013	135.22	135.2	0.02	5.5
Tallapoosa River Near Mont.-Mont. Water Works	Tallapoosa	Lower Tallapoosa	2013	152.47	152.85	-0.38	0.66
Tallapoosa River at Milstead, AL	Tallapoosa	Lower Tallapoosa	2013	185.23	186.17	-0.94	-1.66
Tallapoosa River near New Site, AL (Horseshoe Bend)	Tallapoosa	Martin-Harris	2013	544.15	544.39	-0.24	-8.17
Tallapoosa River at Wadley, AL	Tallapoosa	Martin-Harris	2013	618.57	624.19	-5.62	-5.17
Coosa River at Wetumpka, AL	Coosa	Lower	2013	142.78	144.2	-1.42	-0.66
Coosa River at Gaston Steam Plant	Coosa	LoganMartin-Lay	2013	398.34	398.45	-0.11	3.5
Coosa River at Childersburg, AL	Coosa	LoganMartin-Lay	2013	402.53	402.52	0.01	8.5
Coosa River at Gadsden, AL	Coosa	Coosa Weiss-HNH	2013	509.99	510.41	-0.42	173**
Coosa River at Gadsden Steam Plant	Coosa	Coosa Weiss-HNH	2013	510.56	511.44	-0.88	171.1**
Coosa River at Leesburg, AL	Coosa	Coosa Rome-Weiss	2013	564.43	564.4	0.03	-3.5
Coosa River at State Line, AL/GA	Coosa	Coosa Rome-Weiss	2013	565.2	566.32	-1.12	-341**
Coosa River near Rome, GA	Coosa	Coosa Rome-Weiss	2013	578.69	579.44	-0.75	-306**
Etowah River at Coosa Valley F.G., at Rome	Etowah	Etowah	2013	585.48	585.86	-0.38	-303.6**
Etowah River at GA 1 Loop, Near Rome, GA	Etowah	Etowah	2013	588.05	587.34	0.71	-296.2**
Etowah River Near Kingston, GA	Etowah	Etowah	2013	622.92	621.05	1.87	59.3**
Etowah River at GA 61, Near Cartersville, GA	Etowah	Etowah	2013	667.00	665.89	1.11	47.3**
Etowah River at Allatoona Dam, ABV Cartersville, GA	Etowah	Etowah	2013	694.53	694.91	-0.38	-0.25

Gage Location	River	Reach	Event	Model Peak WSEL (ft, NAVD88)	Observed Peak WSEL (ft, NAVD88)	Diff. Peak WSEL (ft)	Peak Stage Time Diff. (hours)
Etowah River Allatoona Dam TW	Etowah	Etowah	2013	696.74	695.73*	-1.55	26.4*
Oostanaula River US 27 at Rome, GA	Oostanaula	Oostanaula	2013	584.83	585.43	-0.6	-306.7**
Oostanaula River Near Rome, GA	Oostanaula	Oostanaula	2013	587.47	588.95	-1.48	-1.25
Oostanaula River at Calhoun, GA	Oostanaula	Oostanaula	2013	618.9	620.97	-2.07	199.9**
Oostanaula River at Resaca, GA	Oostanaula	Oostanaula	2013	627.13	628.31	-1.18	197.8**
Conasauga River at Sloan Bridge, Below Dalton, GA	Conasauga	Conasauga	2013	639.99	639.76	0.23	190.6**
Conasauga River, at Tilton, GA	Conasauga	Conasauga	2013	645.62	645.65	-0.03	191.3**
Coosawattee River at Pine Chapel, GA	Coosawattee	Coosawattee	2013	632.85	635.5	-2.65	140.6**
Coosawattee River near Pine Chapel, GA	Coosawattee	Coosawattee	2013	635.03	638.28	-3.25	344.2**
Coosawattee River at Carters, GA	Coosawattee	Coosawattee	2013	661.28	661.62	-0.34	-0.25

*Observed data missing that could alter value

**Large differences in peak stage times attributed to multiple peaks in the modeling

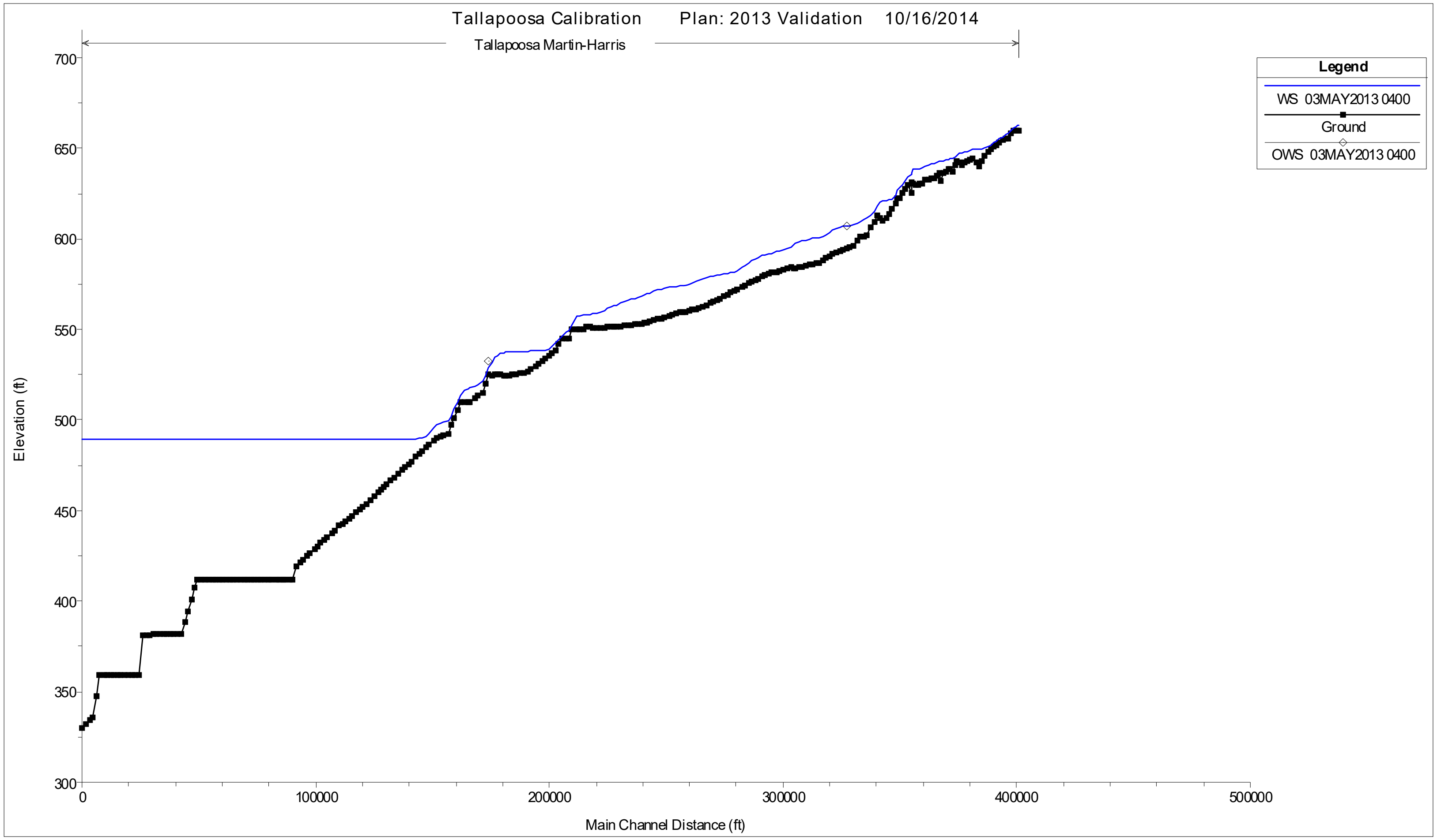

Figure 8.2 – Verification – Simulated vs. Observed – April 2013; Martin-Harris reach of the Tallapoosa River

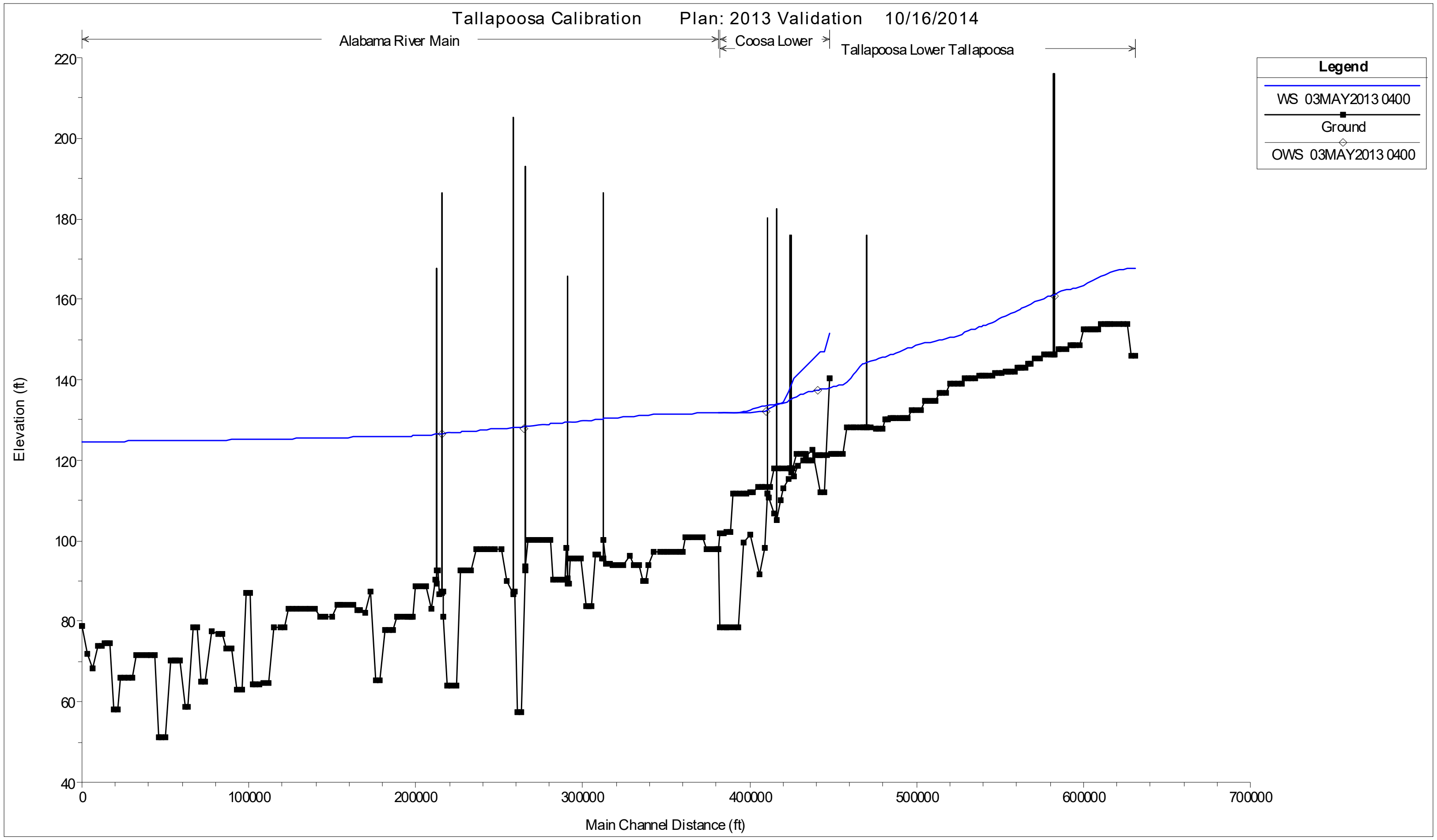

Figure 8.3 – Verification – Simulated vs. Observed – April 2013; Alabama River, Lower Tallapoosa reach of the Tallapoosa River, and Lower reach of the Coosa River

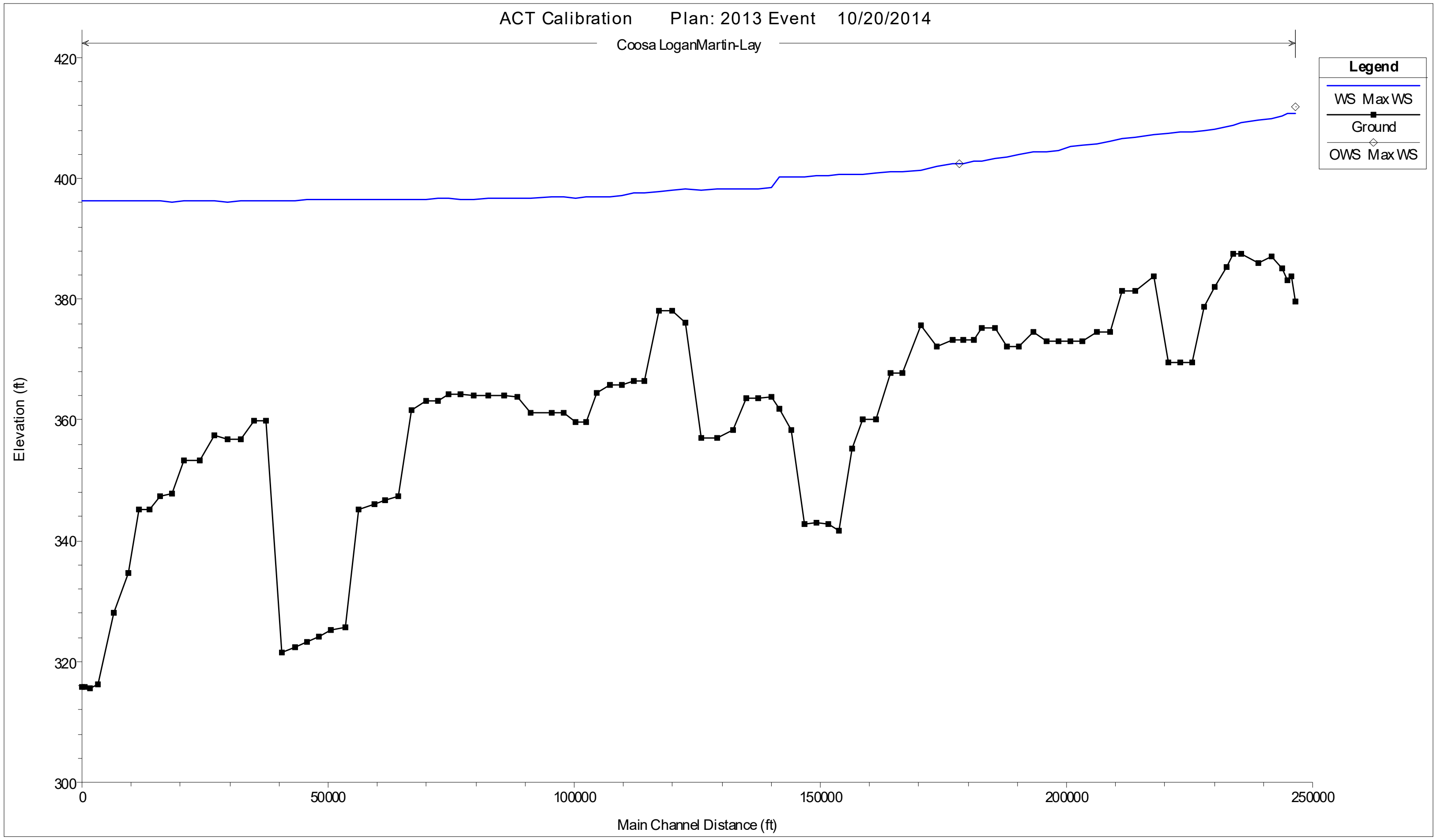

Figure 8.4 – Verification – Simulated vs. Observed – April 2013; LoganMartin-Lay reach of the Coosa River

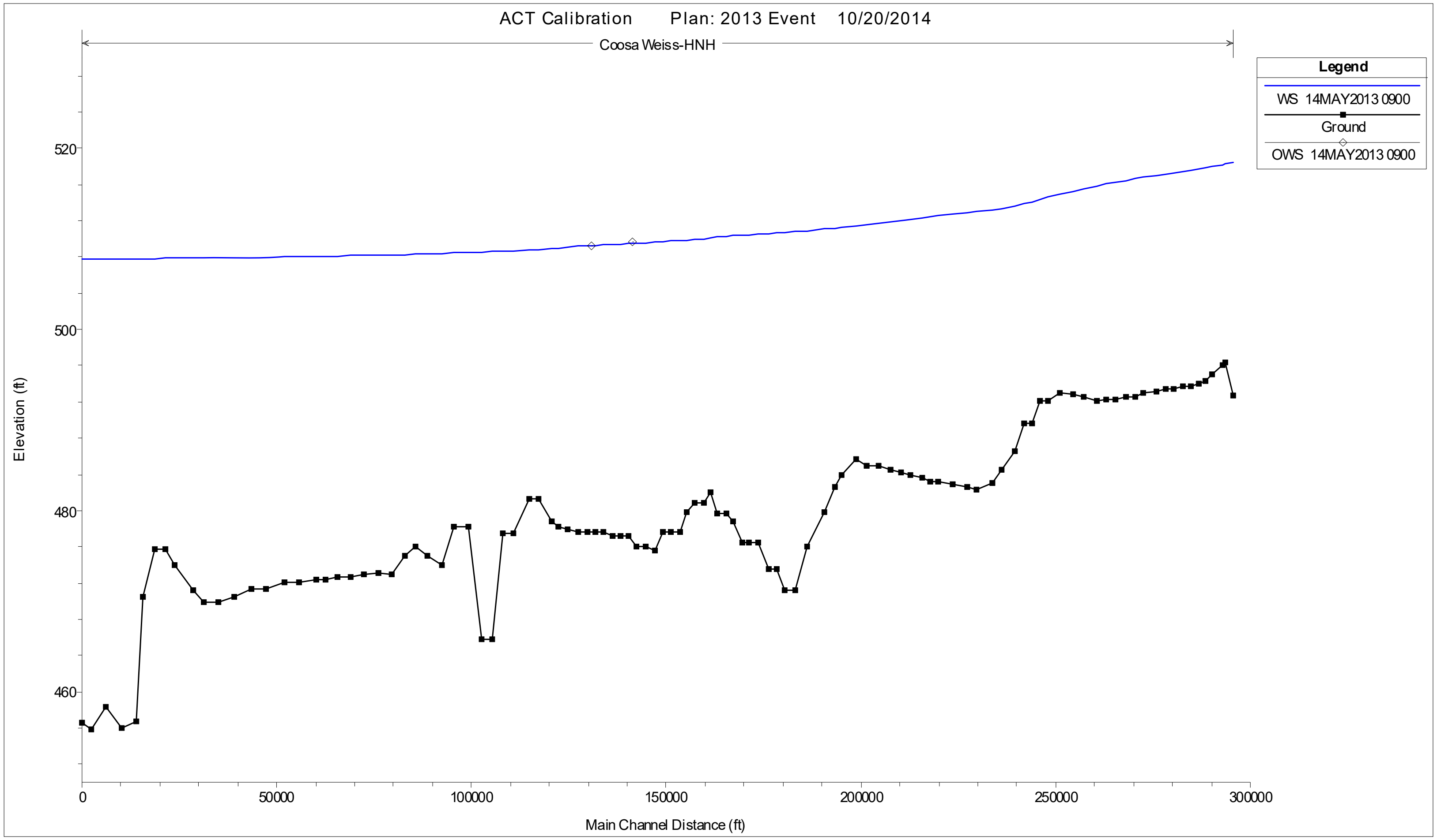

Figure 8.5 – Verification – Simulated vs. Observed – April 2013; Weiss-HNH reach of the Coosa River

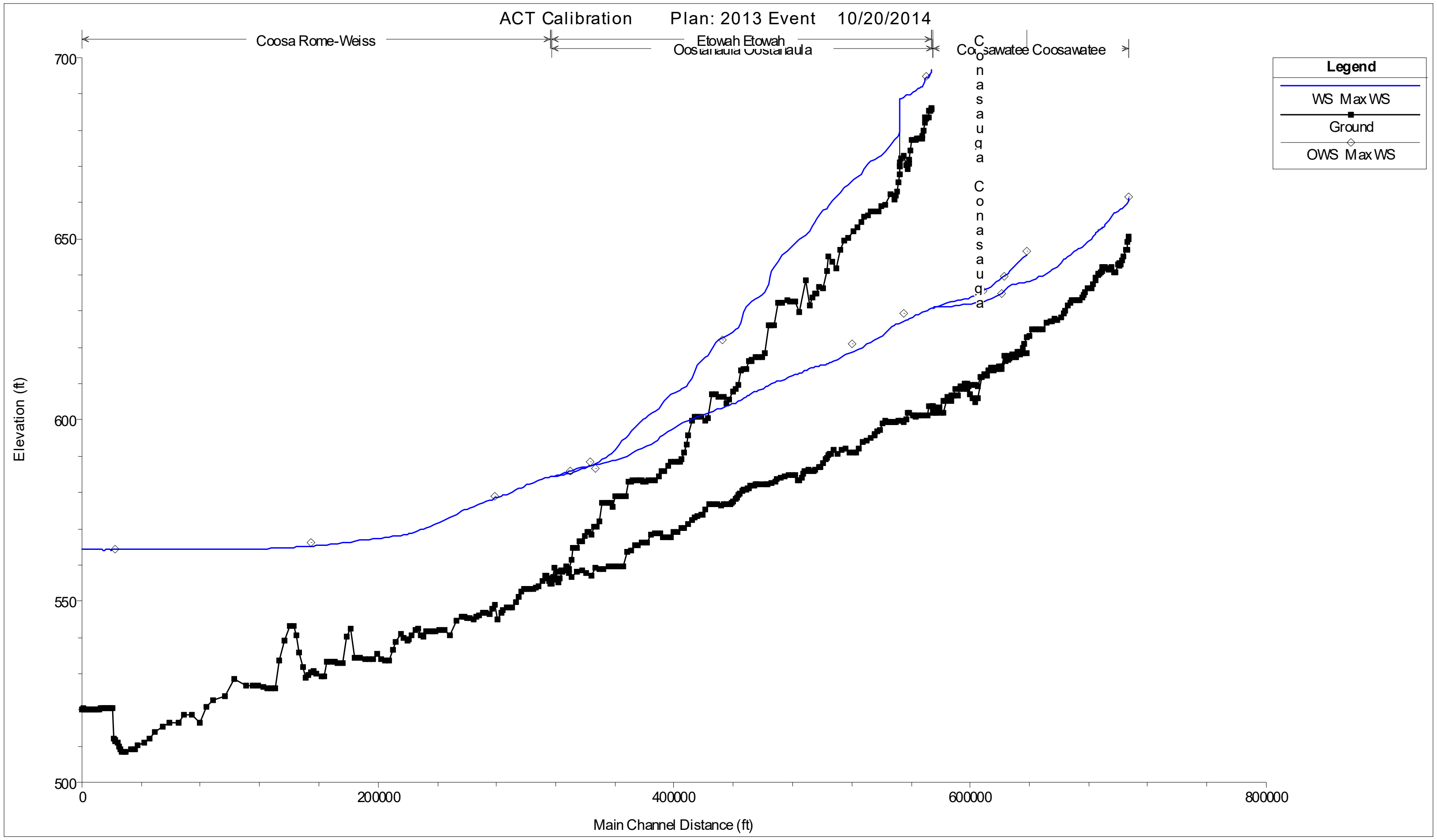

Figure 8.6 – Verification – Simulated vs. Observed – April 2013; Basin above Weiss Dam (Rome-Weiss reach of the Coosa River, Etowah, Oostanaula, Coosawattee, and Conasauga Rivers)

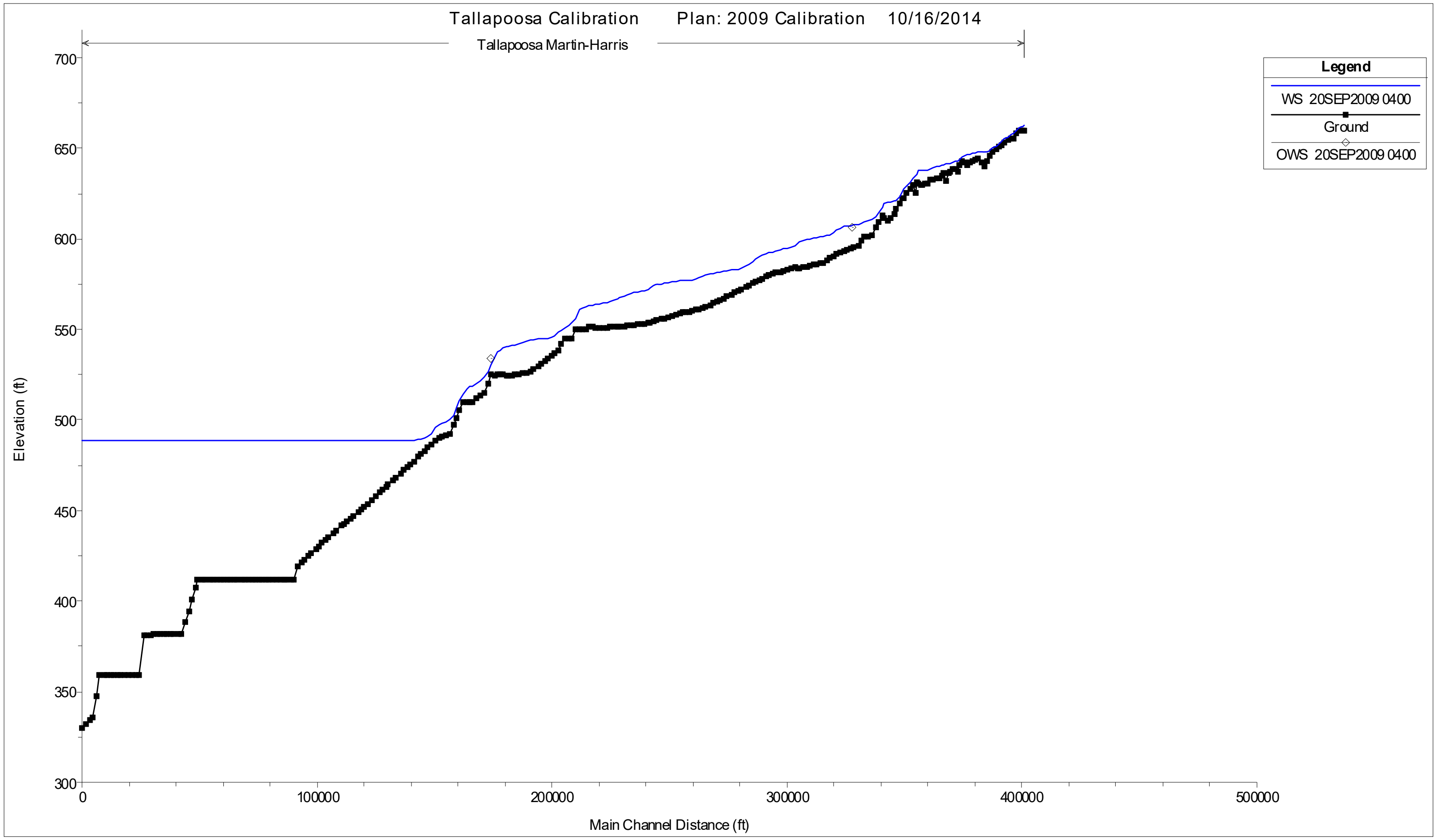

Figure 8.7 – Calibration – Simulated vs. Observed – September 2009; Martin-Harris reach on the Tallapoosa River

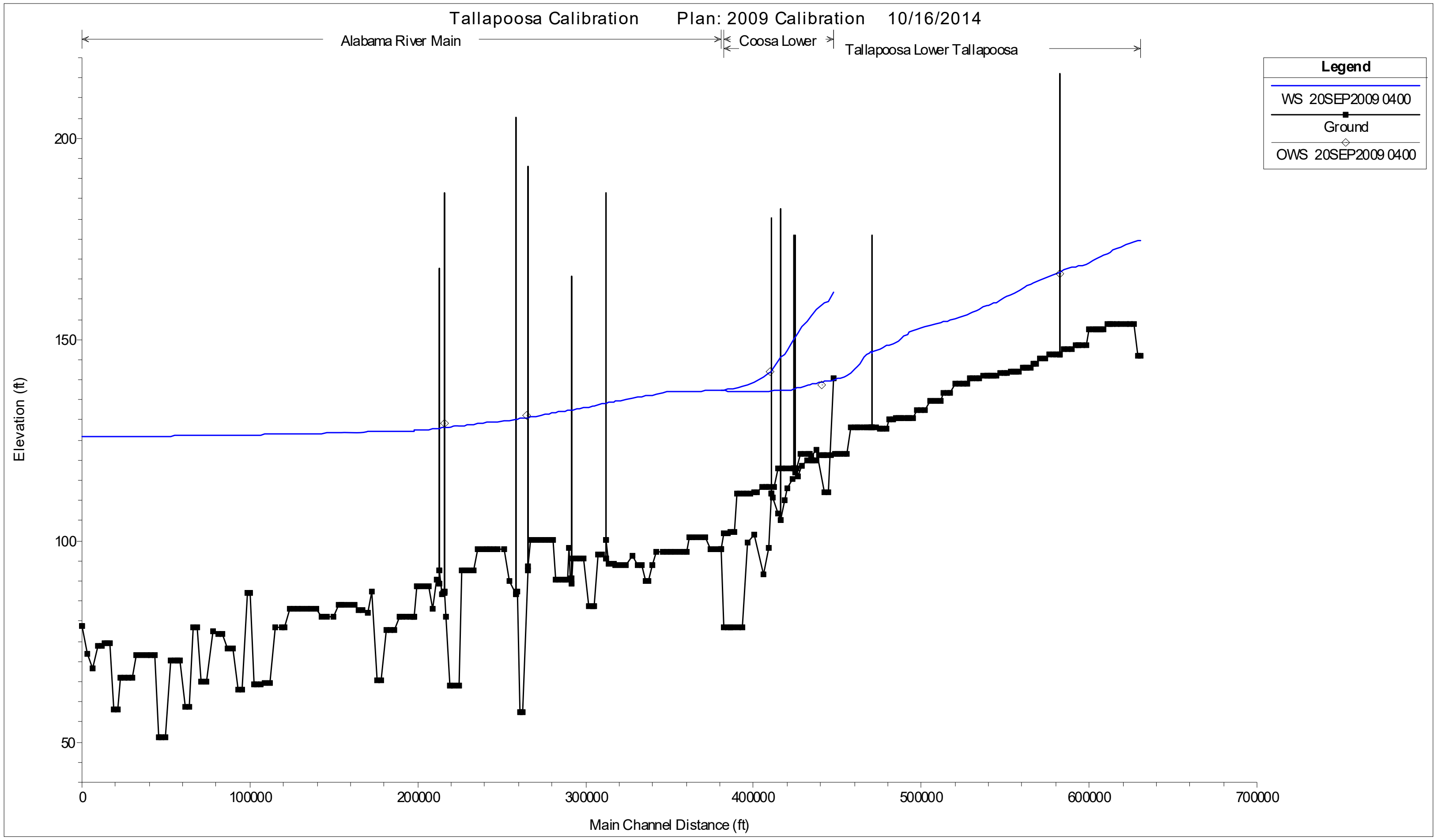

Figure 8.8 – Calibration – Simulated vs. Observed – September 2009; Alabama River, Lower Tallapoosa reach of the Tallapoosa River, and Lower reach of the Coosa River

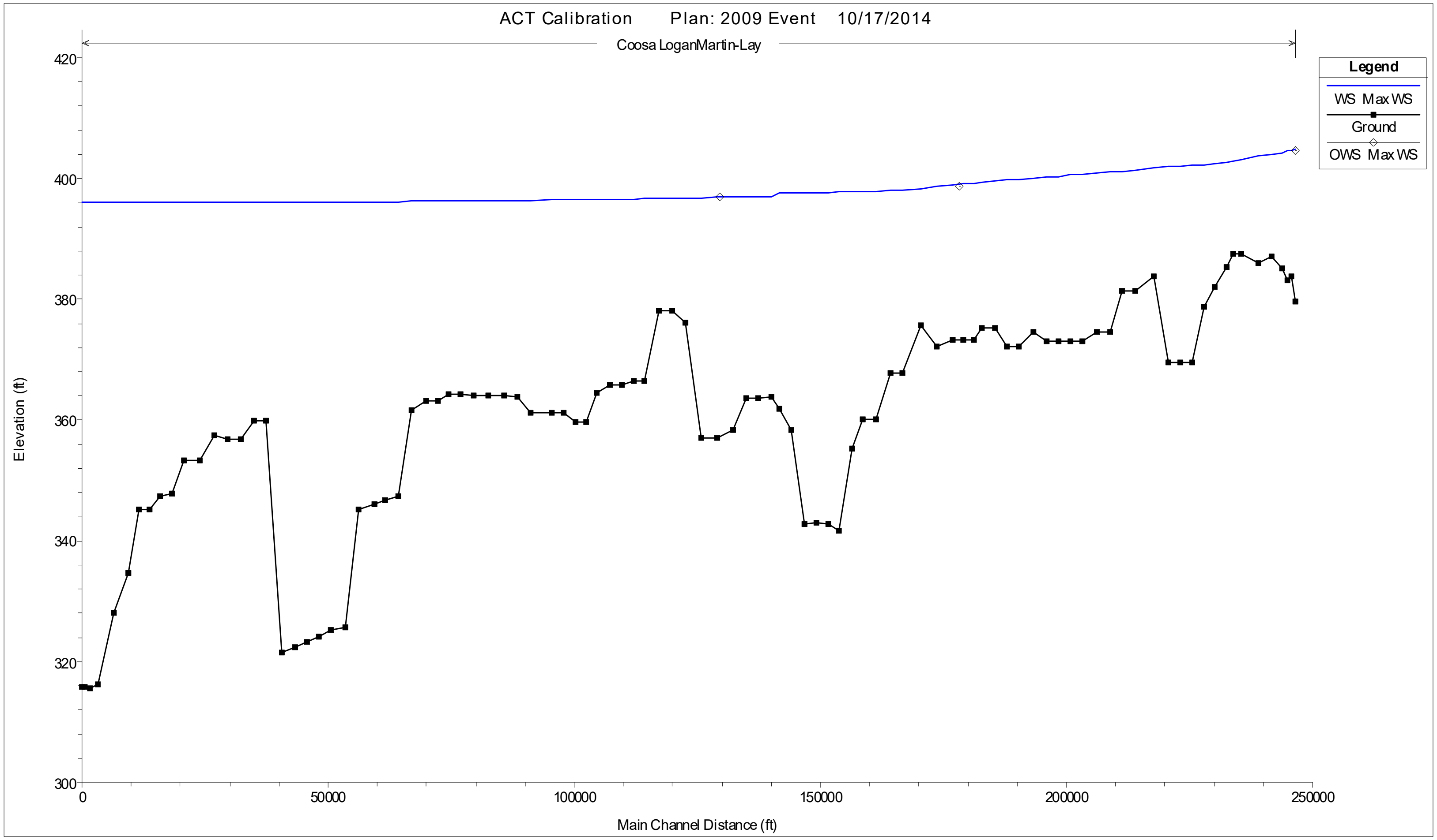

Figure 8.9 – Calibration – Simulated vs. Observed – September 2009; LoganMartin-Lay reach on the Coosa River

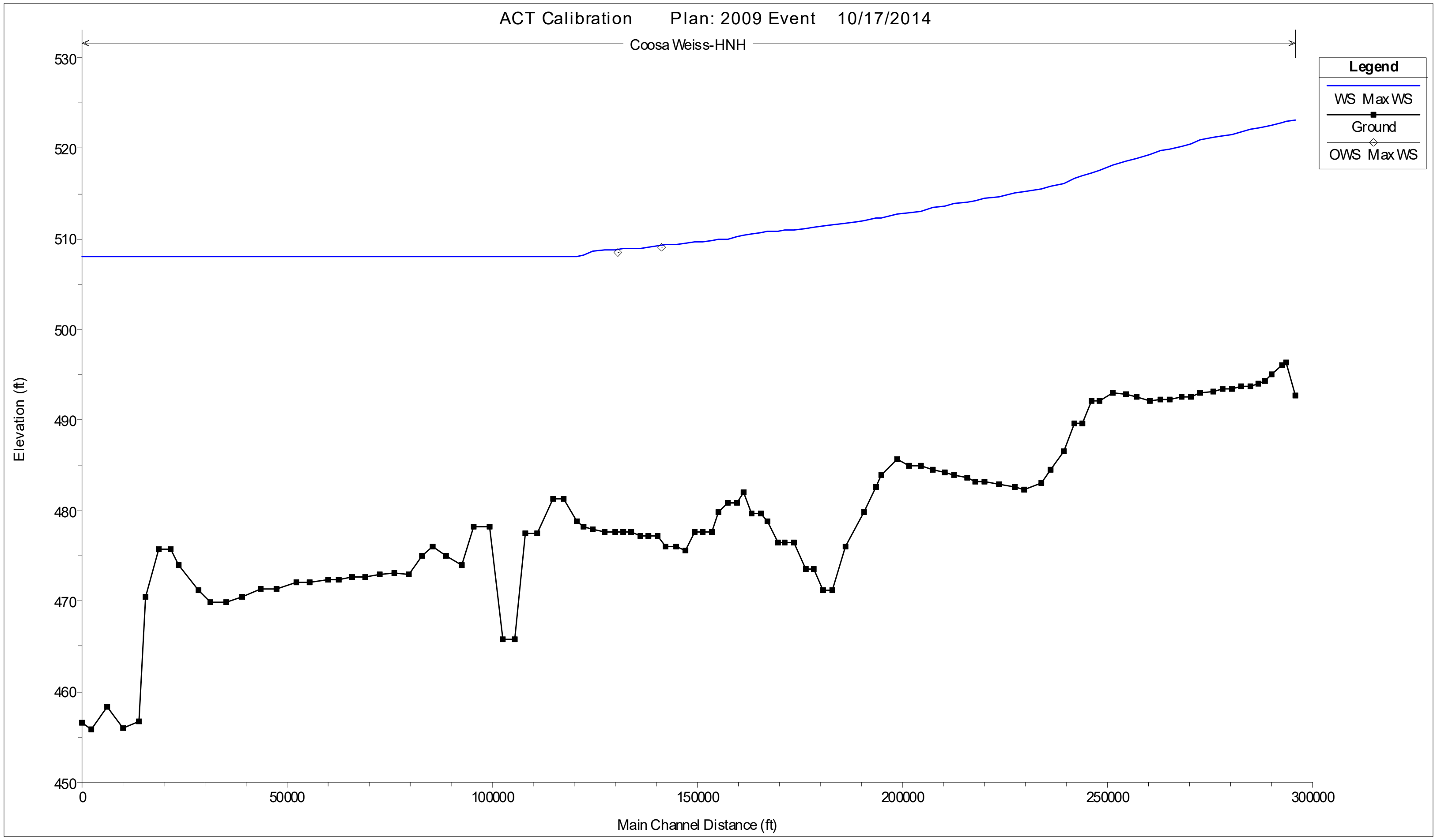

Figure 8.10 – Calibration – Simulated vs. Observed – September 2009; Weiss-HNH reach on the Coosa River

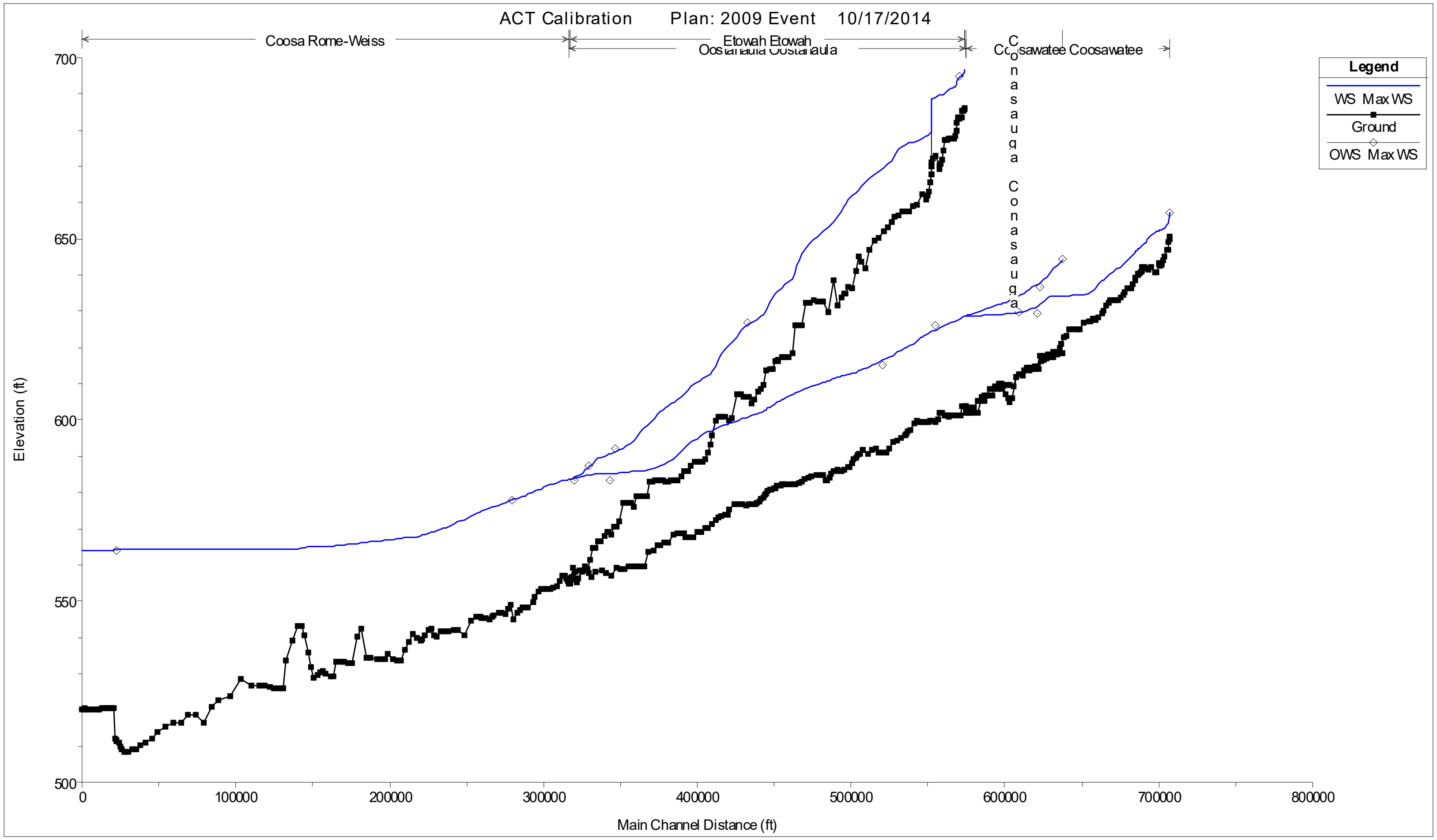

Figure 8.11 – Calibration – Simulated vs. Observed – September 2009; Basin above Weiss Dam (Rome-Weiss reach of the Coosa River, Etowah, Oostanaula, Coosawattee, and Conasauga Rivers)

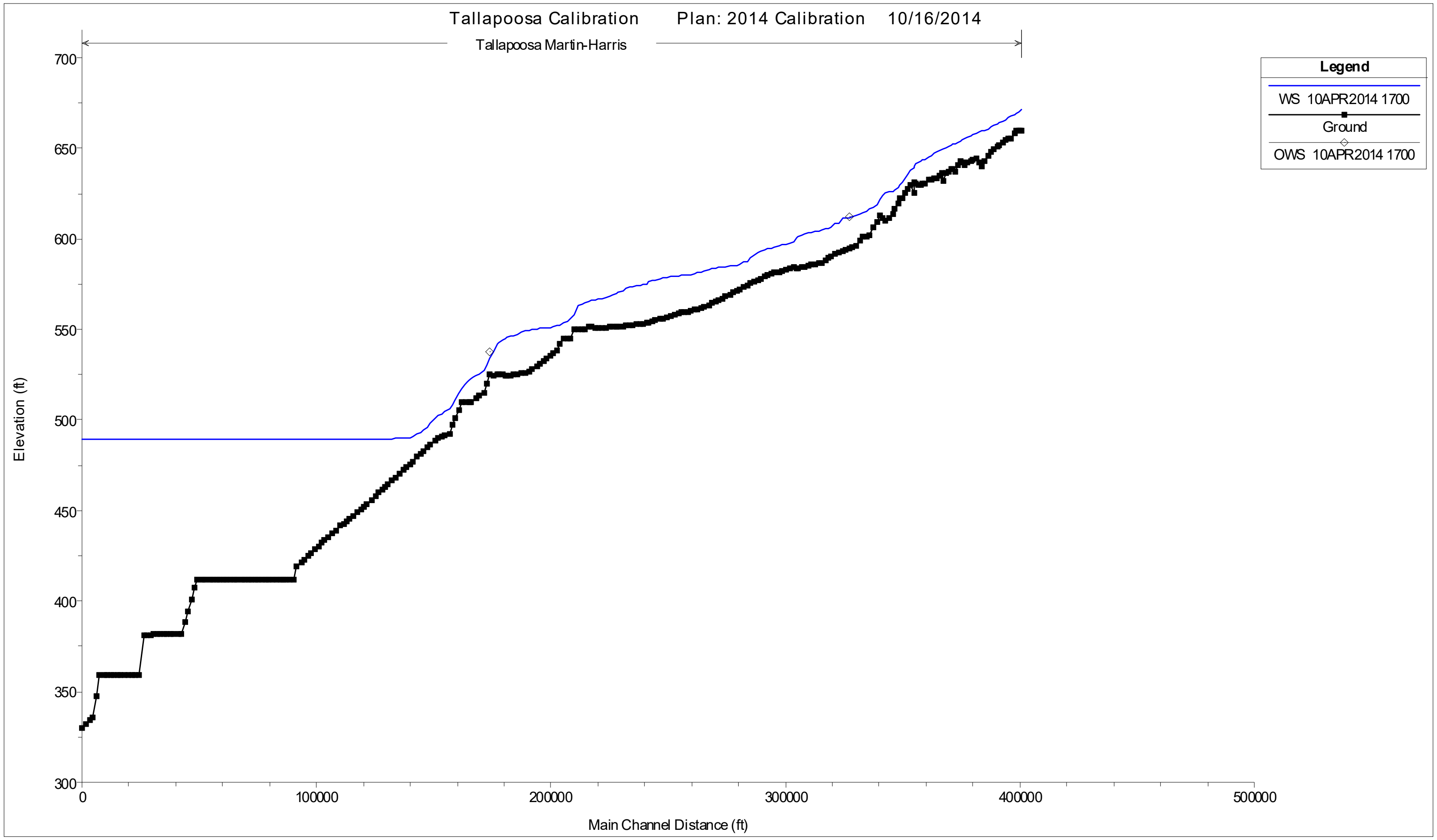

Figure 8.12 – Calibration – Simulated vs. Observed – March 2014; Martin-Harris reach on the Tallapoosa River

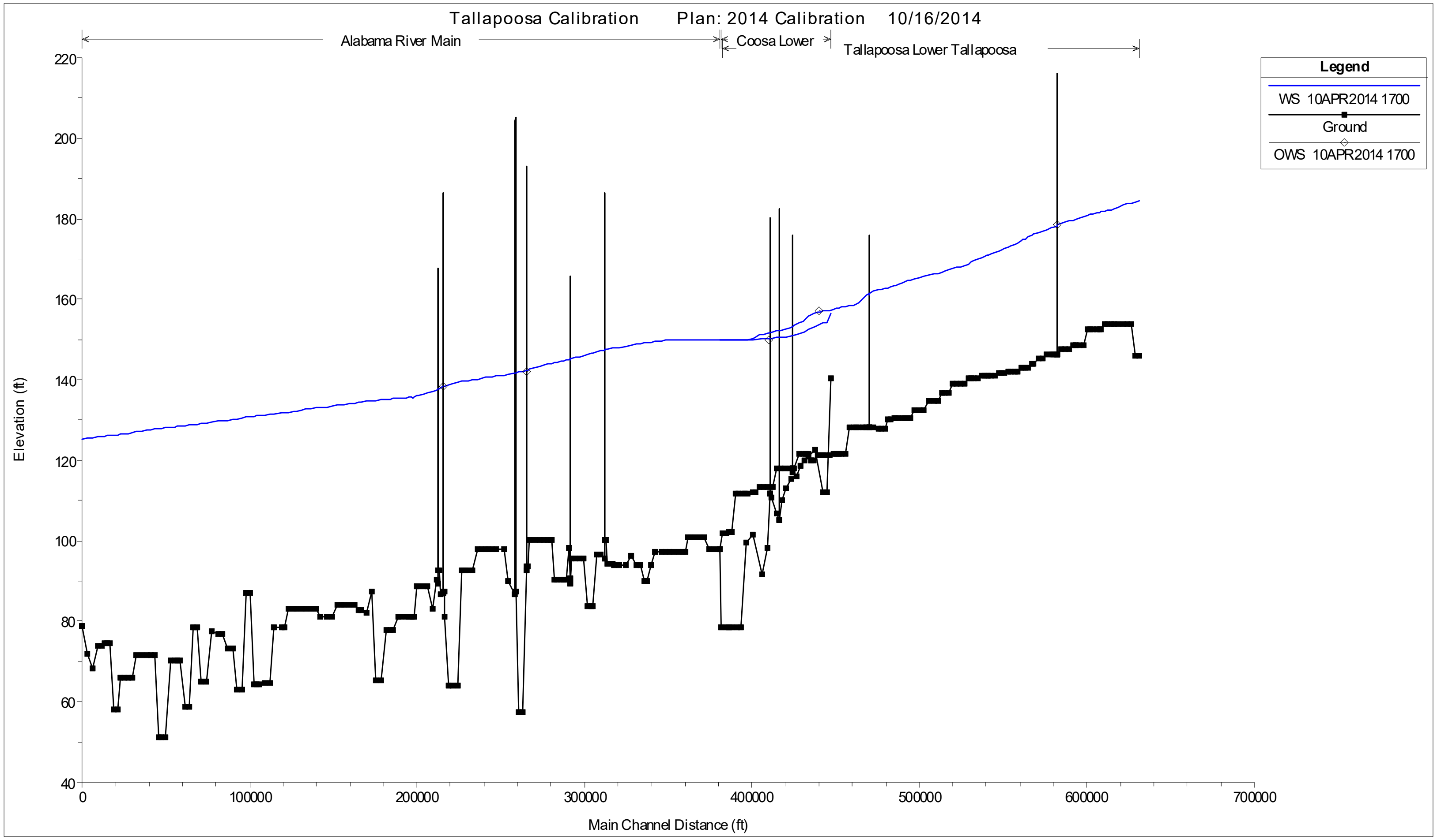

Figure 8.13 – Calibration – Simulated vs. Observed – March 2014; Alabama River, Lower Tallapoosa reach of the Tallapoosa River, and Lower reach of the Coosa River

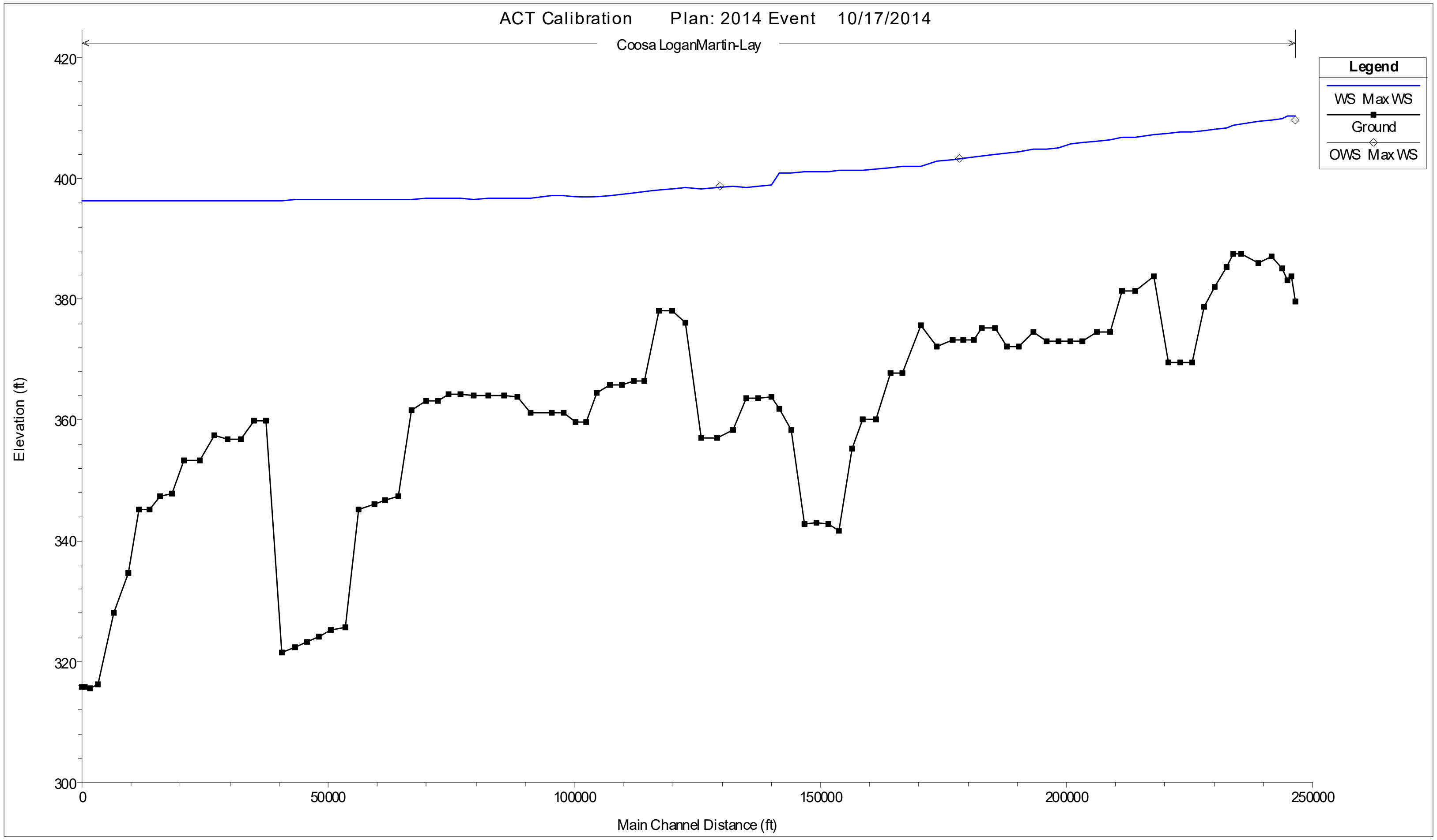

Figure 8.14 – Calibration – Simulated vs. Observed – March 2014; LoganMartin-Lay reach on the Coosa River

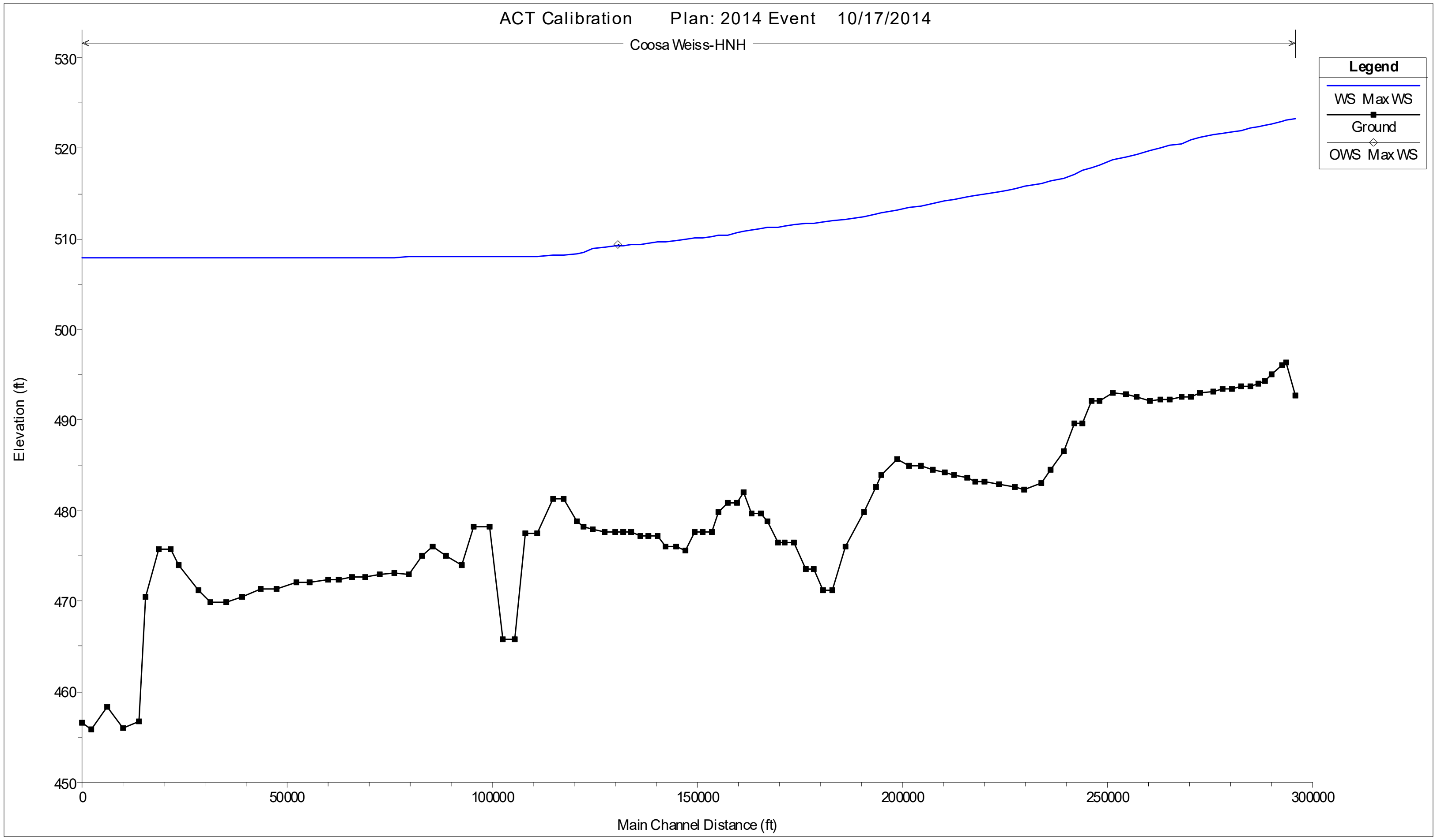

Figure 8.15 – Calibration – Simulated vs. Observed – March 2014; Weiss-HNH reach on the Coosa River

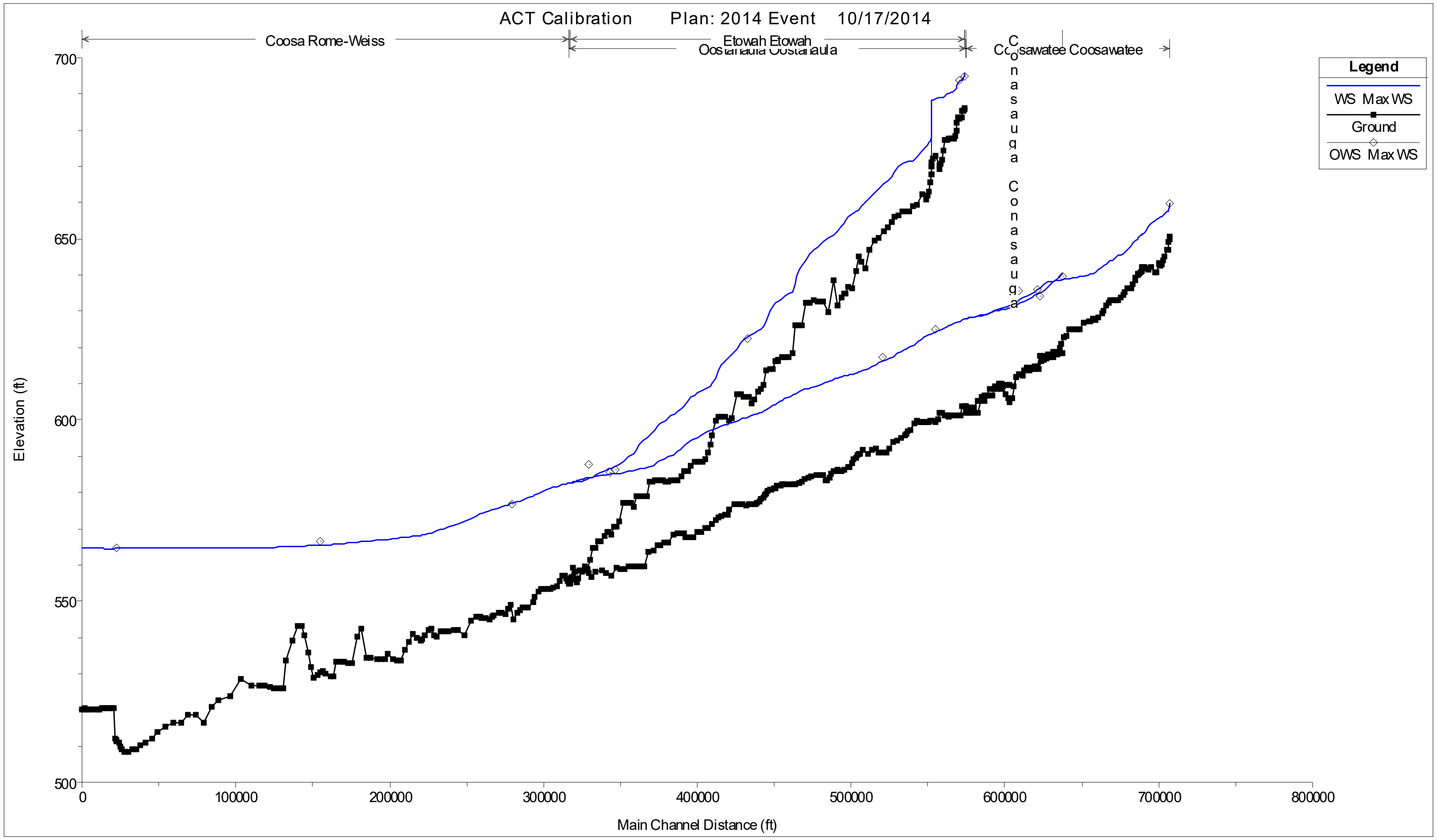

Figure 8.16 – Calibration – Simulated vs. Observed – March 2014; Basin above Weiss Dam (Rome-Weiss reach of the Coosa River, Etowah, Oostanaula, Coosawattee, and Conasauga Rivers)

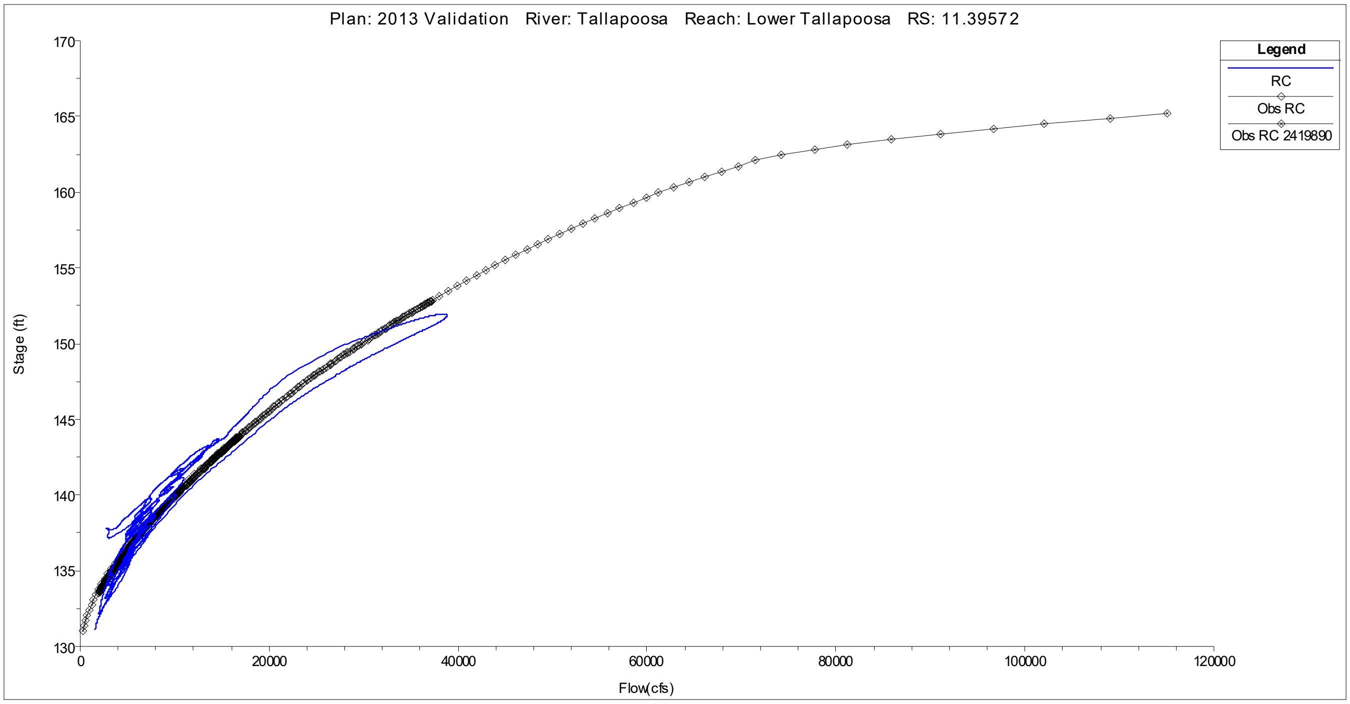

Figure 8.17 – Rating Curve Comparison – HEC-RAS vs. USGS 02419890; 2013 Validation Event (Tallapoosa Lower Tallapoosa XS 11.39572 – Tallapoosa River near Mont.-Mont. Water Works)

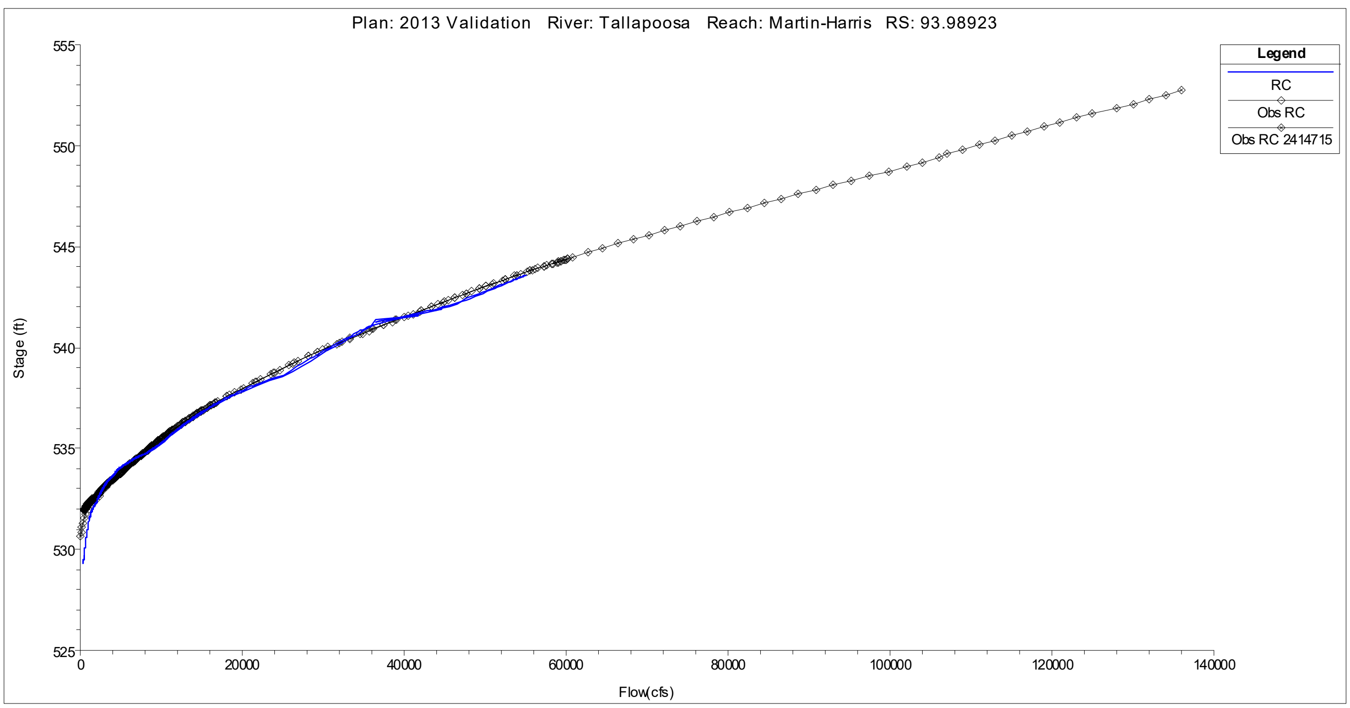

Figure 8.18 – Rating Curve Comparison – HEC-RAS vs. USGS 02414715; 2013 Validation Event (Tallapoosa Martin-Harris XS 93.98923 – Tallapoosa River near New Site, AL (Horseshoe Bend))

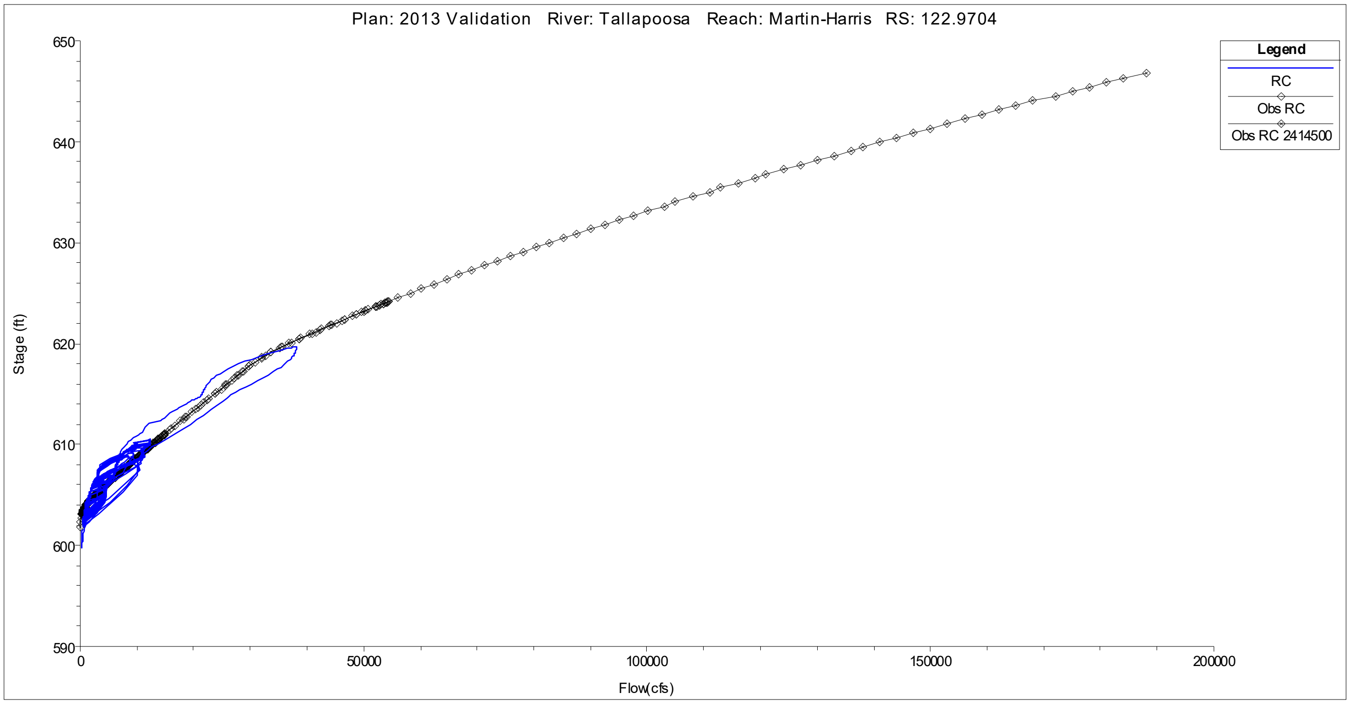

Figure 8.19 – Rating Curve Comparison – HEC-RAS vs. USGS 02414500; 2013 Validation Event (Tallapoosa Martin-Harris XS 122.9704 – Tallapoosa River at Wadley, AL)

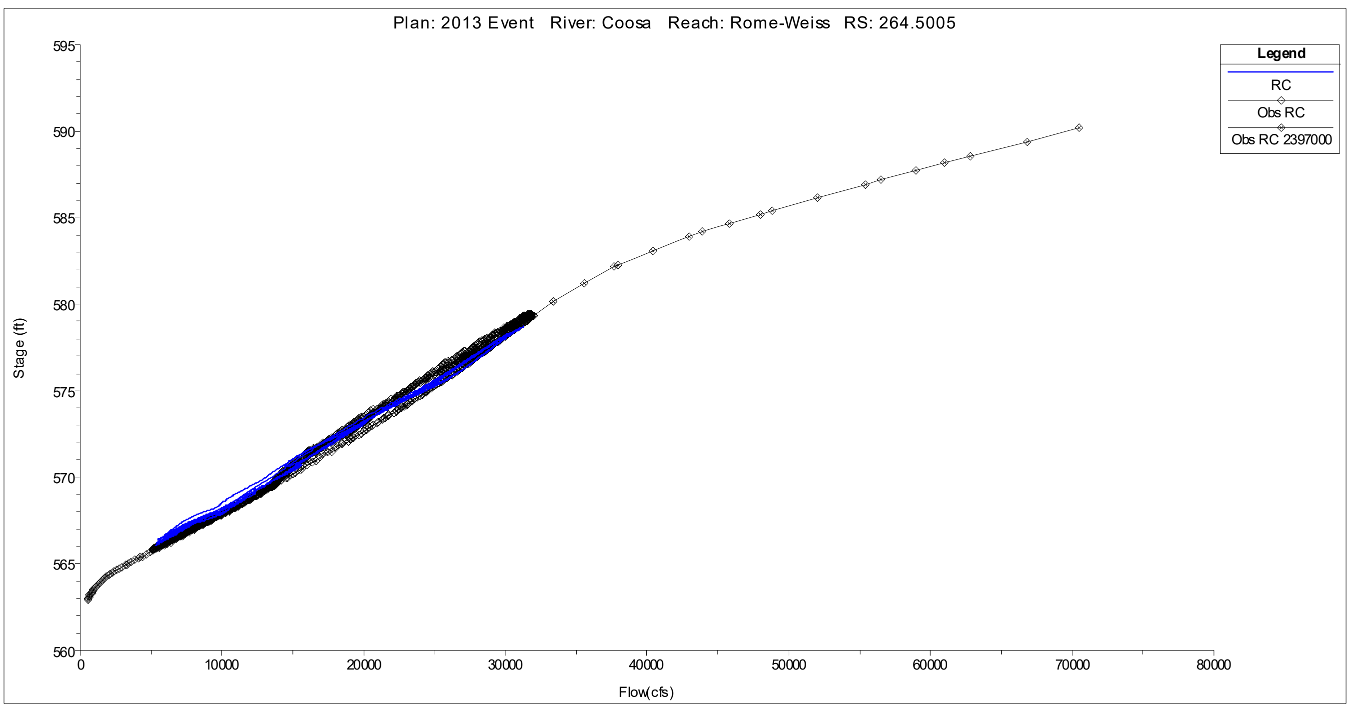

Figure 8.20 – Rating Curve Comparison – HEC-RAS vs. USGS 02397000; 2013 Validation Event (Coosa Rome-Weiss XS 264.5005 – Coosa River near Rome, GA)

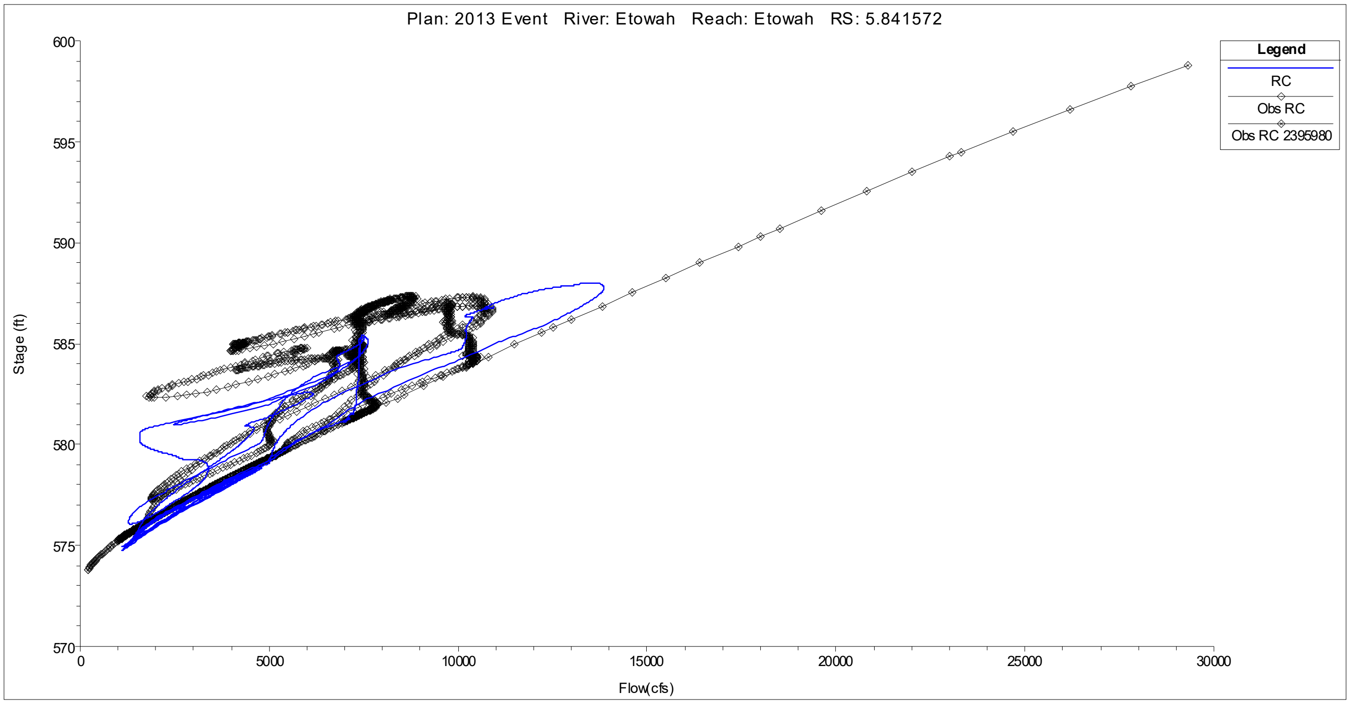

Figure 8.21 – Rating Curve Comparison – HEC-RAS vs. USGS 02395980; 2013 Validation Event (Etowah XS 5.841572 – Etowah River at GA 1 Loop, near Rome, GA);

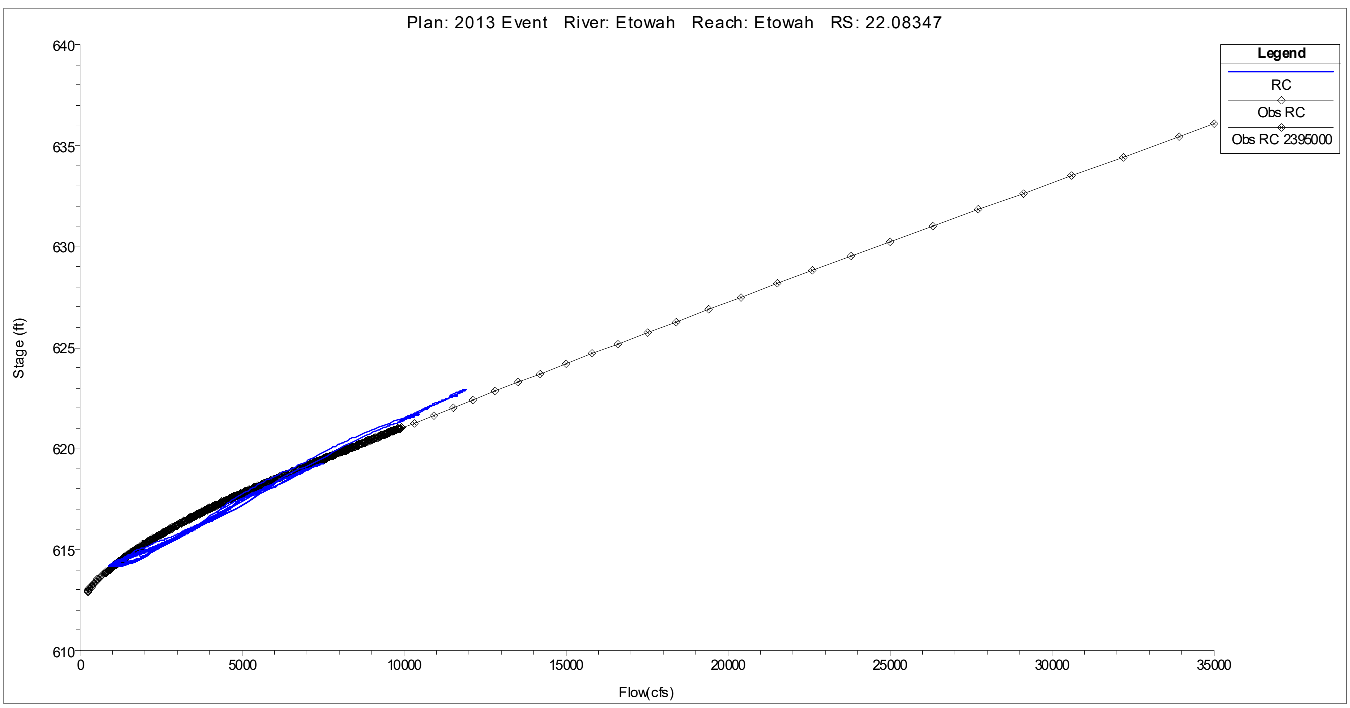

Figure 8.22 – Rating Curve Comparison – HEC-RAS vs. USGS 02395000; 2013 Validation Event (Etowah XS 22.08347 – Etowah River near Kingston, GA);

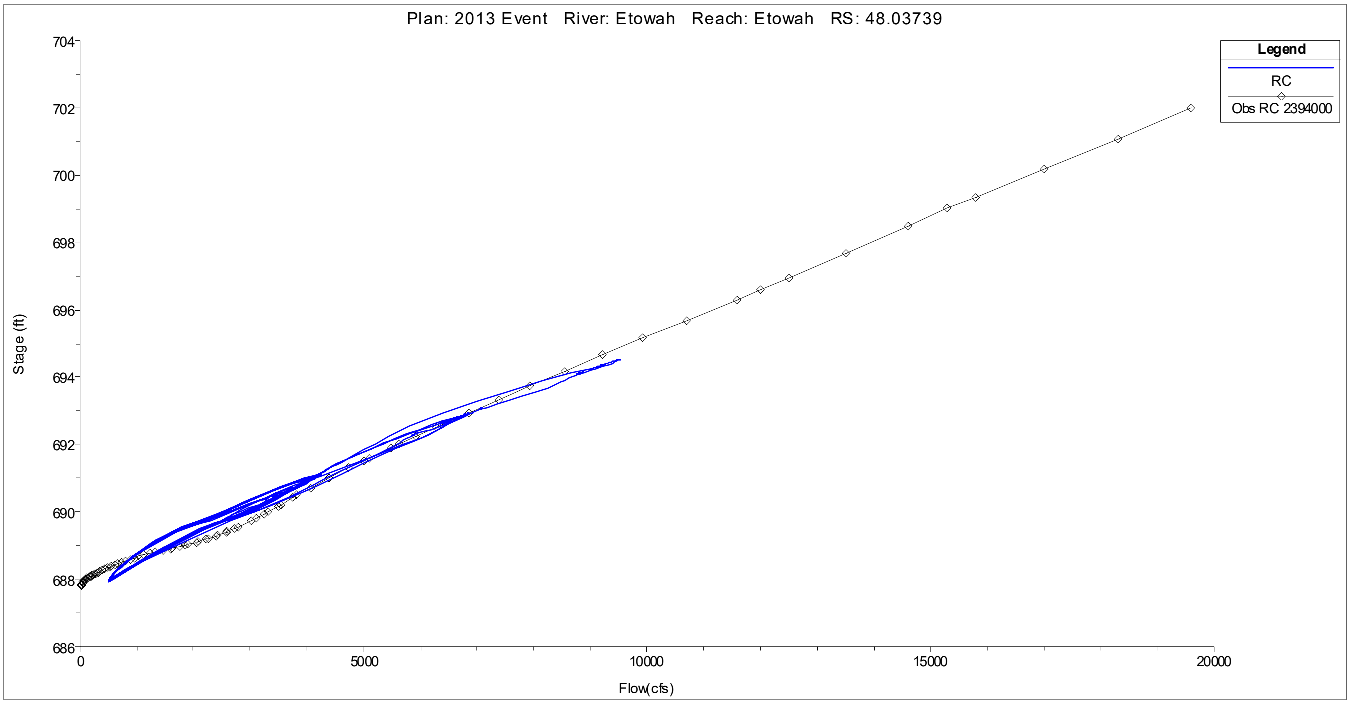

Figure 8.23 – Rating Curve Comparison – HEC-RAS vs. USGS 02394000; 2013 Validation Event (Etowah XS 48.03739 – Etowah River at Allatoona Dam, abv Cartersville, GA);

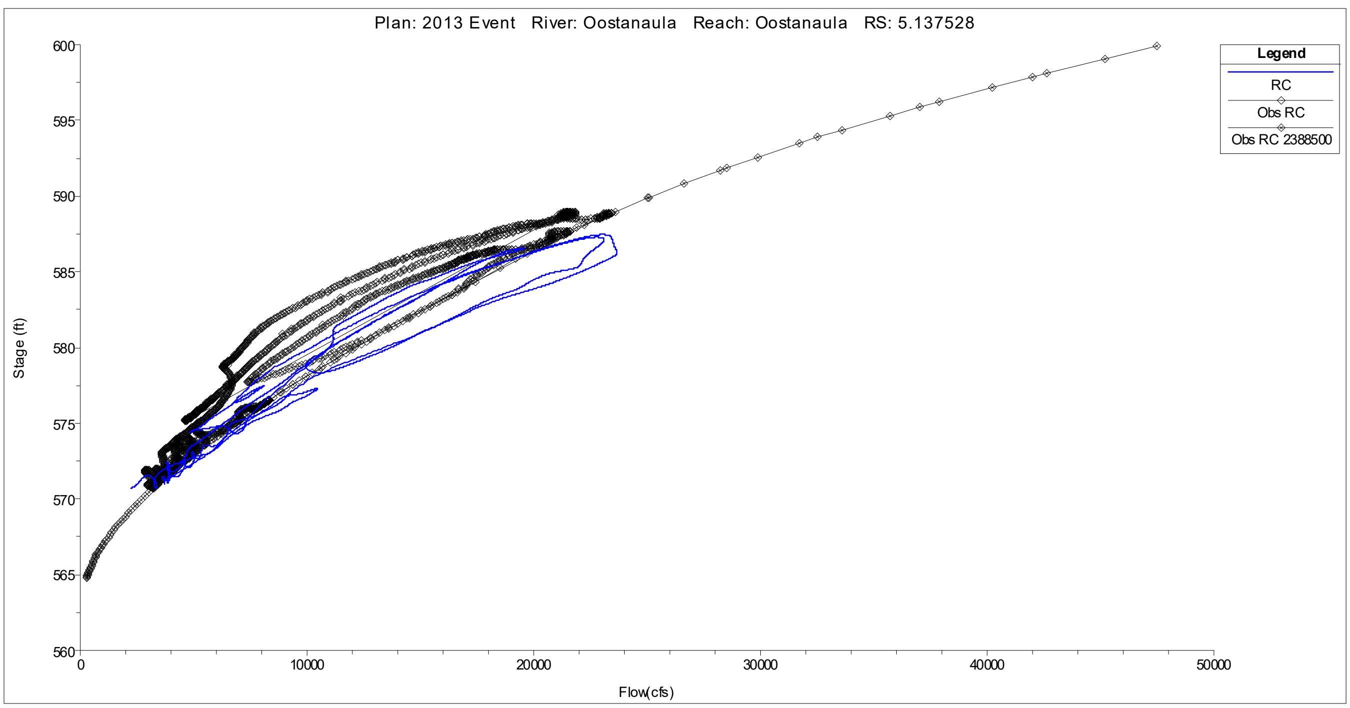

Figure 8.24 – Rating Curve Comparison – HEC-RAS vs. USGS 02388500; 2013 Validation Event (Oostanaula XS 5.137528 – Oostanaula River near Rome, GA);

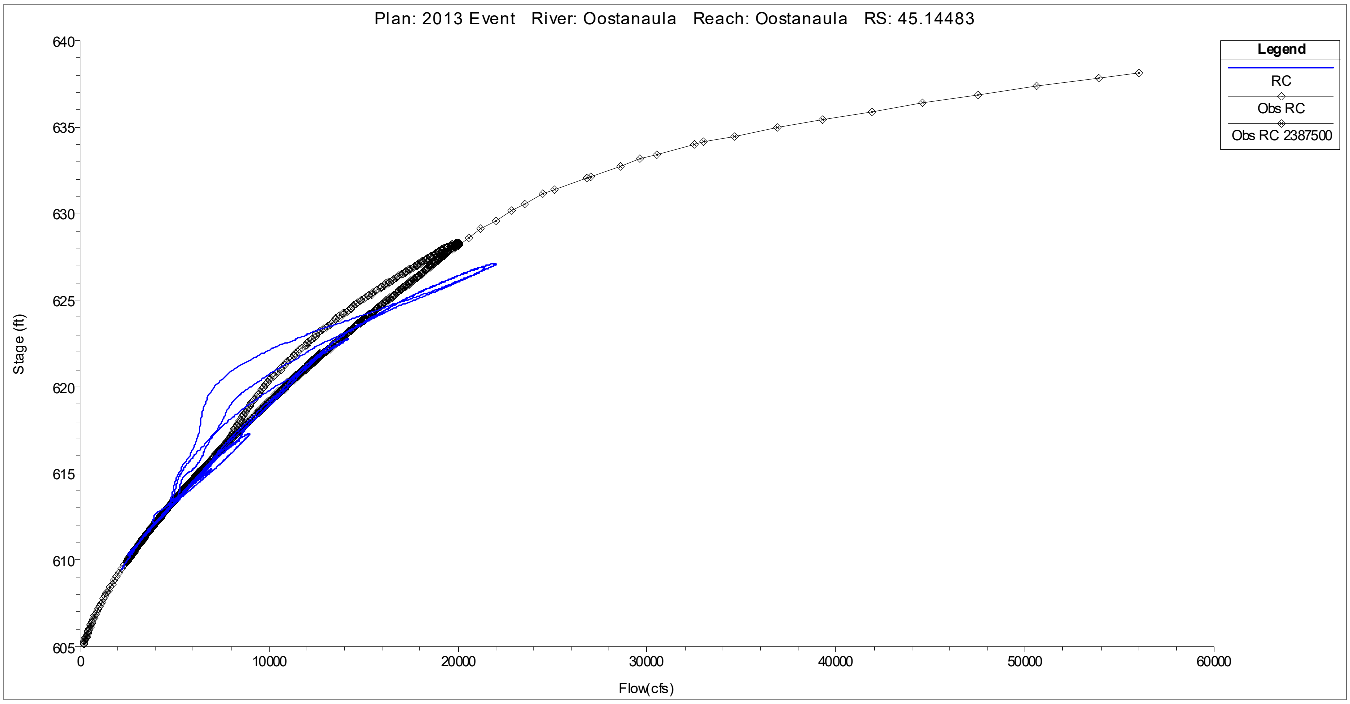

Figure 8.25 – Rating Curve Comparison – HEC-RAS vs. USGS 02387500; 2013 Validation Event (Oostanaula XS 45.14483 – Oostanaula River at Resaca, GA);

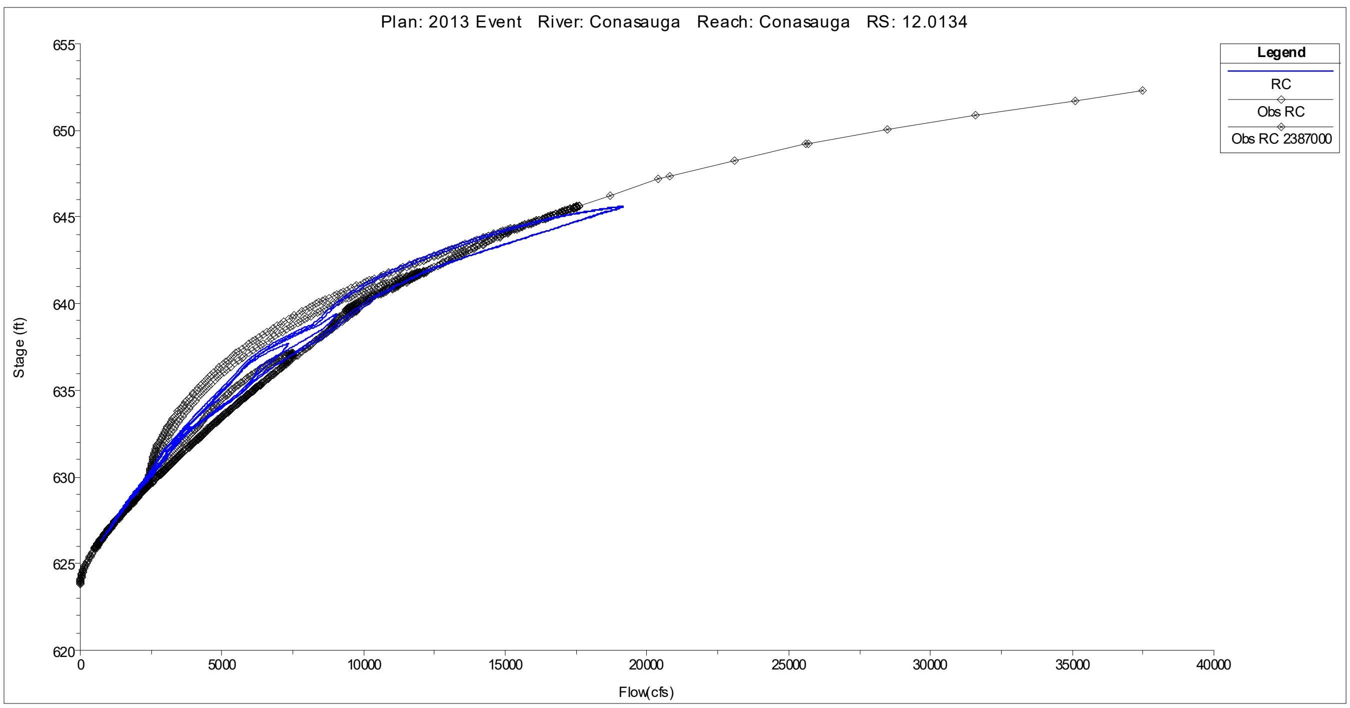

Figure 8.26 – Rating Curve Comparison – HEC-RAS vs. USGS 02387000; 2013 Validation Event (Conasauga XS 12.0134 – Conasauga River, at Tilton, GA);

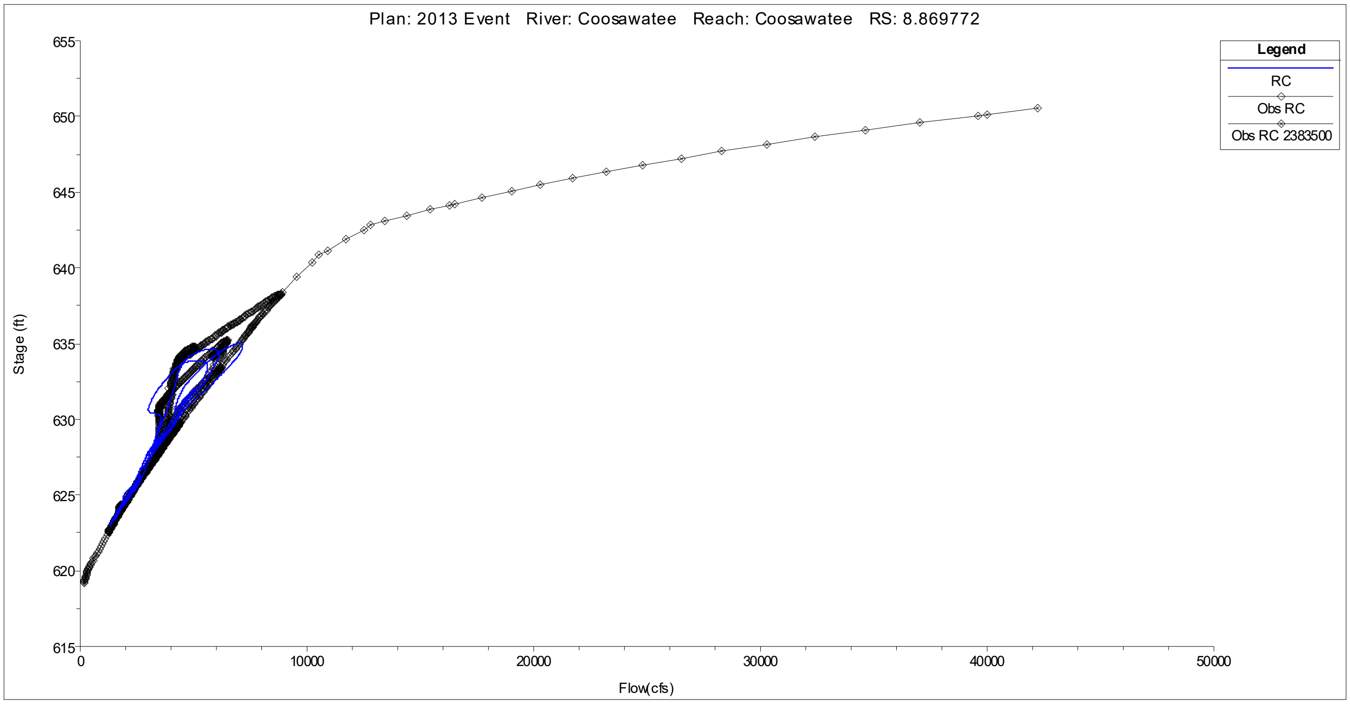

Figure 8.27 – Rating Curve Comparison – HEC-RAS vs. USGS 02383500; 2013 Validation Event (Coosawattee XS 8.869772 – Coosawattee River near Pine Chapel, GA);

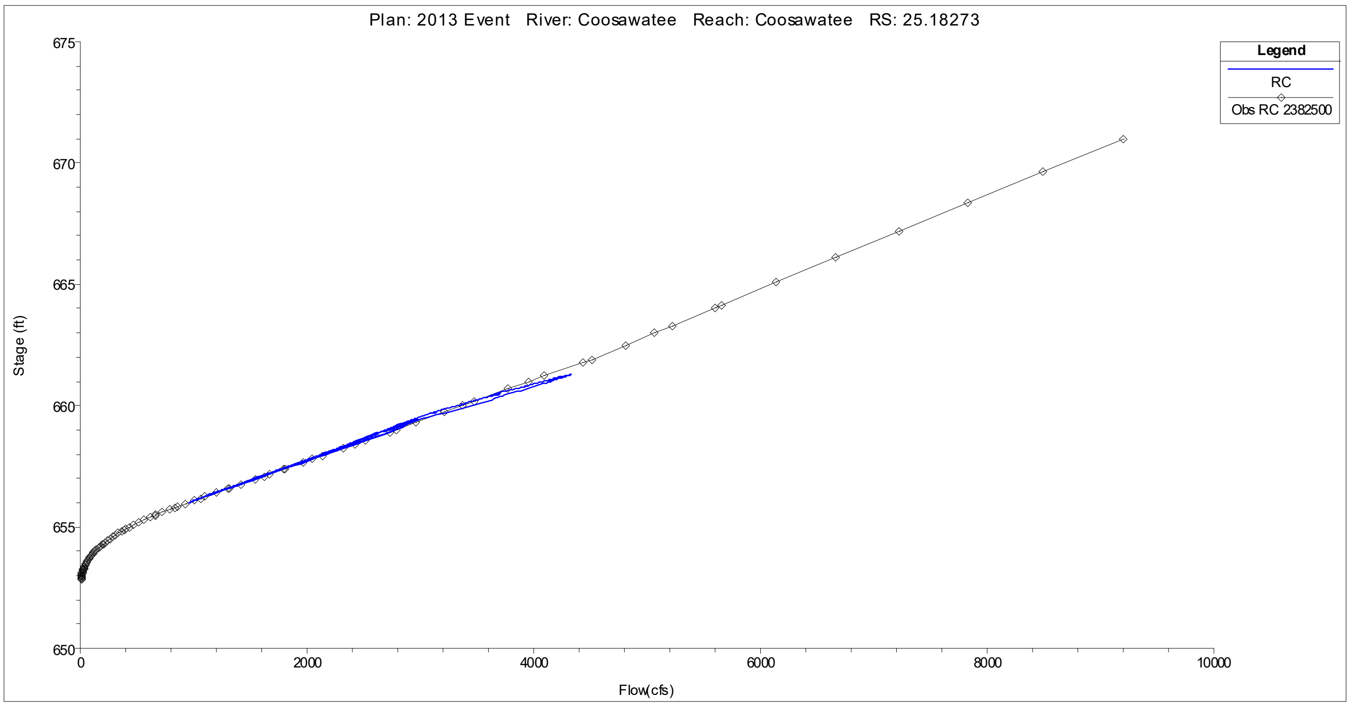

Figure 8.28 – Rating Curve Comparison – HEC-RAS vs. USGS 02382500; 2013 Validation Event (Coosawattee XS 25.18273 – Coosawattee River at Carters, GA);

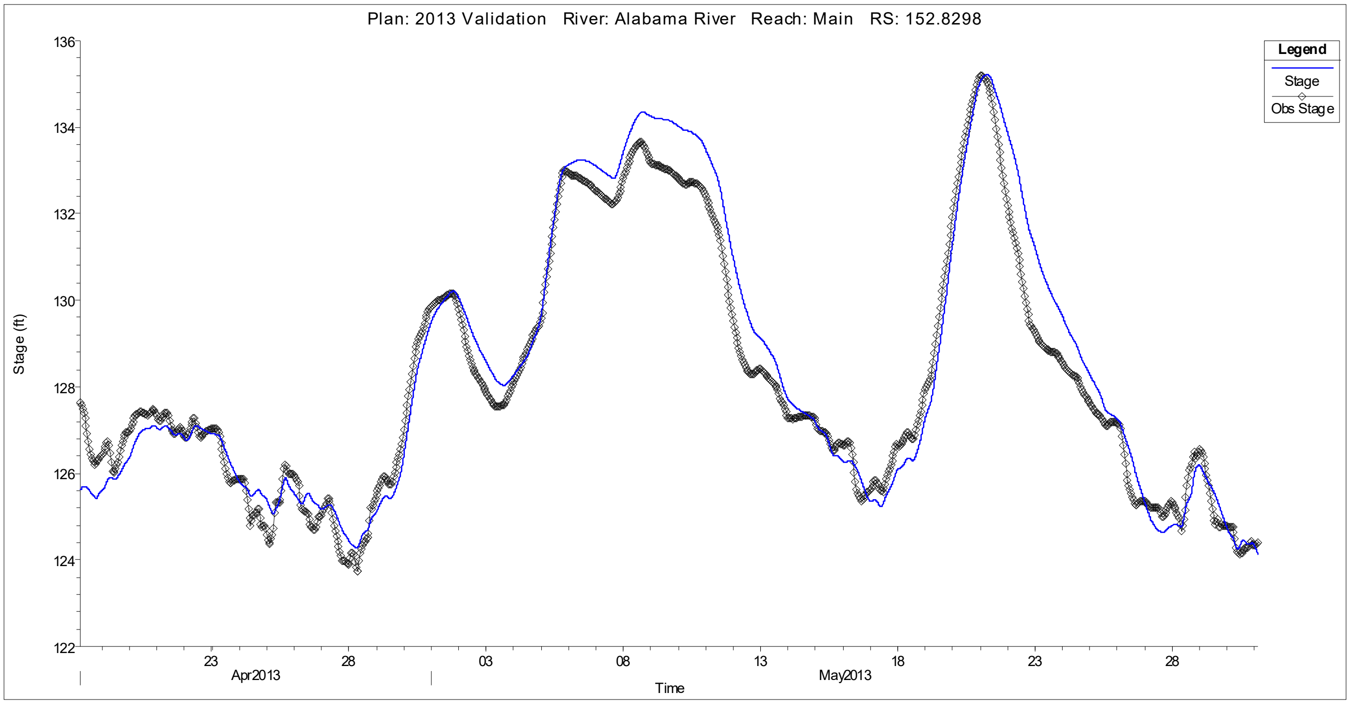

Figure 8.29 – Stage Comparison – HEC-RAS vs. USGS 02419988; 2013 Validation Event (Alabama Main XS 152.8298 – Alabama River at Montgomery, AL)

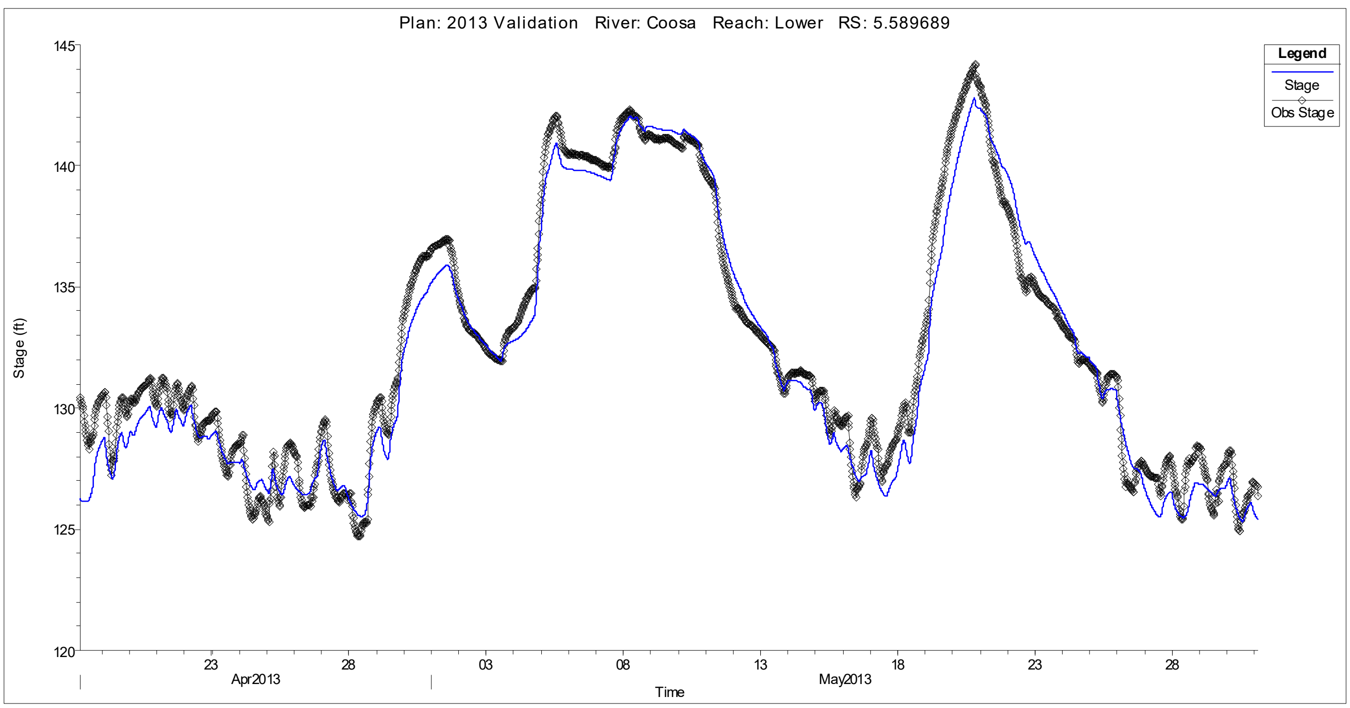

Figure 8.30 – Stage Comparison – HEC-RAS vs. USGS 02411600; 2013 Validation Event (Coosa Lower XS 5.589689 – Coosa River at Wetumpka, AL)

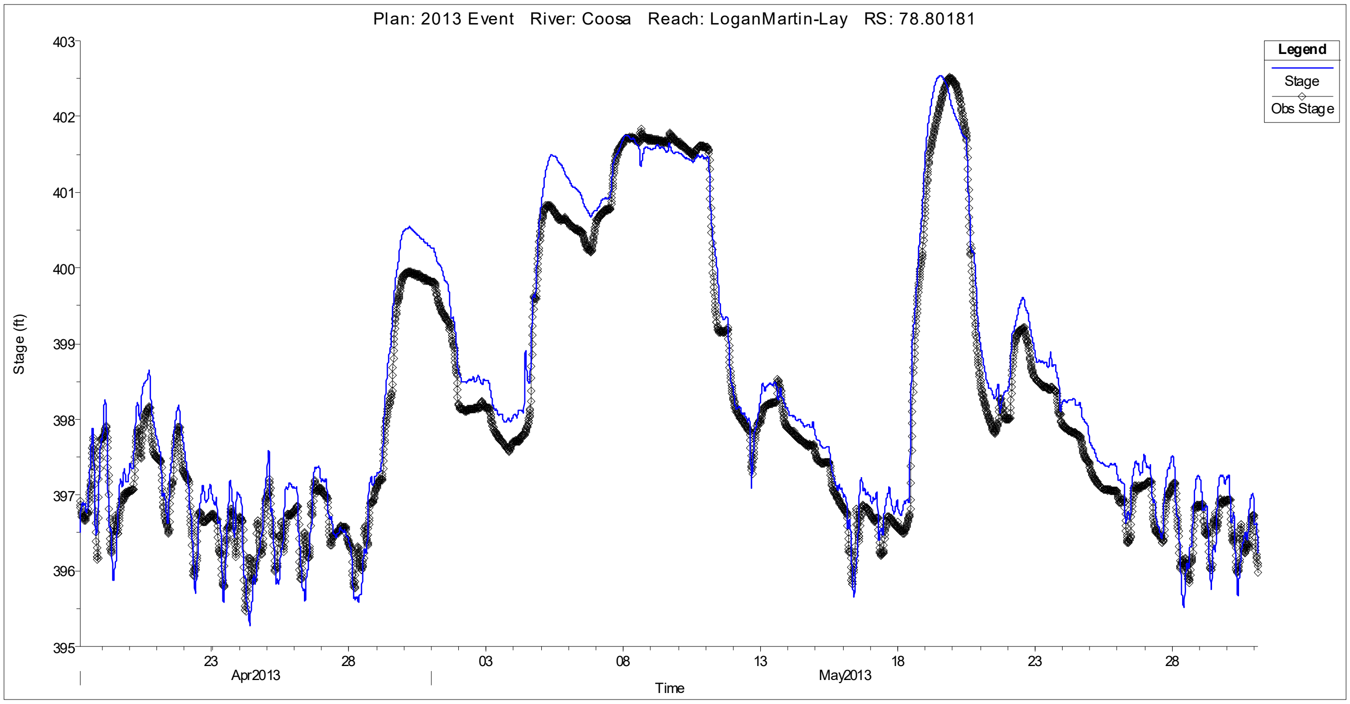

Figure 8.31 – Stage Comparison – HEC-RAS vs. USGS 02407000; 2013 Validation Event (Coosa LoganMartin-Lay XS 78.80181 – Coosa River at Childersburg, AL)

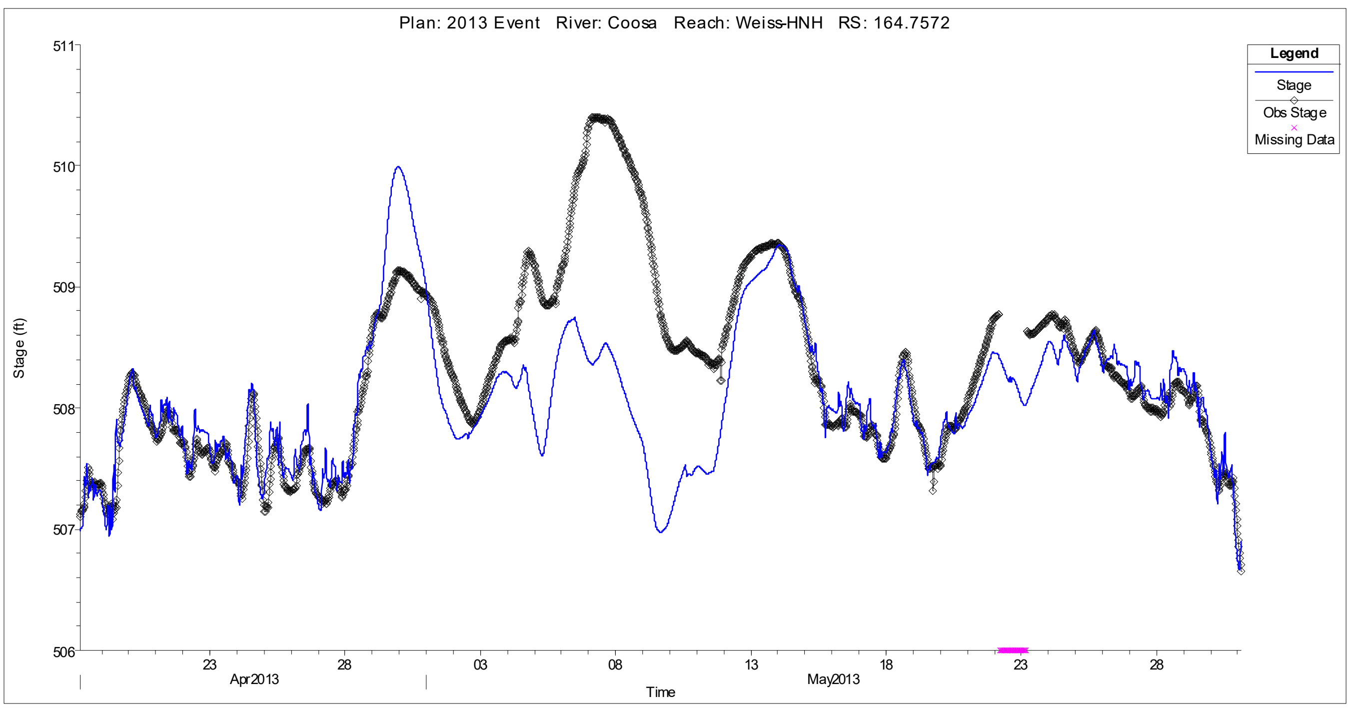

Figure 8.32 – Stage Comparison – HEC-RAS vs. USGS 02400500; 2013 Validation Event (Coosa Weiss-HNH XS 164.7572 – Coosa River at Gadsden, AL)

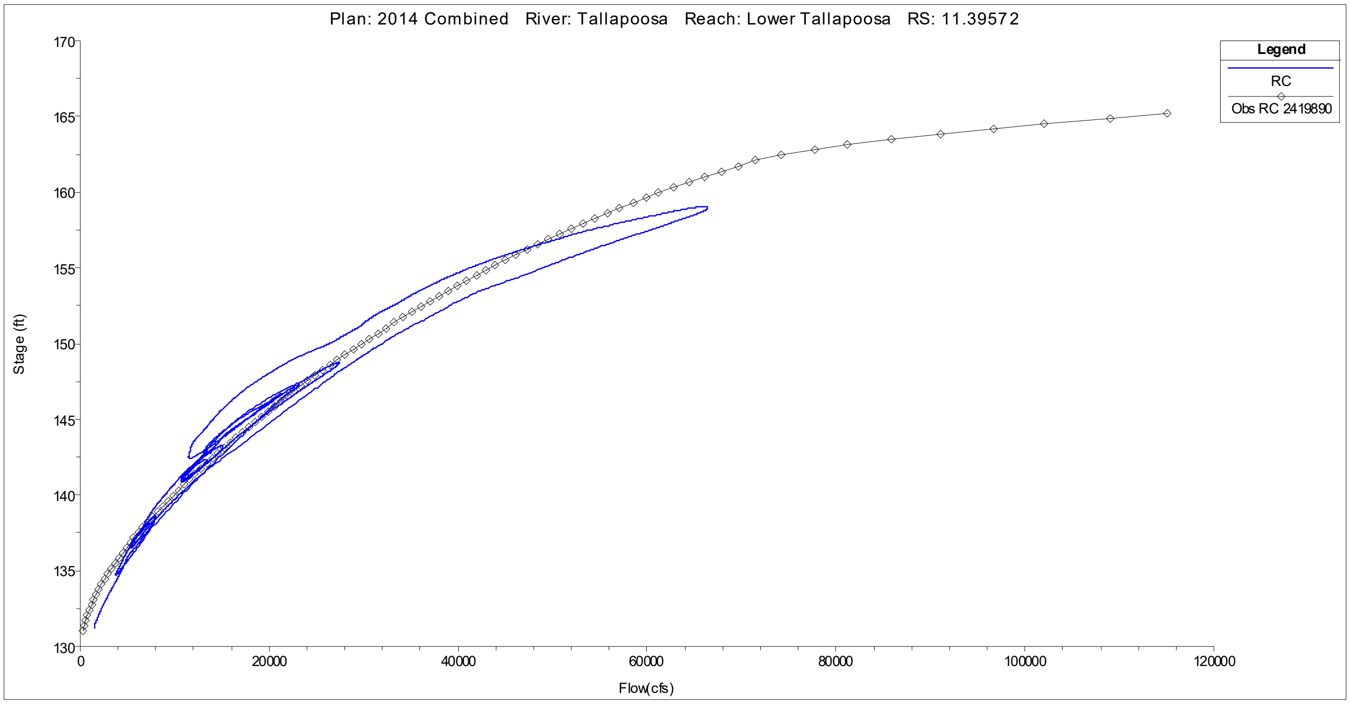

Figure 8.33 – Rating Curve Comparison – HEC-RAS vs. USGS 02419890; 2014 Event (Tallapoosa Lower Tallapoosa XS 11.39572 – Tallapoosa River near Mont.-Mont. Water Works)

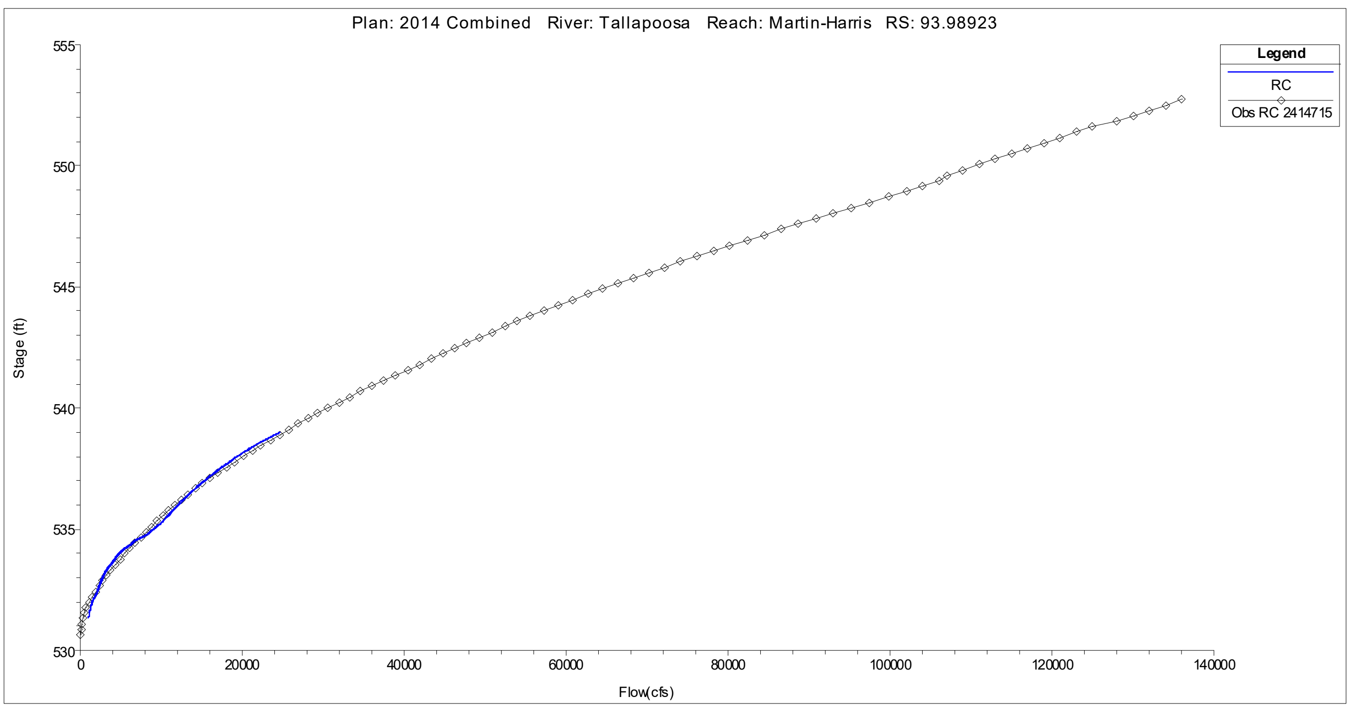

Figure 8.34 – Rating Curve Comparison – HEC-RAS vs. USGS 02414715; 2014 Event (Tallapoosa Martin-Harris XS 93.98923 – Tallapoosa River near New Site, AL(Horseshoe Bend))

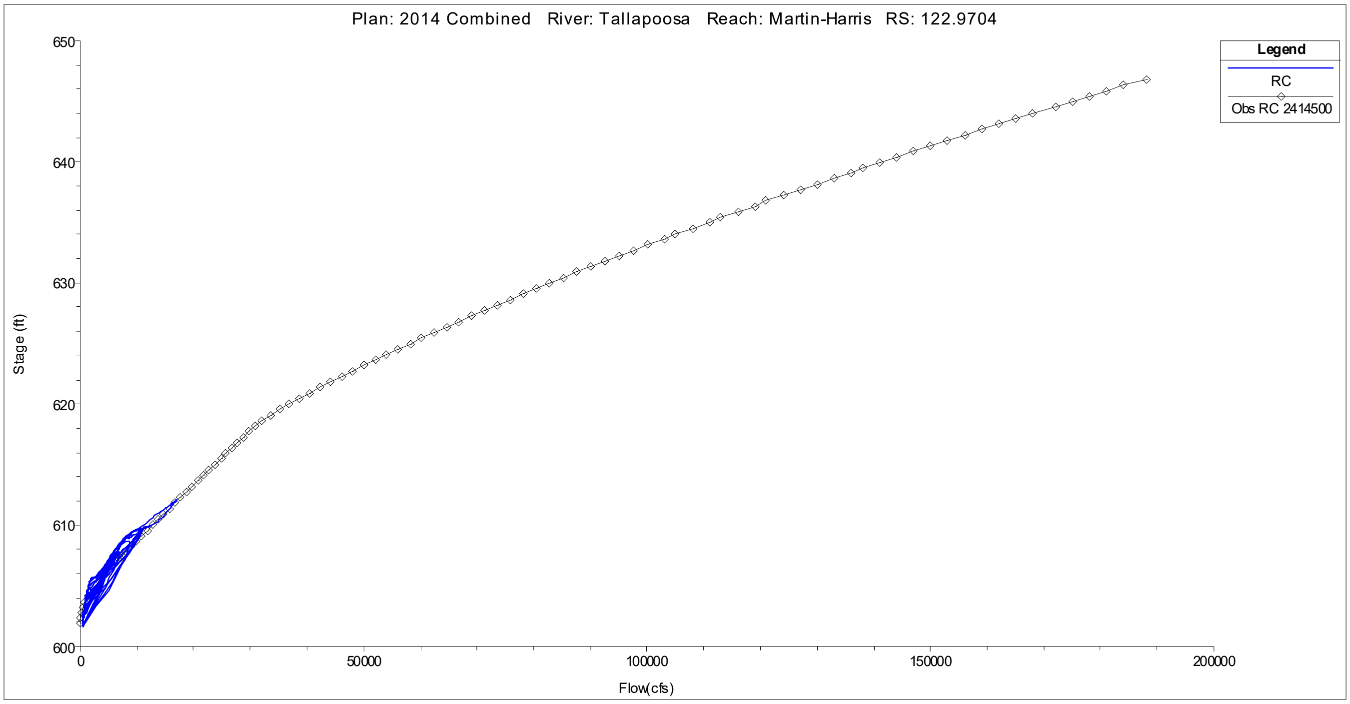

Figure 8.35 – Rating Curve Comparison – HEC-RAS vs. USGS 02414500; 2014 Event (Tallapoosa Martin-Harris XS 122.9704 – Tallapoosa River at Wadley, AL)

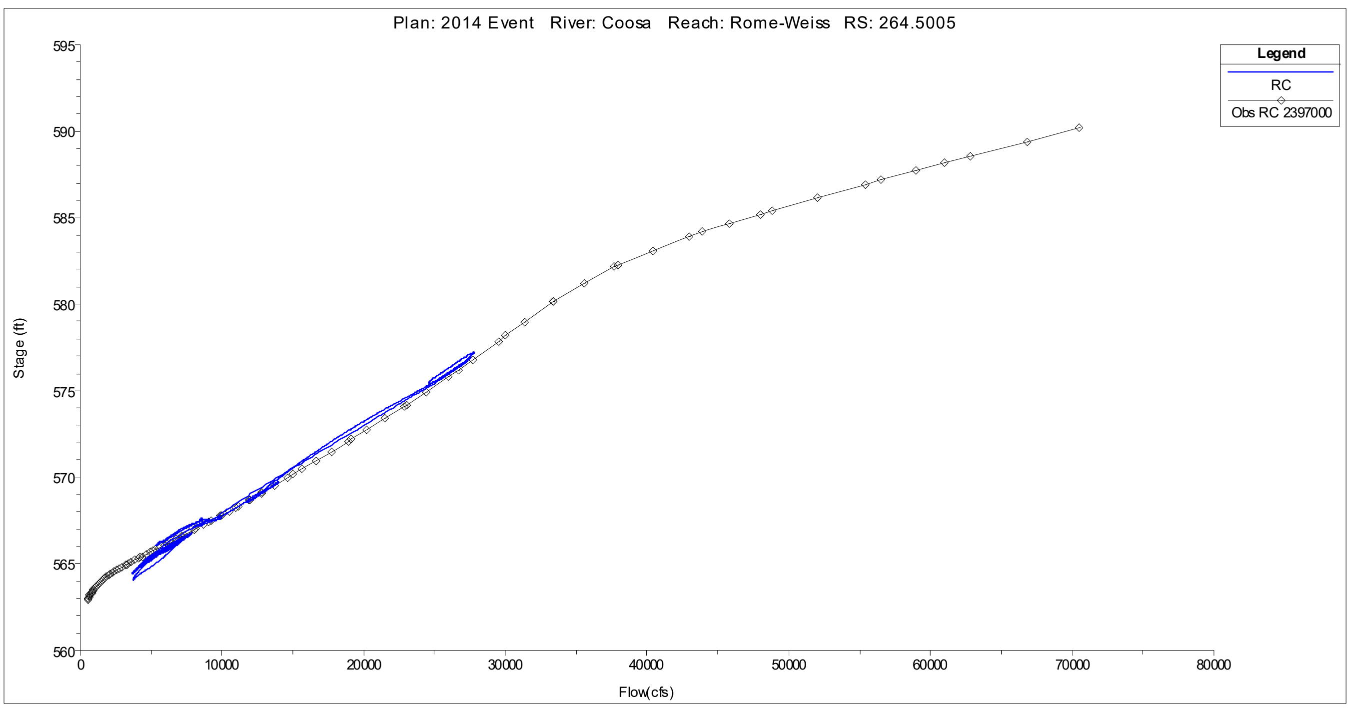

Figure 8.36 – Rating Curve Comparison – HEC-RAS vs. USGS 0297000; 2014 Event (Coosa Rome-Weiss XS 264.5005 – Coosa River near Rome, GA)

