US Army Corps
of Engineers®
Savannah District

Hartwell Lake Integrated Water Supply Storage Reallocation Report and Environmental Assessment and Finding of No Significant Effect
South Carolina and Georgia

Appendix A: Engineering

March 2024

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Introduction

This study evaluates the feasibility of reallocating storage in Hartwell Lake to water supply storage. More specifically, it calculates the acre-feet for the new yield requests; evaluates the impacts on other authorized project purposes and existing users; determines potential environmental effects; determines the price for new requests; and determines appropriate compensation, if any, to existing users. This report summarizes the assumptions, model selection, and process used to develop storage necessary to support requestors' yield and determines the least-cost way for the multiple requestors to receive water supply. Water supply policies and guidance used in this study are defined in the USACE Institute for Water Resources Water Supply Handbook, IWR Report 96-PS-4.

Prior to this study all water supply agreements in the Savannah Basin were treated as if the projects were independent from each other. A systems approach has been discussed and approved by the Water Supply center of expertise for this study. System rules governing project balance, system power generation, and system flood control help achieve system benefits rather than standalone project benefits. Yield is analyzed with system rules implemented to assess impacts on system goals. Yield estimates for all existing water supply agreements have been recalculated using this approach. A reservoir systems model approach results in the most accurate decisions for impacts on existing project purposes because the watershed is managed and operated as an inter-related system. The systems approach will provide a more stable source for water supply, as well as for helping meet the other authorized project purposes of the three multi-purpose projects in the system.

1.0 Water Supply Description

1.1 Existing Water Supply Reallocations/Agreements

The 1996 Water Supply Reallocation for Hartwell Lake, Georgia, the most recent reallocation study for Lake Hartwell, outlines all the current agreements for water storage as well as other uses. Since impacts can be felt across the entire system, Table 1.1-1 shows all three lakes' current water supply reallocations.

Table 1.1-1: Current Water Reallocation Contracts

Project	Recipient	Acre Feet of Water	Reallocated From	Date of Approval
Hartwell, GA & SC	Anderson Regional Joint Municipal Water System (ARJWS)	24,620	Conservation	1967
	City of Lavonia	127	Conservation	1990
	Hart County	1,827	Conservation	1998
J Strom Thurmond, GA & SC	City of Lincolnton	92	Conservation	1964
	City of Washington	632	Conservation	1975
	Savannah Valley Auth.	92	Conservation	1989
	Columbia County	1,056	Conservation	1989
	Town of McCormick	506	Conservation	1999
	City of Lincolnton	83	Conservation	1990
	City of Thompson	1,056	Conservation	1990
	Town of McCormick	316	Conservation	2001
Richard B Russell, GA & SC	SC Public Service Auth. (RAINEY)	491	Flood Control[1]	2001
	City of Elberton	381	Conservation	1990
Total		31,279		

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[1] The 2001 Russell reallocation for SC Public Service Auth was moved from flood control to conservation.

1.2 Current Water Supply Withdrawals and Returns

Water withdrawals and return data for current intakes was initially developed from 2015 thru 2019 reported monthly information provided by each intake representative. This data was refined as additional data became available identifying quantities and specific location of returns. Monthly average withdrawals for each intake covering 2015-2022 was used to define seasonal variation in monthly withdrawals used in the modeling. The seasonal variation in withdrawals and returns is shown in Table 1.2-1 and Table 1.2-2 below. Several of the requestors currently get water from ARJWS. Returns for each intake are expressed as a percentage of the monthly withdrawal. The HEC-ResSim model was configured to reflect this information. Riparian users have no storage account and are labeled "R".

Table 1.2-1: Current Monthly Withdrawal Estimates (cfs)

	CURRENT MONTHLY AVERAGE USAGE																						
	HARTWELL										RUSSELL						THURMOND						
Storage (AC-FT)	24620			127			1827	R	R	R	R	110	381	R	R	491	1056	R	175	822	92.4	1056	632
	Anderson	**Anderson New**	**Pioneer New**	**Lavonia**	**Lavonia New**	**Curahee New**	**Hart County**	**Clemson**	**City of Hartwell**	**JP Stevens**	**Abbeville**	**CalhounFalls**	**Elberton**	**Mohawk**	**RBR State Park**	**Rainey**	**Columbia County**	**Hickory Knobb**	**Lincolnton**	**McCormick**	**Sav Valley**	**Thompson**	**Washington**
Jan	27.70			0.31			1.64	21.81	2.09	0.69	2.76	0.40	4.20	0.41	0.00	2.40	5.09	0.06	0.83	1.33	0.00	2.17	1.03
Feb	27.86			0.31			1.66	21.95	2.31	0.73	2.63	0.41	3.60	0.50	0.00	3.00	4.35	0.05	0.79	1.27	0.01	2.50	1.54
Mar	27.12			0.26			1.37	18.18	1.81	0.70	2.65	0.41	3.70	0.51	0.01	1.81	4.99	0.06	0.63	1.14	0.02	2.00	1.47
Apr	27.81			0.26			1.39	18.27	1.85	0.67	2.47	0.33	2.85	0.57	0.04	1.96	4.46	0.17	0.64	1.28	0.06	2.15	0.99
May	31.06			0.31			1.84	22.00	2.53	0.64	3.39	0.36	3.75	0.57	0.09	3.21	4.36	0.30	0.84	1.52	0.17	2.66	0.95
Jun	33.10			0.31			1.98	22.08	2.60	0.66	3.41	0.17	3.78	0.48	0.12	3.30	5.56	0.49	0.91	1.61	0.31	2.81	0.98
Jul	34.25			0.31			2.03	22.11	2.67	0.64	3.41	0.00	4.30	0.26	0.17	3.41	5.77	0.64	0.99	1.79	0.35	2.76	1.00
Aug	34.47			0.30			1.91	22.05	2.42	0.84	3.53	0.00	4.88	0.34	0.16	4.05	5.86	0.61	0.93	1.78	0.36	2.79	1.00
Sep	34.76			0.28			1.46	22.11	2.68	0.74	3.53	0.00	4.54	0.24	0.19	3.77	5.71	0.20	0.97	1.69	0.49	2.90	1.05
Oct	31.88			0.31			1.73	21.85	2.44	0.67	3.45	0.00	4.41	0.35	0.06	2.76	5.67	0.11	0.87	1.56	0.10	2.75	1.01
Nov	28.59			0.31			1.64	21.96	2.19	0.64	3.10	0.00	4.18	0.30	0.04	2.83	5.37	0.01	0.81	1.32	0.10	2.46	0.99
Dec	27.30			0.31			1.61	21.81	2.16	0.63	2.54	0.00	3.50	0.35	0.00	2.73	4.78	0.05	0.82	1.23	0.00	2.79	1.04
Average Annual	30.49			0.30			1.69	21.35	2.31	0.69	3.07	0.17	3.98	0.41	0.07	2.94	5.16	0.23	0.84	1.46	0.16	2.56	1.09

Table 1.2-2: Current and Proposed Monthly Returns (% of Monthly Withdrawal)

	Percent of Withdrawals Returned																										
	HARTWELL												RUSSELL						THURMOND								
	ARJWS	ARJWS NEW	Pioneer New	Lavonia	Lavonia New	Curahee New	Hart County	Clemson U	Clemson AG	Clemson Golf	City of Hartwell	JP Stevens	Abbeville	CalhounFalls	Elberton	Mohawk	RBR State Park	Rainey	Columbia County	Hickory Knobb	Lincolnton1	McCormick	Monticello Golf	Tara Golf	Sav Valley	Thompson	Washington
Storage (AC-FT)	**24620**	*13000*	4063	**127**	2437	406.2	**1827**	R	R	R	R	R	R	**110**	**381**	R	R	**491**	**1056**	R	92	**822**	0	0	**92.4**	**1056**	**632**
% Returns Hartwell	23.6%	23.6%	22.7%	6.2%	6.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% Returns Russell	64.7%	64.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	52.6%		14.6%	0.0%	23.7%	298.9%	5.0%	42.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% Returns Thurmond	0.0%	0.0%	0.0%	29.1%	29.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		34.2%		49.4%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	3.4%	3.7%
% Returns River	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		0.0%		0.0%	0.0%	0.0%	0.0%	23.1%	0.0%	0.0%	125.9%	0.0%	0.0%	0.0%	0.0%	0.0%

1.3 Water Supply Reallocation Requests

In this study, four separate entities requested M&I water supply storage from Hartwell Reservoir: Anderson Regional Joint Water System (ARJWS); Pioneer Rural Water District (PRWD); the City of Lavonia; and the Currahee Club.

ARJWS, PRWD, and the City of Lavonia all supply M&I water to end users. The Currahee Club would be considered an industrial end user. The City of Lavonia and ARJWS currently have agreements with the Corps to withdraw water from Hartwell Lake. Their new requests would increase water supply storage beyond their existing contracts.

Each new storage request was communicated as a desired yield, in terms of Million Gallons per Day (MGD). The study process required determination of the yield that can be expected from the existing storage accounts at Hartwell. Then the new requests could be translated into approximate estimates of the storage necessary to yield the requested amounts. Many iterations and verification of those calculations are described in the next sections. Table 1.3-1 displays each new request in Million Gallons per Day (MGD) and the initial estimated storage required to support the request in acre-feet. It also displays existing agreements for water supply storage in Hartwell Lake with ARJWS and the City of Lavonia.

Table 1.3-1: Current and Proposed (Storage and Yield)

Project	Existing Agreement Storage (Acre-Feet)	Estimated Current Yield (CFS)	New Requested Yield (MGD)	New Requested Yield (CFS)	Estimated New Required Storage (Acre-Feet)
HARTWELL					
Anderson (ARJWS)	24,620	46.3	16.05	24.83	13142
City of Lavonia	127	0.24	3.0	4.64	2428
Hart County	1827	3.42			
Pioneer (PRWD)	0		5.0	7.74	3975
Currahee Club	0		0.5	0.77	410
Hartwell Total	26574	50.08	24.55	37.98	19954
RUSSELL					
Calhoun Falls	110	2.032			
Elberton	381	16.72			
Rainey	491	23.41			
Russell Total	982	42.082			
THURMOND					
Columbia County	1056	4.35			
Lincolnton	175	0.72			
McCormick	822	3.36			
Savannah Valley	92.4	0.26			
Thompson	1056	4.36			
Washington	632	2.67			
Thurmond Total	3433.4	15.74			

2.0 Model Selection and Development

The HEC-ResSim software was developed by the U.S. Army Corps of Engineers to model reservoir operations at one or more reservoirs for a variety of operational goals and constraints. The software simulates reservoir operations for flood management, low flow augmentation and water supply for planning studies, detailed reservoir regulation plan investigations, and real-time decision support. The following describes the major features of HEC-ResSim:

- Graphical User Interface
- Map-Based Schematic
- Conditional Rule-Based Operations

2.1 Graphical User Interface

Designed to follow Windows® software development standards, HEC-ResSim's interface does not require extensive tutorials to learn to use. Familiar data entry features make model development easy, and localized "mini plots" graph the data entered in most tables so that errors can be seen and corrected quickly. A variety of default plots and reports, along with tools to create customized plots and reports, facilitate output analysis.

2.2 Map-Based Schematic

HEC-ResSim provides a realistic view of the physical river/reservoir system using a map-based schematic with a set of element drawing tools. Also, with the hierarchical outlet structure, the modeler can represent each outlet of the reservoir rather than being limited to a single composite outlet definition.

Schematic - The program's user interface allows the user to draw the network schematic either as a stick figure or an overlay on one or more geo-referenced maps of the watershed.

Drawing Tools - HEC-ResSim represents a system of reservoirs as a network composed of four types of physical elements: junctions, routing reaches, diversions, and reservoirs. By combining these elements, the HEC-ResSim modeler is able to build a network capable of representing anything from a single reservoir on a single stream to a highly developed and interconnected system like that of California's central valley.

Reservoir - A reservoir is the most complex element of the reservoir network and is composed of a pool and a dam. HEC-ResSim assumes that the pool is level (i.e., it has no routing behavior) and its hydraulic behavior is completely defined by an elevation-storage-area table. The real complexity of HEC-ResSim's reservoir network begins with the dam.

Hierarchical Outlet Structure - The dam is the root of an outlet hierarchy or "tree" which allows the user to describe the different outlets of the reservoir in as much detail as is deemed necessary. There are two basic and two advanced outlet types. The basic outlet types are controlled and uncontrolled. An uncontrolled outlet can be used to represent an outlet of the reservoir, such as an overflow spillway, that has no control structure to regulate flow. Controlled outlets can be used to represent any outlet capable of regulating flow, such as a gate or valve. The advanced outlet types are power plant and pump, both of which are controlled outlets with additional features to represent their special purposes. The power plant outlet can be used to track energy production. The pump outlet is even more specialized because its flow direction is opposite that of the other outlet types, and it can draw water up into the reservoir from the pool of another reservoir. The pump outlet type was added to enable the user to model pump-back operation in hydropower systems, although hydropower is not required for its operation.

2.3 Rule-Based Operations

Most reservoirs are constructed for one or more of the following purposes: flood control, power generation, navigation, water supply, recreation, and environmental quality. These purposes typically define the goals and constraints that describe the reservoir's release objectives. Other factors that may influence these objectives include time of year, hydrologic conditions, water temperature, current pool elevation (or zone), and simultaneous operations by other reservoirs in a system. HEC-ResSim is unique among reservoir simulation models because it attempts to reproduce the decision-making process that human reservoir operators must use to set releases. It uses an original rule-based description of the operational goals and constraints that reservoir operators must consider when making release decisions. As HEC-ResSim has developed advanced features such as outlet prioritization, scripted state variables, and conditional logic have made it possible to model more complex systems and operational requirements.

USACE, Savannah District used HEC-ResSim to mimic the operations of the USACE and Duke Energy Savannah River Projects. HEC-ResSim was set to operate on a daily time-step using an unimpaired inflow dataset (UIF) developed by GADNR-EPD. These inflows extended from January 1939 to December 2013. Different alternatives were developed within in HEC-ResSim to mimic the set of study Alternatives that the Comprehensive Study partners came up with. Each HEC-ResSim alternative has its own rule set which defined the behavior/operation of each project in the system. Initially the team came up with four alternatives focused on different goals. These would be evaluated prior to defining the final two alternatives which were based on features of the first four. HEC-ResSim operates on a user prioritized set of rules. Each rule has its own objective. Some rules can coincide with other rules without violating each other. However, many rules will often conflict with each other and the rule highest in the priority stack will be met. Rules lower in the priority stack will only be met if conditions of the higher priority rules have already been met and the lower rule does not cause the higher priority rules to be violated.

2.4 Configuration Development

A new watershed was built using HEC-ResSim Build 3.2.1.99 specifically for this study to ensure no potential influence of residual effects from previous studies or effects from other previously modeled results. See Figure 2.4-1 below for the model schematic. Water supply releases were modeled using diverted outlets directly from each reservoir. As stated previously, monthly varying water supply returns were modeled as negative diversions at each reservoir's inflow node. Water supply diversions downstream of

Thurmond were also held constant at current demands (average of 2017-2019) as provided by GAEPD.

Georgia DNR developed a 75 year (Jan 1939 - Dec 2013) unimpaired inflow dataset which was used for all alternatives. Configurations were developed to reflect the current physical characteristics of the Savannah River system, as well as the current operating rules of the system. These operating rules reflected the 2012 Drought Plan including the addition of a 200 cfs mitigation feature due to the Duke Energy Keowee-Toxaway project relicensing.

Monthly water withdrawal and return information, Table 1.3-1, was provided by the current water supply entities, verified with their state water use permits, and then coded into the HEC-ResSim model. Each user has a slightly different monthly withdrawal pattern, and when projecting future demands, the recent (2015-2022) withdrawal patterns for each user were maintained. Likewise, the ratio of return flows to withdrawals was assumed to remain constant, so future returns were increased proportional to the increased yield requested. The withdrawal/return flow ratio will likely change over time as population and usage patterns change as well as treatment methods become more efficient. The monthly pattern of withdrawals and returns were shown in Table 1.2-1 and Table 1.2-2 respectively.

Updated hydropower capacity and efficiency data was provided by the Hydropower Analysis Center and subsequently coded into the model to increase accuracy.

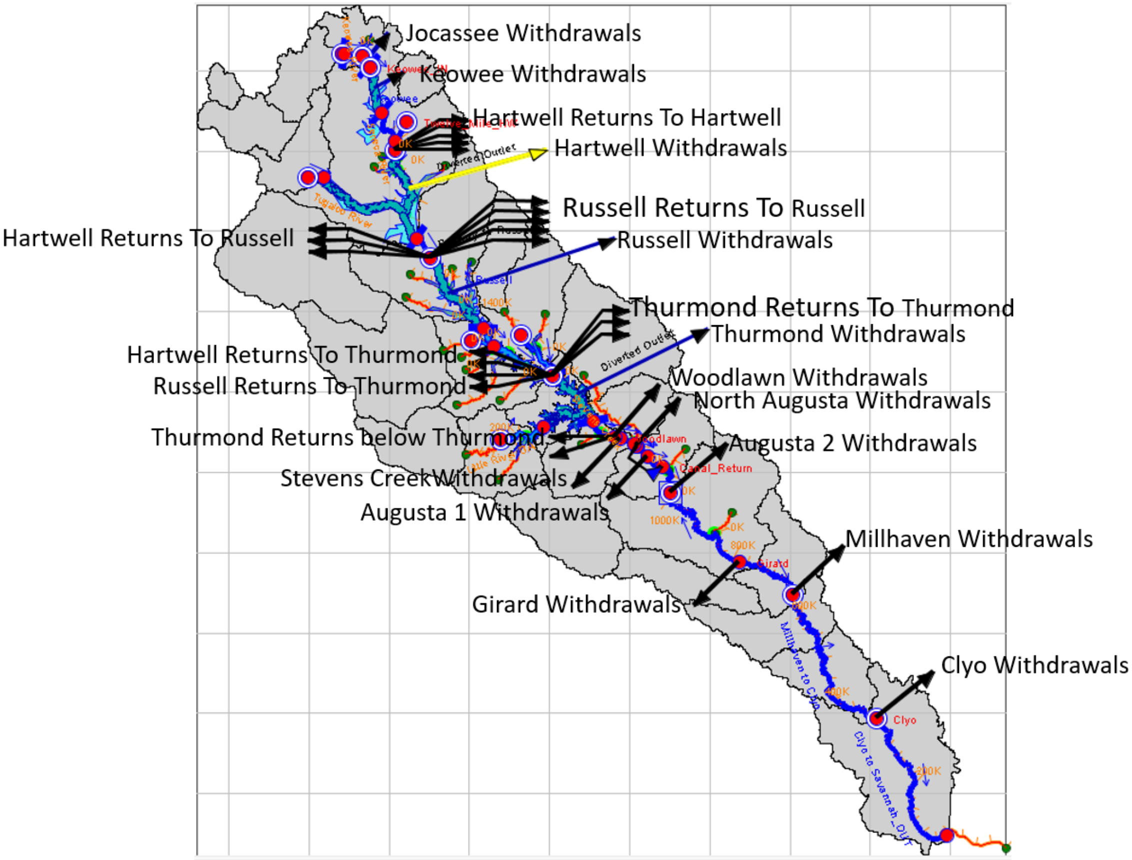


Figure 2.4-1: HEC-ResSim Watershed Diagram

2.5 Reservoir Inflow and Local Incremental Flow Computation

Reservoir inflow is a key component of Unimpaired Flow (UIF) data. In the initial development of UIF for 1939-2008, Arcadis Consultants used two different approaches to compute reservoir inflows. For Jocassee and Keowee, the reservoir inflows were computed from storage change between two adjacent days and releases. For Hartwell, Russell and Thurmond, the better quality controlled USACE net inflow data was used. These USACE inflows were then adjusted to remove accumulated bias from the time series by comparing the annual accumulated change in storage computed using the USACE inflow and outflow with the observed change in storage over a year (Georgia DNR, 2010).

Georgia DNR extended the UIF from 2009 to 2013. The reservoir inflows were computed using storage change and release for all five major reservoirs in the basin given continuous quality-controlled reservoir operational data time series for 2009-2013. After reservoir inflows were computed, the local incremental flow at a downstream node was obtained by subtracting the upstream flow/release from the downstream reservoir inflow. The UIF dataset has a daily timestep, and the routing time between reservoirs is less than a day. Null routing was used where the system passes water directly from reservoir to reservoir.

One unique feature in the Savannah River basin is that Bad Creek-Jocassee-Keowee and Russell-Thurmond are two pump-back systems. During the reservoir local incremental flow (LIF) computation, it was found that reservoir pumping data may introduce much uncertainty and may yield a large number of negative LIFs and consequent negative UIFs. In order to reduce the effect of pumping data, the monthly cumulative LIF was computed first, then was redistributed into daily values according to the flow pattern of a nearby reference gage for each individual reservoir. If a monthly cumulative LIF was negative, then it was evenly redistributed into daily instead of using the flow pattern of the reference gage. This approach was applied to Jocassee, Keowee, Russell, and Thurmond. The comparison in negative UIFs at pump-back system reservoir nodes shows that the redistribution approach reduced negative UIFs in both frequency and degree (Table 2.5-1).

Table 2.5-1: Comparison of raw negative UIFs for 2009-2013 period.

	Count of negative UIFs		**Average negative UIFs (cfs)**		**Extreme negative UIF (cfs)**	
Reservoir Node	**Observed daily data**	**Redistributed daily data**	**Observed daily data**	**Redistributed daily data**	**Observed daily data**	**Redistributed daily data**
Jocassee	526	299	-311	-146	-1747	-558
Keowee	302	153	-1054	-487	-10748	-2113
Russell	891	861	-459	-289	-4789	-1966
Thurmond	184	51	-1050	-681	-24515	-3042

2.5.1 Negative local UIF adjustment

Several factors, such as under-estimate of reservoir net evaporation loss, imperfect stream flow routing process, possible pump-back data effect, and possible natural flow loss (e.g., downstream observed flow without significant water use is less than upstream observed flow), may result in some negative local UIFs. The treatment of negative local UIFs were different between 2009-2013 UIF extension and the original 1939-2008 UIF development.

In 1939-2008 UIF, all negative local UIFs were removed by different adjustments, including local adjustment, annual adjustment, and period of record adjustment. Details of these adjustment approaches can be found in 1939-2007 UIF report (GADNR, 2010). The adjustment of negative UIFs is essentially a temporal redistribution of the UIF while keeping the mass balance.

In 2009-2013 UIF, negative local UIFs were carefully reviewed and adjusted or not adjusted at all depending on the possible major causes of negatives. Several types of treatments are list as follows:

1. At Hartwell node, the very few negative local UIFs that occurred in dry seasons are very likely due to an under-estimate of net evaporation loss. Those negatives were removed by local adjustment approach.

2. At Jocassee, Keowee, Russell and Thurmond nodes, the negative local UIFs are very likely due to a combination of an under-estimate of net evaporation loss and the imperfect pump-back data. Some of the pump-back data could not be reconciled with project elevation (and thus storage) data. For example, on March 2, 2012, Thurmond has a release of 3,896 cfs, a pump-back of 5,247 cfs, receives a release of 7,522 cfs from Russell, and a change of storage of –30,600 acre-feet. Simple mathematic calculation indicates that the reservoir received −13,810 cfs during the day with a precipitation event. EPD staff speculated that the pump-back flow values were calculated from recorded energy consumption, instead of physically measured. The imperfect relationship between energy consumption and flow may have led to overestimate of pumped flow, which in turn leads to negative inflow to the reservoirs. Those negatives were not adjusted.

3. At unregulated nodes, some negative UIFs were caused by imperfect numerical stream flow routing and others appeared to be natural flow loss, which is indicated by observed data, such as that the downstream observed flow is less than upstream observed flow without significant water use at downstream node. For the negatives due to imperfect stream flow routing, local adjustment approach was applied to remove the negatives. For the negatives appeared to be natural flow loss, negative UIFs were not adjusted. The time series of natural flow loss at associated nodes are included in UIF dss files.

   Natural flow loss can be categorized into three cases. The first case is the flow loss due to gage data. For example, the observed data show the persistent differences between Thurmond release and observed Augusta flow, with latter one being lower for several months in 2012 (Figure 2.5-1). This type of flow loss may not be real since there is no evidence showing natural flow loss occurred between Thurmond and Augusta. The reason of such flow difference is not clear and further investigation of observed data is needed. The second case is the real natural flow loss during high flow periods. For example, the observed data show Burtons Ferry gage flow has been lower than the upstream Augusta gage flow in several months of high flow period (Figure 2.5-2). EPD staff believed it was due to floodplain connection and water lost during the overbank flow period has not come back to the main channel. The third case is the real natural flow loss during low flow periods. For example, the observed data show Clyo gage flow has been persistently lower than flow observed at upstream Burton Ferry gage in several months in low flow period (Figure 2.5-3). The hydrographs clearly show that flow peaks and valleys at Clyo were delayed compared to those at Burtons Ferry and the flow magnitudes at Clyo were persistently lower than that at Burtons Ferry. Such flow loss could be due to stream flow recharging to a local surficial aquifer.

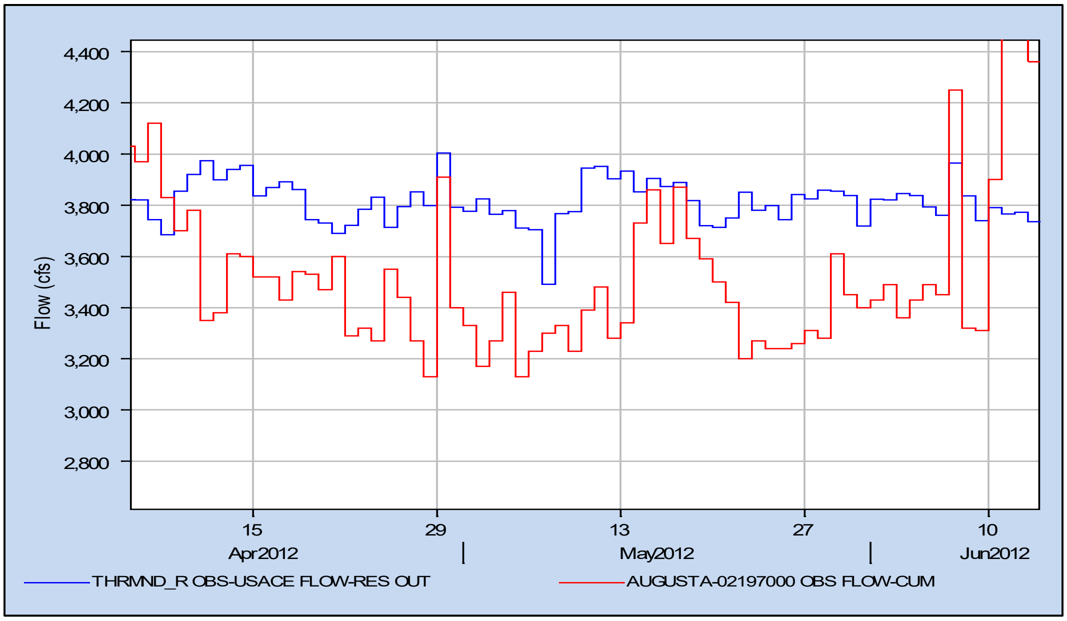


Figure 2.5-1: Flow loss at Augusta node.

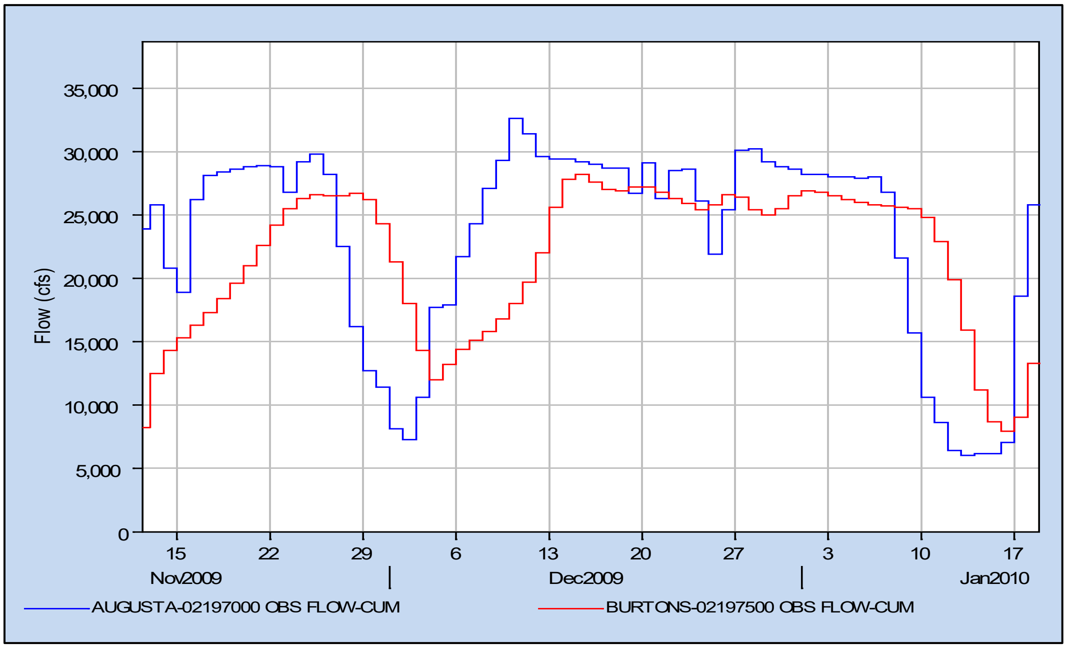


Figure 2.5-2: Natural flow loss at Burtons Ferry node.

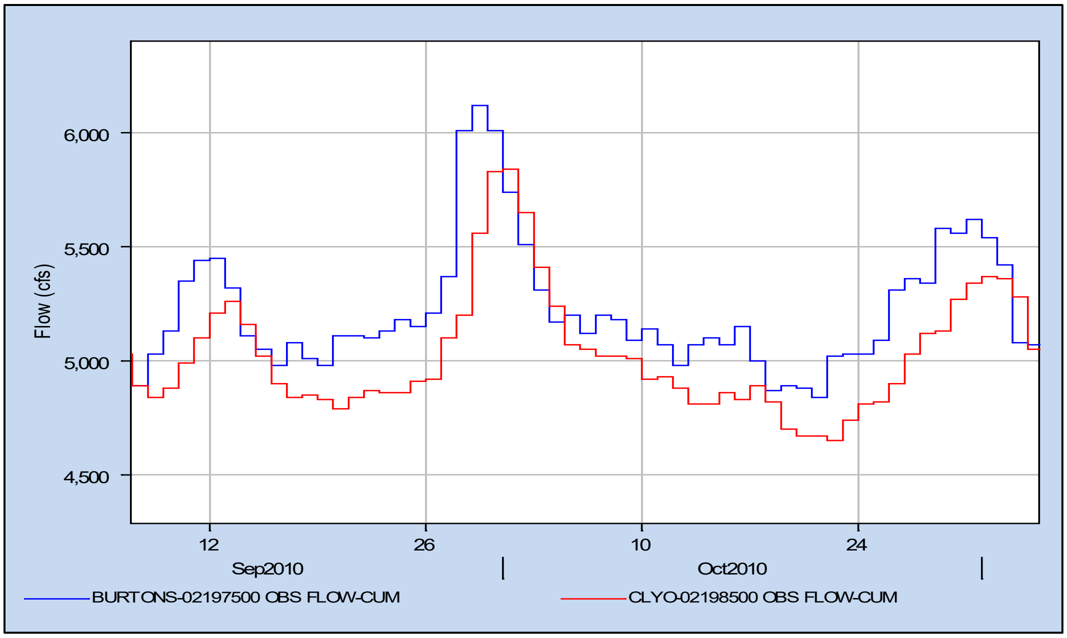


Figure 2.5-3: Natural flow loss at Cylo node.

2.5.2 Preliminary Product

The preliminary product of 2009-2013 UIF extension includes the time series of local UIF for each node in Savannah River basin (see SO-UIFX4.dss). The 2009-2013 UIF time series were also appended to the original 1939-2008 UIF time series (see SO-UIFX4-Merged.dss). Table 2.5-1 and Table 2.5-2 show the time series of the local UIF for each node. Table 2.5-3 shows the descriptions of all the time series in SO-UIFX4.dss and SO-UIFX4-Merged.dss.

There are some differences in node configurations between Georgia EPD and Corps HEC-ResSim model. As shown in Table 2.5-4, ResSim configuration include Bad Creek node while Georgia EPD's configuration does not. Georgia EPD's configuration includes Bell node on Broad River and Millhaven node on Brier Creek while ResSim configuration does not. Due to the difference in node configuration and for ResSim modeling purpose, Jocassee and Bad Creek combined UIF is split into Bad Creek UIF and Jocassee UIF by 1% and 99% respectively. The Bell-Thurmond sub-basin UIF and Millhaven (on Brier Creek)-Clyo sub-basin UIF are also developed for the same reason. The suggested local UIFs for the nodes in the HEC-ResSim model are listed in Table 2.5-6. During the review of the original 1939-2008 UIF data, EPD staff found that water use in Keowee node was credited back to Hartwell node, resulting in an over-estimate of Hartwell local UIF. This over-estimate of Hartwell local UIF has been corrected for the 1939-2008 period (see SO-UIFX4-Merged.dss).

Table 2.5-2: Savannah River basin 2009-2013 UIF time series

Reservoir/Node	DSS Part: B	DSS Part: F
Jocassee and Bad Creek Combined	KEOWEE_R-JOCASS_R	UNIMP*
Keowee	KEOWEE_R	UNIMP*
Hartwell	HARTWL_R	UNIMP-0ADJ LOC*
Russell	RBR_R	UNIMP*
Thurmond[1]	THRMND_R	UNIMP*
Augusta	AUGUSTA	UNIMP-0ADJ LOC*
Burtons Ferry	BURTONS	UNIMP-0ADJ LOC*
Millhaven (Brier Crk)	MILLHAVN	UNIMP*
Clyo	CLYO	UNIMP-0ADJ LOC*
Savannah	SAVANNAH	UNIMP*

[1] Thurmond UIF includes Bell flow.

Table 2.5-3: Savannah River basin 1939-2013 UIF time series

Reservoir/ Node	DSS Part: B	DSS Part: F	DSS Part: F	DSS Part: F
		1939-2008	2009-2013	1939-2013
Jocassee and Bad Creek Combined	KEOWEE_R-JOCASS_R	UNIMP-0ADJ ANNUAL*	UNIMP*	UNIMP-MERGED-EPD2014
Keowee	KEOWEE_R	UNIMP-0ADJ ANNUAL*	UNIMP*	UNIMP-MERGED-EPD2014
Hartwell	HARTWL_R	UNIMP-0ADJ LOC*	UNIMP-0ADJ LOC*	UNIMP-MERGED-EPD2014
Russell	RBR_R	RDIST UNIMP-0ADJ POR*	UNIMP*	UNIMP-MERGED-EPD2014
Thurmond[1]	THRMND_R	RDIST UNIMP-0ADJ ANNUAL*	UNIMP*	UNIMP-MERGED-EPD2014
Augusta	AUGUSTA	UNIMP-0ADJ ANNUAL*	UNIMP-0ADJ LOC*	UNIMP-MERGED-EPD2014
Burtons Ferry	BURTONS	UNIMP-0ADJ ANNUAL*	UNIMP-0ADJ LOC*	UNIMP-MERGED-EPD2014
Millhaven (Brier Crk)	MILLHAVN	UNIMP*	UNIMP*	UNIMP-MERGED-EPD2014
Clyo	CLYO	UNIMP-0ADJ POR*	UNIMP-0ADJ LOC*	UNIMP-MERGED-EPD2014
Savannah	SAVANNAH	UNIMP*	UNIMP*	UNIMP-MERGED-EPD2014

[1] Thurmond and Bell UIFs were separated for 1939-2008 and not separated for 2009-2013.

Table 2.5-4: Descriptions of time series

DSS Part: C	DSS Part: F	Description
FLOW-DIV NET	COMP-REACH TOTAL	Net consumptive water use
FLOW-LOC INC	COMP-MERGED-EPD2014	Impaired local incremental flow
FLOW-LOC INC	UNIMP-RAW-MERGED-EPD2014	Raw unimpaired local incremental flow
FLOW-LOC INC	UNIMP-MERGED-EPD2014	Adjusted unimpaired local incremental flow
FLOW-COMB-INC	UNIMP-MERGED-EPD2014	Sub-basin unimpaired local incremental flow
FLOW-LOC INC	NATURAL LOSS	Natural flow loss
EVAPNET-RATE	POST-PRE RES	Differential net reservoir evaporation rate
FLOW-EVAPNET	POST-PRE RES	Differential net reservoir evaporation effect
FLOW-NET RE	COMP 1DAY	Net reservoir effect
FLOW-HOLDOUT	COMP 1DAY	Reservoir storage change between two consecutive days
EVAPNET-RATE	POST RES	Net reservoir evaporation rate
FLOW-EVAPNET	POST RES	Net reservoir evaporation effect
FLOW-NET RE	COMP 1DAY	Net reservoir effect
FLOW-LOC INC	OBS, or FILLED, or COMP	Impaired LIF
FLOW-LOC INC	UNIMP	Raw Local UIF without any adjustment
FLOW-LOC INC	UNIMP-0ADJ LOC	Local UIF with the removal of negatives using local adjustment approach[1]
FLOW-LOC INC	UNIMP-0ADJ ANNUAL	Local UIF with the removal of negatives using annual adjustment approach[1]
FLOW-LOC INC	UNIMP-0ADJ POR	Local UIF with the removal of negatives using period of record adjustment approach[1]

[1] Details of adjustment approaches see 1939-2007 UIF report (GADNR, 2010).

Table 2.5-5: Node configurations of Georgia EPD and Corps HEC-ResSim model.

DSS Part: B	Georgia EPD Node	HEC-ResSim Node
KEOWEE_R-JOCASS_R	Jocassee and Bad Creek Combined	Bad Creek
KEOWEE_R-JOCASS_R	Jocassee and Bad Creek Combined	Jocassee
KEOWEE_R	Keowee	Keowee
HARTWL_R	Hartwell	Hartwell
RBR_R	Russell	Russell
BELL	Bell	N/A
THRMND_R	Thurmond	Thurmond
AUGUSTA	Augusta	Augusta
BURTONS	Burtons Ferry	Savannah @ Millhaven
MILLHAVN	Millhaven on Brier Creek	N/A
CLYO	Clyo	Clyo

Table 2.5-6: Suggested local UIF DSS time series for HEC-ResSim model

HEC-ResSim Node	DSS Part: B	DSS Part: C	DSS Part: F
Bad Creek[1]	BADCREEK	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Jocassee[2]	JOCASSEE	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Keowee	KEOWEE_R	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Hartwell	HARTWL_R	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Russell	RBR_R	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Thurmond[3]	THRMND_R	FLOW-COMB INC	UNIMP-MERGED-EPD2014
Augusta	AUGUSTA	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Millhaven	BURTONS	FLOW-LOC INC	UNIMP-MERGED-EPD2014
Clyo[4]	CLYO	FLOW-COMB INC	UNIMP-MERGED-EPD2014

[1,2] Bad Creek and Jocassee local UIF in ResSim model are 1% and 99% of Jocassee and Bad Creek combined UIF respectively. Note that Bad Creek gas drainage area of only several square miles.