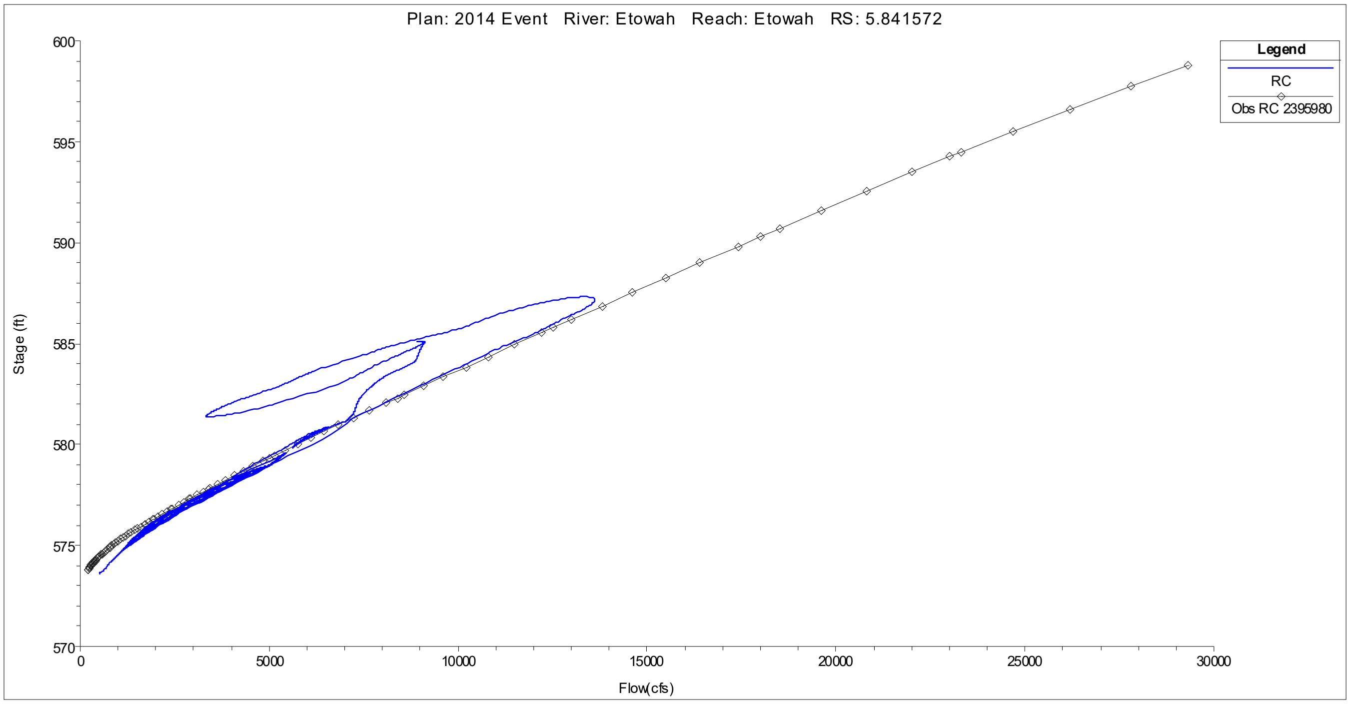

Figure 8.37 – Rating Curve Comparison – HEC-RAS vs. USGS 02395980; 2014 Event (Etowah XS 5.841572 – Etowah River at GA 1 Loop, near Rome, GA)

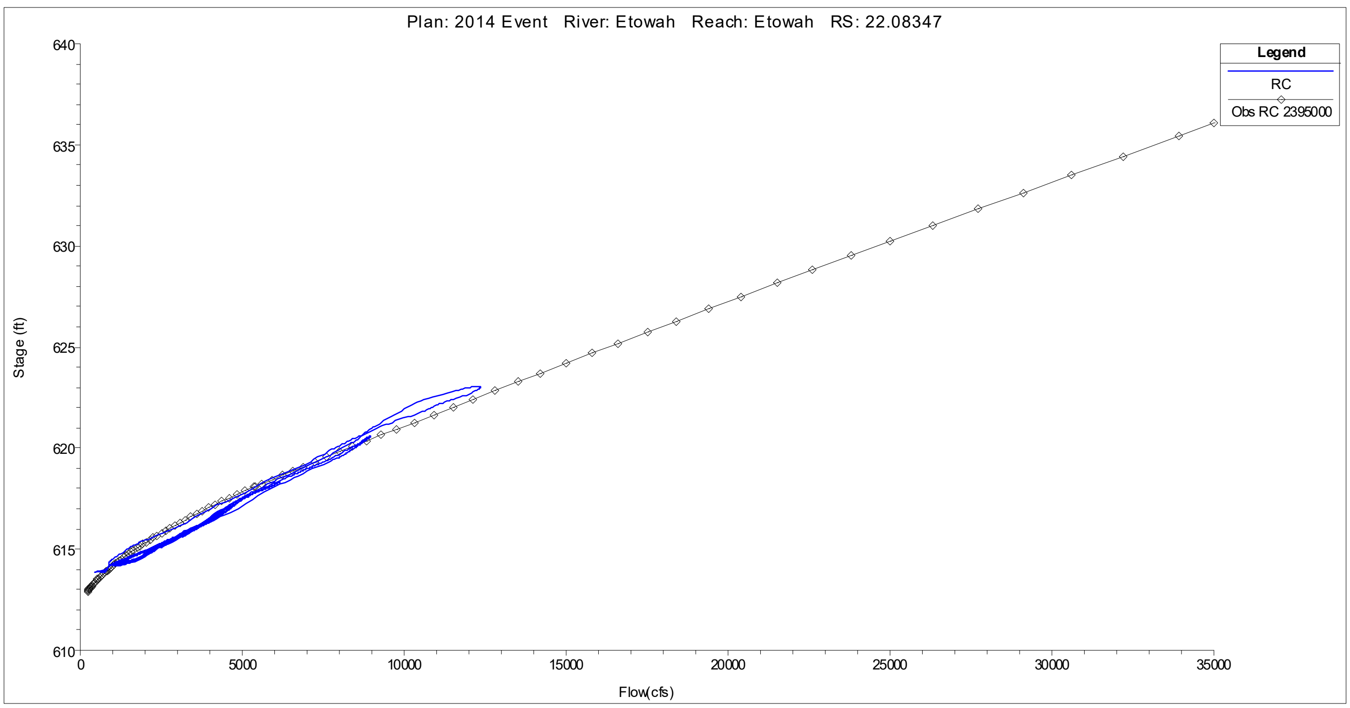

Figure 8.38 – Rating Curve Comparison – HEC-RAS vs. USGS 02395000; 2014 Event (Etowah XS 22.08347 – Etowah River near Kingston, GA)

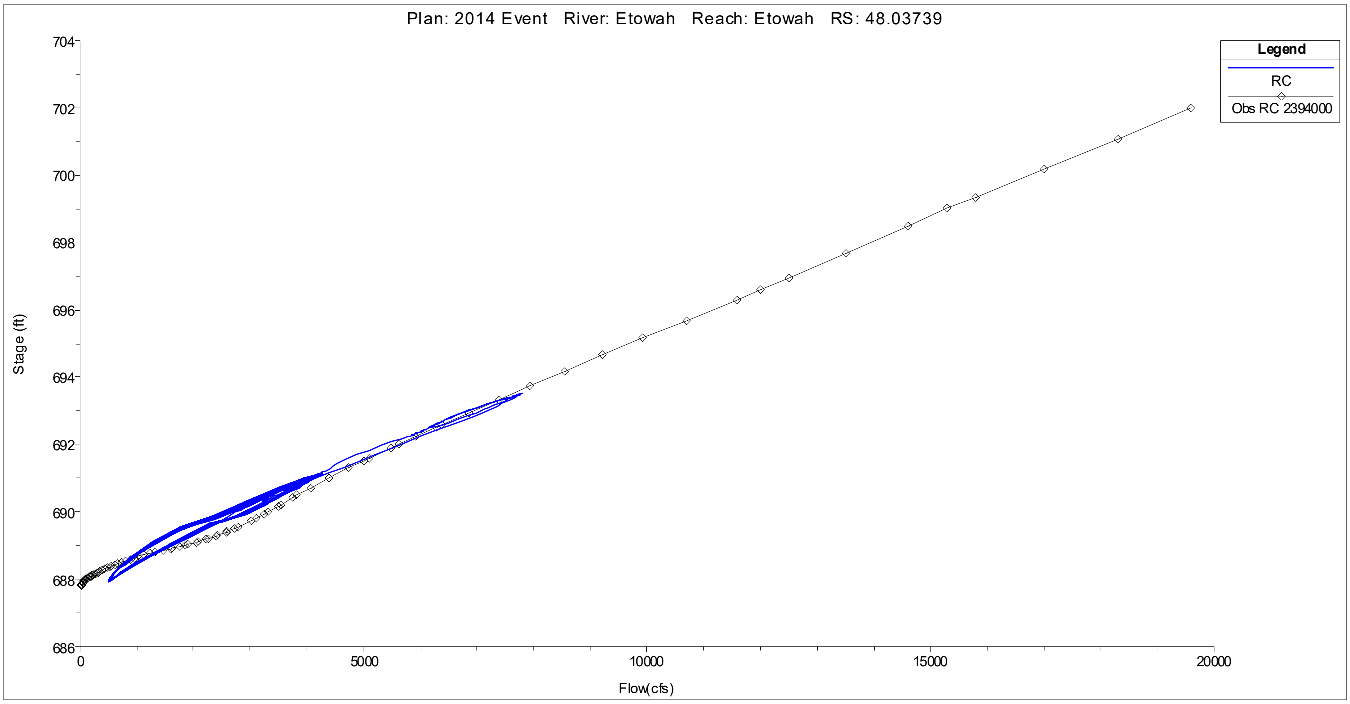

Figure 8.39 – Rating Curve Comparison – HEC-RAS vs. USGS 02394000; 2014 Event (Etowah XS 48.03739 – Etowah River at Allatoona Dam, abv Cartersville, GA)

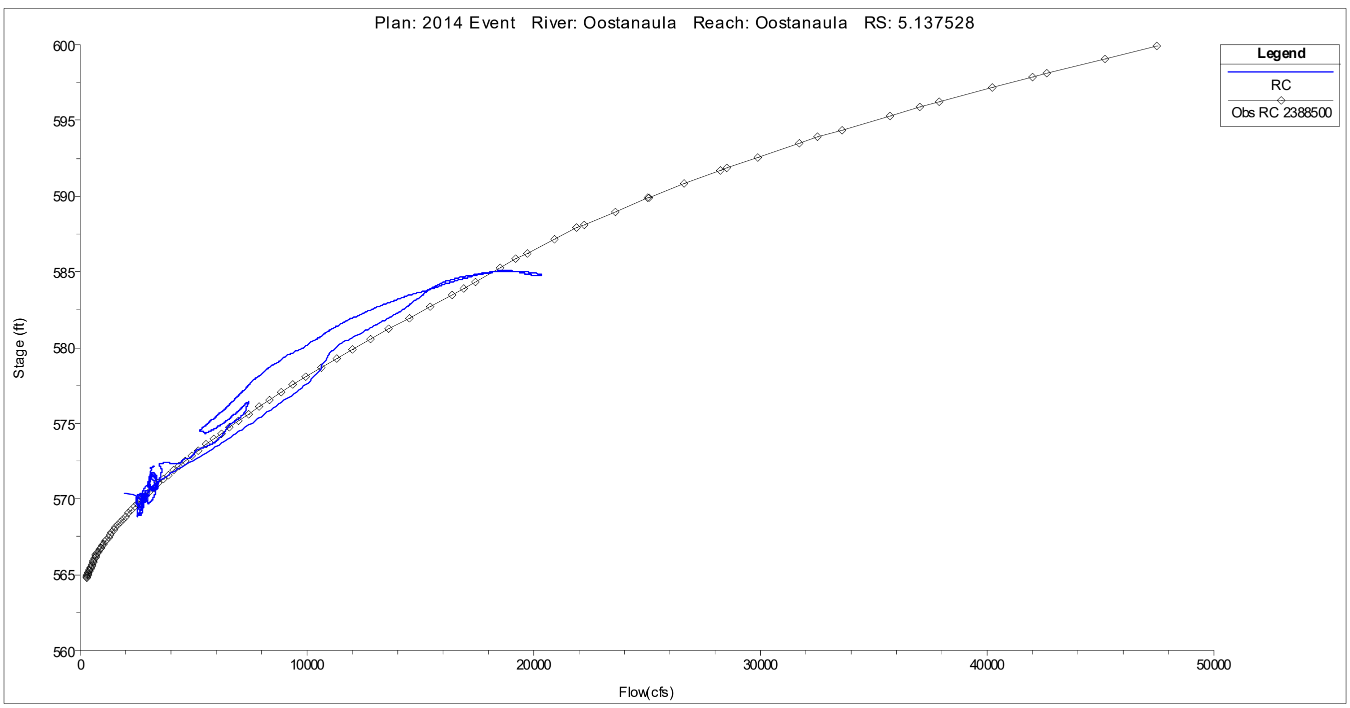

Figure 8.40 – Rating Curve Comparison – HEC-RAS vs. USGS 02388500; 2014 Event (Oostanaula XS 5.137528 – Oostanaula River near Rome, GA)

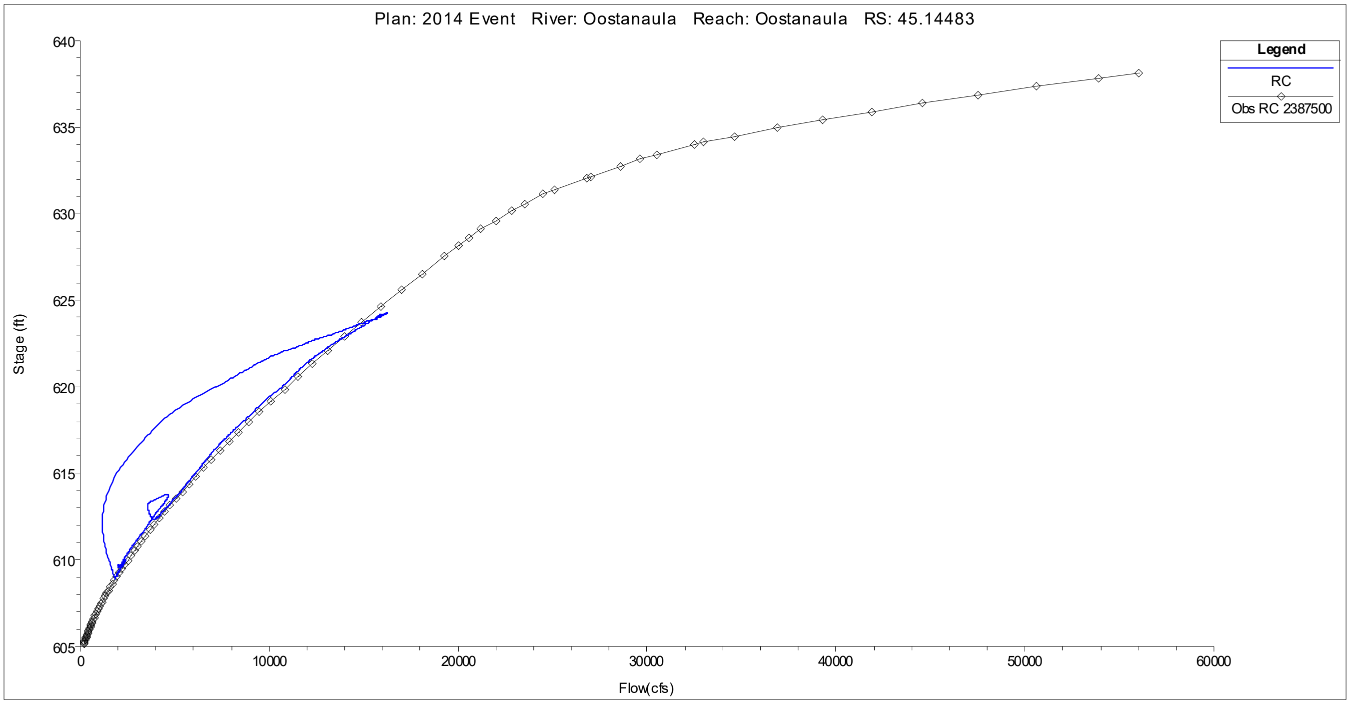

Figure 8.41 – Rating Curve Comparison – HEC-RAS vs. USGS 02387500; 2014 Event (Oostanaula XS 45.14483 – Oostanaula River at Resaca, GA)

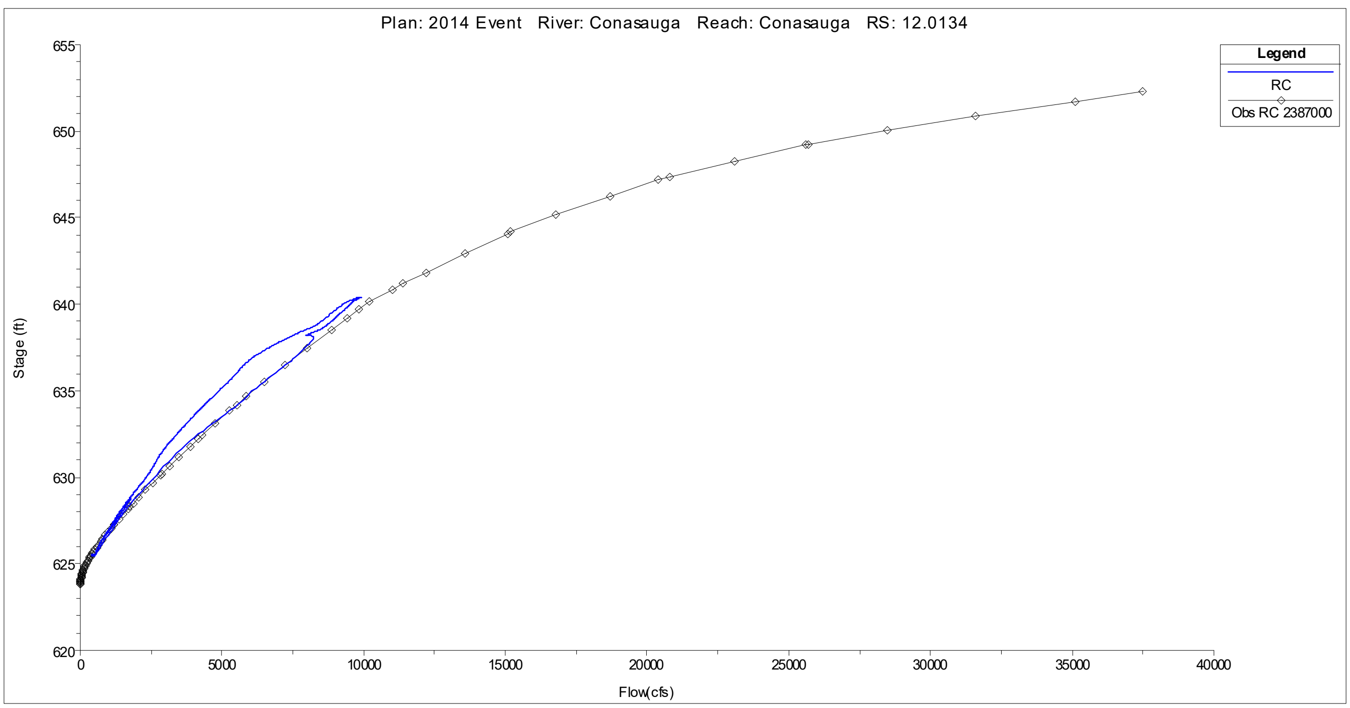

Figure 8.42 – Rating Curve Comparison – HEC-RAS vs. USGS 02387000; 2014 Event (Conasauga XS 12.0134 – Conasauga River at Tilton, GA)

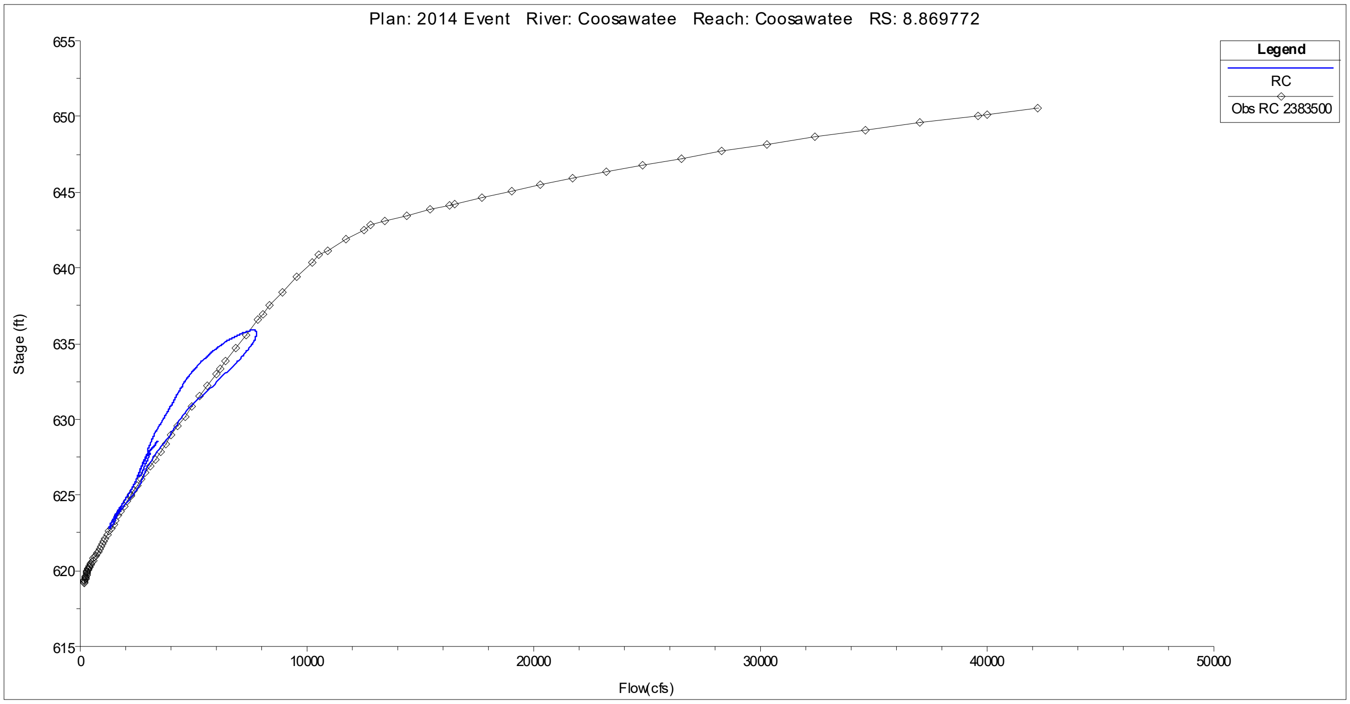

Figure 8.43 – Rating Curve Comparison – HEC-RAS vs. USGS 02383500; 2014 Event (Coosawattee XS 8.869772 – Coosawattee River near Pine Chapel, GA)

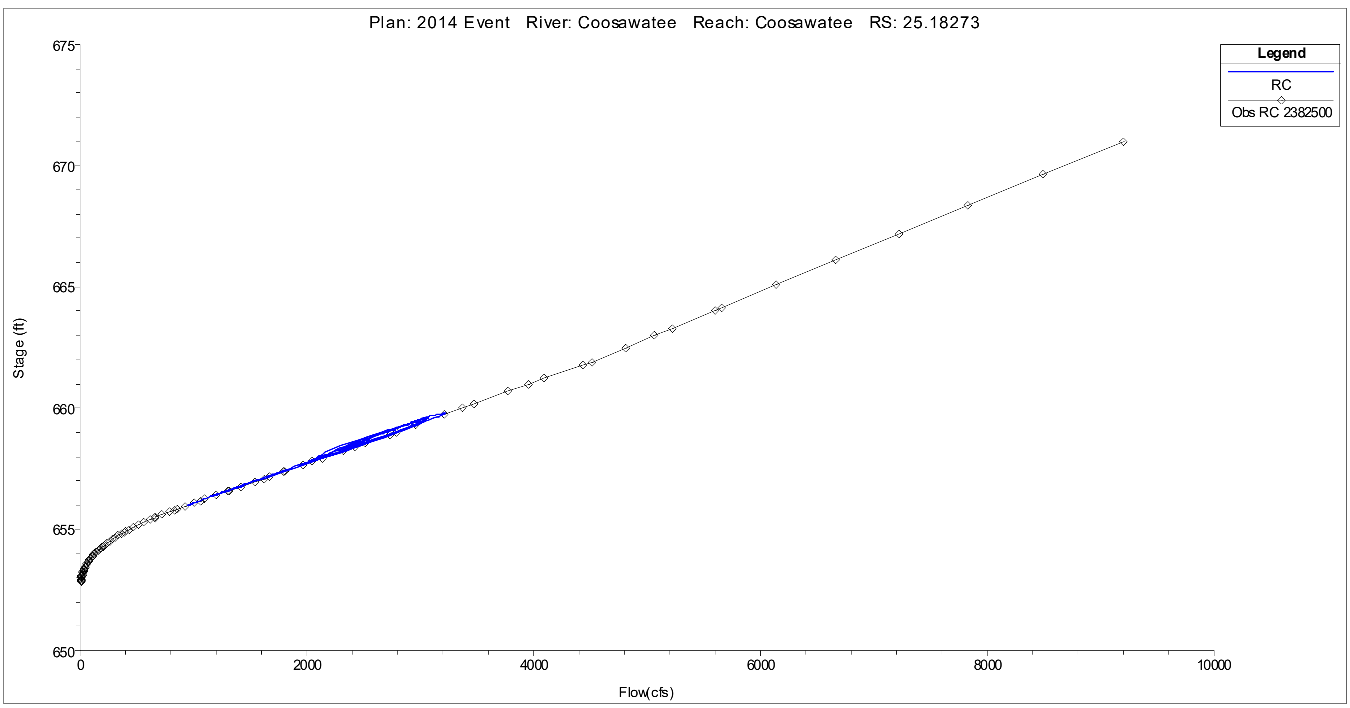

Figure 8.44 – Rating Curve Comparison – HEC-RAS vs. USGS 02382500; 2014 Event (Coosawattee XS 25.18273 – Coosawattee River at Carters, GA)

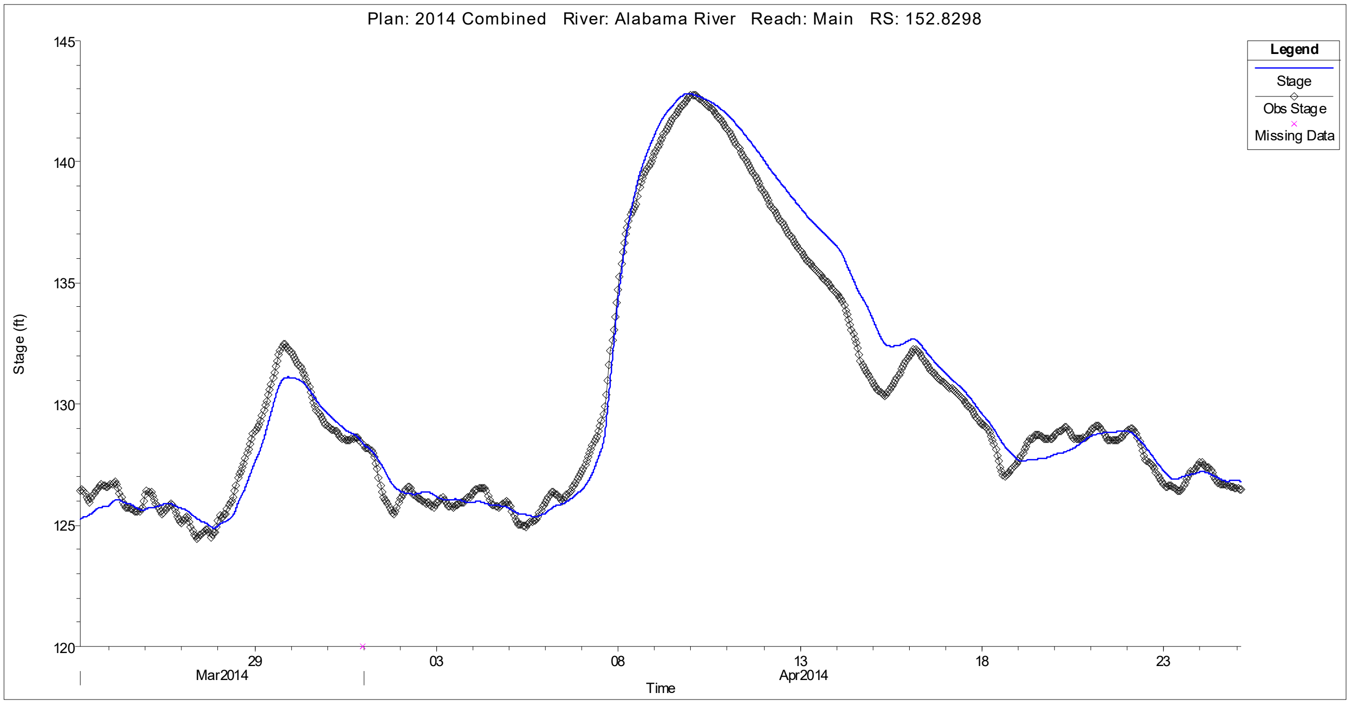

Figure 8.45 – Stage Comparison – HEC-RAS vs. USGS 02419988; 2014 Event (Alabama Main XS 152.8298 – Alabama River at Montgomery, AL)

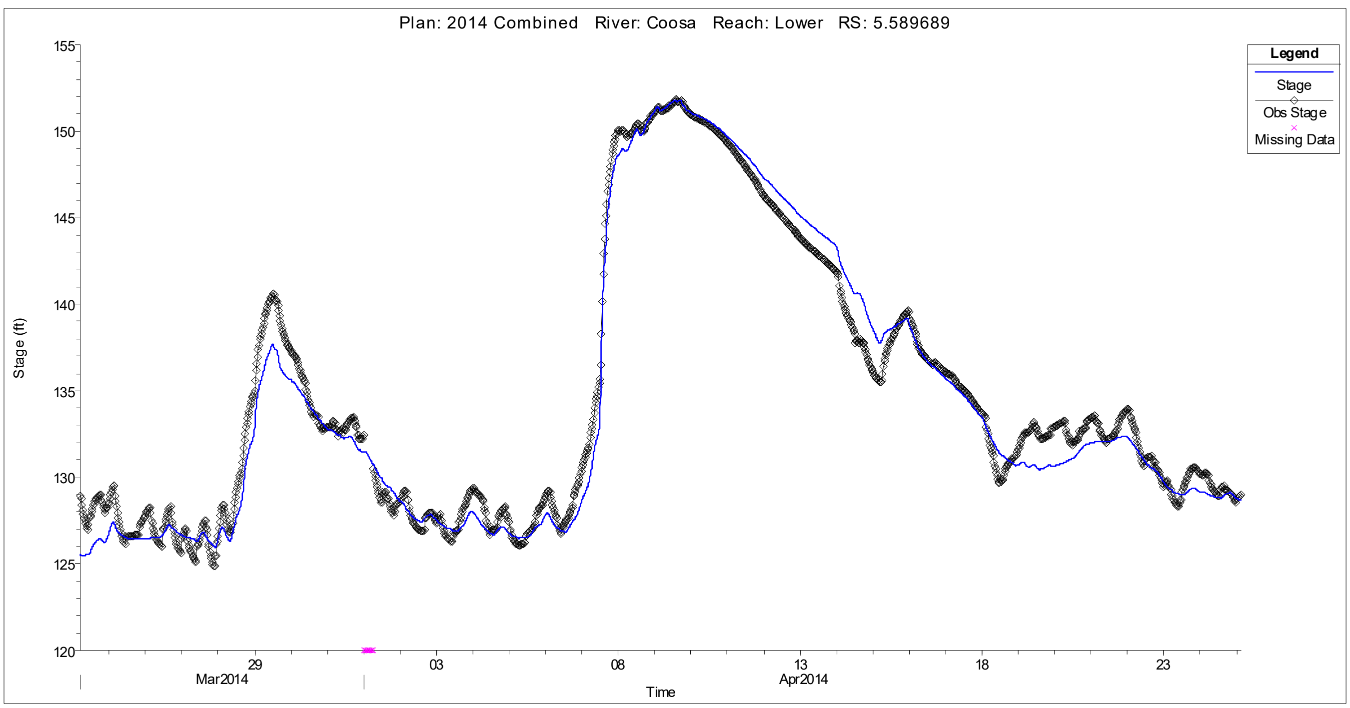

Figure 8.46 – Stage Comparison – HEC-RAS vs. USGS 02411600; 2014 Event (Coosa Lower XS 5.589689 – Coosa River at Wetumpka, AL)

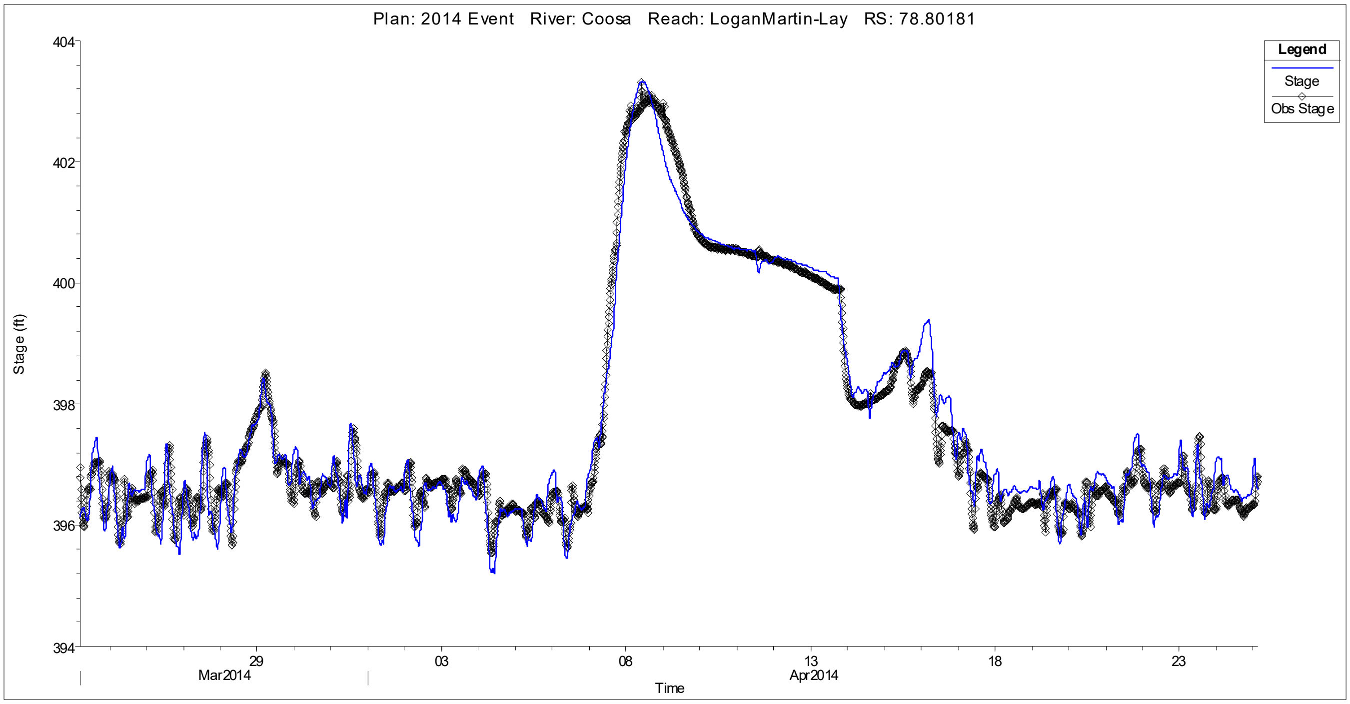

Figure 8.47 – Stage Comparison – HEC-RAS vs. USGS 02407000; 2014 Event (Coosa LoganMartin-Lay XS 78.80181 – Coosa River at Childersburg, AL)

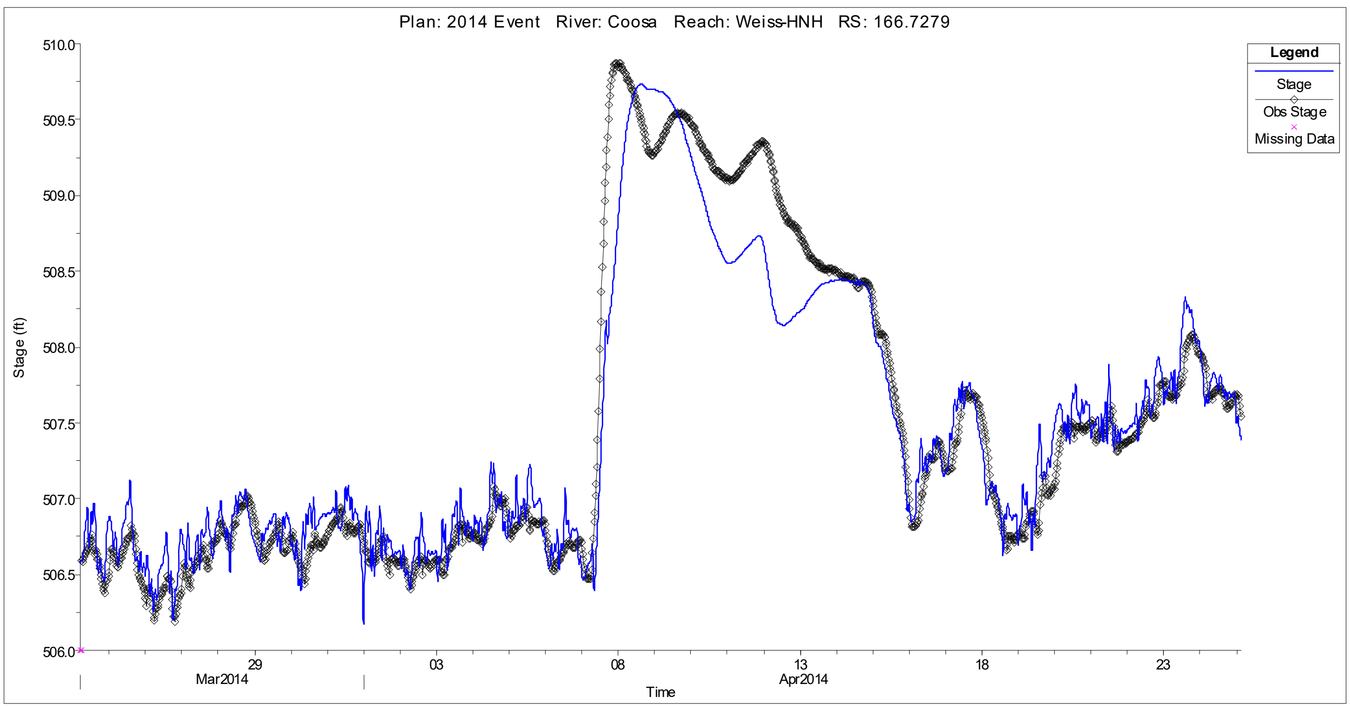

Figure 8.48 – Stage Comparison – HEC-RAS vs. USGS 02400496; 2014 Event (Coosa Weiss-HNH XS 166.7279 – Coosa River at Gadsden Steam Plant)

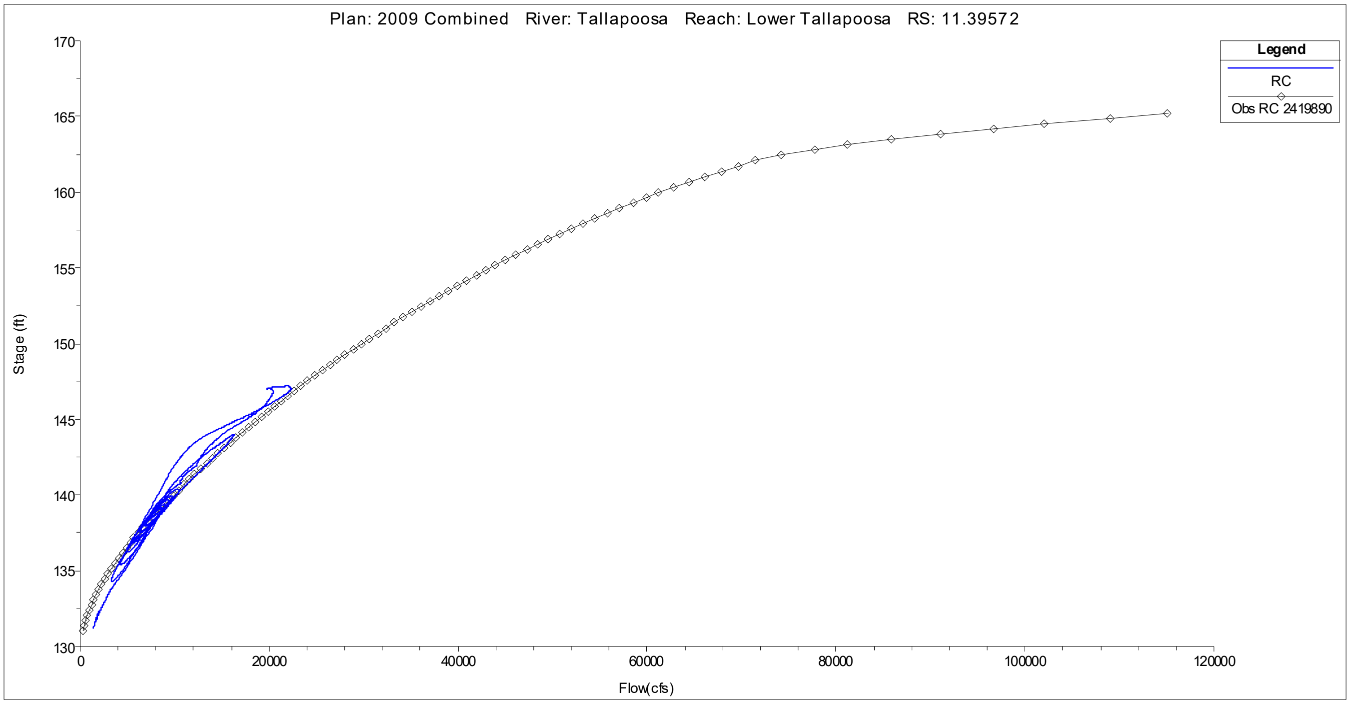

Figure 8.49 – Rating Curve Comparison – HEC-RAS vs. USGS 02419890; 2009 Event (Tallapoosa Lower Tallapoosa XS 11.39572 – Tallapoosa River near Mont.-Mont. Water Works)

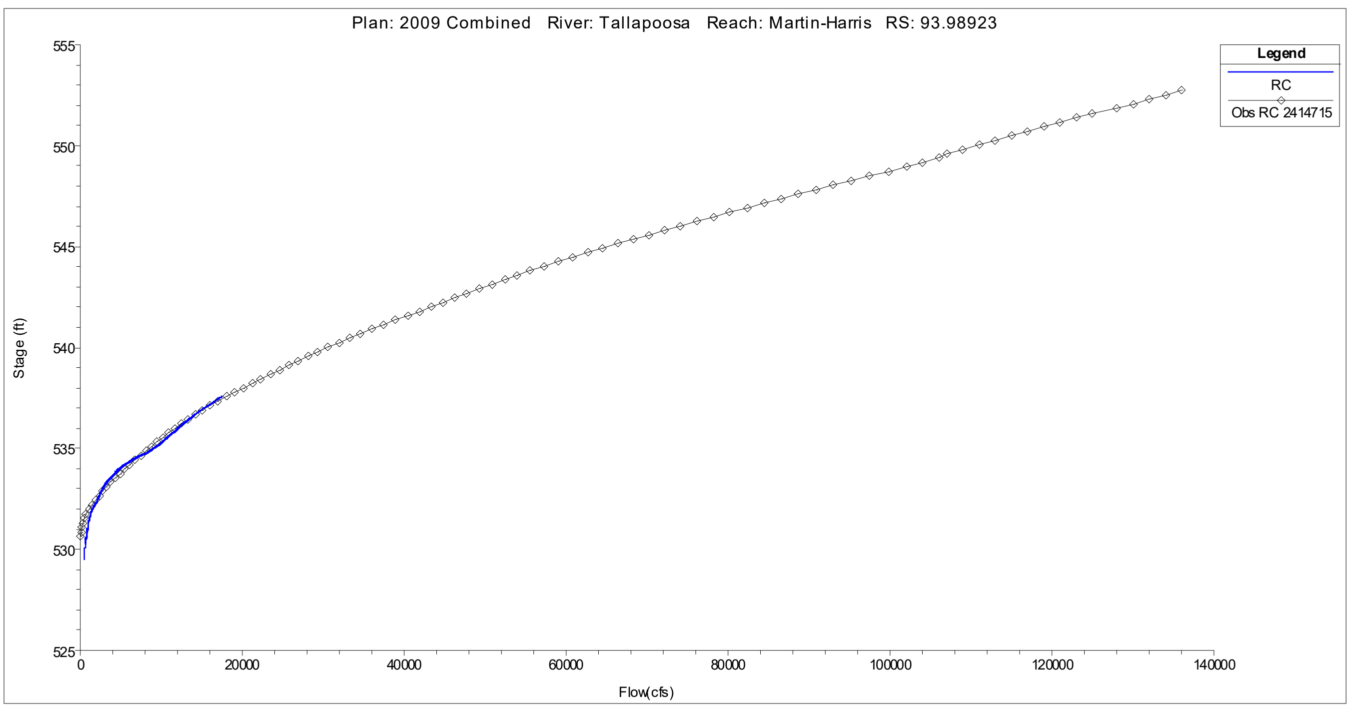

Figure 8.50 – Rating Curve Comparison – HEC-RAS vs. USGS 02414715; 2009 Event (Tallapoosa Martin-Harris XS 93.98923 – Tallapoosa River near New Site, AL(Horseshoe Bend))

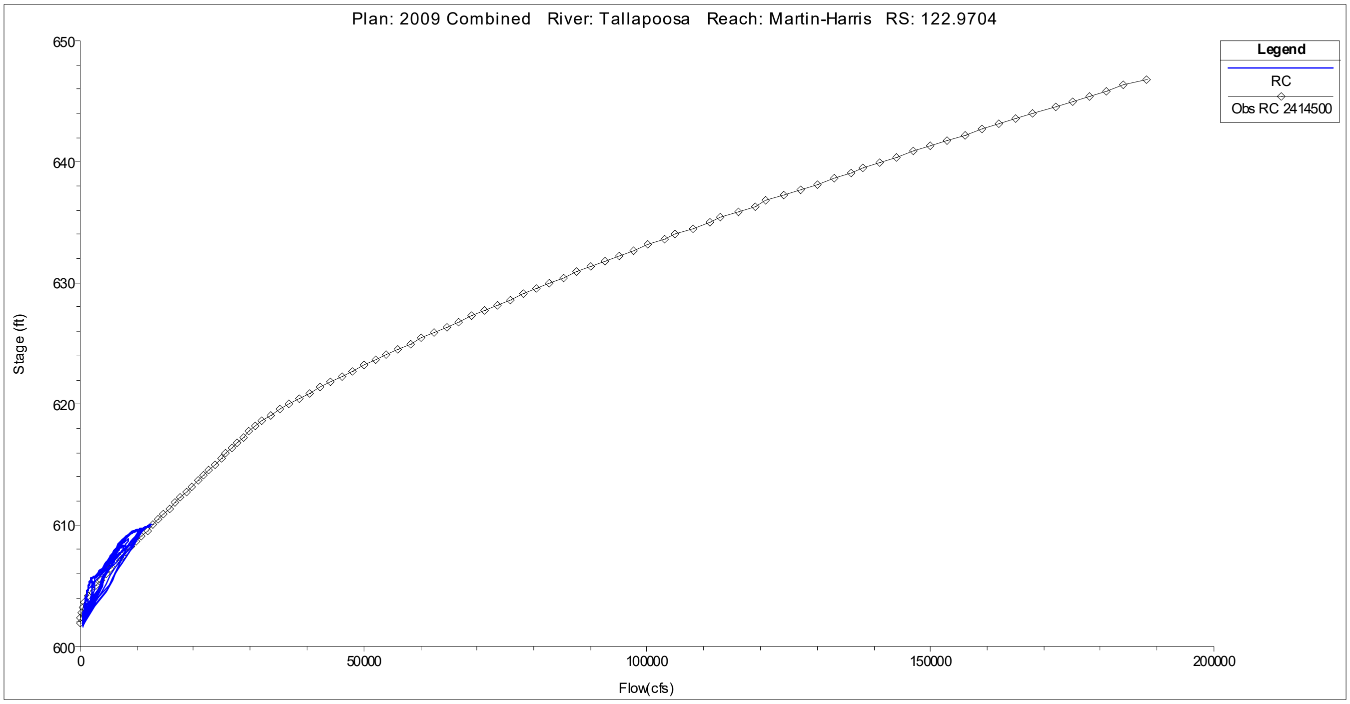

Figure 8.51 – Rating Curve Comparison – HEC-RAS vs. USGS 02414500; 2009 Event (Tallapoosa Martin-Harris XS 122.9704 – Tallapoosa River at Wadley, AL)

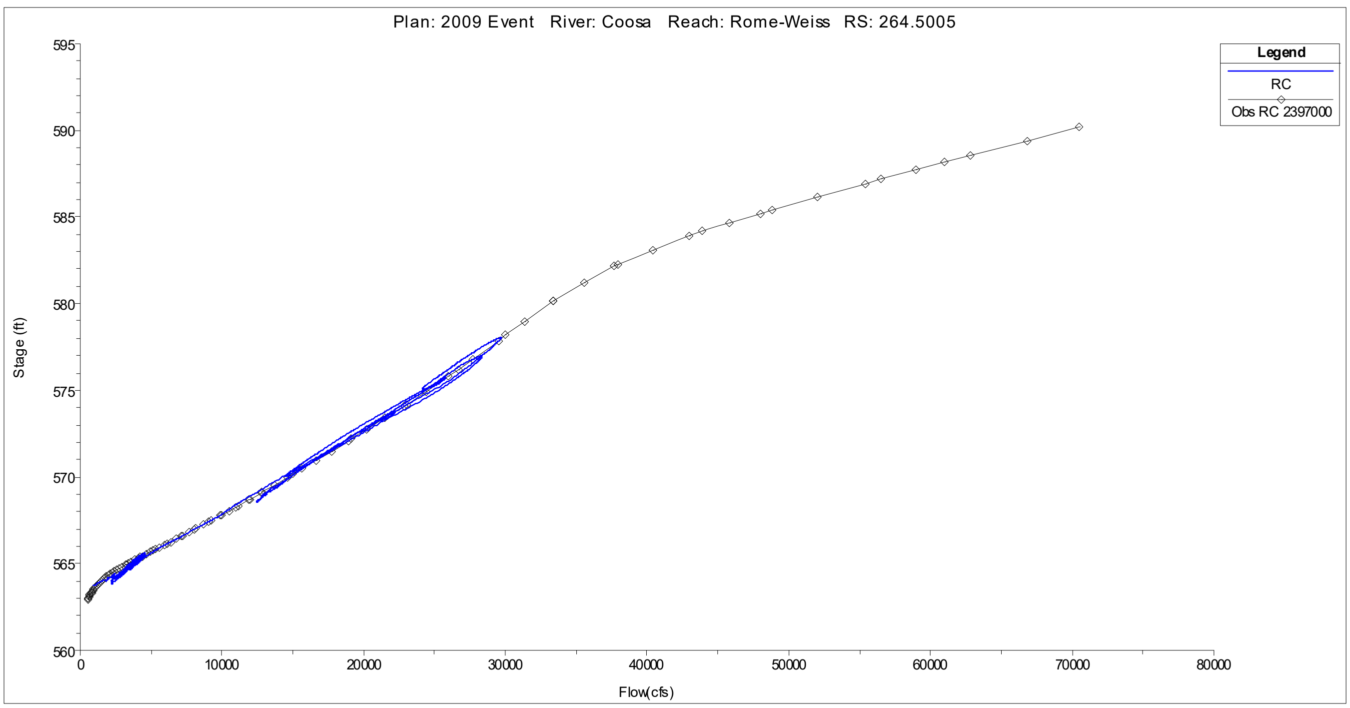

Figure 8.52 – Rating Curve Comparison – HEC-RAS vs. USGS 0297000; 2009 Event (Coosa Rome-Weiss XS 264.5005 – Coosa River near Rome, GA)

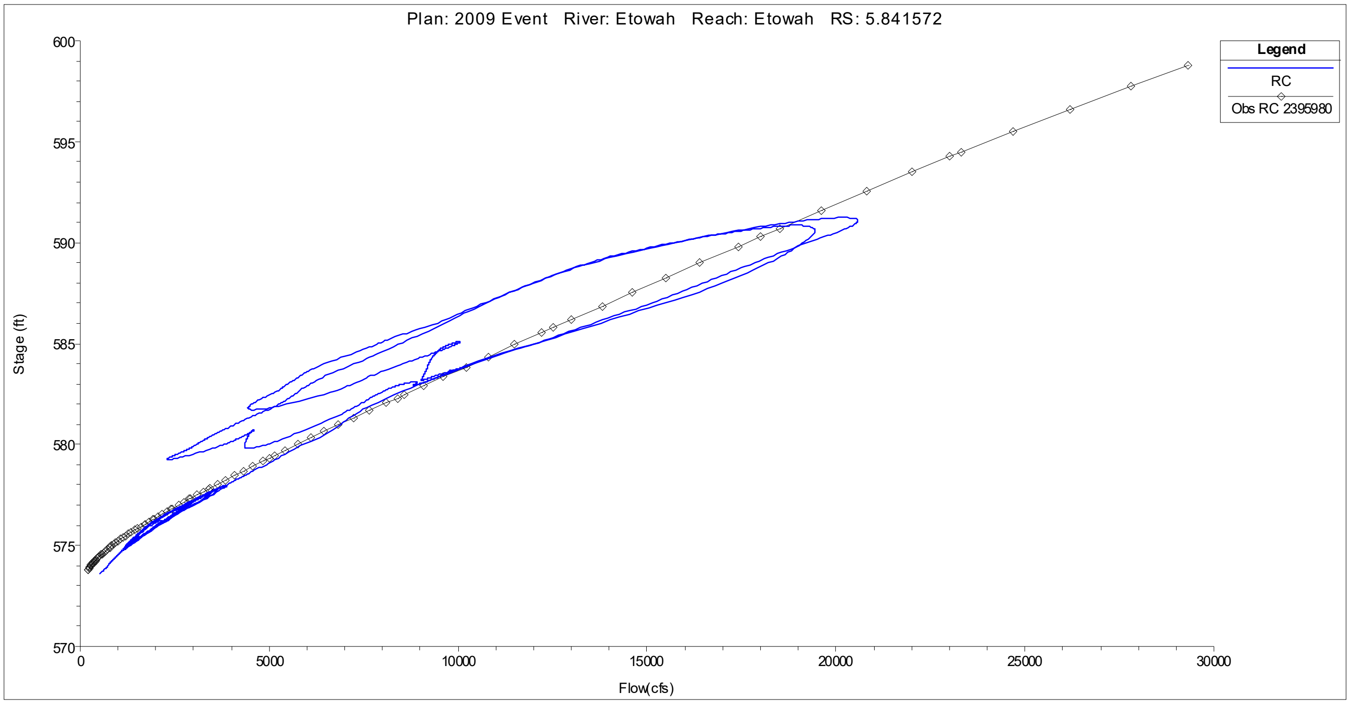

Figure 8.53 – Rating Curve Comparison – HEC-RAS vs. USGS 02395980; 2009 Event (Etowah XS 5.841572 – Etowah River at GA 1 Loop, near Rome, GA)

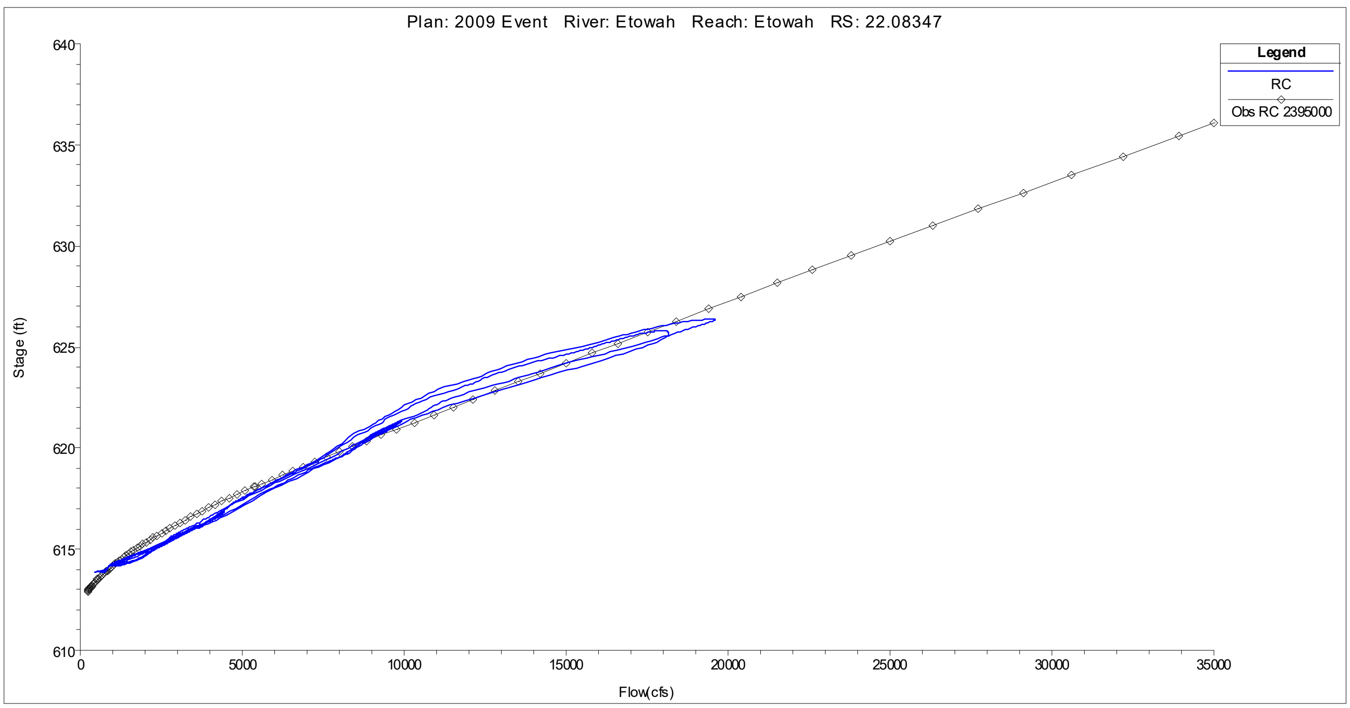

Figure 8.54 – Rating Curve Comparison – HEC-RAS vs. USGS 02395000; 2009 Event (Etowah XS 22.08347 – Etowah River near Kingston, GA)

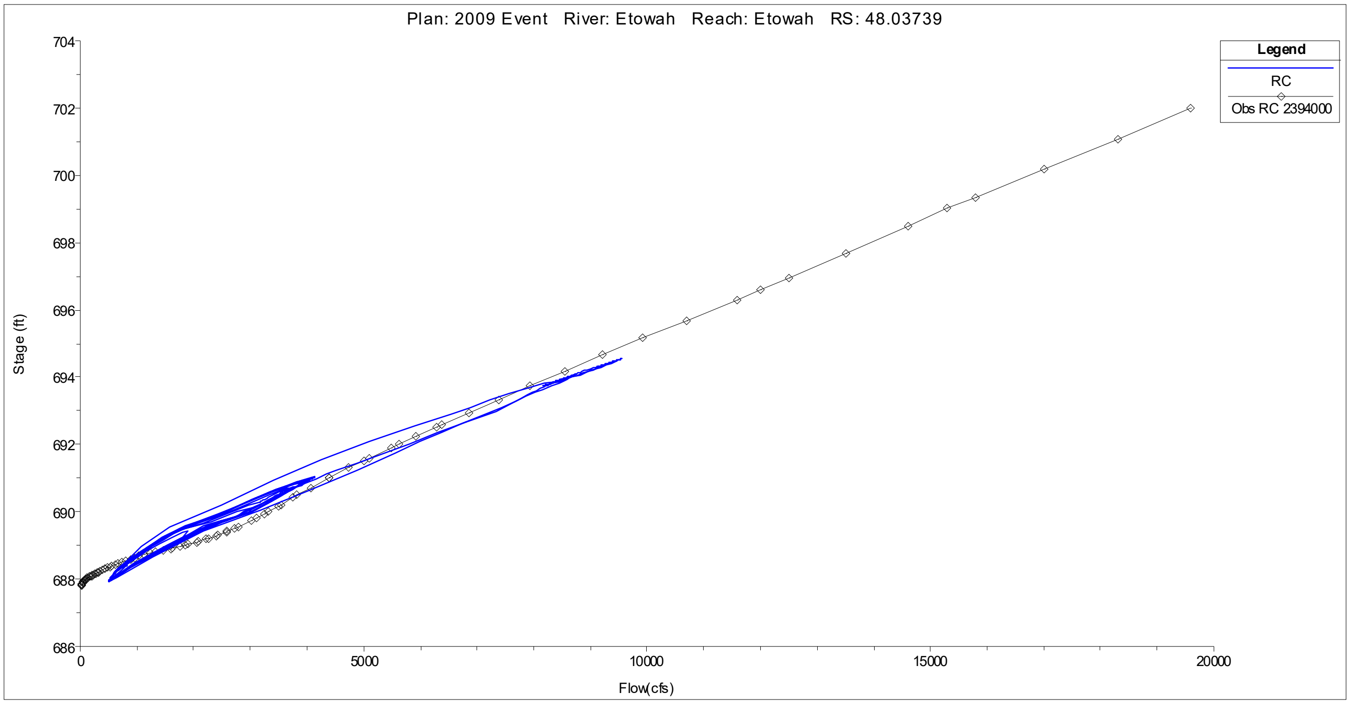

Figure 8.55 – Rating Curve Comparison – HEC-RAS vs. USGS 02394000; 2009 Event (Etowah XS 48.03739 – Etowah River at Allatoona Dam, abv Cartersville, GA)

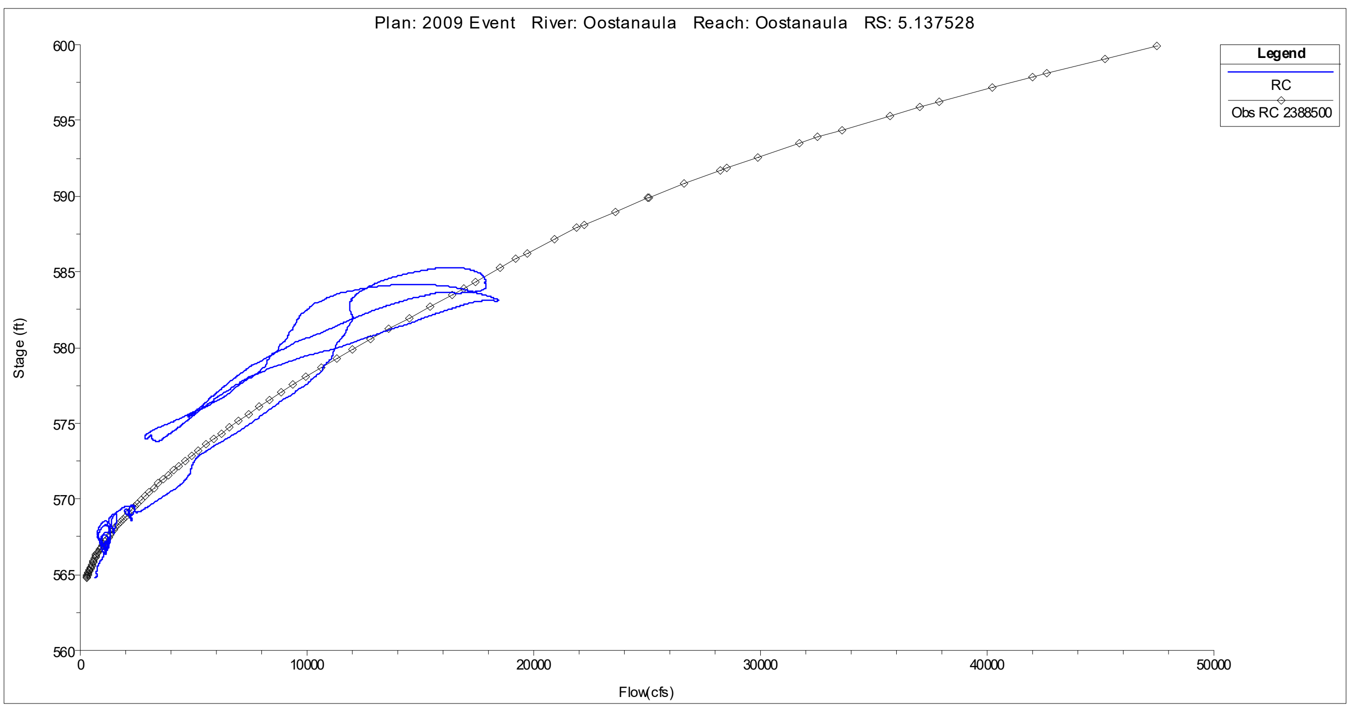

Figure 8.56 – Rating Curve Comparison – HEC-RAS vs. USGS 02388500; 2009 Event (Oostanaula XS 5.137528 – Oostanaula River near Rome, GA)

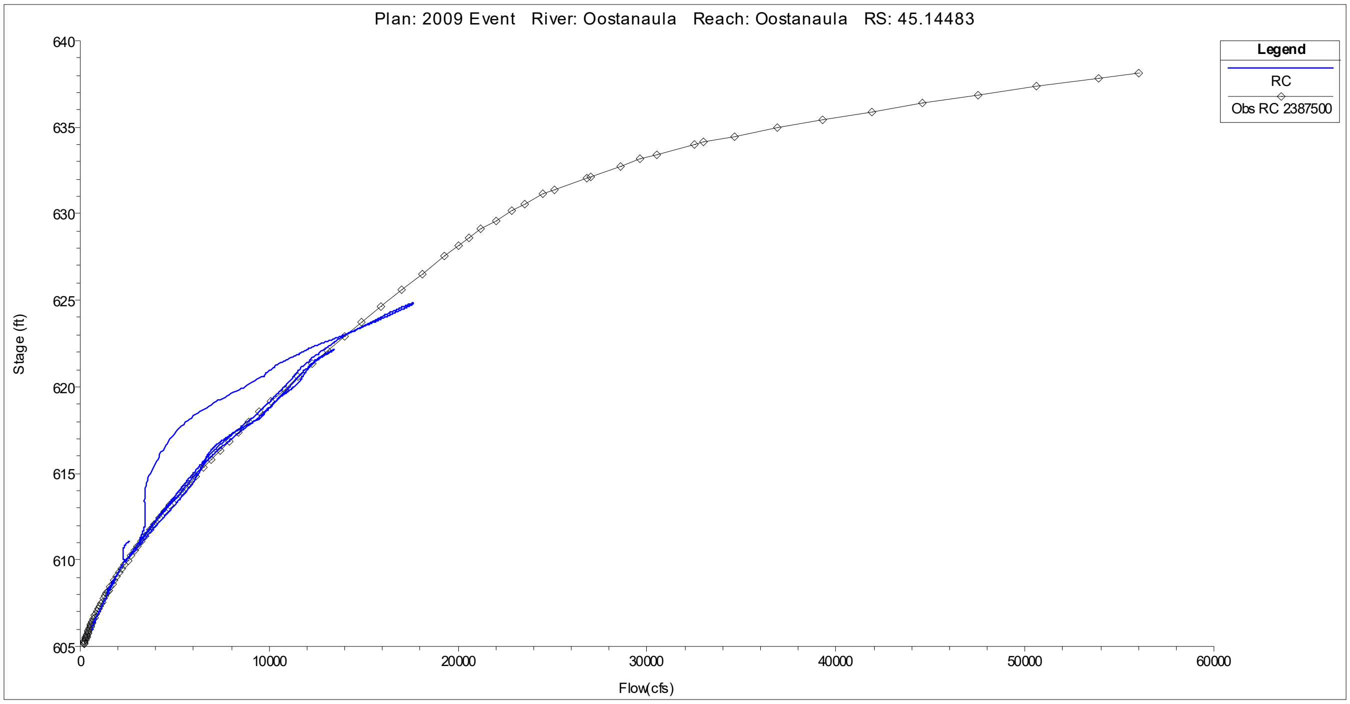

Figure 8.57 – Rating Curve Comparison – HEC-RAS vs. USGS 02387500; 2009 Event (Oostanaula XS 45.14483 – Oostanaula River at Resaca, GA)

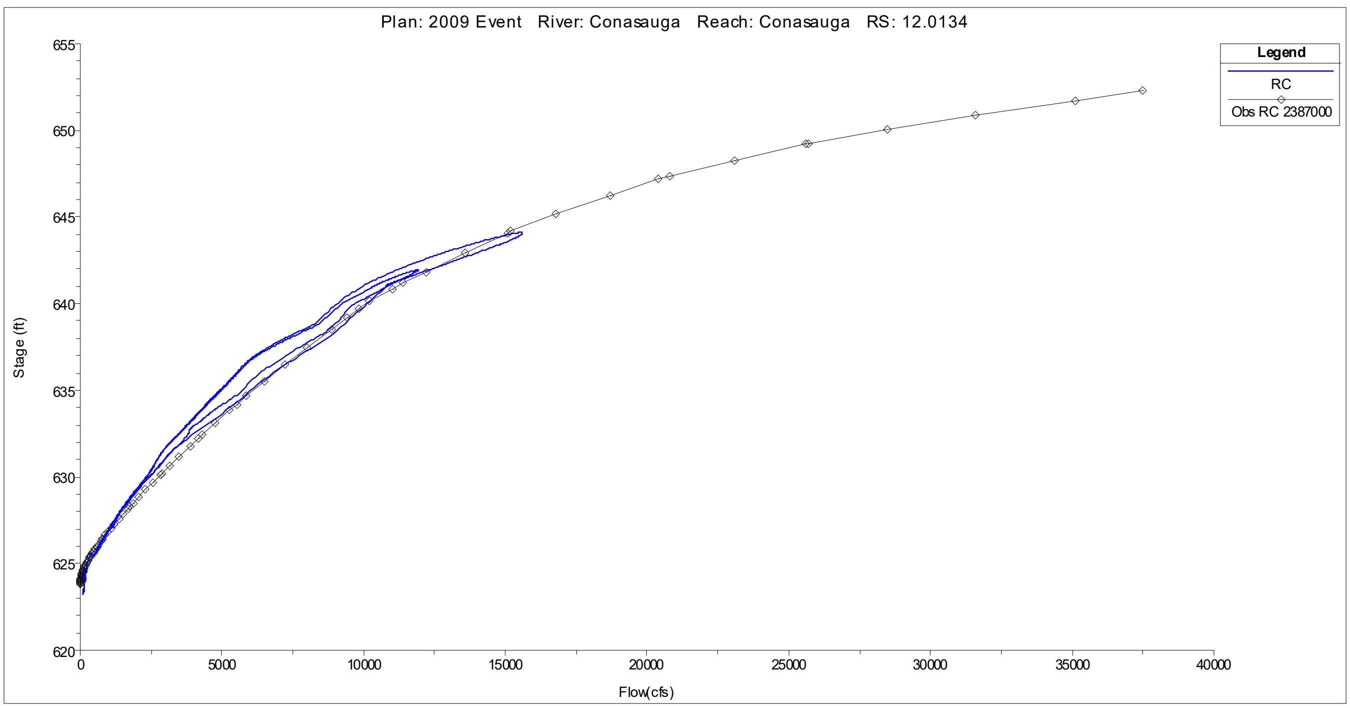

Figure 8.58 – Rating Curve Comparison – HEC-RAS vs. USGS 02387000; 2009 Event (Conasauga XS 12.0134 – Conasauga River at Tilton, GA)

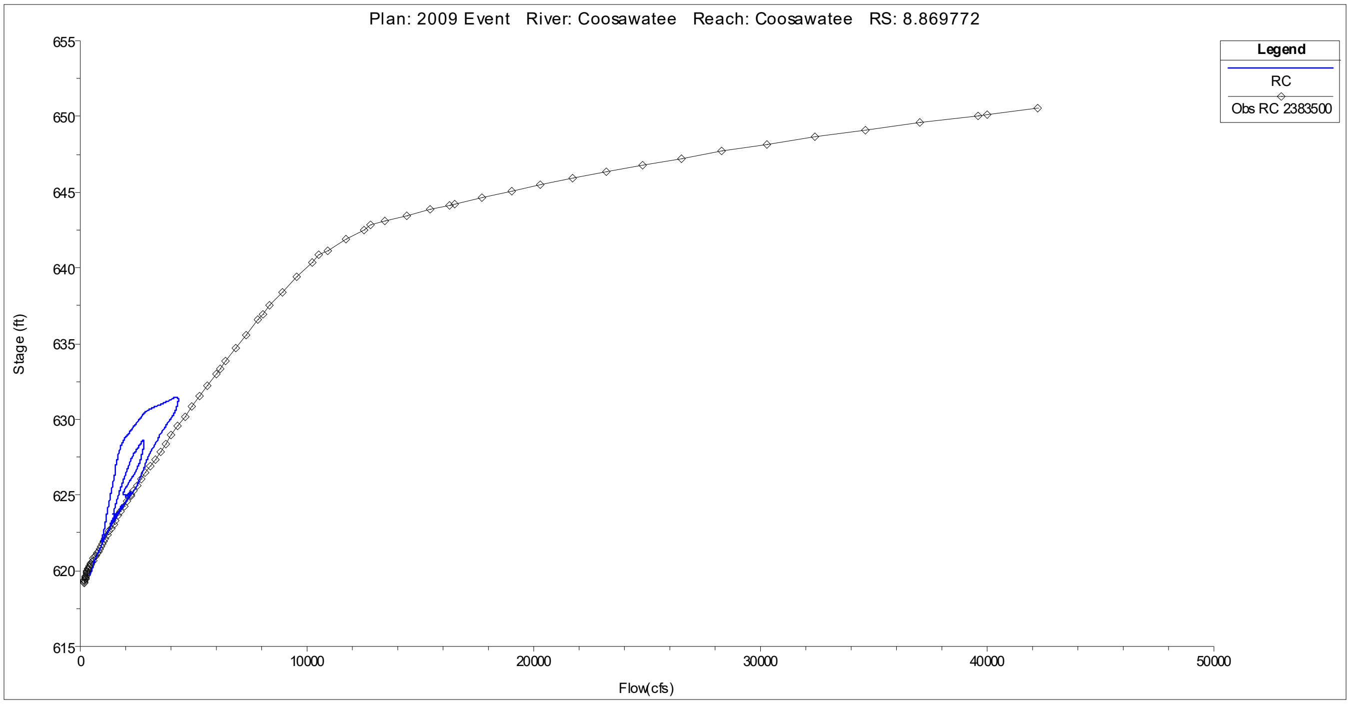

Figure 8.59 – Rating Curve Comparison – HEC-RAS vs. USGS 02383500; 2009 Event (Coosawattee XS 8.869772 – Coosawattee River near Pine Chapel, GA)

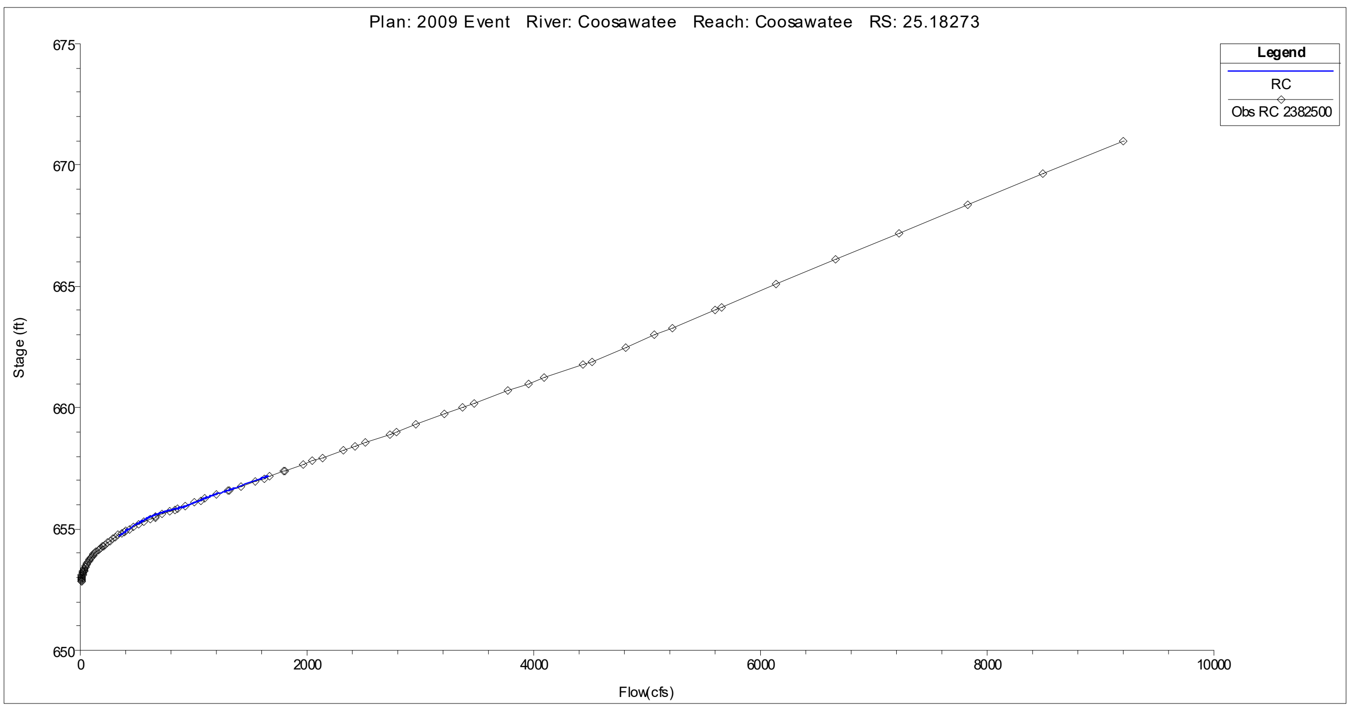

Figure 8.60 – Rating Curve Comparison – HEC-RAS vs. USGS 02382500; 2009 Event (Coosawattee XS 25.18273 – Coosawattee River at Carters, GA)

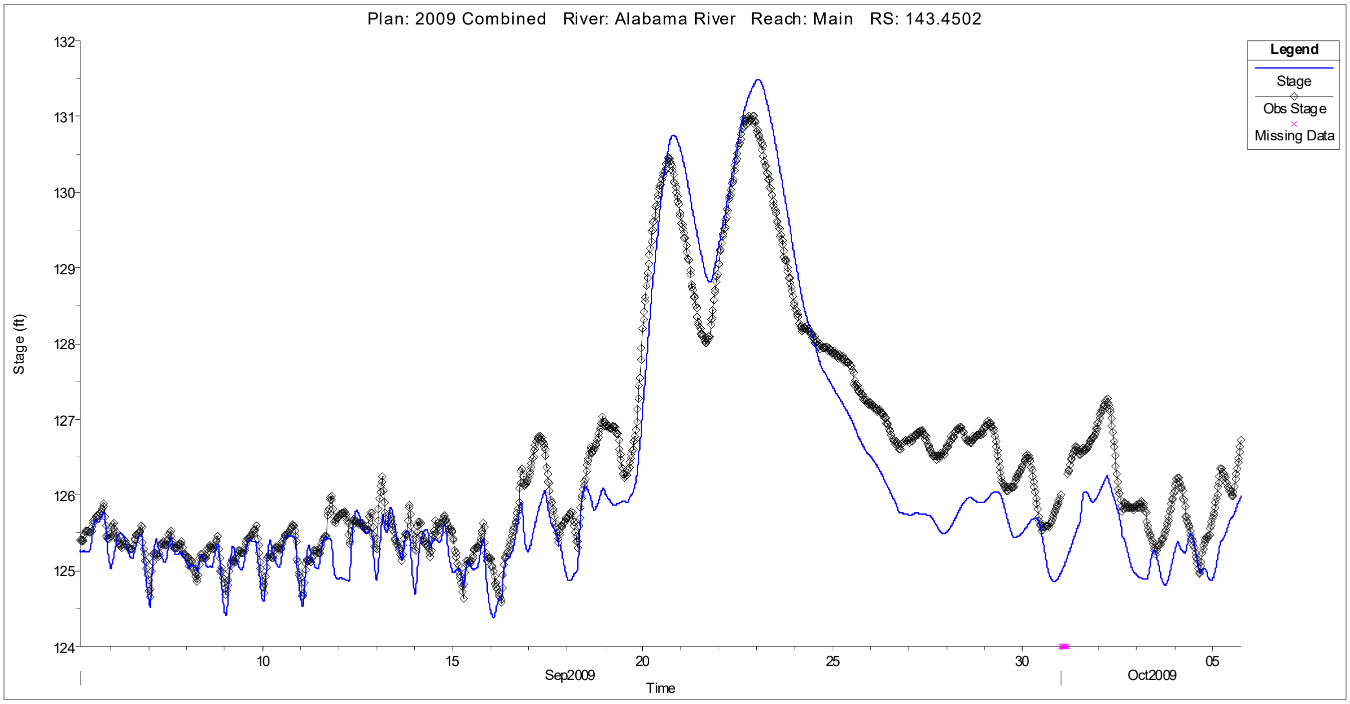

Figure 8.61 – Stage Comparison – HEC-RAS vs. USGS 02420000; 2009 Event (Alabama Main XS 143.4502 – Alabama River near Montgomery, AL)

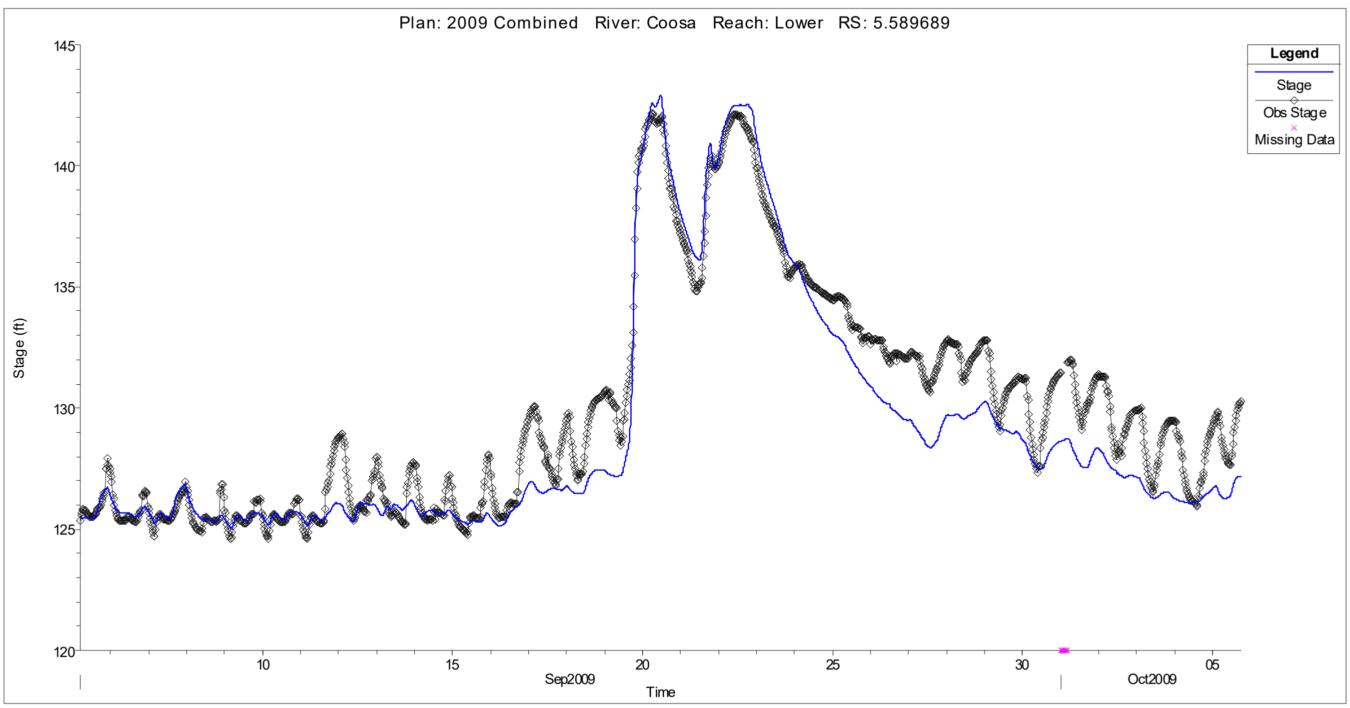

Figure 8.62 – Stage Comparison – HEC-RAS vs. USGS 02411600; 2009 Event (Coosa Lower XS 5.589689 – Coosa River at Wetumpka, AL)

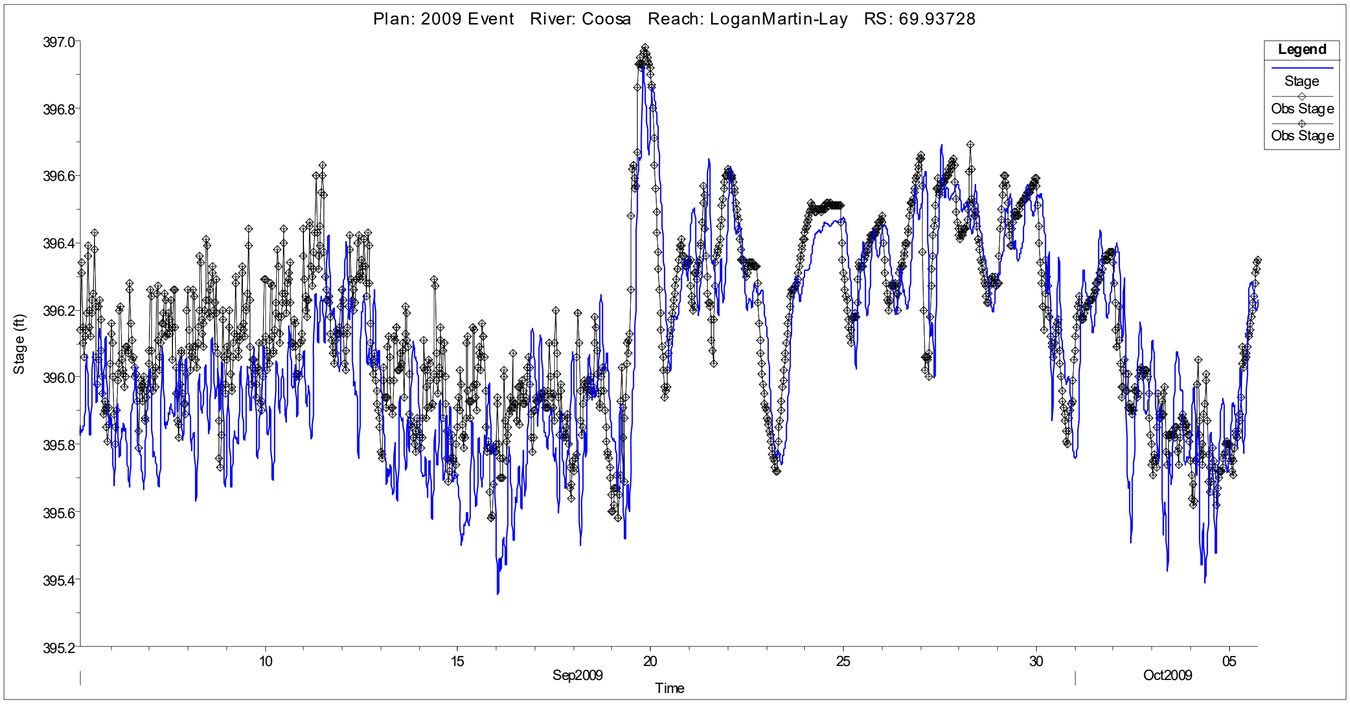

Figure 8.63 – Stage Comparison – HEC-RAS vs. USGS 02407526; 2009 Event (Coosa LoganMartin-Lay XS 69.93728 – Coosa River at Gaston Steam Plant)

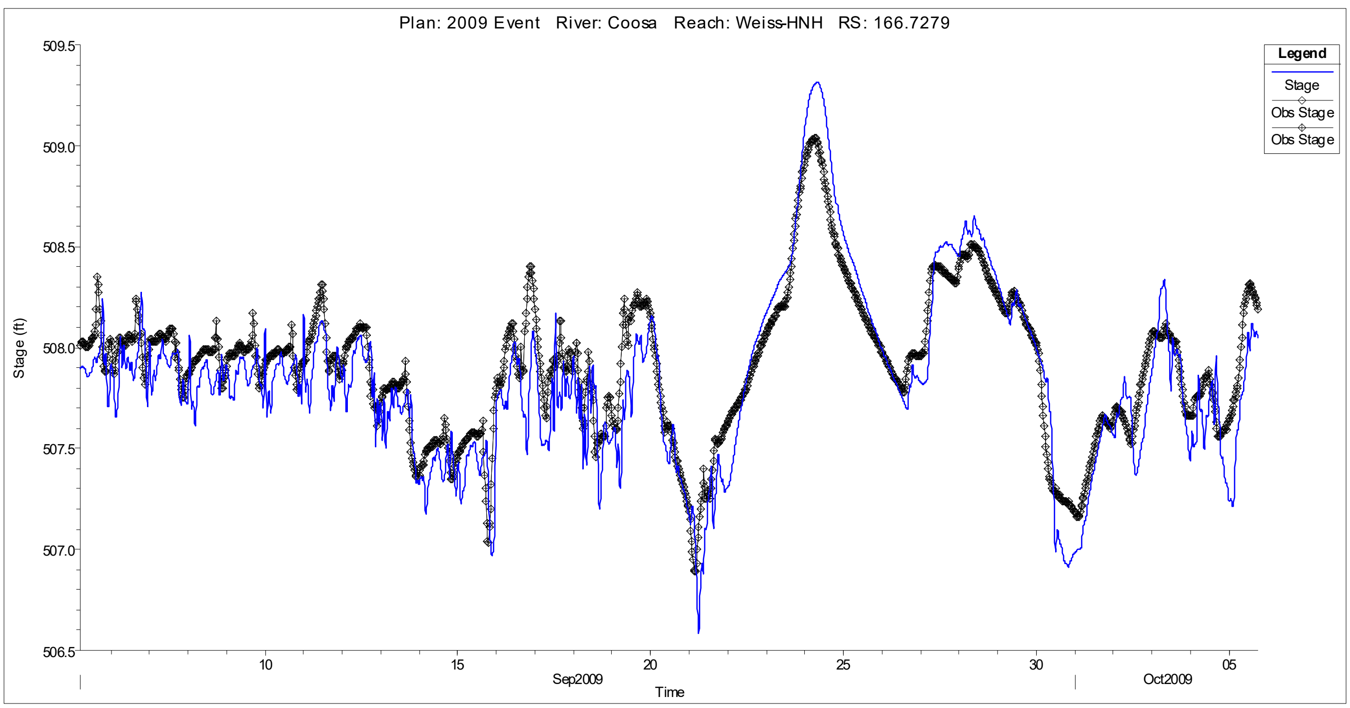

Figure 8.64 – Stage Comparison – HEC-RAS vs. USGS 02400496; 2009 Event (Coosa Weiss-HNH XS 166.7279 – Coosa River at Gadsden Steam Plant)

8.7 Recommendations for HEC-RAS Model Use

Due to a known bug in HEC-RAS version 4.1, the flow roughness factors used to calibrate the model were input through the plan editor rather than the geometry editor. Whenever new plans are created for this model, these flow roughness factors must be included to ensure accurate prediction of flows. However, this bug is fixed in HEC-RAS 5.0 Beta, which is not compatible with the current version of the CWMS model but will be compatible with the next version of CWMS. It is recommended that the district move the flow roughness factors into the geometry data and remove them from the plan data once the new versions of CWMS and HEC-RAS are in use. This will reduce the risk and hassle associated with adding the flow roughness factors to every plan created.

Currently CWMS 2.1 software is limited to using HEC-RAS version 4.1 on the CWMS server. Therefore, it is recommended that HEC-RAS 4.1 be used for all model development associated with CWMS. Inundation maps cannot be created when using RAS on the CWMS server, but can be created by using RAS-Mapper in a standalone model on the PC. HEC-RAS 5.0 Beta can be used to develop inundation maps if they are setup as a standalone model on the PC where the model can be linked to a forecast.dss file that is developed and pulled from the CWMS Server. The only change that should be needed is to create a new plan file for each separate flood event and input the current forecast dates that apply to the latest forecast.dss file. It is recommended that the District create an archived forecast.dss filing system if they would like to keep previous storm event HEC-RAS runs (e.g. forecast_2013_05_22.dss).

8.8 Unresolved Issues with HEC-RAS Model

There are no unresolved issues with the HEC-RAS Model.

8.9 Additional Project Coordination through Conference Calls or Webinars

The kick-off meeting for the ACT Watershed was held at the Mobile District during the week of April 28, 2014. After the kick-off meeting, weekly calls were held for all team members throughout the entire process. These calls allowed for continued discussion and evaluation of progress and problems encountered. On occasion, additional conference calls or webinars were set up to discuss specific issues with individual models.

The final hand off meeting will take place at the Mobile District during the week of December 8, 2014. At this time, the final project deliverables will be submitted to the district

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Attachment 5. Climate Change Hydrology Development in Support of the Allatoona-Coosa Reallocation Study

The climate change analysis covered in this attachment was completed by the USACE Climate Preparedness and Resilience (CPR) Community of Practice as a pilot quantitative climate change project.

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Alabama-Coosa-Tallapoosa (ACT) Watershed

Climate Change Hydrology Development in Support of the Allatoona-Coosa Reallocation Study

Application of Statistical Adjustment Program, STADJ to ACT Basin

04 March 2019

Prepared for:
US Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628-0001

Prepared by:
Climate Preparedness and Resilience Community of Practice
Engineering & Construction
CW Guidance Program US Army Corps of Engineers Headquarters
441 G Street NW
Washington, DC 20314-1000

(202) 761-1878
www.usace.army.mil

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Statistical Adjustment Guide-ACT Example

General Background.

The statistical adjustment program, STADJ (Friedman et al 2016), is used to adjust hydrologic model outputs to obtain quantitative impacts of future climate on stream flows. Global Climate Models, GCMs, provide hindcast and projected climate data that can drive hydrologic modeling. As their title indicates, GCMs model atmospheric and oceanic processes across the entire globe and are not intended to be accurate or detailed enough for regional-scale climate studies. The GCM results are therefore adjusted and spatially downscaled by various methods to make their results applicable for project scale hydrologic modeling. The Corps requires studies incorporating climate-impacted hydrology to use a range of GCM models and Representative Concentration Pathways, RCPs, to understand the full range of potential outcomes and avoid a premature down-selection to a small number of future conditions that might be computationally tractable but not necessarily be representative of the future (USACE 2018). To support this the Corps worked with other agencies and academic experts over the past ten years to develop a publically available database of downscaled GCM results (gdo-dcp.ucllnl.org) that include results from about 100 combinations of GCM and RCP (Reclamation, 2014). The Corps supported database contains daily climate data for water year 1951-2099, representing hindcast and projected periods. The large number of GCM/RCP combinations and the long time period of daily flows can rarely be calibrated to exactly match observed flows for the hindcast period. The model projected period flow results are therefore hard to quantitatively compare to actual observed flows. The Corps developed a statistical method, STADJ, to adjust the hydrologic model flows for the selected hindcast period to match observed flows and then apply the same adjustments to the hydrologic model projected period flows. The adjusted projected period flows can then be compared to observed flows to quantify the impact of future climate projections and uncertainty.

STADJ Program Example.

The STADJ program has options for performing the adjustment and displaying the results. The program explains the options so that the user can apply them as needed for their study. The guide will show how the tool works by applying it to an example study, the Alabama, Coosa Reallocation (ACR) Study. The Compare Models tab of the program was used to develop all plots. This tab is especially helpful since it can show the results for all, or portions of, GCM/RCP combinations. The other tabs in STADJ are useful for obtaining more information on individual GCM/RCPs.

ACR Study Background. The ACR study is evaluating the impact of different reservoir operation plans within the Alabama Coosa Tallapoosa (ACT) Basin. Part of the analysis is to consider how the operating plans perform for different future climate scenarios. The operating plans are being evaluated with a ResSim reservoir operation model (USACE 2013). The hydrologic input to the ResSim model are daily flows at 36 input locations within the ACT basin. The study team has developed unimpaired, without regulation, historic period flows at these locations. The goal of this climate study is to develop future period daily flows at these locations to assess reasonably expected changes in flow at the project. STADJ currently uses a Corps-supported national data base of 97 sets of 1951-2099 daily flows developed with the Variable Infiltration Capacity, VIC, hydrologic model (Liang et al., 1994). The VIC model used to derive the flow values is driven by GCM data adjusted with the Bias Corrected Statistically Downscaled, BCSD, methodology (Reclamation 2014) and is based on natural, unregulated, conditions. The VIC model has a coarse grid, 1/8 degree latitude-longitude, and is only calibrated for flow volume, not daily flows, and only for some major basins.

Given the coarse VIC hydrologic model grid and limited calibration, it would not be expected that the observed period hydrologic model results at the 36 locations match the unimpaired flow results provided by the ACR team. STADJ was used to adjust the VIC hydrologic model results for comparison to the unimpaired flows for the 1951-1999 hindcast period. The STADJ tool itself discards the first year of hindcast data due to variability which could impact goodness of fit testing, and thus uses 1951-1999 as the hindcast time period. The 1951-1999 period was used to adjust flows since that is the period that was used to adjust and downscale the climate data with the BCSD methodology. A different time period could be used to adjust the flow data, but then the adjusted climate data used to drive that portion of the hydrologic model would not be representative of that time period. STADJ adjusts the VIC model flows at each of the 36 gages separately. The adjustment developed from the hindcast period is applied to model flows from the projected period to obtain adjusted projected flows that be used in the ResSim model.

Nonstationarity Check

As mentioned above, ideally the statistical adjustment of flow will use the same hindcast period that was used to adjust the climate data, 1951-1999 in this case. However, if observed flows are not stationary for that period, then it may be better to use a different, but stationary, period for adjusting the model flow data. The Corps nonstationarity detection (USACE 2017) tool (http://corpsmapu.usace.army.mil/cm_apex/f?p=257) was used to test the annual peaks for stationarity. In the ACT example no strong nonstationarities were found in the unimpaired flow data but a possible one was identified for two gages. To test whether this possible nonstationarity should be considered further, STADJ was applied to the total 1951-1999 period for one adjustment and to the shorter stationary period. There was very little difference in the adjusted projected period flows for the different hindcast adjustment periods, therefore the total 1951-1999 period was used for the final adjustment.

Obtaining the VIC model flows.

The VIC model flows currently available in STADJ are for locations of USGS streamgages for rivers that are defined as pristine: natural conditions, not impacted by regulation, diversions, etc. However, VIC flows have been computed for the entire United States and are routed through the streams using the Mizuroute program. The 36 gages used in the ACT basin are not pristine and thus the VIC flows need for additional were added to the program's database. The process for adding the VIC data at these gages is described in Appendix 1, Adding data to STADJ.

Check VIC Model Results.

Since the VIC model results are being used to evaluate the impact of climate change on future flows, the user needs to ensure that VIC results represent overall runoff processes correctly and consistently. The closer the hydrologic model results match observed flows, the more confidence in using STADJ to compute adjusted future flows. However, even if the hydrologic model results vary quite a bit from observed, the adjusted future flows can still be worthwhile if overall the hydrologic model gets the runoff processes correct. The STADJ tool allows users to compare hindcast VIC results to observed flows using flow duration and annual peak flow frequency. Durations can be annual, seasonal, or monthly. In this case three sample gages were used to evaluate the VIC model performance.

Hindcast Duration Comparison.

STADJ adjusts hindcast model flows using one of several methods, selected to best match the observed flow daily exceedance distribution for the total hindcast period. For annual flow exceedance the user can use the annual peaks from the daily exceedance adjustment or STAD can match annual peak exceedance probabilities. It's been found that for annual peak exceedance, the annual peak adjustment works better. To ensure the VIC model correctly represents runoff processes, the hindcast uncorrected model duration curves were compared to unimpaired ACT annual and seasonal curves. Note that the "annual" duration curves computed and displayed in STADJ use all daily values for the entire period of record. Thus, if using the 1951-1999 period of record, the exceedance probability of the largest daily flow is the chance of being exceeded in 49 years. This is different than if the annual duration curves were computed for each of the 49 years and averaged. Sample checks in Appendix 3 found that the "annual" duration curve for the entire 49 year period is quite close to the duration curve based on the average of the annual duration curves for the 49 years.

For the ACT basin three sample gages were used to evaluate the hindcast VIC results: Etowah River near Kingston, GA (USGS 2395000, DA 1,634 square miles), Coosa River at Jordan Dam near Wetumpka, AL (USGS 2411600, DA 10,148 square miles), and Alabama River at Claiborne L&D near Monroeville, AL (USGS 2428400, DA 21,473 square miles). Both annual and seasonal duration curves were compared.

Following are the three Water Year 1951-1999 hindcast annual duration curves for the observed (unimpaired) data and the unadjusted, raw, VIC model results. Some of the duration flow values are also tabulated since the logarithmic vertical axis can make the plots somewhat miss-leading. Red is observed and the 97 VIC model results are light blue.

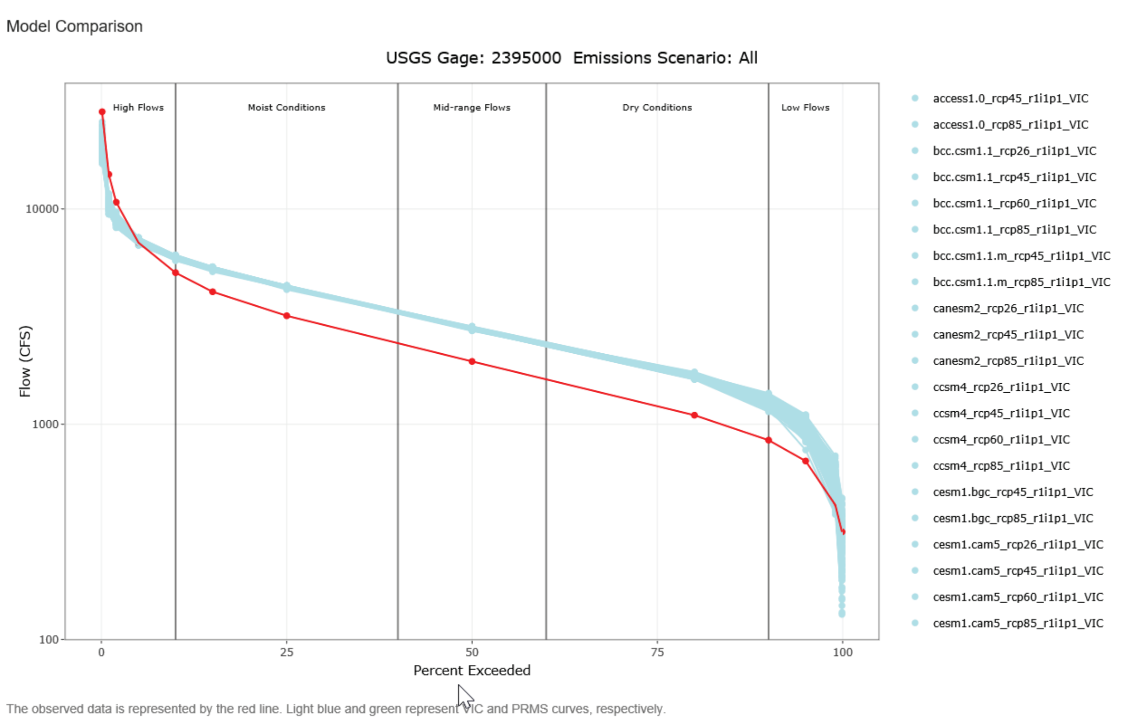


Figure 1 Etowah River, gage 2395000, hindcast annual duration

Table 1 Etowah River, gage 02395000, Daily Flow Exceedance, 1951-1999

Etowah River, gage 02395000, Daily Flow Exceedance, 1951-1999				
Exceedance Probability	Unimpaired - observed	Range-VIC unadjusted, max,median,min	Ratio, max/min	Ratio, observed/VIC median
1%	14,470	11,800, 10,500, 9,450	1.25	1.38
10%	5,060	6,120, 5,950, 5,110	1.07	0.85
50%	1,960	2,860, 2,780, 2,710	1.05	0.71
90%	840	1,400, 1,270, 1,140	1.22	0.66
99%	420	710, 530, 380	1.87	0.79
		Average, all durations	1.42	0.93

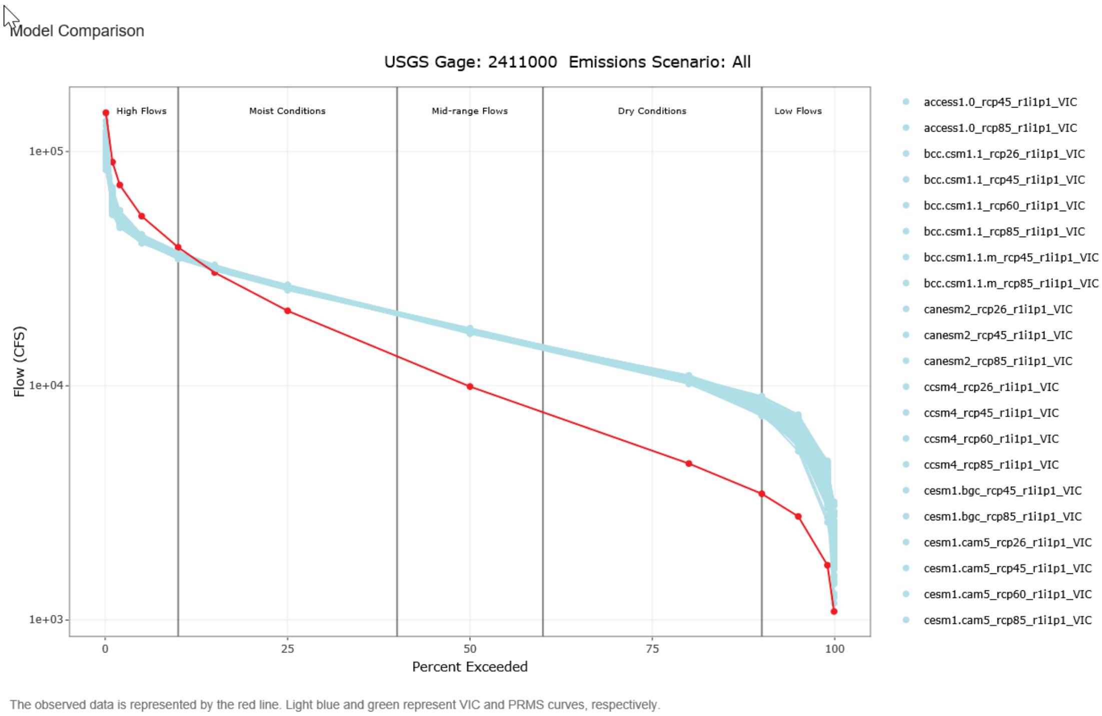


Figure 2 Coosa River, gage 2411000, hindcast annual duration

Table 2 Coosa River, gage 02411000, Daily Flow Exceedance, 1951-1999

Coosa River, gage 02411000, Daily Flow Exceedance, 1951-1999				
Exceedance Probability	Unimpaired - observed	Range-VIC unadjusted, max,median,min	Ratio, max/min	Ratio, observed/VIC median
1%	90,140	70,290, 60,870, 53,590	1.31	1.48
10%	39,020	37,440, 35,930, 34,770	1.08	1.09
50%	9,920	17,630, 17,100, 16,660	1.06	0.58
90%	3,460	9,030, 8,160, 7,430	1.22	0.42
99%	1,710	4,780, 3,780, 2,610	1.83	0.45
		Average	1.37	0.86

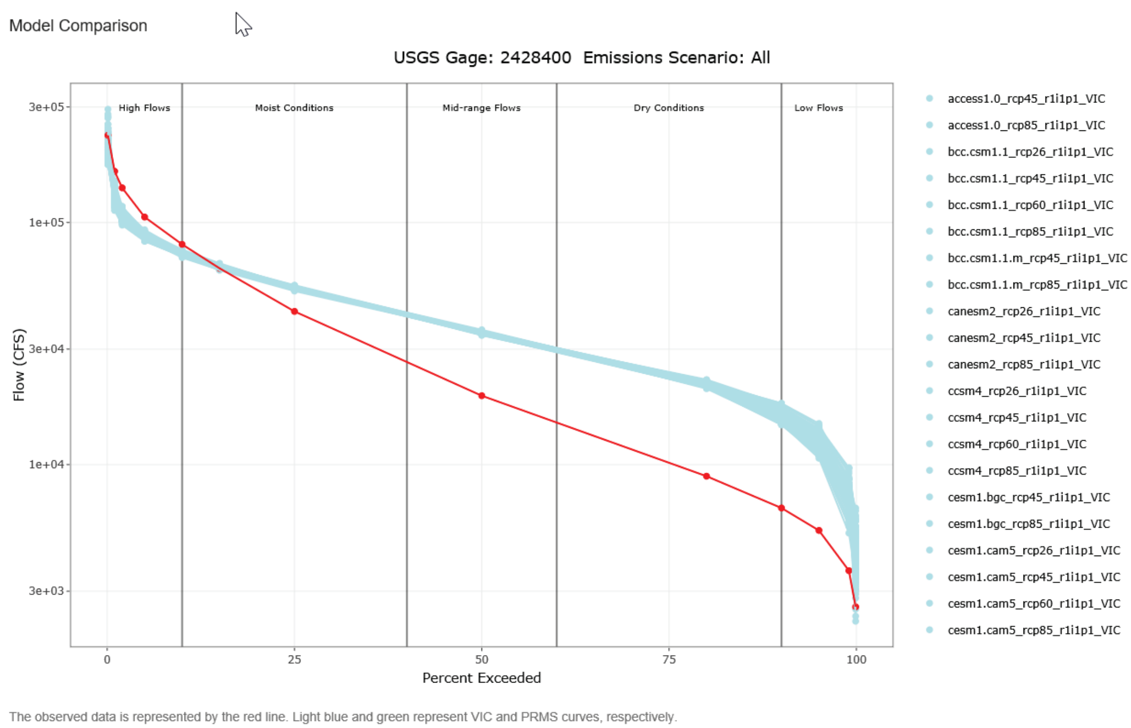


Figure 3 Alabama River, gage 2428400, hindcast annual duration

Table 3 Alabama River, gage 02428400, Daily Flow Exceedance, 1951-1999

Alabama River, gage 02428400, Daily Flow Exceedance, 1951-1999				
Exceedance Probability	Unimpaired - observed	Range-VIC unadjusted, max,median,min	Ratio, max/min	Ratio, observed/VIC median
1%	162,640	148,580, 127,400, 112,140	1.32	1.28
10%	81,250	77,380, 74,020, 71,590	1.08	1.10
50%	19,250	36,060, 34,930, 34,190	1.05	0.55
90%	6,620	17,920, 16,250, 14,570	1.23	0.41
99%	3,650	9,710, 7,330, 5,210	1.86	0.50
		Average	1.39	0.82

The graphs and the tables indicate that the VIC model results are consistently above the observed for most durations but are lower than observed for the higher flows (low annual durations).

The following three graphs are the seasonal duration plots for the three gages.

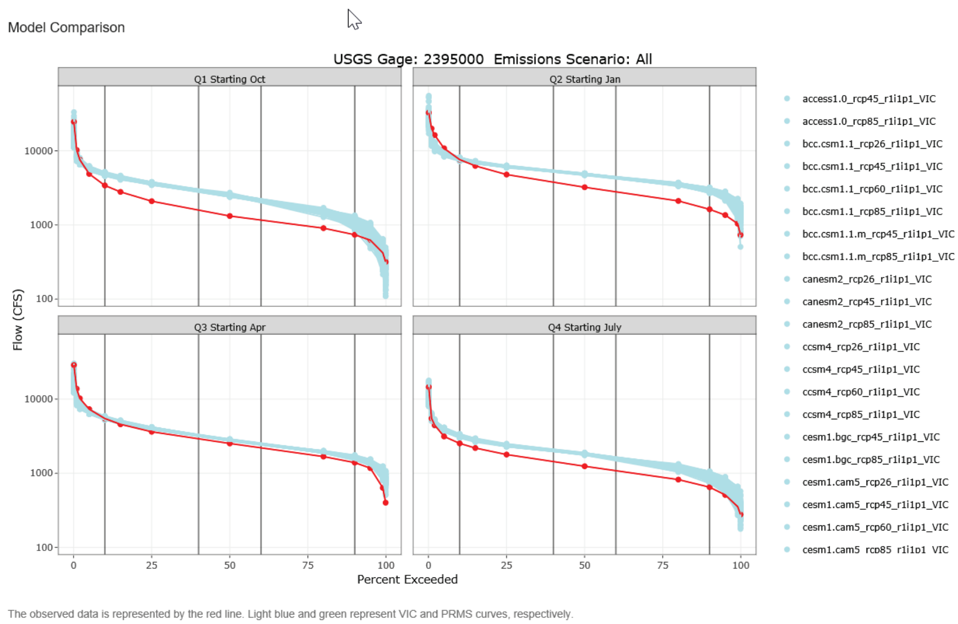


Figure 4 Etowah River, gage 2395000, hindcast seasonal duration

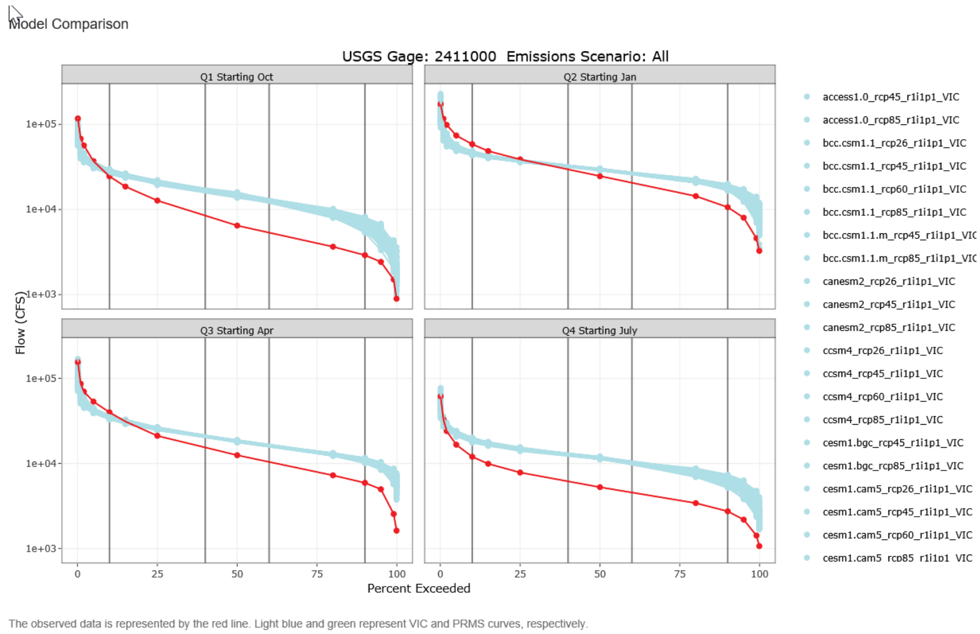


Figure 5 Coosa River, gage 2411000, hindcast seasonal duration

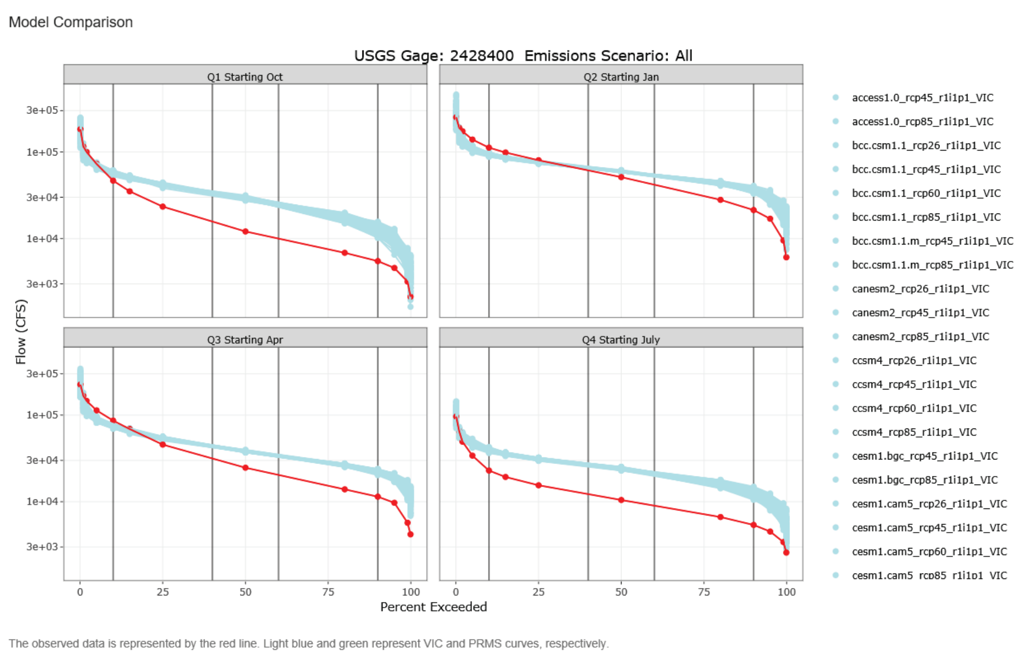


Figure 6 Alabama River, gage 2428400, hindcast seasonal duration

The seasonal curves are fairly consistent with each other and with the annual curves: VIC results are generally higher than observed for most durations for all seasons and lower than observed for infrequent exceedance durations, though summer (July, August, September here) matches well at the infrequent durations.

Annual Exceedance Frequency

The following graphs are the annual flow exceedance graphs for the three gages with some of the results tabulated. Red is observed with the 90% confidence interval shown in gray, while the curves for the 97 unadjusted VIC model results are shown in light blue

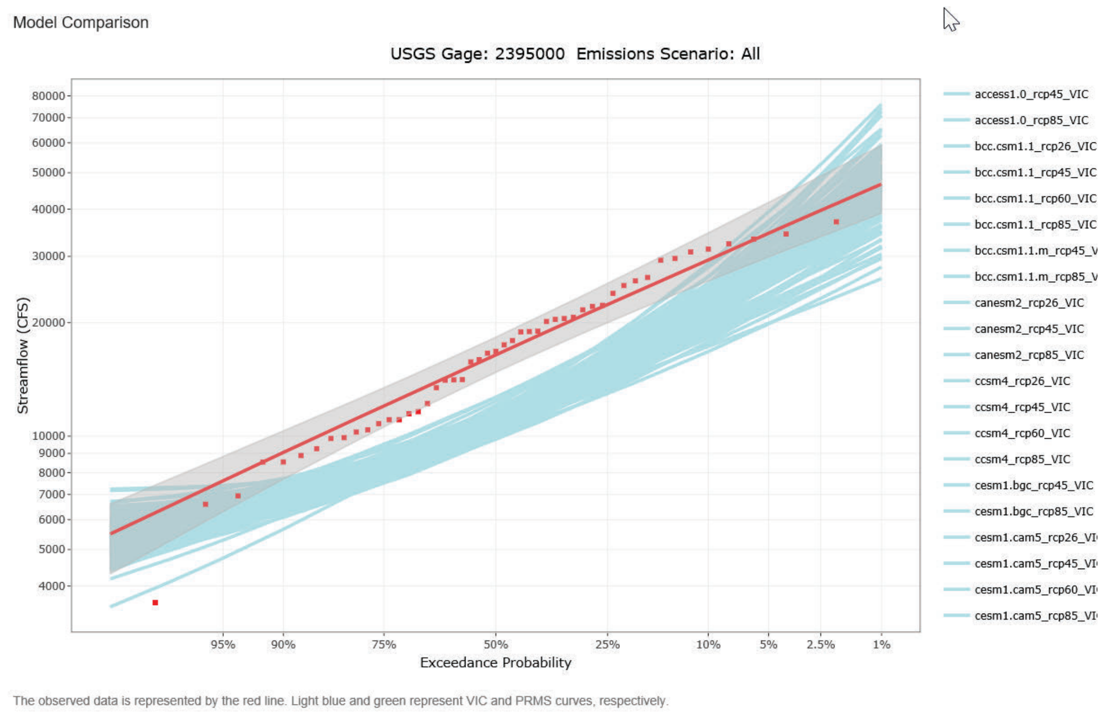


Figure 7 Etowah River, gage 2395000, hindcast annual exceedance

Table 4 Etowah River, gage 02395000, Annual Peak Exceedance, 1951-1999

Etowah River, gage 02395000, Annual Peak Exceedance, 1951-1999				
Exceedance Probability	Unimpaired - observed	Range VIC, unadjusted max,median,min	Ratio, max/min	Ratio, observed/VIC median
1%	46,660	76,030, 45,070, 26,190	2.90	1.04
10%	29,400	28,670, 21,670, 16,770	1.71	1.36
50%	16,440	12,680, 10,960, 9,810	1.29	1.50
90%	9,050	7,720, 6,850, 5,660	1.36	1.32
99%	5,500	7,230, 5,240, 3,520	2.05	1.05
		Average all probabilities	1.69	1.31

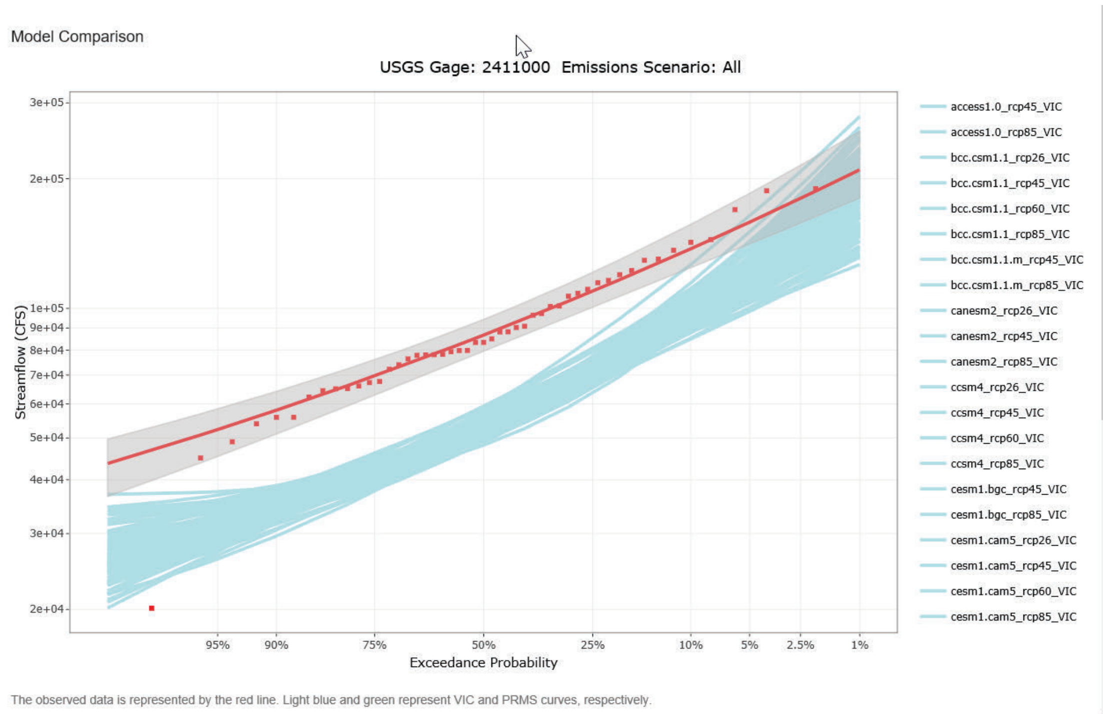


Figure 8 Coosa River, gage 2411000, hindcast annual exceedance

Table 5 Coosa River, gage 02411000, Annual Peak Exceedance, 1951-1999

Coosa River, gage 02411000, Annual Peak Exceedance, 1951-1999				
Exceedance Probability	Unimpaired - observed	Range-VIC, unadjusted max,median,min	Ratio, max/min	Ratio, observed/VIC median
1%	209,820	278,960, 179,220, 126,420	2.21	1.17
10%	137,520	126,440, 97,050, 84,940	1.49	1.42
50%	86,690	59,240, 53,430, 48,130	1.62	1.23
90%	58,020	38,780, 34,380, 29,600	1.69	1.31
99%	43,620	36,990, 25,740, 20,143	1.84	1.69
		Average all probabilities	1.50	1.55

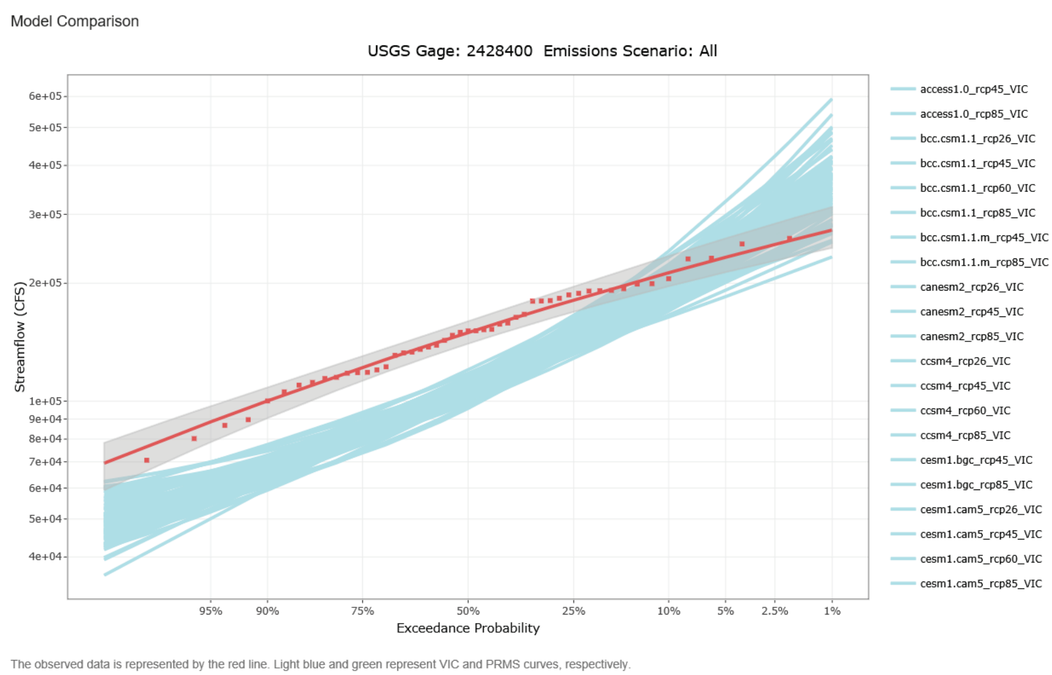


Figure 9 Alabama River, gage 2428400, hindcast annual exceedance

Table 6 Alabama River, gage 0228400, Annual Peak Exceedance, 1951-1999

Alabama River, gage 02428400 Annual Peak Exceedance, 1951-1999				
Exceedance Probability	Unimpaired - observed	Range-VIC, unadjusted max,median,min	Ratio, max/min	Ratio, observed/VIC median
1%	273,480	592,350, 356,500, 233,610	2.54	0.77
10%	212,810	241,670, 196,020, 163,980	1.47	1.09
50%	149,750	120,180, 107,970, 95,850	1.25	1.39
90%	100,170	77,500, 66,760, 59,240	1.31	1.50
99%	69,400	62,400, 49,070, 35,910	1.74	1.41
		Average all probabilities	1.53	1.27

Conclusions about match of VIC model to observed, unimpaired.

_There are two important items that the graphs of observed data vs. the unadjusted model data help determine: how do the VIC model results compare to observed, and how to the VIC model results compare to each other. The above plots and tables for annual duration and annual exceedance frequency are useful for this assessment. For annual duration, the ratio for the ratio of observed to model exceedance varies from 1.48 to 0.41 with the average ratios for the three gages 0.93, 0.86, and 0.82. In all three cases the model is high for most of the duration curve and low for less frequent exceedances. The seasonal duration plot comparisons are fairly similar to each other and also to the annual curve comparison. This last item indicates the VIC model is consistent between seasons and gives confidence the model is capturing major runoff seasonal characteristics. The seasonal comparison is especially useful for sites with snowmelt for a portion of the year and precipitation only events for other parts of the year.

Except for the lower (infrequent) end of the curves, the different GCM/RCP models are close to each other on the duration plots, indicating the results are not sensitive to the methodology used to develop climate data for the VIC models. The variation in the lower end of the duration curves means the modeling results for those flows are more uncertain, which makes sense because observations of extreme low or high flows is generally more uncertain, as shown by the shape of the gray shaded area in the flow exceedance curves above. Thus for low flows, the computed climate change impacts are more uncertain than for mid-range flows. As a result, for low flow studies it is important to consider the full range of modeling results and a single value for the impact might not be appropriate.

In normal hydrologic modeling, it would be preferable to have a better calibrated model, but considering the range of model inputs, the duration results indicate the existing VIC model does appear to capture the overall basin runoff characteristics and the results can be used to estimate a quantitative impact of climate change on flow duration.

The plots indicate that the VIC results for the annual flow exceedance are a poorer match to observed than the duration curves. However, the large spread in the annual flow frequency curves can be misleading for average results. The tables show that average results for the annual exceedance (observed/model 1.31, 1.55, and 1.27) are almost as close to observed as they are for duration (0.93, 0.86, 0.82). The difference between the average maximum and minimum model results are also about the same for annual exceedance (1.69, 1.50, and 1.53) than they are for daily duration (1.42, 1.37, and 1.39). The largest difference between the duration and annual exceedance is the very large spread in the annual exceedance results for infrequent floods. The largest 100-yr peak is 2-3 times the minimum peak for all three gages. Because of the large uncertainty in the low exceedance annual peaks, the model climate change results for these large events is more uncertain, and the user would want to consider a range rather than a single value. Unfortunately, for flood frequency studies the higher flows, smaller exceedance frequency, are usually the most important.

Projected Period, 2053-2084, Results

Annual Duration Curves

Plots from STADJ. Red 1951-1999 observed, light blue VIC model unadjusted 2054-2083, dark blue VIC adjusted 2054-2083.

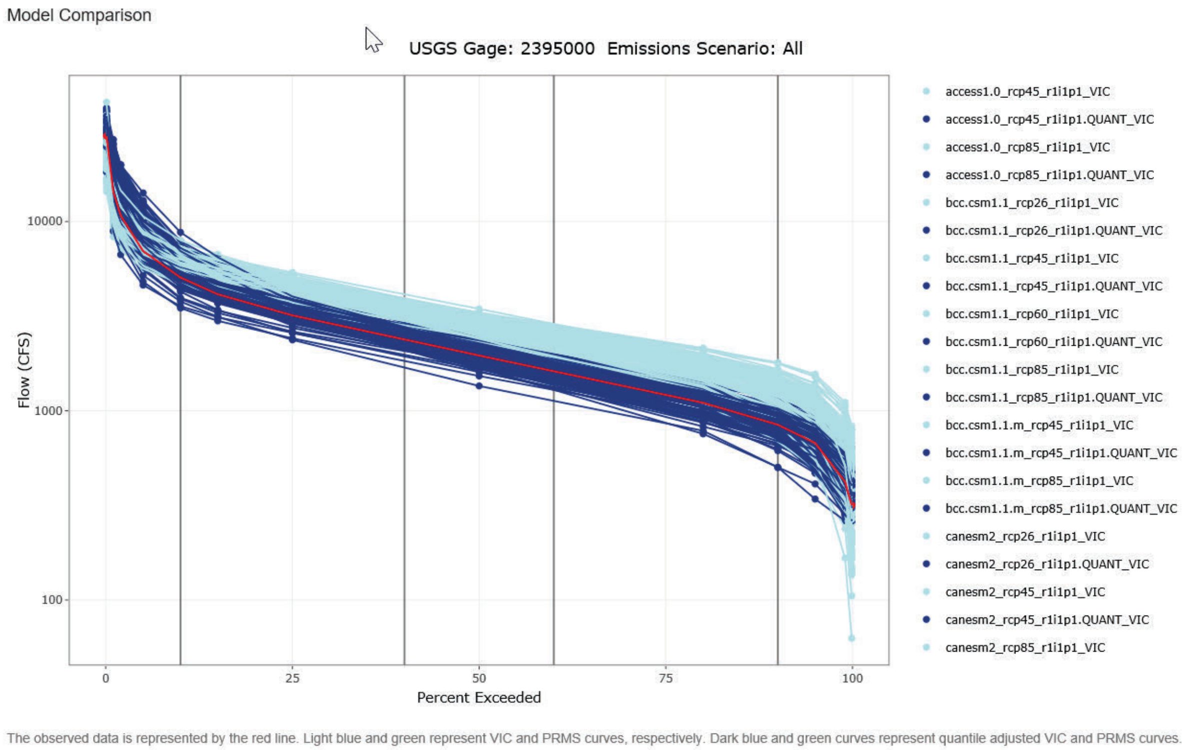


Figure 10 Etowah River Gage 2395000, projected annual duration

Table 7 Etowah River, gage 02395000, Daily Flow Exceedance, 1951-1999 and 2054-2083

Etowah River, gage 02395000, Daily Flow Exceedance, 1951-1999 and 2054-2083				
Exceedance Probability	1951-1999 Unimpaired - observed	Range-2054-2083 Adjusted VIC, 5% max,median,95% min	Ratio, median projected/observed	Ratio, observed/projected max, min
1%	14,470	25,200,17,410, 11,780	1.20	1.74, 0.81
10%	5,060	7,320, 5,380, 4,260	1.06	1.45, 0.84
50%	1,960	2,320, 2,000, 1,670	1.02	1.18, 0.85
90%	840	1,070, 890, 670	1.06	1.27, 0.79
99%	420	660, 450, 310	1.06	1.56, 0.74
		Average, all durations	1.08	1.45, 0.82

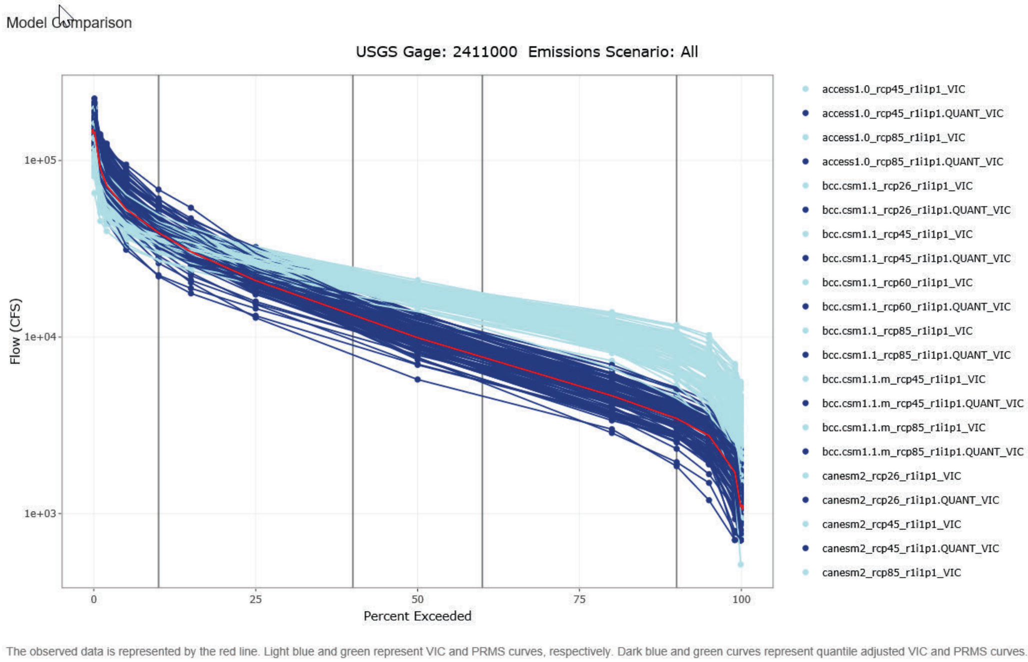
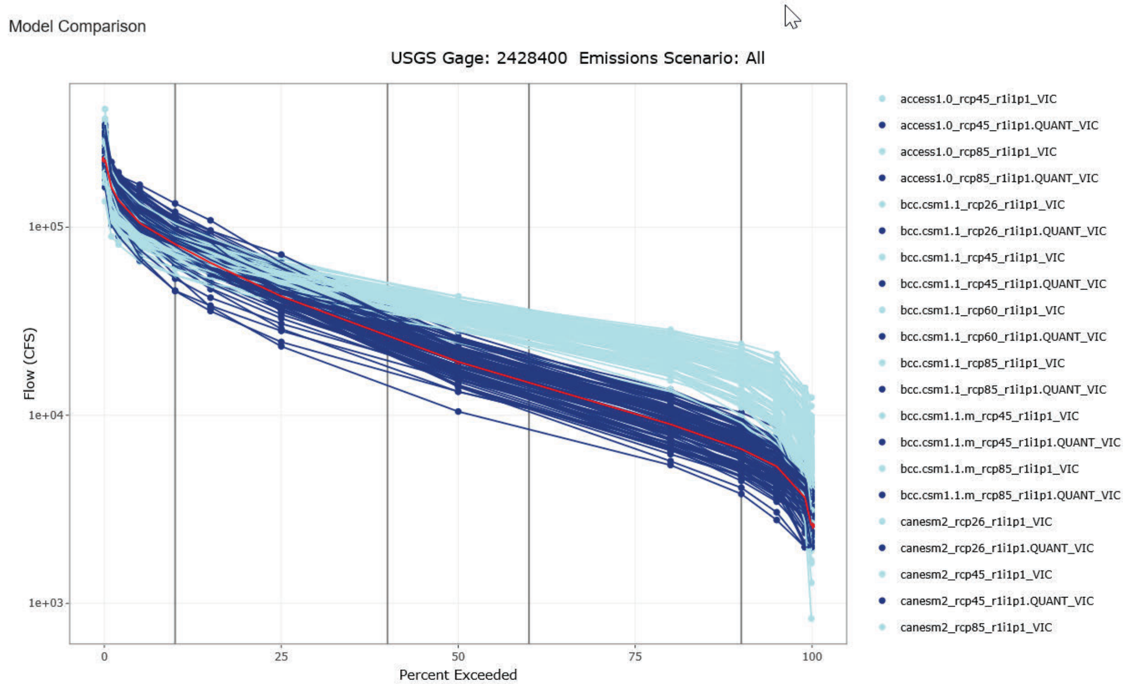


Figure 11 Coosa River Gage 241100, projected annual duration

Table 8 Coosa River, gage 02411000 Daily Flow Exceedance, 1951-1999 and 2054-2083

Coosa River, gage 02411000 Daily Flow Exceedance, 1951-1999 and 2054-2083				
Exceedance Probability	1951-1999 Unimpaired - observed	Range-2054-2083 Adjusted VIC, 5% max,median,95% min	Ratio, median projected/observed	Ratio, observed/projected max, min
1%	90,140	131,590, 99,900, 71,150	1.11	1.46, 0.79
10%	39,020	57,400, 41,140, 31,240	1.05	1.47, 0.80
50%	9,920	13,230, 10,270, 7,680	1.03	1.33, 0.77
90%	3,460	4,530, 3,600, 2,670	1.04	1.31, 0.77
99%	1,710	2,760, 1,870, 990	1.09	1.61, 0.58
		Average, all durations	1.07	1.48, 0.76



The observed data is represented by the red line. Light blue and green represent VIC and PRMS curves, respectively. Dark blue and green curves represent quantile adjusted VIC and PRMS curves.

Figure 12 Alabama River Gage 2428400, projected annual duration

Table 9 Alabama River, gage 02428400, Daily Flow Exceedance, 1951-1999 and 2054-2083

Alabama River, gage 02428400, Daily Flow Exceedance, 1951-1999 and 2054-2083				
Exceedance Probability	1951-1999 Unimpaired - observed	Range-2054-2083 Adjusted VIC, 5% max,median,95% min	Ratio, median projected/observed	Ratio, observed/projected max, min
1%	162,640	208,850, 174,980, 144,080	1.08	1.29, 0.89
10%	81,250	111,970, 83,880, 64,280	1.03	1.38, 0.79
50%	19,250	25,440, 19,640, 14,250	1.02	1.32, 0.74
90%	6,620	9,170, 6,830, 4,670	1.03	1.39, 0.72
99%	3,650	5,320, 3,860, 2,090	1.06	1.46, 0.57
		Average, all durations	1.05	1.40, 0.77

Summary of Duration Impacts. The median 2054-2083 results show only a small increase in flows for all portions of the duration curve. With the uncertainty in the climate model and hydrologic modeling these small increases are not significant. However, since the increases are consistent for all gages and for all flows, it would be prudent to consider these impacts in project studies. While the average changes are small, there is a wide range in the range of impacts on the duration curve. Studies that need projected period durations should consider the full range of the results and include adaptable projects where practical.

As pointed out previously the annual duration curves computed in STADJ are developed from all daily flows in the selected period of record, which is not the same as the average of the annual duration curves computed for each year within the period of record (PoR). Though the STADJ method does not compute or show uncertainty in the curve that is the average of each year's duration curve as it does for flow exceedance, there is uncertainty in the actual observed annual duration curve. This is discussed in more detail in Appendix 3, STADJ Annual Duration Curve vs. Averaged Annual Duration. An example of the variation in annual curves for the 1951-1999 observed data is shown below.

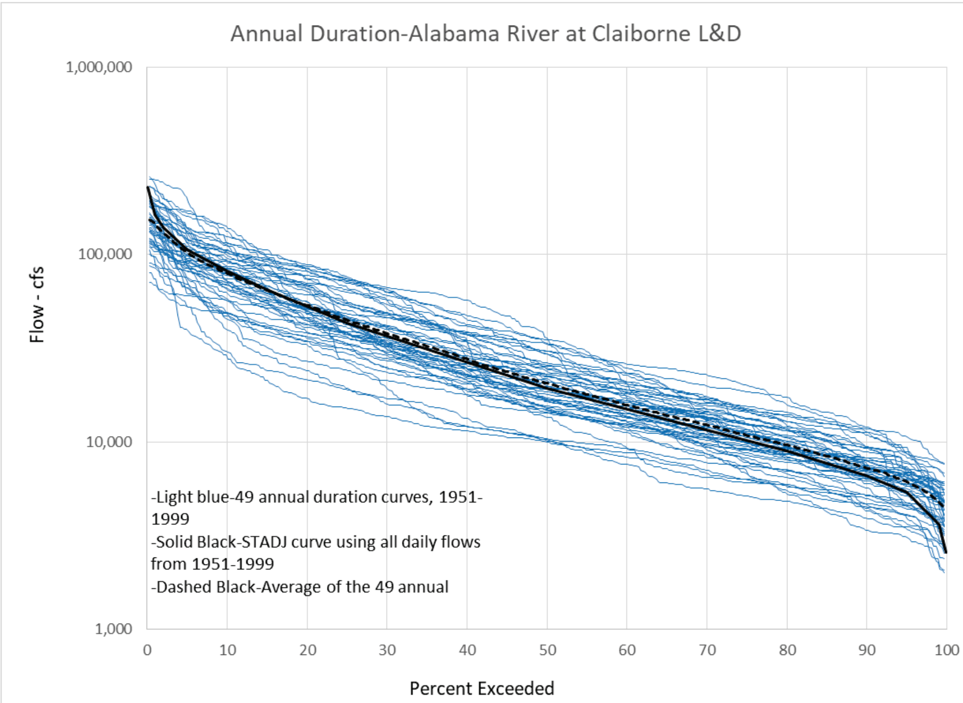


Figure 13 Averaged Annual Duration. An example of the variation in annual curves for the 1951-1999 observed data is shown below.

The variation in the projected period duration curves from STADJ gives an indication of the impact of climate change on the variation in cumulative annual duration curves, but does not directly address how the actual annual frequency curve uncertainty will change. If this is important to the user they can download the daily data and analyze it. If the downloaded daily values are used to drive further analysis, such as ResSim, then the variation in the daily values will be incorporated in the ResSim results.

Seasonal Duration

Only the results for the Alabama gage are shown as an example of seasonal climate impacts. There was not a discernible difference in impacts by season.

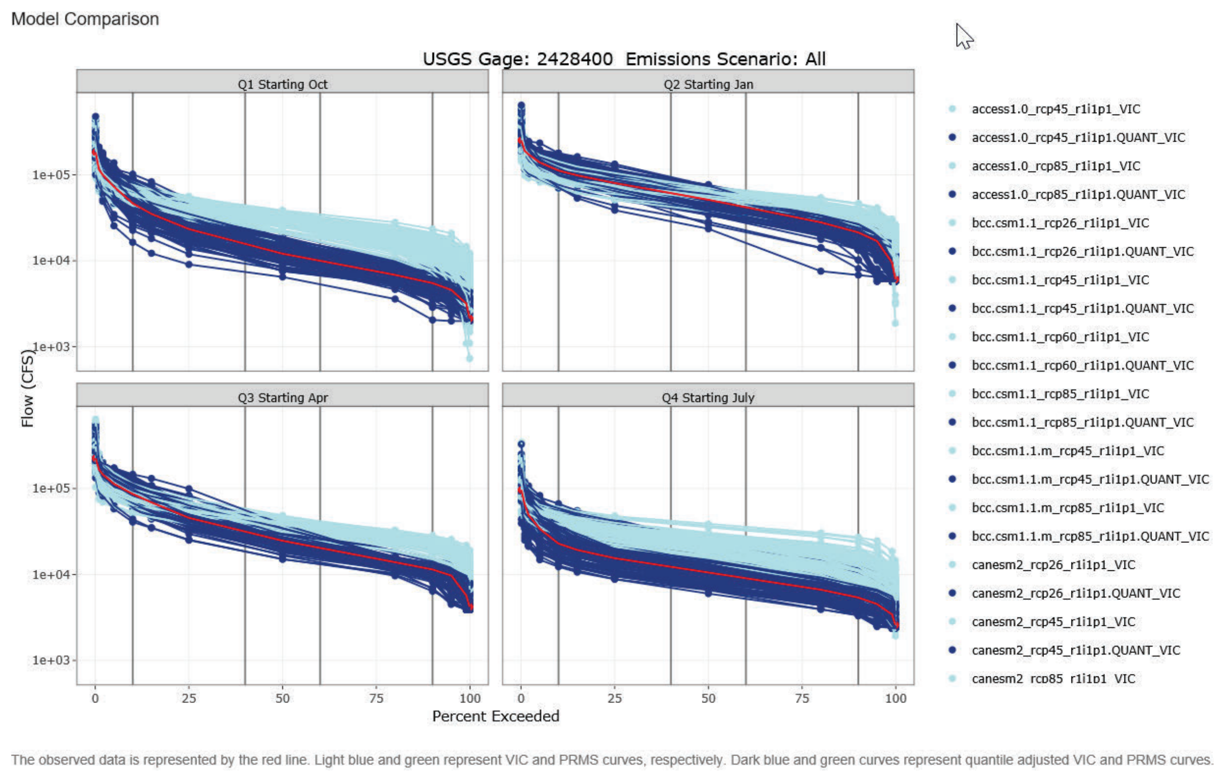


Figure 14 Example of seasonal climate impacts

Annual Exceedance Frequency

STADJ results for the three gages. For the Etowah River gage the first plot includes the unadjusted and adjusted projected period results. For the next Etowah plot and for the other two gages only the adjusted value curves are show to increase the clarity of the plot.

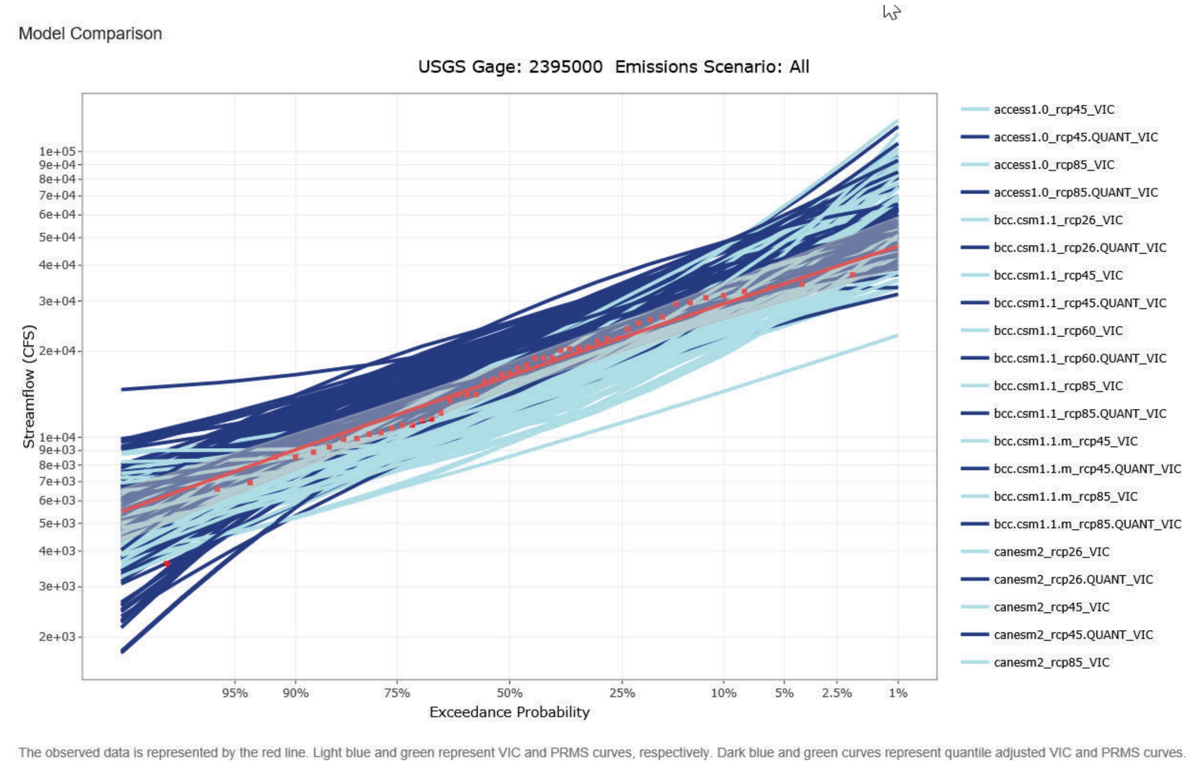


Figure 15 Etowah Gage 2395000, projected annual exceedance, adjusted and unadjusted

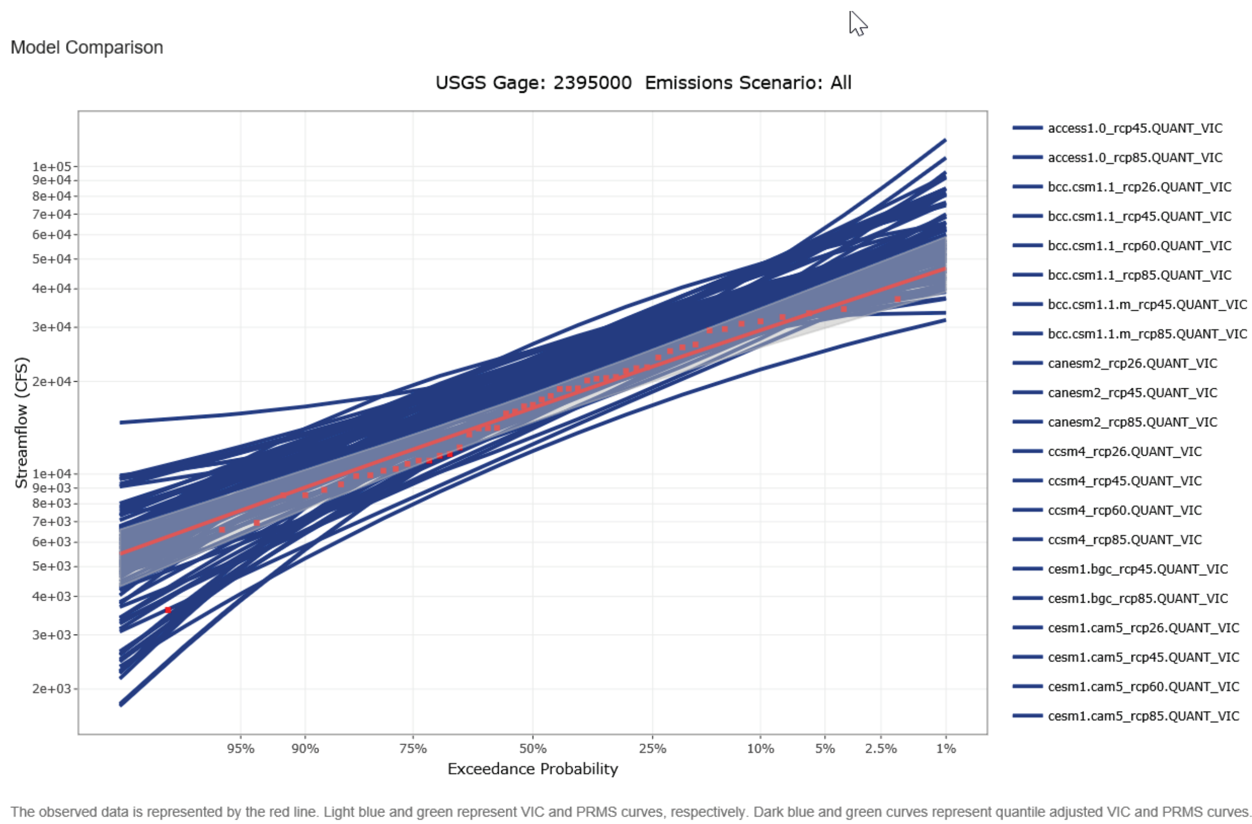


Figure 16 Etowah Gage 2395000, projected annual exceedance, adjusted only

Table 10 Etowah River, gage 02395000, Annual Peak Exceedance, 1951-1999 and 2054-2083

Etowah River, gage 02395000, Annual Peak Exceedance, 1951-1999 and 2054-2083				
Exceedance Probability	1951-1999 Unimpaired - observed	Range-2054-2083 Adjusted VIC, 5% max,median,95% min	Ratio, median projected/observed	Ratio, observed/projected max, min
1%	46,660	92,020, 53,510, 39,050	1.15	2.36, 0.84
10%	29,400	47,540, 34,450, 28,760	1.17	1.65, 0.98
50%	16,440	23,890, 19,120, 14,480	1.16	1.64, 0.89
90%	9,050	13,420, 9.920, 6,440	1.10	2.08, 0.71
99%	5,500	9,620, 5,450, 2,370	0.99	1.75, 0.43
		Average all probabilities	1.13	1.89, 0.81

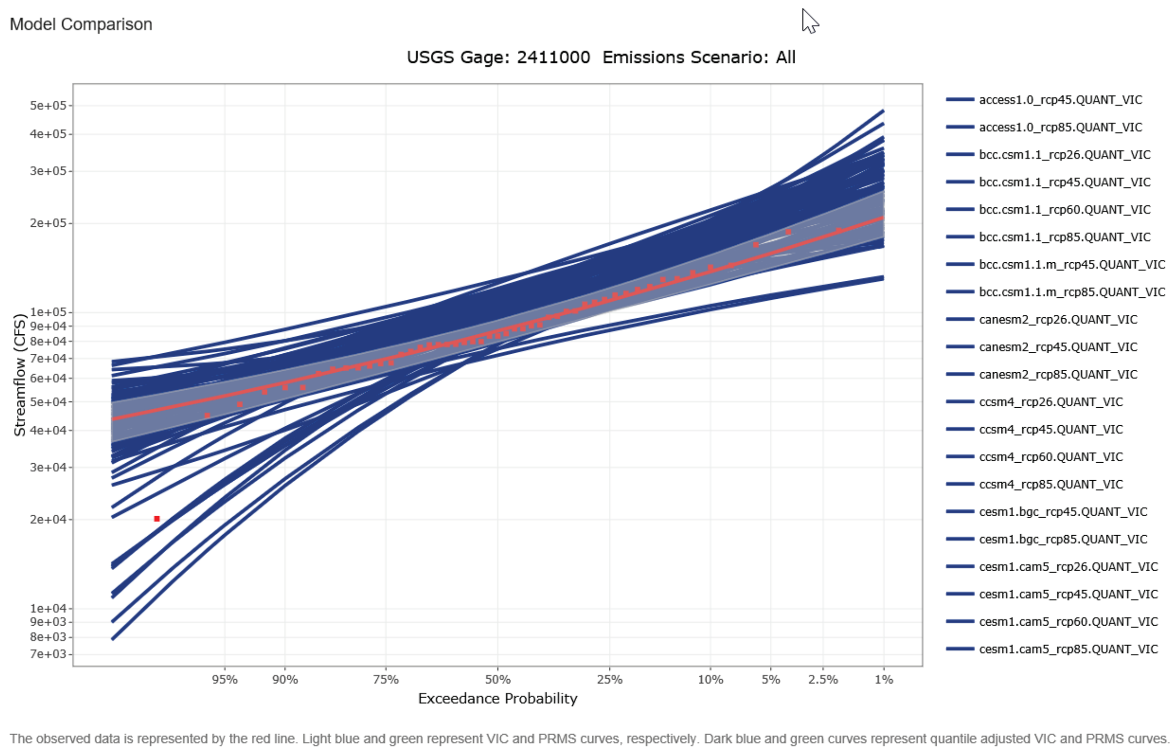


Figure 17 Coosa Gage 2411000, projected annual exceedance

Table 11 Coosa River, gage 02411000, Annual Peak Exceedance, 1951-1999 and 2054-2083

Coosa River, gage 02411000, Annual Peak Exceedance, 1951-1999 and 2054-2083				
Exceedance Probability	1951-1999 Unimpaired - observed	Range-2054-2083 Adjusted VIC, 5% max,median,95% min	Ratio, median projected/observed	Ratio, observed/projected max, min
1%	209,820	382,620, 241,030, 168,270	1.15	2.27, 0.80
10%	137,520	202,610, 160,880, 127,970	1.17	1.58, 0.93
50%	86,690	118,640, 95,890, 79,170	1.11	1.50, 0.91
90%	58,020	75,510, 60,490, 35,650	1.04	2.12, 0.61
99%	43,620	58,940, 41,580, 13,890	0.95	1.35, 0.32
		Average all probabilities	1.09	1.81, 0.77

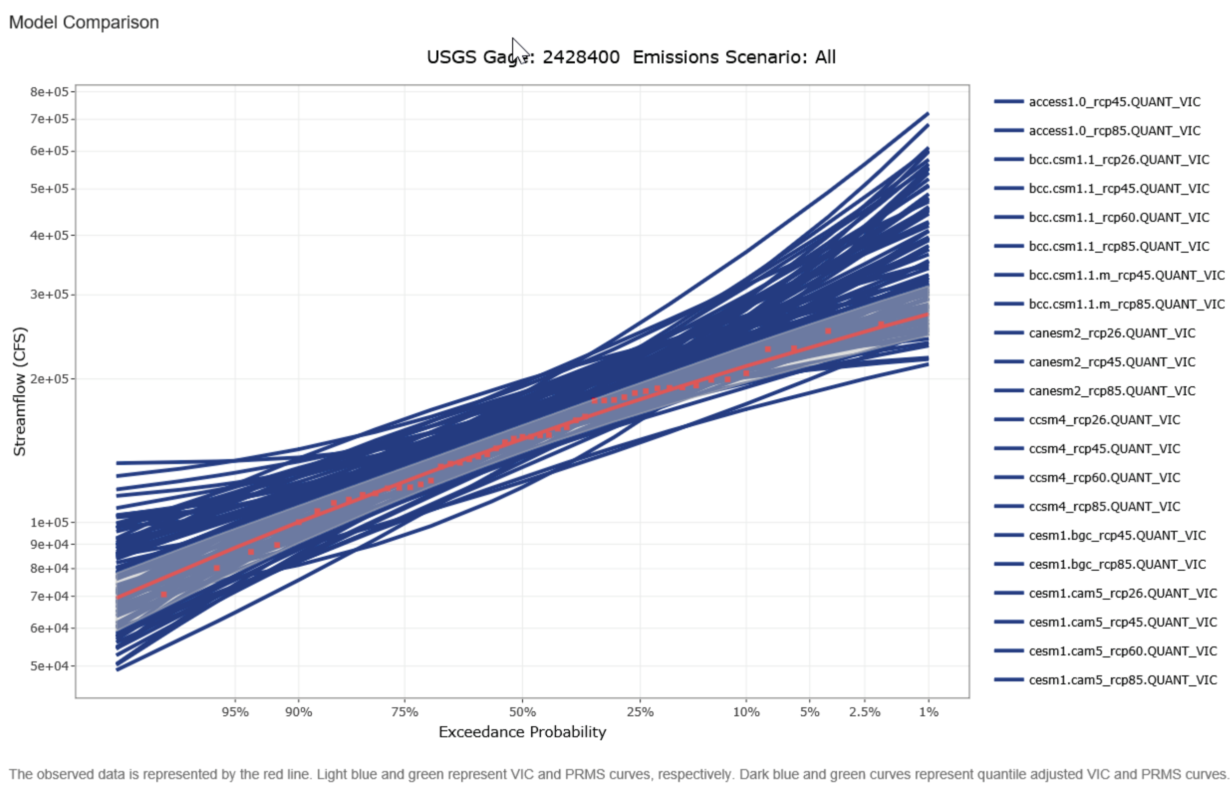


Figure 18 Alabama Gage 2428400, projected annual exceedance

Table 12 Alabama River, gage 02428400, Annual Peak Exceedance, 1951-1999 and 2054-2083

Alabama River, gage 02428400, Annual Peak Exceedance, 1951-1999 and 2054-2083				
Exceedance Probability	1951-1999 Unimpaired - observed	Range-2054-2083 Adjusted VIC, 5% max,median,95% min	Ratio, median projected/observed	Ratio, observed/projected max, min
1%	273,480	599,400, 315,800, 238,100	1.15	2.52, 0.87
10%	212,810	314,270, 237,380, 202,650	1.12	1.55, 0.95
50%	149,750	187,200, 159,510, 136,660	1.07	1.37, 0.91
90%	100,170	130,240, 104,950, 83,620	1.05	1.56, 0.83
99%	69,400	107,150, 72,380, 54,430	1.04	1.54, 0.78
		Average all probabilities	1.08	1.63, 0.88

Summary of Annual Exceedance Impacts. The average impacts of climate change on annual peak exceedance are somewhat greater than for annual duration. The median projected period results are larger than 1951-1999 observed for almost all of the exceedance frequencies for each gage. The increases are less than 20% but could be significant for some studies. For all three gages the median increase in the 1% exceedance, 100-yr, flood is 15%. For many gages this would result in a substantial stage increase and subsequent flooding damages. While there is significant uncertainty in the results of this study, the median results are consistent and prudence would call for acknowledging that climate change would likely increase future flood flow and stages within the project life cycle.

As with duration, there is a very large variation in range of climate change impacts, and the range of the results for the upper end of the curve is much greater than the 90% confidence interval of the observed data curve. The Corps risk and economic analysis uses the uncertainty in the annual exceedance curve in its Monte Carlo type statistical analysis. For analyzing future risk and economics the 17B confidence interval based on the observed data would not be appropriate. The range in the VIC results is not a complete or thorough representation of all uncertainty in projected period frequency curves, but would be a better representation of the future uncertainty than the confidence interval of the observed data curve.

Appendixes

1. Adding Gages to STADJ
2. Impact of GCM Time Series and of Random Daily Disaggregation
3. STADJ Cumulative Annual Duration vs. Averaged Annual Duration
4. Selecting Representative GCM-RCPs.5
5. Deliverable

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Appendix 1. Adding Gages to STADJ Program

There are only a limited set of pristine, non-regulated, gages in the program. If a user wants to apply the program to another gage they can provide unregulated flow data to be used in lieu of observed data. The available VIC and PRMS flows would still be used for the adjustment and for projected period flows. User provided flow data can only be added to STADJ program by the program administrator. The Climate Preparedness and Resilience Communities of Practice should be contacted to arrange the effort. If the user knows that for their purposes the observed flows in a certain flow range are not impacted by regulation, then the observed flows for that gage can be used, but the user has to be careful not to use the STADJ results for flows in the ranges that could be impacted by regulation.

The following steps are required to add unregulated flows for a gage to STADJ.

1. The user provides the program administrator the unregulated daily flows at the gage and the administrator enters these into STADJ. The unregulated flows must be daily and include all, or a significant portion, of water year 1951-1999. STADJ will compare these flows to the VIC/PRMS daily flows for that period. Unimpaired flows are required since the VIC and PRMS models are based on pristine conditions; no regulation, no diversions, stationary hydrologic parameters for 1951-2099, etc.
2. The latitude and longitude of the gage must be provided to the program administrator.
3. The program administer will provide the user with the 10 Mizuroute stream segments that are closest to the gage. Provided for each segment are the starting and ending latitude and longitude and the segment downstream of each segment.
4. The user determines the stream segment that contains the gage and provide that to the program administrator. The Mizuroute program is used to route flows generated by VIC and PRMS. Mizuroute is divided into about 41,000 nationwide stream segments. With a geographic plot tool, like Google Maps, the user can plot the coordinates of each segment to determine the segment that contains the gage. In some cases the closest segment might not contain the gage, for example, if the closest segment start/end is for a tributary near the gage.
5. The program administrator obtains the 1951-2099 VIC and/or PRMS daily flows for that segment and enters them into STADJ. These will be for the 97 combinations of GCM/RCPs. This task involves converting a large amount of data to a different format and requires about 4 hours of computer time for each gage.

The program will compare the user provided unregulated flows to the nationwide database of unregulated VIC and/or PRMS flows to determine the adjustments needed to make the hindcast VIC/PRMS flows match the unregulated flows. This adjustment is applied to VIC/PRMS projected period flows. The user can then use STADJ to evaluate the impacts for climate change on the unregulated flows at the gage.

If a user has generated future daily flows from another hydrologic model with inputs from climate models, those flows could be entered into STADJ in lieu of the VIC and PRMS flows. However, the user needs to coordinate the generated future flows with the CPR CoP leads to be sure they satisfy Corps of Engineers guidance. This method has not been tried to date and could involve some tool development by the program administrator.

Appendix 2. How do GCM monthly time series and the random daily disaggregation of climate data impact the accuracy of STADJ results that are based on full period 1951-1999 flows.

Background on climate and hydrologic data used in the statistical adjustment tool.

The STADJ tool currently (March 2019) uses hydrologic data from VIC and PRMS models that are driven by climate data developed from GCMs that was modified using the BCSD method to get monthly average temperatures and monthly cumulative precipitations. Subsequent to the BCSD procedure the monthly climate data is disaggregated to daily precipitation and temperature using a random selection of similar observed period months. The climate data is obtained from a database of 97 GCM/RCP climate models for the period of water year 1951-2099. The dataset from the climate models provides monthly cumulative precipitation and average temperature at very large gird intervals, 1-degree (approximately 69X69 miles, ~4800 square miles) or larger. Using the Bias Corrected Statistically Downscaled method, BCSD, the 1951-1999 national climate model data have been statistically adjusted to remove bias by matching monthly observed climate data and then downscaled to match observed data at a 1/8 degree grid resolution. The global climate models results have to be adjusted to match observed local area climate exceedance probabilities rather than observed time series of climate data since the climate models do not attempt to match the time series for observed data. The adjusted climate model values will not match observed for the same year and month: for example, the June 1965 precipitation and temperature from any of the 97 adjusted climate model results are not intended to match the June 1965 observed values. However, the monthly exceedance probabilities for climate model adjusted 1951-1999 June precipitations and temperatures will match the observed probabilities for 1951-1999 Junes. Note that each GCM is adjusted separately and provides its own time series of monthly values.

As part of the hydrologic model development the adjusted monthly climate model data have been disaggregated to daily data based on a random sampling of observed monthly disaggregation. The bias corrected and downscaled daily data was used as input to nationwide 1/8 degree grid VIC and PRMS hydrologic models, and flows from those models were routed with the Mizuroute model. The VIC and PRMS models are based on natural conditions: no reservoirs, diversions, etc. Daily flows are available from the Mizuroute model at over 40,000 stream segments identified by starting and ending latitude and longitude. To obtain flow data for a study location it is necessary to find the Mizuroute segment it is in. The calibration of the VIC and Mizuroute results was not done for the total nation and when done was calibrated to match observed volumes for large basins.

Because the VIC and PRMS models have coarse grids and limited calibration, the 1951-1999 flows from the hydrologic modeling will likely not match observed at the study location. To illustrate this, two examples, the Alabama River near Claiborne Lock and Dam in Alabama (USGS Gage 2428400) 21,473 square miles, and the Middle Fork of the Flathead River near West Glacier Montana (USGS Gage 12358500), 1,125 square miles, were examined to evaluate the impact of the variable monthly time series from each GCM and the random daily disaggregation have on the hydrologic results. The impacts of these were evaluated for the flow duration and annual peaks.

Impact of daily disaggregation

Flow Duration

Each of the approximate 30 GCMs provides its own time series of monthly cumulative precipitation and average temperature. Each of the GCMs used 2-4 RCPs. The 1951-1999 adjusted climate model monthly time series should not vary with RCP since the RCPs do not impact the hindcast period. However, the random daily disaggregation does vary for each RCP. Therefore the only difference in 1951-1999 precipitation and temperature between RCPs for a given GCM are the daily disaggregation of climate data the impact of the daily disaggregation, therefore comparison of the hydrologic model results shows the impact of the daily disaggregation.

The plots below from STADJ show the 1951-1999 duration curves for two gages, the Alabama River at Claiborne L&D, AL, USGS gage 2428400, and Middle Fork Flathead River near West Glacier, MT, USGS gage 12358500. Plots are for the raw unadjusted data for one GCM, bcc-cm1.1, all four RCPs. There is little difference between the curves on the plots for the four RCPs, light blue. The variation between the largest and smallest RCP flow is stated in the sentence below each graph. The variation at the tails of the distributions does show the daily disaggregation has some impact on the highest and lowest flows. Thus the daily disaggregation of climate data has very little impact on the hindcast cumulative duration curves for these gages.

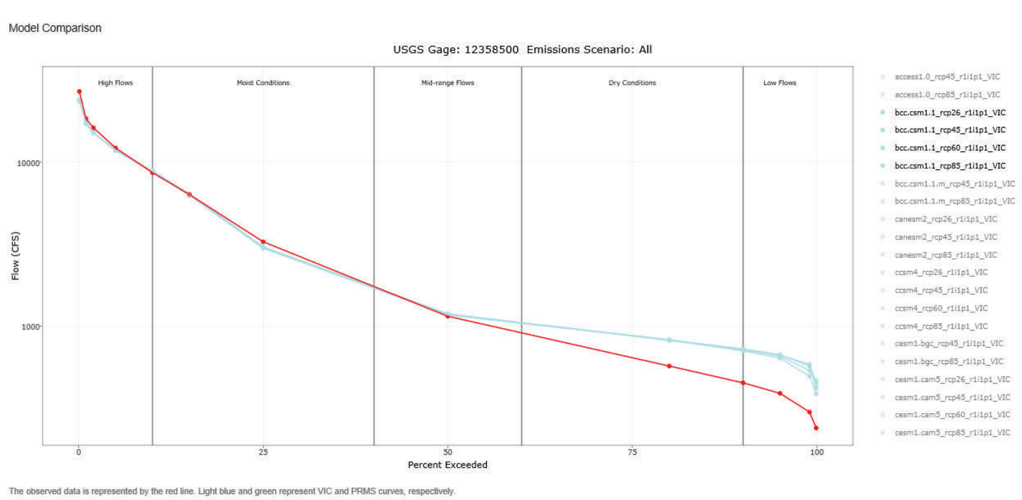


Figure 19Figure 20 Middle Fork Flathead River

The ratio of largest to smallest of the 4 varies from 1.01 to 1.20, averaging 1.05. From 0.1 percent to 95 percent the ratio only varies from 1.01 to 1.05.

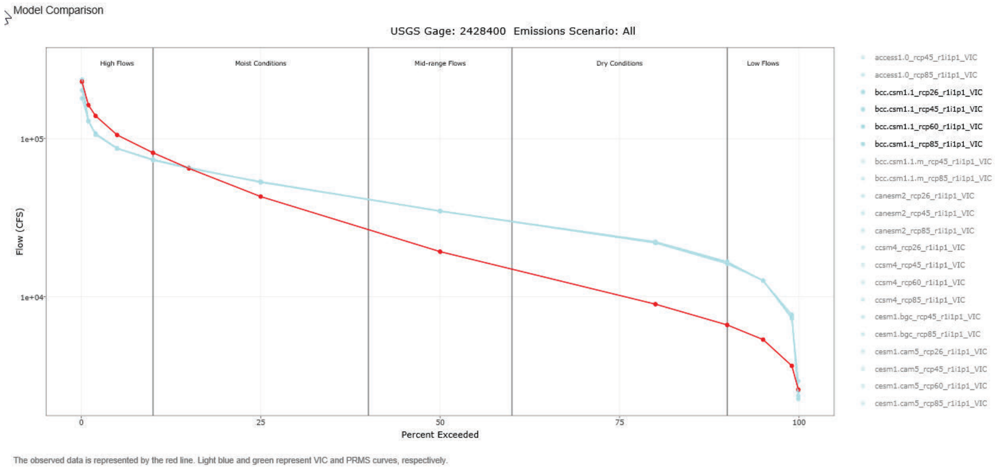


Figure 21 Alabama River

The ratio of largest to smallest of the 4 varies from 1.01 to 1.32, averaging 1.06. From 1.0 percent to 99 percent the ratio only varies from 1.01 to 1.06. For 0.1% it's 1.32 and for 99.9% it's 1.29.

Runoff volumes are the area under the flow duration curves and, as expected, the volumes do not vary much with the daily disaggregation. The impact on annual flow volumes is shown below. The annual volumes are plotted by year for raw, unadjusted, data for the 4 RCPs for one GCM, bcc-cm1.1. The curves are very close, showing the daily disaggregation has little impact on individual year volumes. The plots also shows that the time series for the four RCPs are the same, confirming the only difference between the hindcast data for the four RCPs is the random daily disaggregation of monthly data.

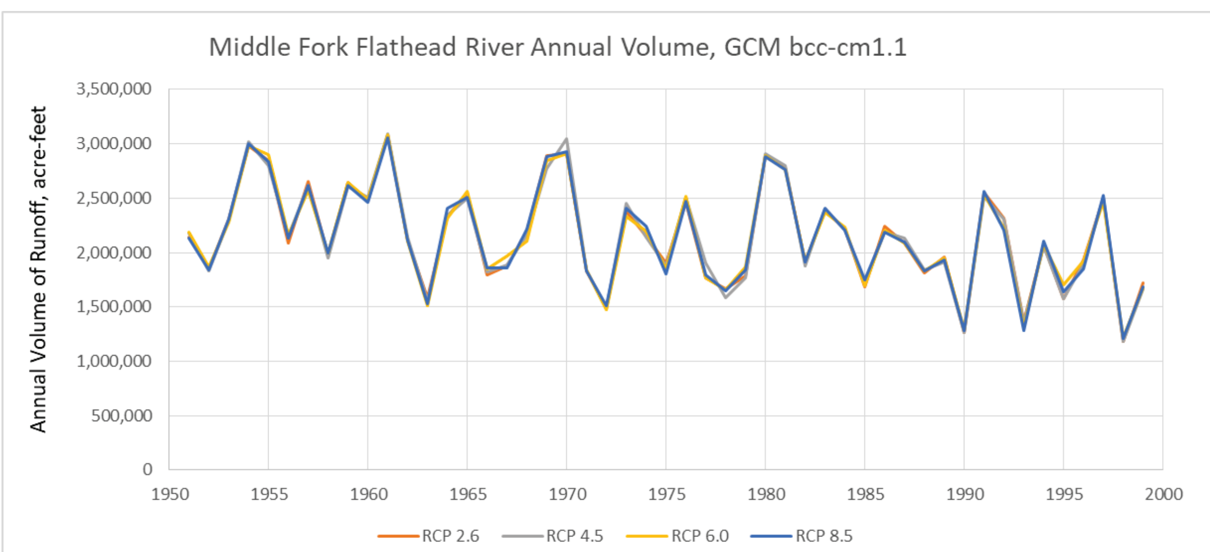


Figure 22 Middle Fork Flathead River Annual Volume, GCM bcc-cm1.1

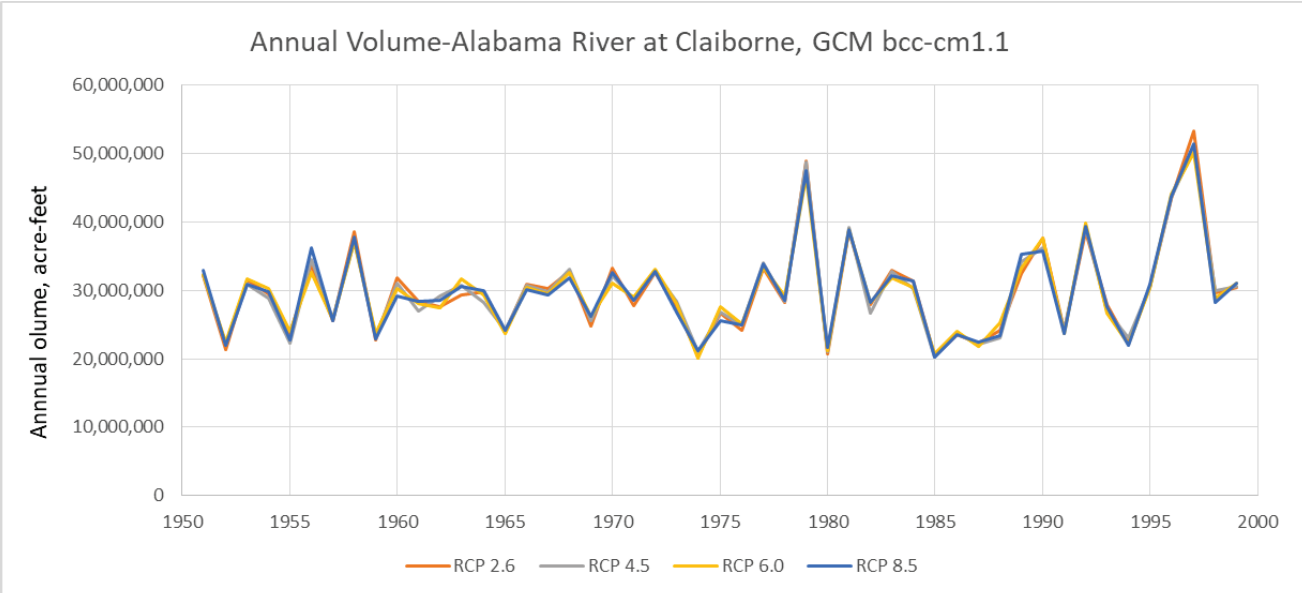


Figure 23 Annual Volume – Alabama River at Claiborne, GCM bss-cm1.1

Below the observed annual volumes has been added to the graphs. They show how the adjusted GCM time series does not attempt to match observed and confirms the GCMs do not attempt to match times series of climate data.

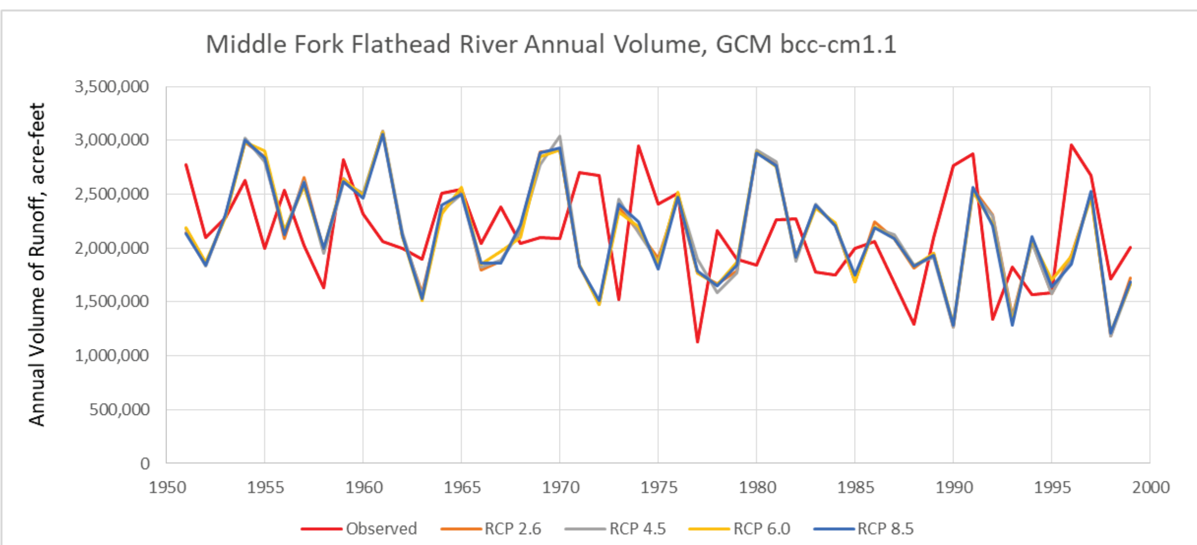


Figure 24 Middle Fork Flathead River Annual Volume, GCM bcc-cm1.1 with observed

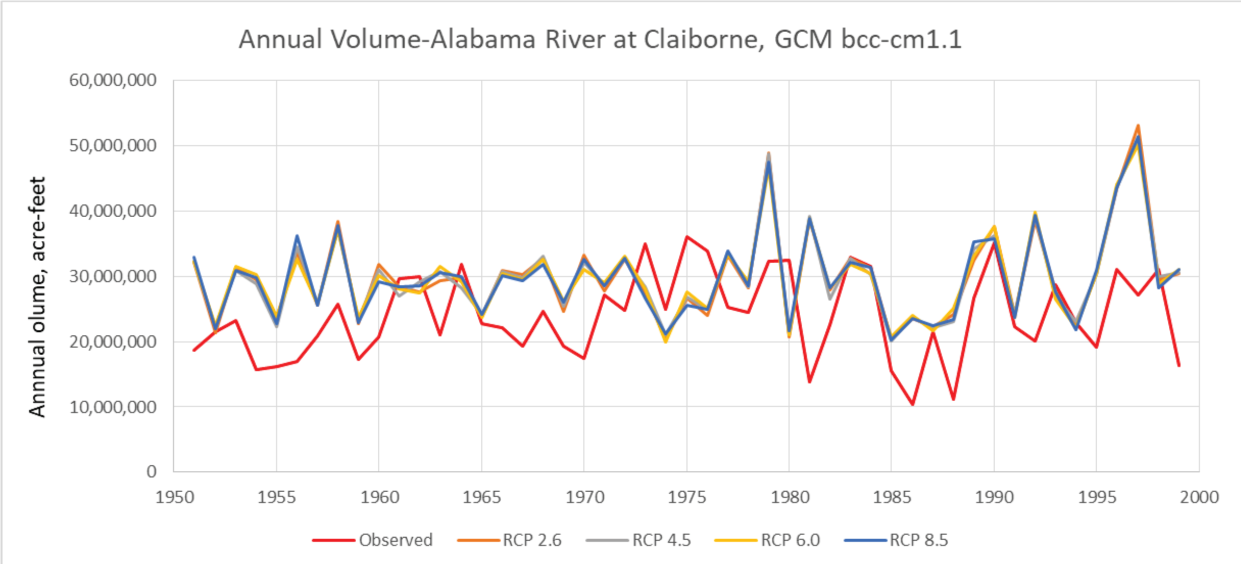


Figure 25 Annual Volume – Alabama River at Claiborne, GCM bss-cm1.1 with observed

Annual Peaks and Annual Exceedance Frequency Curves

Annual Peaks. As shown above the daily disaggregation of climate data has little impact on flow duration and annual volumes, but it can have more impact on individual annual peaks. For the previous two gages the below graphs show the hindcast annual peak flows for the 4 RCPs for the one GCM, bcc-cm1.1. The variation from one RCP to another in annual peaks in the graph is solely due to the daily disaggregation since each of the 4 RCPs have the same monthly climate data time series. The impact of climate change on annual peaks could be hard to separate the impact of using random daily climate data. Another concern is the daily disaggregation is done randomly based on observed patterns and thus any impact of climate change on daily disaggregation is not included in this methodology. This means the results of this method for the impact of climate change on annual peaks may be confused with the impact of the random daily disaggregation of climate data and also doesn't include the impact of climate change on daily climate variations.

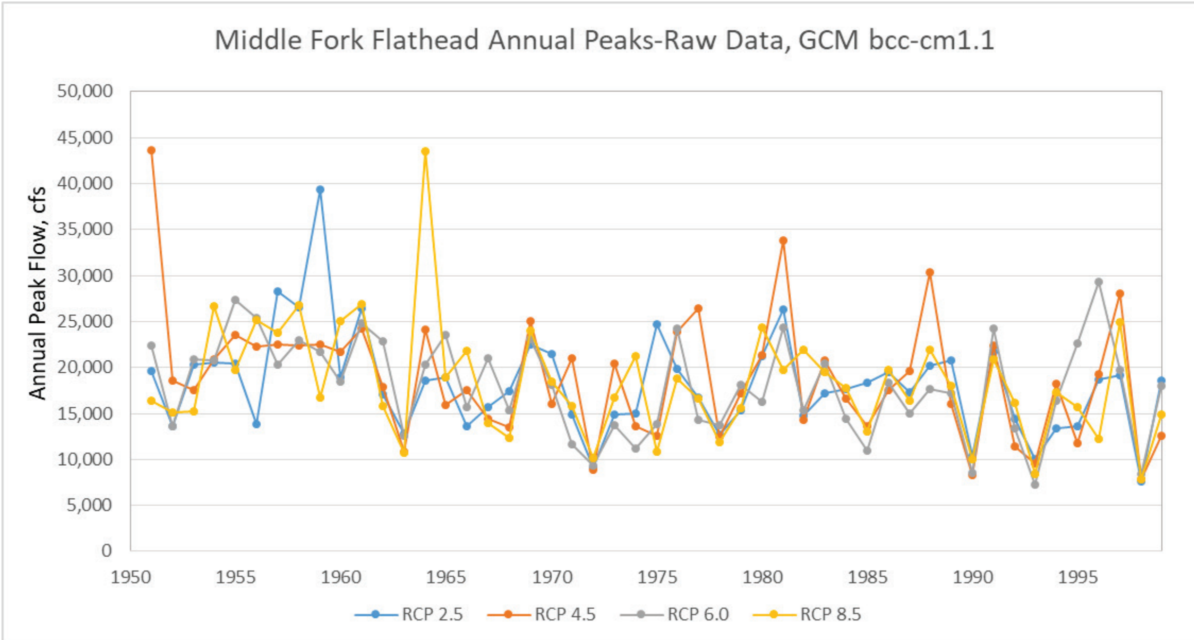


Figure 26 Middle Fork Flathead, hindcast annual peak flows for the 4 RCPs for the one GCM, bcc-cm1.1

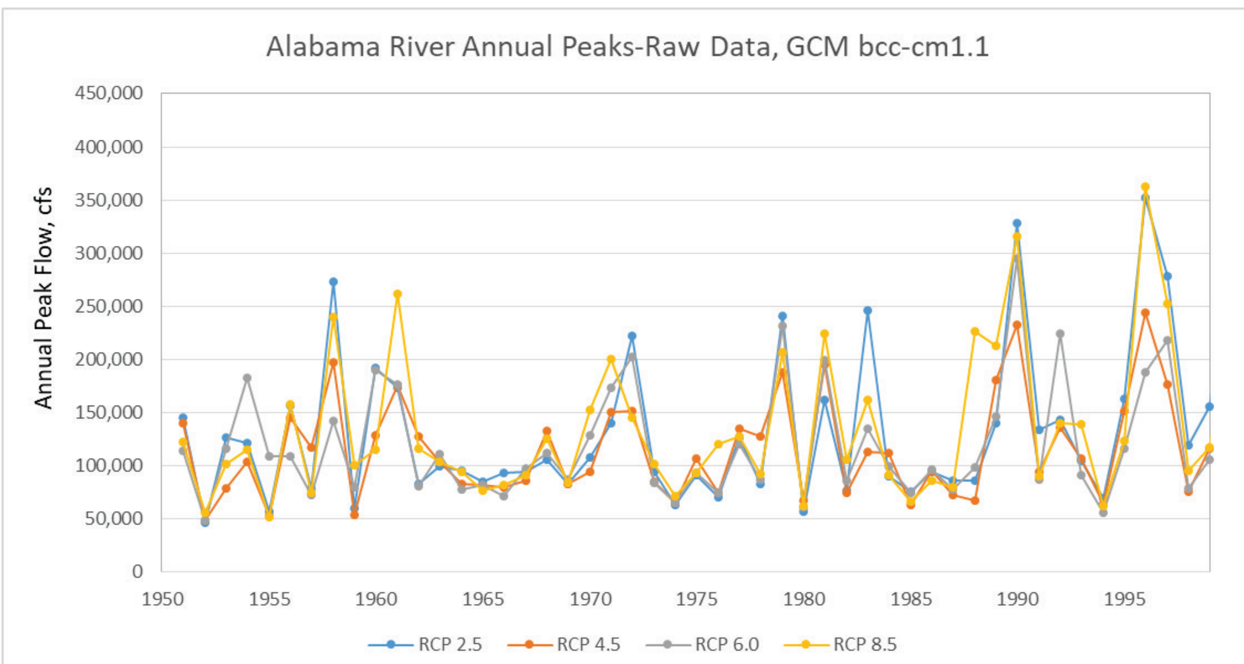


Figure 27 Alabama River, hindcast annual peak flows for the 4 RCPs for the one GCM, bcc-cm1.1

The Alabama River drainage area, 21,473 sq. miles, is much larger than the Middle Fork Flathead River, 1,125 sq. miles. The larger the basin, the less impact the daily climate variation of monthly data would be expected to have on annual peaks. This is the likely reason the annual peaks of the raw RCPs for the Alabama River are more consistent between RCPs than they are for the Flathead River.

Frequency Curves. Since the hindcast individual annual peaks vary for different raw RCPs, the frequency curves for annual peak exceedance for these two gages vary more than the duration curves for a single GCM with different RCPs, see the next two figures. Since the methodology results in significant variation in individual annual peaks, it makes the evaluation of the impact of climate change on the annual exceedance frequency curve using this method more uncertain. This should be evaluated by the user on a case by case basis.

The hindcast period annual peak exceedance frequency curves for the two gages are shown below. The curve for observed data is shown in red and the curves in light blue are raw, unadjusted, data results for one GCM, bcc.cms1.1, and the four RCPs. Since the four RCPs for each GCM have identical monthly climate data, the differences in the blue curves is solely due to the random selection of daily climate data. The variation in the four annual peak frequency curves is greater than the variation in the annual duration curves for a single GCM in previous plots, showing the random selection of daily climate data has more impact on the frequency curves than on the duration curves.

While the variation in the four RCP frequency curves is greater than for the duration curves, the plots with log vertical axis can be somewhat misleading. Tabulating the results shows the frequency curves are still somewhat close for much of their range. For the Middle Fork Flathead River the ratio between the highest and lowest curves varies from 1.04 to 1.39, averaging 1.16. For the Alabama River the ratio highest/lowest of the four varies from 1.06 to 1.51, averaging 1.17. For both cases the largest ratio is for the least frequent, highest, and for most studies the most important, flows.

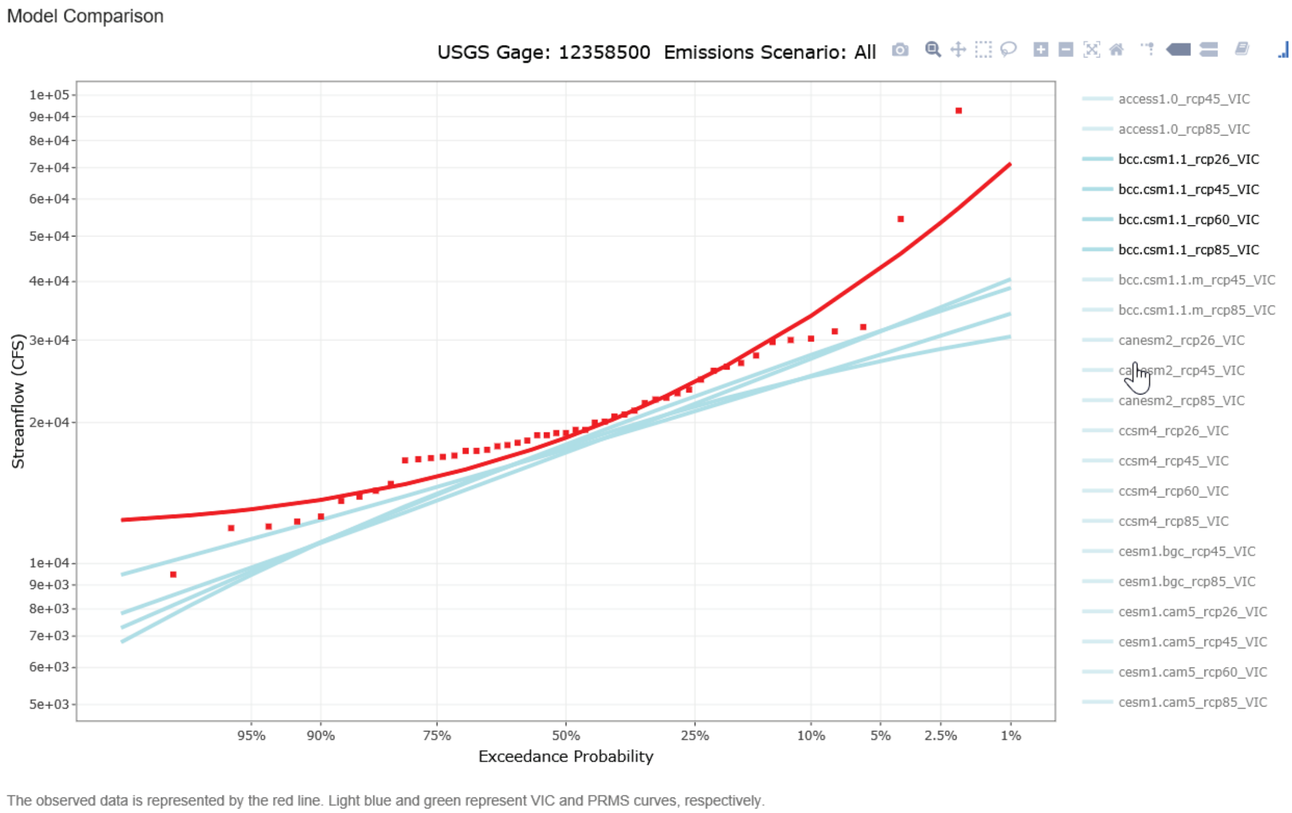


Figure 28 Middle Fork Flathead River, Observed and hindcast period annual peak exceedance frequency curves

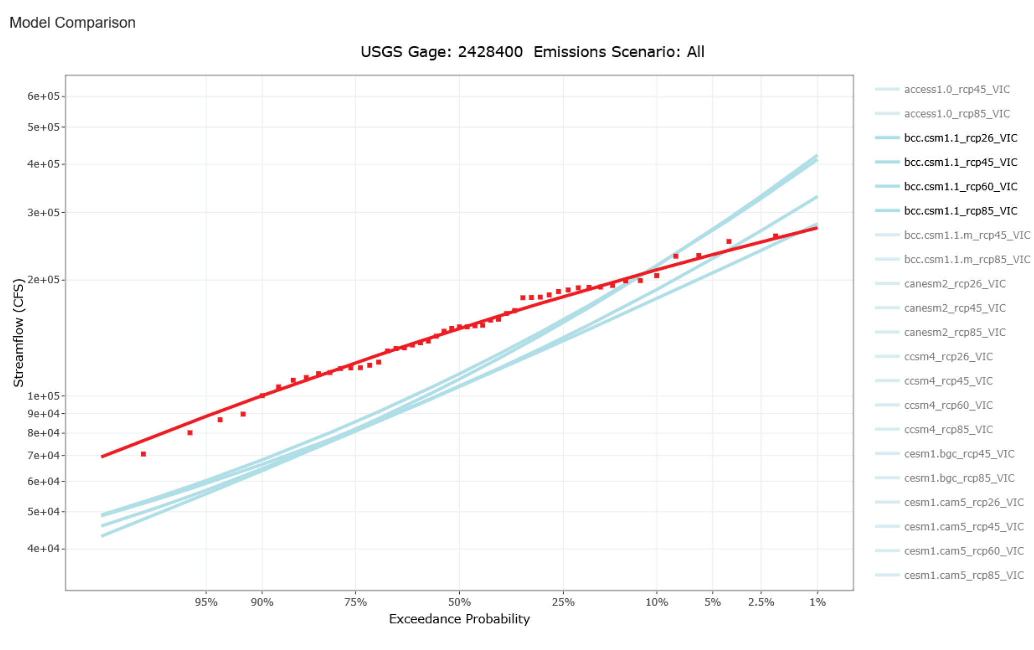


Figure 29 Alabama River, Observed and hindcast period annual peak exceedance frequency curves

Impact of Monthly Time Series.

Flow Duration. Each of the approximate 30 GCMs provides its own time series of monthly cumulative precipitation and average temperature. As stated in the previous section, the hindcast time series for a given GCM does not vary with RCP and that the duration curves for the different RCPs for a given GCM are close to each other. Therefore, the impact of the monthly time series on duration curves can be evaluated by comparing the hydrologic model flow results for different GCMs for 1951-1999.

Plotted below are the 1951-1999 flow duration curves for the Alabama River at Claiborne L&D, USGS gage 2428400, for all 97 GCM/RCPs combinations. The duration curves use all daily data from the total time period, 1951-1999, thus the probability of exceedance is the probability of that daily flow being exceeded during the total 1951-1999 period. The red curve is from the unimpaired natural conditions flow data developed by the study team. The light blue curves are the raw, unadjusted, VIC model results from the models. While the VIC model results are significantly different than the unimpaired data, the 97 raw model curves are close to each other, indicating the monthly time series has little impact on the flow duration results and that the different times series from each GCM is not the reason for the difference in duration curves between the VIC model results and the provided unimpaired flow. It can be concluded that the difference between the observed data curve and the raw model curves is due to the hydrologic modeling not being accurate for all flows.

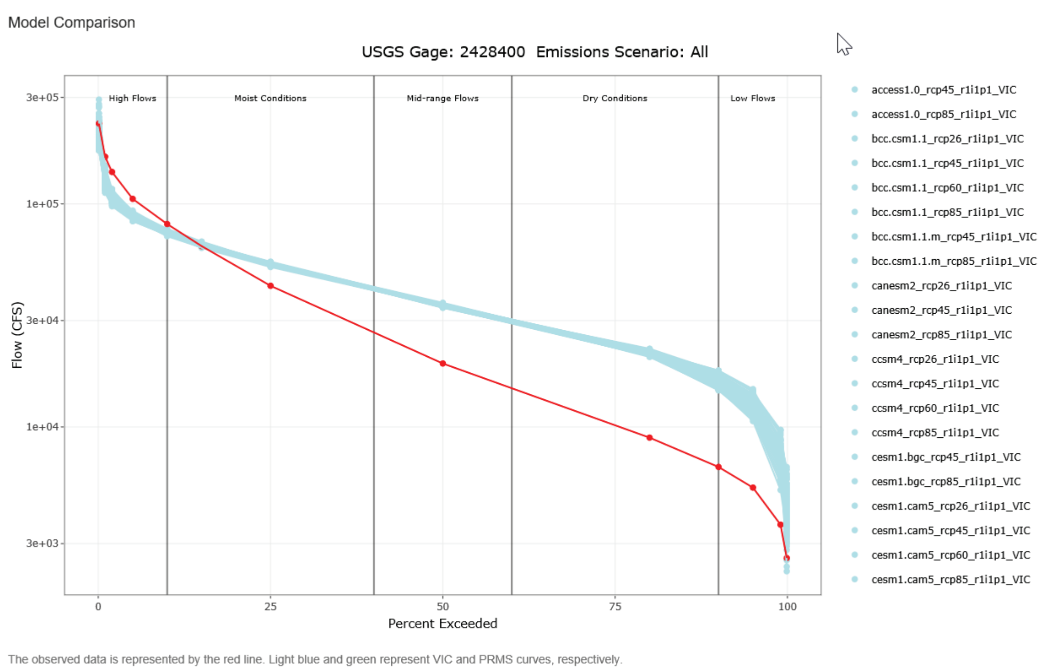


Figure 30 1951-1999 flow duration curves for the Alabama River at Claiborne L&D, USGS gage 2428400, for all 97 GCM/RCPs combinations

The next graph is for the Middle Fork Flathead River near West Glacier, MT, USGS gage 12358500. This gage was selected because the VIC model results were found to be fairly close to the observed results and thus is a better test of STADJ's performance when good hydrologic data is available. This gage is a pristine gage with flows not impacted by humans. Similar to the Alabama River example, the spread in the 97 GCM/RCP results is small, again indicating the time series of monthly flows has little impact on the match of the VIC model results to observed duration curve.

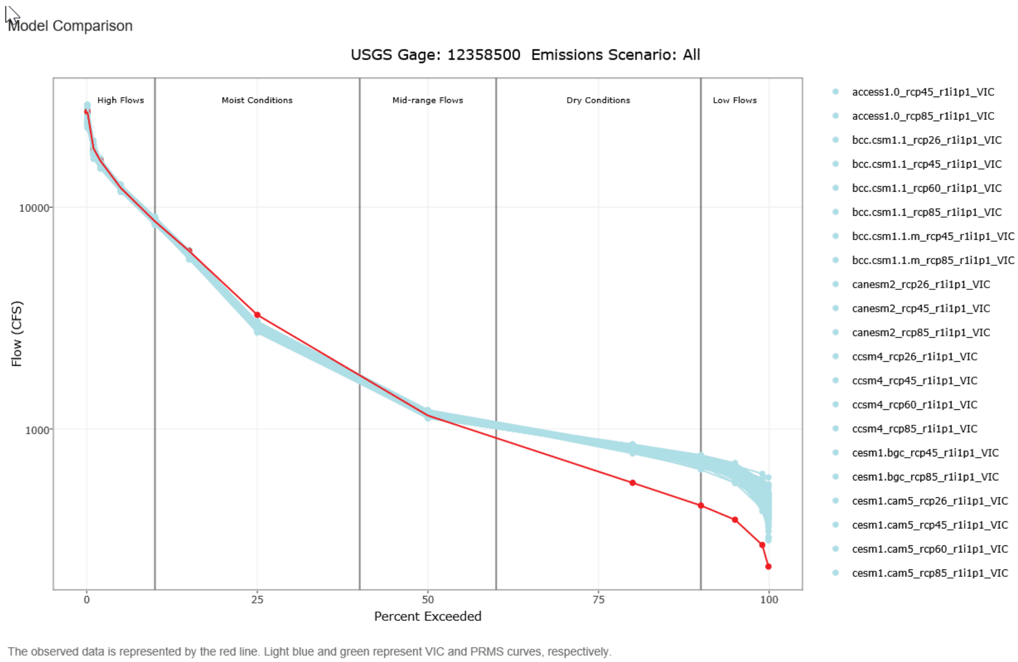


Figure 31 Middle Fork Flathead River near West Glacier, MT, USGS gage 12358500 for all 97 GCM/RCPs combinations

The fact that the model data duration curves are close to each other for the hindcast period implies that computed differences, in median and spread, in duration curve model results for projected periods are due to climate variations and this method is a good way to evaluate those impacts.

Note: As mentioned above these duration curves are for the total time period. They are not the average of the annual duration curves for that period. STADJ does not compute these average annual duration curves. The daily flows can be downloaded and the user can compute annual duration curves.

Annual Exceedance Frequency. In the section on impact of daily disaggregation it was shown that the annual peaks do vary with the randomized disaggregation of monthly data to daily data. The impact of the variation in GCM time series for the hindcast period is shown below in the flood frequency plots for all 97 GCM/RCPs. The variation between the 97 model results is much more than it is for the duration curves. As was shown previously some of this variation is due to the random development of daily climate data, but the variation from all GCMs is much larger than it was for different RCPs for a single GCM, indicating that the different monthly time series for the various GCMs also has an impact.

Hydrologists know that the annual peak exceedance frequency curve derived from the observed annual peaks represent just one possible weather set of that area and the observed flows are just one possibility for the flow data for that period, and thus they always show confidence limits for the observed data curve. The hindcast climate data from the GCMs can be thought of as alternate but reasonable variations in the possible hindcast weather time series. The disaggregation to daily data is randomly selected from actual observed variations and is also thus reasonable alternatives for hindcast climate. In the curves below the 90% confidence interval for the observed frequency curve computed with Bulletin 17B guidance is included. For the Alabama River gage, 2428400, the spread in the GCM results is greater than the confidence interval, especially at the upper end of the curve. For the Middle Fork Flathead gage, 12358500, the spread of the GCM curves is close in size to the size of the observed curve confidence interval. The Flathead River results imply the spread in the GCM results for the projected period could be a good indication of the impact of climate change on the confidence interval for the projected period. However, for the Alabama River the spread in the projected period curves might overestimate the actual spread in the confidence interval.

The large variation in the hindcast period frequency curves makes the use of the monthly BCSD data for quantifying the impact of climate change on annual flood frequency more questionable than for duration curves. The user needs to carefully consider this for their study.

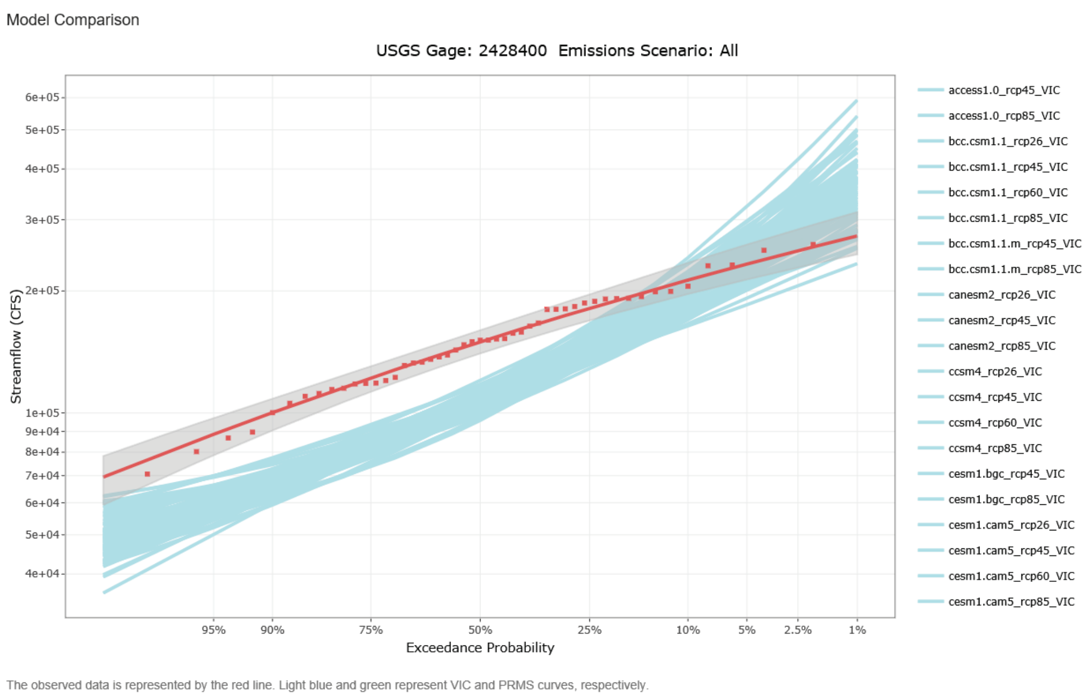


Figure 32 Alabama River gage, 2428400 with 90% confidence interval for the observed frequency curve

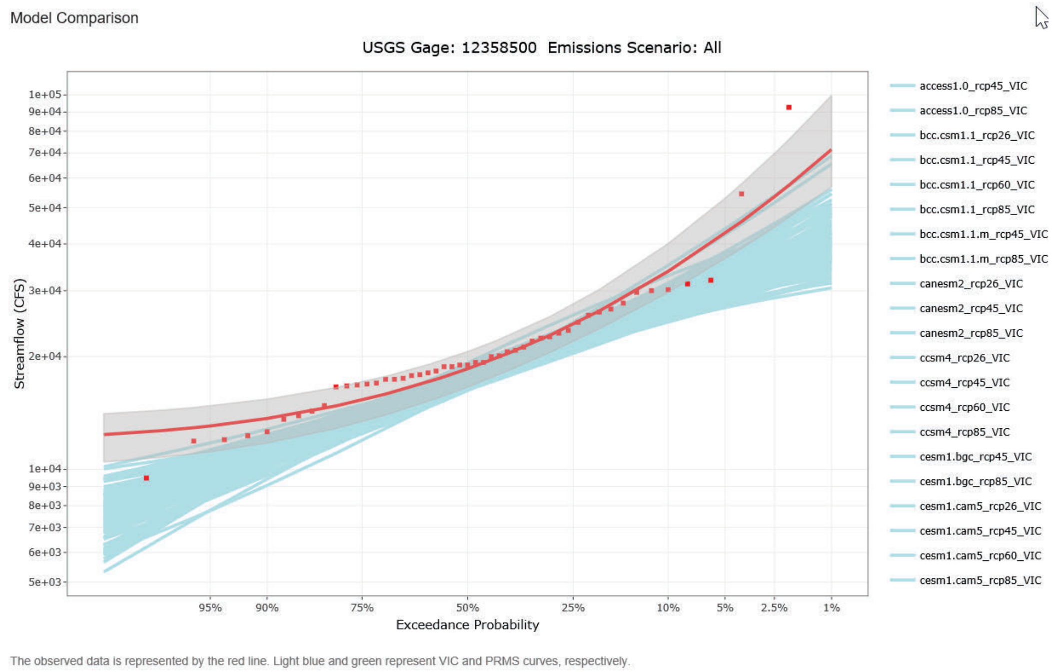


Figure 33 Middle Fork Flathead gage, 12358500 with 90% confidence interval for the observed frequency curve

Additional Appendix Example.

The graph below is the hindcast annual peak exceedance frequency curve from a climate change study for the Red River of the North at Fargo, North Dakota, “Red River of the North at Fargo, North Dakota, Pilot Study, Impact of Climate Change on Flood Frequency Curve, St. Paul District, U.S. Army Corps of Engineers, May 2015”. https://usace.contentdm.oclc.org/utils/getfile/collection/p266001coll1/id/6725 The method used to generate the climate data for the HMS hydrologic modeling was similar, but not exactly the same, as that used for the ACR study. Monthly BCSD data was used and randomly disaggregated to daily. In this case the hydrologic model includes the impact of upstream regulation. Since the hydrologic model was developed for just this basin and calibrated in some detail, the Red River model calibration was better than the STADJ examples: compare black symbols, model with observed climate data, to the red, observed, symbols. The light blue symbols are from 100 iterations of the HMS model driven by the daily climate data selected randomly from the several sets of GCM monthly data. The 100 values are fairly well centered on the observed curve but there is a large variation in the 100 model results. The Red River results confirm that even with good hydrologic model calibration there is a large variation in hindcast annual peaks from the methodology.

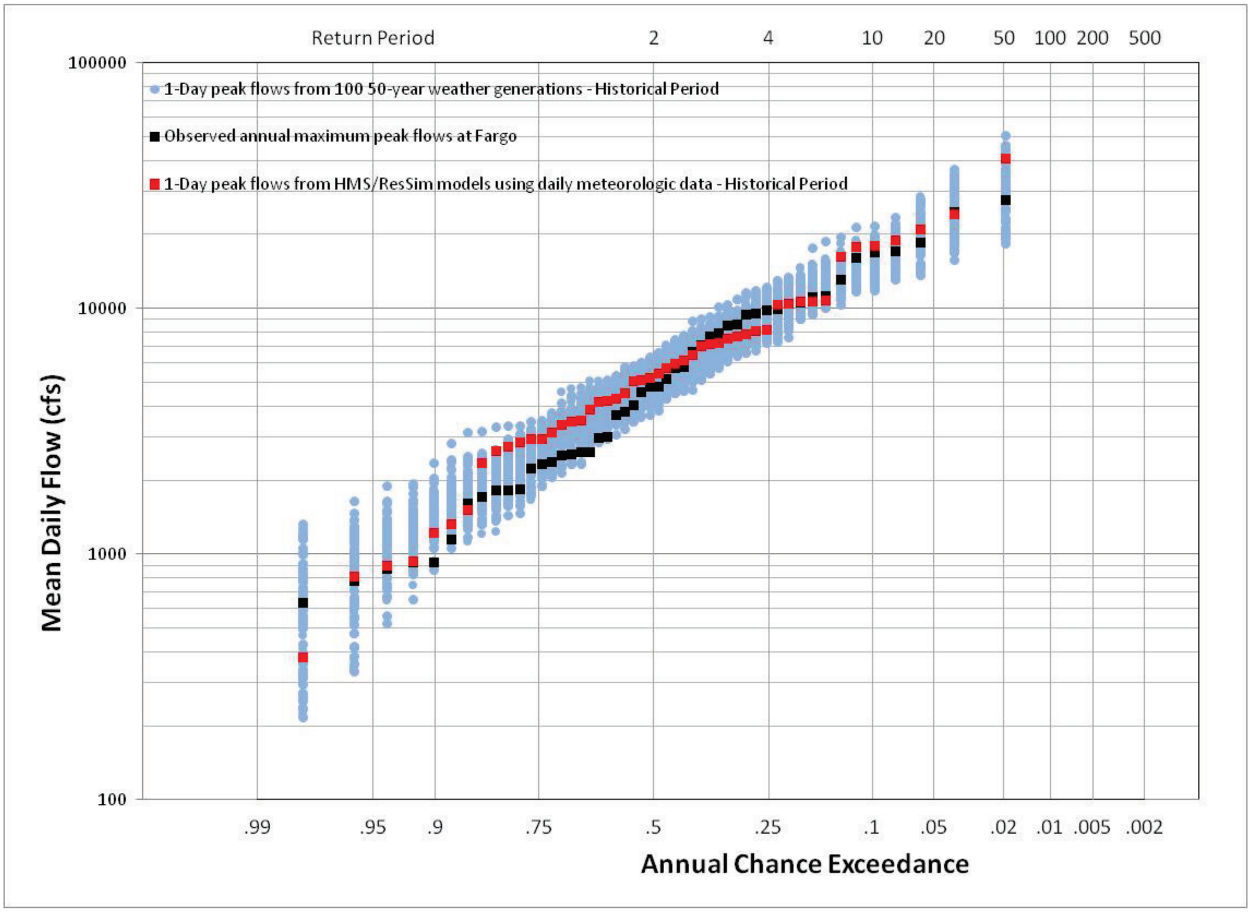


Figure 34 hindcast annual peak exceedance frequency curve from a climate change study for the Red River of the North at Fargo, North Dakota

Appendix 3 STADJ Cumulative Annual Duration vs. Averaged Annual Duration

Comparison of Duration Curves

The statistical adjustment program, STADJ, computes a curve titled the Annual Duration Curve, however, it is actually not the annual duration curve. The duration curve in STADJ uses all of the daily flow values within the period of record. For example, if the period of record used to develop the hindcast duration curve is the program's default of 1951-1999, all of the daily flows during that 49 year period are used, about 49*365 points. Thus the probabilities shown are not the annual probability but rather the probability of that flow over the 49 year period. A sample duration plot from the tool is shown below. The gage used is the Alabama River at Claiborne Lock and Dam near Monroeville, Alabama, the hindcast period is 1951-1999 and daily flow data are unimpaired flows provided by the ACR study team.

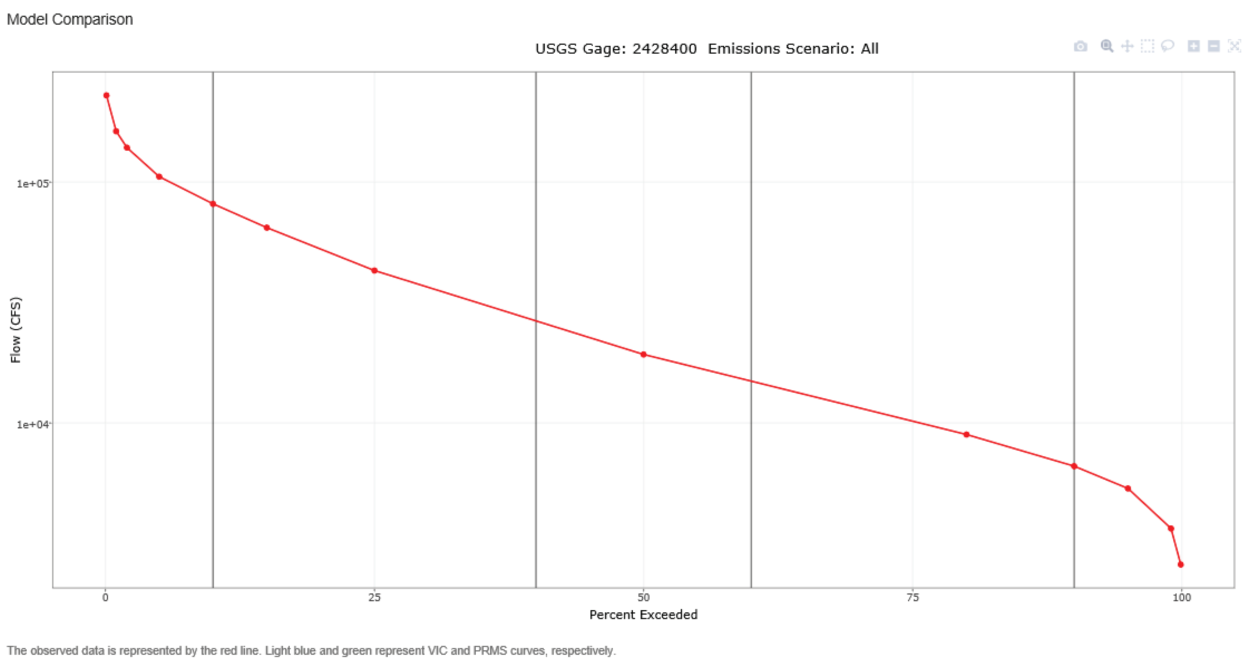


Figure 35 Daily Flow Duration Curve Alabama River Claiborne L&D Unimpaired Flow 1951-1999

One method for determining a representative annual duration curve for a period is to compute the annual duration curve for each year in the period of record and average them. In this case to get the representative annual duration curve 49 annual duration curves would be averaged. The range of the 49 curves gives a measure of the uncertainty in the observed annual duration curve.

The 49 annual duration curves for 1951-1999 were computed in Excel and the average of the curves compared to STADJ duration curve. The plot of the results is shown below. For this specific gage the STADJ curve for the total period, solid black, is close to the average of the 49 annual curves, dashed black. The largest differences are at the tails of the curves. The variation between the individual annual curves is large. The single curve from STADJ gives no indication of this natural variation and some users may assume there is no uncertainty in observed period duration curves. This could deceive users into thinking the uncertainty that STADJ shows for projected period cumulative curve is a measure of the range in the proposed period annual curves.

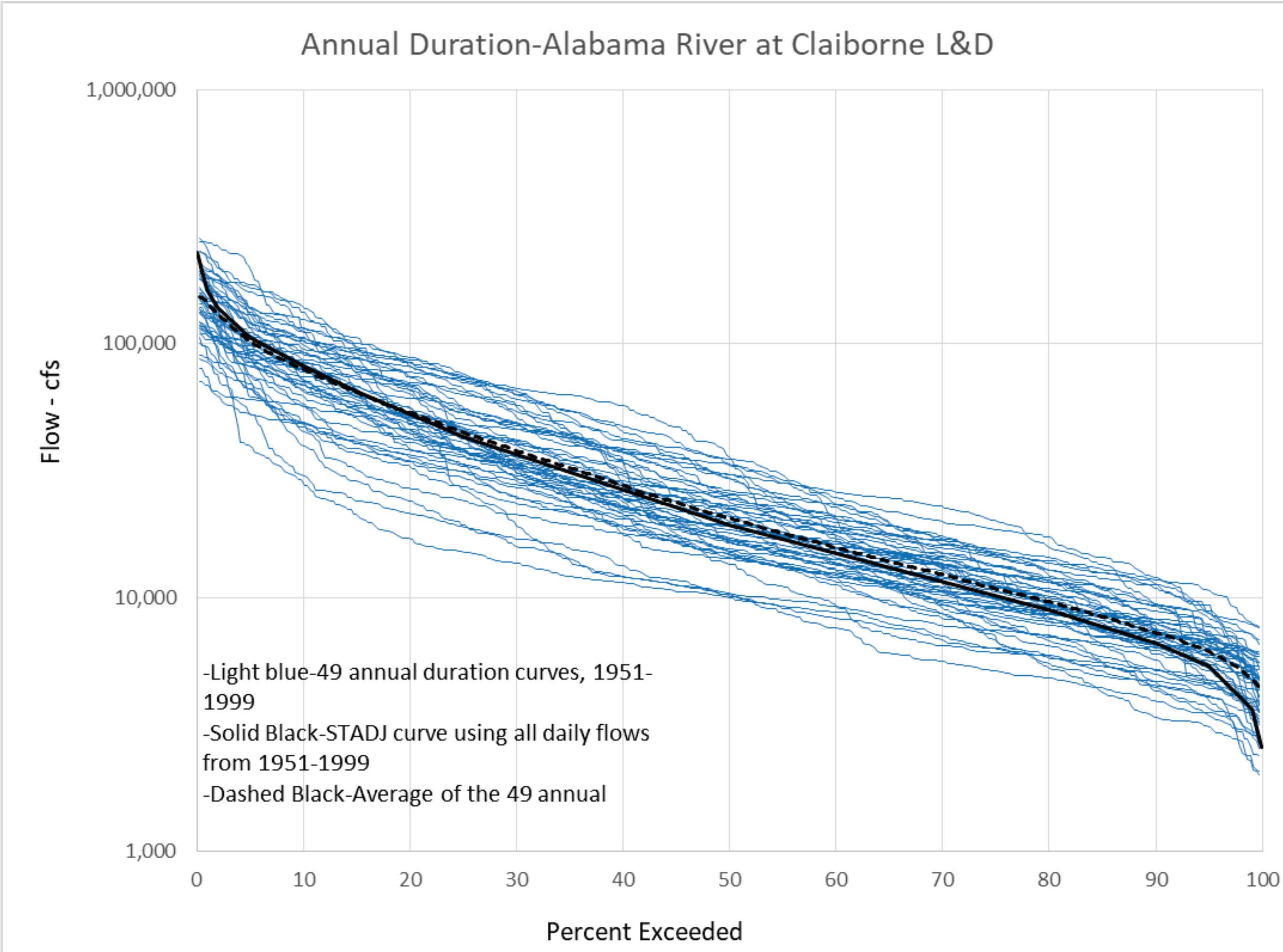


Figure 36 Individual annual duration curves 1951-1999, Average of individual curves, annual duration curve for 1951-1999 period

Fn: RawData_2428400_access_rcp45

In this case to get the impact of climate change STADJ uses 95 combinations of GCM and RCP. Daily flows through 2099 from the VIC program are adjusted to allow a direct comparison with observed hindcast flows. The 95 STADJ adjusted projected period duration curves compared to the STADJ hindcast period curve is shown below. For this analysis the projected period used is 2054-2083. The dark blue lines are the duration curves for the adjusted 95 GCM/RCP combinations. Each of the projected period curves is computed by STADJ in the same manner as it computes the hindcast curve – it uses all daily values within the projected period of record. While the variation in the 95 STADJ projected period duration curves looks similar to the variation in the hindcast period annual duration curves, it's important to remember that they represent different uncertainties. To make a direct comparison to uncertainty in the hindcast annual curve uncertainty each of the 95 projected period duration model results would have to be divided into 30 (2054-2083) annual duration curves.

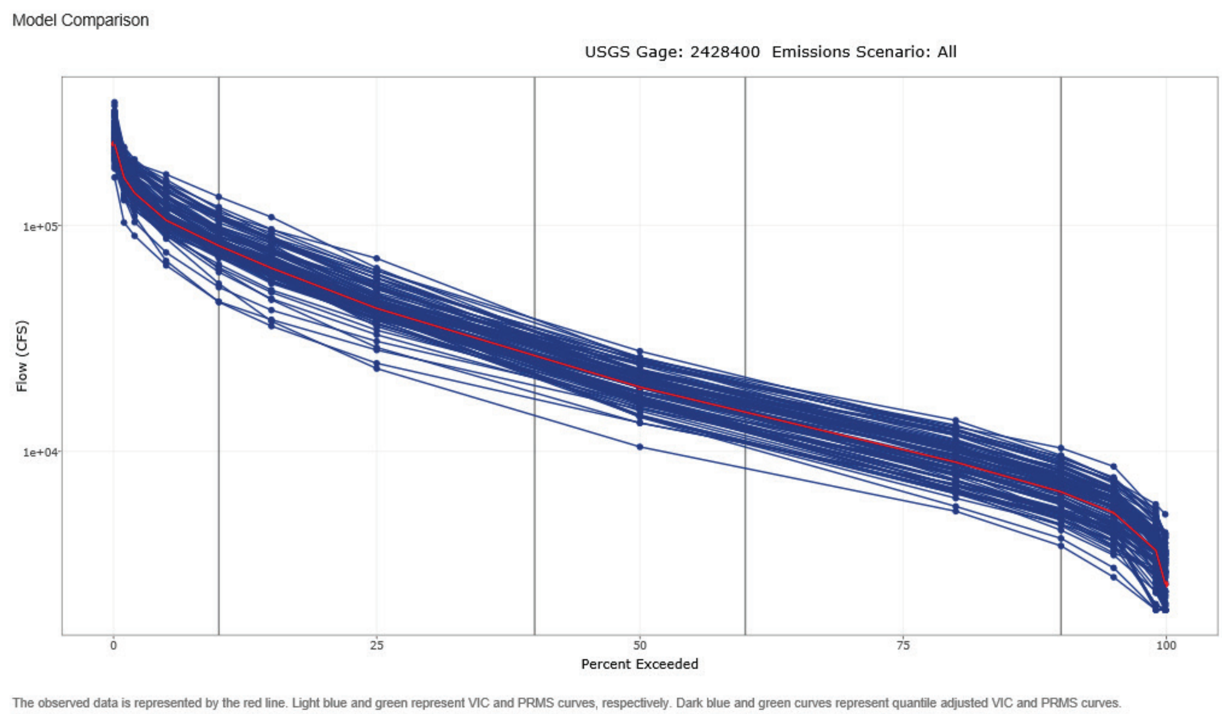


Figure 37 95 STADJ adjusted projected period duration curves compared to the STADJ hindcast period curve

Breaking up all 95 projected period results into 30 separate annual duration curves would be too time consuming (the development of annual duration curves was done manually with Excel) and the very large number of curves could make a comparison to the hindcast annual curves confusing. To get an estimate of the uncertainty in the projected period annual curve the annual duration curves were computed for three GCM/RCP models that represent the range in the 95 results. Flow from GCM/RCP cesm1-cam5_rcp6.0 were approximately the 5% largest flows from all of the 95 models, Flow from miroc-esm-chem_rcp45 are about the average of all 95, and hadgem-ao_rcp45 are the lowest 5%. Only the results for the cesm1 results are plotted but the results of all three are tabulated.

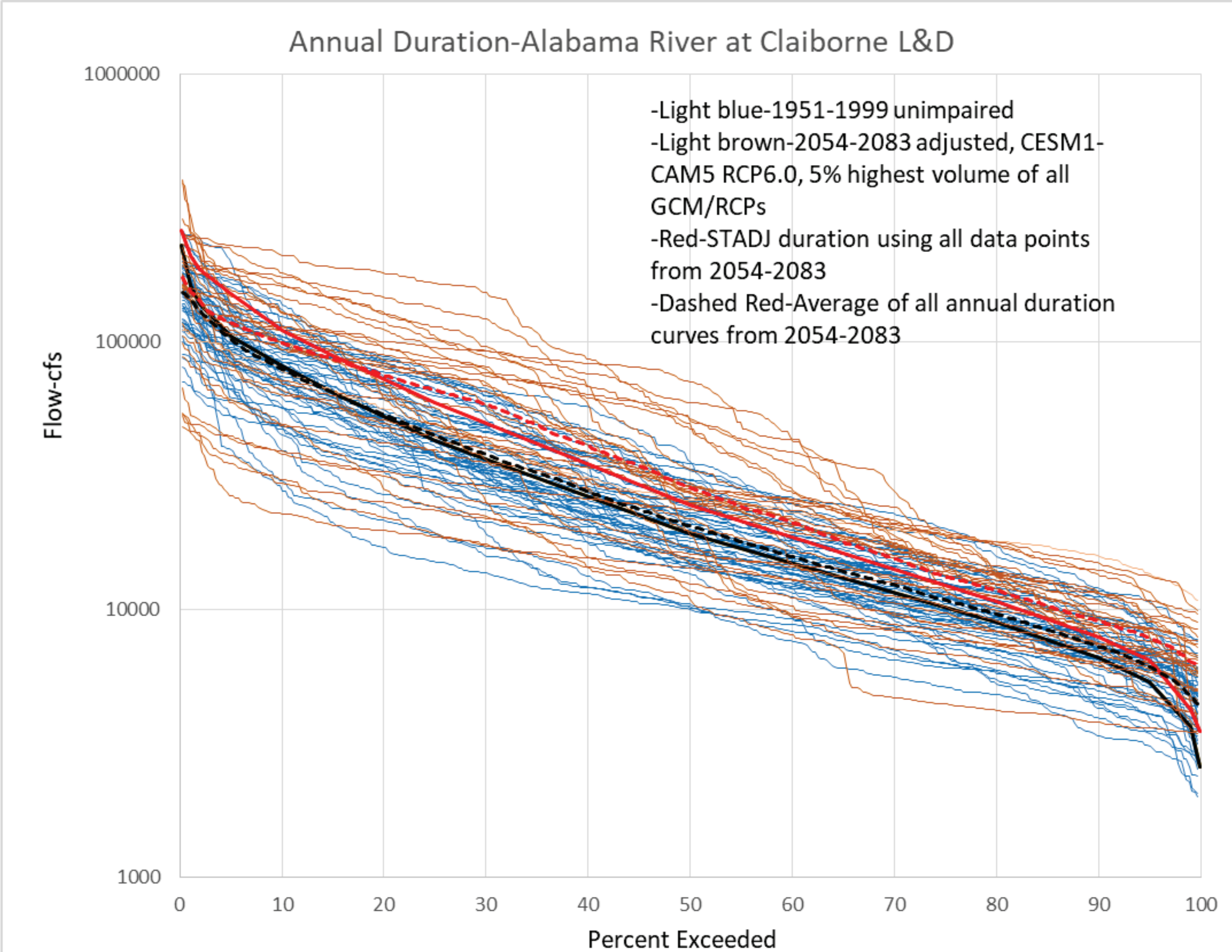


Figure 38 Annual Duration – Alabama River at Claiborne L&D

Table 13 Exceedance Probability Observed and Cesm1-cam5 rcp 6.0 adjusted model results

Observed			Cesm1-cam5 rcp 6.0 adjusted model results			
Exceedance Probability	1951-1999 max, min	Ratio max/min	1951-1999 adjusted max, min	Ratio max/min	2054-2083 max, min	Ratio max/min
1.09%	249,840 70,540	3.64	283,640 36,000	6.63	296,380 45,660	6.49
10.11%	136,960 27,730	4.94	142,180 18,660	7.62	211,060 22,790	9.26
50%	35,660 9,990	3.57	52,350 8,520	6.15	70,670 10,900	6.49
89.89%	12,020 3,370	3.56	17,050 3,430	4.98	15,850 3,780	4.20
98.91%	8,050 2,270	3.54	10,480 2,090	5.03	11,500 3,480	3.31

The curves for GCM miroc-esm-chem rcp4.5 are not plotted but summarized in the table below. This GCM is are approximately the average flows from all of the 95 models

Table 14 Exceedance Probability Observed and Miroc-esm-chem rcp4.5 adjusted model results

Observed		Miroc-esm-chem rcp4.5 adjusted model results				
Exceedance Probability	1951-1999 max, min	Ratio max/min	1951-1999 adjusted max, min	Ratio max/min	2054-2083 max, min	Ratio max/min
1.09%	249,840 70,540	3.64	248,520 34,430	7.22	281,180 28,050	10.02
10.11%	136,960 27,730	4.94	175,070 24,440	7.16	170,340 23,230	7.33
50%	35,660 9,990	3.57	51,210 8,510	6.02	51,210 5,950	8.61
89.89%	12,020 3,370	3.56	19,230 3,010	6.39	15,000 3,230	4.64
98.91%	8,050 2,270	3.54	11,860 2,090	5.68	9,680 2,770	3.49

The curves for GCM hadgem-ao-rcp4.5 are not plotted but summarized in the table below. This GCM is are approximately the 5% smallest flows from all of the 95 models

Table 15 Exceedance Probability Observed and Hadgem-ao-rcp4.5 adjusted model results

Observed		Hadgem-ao-rcp4.5 adjusted model results				
Exceedance Probability	1951-1999 max, min	Ratio max/min	1951-1999 adjusted max, min	Ratio max/min	2054-2083 max, min	Ratio max/min
1.09%	249,840 70,540	3.64	248,660 46,010	5.40	246,060 34,680	7.10
10.11%	136,960 27,730	4.94	160,150 31,190	5.13	161,980 25,060	6.46
50%	35,660 9,990	3.57	46,770 8,200	5.70	24,660 6,190	3.98
89.89%	12,020 3,370	3.56	16,820 2,960	5.68	11,060 2,970	3.72
98.91%	8,050 2,270	3.54	13,540 2,080	6.50	8,220 1,990	4.13

Note: percentages are plotting positions based on 365 days in a year and thus are not even percentages.

From the above figure and tables the spread in the adjusted projected period annual duration curves are similar to the spread in the adjusted model hindcast period curves. The spread in the hindcast adjusted model curves is larger than the observed spread, indicating the model results do not accurately reflect the annual curve uncertainty.

Note there are 49 curves for the hindcast period, 1951-1999, and only 30, 2054-2083, for the projected period, so comparing the maximum and minimum probably underestimates how much larger the range in the projected curves is. From this one example, it's uncertain if climate change impacts the spread of the annual duration curves. This should be evaluated in a case-by-case basis for individual studies.

Comparison of annual volume

The above compared the duration curve based on the total period vs. the annual duration computed for each year. This was done to see if the STADJ data can be used to show the impact of climate change on the uncertainty in the annual duration curve. Another method to see if STADJ can be used to show the impact of climate change on annual flow is to compare average annual volumes using all the data for the period of record vs. using the average of the volumes computed for each year. As shown in the table below, the average annual volumes from the two methods are within 0.4%. The table does show that the average annual volume of flow for the projected period varies from the observed data and that the variation (as measure by standard deviation) in the projected period volumes is greater than the observed data.

Table 16 Annual Volume, Observed and three GCM/RCP models

Annual Volume – acre-feet				
	Observed	2054-2083		
	1951-1999	Hadgem-low	MIROC-ave	Cesm1-high
All Data	23,920,432	19,523,172	23,907,029	31,346,876
Ave of Annual	24,012,470	19,592,431	23,972,124	31,415,053
Ratio	1.004	1.004	1.003	1.002
Std Dev of Annual	6,555,037	7,088,204	10,427,950	13,876,552

The above table shows the uncertainty, standard deviation, in the projected period model results is greater than the uncertainty in the observed record. This could be taken to mean that climate change has increased the uncertainty in annual volumes. However, the greater uncertainty could be due to the method used to get the projected period flows. To address this the uncertainty in the adjusted model results for the hindcast period is compared to the observed record in the following table. As expected the average volume for the hindcast adjusted volumes compares well with the observed volume. However, the adjusted model results for the average and high GCMs show more uncertainty than the observed record. For this example, the methodology has increased the annual variation in volume.

Table 17 Annual Volume, Observed and three GCM/RCP models, hindcast period

Annual Volume – acre-feet				
	Observed	1951-1999 QUANT adjusted		
	1951-1999	Hadgem-low	MIROC-ave	Cesm1-high
All Data	23,920,432			
Ave of Annual	24,012,470	23,916,027	23,842,812	23,908,821
Ratio	1.004			
Std Dev of Annual	6,555,037	9,398,465	9,811,993	8,480,319

Another way to visualize the variations in annual volumes over the period of record are to sort the annual volumes and do an exceedance probability plot. The figure below shows the exceedance probability of annual volumes for the 3 models' adjusted data for the projected period and for the observed data. The projected period curves have steeper slopes than the hindcast curve, black, again showing the projected period results for a single model have more variation than the hindcast period does.

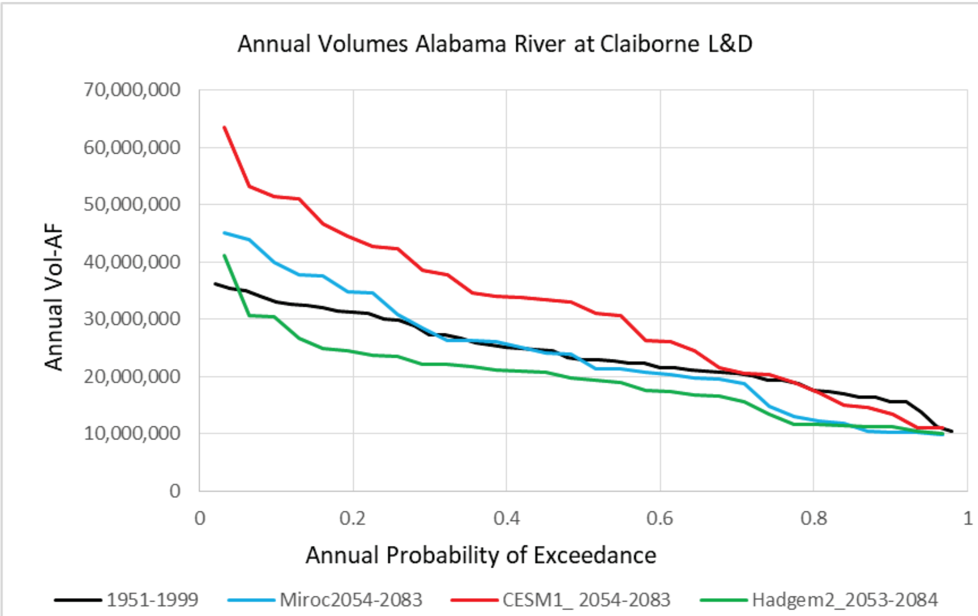


Figure 39 Exceedance probability of annual volumes for the 3 models' adjusted data for the projected period and for the observed data

The Annual Duration Exceedance plots for the observed data and for the adjusted model data for the hindcast period are plotted below. It shows the adjusted model results vary from observed for the larger, less frequently exceeded, volumes. It can be seen that the primary reason the uncertainty is greater for the model data is the differences at these lower exceedances.

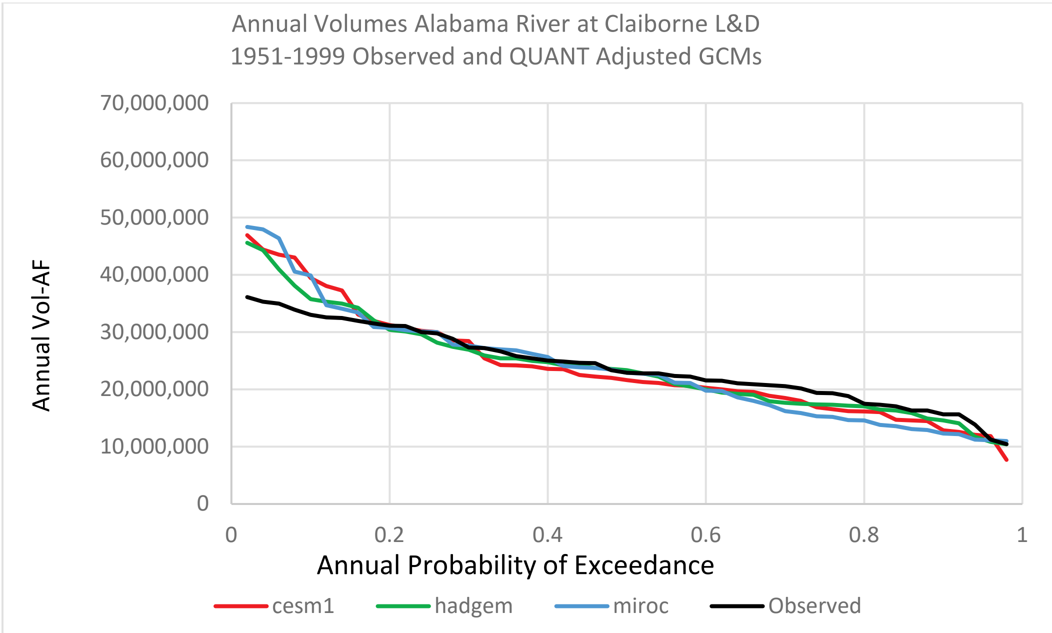


Figure 40 Annual Duration Exceedance plots for the observed data and for the adjusted model data for the hindcast period

Conclusions.

-The STADJ differences in duration curves between the hindcast and projected periods gives a measure of how the average annual duration curves will change, but can be hard to separate the climate impacts from the uncertainty in annual flows generated by the methodology used for BCSD, the VIC modeling, and STADJ.

The reason the spread in the adjusted model hindcast annual duration curves and volumes is greater than observed is uncertain. The adjustment in STADJ is done to the overall period, not to annual values, and thus the method does not attempt to provide accurate annual data so differences between actual annual data and annual data pulled from the STADJ PoR are expected. Changing STADJ to do the flow correction to annual periods might help but is fraught with concerns. The GCMs do not attempt to match annual time series and thus one specific model year cannot be compared to the same observed year, so years could not be easily compared. Also, the climate data for the VIC modeling is done with the BCSD method that adjusted climate data the same way STADJ adjusts flow, over the total 1951-1999 period, not by year. It was not checked, but annual data pulled from the BCSD climate data likely also does not match observed annual climate data. Adjusting flows for different adjustment periods than were used to adjust the climate data is questionable and revising the STADJ method does not seem warranted unless the climate data adjustment is also changed. It should be determined if the LOCA data is adjusted to better time periods.

Appendix 4 Selecting Representative GCM/RCPs

Background. The Corps recommends using as many GCM/RCP combinations as practical for climate change studies. The STADJ program includes 97 combinations of GCM/RCP and in most cases all of these should be used. However, in some cases it will not be practical to use all 97. The goal of this discussion is to develop a manageable number of GCM/RCP model combinations for the ACR study that can represent the range of the flow results from all 95 models (note: data from 2 of the 97 models in STADJ were not available when this analysis was done). The projected period flows from the 95 models (projected period flows are adjusted, not raw model flows) vary significantly: some show a large increase in flows compared to the 1951-1999 base period, while others show a decrease in flows. The reasons for the differences in climate results between GCMs are explained in Chapter 4 of the Science Science Special Report, Fourth National Climate Assessment (NCA4), Volume 1 https://science2017.globalchange.gov/. When evaluating the impact of climate change on projected period flows it is important to consider the full range of possible impacts since all 95 model results are considered possible. For the final portion of the study the ACR team will use the ResSim reservoir simulation model to evaluate the performance of different reservoir operating plans under possible future climate scenarios. The ResSim model has 36 locations where daily inflows need to be provided to the model. The ResSim model can be time intensive to operate and using the results of all 95 GCM/RCP combinations to provide projected period flows at the 36 locations was not considered reasonable. Therefore, representative models were selected that cover the full range of the model results. The 2054-2083 (centered on 2069, 50 years in the future) period was selected as the projected period to use to select the representative models.

There are several ways the range in the model results could be compared: annual peaks, average annual flow, flow volumes, etc. While many flow characteristics are important for this study, volumes of flow are especially important for a reservoir study. Therefore, volume of flow was used to evaluate the varying impacts. Three different exceedance volumes were compared: the average annual total volume, the volume for the wettest 7.5% of the year, and the volume for the driest 7.5% of the year. The figure below is an example gage showing the portions of the year used.

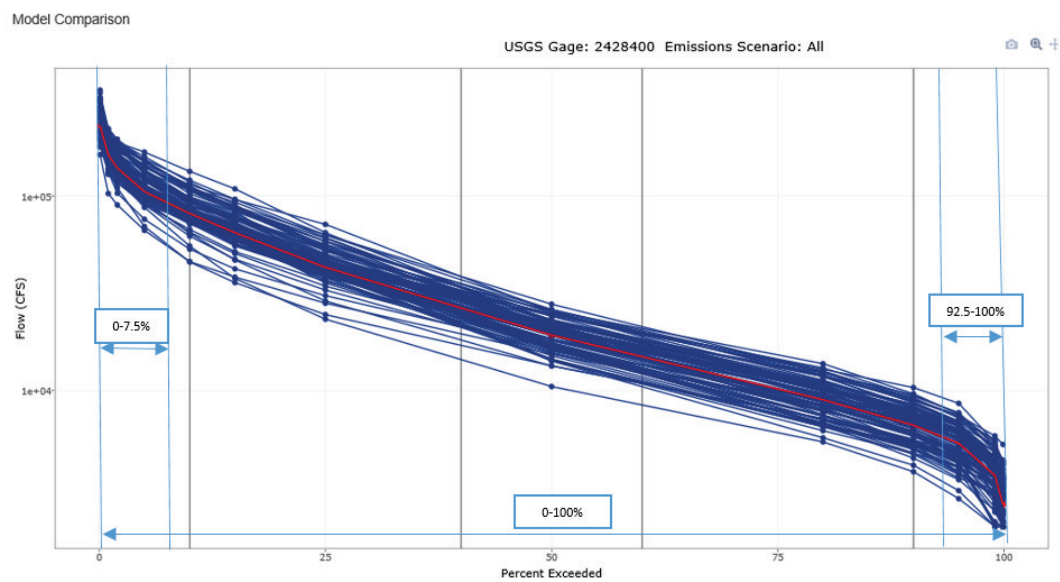


Figure 41 An example gage showing the portions of the year used, wettest, driest and full portion

The parameter used for the comparison was the average annual volume of 2054-2083 flow at a gage divided by the 1951-1999 average annual volume of flow. (Note: all flows are unimpaired flows and therefore do not include reservoir impacts.) To cover the full range of impacts, one GCM/RCP model was selected that gave the largest 2054-2083 volumes at each gage, one the average volumes, and one the lower volumes. Since some models can give outlier results, the very largest, 1st,and smallest, 95th, model volumes were not selected. Instead models that gave approximately the 5th and 90th ranked volume results were used for the high and low volume representatives, respectively. The average model was approximately the 48th ranked volume. Ideally the selected models would be ranked consistently for all three portions of the duration curve (0-7.5%, 0-100%, 92.5-100%) and for all 36 gages, but the possibility existed that different models would be needed to represent the range in the results for different portions of the duration curve and for different gages. For most studeis the tails of the distribution are most important and need to be looked at in some detail. Thankfully, it was found that there was a consistent ranking for the selected model between gages and for total average volumes and one model was consistently ranked for low volumes at all gages. However, it was necessary to select two models to represent high volumes for the different portions of the duration curve. One model was consistent between gages for high volumes for total annual flow and also for the wettest portion of the duration curve; however, another was model was needed to represent the higher volumes for the driest portion of the duration curve for all gages.

Total Annual Volume

The 2054-2083 average annual volumes from each of the 95 models was computed at each of the 36 gages, divided by the 1951-1999 annual volumes, and ranked from 1, highest volume, to 95, lowest volume. The ratios were used to nondimensionalize the results to allow comarisons between the various gages. The ranking for each of the 95 models were averaged over the 36 gages and the models with overall averaged ranks of 5 (~5%), 48 (~50%), and 90 (~95%) were selected as representing the high, average, and low volumes. For each model the range and standard deviation of the rankings over the 36 gages were also evaluated, and the model selections were adjusted if rankings of the initially selected models varied a lot between gages.

The ratios of 2054-2083 total annual volume divided by 1951-1999 volume for each gage and each of the 95 models are plotted below. The drainage area of each gage is used on the x-axis. It was thought the volume ratios might vary consistently with drainage area. Smaller drainage areas might show a larger impact since they are more responsive to localized changes in precipitation. However, as the figure shows, the impact of climate change on ratio of volumes is not consistent with drainage area. The latitude of the gages was also tried for the x-axis but there was no consistency for the impacts with latitude. Latitude was used since the basin tends to run NE to SW thus latitude is a fair measure of geographic location within the basin.

The left part of the graph is expanded in the second graph to make it easier to review. From both graphs you can see that the three selected models are pretty consistently ranked for total volume for all of the gages. For example: the largest volume model was close to the 5th ranked model at each of the gages.

The three selected models are:

Highest volumes: CESM1-CAM5 RCP 6.0

Average volumes: MIROC-ESM-CHEM RCP 4.5

Lowest volumes: HadGEM2-AO RCP 4.5

The highest 2054-2083 average annual volume is usually about 140% of the 1951-1999 volume and the lowest volume is about 85% of the 1951-1999 volume. Thus, for this case, overall climate change usually increases annual volumes but some models show a reduction in volumes. This shows the importance of considering the full range of possible impacts.

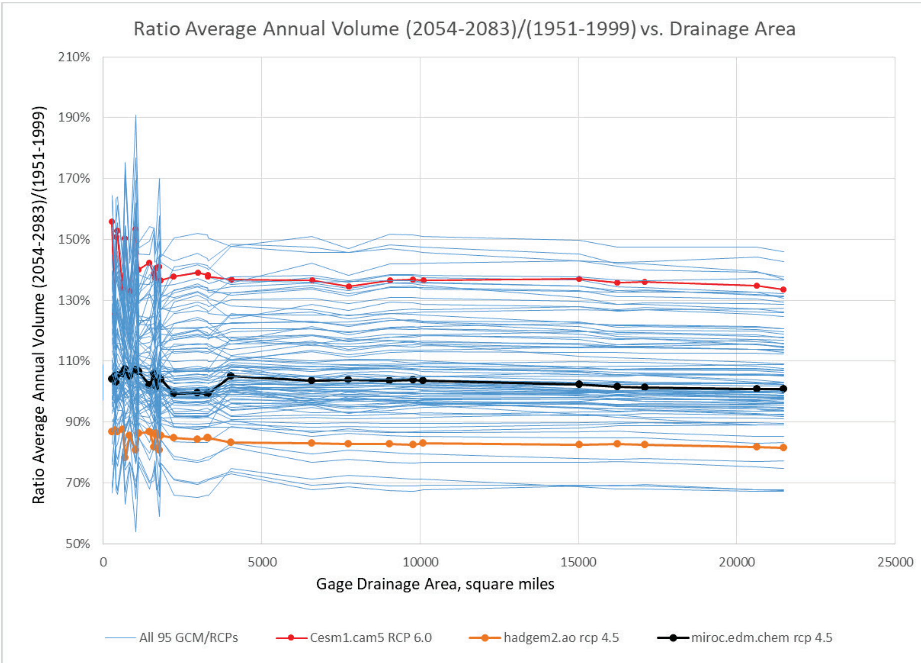


Figure 42 Ratio Average Annual Volume (2054-2083)/(1951-1999) vs. Drainage Area

Expanded left part.

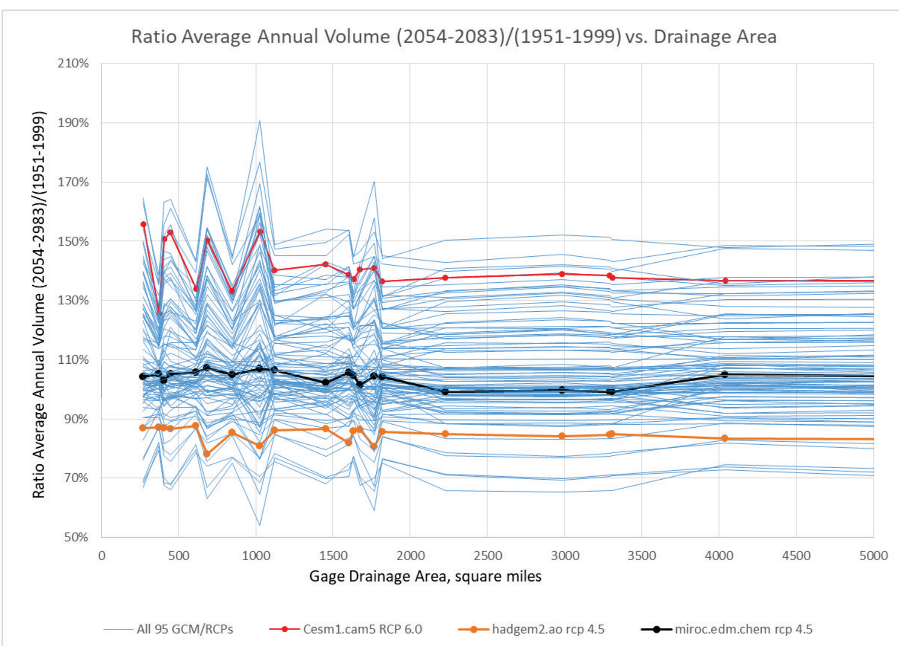


Figure 43 Ratio Average Annual Volume (2054-2083)/(1951-1999) vs. Drainage Area, expanded left portion

From fn: Gage_summary-total_duration_curve.xlsx

Wet part of year – wettest 7.5% of days

The same process that was used above for the total year – 0 to 100% duration – was applied to the wettest part of the year. The projected period divided by the hindcast period average annual volume of flow from 0 to 7.5% was computed for all of the 95 models at all 36 gages. These volume ratios were ranked at each gage from 1 to 95, then averaged for each model. The 3 models previously selected for the total year were checked and found to have rankings close to 5, 48, and 90 for the wet portion of the duration curve. Thus they are considered representative of the range of the 95 models for the high flow end of the duration curve. The three models selected for the total year are plotted below for the wet part of the year.