[3] Thurmond local UIF in ResSim model is Bell-Thurmond sub-basin combined UIF.

[4] Clyo local UIF in ResSim model is Millhaven-Clyo sub-basin combined UIF.

2.5.3 Verification

After the preliminary 2009-2013 UIFs were developed, both Savannah HEC-ResSim model and Excel Spreadsheet model were used to verify the preliminary UIF data at the reservoir nodes. The verification is essentially the mass balance check, using developed UIFs and observed data to back-calculate the reservoir elevation. The verifications using both models show similar results.

In HEC-ResSim model, release overrides (forced release) option was used and simulated reservoir elevations were compared with observed ones. Verification for 2009-2013 period was divided into two periods, 2009-2012 and 2012-2013, since the current Savannah HEC-ResSim version (Version 3.2.1.76 Build 3.2.1.76R, 64-bits) cannot handle the release overrides for more than four years. The comparisons of reservoir elevations between HEC-ResSim simulated and observed show very close match of the two (figures below).

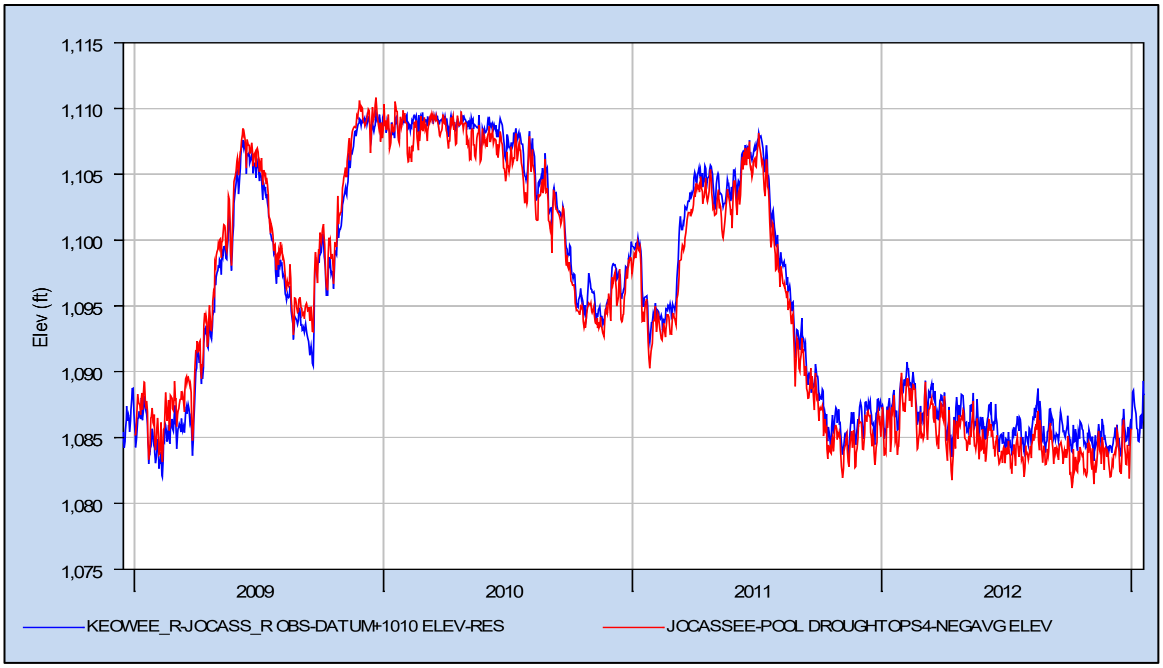


Figure 2.5.3-1. Comparison of Jocassee elevation (2009-2012): simulated (red) and observed (blue).

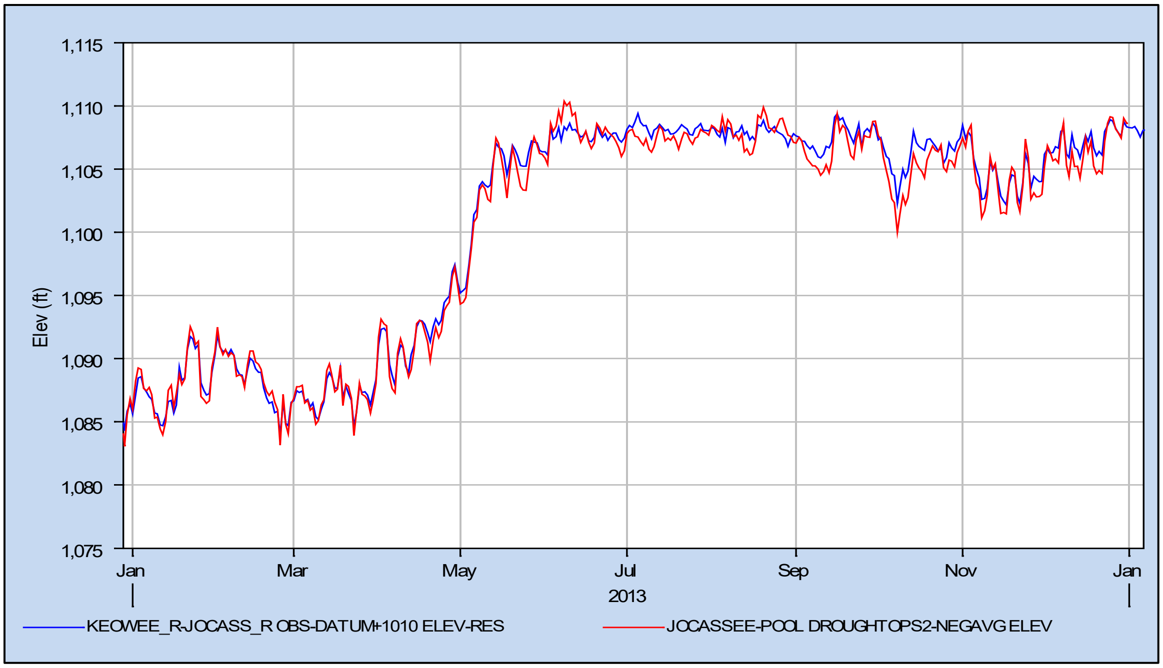


Figure 3.5.3-2. Comparison of Jocassee elevation (2013): simulated (red) and observed (blue).

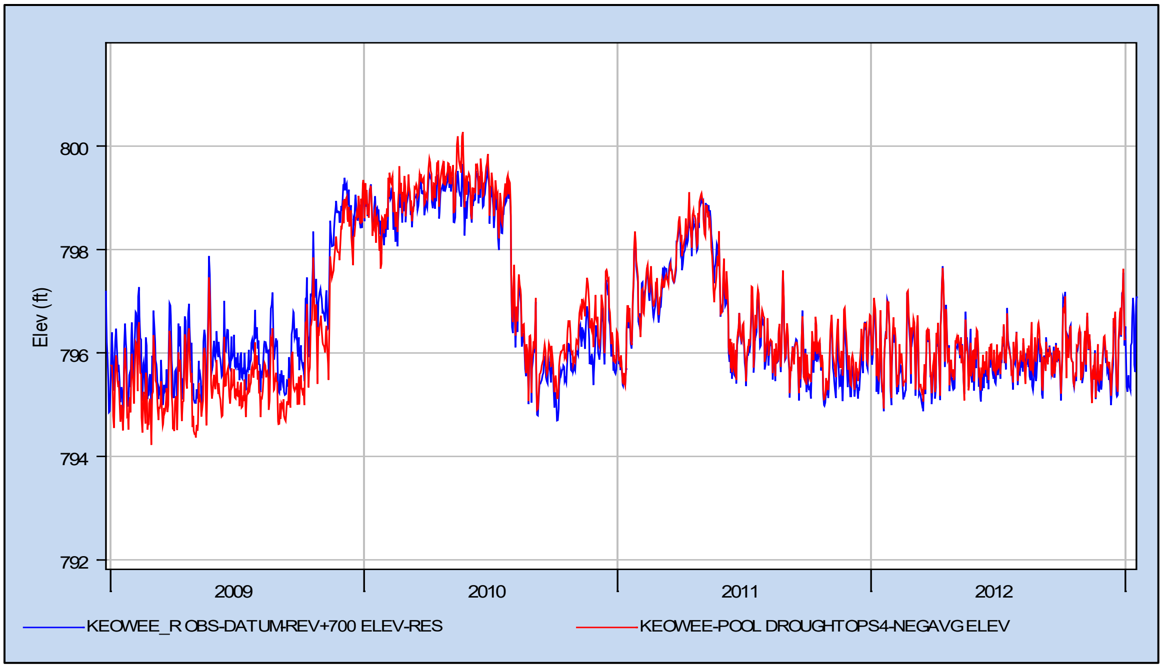


Fig 3.5.3-3. Comparison of Keowee elevation (2009-2012): simulated (red) and observed (blue).

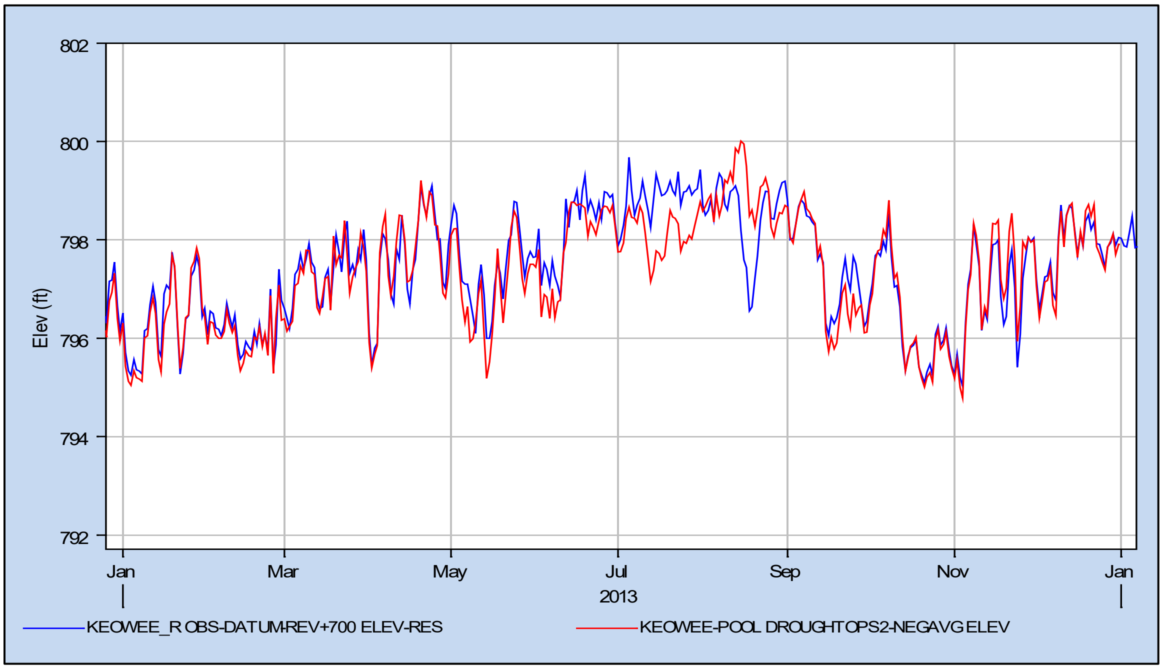


Fig 3.5.3-4. Comparison of Keowee elevation (2013): simulated (red) and observed (blue).

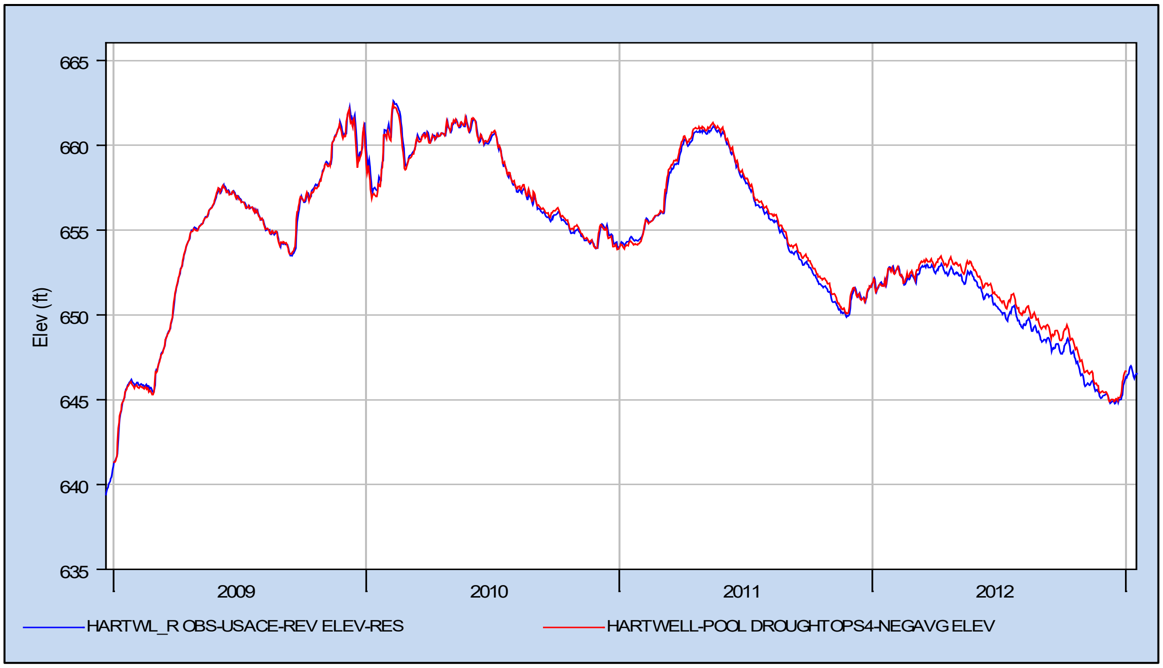


Fig 3.5.3-5. Comparison of Hartwell elevation (2009-2012): simulated (red) and observed (blue).

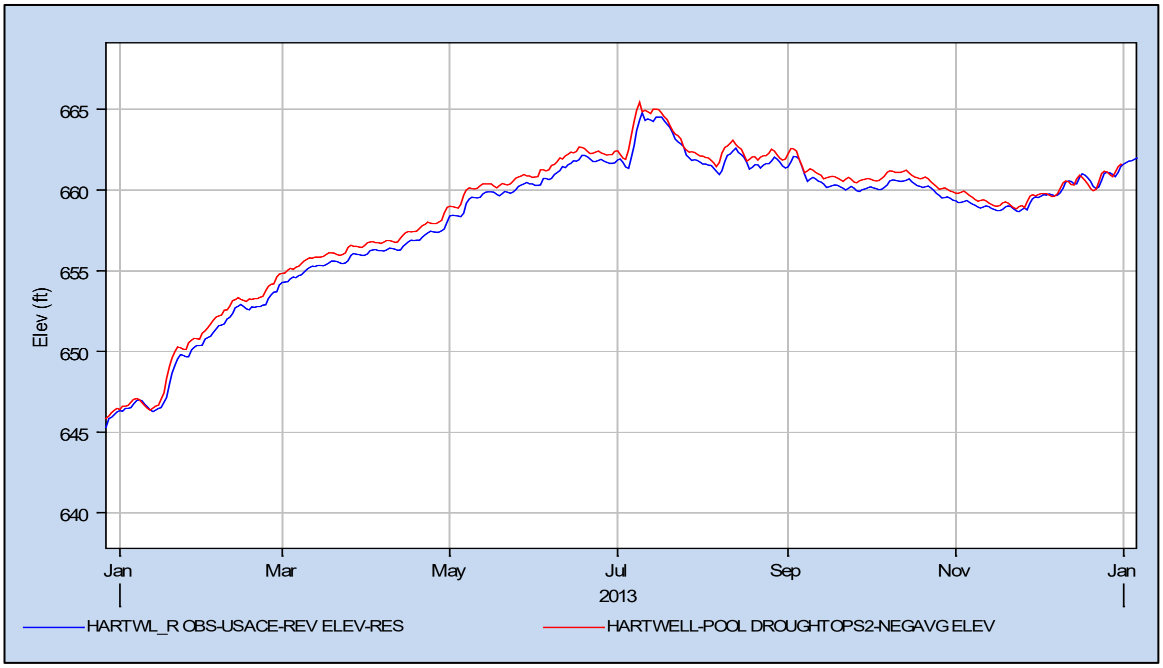


Figure 3.5.3-6. Comparison of Hartwell elevation (2013): simulated (red) and observed (blue).

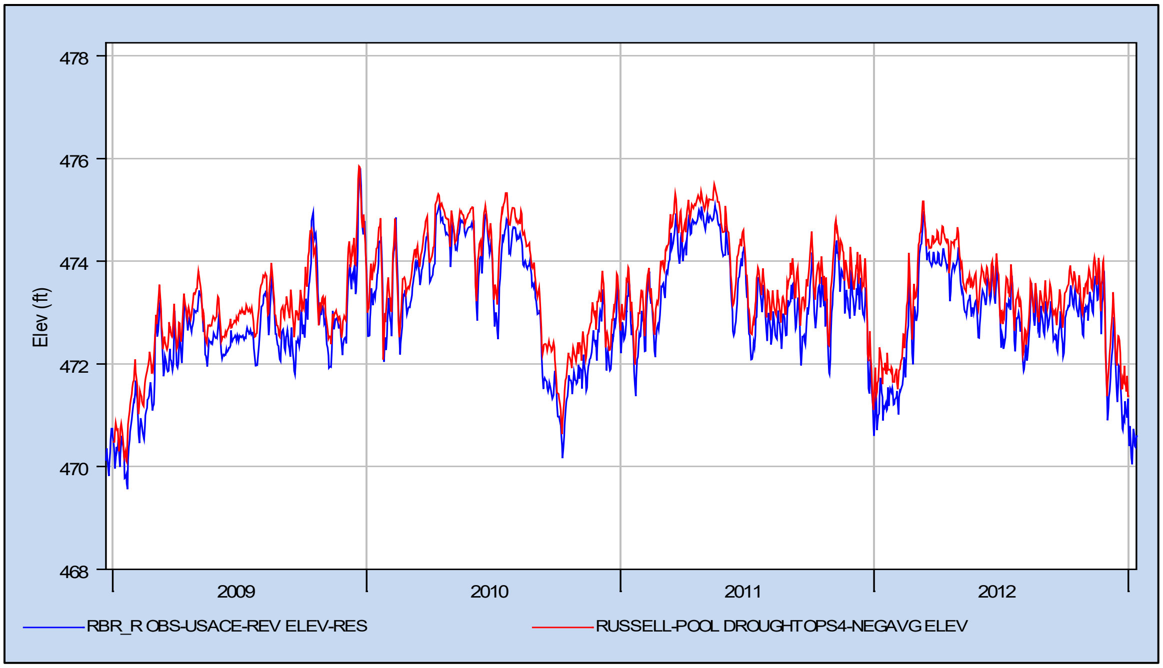


Figure 3.5.3-7. Comparison of Russell elevation (2009-2012): simulated (red) and observed (blue).

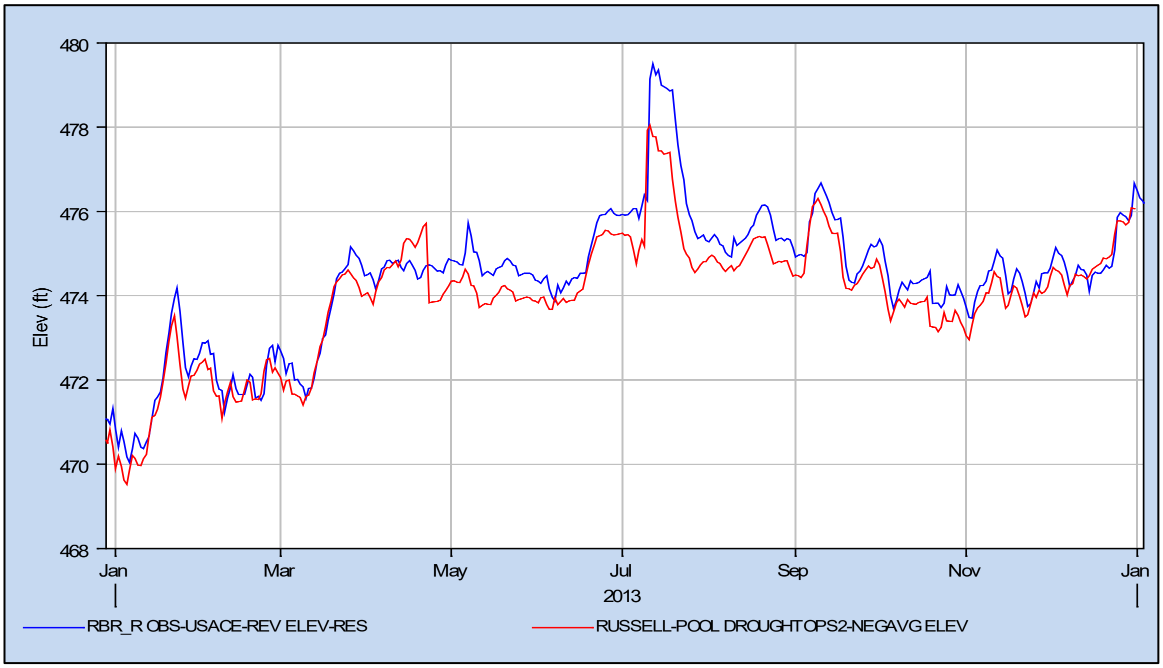


Fig 3.5.3-8. Comparison of Russell elevation (2013): simulated (red) and observed (blue).

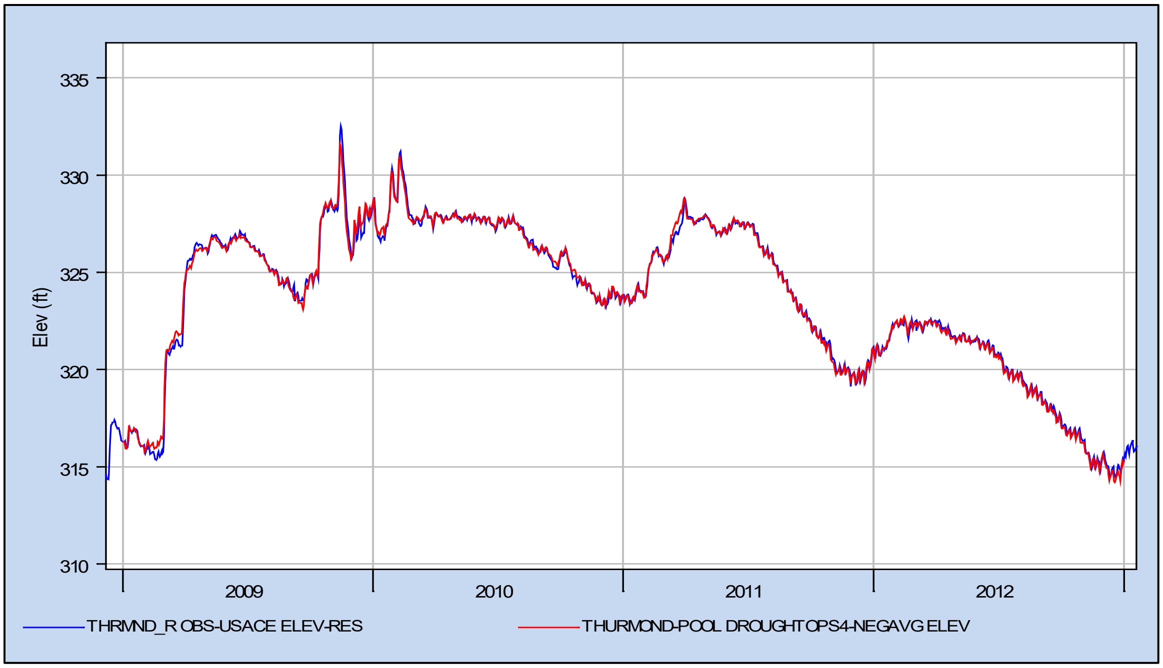


Figure 3.5.3-9. Comparison of Thurmond elevation (2009-2012): simulated (red) and observed (blue).

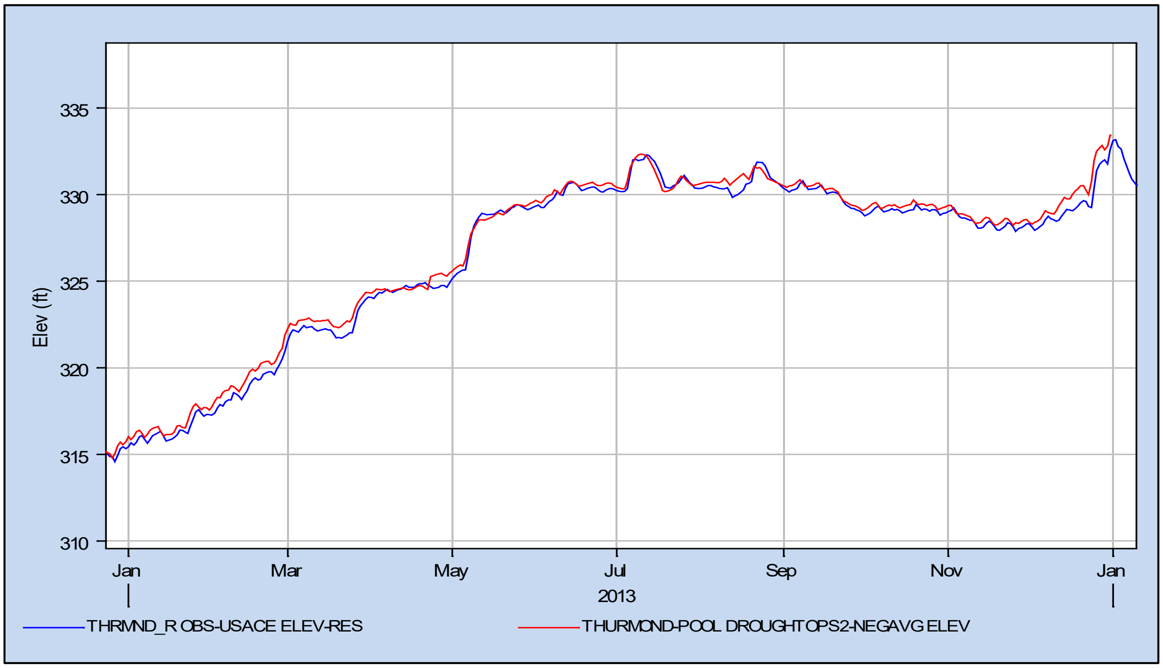


Figure 3.5.3-10. Comparison of Thurmond elevation (2013): simulated (red) and observed (blue).

2.5.4 Limitations

Several factors, such as under-estimate of reservoir net evaporation loss, imperfect stream flow routing process, possible pump-back data effect, and possible natural flow loss that of real or perceived loss of flow due to gage data (e.g. downstream observed flow without significant water use is less than upstream observed flow), may result in some negative local UIFs. However, accuracy of inflow data is suitable for these analyses. There are several ways to further improve UIF development, including obtaining a better estimate of precipitation\evaporation data, better stream flow routing, and better quality-controlled observed data (e.g. pumping data). Field investigation will also be helpful to exclude or confirm the natural flow loss.

2.6 Yield Analysis Assumptions

Assumptions made during the yield analysis model runs are as follows:

1. There is no attempt to address the probability that droughts more severe than those in the period of record (POR) may or may not occur.

2. The Yield analysis focused initially used the entire 75-year POR inflow dataset, (1939-2013). This helped identify the most critical drought periods which fell between 1998 – 2013. Subsequent runs refined the focus of the yield analysis to a 1998-2013 time window.

3. The observed (2017-2022) monthly-varying water supply usage patterns for each water supply contract holder were used for all yield analysis model runs. HEC-ResSim “scales” the withdrawal pattern up or down iteratively until the estimated yield is determined within user specified tolerances.

4. The Base Case (no-action alternative) scenario included the (2017-2022) average monthly water supply withdrawal for each contract holder as a diversion from the source reservoir. A diverted outlet element was used to define the monthly varying withdrawal pattern. The contract holders reported their observed monthly withdrawal values to GAEPD or SC DHEC and subsequently provided their withdrawals to USACE. Critical yield for each of the existing water supply contract holders was initially determined, which established the base condition.

5. Water is often returned to a different basin than it was taken from, i.e., Hartwell to Hartwell, Hartwell to Russell, Hartwell to Thurmond. Water returned to the system was modeled as diversions with negative values applied at the destination reservoir’s inflow node. A flexible diversion rule was used allowing any water that is returned to a reservoir to be estimated as a percentage of the initial withdrawal from the source reservoir. The percentage is based on the most recent 5 years of records, (2017-2022), from each contract holder.

6. Existing area-capacity and stage-storage curves were used as shown in the latest version of the Savannah River Basin Water Control Manual (1996).

7. Water accounts are full at the beginning and end of the analysis period being simulated. All Reservoirs are also full, at guide curve, at the beginning of the simulation run. The pool level at the beginning of a drought simulation is important because it is a variable that directly affects the quantity or volume of water available as critical yield.

8. Reach routings between reservoirs and reaches downstream of Thurmond are null to reduce compute times.

9. All alternatives being compared follow operations based on the existing Drought Management Plan (2012) with modifications resulting from the USACE-Duke Energy Storage Balance Agreement update (July 2014)..

10. Yield analysis is based three possible storage zones.

    a. The first scenario was to reallocate storage from the currently authorized conservation storage, guide curve down to top of inactive storage.
    b. The second scenario was to reallocate storage from the currently allocated flood storage by raising the top of the conservation storage into the flood storage by the amount of storage needed to support the requested yield. This was dropped from further consideration due to Dam Safety Criteria concerning the Clemson Diversion Dams which lie in the Hartwell pool.
    c. The third reallocation scenario was to determine the storage necessary to support the new request. We would then lower the bottom of the conservation pool by that amount, rerun HEC-ResSim to again verify the new yield, and rerun the yield of the existing contracts and determine any mitigation impacts on the existing contracts. This increase in storage of the conservation pool would have little or no impacts on the other intakes. However, the initial screening by HAC suggested that any reallocations from inactive storage would have a slightly negative impact on hydropower and would be less advantageous to the requestors than reallocation from conservation storage or reallocation from flood storage.

11. The yield for each water supply contract was resolved while simultaneously following current operating rules for all other project purposes. The HEC-ResSim model follows a prioritized stack of operational rules which often compete with one another.

12. All withdrawals, riparian or contracted, existing and proposed were modeled with diverted outlets reflecting the monthly varying withdrawals and returns. The same priority was given for meeting contracted demands as for meeting riparian demands.

2.7 Alternatives Modeled

Several iterations of modeling were done focused on reallocation of storage from Conservation Storage, Flood Storage, and Inactive storage. Initial alternatives targeted the existing contracted storage and the existing withdrawal and use seasonal patterns. These initial runs helped refine the later alternatives during which the water accounting algorithms were modified to include the analysis of return flow crediting, to be explained later. The first pass at modeling refers to the existing contracts as No Action Alternative NAA.

2.7.1 NAA Current Contracts (Conservation Storage)

All alternatives modeled were based on the operating rules currently implemented with the 2012 Savannah River Basin Drought Management Plan with several additional rules implemented after the 2014 USACE-Duke Energy Storage balance agreement update. The (NAA) was modeled using the currently defined conservation pools to support the existing water supply contracts. The initial runs established baseline yields for each of the existing water supply contracts at Hartwell, Russell, and Thurmond. Figure 2.7-1 shows the pool definitions at Hartwell and Thurmond.

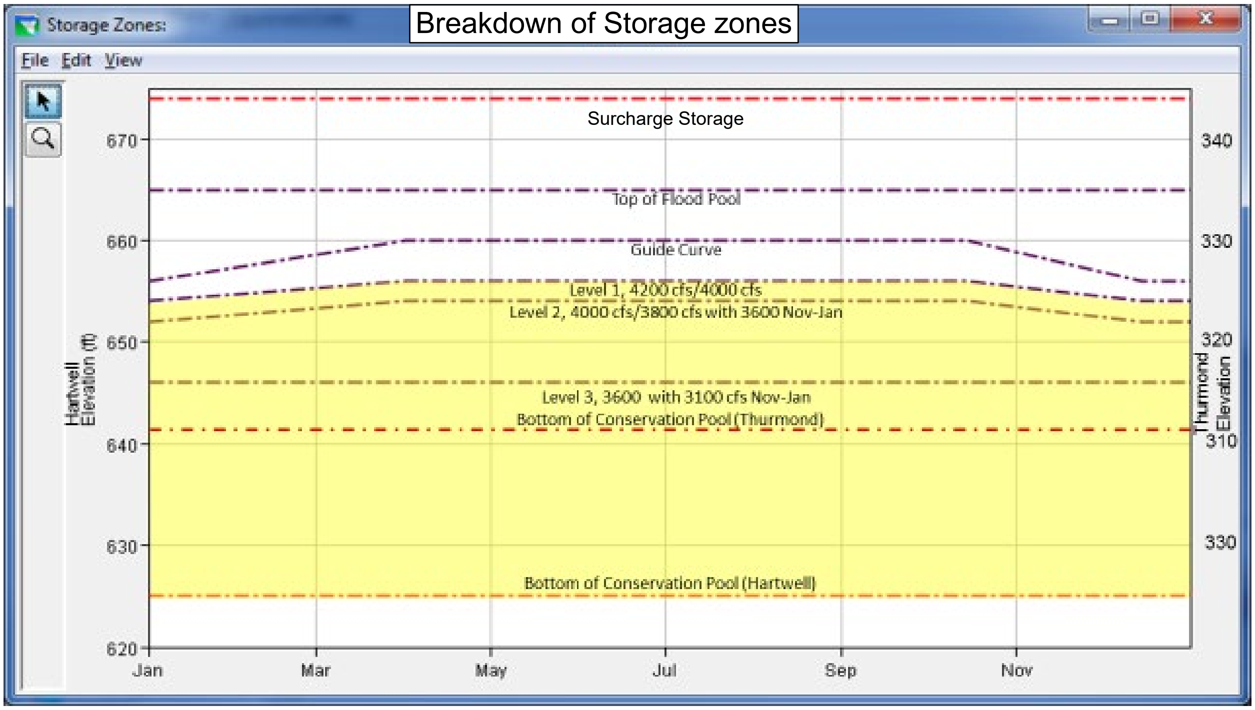


Figure 2.7-1: Hartwell/Thurmond Pool Depiction

The primary goal of HEC-ResSim is to operate a system of projects, attempting to get each pool to its respective guide curve. Additional rules are then created to target various objectives. These rules are set up in a prioritized stack. The highest priority is given to the rules defining the most critical needs during, typically flood control. The next lower priority is given to minimum and maximum flow requirements which then take priority over the drought rules. The maximum flow rules attempt to prevent downstream flooding while the minimum flow rules attempt to preserve downstream water supply and minimize environmental impacts. The drought rules then take priority over the system hydropower rules. Additional rules defining operations during fish spawn season are also implemented.

During drought, release restrictions at Thurmond will be triggered when either Hartwell or Thurmond decline through a drought trigger level. As pools recover the Thurmond flow restriction will not reset to the next higher level of restrictions until both the Hartwell and Thurmond pools have risen 2 feet above the trigger level that set the restriction. All trigger levels will follow this same transition behavior. It is important to note that the same system power rules and Russell pump rules appear in all the alternatives. All alternatives target a maximum channel capacity of 30,000 cfs at Augusta, a minimum release requirement of 3,600 cfs at Thurmond, as well as a minimum of 3,600 cfs at the Augusta gage. The 3,600 cfs minimum release requirement at Thurmond drops to 3,100 cfs between 01Nov and 01Feb if in Drought Level 3.

2.7.2 NAA plus New Request (Conservation Storage)

The NAA plus the new request was then modeled using the existing conservation pool to support the new request.

2.7.3 NAA plus New Request (Inactive Storage)

Finally, the same NAA was modeled allocating the storage needed to support the new request from the top of the inactive storage pool. In essence, the bottom of the conservation pool would be lowered by an amount equal to the amount of storage needed to support the new request. Again, this was an iterative process of estimating the storage needed to provide the new requested yield, running the yield analysis, adjusting the storage account, adjust the bottom of conservation down by that amount, adjusting the water supply returns in proportion to the new estimate of yield and then re-running the yield analysis. This process was repeated until the computed yield for the new water account equaled the yield of the new request with minimal variation.

2.8 System Considerations

The Corps operates the three Savannah River reservoirs, Hartwell, Russell, and Thurmond, as a system. Each of the projects operate to fulfill multiple congressionally authorized purposes. The three-lake system contains 6,909,300 acre-feet of water storage space (823,000 acre-feet for flood control storage, 2,587,800 acre-feet for conservation storage, and 3,498,500 acre-feet for inactive storage). Generally, pools are balanced based on feet down from Guide Curves to maintain equal impacts to projects purposes.

The three projects have an installed generation capacity of nearly 2000 MW. They work as a system to target a monthly varying weekly quantity of energy. The middle project, Richard B. Russell is a pumped-storage project capable of recycling their releases by reversing its turbines and pumping the water from the Thurmond reservoir back up into the Russell reservoir. Additional debugging was necessary to refine water accounting during pump storage operations.

Periods of excess rainfall will push the pool elevations into their flood storage. At this point the primary project purpose is Flood Risk Reduction. Operating rules focus on maintaining flood storage in Thurmond, the downstream project. Upstream Projects typically store inflows during a storm allowing Thurmond to return to Guide Curve by releasing it's flood storage. The primary damage center that can be affected by flooding is Augusta, a short distance downstream from Thurmond. Channel Capacity in the river at Augusta is considered to be 30,000 cfs.

Under normal hydrologic conditions, system rules drive hydropower production to meet a weekly generation target marketed by the Southeastern Power Administration (SEPA). All project purposes should be met at this point. The Hartwell and Thurmond Pools will balance based on feet down from their respective Guide Curve.

When operating for drought conditions, drought rules are progressively applied as the pools decline. The drought rules restrict releases attempting to balance impacts to the authorized project purposes.The current drought rules are based on the 2012 Drought Management Plan. Duke Energy has Projects above Hartwell that are required by agreement with USACE and SEPA to maintain a balance in storage with the USACE Projects. This Storage Balance Agreement was last updated in 2014. Mitigation added during this update requires supplimental releases from USACE and Duke Energy during critical periods of low Dissolved Oxygen DO in the lower Savannah River. There is a 3600 cfs minimum flow requirement at Augusta due to infrastucture impacts.

2.8.1 Hartwell Project

The Hartwell dam consists of a concrete gravity section, 1,900 feet in length, two earth embankment sections and a saddle dike, for a total length of 17,880 feet. The Hartwell Project consists of a concrete dam flanked by earth embankments, and a powerhouse in the west floodplain immediately below. The concrete dam rises about 204 feet above the streambed. The spillway is a concrete gravity ogee section located in the river channel. Tainter gates separated by concrete piers 8 feet thick control the spillway discharge. Two sluices extend through the lower part of the spillway structure. Concrete non-overflow sections 472 feet long and 860 feet long are located on the east and west ends of the spillway section, respectively. The non-overflow section on the west end of the spillway includes 340 feet of power intake section containing five penstocks spaced 68 feet on-centers. The penstock intakes are controlled by tractor-type gates and protected by steel trash racks. The initial power installation consisted of four generators, each having a rated capacity of 66,000 kilowatts. Provisions were included in the powerhouse at initial construction for an additional 66,000 kilowatt unit.

The 5th unit went online in 1984 with an installed capacity of 84,000 kilowatts. This amounts to 264,000 kilowatts and 348,000 kilowatts for the initial and current installations, respectively. The dependable capacity or capacity at maximum drawdown was 250,000 kilowatts for the initial installation and is 327,000 kilowatts with the current turbines and upgrades. U.S. Highway 29 crosses the Savannah River approximately 2,300 feet downstream of the dam.

The Hartwell Project also includes the Upper and Lower Diversion Dams, (also called the Clemson University Protective Works) in Pickens County, South Carolina. These dams were constructed in 1960 and 1961 as part of the Hartwell Project. The Upper Dam is 2,100 feet in length, has a crest width of 16 feet, and has a top elevation of about 680 feet National Geodetic Vertical Datum (NGVD). The design elevation of 679 feet NGVD includes a design freeboard of 5 feet above the maximum design surcharge. The two diversion dams and a pumping station prevent flooding of Clemson University by waters from Lake Hartwell. The Federal Government operates the pumping station to remove runoff and seepage from the protected area. The lowest portion of the 9.4 square mile protected area includes a portion of the old Seneca Riverbed. The Lower Diversion Dam is being monitored for seepage issues. These issues are of sufficient concern to drop the concept of reallocation from flood storage from consideration.

Table 2.8-1 Describes the summer elevations and storage volumes of the flood control, conservation, and inactive storage zones at Hartwell. Figure 2.8-1 Depicts the Hartwell pool storage. Figure 2.8-2 shows the time series of the conservation zone definition, and average elevation as well as historical measured elevation.

Table 2.8-1: Hartwell Pool Properties (Summer)

Feature	Elevation (feet, NGVD)	Capacity (Acre-feet)
Flood Control Storage (Winter)	656.0 – 665.0	508,900
Flood Control Storage (Summer)	660.0 – 665.0	293,000
Conservation Storage (Winter)	625.0 – 656.0	1,199,700
Conservation Storage (Summer)	625.0 – 660.0	1,415,500
Inactive Storage	475.0 – 625.0	1,134,100

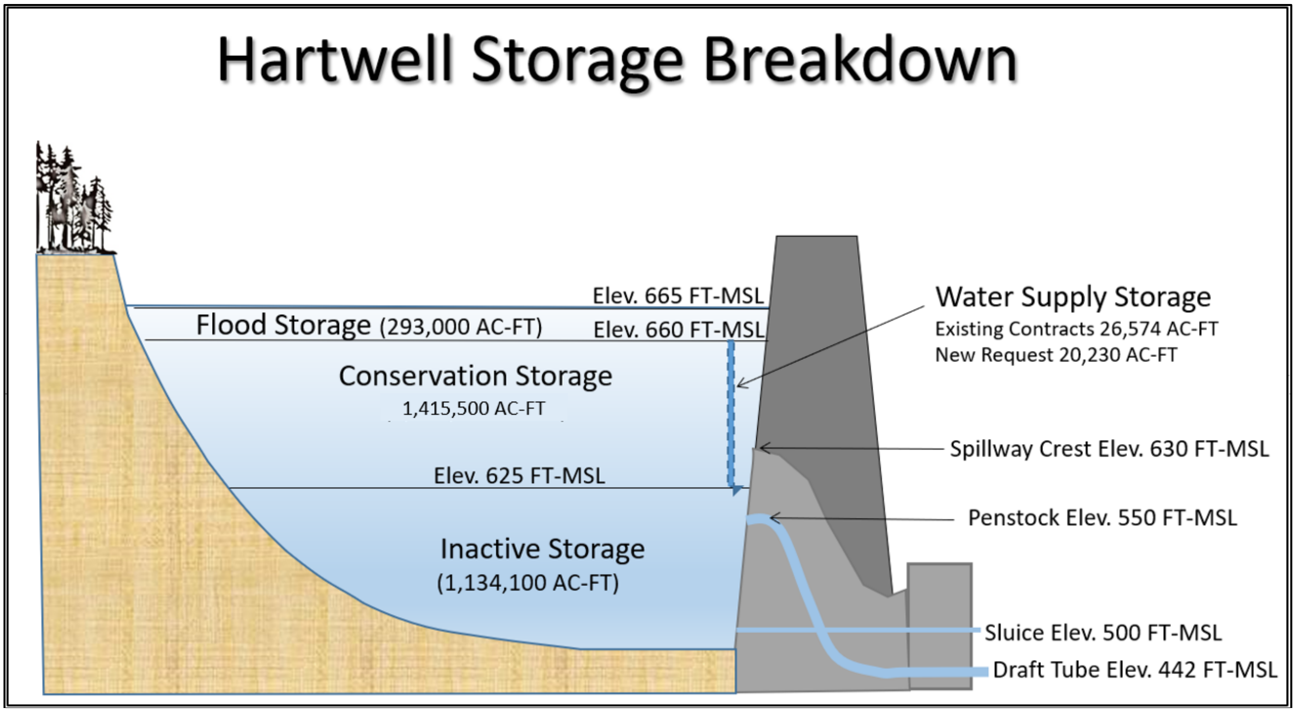


Figure 2.8-1: Hartwell Storage Depiction

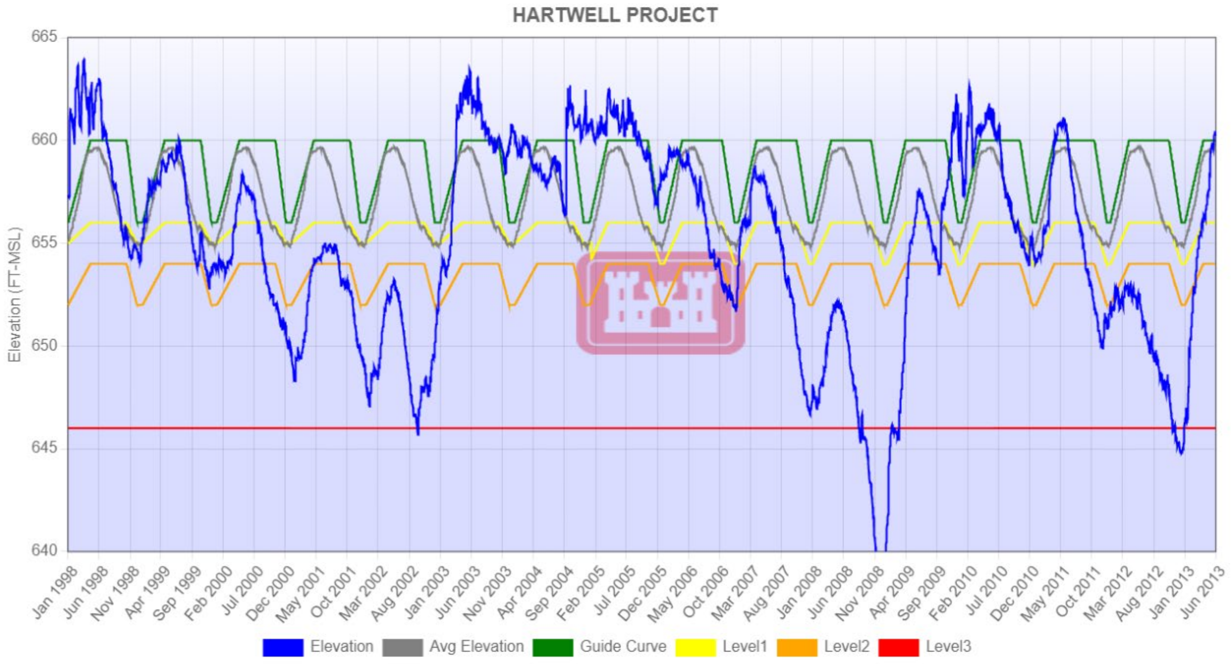


Figure 2.8-2: Hartwell Guide Curve

2.8.2 Richard B. Russell Project

The Richard B. Russell dam consists of a concrete gravity section, which is 1,884 feet in length, and two earth embankment sections, for a total length of 2,640 feet. In the former stream channel, resides a concrete overflow spillway with an ogee-shaped crest surmounted by 10 Tainter gates. The Tainter gates are 50 feet wide by 44 feet high with a spillway crest elevation of 436. Seven 6-foot by 10-foot low level sluices exist for emergency drawdown of the pool, but not for normal flood control operations. During high pool levels, the sluices are not used; therefore, they do not include an energy dissipating device.

The powerhouse, located in the river channel, contains four 75,000 kilowatt generators and four 75,000 kilowatt reversible pump-turbine units. The penstocks, with entrance and gate sections similar to those at Hartwell dam, are 26 feet in diameter with a single gate at the entrance with stoplog slots and trash rack.

Table 2.8-2 describes the summer elevations and storage volumes of the flood control, conservation, and inactive storage zones at Russell. Figure 2.8-3 depicts the Russell pool storage. Figure 2.8-4 shows the time series of the conservation zone definition, and average elevation as well as historical measured elevation.

Table 2.8-2: Richard B. Russell Pool Properties

Feature	Elevation (feet, NGVD)	Capacity (Acre-feet)
Flood Control Storage	475.0 – 480.0	140,000
Conservation Storage	470.0 – 475.0	126,800
Inactive Storage	470.0 – 300.0	899,400

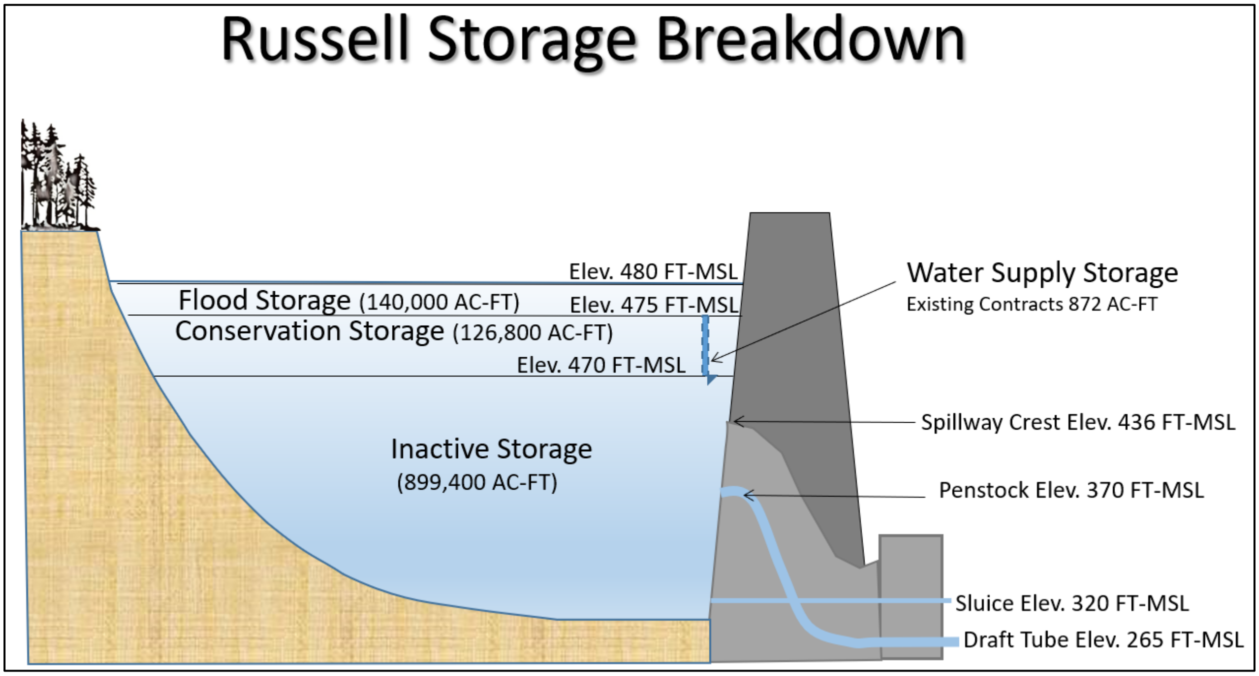


Figure 2.8-3: Russell Storage Depiction

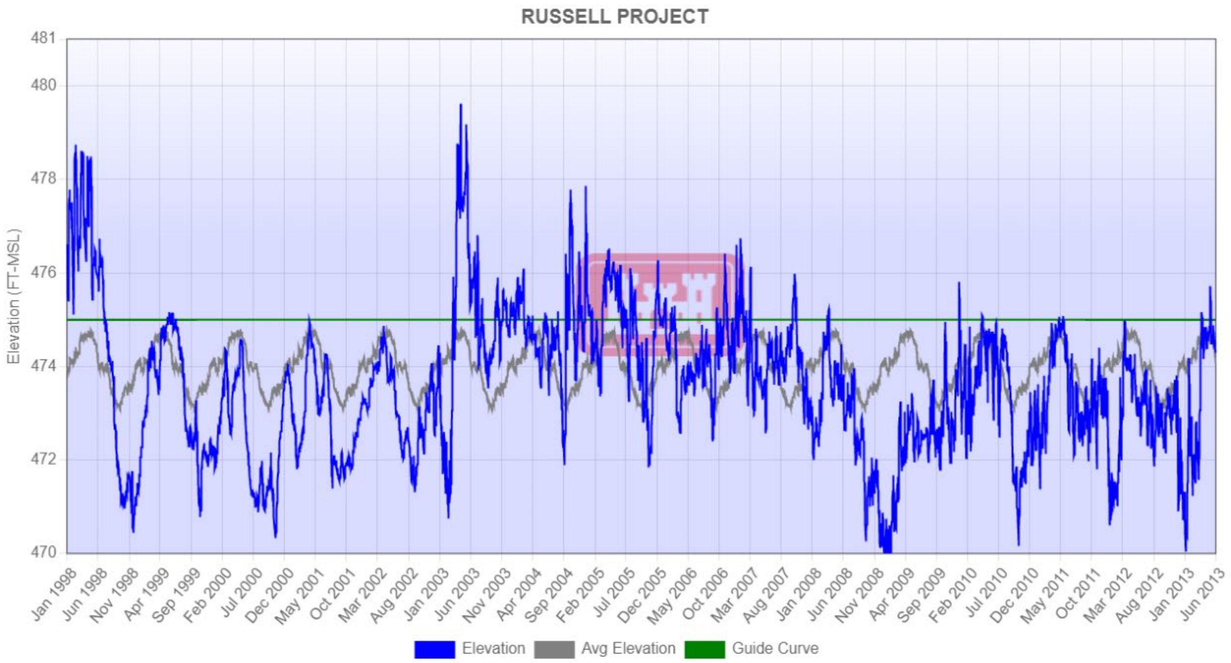


Figure 2.8-4: Russell Guide Curve

2.8.3 J. Strom Thurmond Project

The J. Strom Thurmond dam consists of a concrete gravity section, which is 2,282 feet in length, and two earth embankment sections. The Thurmond dam has a total length of 5,680 feet. In addition to the dam, the structure includes a powerhouse in the east floodplain immediately below the dam. The dam rises about 180 feet above the streambed. The spillway is a concrete gravity ogee section extending across the west floodplain and the river channel. Twenty-three Tainter gates, separated by concrete piers eight-feet thick, control spillway discharge. Hydraulically operated slide gates control eight sluices through the lower part of the spillway structure. The sluices are not intended for flood control use. The spillway is flanked on the west by a 280 feet long concrete non-overflow section and a 906 feet long non-overflow section on the east side of the spillway including the power intake section, which contains seven penstocks each spaced 62 feet on center. Seven recently upgraded generators in the powerhouse generate 57,500-kilowatt maximum capacity. Tractor-type gates protected by steel trash racks control the penstock intakes.

U. S. Highway 221 crosses the dam. Table 2.8-3 describes the summer elevations and storage volumes of the flood control, conservation, and inactive storage zones at Thurmond. Figure 2.8-5 summarizes some of the prominent features of the project. Figure 2.8-6 shows the time series of the conservation zone definition, and average elevation as well as historical measured elevation.

Table 2.8-3: J. Strom Thurmond Pool Properties

Feature	Elevation (feet, NGVD)	Capacity (Acre-feet)
Flood Control Storage (Winter)	326.0 – 335.0	670,000
Flood Control Storage (Summer)	330.0 – 335.0	390,000
Conservation Storage (Winter)	312.0 – 326.0	765,000
Conservation Storage (Summer)	312.0 – 330.0	1,045,000
Inactive Storage	312.0 – 176.0	1,465,000

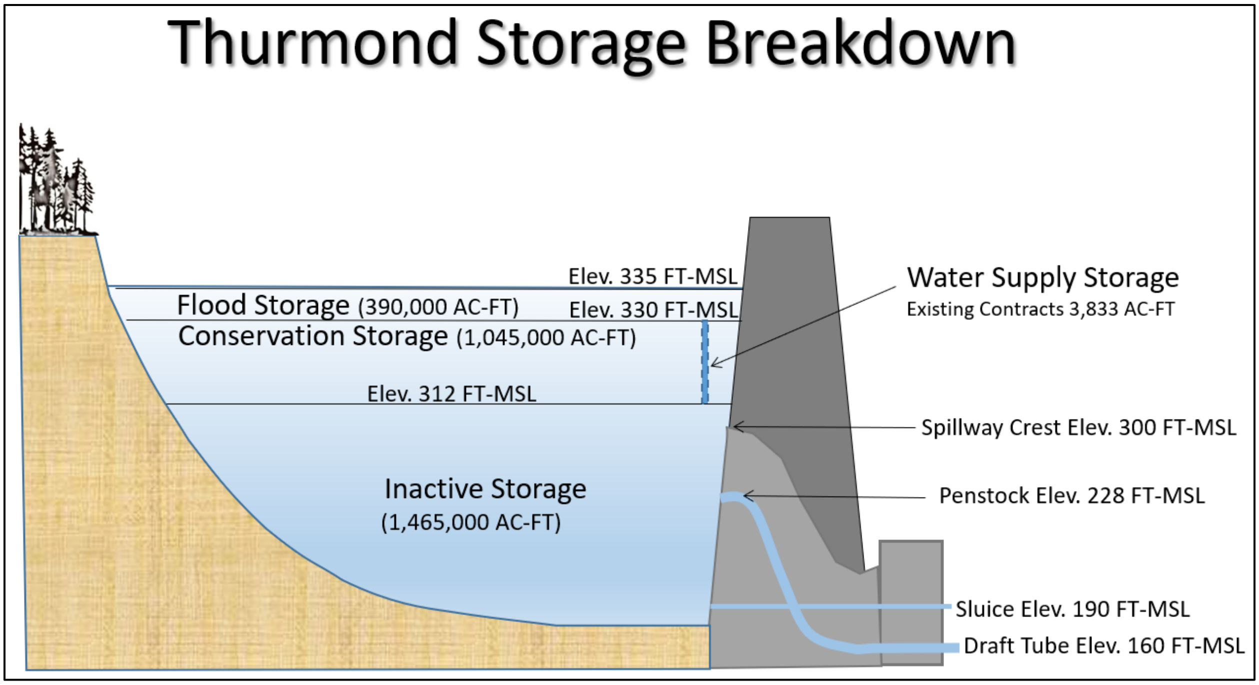


Figure 2.8-5: Thurmond Storage Depiction

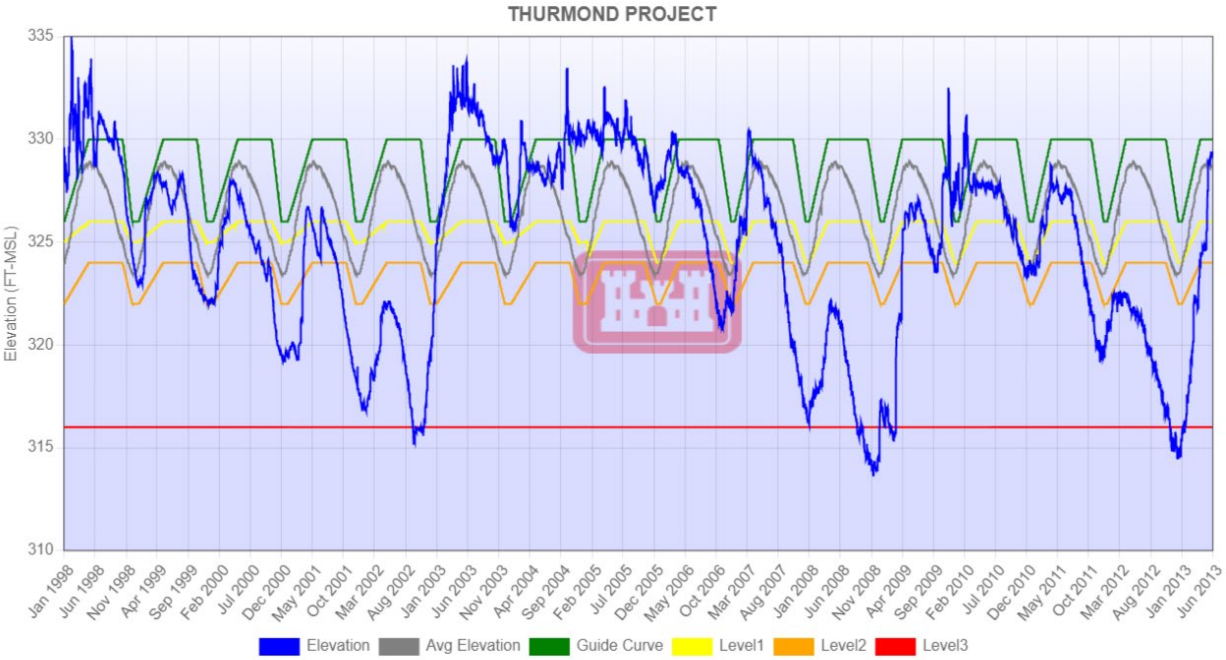


Figure 2.8-6: Thurmond Guide Curve

2.8.4 Sedimentation Analysis

Sedimentation in reservoirs is monitored periodically by surveying several designated areas called sedimentation ranges. These periodic surveys provide an indication of the rate of sedimentation. In 2015, funding became available to do a complete bathymetric survey on Russell Reservoir and 2017 for Thurmond Reservoir. These surveys took over 1 year each and were performed during periods of near normal hydrology while pools were near full pool. The surveys did not provide a complete picture of the upper regions of the conservation pools or of the flood pools which extends above the conservation pool. Hopefully, in the future, Lidar surveys can be flown over the reservoirs during a drawn down pool providing a more accurate depiction of the upper conservation storage. A bathymetric survey of Hartwell Reservoir was initiated April 2023.

The following tables show a comparison between the original Construction surveys and the recent bathymetric surveys. Thurmond's conservation storage extends from 312 ft-msl to a summer full pool of 330 ft-msl, while Russell's conservation storage extends from 470 ft-msl to 475 ft-msl and Hartwell's conservation storage extends from 625 ft-msl to 660 ft-msl.

This analysis is intended to highlight the large volume of reservoir storage remaining below the bottom of the conservation pools. It is noted that the amount of displacement increases with depth. Focus should remain on the conservation pools as the inverts of the water supply intakes being proposed fall within several feet to the bottom of the conservation pools.
The Hartwell Conservation Storage has decreased roughly -17%
The Thurmond Conservation Storage has only changed -4%
The Russell Conservation Storage has changed -19%.

Table 2.8-4: J. Strom Thurmond Sedimentation Analysis

Thurmond Sedimentation Analysis			
	Volume (AC-FT)		
Elevation	Construction	2017	Percent Change
330	2,482,000	2,463,168	-1%
325	2,154,000	2,148,725	-0%
320	1,854800	1,824,101	-2%
315	1,595,500	1,543,095	-3%
310	1,370,900	1,310,263	-4%
305	1,166,127	1,112,473	-5%
300	1,053,740	943,765	-10%

Table 2.8-5: Richard B. Russell Sedimentation Analysis

Russell Sedimentation Analysis			
	Volume (AC-FT)		
Elevation	Construction	2015	Percent Change
475	1,023,581	909,163	-11%
474	997,240	886,701	-11%
473	971,414	864,790	-11%
472	946,098	843,431	-11%
471	921,286	822,723	-11%
470	896,971	802,630	-11%
469	873,148	783,053	-10%
468	849,809	763,916	-10%
467	826,950	745,191	-10%
466	804,564	726,860	-10%
465	783,141	709,093	-9%
460	699,388	624,780	-11%
455	615,636	548,540	-11%
450	532,334	479,640	-10%

Table 2.8-6: Hartwell Sedimentation Analysis

Hartwell Sedimentation Analysis			
	Volume (AC-FT)		
Elevation	Construction	2023	Percent Change
675	3,511,000	3,129,473	-12%
670	3,163,000	2,791,770	-13%
665	2,842,700	2,478,056	-15%
660	2,459,600	2,189,478	-16%
655	2,282,400	1,949385	-17%
650	2,039,100	1,733,975	-18%
645	1,818,600	1,559,554	-17%
640	1,619,700	1,395,736	-16%
635	1,440,800	1,243,426	-16%
630	1,279,600	1,103,344	-16%
625	1,134,100	975,233	-16%

3.0 The Yield Process

In order to size new accounts to meet new requests, a yield study was necessary. The yield process begins with the determination of the existing yield of each current contract. As described in EM 1110-2-1420 Hydrologic Engineering Requirements for Reservoirs, yield is the amount of water that can be supplied from the reservoir to a specified location and in a specified time pattern. Firm yield is the largest continuous flow rate that can be provided throughout the critical period of historic streamflow. The critical period is the period of time during which a reservoir storage account goes from full to empty and back to full. Critical periods are the driest periods of record where the inflow does not satisfy the demand and reservoir storage is required to sustain a dependable flow.

3.1 Yield Determination Methodology

Traditionally, water supply storage accounts have been sized as a percent of the project's firm yield. That firm yield for the full project had to be determined assuming a specific monthly withdrawal pattern, which does not necessarily match the withdrawal pattern of individual account holders. The account yield would be limited based on how that account's pattern compares with the overall withdrawal pattern. The introduction of water account yield analysis in HEC-ResSim has allowed a separate analysis to take place for each water account, solving specifically for the yield of a portion of the reservoir storage rather than the entire storage. This study takes advantage of ResSim's new ability to solve for yield for individual water accounts, using each account's individual monthly withdrawal pattern. Results from this methodology are expected to be comparable to the traditional approach. The version of HEC-ResSim used was Build 3.5.394.

The yield methodology used for this study is considered operational yield, rather than hydrologic yield. This means that operations for other project purposes were included in the yield modeling. Determining the yield with the inclusion of reservoir operation results in a yield that is dependent on the selected reservoir operation set. In the event the operation is altered, the yield is likely to be altered. Future changes to the operational strategy can impact the yield of existing account holders, so a new drought plan or other changes to operations should be done with consideration to their impact on yield. This potential for impact to Water Supply Contracts due to changes in operation should be noted in the water supply agreements.

3.2 Critical Period and Parameters

HEC-ResSim analysis of the 1939 – 2013 dataset covered several droughts, revealing 1998 – 2013 as the most critically dry period in the last century. Yield analysis of the entire 75-year period resulted in run times over 10 hours. The time window was narrowed to 1998-2013 for subsequent yield runs. Monthly water withdrawals and returns were defined for each water supply contract in the Hartwell-Russell-Thurmond system. Average monthly water withdrawals for the riparian users were also defined in the model. The standard operating rules for the system as defined in the Savannah River Water Control Manual, covering Flood, Hydropower Production, and Drought were also coded into the model.

3.3 Establishing Existing Contract Yield

HEC-ResSim was run in an iterative mode, solving for the yield that could be provided by each contract's storage across the most critical time window being analyzed. An initial estimate of yield was first determined for the contracted storage of each existing contract. The yield was iteratively solved one contract at a time, using the newly found yield of each contract as the seasonal withdrawal pattern in the determination of the next contract's yield. This process looped thru each contract, re-solving for yield until little or no change in the average annual yield was exhibited. Mitigation requirements were based on maintaining the current yields of the existing storage agreements.

3.4 Sizing New Contracts to Meet Requested Yield

An initial estimate of storage needed to support each new request was made based on a ratio between the current yield and the new request. The seasonal pattern of withdrawals and returns was based on information provided by the contract holders and verified by the state environmental agencies. HEC-ResSim was again run in an iterative approach adjusting the storage until the yield for the new request was achieved. All project objectives, minimum flow requirements, drought rules, hydropower rules, and flood management rules were present in the ResSim priority stack during the yield calculation.

The yield for each current contact was then re-analyzed to determine if the contracted storage of each existing user could provide the same yield now that the new contracts were drafting the system. If an existing storage contract could no longer provide the earlier determined existing yield, then the storage for the existing user would be increased as needed to support the existing contract. This process was followed for each existing contract. This additional storage was considered as "Dependable Yield Mitigation Storage" necessary to keep the existing water account holders "whole", (i.e., able to maintain their current yield/withdrawals). This process was repeated thru all the existing contracts to ensure the existing yield of each was met and thru the new requests to ensure that each new request was also being met.

The critical period is the period in which the storage account starts full, becomes completely depleted (within the user-specified tolerances), and then fully refills. The critical period varies at each reservoir due to the different sub-basin's hydrology, physical characteristics of each dam, as well as varying operational rules at each dam.

The yield at Russell is consistently higher than at Hartwell and Thurmond. This is because Russell has the benefit of added inflow due to hydropower releases from Hartwell as well as added inflow from pump back operation. During low inflow periods, Russell has the ability to help fulfill weekly power commitments by utilizing pump back operations. This mimics current real-world operations. During severe droughts, Russell can operate all four pumps from one hour after sunset until one hour before sunrise. Note that since yield was calculated as operational yield, it is possible for the yield to be transferred from Thurmond to Russell.

Yield results are displayed in Section 6.

Table 3.4-1: The HEC-ResSim Modeling Process

The Modeling Process

Define Current Water Usage

- Withdrawal and return data collected from each contract holder
- Withdrawal and returns tabulated
- Monthly average withdrawals added to the HEC-ResSim model
    - Diverted outlet added to each pool for each contract holder
    - Operational rule with monthly withdrawal pattern added for each contract holder
- Monthly average returns were added to the HEC-ResSim model
    - Diversion with flexible diversion rule added for each contract holders return
    - Returns configured into appropriate reservoir

Current Yield Calculation

- Iterative Loop using HEC-ResSim solving for current yield of each existing storage contract holder in the system
    - Storage account defined for a user with currently contracted storage for that user
    - ResSim run calculating monthly average yields of that user
    - This seasonal withdrawal pattern for this user is used in subsequent yield calculations for the other users
- Loop back thru all of the users until no changes in yield

- Weight seasonal pattern for each new request and add to model
- Estimate storage required based on existing storage and yield of any user in the Hartwell pool

New Request Yield Calculation

- Iterative Loop using HEC-ResSim solving for requested yield of each of the 4 new requests
    - Estimate storage needed to provide requested yield.
    - ResSim run calculating yield of that user
    - Adjust the storage account needed targeting the users requested yield
- Loop back thru the 4 new requests until no changes in yield

Dependable Yield Mitigation

- Iterative Loop using HEC-ResSim solving for yield of all contract holders including new requests
    - ResSim run calculating yield of that user
    - Increase Storage account as needed to provide same yield as determined in the Current Yield Calculation
    - When solving for New Requests, adjust storage account to ensure resulting yield = requested yield

    - Adjust the storage account needed targeting the users requested yield
- Loop back thru all of the users until New Requests met, and Existing contract holders not impacted

4.0 HEC-ResSim Overview

Figure 4.0-1 below shows the HEC-ResSim basin configuration with water supply withdrawals (Blue Arrows) and return locations (Black Arrows). The following figures are screen shots of the HEC ResSim configuration screens depicting project.

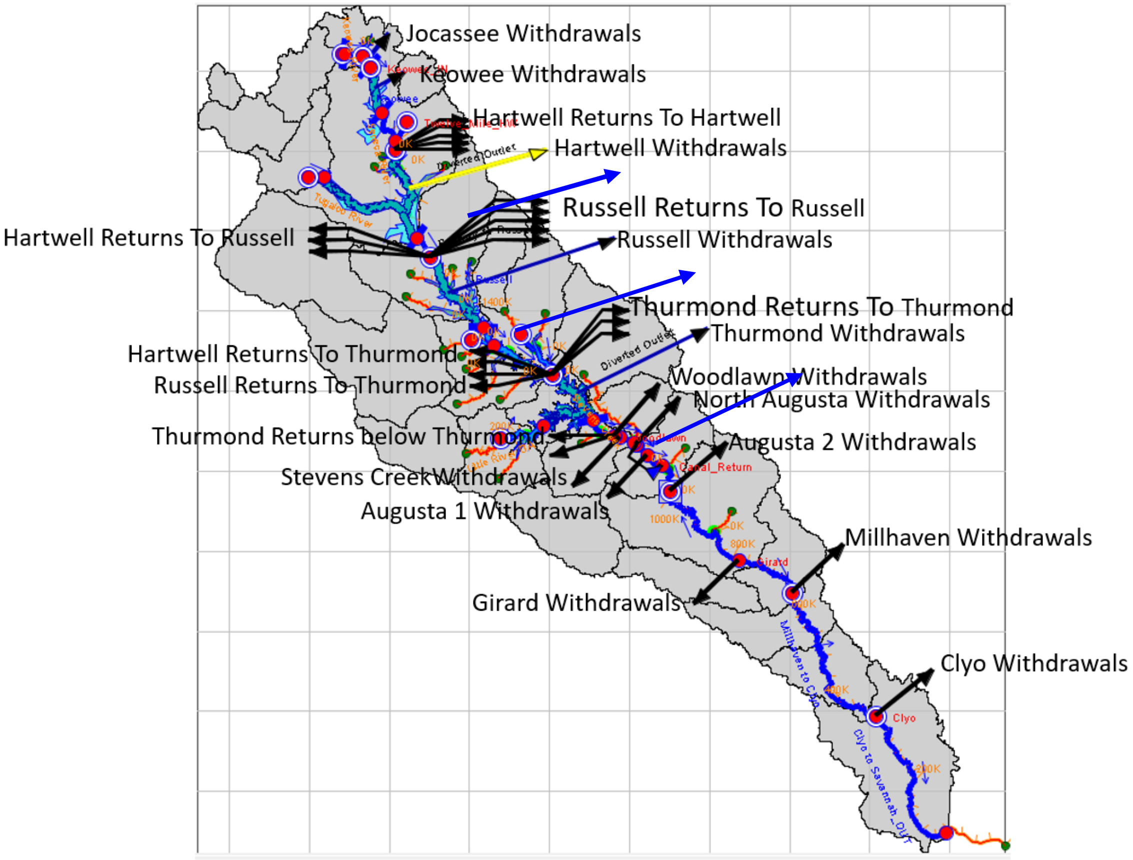
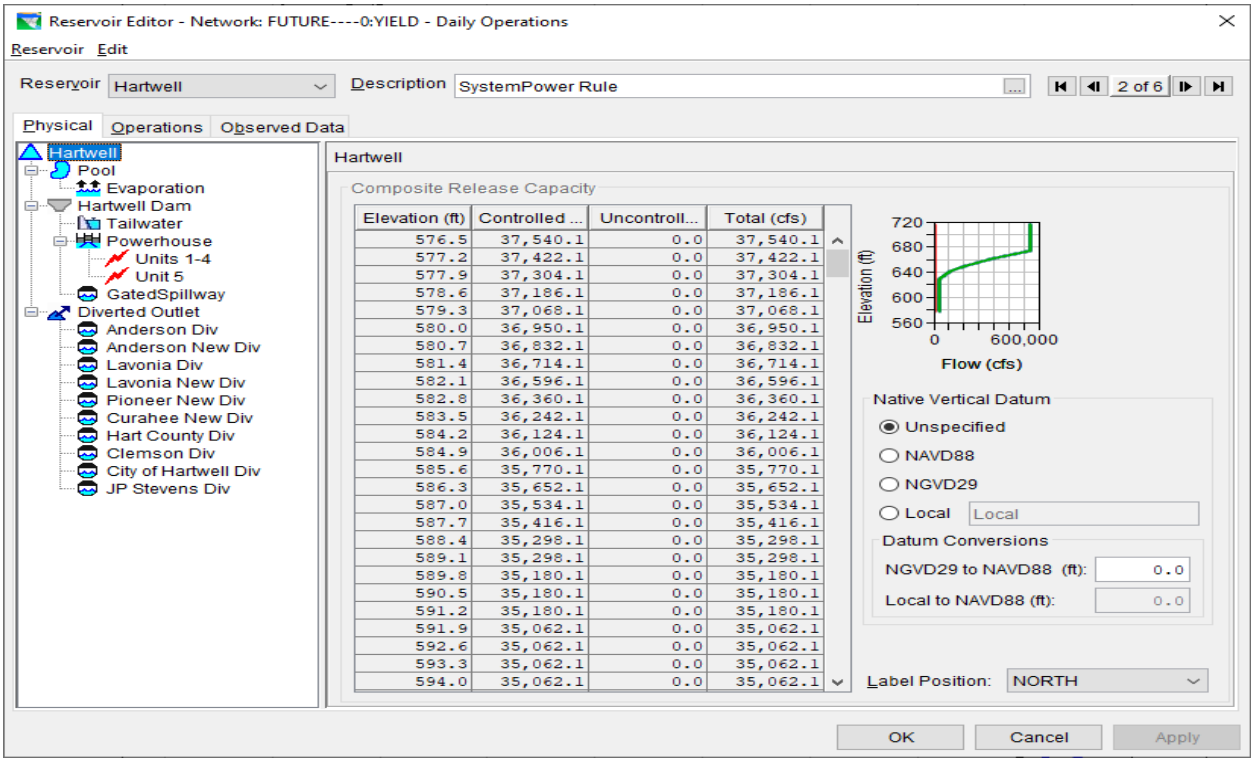


Figure 4.0-1 (Basin Diagram)

Figure 4.0-1, the model schematic, includes the following elements:

Plain red dots – Computational points for the model
Red Points outlined in white – points of Inflow (UIF input)
Blue Arrows – Groups of contracted Withdrawals with water Accounts
Black Arrows – Diversions representing either Withdrawals or for Returns

4.1 Physical Features



Reservoir: Hartwell

Description: SystemPower Rule

Hartwell

Composite Release Capacity

Elevation (ft)	Controlled ...	Uncontroll...	Total (cfs)
576.5	37,540.1	0.0	37,540.1
577.2	37,422.1	0.0	37,422.1
577.9	37,304.1	0.0	37,304.1
578.6	37,186.1	0.0	37,186.1
579.3	37,068.1	0.0	37,068.1
580.0	36,950.1	0.0	36,950.1
580.7	36,832.1	0.0	36,832.1
581.4	36,714.1	0.0	36,714.1
582.1	36,596.1	0.0	36,596.1
582.8	36,360.1	0.0	36,360.1
583.5	36,242.1	0.0	36,242.1
584.2	36,124.1	0.0	36,124.1
584.9	36,006.1	0.0	36,006.1
585.6	35,770.1	0.0	35,770.1
586.3	35,652.1	0.0	35,652.1
587.0	35,534.1	0.0	35,534.1
587.7	35,416.1	0.0	35,416.1
588.4	35,298.1	0.0	35,298.1
589.1	35,298.1	0.0	35,298.1
589.8	35,180.1	0.0	35,180.1
590.5	35,180.1	0.0	35,180.1
591.2	35,180.1	0.0	35,180.1
591.9	35,062.1	0.0	35,062.1
592.6	35,062.1	0.0	35,062.1
593.3	35,062.1	0.0	35,062.1
594.0	35,062.1	0.0	35,062.1