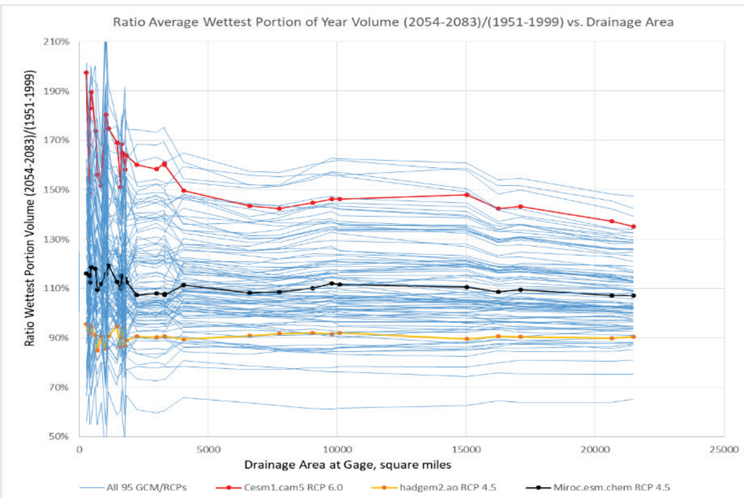


Figure 44 Ratio Average Wettest Portion of Year Volume (2054-2083)/(1951-1999) vs. Drainage Area

Expanded left part

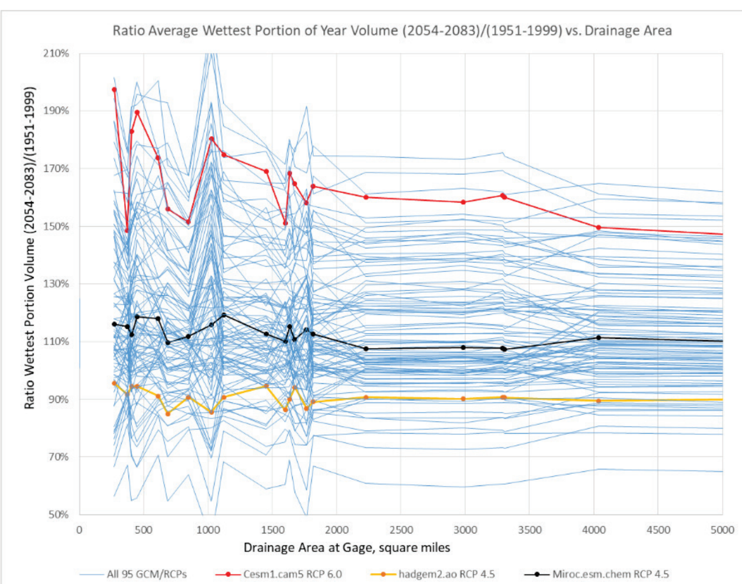


Figure 45 Ratio Average Wettest Portion of Year Volume (2054-2083)/(1951-1999) vs. Drainage Area, expanded left portion

From fn: Gage_summary-upper_duration_curve.xlsx

Driest part of the year – 92.5 to 100% duration

The same process that was used above for the total year and the wet part of the year was applied to the driest part of the year. The ratio of projected to hindcast average annual volume of flow from 92.5 to 100% was computed for all of the 95 models at all 36 gages. These ratios were ranked at each gage from 1 to 95, then averaged for each model. The average volume and low volume models selected for the total year and wet part of the year were checked and found to have rankings close to 48 and 90 for the dry part of the duration curve and are thus representative of the average and low volume impacts for the dry part of the year. However, the model used to represent high volumes for the total year and wet part of the year, CESM1-CAM5 RCP 6.0, was not representative of the high volume impacts for the driest part of the year. The model CSIRO.Mk3-6-0 RCP 2.6 was found to be a better representation for the higher volume impacts for this part of the year.

The plots below show the 3 models used to represent the impact of climate change on this portion of the year. The model used to represent large volume impacts for the total year and the wet part of the year is plotted as a dashed red line and it can be seen that there are more than 4-5 models with higher impacts.

In summary the models that represent the driest portion of the year are:

Highest volumes: CSIRO.Mk3-6-0 RCP 2.6

Average volumes: HadGEM2-AO RCP 4.5

Lowest volumes: MIROC-ESM-CHEM RCP 4.5

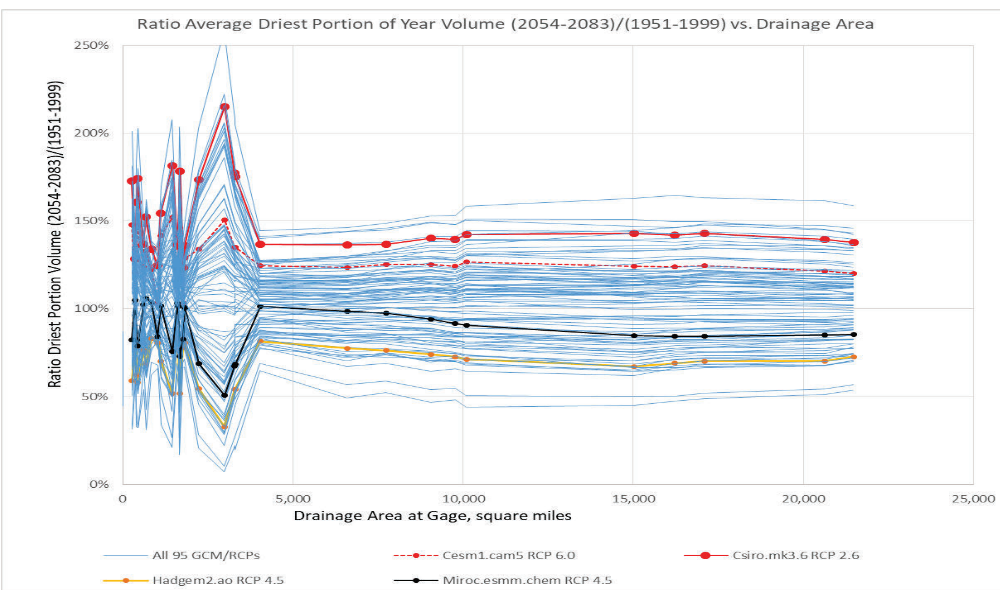


Figure 46 Ratio Average Driest Portion of Year Volume (2054-2083)/(1951-1999) vs. Drainage Area

Expanded left part

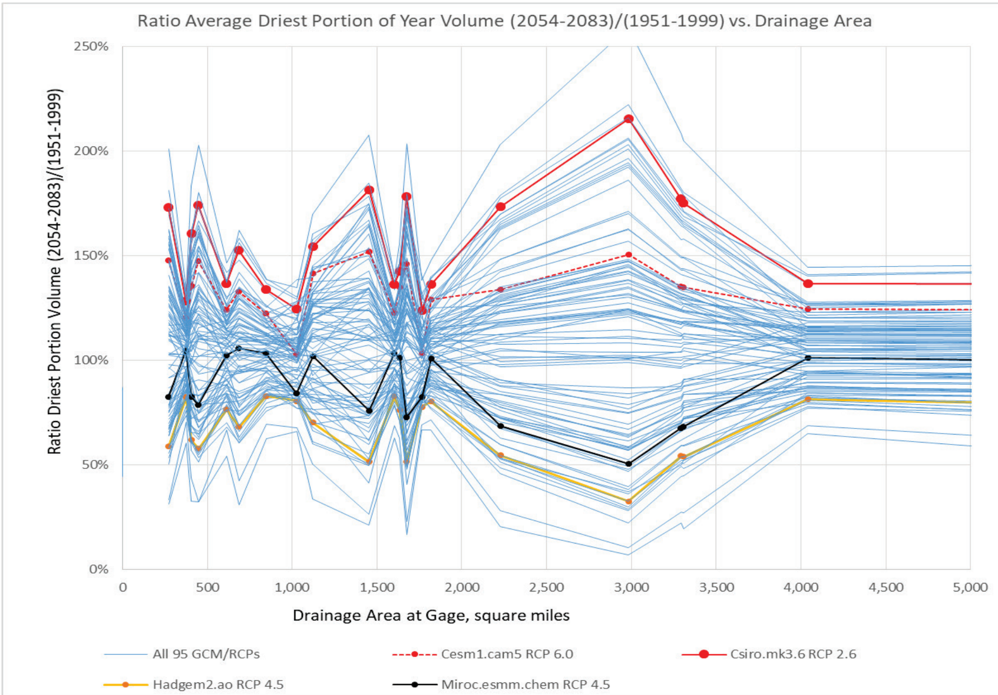


Figure 47 Ratio Average Driest Portion of Year Volume (2054-2083)/(1951-1999) vs. Drainage Area, expanded left portion

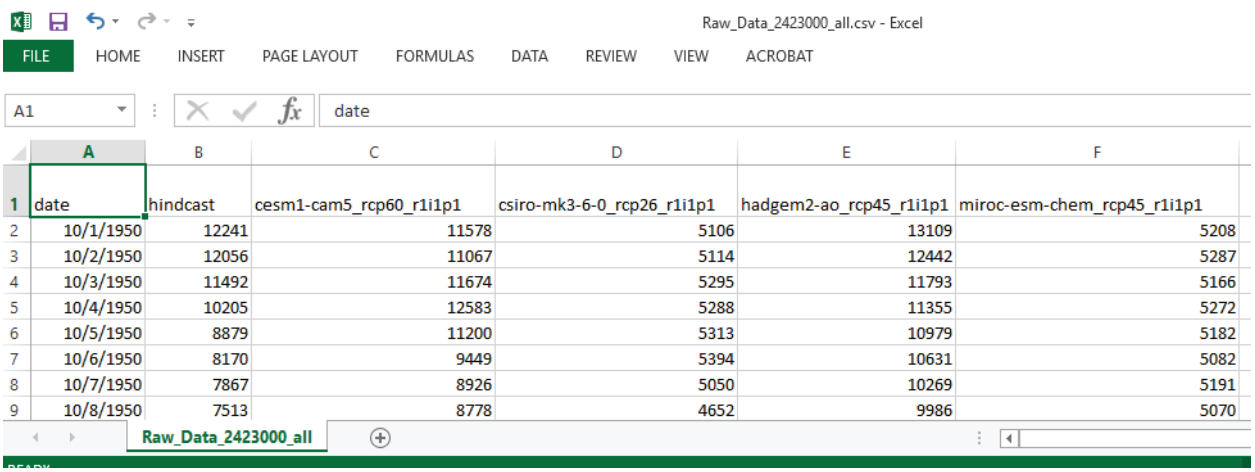
Fn: Gage_summary-lower_flow_duration_curves.xlsx

Appendix 5 Deliverable of Statistical Adjustment Tool (STADJ) Application to ACT Basin

Spreadsheet description

For the final portion of the study the ACR team will use the ResSim reservoir simulation model to evaluate the performance of different reservoir operating plans under possible future climate scenarios. The ResSim model has 36 locations where daily inflows need to be provided to the model

There are 36 files, one for each gage. The files are Excel spreadsheets (.CSV) containing the provided unimpaired flow and results from the four selected climate change models. Below is a snapshot from one of the files for information. The files have daily flows from 1 Oct 1950 to 20 Sept 2099. Column B is called hindcast and is the unimpaired flows provided for that gage. Columns C-F are the adjusted climate impacted flows for 4 combinations of GCM and RCP that represent the full range of the 95 GCM/RCP combinations.



	A	B	C	D	E	F
1	date	hindcast	cesm1-cam5_rcp60_r1i1p1	csiro-mk3-6-0_rcp26_r1i1p1	hadgem2-ao_rcp45_r1i1p1	miroc-esm-chem_rcp45_r1i1p1
2	10/1/1950	12241	11578	5106	13109	5208
3	10/2/1950	12056	11067	5114	12442	5287
4	10/3/1950	11492	11674	5295	11793	5166
5	10/4/1950	10205	12583	5288	11355	5272
6	10/5/1950	8879	11200	5313	10979	5182
7	10/6/1950	8170	9449	5394	10631	5082
8	10/7/1950	7867	8926	5050	10269	5191
9	10/8/1950	7513	8778	4652	9986	5070

Figure 48 Sample spreadsheet containing results of Climate Change Hydrology

Three models were selected for the full duration curve, taking dry scenarios, wet scenarios, and normal scenarios into account together simultaneously. These three models quantified impact similarly for wet scenarios – relatively, these three transformed GCMs maintained their 5th, 50th, and 95th approximate percentiles for just wet conditions. Yet, when the same analysis was run for dry conditions, the model selected to represent larger climate "wetness" impacts (CESM1-CAM5, RCP 6.0) did not persist in the top percentile; therefore, a more consistent model was selected for dry conditions.

Table 18 ***Selected models across normal, wet, and dry conditions***

	Full Annual Volume (Normal Conditions)	Wet Scenarios	Dry Scenarios
Large, Wet Impacts	CESM1-CAM5, RCP 6.0	CESM1-CAM5, RCP 6.0	CSIRO.MK3-6-0 RCP 2.6
Moderate Impacts	MIROC-ESM-CHEM, RCP 4.5	MIROC-ESM-CHEM, RCP 4.5	MIROC-ESM-CHEM, RCP 4.5
Large, Dry Impacts	HADGEM2-AO, RCP 4.5	HADGEM2-AO, RCP 4.5	HADGEM2-AO, RCP 4.5

The process for getting these 4 combinations and what they represent is described in the Appendix 4 Selecting Representative GCM/RCPs. Each file is identified in filename by a gage number. The gage numbers are the USGS gage number, expect some gages don't appear to be USGS gages and those were assigned arbitrary gage numbers as a proxy ID. The table below shows how the assigned gage numbers relate to the gage names.

Table 19 Alabama Coosa Tallapoosa (ACT) Basin gages used to for ResSim Modeling

	River	Gage	USGS Gage Name	ACT CP Number	DA	Lat	Long	ACT Gage Name	Mizuroute segment	USGS/STADJ #
1	Alabama	At St Claiborne Dam	Alabama River at Claiborne L&D near Monroeville, AL	120	21,473	31.6150	-87.5500	Claiborne	4417	2428400
2	Coosa	At Jordan Dam nr Wetumpka	Coosa River at Jordan Dam near Wetunpka, AL	132	10,102	32.6139	-86.2550	Jordan	5461	2411000
3	Tallapoosa	Nr Heflin	Tallapoosa River near Heflin, AL	326	448	33.6228	-85.5133	Heflin	3724	2412000
4	Tallapossa	At Wadley	Tallapoosa River at Wadley, AL	294	1,675	33.1173	-85.5622	Wadley	5324	2414500
5	Cahaba	At Centreville	Cahaba River at Centreville, AL	480	1,027	32.9451	-87.1392	Centreville	5165	2424000
6	Etowah	Nr Kingston	Etowah River near Kingston, AL(GA?)	158	1,634	34.2089	-84.9787	Kingston	1339	2395000
7	Etowah	At Canton	Etowah River at Canton, GA	164	613	34.2398	-84.4947	Canton	1331	2392000
8	Coosawatte	Carter's Main Dam	???? Use "Coosawattee River, Carters Main Dam"	180	374	34.6033	-84.6933	Carters	1280	2381500
9	Consauga	At Tilton	Consauga River at Tilton, GA	386	687	34.6667	-84.9283	Tilton	3444	2387000
10	Alabama	Below Millers Ferry L&D	Alabama River below Millers Ferry L&D near Camden, AL	124	20,637	32.1000	-87.3978	Millers Ferry	4987	2427506
11	Alabama	At Montgomery	Alabama River at Montgomery, AL	130	15,023	32.3919	-86.3178	Montgomery	5231	2419988
12	Alabama	Below Robert F Henry L&D	Alabama River below Robert F Henty L&D near Benton, AL	129	16,233	32.3222	-86.7839	R.F. Henry	5248	2421351
13	Alabama	At Selma	Alabama River at Selma, AL	126	17,095	32.4056	-87.0186	Selma	5257	2423000
14	Cahaba	Near Marion Junction	Cahaba River near Marion Junction, AL	470	1,766	32.4439	-87.1803	Marion Junction	5171	2425000
15	Coosa	At H. Neely Henry Dam	Coosa River at H. Neely Henry Dam near Ohatchee, AL	145	6,596	33.7839	-86.0528	H.N. Henry	5565	2401620
16	Coosa	At Lay Dam nr Clanton	Coosa River at Lay Dam near Clanton, AL	136	9,053	32.9650	-86.5175	Lay	5448	2407950
17	Coosa	At Logan Martin Dam nr Vincent	Coosa River at Logan Martin Dam near Vincent, AL	140	7,743	33.4256	-86.3369	Logan Martin	5396	2405200
18	Coosa	At Mitchell Dam nr Verbena	Coosa River at Mitchell Dam near Verbena, AL	134	9,778	32.8061	-86.4447	Mitchell	5456	2409400
19	Coosa	(Mayo's Bar) nr Rome	Coosa River (Mayo's Bar) near Rome, GA (AL?)	154	4,040	34.2003	-85.2567	Rome_Coosa	3759	2397000
20	Coosawattee	At Pine Chapel	Coosawattee River at Pine Chapel, GA	NA	847	34.5764	-84.8603	Pine Chapel	1283	2383520
21	Etowah	At Allatoona Dam abv Cartersville	Etowah River at Allatoona Dam above Cartersville, GA	160	1,122	34.1631	-84.7411	Allatoona	1347	2394000
22	Etowah	At Rome	Etowah River at Rome, GA	156	1,819	34.2572	-85.1583	Rome_Etowah	1350	2396000
23	Oostanaula	At Resaca	Oostanaula River at Resaca, GA	170	1,602	34.5771	-84.9419	Resaca	1288	2387500
24	Tallapoosa	At Harris Dam nr Cragford	Tallapoosa River at Harris Dam (Pool) near Cragford, GA	300	1,454	33.2603	-85.6167	Harris	5347	2413950

	River	Gage	USGS Gage Name	ACT CP Number	DA	Lat	Long	ACT Gage Name	Mizuroute segment	USGS/STADJ #
25	Tallapoosa	Lake Martin Res. Nr Eclectic	Tallapoosa River Lake Martin Res above Eclectic, GA	288	2,984	32.6806	-85.9125	Martin	5267	2417500
26	Tallapoosa	Below Tallapoosa, GA	Tallapoosa River below Tallapoosa, GA	NA	272	33.7408	-85.3364	Tallapoosa	3722	2411930
27	Tallapoosa	Below Tallassee	Tallapoosa River below Tallassee, GA	282	2,228	32.5125	-85.8892	Tallassee	5269	2418500
28	Tallapoosa	Thurow Res at Tallassee	Tallapoosa River Thurow Res above Tallassee, GA	284	3,308	32.5353	-85.8894	Thurow	5269	2418480
29	Tallapoosa	Yates Res nr Tallassee	Tallapoosa River Yates Res above Tallassee, GA	286	3,293	32.5742	-85.8903	Yates	5269	2418400
30	LittleTallapoosa	Near Newell	LittleTallapoosa River near Newell, GA	310	406	33.4372	-85.3992	Newell	3728	2413300
31	Cahaba	Purdy Big adjustment	???? Use "Cahaba River, Purdy"	500	??? Leave blank	33.4156	-86.4156	Purdy	5139	9900199
32	Conasauga	Conasauga	???? Use "Conasauga River, CP 400"	400	??? Leave blank	34.8279	-84.8491	Conasauga	3430	9900299
33	Coosa	Coosa	???? Use "Coosa River, CP 131"	131	??? Leave blank	32.5370	-86.2089	Coosa	5464	9900399
34	Coosa	? at or below Weiss Lake	Coosa River at Weiss Lake near Leesburg, AL	150	??? Leave blank	34.1717	-85.7533	Weiss	3776	2399499
35	Coosawattee	Carters Rereg	???? Use "Coosawatter River, Carters Rereg"	172	??? Leave blank	34.6033	-84.6933	Carters Rereg	1266	9900499
36	Etowah	Etowah	Use "Etowah River at Etowah"	168	??? Leave blank	34.3837	-84.0596	Etowah	1329	9900599

Attachment 6. Modification of Flood Control Plans for APC Reservoirs – Final HEMP Results (APC's HEC-ResSim Modeling Report)

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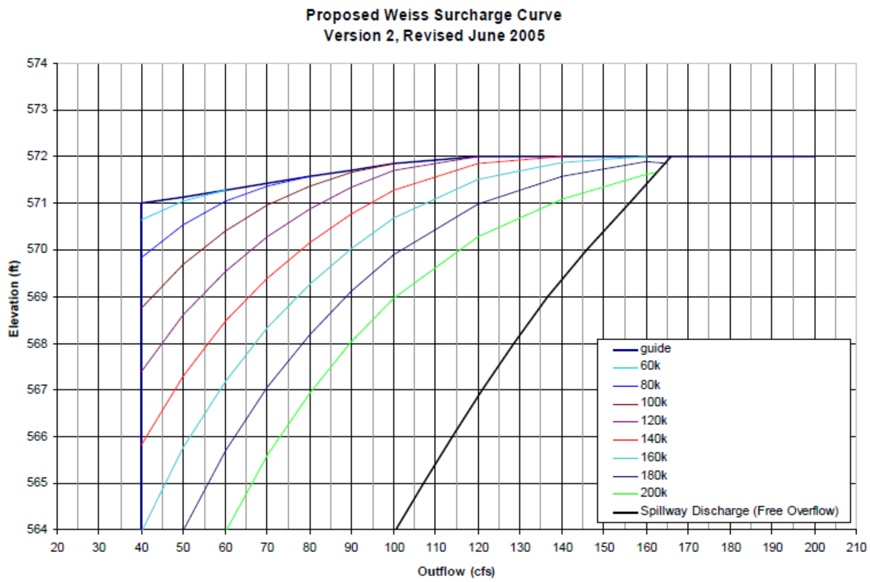
Modification of Flood Control Plans

for

Alabama Power Company Reservoirs

Weiss and Logan Martin

Coosa River, Alabama



Final HEMP Results

Technical Report

February 15, 2019

Introduction

Alabama Power Company (APC) proposes revisions to the Weiss and Logan Martin projects' flood operation plans, which includes raising the winter level (561' MSL and 462' MSL, respectively) and lowering the upper limit of the induced surcharge operation at each reservoir (572' MSL and 473.5' MSL, respectively). This is the Preferred Action Alternative (PAA) and is outlined in detail in the following section.

Current Water Control Plans for Weiss and Logan Martin reservoirs contain surcharge curves with elevations higher than the respective flood easements acquired by APC and approved by FERC following consultation with USACE. The easement at Weiss is 572' MSL and the surcharge curve indicates flood control storage to 574' MSL. On Logan Martin, the easement elevation is 473.5' MSL and the surcharge curve indicates flood control storage to 477' MSL. Routine APC variance requests, evaluated and approved by USACE, during flood events warrants the evaluation of the Weiss and Logan Martin flood operation plans.

In May of 2018, the U.S. Army Corps of Engineers (USACE) and Alabama Power Company laid out a plan to address the longstanding issue at the APC Weiss and Logan Martin projects on the Coosa River. This plan is referred to as the Hydrologic Engineering Management Plan (HEMP). The HEMP outlined historic events that were to be used in evaluating the higher winter pools and revised surcharge curves, using HEC-ResSim.

History

This issue is not new. As far back as 1977, the USACE recognized the need to revise the Water Control Plans for both reservoirs, but subsequently never obtained funding to carry out the necessary studies. Federal Energy Regulatory Commission (FERC) Relicensing of the APC Coosa projects, including Weiss and Logan Martin, began in 2001, which was a perfect opportunity to address the issues at Weiss and Logan Martin. Work began between the USACE and APC on the Coosa River Flood Study (CRFS, Appendix A), and a plan of study was agreed to by both parties. Many years of intense work ensued, and a final, exhaustive comprehensive report, showing that changes in winter pool levels and revised surcharge curves were indeed feasible, was filed with FERC. After several detailed follow-up technical sessions, FERC was satisfied that all necessary steps had been taken, and gave their approval, pending USACE approval. That never happened, as USACE took on a revision to their ACT Water Control Manuals, which itself provided an additional opportunity to evaluate the needed changes at Weiss and Logan Martin. However, USACE made the decision to not evaluate changes at Weiss and Logan Martin during the ACT Manual revision, as this revision was supposed to just show "as is today" conditions.

Preferred Action Alternative:

Weiss

APC proposes to increase the winter pool at Weiss from 558’ MSL to 561’ MSL and reduce the max surcharge elevation from 574’ MSL to 572’ MSL. This will be accomplished by modifying the current Flood Regulation Schedule (see appendix A).

Logan Martin

APC proposes to increase the winter pool at Logan Martin from 460’ MSL to 462’ MSL and reduce the max surcharge elevation from 477’ MSL to 473.5’ MSL. This will be accomplished by modifying the current Flood Regulation Schedule (see appendix A)

Guide Curves and Schedules

As part of this section, the essential charts used in the design flood analysis and proposed for use at Weiss and Logan Martin are included. They include the Proposed Flood Guide Curve, Flood Control Regulation Schedule, and Flood Surcharge Curves for both Weiss and Logan Martin.

Analysis

As outlined in the HEMP, the following storms were modeled using an hourly version of HEC-ResSim:

1. February 1990 increased for Design Storm simulation
2. April 1979
3. February 1990
4. March 1990
5. October 1995
6. May 2003
7. May 2003 increased for back to back simulation
8. Standard Project Flood
9. Probable Maximum Flood

This report shows results of the hourly analysis using HEC-RTS to model the current and proposed operations. Current operations were represented in the model with the base alternative. To fully capture the PAA, the proposed operations were represented with two alternatives, one that reduced surcharge releases up to 50% and one with a 0% reduction (no cut) in surcharge releases. For ease of quick review in this report, for each of these storms represented, a hydrograph of No Action Alternative (NAA) and PAA is presented, along with comparison tables of key indicators.

February 1990 Design

The design flood, developed for the 2005 Coosa River Flood Study, replicates a 100-year, unregulated inflow hydrograph into each reservoir. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from the Proposed alternative, allowing up to a 50% decrease in surcharge releases, show no increase in flooding at the downstream locations.

Comparison of Peak Elevations

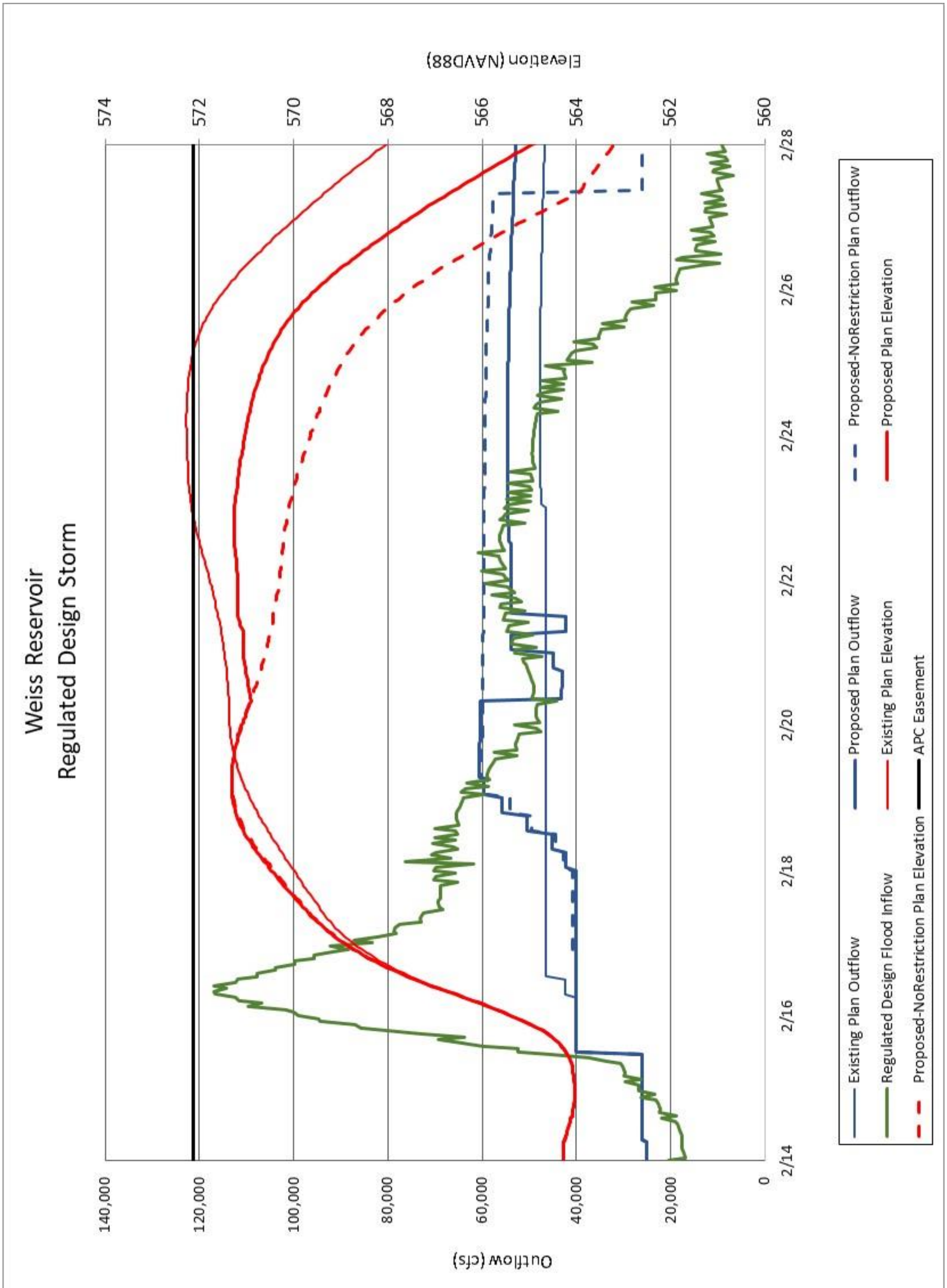
Unregulated Steady-State Design Flood

Model Alternative	**Weiss** (ft NAVD88)	**Gadsden** (ft NGVD29)	**Logan Martin** (ft NAVD88)	**Childersburg** (ft NGVD29)
BASE	572.28	515.70	475.33	411.82
PROPOSED (NO CUT)	571.31	515.96	473.53	411.07
PROPOSED	571.32	515.23	473.59	411.76

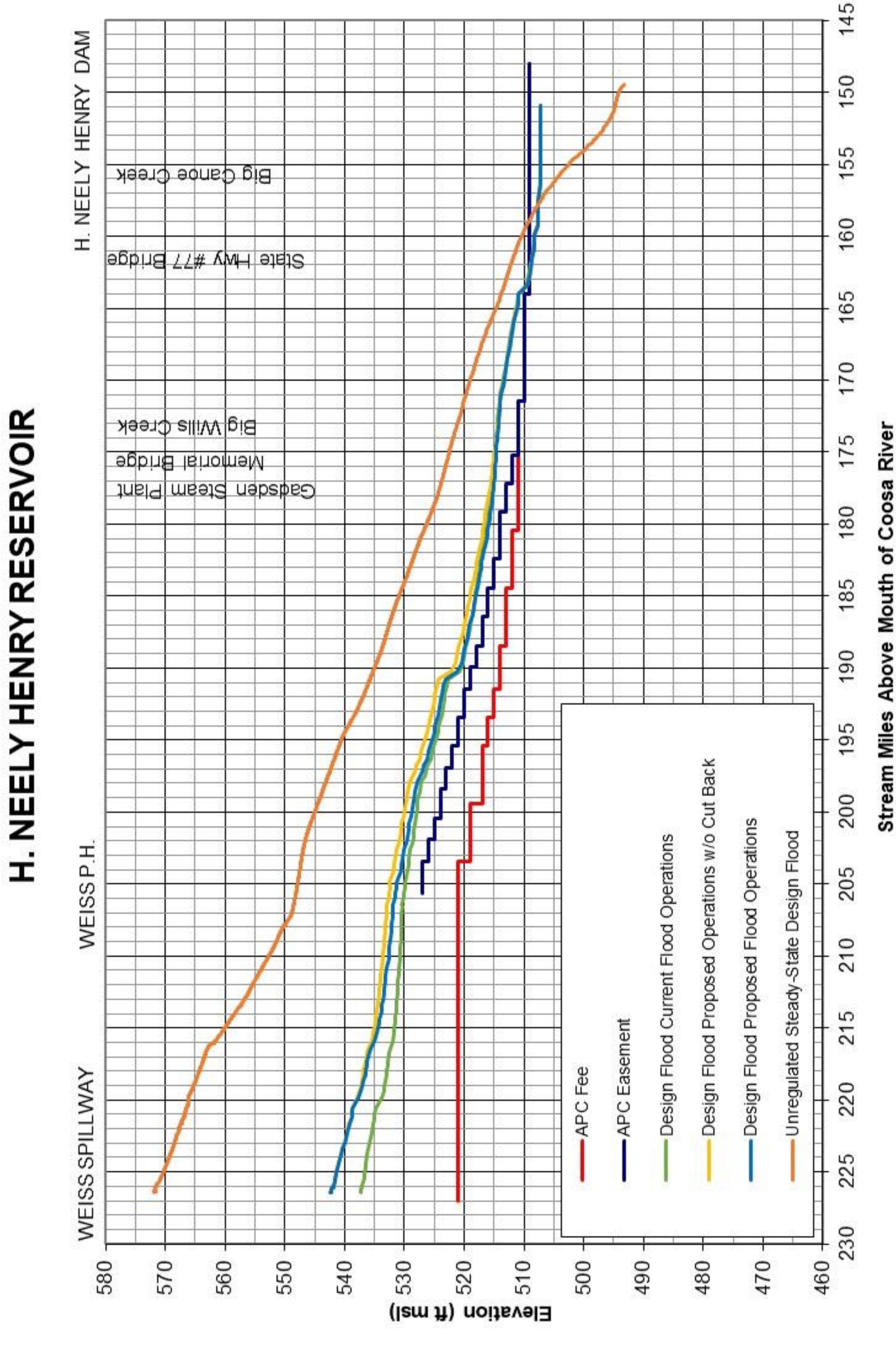
Design Flood Event
Lookback Elevations

	Base	Proposed
Weiss	564.28*	564.28*
Henry	507.18	507.18
Logan	462.02	462.09
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

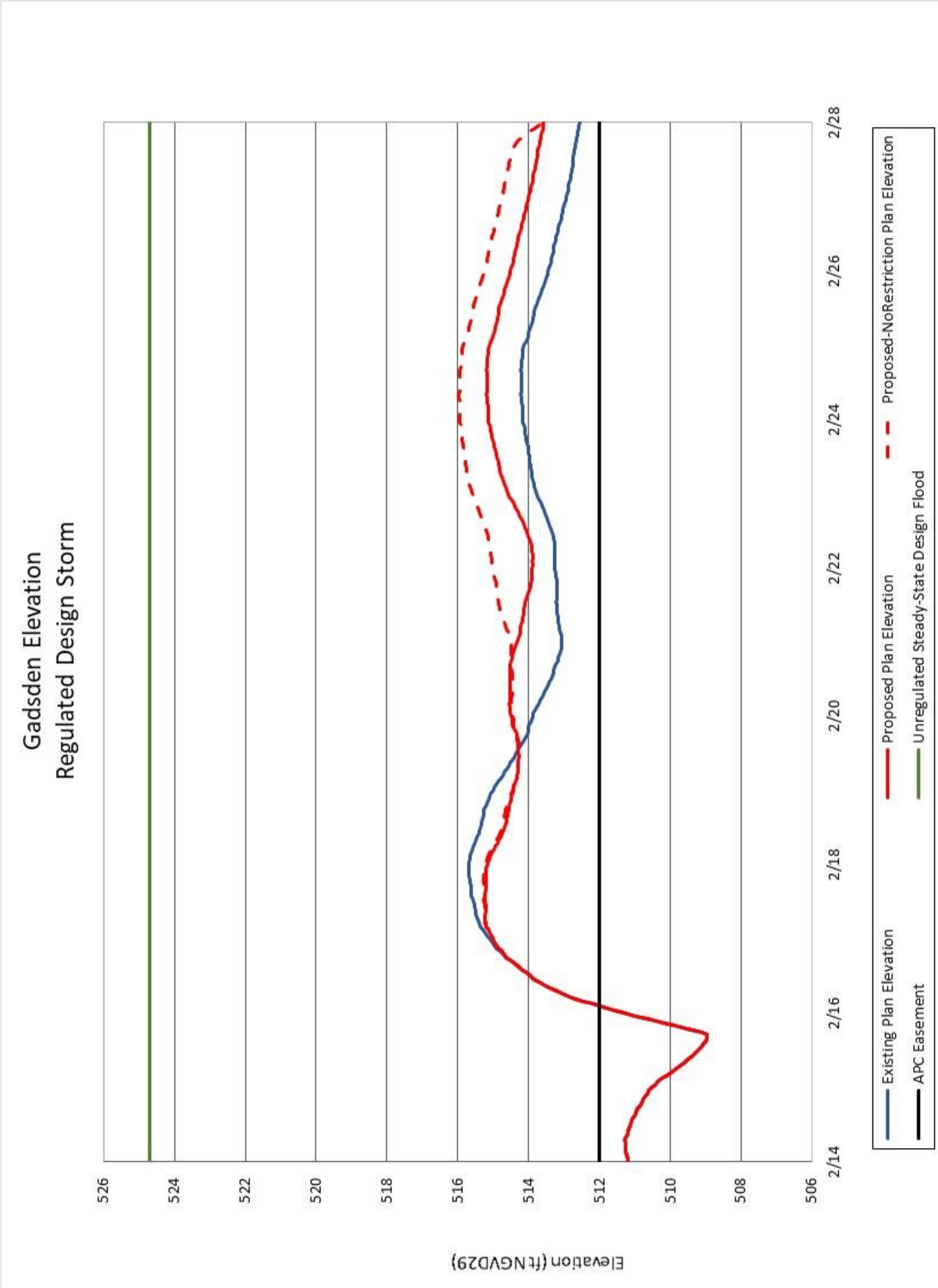
*indicates a historical elevation



Weiss Reservoir
Regulated Design Storm
Outflow (cfs)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Elevation (NAVD88)
574
572
570
568
566
564
562
560
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Outflow
Regulated Design Flood Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation

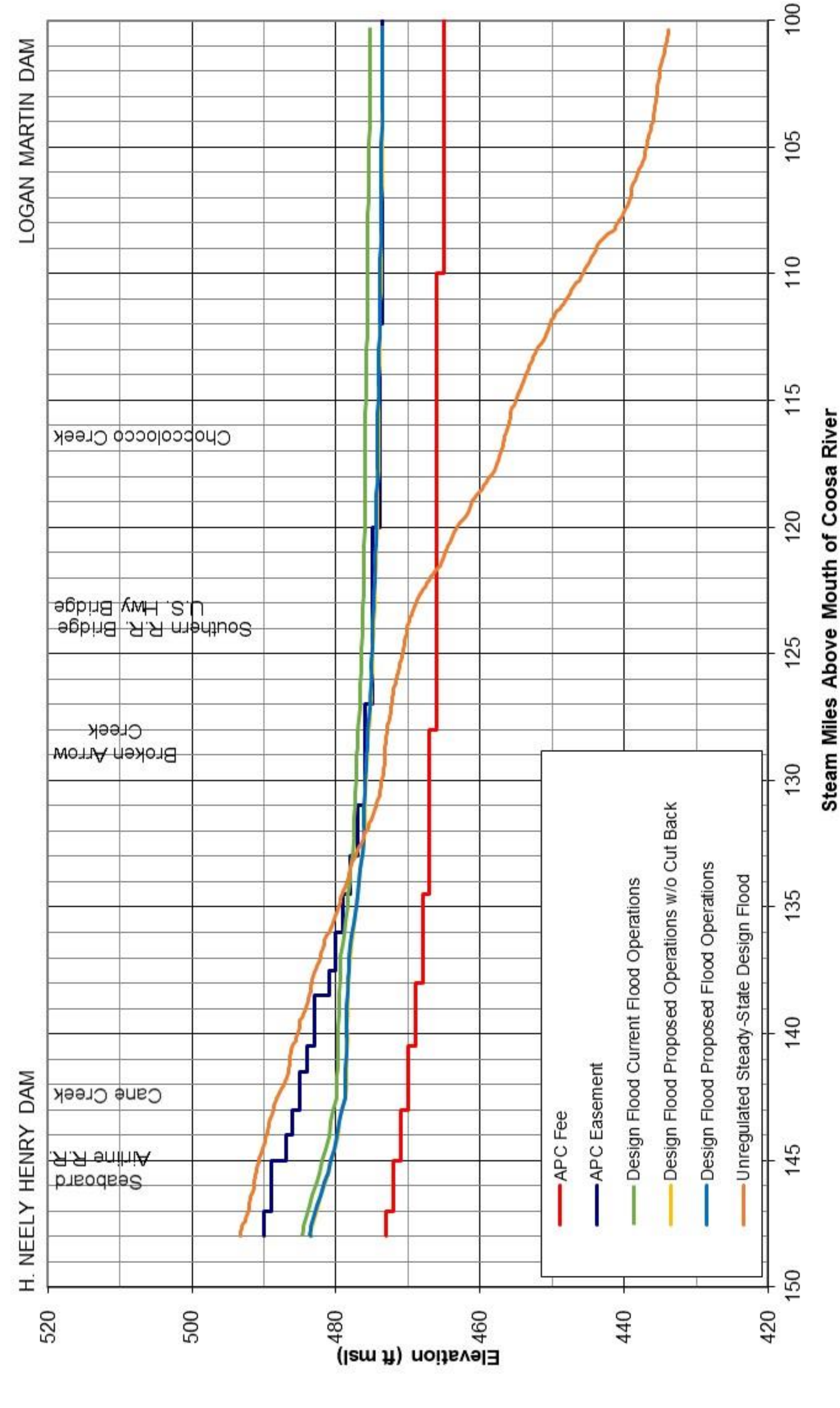


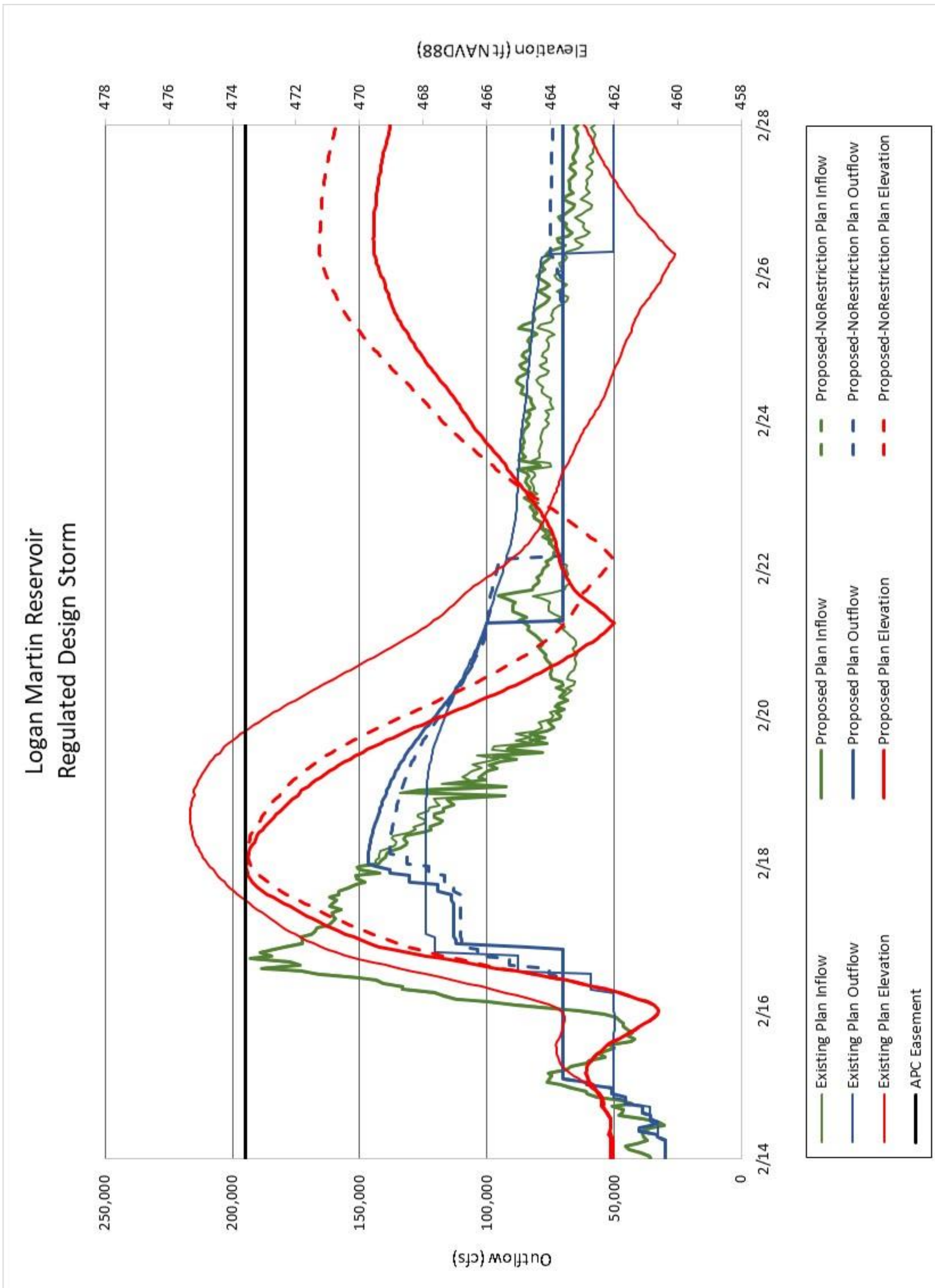
H. NEELY HENRY RESERVOIR
WEISS SPILLWAY
WEISS P.H.
H. NEELY HENRY DAM
Big Canoe Creek
State Hwy #77 Bridge
Big Wills Creek
Memorial Bridge
Gadsden Steam Plant
Elevation (ft msl)
Stream Miles Above Mouth of Coosa River
APC Fee
APC Easement
Design Flood Current Flood Operations
Design Flood Proposed Operations w/o Cut Back
Design Flood Proposed Flood Operations
Unregulated Steady-State Design Flood

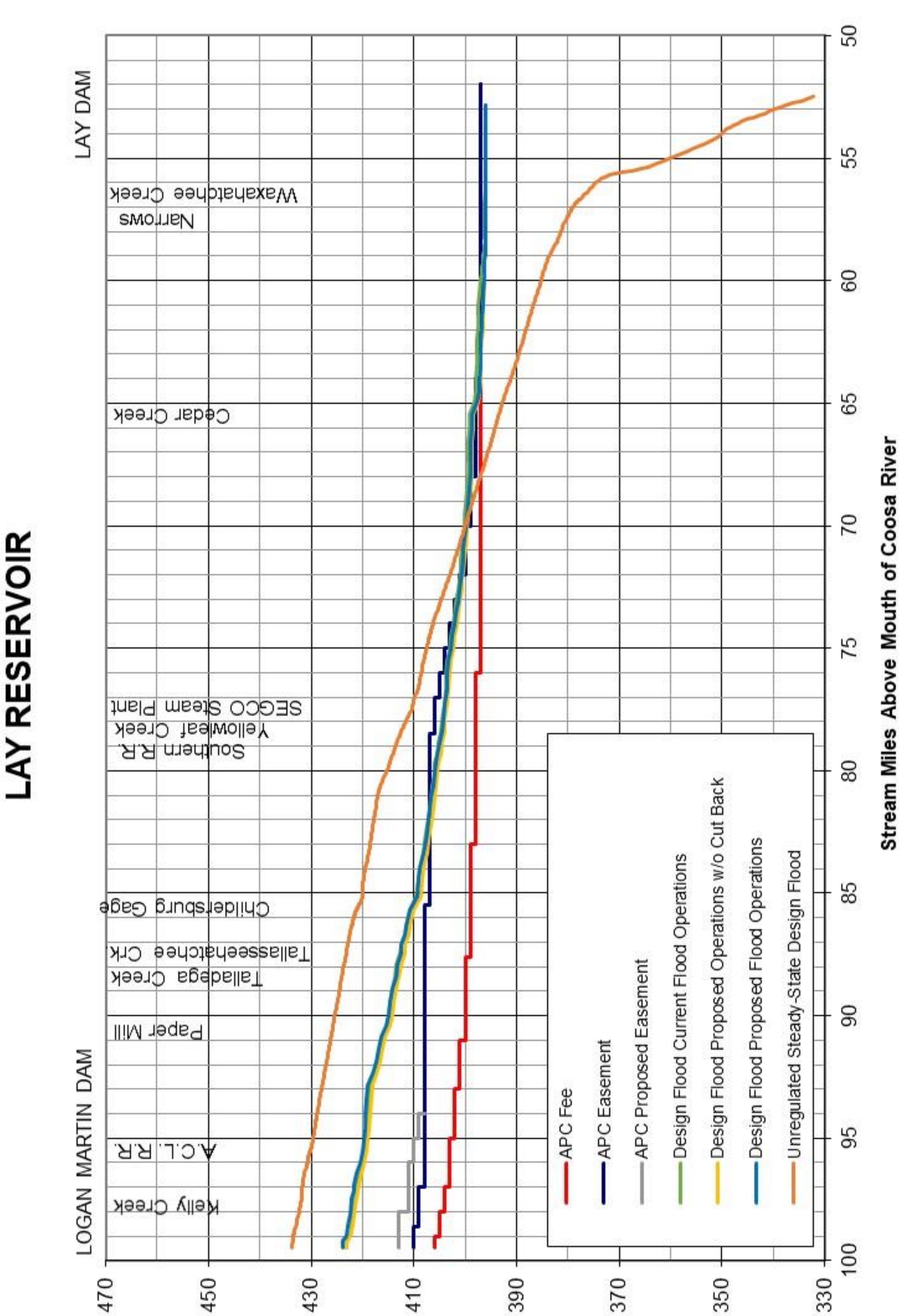


Gadsden Elevation
Regulated Design Storm
Elevation (ft NGVD29)
526
524
522
520
518
516
514
512
510
508
506
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Elevation
APC Easement
Proposed Plan Elevation
Unregulated Steady-State Design Flood
Proposed-NoRestriction Plan Elevation

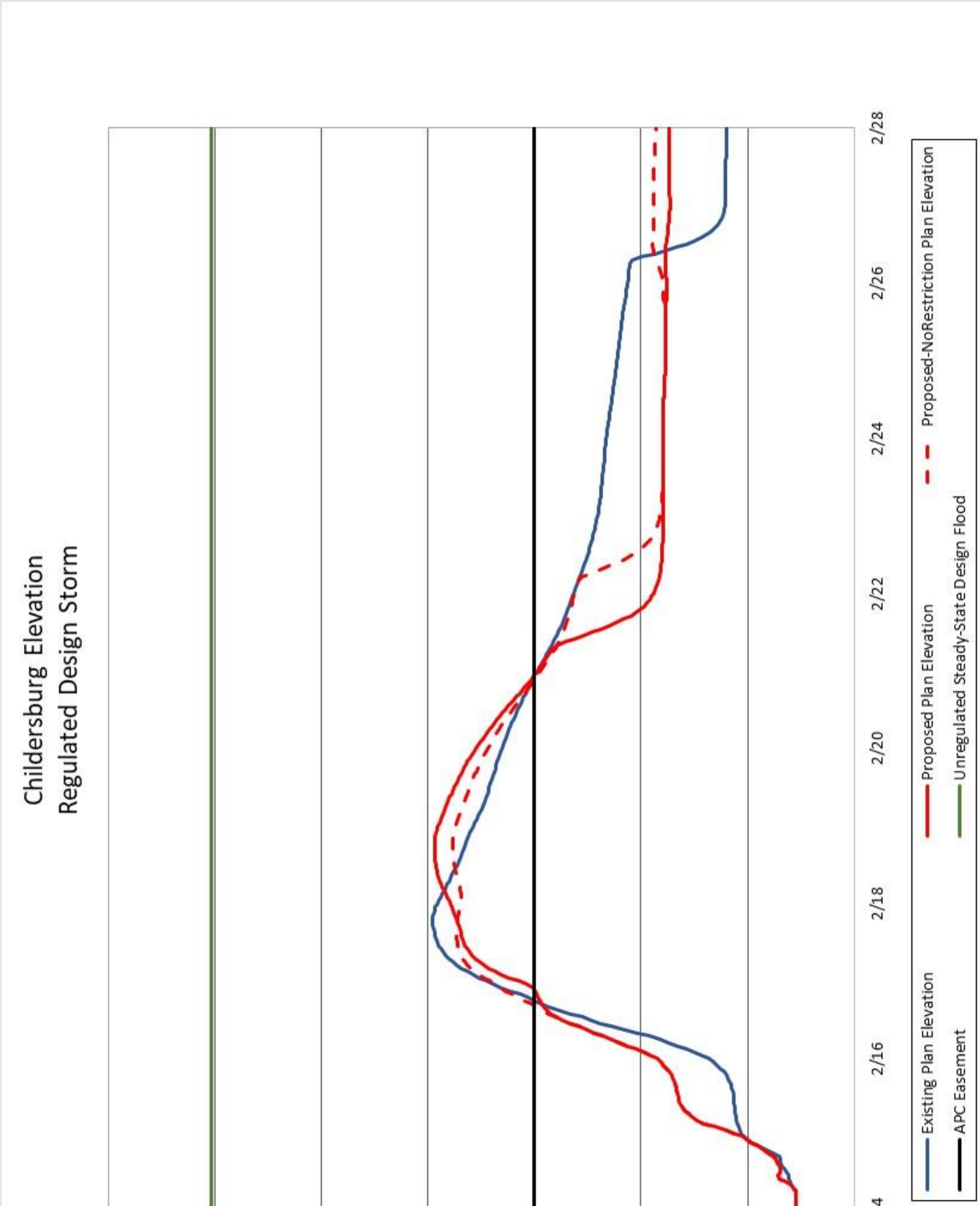
LOGAN MARTIN RESERVOIR




Logan Martin Reservoir
Regulated Design Storm
Outflow (cfs)
250,000
200,000
150,000
100,000
50,000
0
Elevation (ft NAVD88)
478
476
474
472
470
468
466
464
462
460
458
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation



LAY RESERVOIR
Elevation (ft msl)
470
450
430
410
390
370
350
330
Stream Miles Above Mouth of Coosa River
100
95
90
85
80
75
70
65
60
55
50
LOGAN MARTIN DAM
LAY DAM
Kelly Creek
A.C.L. R.R.
Paper Mill
Talladega Creek
Tallasseehatchee Crk
Childersburg Gage
Southern R.R.
Yellowleaf Creek
SEGCO Steam Plant
Cedar Creek
Narrows
Waxahatchee Creek
APC Fee
APC Easement
APC Proposed Easement
Design Flood Current Flood Operations
Design Flood Proposed Operations w/o Cut Back
Design Flood Proposed Flood Operations
Unregulated Steady-State Design Flood



Childersburg Elevation
Regulated Design Storm
Elevation (ft NGVD29)
424
420
416
412
408
404
400
396
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

April 1979

The April 1979 event was a major historical event with a frequency ranging from 50-year to greater than 250-year at different locations on the Coosa River. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from the Proposed alternative with 0% reduction in surcharge releases show no increase in flooding at the downstream locations.

Comparison of Peak Elevations

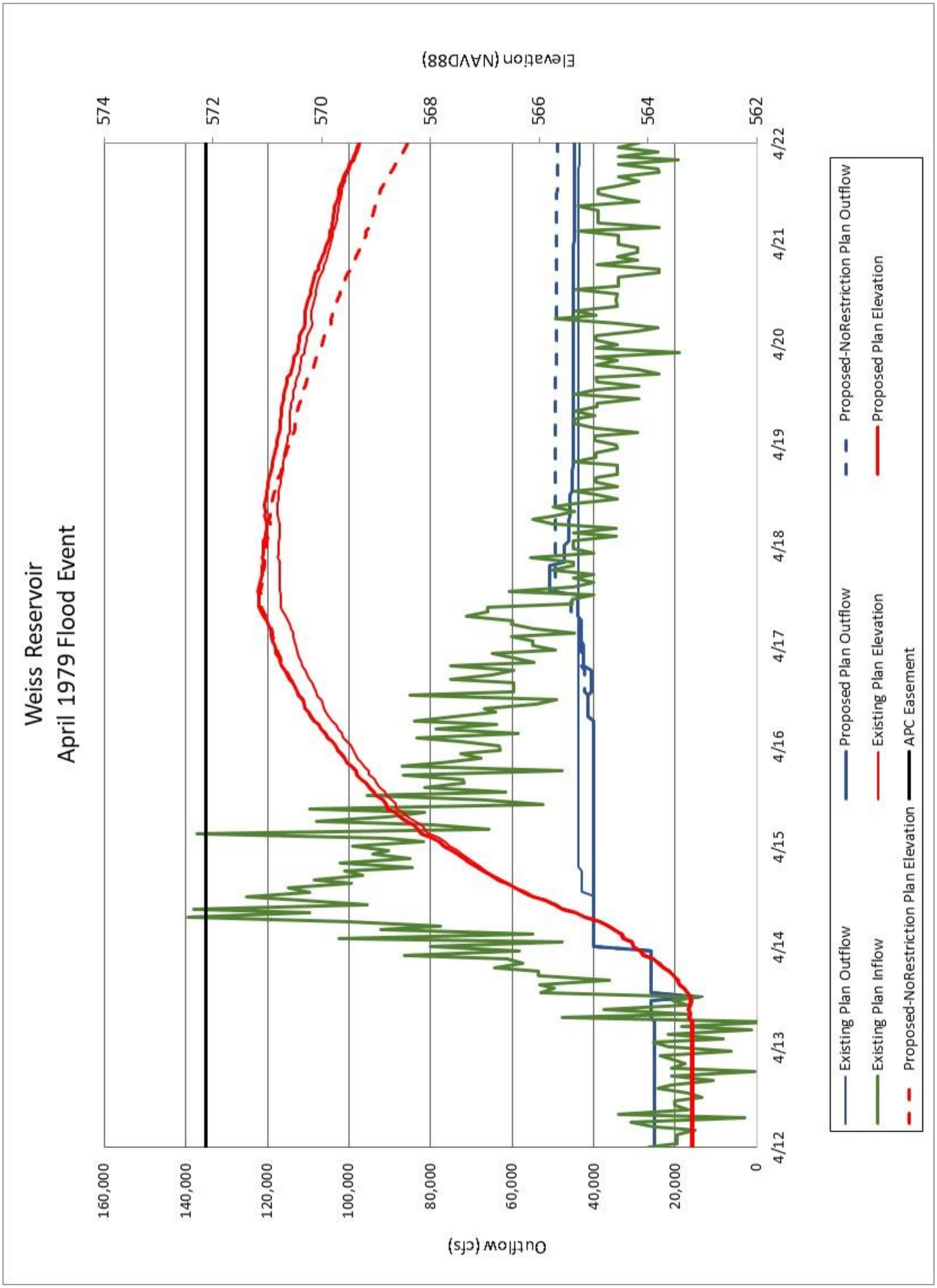
April 1979 Event

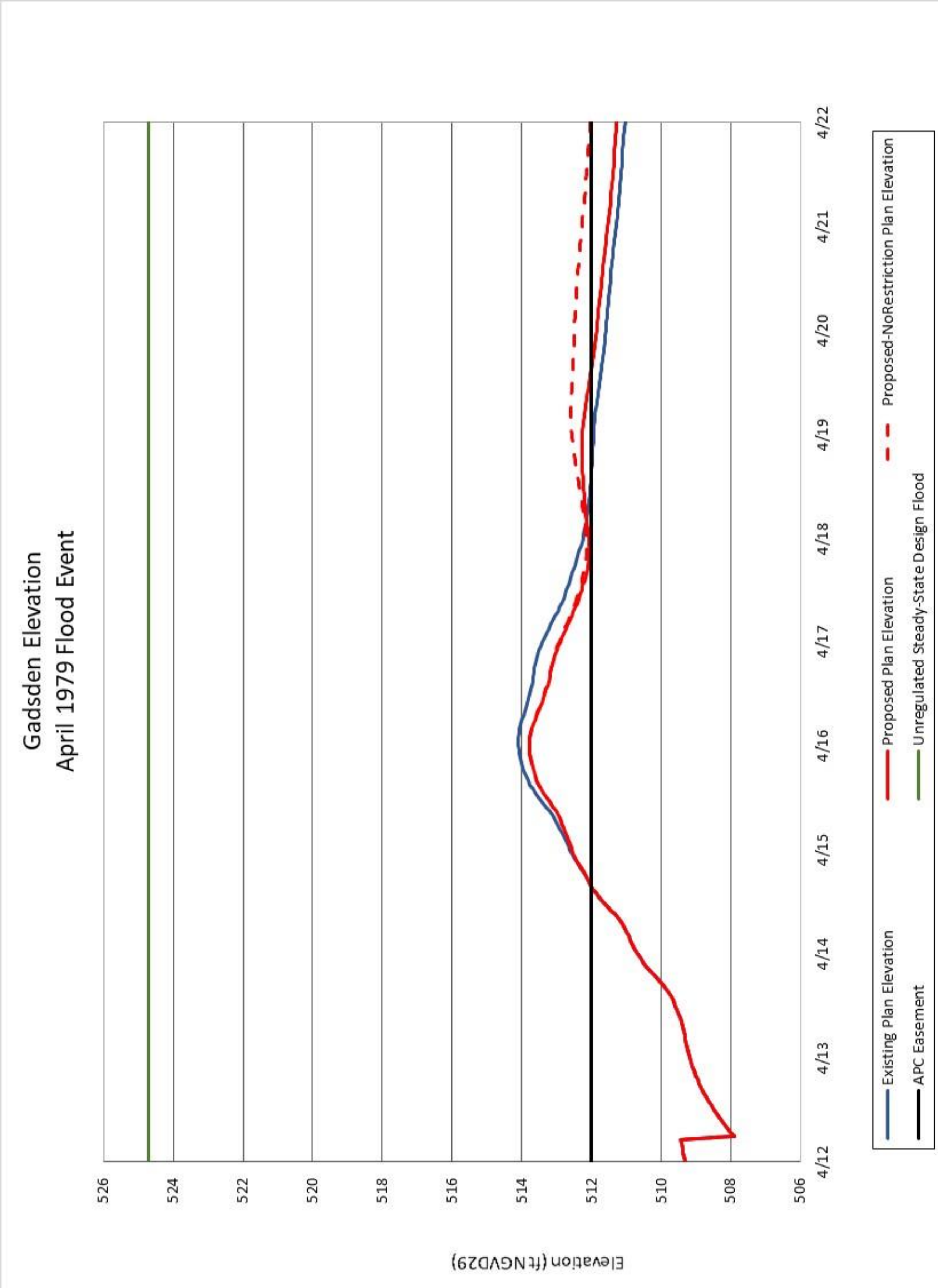
Model Alternative	**Weiss** (ft NAVD88)	**Gadsden** (ft NGVD29)	**Logan Martin** (ft NAVD88)	**Childersburg** (ft NGVD29)
BASE	570.82	514.10	473.92	411.56
PROPOSED (NO CUT)	571.13	513.78	473.30	411.46
PROPOSED	571.17	513.78	473.46	412.37

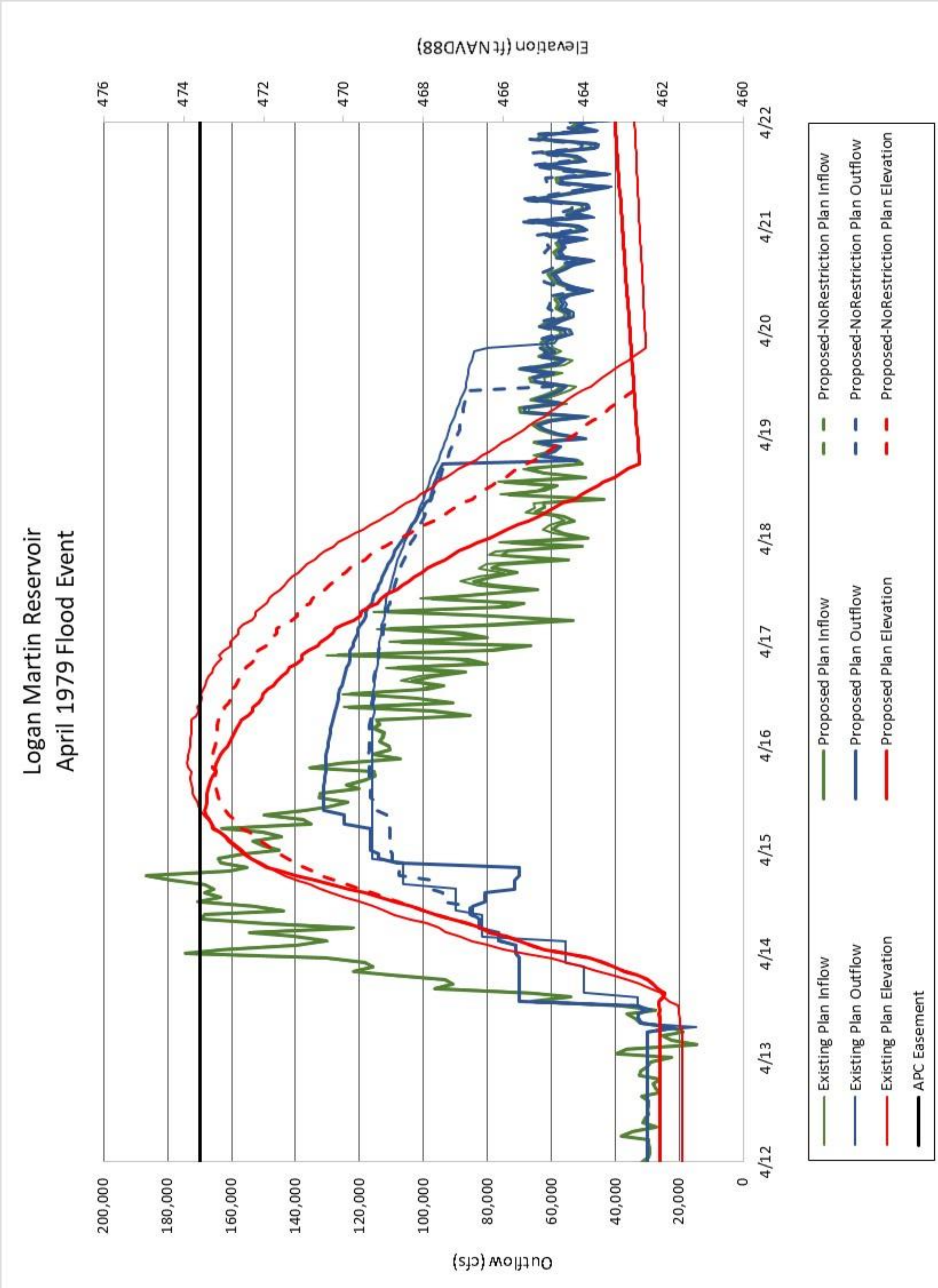
April 1979 Flood Event
Lookback Elevations

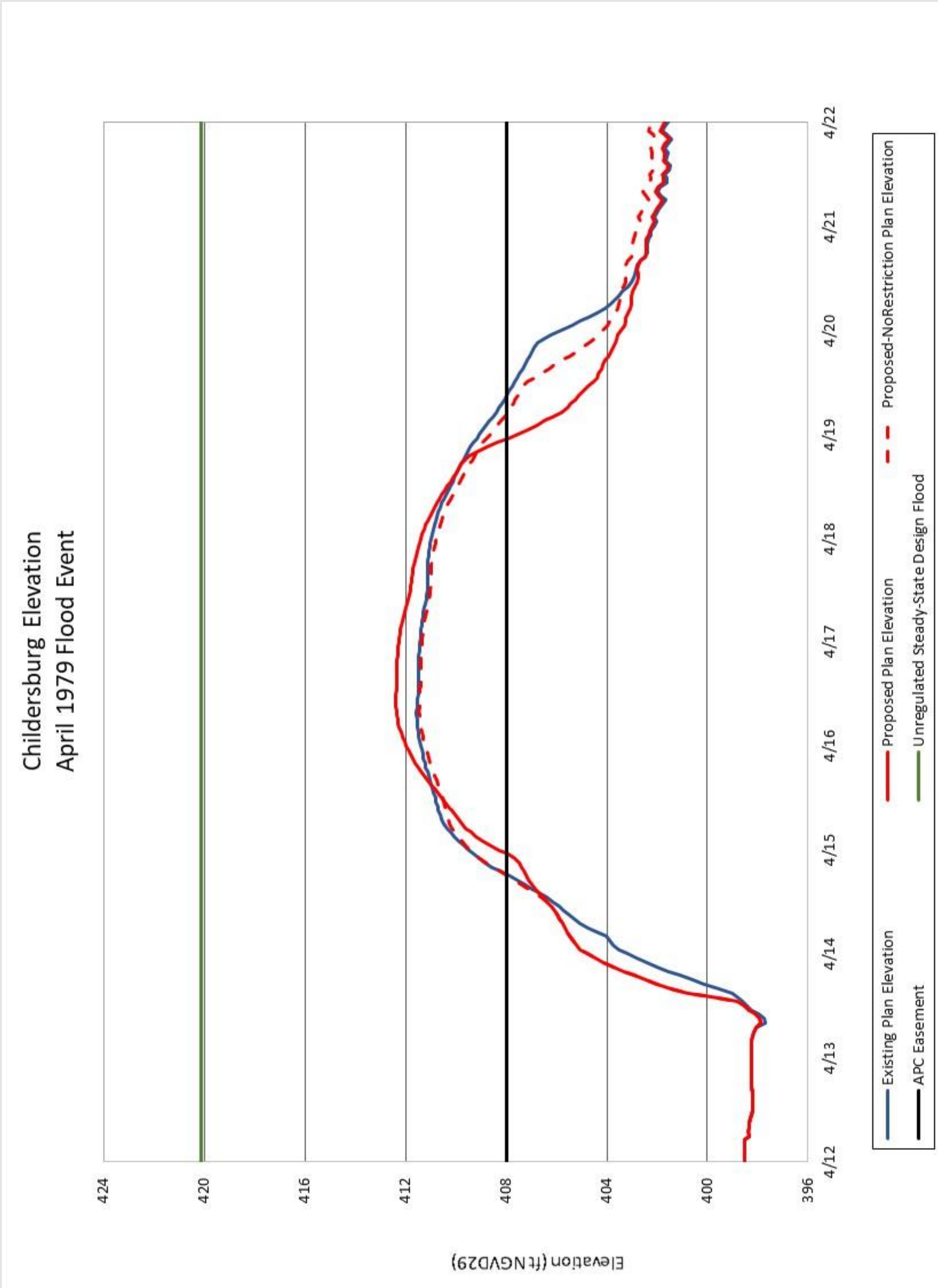
	Base	Proposed
Weiss	563.17	563.19
Henry	507.55	507.55
Logan	461.53	462.09
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

*indicates a historical elevation


Weiss Reservoir
April 1979 Flood Event
Outflow (cfs)
Elevation (NAVD88)
Existing Plan Outflow
Existing Plan Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation


Gadsden Elevation
April 1979 Flood Event
Elevation (ft NGVD29)
526
524
522
520
518
516
514
512
510
508
506
4/12
4/13
4/14
4/15
4/16
4/17
4/18
4/19
4/20
4/21
4/22
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood


Logan Martin Reservoir
April 1979 Flood Event
Outflow (cfs)
Elevation (ft NAVD88)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
476
474
472
470
468
466
464
462
460
4/12
4/13
4/14
4/15
4/16
4/17
4/18
4/19
4/20
4/21
4/22
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation


Childersburg Elevation
April 1979 Flood Event
Elevation (ft NGVD29)
424
420
416
412
408
404
400
396
4/12
4/13
4/14
4/15
4/16
4/17
4/18
4/19
4/20
4/21
4/22
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

February 1990

The February 1990 event was a major historical event with a frequency ranging from 25-year to 100-year at different locations on the Coosa River. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from both Proposed alternatives show no increase in flooding at the downstream locations.

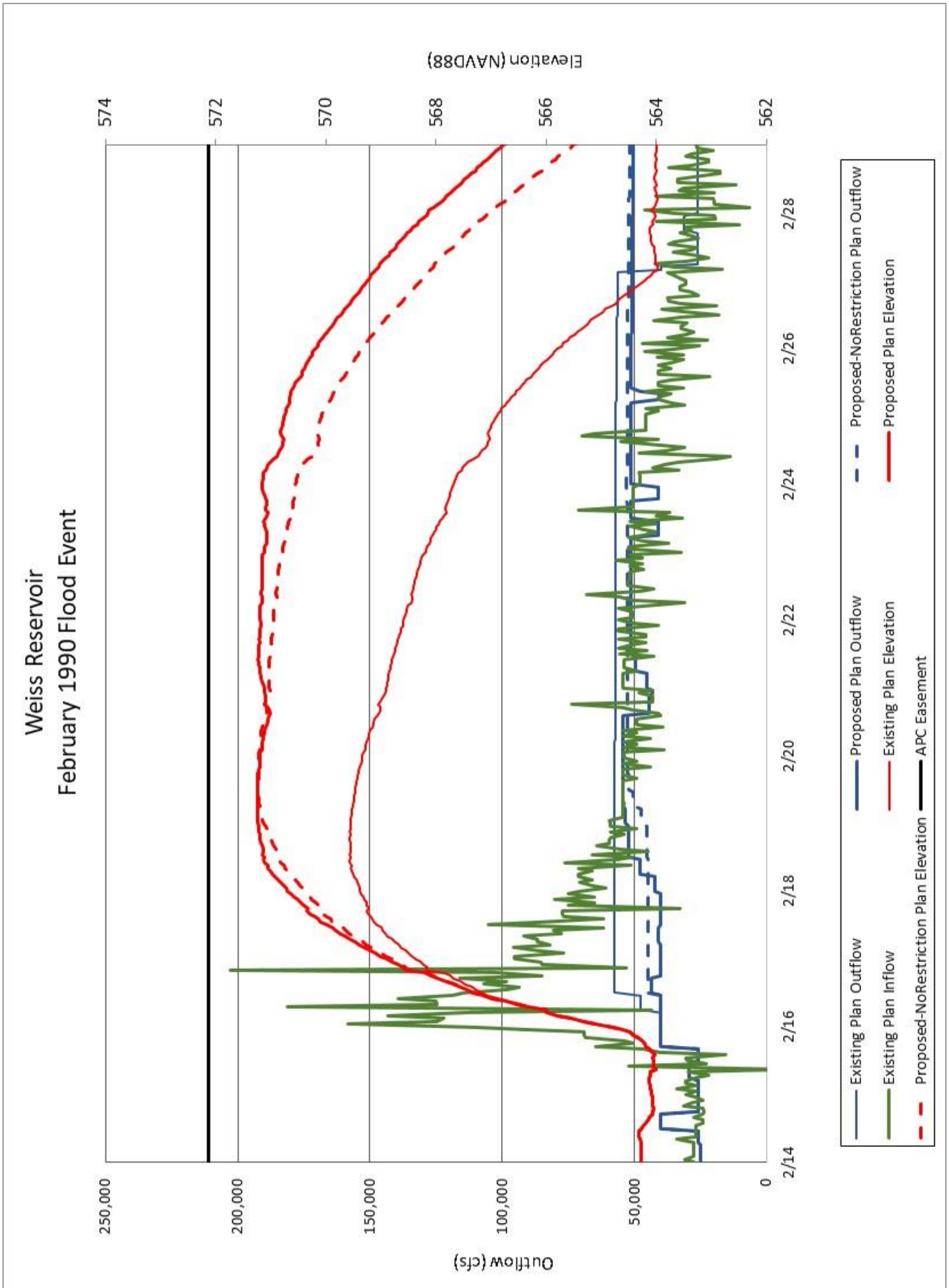
Comparison of Peak Elevations
February 1990 Event

Model Alternative	Weiss (ft NAVD88)	Gadsden (ft NGVD29)	Logan Martin (ft NAVD88)	Childersburg (ft NGVD29)
BASE	569.57	516.17	475.18	405.69
PROPOSED (NO CUT)	571.24	514.98	472.08	405.35
PROPOSED	571.24	514.56	471.92	405.35

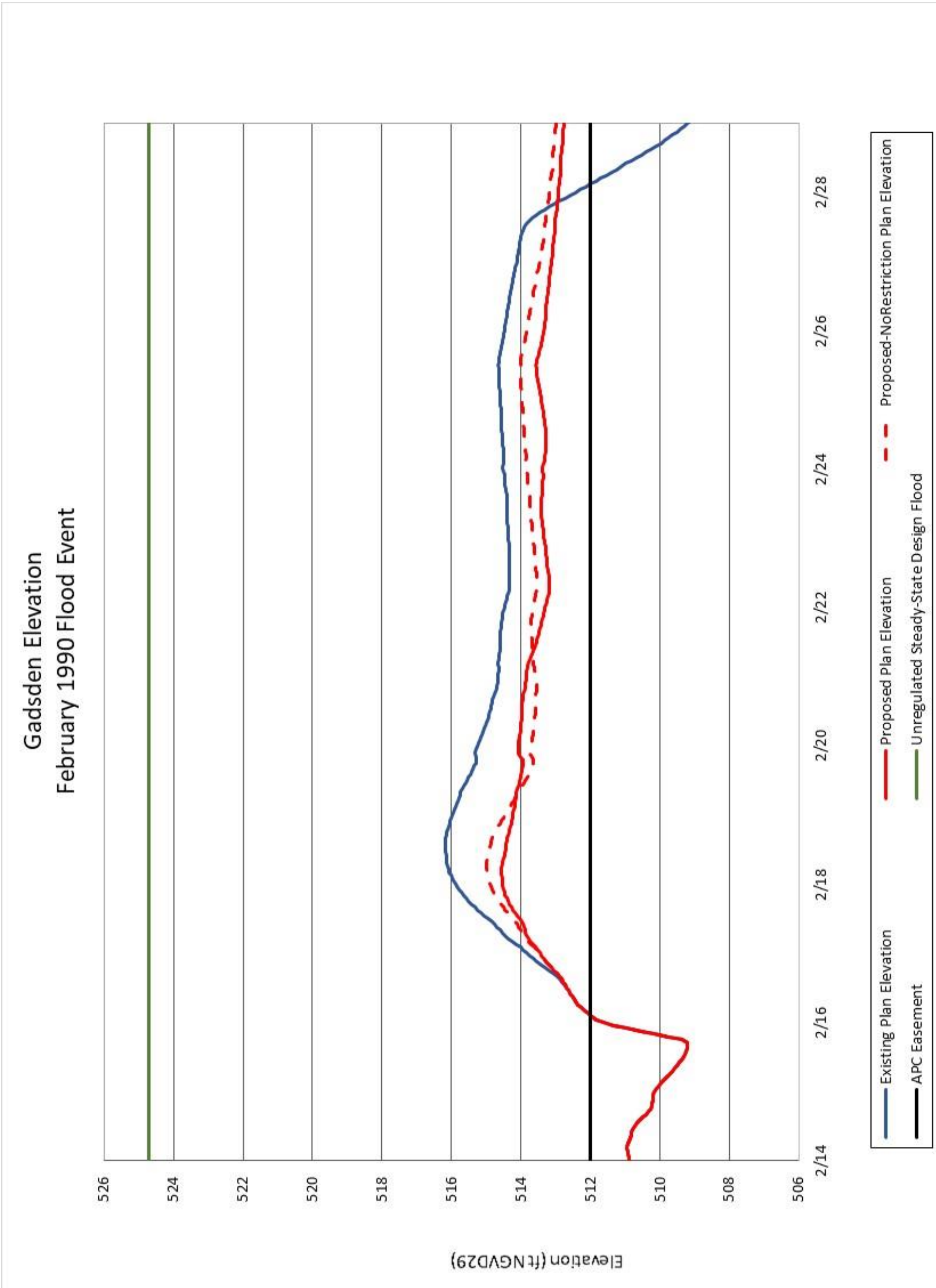
February 1990 Flood Event
Lookback Elevations

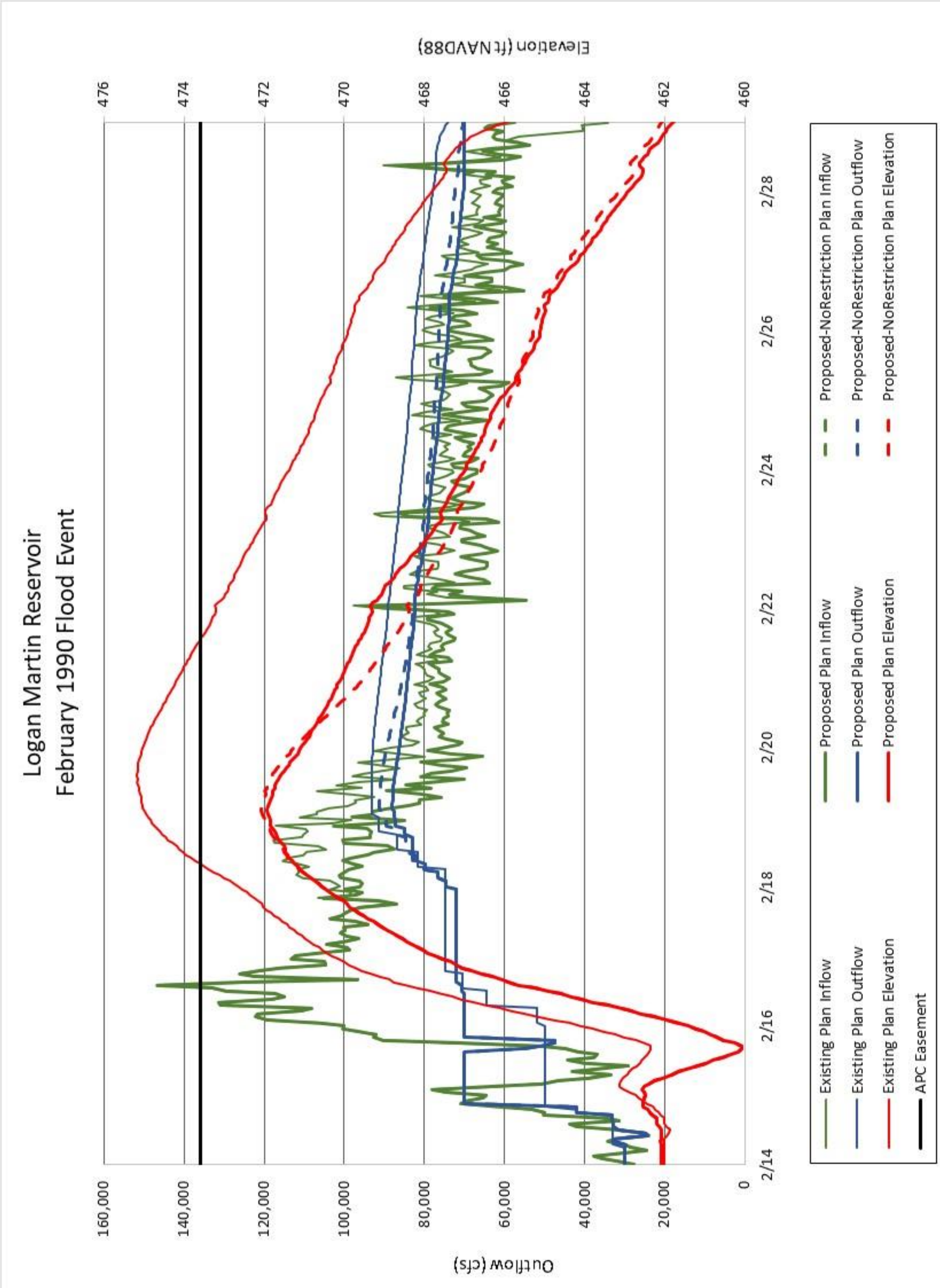
	Base	Proposed
Weiss	564.28*	564.28*
Henry	507.18	507.18
Logan	461.71*	462.09
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

*indicates a historical elevation

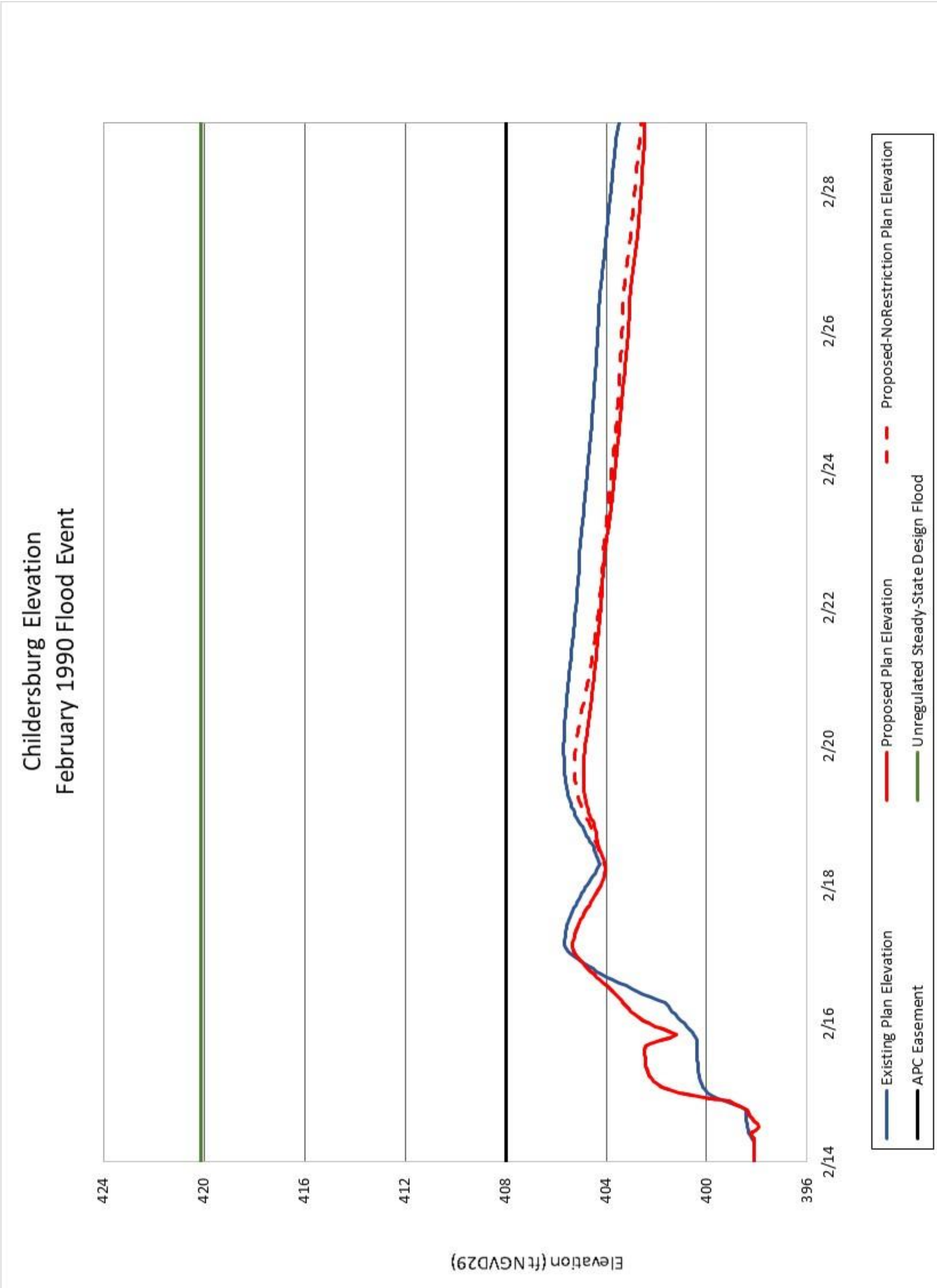


Weiss Reservoir
February 1990 Flood Event
Outflow (cfs)
Elevation (NAVD88)
250,000
200,000
150,000
100,000
50,000
0
574
572
570
568
566
564
562
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Outflow
Existing Plan Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation


Gadsden Elevation
February 1990 Flood Event
Elevation (ft NGVD29)
526
524
522
520
518
516
514
512
510
508
506
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood



Logan Martin Reservoir
February 1990 Flood Event
Outflow (cfs)
Elevation (ft NAVD88)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
476
474
472
470
468
466
464
462
460
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation



Childersburg Elevation
February 1990 Flood Event
Elevation (ft NGVD29)
424
420
416
412
408
404
400
396
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

March 1990

The March 1990 event was a major historical event with a frequency ranging from 5-year to 17-year at different locations on the Coosa River. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from both Proposed alternatives show no increase in flooding at the downstream locations.

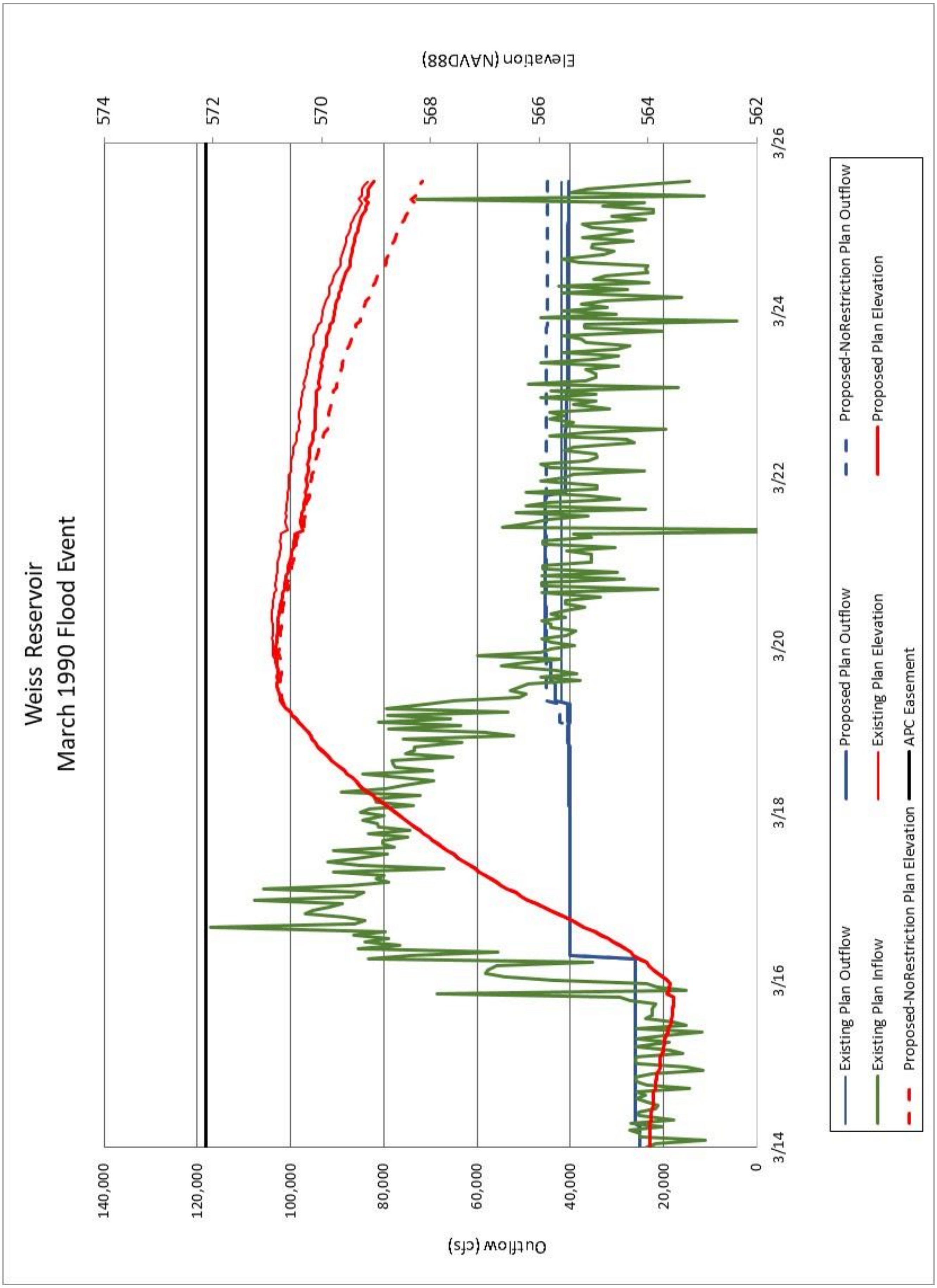
Comparison of Peak Elevations
March 1990 Event

Model Alternative	**Weiss** (ft NAVD88)	**Gadsden** (ft NGVD29)	**Logan Martin** (ft NAVD88)	**Childersburg** (ft NGVD29)
BASE	570.91	514.41	472.56	405.93
PROPOSED (NO CUT)	570.80	514.40	472.08	405.49
PROPOSED	570.85	514.40	472.08	405.49

March 1990 Flood Event
Lookback Elevations

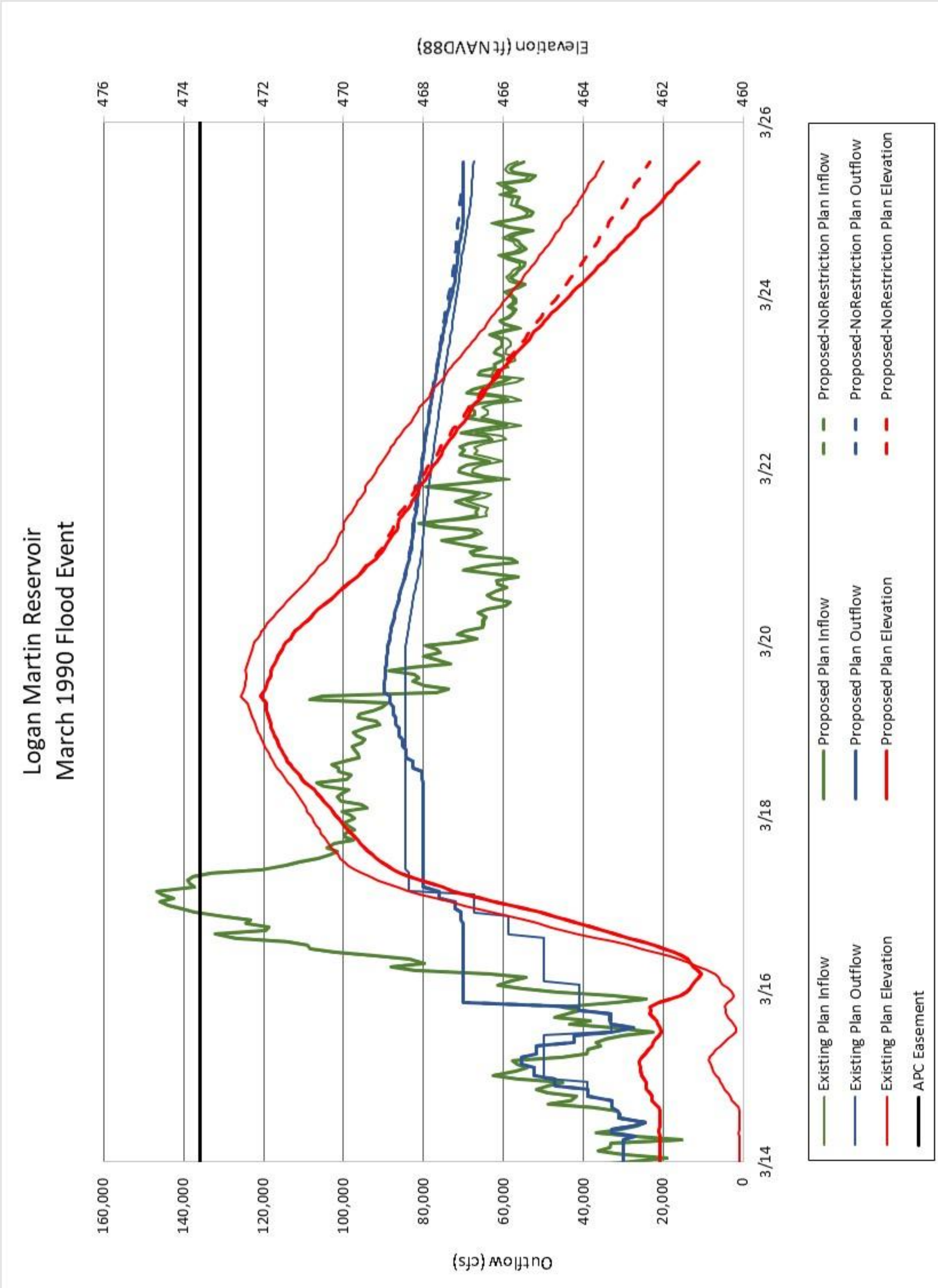
	Base	Proposed
Weiss	563.97*	563.97*
Henry	507.18	507.18
Logan	460.09	462.09
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

*indicates a historical elevation



Weiss Reservoir
March 1990 Flood Event
Outflow (cfs)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Elevation (NAVD88)
574
572
570
568
566
564
562
3/14
3/16
3/18
3/20
3/22
3/24
3/26
Existing Plan Outflow
Existing Plan Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation


Gadsden Elevation
March 1990 Flood Event
Elevation (ft NGVD29)
526
524
522
520
518
516
514
512
510
508
506
3/14
3/16
3/18
3/20
3/22
3/24
3/26
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood


Logan Martin Reservoir
March 1990 Flood Event
Outflow (cfs)
Elevation (ft NAVD88)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
476
474
472
470
468
466
464
462
460
3/14
3/16
3/18
3/20
3/22
3/24
3/26
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation

Childersburg Elevation
March 1990 Flood Event
Elevation (ft NGVD29)
424
420
416
412
408
404
400
396
3/14
3/16
3/18
3/20
3/22
3/24
3/26
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

October 1995

The October 1995 event was a minor historical event with a 5-year frequency at different locations on the Coosa River. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from both Proposed alternatives show no increase in flooding at the downstream locations. The 0.03 ft increase at Gadsden should be considered within the margin of error for the RTS input data.

Comparison of Peak Elevations

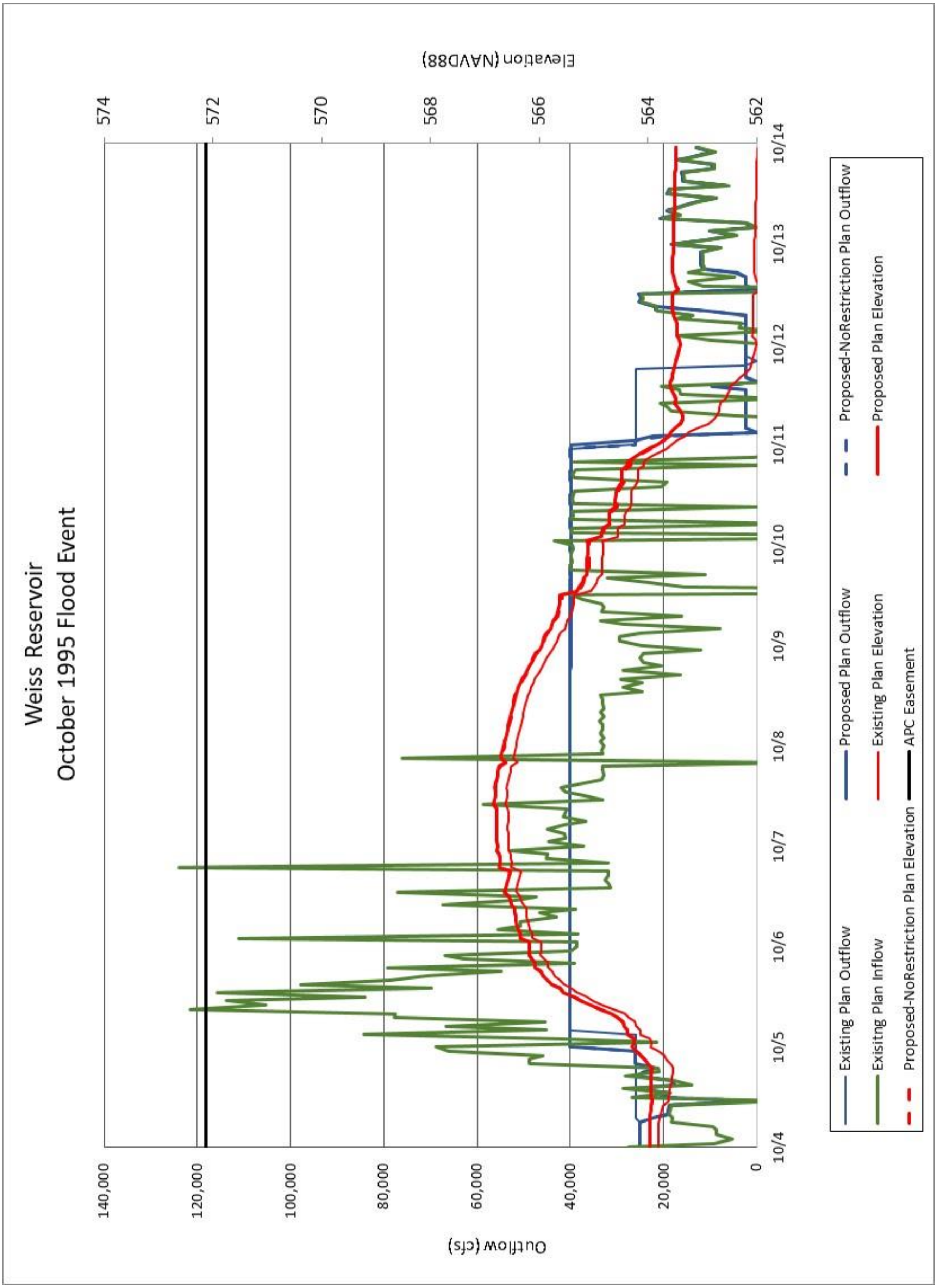
October 1995 Event

Model Alternative	**Weiss** (ft NAVD88)	**Gadsden** (ft NGVD29)	**Logan Martin** (ft NAVD88)	**Childersburg** (ft NGVD29)
BASE	566.62	514.45	470.75	406.49
PROPOSED (NO CUT)	566.83	514.48	471.84	405.20
PROPOSED	566.84	514.48	471.84	405.20

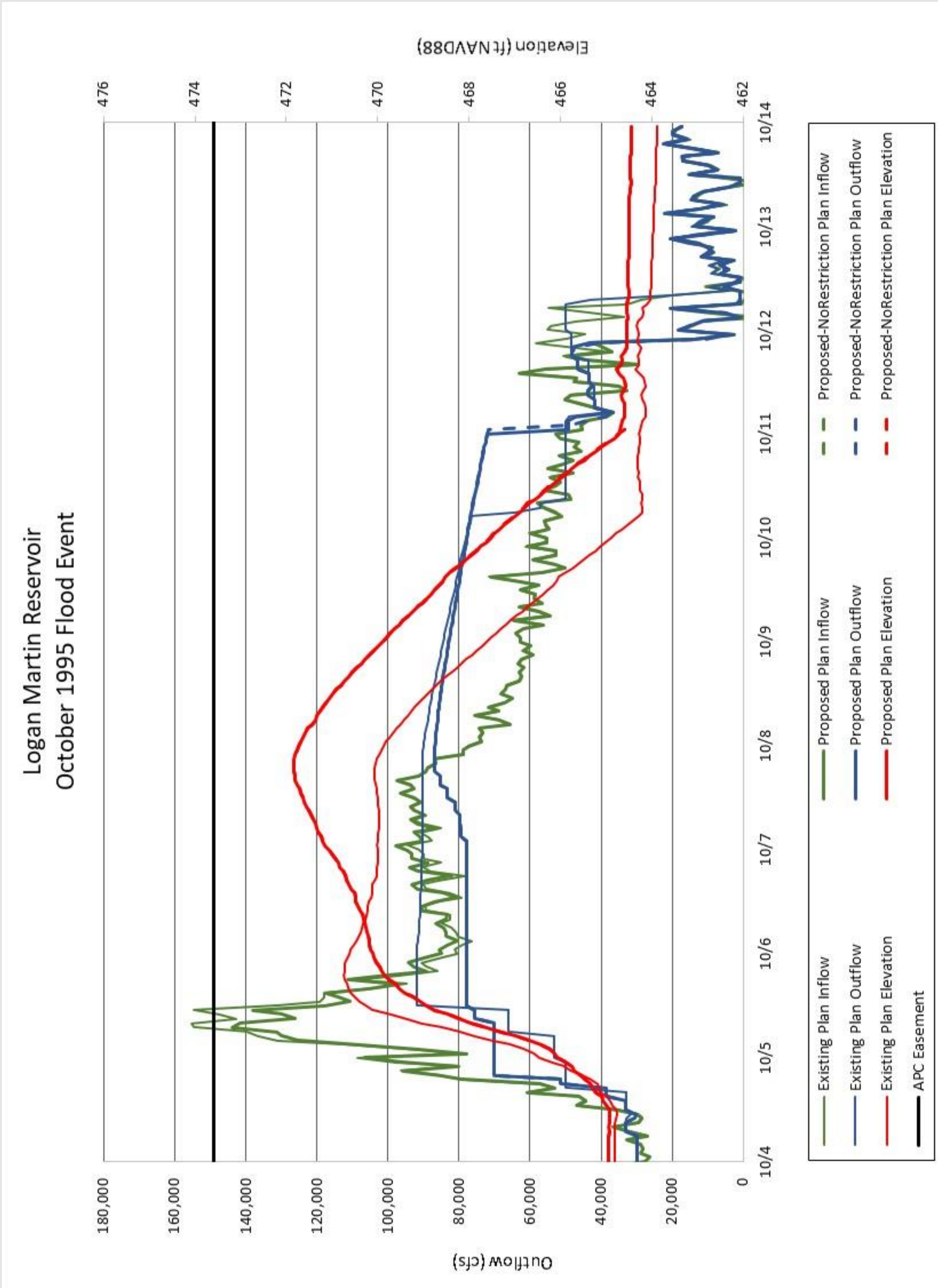
October 1995 Flood Event
Lookback Elevations

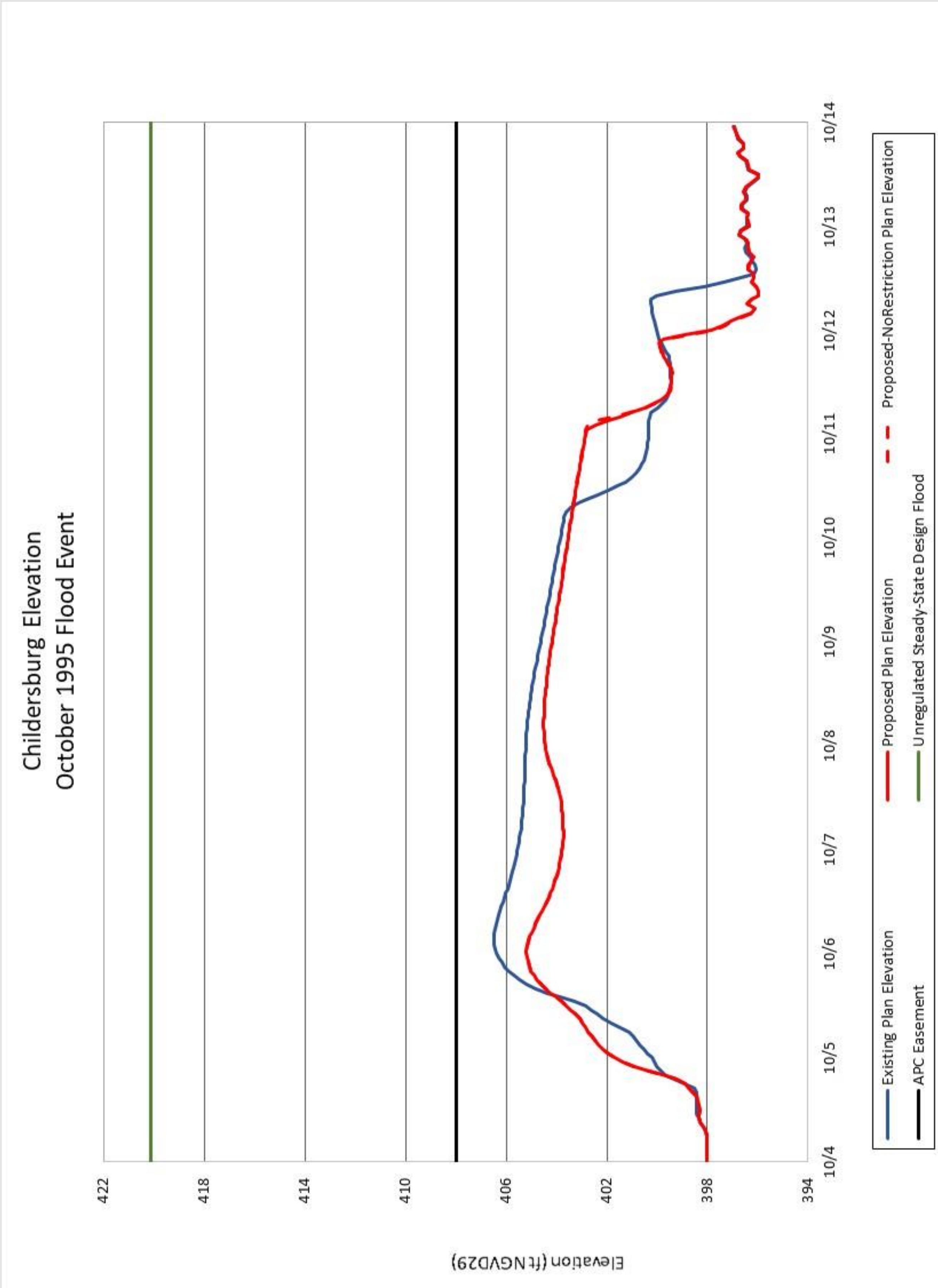
	Base	Proposed
Weiss	563.81*	563.97
Henry	508.13	508.13
Logan	464.81	464.94
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

*indicates a historical elevation


Weiss Reservoir
October 1995 Flood Event
Outflow (cfs)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Elevation (NAVD88)
562
564
566
568
570
572
574
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
10/12
10/13
10/14
Existing Plan Outflow
Exisitng Plan Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation


Gadsden Elevation
October 1995 Flood Event
Elevation (ft NGVD29)
527
522
517
512
507
502
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
10/12
10/13
10/14
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood


Logan Martin Reservoir
October 1995 Flood Event
Outflow (cfs)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
Elevation (ft NAVD88)
462
464
466
468
470
472
474
476
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
10/12
10/13
10/14
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation


Childersburg Elevation
October 1995 Flood Event
Elevation (ft NGVD29)
422
418
414
410
406
402
398
394
10/4
10/5
10/6
10/7
10/8
10/9
10/10
10/11
10/12
10/13
10/14
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

May 2003

The May 2003 event was a smaller historical event with a frequency ranging from 5-year to 20-year at different locations on the Coosa River. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from both Proposed alternatives show no increase in flooding at the downstream locations.

Comparison of Peak Elevations

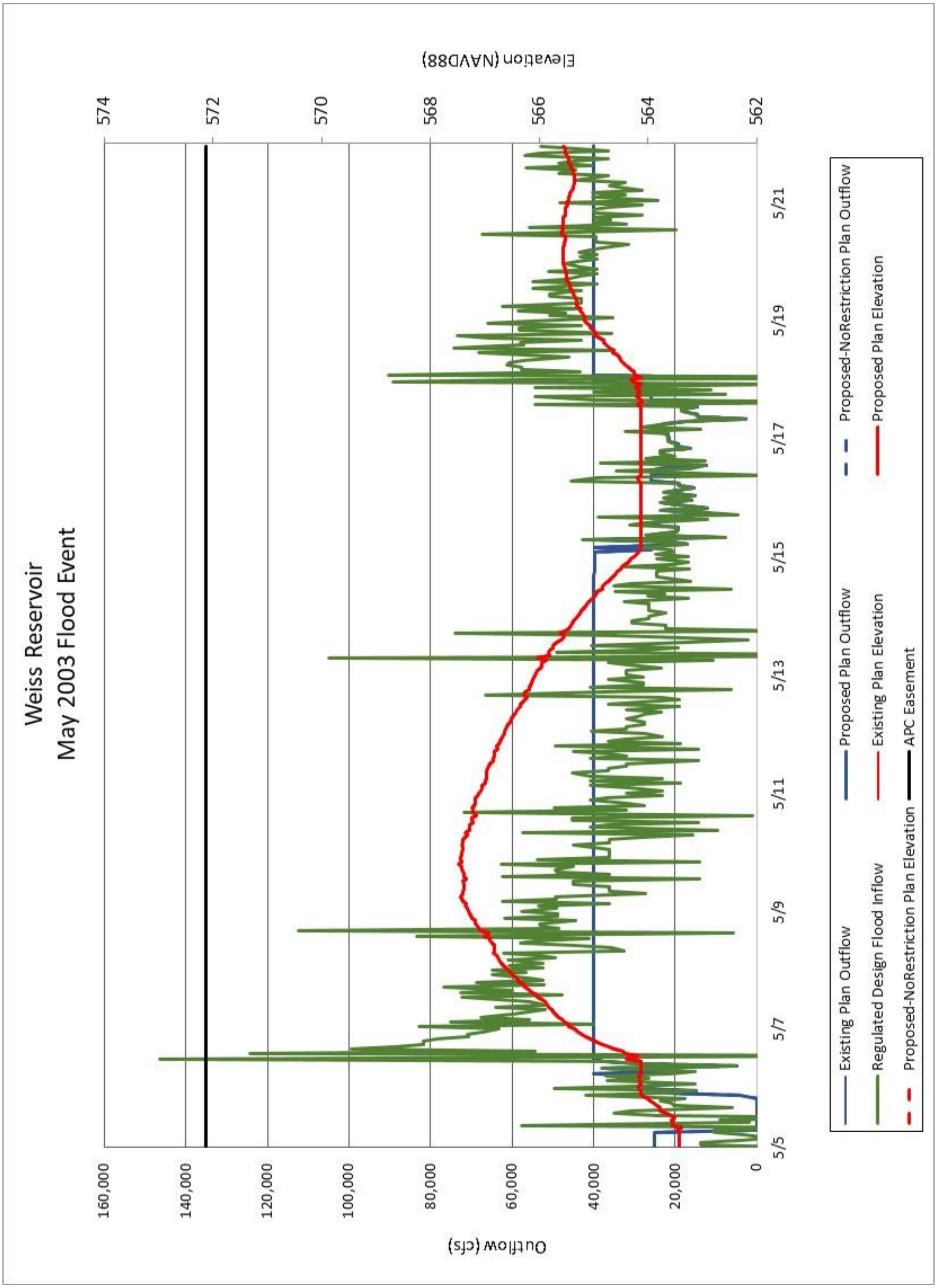
May 2003 Event

Model Alternative	**Weiss** (ft NAVD88)	**Gadsden** (ft NGVD29)	**Logan Martin** (ft NAVD88)	**Childersburg** (ft NGVD29)
BASE	567.48	511.74	472.65	406.79
PROPOSED (NO CUT)	567.48	511.74	471.75	406.72
PROPOSED	567.48	511.74	471.75	406.72

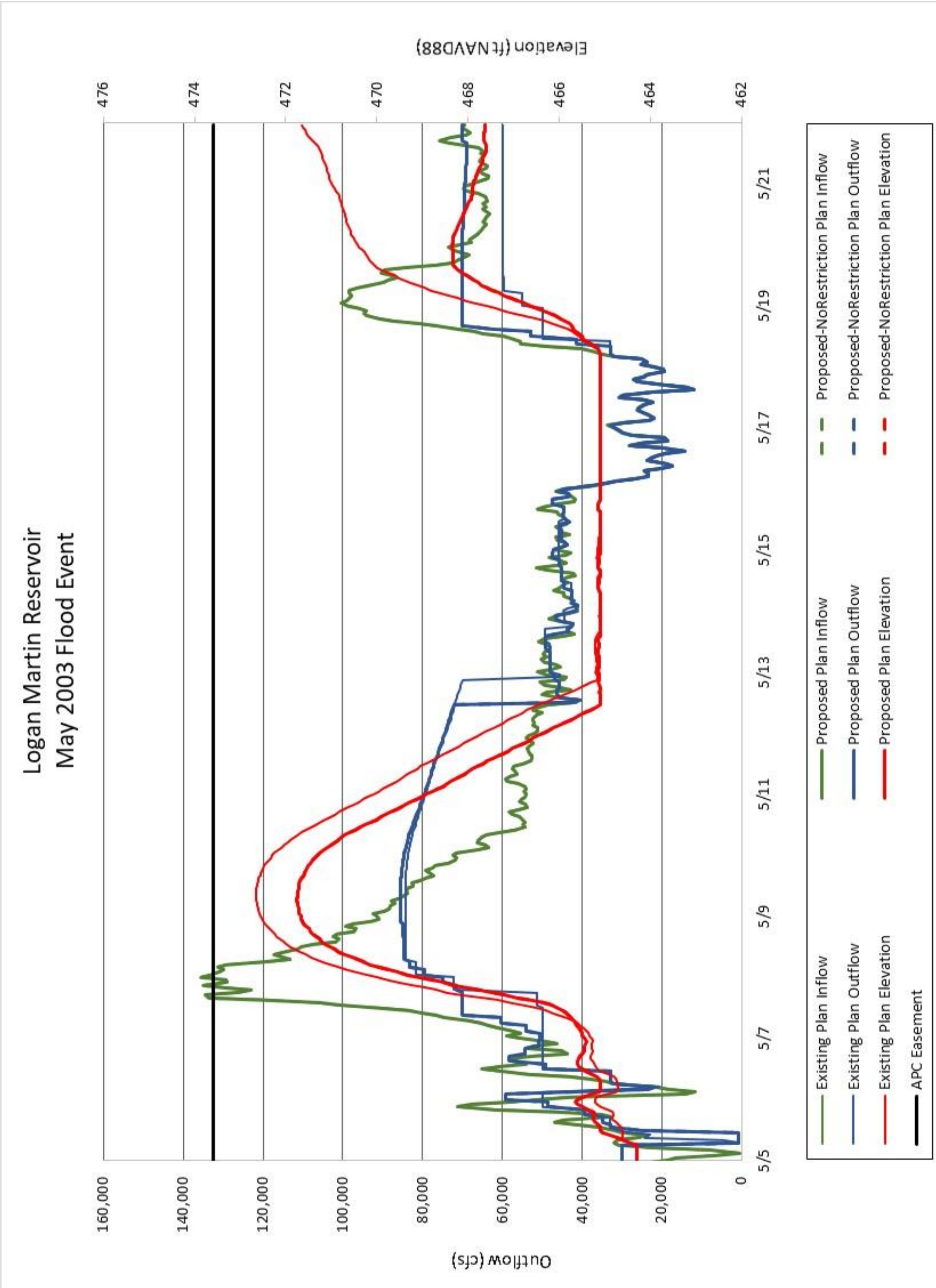
May 2003 Flood Event
Lookback Elevations

	Base	Proposed
Weiss	563.43*	563.43*
Henry	507.69*	507.69*
Logan	464.29*	464.29*
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

*indicates a historical elevation


Weiss Reservoir
May 2003 Flood Event
Outflow (cfs)
Elevation (NAVD88)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
574
572
570
568
566
564
562
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Outflow
Regulated Design Flood Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation


Gadsden Elevation
May 2003 Flood Event
Elevation (ft NGVD29)
527
522
517
512
507
502
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood


Logan Martin Reservoir
May 2003 Flood Event
Outflow (cfs)
Elevation (ft NAVD88)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
462
464
466
468
470
472
474
476
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation


Childersburg Elevation
May 2003 Flood Event
Elevation (ft NGVD29)
422
418
414
410
406
402
398
394
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

May 2003 Back to Back

The May 2003 event inflows at all model locations were increased by 30% to develop the back to back event. The resulting inflows represent an event with a frequency ranging from 15-year to greater than 150-year at different locations on the Coosa River. Consistent with the 2005 study, the modeled starting pool elevations were determined to be the higher of historical or guide curve elevations for each alternative. Results from both Proposed alternatives show no increase in flooding at the downstream locations.