Native Vertical Datum

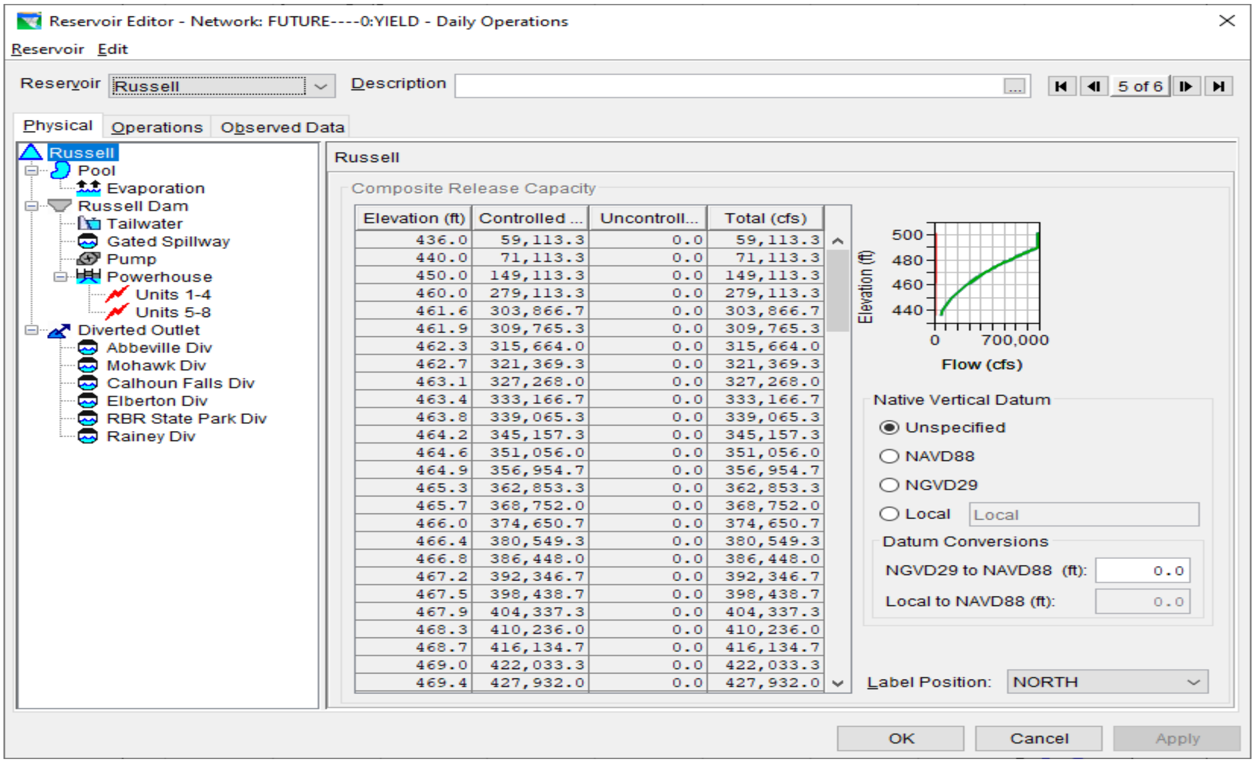
● Unspecified
○ NAVD88
○ NGVD29
○ Local: Local

Datum Conversions

NGVD29 to NAVD88 (ft): 0.0
Local to NAVD88 (ft): 0.0

Label Position: NORTH

Figure 4.1-1: (Hartwell Outlet Capacities)



Reservoir: Russell

Description:

5 of 6

Russell

Composite Release Capacity

Elevation (ft)	Controlled ...	Uncontroll...	Total (cfs)
436.0	59,113.3	0.0	59,113.3
440.0	71,113.3	0.0	71,113.3
450.0	149,113.3	0.0	149,113.3
460.0	279,113.3	0.0	279,113.3
461.6	303,866.7	0.0	303,866.7
461.9	309,765.3	0.0	309,765.3
462.3	315,664.0	0.0	315,664.0
462.7	321,369.3	0.0	321,369.3
463.1	327,268.0	0.0	327,268.0
463.4	333,166.7	0.0	333,166.7
463.8	339,065.3	0.0	339,065.3
464.2	345,157.3	0.0	345,157.3
464.6	351,056.0	0.0	351,056.0
464.9	356,954.7	0.0	356,954.7
465.3	362,853.3	0.0	362,853.3
465.7	368,752.0	0.0	368,752.0
466.0	374,650.7	0.0	374,650.7
466.4	380,549.3	0.0	380,549.3
466.8	386,448.0	0.0	386,448.0
467.2	392,346.7	0.0	392,346.7
467.5	398,438.7	0.0	398,438.7
467.9	404,337.3	0.0	404,337.3
468.3	410,236.0	0.0	410,236.0
468.7	416,134.7	0.0	416,134.7
469.0	422,033.3	0.0	422,033.3
469.4	427,932.0	0.0	427,932.0

Native Vertical Datum

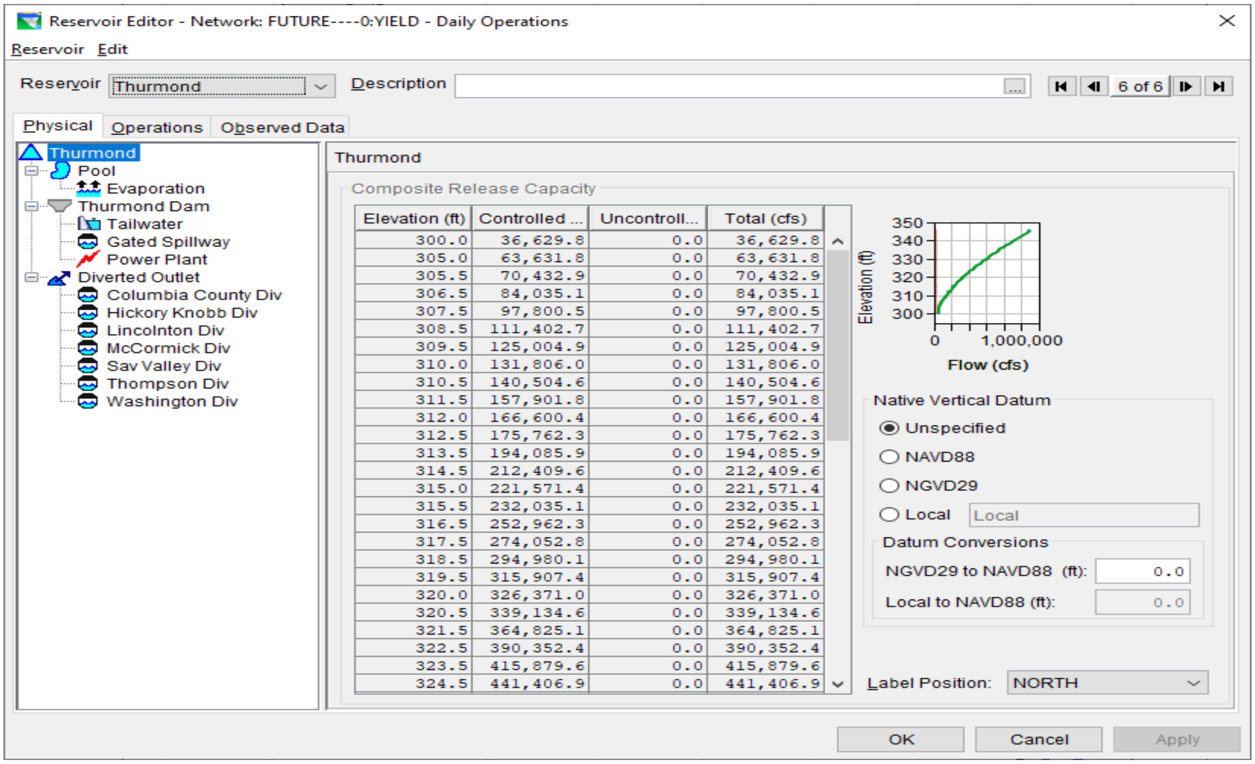
● Unspecified
○ NAVD88
○ NGVD29
○ Local Local

Datum Conversions

NGVD29 to NAVD88 (ft): 0.0
Local to NAVD88 (ft): 0.0

Label Position: NORTH

Figure 4.1-2: (Russell Outlet Capacities)



Reservoir: Thurmond

Description:

6 of 6

Thurmond

Composite Release Capacity

Elevation (ft)	Controlled ...	Uncontroll...	Total (cfs)
300.0	36,629.8	0.0	36,629.8
305.0	63,631.8	0.0	63,631.8
305.5	70,432.9	0.0	70,432.9
306.5	84,035.1	0.0	84,035.1
307.5	97,800.5	0.0	97,800.5
308.5	111,402.7	0.0	111,402.7
309.5	125,004.9	0.0	125,004.9
310.0	131,806.0	0.0	131,806.0
310.5	140,504.6	0.0	140,504.6
311.5	157,901.8	0.0	157,901.8
312.0	166,600.4	0.0	166,600.4
312.5	175,762.3	0.0	175,762.3
313.5	194,085.9	0.0	194,085.9
314.5	212,409.6	0.0	212,409.6
315.0	221,571.4	0.0	221,571.4
315.5	232,035.1	0.0	232,035.1
316.5	252,962.3	0.0	252,962.3
317.5	274,052.8	0.0	274,052.8
318.5	294,980.1	0.0	294,980.1
319.5	315,907.4	0.0	315,907.4
320.0	326,371.0	0.0	326,371.0
320.5	339,134.6	0.0	339,134.6
321.5	364,825.1	0.0	364,825.1
322.5	390,352.4	0.0	390,352.4
323.5	415,879.6	0.0	415,879.6
324.5	441,406.9	0.0	441,406.9

Native Vertical Datum

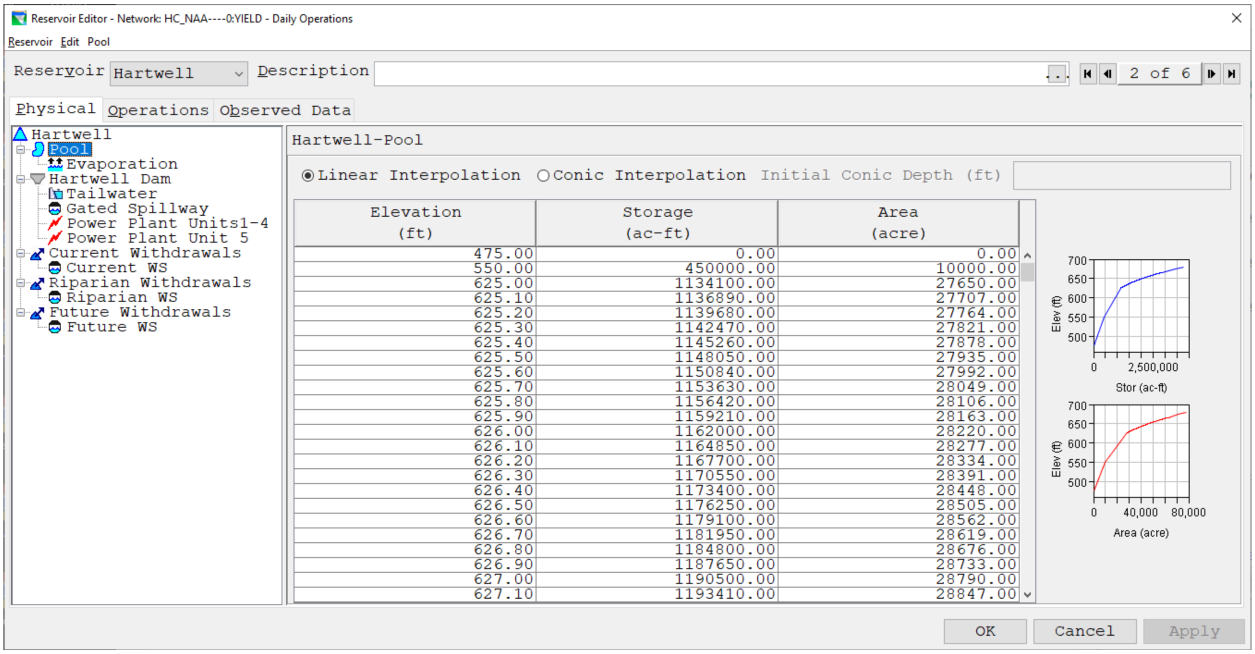
● Unspecified
○ NAVD88
○ NGVD29
○ Local Local

Datum Conversions

NGVD29 to NAVD88 (ft): 0.0
Local to NAVD88 (ft): 0.0

Label Position: NORTH

Figure 4.1-3: (Thurmond Outlet Capacities)



Reservoir: Hartwell

Description:

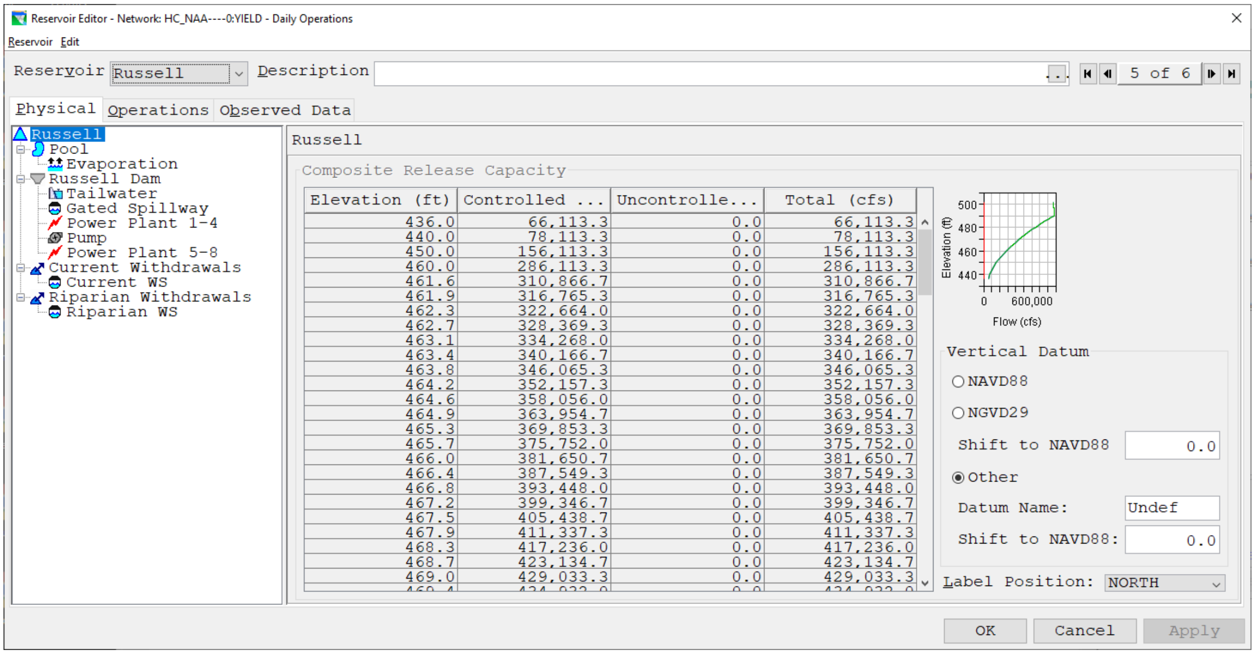
2 of 6

Hartwell-Pool

● Linear Interpolation ○ Conic Interpolation Initial Conic Depth (ft)

Elevation (ft)	Storage (ac-ft)	Area (acre)
475.00	0.00	0.00
550.00	450000.00	10000.00
625.00	1134100.00	27650.00
625.10	1136890.00	27707.00
625.20	1139680.00	27764.00
625.30	1142470.00	27821.00
625.40	1145260.00	27878.00
625.50	1148050.00	27935.00
625.60	1150840.00	27992.00
625.70	1153630.00	28049.00
625.80	1156420.00	28106.00
625.90	1159210.00	28163.00
626.00	1162000.00	28220.00
626.10	1164850.00	28277.00
626.20	1167700.00	28334.00
626.30	1170550.00	28391.00
626.40	1173400.00	28448.00
626.50	1176250.00	28505.00
626.60	1179100.00	28562.00
626.70	1181950.00	28619.00
626.80	1184800.00	28676.00
626.90	1187650.00	28733.00
627.00	1190500.00	28790.00
627.10	1193410.00	28847.00

Figure 4.1-4: (Hartwell Elevation/Storage/Area Curve)



Reservoir: Russell

Description:

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Russell

Composite Release Capacity

Elevation (ft)	Controlled ...	Uncontrolle...	Total (cfs)
436.0	66,113.3	0.0	66,113.3
440.0	78,113.3	0.0	78,113.3
450.0	156,113.3	0.0	156,113.3
460.0	286,113.3	0.0	286,113.3
461.6	310,866.7	0.0	310,866.7
461.9	316,765.3	0.0	316,765.3
462.3	322,664.0	0.0	322,664.0
462.7	328,369.3	0.0	328,369.3
463.1	334,268.0	0.0	334,268.0
463.4	340,166.7	0.0	340,166.7
463.8	346,065.3	0.0	346,065.3
464.2	352,157.3	0.0	352,157.3
464.6	358,056.0	0.0	358,056.0
464.9	363,954.7	0.0	363,954.7
465.3	369,853.3	0.0	369,853.3
465.7	375,752.0	0.0	375,752.0
466.0	381,650.7	0.0	381,650.7
466.4	387,549.3	0.0	387,549.3
466.8	393,448.0	0.0	393,448.0
467.2	399,346.7	0.0	399,346.7
467.5	405,438.7	0.0	405,438.7
467.9	411,337.3	0.0	411,337.3
468.3	417,236.0	0.0	417,236.0
468.7	423,134.7	0.0	423,134.7
469.0	429,033.3	0.0	429,033.3

Vertical Datum

○ NAVD88

○ NGVD29

Shift to NAVD88: 0.0

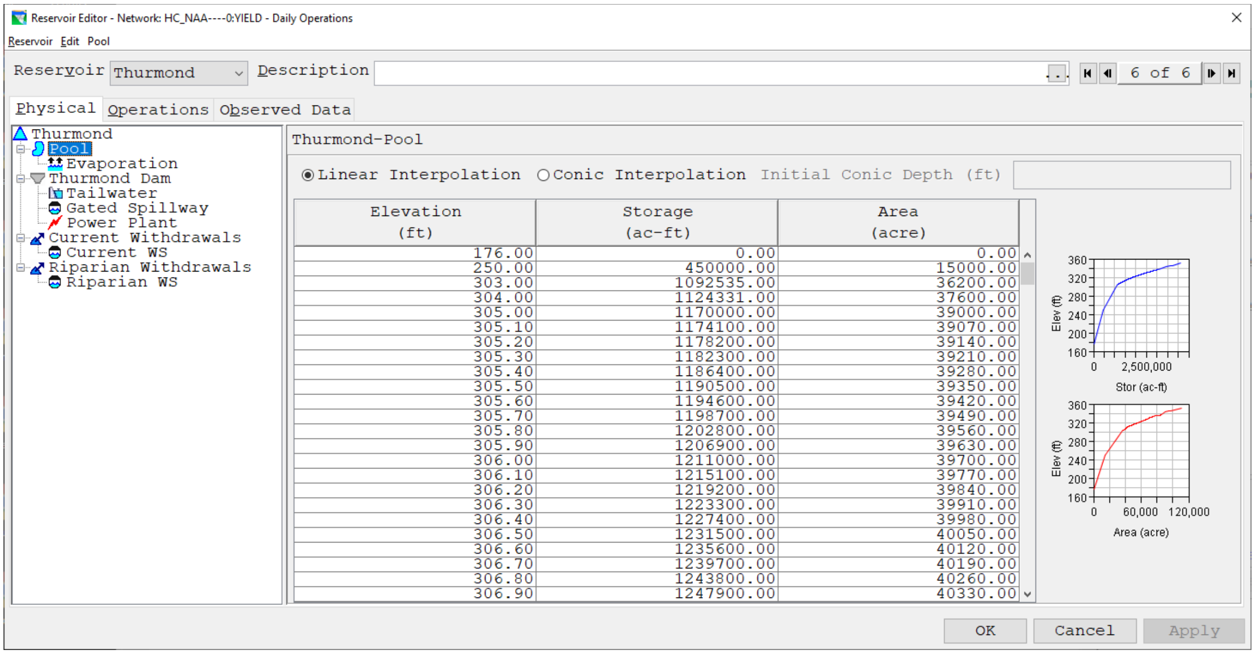
● Other

Datum Name: Undef

Shift to NAVD88: 0.0

Label Position: NORTH

Figure 4.1-5: (Russell Elevation/Storage/Area Curve)



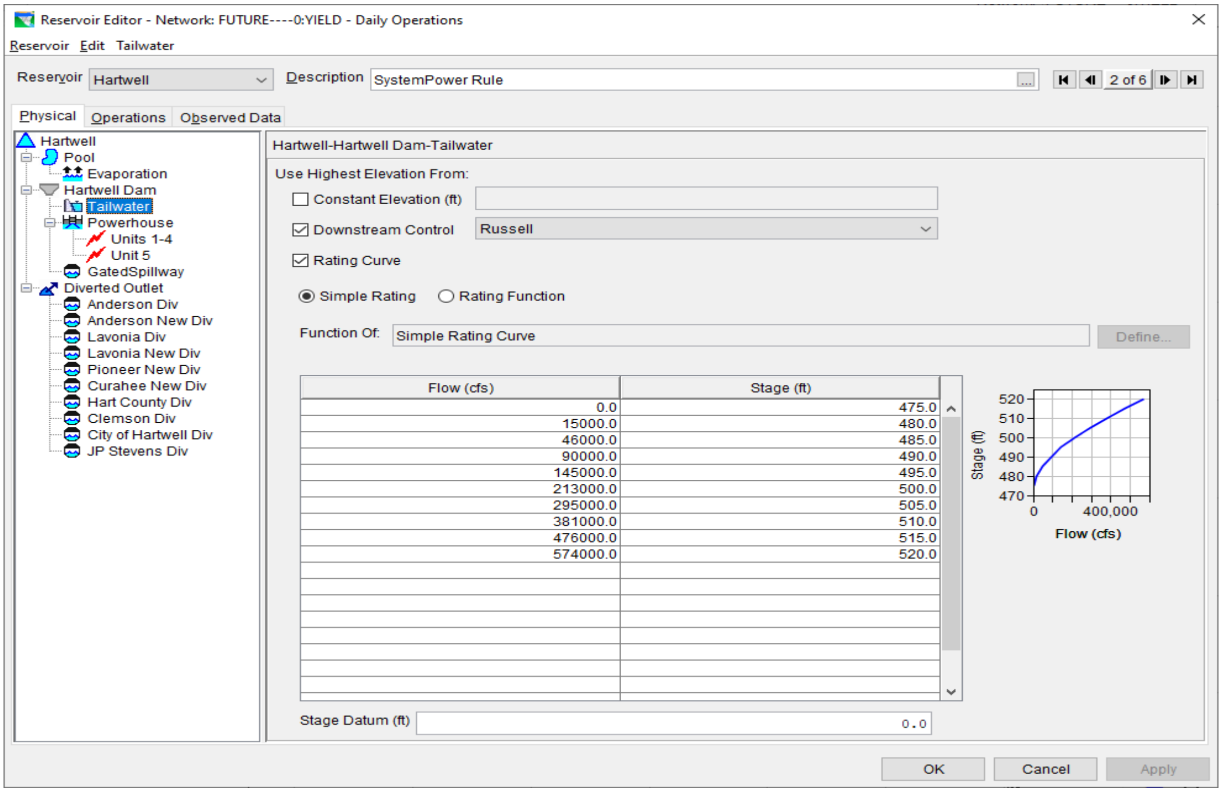
Reservoir: Thurmond
Description:
6 of 6

Thurmond-Pool

● Linear Interpolation ○ Conic Interpolation Initial Conic Depth (ft)

Elevation (ft)	Storage (ac-ft)	Area (acre)
176.00	0.00	0.00
250.00	450000.00	15000.00
303.00	1092535.00	36200.00
304.00	1124331.00	37600.00
305.00	1170000.00	39000.00
305.10	1174100.00	39070.00
305.20	1178200.00	39140.00
305.30	1182300.00	39210.00
305.40	1186400.00	39280.00
305.50	1190500.00	39350.00
305.60	1194600.00	39420.00
305.70	1198700.00	39490.00
305.80	1202800.00	39560.00
305.90	1206900.00	39630.00
306.00	1211000.00	39700.00
306.10	1215100.00	39770.00
306.20	1219200.00	39840.00
306.30	1223300.00	39910.00
306.40	1227400.00	39980.00
306.50	1231500.00	40050.00
306.60	1235600.00	40120.00
306.70	1239700.00	40190.00
306.80	1243800.00	40260.00
306.90	1247900.00	40330.00

Figure 4.1-6: (Thurmond Elevation/Storage/Area Curve)



Reservoir: Hartwell
Description: SystemPower Rule
2 of 6

Hartwell-Hartwell Dam-Tailwater

Use Highest Elevation From:

☐ Constant Elevation (ft)
☑ Downstream Control: Russell
☑ Rating Curve

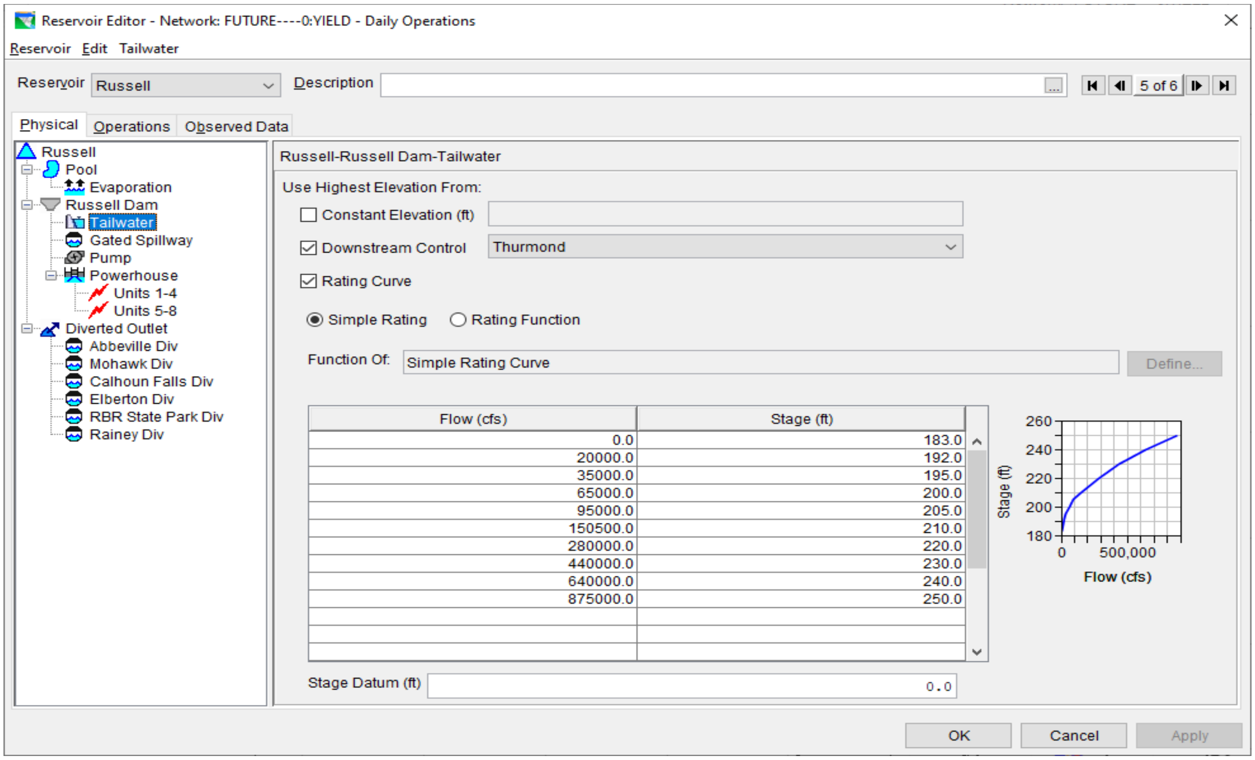
● Simple Rating ○ Rating Function

Function Of: Simple Rating Curve

Flow (cfs)	Stage (ft)
0.0	475.0
15000.0	480.0
46000.0	485.0
90000.0	490.0
145000.0	495.0
213000.0	500.0
295000.0	505.0
381000.0	510.0
476000.0	515.0
574000.0	520.0

Stage Datum (ft): 0.0

Figure 4.1-7: (Hartwell Tailwater Rating Curve)



Reservoir: Russell

Description:

Russell-Russell Dam-Tailwater

Use Highest Elevation From:

☐ Constant Elevation (ft)

☑ Downstream Control: Thurmond

☑ Rating Curve

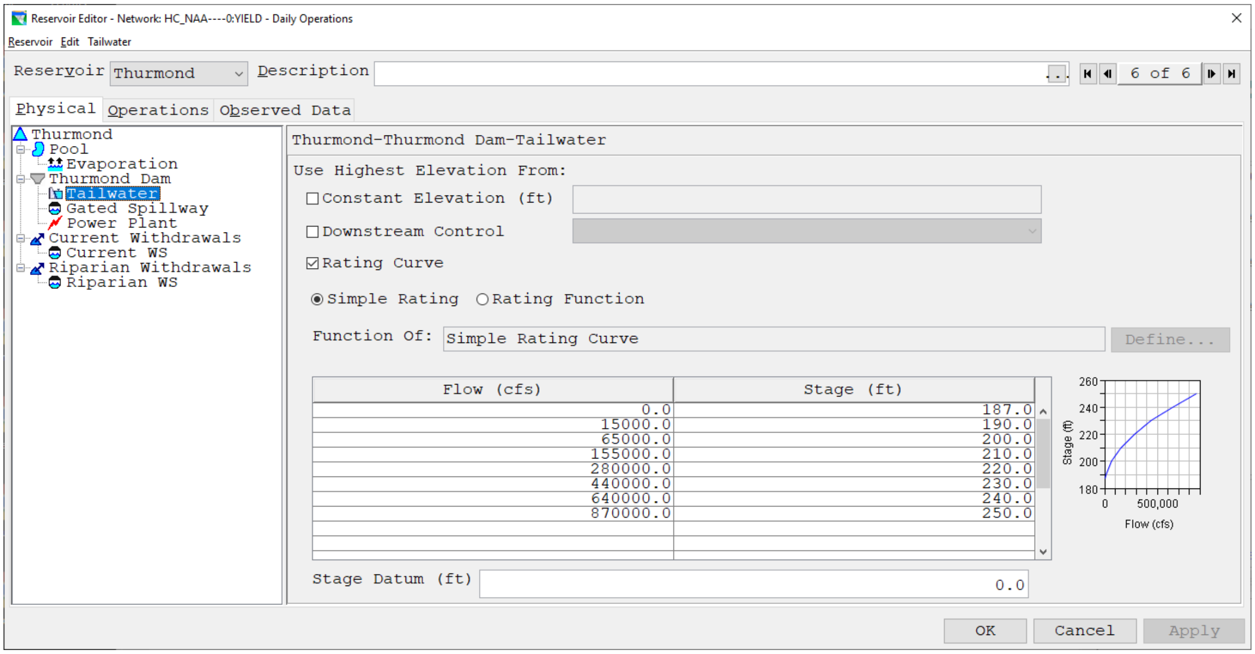
● Simple Rating ○ Rating Function

Function Of: Simple Rating Curve

Flow (cfs)	Stage (ft)
0.0	183.0
20000.0	192.0
35000.0	195.0
65000.0	200.0
95000.0	205.0
150500.0	210.0
280000.0	220.0
440000.0	230.0
640000.0	240.0
875000.0	250.0

Stage Datum (ft): 0.0

Figure 4.1-8: Russell Tailwater Rating Curve



Reservoir: Thurmond

Description:

Thurmond-Thurmond Dam-Tailwater

Use Highest Elevation From:

☐ Constant Elevation (ft)

☐ Downstream Control

☑ Rating Curve

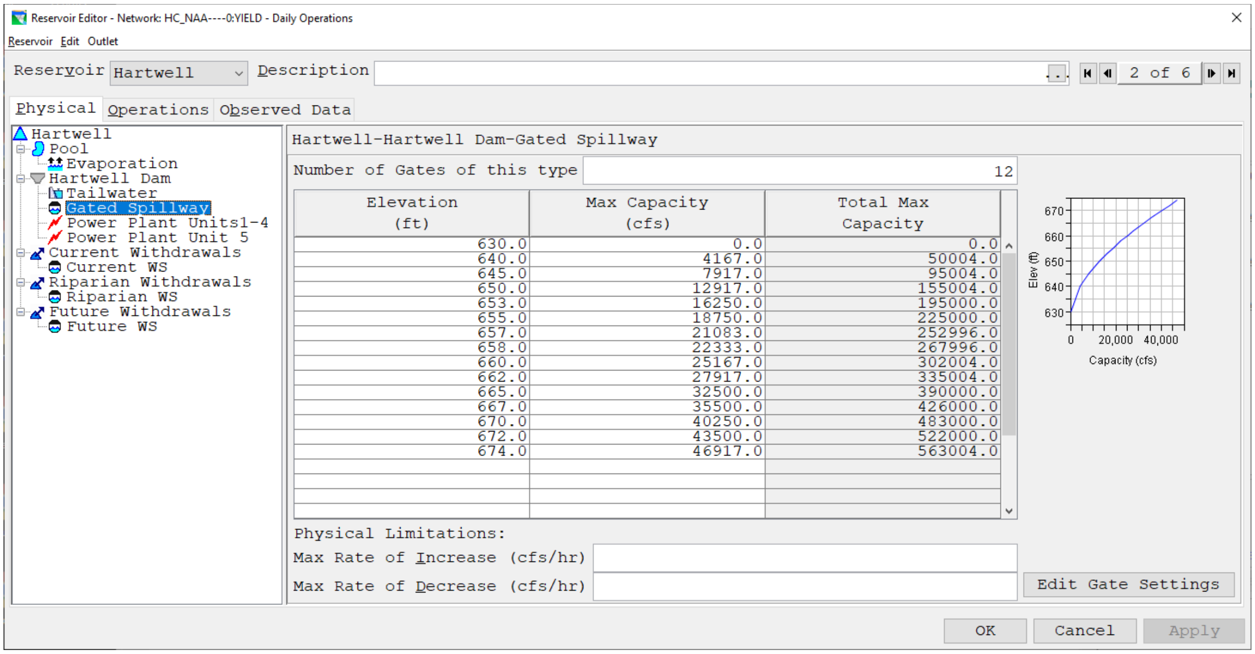
● Simple Rating ○ Rating Function

Function Of: Simple Rating Curve

Flow (cfs)	Stage (ft)
0.0	187.0
15000.0	190.0
65000.0	200.0
155000.0	210.0
280000.0	220.0
440000.0	230.0
640000.0	240.0
870000.0	250.0

Stage Datum (ft): 0.0

Figure 4.1-9: (Thurmond Tailwater Rating Curve)



Reservoir: Hartwell

Description:

2 of 6

Hartwell-Hartwell Dam-Gated Spillway

Number of Gates of this type: 12

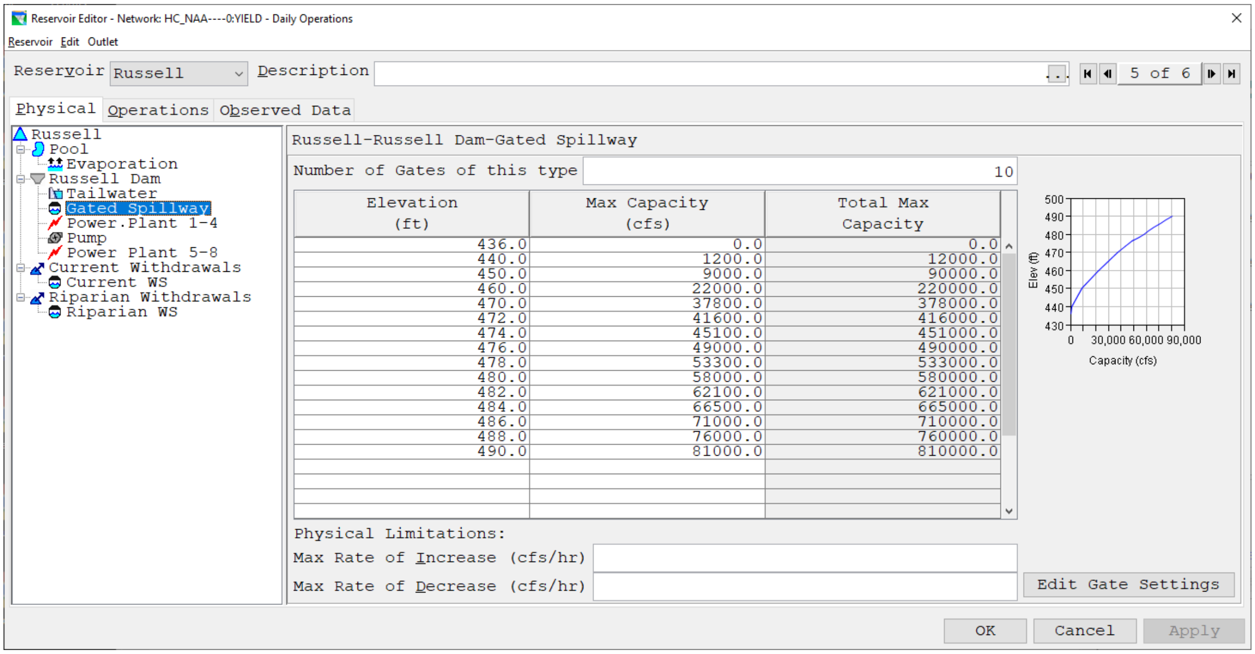
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
630.0	0.0	0.0
640.0	4167.0	50004.0
645.0	7917.0	95004.0
650.0	12917.0	155004.0
653.0	16250.0	195000.0
655.0	18750.0	225000.0
657.0	21083.0	252996.0
658.0	22333.0	267996.0
660.0	25167.0	302004.0
662.0	27917.0	335004.0
665.0	32500.0	390000.0
667.0	35500.0	426000.0
670.0	40250.0	483000.0
672.0	43500.0	522000.0
674.0	46917.0	563004.0

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-10: (Hartwell Spillway Outlet Capacity)



Reservoir: Russell

Description:

5 of 6

Russell-Russell Dam-Gated Spillway

Number of Gates of this type: 10

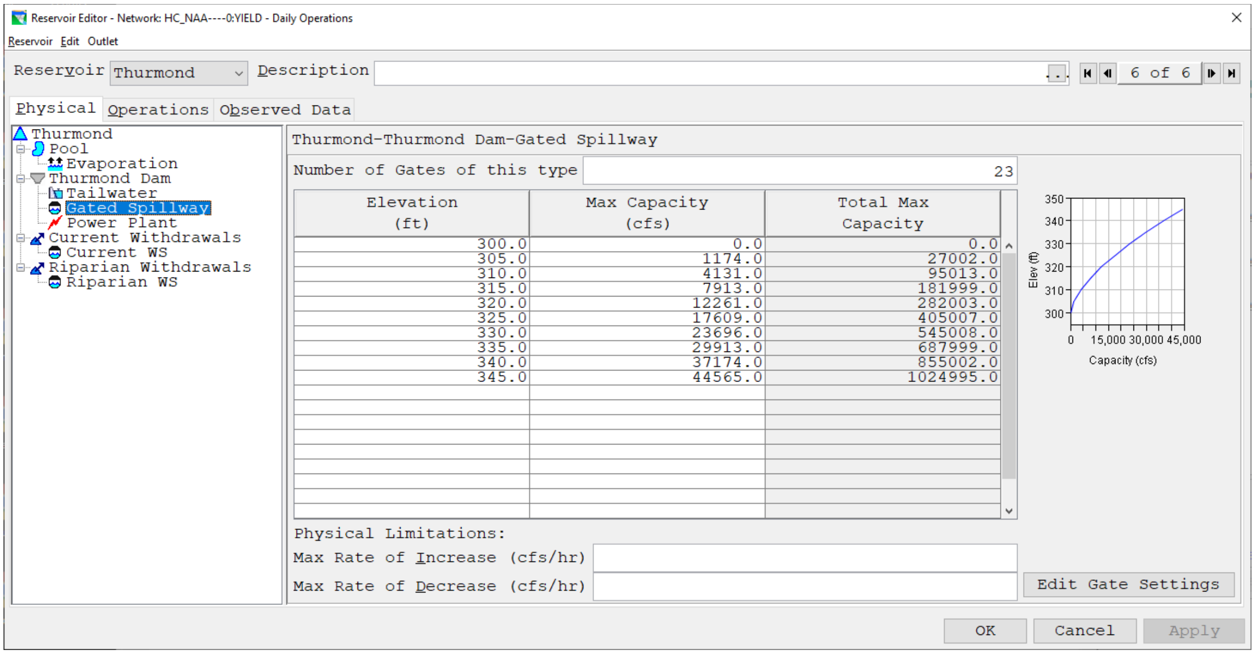
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
436.0	0.0	0.0
440.0	1200.0	12000.0
450.0	9000.0	90000.0
460.0	22000.0	220000.0
470.0	37800.0	378000.0
472.0	41600.0	416000.0
474.0	45100.0	451000.0
476.0	49000.0	490000.0
478.0	53300.0	533000.0
480.0	58000.0	580000.0
482.0	62100.0	621000.0
484.0	66500.0	665000.0
486.0	71000.0	710000.0
488.0	76000.0	760000.0
490.0	81000.0	810000.0

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-11: (Russell Spillway Outlet Capacity)



Reservoir: Thurmond

Description:

Thurmond-Thurmond Dam-Gated Spillway

Number of Gates of this type: 23

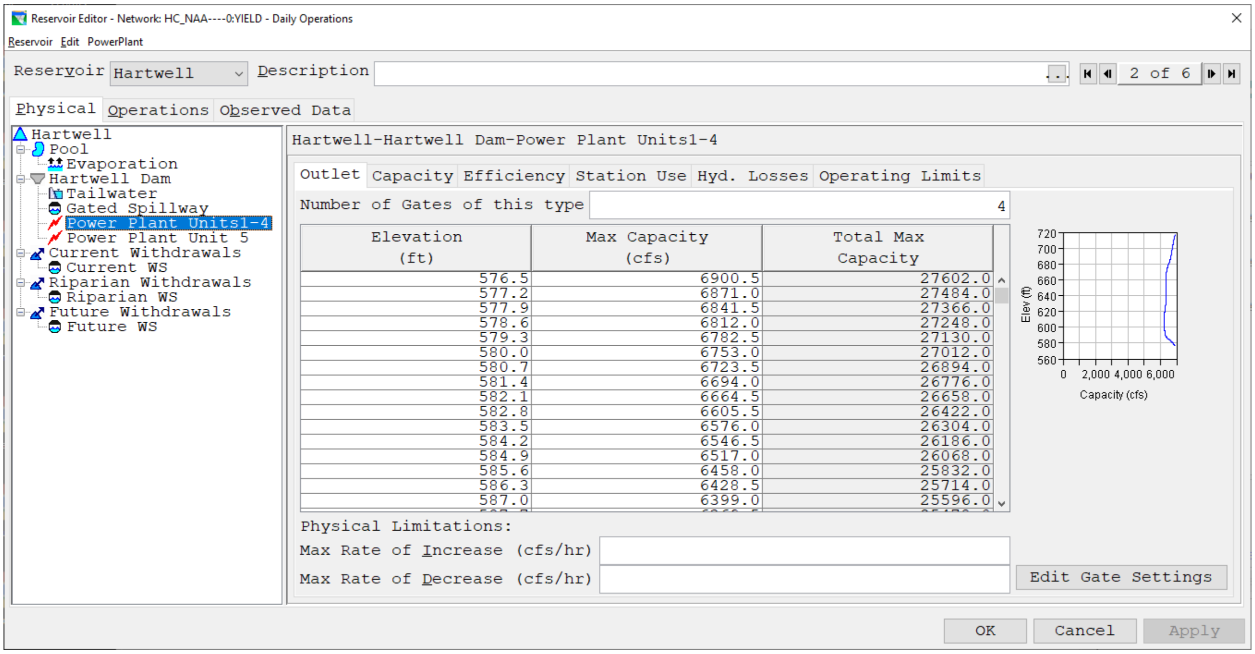
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
300.0	0.0	0.0
305.0	1174.0	27002.0
310.0	4131.0	95013.0
315.0	7913.0	181999.0
320.0	12261.0	282003.0
325.0	17609.0	405007.0
330.0	23696.0	545008.0
335.0	29913.0	687999.0
340.0	37174.0	855002.0
345.0	44565.0	1024995.0

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-12: (Russell Spillway Outlet Capacity)



Reservoir: Hartwell

Description:

Hartwell-Hartwell Dam-Power Plant Units1-4

Number of Gates of this type: 4

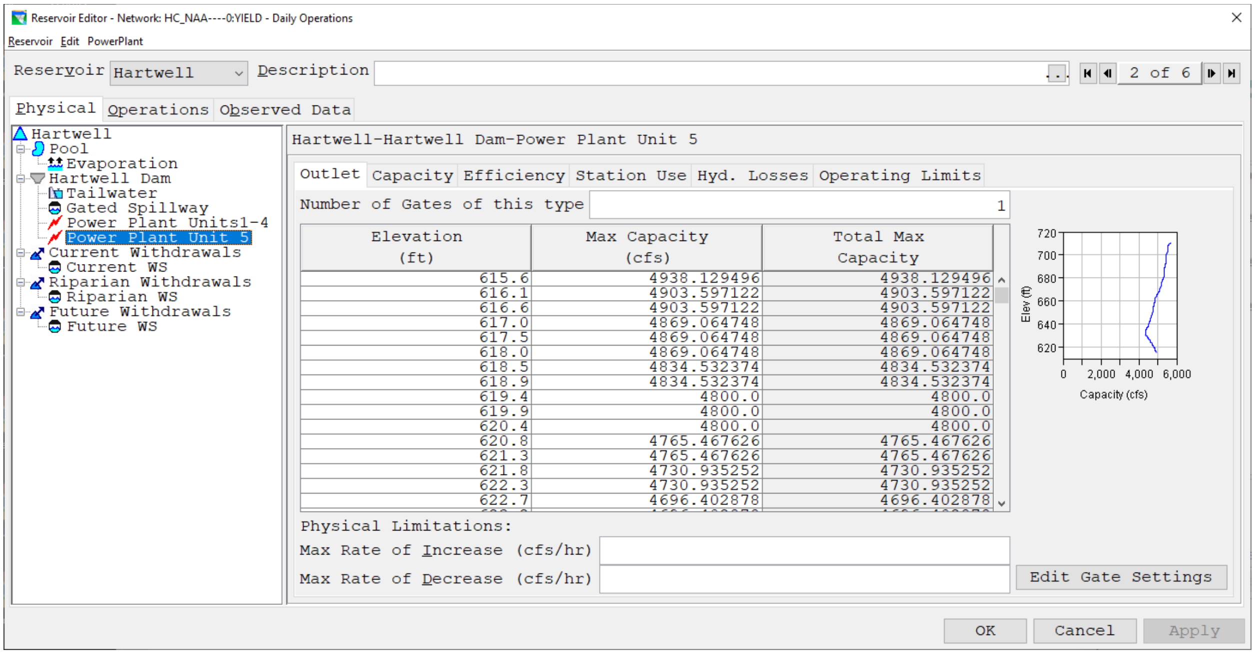
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
576.5	6900.5	27602.0
577.2	6871.0	27484.0
577.9	6841.5	27366.0
578.6	6812.0	27248.0
579.3	6782.5	27130.0
580.0	6753.0	27012.0
580.7	6723.5	26894.0
581.4	6694.0	26776.0
582.1	6664.5	26658.0
582.8	6605.5	26422.0
583.5	6576.0	26304.0
584.2	6546.5	26186.0
584.9	6517.0	26068.0
585.6	6458.0	25832.0
586.3	6428.5	25714.0
587.0	6399.0	25596.0

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-13: (Hartwell Power plant Units 1-4)



Reservoir Editor - Network: HC_NAA----0:YIELD - Daily Operations

Reservoir: Hartwell

Description:

2 of 6

Hartwell-Hartwell Dam-Power Plant Unit 5

Number of Gates of this type: 1

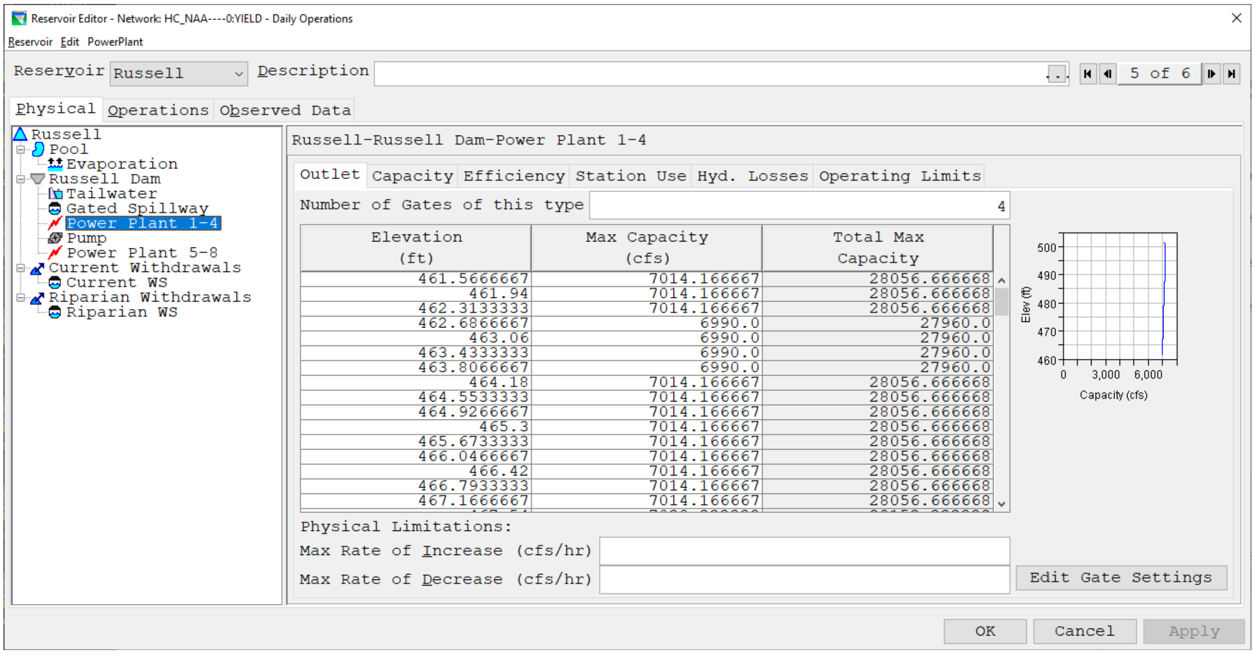
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
615.6	4938.129496	4938.129496
616.1	4903.597122	4903.597122
616.6	4903.597122	4903.597122
617.0	4869.064748	4869.064748
617.5	4869.064748	4869.064748
618.0	4869.064748	4869.064748
618.5	4834.532374	4834.532374
618.9	4834.532374	4834.532374
619.4	4800.0	4800.0
619.9	4800.0	4800.0
620.4	4800.0	4800.0
620.8	4765.467626	4765.467626
621.3	4765.467626	4765.467626
621.8	4730.935252	4730.935252
622.3	4730.935252	4730.935252
622.7	4696.402878	4696.402878

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-14: (Hartwell Power plant Unit 5)



Reservoir Editor - Network: HC_NAA----0:YIELD - Daily Operations

Reservoir: Russell

Description:

5 of 6

Russell-Russell Dam-Power Plant 1-4

Number of Gates of this type: 4

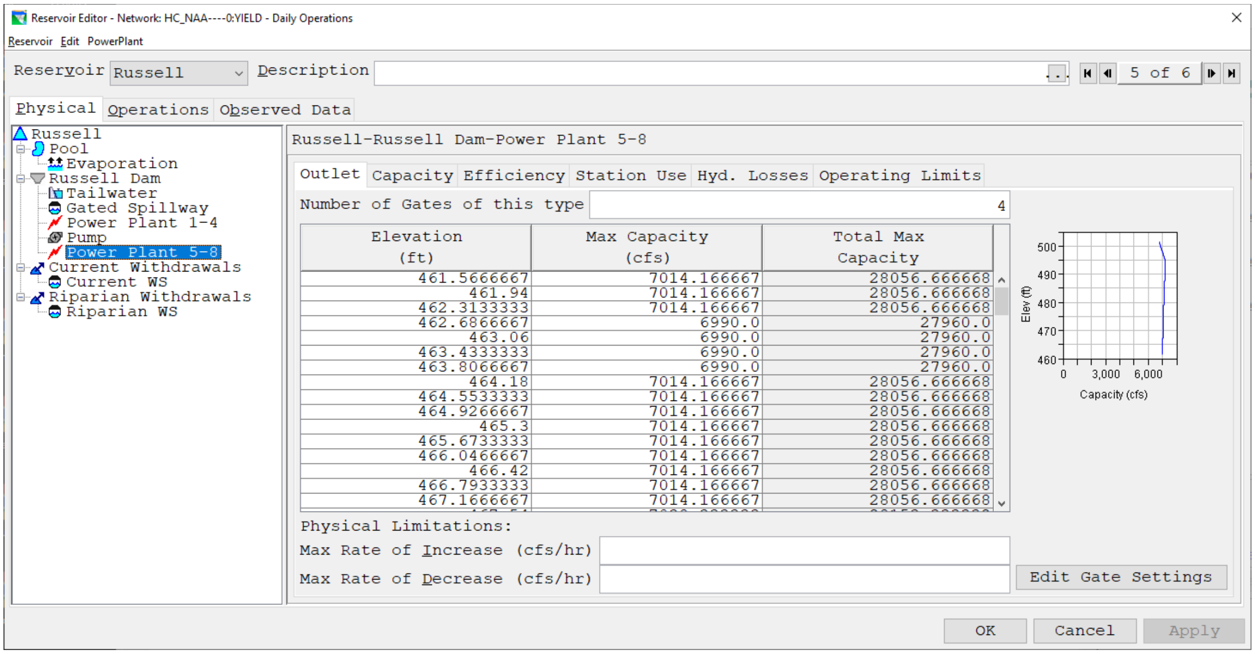
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
461.5666667	7014.166667	28056.666668
461.94	7014.166667	28056.666668
462.3133333	7014.166667	28056.666668
462.6866667	6990.0	27960.0
463.06	6990.0	27960.0
463.4333333	6990.0	27960.0
463.8066667	6990.0	27960.0
464.18	7014.166667	28056.666668
464.5533333	7014.166667	28056.666668
464.9266667	7014.166667	28056.666668
465.3	7014.166667	28056.666668
465.6733333	7014.166667	28056.666668
466.0466667	7014.166667	28056.666668
466.42	7014.166667	28056.666668
466.7933333	7014.166667	28056.666668
467.1666667	7014.166667	28056.666668

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-15: (Russell Power plant Units 1-4)



Reservoir: Russell
Description:
5 of 6

Russell-Russell Dam-Power Plant 5-8

Number of Gates of this type: 4

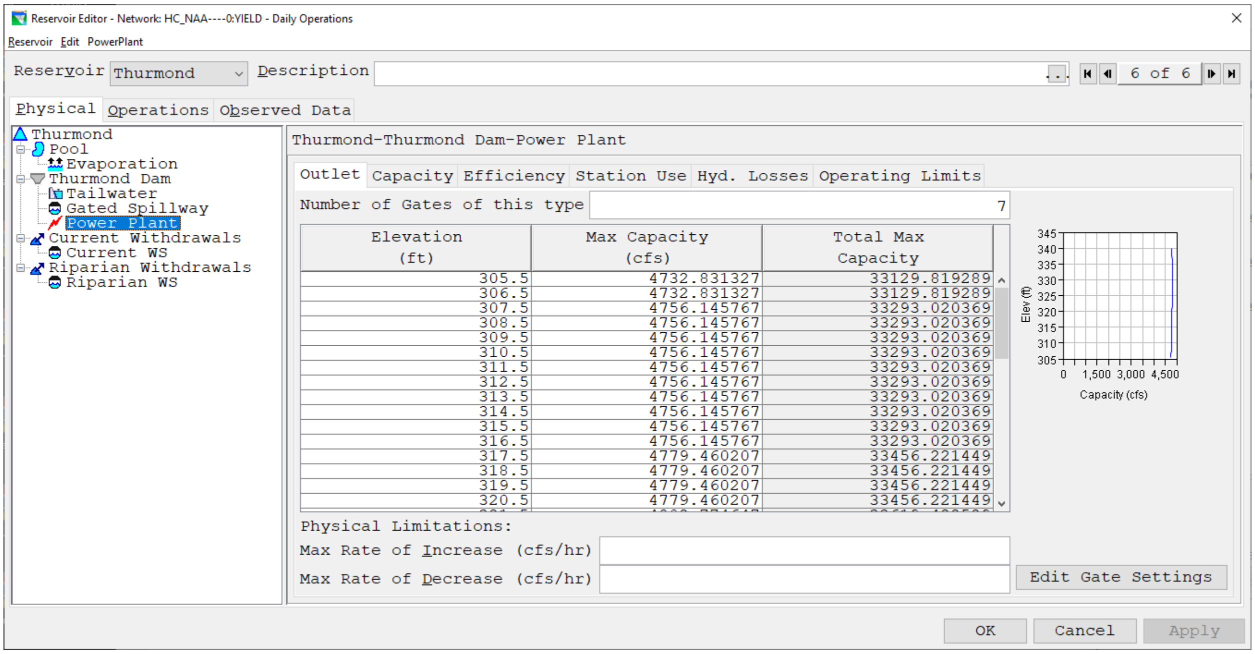
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
461.5666667	7014.166667	28056.666668
461.94	7014.166667	28056.666668
462.3133333	7014.166667	28056.666668
462.6866667	6990.0	27960.0
463.06	6990.0	27960.0
463.4333333	6990.0	27960.0
463.8066667	6990.0	27960.0
464.18	7014.166667	28056.666668
464.5533333	7014.166667	28056.666668
464.9266667	7014.166667	28056.666668
465.3	7014.166667	28056.666668
465.6733333	7014.166667	28056.666668
466.0466667	7014.166667	28056.666668
466.42	7014.166667	28056.666668
466.7933333	7014.166667	28056.666668
467.1666667	7014.166667	28056.666668

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-16: (Russell Power plant Units 5-8)



Reservoir: Thurmond
Description:
6 of 6

Thurmond-Thurmond Dam-Power Plant

Number of Gates of this type: 7

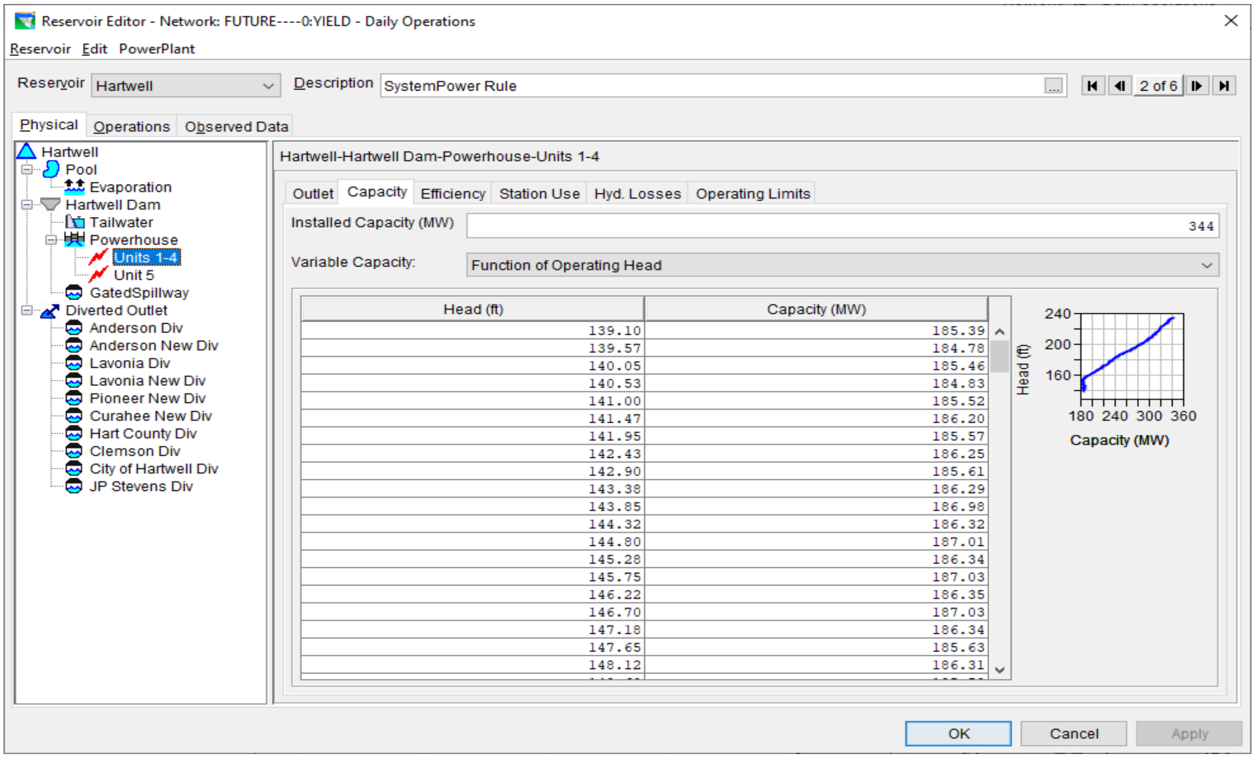
Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
305.5	4732.831327	33129.819289
306.5	4732.831327	33129.819289
307.5	4756.145767	33293.020369
308.5	4756.145767	33293.020369
309.5	4756.145767	33293.020369
310.5	4756.145767	33293.020369
311.5	4756.145767	33293.020369
312.5	4756.145767	33293.020369
313.5	4756.145767	33293.020369
314.5	4756.145767	33293.020369
315.5	4756.145767	33293.020369
316.5	4756.145767	33293.020369
317.5	4779.460207	33456.221449
318.5	4779.460207	33456.221449
319.5	4779.460207	33456.221449
320.5	4779.460207	33456.221449

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-17: (Thurmond Power plant Outlet Capacity)



Reservoir Editor - Network: FUTURE----0:YIELD - Daily Operations

Reservoir: Hartwell

Description: SystemPower Rule

2 of 6

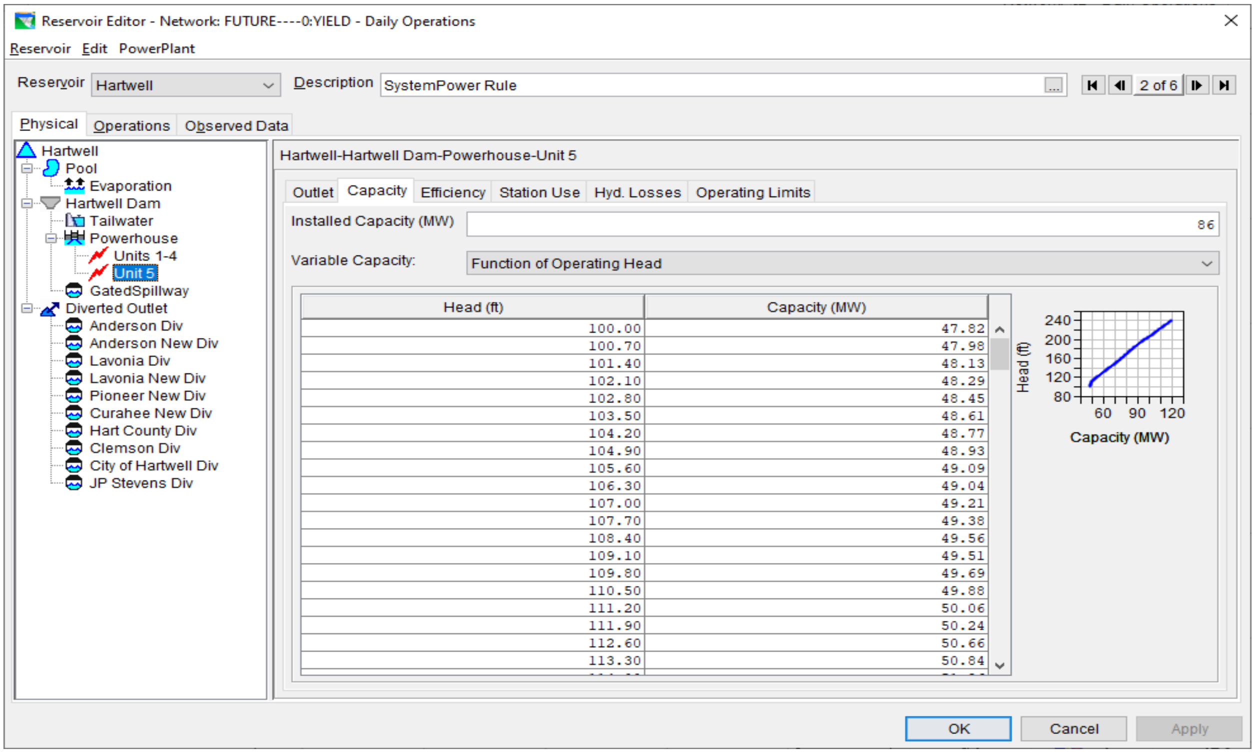
Hartwell-Hartwell Dam-Powerhouse-Units 1-4

Installed Capacity (MW): 344

Variable Capacity: Function of Operating Head

Head (ft)	Capacity (MW)
139.10	185.39
139.57	184.78
140.05	185.46
140.53	184.83
141.00	185.52
141.47	186.20
141.95	185.57
142.43	186.25
142.90	185.61
143.38	186.29
143.85	186.98
144.32	186.32
144.80	187.01
145.28	186.34
145.75	187.03
146.22	186.35
146.70	187.03
147.18	186.34
147.65	185.63
148.12	186.31

Figure 4.1-18: (Hartwell Installed Generating Capacity Units 1-4)



Reservoir Editor - Network: FUTURE----0:YIELD - Daily Operations

Reservoir: Hartwell

Description: SystemPower Rule

2 of 6

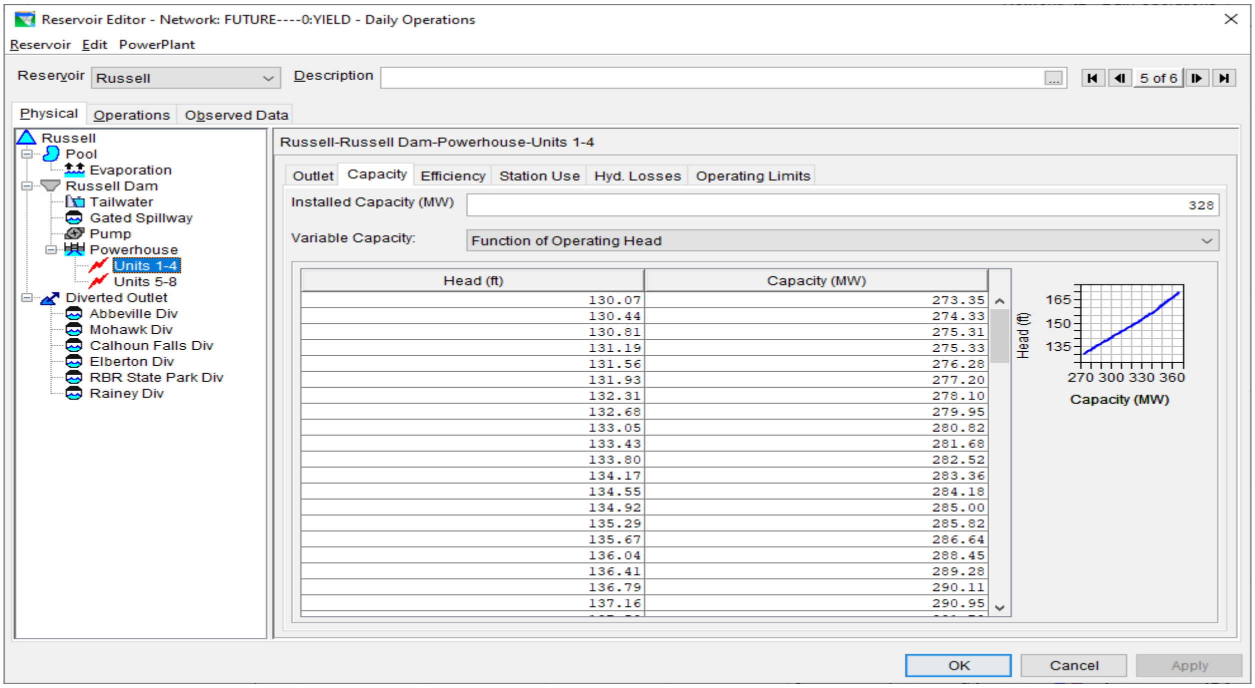
Hartwell-Hartwell Dam-Powerhouse-Unit 5

Installed Capacity (MW): 86

Variable Capacity: Function of Operating Head

Head (ft)	Capacity (MW)
100.00	47.82
100.70	47.98
101.40	48.13
102.10	48.29
102.80	48.45
103.50	48.61
104.20	48.77
104.90	48.93
105.60	49.09
106.30	49.04
107.00	49.21
107.70	49.38
108.40	49.56
109.10	49.51
109.80	49.69
110.50	49.88
111.20	50.06
111.90	50.24
112.60	50.66
113.30	50.84

Figure 4.1-19: (Hartwell Installed Generating Capacity Unit 5)



Reservoir: Russell

Description:

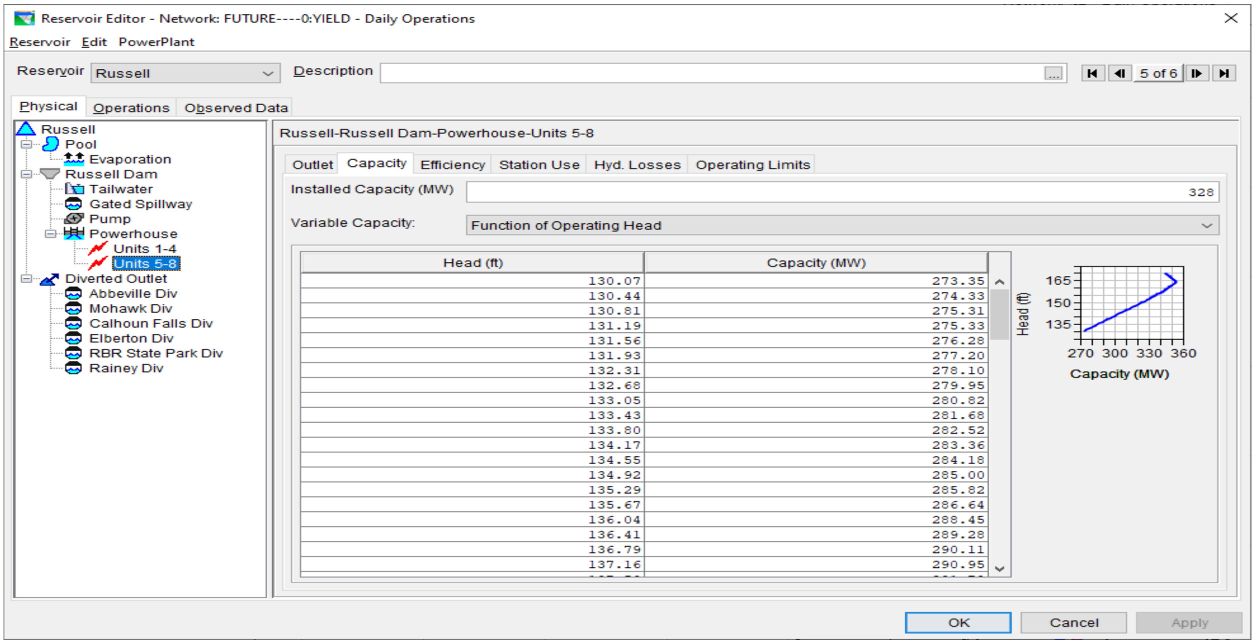
Russell-Russell Dam-Powerhouse-Units 1-4

Installed Capacity (MW): 328

Variable Capacity: Function of Operating Head

Head (ft)	Capacity (MW)
130.07	273.35
130.44	274.33
130.81	275.31
131.19	275.33
131.56	276.28
131.93	277.20
132.31	278.10
132.68	279.95
133.05	280.82
133.43	281.68
133.80	282.52
134.17	283.36
134.55	284.18
134.92	285.00
135.29	285.82
135.67	286.64
136.04	288.45
136.41	289.28
136.79	290.11
137.16	290.95

Figure 4.1-20: (Russell Installed Generating Capacity Units 1-4)



Reservoir: Russell

Description:

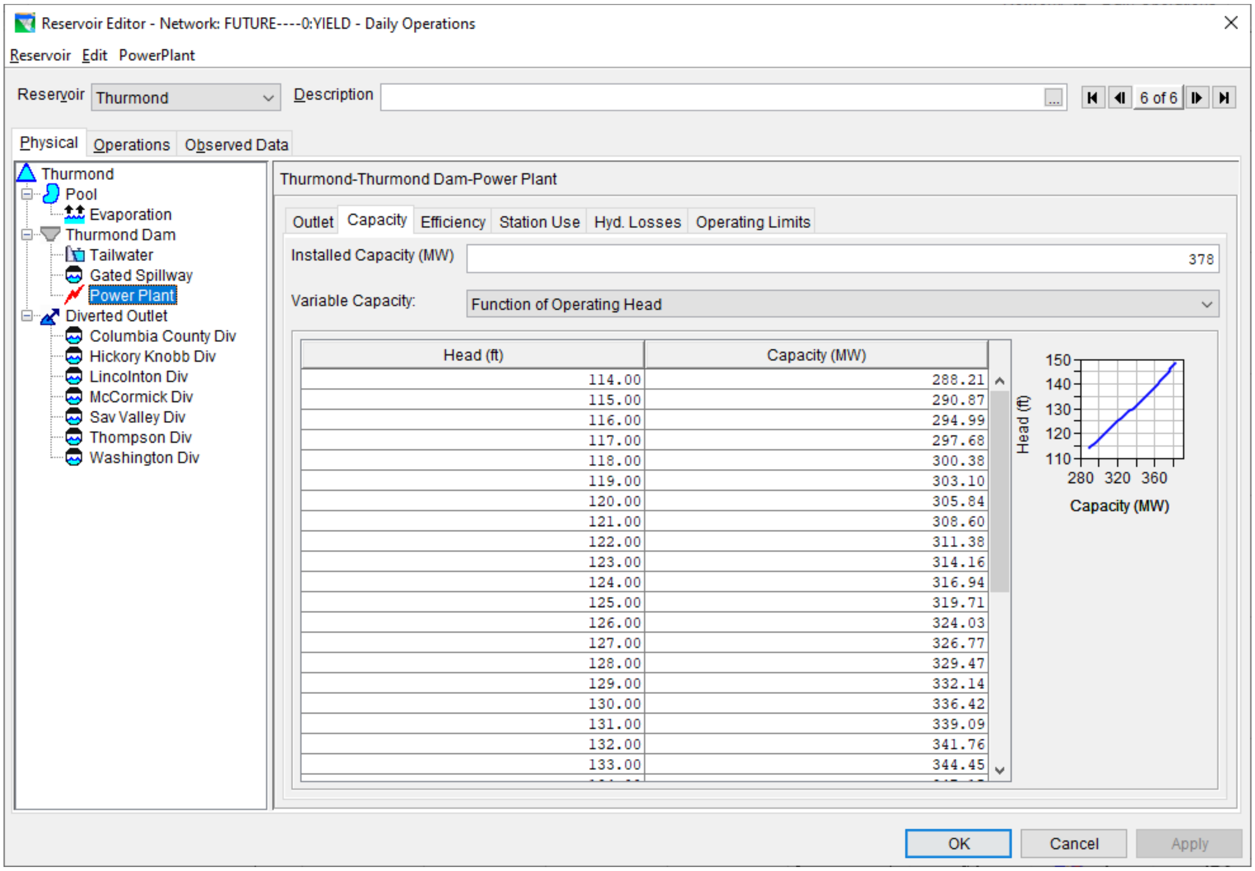
Russell-Russell Dam-Powerhouse-Units 5-8

Installed Capacity (MW): 328

Variable Capacity: Function of Operating Head

Head (ft)	Capacity (MW)
130.07	273.35
130.44	274.33
130.81	275.31
131.19	275.33
131.56	276.28
131.93	277.20
132.31	278.10
132.68	279.95
133.05	280.82
133.43	281.68
133.80	282.52
134.17	283.36
134.55	284.18
134.92	285.00
135.29	285.82
135.67	286.64
136.04	288.45
136.41	289.28
136.79	290.11
137.16	290.95

Figure 4.1-21: (Russell Installed Generating Capacity Units 5-8)



Reservoir: Thurmond

Description:

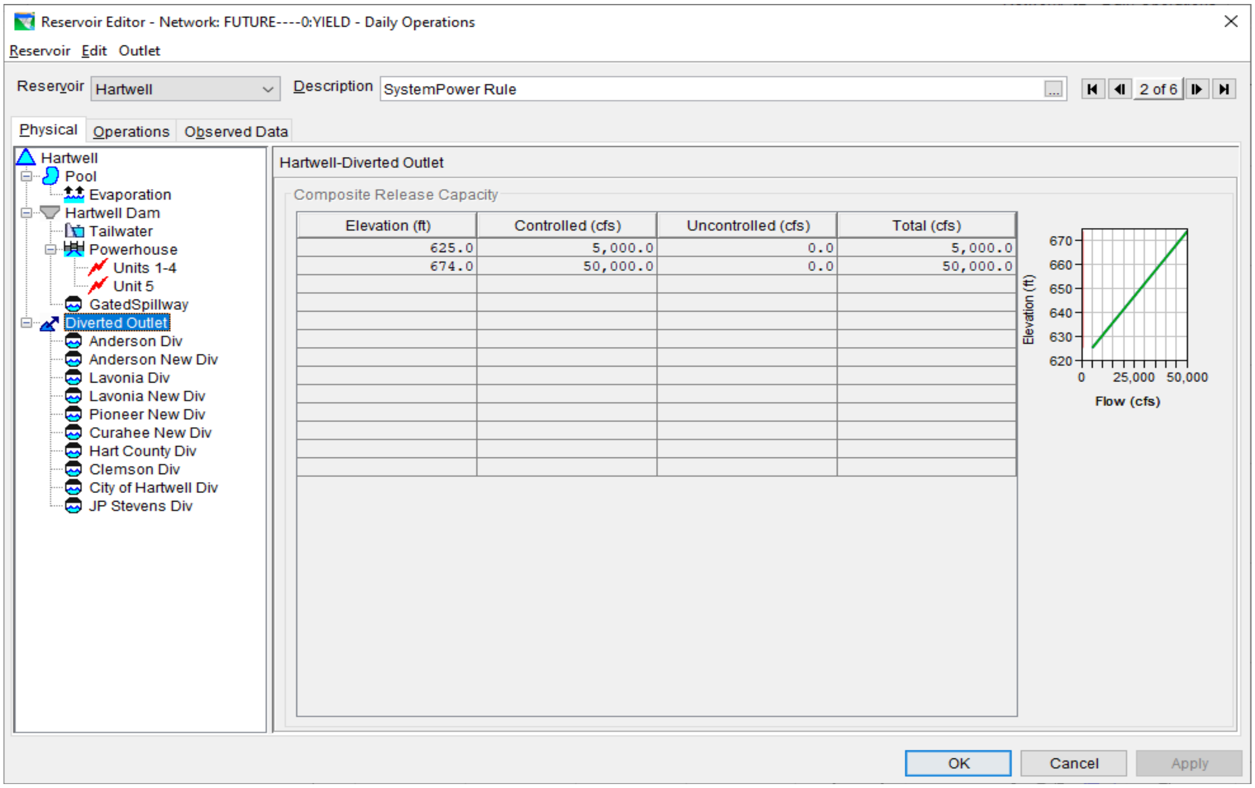
Thurmond-Thurmond Dam-Power Plant

Installed Capacity (MW): 378

Variable Capacity: Function of Operating Head

Head (ft)	Capacity (MW)
114.00	288.21
115.00	290.87
116.00	294.99
117.00	297.68
118.00	300.38
119.00	303.10
120.00	305.84
121.00	308.60
122.00	311.38
123.00	314.16
124.00	316.94
125.00	319.71
126.00	324.03
127.00	326.77
128.00	329.47
129.00	332.14
130.00	336.42
131.00	339.09
132.00	341.76
133.00	344.45

Figure 4.1-22: (Thurmond Installed Generating Capacity)



Reservoir: Hartwell

Description: SystemPower Rule

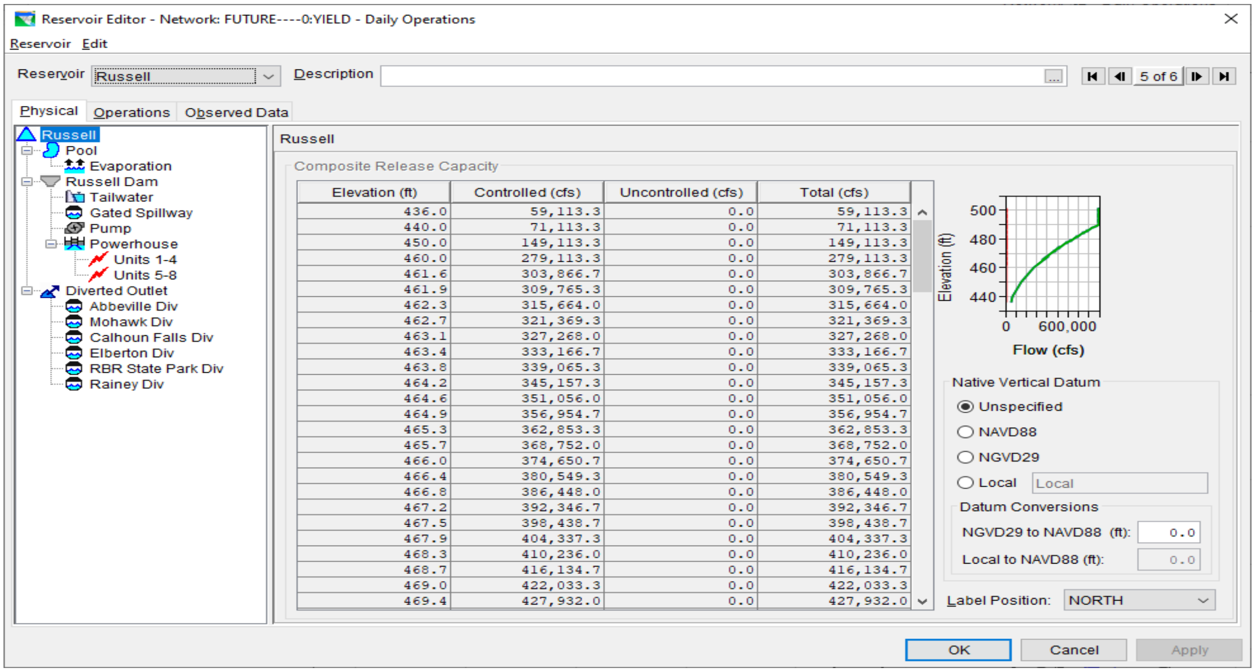
2 of 6

Hartwell-Diverted Outlet

Composite Release Capacity

Elevation (ft)	Controlled (cfs)	Uncontrolled (cfs)	Total (cfs)
625.0	5,000.0	0.0	5,000.0
674.0	50,000.0	0.0	50,000.0

Figure 4.1-23: (Hartwell Diverted Outlet Group Definition)



Reservoir: Russell

Description:

5 of 6

Russell

Composite Release Capacity

Elevation (ft)	Controlled (cfs)	Uncontrolled (cfs)	Total (cfs)
436.0	59,113.3	0.0	59,113.3
440.0	71,113.3	0.0	71,113.3
450.0	149,113.3	0.0	149,113.3
460.0	279,113.3	0.0	279,113.3
461.6	303,866.7	0.0	303,866.7
461.9	309,765.3	0.0	309,765.3
462.3	315,664.0	0.0	315,664.0
462.7	321,369.3	0.0	321,369.3
463.1	327,268.0	0.0	327,268.0
463.4	333,166.7	0.0	333,166.7
463.8	339,065.3	0.0	339,065.3
464.2	345,157.3	0.0	345,157.3
464.6	351,056.0	0.0	351,056.0
464.9	356,954.7	0.0	356,954.7
465.3	362,853.3	0.0	362,853.3
465.7	368,752.0	0.0	368,752.0
466.0	374,650.7	0.0	374,650.7
466.4	380,549.3	0.0	380,549.3
466.8	386,448.0	0.0	386,448.0
467.2	392,346.7	0.0	392,346.7
467.5	398,438.7	0.0	398,438.7
467.9	404,337.3	0.0	404,337.3
468.3	410,236.0	0.0	410,236.0
468.7	416,134.7	0.0	416,134.7
469.0	422,033.3	0.0	422,033.3
469.4	427,932.0	0.0	427,932.0

Native Vertical Datum

● Unspecified
○ NAVD88
○ NGVD29
○ Local Local

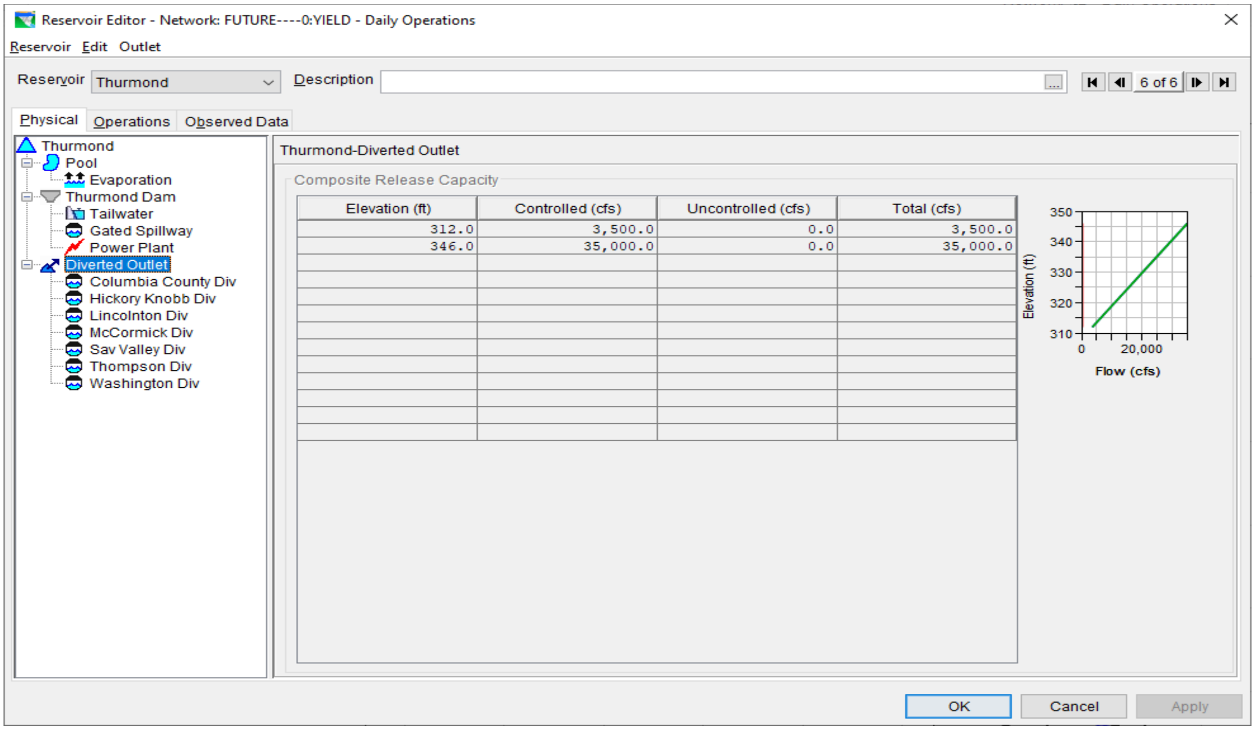
Datum Conversions

NGVD29 to NAVD88 (ft): 0.0

Local to NAVD88 (ft): 0.0

Label Position: NORTH

Figure 4.1-24: (Russell Diverted Outlet Definition)



Reservoir: Thurmond

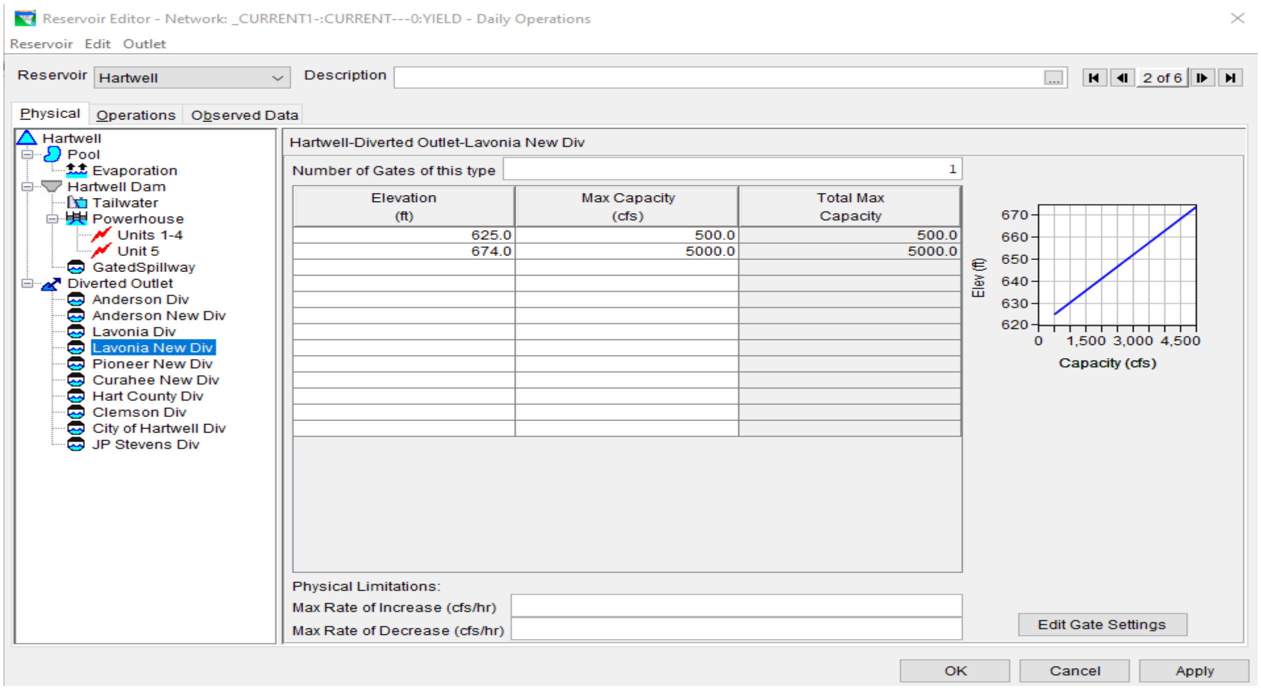
Description:

6 of 6

Thurmond-Diverted Outlet

Elevation (ft)	Controlled (cfs)	Uncontrolled (cfs)	Total (cfs)
312.0	3,500.0	0.0	3,500.0
346.0	35,000.0	0.0	35,000.0

Figure 4.1-25: (Thurmond Diverted Outlet Group Definition)



Reservoir: Hartwell

Description:

2 of 6

Hartwell-Diverted Outlet-Lavonia New Div

Number of Gates of this type: 1

Elevation (ft)	Max Capacity (cfs)	Total Max Capacity
625.0	500.0	500.0
674.0	5000.0	5000.0

Physical Limitations:

Max Rate of Increase (cfs/hr):

Max Rate of Decrease (cfs/hr):

Figure 4.1-26: (Typical Diverted Outlet Definition)

4.2 Operations

Operational rules define the releases from each project and the interactions between the different projects in the system. A project’s yield is dependent on the reservoir operation, not just the hydrology. This is an operational yield, not hydrologic yield. Outflows from upstream projects may help support a yield at a downstream location.

Water supply accounts define a portion of the available conservation storage, and therefore receive a portion of the specific reservoir’s inflow. However, the only outflow from a water account are the withdrawals from that account. Water returned to a reservoir by a water account’s owner is hydraulically accounted for as inflow to the reservoir and not specifically as inflow to a water account. The concept of crediting water returned to a contracted water account rather than to the entire reservoir is not currently approved by USACE.

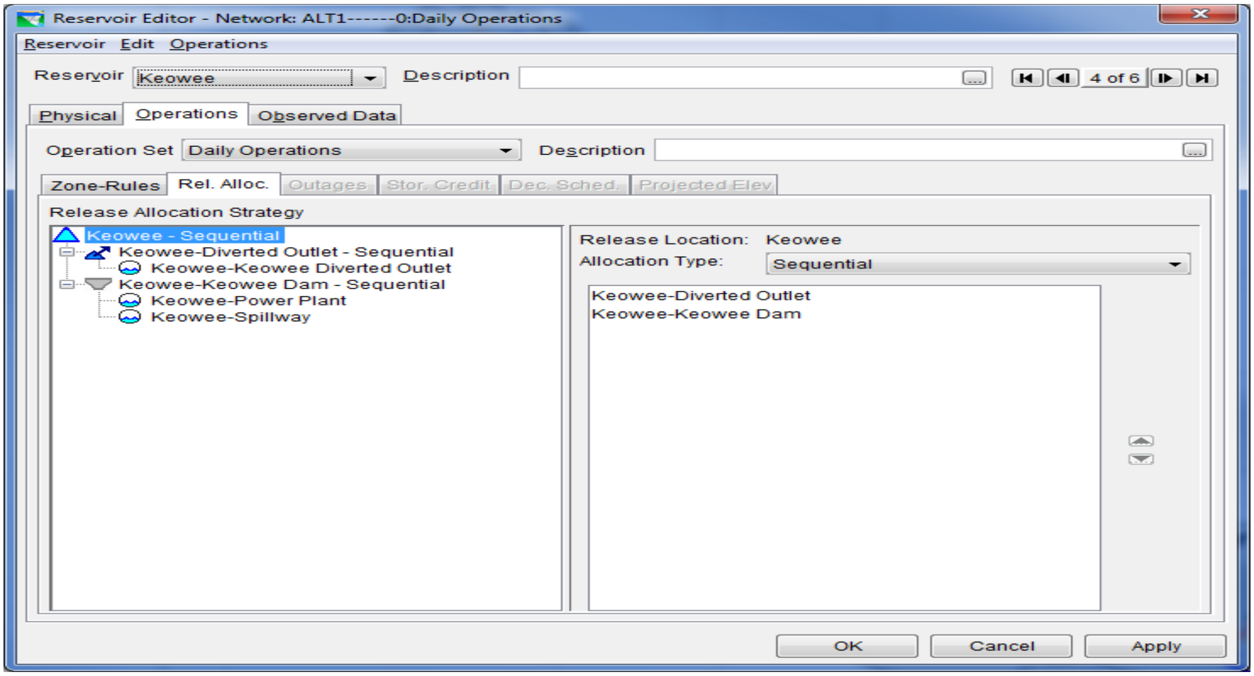
Changes in, or additions of, storage agreements have impacts on other project purposes. Changes in operating rules for other project purposes will also have impacts on the yield of storage agreements. Therefore, it is recommended that whenever changes in any operating rules are proposed, the impacts on all project purposes including water supply are evaluated.

4.2.1 Release Allocation

Each project in the system has their own release allocation specifying how water releases are prioritized from that project’s outlets (figures below).

Sequential release strategies at the main dam ensure that water is released from the project thru the power plant first until the release capacity of the power plant is exhausted, then flow is supplemented as needed from the gated spillway.

The projects that use diverted outlets to represent water account users allocate water to the diverted outlets separately than releases from the main dam. Each diverted outlet is controlled by a specified rule that does not allow releases of more or less water than specified.



Reservoir Editor - Network: ALT1------0:Daily Operations

Reservoir: Keowee

4 of 6

Operation Set: Daily Operations

Release Allocation Strategy

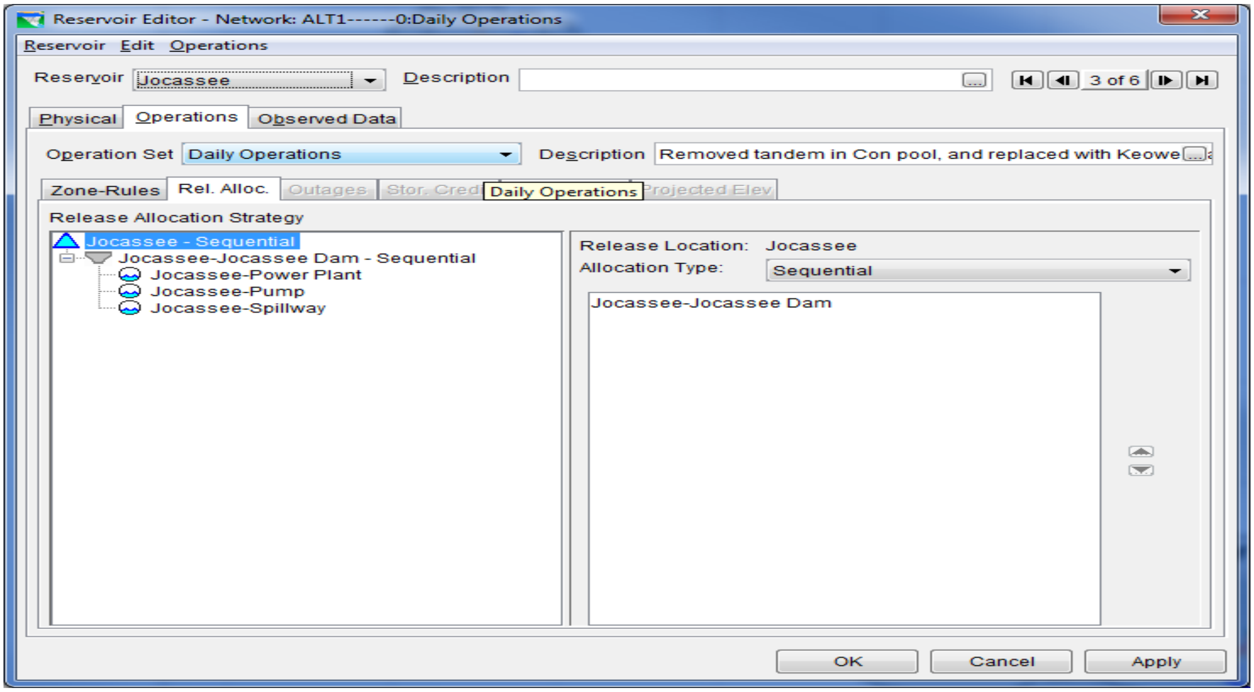
- Keowee - Sequential
  - Keowee-Diverted Outlet - Sequential
    - Keowee-Keowee Diverted Outlet
  - Keowee-Keowee Dam - Sequential
    - Keowee-Power Plant
    - Keowee-Spillway

Release Location: Keowee

Allocation Type: Sequential

Keowee-Diverted Outlet
Keowee-Keowee Dam

Figure 4.2-1: (Keowee Release Allocation Strategy)



Reservoir Editor - Network: ALT1------0:Daily Operations

Reservoir: Jocassee

3 of 6

Operation Set: Daily Operations

Description: Removed tandem in Con pool, and replaced with Keowe

Release Allocation Strategy

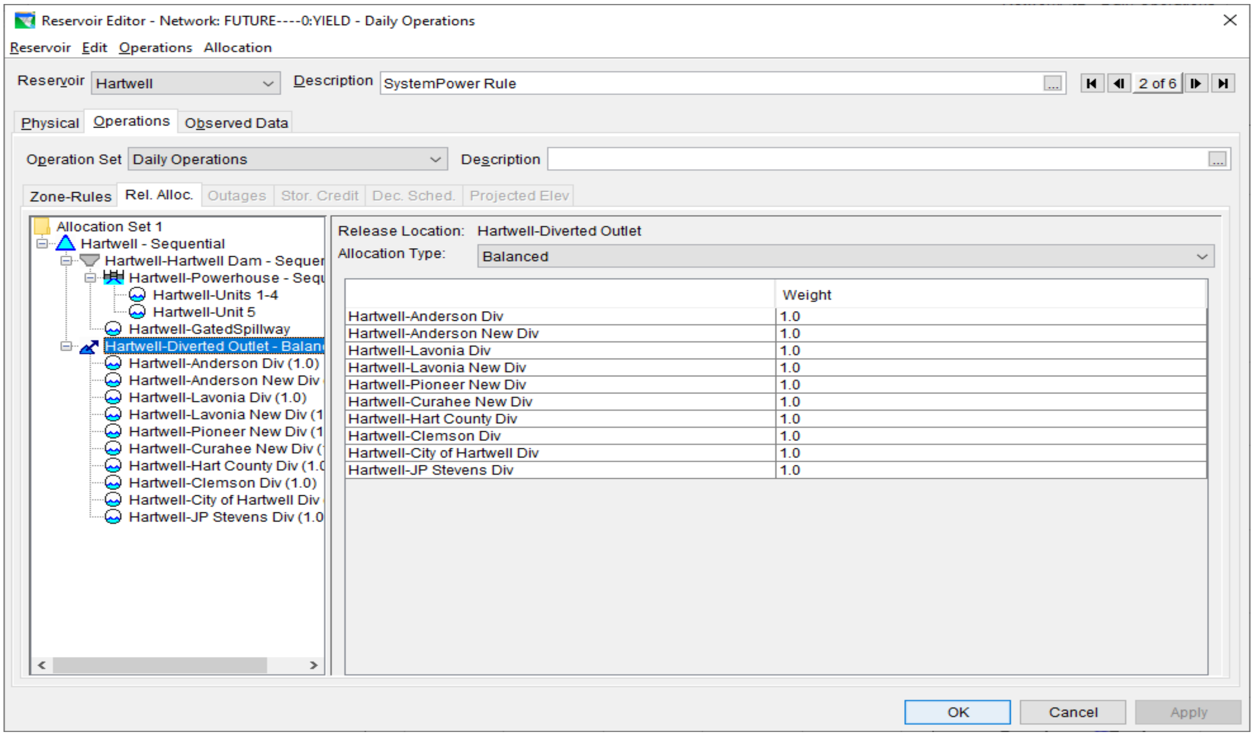
- Jocassee - Sequential
  - Jocassee-Jocassee Dam - Sequential
    - Jocassee-Power Plant
    - Jocassee-Pump
    - Jocassee-Spillway

Release Location: Jocassee

Allocation Type: Sequential

Jocassee-Jocassee Dam

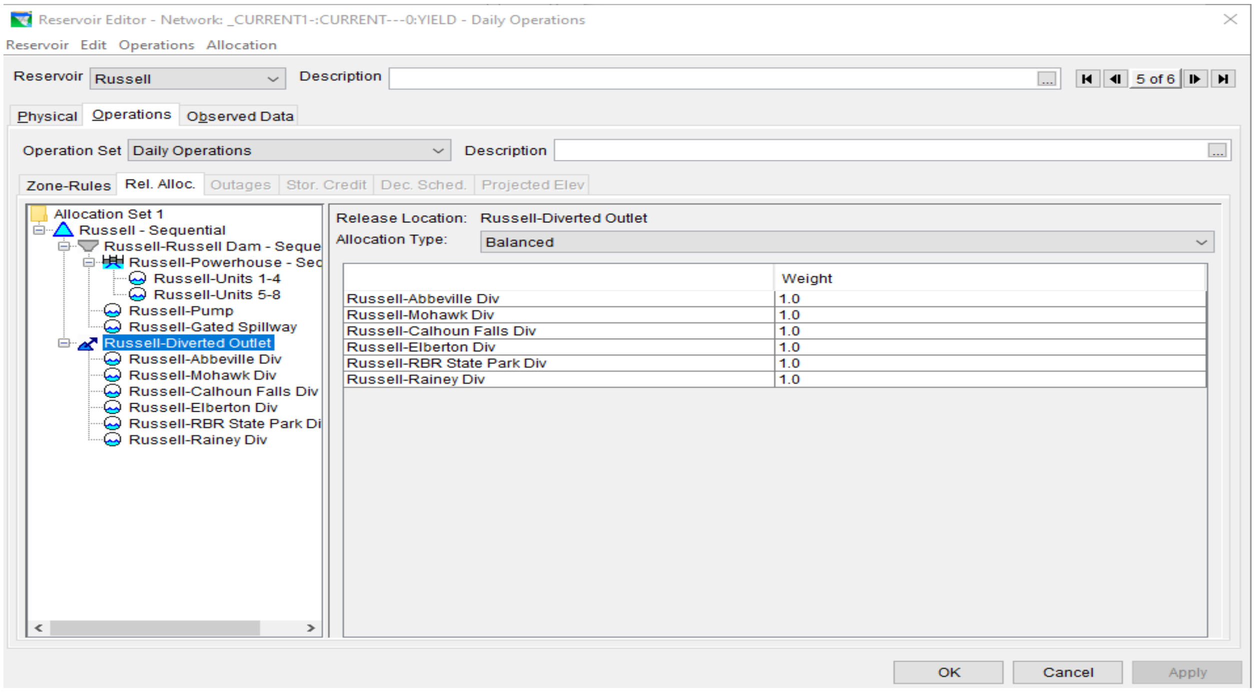
Figure 4.2-2: (Jocassee Release Allocation Strategy)



Reservoir: Hartwell
Description: SystemPower Rule
2 of 6
Operation Set: Daily Operations
Description:
Release Location: Hartwell-Diverted Outlet
Allocation Type: Balanced

	Weight
Hartwell-Anderson Div	1.0
Hartwell-Anderson New Div	1.0
Hartwell-Lavonia Div	1.0
Hartwell-Lavonia New Div	1.0
Hartwell-Pioneer New Div	1.0
Hartwell-Curahee New Div	1.0
Hartwell-Hart County Div	1.0
Hartwell-Clemson Div	1.0
Hartwell-City of Hartwell Div	1.0
Hartwell-JP Stevens Div	1.0

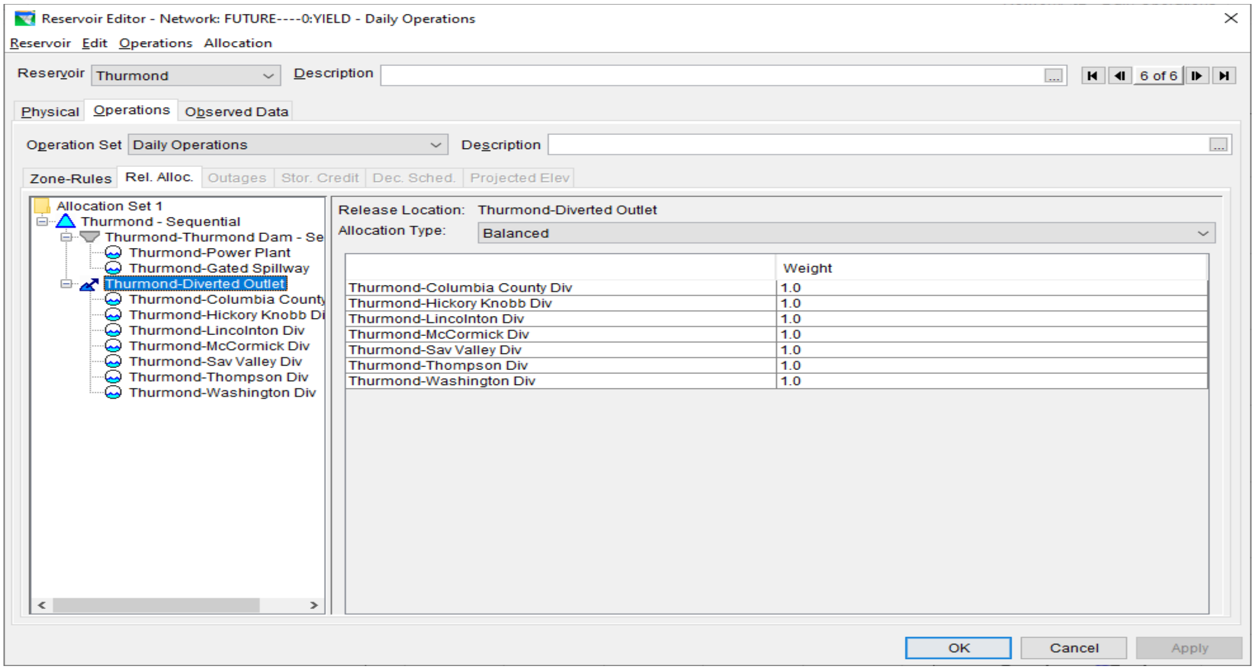
Figure 4.2-3: (Hartwell Release Allocation Strategy)



Reservoir: Russell
Description:
5 of 6
Operation Set: Daily Operations
Description:
Release Location: Russell-Diverted Outlet
Allocation Type: Balanced

	Weight
Russell-Abbeville Div	1.0
Russell-Mohawk Div	1.0
Russell-Calhoun Falls Div	1.0
Russell-Elberton Div	1.0
Russell-RBR State Park Div	1.0
Russell-Rainey Div	1.0

Figure 4.2-4: (Russell Release Allocation Strategy)



Reservoir: Thurmond

Description:

Operation Set: Daily Operations

Description:

Release Location: Thurmond-Diverted Outlet

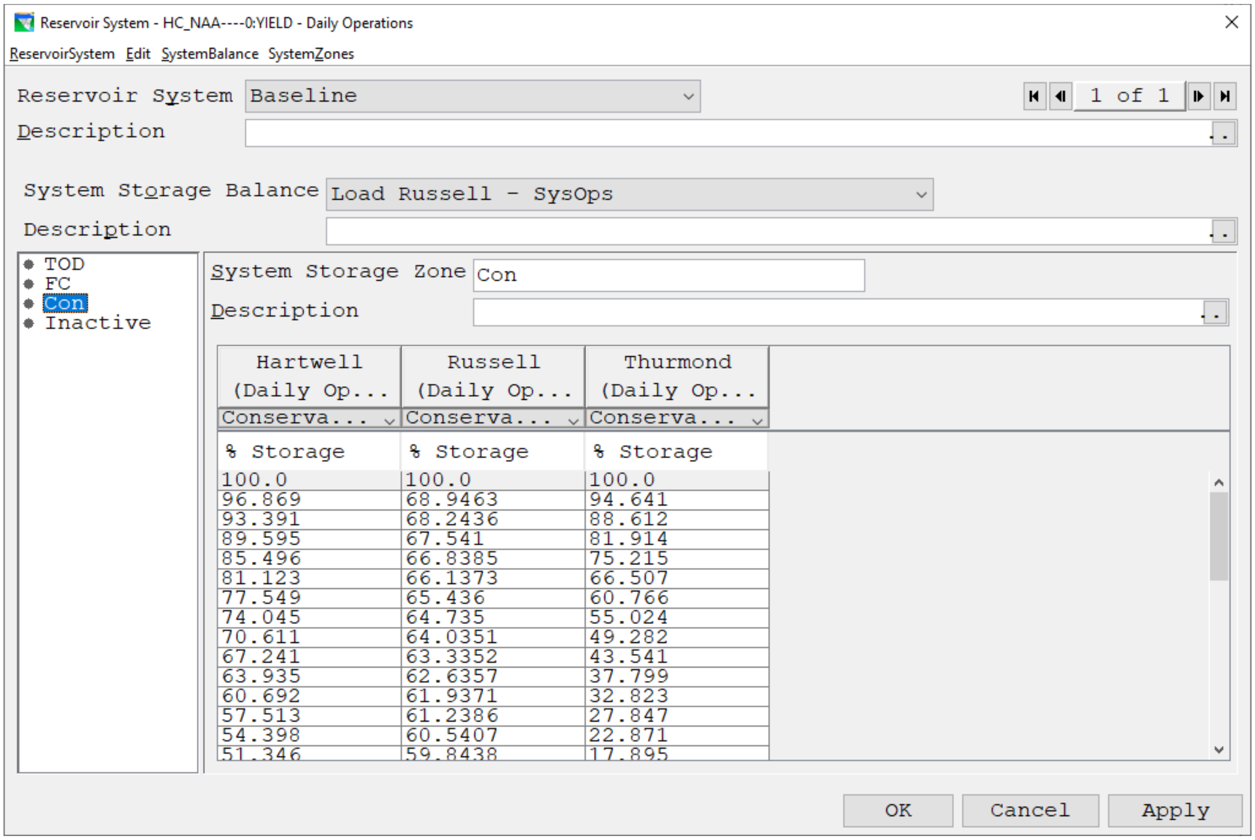
Allocation Type: Balanced

	Weight
Thurmond-Columbia County Div	1.0
Thurmond-Hickory Knobb Div	1.0
Thurmond-Lincolnton Div	1.0
Thurmond-McCormick Div	1.0
Thurmond-Sav Valley Div	1.0
Thurmond-Thompson Div	1.0
Thurmond-Washington Div	1.0

Figure 4.2-5: (Thurmond Release Allocation Strategy)

4.2.2 System Storage Balance

Projects balance their individual storage with one another based on the below table. Water releases from Thurmond are based on flow rules applied at Thurmond. Upstream projects release only what is needed to maintain the balance defined in this table. The Duke Energy Projects maintain a storage balance with the USACE projects on the Savannah River. This requirement ensures that the Duke projects release water as the USACE projects decline due to dry conditions. Duke storage balancing with USACE projects is done thru a scripted rule, per the 2014 Storage Balance Agreement. The system storage balance rules purposefully change the from flood zone to the conservation zone. It is this rule that keeps Hartwell and Thurmond in balance foot for foot in the top 15 feet of conservation storage and then changes priorities and can store more water in an upstream project during a flood.



Reservoir System: Baseline

Description:

System Storage Balance: Load Russell - SysOps

Description:

- TOD
- FC
- Con
- Inactive

System Storage Zone: Con

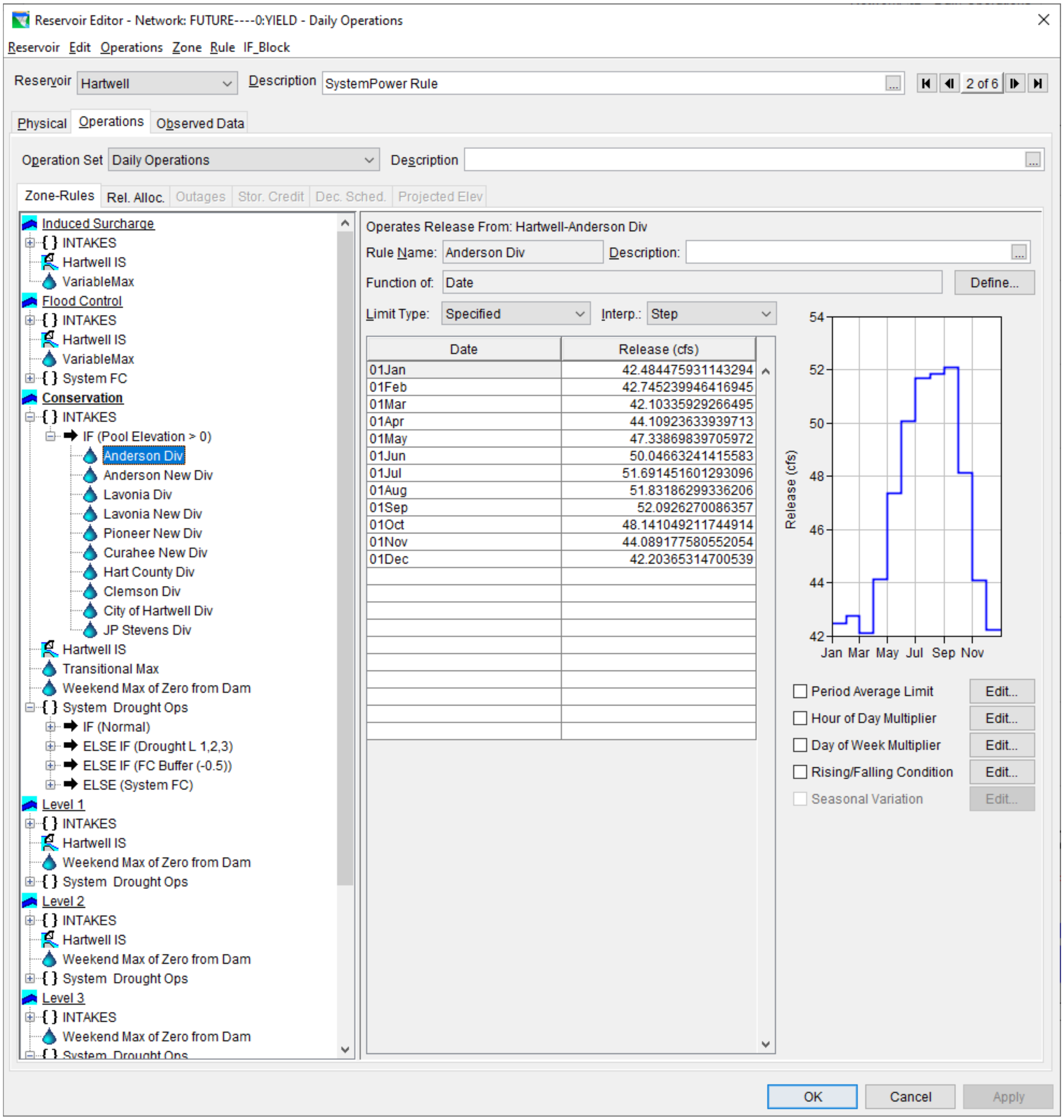
Description:

Hartwell (Daily Op...	Russell (Daily Op...	Thurmond (Daily Op...
Conserva...	Conserva...	Conserva...
% Storage	% Storage	% Storage
100.0	100.0	100.0
96.869	68.9463	94.641
93.391	68.2436	88.612
89.595	67.541	81.914
85.496	66.8385	75.215
81.123	66.1373	66.507
77.549	65.436	60.766
74.045	64.735	55.024
70.611	64.0351	49.282
67.241	63.3352	43.541
63.935	62.6357	37.799
60.692	61.9371	32.823
57.513	61.2386	27.847
54.398	60.5407	22.871
51.346	59.8438	17.895

Figure 4.2-6: (System Storage Balance)

4.2.1 Operational Rule Stacks

Project purposes other than water supply do not have water accounts. Their needs are met thru a prioritized rule stack that is shown in section 5.2. The water supply rules used in this study are always met (using specific release rules) and fall near the top of the rule stack for each project.