Comparison of Peak Elevations

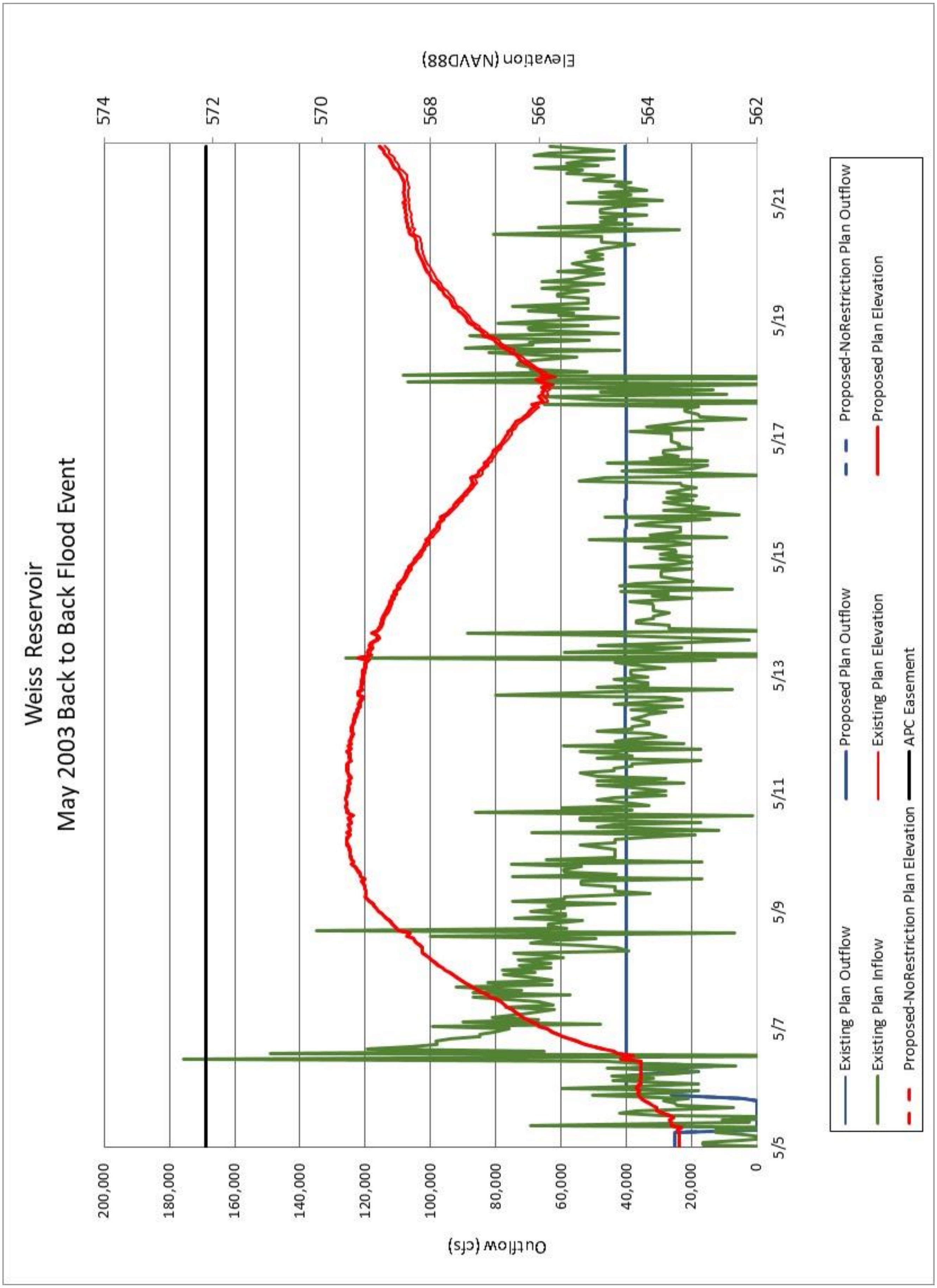
May 2003 Back to Back Event

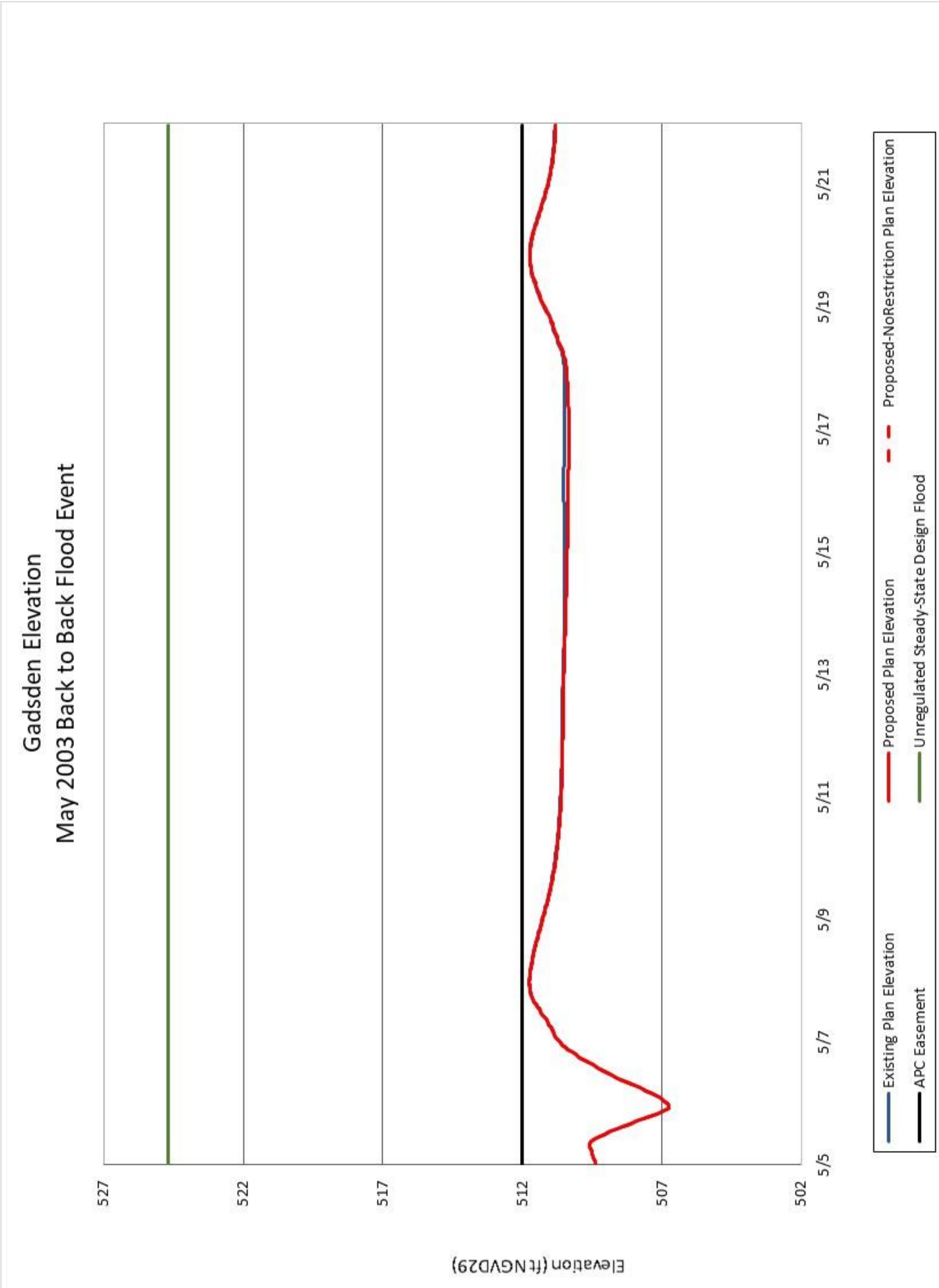
Model Alternative	**Weiss** (ft NAVD88)	**Gadsden** (ft NGVD29)	**Logan Martin** (ft NAVD88)	**Childersburg** (ft NGVD29)
BASE	569.54	511.75	473.80	409.06
PROPOSED (NO CUT)	569.57	511.74	472.75	408.57
PROPOSED	569.57	511.74	473.00	408.66

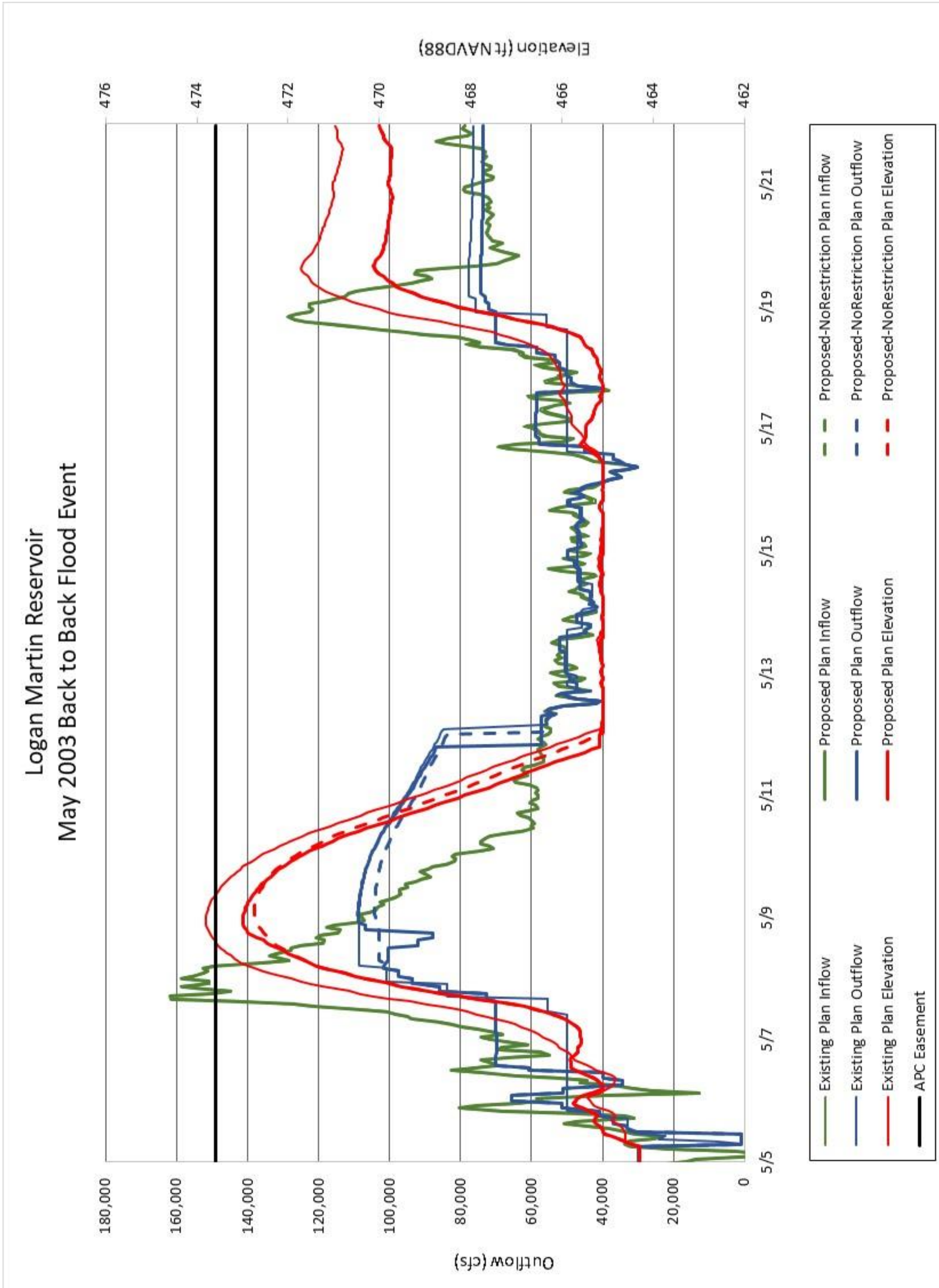
May 2003 Back to Back Flood Event Lookback Elevations

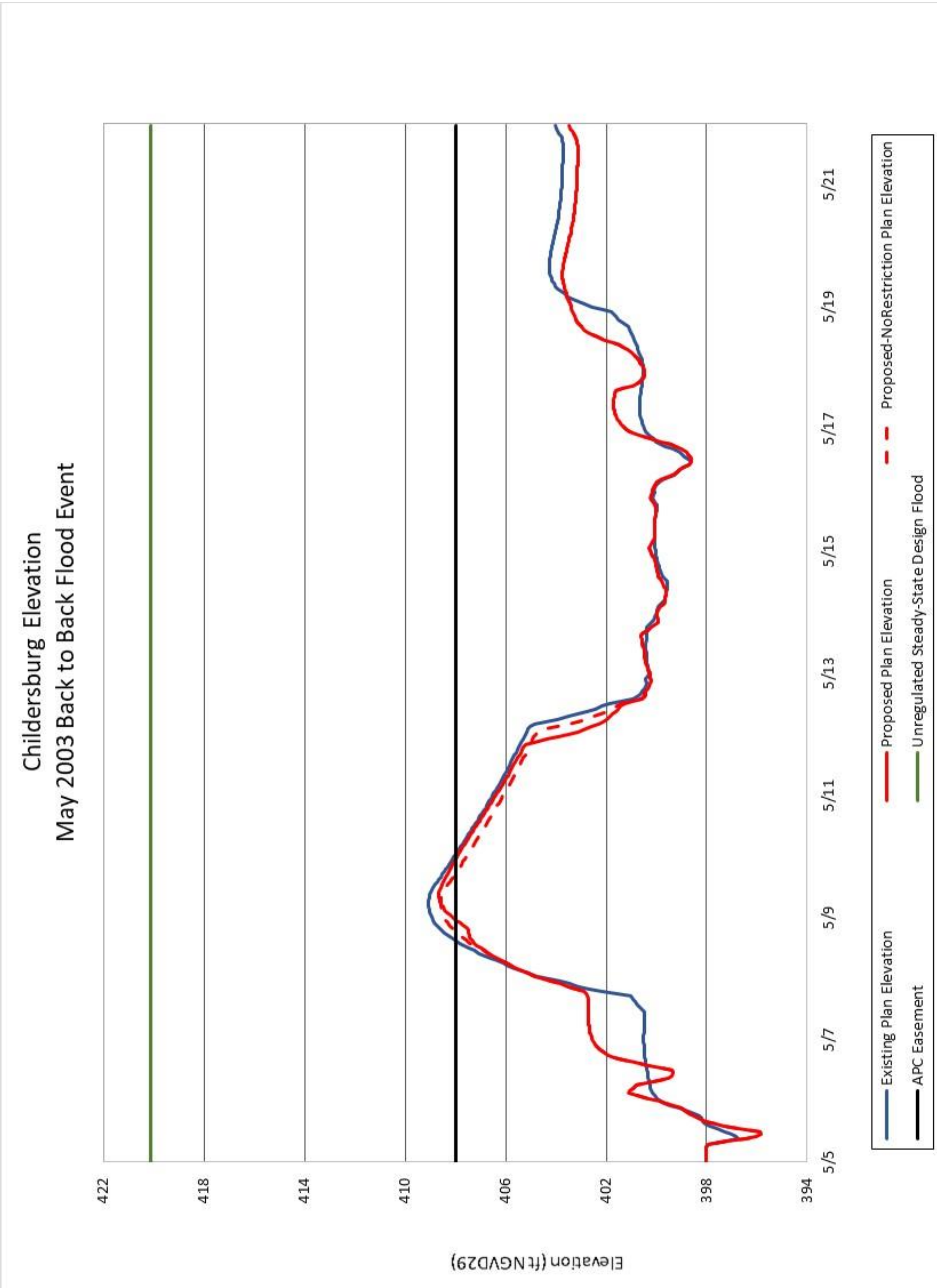
	Base	Proposed
Weiss	563.43*	563.43*
Henry	507.69*	507.69*
Logan	464.29*	464.29*
Lay	396.13	396.13
Mitchell	312.08	312.08
Jordan	252.08	252.08
Bouldin	252.08	252.08

*indicates a historical elevation


Weiss Reservoir
May 2003 Back to Back Flood Event
Outflow (cfs)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Elevation (NAVD88)
574
572
570
568
566
564
562
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Outflow
Existing Plan Inflow
Proposed-NoRestriction Plan Elevation
Proposed Plan Outflow
Existing Plan Elevation
APC Easement
Proposed-NoRestriction Plan Outflow
Proposed Plan Elevation


Gadsden Elevation
May 2003 Back to Back Flood Event
Elevation (ft NGVD29)
527
522
517
512
507
502
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood


Logan Martin Reservoir
May 2003 Back to Back Flood Event
Outflow (cfs)
Elevation (ft NAVD88)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
476
474
472
470
468
466
464
462
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Inflow
Existing Plan Outflow
Existing Plan Elevation
APC Easement
Proposed Plan Inflow
Proposed Plan Outflow
Proposed Plan Elevation
Proposed-NoRestriction Plan Inflow
Proposed-NoRestriction Plan Outflow
Proposed-NoRestriction Plan Elevation


Childersburg Elevation
May 2003 Back to Back Flood Event
Elevation (ft NGVD29)
422
418
414
410
406
402
398
394
5/5
5/7
5/9
5/11
5/13
5/15
5/17
5/19
5/21
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

Standard Project Flood

Inflows for the Standard Project Flood event at Weiss and Logan Martin were assumed to be 50% of the PMF inflow informally modeled for this study. As flows downstream of the project in question were not determined in updated studies, the proposed rules operating for a downstream control point were not modeled. The proposed operation to lower Logan Martin to 460' MSL was also removed. These assumptions result in a conservatively simplified model.

Starting pool elevations were 564.12' MSL at Weiss and 460.09' MSL for the Base alternative and 462.09' MSL for the Proposed alternative at Logan Martin, consistent with previous PMF evaluations.

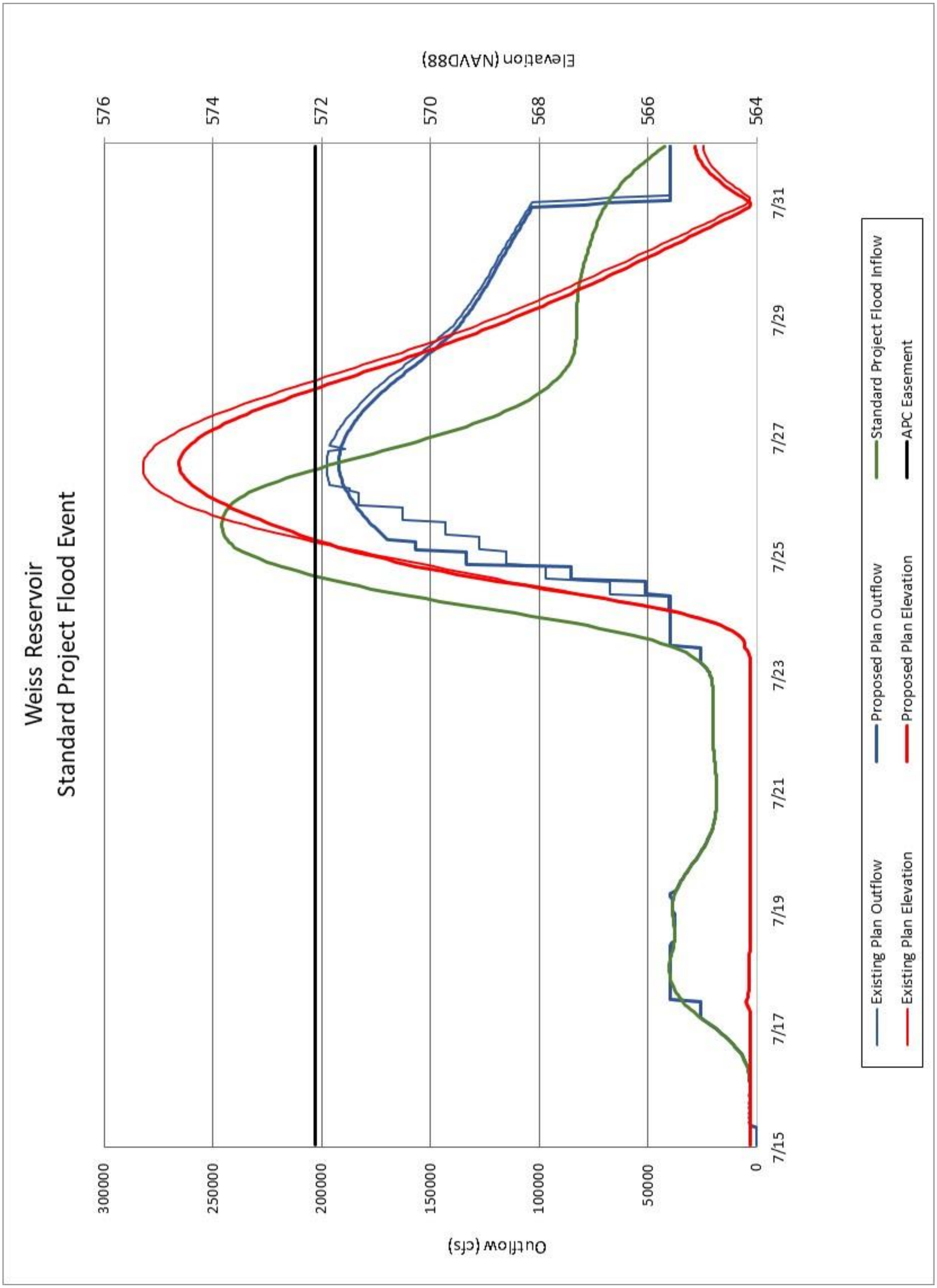
Routing the SPF inflows through Weiss and Logan Martin was done at the request of the USACE and does not represent official SPF data for APC projects.

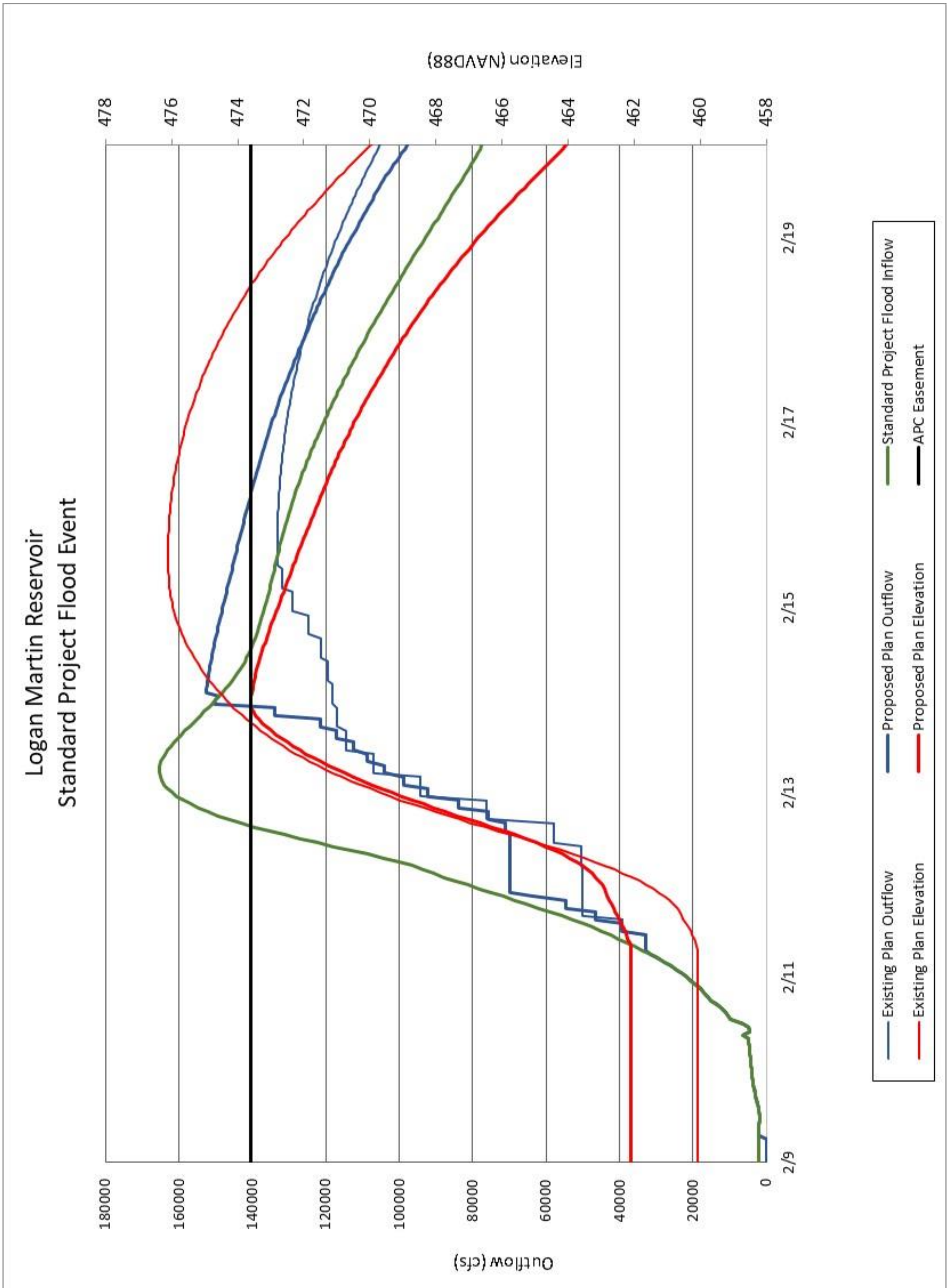
Comparison of Peak Elevations
Standard Project Flood Event

Model Alternative	Weiss (ft NAVD88)	Logan Martin (ft NAVD88)
BASE	575.29	476.11
PROPOSED	574.62	473.59

Comparison of Peak Discharges
Standard Project Flood Event

Model Alternative	Weiss (cfs)	Logan Martin (cfs)
BASE	197,700	133,200
PROPOSED	192,200	152,500


Weiss Reservoir
Standard Project Flood Event
Outflow (cfs)
300000
250000
200000
150000
100000
50000
0
Elevation (NAVD88)
576
574
572
570
568
566
564
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Existing Plan Outflow
Existing Plan Elevation
Proposed Plan Outflow
Proposed Plan Elevation
Standard Project Flood Inflow
APC Easement



Logan Martin Reservoir
Standard Project Flood Event
Outflow (cfs)
Elevation (NAVD88)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
478
476
474
472
470
468
466
464
462
460
458
2/9
2/11
2/13
2/15
2/17
2/19
Existing Plan Outflow
Existing Plan Elevation
Proposed Plan Outflow
Proposed Plan Elevation
Standard Project Flood Inflow
APC Easement

Probable Maximum Flood

Inflow hydrographs for the Probable Maximum Flood events at Weiss and Logan Martin were determined in previous evaluations. Flows downstream of the evaluated projects were not determined in the updated PMF re-studies. Therefore, the proposed rules operating for a downstream control point were not modeled. The proposed operation to lower Logan Martin to 460' MSL was also removed. These assumptions result in a conservatively simplified model.

Starting pool elevations were 564.12' MSL at Weiss and 460.09' MSL for the Base alternative and 462.09' MSL for the Proposed alternative at Logan Martin, consistent with previous PMF evaluations.

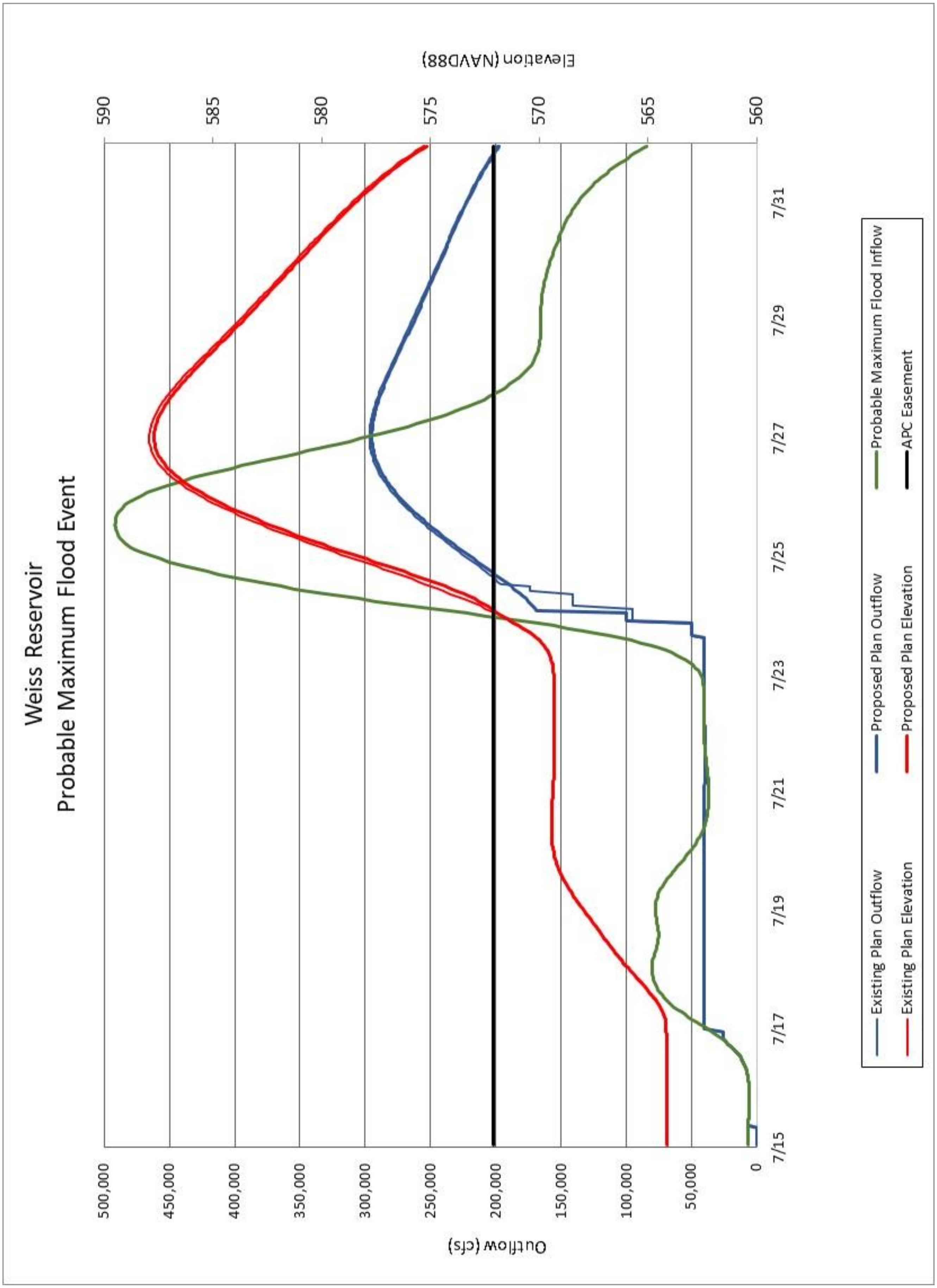
Routing the PMF inflows through Weiss and Logan Martin was done at the request of the USACE and does not represent official PMF data for APC projects.

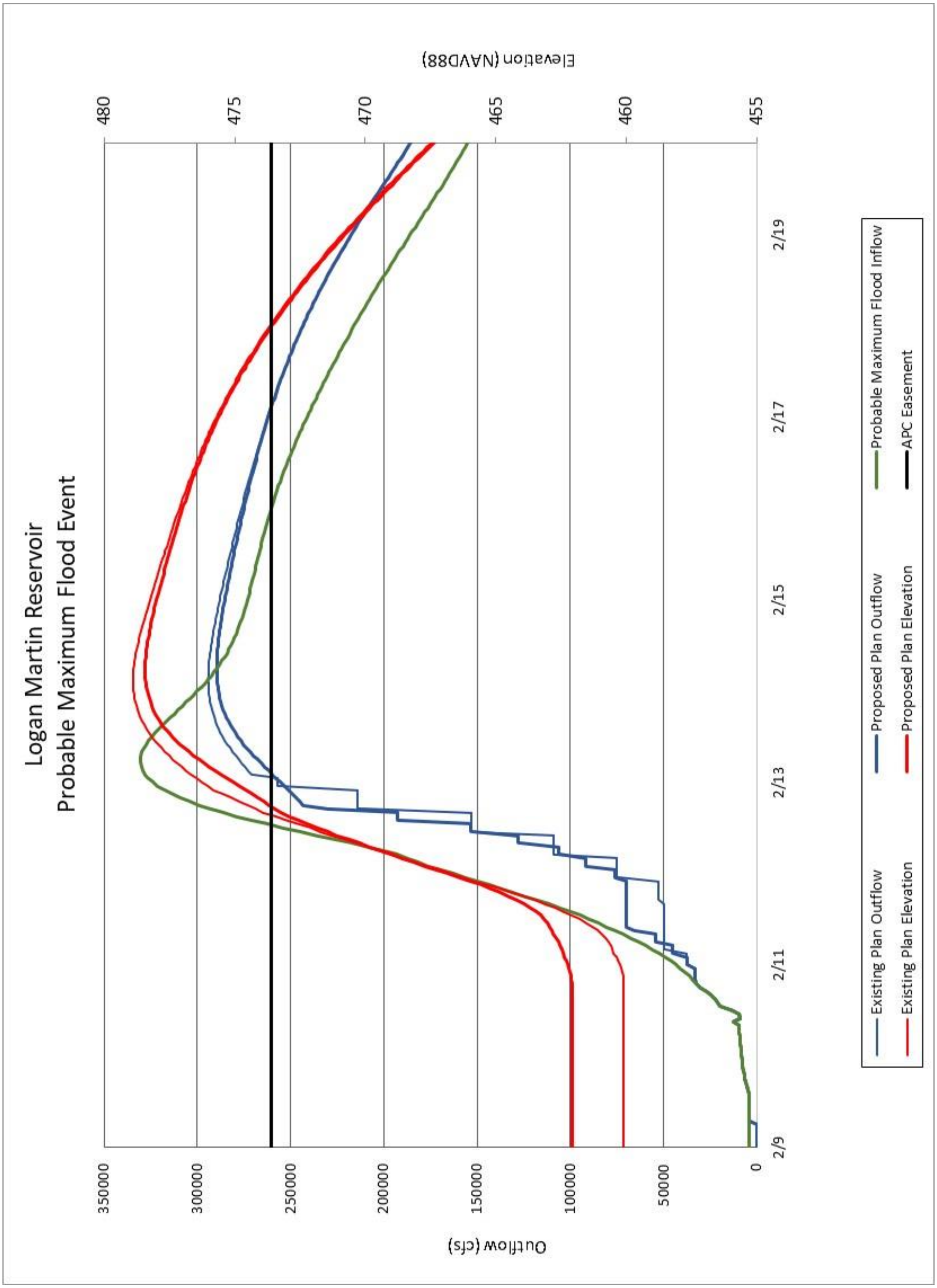
Comparison of Peak Elevations
Probable Maximum Flood Event

Model Alternative	**Weiss** (ft NAVD88)	**Logan Martin** (ft NAVD88)
BASE	587.94	478.90
PROPOSED	587.71	478.43

Comparison of Peak Discharges
Probable Maximum Flood Event

Model Alternative	**Weiss** (cfs)	**Logan Martin** (cfs)
BASE	296,700	294,200
PROPOSED	294,800	289,600


Weiss Reservoir
Probable Maximum Flood Event
Outflow (cfs)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Elevation (NAVD88)
590
585
580
575
570
565
560
7/15
7/17
7/19
7/21
7/23
7/25
7/27
7/29
7/31
Existing Plan Outflow
Proposed Plan Outflow
Probable Maximum Flood Inflow
Existing Plan Elevation
Proposed Plan Elevation
APC Easement

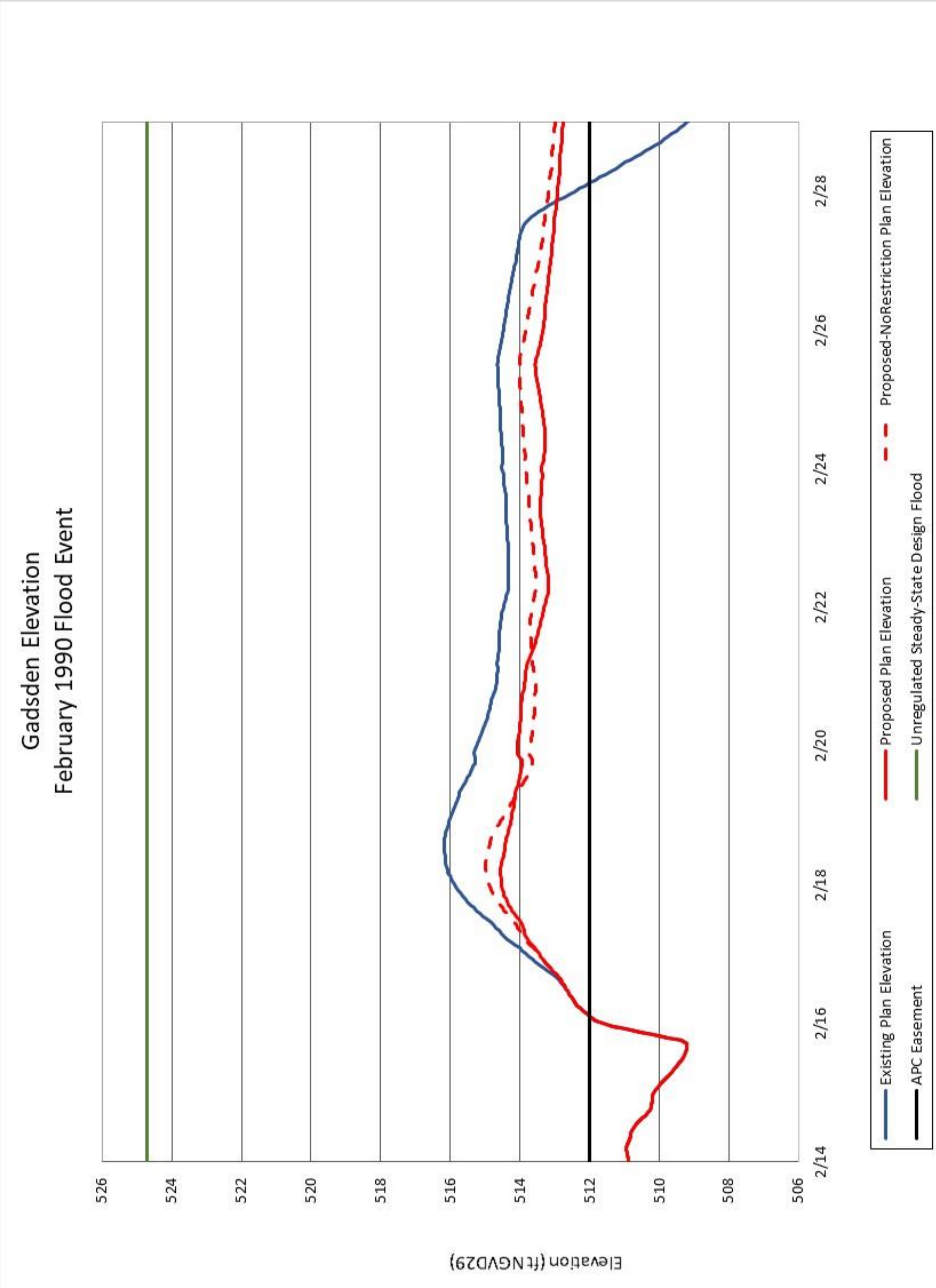


Logan Martin Reservoir
Probable Maximum Flood Event
Outflow (cfs)
350000
300000
250000
200000
150000
100000
50000
0
Elevation (NAVD88)
480
475
470
465
460
455
2/9
2/11
2/13
2/15
2/17
2/19
Existing Plan Outflow
Existing Plan Elevation
Proposed Plan Outflow
Proposed Plan Elevation
Probable Maximum Flood Inflow
APC Easement

Rationale for Surcharge Cutback

One of the proposals for flood control operations is to reduce surcharge operations under certain conditions. These operations are defined in steps 7 and 5, respectively, of the proposed Weiss and Logan Martin Flood Control Regulation Schedule. Modeling has shown that under certain conditions, temporarily reducing the required surcharge releases up to 50% can benefit downstream stages. These steps are not required steps, but rather to be implemented when real time operations show a benefit from those cutbacks. Generally, this surcharge cutback works best during smaller events to help minimize flooding at downstream locations.

The best way to understand this rationale is to see how it helps under certain modeling conditions. During the 1990 flood event, at these particular conditions, implementing the surcharge cutback resulted in a stage of 0.42 feet lower than under no-cutback conditions at the Gadsden gage. The graph on the following page illustrates the benefits of cutting back, when conditions warrant.



Gadsden Elevation
February 1990 Flood Event
Elevation (ft NGVD29)
526
524
522
520
518
516
514
512
510
508
506
2/14
2/16
2/18
2/20
2/22
2/24
2/26
2/28
Existing Plan Elevation
Proposed Plan Elevation
Proposed-NoRestriction Plan Elevation
APC Easement
Unregulated Steady-State Design Flood

Summary of Modeling Efforts

As can be seen in the report, modeling of these storms shows that APC easements are adequate to contain 100-year design flood with the control plan changes contained in this report. A small additional easement has already been acquired below Logan Martin Dam to accommodate plan changes. The Flood Frequency Analysis reviewed by the Corps, the USGS, and the Office of Water Resources during the CRFS was utilized. Additionally, modeling shows that changing the flood control guide curve is feasible from a flood control standpoint. The changes do not result in higher peak flood elevations. Because of the intense work done on the hourly HEC-ResSim model, Alabama Power will be incorporating these flow models into an operational model.

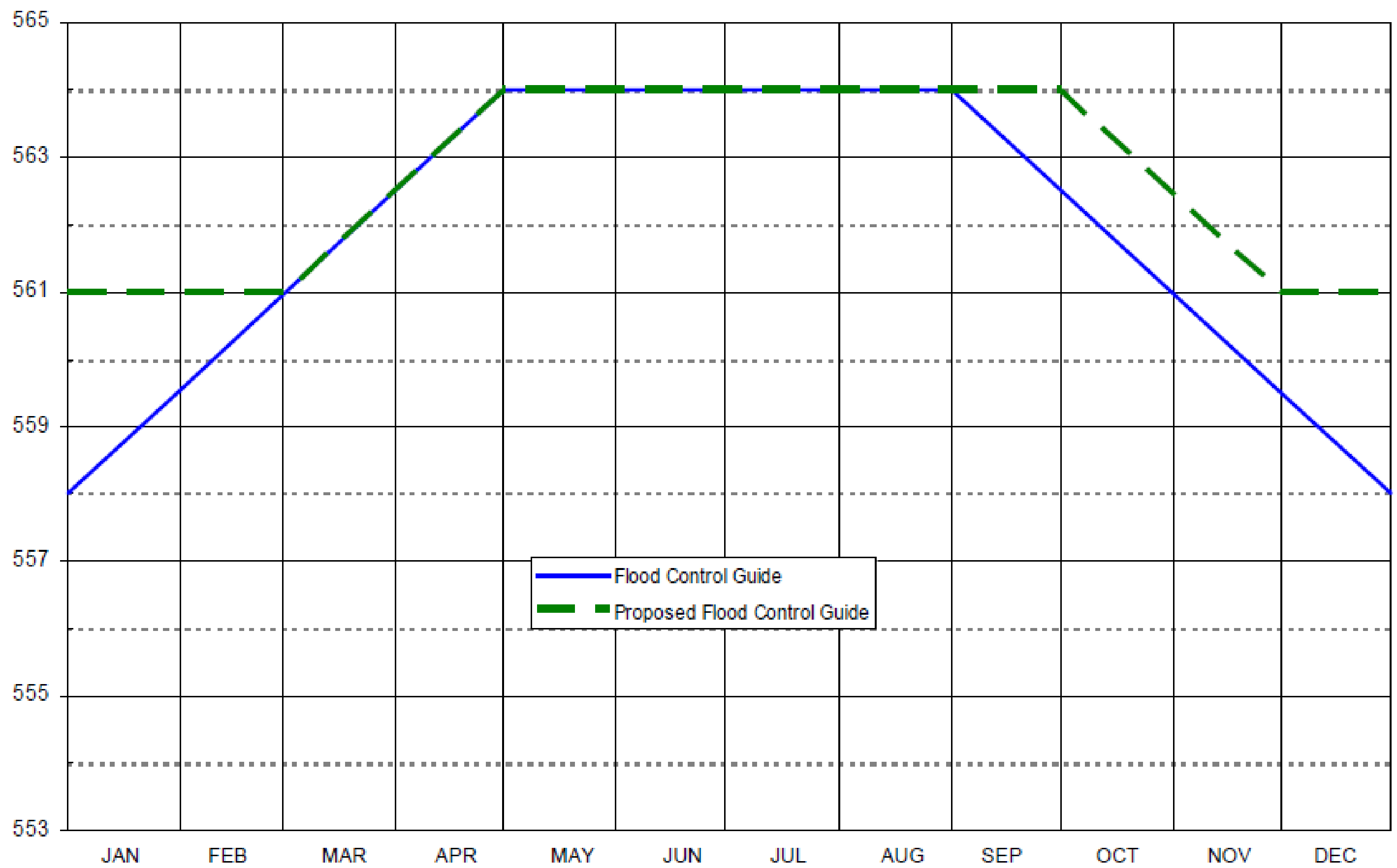
Appendix A

1. Proposed Weiss Flood Control Regulation Schedule (with changes denoted)
2. Weiss Reservoir Rule Curve (with proposed)
3. Proposed Weiss Surcharge Curve
4. Proposed Logan Martin Flood Control Regulation Schedule (with changes denoted)
5. Logan Martin Reservoir Rule Curve (with proposed)
6. Proposed Logan Martin Surcharge Curve

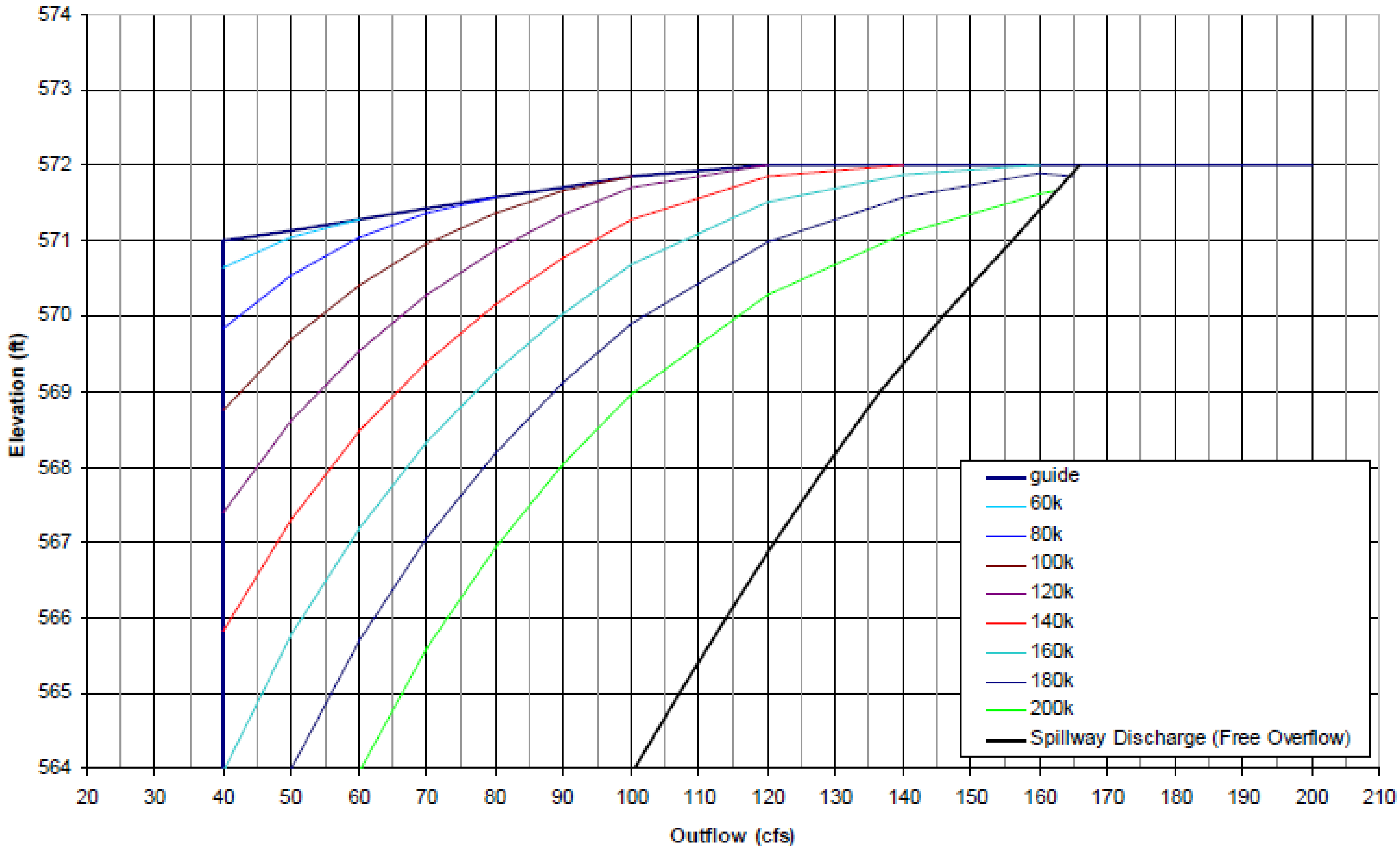
Proposed Weiss Flood Control Regulation Schedule

Rule	Condition	Outflow	Operation	Proposed Change
1	Below flood control guide	Ranging up to full discharge capacity of power plant	Operate power plant as required to satisfy normal system load requirements.	None
2	At flood control guide and below elev. 564.0 ft	Ranging up to full discharge capacity of power plant	Releases shall be made through power plant at rates up to continuous operation at plant capacity (3 units at full gate) as required to keep reservoir stage at or below flood control guide, as long as this level is below elevation 564.0 ft.	None
3	Above flood control guide and below elev. 564.0 ft	Full discharge capacity of power plant	Releases shall be made through power plant operating continuously at plant capacity (3 units at full gate) until reservoir stage: (a) Recedes to flood control guide after which rule 2 applies, or (b) Reaches elevation 564.0 ft after which rule 4 applies.	None
4	At elev. 564.0 ft	Ranging up to 40,000 cfs	Maintain reservoir stage at elevation 564.0 ft by passing the inflow up to 40,000 cfs. Releases will be made through the power plant operating continuously at plant capacity (3 units at full gate) supplemented by spillway discharge as required.	None
5	Rising above elev. 564.0 ft	40,000 cfs unless higher rate is specified by induced surcharge schedule	Maintain total discharge of 40,000 cfs by discharging through the power plant operating continuously at plant capacity (3 units at full gate) supplemented by spillway discharge as required. Continue this operation until: (a) Reservoir stage recedes to elev. 564.0 ft after which rule 4 applies, or, (b) Reservoir stage and rate of inflow are such that higher rate of outflow is required by induced surcharge schedule, in which case rule 6 applies.	None
6	Rising above elev. 564.0 ft with releases above 40,000 cfs specified by induced surcharge schedule	As specified by induced surcharge schedule	Operate according to induced surcharge schedule, passing the required outflow through the power plant and spillway.	**NEW SURCHARGE CURVES**
7	Stages downstream of Weiss exceed or are expected to exceed flood stage as a result of local inflows	Reduce up to 50% of surcharge schedule	Temporarily reduce the release prescribed by the plan, provided that the release will not be reduced below 50% of the amount required by the surcharge schedule and that the total addition of floodwaters stored in Weiss will not exceed a volume of 22,500 cfs-days.	**ENTIRELY NEW RULE**
8	Above elev. 564.0 ft and falling	As specified by induced surcharge schedule	When the reservoir level begins to fall maintain the gate openings in effect at time of peak reservoir stage and continue power plant discharge in effect at that time until reservoir level recedes to elevation 564.0 ft. When pool recedes to elevation 564.0 ft rule 4 applies.	None

WEISS RESERVOIR
RULE CURVE

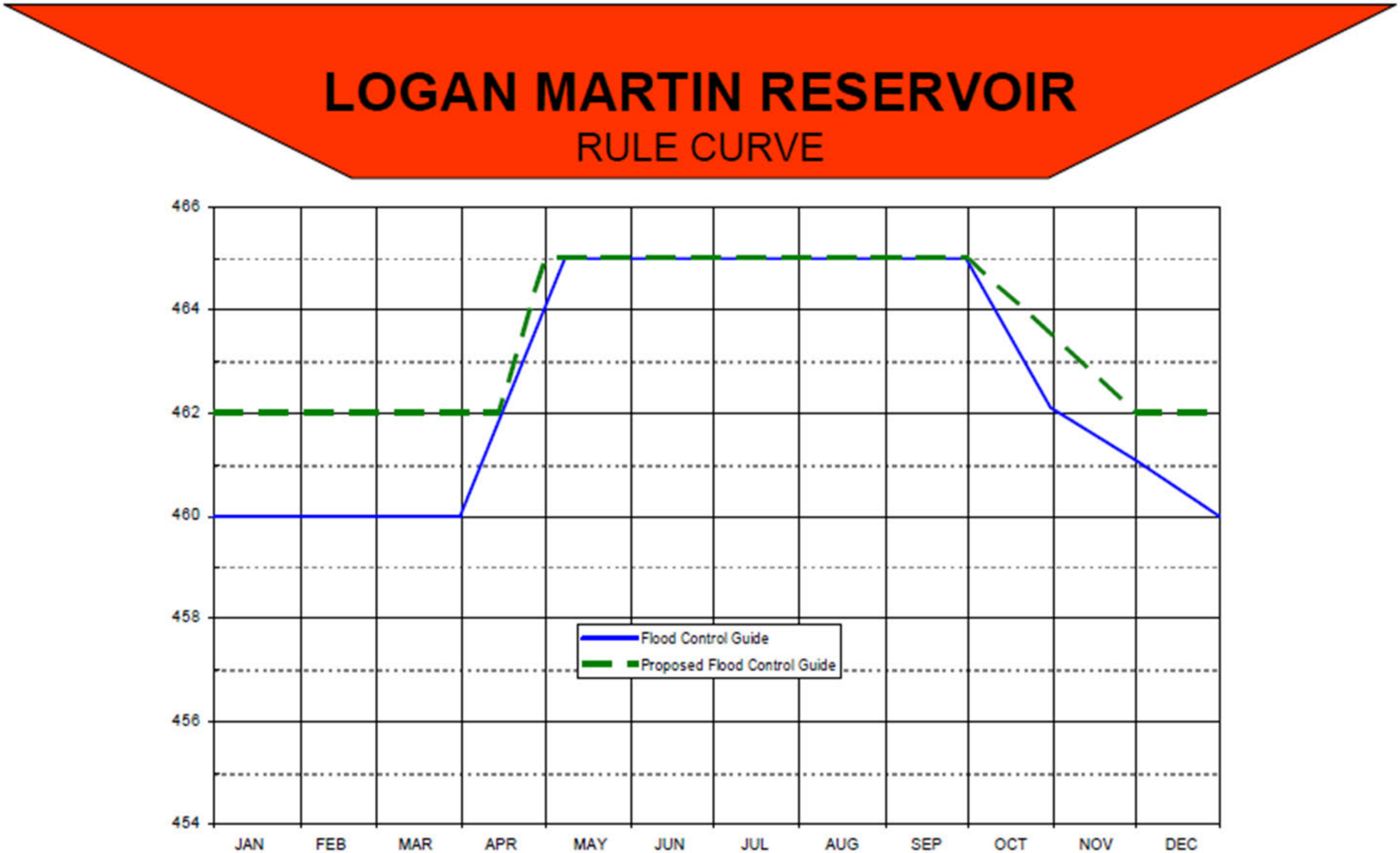


Proposed Weiss Surcharge Curve
Version 2, Revised June 2005

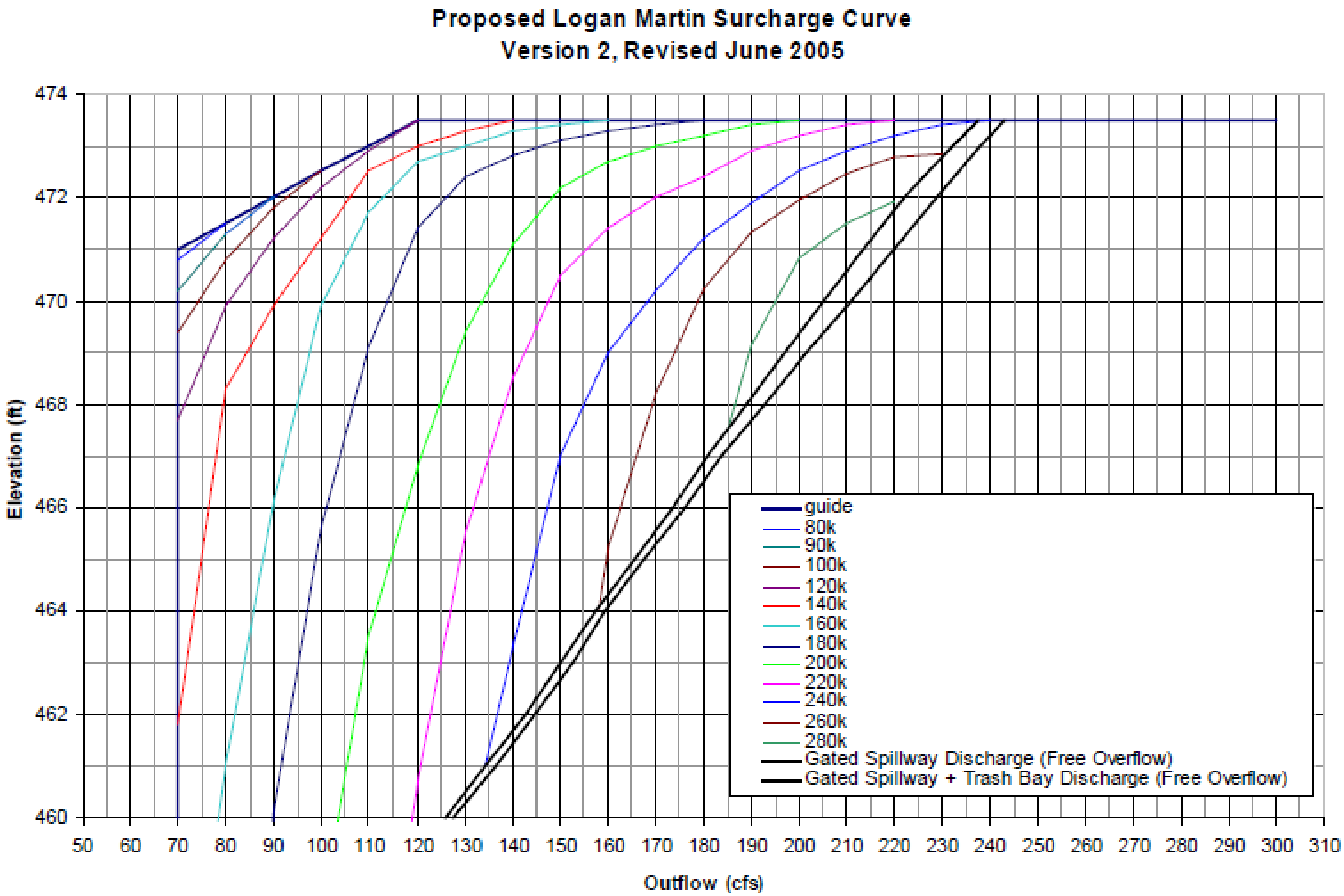


Proposed Logan Martin Flood Control Regulation Schedule

Rule	Condition	Outflow	Operation	Proposed Change
1	Below flood control guide	Up to Plant capacity.	Operate power plant as required to satisfy normal system load requirements.	None
2	Below flood control guide and Weiss above elev. 564.0 ft and inflow into Logan Martin and Weiss at plant capacity and increasing	70,000 cfs	Pull Logan Martin to elev. 460.0 ft by discharging 70,000 cfs. Once at elev. 460.0 ft hold the elevation by passing the hourly inflow.	**ENTIRELY NEW RULE**
3	At flood control guide	Ranging up to 70,000 cfs	Maintain reservoir stage at top-of-power pool elevation by passing the inflow up to 70,000 cfs.	**MAX RELEASE INCREASED TO 70,000 CFS FROM 50,000 CFS**
4	Above flood control guide and rising	Rate specified by Induced surcharge schedule	Operate according to induced surcharge schedule passing the required outflow through the power plant and spillway.	**NEW SURCHARGE CURVES**
5	Above flood control guide elevation with downstream control in place	Reduce up to 50% of surcharge schedule	Operation dictated by high downstream stages. Reduction in release not to exceed 11,000 cfs-days in added storage.	**ENTIRELY NEW RULE**
6	Above flood control guide elevation and falling		When the reservoir level begins to fall maintain the gate openings in effect at time of peak reservoir stage and continue power plant discharge in effect at that time until reservoir level recedes to flood control guide elevation.	None



LOGAN MARTIN RESERVOIR
RULE CURVE
466
464
462
460
458
456
454
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Flood Control Guide
Proposed Flood Control Guide

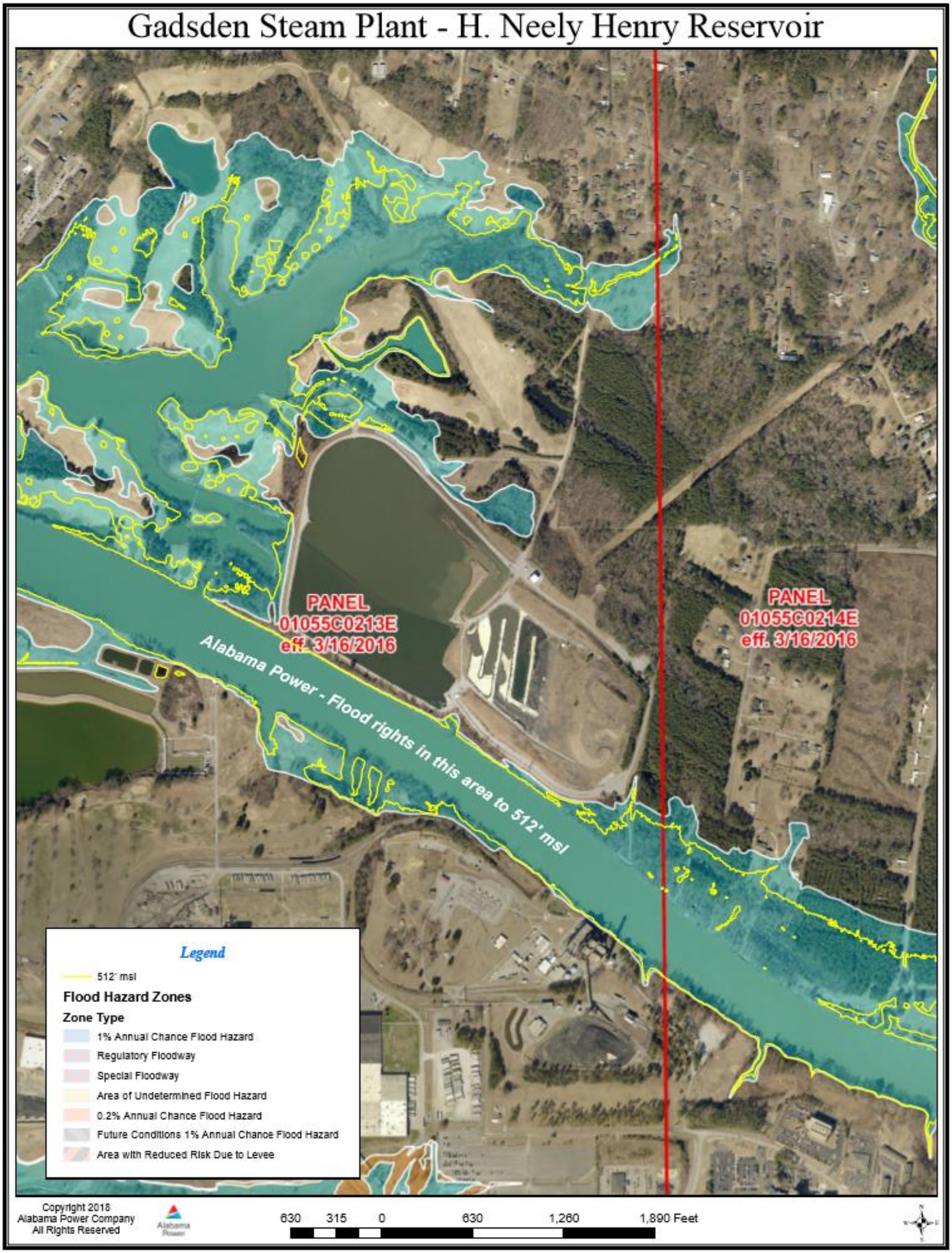

Proposed Logan Martin Surcharge Curve
Version 2, Revised June 2005
Elevation (ft)
474
472
470
468
466
464
462
460
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
Outflow (cfs)
guide
80k
90k
100k
120k
140k
160k
180k
200k
220k
240k
260k
280k
Gated Spillway Discharge (Free Overflow)
Gated Spillway + Trash Bay Discharge (Free Overflow)

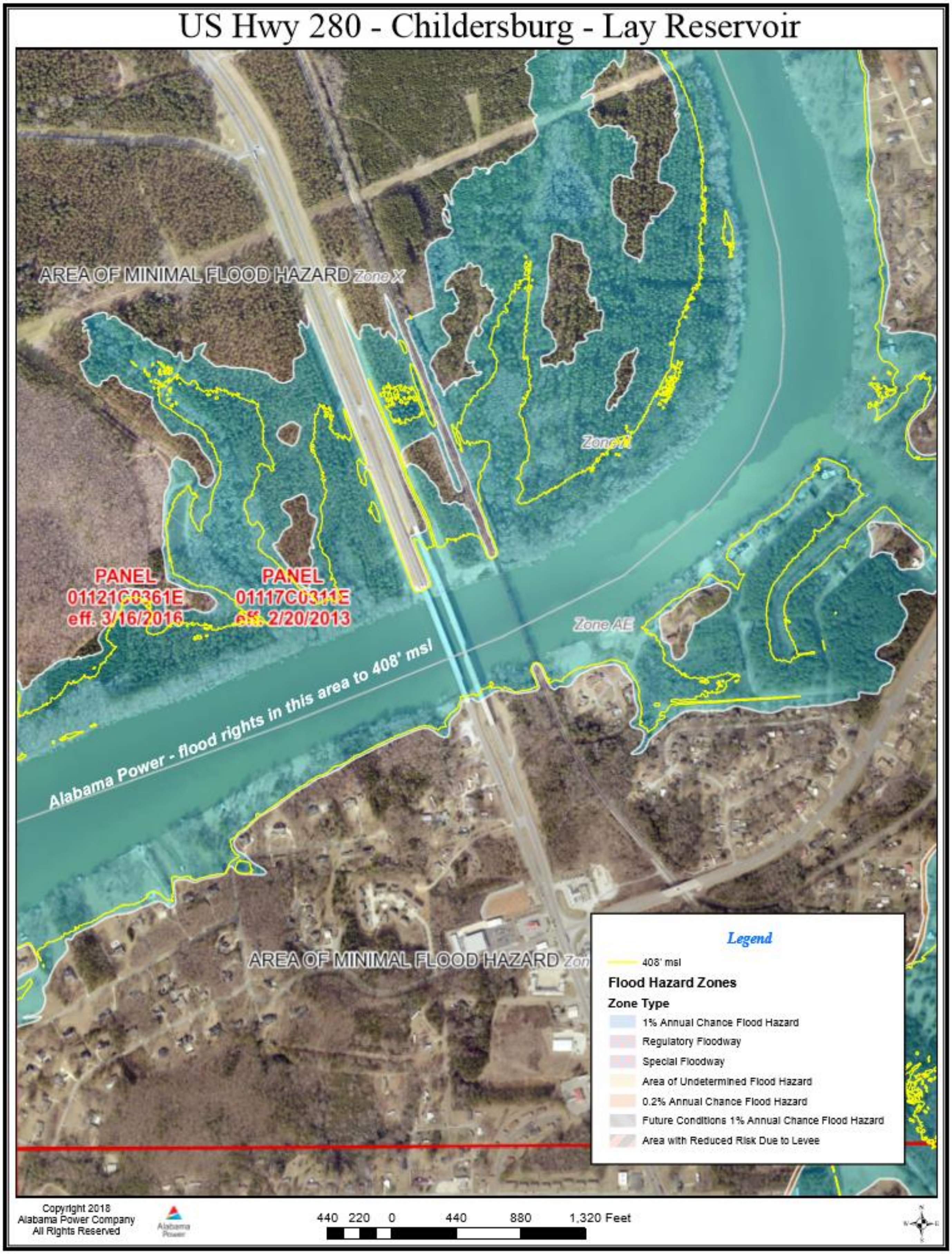
Appendix B

Flood Hazard Zone Maps

1. Gadsden Mall – H. Neely Henry Reservoir
2. Gadsden Steam Plant – H. Neely Henry Reservoir
3. US Hwy 280 – Childersburg – Lay Reservoir

Gadsden Mall - H. Neely Henry Reservoir
PANEL
01055C0194E
eff. 3/16/2016
AREA OF MINIMAL FLOOD HAZARD Zone X
Alabama Power - flood rights in this area to 511' msl
PANEL
01115C0075G
eff. 8/17/2016
PANEL
01055C0332E
eff. 3/16/2016
Zone AE
Legend
511' msl
Flood Hazard Zones
Zone Type
1% Annual Chance Flood Hazard
Regulatory Floodway
Special Floodway
Area of Undetermined Flood Hazard
0.2% Annual Chance Flood Hazard
Future Conditions 1% Annual Chance Flood Hazard
Area with Reduced Risk Due to Levee
Copyright 2018
Alabama Power Company
All Rights Reserved
440 220 0 440 880 1,320 Feet


Gadsden Steam Plant - H. Neely Henry Reservoir
PANEL
01055C0213E
eff. 3/16/2016
PANEL
01055C0214E
eff. 3/16/2016
Alabama Power - Flood rights in this area to 512' msl
Legend
512' msl
Flood Hazard Zones
Zone Type
1% Annual Chance Flood Hazard
Regulatory Floodway
Special Floodway
Area of Undetermined Flood Hazard
0.2% Annual Chance Flood Hazard
Future Conditions 1% Annual Chance Flood Hazard
Area with Reduced Risk Due to Levee
Copyright 2018
Alabama Power Company
All Rights Reserved
630 315 0 630 1,260 1,890 Feet


US Hwy 280 - Childersburg - Lay Reservoir
AREA OF MINIMAL FLOOD HAZARD Zone X
Zone AE
PANEL
01121C0361E
eff. 3/16/2016
PANEL
01117C0311E
eff. 2/20/2013
Zone AE
Alabama Power - flood rights in this area to 408' msl
AREA OF MINIMAL FLOOD HAZARD
Legend
408' msl
Flood Hazard Zones
Zone Type
1% Annual Chance Flood Hazard
Regulatory Floodway
Special Floodway
Area of Undetermined Flood Hazard
0.2% Annual Chance Flood Hazard
Future Conditions 1% Annual Chance Flood Hazard
Area with Reduced Risk Due to Levee
Copyright 2018
Alabama Power Company
All Rights Reserved
440 220 0 440 880 1,320 Feet

Appendix C

Model Parameters

1. Script Descriptions
2. Weiss Rules
3. H. Neely Henry Rules
4. Logan Martin Rules
5. Lay Rules

1. Script Descriptions

Weiss Surcharge Cutback

The Weiss script to cut surcharge releases operates to minimize impacts downstream of the dam by limiting the surcharge when the stage at Gadsden is rising over the easement of 512’ MSL due to a combination of discharges from Weiss and local inflow. When the rating curve at Gadsden indicates that a combination of local inflow and surcharge values from Weiss will cause the stage at Gadsden to rise over elevation 512’ MSL, surcharge releases can be cut up to 50% to provide time for the local inflows to recede. The total volume of the cutback cannot exceed 22,500 CFS-DAYS per event. The total cutback volume does not have to be used consecutively but can be implemented as multiple cutback periods during an event. Once this volume has been utilized, the project will return to the normal surcharge release schedule.

Weiss Surcharge Max Step

This script takes the prescribed releases from the induced surcharge rule, limit the change to the appropriate time interval and make the new surcharge value a maximum release rule to allow it to be displayed in the release decision report. The scripts for both Weiss base and proposed operation sets are identical because the decision interval is six hours for each.

Weiss Lower Flood Control

The Weiss lower flood control script is used primarily to manage the operation of spillway gate discharges in a different manner from the normal unit discharges. Spillway gate operations at Weiss should be performed on a 6-hour interval using the 6-hour average inflow for the discharge calculation. The two following shortcomings in ResSim led to the development of this script:

1. It is not possible to set a decision interval for the surcharge releases.
2. Using a decision interval for the reservoir operations affects both unit discharges and spillway discharges. This prevents proper peaking power releases and can cause swings in the reservoir elevation when inflows are fluctuating and only unit discharges are specified.

The script first checks to see if the current hour is a multiple of six. If so, it determines the appropriate discharge as either plant capacity or the channel capacity, which is 40,000 CFS. If the current hour is not a multiple of six, the previously calculated discharge is used for the current timestep.

This script acts as a maximum release rule. Weiss can discharge plant capacity when above guide curve and below summer pool elevation. At summer pool, Weiss can discharge up to 40,000 CFS to remain at summer pool.

This script acts as a maximum release rule.

Weiss Bypass

The Weiss bypass flow script simulates the rules for the minimum flow discharge from the trash gate at the diversion dam into the spillway, which is the old river channel. The flow is recalculated every Tuesday and Friday based on the flow at the USGS Mayo’s Bar gauge. The flow used in the calculation is the average of the past four days for Tuesdays and the average of the past three days for Fridays. Since the flow at Mayo’s Bar is not available in the current models, the inflow into the Weiss reservoir was used as a surrogate. The inflow was then modified by the ratio of drainage areas for the Weiss Reservoir and the Mayo's Bar gauge, which is a multiplier of 0.83. Once this flow value has been determined, the release from the trash gate is calculated using the following table of multipliers based on the current month:

Months	Multiplier
January, September	0.06
February, March, April, May, October	0.09
June	0.05
July, August	0.04
November	0.08
December	0.07

Gadsden Flood Ops

The Gadsden flood ops script implements the Henry pool drawdown rules. These rules determine the appropriate Henry forebay elevation according to the current Gadsden stage value. Due to the path of the river downstream of Gadsden, the Henry flood regulations call for lowering the Henry forebay elevation as the Gadsden stage rises. This is to attempt to overcome the hydraulic properties of the flow near what is referred to as Minnesota Bend just downstream of Gadsden. The geography and geometry of the river at this location causes the flow to decrease significantly causing backwater effects at Gadsden. Lowering the Henry pool elevation creates a greater slope difference and helps to pull water through the bend. As the Gadsden stage begins to fall, the Henry forebay is then allowed to rise in a similar fashion.

Since the hydraulics of this river reach are difficult to simulate with a rating curve, an iterative process with HEC-ResSim and HEC-RAS is used to determine a better approximation of the Gadsden stage. The improved stage estimation allows for more accurate operations for the Henry reservoir in HEC-ResSim. In the first iteration, no HEC-RAS results are available, and the script uses the estimated Gadsden elevation from the rating curve specified in the junction properties. On additional iterations, the script will pull the modeled Gadsden elevation from the HEC-RAS results in the forecast DSS file.

Logan Martin Pull 460

The Logan Martin script to pull the pool elevation down to 460' MSL is used only when the project is at the new winter pool elevation of 462' MSL. This allows the project to return to the previous winter pool elevation when conditions at the Logan Martin and Weiss reservoirs are in or approaching flood control triggers. The triggers for this script are as follows:

1. Logan Martin is at the new winter pool elevation of 462' MSL
2. Weiss is at summer pool elevation of 564' MSL
3. Logan Martin inflows are rising above plant capacity
4. Weiss inflows are rising above plant capacity

When the triggers are met, Logan Martin will begin discharging 70,000 CFS to pull the pool elevation to 460' MSL. Once at that elevation, it will attempt to match inflow to remain at that elevation until inflows rise above 70,000 CFS preventing it from remaining at 460' MSL or the inflows drop below plant capacity.

Logan Martin Surcharge Cutback

The Logan Martin script to cut surcharge releases operates to minimize impacts downstream of the dam by limiting the surcharge when the stage at Childersburg is rising over the easement of 408' MSL due to a combination of discharges from Logan Martin and local inflow. When the rating curve at Childersburg indicates that a combination of local inflow and surcharge values from Logan Martin will cause the stage at Childersburg to rise over elevation 408' MSL, surcharge releases can be cut up to 50% to provide time for the local inflows to recede. The total volume of the cutback cannot exceed 11,000 CFS-DAYS per event. The total cutback volume does not have to be used consecutively but can be implemented as multiple cutback periods during an event. Once this volume has been utilized, the project will return to the normal surcharge release schedule.

Logan Martin Surcharge Max Step

These scripts take the prescribed releases from the induced surcharge rule, limit the change to the appropriate time interval and make the new surcharge value a maximum release rule to allow it to be displayed in the release decision report. There are versions of this script for Logan Martin for both the base operations and proposed operations. The scripts for the Logan Martin operation sets differ only in the decision interval. The decision interval for base operations is six hours while the decision interval for the proposed operations is three hours.

Logan Martin Lower Flood Control

The Logan Martin lower flood control script is used primarily to manage the operation of spillway gate discharges in a different manner from the normal unit discharges. Spillway gate operations at Logan Martin should be performed on a six-hour interval for current operations and a three-hour interval for the proposed operations. A six-hour average inflow is used for the discharge calculation. The two following shortcomings in ResSim led to the development of this script:

1. It is not possible to set a decision interval for the surcharge releases.
2. Using a decision interval for the reservoir operations affects both unit discharges and spillway discharges. This prevents proper peaking power releases and can cause swings in the reservoir elevation when inflows are fluctuating and only unit discharges are specified.

The script first checks to see if the current hour is a multiple of the decision interval. If so, it determines the appropriate discharge as either plant capacity, the six-hour average inflow or the channel capacity, which is 70,000 CFS. If the current hour is not a multiple of the specified discharge interval, the previously calculated discharge is used for the current timestep.

Logan Martin operates to match inflow above plant capacity up to the channel capacity when the project is over guide curve but below the summer pool elevation.

This script acts as a maximum release rule.

Lay Pull 395

The Lay script to pull the pool to elevation 395’ MSL operates to lower the forebay elevation over a 12-hour period whenever Logan Martin discharge reaches 70,000 CFS. This flexibility already exists in the current operations and may prove helpful in preventing water from backing up to Childersburg by implementing a higher discharge before the Logan Martin releases reach the dam. When the Logan Martin releases drop back below 70,000 CFS, the Lay pool returns to elevation 396’ MSL.

Jordan Cap for Mitchell

The Mitchell maximum discharge script attempts to limit impacts at the Jordan reservoir in high flow events. The Mitchell discharge plus the local inflow at Jordan could push the reservoir up to or above easement during a large flood event. Impacts are minimized by utilizing the volume between the Mitchell guide curve at 312’ MSL and the Mitchell easement at 317’ MSL to store water. The script calculates a maximum discharge for Mitchell as the higher of the Mitchell inflow or the Jordan capacity minus intervening flows.

2. WEISS

Rule Descriptions

1. Max40000
This rule limits the release from Weiss Dam to 40,000 CFS. The higher priority Induced Surcharge function can cause this release to be exceeded in both the Top of Surcharge zone and the Flood Control zone.

2. MaxCapPower
This rule sets the maximum release in the Conservation zone to 26,021 CFS. This value is the modeled release capacity for the power plant.

3. InducedSurchargeBase
This rule represents the current induced surcharge operation for flood control. A six-hour average inflow lagged one hour, as defined in the Inflow Time Series Options, is used to determine the release. The Falling Pool Transition Elev (564' MSL for Weiss) is the pool elevation below which the induced surcharge rule will no longer operate. The Release Options are to designate the method for computing falling pool releases. For Weiss, the option of Maintain Peak Gate Openings is selected.

4. SurchargeMaxStepBase
This rule allows the surcharge releases at Weiss to change on a six-hour timestep. See Script Descriptions in Appendix A.1 for further detail.

5. No Main Gate
Releases from the main spillway are prevented below 564' MSL at Weiss.

6. ByPass Flow
This is a minimum release rule used to capture the adaptive management flow target into the Weiss Bypass. Dependent on the flow at the Rome-Coosa node, the state variable has been modified to determine releases based on Weiss inflow based on a drainage basin area ratio.

7. RestrictWeissSurcharge
The Weiss script to cut surcharge releases operates to minimize impacts downstream of the dam by limiting the surcharge when the stage at Gadsden is rising over the easement of 512' MSL due to a combination of discharges from Weiss and local inflow. See Script Descriptions in Appendix A.1 for further detail.

8. SurchargeMaxStepProp
This rule allows the surcharge releases at Weiss to change on a six-hour timestep. See Script Descriptions in Appendix A.1 for further detail.

9. InducedSurchargeProp
This rule represents the proposed induced surcharge operation for flood control. A six-hour average inflow lagged one hour, as defined in the Inflow Time Series Options, is used to determine the release. The Falling Pool Transition Elev (564' MSL for Weiss) is the pool elevation below which the induced surcharge rule will no longer operate. The Release Options are to designate the method for computing falling pool releases. For Weiss, the option of Maintain Peak Gate Openings is selected.

10. Lower Flood Control

The Weiss lower flood control script is used primarily to manage the operation of spillway gate discharges in a different manner from the normal unit discharges. See Script Descriptions in Appendix A.1 for further detail.

11. JBT Goal

This is a minimum release rule that is a function of the flow at JBT Goal. The returned minimum release from Weiss is always zero. This dummy rule has no direct operational effect on Weiss but forces the compute blocking needed in the model.

3. HENRY

Rule Descriptions

1. Max96000

This rule sets the maximum release from Henry to 96,000 CFS. This rule is applied in the Flood Control, Conservation, and Drought zones.

2. GadsdenFloodOp_APC

The Gadsden flood ops script implements the Henry pool drawdown rules. These rules determine the appropriate Henry forebay elevation according to the current Gadsden stage value. See Script Descriptions in Appendix A.1 for further detail.

4. LOGAN MARTIN

Rule Descriptions

1. InducedSurchargeBase

This rule represents the current induced surcharge operation for flood control. A six-hour average inflow lagged one hour, as defined in the Inflow Time Series Options, is used to determine the release. The Falling Pool Transition Elev (460’ MSL for Logan Martin) is the pool elevation below which the induced surcharge rule will no longer operate. The Release Options are to designate the method for computing falling pool releases. For Logan Martin, the option of Maintain Peak Gate Openings is selected.

2. SurchargeMaxStepBase

This rule allows the surcharge releases at Logan Martin to change on a six-hour timestep. See Script Descriptions in Appendix A.1 for further detail.

3. Max50000

This rule sets the maximum release from Logan Martin to 50,000 CFS when in the flood control, conservation, and drought zones. When in the flood control zone, this release can be exceeded by the higher priority induced surcharge operation.

4. LowerFloodControlBase

The Logan Martin lower flood control script is used primarily to manage the operation of spillway gate discharges in a different manner from the normal unit discharges. Spillway gate operations at Logan Martin should be performed on a six-hour interval using the six-hour average inflow for the discharge calculation. See Script Descriptions in Appendix A.1 for further detail.

5. No Spillway

Releases from the spillway are prevented in the Drought zone at Logan Martin.

6. LoganPull460

The Logan Martin script to pull the pool elevation down to 460’ MSL is used only when the project is at the new winter pool elevation of 462’ MSL. This allows the project to return to the previous winter pool elevation when conditions at the Logan Martin and Weiss reservoirs are in or approaching flood control triggers. See Script Descriptions in Appendix A.1 for further detail.

7. Max70000

This rule sets the maximum release from Logan Martin to 70,000 CFS when in the flood control, conservation, and drought zones. When in the flood control zone, this release can be exceeded by the higher priority induced surcharge operation

8. LowerFloodControlProposed

The Logan Martin lower flood control script is used primarily to manage the operation of spillway gate discharges in a different manner from the normal unit discharges. Spillway gate operations at Logan Martin should be performed on a three-hour interval using the six-hour average inflow for the discharge calculation See Script Descriptions in Appendix A.1 for further detail.

9. SurchargeMaxStepProposed

This rule allows the surcharge releases at Logan Martin to change on a three-hour timestep. See Script Descriptions in Appendix A.1 for further detail.

10. InducedSurchargeProposed

This rule represents the proposed induced surcharge operation for flood control. A six-hour average inflow lagged one hour, as defined in the Inflow Time Series Options, is used to determine the release. The Falling Pool Transition Elev (460' MSL for Logan Martin) is the pool elevation below which the induced surcharge rule will no longer operate. The Release Options are to designate the method for computing falling pool releases. For Logan Martin, the option of Maintain Peak Gate Openings is selected.

5. Lay

Rule Descriptions

1. LayDrawdown

The Lay script to pull the pool to elevation 395’ MSL operates to lower the forebay elevation over a 12-hour period whenever Logan Martin discharge reaches 70,000 CFS. See Script Descriptions in Appendix A.1 for further detail.

6. Mitchell

Rule Descriptions

1. JordanCapForMitchell

The Mitchell maximum discharge script attempts to limit impacts at the Jordan reservoir in high flow events. See Script Descriptions in Appendix A.1 for further detail.

Appendix D

2005 Coosa River Flood Study, version 2

COOSA RIVER STUDY
VERSION 2

Weiss Dam

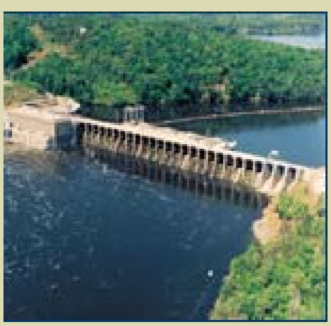
Henry Dam

Logan Martin Dam

Lay Dam

Alabama Power

A Southern Company



Mitchell Dam

Jordan Dam

Bouldin Dam

ALABAMA POWER COMPANY

COOSA RIVER FLOOD STUDY

Version 2

June 14, 2005

Prepared by: Reservoir Management
Hydro Services
Southern Company

Table of Contents

Appendix 3 **Comments**

USACE Comments

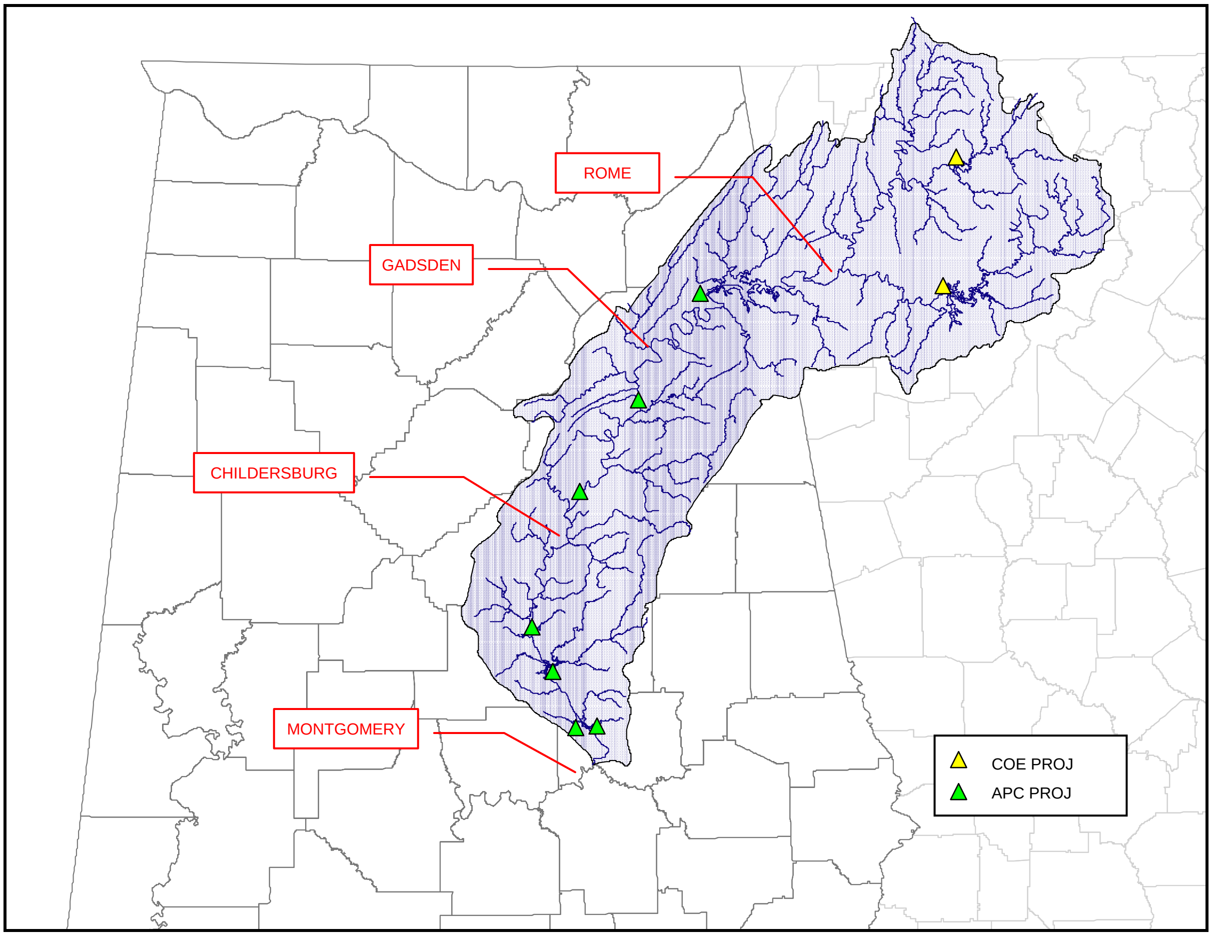
Appendix 4 **Proposed MOU's**

Weiss MOU
H. Neely Henry MOU
Logan Martin MOU

Section 1

Scope of Flood Study

This flood study was conducted on the Coosa River as part of the relicensing of Federal Energy Regulatory Commission (FERC) projects 2146, 618 and 82 all located within Alabama and Georgia. The study extended from Alabama River at Montgomery upstream to Carters dam on the Coosawattee River and Allatoona Dam on the Etowah River, both in Georgia.



This is the first comprehensive basin-wide review of flood control of all the projects of the Coosa River Basin. The first project, Lay Dam, was completed by Alabama Power Company in 1914 and the last project, Carters Dam, was completed by the U. S. Army Corps of Engineers in 1974. In the 1960's Alabama Power completed construction of Weiss, Henry and Logan Martin Dams pursuant to public law 83-436 which required flood control to be included in the project design and operation. The Corps of Engineers is the agency given the responsibility for the review and approval of those flood plans and accordingly each of the three mentioned projects is governed by a Reservoir Regulation Manual issued by the Corps.

In 1977 and again in 1979, large floods caused widespread flooding and concern was expressed over the effectiveness of flood control plans by both Alabama Power and the Corps of Engineers. Considerable discussion ensued regarding conducting flood operational flood studies of the Coosa River Basin. While no new operational flood studies were conducted at that time, several significant developments have occurred:

- Alabama Power developed an automated system of rainfall, river monitoring and modeling to improve the effectiveness of flood control operations referred to as the Hydro Optimization Management System or HOMS.

- During floods since, Alabama Power has requested and the Corps of Engineers has granted variances to the published guidelines.

- Improved river analysis tools have become available such as the HEC-RAS model and the computers to run such models have become much more powerful.

- Years of detailed flow data has been collected, much of it on an hourly time step.

- In the 1990s the Corps of Engineers as part of the ACT Comprehensive Study developed a surface water database covering 1939 through 1993 (and later extended through 2000).

- The density of development on the Coosa reservoirs has increased dramatically as well as the value of those properties.

- Federal (FEMA) flood insurance programs have identified flood hazard areas and require homeowners to purchase insurance on mortgaged property. In many areas there is a disconnect between flood designations and flood easements causing confusion on the part of the public.

- Finally, Alabama Power is engaged in a collaborative FERC relicensing process involving all of Alabama Power's Coosa projects. From this process, stakeholders have proposed changes to flood control guide curves as a solution to several purported issues. Thus, there is a necessity to evaluate those changes.

For these reasons this study was made. Additional details about the scope of this study may be found in Appendix I in the *Plan of Study* agreement.

Additional details about the projects themselves may be found in Appendix 2 in the Reservoir Regulation Manuals.

Section 2

Study Objectives

1. Provide a basis for revising flood control plans to improve effectiveness at Weiss, H Neely Henry and Logan Martin.

2. Establish a design criteria equivalent to the 100 year flood and evaluate on a comprehensive mode of the entire basin.

3. Demonstrate the feasibility of altering flood control guide curves at Weiss, H Neely Henry and Logan Martin as proposed in the relicensing of those projects.

4. Provide the water surface elevations along the Coosa River that may be used on the FEMA Federal Insurance Rate Maps (FIRM).

5. Provide accurate flow models to incorporate into the HOMS for real time operations.

Results

1. APCO easements are adequate to contain 100 year design flood with the control plan changes contained in this report. A small additional easement will be acquired below Logan Martin Dam to accommodate plan changes.

2. The Flood Frequency Analysis was made and is included on CD in Appendix 2. The FFA has been reviewed by the Corps, the USGS, and the Office of Water Resources.

3. Changing flood control guide curve is feasible from a flood control standpoint. The changes do not result in higher peak flood elevations.

4. A copy of this study will be furnished to the State of Alabama Office of Water Resources for use in the FEMA FIRM map update program now underway.

5. Alabama Power will be incorporating these flow models into the HOMS.

Section 3

Method of Study

A consistent approach was taken to study each reach of the Coosa River involved in this study originating just downstream of Carter's Regulation Dam and Allatoona Dam and proceeding down the Coosa River through Weiss, H Neely Henry, Logan Martin, Lay, Mitchell and Jordan reservoirs.

Development of HEC-RAS Routing Models

After an initial evaluation of the National Weather Service's FLDWAV model it was decided that the Corps of Engineers' HEC-RAS unsteady flow (*UNET*) model was the best platform for performing this study. A lengthy and detailed process ensued whereupon HEC-RAS models were developed for each reach and calibrated to historical flood events.

Data for several historical floods were utilized in the calibrations including 1951, 1979, 1990 and 2003. Cross sections for over 400 miles of channel were assembled from existing and new surveys and enhanced with map data.

These calibration efforts were submitted for review to Alabama's Office of Water Resources (OWR) as well as the Corps of Engineers as part of the modeling IAG in the Coosa Relicensing process. In Appendix 2 there is a CD for each river reach containing the model, supporting data and detailed descriptions.

Flood frequency

A flood frequency analysis (FFA) for the entire river basin was conducted for this study. To produce a true FFA required using unimpaired river flows not impacted by reservoir regulation. It was decided that the ACT surface water database as expanded through 2000 could provide the basis for such an analysis. This database provides unregulated flows at key gauging points throughout the basin. The FFA produced a flood frequency curve at each of these key gage sites.

A detailed description and the complete FFA are included on a CD in Appendix 2.

Water surface profile for pre-project conditions

In order to determine the adequacy of flood easement lands it was desirous to know the water surface elevation profile for pre-project conditions. To achieve this, the FFA flows at the 1% recurrence interval for key gage sites along the river were modeled with HEC- RAS as steady flows. The resulting water surface elevations were checked against historical pre-project rating curves obtained from the USGS to see if any adjustments were needed in the roughness coefficients to account for reservoir clearing. Comparing the HEC-RAS results with the historical USGS rating curves prompted slight changes to the roughness coefficients.

Creation of the Design Flood

Rather than creating a design flood from rainfall-runoff models it was deemed that patterning the design flood after a historical flood had some distinct advantages, particularly with a large number of historical floods to pick from. From the unregulated flow data set the 1990 flood event was determined to be the historical flood event closest to the 1% recurrence interval flood at the most nodes along the river. At each major node the intervening inflow for the 1990 hydrograph was adjusted up or down to match the volume and peak elevation within 10% of the 1% recurrence interval flood. In routing the flow from reservoir to reservoir these unregulated flows were routed through full reservoirs at flat or unchanging pools. By using this approach the impacts of valley storage (which were not removed in the development of the Corps of Engineers' surface water database) were not "double counted" as the design flood hydrographs were constructed for each segment of the Coosa River Basin.

Evaluation of Proposed Changes

Once the design flood hydrographs were developed they were then utilized in each HEC-RAS model starting with the Weiss model. In addition to the HEC-RAS models, reservoir storage routing models were developed to evaluate both the existing flood control procedures as well as the proposed flood control procedures for Weiss, H Neely Henry, and Logan Martin Dams.

The regulated design flood inflow was developed by routing the design flood from just below Carter's Regulation Dam and Allatoona Dam downstream to Weiss Dam using the HEC-RAS unsteady-state model. From the model the outflow was determined and by using the assumed elevation at Weiss Dam an inflow was calculated based off the elevation-storage table relationship for each reservoir. At this point the inflow was then routed in the reservoir routing model thru either the existing or the proposed flood control procedure. New elevations at the dam were determined, again using the storage-elevation tables, and then input back into the HEC-RAS model as the new downstream boundary condition. This iteration process was continued until there was a convergence in the projected inflows.

Section 4

Guide Curves and Schedules

This section contains the essential charts proposed for use at the Coosa projects. They were used in the design flood analysis.

Weiss
Proposed Flood Guide Curve
Flood Control Regulation Schedule
Flood Surcharge Curves

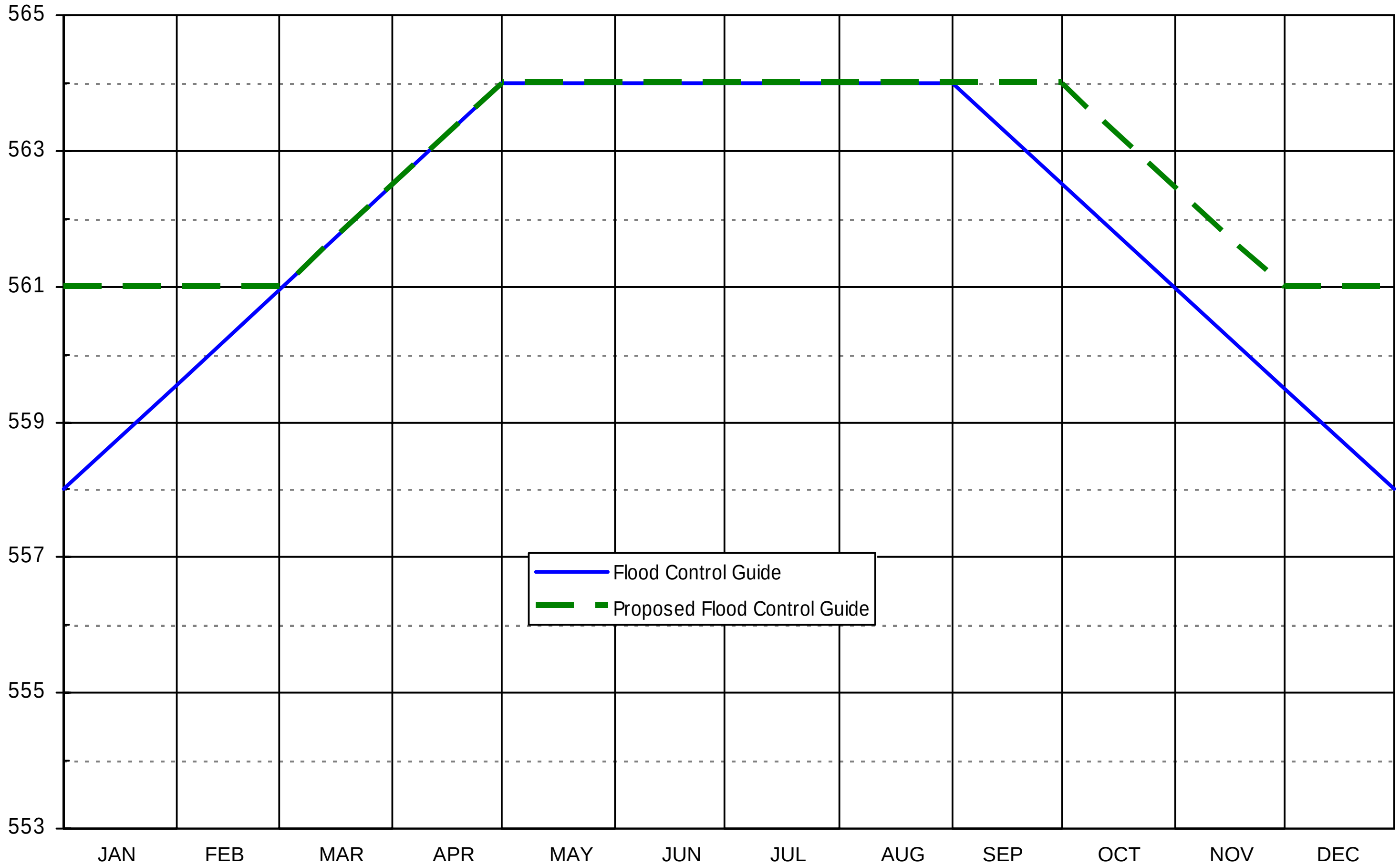
H Neely Henry
Proposed Flood Guide Curve
Flood Evacuation Schedule

Logan Martin
Proposed Flood Guide Curve
Flood Control Regulation Schedule
Flood Surcharge Curves

Lay
Also included is a description of the additional flood easement to be acquired below Logan Martin dam to effect the implementation of these flood schedules.

WEISS RESERVOIR

RULE CURVE



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ALABAMA HYDRO

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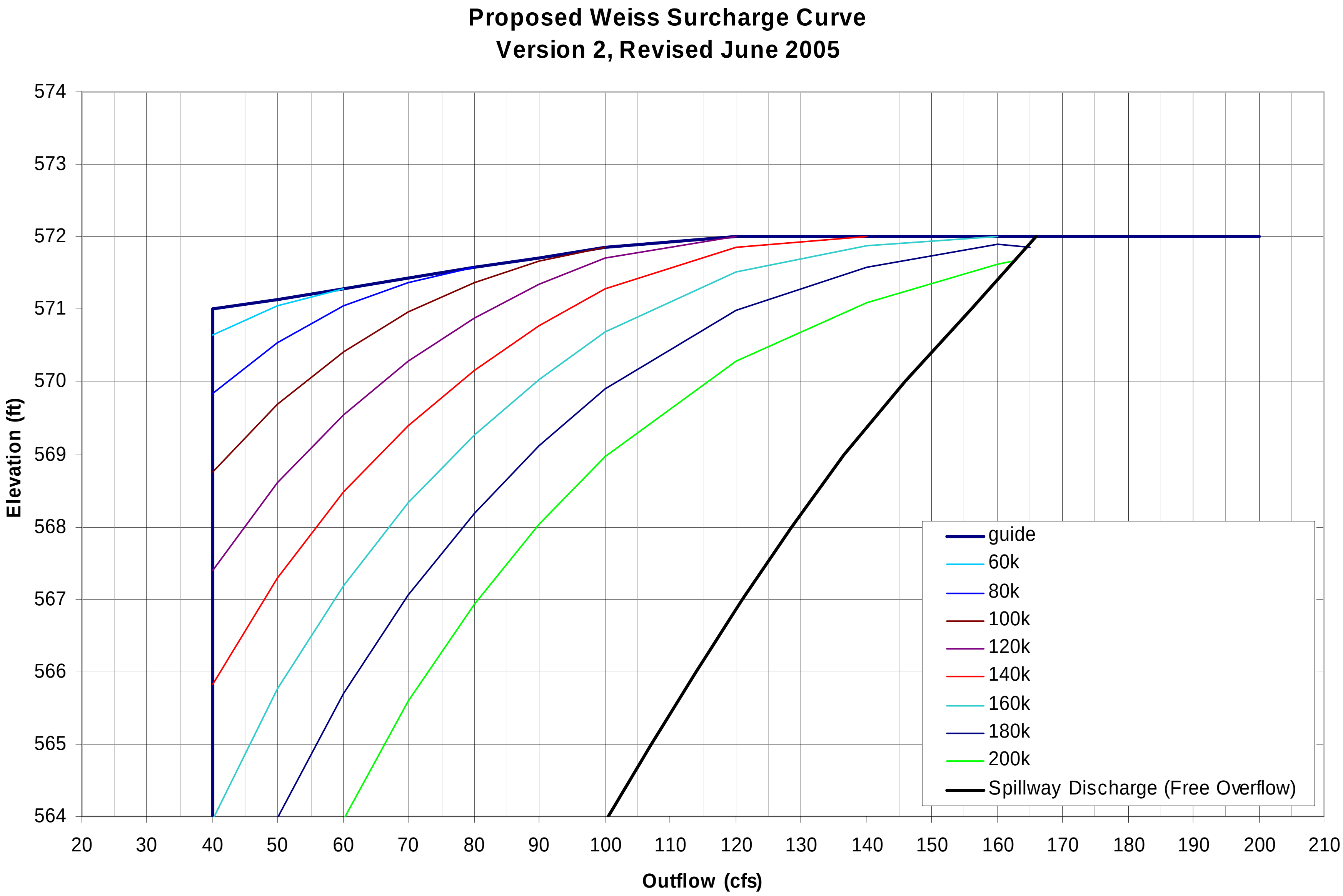
Flood-Control Regulation Schedule

Weiss Reservoir

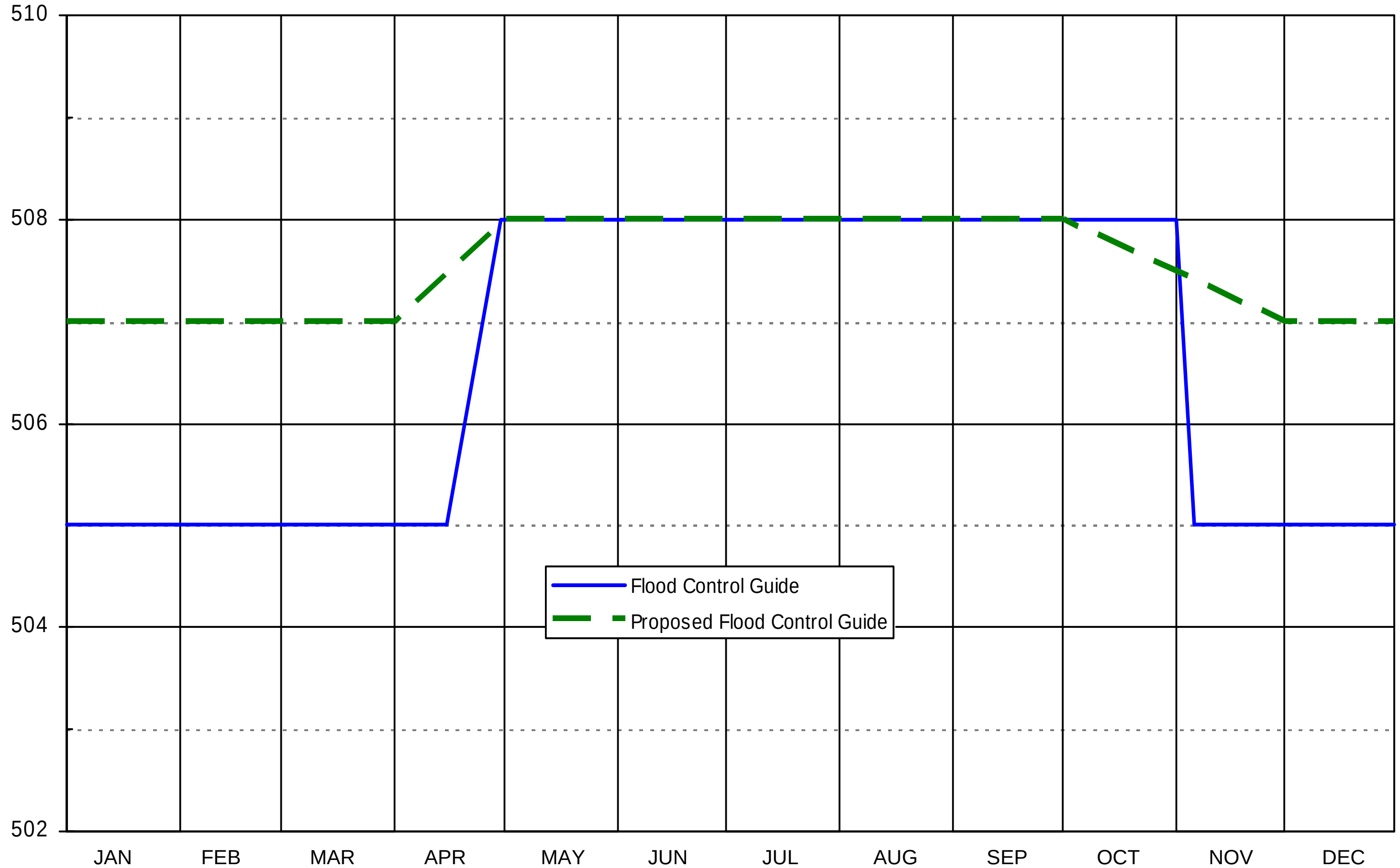
Rule	Condition	Outflow	Operation
1	Below flood control guide	Ranging up to full discharge capacity of power plant.	Operate power plant as required to satisfy normal system load requirements.
2	At flood control guide and below elev.564.0.	Ranging up to full discharge capacity of power plant.	Releases shall be made through power plant at rates up to continuous operation at plant capacity (3 units at full gate) as required to keep reservoir stage at or below flood control guide, as long as this level is below elev. 564.0.
3	Above flood control guide and below elev. 564.0	Full discharge capacity of power plant.	Releases shall be made through power plant operating continuously at plant capacity (3 units at full gate) until reservoir stage: (a) Recedes to flood control guide after which rule 2 applies, or (b) Reaches elevation 564.0 after which rule 4 applies.
4	At elevation 564.0.	Ranging up to 40,000 cfs	Maintain reservoir stage at elevation 564.0 by passing the inflow up to 40,000 cfs. Releases will be made through the power plant operating continuously at plant capacity (3 units at full gate) supplemented by spillway discharge as required.
5	Rising above elevation 564.0.	40,000 cfs unless higher rate is specified by induced surcharge schedule.	Maintain total discharge of 40,000 cfs by discharging through the power plant operating continuously at plant capacity (3 units at full gate) supplemented by spillway discharge as required. Continue this operation until: (a) Reservoir stage recedes to elev. 564.0 after which rule 4 applies, or, (b) Reservoir stage and rate of inflow are such that higher rate of outflow is required by induced surcharge schedule, in which case rule 6 applies.
6	Rising above elev. 564.0 with releases above 40,000 cfs specified by induced surcharge schedule.	As specified by induced surcharge schedule.	Operate according to induced surcharge schedule, passing the required outflow through the power plant and spillway.
7	Stages downstream of Weiss exceed or are expected to exceed flood stage as a result of local inflows	Reduce up to 50% of surcharge schedule	Temporarily reduce the release prescribed by the plan, provided that the release will not be reduced below 50% of the amount required by the surcharge schedule and that the total addition of floodwaters stored in Weiss will not exceed a volume of 22,500 cfs-days.
8	Above elev. 564.0 and falling.	As specified by induced surcharge schedule.	When the reservoir level begins to fall maintain the gate openings in effect at time of peak reservoir stage and continue power plant discharge in effect at that time until reservoir level recedes to elev. 564.0. When pool recedes to elev. 564.0 rule 4 applies.



Proposed Weiss Surcharge Curve
Version 2, Revised June 2005
Elevation (ft)
574
573
572
571
570
569
568
567
566
565
564
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
Outflow (cfs)
guide
60k
80k
100k
120k
140k
160k
180k
200k
Spillway Discharge (Free Overflow)

H. NEELY HENRY RESERVOIR

RULE CURVE



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H. Neely Henry Reservoir
Flood Evacuation Schedule

Trigger Points	When Coosa River at Gadsden Steam Plant Rises Above	Reservoir Change	Evacuation Rate
1	508.00	No Change	N/A
2	508.50	508.00 to 507.00	1 foot in a 12 hour period
3	509.00	507.00 to 506.00	1 foot in a 12 hour period
4	509.50	506.00 to 505.00	1 foot in a 12 hour period
5	510.00	505.00 to 504.00	1 foot in a 12 hour period
6	510.50	504.00 to 503.00	1 foot in a 12 hour period
7	511.00	503.00 to 502.50	1/2 foot in a 12 hour period
	When Coosa River at Gadsden Steam Plant Lowers Below		
8	511.00	No Change	N/A
9	510.50	502.50 to 503.00	N/A
10	510.00	503.00 to 504.00	N/A
11	509.50	504.00 to 505.00	N/A
12	509.00	505.00 to 506.00	N/A
13	508.50	506.00 to 507.00	N/A
14	508.00	507.00 to 508.00	N/A
15	**PRIORITY**		The evacuation schedule above shall apply during refilling if conditions warrant.

Exception 1

When the rule curve is at 508 the initial trigger point (508.5) will be skipped if the following three conditions are met:
1) Gadsden SP gage does not exceed 509,
2) Weather forecasts do no indicate significant rain potential, and
3) Weiss releases are not expected to go above 26,000 in the next 24 hours

Should any of these 3 conditions change then the evacuation rate schedule should be initiated, or if the reservoir reaches the second trigger point (509.0) then the evacuation rate should be doubled to reach the second step of the drawdown so as to return to the schedule.

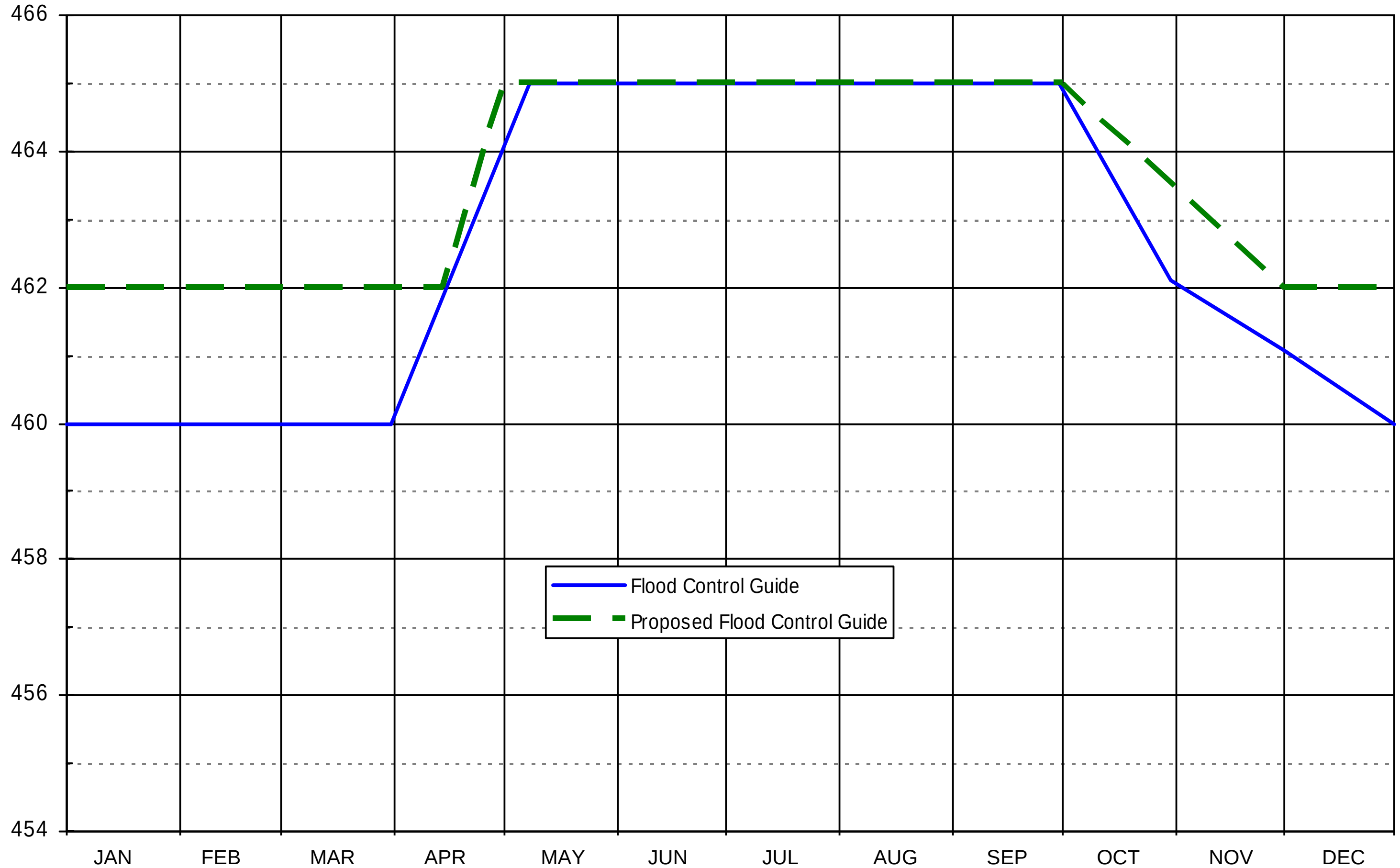
Exception 2

If after the initial stage of evacuation and Gadsden elevation begins to fall then Henry elevation may be allowed to rise so long as the following conditions are met:
1) Gadsden SP gage does not exceed 510,
2) Weather forecasts do not indicate significant rain potential,
3) Inflows into Henry Reservoir are not increasing, and
4) Weiss releases are not expected to go above 40,000 in the next 24 hours.

Should any of these 4 conditions change then the evacuation rate schedule should be re-initiated.

LOGAN MARTIN RESERVOIR

RULE CURVE



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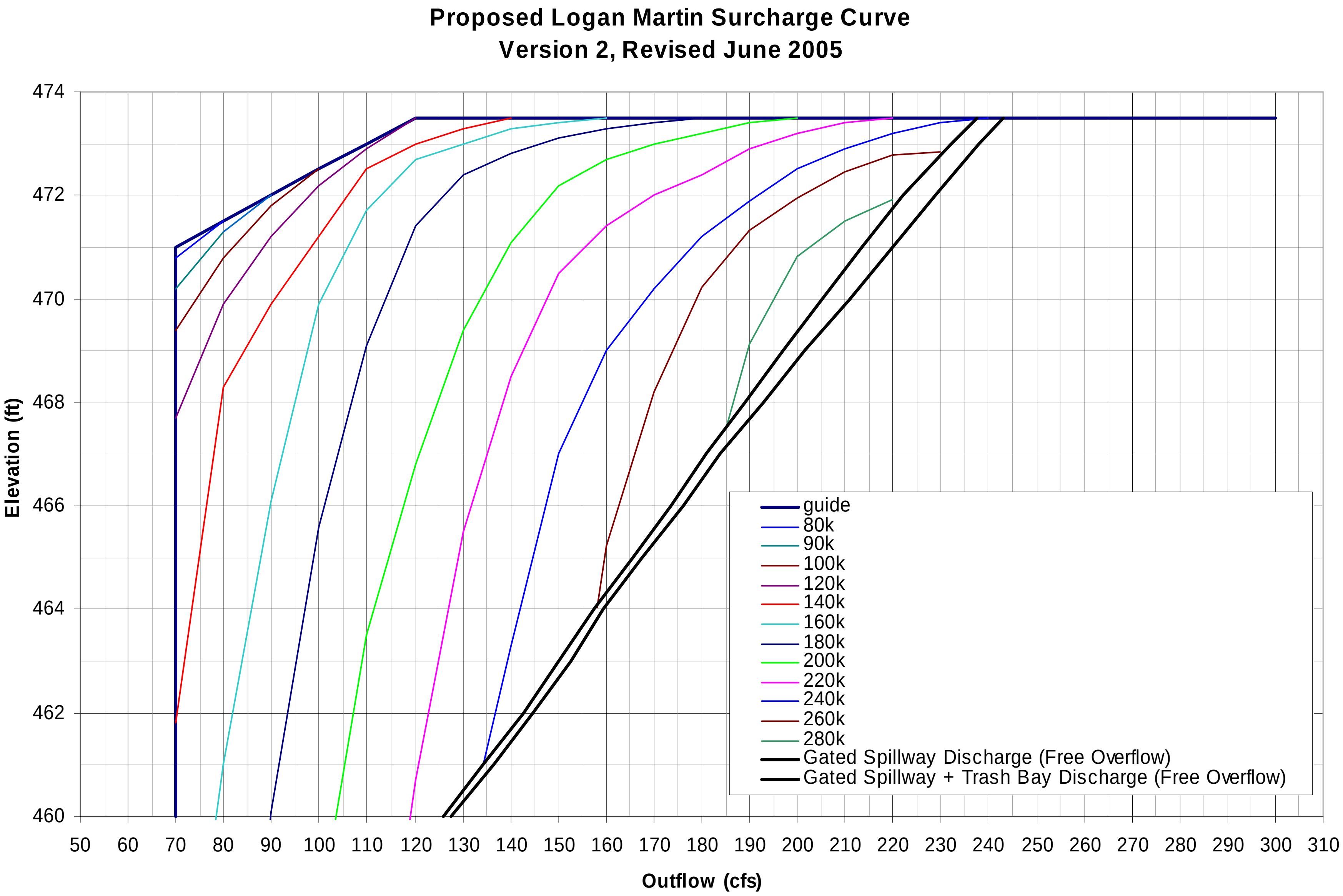
ALABAMA HYDRO
Powered By Nature

Flood-Control Regulation Schedule

Logan Martin Reservoir

Rule	Condition	Outflow	Operation
1	Below flood control guide.	Up to Plant capacity.	Operate power plant as required to satisfy normal system load requirements.
2	Below flood control guide and Weiss above elev 564 and inflow into Logan Martin and Weiss at plant capacity and increasing	70,000 cfs	Pull Logan Martin to elevation 460 by discharging 70,000 cfs. Once at 460 hold the elevation by passing the hourly inflow
3	At flood control guide.	Ranging up to 70,000 cfs.	Maintain reservoir stage at top-of-power pool elevation by passing the inflow up to 70,000 cfs.
4	Above flood control guide and rising.	Rate specified by induced surcharge schedule.	Operate according to induced surcharge schedule passing the required outflow through the power plant and spillway.
5	Above flood control guide elevation with downstream control in place.	Reduce release down to 50%.	Operation dictated by high downstream stages. Reduction in release not to exceed 11,000 cfs-days in added storage.
6	Above flood control guide elevation and falling		When the reservoir level begins to fall maintain the gate openings in effect at time of peak reservoir stage and continue power plant discharge in effect at that time until reservoir level recedes to flood control guide elevation.


Proposed Logan Martin Surcharge Curve
Version 2, Revised June 2005
Elevation (ft)
474
472
470
468
466
464
462
460
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
Outflow (cfs)
guide
80k
90k
100k
120k
140k
160k
180k
200k
220k
240k
260k
280k
Gated Spillway Discharge (Free Overflow)
Gated Spillway + Trash Bay Discharge (Free Overflow)

Operational Considerations

Certain operational considerations were utilized in the reservoir routing model in order to raise the winter pool elevations and change flood control procedures without negatively impacting flooding in areas outside of Alabama Power's easements. These operational procedures are outlined in the Flood Control Regulation Schedule for Weiss, H Neely Henry, and Logan Martin Dams.

Several assumptions relate to time interval for measurements and discharge adjustments. For each of these three reservoirs inflows would be computed using the continuity equation as six hour average inflows. At Weiss the change in discharge was made on six hour intervals. At Logan Martin changes to discharge were made on 3 hour intervals.

H Neely Henry has its own time table for operational changes to be made which has been tested over the past four years in a trial state. Some exceptions were added to the H Neely Henry plan in order to give more flexibility in re-filling that have also been tested over the past year.

In order to make the Logan Martin flood control guide curve changes possible the following change in its flood control operations was required. When Weiss Reservoir is above elevation 564' and inflows into Weiss and Logan Martin are increasing above plant capacity Logan Martin will be drawn down to elevation 460' by discharging 70,000 cfs. Once Logan Martin is at elevation 460' that elevation would be maintained by discharging up to 70,000.

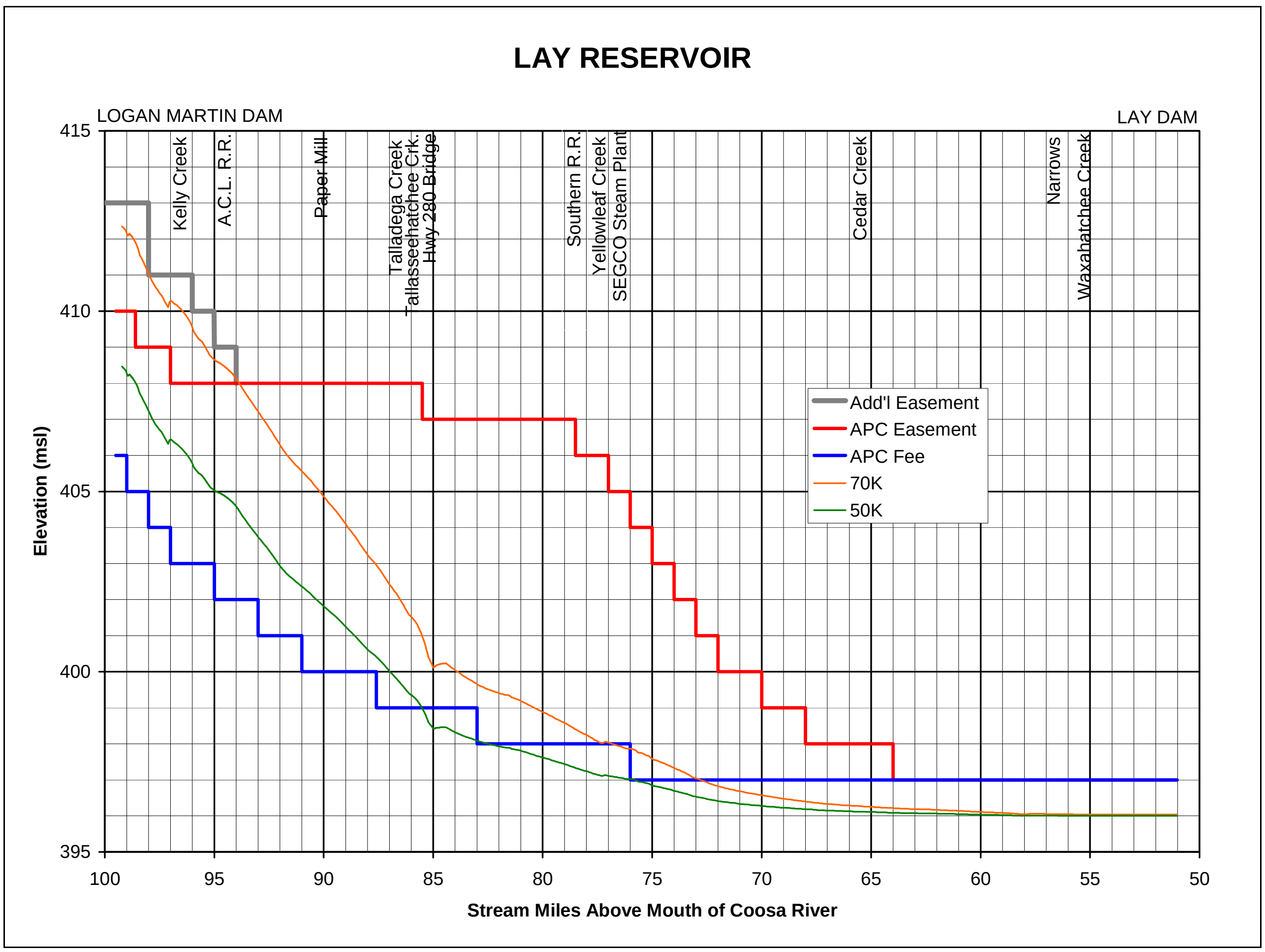
Both Weiss and Logan Martin follow the flood surcharge schedule to the point at which the reservoir elevation is falling and then maintain the gate setting until the reservoir elevation has receded to the flood guide curve, unless there is another flood event that would require resetting the gates according to the surcharge schedule.

The final consideration that was evaluated involved Lay Reservoir. It was determined that there was some benefit to pulling Lay Reservoir one foot from elevation 396' to elevation 395' during the onset of high flow flood events.

Additional Flood Easements on Lay Reservoir

One part of the relicensing efforts that Alabama Power Company is engaged in is the revision of flood control operations for the Upper Coosa Projects, specifically at the Weiss and Logan Martin Projects. The current flood control operations at these projects were developed in the 1960's. The intense development on these reservoirs along with the experience of several major floods and the potential changes of winter pool elevations which are being considered in the relicensing process prompts the need to revise the flood control procedures.

One of the changes in the flood control procedures involves modifying the induced surcharge operations at both projects, with specific higher starting discharges from Logan Martin. This increase at Logan Martin (from 50,000 cfs up to 70,000 cfs) prompts the need of additional flood easement. Routings of the Coosa River from Logan Martin Dam downstream to Lay Dam have been performed for 50,000 cfs up to 70,000 cfs to ascertain impacts to elevations above current flood easements. These routings have determined that additional flood easement is needed for a six mile stretch of the Coosa River on Lay Reservoir just downstream of Logan Martin Dam.



LIDAR aerial survey was performed in late 2003 to determine the extent of property impacted with higher river elevations. From this survey, 762 acres was determined as the property needed in additional flood easement. 312 acres of these 762 acres is non-APC land which is contained in 56 parcels of land. Plans are to acquire additional easement on these properties in the years 2005 and 2006.

TIMELINE OF EVENTS:

Mid 2004:

Alabama Power approved acquisition of 762 acres of flood easement.

Late 2004 and Early 2005:

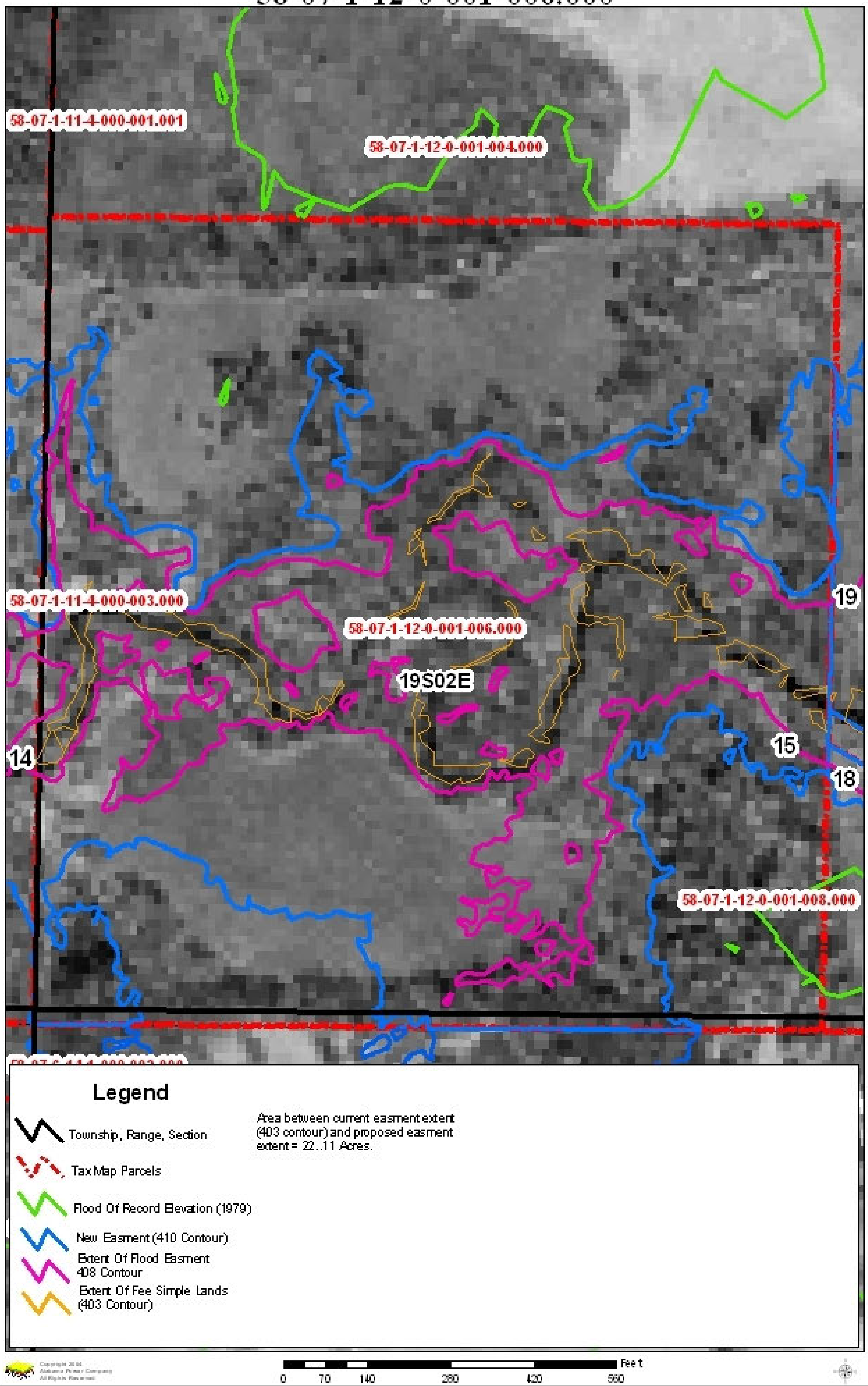
GIS will produce parcel maps (sketches) of each 56 parcel of land, showing property corners, existing flood easement contour, proposed flood easement contour, and a high water contour. Included on each map will be land features such as section corners, township and range lines, etc. (example sketch on next page).

Jul 2005 thru Dec 2006:

Purchase 450 acres of additional flood easement (involves 56 parcels).

Modify property description for 312 acres of APC non-utility land to reflect additional flood easement.

58-07-1-12-0-001-006.000



Section 5

Design Flood Analysis

In each of the following reservoir sections there is a graph that depicts Alabama Power Company's easements as well as land owned in fee. Plotted against the fee and easement lines are the maximum water surface elevation profiles resulting from running the design flood thru the HEC-RAS model for both the existing flood control plans and the proposed flood control plans. A third water surface elevation, plotted in green, is the unregulated pre-project flood elevation.

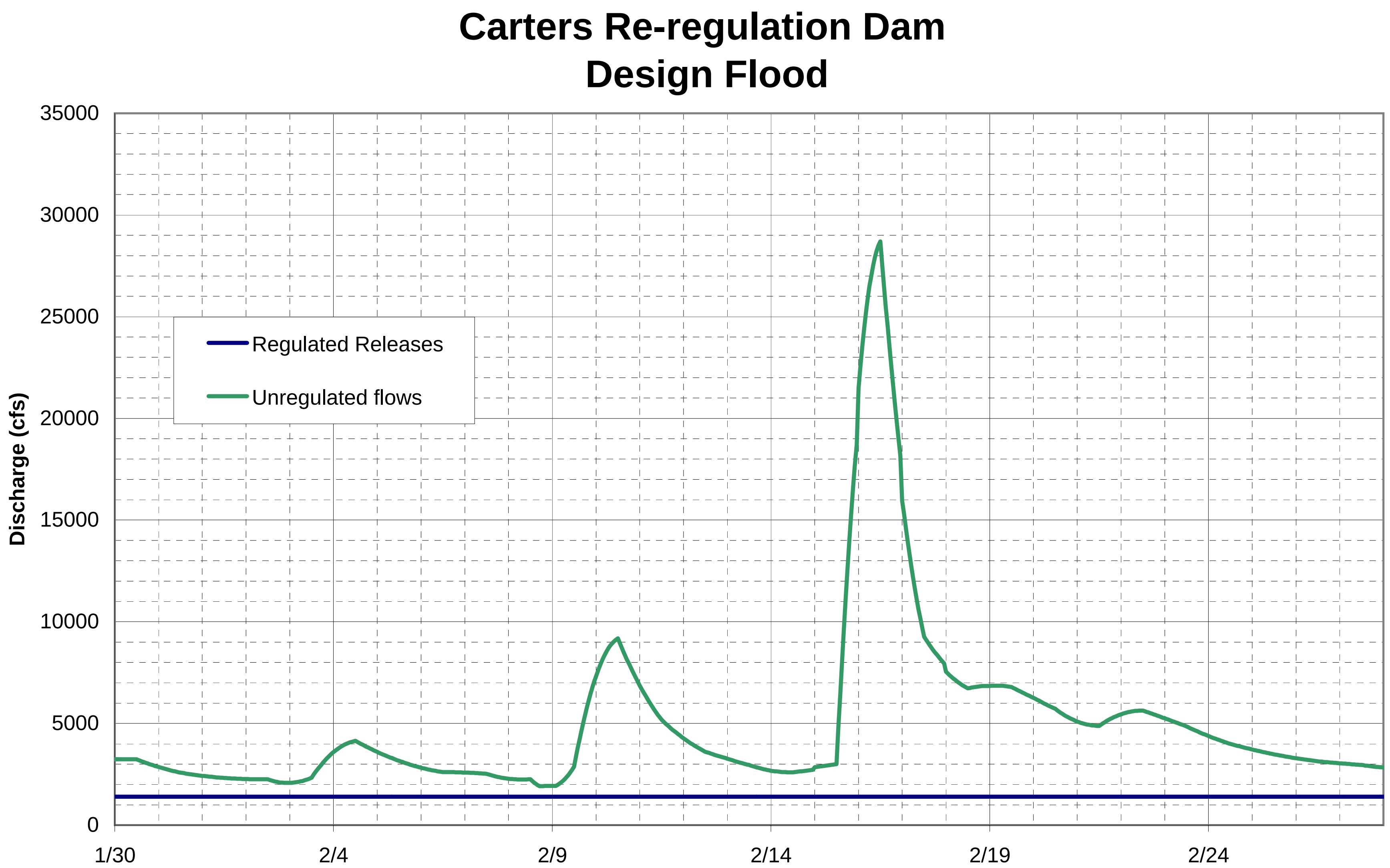
From these graphs it is observed that the proposed flood control design flood elevations are not higher than the existing flood control plan elevations and in some instances are actually lower. At Weiss the peak flood elevation is 571.21 or 0.79 feet below the easement and Logan Martin the peak flood elevation is 472.64 or 0.86 feet below the easement.

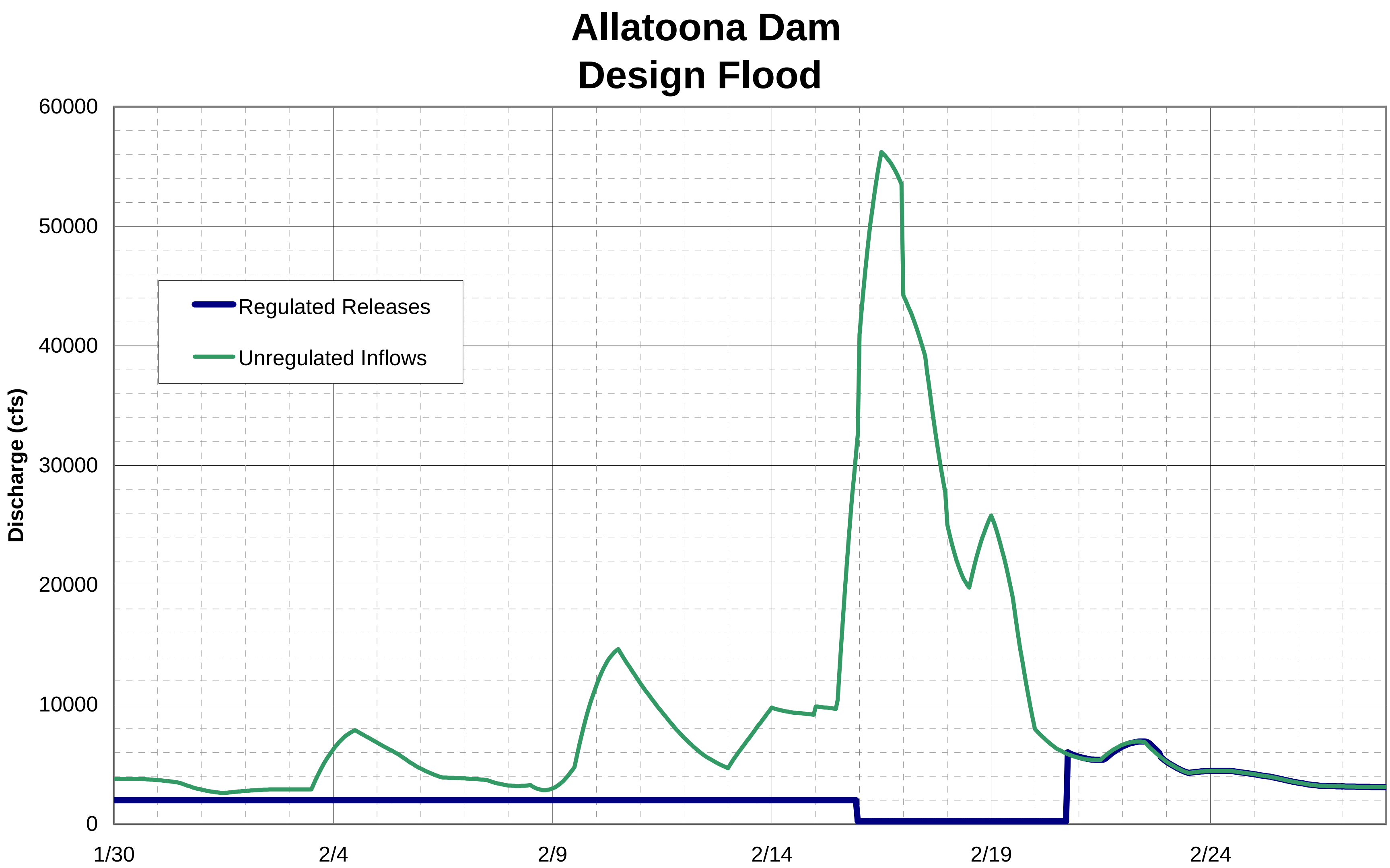
Weiss, H Neely Henry and Logan Martin sections all include a graph that plots the regulated design flood inflow, the existing plan discharge and elevation as well as the proposed plan discharge and elevation.

The Lay, Mitchell and Jordan sections only include a plot that compares the existing plan discharge to the proposed plan discharge as they are not storage reservoirs.

Due to the sensitivity to flooding, Gadsden and Childersburg were determined to be areas where closer evaluation of the procedures was needed. The H Neely Henry section contains the Gadsden graph and the Lay section contains the Childersburg graph. The graphs plot the elevation at each location for both the existing flood control procedures and the proposed flood control procedures at Weiss, H Neely Henry and Logan Martin dams. At each of these locations the proposed plan elevation does not exceed the existing plan elevation.

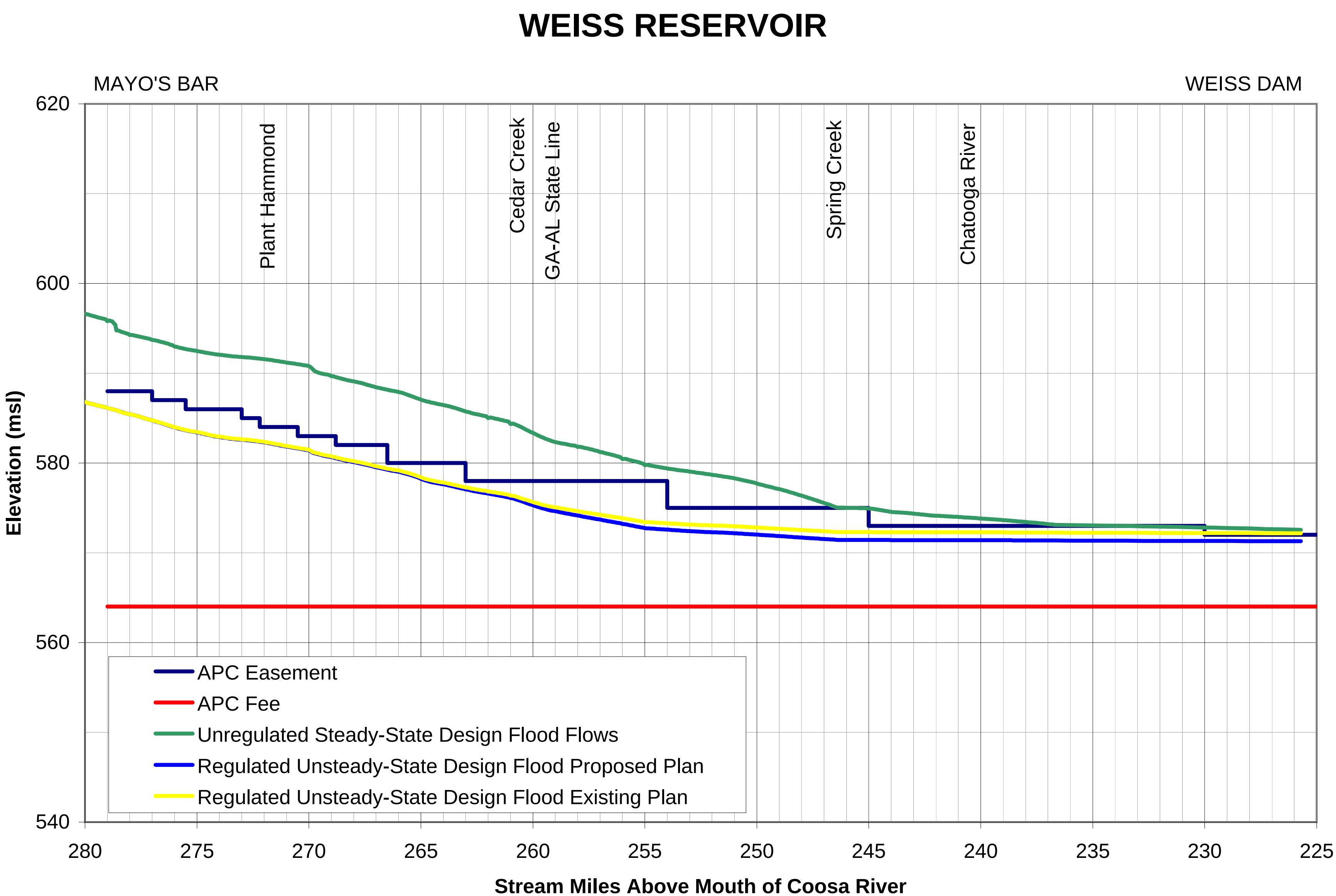
NorthWest GA


Carters Re-regulation Dam
Design Flood
Discharge (cfs)
35000
30000
25000
20000
15000
10000
5000
0
1/30
2/4
2/9
2/14
2/19
2/24
Regulated Releases
Unregulated flows

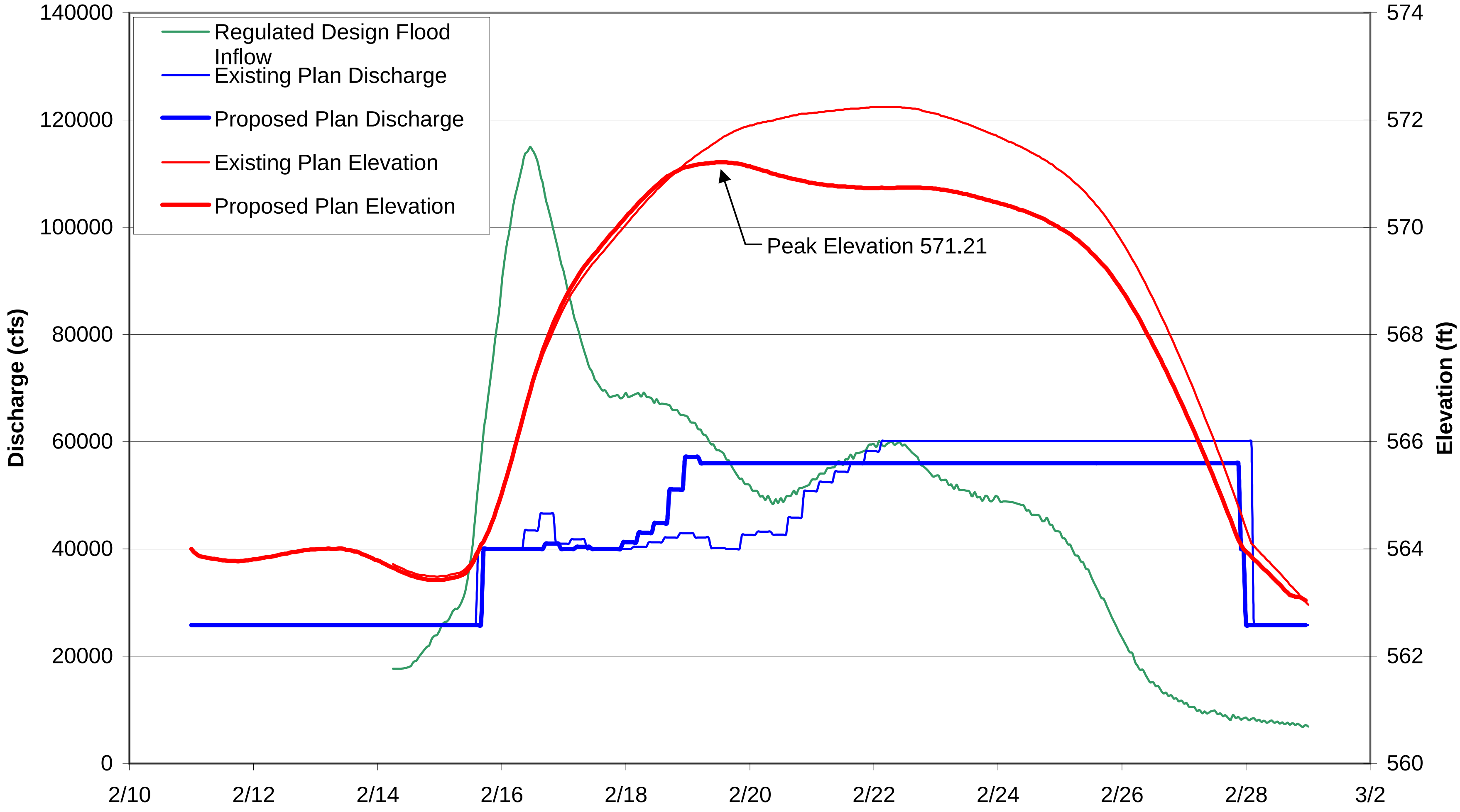


Allatoona Dam
Design Flood
Discharge (cfs)
60000
50000
40000
30000
20000
10000
0
1/30
2/4
2/9
2/14
2/19
2/24
Regulated Releases
Unregulated Inflows

Weiss

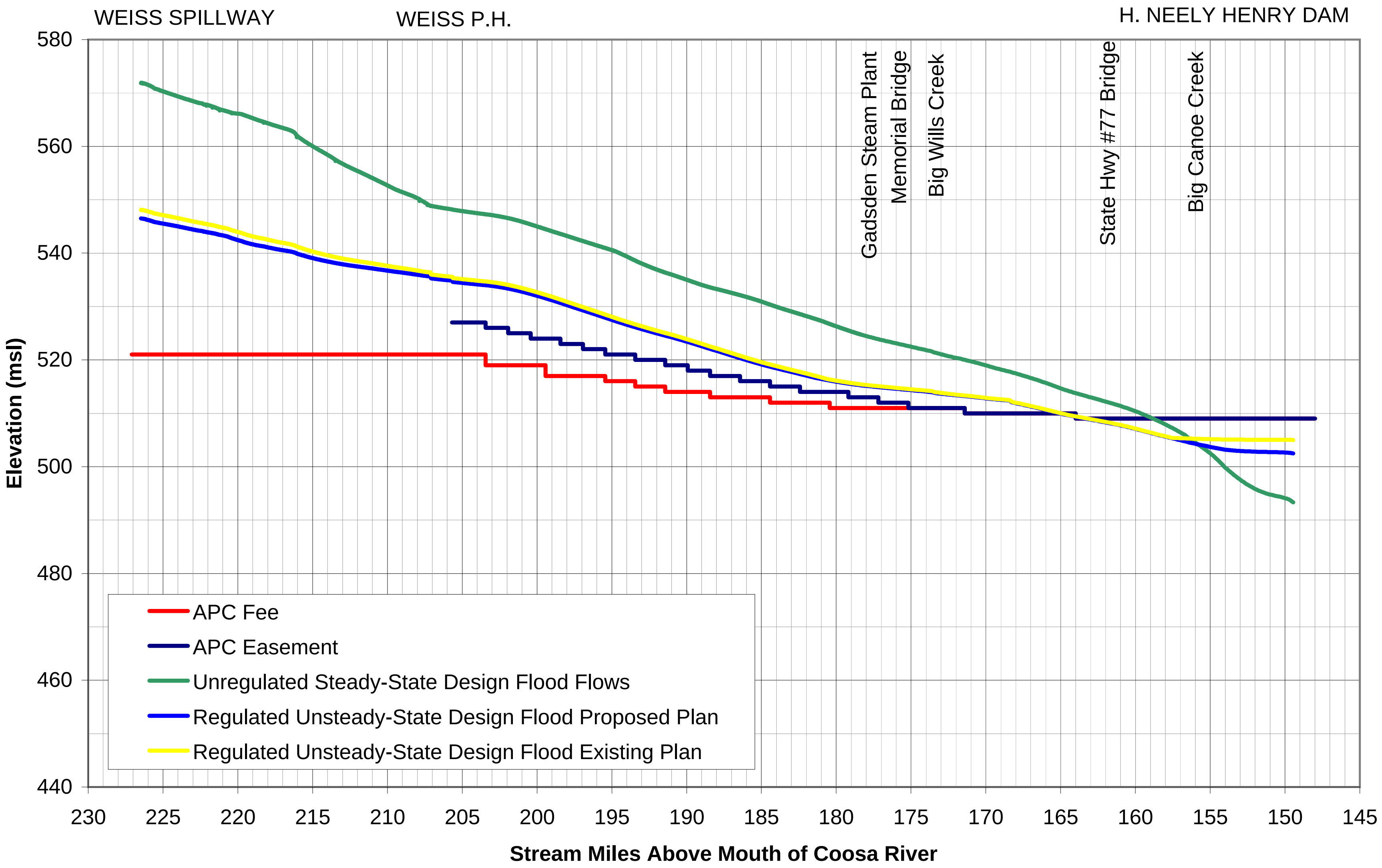

WEISS RESERVOIR
MAYO'S BAR
WEISS DAM
Plant Hammond
Cedar Creek
GA-AL State Line
Spring Creek
Chatooga River
620
600
580
560
540
Elevation (msl)
280
275
270
265
260
255
250
245
240
235
230
225
Stream Miles Above Mouth of Coosa River
APC Easement
APC Fee
Unregulated Steady-State Design Flood Flows
Regulated Unsteady-State Design Flood Proposed Plan
Regulated Unsteady-State Design Flood Existing Plan

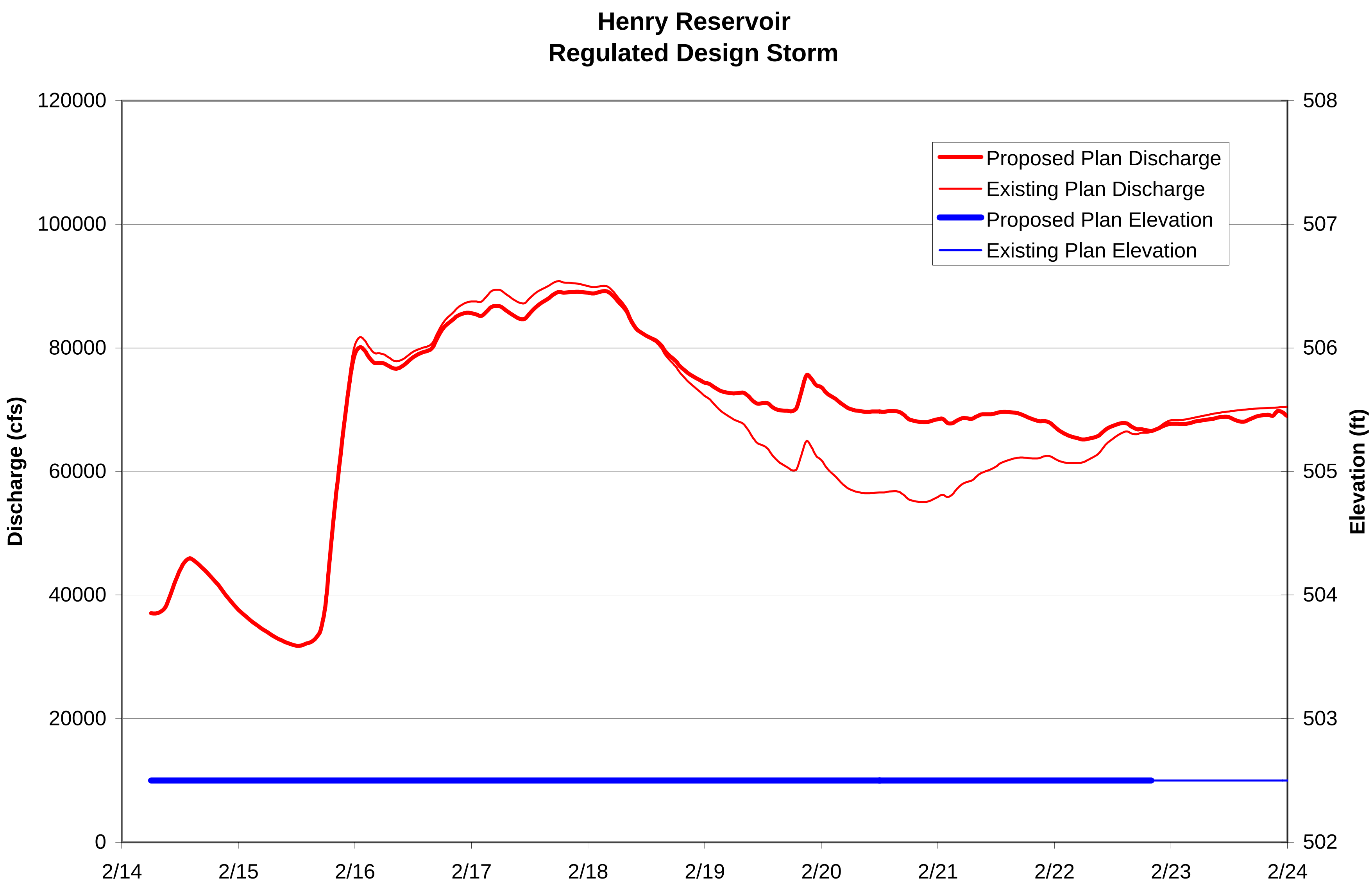
Weiss Reservoir
Regulated Design Storm



Henry

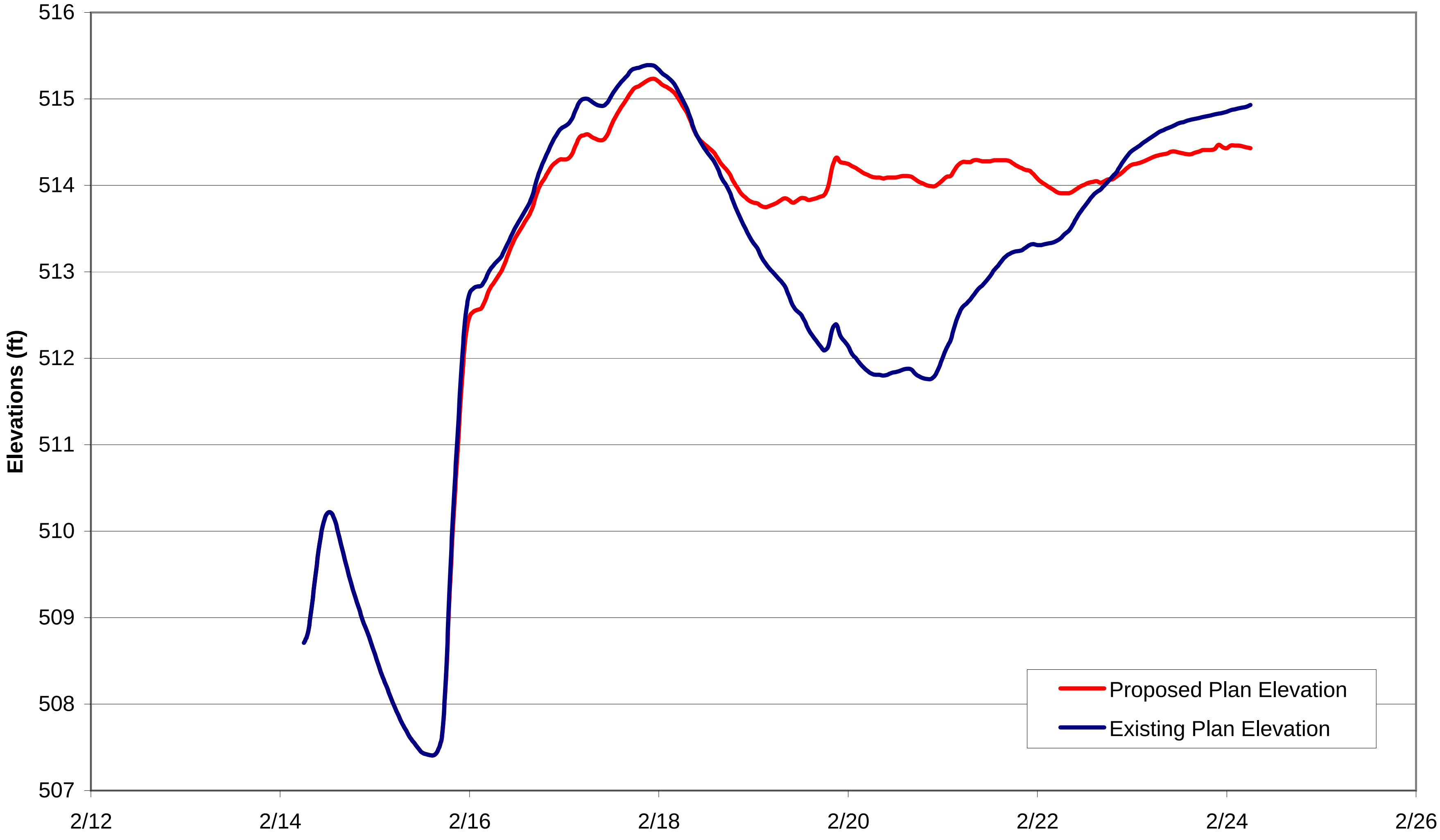
H. NEELY HENRY RESERVOIR



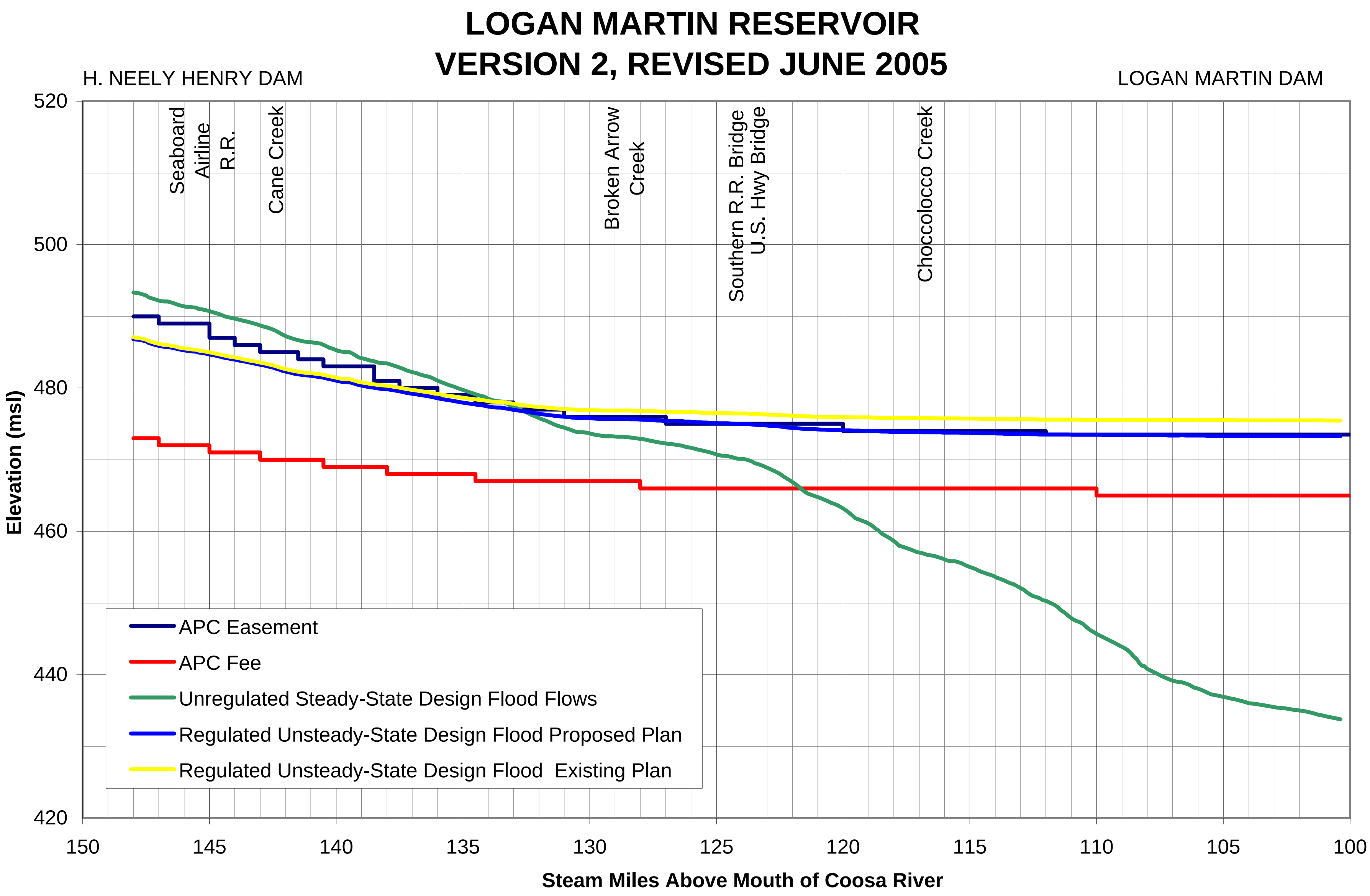


Henry Reservoir
Regulated Design Storm
Proposed Plan Discharge
Existing Plan Discharge
Proposed Plan Elevation
Existing Plan Elevation
Discharge (cfs)
Elevation (ft)
120000
100000
80000
60000
40000
20000
0
508
507
506
505
504
503
502
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22
2/23
2/24

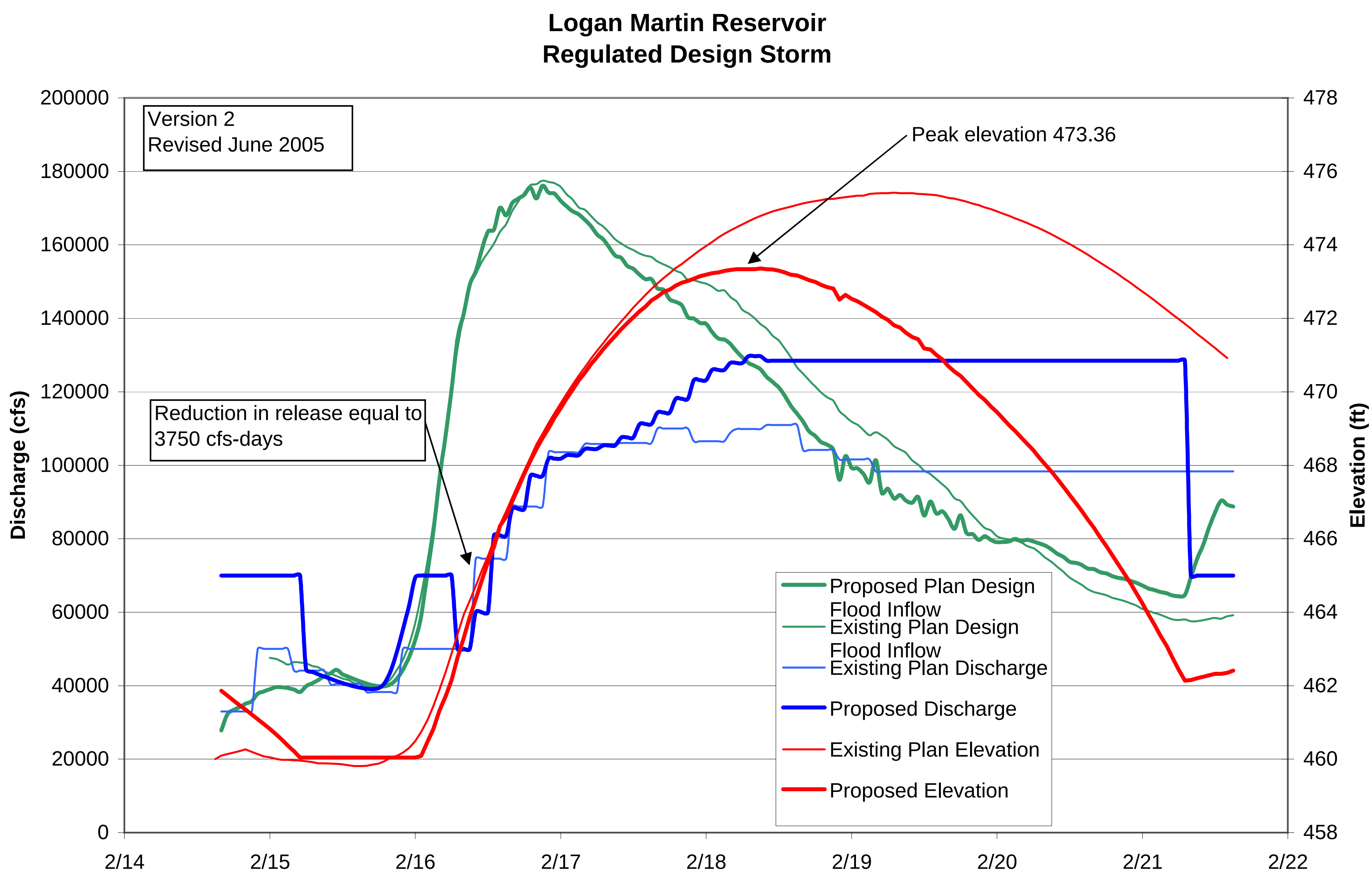
Gadsden Elevation
Regulated Design Flood



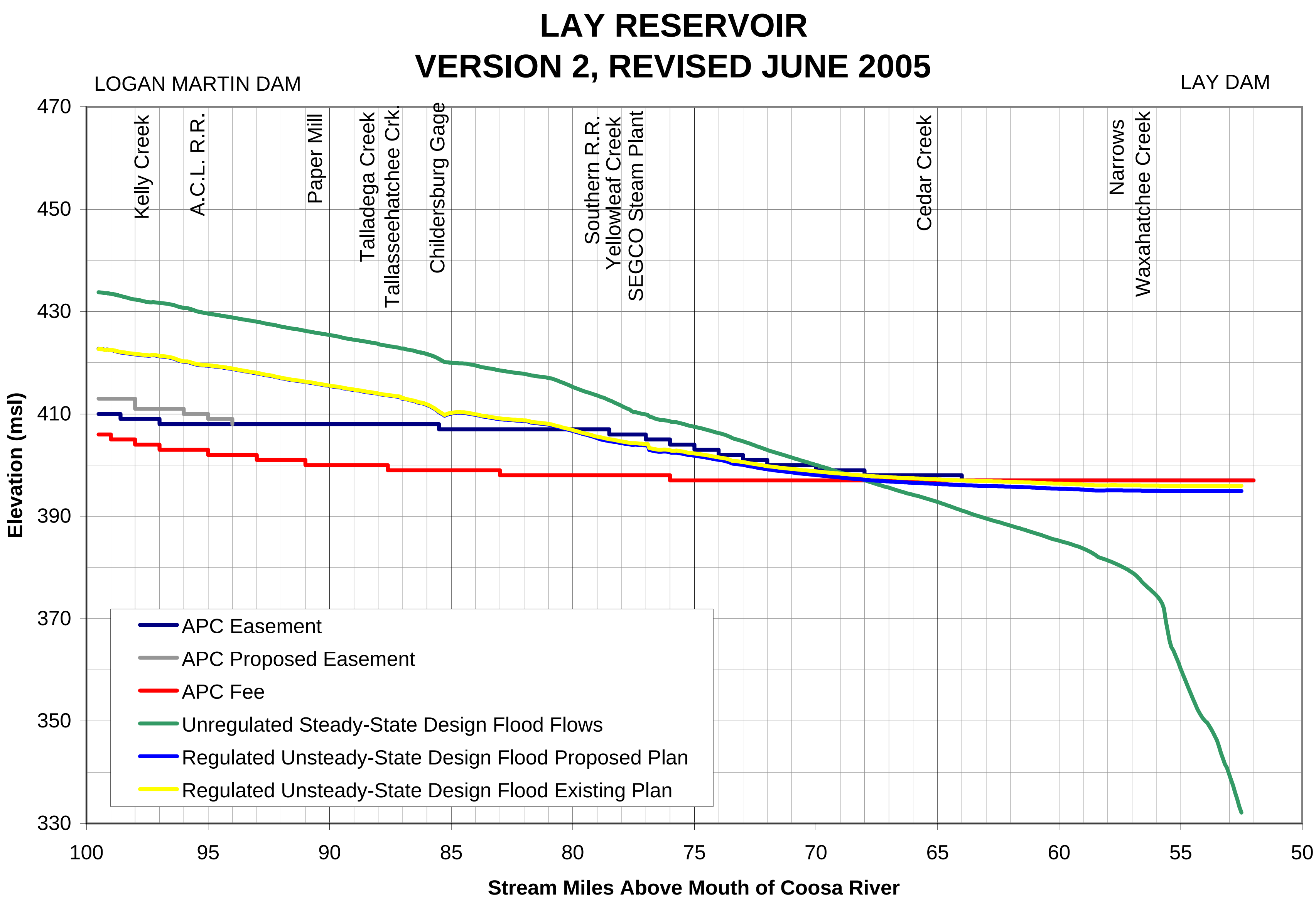
Logan Martin



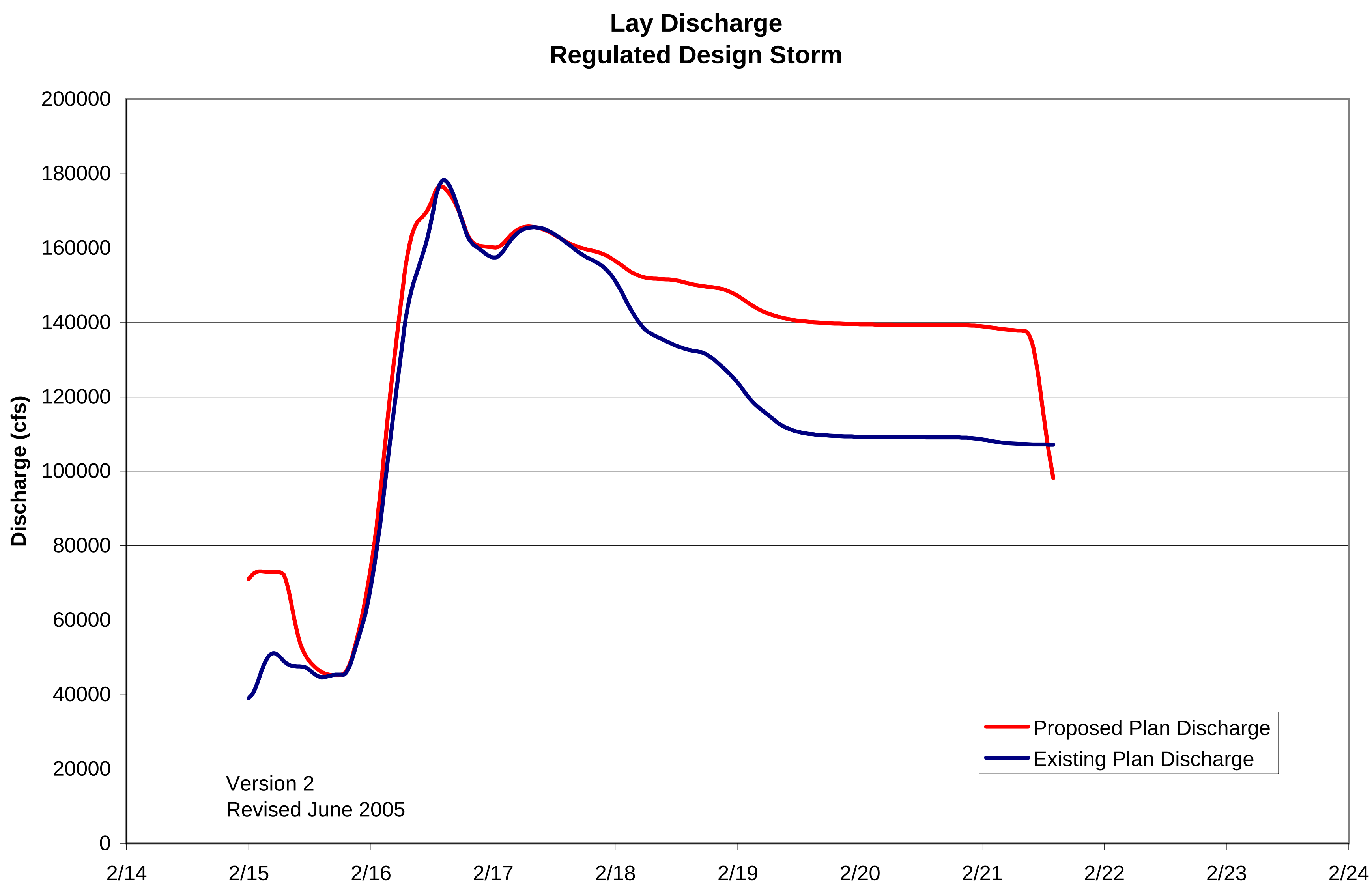
LOGAN MARTIN RESERVOIR
VERSION 2, REVISED JUNE 2005
H. NEELY HENRY DAM
LOGAN MARTIN DAM
Seaboard Airline R.R.
Cane Creek
Broken Arrow Creek
Southern R.R. Bridge
U.S. Hwy Bridge
Choccolocco Creek
Elevation (msl)
520
500
480
460
440
420
150
145
140
135
130
125
120
115
110
105
100
Steam Miles Above Mouth of Coosa River
APC Easement
APC Fee
Unregulated Steady-State Design Flood Flows
Regulated Unsteady-State Design Flood Proposed Plan
Regulated Unsteady-State Design Flood Existing Plan


Logan Martin Reservoir
Regulated Design Storm
Version 2
Revised June 2005
Peak elevation 473.36
Reduction in release equal to 3750 cfs-days
Discharge (cfs)
Elevation (ft)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
478
476
474
472
470
468
466
464
462
460
458
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22
Proposed Plan Design Flood Inflow
Existing Plan Design Flood Inflow
Existing Plan Discharge
Proposed Discharge
Existing Plan Elevation
Proposed Elevation

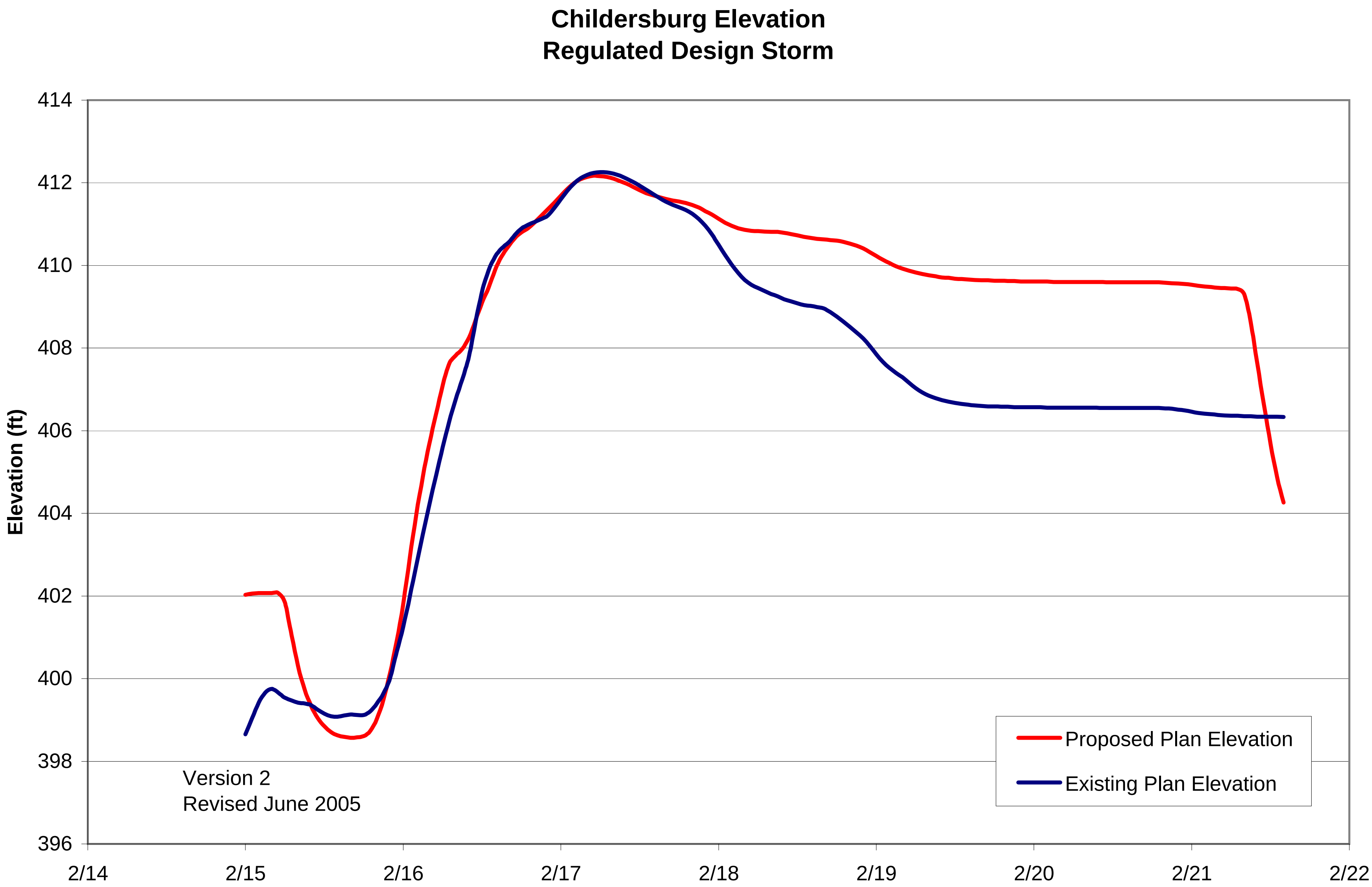
Lay



LAY RESERVOIR
VERSION 2, REVISED JUNE 2005
LOGAN MARTIN DAM
LAY DAM
Kelly Creek
A.C.L. R.R.
Paper Mill
Talladega Creek
Tallasseehatchee Crk.
Childersburg Gage
Southern R.R.
Yellowleaf Creek
SEGCO Steam Plant
Cedar Creek
Narrows
Waxahatchee Creek
Elevation (msl)
470
450
430
410
390
370
350
330
100
95
90
85
80
75
70
65
60
55
50
Stream Miles Above Mouth of Coosa River
APC Easement
APC Proposed Easement
APC Fee
Unregulated Steady-State Design Flood Flows
Regulated Unsteady-State Design Flood Proposed Plan
Regulated Unsteady-State Design Flood Existing Plan

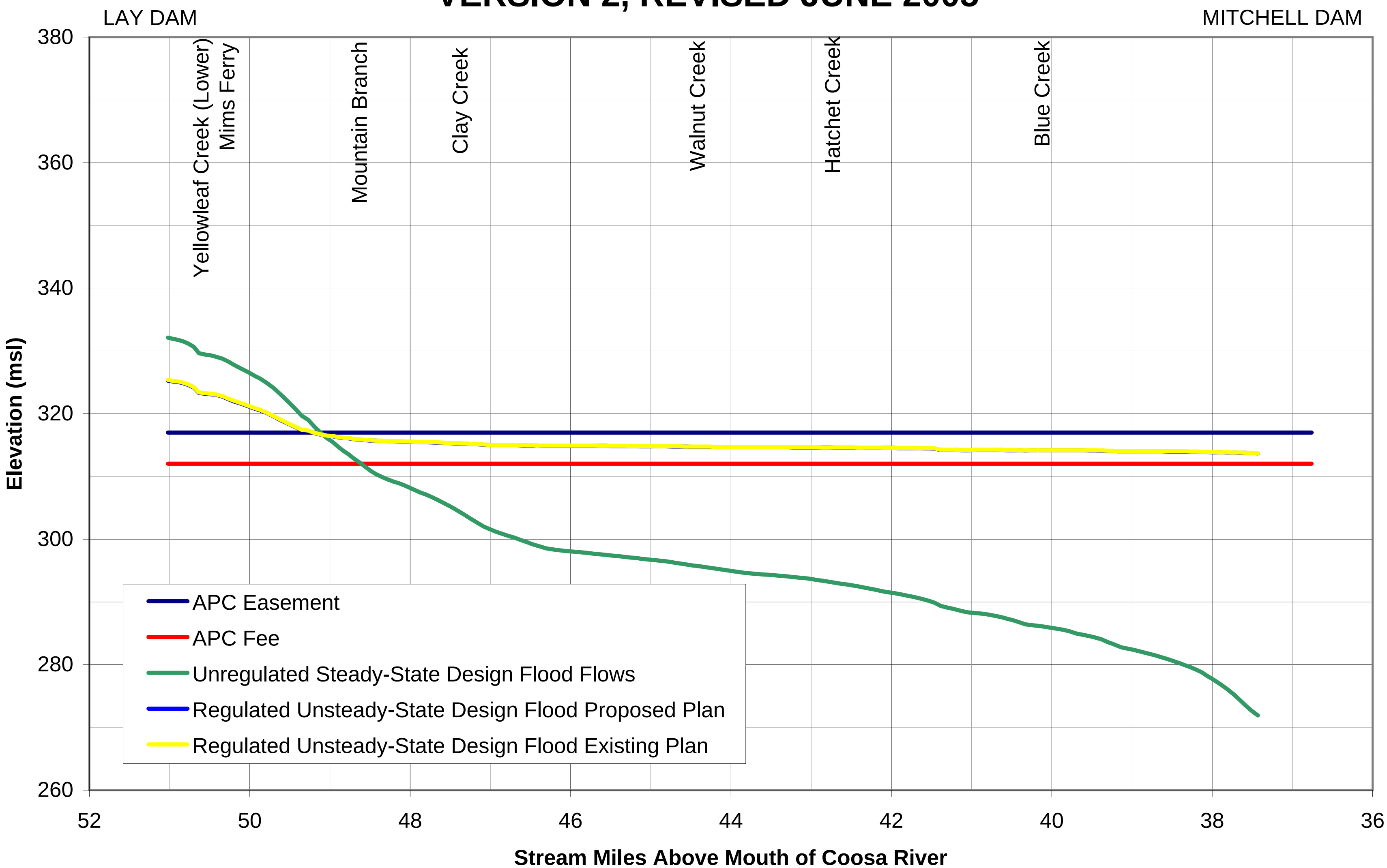


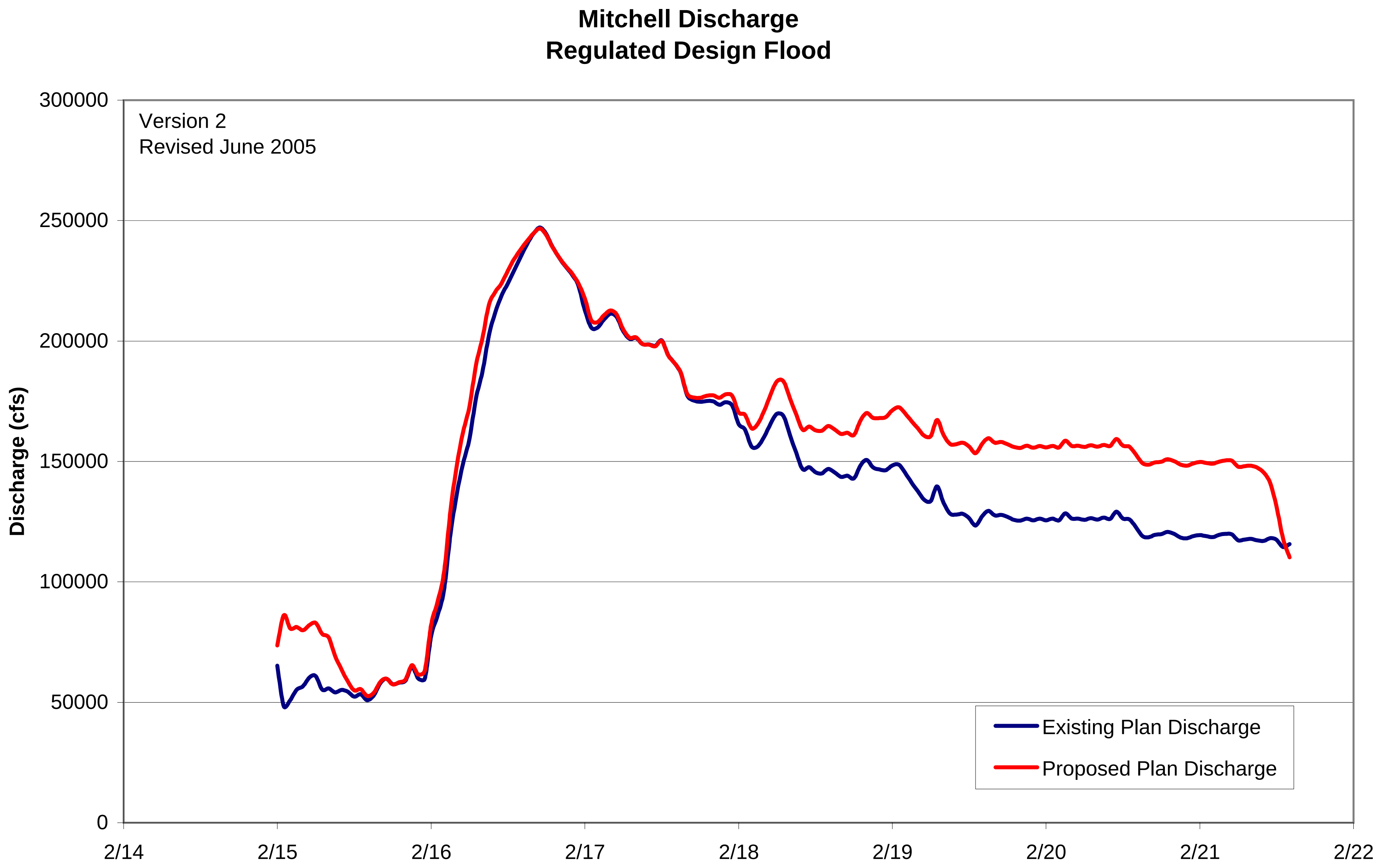
Lay Discharge
Regulated Design Storm
Discharge (cfs)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22
2/23
2/24
Proposed Plan Discharge
Existing Plan Discharge
Version 2
Revised June 2005


Childersburg Elevation
Regulated Design Storm
Elevation (ft)
414
412
410
408
406
404
402
400
398
396
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22
Proposed Plan Elevation
Existing Plan Elevation
Version 2
Revised June 2005

Mitchell

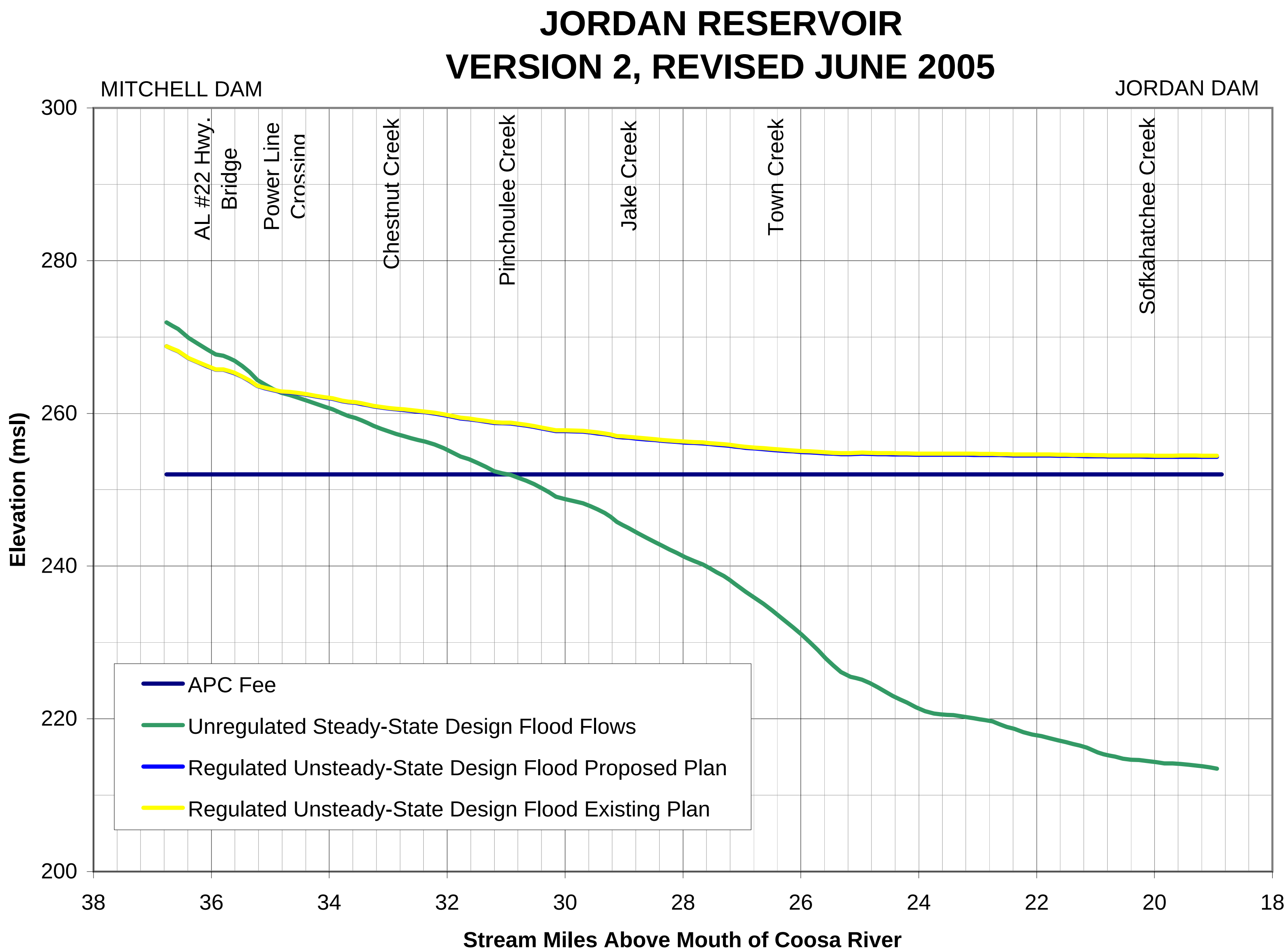
MITCHELL RESERVOIR
VERSION 2, REVISED JUNE 2005



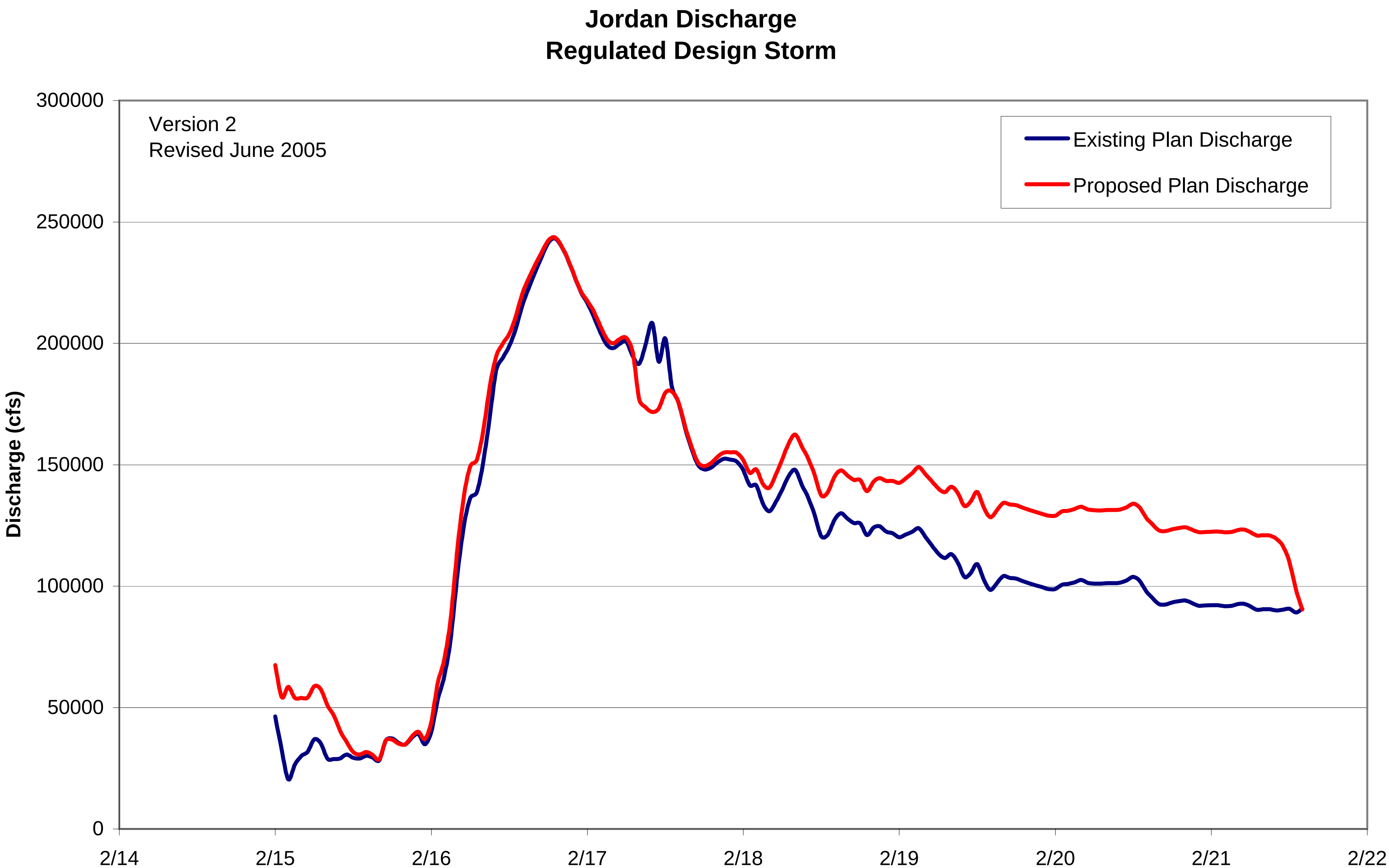


Mitchell Discharge
Regulated Design Flood
Version 2
Revised June 2005
Discharge (cfs)
300000
250000
200000
150000
100000
50000
0
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22
Existing Plan Discharge
Proposed Plan Discharge

Jordan/Bouldin



JORDAN RESERVOIR
VERSION 2, REVISED JUNE 2005
MITCHELL DAM
JORDAN DAM
AL #22 Hwy. Bridge
Power Line Crossing
Chestnut Creek
Pinchoulee Creek
Jake Creek
Town Creek
Sofkahatchee Creek
Elevation (msl)
300
280
260
240
220
200
38
36
34
32
30
28
26
24
22
20
18
Stream Miles Above Mouth of Coosa River
APC Fee
Unregulated Steady-State Design Flood Flows
Regulated Unsteady-State Design Flood Proposed Plan
Regulated Unsteady-State Design Flood Existing Plan


Jordan Discharge
Regulated Design Storm
Version 2
Revised June 2005
Existing Plan Discharge
Proposed Plan Discharge
Discharge (cfs)
300000
250000
200000
150000
100000
50000
0
2/14
2/15
2/16
2/17
2/18
2/19
2/20
2/21
2/22

Appendix 1

Appendix 1 Approvals and Transmittals

Transmittal of Model Calibration Packages

Approved Plan of Study

Request for Review of H Neely Henry Interim Flood Control Plan

Approval of Extension of Temporary Variance on H Neely Henry Project

Letter to Colonel Keyser

Plan of Study

for

Modification, Updating and/or Inclusion of Flood Control Plans for Alabama Power Company Owned and Operated Reservoirs

on the

Coosa River, State of Alabama

1. PURPOSE

This Plan of Study defines the parameters, procedures and study methodology required to modify, update and/or include flood control operational plans for the reservoirs owned and operated by Alabama Power Company (APC) on the Coosa River, State of Alabama. This document delineates the responsibilities and products that each party will implement or develop during the formulation of the new operating plans. However, this document is not intended to be legally binding on either party.

The following table lists the Alabama Power Company owned dams on the Coosa River, reservoir capacities at normal pool, and the approval date of the operational Memorandums of Understanding (MOU) currently in effect. The final column indicates whether the new plan will be modified, updated, or not changed. If flood control is not currently part of the operational plan and it is desired to include flood control the project is marked as "include".

Dam	Total Storage Ac-Ft.	Date of MOU	Flood Control Plan	Modify/Update/
Jordan/Bouldin	236,126	-	(none)	Include
Mitchell	170,781	-	(none)	Include
Lay	262,883	-	(none)	Include
Logan Martin	273,300	Oct. '67	Appendix C	Modify
Neely Henry	121,860	Jan. '79	Appendix D	Modify
Weiss	306,400	Oct. '65	Appendix B	Modify

NOTE: Flood control is currently not part of the operational procedures for Jordan, Mitchell and Lay

2. BACKGROUND

The District Engineer, U. S. Army Corps of Engineers (USACE), Mobile, Alabama prepared the existing flood control requirements in cooperation with Alabama Power Company in compliance with provisions of Public Law 83-436 and Federal Power Commission License for Project No. 2146. These manuals were approved with the understanding that they could be subjected to review at any time upon request of the Alabama Power Company or the District Engineer. Revisions can be made as often as changing conditions and operating experience may dictate.

The manuals were included in the ALABAMA-COOSA RIVER BASIN WATER CONTROL MANUAL for reservoir regulation for the Alabama-Coosa River system as appendices. This document was published and is maintained by the Mobile District, U. S. Army Corps of Engineers.

Flood control operational plans were developed in accordance with regulations prescribed by the Secretary of the Army as published in the Code of Federal Regulations (CFR), Title 33, Chapter II, Part 208, Section 208.65. A Memorandum of Understanding concerning the operation of the each project was adopted by the Alabama Power Company and the Corps of Engineers along with the regulation manuals. The regulation manuals for Weiss, H Neely Henry and Logan Martin projects were published in October, 1965, January, 1979, and January, 1968, respectively. The initial Memorandum clarified the responsibilities of the two agencies with regard to operation of the project for flood control, other purposes and provided for the orderly exchange of hydrologic data.

Over 25 years of operational experience and hydrologic data has been assembled since the last modification or inclusion into the currently standing operational plan for the Coosa River system. Economic development, environmental regulations and shifting demographics have raised concerns that the constraints and limitations defined in the existing flood control plans may no longer be appropriate. Stakeholders, including home owner associations, have requested a re-evaluation of the current water control plans.

For over a decade Alabama Power had been developing and using extensive real time gaging and computer technology to better manage flood control operations. In recent years better information and understanding has allowed floods to be managed with the use of variances from the water control plans. Therefore the need exists to develop more effective, responsive and refined flood control plans. Alabama Power Company has requested an opportunity to review the existing plans, update the information and propose appropriate modifications.

3. STUDY METHODOLGY

3.1. Authorities and Approval Requirements.

Several Federal statutes authorize the Secretary of the Army to prescribe rules and regulations for project operation of privately owned dams in the interest of flood control and navigation. These authorities are implemented in **33** CFR **208.11,** which sets forth the regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to the authority of the Secretary of the Army in the interest of flood control and navigation. The intent of this regulation is to establish an understanding between project owners, operating agencies, and the Corps of Engineers in regards to flood control and navigation.

The basic process set out in this regulation specifies that the Chief of Engineers, U.S. Army Corps of Engineers, is designated the duly authorized representative of the Secretary of the Army to exercise the authority set out in the Congressional Acts. Normally the regulation will be implemented by letters of understanding between the Corps of Engineers and project owner and will incorporate the provisions of such letters of understanding prior to the time of significant impoundment of water. A water control agreement is signed by both parties when deliberate impoundment first begins. Such actions were accomplished for projects in the Coosa River that had been identified at the time of construction to have flood control. Regulation of the system for navigation was deferred until such time that it would be established on the system.

The project owner is responsible for real-time implementation of the water control plan. Consultation and assistance is to be provided by the Corps of Engineers when appropriate and to the extent possible. During any emergency that affects flood control and/or navigation, the Corps of Engineers may temporarily prescribe regulation of flood control or navigation storage space on a day-to-day (real-time) basis without request of the project owner. Appropriate consideration will be given for other authorized project functions.

The water control plan and all associated documents will be revised by the Corps of Engineers as necessary, in coordination with the owner, to reflect changed conditions that come to bear upon flood control and navigation, e.g., reallocation of reservoir storage space due to sedimentation or transfer of storage space to a neighboring project. Revision of the water control plan, water control agreement, water control diagram, or release schedule requires approval of the Chief of Engineers or his duly authorized representative with each revision becoming effective upon the date specified in the approval. The original (signed document) water control agreement is kept on file in the respective Office of the Division Engineer, Corps of Engineers, Department of the Army. The USACE Division Office for the Operational MOU's developed by this study will be the South Atlantic Division, located in Atlanta, GA. The USACE Mobile District Office will serve as the Corps of Engineers' point of contact and coordinator for the implementation of this study effort.

Approval of the Chief of Engineers or his authorized representative is required before changes can be made to an approved water control plan (33 CFR 208.11, p.6). ER 11110-2-240, Appendix C, delegates that authority to the MSC Commander.

On 28 June 1954, Congress enacted Public Law 83-436 which suspended the authorization under the River and Harbor Act of 2 March 1945 insofar as it concerned Federal development of the Coosa River for the development of electric power, to permit development by private interests under a license to be issued by the Federal Power Commission. The law stipulated that the license require the provision of flood control storage and the projects be operated for flood control and navigation in accordance with reasonable rules and regulations of the Secretary of the Army. The Federal Energy Regulatory Commission (formally the Federal Power Commission) is responsible for granting the operational licenses for the non-Federal projects on the Coosa River system with the flood control plan as a significant part of the operational license. Therefore FERC will be included in the process of the developing the study plan and ultimately will be asked to include any modifications to the flood control plan in the new license to be issued for the Coosa River Project.

Legislation passed since the initial license requires that FERC prepare an environmental assessment (EA) for the new Coosa River Project license. Since the flood control plan will be a significant part of the overall operational plans in the new license, FERC's EA will include an evaluation of the final flood control plans. It is anticipated that the Corps will, with respect to the environmental assessment of the final flood control plans, cooperate closely with Alabama Power as it prepares a draft EA for inclusion in the license application and with FERC as it prepares the final EA to support its license decision. The FERC will be the Lead Agency for the NEPA documentation and the Corps will serve as a Cooperating Agency.

The final MOU will also address navigational requirement on the Coosa River and downstream on the Alabama River. Existing documentation does not address current low flow release requirements; therefore, the navigation portion will be a separate section in the final MOU and, since it is a system wide requirement, each reservoir regulation manual will have one common navigation procedure.

A new operating plan is currently under consideration for the Corps owned Allatoona Dam, which is upstream of the dams owned by Alabama Power. The final operational plan for the Alabama Power Dams will consider the proposed new Allatoona rule curve impacts. This will be a post analysis after a recommended plan is developed.

3.2. Procedures For Developing And Processing Regulations for Non-Corps Projects in Conformance with 33 CFR 208.11

Evaluation of any proposed changes will factor in any significant changes in downstream damage centers, dam safety criteria, and upstream recreational use. Hydrological data will be updated.

Specific analyses are not specified in existing guidance, but rather, the water control plans will be "tested" to see how the projects would perform under multiple scenarios. This will include modeling of both historical events and hypothetical events, including the project's design flood. Justification will be required to support any operational change that would reduce the flood control benefits currently afforded by the project(s) and risk to a project's structural integrity will not be increased.

Background information on the project and conditions requiring flood control or navigation services, and other relevant factors, are assembled by the District Engineer and incorporated in a "Preliminary Information Report". The Preliminary Information Report will be submitted to the Division Engineer for review and approval. Alabama Power Company will furnish information on project features, the basis for storage allocations, requested modifications and any other available data pertinent to the studies. The Corps of Engineers, Mobile District will supplement this information as required.

The Corps of Engineers, at District level, is responsible for the necessary studies to develop reservoir regulation schedules and plans, except where the project regulation affects flows in more than one district, in which case the studies will be conducted by or under supervision of Division personnel. Assistance can be provided by the project operating agency/owner or others concerned Federal or State entities.

It is anticipated that any changes made will be processed substantially in the manner described in 33 C.F.R. 222.5, Appendix C, paragraph f.

3.3. Guidance Documents.
Design guidance documents that are considered relevant include:

a.) Section 7 of the Flood Control Act of 1944 grants authority to the Corps to prescribe flood control and navigation regulations on certain non-Corps dams.

b.) PL 83-436 83rd Congress 1954 provides for the development of the Coosa River by private interests under a license from the Federal Power Commission.

c.) Code of Federal Regulation, Title 33, Part 208 (33 CFR 208.11) prescribes the responsibilities and procedures for flood control or navigation and the use of allocated storage.

d.) EM 1110-2-3600 – "Engineering and Design for MANAGEMENT OF WATER CONTROL SYSTEMS" provides guidance for the management of water control projects authorized by Congress and planned, designed and constructed by the Corps. It also applies to certain aspects of water control projects constructed by other agencies.

e.) ER 1110-2-240 – "Engineering and Design for WATER CONTROL MANAGEMENT" provides policies and procedures for carrying out water management activities, including establishment of water control plans for Corps and non-Corps projects.

f.) ER 1110-2-241 – "Engineering and Design for USE OF STORAGE ALLOCATED FOR FLOOD CONTROL AND NAVIGATION AT NON-CORPS PROJECTS" provides the responsibilities and general procedures for regulating reservoir projects for flood control or navigation and the allocated storage for such uses.

g.) EM 1110-2-1420 – "Engineering and Design for HYDROLOGIC ENGINEERING REQUIREMENTS FOR RESERVOIRS" provides guidance for hydrologic engineering investigations for planning and design of reservoir projects.

3.4. Evaluation Parameters and Tools.

Alabama Power proposes to update the hydrologic data for all their reservoirs on the Coosa River and to consider modification of the rule curves for Weiss and Logan Martin Reservoirs. The original water control plans for each reservoir only considered the impact of the reservoir in question on historical flood events. Some plans were developed before the construction of some upstream impoundments, such as Carters Lake. New technology with simulation modeling will permit the analysis to not only update upstream influences but consider the accumulative impacts on the system as a whole. For example: The evaluation will reflect the impacts of the proposed new rule curve at Weiss on operation of downstream reservoirs. The following paragraphs describe the proposed changes but, as is the purpose of an evaluation, these changes may be adjusted during the study process to assure the operation plan conforms to regulatory and operational requirements.

During this evaluation the analysis will consider raising the Weiss Reservoir winter pool from elevation 558 ft. MSL to elevation 561 ft. MSL and extending the summer pool duration by one month. Analysis will also consider raising Logan Martin's winter pool from elevation 460 ft. MSL to elevation 462 ft. MSL, transitioning to winter pool one earlier and modifying the transition from summer pool to winter pool. Analysis and evaluation of proposed modifications to the flood control procedures, as well as increased winter pool elevations, must be able to show that there would not be a significant increase in flood damages due to the proposed changes. Where increased flood stages are experienced, mitigation alternatives will be considered; including refining the proposed modification, purchase of additional flood easements, and/or other measures. Evaluation of the mitigation alternatives will take into account and seek to minimize impacts to project purpose, economics, environmental requirements, and stakeholder concerns.

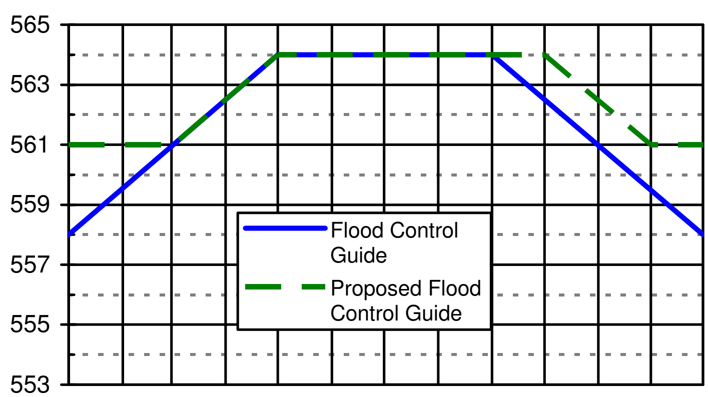


Figure 1 - Weiss Rule Curve

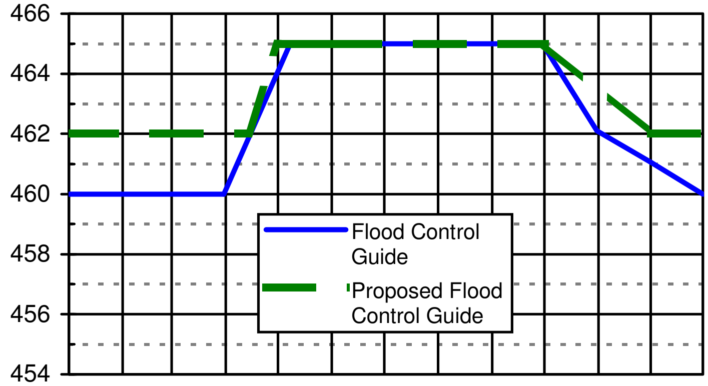


Figure 2 - Logan Martin Rule Curve

Simulation modeling will be used to evaluate the impacts of the existing and proposed operating plans. USACE simulation model, HEC-RAS – River Analysis System, will be used in the unsteady flow mode to simulate the movement of the flood hydrographs through the reservoirs and determine the impacts on flooding at downstream control points. The APC Reservoir Operations Model will be used to develop the outflow hydrographs from the reservoirs as operational criterion is employed. Updated hydrologic and hydraulic data will be used to establish "existing condition" models of the reservoirs. Calibration of the HEC-RAS models will be based on measured water surface profiles, discharges and travel times of the flood peaks. Geometric data in the models will be derived from surveys conducted by USACE, APC and others as available.

Historical flood events in the years 1951, 1979, 1990 and 2003 will be evaluated. The 1951 flood was also considered in the original water control plans and the remaining floods are significant events after the original plans were approved. Models will incorporate existing and proposed surcharge curves and compare impacts from the increased winter rule curve elevations for each reservoir. The results of the reservoir models will be combined into one Water Control Plan, thus the downstream reservoirs will take into account changes and updated information from upstream systems.

In addition to evaluation of the historical flood events cited above, a synthetic flood will be derived for each reservoir and routed through the system with both existing and proposed water control plans. The synthetic flood hydrograph will be based on a peak discharge for a 100 year return period. ACT compact unimpaired flows will be "unsmoothed" and used to develop frequency curves. Algorithms specified by the Corps of Engineers will be used to "unsmooth" the unimpaired database creating a data set of that approximates daily peak flows. A historical flood event with a peak discharge that most closely approximates the 100 year return discharge will be scaled up or down to produce the synthetic hydrograph.

In addition to flood control operations, the evaluation process will also take into account updated Federal and State regulations with respect to Fisheries, Public Safety, Energy Impacts, Erosion, Water Quality, Recreation, and Aesthetics.

4. RESPONSIBILITY OF THE CORPS OF ENGINEERS

The Corps will provide guidance to APC in coordination with APC, review the analysis and approve the plans. Guidance will incorporate requirements set forth in the Code of Federal Regulations, Title 33, Part 208, Section 208.11 and other documents identified by the Corps as appropriate. The plan will also take into consideration effective and efficient operation for other purposes (such as, hydropower) to the extent possible to assure that operational requirements do not severely reduce other purposes of the developments. The Mobile District Corps of Engineers will coordinate with USACE Division and HQ to facilitate the required higher level approval.

The Corps will also coordinate, facilitate and document reviews and comments from other appropriate State and Federal regulatory agencies. Sufficient advanced notice for any meetings and other communications will be provided to allow APC to prepare appropriate documentation and scheduling of critical personnel.

5. RESPONSIBILTY OF ALABAMA POWER

APC will conduct the necessary analysis, simulation modeling and develop a proposed flood control plan for the designated projects that incorporate the objectives defined in paragraph III. APC will submit a proposed control plan to Mobile District Corps of Engineers, which will be the basis for the higher level coordination.

6. COORDINATION

6.1. Schedule.

Complete Initial Flood Analysis	3/1/04	COE/APC
Final Flood Studies	6/1/2004	COE/APC
Draft MOU	7/1/2004	COE/APC
Draft Environmental Assessment	8/1/2004	APC
Final MOU	11/30/04	COE/APC
Environmental Assessment	12/31/2004	FERC/APC
License submitted to FERC	7/31/2005	APC
Publish new Water Control Manuals		COE/APC

6.2. Coordination Authority.

Division Commanders are designated representatives of the Chief of Engineers in matters relating to development and processing of 33 CFR 208.11 regulations for eventual promulgation through publication of selected data specified in paragraph 208.11 (d; (11) of 33 CFR 208.11. Division Commanders are designated as the Corps of Engineers signature authority on all letters of understanding, water control agreements and other documents which may become part of prescribed regulations for projects located in their respective geographic areas, and which are subject to the provisions of 33 CFR 208.11.

ER 1110-2-240, Appendix C, Section 1.g, specifies that all coordination required between the Corps of Engineers and the operating agency will be accomplished at field level.

6.3. Contents of Final MOU.

Just as the development of the original water control plan balanced all authorized project purposes, any reevaluation should do the same. If the original water control plan did not include environmental or social aspects of project regulation as considerations, they should be included to conform to current public law.

7. CLARIFICATION AND APPROVAL

This Plan of Study is submitted to establish the procedures to be followed and lines of communications to be used in exchanging the data to accomplish updating of the Water Control Plans for reservoirs on the Coosa River.

ALABAMA POWER COMPANY

Charles M. Stover
Supervisor Reservoir Management

Date 1-15-2004

UNITED STATES OF AMERICA
U. S. Army Corps of Engineers

Douglas C. Otto, Jr.
Chief Hydrology and Hydraulics Br.

Date 15 JAN 2004

600 North 18th Street
Post Office Box 2641
Birmingham, Alabama 35291

Tel 205.257.1000

ALABAMA POWER
A SOUTHERN COMPANY

January 12, 2004

Mr. Doug Otto
P.O. Box 2288
Mobile, AL 36628

Dear Mr. Otto:

Alabama Power Company owns and operates the H. Neely Henry Hydroelectric Project, FERC License 2146, located on the Coosa River near Gadsden, Alabama. This project is subject to regulation by the Mobile District Corps of Engineers as prescribed in the Alabama-Coosa River Basin Reservoir Manual Appendix D, dated January 1979.

On May 19, 1999, Alabama Power Company sent a letter to Colonel J. David Norwood requesting approval of potential changes to the existing operating guidelines for this project. The potential changes to be reviewed consisted of the winter rule curve being raised from 505 to 507 as well as a new operation guideline for evacuation of the this reservoir for flood control. Attached with this letter is the original report sent to the COE titled "Interim Flood Control Plan".

On February 26, 2001, the Director of the FERC issued an order granting temporary variance, for 3 years from this date, to maintain higher water levels during the winter on Neely Henry Reservoir as contained in APC's "Interim Flood Control Plan" report. This order came about as a result of the findings of a joint Environmental Assessment report by FERC and Mobile District COE.

Attached is the "Interim Flood Control Plan Results" report. This report includes the current interim flood control plan along with the results of the evacuation of Neely Henry for floods occurring since the February 26, 2001 order. From this report, the results show that the interim flood control plan has been capable of capturing the needed evacuation of Neely Henry Reservoir in order to minimize flooding upstream in the Gadsden area. In addition to the current flood control plan, a proposed flood control plan is also in the report, which contains some exceptions to maximize the benefits of the plan.

During the May 2003 flood event on the Coosa Basin, some complaints arose from homeowners on Neely Henry Reservoir south of the Minnesota Bend area (south of Gadsden). The complaints centered on the restriction of flow through the Minnesota Bend and in turn, the evacuation of floodwaters at Henry dam keeping the lake at a low elevation for an extended period. Alabama Power Company agreed to look at the restriction of flow in this area and provide the homeowners with the findings of the study. Alabama Power Company engaged Malcolm Pirnie Consulting, Inc. to evaluate this area. The detailed findings of the Malcolm Pirnie report can be found attached. In general, it was found that no amount of reasonable modifications could be made in the Minnesota Bend area that would have a significant improvement on the flooding conditions in Gadsden that dictate the evacuation of Neely Henry dam.

Another issue that needed further examination is the timing of the refilling of Neely Henry Reservoir after a flood event has occurred. In May 2003, Alabama Power Company received a variance from the Mobile District Corps of Engineers to begin refilling Neely Henry Reservoir earlier than what is stated in the interim flood control plan. This variance was asked for due to the timing of the flood event occurring immediately before the Memorial Day holiday weekend. Alabama Power Company believes there are some modifications that can be made to the refilling schedule of the interim flood control plan, which may help to alleviate some of the concern from the homeowners. A meeting will be scheduled for early 2004 with the Neely Henry Lake Association to discuss the outcome of the Malcolm Pirnie report as well as to discuss the intent of this letter.

Based on the positive experience gained over nearly three years of study, Alabama Power Company will seek a permanent change in the Rule Curve and Flood Control Procedure for the Neely Henry Reservoir as a part of the relicensing process for the Coosa project. According to the FERC order that approved the temporary variance, at the end of the three-year variance period (February 26, 2004), APC would decide whether to apply to the commission to make its proposed changes permanent; this would require amending Article 50 of the current license. Because APC is currently going through the relicensing of the Coosa Project in which the Neely Henry Reservoir is a part, and due to the revisions that may be possible to the flood evacuation plan, APC has decided to seek, from FERC, in concurrence with the COE, an extension of the time for the temporary variance to remain in effect until the expiration of the current license (July 31, 2007). The license application that will be filed with FERC in July 2005 would contain the revised rule curve to be made a part of the new license. The relicensing process will provide a venue for detailed review and evaluation, of the request to permanently change the rule curve, by all interested stakeholders.

I plan to be in your office Thursday afternoon and we can discuss this matter at that time.

Sincerely,

Charles M. Stover
Reservoir Management

CMS:ejc

Enclosure

cc: Colonel Robert B. Keyser
Mr. Memphis Vaughan
Mr. Bob Allen
Mr. Hap Bryant

DEPARTMENT OF THE ARMY
MOBILE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2288
MOBILE, ALABAMA 36628-0001

FEB 19 2004

REPLY TO
ATTENTION OF:

Hydrology and Hydraulics Branch

Mr. Charles M. Stover
Alabama Power Company
600 N. 18th Street
Birmingham, AL 35203

Dear Mr. Stover:

We appreciate the opportunity to have met with you on December 15th, 2003 to discuss the "H. Neely Henry Interim Flood Control Plan". We have reviewed the report submitted by Alabama Power to the Federal Energy Regulatory Commission (FERC) covering the past three years of operation under this Interim Plan, which included several minor changes proposed to the Interim Plan, and found both to adequately address flood control concerns.

On May 19, 1999, Alabama Power Company sent a letter to Colonel David Norwood requesting approval of potential changes to the existing guidelines for this project. The potential changes to be reviewed consisted of the winter rule curve being raised from 505' to 507' as well as a new operation guideline for evacuation of the reservoir for flood control. FERC and the Mobile District Corps of Engineers prepared a joint Environmental Assessment Report and as a result of this coordination, the Director of FERC issued an order granting temporary variance for three years from February 26, 2001 to maintain higher water levels during the winter on Neely Henry Reservoir as contained in APC's "Interim Flood Control Plan" report.

Based on the positive experience gained over nearly three years of study, we understand that APC will seek a permanent change in the Rule Curve and Flood Control Procedure for the Neely Henry Reservoir as part of the re-licensing process for the Coosa project that will begin in July 2005. The re-licensing process will provide a venue for detailed review and evaluation, of the request to permanently change the rule curve, by all interested stakeholders. Rather than amending Article 50 of the current license at this time, Alabama Power Company has applied to FERC for an extension of the temporary variance. The Mobile District Corps of Engineers has no objection to extending the temporary variance previously issued on February 26, 2001, along with the proposed minor modifications.

We look forward to working with you during re-licensing on the review of the flood plans for the entire Coosa River with the goal of improving flood control operations throughout the system.

Sincerely,

Douglas C. Otto Jr., P.E.
Chief, Hydrology & Hydraulics Branch

July 6, 2004

Colonel Robert Keyser
US Army Corps of Engineers
PO Box 2288
Mobile, Alabama 36628

Dear Colonel Keyser,

At our meeting on April 6, 2004 we discussed our need to update the flood control plans for the Alabama Power Company Coosa and Warrior River projects to coincide with the ongoing Federal Energy Regulatory Commission relicensing of those facilities. As you may recall we discussed the ongoing flood control study being conducted as a cooperative effort between Reservoir Management at Alabama Power Company and the Hydrology and Hydraulics branch of the Mobile District. While the study has been underway for a number of years Doug Otto and I signed a "Plan of Study" in January 2004 detailing how it is to be completed. I am confident that with the full support of your staff we will be able to present completed flood studies on both rivers that will warrant the approval of your office.

We also discussed the need to revise Reservoir Regulation Manuals to reflect current information at Smith, Bankhead, Holt, Weiss, Neely Henry, Logan Martin and Harris dams. Everyone present thought that this was needed. Accordingly we are pursuing completion of this item. I would emphasize that these revised manuals will not include any elements of the new flood plans, and thus a further revision would be necessary after our new FERC licenses are approved.

Finally we considered the necessity of revising the Memorandum of Understanding between the United States Army Corps of Engineers and the Alabama Power Company. When we met I presented a package of four MOUs at the affected projects with the current and revised text and graphs. In that proposal was also an agreement that would consummate this phase of the process and facilitate the filing of the FERC license application next year. While Alabama Power is comfortable with the changes requested the final say lies with the district engineer.

A point of discussion at out meeting was to what extent your office could approve the revised MOUs prior to the Environmental Assessment. Alabama Power anticipates the EA being prepared for the FERC re-licensing would include these flood control changes. In light of that discussion I have attached a revised agreement which incorporates a very conservative view of implementing the needed changes. We believe it will remove some of the obvious hurdles faced by your legal staff in their review of the originally proposed agreement. If they would like to discuss this proposal with our relicensing counsel, please have then contact Mr. Jim Hancock at (205)226-3418.

In closing, as your retirement nears, let me take this opportunity to thank you for your service to the Mobile District and to the country. While we are anxious to complete this work as soon as possible we recognize that the job may fall to Colonel Taylor. If that is the case then we request your assistance in shepherding this important task thru the transition.

Sincerely,

Charles M Stover

w/ attachment

Cc: Douglas C. Otto Jr.
Memphis Vaughn
Pat Robbins
Willard Bowers
Mike Akridge
James Hancock

Agreement

Item 1 The Coosa River Flood Control Study is accepted by both parties as the basis for modifying flood control plans at Alabama Power Company Projects on the Coosa River.

Item 2 The Black Warrior River Flood Control Study is accepted by both parties as the basis for modifying flood control plans at the Smith project of the Alabama Power Company on the Warrior River.

Item 3 The MOU proposed changes are approved for submittal to the Federal Energy Regulatory Commission as part of the application for a new license for projects 2146 (Coosa) and 2165 (Warrior) by Alabama Power. Neely Henry Reservoir may continue to operate under the interim flood control procedure.

Item 4 The existing regulation manuals at Bankhead, Smith, Weiss, Henry and Logan Martin will be updated to reflect changes made to date.

Item 5 Alabama Power Company and the Mobile District will cooperate to revise the aforementioned flood studies if required after a new license is issued to Alabama Power by the Federal Energy Regulatory Commission (FERC).

Item 6 Alabama Power Company and the Mobile District will cooperate to finalize these MOUs after a new license is issued to Alabama Power by the FERC.

Item 7 New Water Control Plans will be prepared to replace the modified Reservoir Regulation Manuals after a new license is issued to Alabama Power by the FERC.

Item 8 Alabama Power Company and the Mobile District will cooperate to adjust final MOUs and Water Control Plans if necessary to comply with subsequent changes in federal law.

Item 9 Alabama Power and the Mobile District will continue to cooperate in the development of basin-wide real time data collection and advanced water management tools.

ALABAMA POWER COMPANY	UNITED STATES OF AMERICA
/s/_________________	/s_____________
Jerry Stewart Executive Vice President and Chief Production Officer	Robert Keyser Colonel, Corps of Engineers District Engineer

Date __________

Appendix 2

Appendix 2 DVD

COE ACT/ACF Surface Water Database

Flood Frequency Analysis

HEC RAS Model Code

Design Flood

Upper Coosa RAS Model

H Neely Henry RAS Model

Logan Martin RAS Model

Lay RAS Model

Mitchell RAS Model

Jordan RAS Model

Montgomery RAS Model

Weiss Regulation Manual

H Neely Henry Regulation Manual

Logan Martin Regulation Manual

Brief Description of DVD in Appendix 2

COE ACT/ACF Surface Water Database

As part of the ACT/ACT Comprehensive Water Resources Study that was conducted in the 1990’s, the US Army Corps of Engineers developed an Unimpaired Flow dataset for each river basin. This data set contained fifty-five years of river flow from 1939 through 1993. These datasets were modified to remove effects such as reservoir regulation, water withdrawals and returns. Also, a smoothing of these flow datasets was performed to ensure that no negative flows existed in these datasets.

In 2001, the Unimpaired Flow dataset was extended through the year 2000, providing six-two years of flow record for both the ACT and the ACF river basins. From this new flow dataset, flow records for the Coosa River Basin were unsmoothed in order that these flow data sets could be utilized in performing flood frequency analyses.

Flood Frequency Analysis

Utilizing the unsmoothed river flow data from the Comprehensive Water Resources Study, flood frequency analyses were performed on rivers in the Coosa River Basin, from upstream at Carters and Allatoona Dams, downstream to the City of Montgomery which is on the Alabama River. Technical Bulletin #17B was utilized to develop input data. The US Army Corps of Engineers’ Flood Frequency Analysis (FFA) program was used in performing one, three and five daily volumes for sixteen locations in the Coosa River Basin, starting in northwest Georgia, and ending at Montgomery, AL.

HEC-RAS Model Code

HEC-RAS version 3.1.1 river analysis system as developed by the U.S. Army Corps of Engineers at the Hydrologic Engineering Center. This was the version of HEC-RAS that was used in all model runs. It will be necessary for the reviewer to re-run the HEC-RAS projects in order to view the output files.

Design Flood

The Coosa River design flood includes all HEC-RAS model input files needed to model the steady-state 100yr elevations as well as the design flood for both existing and proposed flood control procedures for Henry, Logan, Lay, Mitchell, and Jordan dams.

Upper Coosa RAS Model

Contains HEC-RAS models that consider a reach of the Coosa River and its upper tributaries, beginning at the Weiss Dam site and extending upstream to the confluence of the Oostanaula and Etowah Rivers at Rome, Georgia, which form the Coosa River. The model further includes the Oostanaula River from Rome to its head at the Confluence of the Conasauga and Coosawattee Rivers, also to the Carters Reregulation Dam on the Coosawattee River, and to Tilton, GA on the Conasauga River. The Etowah River is included to the outflow of the Allatoona Dam. This represents approximately 144 miles of river. Four conditions are modeled:

1. The February 1990 flood is used to calibrate the model.
2. The Feb. 1990 flood is reproduced on an unregulated system.
3. The design flood is simulated with current regulation procedures applied
4. The design flood is simulated with the proposed modified operation plan applied at Weiss Dam.

Only the project and input files are provided. Simulations must be rerun to produce the DSS and output files.

Also included is a summary report in PDF format of the modeling effort as well as a Word document summarizing what files make up each HEC-RAS model.

Henry RAS Model

Includes the HEC-RAS input files for the calibrated model from just downstream of Weiss spillway to Henry dam. A calibrated model report is also included which contains all of the boundary conditions used and resulting output. This report and HEC-RAS data was sent to the Corps of Engineers Mobile District and the Alabama Office of Water as part of the Modeling IAG in the relicensing process.

Logan Martin RAS Model

Includes the HEC-RAS input files for the calibrated model from just downstream of Henry dam to Logan Martin dam. A calibrated model report is also included which contains all of the boundary conditions used and resulting output. This report and HEC-RAS data was sent to the Corps of Engineers Mobile District and the Alabama Office of Water as part of the Modeling IAG in the relicensing process.

Lay RAS Model

Includes the HEC-RAS input files for the calibrated model from just downstream of Logan Martin dam to Lay dam. A calibrated model report is also included which contains all of the boundary conditions used and resulting output. This report and HEC-RAS data was sent to the Corps of Engineers Mobile District and the Alabama Office of Water as part of the Modeling IAG in the relicensing process.

Mitchell RAS Model

Includes the HEC-RAS input files for the calibrated model from just downstream of Lay dam to Mitchell dam. A calibrated model report is also included which contains all of the boundary conditions used and resulting output. This report and HEC-RAS data was sent to the Corps of Engineers Mobile District and the Alabama Office of Water as part of the Modeling IAG in the relicensing process.

Jordan RAS Model

Includes the HEC-RAS input files for the calibrated model from just downstream of Mitchell dam to Jordan dam. A calibrated model report is also included which contains all of the boundary conditions used and resulting output. This report and HEC-RAS data was sent to the Corps of Engineers Mobile District and the Alabama Office of Water as part of the Modeling IAG in the relicensing process.

Montgomery RAS Model

Includes the HEC-RAS input files for the calibrated model from just downstream of Jordan dam to R.F. Henry dam. A calibrated model report is also included which contains all of the boundary conditions used and resulting output. This model is in the process of being revised and an updated version will be supplied at a later date.

Weiss, Henry, and Logan Martin Regulation Manuals

The reservoir regulation manuals currently being used by APC have not been updated since the 1960's. With the relicensing efforts of the Coosa projects and the need for updated versions of the manuals for operations, Reservoir Management began the process of scanning the text of the original copies into a Microsoft Word document. The second step of the procedure was to reconstruct the graphs and tables found in the manuals into an electronic format.

During this process, there was an apparent need to update basic information contained within the manuals. Items that were revised: Organization for Reservoir Regulation, Table for APC & COE Organization & Contact Numbers, Communications and Reporting Networks, Table for Rainfall Reporting Network, and Table for River-Stage Reporting Network and Other River Stations.

The first file under each folder contains the complete revised edition of the reservoir regulation manual. The second file contains only the modified pages of the reservoir regulation manual. The two files are provided for easy comparison to the earlier versions of the manual.

Appendix 3

Appendix 3 Comments

USACE Comments

Consultation between Alabama Power Company (APC) and the Mobile District, Corps of Engineers (COE) has been ongoing since 2002 pertaining to the development of new flood control plans and the supporting hydraulic and hydrologic models related to the raising of the winter pool elevations at the Weiss, Neely Henry and Logan Martin reservoirs. Coordination has occurred within the Coosa Relicensing process and in numerous meetings with the COE H&H staff at their office in Mobile. The COE has provided guidance to APC as well as technical feedback throughout the development of the proposed flood plan changes.

This year the COE reviewed APC's December 2004 Coosa River Study (Version 1) and provided draft comments. APC has addressed these draft comments in several notable ways:

1) Flood control procedures were modified and the 100 year design flows were analyzed with the unsteady flow models to eliminate any increase in elevation resulting from flood plan changes.
2) APC compared the Coosa Flood Frequency Analysis of the 3 and 5 day average flows to the 3 and 5 day volumes.
3) Editorial corrections to charts, graphs and text were made.

APC will continue to consult with the COE while FERC reviews the Coosa River license application to address comments related to the Coosa River Study and to develop a Memorandum of Understanding that the COE can use as the basis for revising the Reservoir Regulation Manuals for Weiss, Neely Henry and Logan Martin reservoirs. APC will supplement its license application by filing with FERC these documents as they are finalized.

Appendix 4

Appendix 4 Proposed MOU’s

Weiss MOU

H. Neely Henry MOU

Logan Martin MOU

Memorandum of Understanding

between

U. S. ARMY ENGINEER DISTRICT, MOBILE, CORPS OF ENGINEERS

and

ALABAMA POWER COMPANY

concerning

OPERATION OF WEISS DAM

for

FLOOD CONTROL AND NAVIGATION

SECTION—PURPOSE

1.1 The purpose of this memorandum of understanding is to delineate and affirm:

a) The responsibilities of the Alabama Power Company and the Corps of Engineers in fulfilling their obligations under 33 CFR 208.11, insofar as they concern the operation of Weiss Dam for flood control and navigation; and

b) The functions and procedures of the two agencies in carrying out their responsibilities.

SECTION 2 - REFERENCES

2.1 Section 7 of the Flood Control Act of 1944 grants authority to the Corps to prescribe flood control and navigation regulations on certain non-Corps dams.

2.2 PL 436 83rd Congress, 1954 provides for the development of the Coosa River by private interests under a license from the Federal Power Commission (now Federal Energy Regulatory Commission.

2.3 Code of Federal Regulation, Title 33, Part 208 (33 CFR 208.11) prescribes the responsibilities and procedures for flood control or navigation and the use of allocated storage.

2.4 EM 1110-2-3600 – "Engineering and Design for MANAGEMENT OF WATER CONTROL SYSTEMS" provides guidance for the management of water control projects authorized by Congress and planned, designed and constructed by the Corps. It also applies to certain aspects of water control projects constructed by other agencies.

2.5 ER 1110-2-240 – "Engineering and Design for WATER CONTROL MANAGEMENT" provides policies and procedures for carrying out water management activities, including establishment of water control plans for Corps and non-Corps projects.

2.6 Corps of Engineers' Reservoir Regulation Manual for the Alabama-Coosa River Basin, Appendix B, Reservoir Regulation Manual for Weiss Dam. Describes in detail the procedures to be followed in carrying out the rules and regulations for operation of Weiss Dam for flood control and navigation as set forth in this memorandum of understanding

SECTION 3—DESCRIPTION OF PROJECT

3.1 The Weiss development, located on the Coosa River near Leesburg, Alabama, consists of a dam having a concrete gated spillway section with compacted earth abutment dikes; a reservoir with full power pool at elevation 564 feet msl., having a surface area of approximately 27,800 acres; a diversion canal from the reservoir to a forebay created by dikes; an 87,750 KW power plant; a substation; and appurtenant electrical and mechanical facilities. The dam is located at river mile 226, about 50 miles upstream from Gadsden, Alabama, and about 1 mile southeast of the town of Leesburg. Total drainage area above the dam is 5,270 square miles. Two U. S. Army Corps of Engineers lakes, located on tributaries to the Coosa River, control approximately 1,486 square miles of this basin. Carters Dam, a pump-storage facility, provides hydroelectric power and flood control, is located on the Coosawattee River, and controls 376 square miles of drainage. Allatoona Dam provides hydroelectric power and flood control and is located on the Etowah River. Weiss Reservoir, extending from the dam about 52 miles upstream to Mayo's Bar, is located in Cherokee County, Alabama, and Floyd County, Georgia. The power plant, situated on the right bank of the river, is located about *3* miles from the dam, below the forebay lake and diversion canal which were constructed across a twenty mile bend of the river. Exhibit 1 presents a general layout of the Weiss project.

Weiss is a multiple purpose project and is the most upstream project in the existing development of the water resources of the Coosa River below Rome, Georgia. It was designed and constructed by the Alabama Power Company principally for the production of hydroelectric power and to provide flood control benefits as authorized by Public Law 436. Its design included appurtenances to facilitate development of the river for navigation when such development becomes economically feasible. The reservoir is also a source of water supply for domestic, agricultural, municipal and industrial uses. The lake creates a large recreational area providing opportunities for fishing, boating and other water sports.

SECTION 4—RESPONSIBILITIES OF ALABAMA POWER COMPANY AND CORPS OF ENGINEERS

4.1 As stated in Public Law 436, 83rd Congress, and in the Federal Energy Regulatory Commission license for the construction, operation and maintenance of Project No. 2146, it is the responsibility of the Alabama Power Company to operate and maintain the Weiss development in accordance with such reasonable rules and regulations as may be prescribed by the Secretary of the Army in the interest of flood control and navigation. The license further specifies certain terms and conditions to be met by the licensee in operating and maintaining the project in the interest of navigation. These authorities are implemented in **33** CFR **208.11,** which sets forth the regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to the authority of the Secretary of the Army in the interest of flood control and navigation.

4.2 It is the responsibility of the Secretary of the Army to prescribe the aforementioned rules and regulations for the proper operation of the Weiss development in the interest of flood control and navigation. This responsibility is administered through the District Engineer of the Mobile District who will monitor the operation of the Weiss project for compliance with the established rules and regulations.

SECTION 5—REGULATION PLAN

5.1 The Weiss project will normally operate to produce peaking power. The normal range of power pool drawdown is between elevations 564.0 and 561.0, amounting to 82,000 acre feet. This storage will also be available seasonally for flood control. During periods of low stream flow releases from storage below 561.0 will augment the flow of the river downstream. Above the top of the power pool and extending to elevation 572.0, there is available for control of floods surcharge storage totaling 302,000 acre-feet, within which reservoir releases will be scheduled as dictated by an induced surcharge schedule which will achieve significant improvement in downstream flow resulting from high to moderate frequency floods.

5.2 Reservoir operation for power production. A curve delineates the storage in Weiss reservoir allocated to power generation and to flood control throughout the year. This seasonally varying flood guide curve is a division between the power and flood control pools and normally the reservoir level will be maintained at or below the curve except when storing floodwaters. The drawdown each year is to elevation 561.0 ft msl. Normally, the plant will operate on a weekly cycle and the power generated will be available for use in daily peak-load periods. At such times as the reservoir level is below the flood guide curve, the power plant will be operated in accordance with the electric system requirements.

5.3 Reservoir operation for flood control. Insofar as possible, within the limits of the discharge capacity of the power plant, the reservoir level will be maintained on or below the flood guide curve. When the reservoir is below elevation 564.0 and the inflow causes it to rise above the flood guide curve with the power plant operating at full-gate capacity, the plant will operate continuously at full-gate capacity until the reservoir reaches the flood guide curve.

a) When the reservoir is at elevation 564.0, all inflow will be passed through the power plant until its discharge capacity is exceeded. Thereafter, the excess will be passed through the spillway with gate positions adjusted at the end of each 6-hour period as required to maintain the reservoir at elevation 564.0, until the total release rate (spillway plus powerhouse), reaches 40,000 cfs. Thereafter, as long as the inflow continues to equal or exceed 40,000 cfs, the release rate will be limited to 40,000 cfs until the reservoir rises and/or the inflow increases to a point where a higher release rate is dictated by the induced surcharge schedule. Every 6 hours thereafter the release rate will be adjusted to conform to the induced surcharge schedule.

b) Above elevation 564.0 when the reservoir has crested and spillway gates are open, the positions of the spillway gates at that time are maintained during the evacuation of flood storage until the reservoir level recedes to elevation 564.0. If a second flood begins prior to completion of evacuation to elevation 564.0, the rate of reservoir release will be dictated by the induced surcharge schedule even if spillway gates must be set lower. When the reservoir level has receded to elevation 564.0 the power plant will operate at capacity continuously until the reservoir reaches the flood guide curve.

5.4 Reduction of Downstream *Stages* When stages downstream of Weiss exceed or are expected to exceed flood stage as a result of local inflows it is acceptable to temporarily reduce the release prescribed by the plan; provided that the release will not be reduced below 50% of the amount required by the surcharge schedule and that the total addition of floodwaters stored in Weiss will not exceed a volume of 22,500 cfs-days.

5.5 Deviation from Flood Plans. Normally all flood control operation will be in accordance with the regulation plan described above. There are times when it is appropriate and desirable to deviate from the prescribed plan. Deviations will be in the form of a variance issued by the designee of the District Engineer either at his own initiative or at the request of the Company representative.

a) Small Floods, those of approximately less than one year recurrence interval, provide many opportunities for variances without impact to flood control. Valid justification for deviating from the flood plan would be to improve water management for the benefit of power, navigation, the environment and recreation. Before issuing a variance the designee of the District Engineer will determine from available information that no significant negative impact to flood control is expected.

b) Major Floods, generally those between 1 and 100 years, present the opportunity to improve flood operations with the use of variances. Because rainfall will not be evenly distributed throughout the watershed, variances may be used in order to maximize the collective flood control effects afforded by the projects along the river. The designee of the District Engineer may issue a variance if he determines from available information whether a deviation from the flood plan will improve flood control operations.

c) In Extreme Floods, those greater than 100 year recurrence interval, the reservoir is expected to be at or near the top limit curve of the induced surcharge schedule. During an extreme flood the Company representative and the designee of the District Engineer will collaborate in the prompt analysis of all available information and in determining whether a deviation from the induced surcharge schedule will improve flood control operations; however, for reasons of dam safety it is of importance that the elevation/discharge relationship of limit curve not be exceeded.

d) Advance water management techniques including streamflow forecasting and unsteady routings continue to be developed and implemented by both the Corps of Engineers and Alabama Power as tools to improve flood control operations. When it is reasonable to expect that an improvement in flood control effectiveness will result, these tools will be utilized in place of the induced surcharge operations. These tools will be interchangeable with the induced surcharge operations at any point during a flood.

5.6 Reservoir operation for navigation. Weiss Reservoir operates along with 10 other FERC licensed projects in Alabama and two COE projects in Georgia to supply water for navigation on the Alabama River.

a) Whenever the Weiss project is above the drought guide curve the reservoir will help support the following flow as measured by the combined release from Bouldin, Jordan and Thurlow dams:

A 7 day release of not less that 32,480 cfs-days
A 3 day release of not less that 8,000 cfs-days.

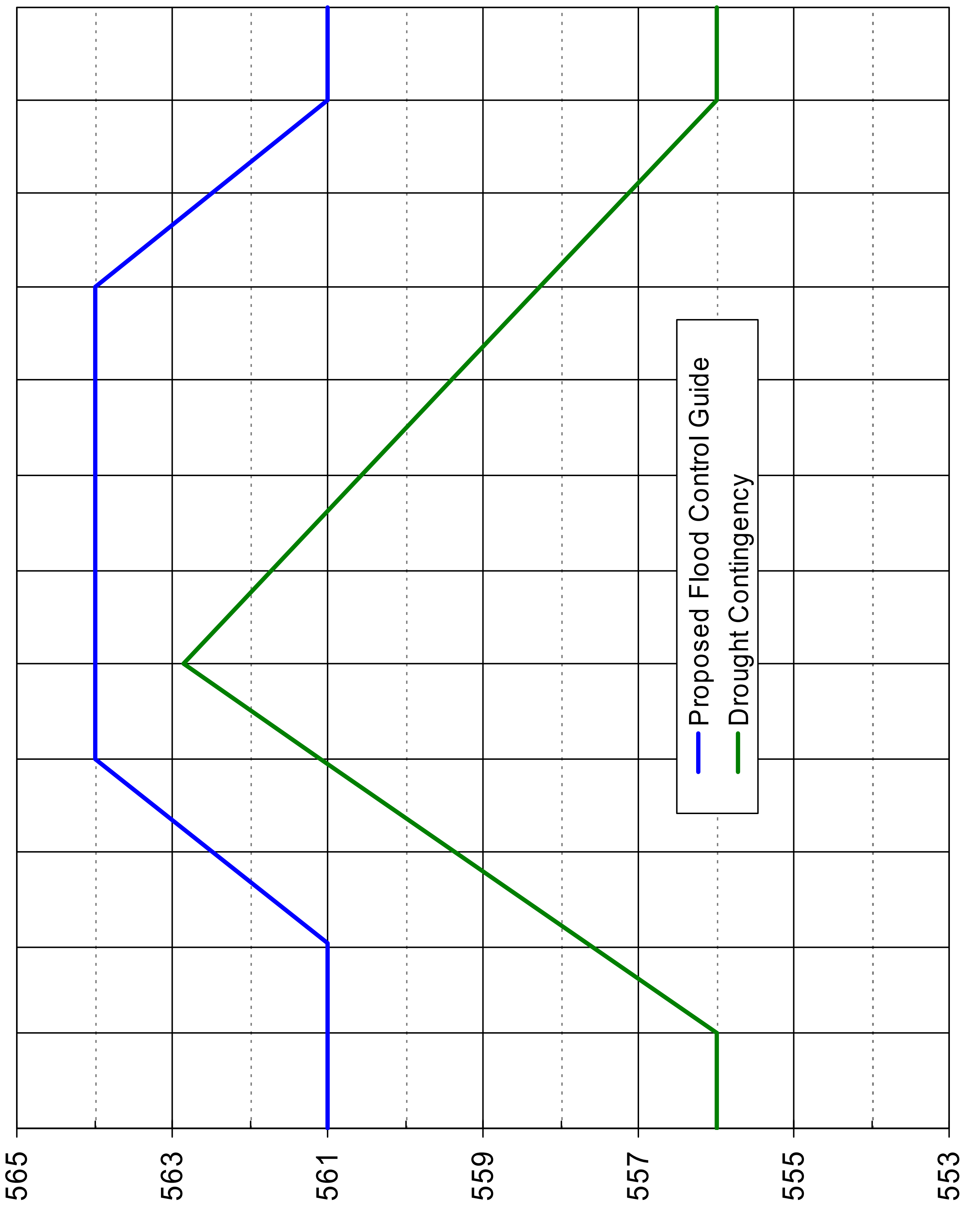
b) Additional specific rules for operation of the reservoir in the interest of navigation on the Coosa River will be prescribed and listed in the reservoir regulation manual if navigation is developed on the Coosa River.

SECTION 6—COLLECTION AND EXCHANGE OF DATA

6.1 Both the Alabama Power Company and the Corps of Engineers collect and maintain records of hydrologic data and other information in connection with the operation of projects in the Coosa River basin. Each party will furnish the other with such of its hydrologic data as may be needed or found bene-ficial in order to properly operate the Weiss project and follow the regulation plan.

ALABAMA POWER COMPANY	UNITED STATES OF AMERICA
/s/________________	/s_____________
	Peter F. Taylor
Jerry Stewart	Colonel, Corps of Engineers
Executive Vice President and	District Engineer
Chief Production Officer	

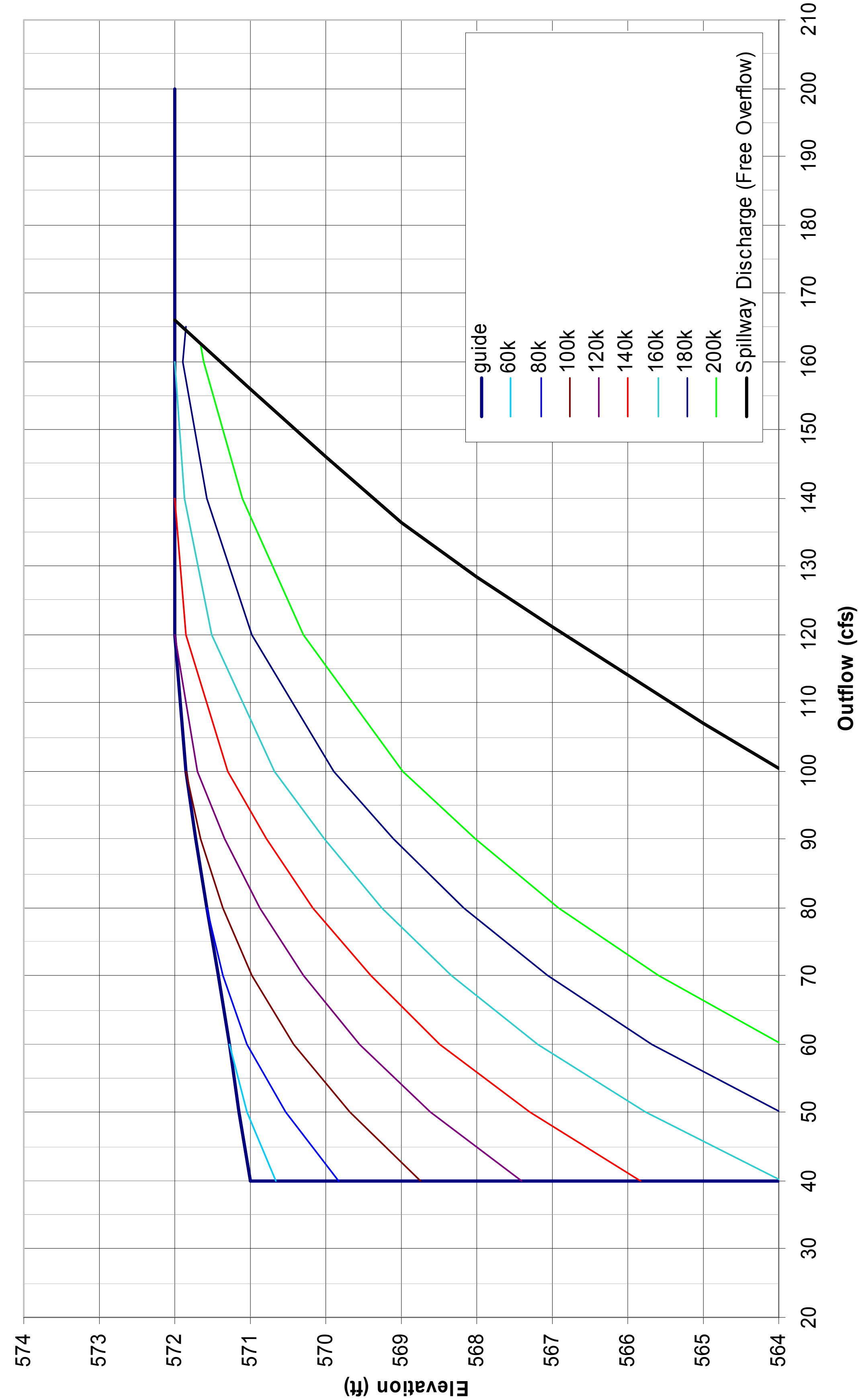
Weiss Proposed Rule Curve



Weiss Flood Control Regulation Schedule

Rule	Condition	Outflow	Operation
1	Below flood control guide	Ranging up to full discharge capacity of power plant.	Operate power plant as required to satisfy normal system load requirements.
2	At flood control guide and below elev.564.0.	Ranging up to full discharge capacity of power plant.	Releases shall be made through power plant at rates up to continuous operation at plant capacity (3 units at full gate) as required to keep reservoir stage at or below flood control guide, as long as this level is below elev. 564.0.
3	Above flood control guide and below elev. 564.0	Full discharge capacity of power plant.	Releases shall be made through power plant operating continuously at plant capacity (3 units at full gate) until reservoir stage: (a) Recedes to flood control guide after which rule 2 applies, or (b) Reaches elevation 564.0 after which rule 4 applies.
4	At elevation 564.0.	Ranging up to 40,000 cfs	Maintain reservoir stage at elevation 564.0 by passing the inflow up to 40,000 cfs. Releases will be made through the power plant operating continuously at plant capacity (3 units at full gate) supplemented by spillway discharge as required.
5	Rising above elevation 564.0.	40,000 cfs unless higher rate is specified by induced surcharge schedule.	Maintain total discharge of 40,000 cfs by discharging through the power plant operating continuously at plant capacity (3 units at full gate) supplemented by spillway discharge as required. Continue this operation until: (a) Reservoir stage recedes to elev. 564.0 after which rule 4 applies, or, (b) Reservoir stage and rate of inflow are such that higher rate of outflow is required by induced surcharge schedule, in which case rule 6 applies.
6	Rising above elev. 564.0 with releases above 40,000 cfs specified by induced surcharge schedule.	As specified by induced surcharge schedule.	Operate according to induced surcharge schedule, passing the required outflow through the power plant and spillway.
7	Stages downstream of Weiss exceed or are expected to exceed flood stage as a result of local inflows	Reduce up to 50% of surcharge schedule	Temporarily reduce the release prescribed by the plan, provided that the release will not be reduced below 50% of the amount required by the surcharge schedule and that the total addition of floodwaters stored in Weiss will not exceed a volume of 22,500 cfs-days.
8	Above elev. 564.0 and falling.	As specified by induced surcharge schedule.	When the reservoir level begins to fall maintain the gate openings in effect at time of peak reservoir stage and continue power plant discharge in effect at that time until reservoir level recedes to elev. 564.0. When pool recedes to elev. 564.0 rule 4 applies.

Weiss Proposed Surcharge Curves



Memorandum of Understanding

between

U. S. ARMY ENGINEER DISTRICT, MOBILE, CORPS OF ENGINEERS

and

ALABAMA POWER COMPANY

concerning

OPERATION OF NEELY HENRY DAM

for

FLOOD CONTROL AND NAVIGATION

SECTION 1—PURPOSE

1.1 The purpose of this memorandum of understanding is to delineate and affirm:

a) The responsibilities of the Alabama Power Company and the Corps of Engineers in fulfilling their obligations under 33 CFR 208.11, insofar as they concern the operation of Henry Dam for flood control and navigation; and

b) The functions and procedures of the two agencies in carrying out their responsibilities.

SECTION 2—REFERENCES

2.1 Section 7 of the Flood Control Act of 1944 grants authority to the Corps to prescribe flood control and navigation regulations on certain non-Corps dams.

2.2 PL 436 83rd Congress, 1954 provides for the development of the Coosa River by private interests under a license from the Federal Power Commission (now Federal Energy Regulatory Commission.

2.3 Code of Federal Regulation, Title 33, Part 208 (33 CFR 208.11) prescribes the responsibilities and procedures for flood control or navigation and the use of allocated storage.

2.4 EM 1110-2-3600 – "Engineering and Design for MANAGEMENT OF WATER CONTROL SYSTEMS" provides guidance for the management of water control projects authorized by Congress and planned, designed and constructed by the Corps. It also applies to certain aspects of water control projects constructed by other agencies.

2.5 ER 1110-2-240 – "Engineering and Design for WATER CONTROL MANAGEMENT" provides policies and procedures for carrying out water management activities, including establishment of water control plans for Corps and non-Corps projects.

2.6 Corps of Engineers' Reservoir Regulation Manual for the Alabama-Coosa River Basin, Appendix B, Reservoir Regulation Manual for Henry Dam. Describes in detail the procedures to be followed in carrying out the rules and regulations for operation of Henry Dam for flood control and navigation as set forth in this memorandum of understanding.

SECTION 3
DESCRIPTION OF PROJECT

3.1 The H. Neely Henry development is situated on the Coosa River at river mile 148.0, approximately 27 miles downstream from Gadsden, Alabama. It consists of a dam having a concrete gated spillway section with compacted earth abutment dikes; a reservoir, with full power pool at elevation 508 feet msl, having a surface area of approximately 11,235 acres, a 72,900 KW power plant; a substation; and appurtenant electrical and mechanical facilities. The total drainage area above the dam, including the area controlled by Weiss and Allatoona Darns, is 6,600 square miles. The reservoir, extending upstream 77.65 miles to Weiss Dam, is located in St. Clair, Calhoun, Etowah and Cherokee counties. Exhibit 1 presents a general layout of the 1-1. Neely Henry project.

SECTION 4 - RESPONSIBILITIES OF ALABAMA POWER COMPANY AND CORPS OF ENGINEERS

4.1 As stated in Public Law 436, 83rd Congress, and in the Federal Energy Regulatory Commission license for the construction, operation and maintenance of Project No. 2146, it is the responsibility of the Alabama Power Company to operate and maintain the Henry development in accordance with such reasonable rules and regulations as may be prescribed by the Secretary of the Army in the interest of flood con-trol and navigation. The license further specifies certain terms and conditions to be met by the licensee in operating and maintaining the project in the interest of navigation. These authorities are implemented in **33** CFR **208.11,** which sets forth the regulations for use of storage allocated for flood control or navigation and/or project operation at reservoirs subject to the authority of the Secretary of the Army in the interest of flood control and navigation.

4.2 It is the responsibility of the Secretary of the Army to prescribe the aforementioned rules and regulations for the proper operation of the Henry development in the interest of flood control and navigation. This responsibility is administered through the District Engineer of the Mobile District who will monitor the operation of the Henry project for compliance with the established rules and regulations.

SECTION 5
REGULATION PLAN

5.1 General. The H. Neely Henry project will normally operate to produce peaking power. The normal range of power pool drawdown is between elevations 508.0 and 507.0, amounting to 10,853 acre-feet. During periods of low stream flow the storage below elevation 507, will augment the flow of the river downstream.

5.2 Reservoir operation for power production. A curve delineating the seasonally varying top of power pool level in H. Neely Henry Reservoir is shown on Exhibit 2. Normally the reservoir level will be maintained on or below the curve. The drawdown each year to elevation 507 ft msl. Normally, the plant will operate on a weekly peak load period. At such times as the reservoir level is below that shown on the rule curve, the power plant will be operated in accordance with system requirements. Whenever the reservoir reaches the elevation shown on the rule curve, the power plant will be operated as necessary up to full-gate capacity to discharge the amount of water required to keep the reservoir level from exceeding that shown on the rule curve.