Reservoir: Hartwell
Description: SystemPower Rule
Operation Set: Daily Operations
Description:

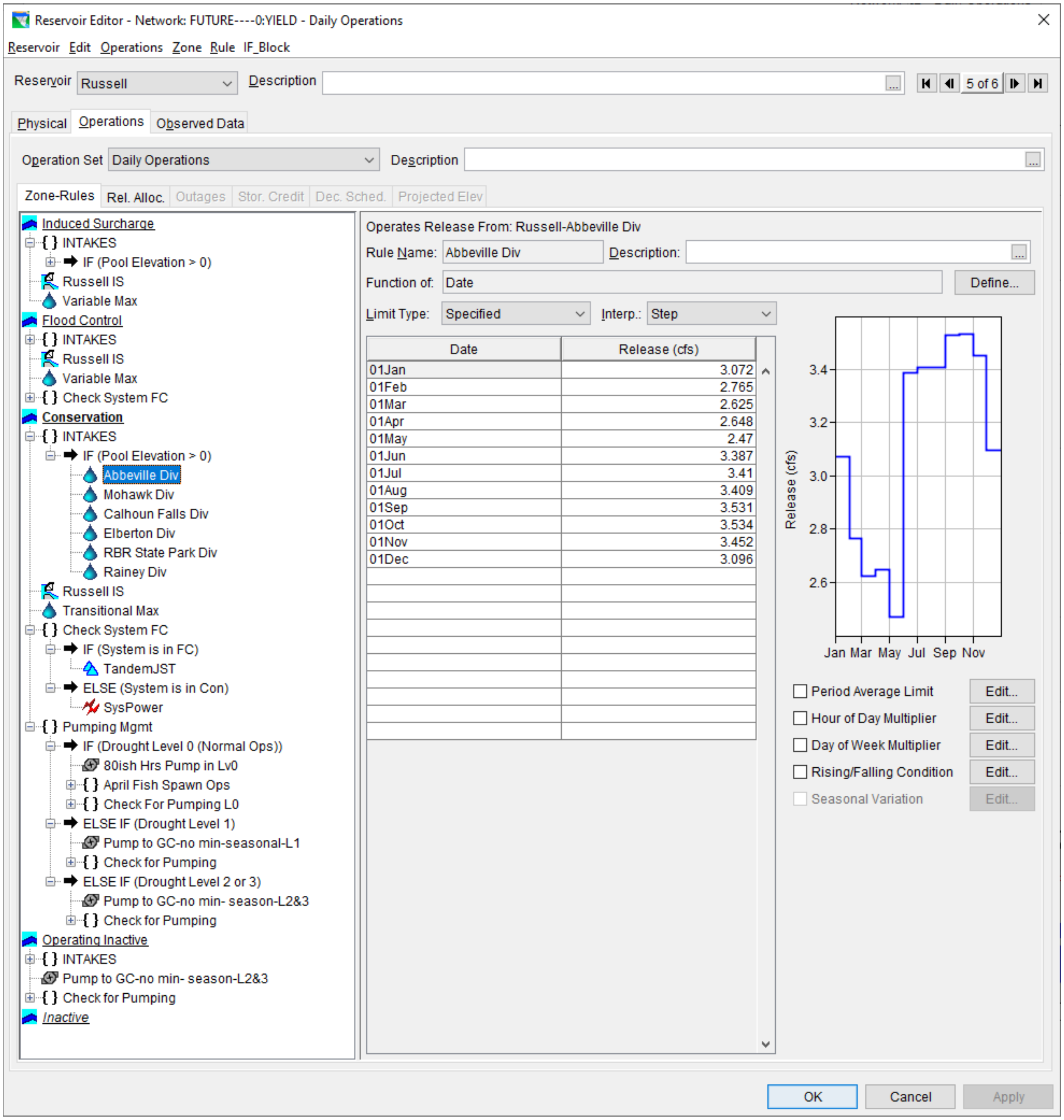
Operates Release From: Hartwell-Anderson Div
Rule Name: Anderson Div
Description:
Function of: Date
Limit Type: Specified
Interp.: Step

Date	Release (cfs)
01Jan	42.484475931143294
01Feb	42.745239946416945
01Mar	42.10335929266495
01Apr	44.10923633939713
01May	47.33869839705972
01Jun	50.04663241415583
01Jul	51.691451601293096
01Aug	51.83186299336206
01Sep	52.0926270086357
01Oct	48.141049211744914
01Nov	44.089177580552054
01Dec	42.20365314700539

☐ Period Average Limit
☐ Hour of Day Multiplier
☐ Day of Week Multiplier
☐ Rising/Falling Condition
☐ Seasonal Variation

Figure 4.2-7: (Hartwell Zone Rules)

Diversions were grouped and configured to mimic the monthly varying withdrawal of each entity.



Reservoir: Russell
Description:
Operation Set: Daily Operations
Description:

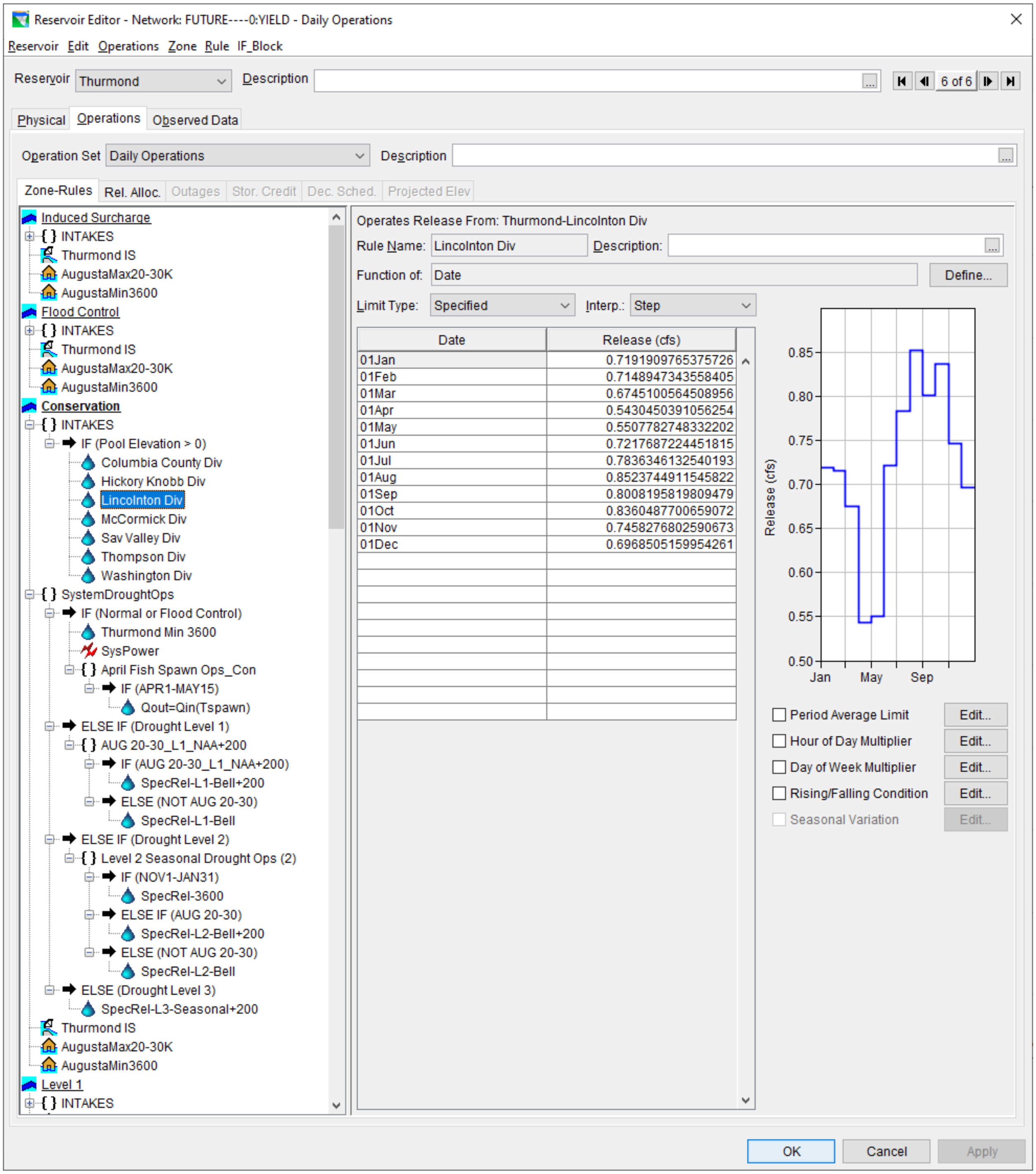
Operates Release From: Russell-Abbeville Div
Rule Name: Abbeville Div
Description:
Function of: Date
Limit Type: Specified
Interp.: Step

Date	Release (cfs)
01Jan	3.072
01Feb	2.765
01Mar	2.625
01Apr	2.648
01May	2.47
01Jun	3.387
01Jul	3.41
01Aug	3.409
01Sep	3.531
01Oct	3.534
01Nov	3.452
01Dec	3.096

☐ Period Average Limit
☐ Hour of Day Multiplier
☐ Day of Week Multiplier
☐ Rising/Falling Condition
☐ Seasonal Variation

Figure 4.2-8: (Russell Zone Rules)

Each project has different sets of diversions that fall within their again configured to mimic the monthly varying withdrawal of each entity. The Russell pool also has a block of rules to define hydropower pump management.



Reservoir: Thurmond
Description:

Operation Set: Daily Operations
Description:

Operates Release From: Thurmond-Lincolnton Div

Rule Name: Lincolnton Div
Description:

Function of: Date

Limit Type: Specified
Interp.: Step

Date	Release (cfs)
01Jan	0.7191909765375726
01Feb	0.7148947343558405
01Mar	0.6745100564508956
01Apr	0.5430450391056254
01May	0.5507782748332202
01Jun	0.7217687224451815
01Jul	0.7836346132540193
01Aug	0.8523744911545822
01Sep	0.8008195819809479
01Oct	0.8360487700659072
01Nov	0.7458276802590673
01Dec	0.6968505159954261

Figure 4.2-9: (Thurmond Zone Rules)

Figure 4.2-9 illustrates the rules associated with Current Operations.

While each project has its own set of rules, the Thurmond zone rules tend to regulate water leaving the system while the Hartwell and Russell zone rules focus on maintaining balance in the system and meeting system energy goals. All 3 projects have local zone rules to manage flood storage and seasonal fish-spawn.

HEC-ResSim (Thurmond Zone Rules)
(Rule Stack Diagram)

INDUCED SURCHARGE ZONE - (Top of FLOOD CONTROL ZONE to Elevation 346)
Thurmond IS – Hourly Rule for Induced Surcharge operations. Replaced with **GateReg** rule to Mimic IS rule in daily timestep model.
AugustaMax 20-30K – This rule defines the required release from Thurmond during Flood Control operations.
Guide Curve to 330, Target 20,000 cfs at Augusta.
Guide Curve to 333, Target 30,000 cfs at Augusta.
Thurmond Minimum 3600 – This rule sets the min daily release to 3600 cfs
AugustaMin3600 - This rule sets the min flow at Augusta to 3600 cfs
FLOOD CONTROL ZONE – Top of CONSERVATION ZONE to Elevation 335
Same rules as Induced Surcharge zone
CONSERVATION ZONE – Top of LEVEL 1 ZONE to Top of CONSERVATION ZONE
Same rules as Induced Surcharge zone

Two additional *blocks* of rules apply
Fish Spawn Ops – This block defines operations 1Apr-15May
Qout=Qin, attempts to hold flat pool (Outflow=Inflow)
SystemDroughtOps - Conditional rules based on Drought Trigger Level State Variable

If Drought Trigger Level <=0
Thurmond Minimum LO – This rule sets the min daily release to 3600 cfs
Weekly System Power – sets weekly generation goals based on a monthly varying power requirement

If Drought Trigger Level =1
If August 20 – 30 (*Add 200 cfs to required release*)
SpecRel-L1-Bell+200
If Bell 28 day average <10%, release 4200 cfs else 4400 cfs
If NOT August 20 – 30
SpecRel-L1- Bell
If Bell 28 day average <10%, release 4000 cfs else 4200 cfs

If Drought Trigger Level =2
If Nov 01 – 31 Jan (Winter Low Flow Period)
SpecRel-3600
This rule targets 3600 cfs at Augusta
If August 20 – 30 (*Add 200 cfs to required release*)
SpecRel-L2- Bell+200
If Bell 28 day average <10%, Release 4000 cfs else 4200 cfs
Else
SpecRel-L2-Bell
If Bell 28 day average <10%, release 3800 cfs else 4000 cfs

If Drought Trigger Level =3
SpecRel-L3-Seasonal+200
Jan1 – Feb 1, release 3100 cfs (L3 Winter Reduction)
Feb 1 – Aug 20, release 3800 cfs
Aug 20 – Aug 30, release 4000 cfs
Aug 30 – Nov 01, release 3800 cfs
Nov 01 – Jan 01 – release 3100 cfs

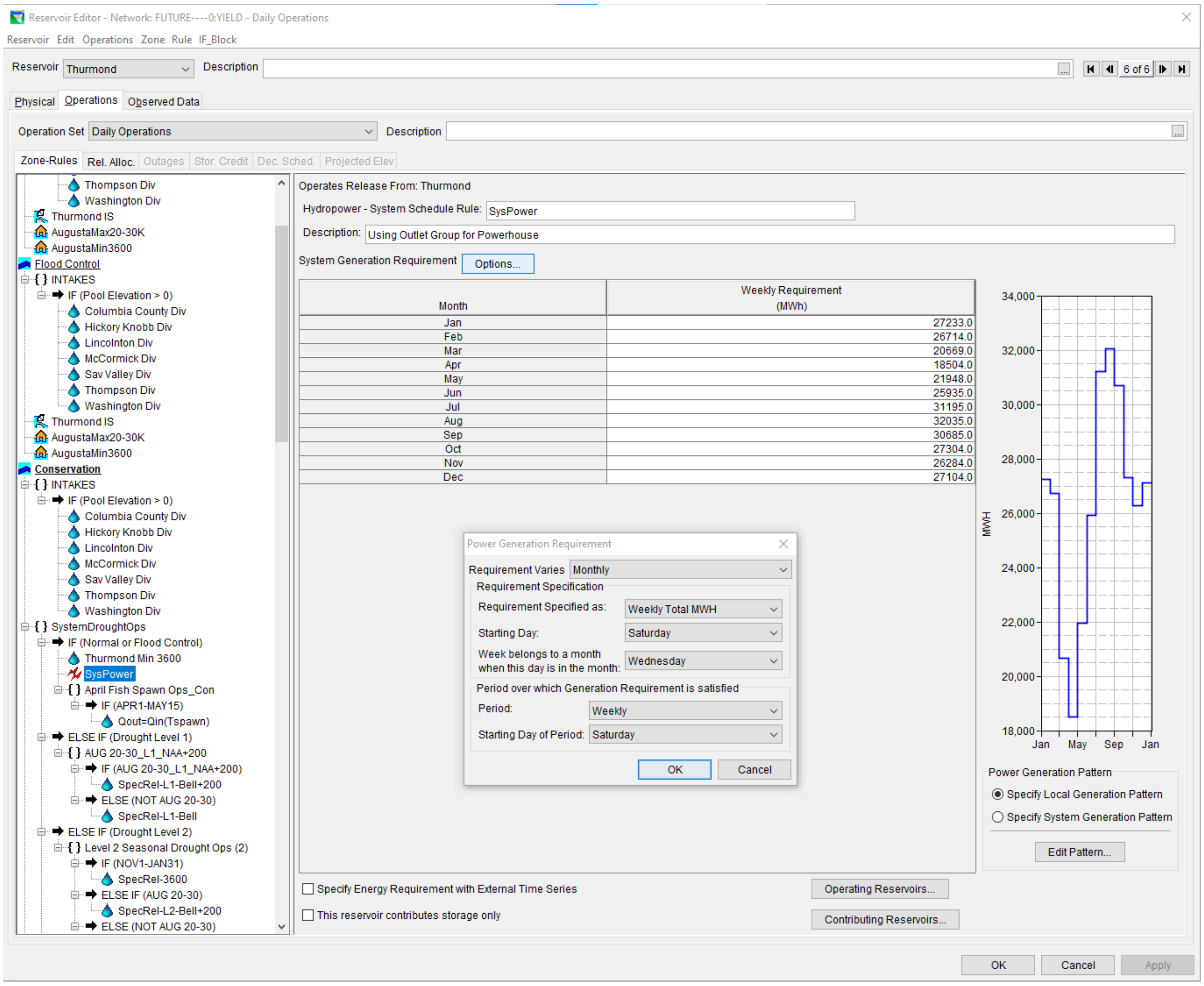
LEVEL 1 ZONE – LEVEL 1 to LEVEL 2
AugustaMax 20-30K
AugustaMin3600
April Fish Spawn Ops

SystemDroughtOps

LEVEL 2 ZONE – LEVEL 2 to LEVEL 3
AugustaMax 20-30K
AugustaMin3600
April Fish Spawn Ops
SystemDroughtOps

LEVEL 3 ZONE – LEVEL 3 to 312
AugustaMax 20-30K
AugustaMin3600
April Fish Spawn Ops
SystemDroughtOps

Table 4.2-10: (Thurmond Zone Rules)



Reservoir: Thurmond
Operation Set: Daily Operations

```
    Thompson Div
    Washington Div
  Thurmond IS
  AugustaMax20-30K
  AugustaMin3600
Flood Control
{ } INTAKES
  IF (Pool Elevation > 0)
    Columbia County Div
    Hickory Knobb Div
    Lincolnton Div
    McCormick Div
    Sav Valley Div
    Thompson Div
    Washington Div
  Thurmond IS
  AugustaMax20-30K
  AugustaMin3600
Conservation
{ } INTAKES
  IF (Pool Elevation > 0)
    Columbia County Div
    Hickory Knobb Div
    Lincolnton Div
    McCormick Div
    Sav Valley Div
    Thompson Div
    Washington Div
{ } SystemDroughtOps
  IF (Normal or Flood Control)
    Thurmond Min 3600
    SysPower
    { } April Fish Spawn Ops_Con
      IF (APR1-MAY15)
        Qout=Qin(Tspawn)
  ELSE IF (Drought Level 1)
    { } AUG 20-30_L1_NAA+200
      IF (AUG 20-30_L1_NAA+200)
        SpecRel-L1-Bell+200
      ELSE (NOT AUG 20-30)
        SpecRel-L1-Bell
  ELSE IF (Drought Level 2)
    { } Level 2 Seasonal Drought Ops (2)
      IF (NOV1-JAN31)
        SpecRel-3600
      ELSE IF (AUG 20-30)
        SpecRel-L2-Bell+200
      ELSE (NOT AUG 20-30)
```

Operates Release From: Thurmond
Hydropower - System Schedule Rule: SysPower
Description: Using Outlet Group for Powerhouse
System Generation Requirement

Month	Weekly Requirement (MWh)
Jan	27233.0
Feb	26714.0
Mar	20669.0
Apr	18504.0
May	21948.0
Jun	25935.0
Jul	31195.0
Aug	32035.0
Sep	30685.0
Oct	27304.0
Nov	26284.0
Dec	27104.0

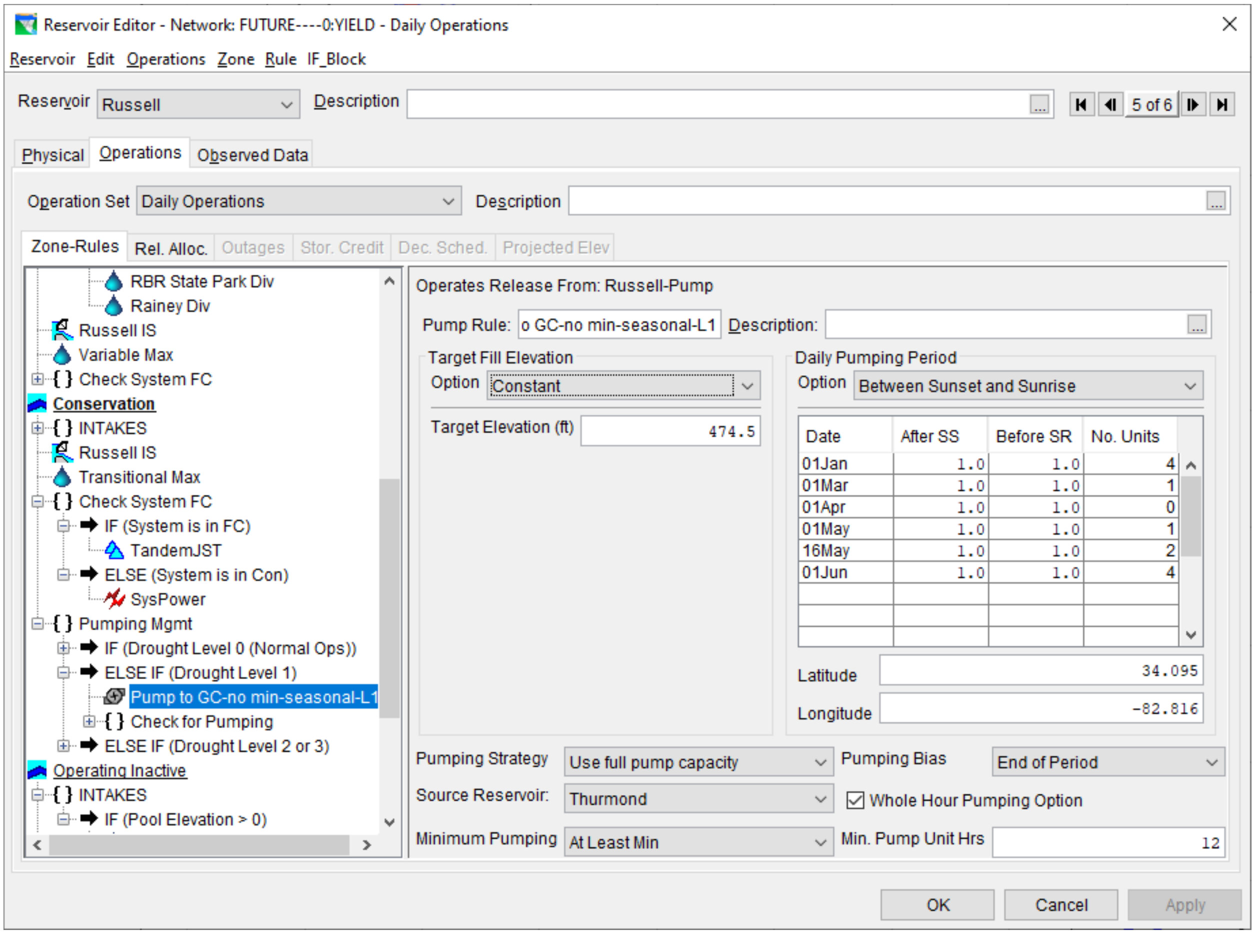
Power Generation Requirement
Requirement Varies: Monthly
Requirement Specification
Requirement Specified as: Weekly Total MWH
Starting Day: Saturday
Week belongs to a month when this day is in the month: Wednesday
Period over which Generation Requirement is satisfied
Period: Weekly
Starting Day of Period: Saturday

Power Generation Pattern
● Specify Local Generation Pattern
○ Specify System Generation Pattern

☐ Specify Energy Requirement with External Time Series
☐ This reservoir contributes storage only

Figure 4.2-11: System Power Rules

The Hartwell, Russell, and Thurmond projects operate to meet a monthly varying weekly system power goal. This goal is established by the Southeastern Power Administration (SEPA). SEPA further takes the daily flow declaration and sets up hourly generating schedules for its customers.



Reservoir: Russell
Description:
5 of 6

Operation Set: Daily Operations
Description:

Operates Release From: Russell-Pump

Pump Rule: o GC-no min-seasonal-L1
Description:

Target Fill Elevation
Option: Constant
Target Elevation (ft): 474.5

Daily Pumping Period
Option: Between Sunset and Sunrise

Date	After SS	Before SR	No. Units
01Jan	1.0	1.0	4
01Mar	1.0	1.0	1
01Apr	1.0	1.0	0
01May	1.0	1.0	1
16May	1.0	1.0	2
01Jun	1.0	1.0	4

Latitude: 34.095
Longitude: -82.816

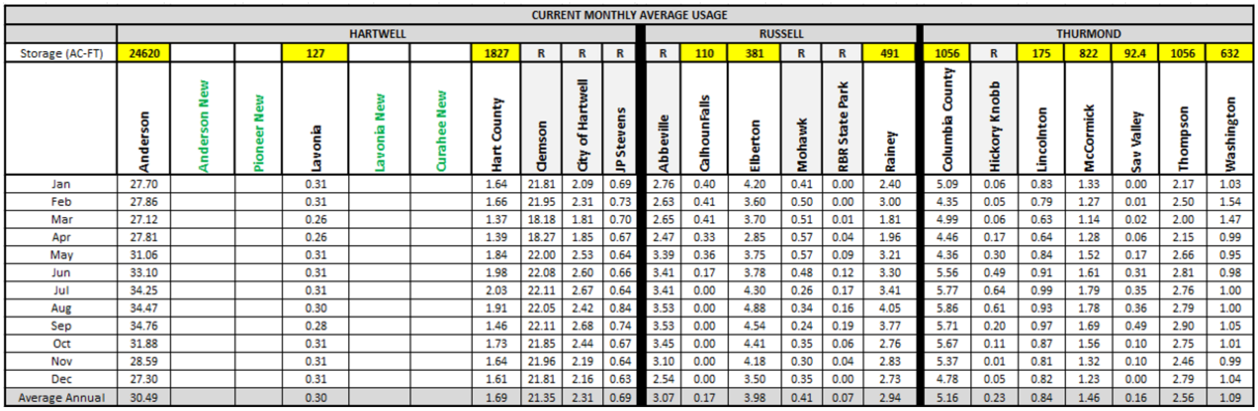
Pumping Strategy: Use full pump capacity
Pumping Bias: End of Period
Source Reservoir: Thurmond
☑ Whole Hour Pumping Option
Minimum Pumping: At Least Min
Min. Pump Unit Hrs: 12

Figure 4.2-12: Russell Pump Storage Rules

The Richard B. Russell project is a pump storage project. Part of the weekly generating energy target is based on pumped water rather than water from streamflow. Environmental limitations on the use of the pump units are found here. The environmental limitations are focused on minimizing entrainment during pumping. Limitations on the use of these units also vary with drought conditions. Under drought conditions, pump usage may increase up to the full night-time window, 1 hour after sunset to 1 hour before sunrise, attempting to meet system energy demands.

4.3 HEC-ResSim Water Accounts

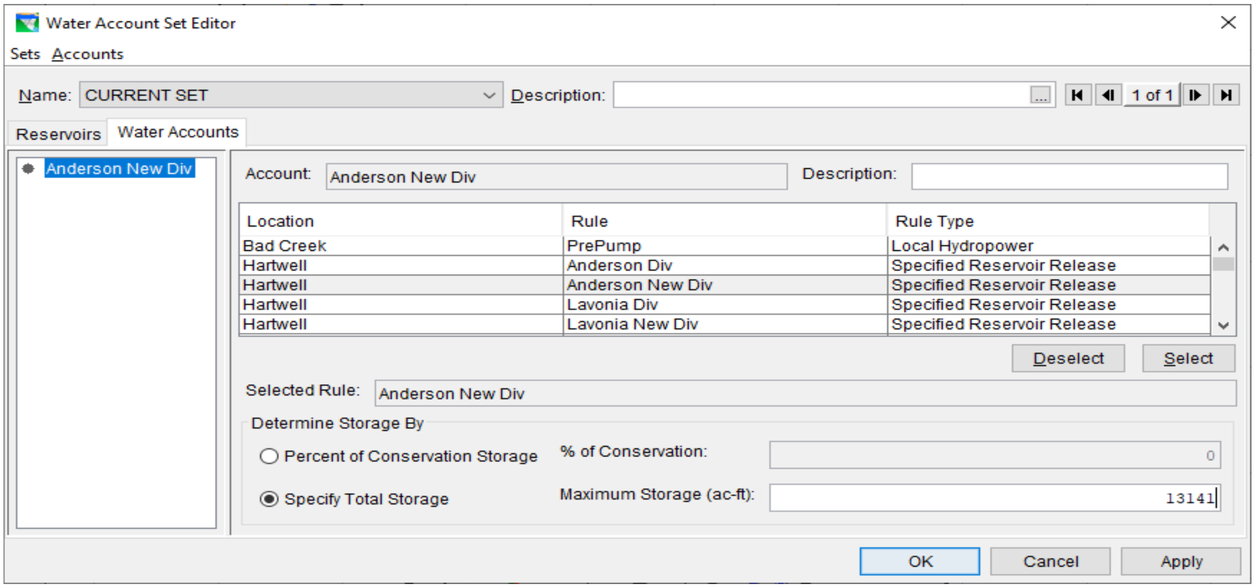
Monthly water withdrawal data was obtained from each contract holder and from each riparian user and verified with the state environmental protection agencies. Estimated average monthly usage patterns were developed. These patterns will be used determine the maximum possible yield for each entity with the storage that they currently own. Water account "sets" were created for each Savannah District reservoir: Hartwell, Russell, and Thurmond with separate account sets for Current Contracts and for the New Request, Figure 4.3-1 below. "R" stands for Riparian user.



CURRENT MONTHLY AVERAGE USAGE																							
	HARTWELL										RUSSELL						THURMOND						
Storage (AC-FT)	24620			127			1827	R	R	R	R	110	381	R	R	491	1056	R	175	822	92.4	1056	632
	Anderson	Anderson New	Pioneer New	Lavonia	Lavonia New	Curahee New	Hart County	Clemson	City of Hartwell	JP Stevens	Abbeville	CalhounFalls	Elberton	Mohawk	RBR State Park	Rainey	Columbia County	Hickory Knobb	Lincolnton	McCormick	Sav Valley	Thompson	Washington
Jan	27.70			0.31			1.64	21.81	2.09	0.69	2.76	0.40	4.20	0.41	0.00	2.40	5.09	0.06	0.83	1.33	0.00	2.17	1.03
Feb	27.86			0.31			1.66	21.95	2.31	0.73	2.63	0.41	3.60	0.50	0.00	3.00	4.35	0.05	0.79	1.27	0.01	2.50	1.54
Mar	27.12			0.26			1.37	18.18	1.81	0.70	2.65	0.41	3.70	0.51	0.01	1.81	4.99	0.06	0.63	1.14	0.02	2.00	1.47
Apr	27.81			0.26			1.39	18.27	1.85	0.67	2.47	0.33	2.85	0.57	0.04	1.96	4.46	0.17	0.64	1.28	0.06	2.15	0.99
May	31.06			0.31			1.84	22.00	2.53	0.64	3.39	0.36	3.75	0.57	0.09	3.21	4.36	0.30	0.84	1.52	0.17	2.66	0.95
Jun	33.10			0.31			1.98	22.08	2.60	0.66	3.41	0.17	3.78	0.48	0.12	3.30	5.56	0.49	0.91	1.61	0.31	2.81	0.98
Jul	34.25			0.31			2.03	22.11	2.67	0.64	3.41	0.00	4.30	0.26	0.17	3.41	5.77	0.64	0.99	1.79	0.35	2.76	1.00
Aug	34.47			0.30			1.91	22.05	2.42	0.84	3.53	0.00	4.88	0.34	0.16	4.05	5.86	0.61	0.93	1.78	0.36	2.79	1.00
Sep	34.76			0.28			1.46	22.11	2.68	0.74	3.53	0.00	4.54	0.24	0.19	3.77	5.71	0.20	0.97	1.69	0.49	2.90	1.05
Oct	31.88			0.31			1.73	21.85	2.44	0.67	3.45	0.00	4.41	0.35	0.06	2.76	5.67	0.11	0.87	1.56	0.10	2.75	1.01
Nov	28.59			0.31			1.64	21.96	2.19	0.64	3.10	0.00	4.18	0.30	0.04	2.83	5.37	0.01	0.81	1.32	0.10	2.46	0.99
Dec	27.30			0.31			1.61	21.81	2.16	0.63	2.54	0.00	3.50	0.35	0.00	2.73	4.78	0.05	0.82	1.23	0.00	2.79	1.04
Average Annual	30.49			0.30			1.69	21.35	2.31	0.69	3.07	0.17	3.98	0.41	0.07	2.94	5.16	0.23	0.84	1.46	0.16	2.56	1.09

Figure 4.3-1: Water Account Setup using HEC-ResSim

Within each set, water accounts were then created for each storage contract holder. In the ResSim Model, each water account represents a conglomerate of the existing contracts owned by each entity.



Name: CURRENT SET

Description:

Account: Anderson New Div

Description:

Location	Rule	Rule Type
Bad Creek	PrePump	Local Hydropower
Hartwell	Anderson Div	Specified Reservoir Release
Hartwell	Anderson New Div	Specified Reservoir Release
Hartwell	Lavonia Div	Specified Reservoir Release
Hartwell	Lavonia New Div	Specified Reservoir Release

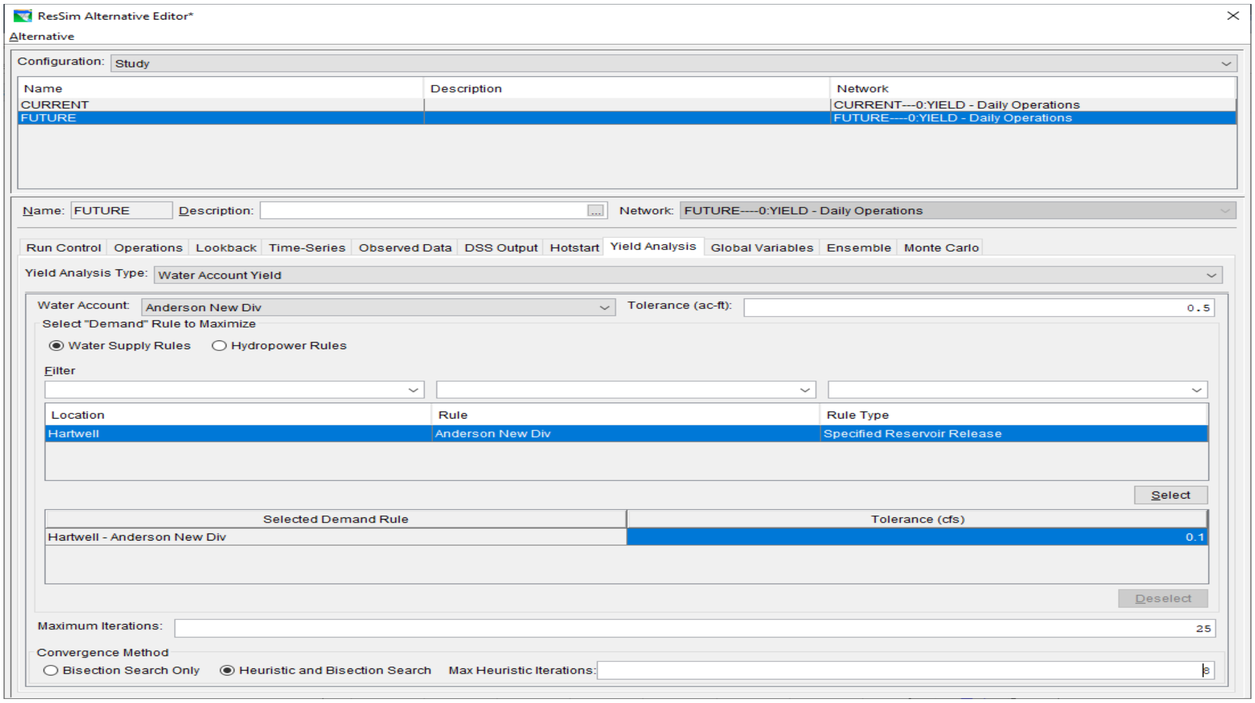
Selected Rule: Anderson New Div

Determine Storage By

○ Percent of Conservation Storage — % of Conservation: 0

● Specify Total Storage — Maximum Storage (ac-ft): 13141

Figure 4.3-2: Typical Water Account setup using HEC-ResSim



Configuration: Study

Name	Description	Network
CURRENT		CURRENT----0:YIELD - Daily Operations
FUTURE		FUTURE----0:YIELD - Daily Operations

Name: FUTURE
Description:
Network: FUTURE----0:YIELD - Daily Operations

Yield Analysis Type: Water Account Yield

Water Account: Anderson New Div
Tolerance (ac-ft): 0.5

Select "Demand" Rule to Maximize

● Water Supply Rules ○ Hydropower Rules

Filter

Location	Rule	Rule Type
Hartwell	Anderson New Div	Specified Reservoir Release

Selected Demand Rule	Tolerance (cfs)
Hartwell - Anderson New Div	0.1

Maximum Iterations: 25

Convergence Method

○ Bisection Search Only ● Heuristic and Bisection Search Max Heuristic Iterations: 8

Figure 4.3-3: ARJWS New Water Account using HEC-ResSim

When computing yield analyses model runs, the user must define a water account storage tolerance (AC-FT) as well as a demand rule flow tolerance (CFS). Initially, these tolerances were tested for sensitivity analysis to optimize accurate yield convergence values with shortest possible compute times.

On average, the larger tolerance model runs took between 10-12 iterations to converge while the smaller tolerance runs took between 15-17 iterations to converge. However, compute times were significantly larger, up to 6 hours, for the smaller tolerances.

Yield was then resolved for each water account using each entity's currently contracted storage at each of the projects. This set the base case yield for alternative comparison.

Once each yield analysis was completed, the HEC-ResSim model was re-configured to reflect the critical yield for that water account in the withdrawals and returns of the account. The process looped thru all of the water accounts several times until the yields stabilized and stopped changing. This was done with and without the new requested allocation. A similar analysis was performed allocating storage from the inactive storage pool to meet the needs of the new request. Once the yield runs were complete, a standard model for the 75-year period of record (1939-2013) was run for each alternative. The results were then passed on to the Hydropower Analysis Center, HAC, for a detailed hydropower impact analysis.