5.3 Reservation Operation for flood control. In order to minimize flood damages in the Gadsden area of the H. Neely Henry Reservoir the reservoir will he drawn down below its normal operating level in advance of an im-pending flood. The time to begin evacuation, the rate of evacuation and the level at the dam will be determined by the elevation at the Gadsden Steam Plant gage. As series of trigger points at 0.5 foot increments between 508 and 511 correspond to the lowering (and raising) of the water at the dam in increments down to 502.5. In times of rapidly rising water at Gadsden crossing multiple trigger points raise the initial evacuation rate of 1 foot in 12 hours by multiple times.

5.4 There are three adjustments or exceptions to the Evacuation Rate Schedule:

a) Exception 1 When the rule curve is at 508 the initial trigger point (508.5) will be skipped if the following three conditions are met:
Gadsden SP gage does not exceed 509,
Weather forecasts do no indicate significant rain potential, and
Weiss releases are not expected to go above 26,000 in the next 24 hours
Should any of these 3 conditions change then the evacuation rate schedule should be initiated, or if the reservoir reaches the second trigger point (509.0) then the evacuation rate should be doubled to reach the second step of the drawdown so as to return to the schedule.

b) Exception 2 If after the initial stage of evacuation and Gadsden elevation begins to fall then Henry elevation may be allowed to rise so long as the following conditions are met:
Gadsden SP gage does not exceed 510,
Weather forecasts do not indicate significant rain potential,
Inflows into Henry Reservoir are not increasing, and
Weiss releases are not expected to go above 40,000 in the next 24 hours.
Should any of these 4 conditions change then the evacuation rate schedule should be reinitiated.

c) Exception 3 Immediately below Neely Henry Dam the Alabama Power Company has acquired flood rights to elevation 490 msl for the Logan Martin Reservoir. This corresponds to a discharge of 96,000 cfs. The evacuation is to proceed according to the schedule until the release reaches 96,000 whereupon the rate of evacuation will be reduced all the way to zero if need be to maintain a release of 96,000. At that point the release can be increased to prevent the pool from rising and the maximum rate of release will continue until the reservoir reaches 502.5 or the spillway gates are raised out of the water.

5.5 Deviation from Flood Plans. Normally all flood control operation will be in accordance with the regulation plan described above. There are times when it is appropriate and desirable to deviate from the prescribed plan. Deviations will be in the form of a variance issued by the designee of the District Engineer either at his own initiative or at the request of the Company representative.

a) Small Floods, those of approximately less than one year recurrence interval, provide many opportunities for variances without impact to flood control. Valid justification for deviating from the flood plan would be to improve water management for the benefit of power, navigation, the environment and recreation. Before issuing a variance the designee of the District Engineer will determine from available information that no significant negative impact to flood control is expected.

b) Major Floods, generally those between 1 and 100 years, present the opportunity to improve flood operations with the use of variances. Because rainfall will not be evenly distributed throughout the watershed, variances may be used in order to maximize the collective flood control effects afforded by the projects along the river. The designee of the District Engineer may issue a variance if he determines from available information whether a deviation from the flood plan will improve flood control operations.

c) In Extreme Floods, those greater than 100 year recurrence interval, the Company representative and the designee of the District Engineer will collaborate in the prompt analysis of all available information and in determining whether a deviation will improve flood control operations

d) Advance water management techniques including stream-flow forecasting and unsteady routings continue to be developed and implemented by both the Corps of Engineers and Alabama Power as tools to improve flood control operations. When it is reasonable to expect that an improvement in flood control effectiveness will result, these tools will be utilized. These tools will be interchangeable with the Evacuation Rate Schedule at any point during a flood.

5.6 Reservoir operation for navigation. Henry Reservoir operates along with 10 other FERC licensed projects in Alabama and two COE projects in Georgia to supply water for navigation on the Alabama River.

a) Whenever the Henry project is above the drought guide curve the reservoir will help support the following flow as measured by the combined release from Bouldin, Jordan and Thurlow dams:

A 7 day release of not less that 32,480 cfs-days
A 3 day release of not less that 8,000 cfs-days.

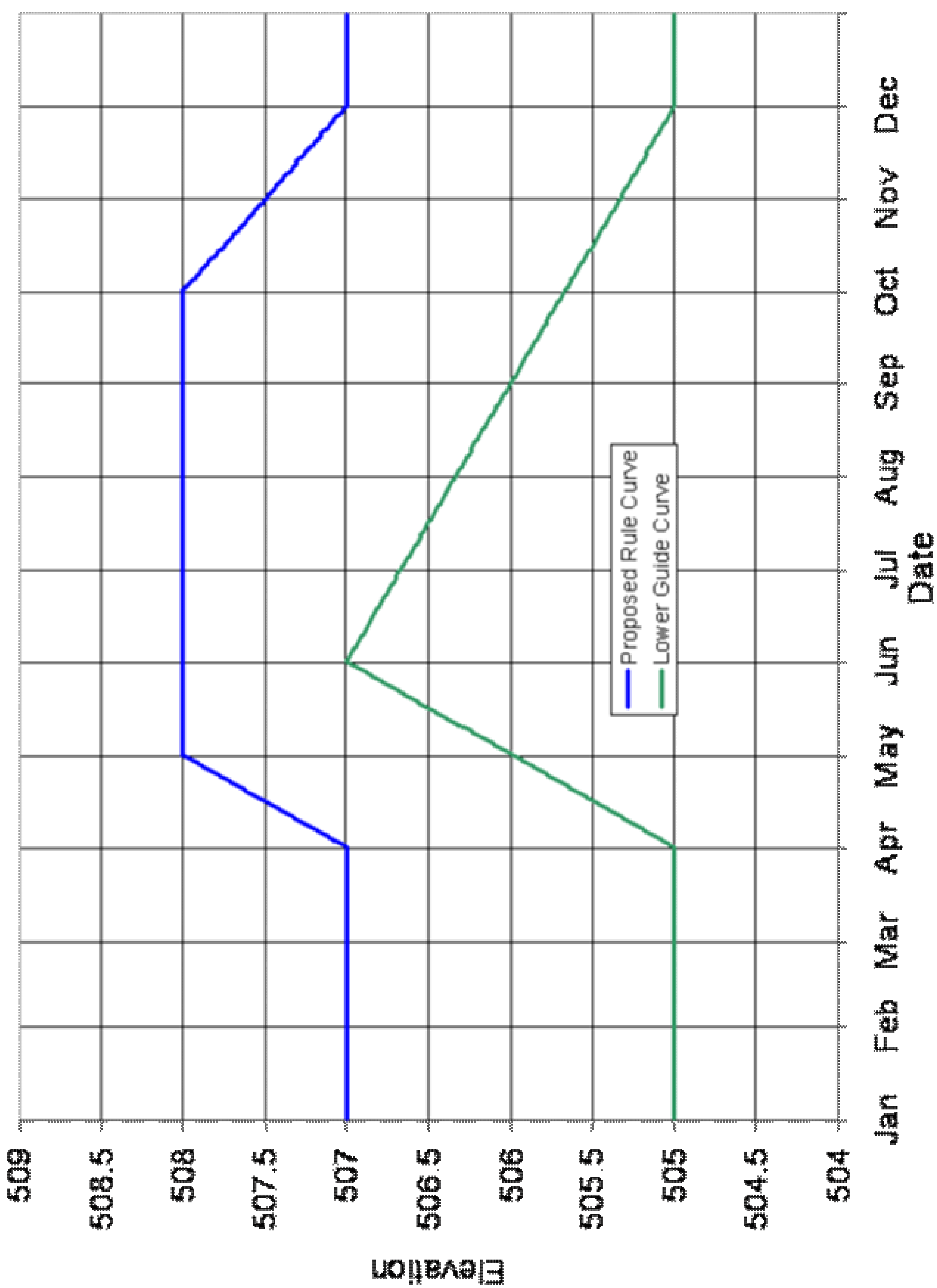
b) Additional specific rules for operation of the reservoir in the interest of navigation on the Coosa River will be prescribed and listed in the reservoir regulation manual if navigation is developed on the Coosa River.

SECTION 6
COLLECTION AND EXCHANGE OF DATA

6.1 Both the Alabama Power Company and the Corps of Engineers collect and maintain records of hydrologic data and other information in connection with the operation of projects in the Coosa River basin. Each party will furnish the other with such of its hydrologic data as may be needed or found beneficial in order to properly operate the Henry project and follow the regulation plan.

ALABAMA POWER COMPANY	UNITED STATES OF AMERICA
/s/_________________	/s_____________
	Peter F. Taylor
Jerry Stewart	Colonel, Corps of Engineers
Executive Vice President and	District Engineer
Chief Production Officer	
Date _________	Date __________

Henry Proposed Rule Curve



Proposed Henry Evacuation Rate Schedule

Trigger Points	When Coosa River at Gadsden Steam Plant Rises Above	Reservoir Change	Evacuation Rate
1	508.00	No Change	N/A
2	508.50	508.00 to 507.00	1 foot in a 12 hour period
3	509.00	507.00 to 506.00	1 foot in a 12 hour period
4	509.50	506.00 to 505.00	1 foot in a 12 hour period
5	510.00	505.00 to 504.00	1 foot in a 12 hour period
6	510.50	504.00 to 503.00	1 foot in a 12 hour period
7	511.00	503.00 to 502.50	1/2 foot in a 12 hour period
8	511.00	No Change	N/A
9	510.50	502.50 to 503.00	N/A
10	510.00	503.00 to 504.00	N/A
11	509.50	504.00 to 505.00	N/A
12	509.00	505.00 to 506.00	N/A
13	508.50	506.00 to 507.00	N/A
14	508.00	507.00 to 508.00	N/A
15	**PRIORITY**		The evacuation schedule above shall apply during refilling if conditions warrant.

Continued on next page

Proposed Henry Evacuation Rate Schedule

Exception 1 When the rule curve is at 508 the initial trigger point (508.5) will be skipped if the following three conditions are met: Gadsden SP gage does not exceed 509, Weather forecasts do no indicate significant rain potential, and Weiss releases are not expected to go above 26,000 in the next 24 hours Should any of these 3 conditions change then the evacuation rate schedule should be initiated, or if the reservoir reaches the second trigger point (509.0) then the evacuation rate should be doubled to reach the second step of the drawdown so as to return to the schedule.
Exception 2 If after the initial stage of evacuation and Gadsden elevation begins to fall then Henry elevation may be allowed to rise so long as the following conditions are met: Gadsden SP gage does not exceed 510, Weather forecasts do not indicate significant rain potential, Inflows into Henry Reservoir are not increasing, and Weiss releases are not expected to go above 40,000 in the next 24 hours. Should any of these 4 conditions change then the evacuation rate schedule should be re-initiated.
Exception 3 Immediately below Neely Henry Dam the Alabama Power Company has acquired flood rights to elevation 490 msl for the Logan Martin Reservoir. This corresponds to a discharge of 96,000 cfs. The evacuation is to proceed according to the schedule until the release reaches 96,000 whereupon the rate of evacuation will be reduced all the way to zero if need be to maintain a release of 96,000. At that point the release can be increased to prevent the pool from rising and the maximum rate of release will continue until the reservoir reaches 502.5 or the spillway gates are raised out of the water.

REVISED MEMORANDUM OF UNDERSTANDING

Between

U, S. ARMY ENGINEER DISTRICT, MOBILE, CORPS OF ENGINEERS

And

ALABAMA POWER COMPANY

Concerning

OPERATION OF LOGAN MARTIN DAM

For
FLOOD CONTROL AND NAVIGATION

SECTION 1 - PURPOSE

1.1 The purpose of this memorandum of understanding is to delineate and affirm:

a, The responsibilities of the Alabama Power Company and the Corps of Engineers in fulfilling their obligations under Public Law 436, 83rd Congress, insofar as they concern the operation of Logan Martin Dam for flood control and navigation; and

b, The functions and procedures of the two agencies in carrying out their responsibilities.

SECTION 2 - REFERENCES

2.1 Section 7 of the Flood Control Act of 1944 grants authority to the Corps to prescribe flood control and navigation regulations on certain non-Corps dams.

2.2 PL 436 83rd Congress, 1954 provides for the development of the Coosa River by private interests under a license from the Federal Power Commission (now Federal Energy Regulatory Commission.

2.3 Code of Federal Regulation, Title 33, Part 208 (33 CFR 208.11) prescribes the responsibilities and procedures for flood control or navigation and the use of allocated storage.

2.4 EM 1110-2-3600 – "Engineering and Design for MANAGEMENT OF WATER CONTROL SYSTEMS" provides guidance for the management of water control projects authorized by Congress and planned, designed and constructed by the Corps. It also applies to certain aspects of water control projects constructed by other agencies.

2.5 ER 1110-2-240 – "Engineering and Design for WATER CONTROL MANAGEMENT" provides policies and procedures for carrying out water management activities, including establishment of water control plans for Corps and non-Corps projects.

2.6 Corps of Engineers' Reservoir Regulation Manual for the Alabama-Coosa River Basin, Appendix B, Reservoir Regulation Manual for Logan Martin Dam. Describes in detail the procedures to be followed in carrying out the rules and regulations for operation of Weiss Dam for flood control and navigation as set forth in this memorandum of understanding

SECTION 3 – DESCRIPTION OF PROJECT

3.1 The Logan Martin development is situated on the Coosa River at river mile 99.5, approximately 13 miles upstream from Childersburg, Alabama. It consists of a dam having a concrete gated spillway section with compacted earth abutment dikes; a reservoir, with full power pool at elevation 465 feet msl, having a surface area of approximately 15,300 acres; a 128,250 KW power plant; a substation, and appurtenant electrical and mechanical facilities. The total drainage area above the dam is 7,770 square miles. The reservoir, extending upstream 48.5 miles to H. Neely Henry Darn, is located in Talladega, St. Clair and Calhoun counties. Exhibit I presents a general layout of the Logan Martin project.

SECTION 4 - RESPONSIBILITIES OF ALABAMA POWER COMPANY AND CORPS OF ENGINEERS

4.1 As stated In Public Law 436, 83rd Congress, and in the Federal Energy Regulatory Commission license for the construction, operation and maintenance of Project No 2146, it is the responsibility of the Alabama Power Company to operate and maintain the Logan Martin development in accordance with such reasonable rules and regulation as may be prescribed by the Secretary of the Army in the interest of flood control and navigation The license further specifies certain terms and conditions to be met by the licensee in operating and maintaining the project in the interest of navigation

4.2 It is the responsibility of the Secretary of the Army to prescribe the aforementioned rules and regulations for the proper operation of the Logan Martin development in the interest of flood control and navigation. This responsibility is administered through the District Engineer of the Mobile District who will monitor the operation of the Logan Martin project for compliance with the established rules and regulations.

SECTION 5 - REGULATION PLAN

5.1 General. The Logan Martin project will normally operate to produce peaking power. The normal range of power pool drawdown is between elevations 465 and 462 amounting to 42,600 acre-ft. This storage will also be available seasonally for flood control. During periods of low stream flow the storage below 462, will augment the flow of the river downstream. Above the top of the power pool and extending to elevation 473.5 there is available for control of floods surcharge storage totaling 160,000acre-feet, within which reservoir releases will be scheduled as dictated by an induced surcharge schedule which will achieve significant improvement in downstream flow resulting from high to moderate frequency floods.

5.2 Reservoir operation for power production. A curve delineating the storage in Logan Martin reservoir allocated to power generation and to flood control throughout the year is shown on Exhibit 2. This seasonally varying top-of-power pool curve is a firm division between the power and flood control pools and normally the reservoir level will be maintained at or below the curve except when storing flood waters. The compulsory drawdown each year is to elevation 462.0. Normally, the plant will operate on a weekly cycle and the power generated will be available for use in daily peak-load periods. At such times as the reservoir level is below the flood guide curve the power plant will be operated in accordance with the electric system requirements.

a) Reservoir operation for flood control. When the reservoir is at the flood guide curve, the inflow up to a total of 70,000 cfs will be passed. Normally the inflow will be passed through the power plant until its discharge capacity is exceeded after which the excess will be passed through the spillway with gate positions adjusted at the end of each 3-hour period as required to maintain the reservoir at the elevation indicated by the storage delineation curve. If for any reason the power plant is inoperative, the total required discharge will be passed through the spillway. Thereafter, as long as the inflow continues to equal or exceed 70,000 cfs, the release rate will be limited to 70,000 cfs until the reservoir rises and/or the inflow increases to a point where a higher release rate is dictated by the induced surcharge schedule shown on Exhibit 3. Every 3 hours thereafter the release rate will be adjusted to conform to the induced surcharge schedule,

b) When the rate of reservoir inflow reduces to the reservoir release rate, the position of the spillway gates in effect at that time will be maintained during the evacuation of flood storage until the reservoir level recedes to the elevation indicated by the flood control guide curves. In the event a second flood enters the reservoir prior to completion of evacuation to the elevation indicated by the flood control guide curve, the position of the spillway gates will not be changed unless a greater release is dictated by the induced surcharge schedule, When the reservoir level has receded to the elevation indicated by the flood control guide curve, the spillway gates and the power plant will be operated as required to maintain the reservoir on or below the limits shown on the flood control guide curve.

5.4 Reduction of Downstream Stages When stages downstream of Logan Martin exceed or are expected to exceed flood stage as a result of local inflows it is acceptable to temporarily reduce the release prescribed by the plan; provided that the release will not be reduced below 50% of the amount required by the surcharge schedule and that the total addition of floodwaters stored in Logan Martin will not exceed a volume of 11,000 cfs-days.

5.5 Deviation from Flood Plans. Normally all flood control operation will be in accordance with the regulation plan described above. There are times when it is appropriate and desirable to deviate from the prescribed plan. Deviations will be in the form of a variance issued by the designee of the District Engineer either at his own initiative or at the request of the Company representative.

a) Small Floods, those of approximately less than one year recurrence interval, provide many opportunities for variances without impact to flood control. Valid justification for deviating from the flood plan would be to improve water management for the benefit of power, navigation, the environment and recreation. Before issuing a variance the designee of the District Engineer will determine from available information that no significant impact to flood control is expected.

b) Major Floods, generally those between 1 and 100 years, present the opportunity to improve flood operations with the use of variances. Because rainfall will not be evenly distributed throughout the watershed, variances may be used in order to maximize the collective flood control effects afforded by the projects along the river. The designee of the District Engineer may issue a variance if he determines from available information whether a deviation from the flood plan will improve flood control operations.

c) In Extreme Floods, those greater than 100 year recurrence interval, the reservoir is expected to be at or near the top limit curve of the induced surcharge schedule. During an extreme flood the Company representative and the designee of the District Engineer will collaborate in the prompt analysis of all available information and in determining whether a deviation from the induced surcharge schedule will improve flood control operations; however, for reasons of dam safety it is of importance that the elevation/discharge relationship of limit curve not be exceeded.

d) Advance water management techniques including stream-flow forecasting and unsteady routings continue to be developed and implemented by both the Corps of Engineers and Alabama Power as tools to improve flood control operations. When it is reasonable to expect that an improvement in flood control effectiveness will result, these tools will be utilized in place of the induced surcharge operations. These tools will be interchangeable with the induced surcharge operations at any point during a flood.

5.6 Reservoir operation for navigation. Logan Martin Reservoir operates along with other 10 other FERC licensed projects on the Coosa and Tallapoosa river to supply water for navigation on the Alabama River.

a) Whenever the Logan Martin project is above the drought guide curve Weiss will supply a portion of the following flow as measured by the combined release from Bouldin, Jordan and Thurlow dams:

A 7 day release of not less that 32,480 cfs-days
A 3 day release of not less that 8,000 cfs-days.

b) Additional specific rules for operation of the reservoir in the interest of navigation will be prescribed and listed in the reservoir regulation manual if navigation is developed on the Coosa River.

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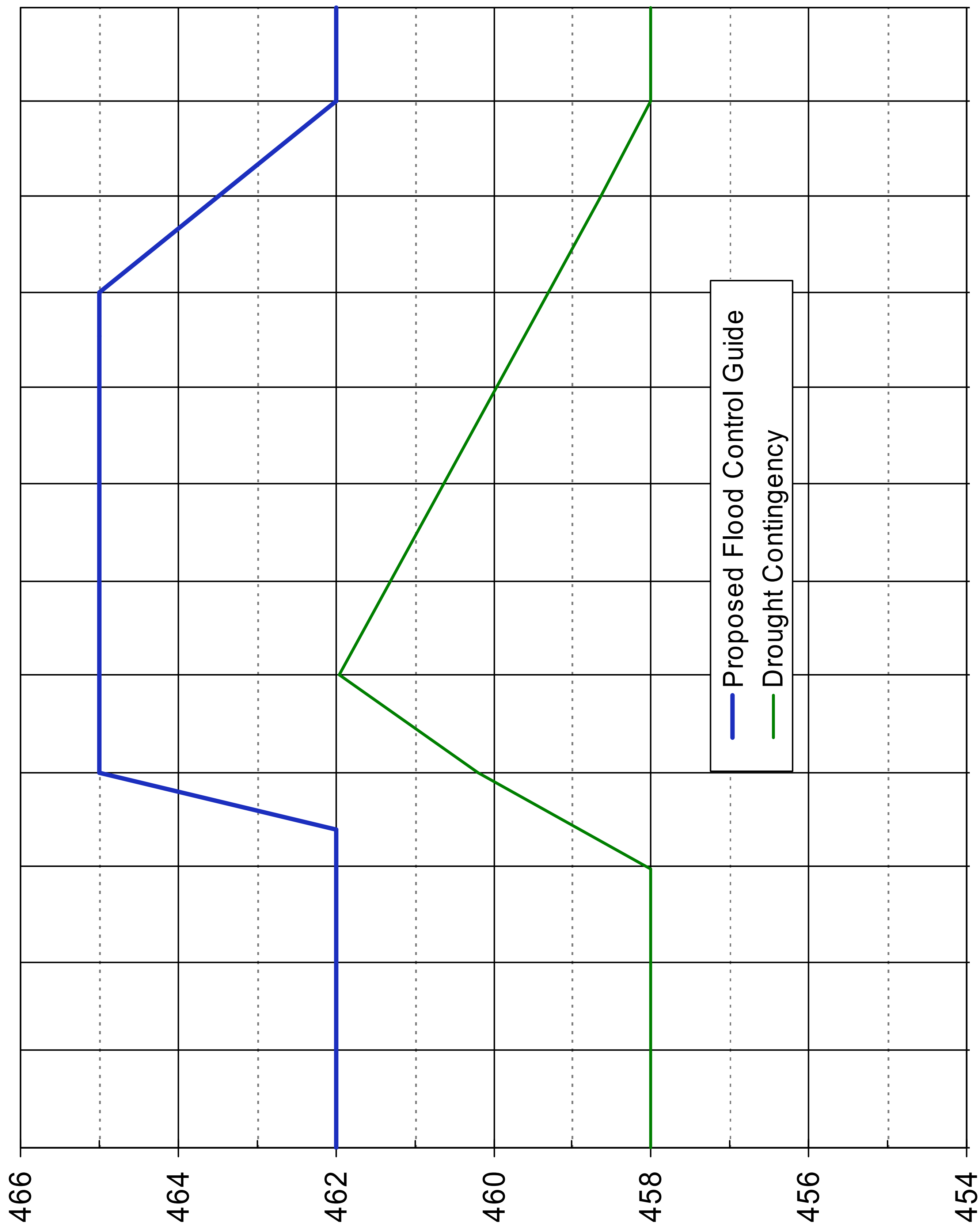
SECTION 6 - COLLECTION AND EXCHANGE OF DATA

6.1 Both the Alabama Power Company and the Corps of Engineers collect and maintain records of hydrologic data and other information in connection with the operation of projects in the Coosa River basin. Each party will furnish the other with such of its hydrologic data as may be needed or found beneficial in order to properly operate the Logan Martin project and follow the regulation plan.

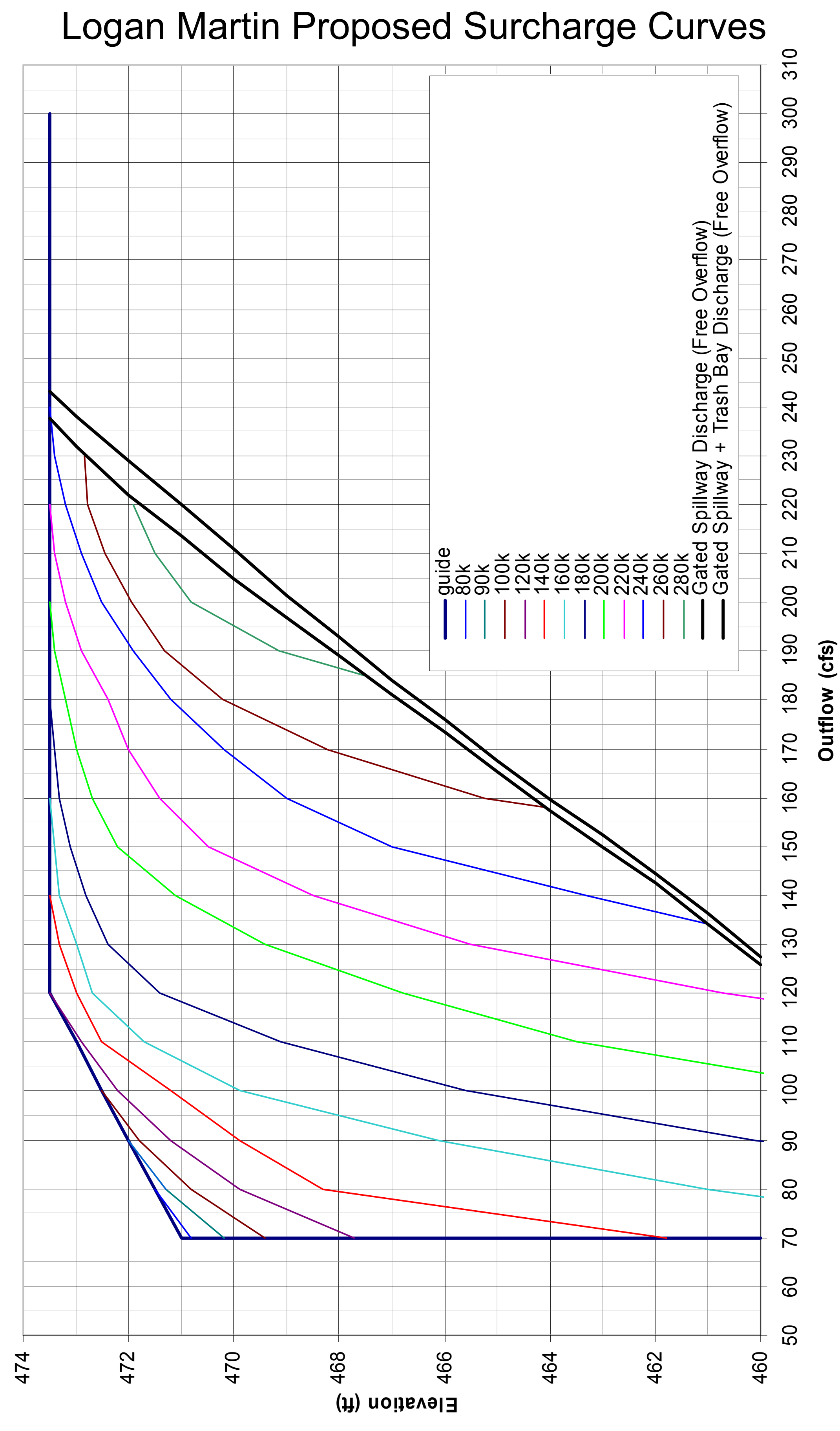
ALABAMA POWER COMPANY	UNITED STATES OF AMERICA
/s/________________	/s______________
Jerry Stewart Executive Vice President and Chief Production Officer	Peter F. Taylor Colonel, Corps of Engineers District Engineer
Date _________	Date________________

Logan Martin Proposed Rule Curve



Proposed Logan Martin Flood Control Regulation

Rule	Condition	Outflow	Operation
1	Below flood control guide.	Up to Plant capacity.	Operate power plant as required to satisfy normal system load requirements.
2	Below flood control guide and Weiss above elev 564 and inflow into Logan Martin and Weiss at plant capacity and increasing	70,000 cfs	Pull Logan Martin to elevation 460 by discharging 70,000 cfs. Once at 460 hold the elevation by passing the hourly inflow
3	At flood control guide.	Ranging up to 70,000 cfs.	Maintain reservoir stage at top-of-power pool elevation by passing the inflow up to 70,000 cfs.
4	Above flood control guide and rising.	Rate specified by induced surcharge schedule.	Operate according to induced surcharge schedule passing the required outflow through the power plant and spillway.
5	Above flood control guide elevation with downstream control in place.	Reduce release down to 50%.	Operation dictated by high downstream stages. Reduction in release not to exceed 11,000 cfs-days in added storage.
6	Above flood control guide elevation and falling		When the reservoir level begins to fall maintain the gate openings in effect at time of peak reservoir stage and continue power plant discharge in effect at that time until reservoir level recedes to flood control guide elevation.



Logan Martin Proposed Surcharge Curves
Elevation (ft)
Outflow (cfs)
474
472
470
468
466
464
462
460
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
guide
80k
90k
100k
120k
140k
160k
180k
200k
220k
240k
260k
280k
Gated Spillway Discharge (Free Overflow)
Gated Spillway + Trash Bay Discharge (Free Overflow)

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Attachment 7. Draft Hydrologic Engineering Management Plan (HEMP)

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Modification of Flood Control Plans

for

Alabama Power Company Reservoirs

Weiss and Logan Martin

Coosa River, Alabama

Hydrologic Engineering Management Plan

Draft – April 2018

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1.0 Introduction

Alabama Power Company (APC) proposes revisions to the Weiss and Logan Martin projects' flood operation plan, which includes raising the winter level and lowering the upper limit of the induced surcharge operation at each reservoir. Current Water Control Plans for Weiss and Logan Martin reservoirs contain surcharge curves with elevations higher than the respective flood easements acquired by APC and approved by FERC following consultation with USACE. The easement at Weiss is 572' msl and the surcharge curve indicates flood control storage to 574' msl. On Logan Martin, the easement elevation is 473.5' msl and the surcharge curve indicates flood control storage to 477' msl. Routine APC variance requests, evaluated and approved by USACE, during flood events warrants the evaluation of the Weiss and Logan Martin flood operation plans.

2.0 HEMP Purpose

This Hydrologic Engineering Management Plan (HEMP) describes the hydrologic and hydraulic (H&H) engineering analysis required by U.S. Army Corps of Engineers (USACE) to evaluate the APC proposed changes in flood operation for the Weiss and Logan Martin projects. This HEMP includes the following objectives:

- H&H analysis supporting the proposed APC plan to address issues with flood plans/surcharge curves at Weiss and Logan Martin projects identified in the late 1970's, which will reduce the need for routine variances during flood control operations.
- Evaluation of proposed higher winter pools in conjunction with the new flood plans.
- Evaluation of revised surcharge curves.
- Recommended flood mitigation plan as part of the proposed plan, as needed.
- Basis of the supporting documentation for the APC proposed plan submittal.

3.0 History

1977 Flooding at Logan Martin caused the reservoir level to rise above its easement. Following this event, APC began working with the USACE Mobile District to obtain variances, primarily to let out more water earlier during a flood event at Logan Martin. To date, Weiss has never risen above easement; however, variances have been obtained through the years at Weiss as well.

2001 APC Coosa Hydro Project relicensing began. The #1 priority of stakeholders was to raise winter pools at Weiss and Logan Martin. This was an opportune time to update flood procedures to align with APC easements, as well as study proposed rule curve changes.

2003 APC began work with USACE on technical issues and obtaining guidance on how to accomplish objectives.

2004 In January, APC signed a Plan of Study with USACE Mobile District H&H Branch (Doug Otto) as a template for how the flood study would be conducted. The parameters, procedures and study methodology required to modify, update and/or include flood control operational plans for the Coosa projects were defined.

2004 On December 6, the Coosa River Flood Study was submitted to USACE.

2005 In May, USACE provided draft comments on the Coosa River Flood Study.

2005 In June, APC filed the Coosa license application with FERC, which included proposed changes to winter pools, along with revised flood storage used for flooding. Coosa River Study Version 2 was filed as an appendix to Exhibit B of the license application.

2006 In July, supporting documentation and modeling for the Coosa River Flood Study was filed with FERC in the 1st Additional Information Request (AIR).

2006 APC began purchasing some of the flood easement below Logan Martin Dam for the proposed change to discharge 70,000 cfs at the beginning of a flood event as opposed to 50,000 cfs.

2006 In September, USACE became a cooperating agency on the FERC Environmental Assessment (EA). This allows USACE to use the Coosa EA that evaluated the proposed changes.

2006 In December, FERC issued a second AIR, requesting APC to consider the 2, 10, 50 and 100-yr floods and the resulting socioeconomics.

2007 In April, APC submitted response to second AIR, including the frequencies these floods represented at various points along the Coosa as well as the resulting flooding outside of APC easements. APC demonstrated that less land would be flooded by the new procedures, even with the rule curve changes, than is flooded under existing flood control plans.

2007 On July 12th, APC held a technical workshop with USACE, FERC and others to discuss modeling included in the AIR.

2008 On August 15th, APC submitted to FERC follow-up information for the second AIR.

2008 In February 2008, APC submitted to FERC the final follow-up to second AIR.

2008 USACE began work on ACT water control manual (WCM) updates.

2009 In December, FERC issued the final EA for the Coosa projects, which evaluated the effects of the proposed rule curve changes.

2009 - 2010 As part of the ACT WCM update, APC and USACE work focused on ADROP (drought plan) and navigation flows. During this time, APC was focused on Martin relicensing and proposed rule curve changes at that reservoir.

2011 In the spring, due to concerns by APC about signing new MOU's for Weiss and Logan Martin with known issues of the existing flood control plans, APC and USACE agreed that the Weiss and Logan Martin manuals would not be updated at that time. The Neely Henry project's WCM would be updated and would make the Neely Henry interim flood control plan and rule curve operation permanent. The Harris project's WCM would also be updated with no changes to operations. APC and USACE agreed that the Weiss and Logan Martin flood control operation plan study would be a focus of a joint effort.

2011-2012 APC and USACE had multiple meetings, primarily focused on operations, manual updates, variances, etc. In a meeting held December 6, 2012, APC and USACE agreed to schedule a kick-off meeting to discuss next steps for the Coosa Flood Study.

2013 On January 29, APC and USACE met to discuss the history of the Coosa River Flood Study, the work that had been completed to date and what work was needed in order to make APC's proposed changes. At the conclusion of this meeting, USACE agreed to develop the process (additional studies, methods, etc.) that would be required to evaluate flood re-allocation consistent with USACE regulations and provide the plan/process to APC before the public release of the ACT Manual updates in March 2013.

2013 On July 8, following the release of the Draft EIS and Manuals for the ACT, APC and USACE met to discuss issues concerning flood easement at Logan Martin.

2014 On November 7, the final EIS and Manuals for the ACT were released by USACE.

2015 On January 16, APC and USACE met to discuss what else, from a modeling and study perspective and from a procedural perspective, needed to take place in order to make the proposed changes at Weiss and Logan Martin.

2015 On January 22, USACE committed to provide Alabama Power along with Weiss and Logan Martin stakeholders a framework for evaluating the proposed changes.

2015-2017 USACE provided a listing of required additional H&H analysis, which APC reviewed and responded with comments. Stakeholders were informed that USACE and APC would be coordinating on the required analysis and evaluation, subject to USACE receiving requested funding to engage in the process to evaluate proposed changes to the flood operation plans and associated updates to the Weiss and Logan Martin WCMs.

2018 USACE Mobile District received funding to initiate the Weiss and Logan Martin flood operation plan evaluations and WCM updates.

4.0 Overview of Analysis Performed to Date

The following comment from APC is provided for reference as to their approach to the 2005 Coosa River Flood Study. APC Comment: *Public Law 436-83rd Congress (68 Stat.303) requires a private developer to provide "the maximum flood control storage which is economically feasible with respect to past floods of record but in no event shall such flood control storage be less than that required to compensate for the effects of valley storage displaced by the proposed reservoirs of the licensee or less in quantity and effectiveness than the amount of flood control storage which could feasibly be provided by the currently authorized Federal multiple purpose project at Howell Mills Shoals constructed to elevation 490 with surcharge storage to elevation 495." As only flood storage above full summer pool was considered in the original design, the projects remain well within this requirement and it is* *not impacted by the proposed changes. Also, flood control must be adequate to off-set lost valley storage from the reservoirs. This was addressed in the original design of the projects and again in the 2005 Coosa Flood Study with similar positive findings.* The analysis required pursuant to this HEMP must provide documentation that clearly presents evidence indicating the flood storage required by law is maintained with the proposed modification of the flood storage associated with changes to the guide curves and reduction in the induced surcharge operation. The analysis indicating off-set of lost valley storage must be provided with the proposed plan submittal documentation.

In the 2005 Coosa River Flood Study, APC used computer simulation models to evaluate the proposed changes at Weiss, Neely Henry and Logan Martin. [Note: The Neely Henry winter pool change has been evaluated and approved by both FERC and USACE and included by USACE in the updated Neely Henry Water Control Manual]. These models included HEC-RAS, HEC-FFA/HEC-SSP, Reservoir Routing Models (RRM) and APC's HydroBudget model. The HydroBudget model was used to evaluate hydropower generation impacts resulting from the proposed operational changes. HEC-RAS models, operated in unsteady mode, were established from the upstream reservoir(s) to the dam of the next downstream reservoir as follows:

- From Allatoona and Carters Dam to Weiss Dam
- From Weiss Dam to Neely Henry
- From Neely Henry to Logan Martin
- From Logan Martin to Lay
- From Lay to Mitchell
- From Mitchell to Jordan/Bouldin
- From Jordan/Thurlow to Robert F Henry (Jones Bluff)

These models were developed from USACE and APC channel cross-section surveys at approximately 0.1-5 mile intervals, and the floodplains were coded from USGS Quad sheets. The models were calibrated and verified using significant events that contained sufficient hourly data. Calibration not only focused on matching the peak elevation but also the hydrograph shape and volume, since the latter has more significant impacts on reservoir operations.

Several flood events were simulated during the calibration and verification process for the APC dams; however, some events did not contain enough data to accommodate a simulation at some dams. The following matrix indicates which flood events were simulated for each dam during the calibration and verification process.

Dam/event	Calibration	Verification	Verification	Verification
Jordan	Apr 1979	Feb 1990	May 2003	
Mitchell	Apr 1979	Feb 1990	May 2003	
Lay	Apr 1979	Feb 1990	May 2003	
Logan Martin	Apr 1979	Apr 1977	Feb 1990	May 2003
Henry	Apr 1979	Apr 1977	Feb 1990	May 2003
Weiss	Feb 1990			

At the time of the development of the APC 2005 study, HEC ResSim did not have the capability to handle reservoir operational surcharge curves. Therefore, APC developed Reservoir Routing models (RRM's), which incorporated the operational surcharge curves. The RRM's were verified to simulate the operations at the dams by passing historical events. These models also had the ability to include human decision points or variances that are found quite frequently in the operational records during large flood events, thus allowing accurate simulation of observed events. The RRM's were used to pass a hydrograph that flowed into the respective reservoir. These hydrographs were routed downstream from the upstream reservoirs by HEC-RAS.

APC developed a design flood that replicated a 100 year, unregulated inflowing hydrograph into each reservoir. The design flood was developed to evaluate the impacts of the proposed operational changes on the release hydrographs and downstream flooding compared with historical operation. Each design flood was developed by applying the 2004 Coosa River Basin Flood Frequency Analysis (HEC-FFA)(which has now been replaced with HEC-SSP, or Statistical Software Package) to the USACE unimpaired, unsmoothed database inflows for the respective reservoirs. Three sets of frequency information were generated: (1) daily frequency volumes, (2) 3-day frequency volumes, (3) 5-day frequency volumes. The USACE database included average daily flows which reflected the appropriate volumes. These data, generated by HEC-FFA, were used to scale a historical hydrograph (February 1990 flood) to match the 1% chance exceedance volumes for 1, 3 and 5 day average volumes. The 1% chance of exceedance values were used to generate the design flood. Events with much less inflow volume were not selected as they would not have impacts, specifically those with total volume less or very near the remaining flood storage in the reservoirs.

However, in a second AIR issued in Dec. 2006 (see Appendix for all AIR files), FERC requested that APC consider the 2, 10, 50 and 100 year floods and the resulting socioeconomics. APC consulted with FERC, USACE, and other interested stakeholders in the 1st Technical conference held in February 2007. Due to issues with developing synthetic floods, such as what volume to represent (1, 3 or 5 day), it was decided to look at higher frequency historical floods. USACE, FERC and APC agreed to evaluate the October 1995, February 1990 and May 2003 events. The frequencies these floods represented at various points along the river as well as the resulting flooding outside of APC easements were submitted to FERC in April 2007 in response to the second AIR request. APC demonstrated that less land would be flooded by the new procedures, even with rule curve changes, than is flooded under the existing flood control plans.

The following is a table of the storms evaluated in the Coosa AIR process in consultation with FERC and USACE and the corresponding frequencies assigned:

Dam/event	Apr 1979	Feb 1990	Design Flood	Oct 1995	May 2003
Jordan	250-yr < X < 500-yr	25-yr	Unregulated 100-yr	5-yr	5-yr
Mitchell	250-yr < X < 500-yr	25-yr	Unregulated 100-yr	5-yr	8-yr
Childersburg		33-yr		5-yr	16-yr
Lay	250-yr	33-yr	Unregulated 100-yr	5-yr	13-yr
Logan Martin	250-yr	25-yr < X < 50-yr	Unregulated 100-yr		20-yr
Gadsden		90-yr		5-yr	10-yr
Henry	100-yr < X < 250-yr	75-yr	Unregulated 100-yr	5-yr	15-yr
Weiss	50-yr	100-yr	Unregulated 100-yr	5-yr	8-yr

5.0 Guidance Documents

There are no set USACE procedures for flood control changes at privately owned storage projects where the USACE has the flood control authority. However, the following Engineering Manuals support the justification for additional analysis:

- EM 1110-2-3600 "Management of Water Control Systems" sections 3-3-c and 3-4-b
- EM 1110-2-1419 "Hydrologic Engineering Requirements for Flood Damage Reduction Studies" Table 4-2 and 4-5
- EM 1110-2-1420 "Hydrologic Engineering Analysis for Reservoirs" paragraph 4-5 and Chapter 10
- EM 1110-2-1417 "Flood-runoff Analysis" Table 3-1
- ER 1110-8-2 "Inflow Design Floods for Dams and Reservoirs"

6.0 Additional Analysis Required

The following additional items and analysis will be required for USACE to review and make a decision of the proposed changes in flood operation for projects Weiss and Logan Martin dams. The ACT Basin models developed by the Mobile District Water Management for use in CWMS (Corps Water Management System) and HEC-RTS (Real Time Simulation) will be used with the analysis.

1. *Define a set of without-project inflow hydrographs. These should cover the range of likely events, including frequent small events, infrequent large events, major historical events, etc.*

   Using the events already evaluated during the 2005 Coosa Flood Study and subsequent FERC Additional Information Request responses will provide a substantial starting point for evaluation of impacts from the proposed operational changes. These events include:

   - Frequent small events – 1990, 1995, 2003 floods
   - Major historical events – 1990 flood, 1979 flood

   Additional events required for evaluation include:

   - Infrequent large events – design flood, SPF, PMF[1]
   - Back-to-back event – for example December 2015

   [1]ER 1110-8-2 includes methodology for evaluating the inflow design flood IDF or PMF. Minimum starting elevations for routing the IDF (PMF) will be assumed as the full flood control pool level or the elevation prevailing five days after the last significant rainfall of a storm that produced ½ the IDF, whichever is most appropriate. A comparison of surcharge elevations computed under alternative starting elevations is required to reveal the sensitivity of the maximum pool to the starting elevation.

For these additional events that require evaluation, the following analyses will be completed:

a. Assign a frequency to these events based on the frequency analysis of the unimpaired unsmoothed flows.
b. Based on the results of the events, compare peak stages for the current written operating procedure to the proposed operating procedure for critical flood damage locations downstream of each dam.
c. If it is determined there are increases of the peak elevations at critical locations, identify the damages at those points.
d. The new HEC-RAS models developed for the ACT basin CWMS will be used in the analysis, including the defined event hydrograph flows. Flood inundation mapping of the downstream reaches including the critical locations will be developed to support the analysis.

2. *Identify a "target" for reliability analysis. This may be the channel capacity downstream, the flow corresponding to the maximum stage before damage is incurred, or any other target appropriate for a particular floodplain.*

   The "target" points will be the critical locations downstream of the respective dams, such as a city, community or some major structures in the floodplain. SERFC has already defined flooding impacts at locations such as the cities of Gadsden and Childersburg. Impacts to areas around the reservoirs and APC easements will also be considered. These target points will be consistent with the work already completed to date.

3. *Select/develop a trial reservoir operation plan. Develop the elevation-area-discharge functions required for reservoir routing for this alternative.*

   A proposed alternative to the current flood operating procedures for Weiss and Logan Martin has already been developed in the 2005 Coosa Flood Study. Elevation-area-discharge functions required for reservoir routing for the proposed alternative developed during the 2005 Coosa Flood Study will be used in this effort.

4. *For each inflow hydrograph, in turn, compute the corresponding outflow hydrograph.*

   The new version of Corps Water Management System (CWMS) for the ACT Basin developed by the Mobile District Water Management will be used to simulate the operations at Weiss, H Neely Henry and Logan Martin dams and to generate outflow hydrographs. The current version of HEC-ResSim correctly simulates operations during a large flood and should be used to evaluate the proposed flood operation for Weiss and Logan Martin Dams. The Mobile District water management team working with APC has developed an hourly ResSim model for the ACT Basin. The model is a component of the recently developed Corps Water Management System (CWMS) for the ACT Basin. This ResSim real-time model component can be exported and utilized as a planning simulation model to evaluate the proposed flood operation for Weiss and Logan Martin Dams. Whereas the APC Reservoir Routing Model spreadsheet model used in the 2005 Coosa Flood Study is labor intensive and limited in application, a specialized reservoir simulation software package such as HEC-ResSim is better suited to simulate the proposed reservoir flood operation.

The HEC-RAS model developed for the new CWMS model can be used to evaluate the proposed changes in operations by quantifying flood elevations downstream resulting from the larger rainfall events and multiple storm event identified above. However, general review by APC consultant of the HEC-RAS models in the CWMS model indicated that some of the updating was not complete, specifically regarding off-channel storage capacity. Updating of these models will need to be completed, calibrated and verified by the USACE before proceeding with the proposed analysis. If these models cannot be completed in a timely fashion an option would be to use the existing APC HEC-RAS models.

5. *Compute the flood damage corresponding to the hydrograph peak.*

   APC was instructed by USACE during the 2005 Coosa Flood Study that proposed changes to flood operations could not result in an increase in peak downstream water surface elevation and be approved. The "no change" criteria established by USACE was evaluated to the operational alternative with the design flood and the final recommended operational changes were based on that criteria. Therefore, if there is no increase in downstream peak elevation and subsequently no increase in flood damage, an economic study using the FIA model should not be necessary.

6. *Compare the outflow peak at the target to determine if the regulated flow or stage exceeds the target, including comparison of the proposed plan's duration of the regulated flow and stage above the existing plan's regulated flow and stage.*

   Compare the results from the HEC-RAS model runs of the events selected in (1.) above at the targets previously identified (2.) for the current operating procedures to results with the proposed changes in operation.

7. *Analysis of large rainfall events to support a reliable determination.*

   The modeling and analysis within this study should include induced surcharge operations during a multiple storm event. In the 2005 Coosa Flood Study, APC limited the analysis of large events to the 100 year (1% chance of occurrence) unregulated runoff to each reservoir labeled as the design storm and did not consider the impact of back-to-back storm events. As provided in earlier comments from APC, during the 2005 Coosa Flood Study, APC noted that the event developed as described above would actually be greater than the magnitude of a 1% chance of occurrence with regulation from the upstream reservoirs applied. For this reason, it is referred to as a design flood, rather than a 100-year event. The goal was to identify a standardized event to compare the proposed project changes to current operations.

   The December 2015 event may be selected to represent the multiple storm event. This was a series of rain events causing complete soil saturation. A comparison of the HEC-RAS results from the current and proposed operating procedures at the downstream targets should be used.

a. *Probable Maximum Flood (PMF).*

Definition of Probable Maximum flood.

"b. Probable maximum flood. The probable maximum flood (PMF) is the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. It is used in the design of projects for which virtually complete security from flood-induced failure is desired. Examples are the design of dam height and spillway size for major dams and protection works for nuclear power plants "(EM-1110-2-1417 Flood-Runoff Analysis, P13-7).

It is not necessary to reproduce the PMF storms, but previous evaluations will be included with this study. Any evaluation of PMF's should be consistent with what FERC, as the regulatory authority for APC Dam Safety, has approved. As previously commented by APC, an updated report for Logan Martin was not created in the 2006 PMF update, and APC agrees to produce one as part of this study effort using the APC HMS model. The current version of HEC-ResSim will simulate operations during PMF event and will be used to evaluate (produce pool elevation and outflow hydrograph time series) the current and proposed flood operation for Weiss and Logan Martin Dams.

In 1986 Shah W. Khan of SCS prepared a Coosa River PMF report for APC to address FERC safety concerns with APC structures during a PMF event. Minor revisions were made following FERC review and a revised study report was issued in 1990 and subsequently approved by FERC. In this study, probable maximum precipitation (PMP) storms for all of the APC reservoirs on the Coosa River were developed. Standard hydrologic methods were applied. These storms were then incorporated into the USACE Hydrologic Engineering Center (HEC) HEC-1 model to simulate the PMF on each reservoir. An array of simulations was tested with different storm centers to derive the most severe conditions for each reservoir. The 1990 study utilized unit hydrographs that had been developed by the USACE. The upstream USACE dams, Carters and Allatoona, control 29% of the drainage areas above Weiss Dam. The effect of these reservoirs was not included in the 1990 PMF study. In addition, limitations of the HEC-1 model required that operations at some APC dams be conservatively simplified. Therefore, in 2006, Maurice James, a consultant to APC, updated the PMF study by importing the HEC-1 models to HEC-HMS, assuring that they replicate the original results and then modifying the HEC-HMS models to include the effects of the upstream dams. Spillway capacity at the APC dams was designed to manage a PMF without overtopping the dams. That fact, coupled with the assurance the dams would not fail, is essentially all that can be derived from a PMF study.

b. *Standard Project Flood (SPF). Insufficient analysis has been provided to make a reliable determination of the Standard Project Flood.*

Frequencies are not normally associated with the Standard Project Flood. Sometimes estimates of peak discharges of the order of 50 percent of probable maximum peak discharges are used to estimate the SPF.

Definition of Standard Project flood.

"a. Standard project flood. The standard project flood (SPF) is the flood that can be expected from the most severe combination of meteorological and hydrologic conditions that are considered reasonably characteristic of the region in which the study basin is located. The SPF is generally based on analysis (and transposition) of major storms that have occurred in the region and selection of a storm magnitude and temporal distribution that is as severe as any of the transposed storms, with the possible exception of any storm or storms that are exceptionally larger than others and are considered to be extremely rare. Studies compiled in the United States indicate that SPF peak discharges are usually of the order of 40 to 60 percent of probable maximum peak discharges. (1) The SPF is intended as a practicable expression of the degree of protection to be considered for situations where protection of human life and high-valued property is required, such as for an urban levee or floodwall. It also provides a basis of comparison with the recommended protection for a given project. Although a specific frequency cannot be assigned to the SPF, a return period of a few hundred to a few thousand years is commonly associated with it.

EM-1110-2-1417 Flood-Runoff Analysis P13-7"

The current version of HEC-ResSim will simulate operations during the Standard Project Flood event and will be used to evaluate (produce pool elevation and outflow hydrograph time series) the current and proposed flood operation for Weiss and Logan Martin Dams.

7.0 Responsibility of USACE

USACE will provide guidance to APC and in coordination with APC, review the analysis and approve the plans. USACE will coordinate any necessary technical assistance from the Hydrologic Engineering Center (HEC) regarding use and implementation of their software products. USACE will incorporate approved plans into updated Weiss and Logan Martin WCMs, as needed.

8.0 Responsibility of APC

APC will conduct the necessary analyses, simulation modeling and provide necessary documentation for USACE to complete a review of the analysis and proposed plan. APC will provide all models to USACE for review.

9.0 Schedule

APC and USACE will jointly develop a work plan schedule to include coordination meetings, critical task milestones, interim submittals, reviews, and final proposed plan submittal. The work plan and schedule will be completed within 10 business days from the date of this HEMP approval by both parties. The proposed Weiss and Logan Martin flood operation plan should be submitted by APC to USACE by Sep-2018. The work plan and schedule shall include weekly in-progress coordination web-meetings and monthly face-to-face coordination and review meetings.

[SIGNATURES]

________________________________	________________________________
Alan Peeples Supervisor, Reservoir Management Southern Company Hydro Alabama Power Company	Randall B. Harvey, P.E. Chief, Water Resources Branch Engineering Division U.S. Army Corps of Engineers, Mobile District

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Attachment 8. Flood Frequency Hydrology Development

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Alabama-Coosa-Tallapoosa (ACT) Watershed

HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update

Appendix O – Development of Sub-daily Flows for the Upper Coosa

March 2011 (DRAFT)

Prepared for:
US Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628-0001

Prepared by:
US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

(530) 756-1104
(530) 756-8250 FAX
www.hec.usace.army.mil

DEVELOPMENT OF HOURLY HYPOTHETICAL STORM HYDROGRAPHS FOR THE ALABAMA-COOSA-TALLAPOOSA RIVER SYSTEM BASIN ABOVE ROME, GEORGIA

US Army Corps of Engineers
Mobile District

JULY 2009

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Appendix O-A Figures *(Continued)*:

Appendix O-B Figures:

Appendix O-C Figures:

Appendix O

Development of Sub-daily Flows for the Upper Coosa

1. INTRODUCTION

The U.S. Army Corps of Engineers (USACE) Mobile District was tasked to develop hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events on the Alabama Coosa Tallapoosa (ACT) River system basin above Rome, GA. The data will be used to evaluate the impact of varied operation of the federal projects in the basin, Allatoona Dam and Carters Main Dam and Re-regulation Dam. The 4040 square mile ACT basin above Rome, GA is formed by the Oostanaula River and the Etowah River basins. These rivers join at Rome, GA to form the Coosa River. The Oostanaula and Etowah Rivers have approximately the same drainage area. The Oostanaula River is formed by the Conasauga and Coosawattee Rivers near Resaca, GA. Carters Dam and Carters Reregulation Dam are located on the Coosawattee River approximately 1 mile apart. Allatoona Dam is located on the Etowah River. The area is shown in Figure O.01.

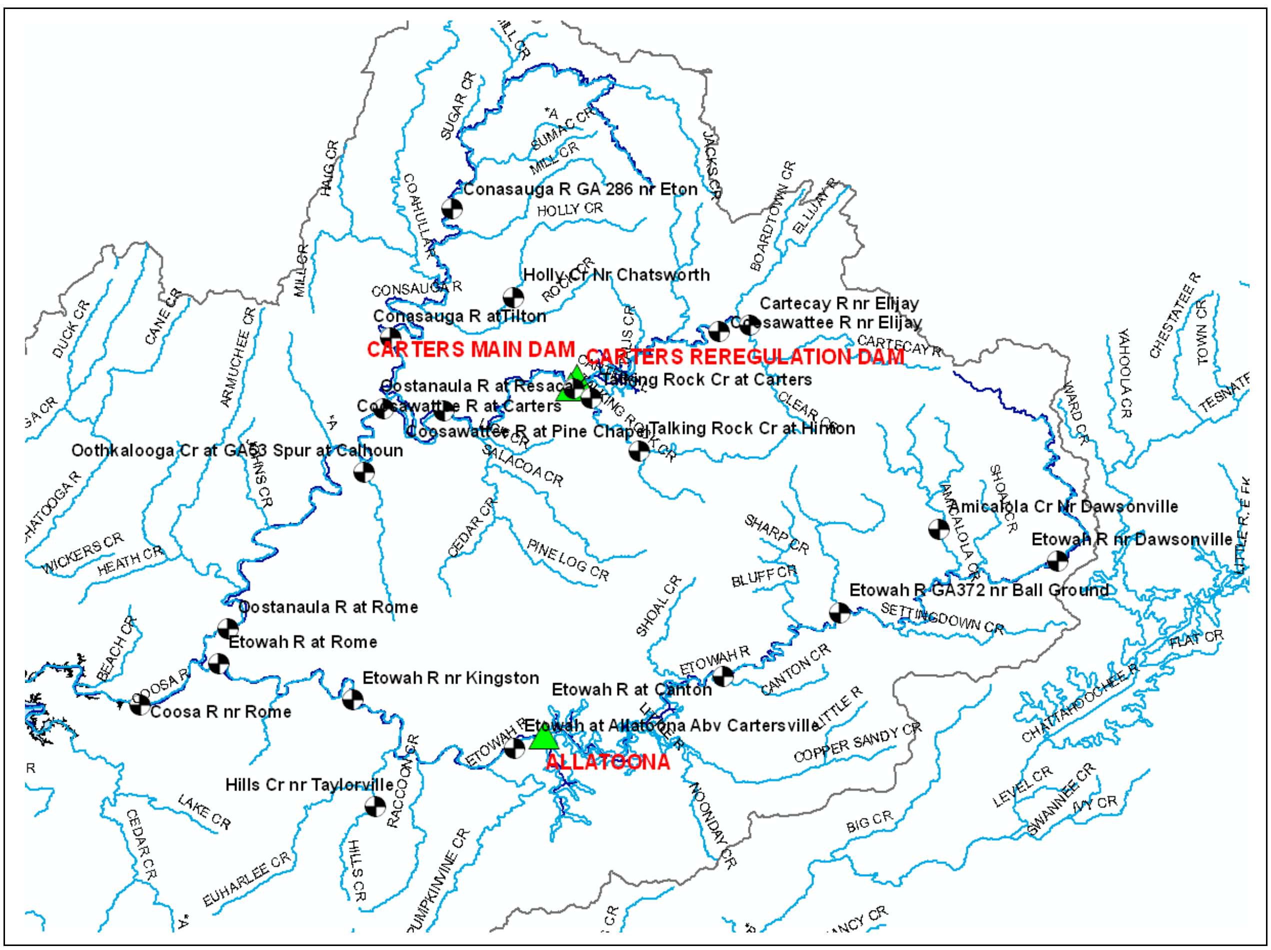

Figure O.01 ACT Basin above Rome, GA

The hourly hypothetical hydrographs developed in this analysis were developed for input to a reservoir system simulation (HEC-ResSim) model of the ACT River system above Rome. The HEC-ResSim model will be used to analyze reservoir operations at Allatoona Dam and at Carters Dam during various hypothetical flood events and determine the downstream impacts at Rome, GA. To develop the hourly hydrographs, a routing model of the basin was constructed using version 3.3 of the Hydrologic Engineering Center's application Hydrologic Modeling System (HEC-HMS). A schematic of the watershed is shown below in Figure O.02.

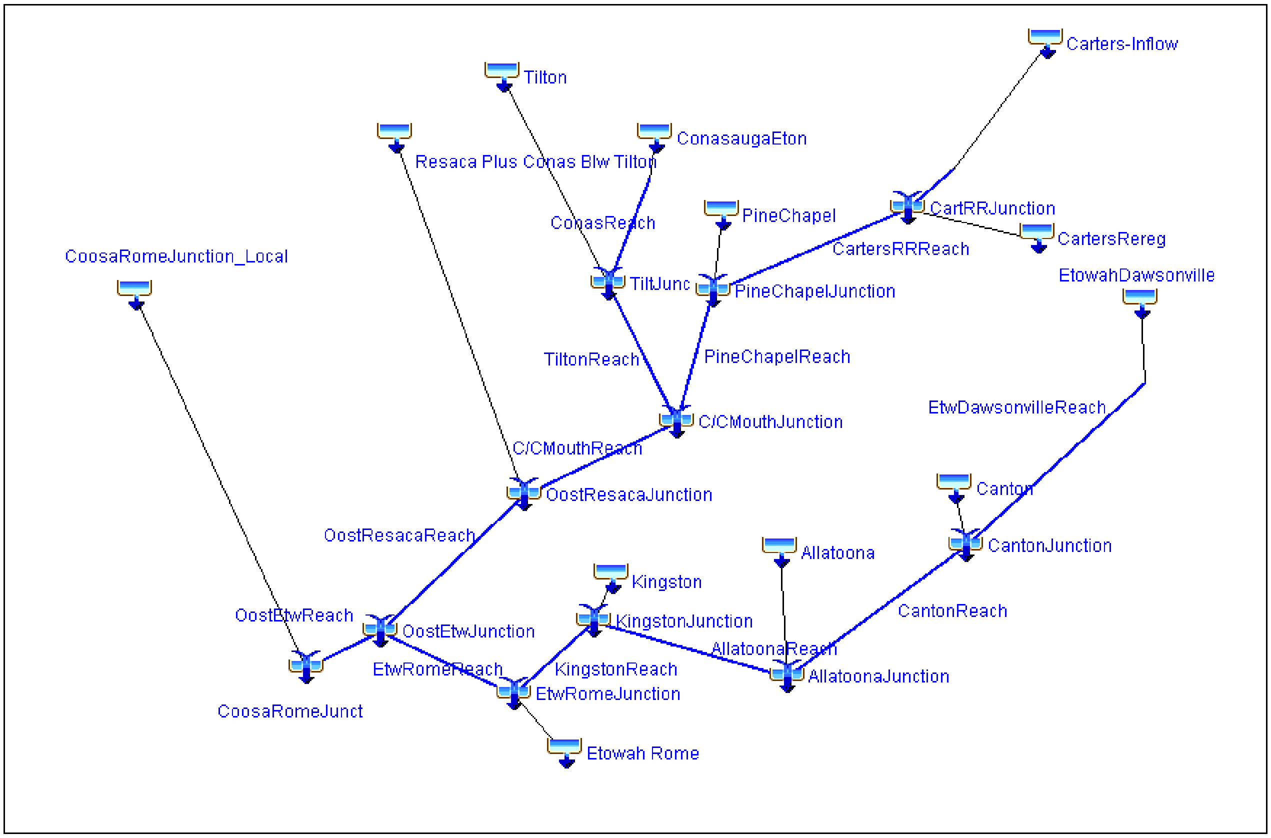

Figure O.02 ACT Above Rome Schematic

In order to determine the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events at the inflow locations and points of interest shown in Figure O.02, the USACE Mobile District and the USACE Hydrologic Engineering Center (HEC) developed a 6 step process. This process consisted of (1) generating a daily vs. instantaneous peak flow relationships at various gages throughout the basin, (2) developing instantaneous, 1-, 3-, 5-, and 45-day frequency curves at Rome, (3) identification of three historic storm events, (4) converting the daily unimpaired data to hourly for these three historic storm events, (5) development and calibration of an HEC-HMS model, and (6) scaling the hourly data to produce the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events in the HEC-HMS model. Additional details of this process are addressed in the following sections.

2. DEVELOPMENT OF HOURLY HYPOTHETICAL STORM HYDROGRAPHS

2.1 Development Daily vs. Instantaneous Peak Relationship

The first task in the development of the hourly hypothetical storm hydrographs was to generate a daily vs. instantaneous peak relationship at various locations in the basin. This was done by comparing the annual peak flows with the average daily flows on the same day at USGS gages in the basin. Details are provided in Appendix O-A. The daily vs. instantaneous peak relationship at Rome is shown in Figure O.03 below.

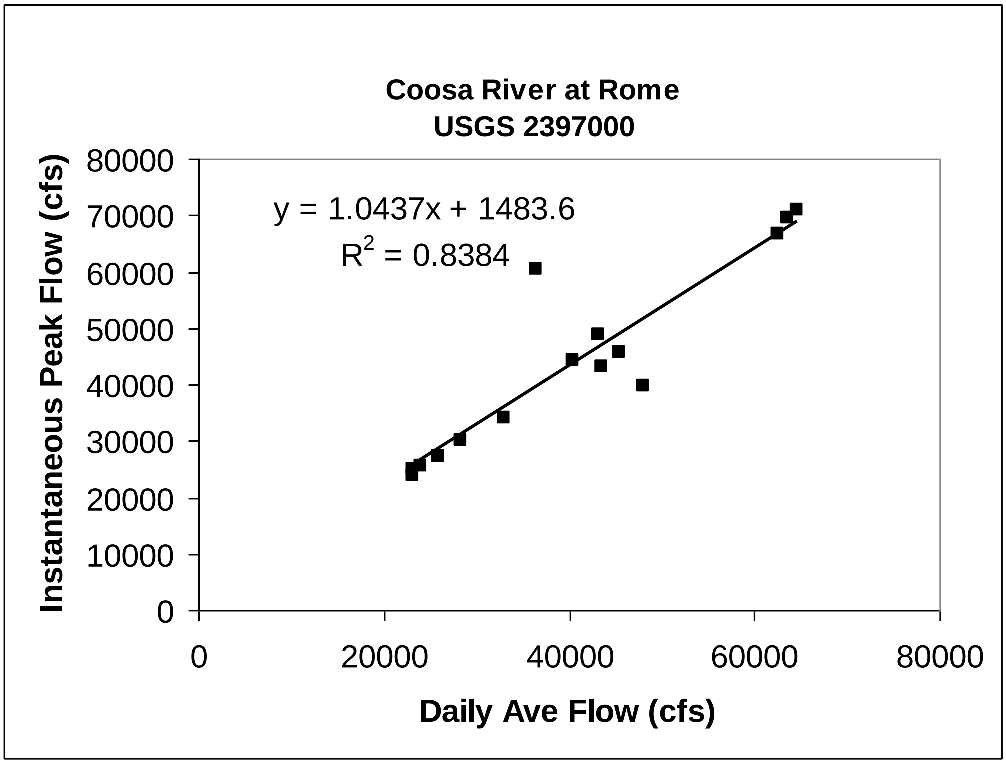

Figure O.03 Instantaneous Peak Flow vs. Daily Average Flow Relationship at Rome

2.2 Development of Unimpaired Flow Frequencies at Rome

The second task in the development of the hourly unimpaired flow hypothetical storm hydrographs was to compute the instantaneous peak, and 1-day, 3-day, 5-day, and 45-day flow frequencies from the USGS gage at Rome. These were computed using the Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) and are shown in Table O.01 below. Details of this analysis are provided in Appendix O-B of this report.

Table O.01 Unimpaired Flow Frequencies at USGS Gage Coosa River at Rome

Percent Exceedance Frequency	Peak	1-Day	3-Day	5-Day	45-Day
99.0	20,767	16,061	14,449	12,171	5,374
95.0	26,871	22,385	20,446	17,676	7,617
90.0	30,723	26,442	24,272	21,217	9,065
80.0	36,022	32,046	29,511	26,082	11,069
50.0	48,377	44,993	41,360	37,062	15,703
20.0	64,183	60,938	55,372	49,877	21,378
10.0	74,047	70,432	63,387	57,075	24,728
5.0	83,123	78,829	70,268	63,159	27,670
2.0	94,425	88,835	78,206	70,053	31,144
1.0	102,645	95,798	83,563	74,624	33,542
0.5	110,674	102,354	88,480	78,756	35,783
0.2	121,086	110,504	94,421	83,661	38,545
0.1	128,856	116,336	98,556	87,015	40,504

2.3 Selection of Storm Events

The third step in development the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events was identification of three separate storm events. Three historic storm events were identified from the daily average unimpaired data set for use in this analysis (Nov-Dec 1961, Jan - Mar 1979, and Feb-Apr 1990). These storms were selected from the period of record because of their high 45-day volume, and their high peaks. The daily average unimpaired flow hydrographs for the three events at Rome, GA are shown in Figure O.04, Figure O.05, and Figure O.06.

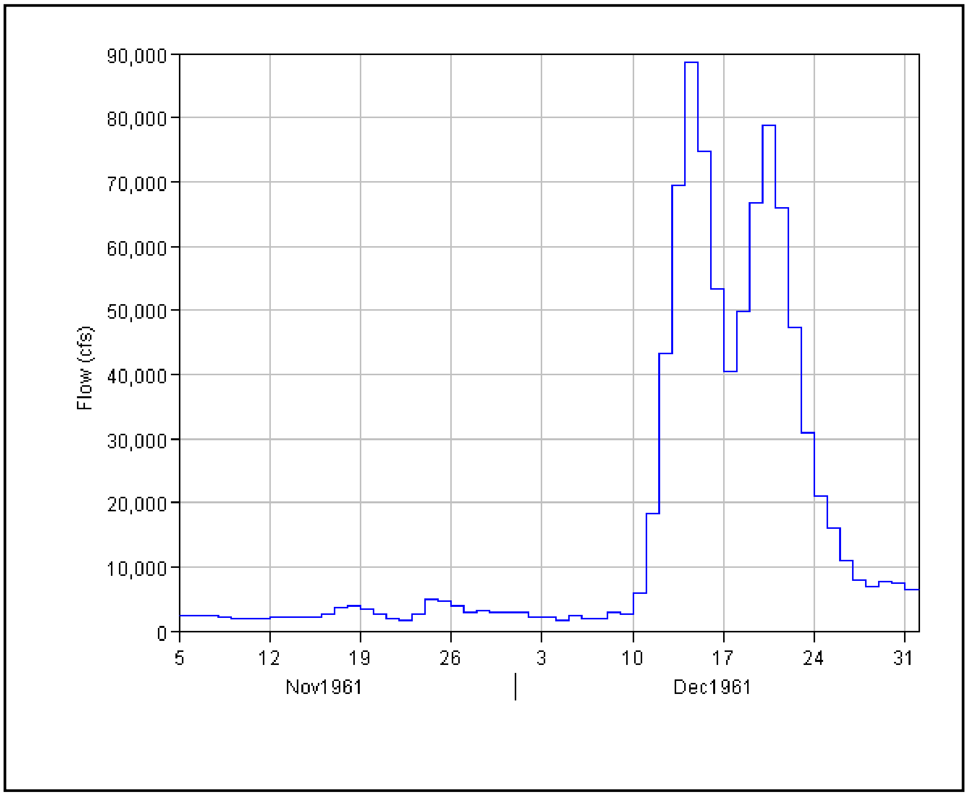

Figure O.04 November – December 1961 Flood Event at Rome, GA

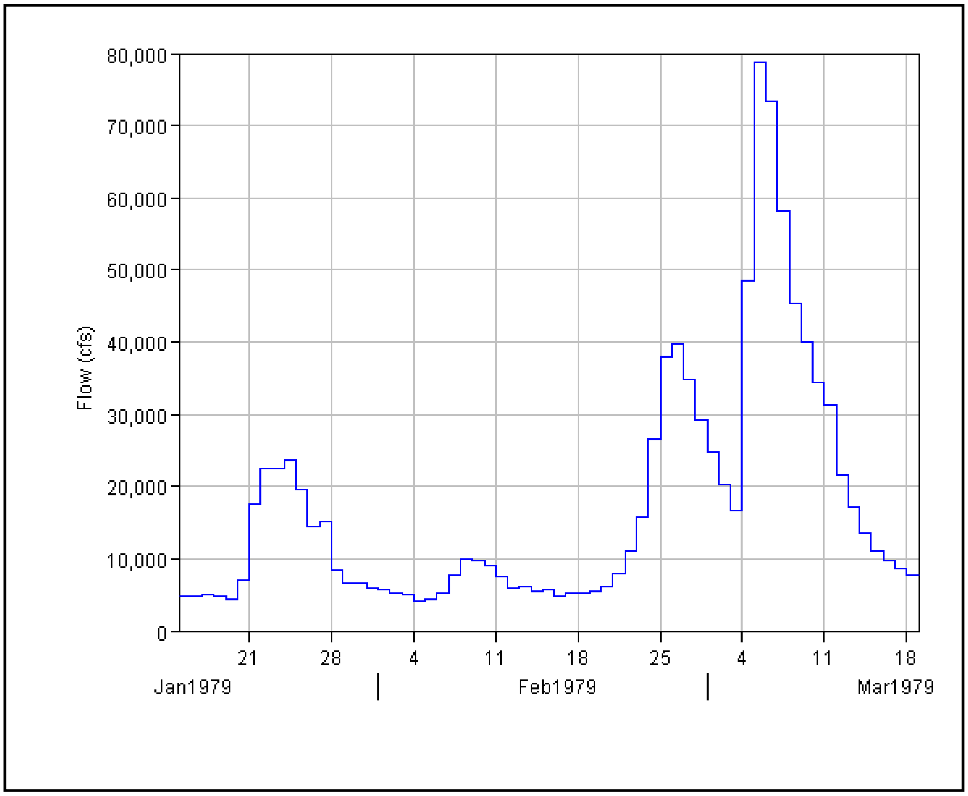

Figure O.05 January - March 1979 Flood Event at Rome, GA

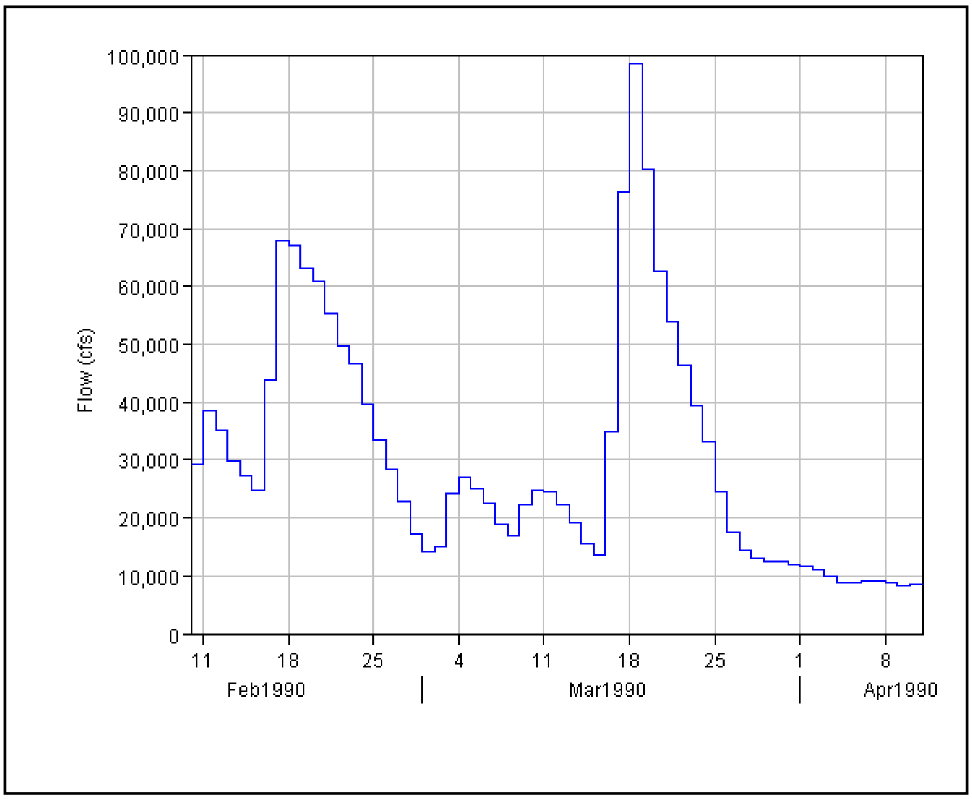

Figure O.06 February – April 1990 Flood Event at Rome, GA

2.4 Conversion of Daily Average Unimpaired Data to Hourly Values

The fourth step in the development the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events was to convert the selected flood events from daily average flows to hourly flows at main-stem gages (junctions in the HEC-HMS model), or HEC-ResSim nodes and, for the 1990 flood, the local inflow (between gages) and for the most upstream inflow locations. The hourly hydrographs at these locations were used for calibrating and checking the HMS model. This was done for the 1990 flood because this flood and these local inflows were used to determine routing parameters in the HEC-HMS model. The local inflow for the 1961 and 1979 floods were determined by other means described in Appendix O-C.

To determine the hourly hydrographs, the instantaneous peak flow values derived from methods described in **Section 2.1** were used to shape the hydrograph. For each hydrograph, once the instantaneous peak value was determined, a SCS unit hydrograph was used in Excel spreadsheets to shape the hydrograph around the peak while the rest of the hydrograph was shaped using a combination of power equations, exponential equations, and other methods to shape the hydrograph appropriately. Generally, only the last peak of a multi-peak flood was converted to hourly values using this method, since the timing of this peak would be the most critical. For the prior peaks and other low flow values, the average daily values were used for 24 hours to get the hourly values for that day. However, for the 1961 flood, hourly values for both peaks were developed because the larger peak occurred first at some locations, and because they were relatively close together.

In shaping these hydrographs, the hourly values were adjusted to match not only the peak value, but also to preserve, for each day of the hydrograph, the daily volumes of the existing unimpaired average daily flow hydrograph.

The daily and hourly hydrographs for the three flood events at Rome are shown in Figure O.07, Figure O.08, and Figure O.09.

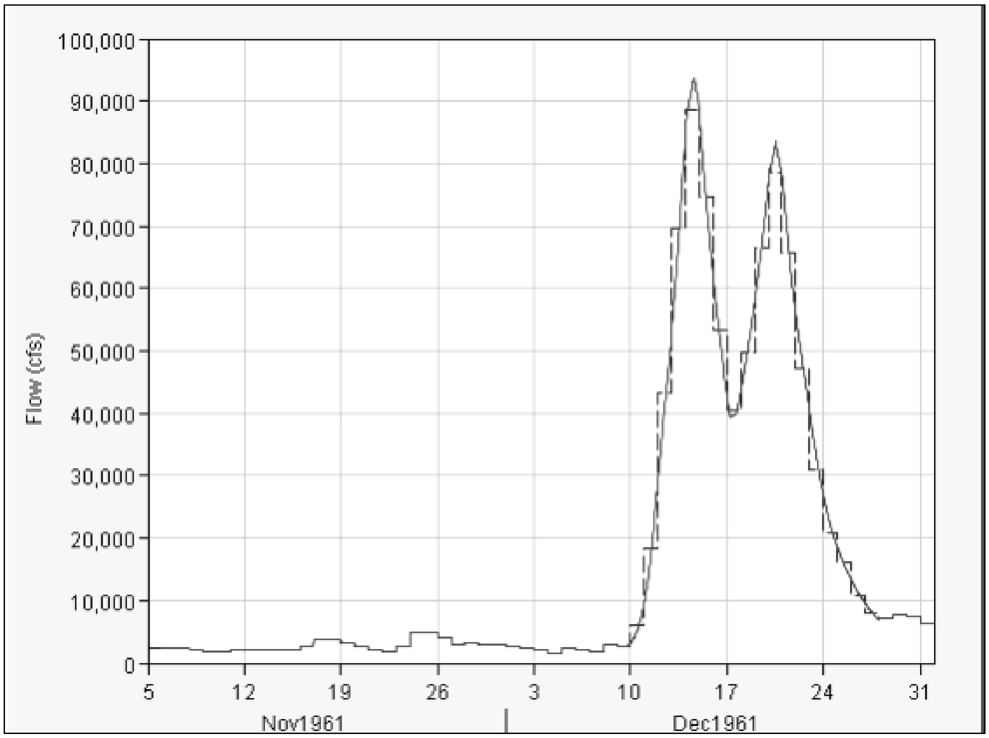

Figure O.07 Daily vs. Hourly Flow Hydrographs for the 5 Nov. – 31 Dec. 1961Storm Event at Rome

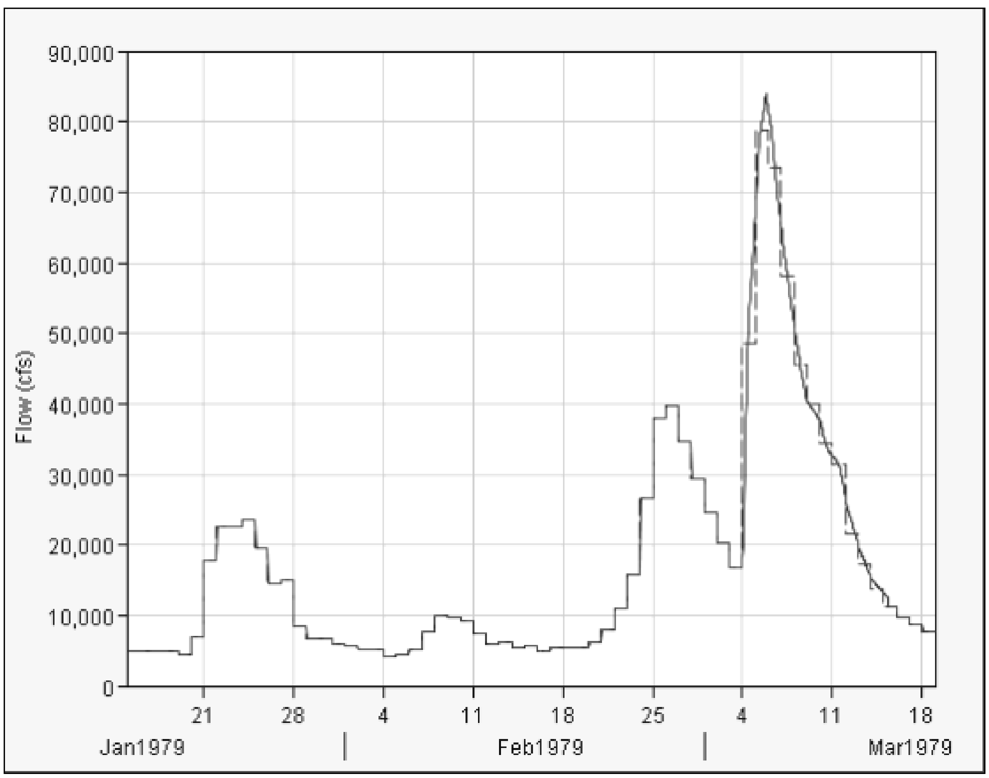

Figure O.08 Daily vs. Hourly Flow Hydrographs for the 15 Jan – 18 Mar 1979 Storm Event at Rome

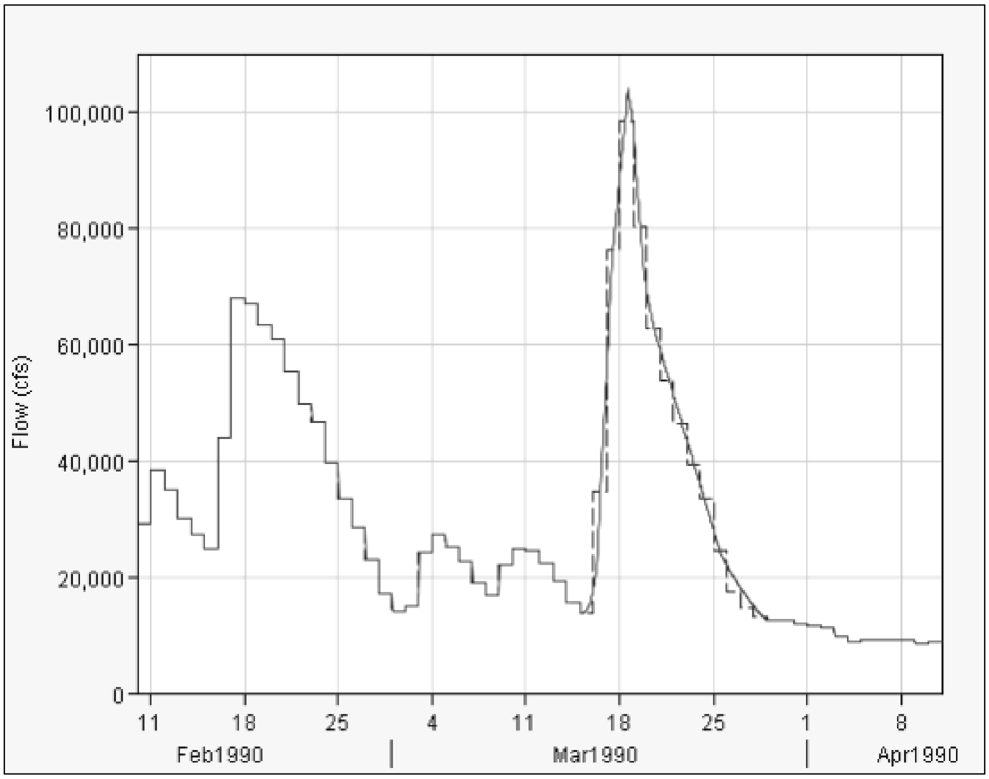

Figure O.09 Daily vs. Hourly Flow Hydrographs for the 10 Feb – 10 Apr 1990 Storm Event at Rome

2.5 Development and Calibration of HEC-HMS Model

The fifth step in the development the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events was to develop a calibrated HEC-HMS routing model of the basin above Rome. This was done using Muskingum-Cunge routing method initially, but was later changed to Muskingum because of better matching and ease of calibration. The historic 1990 local inflow (flow between the gages) hydrographs, and cumulative flow at the gages, both of which were converted to hourly values, were used to calibrate the model. The calibration of the HEC-HMS model was done by HEC staff and the details are described Appendix C. The calibrated model was then used for the 1961 and 1979 floods.

2.6 Design Floods.

The sixth step in the development the hourly hypothetical unimpaired flow storm hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events at Rome was scaling the hourly data to produce these events in the HEC-HMS model.

Local (incremental) flow hydrographs were developed that would result in the HEC-HMS model in the unregulated instantaneous peak flow of the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events at Rome that match the similar data derived from the gage at Rome. The local flows were also adjusted to match the 1-day, 3-day, 5-day, and 45-day unregulated volume-duration frequency curves developed by the Hydrological Engineering Center's Statistical Software Package (HEC-SSP) from the gage data at Rome.

For each of the three storms, these design flow local hydrographs were developed by a two-step process. First, all the historic local hydrographs were multiplied by the same factor. The factor was basically the ratio of the peak from the gage and the peak from the HEC-HMS model at Rome. These were then re-run in the model. The 1-day, 3-day, 5-day, and 45-day unregulated volume-durations were checked in a spreadsheet to assure they matched within 10 percent. For every flood, the 45-day durations did not match those from the HEC-HMS model. Therefore a second adjustment was made to the local hydrograph values preceding or after the 5-day peak up or down and the model re-run. Most of the time, the peaks and the volume durations matched within 10 percent the values from the gage at Rome with the second adjustment. If not a third adjustment was made for the 45-day volumes.

The instantaneous peak frequency data and volume-duration table developed from gage data at Rome for specific design frequencies is shown in Table O.02, Table O.03, and Table O.04, below. The tables also show the frequency table developed for the desired specific design frequencies from the HEC-HMS model at Rome using each of the different flood events as a base. The tables also show the difference between the gage data and the HEC-HMS model data. The difference was kept at 10 percent or lower.

Table O.02. Flow Frequencies from 1961 Flood

Gage and HEC-HMS Flow Frequency and Volume Duration Data at Rome, GA from 1961 Flood															
	From Rome Gage					From HEC-HMS Model using 1961 Flood					Difference (%)				
Percent Chance Exceedance	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.
5	83,123	78,829	70,268	63,159	27,670	83469	80,777	69,330	58,540	26,655	0.42%	2.47%	-1.34%	-7.31%	-3.67%
2	94,425	88,835	78,206	70,053	31,144	94445	91,410	78,426	66,215	29,760	0.02%	2.90%	0.28%	-5.48%	-4.44%
1	102,645	95,798	83,563	74,624	33,542	102,666	99,366	85,253	71,978	32,388	0.02%	3.72%	2.02%	-3.55%	-3.44%
0.5	110,674	102,354	88,480	78,756	35,783	110698	107,140	91,922	77,609	36,432	0.02%	4.68%	3.89%	-1.46%	1.81%
0.2	121,086	110,504	94,421	83,661	38,545	121112	117,219	100,570	84,910	39,860	0.02%	6.08%	6.51%	1.49%	3.41%

All of the design floods were adjusted to match the frequency and volume duration data developed from the gage data within 10 percent.

The 1979 flood calibration table is shown below.

Table O.03. Flow Frequencies from 1979 Flood

Gage and HEC-HMS Flow Frequency and Volume Duration Data at Rome, GA from 1979 Flood															
	From Rome Gage					From HEC-HMS Model using 1979 Flood					Difference (%)				
Percent Chance Exceedance	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.
5	83,123	78,829	70,268	63,159	27,670	83,123	79,131	68,621	61,956	27,511	0.00%	-0.38%	2.34%	1.90%	0.58%
2	94,425	88,835	78,206	70,053	31,144	94,425	89,890	77,951	70,381	30,645	0.00%	-1.19%	0.33%	-0.47%	1.60%
1	102,645	95,798	83,563	74,624	33,542	102,690	97,755	84,777	76,549	32,816	-0.04%	-2.04%	-1.45%	-2.58%	2.16%
0.5	110,674	102,354	88,480	78,756	35,783	110,674	105,359	91,365	82,491	35,612	0.00%	-2.94%	-3.26%	-4.74%	0.48%
0.2	121,086	110,504	94,421	83,661	38,545	121,086	115,266	99,965	90,265	38,137	0.00%	-4.31%	-5.87%	-7.89%	1.06%

The table shows all values matched within 10 percent.

The 1990 flood calibration table is shown below.

Table O.04. Flow Frequencies from 1990 Flood

Gage and HEC-HMS Flow Frequency and Volume Duration Data at Rome, GA from 1990 Flood															
	From Rome Gage					From HEC-HMS Model using 1990 Flood					Difference (%)				
Percent Chance Exceedance	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.	Inst Peak Flow	1-Day Max Vol-Dur.	3-Day Max Vol-Dur.	5-Day Max Vol-Dur.	45-Day Max Vol-Dur.
5	83,123	78,829	70,268	63,159	27,670	82,898	78,727	68,444	60,986	28,306	-0.27%	-0.13%	-2.60%	-3.44%	2.30%
2	94,425	88,835	78,206	70,053	31,144	95,072	90,280	78,480	69,937	31,974	0.69%	1.63%	0.35%	-0.17%	2.67%
1	102,645	95,798	83,563	74,624	33,542	102,232	96,604	83,381	74,745	34,557	-0.40%	0.84%	-0.22%	0.16%	3.03%
0.5	110,674	102,354	88,480	78,756	35,783	109,388	103,367	89,218	79,977	36,976	-1.16%	0.99%	0.83%	1.55%	3.33%
0.2	121,086	110,504	94,421	83,661	38,545	118,563	111,994	96,612	86,645	39,895	-2.08%	1.35%	2.32%	3.57%	3.50%

The table shows all values matched within 10 percent.

Appendix O-A

Instantaneous Peak Flow
vs.
Daily Ave. Flow Relationships

Appendix O-A

Instantaneous Peak Flow
vs.
Daily Average Flow Relationships

This procedure is to develop the instantaneous peak flow vs. daily average flow relationships for various stream gages in the Coosa River basin above Rome, GA. Results from this analysis were used to compute instantaneous peak flow given daily average flow data. This was later used to develop instantaneous unregulated flow frequency curves and 1-hour local runoff hydrographs.

Figure O-A.01shows the Coosa River basin, major reservoir locations and stream gage locations used in this analysis. Table O-A-01 and Table O-A-02 contain a description of USGS stream gages and major reservoirs, respectively.

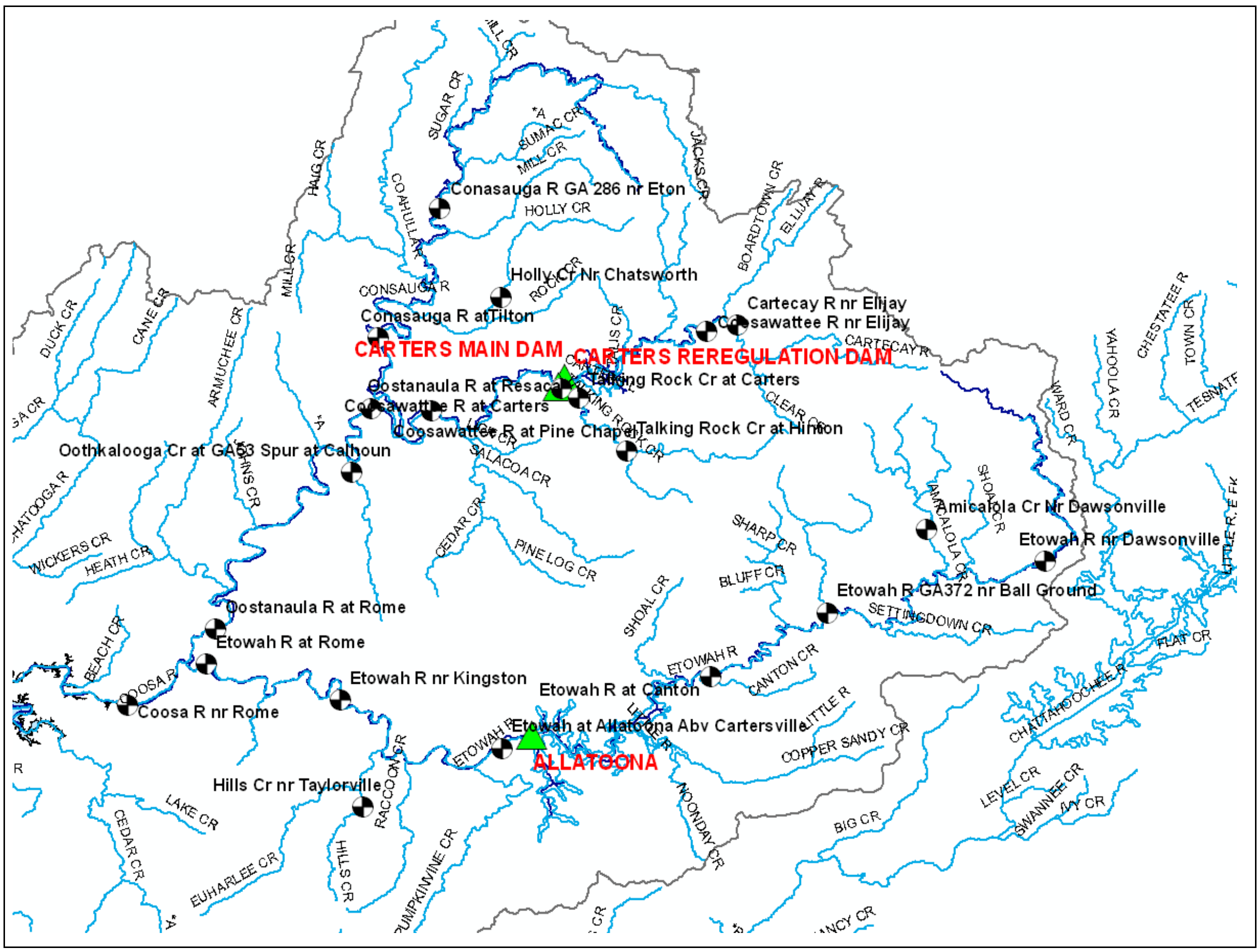

Figure O-A.01 Drainage Basin above Rome, GA.

Table O-A-01. USGS Stream Gages

Gage Name	USGS ID	Latitude	Longitude	Drainage Area (sq miles)
Amicalola Cr Nr Dawsonville	2390000	34.4242	-84.2139	89
Cartecay R Nr Ellijay	2379500	34.6811	-84.4614	134
Conasauga River Ga 286 Near Eton	2384500	34.8278	-84.8492	252
Conasauga River At Tilton	2387000	34.6653	-84.9294	687
Coosa R Nr Rome	2397000	34.2014	-85.2569	4040
Coosawattee River Near Carters	2381500	34.6125	-84.6708	374
Coosawattee River At Carters	2382500	34.6019	-84.6911	521
Coosawattee River Near Ellijay	2380500	34.6733	-84.5008	236
Coosawattee River Nr Pine Chapel	2383500	34.5728	-84.86	831
Etowah R At Allatoon Abv Cartersville	2394000	34.1475	-84.7683	1119
Etowah R At Canton	2392000	34.2386	-84.4953	613
Etowah R Dawsonville (near)	2389000	34.3836	-84.0597	107
Etowah R Ga 1 Loop Nr Rome	2395980	34.2322	-85.1169	1801
Etowah R Ga 372, nr Ball Ground	2391000	34.3183	-84.3442	477
Etowah R Near Kingston	2395000	34.2081	-84.9789	1634
Etowah R Rome (at)	2396000	34.2539	-85.1539	1819
Hills Creek nr Taylorville	2394950	34.0754	-84.9507	25
Holly Creek Near Chatsworth	2385800	34.7164	-84.7697	64
Oostanaula River At Resaca	2387500	34.5764	-84.9389	1602
Oostanaula River Nr Rome	2388500	34.2978	-85.1422	2115
Oothkalooga C At Ga53Spur At Calhoun	2387600	34.4955	-84.9653	63
Talking Rock Cr Nr Carters	2382300	34.5889	-84.6681	142
Talking Rock Cr Nr Hinton,	2382200	34.5228	-84.6053	119

Table O-A-02. Reservoirs

Reservoir Name	Description	Alias	Completion Date	Lat.	Long.	Drainage Area (sq miles)
Allatoona	USACE	Allatoona Lake	1949	34.1633	-84.72833	1117
Carters	USACE	Carters Lake	1977	34.6133	-84.685	373
Carters Reregulation Dam	CE	Carters Reregulation Pool	1977	34.6033	-84.69333	520

An effort was made to remove the influence of reservoirs when developing the instantaneous peak flow vs. daily average flow relationships. Therefore, only stream flow records prior to 1947 (two years prior to the Allatoona Dam completion date) were included in the analysis of the Etowah downstream of Allatoona Dam. On the Coosawattee and Oostanaula, only records prior to 1975 (two years prior to the completion date for Carters Dam) were considered for those gages downstream of Carters Dam. On the Coosa, only records prior to 1947 were used.

These instantaneous peak flow vs. daily average flow relationships were developed by comparing the annual peak discharge and average daily discharge on the day of the peak. The data is available at the gages listed from the USGS.

The relationships were plotted for each of the Oostanaula, Coosawattee, and Etowah basins separately to show the variance with drainage area.

The instantaneous peak flow vs. daily average flow relationship Oostanaula River, shown in Figure O-A.02, shows little difference in the instantaneous peak and corresponding daily average flow from the upper end at Resaca to the lower end at Rome. This is a result of the large drainage area upstream of the Oostanaula at Rome gage, 2115 square miles, and possibly the impact of the backwater from the Etowah River, which meets the Oostanaula at Rome. In addition, the instantaneous peak and corresponding daily average flow at the Coosa at Rome gage is shown for comparison. Figure O-A.03 shows the variance on the Coosawattee River with drainage basin area. This basin has a smaller drainage basin and the variances are greater.

Figure O-A.04 shows the instantaneous peak flow vs. daily average flow relationships for Etowah River gages as well as for the Coosa at Rome gage. The changing slopes of the lines plotted for the Etowah demonstrate the expected variance and trend (toward a 1:1 slope) in the relationships as the basin area increases.

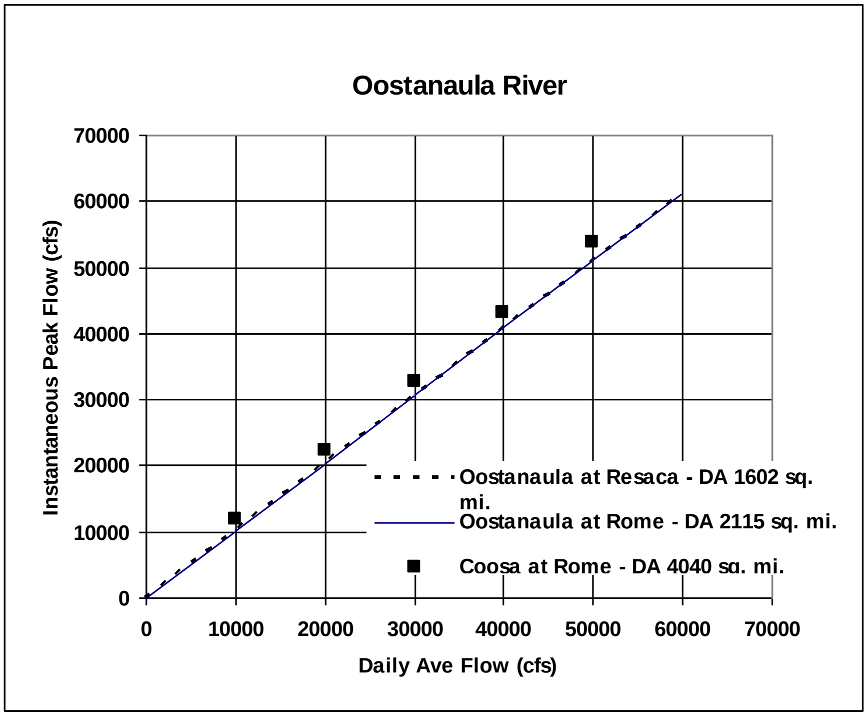

Figure O-A.02 Instantaneous Peak Flow vs. Daily Average Flow Relationship on the Oostanaula River and the Coosa at Rome

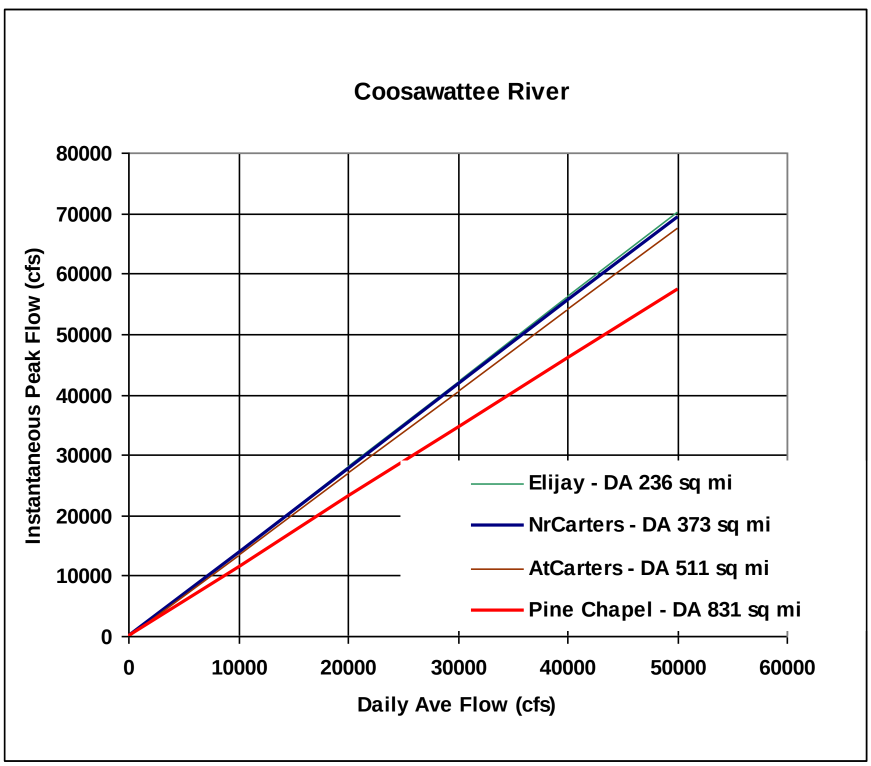

Figure O-A.03 Instantaneous Peak Flow vs. Daily Average Flow Relationship on the Coosawattee River

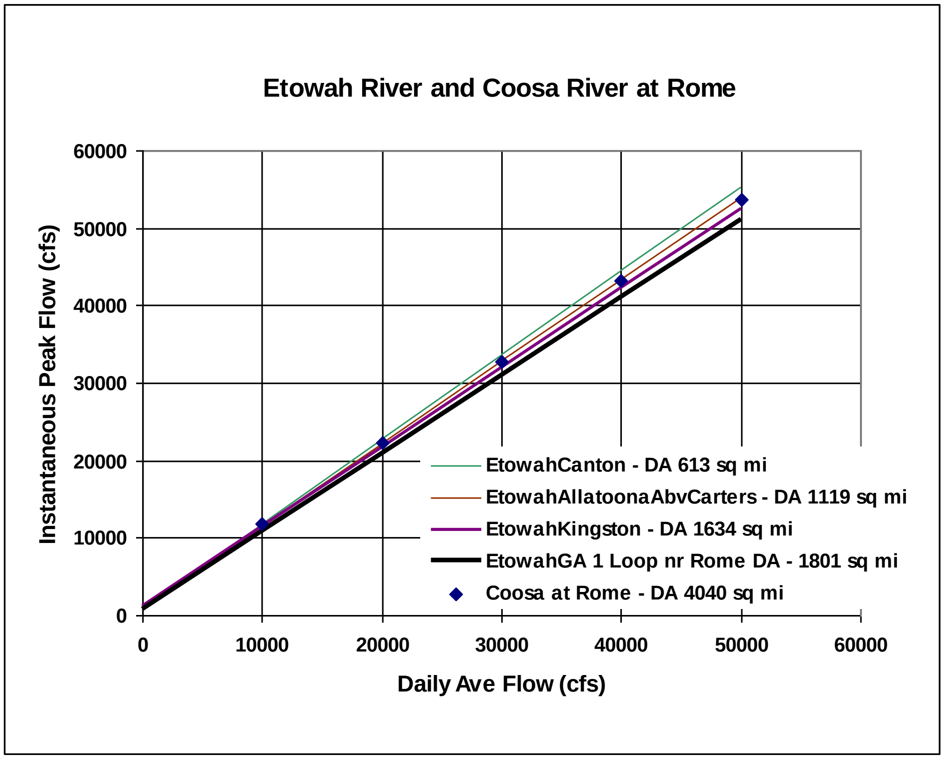

Figure O-A.04 Instantaneous Peak Flow vs. Daily Average Flow Relationship for Various Stream Gages on the Etowah River and the Coosa River at Rome

Figures A - 5 through A - 27 show the instantaneous peak vs. daily average flow relationship for each of the USGS gages listed. The data used to develop these figures and relationships is shown in Tables A - 3 through A - 25.

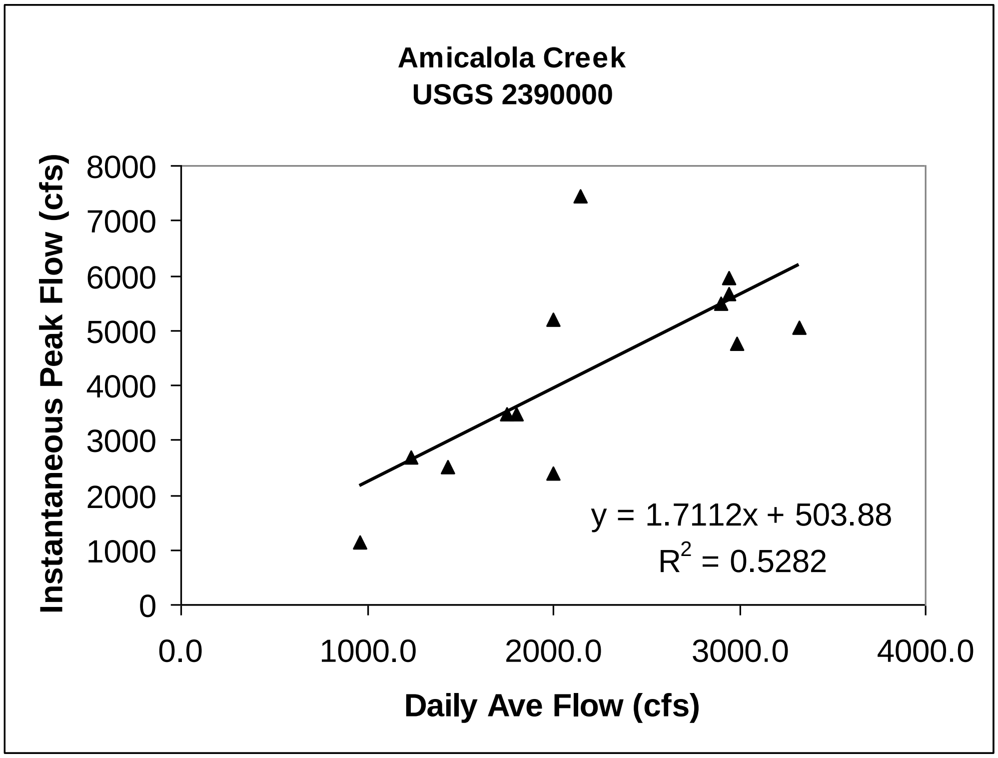

Figure O-A.05 Instantaneous Peak Flow vs. Daily Average Flow Relationship at Amicalola nr Dawsonville

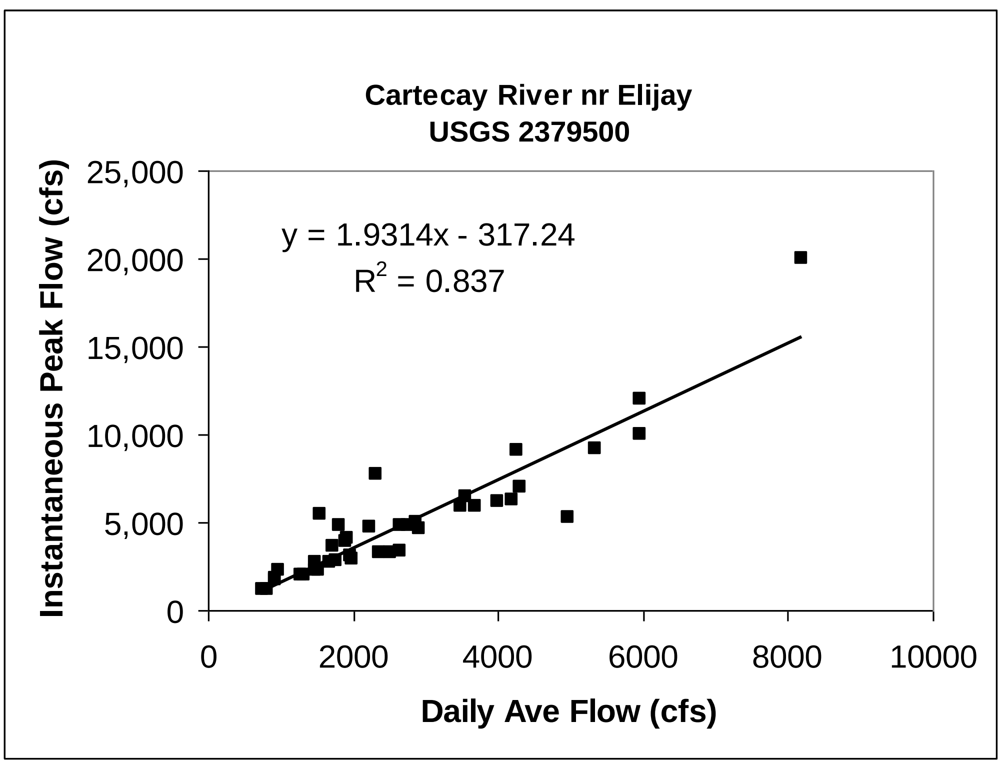

Figure O-A.06 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Cartecay gage nr Elijay

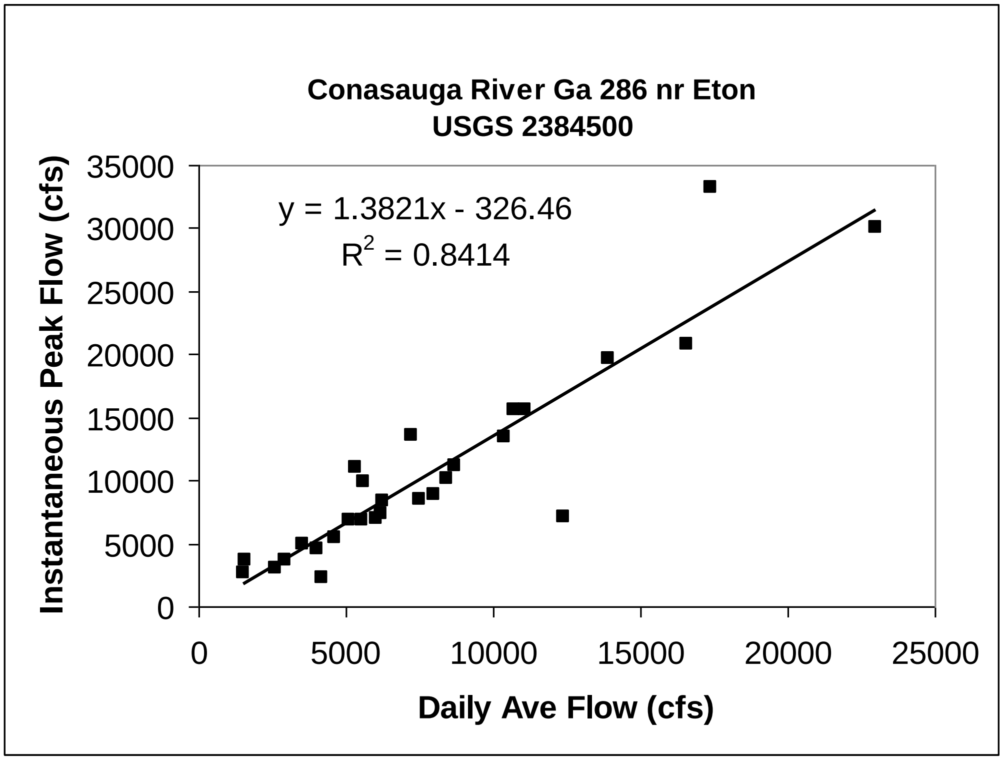

Figure O-A.07 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Conausauga R nr Eton Gage

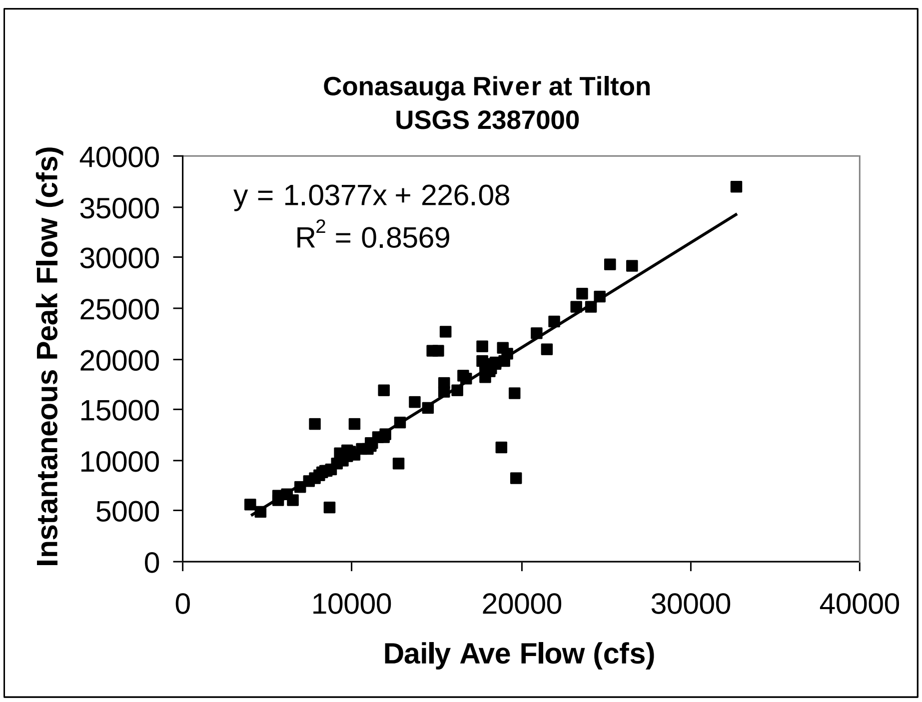

Figure O-A.08 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Canausauga R nr Tilton Gage

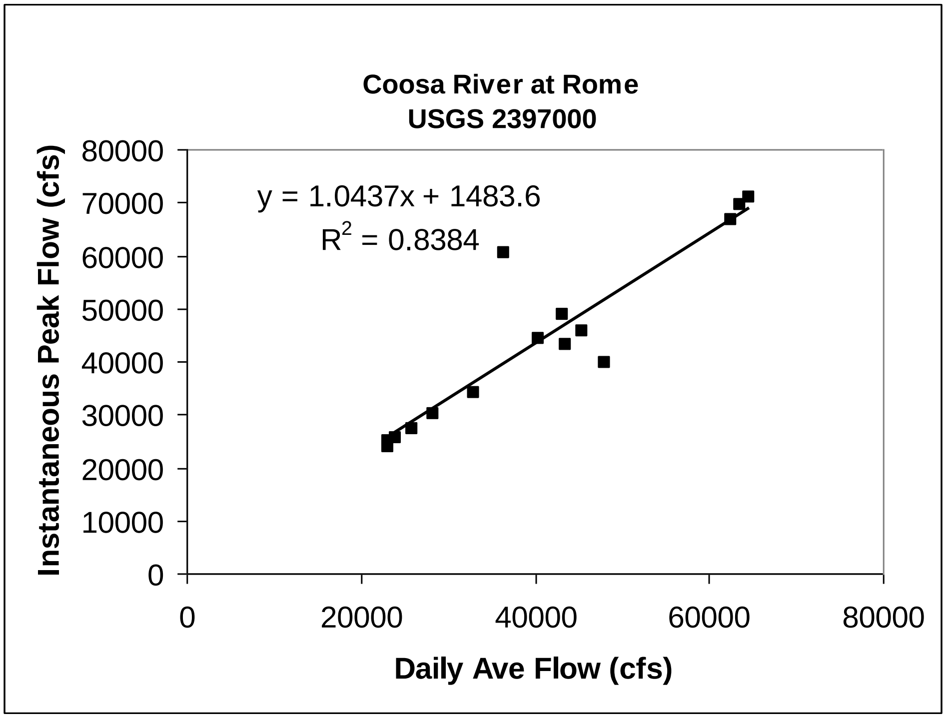

Figure O-A.09 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosa R nr Rome Gage

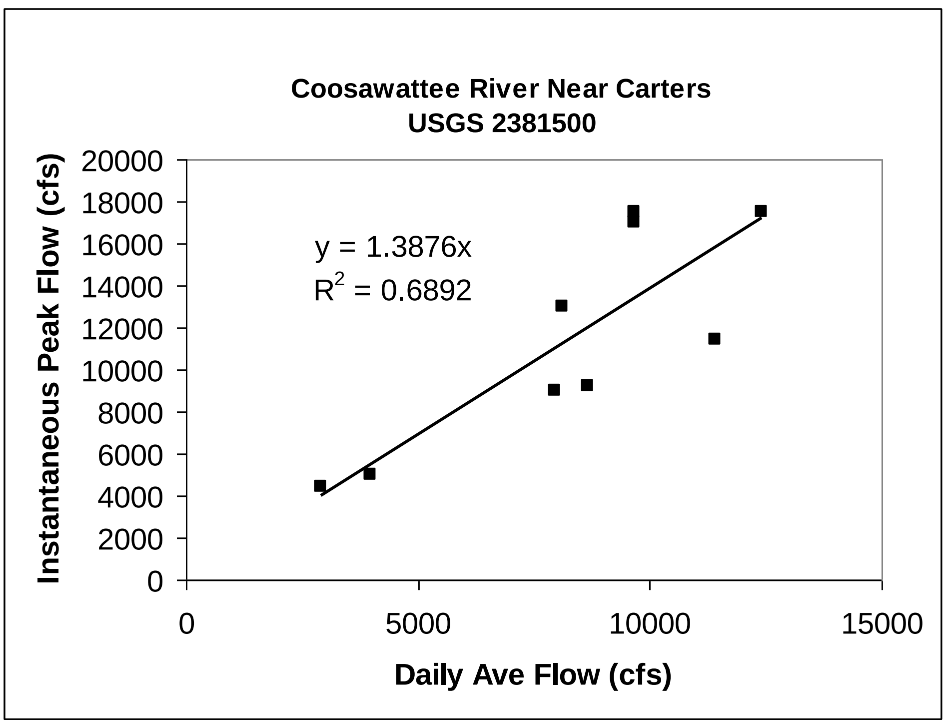

Figure O-A.10 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee R nr Carters Gage

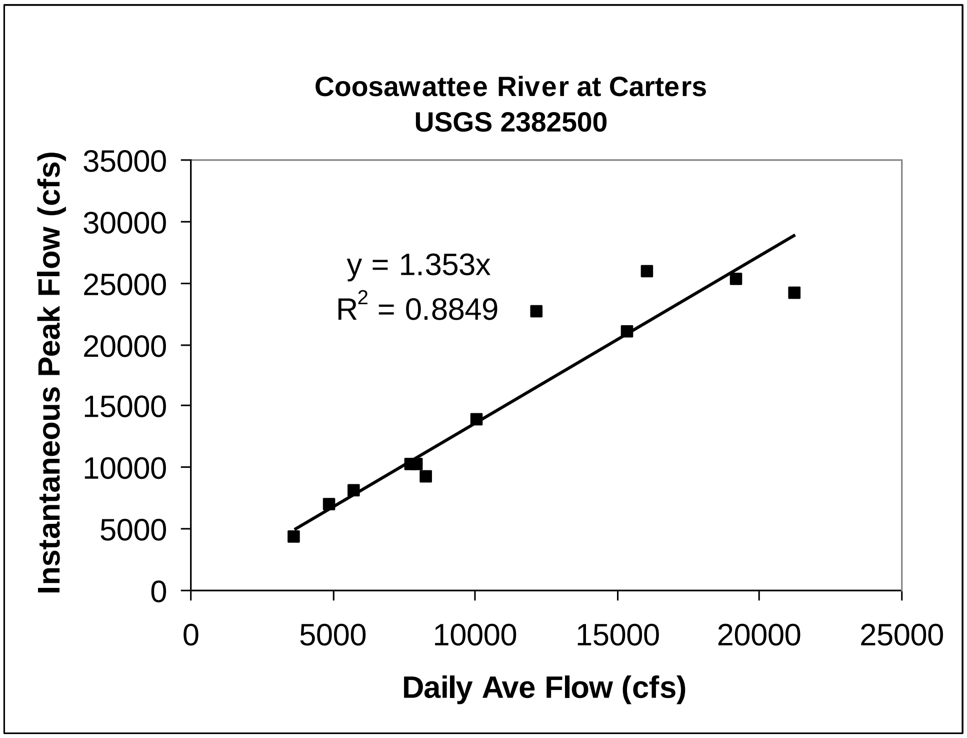

Figure O-A.11 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee R at Carters Gage

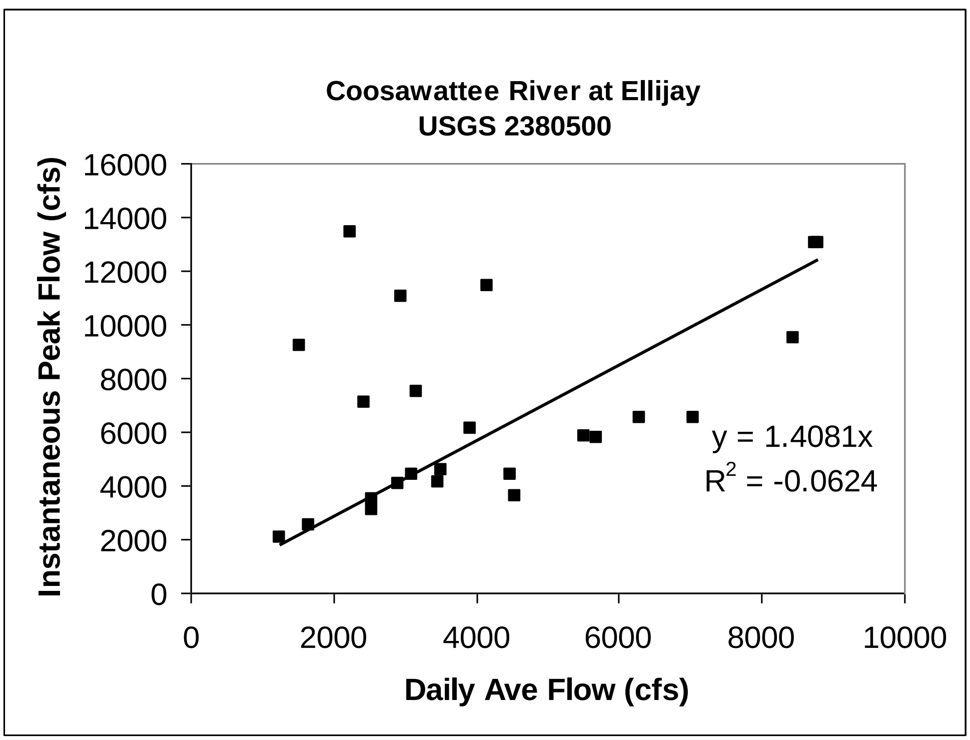

Figure O-A.12 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee R at Ellijay Gage

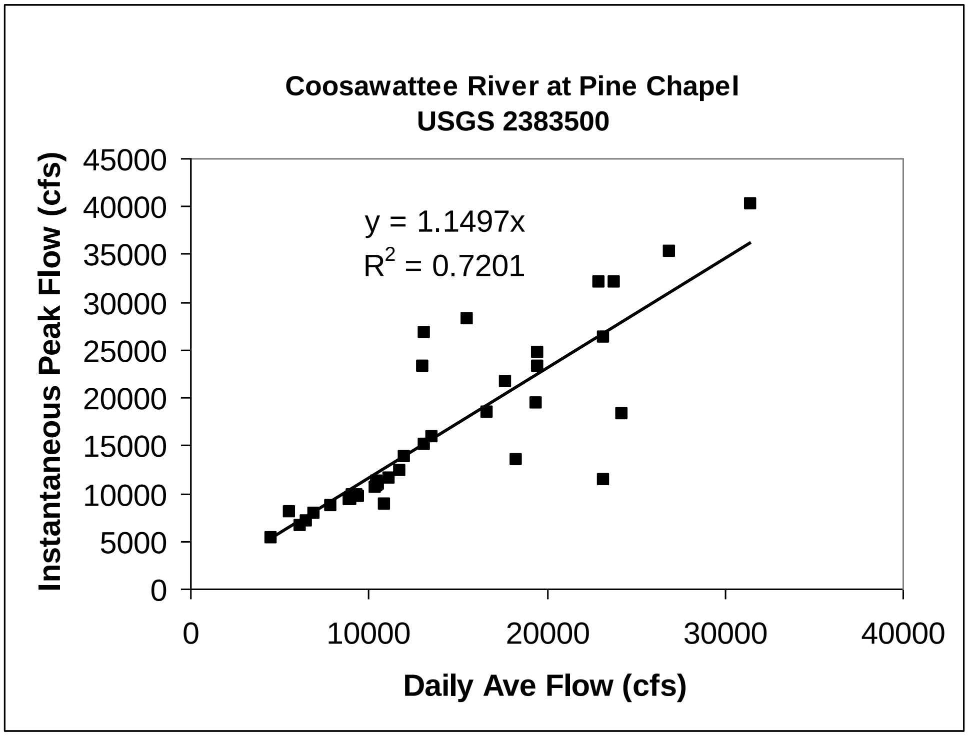

Figure O-A.13 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee R nr Pine Chapel Gage

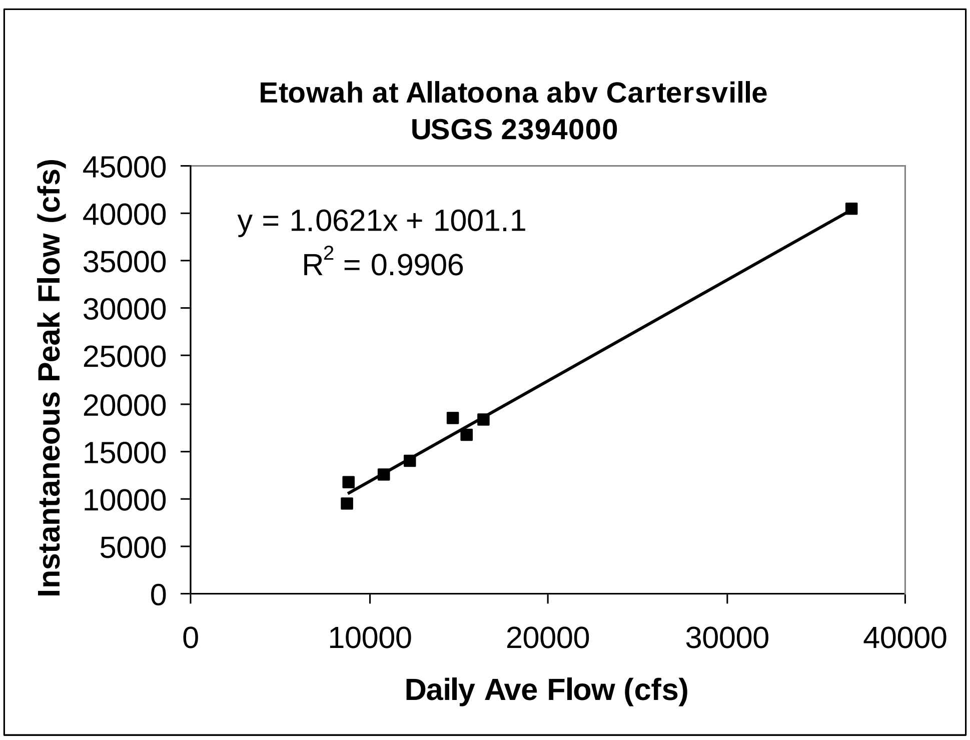

Figure O-A.14 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah at Allatoona above Cartersville Gage

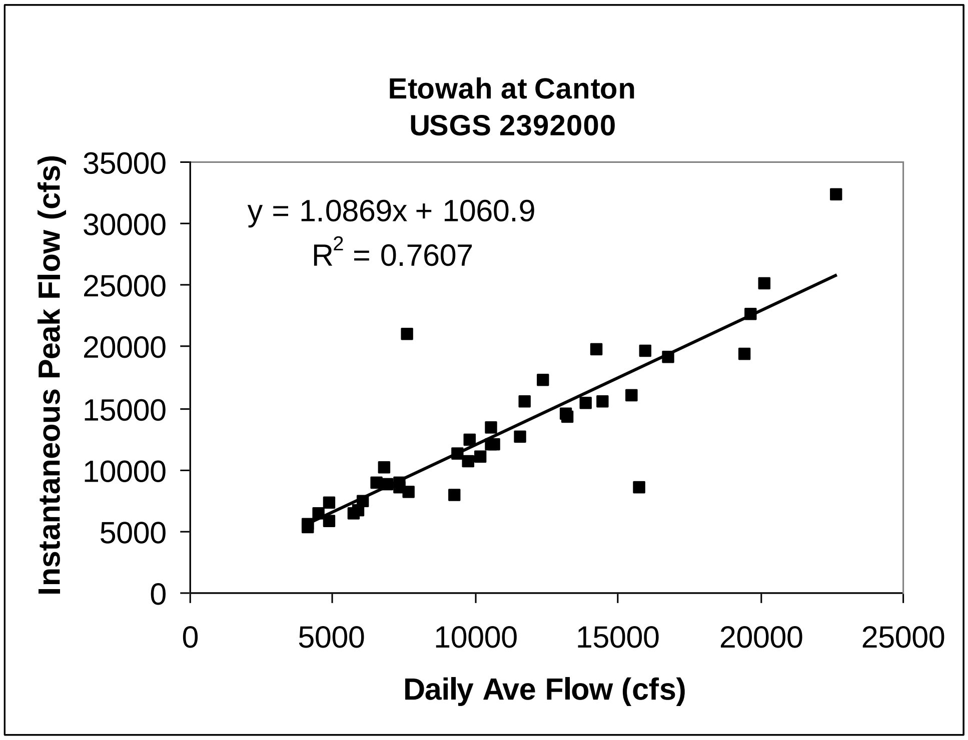

Figure O-A.15 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at Canton Gage

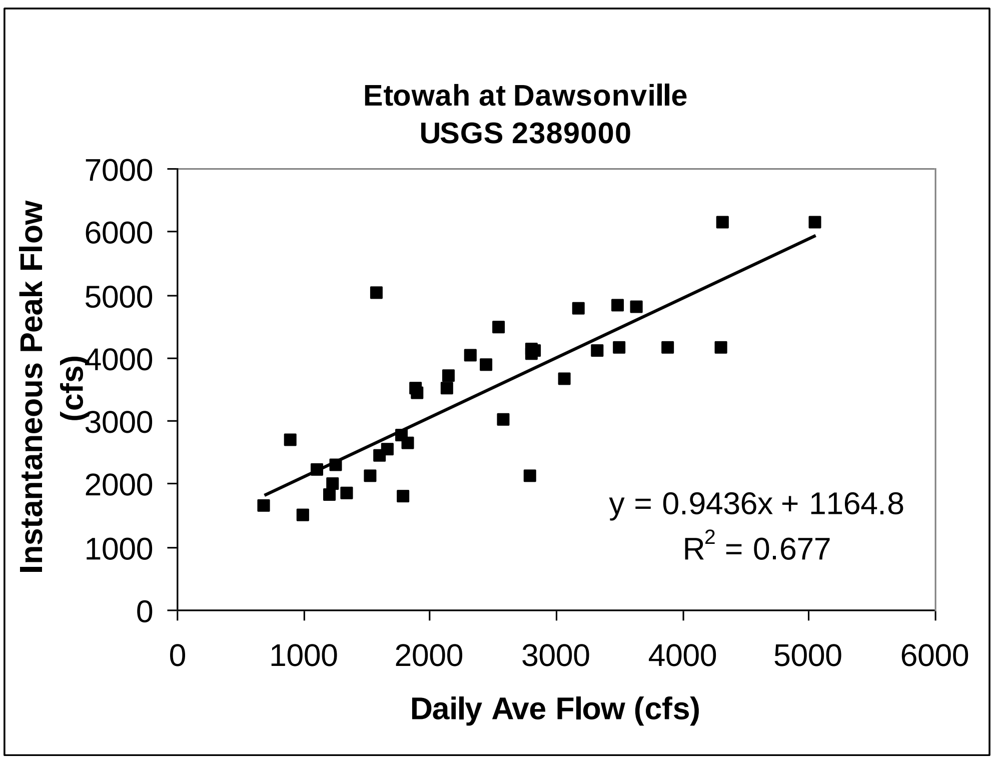

Figure O-A.16 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R nr Dawsonville Gage

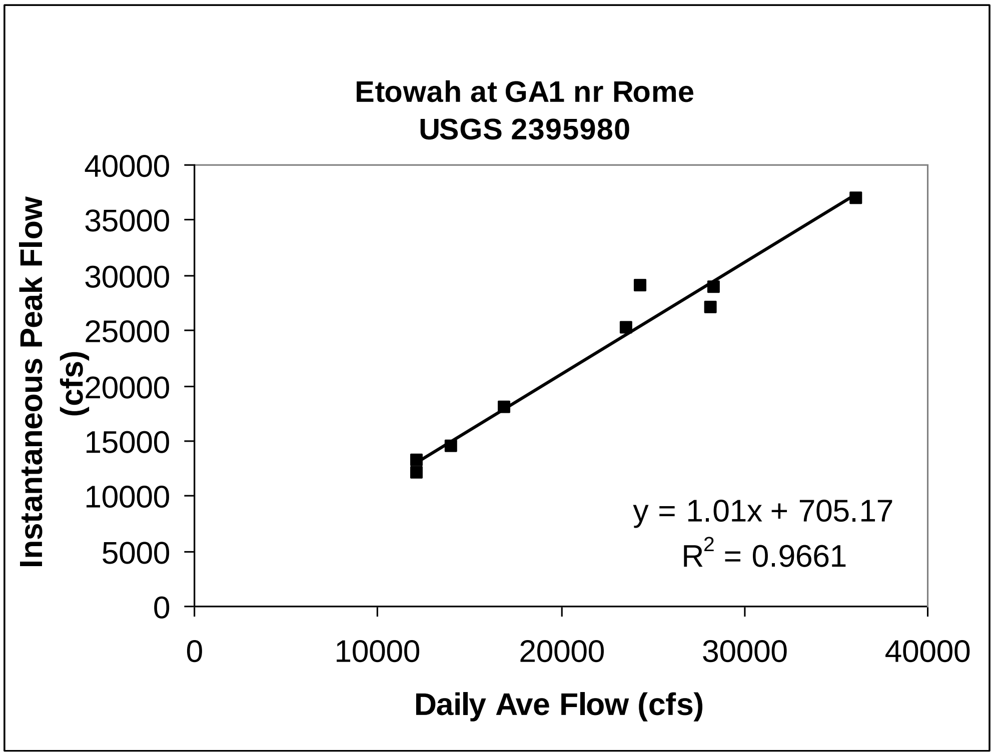

Figure O-A.17 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at GA 1 nr Rome Gage

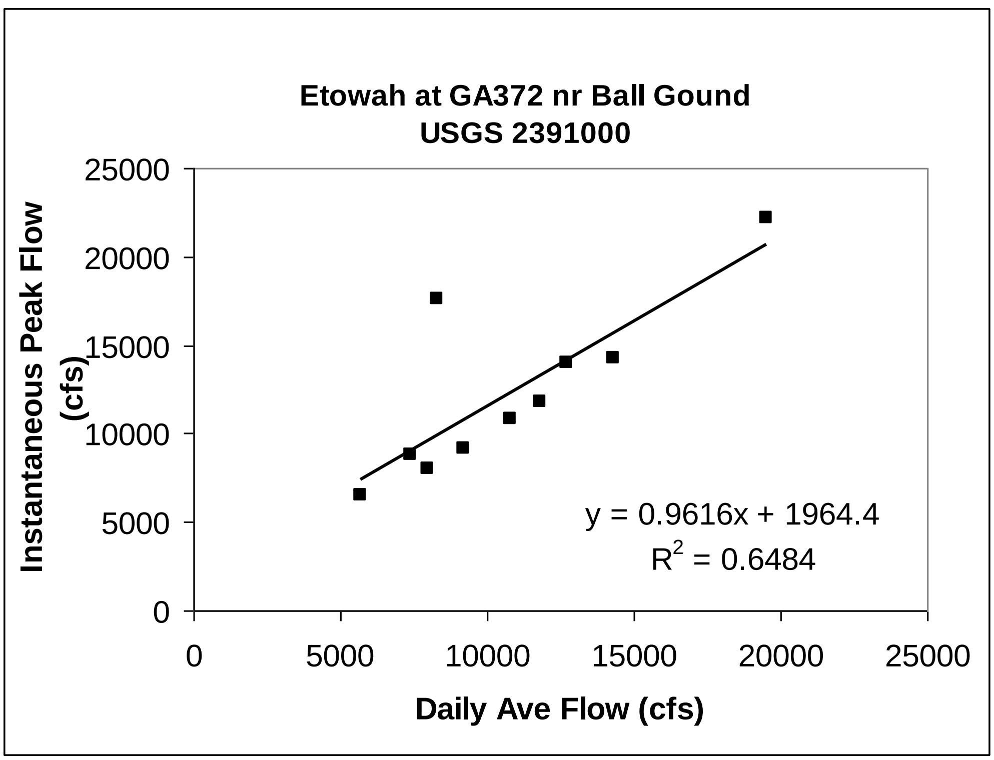

Figure O-A.18 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at GA 372 nr Ball Ground

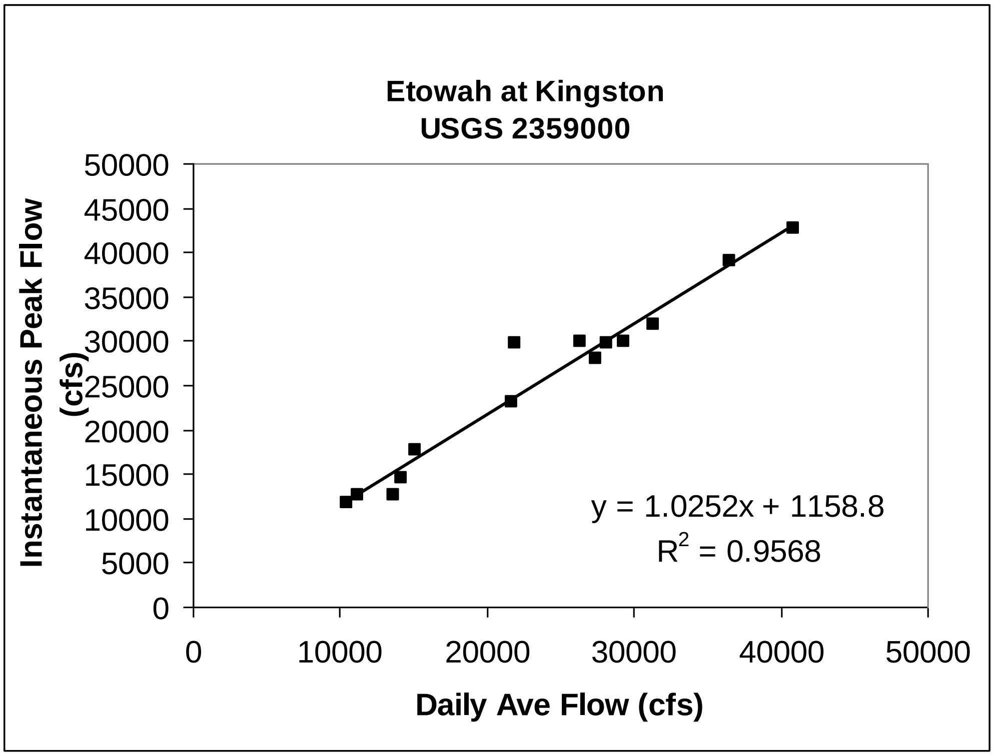

Figure O-A.19 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at Kingston gage.

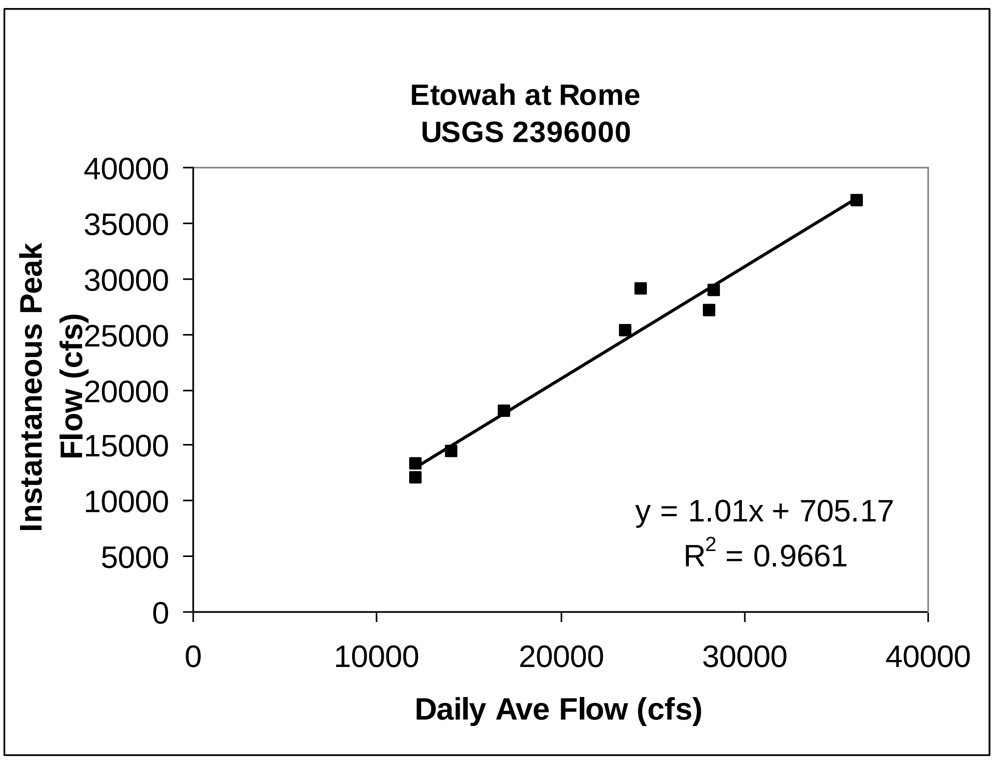

Figure O-A.20 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at Rome gage

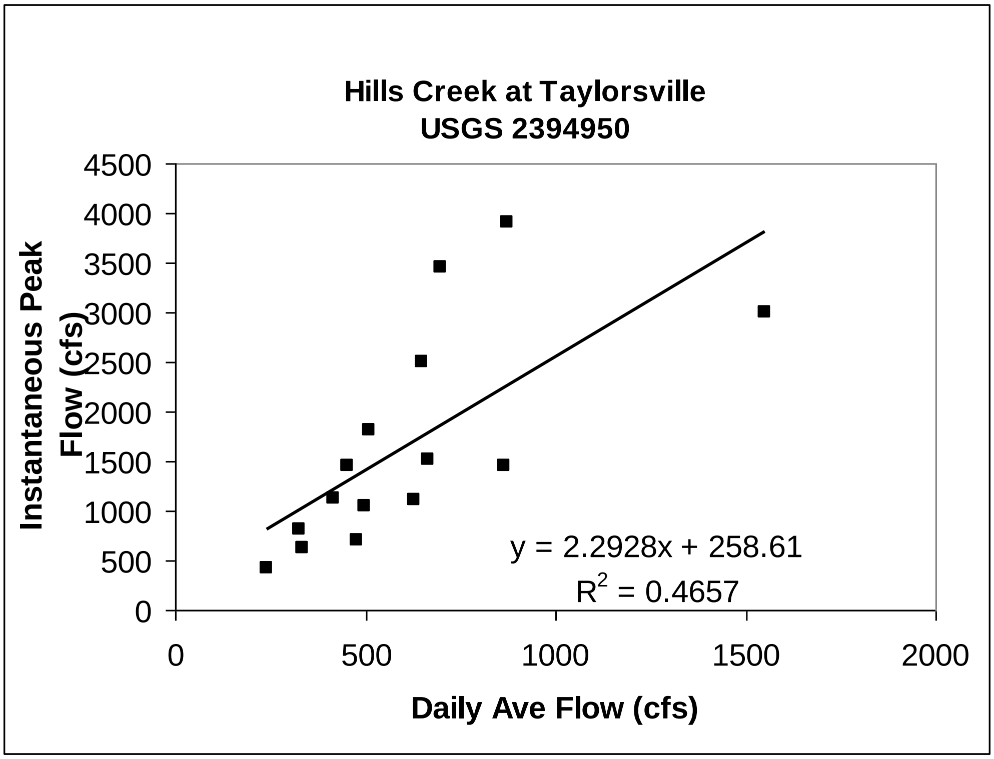

Figure O-A.21 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Hills Cr at Taylorsville gage

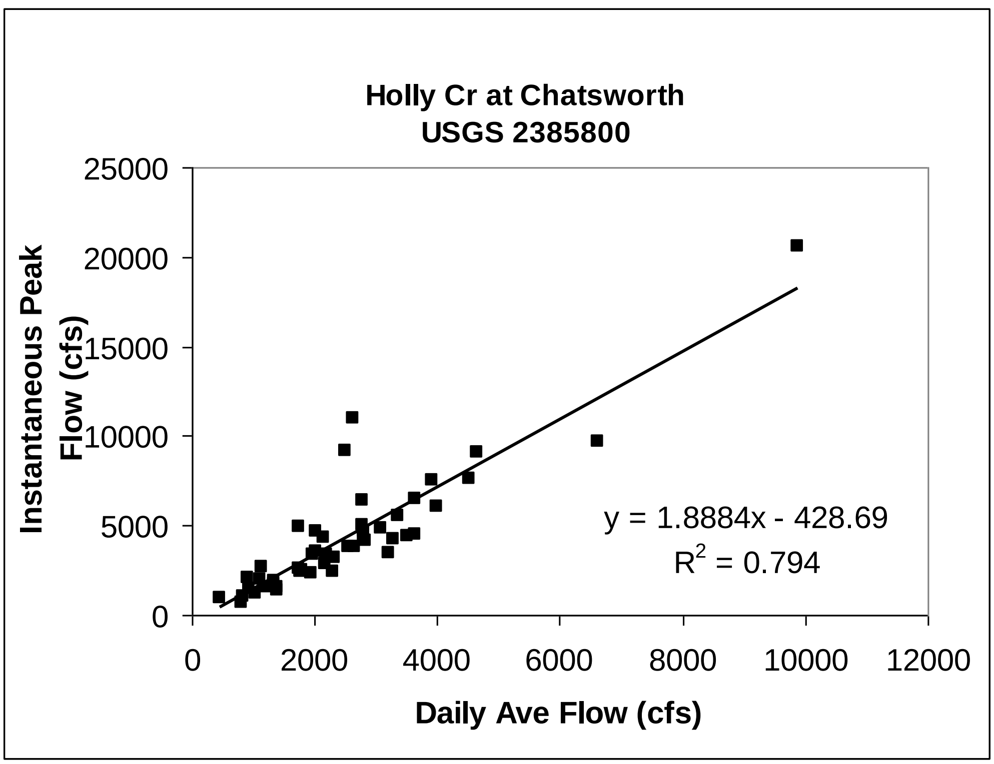

Figure O-A.22 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Holly Cr at Chatsworth gage

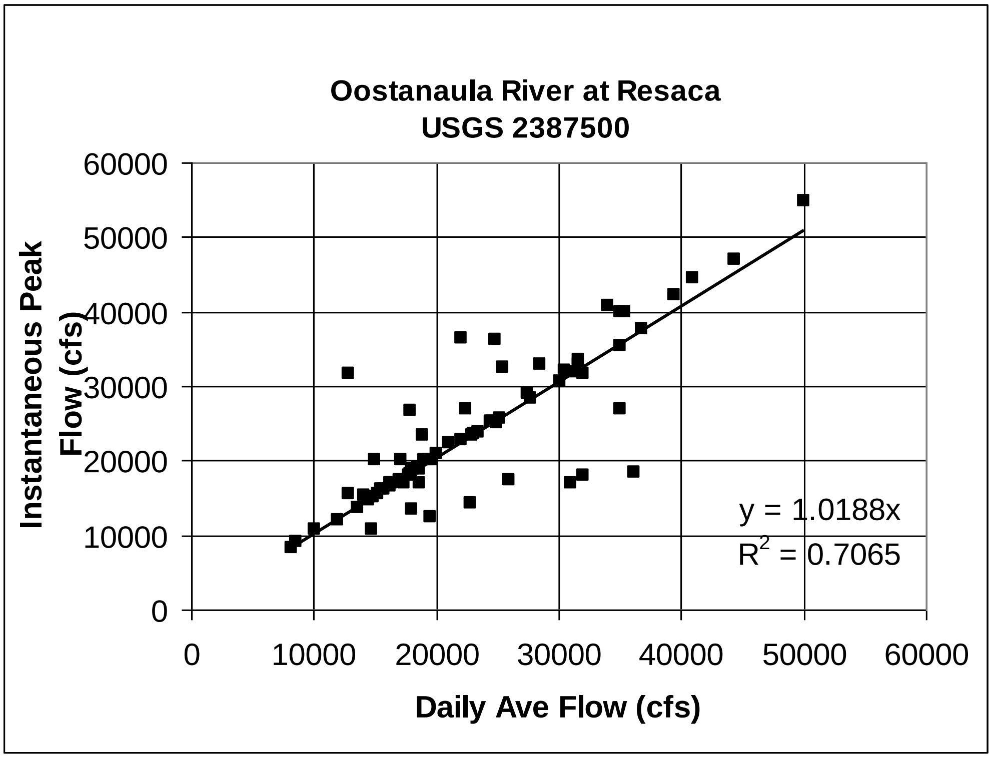

Figure O-A.23 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oostanaula River at Resaca gage

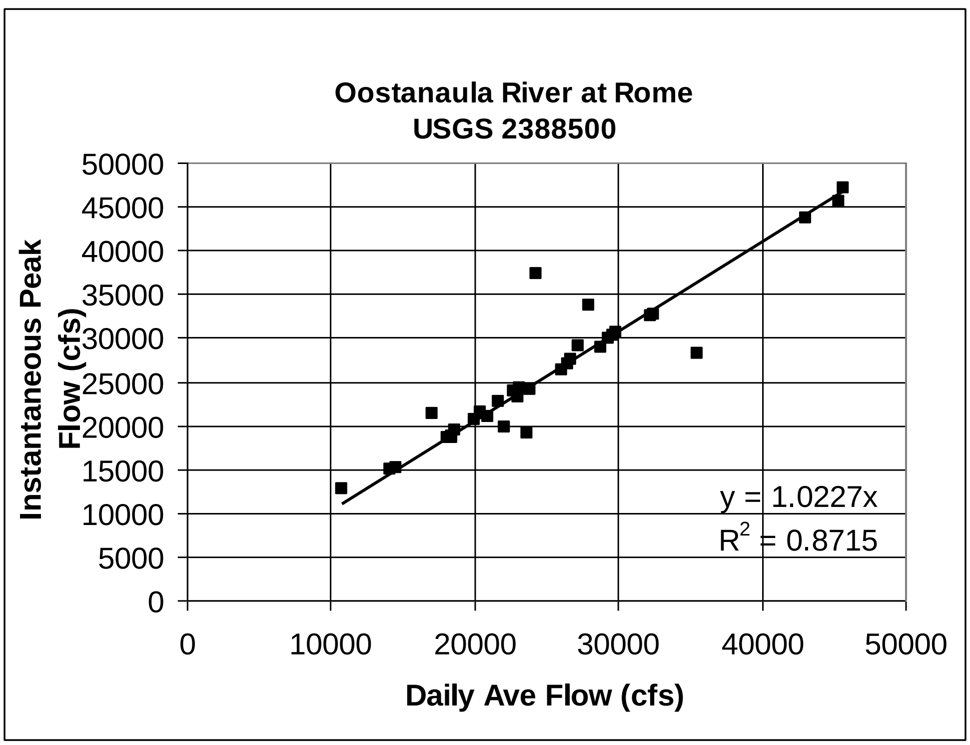

Figure O-A.24 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oostanaula River nr Rome gage

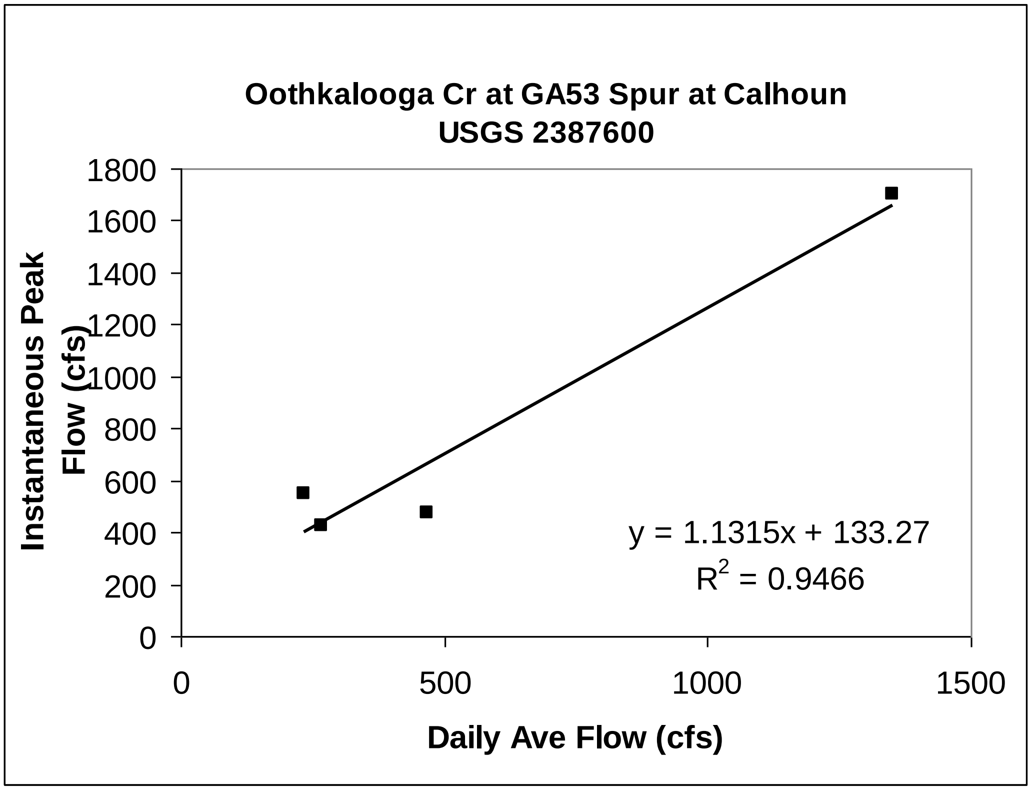

Figure O-A.25 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oothkalooga Cr at Calhoun gage

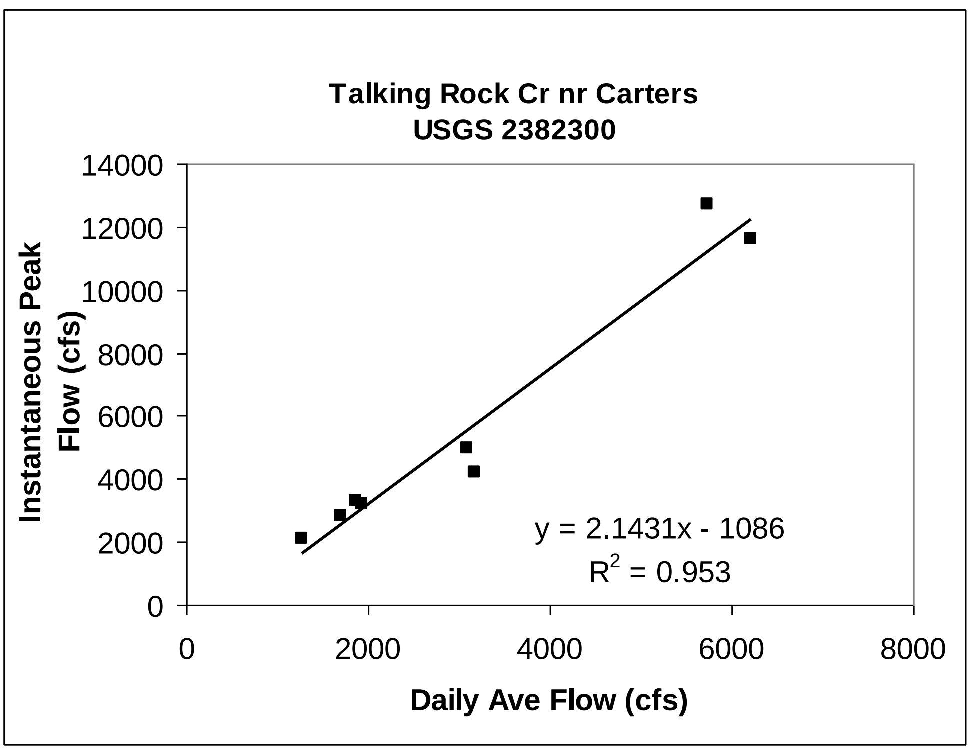

Figure O-A.26 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Talking Rock Cr nr Carters gage

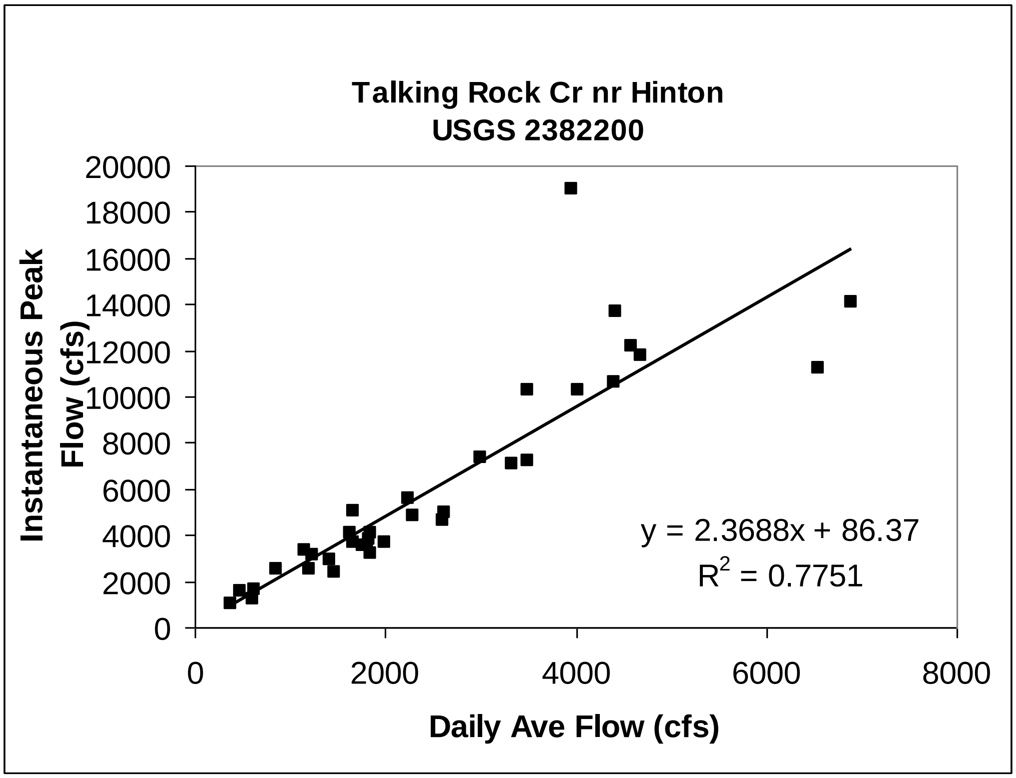

Figure O-A.27 Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Talking Rock Cr nr Hinton gage

Table O-A-03. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Amicalola Gage (2390000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
14Aug1940 0000	1430	2500
06Jul1941 0000	2000	5200
18Feb1942 0000	2150	7450
30Dec1942 0000	1240	2680
20Mar1944 0000	1750	3460
14Feb1945 0000	965	1130
11Feb1946 0000	3320	5050
21Jan1947 0000	2990	4770
05Aug1948 0000	2940	5650
29Nov1948 0000	2900	5500
14Mar1950 0000	1800	3460
30Mar1951 0000	2000	2380
12Mar1952 0000	2940	5960

Table O-A-04. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Cartecay nr Elijay Gage (2379500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
08 Apr 38, 24:00	8190	20,000
15 Feb 39, 24:00	1480	2,280
13 Aug 40, 24:00	1290	1,980
05 Jul 41, 24:00	923	1,700
17 Feb 42, 24:00	2660	3,360
29 Dec 42, 24:00	1730	3,620
27 Feb 44, 24:00	1960	3,120
17 Feb 45, 24:00	814	1,150
10 Feb 46, 24:00	4300	6,960
20 Jan 47, 24:00	3680	5,940
12 Feb 48, 24:00	2520	3,240
28 Nov 48, 24:00	1800	4,860
13 Mar 50, 24:00	4200	6,260
29 Mar 51, 24:00	5970	12,000
11 Mar 52, 24:00	2770	4,860
21 Feb 53, 24:00	1990	2,940
16 Jan 54, 24:00	5950	10,000
22 Mar 55, 24:00	2640	4,860
15 Apr 56, 24:00	1900	3,880
04 Apr 57, 24:00	3480	5,940
20 Dec 57, 24:00	964	2,280
21 Jan 59, 24:00	923	1,780
03 Mar 60, 24:00	741	1,140
25 Feb 61, 24:00	4960	5,300
12 Dec 61, 24:00	2310	7,760
30 Apr 63, 24:00	3550	6,440
26 Mar 64, 24:00	4000	6,160
04 Oct 64, 24:00	1540	5,420
04 Mar 66, 24:00	2880	5,010
23 Aug 67, 24:00	1930	4,090
05 Apr 68, 24:00	1530	2,230
02 Feb 69, 24:00	2360	3,240
04 Jun 70, 24:00	1480	2,730
24 Jan 71, 24:00	1320	1,980
10 Jan 72, 24:00	1770	2,790
28 May 73, 24:00	4270	9,100
13 Apr 74, 24:00	2230	4,720
25 Jan 75, 24:00	1670	2,740
15 May 76, 24:00	2910	4,640
30 Mar 77, 24:00	5340	9,190

Table O-A-05. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Conasauga nr Eton Gage 2384500).

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
12Feb1981 0000	1570.0	3680.0
05Jan1982 0000	8720.0	11200.0
03Dec1982 0000	5610.0	9910.0
05May1984 0000	8010.0	8880.0
03Feb1985 0000	7520.0	8510.0
20Feb1986 0000	2590.0	3030.0
21Jan1987 0000	5520.0	6850.0
22Jan1988 0000	3530.0	4940.0
02Mar1989 0000	12400.0	7140.0
17Feb1990 0000	17400.0	33200.0
25Dec1990 0000	7250.0	13600.0
04Dec1991 0000	5130.0	6790.0
25Mar1993 0000	4610.0	5490.0
29Mar1994 0000	23000.0	30000.0
18Feb1995 0000	16600.0	20800.0
28Jan1996 0000	11100.0	15600.0
04May1997 0600	6170.0	7370.0
20Apr1998 0600	10400.0	13400.0
07May1999 0400	6010.0	6990.0
04Apr2000 2030	8440.0	10100.0
21Mar2001 1200	4010.0	4600.0
25Jan2002 2315	6260.0	8370.0
08May2003 0030	13900.0	19700.0
17Sep2004 2245	10700.0	15600.0
25Nov2004 0815	5300.0	11000.0
18Jan2006 2215	2930.0	3730.0
16Nov2006 1815	1500.0	2610.0
07Feb2008 0600	4190.0	2340.0

Table O-A-06. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Conasauga nr Tilton Gage (2387000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
11Apr1938 0000	19300.0	20300.0
18Feb1939 0000	11200.0	11300.0
17Mar1940 0000	5770.0	5880.0
09Jul1941 0000	4700.0	4700.0
20Feb1942 0000	19800.0	8090.0
01Jan1943 0000	15200.0	20700.0
31Mar1944 0000	16800.0	17900.0
21Feb1945 0000	9950.0	10700.0
13Feb1946 0000	21000.0	22400.0
22Jan1947 0000	24700.0	26000.0
15Feb1948 0000	21600.0	20800.0
01Dec1948 0000	15600.0	22500.0
16Mar1950 0000	18000.0	19300.0
31Mar1951 0000	26600.0	29000.0
14Mar1952 0000	11000.0	11000.0
25Feb1953 0000	9770.0	10800.0
19Jan1954 0000	18000.0	19100.0
10Feb1955 0000	8860.0	8970.0
07Feb1956 0000	11200.0	11600.0
04Feb1957 0000	23300.0	25000.0
21Nov1957 0000	15500.0	17500.0
23Apr1959 0000	9180.0	9530.0
06Mar1960 0000	11600.0	12100.0
26Feb1961 0000	19700.0	16500.0
21Dec1961 0000	14800.0	20700.0
16Mar1963 0000	15500.0	16600.0
18Mar1964 0000	17800.0	21100.0
29Mar1965 0000	18600.0	19500.0
07Mar1966 0000	12000.0	12100.0
11Jul1967 0000	12800.0	9530.0
25Dec1967 0000	7880.0	13400.0
05Feb1969 0000	16700.0	18200.0
05Apr1970 0000	8190.0	8330.0
09Feb1971 0000	8490.0	8820.0
08Jan1972 0000	7910.0	8070.0
19Mar1973 0000	23700.0	26300.0
01Dec1973 0000	9380.0	10500.0
02Apr1975 0000	16300.0	16800.0
08Jul1976 0000	10200.0	10400.0
07Apr1977 0000	17800.0	19700.0
10Nov1977 0000	10000.0	10700.0
07Mar1979 0000	18300.0	18900.0

… Continued …

Table O-A-07. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Conasauga nr Tilton Gage (2387000) - *Continued*

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
	... Continuation ...	
24Mar1980 0000	22000.0	23500.0
14Feb1981 0000	5700.0	6300.0
07Jan1982 0000	18200.0	18700.0
05Dec1982 0000	10200.0	13500.0
07May1984 0000	12900.0	13600.0
05Feb1985 0000	9560.0	9870.0
20Feb1986 0000	6600.0	5960.0
03Mar1987 0000	11300.0	11500.0
23Jan1988 0000	7530.0	7820.0
03Mar1989 0000	18900.0	11100.0
18Feb1990 0000	32800.0	36800.0
26Dec1990 0000	13800.0	15600.0
29Feb1992 0000	8580.0	8850.0
27Mar1993 0000	7020.0	7210.0
30Mar1994 0000	25300.0	29100.0
19Feb1995 0000	19000.0	21000.0
30Jan1996 0000	19100.0	19600.0
05May1997 0900	12100.0	12400.0
22Apr1998 0000	18000.0	18000.0
08May1999 2200	9800.0	10200.0
06Apr2000 0900	14600.0	15000.0
22Mar2001 0630	8330.0	8660.0
27Jan2002 0945	10700.0	11000.0
09May2003 1000	24200.0	25000.0
19Sep2004 1745	18600.0	19300.0
26Nov2004 2000	12000.0	16700.0
19Jan2006 1530	6280.0	6480.0
17Nov2006 1000	4040.0	5520.0
08Mar2008 1515	8790.0	5200.0

Table O-A-08. Instantaneous Peak Flow vs. Daily Average Flow Relationship at Coosa nr Rome Gage (2397000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
18Dec1927 0000	23200.0	23700.0
17Mar1929 0000	43500.0	43000.0
10Mar1930 0000	40500.0	44200.0
18Nov1930 0000	28300.0	30000.0
05Jan1937 0000	36500.0	60500.0
11Apr1938 0000	62600.0	66600.0
02Mar1939 0000	33000.0	34000.0
15Mar1940 0000	24000.0	25500.0
07Jul1941 0000	23200.0	25000.0
23Mar1942 0000	48000.0	39600.0
01Jan1943 0000	43200.0	48800.0
01Apr1944 0000	45400.0	45700.0
15Feb1945 0000	25900.0	27100.0
13Feb1946 0000	63600.0	69500.0
23Jan1947 0000	64600.0	71000.0

Table O-A-09. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee nr Carters Gage (2381500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
19260118	3990	5000
19270410	8670	9200
19280330	7950	9000
19290731	8100	13000
19291115	11400	11400
19310404	2900	4400
19611212	12400	17500
19630306	9680	17500
19640326	9650	17000

Table O-A-10. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee at Carters Gage (2382500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
13Dec1961 0000	19200.0	25200.0
07Mar1963 0000	12200.0	22600.0
27Mar1964 0000	16100.0	25800.0
06Oct1964 0000	21300.0	24100.0
05Mar1966 0000	15400.0	20900.0
25Aug1967 0000	8310.0	9220.0
23Dec1967 0000	7770.0	10100.0
03Feb1969 0000	10100.0	13800.0
06Jun1970 0000	4890.0	6910.0
25Jan1971 0000	5790.0	8030.0
05Jan1972 0000	8000.0	10100.0
26Jan1975 0000	3660.0	4240.0

Table O-A-11. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee R at Ellijay Gage (2380500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
16Feb1939 0000	3520.0	4570.0
14Aug1940 0000	1660.0	2500.0
06Jul1941 0000	1260.0	2040.0
18Feb1942 0000	5690.0	5790.0
30Dec1942 0000	3170.0	7470.0
28Feb1944 0000	3930.0	6090.0
14Feb1945 0000	2550.0	3500.0
11Feb1946 0000	8740.0	13000.0
21Jan1947 0000	8790.0	13000.0
13Feb1948 0000	6300.0	6490.0
29Nov1948 0000	4160.0	11400.0
05Mar1966 0000	1540.0	9210.0
24Aug1967 0000	8440.0	9470.0
23Dec1967 0000	3480.0	4110.0
03Feb1969 0000	5520.0	5810.0
05Jun1970 0000	4550.0	3610.0
25Jan1971 0000	2550.0	3100.0
11Jan1972 0000	4490.0	4410.0
29May1973 0000	2250.0	13400.0
01Jan1974 0000	2440.0	7090.0
26Jan1975 0000	2900.0	4060.0
16May1976 0000	7050.0	6500.0
31Mar1977 0000	2950.0	11000.0
06Nov1977 0000	3100.0	4400.0

Table O-A-12. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Coosawattee R at Pine Chapel Gage (2383500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
17Feb1939 0000	9480.0	9680.0
14Jul1940 0000	6180.0	6560.0
17Jul1941 0000	4600.0	5290.0
19Feb1942 0000	18300.0	13500.0
31Dec1942 0000	13100.0	23300.0
31Mar1944 0000	13600.0	15900.0
15Feb1945 0000	9400.0	9750.0
12Feb1946 0000	23000.0	32000.0
22Jan1947 0000	19400.0	19400.0
14Feb1948 0000	23200.0	11300.0
30Nov1948 0000	13200.0	26700.0
15Mar1950 0000	23200.0	26200.0
31Mar1951 0000	31500.0	40200.0
13Mar1952 0000	11800.0	12300.0
11Jan1953 0000	9060.0	9310.0
18Jan1954 0000	26900.0	35200.0
09Feb1955 0000	12000.0	13800.0
18Apr1956 0000	10500.0	10800.0
07Apr1957 0000	19500.0	24600.0
20Nov1957 0000	5630.0	7980.0
15Feb1959 0000	6530.0	7100.0
05Mar1960 0000	9160.0	9840.0
27Feb1961 0000	24300.0	18200.0
14Dec1961 0000	15600.0	28200.0
08Mar1963 0000	17700.0	21600.0
27Mar1964 0000	23800.0	32000.0
28Mar1965 0000	10400.0	10600.0
06Mar1966 0000	16700.0	18400.0
26Aug1967 0000	10900.0	8820.0
12Jan1968 0000	11200.0	11500.0
04Feb1969 0000	13200.0	15000.0
22Mar1970 0000	7910.0	8680.0
26Jan1971 0000	8910.0	9360.0
13Jan1972 0000	10600.0	10900.0
30May1973 0000	19500.0	23200.0
02Jan1974 0000	10500.0	11200.0
15Mar1975 0000	6970.0	7910.0

Table O-A-13. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at Allatoona abv Cartersville Gage (2394000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
01Mar1939 0000	8910.0	11600.0
15Aug1940 0000	12400.0	13800.0
07Jul1941 0000	10900.0	12400.0
22Mar1942 0000	16500.0	18200.0
30Dec1942 0000	14800.0	18400.0
30Mar1944 0000	15500.0	16600.0
26Apr1945 0000	8820.0	9300.0
09Jan1946 0000	37100.0	40400.0

Table O-A-14. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R nr Canton Gage (2392000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
04Jan1937 0000	13900.0	15300.0
09Apr1938 0000	14300.0	19700.0
01Mar1939 0000	4570.0	6360.0
14Aug1940 0000	7400.0	8900.0
06Jul1941 0000	6580.0	8820.0
18Feb1942 0000	10600.0	13300.0
31Dec1942 0000	6840.0	10100.0
21Mar1944 0000	9790.0	10600.0
26Apr1945 0000	4160.0	5180.0
08Jan1946 0000	22700.0	32300.0
22Jan1947 0000	13200.0	14500.0
06Aug1948 0000	15800.0	8500.0
30Nov1948 0000	12400.0	17200.0
15Mar1950 0000	7370.0	8500.0
31Mar1951 0000	9330.0	7790.0
24Mar1952 0000	16000.0	19500.0
11Jan1953 0000	7720.0	8140.0
18Jan1954 0000	14500.0	15500.0
08Feb1955 0000	11600.0	12600.0
17Apr1956 0000	6090.0	7300.0
06Apr1957 0000	11800.0	15500.0
22Dec1957 0000	4180.0	5440.0
15Feb1959 0000	4940.0	7230.0
05Apr1960 0000	5760.0	6320.0
27Feb1961 0000	19500.0	19300.0
14Dec1961 0000	7650.0	20900.0
01May1963 0000	19700.0	22600.0
27Mar1964 0000	20200.0	25000.0
26Mar1965 0000	6970.0	8740.0
05Mar1966 0000	16800.0	19000.0
26Aug1967 0000	15500.0	15900.0
12Jan1968 0000	10200.0	11000.0
24Aug1969 0000	10600.0	11900.0
21Mar1970 0000	5940.0	6590.0
25Jul1971 0000	4910.0	5790.0
12Jan1972 0000	13300.0	14200.0
17Dec1972 0000	9420.0	11200.0
06Apr1974 0000	9870.0	12300.0
15Mar1975 0000	10700.0	11900.0

Table O-A-15. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R nr Dawsonville Gage (2389000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
14Aug1940 0000	1350.0	1840.0
06Jul1941 0000	1110.0	2200.0
18Feb1942 0000	2840.0	4100.0
30Dec1942 0000	1610.0	2430.0
21Mar1944 0000	1840.0	2640.0
17Sep1945 0000	1210.0	1820.0
08Jan1946 0000	3640.0	4780.0
21Jan1947 0000	3070.0	3660.0
05Aug1948 0000	2810.0	4050.0
07Jan1949 0000	2450.0	3870.0
14Mar1950 0000	1790.0	2760.0
30Mar1951 0000	2800.0	2120.0
12Mar1952 0000	3340.0	4100.0
11Jan1953 0000	1540.0	2120.0
17Jan1954 0000	3510.0	4150.0
08Feb1955 0000	2330.0	4010.0
17Apr1956 0000	1670.0	2520.0
06Apr1957 0000	2590.0	3000.0
21Dec1957 0000	692.0	1630.0
23Jan1959 0000	1270.0	2290.0
29Sep1960 0000	1240.0	1980.0
26Feb1961 0000	4320.0	4150.0
13Dec1961 0000	1590.0	5010.0
13Mar1963 0000	3500.0	4810.0
27Mar1964 0000	3890.0	4150.0
06Oct1964 0000	904.0	2670.0
05Mar1966 0000	4330.0	6140.0
25Aug1967 0000	5060.0	6140.0
13Mar1968 0000	2550.0	4470.0
23Aug1969 0000	1900.0	3500.0
01Jan1970 0000	1000.0	1490.0
23Jul1971 0000	1800.0	1790.0
15May1972 0000	2150.0	3500.0
29May1973 0000	3190.0	4770.0
05Apr1974 0000	1910.0	3420.0
15Mar1975 0000	2160.0	3710.0
01Apr1976 0000	2820.0	4130.0

Table O-A-16. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at GA1 nr Rome Gage (2396000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
02Mar1939 0000	17000.0	18000.0
15Aug1940 0000	14100.0	14400.0
08Jul1941 0000	12200.0	13200.0
23Mar1942 0000	28200.0	27000.0
31Dec1942 0000	24400.0	29000.0
31Mar1944 0000	23600.0	25200.0
27Apr1945 0000	12200.0	12000.0
10Jan1946 0000	36200.0	36900.0
22Jan1947 0000	28400.0	28900.0

Table O-A-17. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at GA372 nr Ball Ground Gage (2391000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
25Mar1908 0000	10800.0	10800.0
15Mar1909 0000	12700.0	14000.0
22May1910 0000	5680.0	6500.0
06Apr1911 0000	7980.0	7980.0
16Mar1912 0000	14300.0	14300.0
16Mar1913 0000	9180.0	9180.0
27Dec1914 0000	7390.0	8780.0
23Dec1918 0000	19500.0	22200.0
11Dec1919 0000	8300.0	17600.0
10Feb1921 0000	11800.0	11800.0

Table O-A-18. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at the Kingston Gage (2359000)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
03May1929 0000	28200.0	29700.0
08Mar1930 0000	26400.0	29900.0
17Nov1930 0000	13700.0	12600.0
04Jan1937 0000	31400.0	31800.0
10Apr1938 0000	40900.0	42700.0
01Mar1939 0000	15100.0	17600.0
15Aug1940 0000	14200.0	14500.0
08Jul1941 0000	11200.0	12600.0
23Mar1942 0000	27400.0	28000.0
30Dec1942 0000	21900.0	29800.0
31Mar1944 0000	21700.0	23100.0
26Apr1945 0000	10500.0	11700.0
10Jan1946 0000	36500.0	39000.0
22Jan1947 0000	29300.0	29900.0

Table O-A-19. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Etowah R at Rome Gage (2396000)

(this is the same gage as Etowah R at GA1 Loop nr Rome 2395980, above)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
02Mar1939 0000	17000.0	18000.0
15Aug1940 0000	14100.0	14400.0
08Jul1941 0000	12200.0	13200.0
23Mar1942 0000	28200.0	27000.0
31Dec1942 0000	24400.0	29000.0
31Mar1944 0000	23600.0	25200.0
27Apr1945 0000	12200.0	12000.0
10Jan1946 0000	36200.0	36900.0
22Jan1947 0000	28400.0	28900.0

Table O-A-20. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Hills Cr at Taylorsville Gage (2394950)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
01Feb1960 0000	334.0	624.0
22Feb1961 0000	1550.0	3000.0
13Dec1961 0000	648.0	2500.0
13Mar1963 0000	875.0	3900.0
27Mar1964 0000	864.0	1450.0
13Apr1965 0000	327.0	805.0
05Mar1966 0000	629.0	1110.0
27Apr1967 0000	497.0	1050.0
06Apr1968 0000	476.0	697.0
21Jan1969 0000	239.0	423.0
21Mar1970 0000	512.0	1820.0
24Apr1971 0000	418.0	1130.0
05Jan1972 0000	667.0	1510.0
17Mar1973 0000	452.0	1460.0
05Apr1974 0000	697.0	3460.0

Table O-A-21. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Holly Cr at Chatsworth Gage (2385800)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
24Feb1961 0000	3220.0	3480.0
13Dec1961 0000	1750.0	4920.0
13Mar1963 0000	3080.0	4810.0
16Mar1964 0000	3990.0	6040.0
27Mar1965 0000	2800.0	4700.0
14Feb1966 0000	2640.0	3840.0
28Aug1967 0000	1770.0	2430.0
23Dec1967 0000	1130.0	2700.0
03Feb1969 0000	2170.0	2850.0
01Jan1970 0000	1100.0	2030.0
01Aug1971 0000	942.0	1510.0
06Jan1972 0000	1400.0	1410.0
29May1973 0000	2820.0	4170.0
01Jan1974 0000	2010.0	4700.0
31Mar1975 0000	2200.0	3350.0
06Jul1976 0000	1790.0	2520.0
06Apr1977 0000	3370.0	5500.0
10Jan1978 0000	2560.0	3780.0
05Mar1979 0000	4650.0	9110.0
15Apr1980 0000	2800.0	4210.0
12Feb1981 0000	1200.0	1560.0
05Jan1982 0000	3510.0	4430.0
02Dec1982 0000	1980.0	3380.0
29Dec1983 0000	1750.0	2600.0
02Feb1985 0000	1400.0	1560.0
19Feb1986 0000	1040.0	1170.0
20Jan1987 0000	1940.0	2370.0
21Jan1988 0000	1350.0	1910.0
21Jun1989 0000	3290.0	4260.0
17Feb1990 0000	9890.0	20600.0
24Dec1990 0000	2490.0	9150.0
15Jun1992 0000	2030.0	3540.0
18Dec1992 0000	916.0	2040.0
29Mar1994 0000	3630.0	6490.0
17Feb1995 0000	2780.0	6420.0
28Jan1996 0000	4510.0	7630.0
03May1997 1300	3630.0	4520.0
19Apr1998 1900	2780.0	4980.0
15Jan1999 1000	1350.0	1760.0
04Apr2000 1000	2300.0	2440.0
25Jul2001 1830	2140.0	4310.0
04May2002 2200	2330.0	3170.0
22May2003 1730	3920.0	7520.0
17Sep2004 0930	6620.0	9680.0
24Nov2004 1800	2630.0	11000.0
18Jan2006 0615	838.0	1070.0
16Nov2006 0800	443.0	919.0
04Mar2008 2315	808.0	681.0

Table O-A-22. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oostanaula R at Resaca Gage (2387500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
15Feb1900 0000	18000.0	18800.0
14Jan1901 0000	22000.0	22700.0
01Jan1902 0000	21000.0	22300.0
03Mar1903 0000	23500.0	23800.0
25Mar1904 0000	8180.0	8340.0
23Feb1905 0000	17000.0	17300.0
17Mar1906 0000	31000.0	16900.0
21Nov1906 0000	12900.0	31700.0
17Feb1908 0000	14900.0	15100.0
15Mar1909 0000	35400.0	39900.0
22May1910 0000	14600.0	15100.0
10Apr1911 0000	16400.0	16900.0
01Apr1912 0000	19400.0	20000.0
17Mar1913 0000	20000.0	20900.0
16Apr1914 0000	14700.0	10800.0
03Feb1915 0000	18700.0	16900.0
13Jul1916 0000	23000.0	23300.0
07Mar1917 0000	31700.0	33500.0
01Feb1918 0000	18000.0	18400.0
25Dec1918 0000	17400.0	16900.0
05Apr1920 0000	35000.0	39900.0
12Feb1921 0000	41000.0	44400.0
23Jan1922 0000	34000.0	40800.0
19Dec1922 0000	12900.0	15500.0
21Apr1924 0000	19000.0	20000.0
21Jan1925 0000	16300.0	16600.0
20Jan1926 0000	19500.0	12400.0
30Dec1926 0000	15000.0	20000.0
01Apr1928 0000	15500.0	16100.0
26Mar1929 0000	26000.0	17300.0
18Nov1929 0000	17900.0	26700.0
06Apr1931 0000	18000.0	13400.0
17Dec1931 0000	36200.0	18400.0
30Dec1932 0000	22000.0	36500.0
07Mar1934 0000	24600.0	25300.0
14Mar1935 0000	14100.0	15300.0
04Apr1936 0000	35000.0	35300.0
06Jan1937 0000	23100.0	23500.0
10Apr1938 0000	36800.0	37700.0
18Feb1939 0000	16200.0	17000.0
15Mar1940 0000	10100.0	10700.0
09Jul1941 0000	8610.0	9150.0

… Continued …

Table O-A-23. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oostanaula R at Resaca Gage (2387500) - *Continued*

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
... Continuation ...		
20Feb1942 0000	32000.0	18000.0
30Dec1942 0000	28500.0	33000.0
01Apr1944 0000	27700.0	28300.0
16Feb1945 0000	14500.0	14700.0
12Feb1946 0000	39400.0	42200.0
22Jan1947 0000	44400.0	47000.0
16Feb1948 0000	35000.0	26800.0
01Dec1948 0000	24800.0	36300.0
16Mar1950 0000	31300.0	31900.0
01Apr1951 0000	50000.0	54800.0
26Mar1952 0000	19700.0	20100.0
24Feb1953 0000	15300.0	15600.0
19Jan1954 0000	30100.0	30700.0
10Feb1955 0000	18500.0	19100.0
19Apr1956 0000	17900.0	18200.0
05Feb1957 0000	31700.0	32800.0
22Nov1957 0000	17200.0	20000.0
21Apr1959 0000	12000.0	12100.0
06Mar1960 0000	16300.0	17000.0
28Feb1961 0000	32000.0	31700.0
15Dec1961 0000	25400.0	32400.0
03May1963 0000	25200.0	25700.0
18Mar1964 0000	30500.0	32000.0
30Mar1965 0000	25000.0	25000.0
07Mar1966 0000	24500.0	25200.0
27Aug1967 0000	22800.0	14200.0
26Dec1967 0000	18900.0	23300.0
06Feb1969 0000	22400.0	26800.0
23Mar1970 0000	13600.0	13700.0
27Jan1971 0000	15700.0	16100.0
14Jan1972 0000	17800.0	18100.0
20Mar1973 0000	27500.0	29000.0
04Jan1974 0000	18700.0	18900.0
03Apr1975 0000	18200.0	18800.0

Table O-A-24. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oostanaula R at Rome Gage (2388500)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
16Mar1940 0000	14200.0	15000.0
09Jul1941 0000	10800.0	12800.0
25Mar1942 0000	22100.0	19700.0
03Jan1943 0000	29300.0	29900.0
02Apr1944 0000	27300.0	29100.0
16Feb1945 0000	18700.0	19400.0
14Feb1946 0000	45400.0	45500.0
24Jan1947 0000	45700.0	47000.0
19Feb1948 0000	35500.0	28200.0
03Dec1948 0000	24300.0	37300.0
18Mar1950 0000	29900.0	30500.0
03Apr1951 0000	43100.0	43600.0
13Mar1952 0000	23100.0	23900.0
23Feb1953 0000	18400.0	18800.0
24Jan1954 0000	28800.0	28900.0
08Feb1955 0000	22700.0	23800.0
18Apr1956 0000	20000.0	20600.0
07Feb1957 0000	32300.0	32500.0
21Nov1957 0000	17100.0	21300.0
22Apr1959 0000	14600.0	15100.0
06Mar1960 0000	18400.0	18600.0
25Feb1961 0000	32500.0	32700.0
20Dec1961 0000	28000.0	33700.0
02May1963 0000	26500.0	27000.0
29Mar1964 0000	29700.0	30200.0
01Apr1965 0000	26100.0	26300.0
06Mar1966 0000	26700.0	27500.0
12Jul1967 0000	23700.0	19000.0
24Dec1967 0000	23200.0	24300.0
08Feb1969 0000	23100.0	23200.0
23Mar1970 0000	18100.0	18500.0
27Jan1971 0000	18500.0	18800.0
15Jan1972 0000	21000.0	21000.0
23Mar1973 0000	23900.0	24100.0
07Apr1974 0000	21700.0	22600.0
01Apr1975 0000	20400.0	21400.0

Table O-A-25. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Oothkalooga Cr at GA 53 Spur at Calhoun Gage (2387600)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
28Jun2005 0400	1350.0	1700.0
21Mar2006 0715	468.0	477.0
16Nov2006 0215	234.0	551.0
11May2008 0745	266.0	428.0

Table O-A-26. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Talking Rock Cr at Carters Gage (2382300)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
27Mar1964 0000	6220.0	11600.0
05Oct1964 0000	1870.0	3300.0
05Mar1966 0000	5740.0	12700.0
25Aug1967 0000	1940.0	3200.0
11Jan1968 0000	3170.0	4200.0
03Feb1969 0000	3090.0	4980.0
20Mar1970 0000	1270.0	2080.0
25Jan1971 0000	1700.0	2830.0

Table O-A-27. Instantaneous Peak Flow vs. Daily Average Flow Relationship at the Talking Rock Cr at Hinton Gage (2382300)

Date	Daily Average Flow cfs	Instantaneous Peak Flow cfs
14Apr1974 0000	2290.0	4850.0
03Jul1975 0000	1760.0	3550.0
16May1976 0000	2600.0	4600.0
05Apr1977 0000	4030.0	10300.0
06Nov1977 0000	1630.0	4060.0
05Mar1979 0000	6890.0	14100.0
22Mar1980 0000	3340.0	7090.0
05Jun1981 0000	858.0	2500.0
04Jan1982 0000	4680.0	11800.0
03Feb1983 0000	1840.0	3170.0
21Mar1984 0000	1810.0	3570.0
02Feb1985 0000	1460.0	2370.0
22Aug1986 0000	622.0	1620.0
01Mar1987 0000	1990.0	3680.0
21Jan1988 0000	1210.0	2530.0
01Oct1989 0000	2620.0	4980.0
17Feb1990 0000	6550.0	11200.0
24Dec1990 0000	1850.0	4050.0
03Jul1992 0000	1830.0	3800.0
26Nov1992 0000	1150.0	3330.0
28Mar1994 0000	3000.0	7320.0
17Feb1995 0000	2250.0	5590.0
28Jan1996 0000	4590.0	12200.0
03May1997 0600	3500.0	7240.0
17Apr1998 0430	4420.0	13700.0
07May1999 1930	1230.0	3110.0
03Apr2000 0345	4410.0	10600.0
19Jan2001 1415	1660.0	3640.0
25Jan2002 0100	1420.0	2940.0
17Jul2003 0000	3960.0	19000.0
17Sep2004 0000	3500.0	10300.0
09Dec2004 0930	1670.0	5050.0
18Jan2006 0000	615.0	1240.0
15Nov2006 2115	479.0	1560.0
04Mar2008 1815	372.0	1040.0

Appendix O-B

Development of Unimpaired Flow Frequency Curves at Rome

Appendix O-B

Development of Unimpaired Flow Frequency Curves at Rome

The following procedure developed by HEC staff shows how the peak, 1-day, 3-day, 5-day, and 45-day unimpaired frequency curves were developed for the Coosa River at Rome.

The 1-day, 3-day, 5-day, and 45-day unimpaired volume duration frequency curves at Rome were initially computed using the Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) and the 1939 – 2007 unimpaired flow data set. These curves are shown in Figure O-B.01. One of the outputs from the HEC-SSP analysis is a series of 1-day maximum flows for each year. HEC-DSSVue was used to copy this record and then these annual maximum daily average flows were converted to instantaneous maximums using the instantaneous peak flow vs. daily average flow relationship developed from USGS gage data, as shown in Appendix O-A and in Figure O-B.02 below. Table O-B-01 contains the 1-day annual maximum and the instantaneous peak flows computed using the linear relationship shown in Figure O-B.02.

The computed instantaneous peak flows were then imported into HEC-SSP and a General Frequency Analysis was performed on the instantaneous peak flow data. Currently, there is no option in HEC-SSP to plot results from Volume-Duration and Bulletin 17B analyses in one graph. Therefore, a spreadsheet was developed that takes output from HEC-SSP and plots all the frequency curves in one graph, as shown in Figure O-B.03 and contained in Table O-B-02.

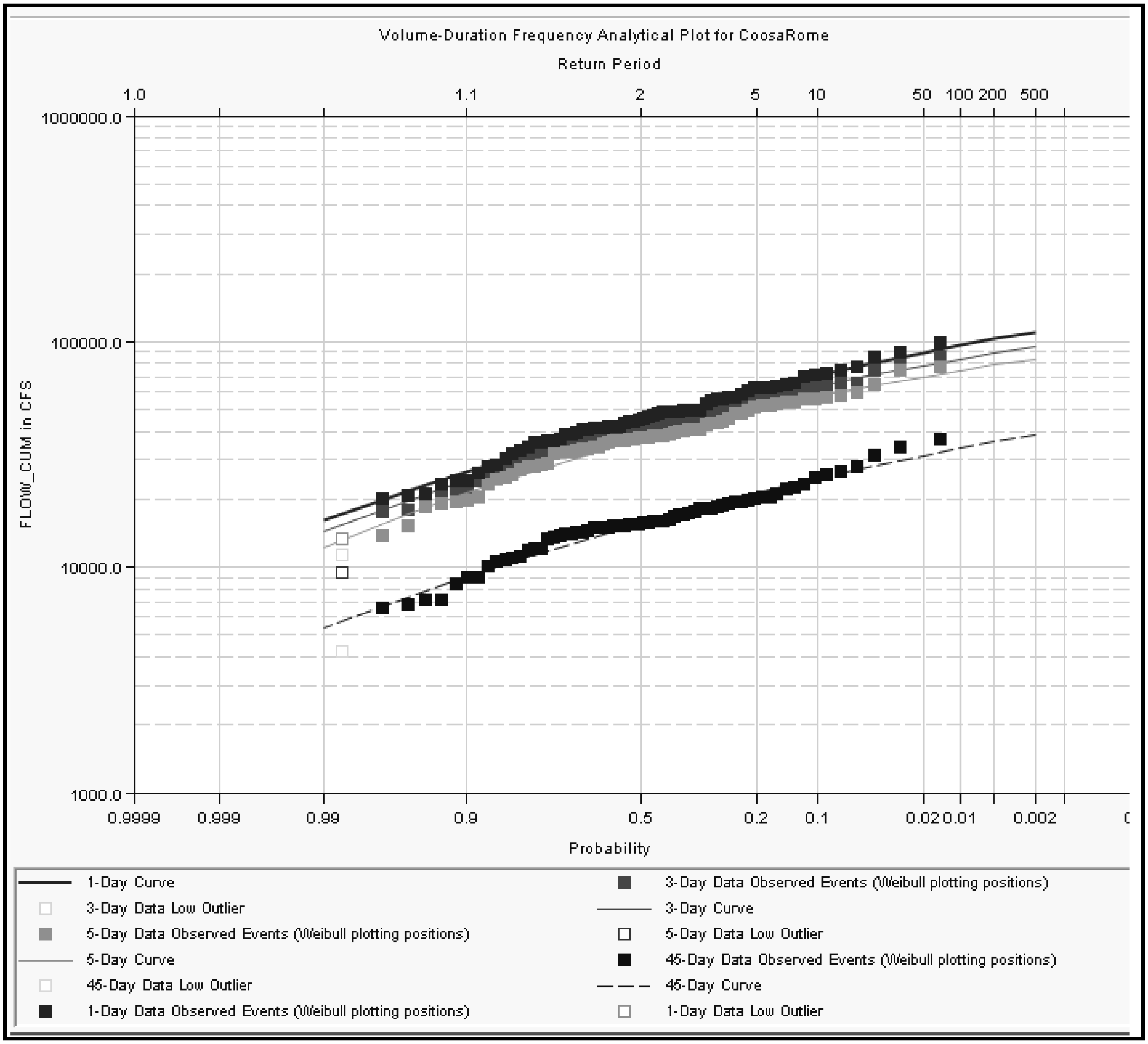

Figure O-B.01 The 1-Day, 3-Day, 5-day and 45-Day Unimpaired Volume Frequency Curves at CoosaRome Gage

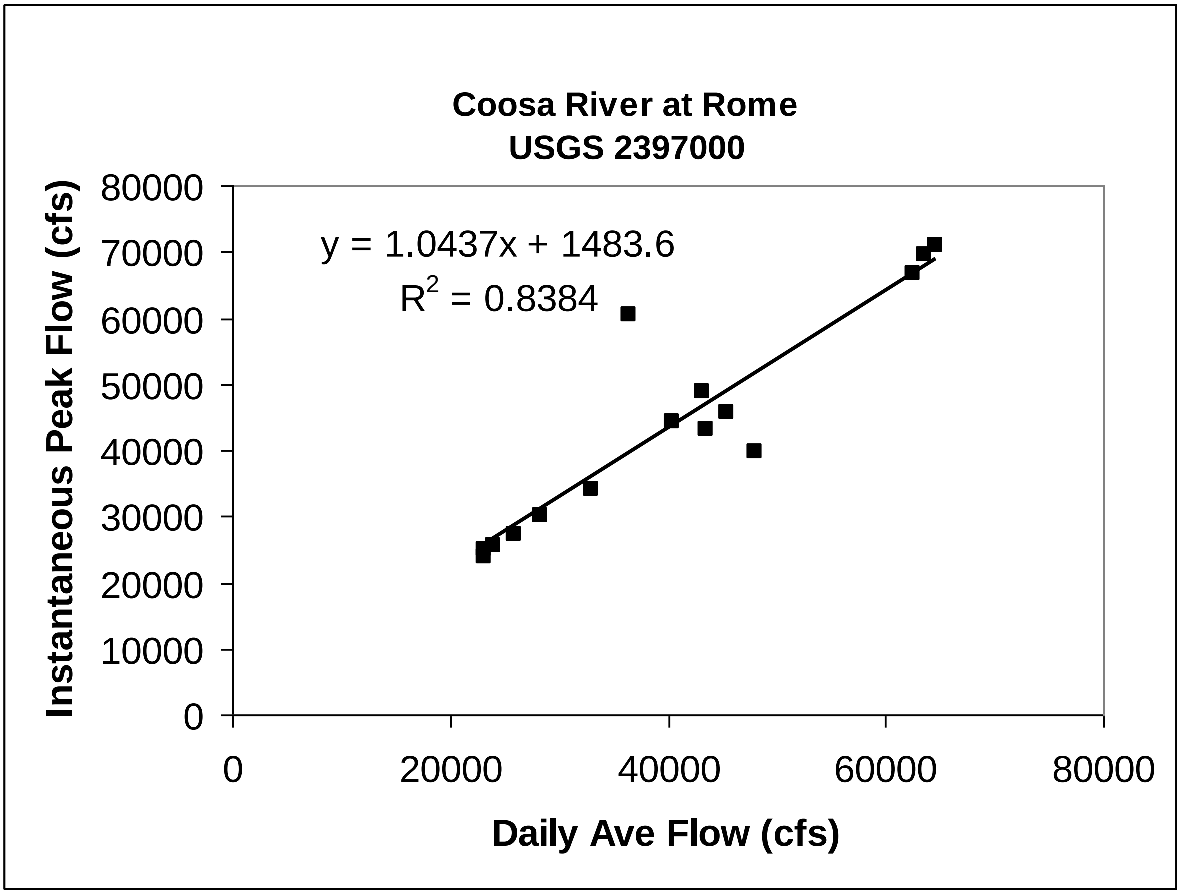

Figure O-B.02 Instantaneous Peak Flow vs. Daily Average Flow Relationship from USGS data at the Coosa Rome Gage

Table O-B-01. 1-Day Max. and Instantaneous Peak Flows at Rome from HEC-SSP

Date	1-Day Annual Maximum CFS	Instantaneous Annual Peak (Compute) CFS
15Mar1940 0000	24027	26560
08Jul1941 0000	23227	25725
01Jan1943 0000	48027	51609
02Jan1943 0000	43227	46599
01Apr1944 0000	45427	48896
16Feb1945 0000	25927	28543
13Feb1946 0000	63627	67891
23Jan1947 0000	64627	68935
02Dec1948 0000	62027	66221
09Jan1949 0000	41327	44616
15Mar1950 0000	41209	44494
31Mar1951 0000	56479	60431
25Mar1952 0000	54809	58688
12Jan1953 0000	33605	36557
18Jan1954 0000	48499	52102
09Feb1955 0000	42033	45353
18Mar1956 0000	31840	34715
07Apr1957 0000	55333	59235
04May1958 0000	21092	23497
21Apr1959 0000	28264	30983
06Mar1960 0000	35329	38357
15Dec1961 0000	88524	93876
15Apr1962 0000	60453	64578
02May1963 0000	57816	61826
28Mar1964 0000	74225	78952
28Mar1965 0000	36412	39487
06Mar1966 0000	54594	58463
27Aug1967 0000	41895	45210
12Jan1968 0000	43990	47396
05Feb1969 0000	35435	38467
23Mar1970 0000	38705	41880
05Mar1971 0000	32570	35477
13Jan1972 0000	48265	51858
19Mar1973 0000	41747	45055
06Apr1974 0000	49157	52789
16Mar1975 0000	46277	49783
02Apr1976 0000	62880	67112
07Apr1977 0000	71602	76214
28Jan1978 0000	44931	48378
15Apr1979 0000	85061	90262
23Mar1980 0000	62257	66462
13Feb1981 0000	27570	30258
05Feb1982 0000	77235	82094
08Dec1983 0000	52623	56406

... Continued ...

Table O-B-01. 1-Day Max. and Instantaneous Peak Flows at Rome from HEC-SSP
- Continued

Date	1-Day Annual Maximum CFS	Instantaneous Annual Peak (Compute) CFS
	… Continuation …	
05May1984 0000	40289	43533
04Feb1985 0000	30119	32919
28Nov1986 0000	20023	22382
02Mar1987 0000	48446	52046
22Jan1988 0000	36042	39101
03Oct1989 0000	70862	75442
19Mar1990 0000	98485	104272
22Feb1991 0000	40206	43446
28Feb1992 0000	39087	42278
14Jan1993 0000	48955	52578
30Mar1994 0000	40859	44128
07Oct1995 0000	49350	52990
29Jan1996 0000	68958	73455
03Mar1997 0000	48510	52114
06Feb1998 0000	61633	65810
03Feb1999 0000	23766	26288
06Apr2000 0000	43582	46971
22Mar2001 0000	35970	39025
02Apr2002 0000	38401	41563
09May2003 0000	55910	59837
19Sep2004 0000	47087	50628
13Jul2005 0000	49293	52931
18Nov2006 0000	20513	22893
04Mar2007 0000	13274	15338

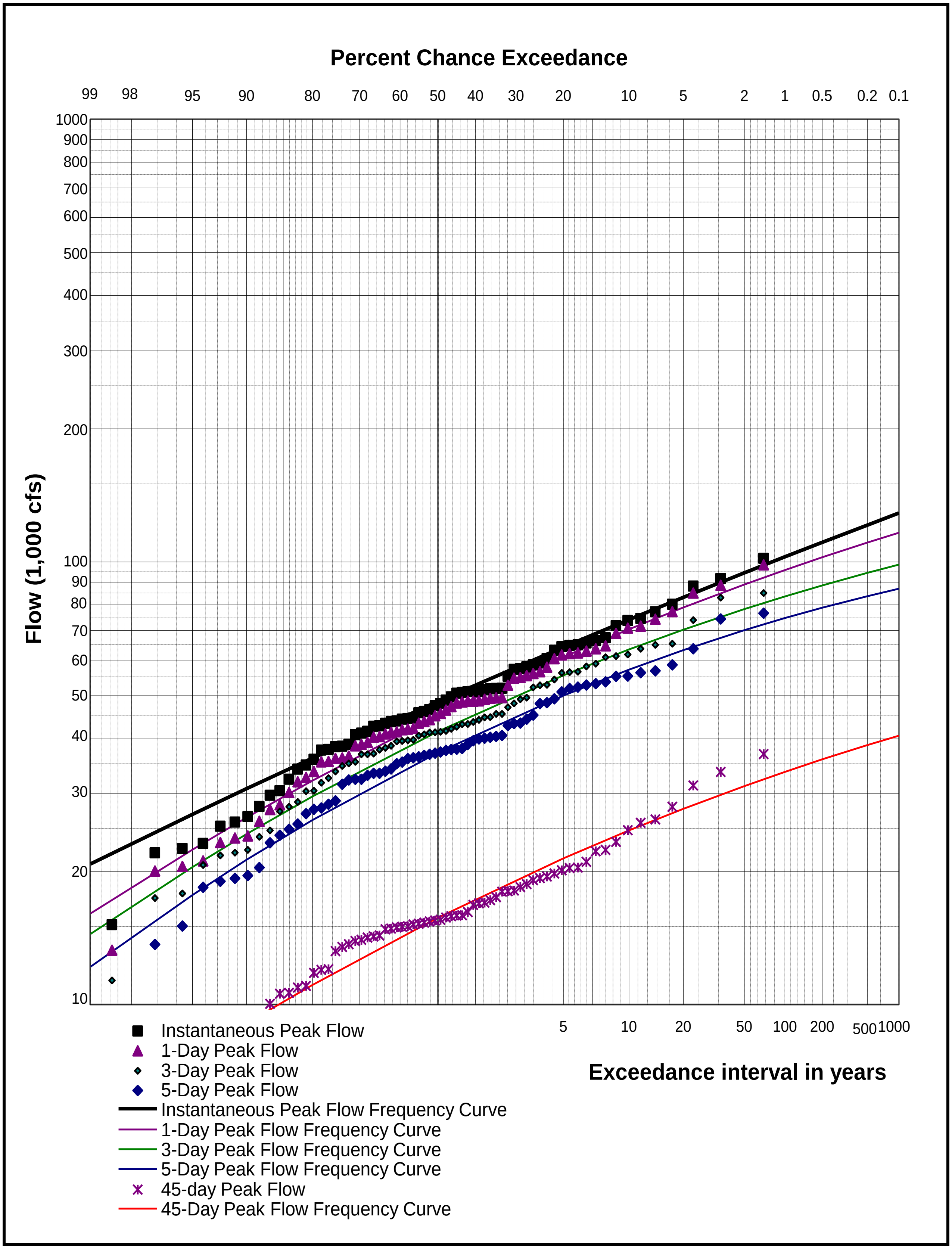

Figure O-B.03 Peak, 1-Day, 3-Day, 5-day and 45-Day Frequency Curves at Rome

Table O-B-02. Peak, 1-Day, 3-Day, 5-day and 45-Day Frequency Curves at Rome.

Frequency	Peak	1-Day	3-Day	5-Day	45-Day
99.0	20,767	16,061	14,449	12,171	5,374
95.0	26,871	22,385	20,446	17,676	7,617
90.0	30,723	26,442	24,272	21,217	9,065
80.0	36,022	32,046	29,511	26,082	11,069
50.0	48,377	44,993	41,360	37,062	15,703
20.0	64,183	60,938	55,372	49,877	21,378
10.0	74,047	70,432	63,387	57,075	24,728
5.0	83,123	78,829	70,268	63,159	27,670
2.0	94,425	88,835	78,206	70,053	31,144
1.0	102,645	95,798	83,563	74,624	33,542
0.5	110,674	102,354	88,480	78,756	35,783
0.2	121,086	110,504	94,421	83,661	38,545
0.1	128,856	116,336	98,556	87,015	40,504

Appendix O-C

Development and Calibration of HEC-HMS Model

Appendix O-C

Development and Calibration of HEC-HMS Model

General

The 4040 square mile ACT basin above Rome, GA is formed by the Oostanaula River and the Etowah River basins. These rivers join at Rome, GA to form the Coosa River. The Oostanaula and Etowah Rivers have approximately the same drainage area. The Oostanaula River is formed by the Conasauga and Coosawattee Rivers near Resaca, GA. Carters Dam and Carters Reregulation Dam are located on the Coosawattee River. Allatoona Dam is located on the Etowah River. The area is shown in Figure O-C.01 below.

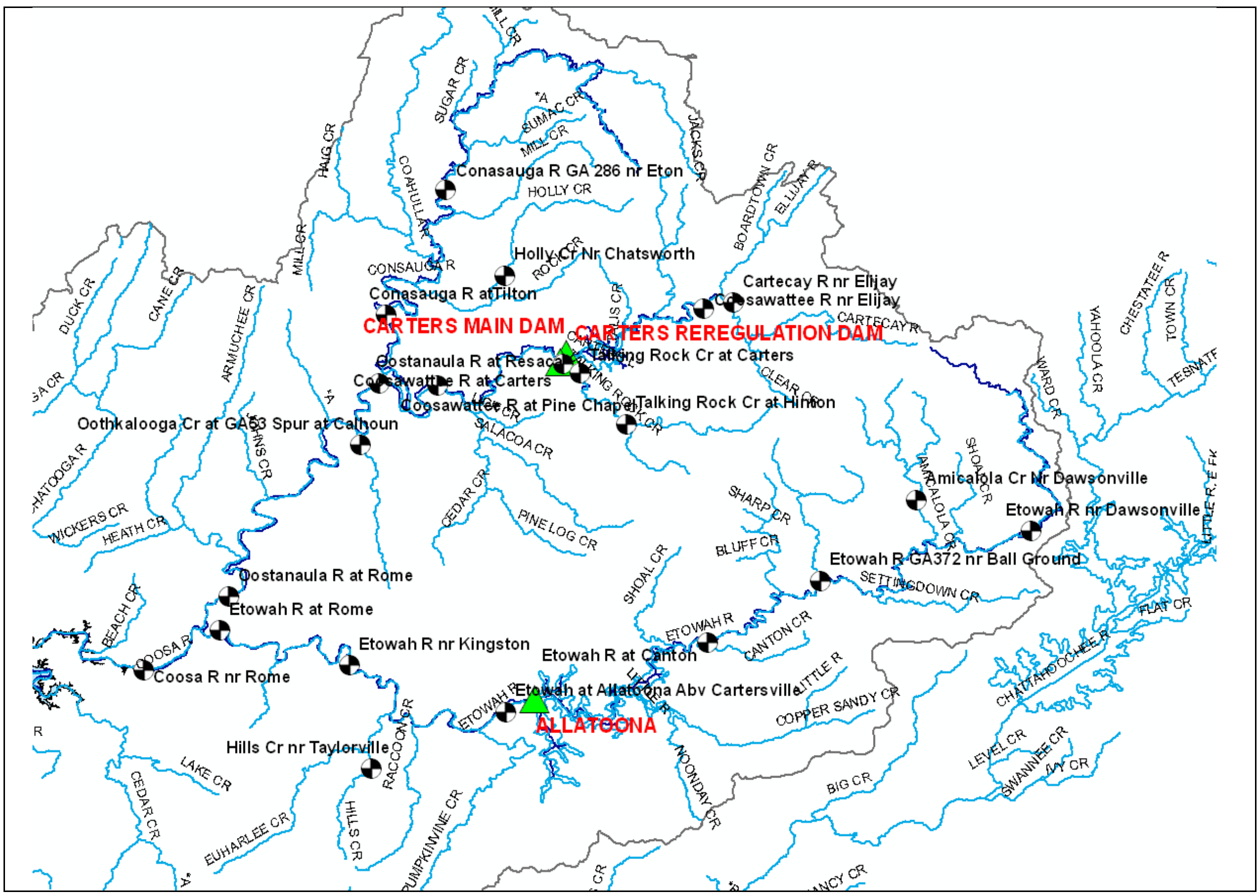

Figure O-C.01 Drainage Basin above Rome, GA.

A routing model of the basin was constructed using version 3.3 of the Hydrologic Engineering Center's application Hydrologic Modeling System (HEC-HMS). The model is similar to the HEC-ResSim model previously developed for the area. A schematic of the watershed is shown in Figure O-C.02. The data developed from the HEC-HMS model will be used in the HEC-ResSim model to route design frequency events to evaluate the impact at Rome of varied operating plans at Carters Dam and Allatoona Dam. The flows for the design frequency events were generated by adjusting three historic storms' flows up or down to match the target design flow frequency at Rome. The target design flows were the 5-, 2-, 1-, 0.5-, and 0.2-percent exceedance events. This was done for the 1961, 1979, and 1990 storms so that varied storm distributions could be evaluated.

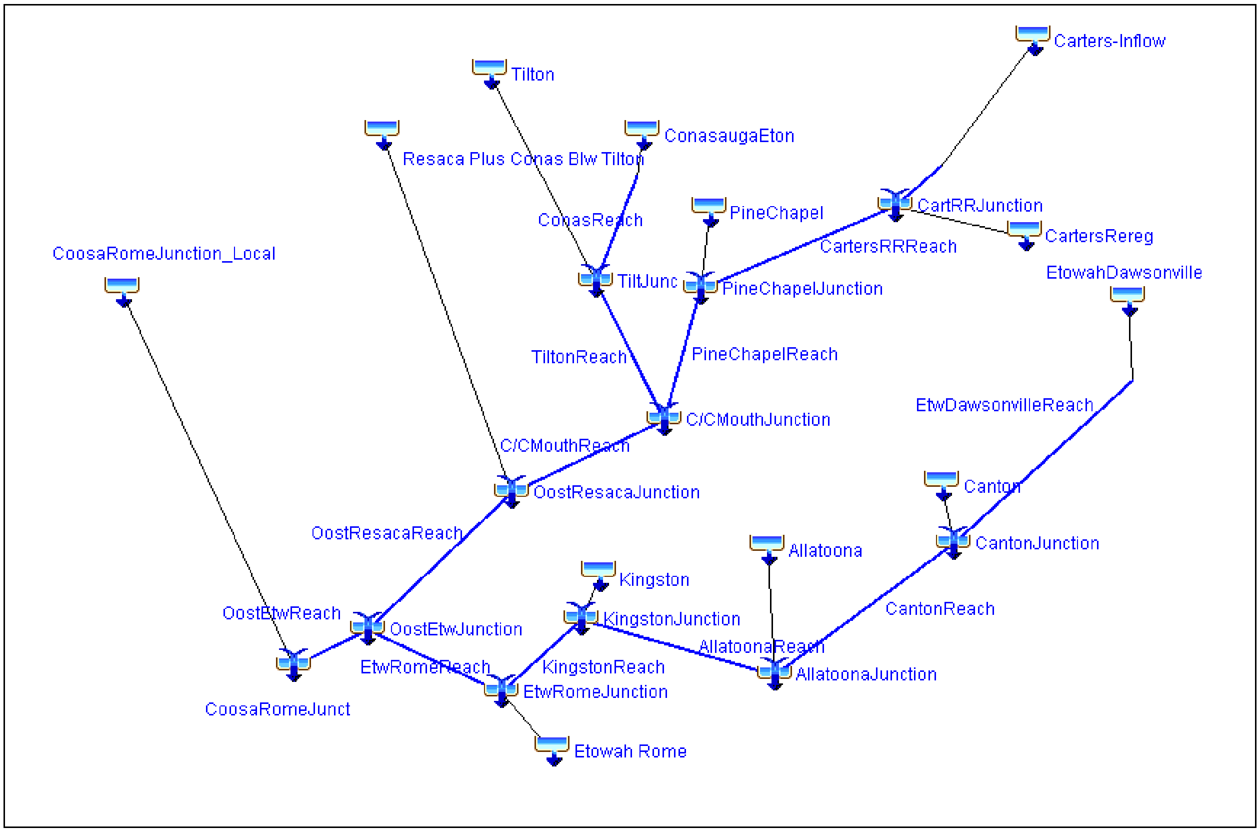

Figure O-C.02 HEC-HMS Schematic

Calibration

The calibration was done using the 1990 flood event existing daily average flow local runoff hydrographs produced in the ACT/ACT Comprehensive Water Resources Study, Surface Water Availability, Volume I, Unimpaired Flow, Corps of Engineers, Mobile District, July 8, 1997. (COE,1997) These local hydrographs, as well as hydrographs at the upper reach inflow points and at node/gage (junction) locations were converted to hourly hydrographs using the methods described in Section **2.4** of this report. The hourly local inflow and inflow point hydrographs were entered as input to the HMS model. Hourly hydrographs were then computed using HMS at the node/gage locations (junctions). These were checked against the 1990 hourly hydrographs derived at the node/gage locations to adjust the Muskingum parameters.

Development of Local Inflow Hydrographs

As stated above, the local hourly hydrographs for the 1990 flood were determined from the daily values available from the previous (COE, 1997) study.

However, local hydrographs for the 1961 and 1979 events were determined using a different method for reasons explained below. These local hydrographs were determined using only the cumulative hourly flow hydrographs derived at the nodes/gages/junctions as described in **Section 2.4**. Using the calibrated model, these hourly junction hydrographs were routed downstream and subtracted from the next downstream junction hydrograph to compute the local hydrographs between junctions. For the most upstream inflow reaches the hourly hydrographs were developed as described in **Section 2.4** from the average daily values in the COE 1997 study.

This process of determining the local hydrographs by subtracting the junction hydrographs from the routed upstream hydrograph was used for the 1961 and 1979 floods to circumvent the difficulty in calibration of the HEC-HMS model developed for the ACF basin. See the footnote below [1].

The Muskingum parameters developed from the 1990 flood are shown in Table O-C-01, below. The Muskingum K for the C/CMouthReach seemed a bit long. However, it was set by looking at the hydrograph peaks at PineChapelJunction and the OostResacaJunction. Possibly high flows at the confluence of the Conasauga and Coosawattee caused some detention and attenuation.

Table O-C-01. HEC-HMS Routing Parameters

River	Reach Description	HMS Reach Name	Length (mi)	Musk "K"	Musk "X"	Sub-reaches
Coosa	Oostanaula/Etowah confluence to Rome(Coosa) gage (Mayos Bar)	OostEtwReach	7.1	4	0	1
Etowah	Rome(Etowah) gage to Oostanaula/Etowah confluence	EtwRomeReach	2.4	2	0	1
Etowah	Kingston gage to Rome(Etowah) gage	KingstonReach	20	8	0	1
Etowah	Allatoona gage to Kingston gage	AllatoonaReach	26	8	0	1
Etowah	Allatooona gage to Canton Gage	CantonReach	29	3	0	1
Etowah	Dawsonville gage to Canton gage	EtwDawsonvilleReach	51	15	0	1
Oostanaula	Resaca gage to Oostanaula/Etowah confluence	OostResacaReach	45	24	0	1
Oostanaula	Conasauga/Coosawattee confluence to Resaca gage	C/CMouthReach	3.7	14	0	1
Coosawattee	Pine Chapel gage to Conasauga/ Coosawattee confluence	PineChapelReach	6.5	4	0	1
Coosawattee	Carters Rereg gage to Pine Chapel gage	CartersRRReach	18.6	30	0	2
Conasauga	Tilton gage to Conasauga/ Coosawattee confluence	TiltonReach	12.1	8	0	1
Conasauga	Eton gage to Tilton gage	ConasauagEton	31.3	12	0	1

[1] Basically, several of the ACF routing reaches in that basin were short and the daily time step used in the HEC-HMS model for the COE 1997 study resulted in the use of lag routing in these reaches. This resulted in some negative values in the local inflow hydrographs and accumulated volume errors in the downstream reaches. In an effort to avoid this error in the hourly hydrographs, it was decided to use the hourly gage data to re-compute the local hourly hydrographs where possible. The ACF hydrograph development is documented in the report, Development Of Unimpaired Hourly Hypothetical Storm Hydrographs for the Apalachicola-Chattahoochee-Flint River System from West Point to Columbus, Corps of Engineers, July 2009.

The model calibration results using the 1990 flood are shown in Figure O-C.03 through Figure O-C.11 below.

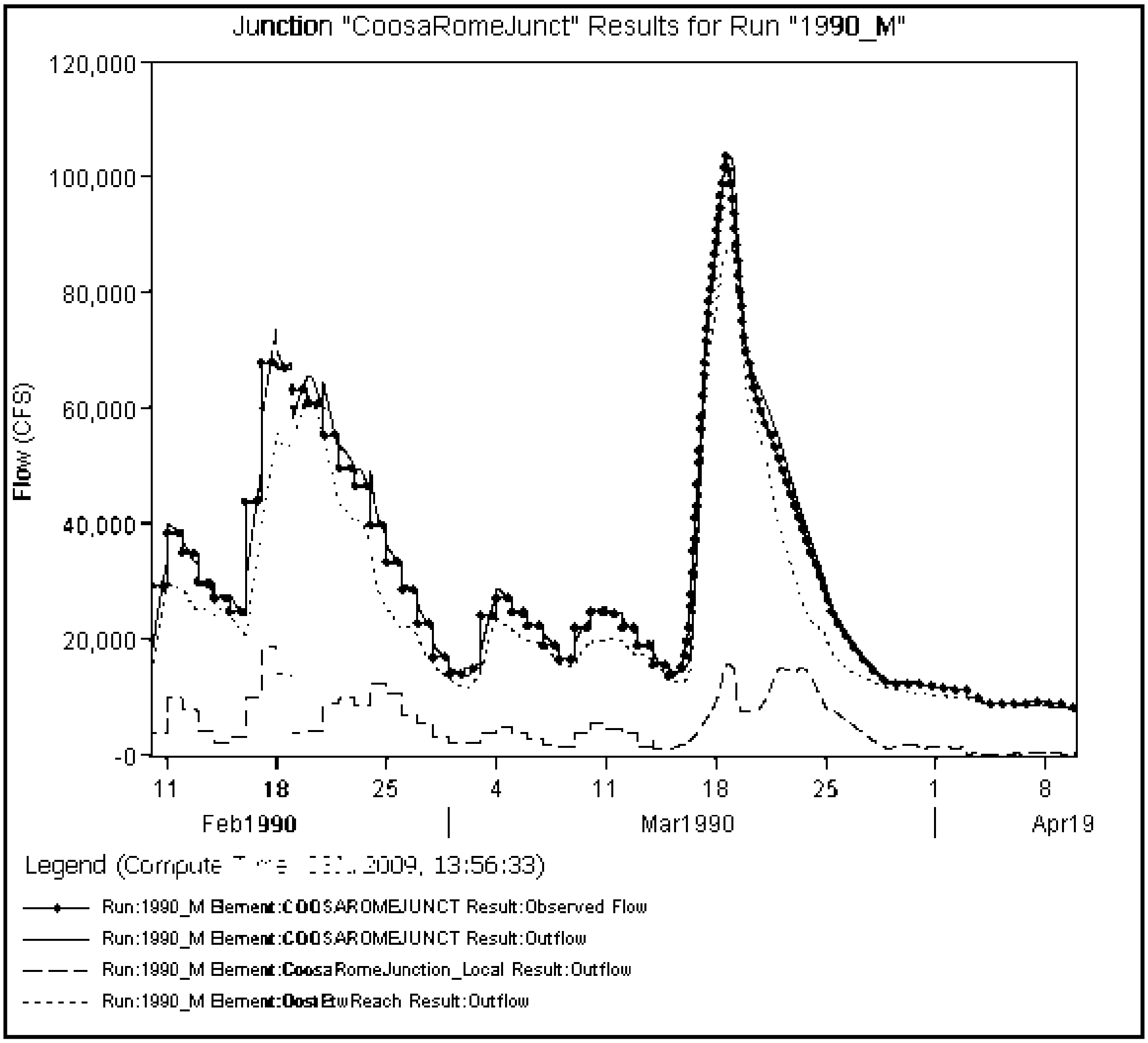

Figure O-C.03 1990 Flood CoosaRome Junction

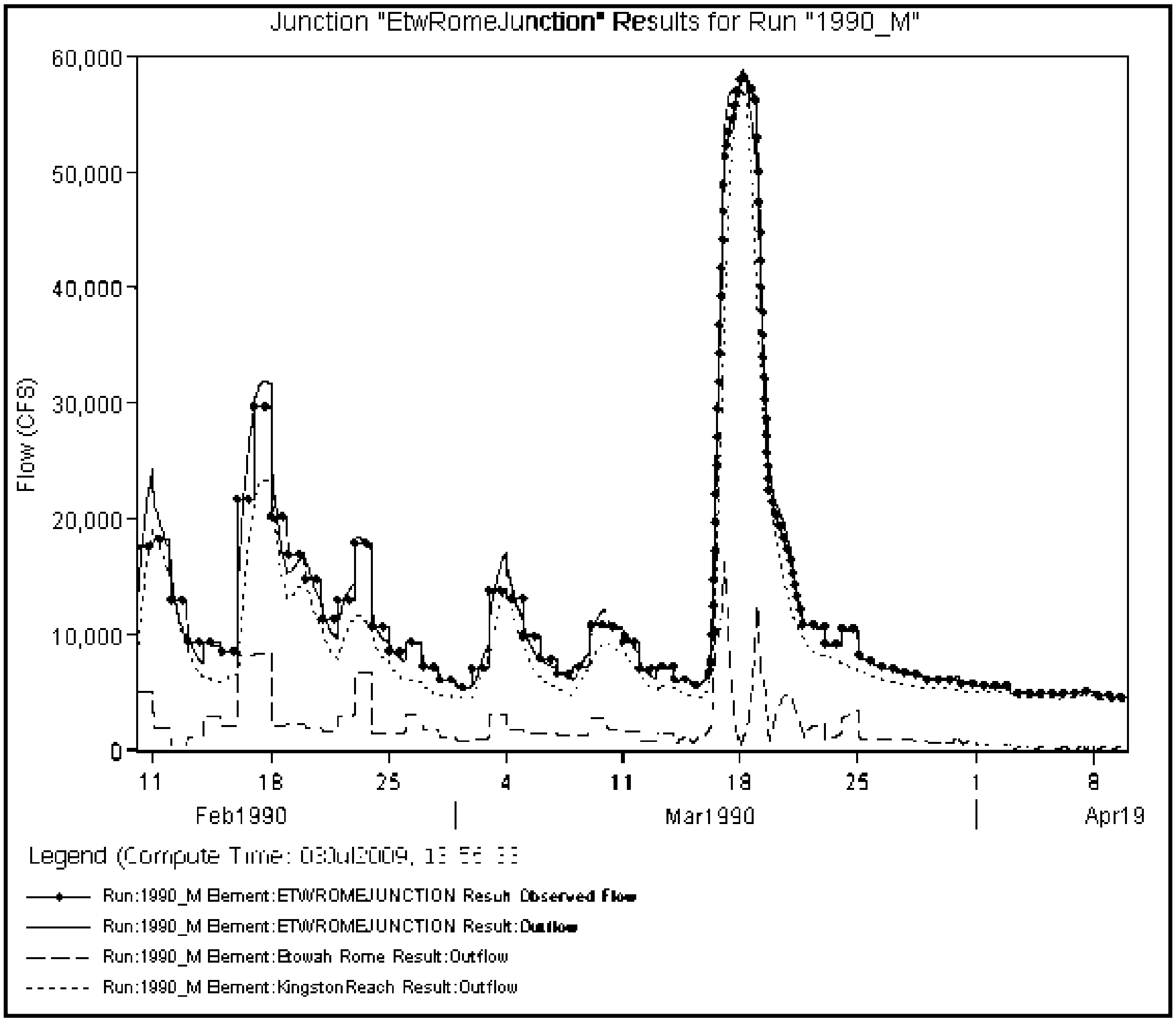

Figure O-C.04 1990 Flood EtowahRome Junction

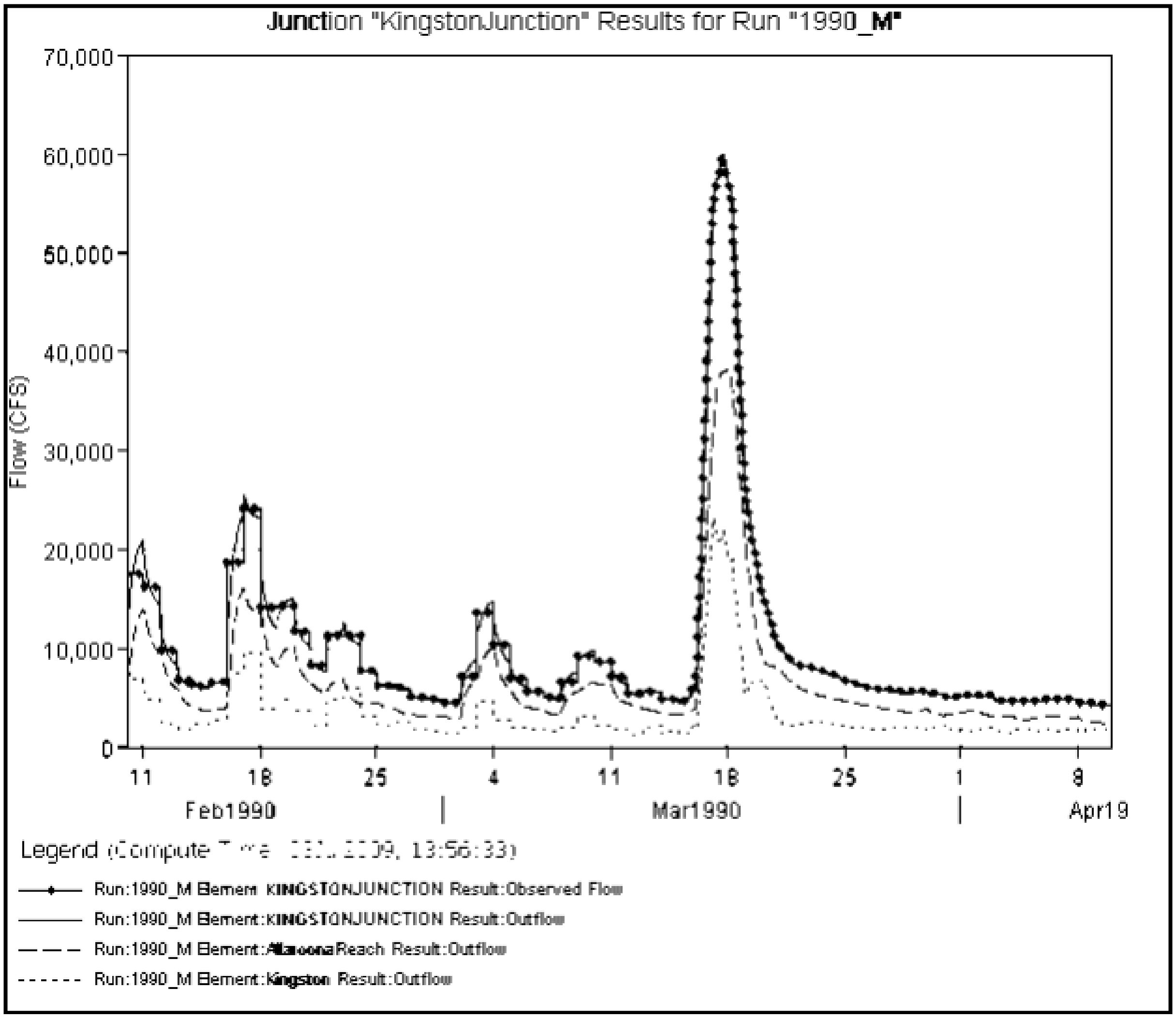

Figure O-C.05 1990 Flood Etowah River Kingston Junction

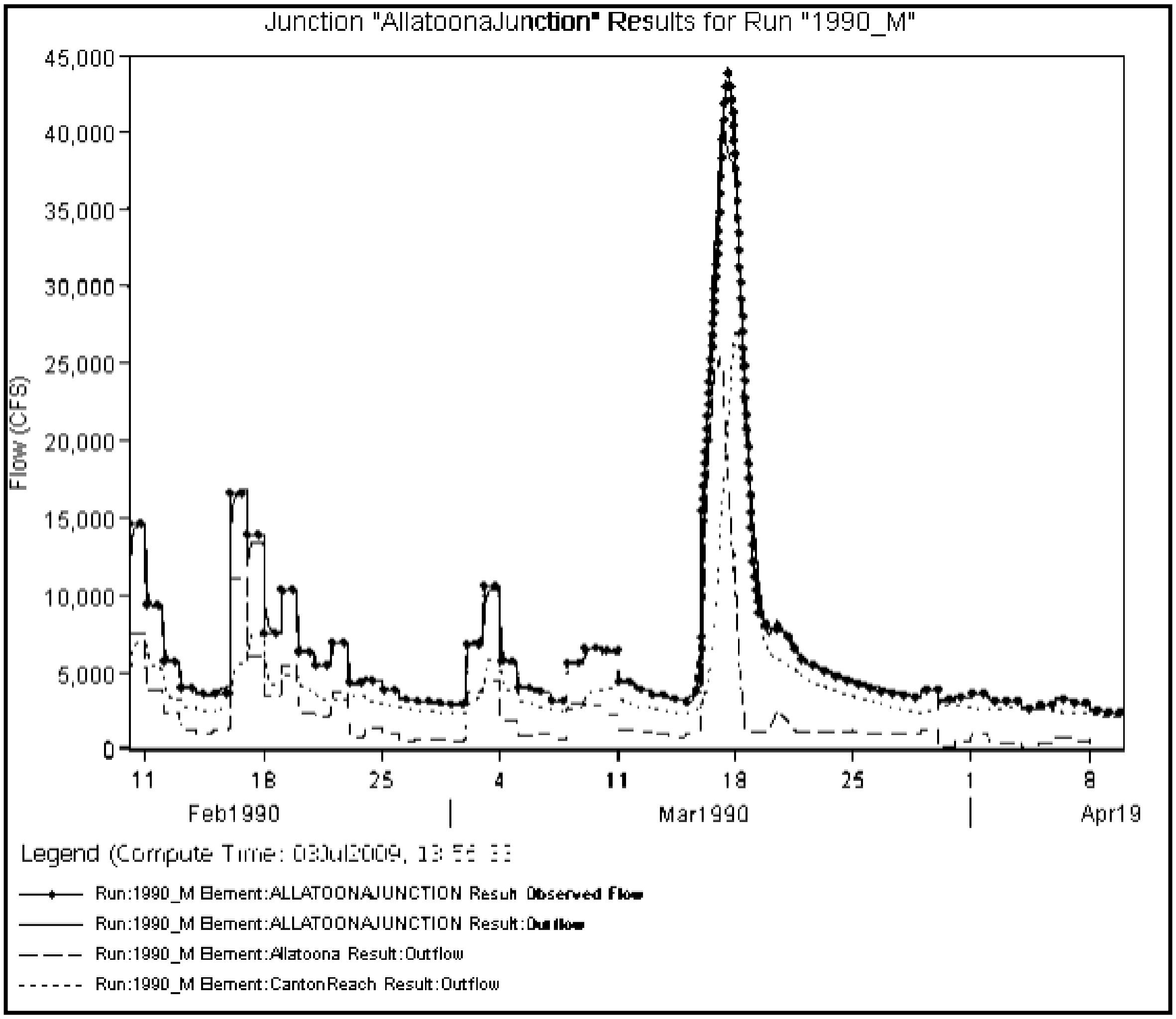

Figure O-C.06 1990 Flood Etowah River Allatoona Junction

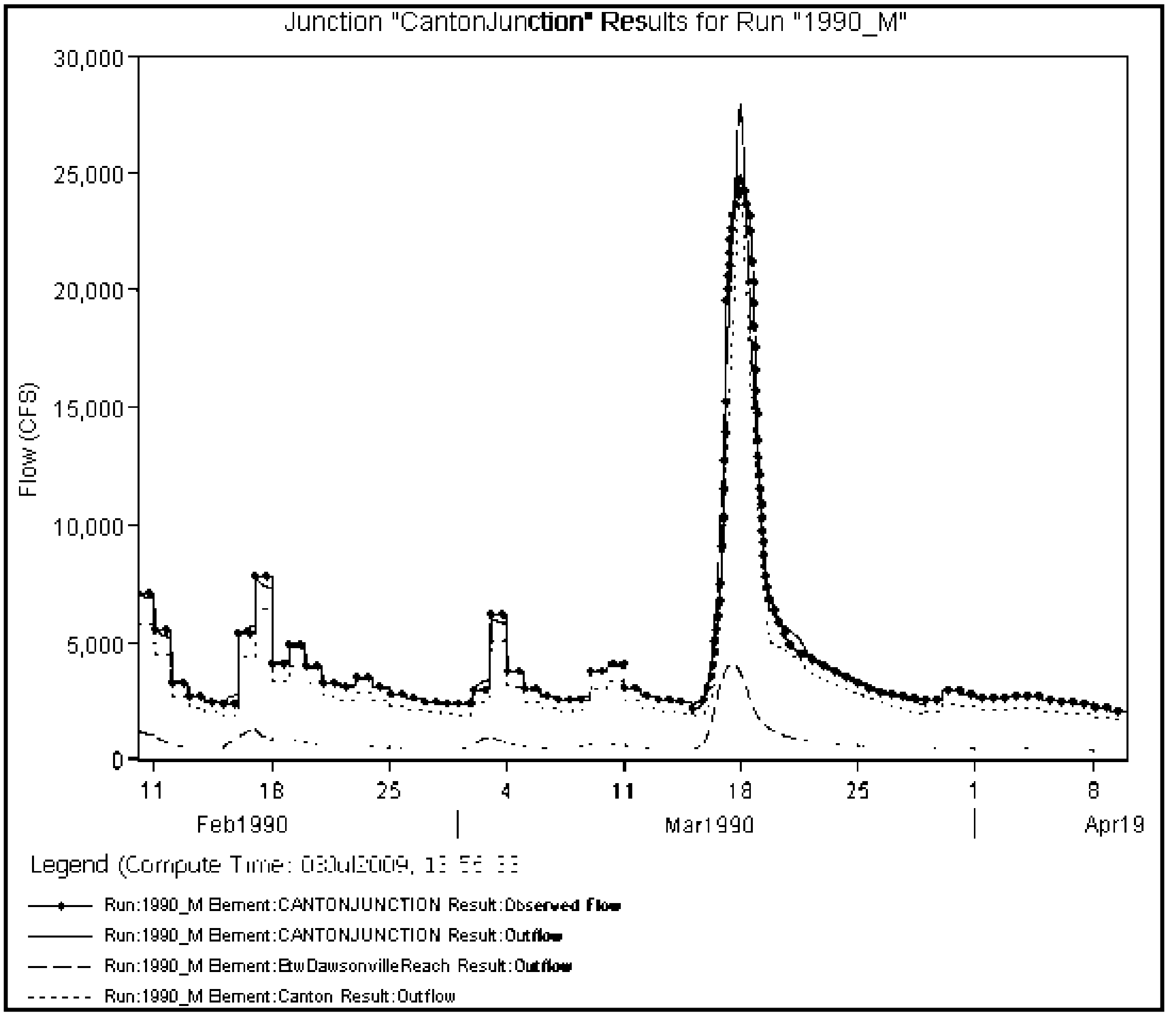

Figure O-C.07 1990 Flood Etowah River Canton Junction

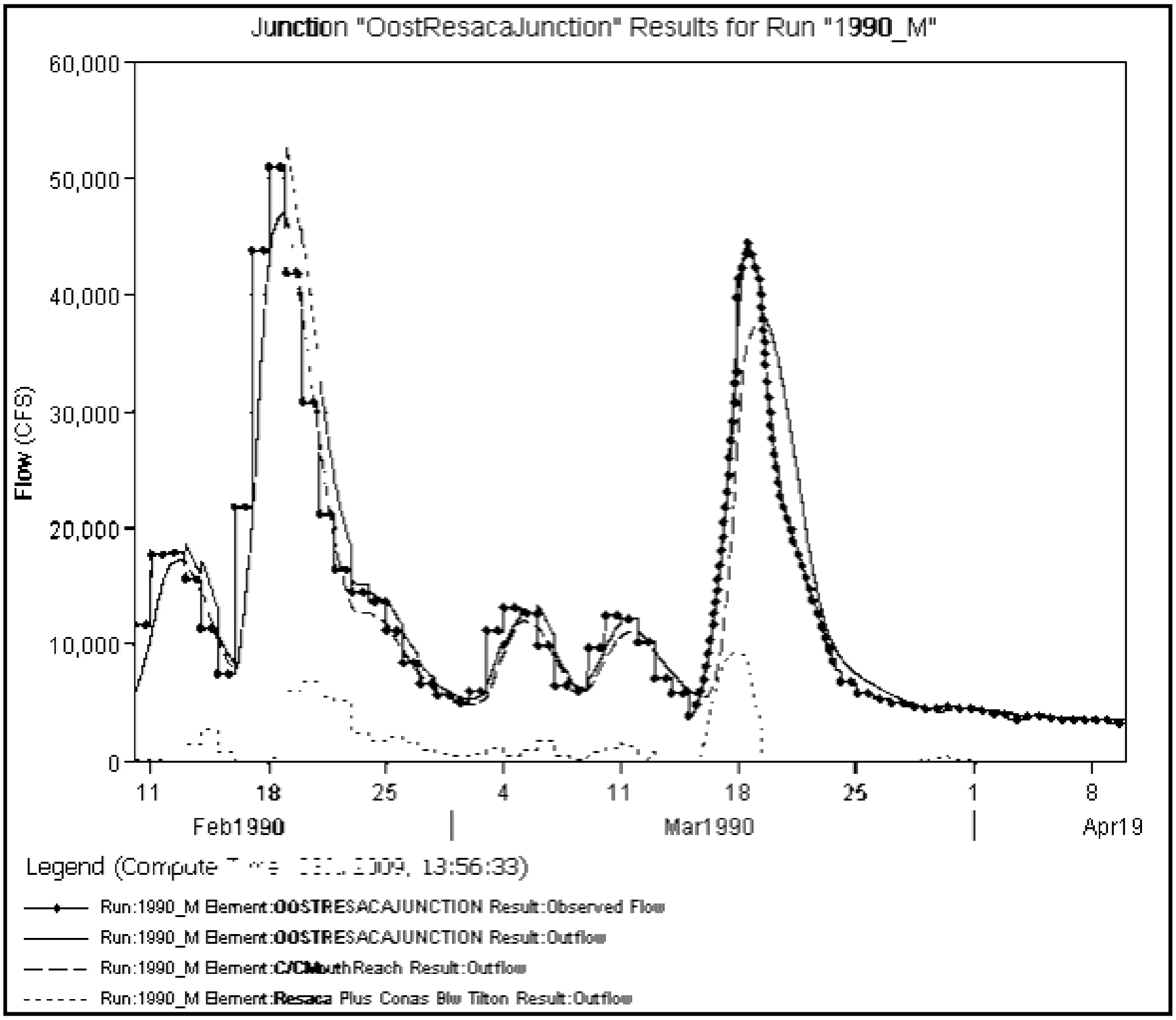

Figure O-C.08 1990 Flood Oostanaula River Resaca Junction

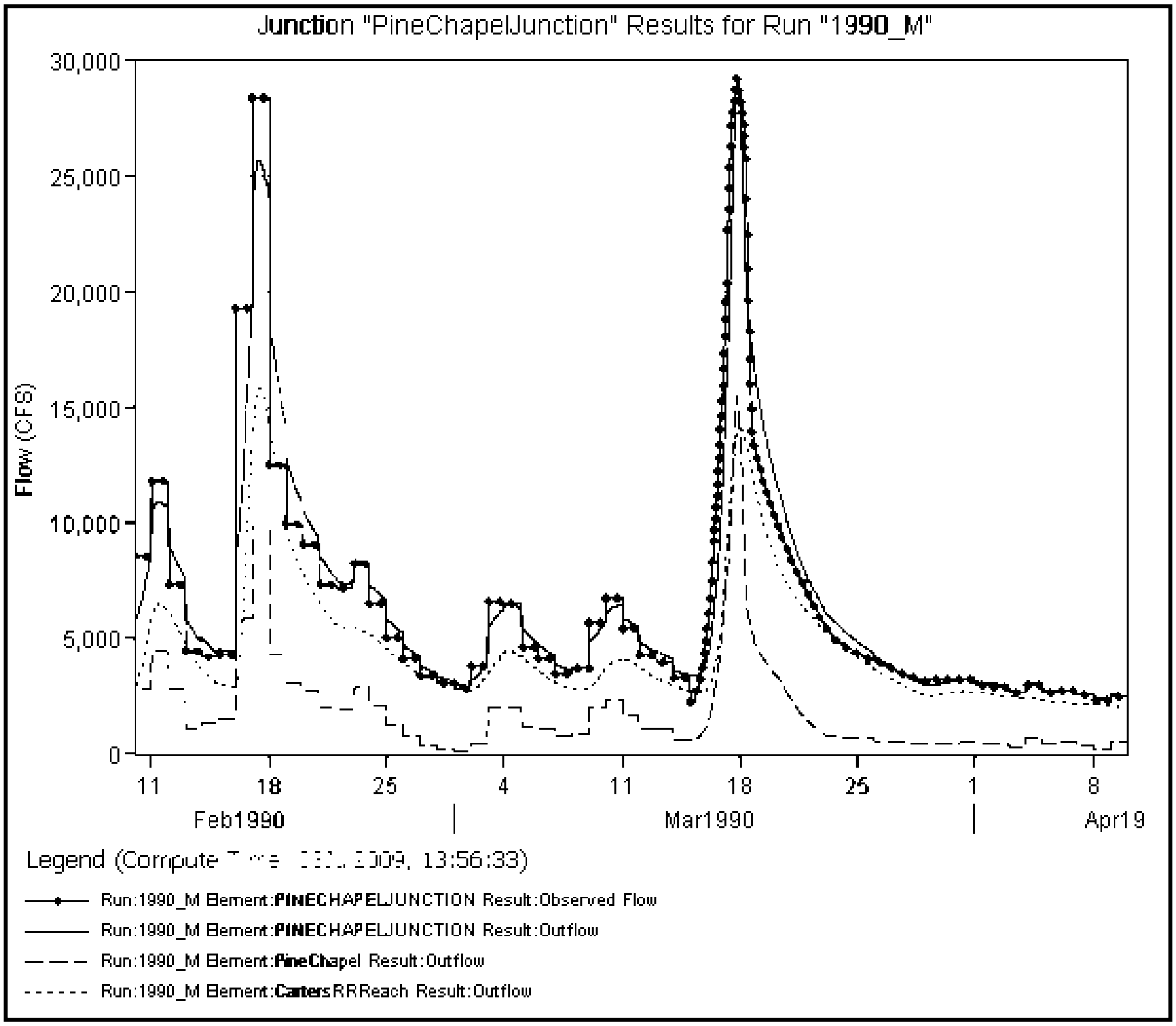

Figure O-C.09 1990 Flood Coosawattee River Pine Chapel Junction

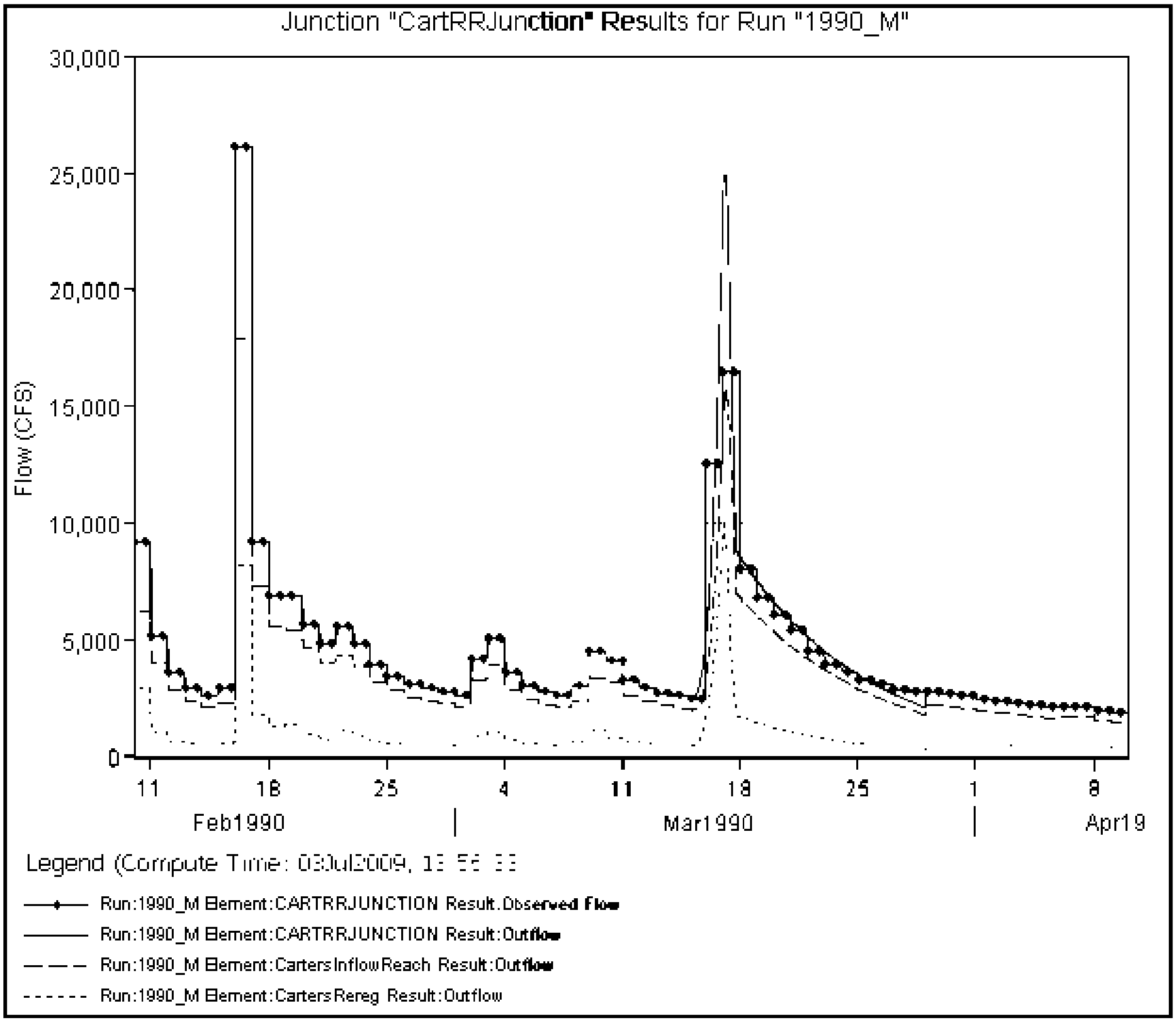

Figure O-C.10 1990 Flood Coosawattee River Carters Rereg Junction

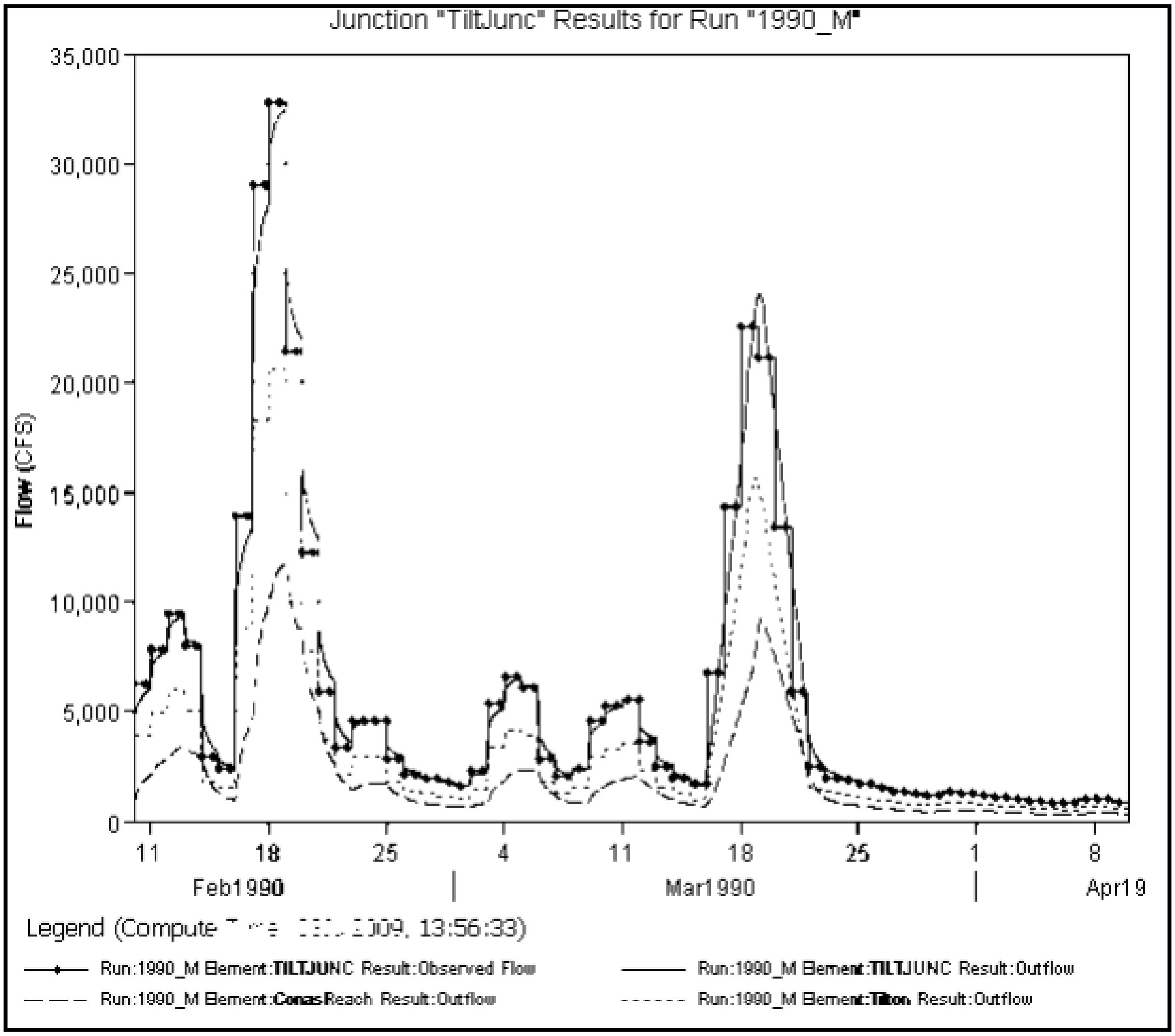

Figure O-C.11 1990 Flood Conasauga River Tilton Junction