5.0 Initial Modeling Results

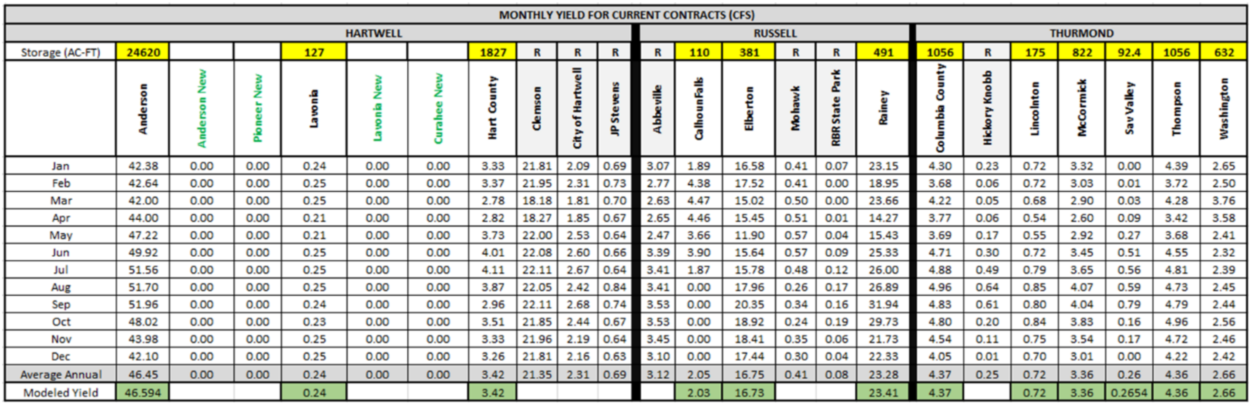
Sections 5.1 thru 5.4 discuss the default storage accounting methods built into HEC ResSim.

5.1 Calculation of Project Yields for EXISTING contracted storage

This analysis assumes rules of operation from the current Water Control Plan, updated to reflect the 2012 Drought Management Plan, the 2014 Storage Balance update, and drought mitigation features. See Table 1.1-1 for current contract holders and contracted storage.

In this analysis, water supply storage is being reallocated from conservation storage at Hartwell which remains from elevation 625.0 ft-msl to the seasonally varying Guide Curve (656.0 ft-msl in winter to 660.0 ft-msl in summer).

ResSim was used to solve for the monthly yield for each existing storage account, consistent with each user's specified monthly withdrawal pattern.



MONTHLY YIELD FOR CURRENT CONTRACTS (CFS)																							
	HARTWELL										RUSSELL						THURMOND						
Storage (AC-FT)	24620			127			1827	R	R	R	R	110	381	R	R	491	1056	R	175	822	92.4	1056	632
	Anderson	Anderson New	Pioneer New	Lavonia	Lavonia New	Curahee New	Hart County	Clemson	City of Hartwell	JP Stevens	Abbeville	CalhounFalls	Elberton	Mohawk	RBR State Park	Rainey	Columbia County	Hickory Knobb	Lincolnton	McCormick	Sav Valley	Thompson	Washington
Jan	42.38	0.00	0.00	0.24	0.00	0.00	3.33	21.81	2.09	0.69	3.07	1.89	16.58	0.41	0.07	23.15	4.30	0.23	0.72	3.32	0.00	4.39	2.65
Feb	42.64	0.00	0.00	0.25	0.00	0.00	3.37	21.95	2.31	0.73	2.77	4.38	17.52	0.41	0.00	18.95	3.68	0.06	0.72	3.03	0.01	3.72	2.50
Mar	42.00	0.00	0.00	0.25	0.00	0.00	2.78	18.18	1.81	0.70	2.63	4.47	15.02	0.50	0.00	23.66	4.22	0.05	0.68	2.90	0.03	4.28	3.76
Apr	44.00	0.00	0.00	0.21	0.00	0.00	2.82	18.27	1.85	0.67	2.65	4.46	15.45	0.51	0.01	14.27	3.77	0.06	0.54	2.60	0.09	3.42	3.58
May	47.22	0.00	0.00	0.21	0.00	0.00	3.73	22.00	2.53	0.64	2.47	3.66	11.90	0.57	0.04	15.43	3.69	0.17	0.55	2.92	0.27	3.68	2.41
Jun	49.92	0.00	0.00	0.25	0.00	0.00	4.01	22.08	2.60	0.66	3.39	3.90	15.64	0.57	0.09	25.33	4.71	0.30	0.72	3.45	0.51	4.55	2.32
Jul	51.56	0.00	0.00	0.25	0.00	0.00	4.11	22.11	2.67	0.64	3.41	1.87	15.78	0.48	0.12	26.00	4.88	0.49	0.79	3.65	0.56	4.81	2.39
Aug	51.70	0.00	0.00	0.25	0.00	0.00	3.87	22.05	2.42	0.84	3.41	0.00	17.96	0.26	0.17	26.89	4.96	0.64	0.85	4.07	0.59	4.73	2.45
Sep	51.96	0.00	0.00	0.24	0.00	0.00	2.96	22.11	2.68	0.74	3.53	0.00	20.35	0.34	0.16	31.94	4.83	0.61	0.80	4.04	0.79	4.79	2.44
Oct	48.02	0.00	0.00	0.23	0.00	0.00	3.51	21.85	2.44	0.67	3.53	0.00	18.92	0.24	0.19	29.73	4.80	0.20	0.84	3.83	0.16	4.96	2.56
Nov	43.98	0.00	0.00	0.25	0.00	0.00	3.33	21.96	2.19	0.64	3.45	0.00	18.41	0.35	0.06	21.73	4.54	0.11	0.75	3.54	0.17	4.72	2.46
Dec	42.10	0.00	0.00	0.25	0.00	0.00	3.26	21.81	2.16	0.63	3.10	0.00	17.44	0.30	0.04	22.33	4.05	0.01	0.70	3.01	0.00	4.22	2.42
Average Annual	46.45	0.00	0.00	0.24	0.00	0.00	3.42	21.35	2.31	0.69	3.12	2.05	16.75	0.41	0.08	23.28	4.37	0.25	0.72	3.36	0.26	4.36	2.66
Modeled Yield	46.594			0.24			3.42					2.03	16.73			23.41	4.37		0.72	3.36	0.2654	4.36	2.66

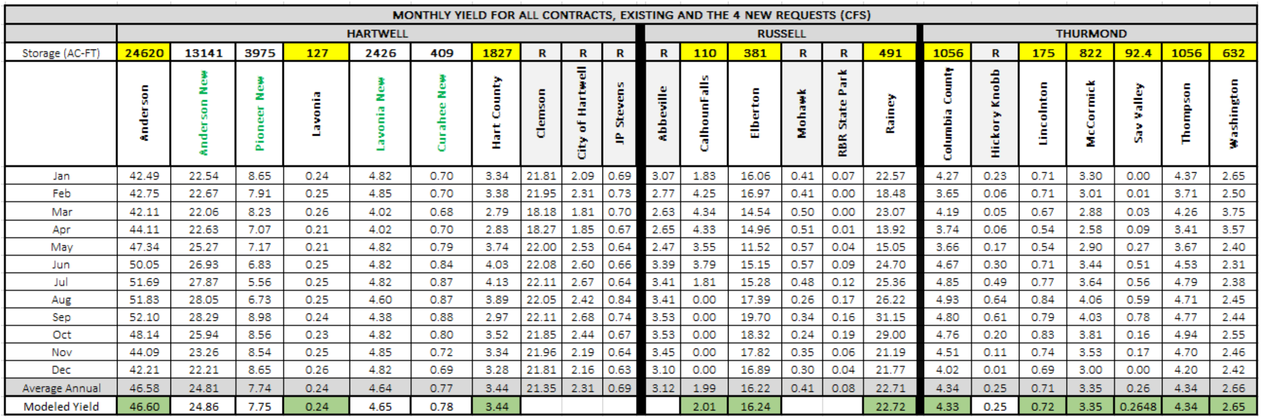
Figure 5.1-1: Typical Water Account setup using HEC-ResSim

Existing Contracted storage and associated yields provided the baseline for analysis.
Hartwell Critical Period: 14 May 1999 – 07 Mar 2003

5.2 Calculation of Project Yields for NEW Requests (Using estimates based on ratios of storage)

This analysis assumes rules of operation from the current Water Control Plan, updated to reflect the 2012 Drought Management Plan, the 2014 Storage Balance update, and drought mitigation features.

In this analysis, water supply storage for the new contracts is reallocated from the current Conservation Storage at Hartwell which remains from elevation 625.0 ft-msl to the seasonally varying Guide Curve. A water account is set up for each new request and the requestor's monthly withdrawal (monthly yield) is set. Then the storage to support that yield is determined thru trial and error. Initial estimates of storage required for each of the new contracts was based on a ratio of the storage required to provide the current yield for ARJWS. The yield was calculated for each of the new storage requests, and the estimated storage needed was adjusted until the yield matched the request. Again, this process was very iterative, requiring many re-runs until the storage for each of the new contracts was determined.

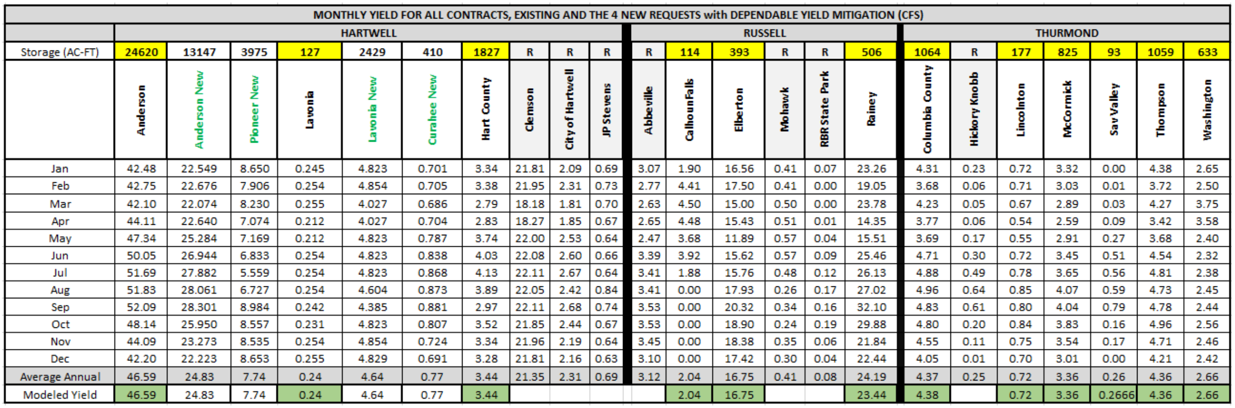


MONTHLY YIELD FOR ALL CONTRACTS, EXISTING AND THE 4 NEW REQUESTS (CFS)																							
	HARTWELL										RUSSELL						THURMOND						
Storage (AC-FT)	24620	13141	3975	127	2426	409	1827	R	R	R	R	110	381	R	R	491	1056	R	175	822	92.4	1056	632
	Anderson	Anderson New	Pioneer New	Lavonia	Lavonia New	Curahee New	Hart County	Clemson	City of Hartwell	JP Stevens	Abbeville	CalhounFalls	Elberton	Mohawk	RBR State Park	Rainey	Columbia Count	Hickory Knobb	Lincolnton	McCormick	Sav Valley	Thompson	Washington
Jan	42.49	22.54	8.65	0.24	4.82	0.70	3.34	21.81	2.09	0.69	3.07	1.83	16.06	0.41	0.07	22.57	4.27	0.23	0.71	3.30	0.00	4.37	2.65
Feb	42.75	22.67	7.91	0.25	4.85	0.70	3.38	21.95	2.31	0.73	2.77	4.25	16.97	0.41	0.00	18.48	3.65	0.06	0.71	3.01	0.01	3.71	2.50
Mar	42.11	22.06	8.23	0.26	4.02	0.68	2.79	18.18	1.81	0.70	2.63	4.34	14.54	0.50	0.00	23.07	4.19	0.05	0.67	2.88	0.03	4.26	3.75
Apr	44.11	22.63	7.07	0.21	4.02	0.70	2.83	18.27	1.85	0.67	2.65	4.33	14.96	0.51	0.01	13.92	3.74	0.06	0.54	2.58	0.09	3.41	3.57
May	47.34	25.27	7.17	0.21	4.82	0.79	3.74	22.00	2.53	0.64	2.47	3.55	11.52	0.57	0.04	15.05	3.66	0.17	0.54	2.90	0.27	3.67	2.40
Jun	50.05	26.93	6.83	0.25	4.82	0.84	4.03	22.08	2.60	0.66	3.39	3.79	15.15	0.57	0.09	24.70	4.67	0.30	0.71	3.44	0.51	4.53	2.31
Jul	51.69	27.87	5.56	0.25	4.82	0.87	4.13	22.11	2.67	0.64	3.41	1.81	15.28	0.48	0.12	25.36	4.85	0.49	0.77	3.64	0.56	4.79	2.38
Aug	51.83	28.05	6.73	0.25	4.60	0.87	3.89	22.05	2.42	0.84	3.41	0.00	17.39	0.26	0.17	26.22	4.93	0.64	0.84	4.06	0.59	4.71	2.45
Sep	52.10	28.29	8.98	0.24	4.38	0.88	2.97	22.11	2.68	0.74	3.53	0.00	19.70	0.34	0.16	31.15	4.80	0.61	0.79	4.03	0.78	4.77	2.44
Oct	48.14	25.94	8.56	0.23	4.82	0.80	3.52	21.85	2.44	0.67	3.53	0.00	18.32	0.24	0.19	29.00	4.76	0.20	0.83	3.81	0.16	4.94	2.55
Nov	44.09	23.26	8.54	0.25	4.85	0.72	3.34	21.96	2.19	0.64	3.45	0.00	17.82	0.35	0.06	21.19	4.51	0.11	0.74	3.53	0.17	4.70	2.46
Dec	42.21	22.21	8.65	0.26	4.82	0.69	3.28	21.81	2.16	0.63	3.10	0.00	16.89	0.30	0.04	21.77	4.02	0.01	0.69	3.00	0.00	4.20	2.42
Average Annual	46.58	24.81	7.74	0.24	4.64	0.77	3.44	21.35	2.31	0.69	3.12	1.99	16.22	0.41	0.08	22.71	4.34	0.25	0.71	3.35	0.26	4.34	2.66
Modeled Yield	46.60	24.86	7.75	0.24	4.65	0.78	3.44					2.01	16.24			22.72	4.33	0.25	0.72	3.35	0.2648	4.34	2.65

Figure 5.2-1**: Typical Water Account setup using HEC-ResSim**

5.3 Dependable Yield Mitigation

Dependable Yield Mitigation is a calculation made to determine if additional storage is required to keep the existing contract holders whole at their current yield levels. The default ResSim storage accounting methodology suggested that no additional storage was required at Hartwell to maintain their current yield. However, Russell and Thurmond existing contracts lost yield due to the addition on the 4 new contracts at Hartwell. Russell required 31 additional AC-FT storage and Thurmond required 16.6 AC-FT to restore the current yield levels (Figure 5.3-1). The 4 new requests at Hartwell required 19,961 AC-FT of conservation storage to meet the requested annual demand of 24.54 MGD. Results from the preliminary non-RFC runs are summarized in Table 5.3-1.



MONTHLY YIELD FOR ALL CONTRACTS, EXISTING AND THE 4 NEW REQUESTS with DEPENDABLE YIELD MITIGATION (CFS)																							
	HARTWELL										RUSSELL						THURMOND						
Storage (AC-FT)	24620	13147	3975	127	2429	410	1827	R	R	R	R	114	393	R	R	506	1064	R	177	825	93	1059	633
	Anderson	Anderson New	Pioneer New	Lavonia	Lavonia New	Curahee New	Hart County	Clemson	City of Hartwell	JP Stevens	Abbeville	CalhounFalls	Elberton	Mohawk	RBR State Park	Rainey	Columbia County	Hickory Knobb	Lincolnton	McCormick	Sav Valley	Thompson	Washington
Jan	42.48	22.549	8.650	0.245	4.823	0.701	3.34	21.81	2.09	0.69	3.07	1.90	16.56	0.41	0.07	23.26	4.31	0.23	0.72	3.32	0.00	4.38	2.65
Feb	42.75	22.676	7.906	0.254	4.854	0.705	3.38	21.95	2.31	0.73	2.77	4.41	17.50	0.41	0.00	19.05	3.68	0.06	0.71	3.03	0.01	3.72	2.50
Mar	42.10	22.074	8.230	0.255	4.027	0.686	2.79	18.18	1.81	0.70	2.63	4.50	15.00	0.50	0.00	23.78	4.23	0.05	0.67	2.89	0.03	4.27	3.75
Apr	44.11	22.640	7.074	0.212	4.027	0.704	2.83	18.27	1.85	0.67	2.65	4.48	15.43	0.51	0.01	14.35	3.77	0.06	0.54	2.59	0.09	3.42	3.58
May	47.34	25.284	7.169	0.212	4.823	0.787	3.74	22.00	2.53	0.64	2.47	3.68	11.89	0.57	0.04	15.51	3.69	0.17	0.55	2.91	0.27	3.68	2.40
Jun	50.05	26.944	6.833	0.254	4.823	0.838	4.03	22.08	2.60	0.66	3.39	3.92	15.62	0.57	0.09	25.46	4.71	0.30	0.72	3.45	0.51	4.54	2.32
Jul	51.69	27.882	5.559	0.254	4.823	0.868	4.13	22.11	2.67	0.64	3.41	1.88	15.76	0.48	0.12	26.13	4.88	0.49	0.78	3.65	0.56	4.81	2.38
Aug	51.83	28.061	6.727	0.254	4.604	0.873	3.89	22.05	2.42	0.84	3.41	0.00	17.93	0.26	0.17	27.02	4.96	0.64	0.85	4.07	0.59	4.73	2.45
Sep	52.09	28.301	8.984	0.242	4.385	0.881	2.97	22.11	2.68	0.74	3.53	0.00	20.32	0.34	0.16	32.10	4.83	0.61	0.80	4.04	0.79	4.78	2.44
Oct	48.14	25.950	8.557	0.231	4.823	0.807	3.52	21.85	2.44	0.67	3.53	0.00	18.90	0.24	0.19	29.88	4.80	0.20	0.84	3.83	0.16	4.96	2.56
Nov	44.09	23.273	8.535	0.254	4.854	0.724	3.34	21.96	2.19	0.64	3.45	0.00	18.38	0.35	0.06	21.84	4.55	0.11	0.75	3.54	0.17	4.71	2.46
Dec	42.20	22.223	8.653	0.255	4.829	0.691	3.28	21.81	2.16	0.63	3.10	0.00	17.42	0.30	0.04	22.44	4.05	0.01	0.70	3.01	0.00	4.21	2.42
Average Annual	46.59	24.83	7.74	0.24	4.64	0.77	3.44	21.35	2.31	0.69	3.12	2.04	16.75	0.41	0.08	24.19	4.37	0.25	0.72	3.36	0.26	4.36	2.66
Modeled Yield	46.59	24.83	7.74	0.24	4.64	0.77	3.44					2.04	16.75			23.44	4.38		0.72	3.36	0.2666	4.36	2.66

Figure 5.3-1: Typical Water Account setup with Dependable Yield Mitigation

Table 5.3-1: Yield Results with the following: New Accounts, Default ResSim Accounting and No Return Flow Credit

SUMMARY OF YIELD ANALYSIS RESULTS WITHOUT RETURN CREDIT ACCOUNTING								
	Contract Holder	Current Contract Storage (AC-FT)	Future Contract Storage (AC-FT)	Mitigation Storage Required (AC-FT)	Current Yield (CFS)	Future Yield (CFS)	Yield Request (CFS)	Yield Request (MGD)
HARTWELL	Anderson ARJWS	24620	24620	0	46.34	46.59		
	ARJWS New		13147			24.83	24.83	16.05
	Pioneer New		3975			7.74	7.74	5
	Lavonia	127	127	0	0.24	0.24		
	Lavonia New		2429			4.64	4.64	3
	Currahee New		410			0.77	0.77	0.5
	Hart County	1827	1827	0	3.42	3.44		
HARTWELL CONTRACTS		26574	46535	0	50.08	88.26		
RUSSELL	Calhoun Falls	110	114	4	2.03	2.04		
	Elberton	381	393	12	16.72	16.75		
	Rainey	491	506	15	23.41	23.44		
RUSSELL CONTRACTS		982	1013	31	42.18	42.23		
THURMOND	Columbia County	1056	1064	8	4.35	4.38		
	Lincolnton	175	177	2	0.72	0.72		
	McCormick	822	825	3	3.36	3.36		
	Sav Valley	92.4	93.0	0.6	0.27	0.27		
	Thompson	1056	1059	3	4.36	4.36		
	Washington	632	633	1	2.66	2.66		
THURMOND CONTRACTS		3833.4	3851	18	15.74	15.74		
TOTAL SYSTEM		31389.4	51399	49	108.0	146.2		

(Flood Storage, 665 ft-msl - 660 ft-msl = 2842700 AC-FT-2549600 AC-FT) = 293,100 AC-FT
(Conservation Storage, 660 ft-msl - 625 ft-msl = (2,549,600 AC-FT-1,134,100 AC-FT) = 1,415,500 AC-FT

5.4 Interpretation and Accuracy of Modeled Yield Results

The process of determining yield for individual accounts, each of which uses a different monthly demand pattern, is iterative and the impact of one account's demands can change another's yield. Thus, the account yields were calculated numerous times to reach the final numbers. It is important to note some margin of error associated with those values. Although the model will report very precise yield flows, the modelers accept these within a range of 1 cfs uncertainty.

Initially, HEC-ResSim yield analysis was performed for the entire 75yr period with run times approaching days. In order to shorten the time necessary to compute, 1998-2013 was determined to be the critical period and subsequent modeling runs focused on the 15 yr period, 1998-2013, rather than the full 75 yr period of record. Due to the different demand patterns of the different users, it is possible that the critical period is different for different users, however, the 1998-2013 period was particularly stressful on the system and is likely a sufficient representative of the critical period for all users. This assumption was checked during the Phase 2 modeling, which showed a few accounts had very small shortages during other periods, but these were small enough to not be significant to the analysis.

When the new requests were added as demand time series to the yield modeling, the results showed slightly increased yields for existing accounts at Hartwell. It is likely that these slight increases in yield were caused by the proportional increase in return flows to Hartwell. Adding new accounts by reallocating conservation storage would not normally be expected to increase the yield of existing accounts. Returned flows increase the total inflow to the reservoir. By current USACE water accounting, the total reservoir inflow is divided among account holders, proportional to their percentage of pool storage. Thus, the existing account holders receive more inflow and are able to hold water in their account for slightly longer before emptying.

Downstream effects of adding new storage accounts are different than the local ones at the same reservoir. During dry periods, the downstream reservoirs and users do not receive the increased inflow (from return flows) that would occur at Hartwell. More upstream use generally means less flow is sent downstream. The impact of this decrease was reflected in the DYM analysis above.

The yield modeling was performed using the assumption that the new account holders would continue to return flows to Hartwell at an increased rate proportional to their withdrawals. When these yield model scenarios were run, all users (except the one whose yield is being actively computed) are assumed to be withdrawing the maximum demand that their account will provide and returning a set percentage of that withdrawal. This may not occur in practice; none of the users are currently withdrawing their maximum yield. While the amount of water required for treatment may or may not increase in the future, it was assumed the returns would remain the same proportion to current withdrawals.

6.0 Phase 2 Modeling: Water Storage Accounting for Return Flow Credit Analysis

In 2022, after ARJWS (and later other water account holders) requested credit for the water they return to Hartwell Reservoir, the modeling work was extended to accommodate analysis of the use of Return Flow Credit (RFC) Accounting at Hartwell Reservoir. Return Flow Credit (RFC) Accounting is the concept that the entity who owns the storage account also owns the water. Under RFC accounting, any returns that the contract holder makes back to the source pool are accounted as 100% return to their storage account rather than simply part of the total inflow to the source pool. The storage account gets 100% of the return quantity rather than only part of the source reservoir's inflow based on the percentage of the conservation pool that the contract holder owns. This change in the accounting method could significantly help keep the storage account full if the contract holder returns a large portion of the withdrawal to the source pool. It would likely also reduce the amount of storage required to meet a specific yield. However, RFC accounting at Hartwell also reduces the total inflow available to the other contract holders in Hartwell. A reduction in inflow will result in lower yields which will require mitigation by the requestors switching to RFC. This mitigation will ensure existing contracts continue to yield the same as prior to this reallocation.

6.1 Water Storage Accounting Modeling Approach

Additional reservoir modeling was performed to analyze the impact of return flow credit accounting. This modeling was conducted using HEC-ResSim beta version 3.5, build 394, produced in Jan 2023. ResSim version 3.5 has a recently improved water accounting feature that tracks storage in water accounts over time, but this feature does not currently provide for RFC accounting. In order to model RFC, additional programming thru scripting was necessary.

A water accounting state variable script (called "Accounting") was developed to track the water storage accounts at Hartwell reservoir. ResSim's existing water accounting feature was used to help verify the results from the state variable script.

6.1.1 Reason for using a New Model in Phase 2 Modeling

The yield modeling initially performed for this project used the HEC-ResSim yield analysis feature, which runs the Period of Record iteratively, solving for the maximum yield possible from a given pool or account. This feature, even with the new storage accounting capability, is not currently capable of considering return flow credit (RFC) during this yield calculation. Therefore, the scripted approach was taken since it provides the flexibility to track water accounts over time and provide RFC.

6.1.2 Water Accounting Assumptions

The assumptions and technique involved in water storage accounting varies from place to place. In the Savannah region, water storage accounting has historically been performed though spreadsheet mass balance accounting.

The addition of the water accounting in the ResSim software aimed to provide enough flexibility that it could be applied in different situations, however, the full flexibility has not yet been implemented.

Table 6.1-1 summarizes the water storage account assumptions made for the script-based water accounting. Note that the assumptions made for the modeled water accounting approach can impact the resulting calculation of critical yield for different account sizes. Further explanation follows.

Table 6.1-1: Script-Based Modeled Water Accounting Assumptions

1. Water Accounts are portions of the Conservation Pool	The conservation storage in the reservoir is defined as the space between the top of the inactive pool to the top of the conservation pool. Water accounts are defined volumes of storage in the conservation pool.
2. Storage Account Yield	Individual yield for each Hartwell storage account was calculated based on that user's monthly demand pattern, rather than estimating yield as a proportion of the total conservation yield. No firm yield is guaranteed to water account holders.
3. Net Inflow = Qin - Losses	Losses from evaporation and leakages are incorporated in the computation of Net Inflow.
4. Inflow Distribution	A portion of net inflow is credited to each user's storage account based on their percentage of the total conservation pool. The percent of inflow credited to each account holder varies with the varying size of the conservation pool. Under Return Flow Crediting, individual account holders get full credit for returning flow to Hartwell, and that amount is subtracted from the net inflow.
5. Excess Inflow	If one or more users have full accounts, any inflow not used by them is credited to the USACE account[2].
6. Variable Guide Curve	Reservoir drawdown according to a variable guide curve is charged to the general, multipurpose USACE storage account.
7. Flood Pool Storage	When the reservoir pool is above the top of conservation, no accounts are charged for withdrawing water.

1. **Water Accounts are defined as a portion of the Conservation Pool**
   The conservation storage in the reservoir is divided up among a given number of users or accounts, including USACE. The conservation storage is equal to the storage at the top of the conservation pool minus the storage in the inactive pool. The conservation pool volume can vary over the course of the year if the guide curve varies.

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[2] This approach to excess inflow (crediting it to the default pool) is not as recommended in ECB 2023-12, however, it proved to have little to no effect on the critical period results.

Hartwell Reservoir’s conservation pool varies between 1,199,700 ac-ft in winter to 1,415,500 in summer, as described in Table 6.1-2. Current storage account holders use small fractions of the total conservation pool (shown later in).

Table 6.1-2: Hartwell Conservation Pool Volume

Hartwell Conservation Pool		
	Elev (ft)	Storage (acre-ft)
Summer Top of Con Pool	660	2,549,600
Winter Top of Con Pool	656	2,333,800
Top of Inactive Pool	625	1,134,100
Summer Conservation Pool Volume		1,415,500
Winter Conservation Pool Volume		1,199,700

2. **Water Account Yield**

   The yield of the conservation pool can be calculated as can yield from the individual storage accounts. However, since each individual water user may make withdrawals at different rates and different monthly patterns, the yield of the water accounts isn't necessarily determined as a simple proportion of the total reservoir yield.

   As described in Section 3, for this study, the percent of conservation storage to which usage rights are purchased is NOT simply calculated as a percentage of the water supply need (anticipated yield) to the reservoir critical yield because the monthly usage patterns vary per user. Although we can model and make estimates of the firm yield during a critical drought period, future weather conditions are not known, and no firm yield is guaranteed. The water account holder recognizes that the agreement provides for the use of storage space for raw water withdrawals only. Although the storage space is estimated to provide a dependable yield sufficient to meet the requested need, the Government makes no guarantees with respect to the quality or availability of water and assumes no responsibility therefor, or for the treatment of the water.

3. **Account Inflow**

   Inflow to accounts is based on the net inflow – total inflow minus losses due to evaporation or leakage.

4. **Inflow Distribution**

   For ResSim's default storage accounting, inflow is added to the accounts on a "per time-step" (daily) basis. Inflow is credited to account holders based on their percentage of the total conservation storage, as measured by the variable conservation pool storage; thus, their percentage of the total inflow varies in time along with the conservation pool. The storage in the conservation pool varies due to a seasonally changing guide curve and the calculation of storage in both the conservation pool and in the storage account will be clearly defined in each storage agreement.

   Return Flow Credit was not historically offered at Hartwell Reservoir. Under RFC model scenarios, 100% of a user's returned flow (to Hartwell) is credited to their storage account, and that volume of inflow is removed from the net inflow that is distributed across all accounts, effectively reducing inflow to other account holders.

5. **Excess Inflow from Full Accounts**
   In the ResSim storage accounting feature, if one or more users have full accounts, any inflow not used by them is proportionally credited to the other account holders. However, in the scripted approach to storage accounting, excess inflow not needed by full accounts is credited to the general pool or “default account”. The default account is defined as the portion of the conservation pool that is not otherwise apportioned to account holders. In the model, it is sometimes labeled the USACE account since USACE is responsible for all other operations and uses of the conservation pool.

   This approach for handling excess inflow by crediting it to the default pool was selected because it is conservative when sizing accounts to ensure they can meet demand. It is not in accordance with ECB 2023-12 Methods for Storage Yield Analysis, which requires distribution of excess inflow across all accounts. However, the scenario in which excess inflow is present is typically only encountered during high flow conditions, when most accounts are full anyway. It is unlikely to cause much difference during the critical period. The impact of this difference in approach is estimated to be very minor during the critical period, when typically none of the storage accounts are full, so there is no excess inflow to distribute. A sensitivity analysis was performed on the “current” conditions alternative. It was found that while very small differences were seen in the overall storage of the three accounts, all three showed the exact same conditions during the complete drawdown (drew down to the same storage within the tolerance of considering the account empty), so it was concluded that the excess inflow crediting approach was reasonable for this study.

6. **Variable Guide Curve**
   Reservoir drawdown according to a variable guide curve is charged to the general, multipurpose conservation storage account (or “default account” or “USACE storage account”), not to water supply users. For example, at Hartwell Lake, the Hartwell 4-foot winter drawdown from elevation 660 feet to 656 feet is considered as a withdrawal (release) from the USACE storage account for storage accounting purposes. During winter period the conservation pool volume is smaller than summer, and thus the volumes of the contract holders make up a larger percentage of the pool volume. Since inflow is distributed to the account holders based on their fraction of the total conservation volume, contract holders get a greater percentage of the inflow in the winter.

7. **Flood Pool Storage**
   Any water held above the top of conservation storage (660 feet) is not subject to the Corps’ storage accounting. Thus, withdrawals under those circumstances are not charged to individual users’ accounts and are essentially free to users. This applies for the entire calendar year because the reservoir drawdown according to a variable guide curve—for example, the 4-foot winter drawdown from elevation

660 feet to 656 feet at Hartwell Lake— is considered a withdrawal (release) from the USACE storage account.

6.2 Existing Hartwell Water Storage Accounts

At Hartwell Lake three water users, ARJWS, Lavonia, and Hart County, hold existing water storage accounts of 24,620 acre-feet, 127 acre-feet, and 1,827 acre-feet respectively. For water accounting purposes, the remaining volume is part of the default or USACE storage account. When ARJWS, Lavonia, and Hart County withdraw water, the withdrawn volume is deducted from their accounts. Inflows to the reservoir are distributed to each account based on that account's percentage of the total conservation volume, which varies in time with the seasonally-variable guide curve. See Table 6.1-2 for the existing storage account sizes relative to the total conservation pool by season.

Currently the account holders do not withdraw the full amount possible from their accounts. The Yield Analysis described in previous sections determined an estimated critical yield for each existing account holder, based on recent monthly usage patterns.

The scripted water storage accounting approach found slightly different firm yields for the existing accounts. The scripted storage accounting does not explicitly differentiate between releases made from the conservation pool and the flood pool. Instead, a mass balance is computed for each storage account and the rest of the reservoir is considered default (or USACE) pool. That default account is made up of all the water in the pool minus the water in each storage account, so its definition is not limited by the confines of the conservation pool.

In each timestep, after inflows have been added and withdrawals have been subtracted from each account, the elevation of the pool is compared with the guide curve. If the pool is above the guide curve, it is in flood control, and all user accounts are set to full, and the default account volume is deducted accordingly to maintain the overall pool mass balance. For consistency within each model (the yield model and the storage accounting model), the demand values used in each model were based on the values computed with the individual models. The difference in calculations were then analyzed to describe the significance of the difference.

Table 6.2-1: Existing water accounts as a percentage of the conservation pool.

	Existing Water Accounts		
	ARJWS	**Lavonia**	**Hart Co.**
Storage (ac-ft)	24,620	127	1827
% of Summer Pool	1.74%	0.01%	0.13%
% of Winter Pool	2.05%	0.01%	0.15%

6.3 Return Flow Credit

ARJWS and Lavonia return a percentage of their withdrawal back to Hartwell Lake. Currently, for water accounting purposes, these returned flows are considered part of the rest of the net inflow to Hartwell and distributed to accounts normally, according to their percent of conservation pool storage.

Following a decision to offer return flow credit for State of Georgia storage accounts at all Allatoona Lake, ARJWS has requested return flow credit for its new storage account request. Giving water account holders full credit for their returned flow would remove the return flow from the total inflow and credit it to the individual's account instead. The remaining inflow would be divided according to percent of pool storage.

Return flow to Hartwell for ARJWS, ARJWS New, Pioneer, Lavonia, and Lavonia New are represented in the ResSim model by using negative diversions at the Hartwell inflow junction. The volume of this return flow is calculated using the ***Accounting*** state variable based on a fixed average return rate for each user.

This is not the historic approach to return flows for water storage accounting at Hartwell.

6.4 Storage Accounting Script Logic

The Scripted Model storage accounting is done using a ResSim State Variable script which was developed by modifying a storage accounting script that was used in a previous model for Allatoona Reservoir.

The script is used to calculate and save water account statuses at every timestep. Each water account is tracked using its own state variable whose value is calculated by the primary "Accounting" state variable script.

At the beginning of an alternative run, the modeler sets the size of each water account, and all water accounts are set to full. Then each timestep of the compute, total Hartwell inflow is divided between account holders based on their account size, relative to the total conservation pool. For alternatives that allow RFC, return flows are credited directly to the respective account holder, while the rest of the inflow is divided by account size. The demand withdrawn from each account is subtracted from the existing account in each time step.
This provides a running accounting of the total storage in each water account at each timestep.

In order to determine the account sizing needed for different alternatives, the critical drought period had to be run iteratively with different account sizes until a size was found that drew the account down almost entirely while still maintaining the demanded withdrawals during the critical period.

The water storage accounting script is reproduced in Chapter 9.0 in full.

6.5 Critical Drought Water Accounting Runs

The following model runs were made with the water accounting version of the HEC-ResSim model. Each run is labeled starting with “A” for accounting[3].

Table 6.5-1: Phase 2 modeling alternatives

Alternative Name		**Alternative Description**	**Hartwell Account Sizes**			**Demand Time Series**		**RFC**
ResSim Scripted Accting	**PDT**		**Existing Accts Only**	**Sized for New Requests**	**Sized for New Req. w/RFC**	**Existing Yield**	**Future Requests**	
ACur	model only	Used to confirm yield of existing accounts	✓			✓		
AFWOP	**FWOP**	Future without project - future demands; no new water accounts	✓				✓	
AFut0	**Alt 2**	Future with New Accounts		✓			✓	
AFut1	model only	Future with New Accounts and RFC			✓		✓	✓
AFut1d	**Alt 5**	Future with New Accounts and RFC and increased accounts for Hart Co & Currahee			✓+		✓	✓

6.5.1 Model Run “ACur”: Current Conditions, Demands=Account Yields

This modeling scenario (labeled “ACur”) represents the current conditions if existing account holders were to maximize the use of their storage accounts by withdrawing the monthly pattern that could be sustained by their account under the critical drought period (Table 6.4-2).

This model run is not an official PDT alternative. It was used for verification and model comparison purposes. Initially the demand pattern that could be sustained based on the prior yield modeling was used in the Scripted Model, but it was found that there were

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[3] Note that for the water accounting scripted model scenarios, alternatives that start with “A2” are the same as alternatives that start with “A”. The inputs, parameters, and results are the same. The “A2” versions only differ in the tracking of additional output.

small shortages. This difference between the two models is likely due to tiny differences in the storage tracking calculations. So, for the scripted model, the demand timeseries were reduced until they could be consistently met for the full period of record. The difference between the ResSim yield calculation and the Scripted Model calculation for the current accounts sizes was marginal, as shown in Table 6.4-3.

Table 6.5.1-1: Existing Account Yield as determined and used by the Scripted Model

Stor (ac-ft)	24,620	127	1,827
	ARJWS	Lavonia	Hart County
Jan	41.998	0.250	3.323
Feb	42.235	0.252	3.358
Mar	41.114	0.209	2.780
Apr	42.168	0.209	2.814
May	47.092	0.250	3.724
Jun	50.185	0.250	4.009
Jul	51.933	0.250	4.107
Aug	52.265	0.239	3.866
Sep	52.711	0.227	2.961
Oct	48.334	0.250	3.503
Nov	43.348	0.252	3.330
Dec	41.390	0.250	3.254
Average of Monthly Flows (cfs)	46.231	0.241	3.421
Annual Avg (cfs)	46.252	0.241	3.419
Annual Avg (MGD)	29.893	0.156	2.211

Table 6.5.1-2: Existing Account Yield as determined by the ResSim Yield Analysis vs. Scripted Model

	ARJWS	Lavonia	Hart County
ResSim Yield (cfs)	46.336	0.2423	3.4244
Script Yield (cfs)	46.252	0.2408	3.4209
Diff (cfs)	0.0843	0.0015	0.0035

6.5.2 Model Run “AFWOP”: Future, No New Accounts

This modeling scenario (AFWOP) represents the future without project condition, wherein no new accounts exist.

The 2035 Future Demands were determined based on each user’s monthly demand pattern and their requested average annual yield. For ARJWS and Lavonia, who have existing accounts, their total 2035 demand was established by adding the existing account yields (found using run "ACur") to the new request amounts. Hart County has an existing account and did not make a new request, so their 2035 demands were assumed to be the yield of their current account. Table 6.4-4 shows the annual average demands used for the water accounting modeling. The current usage pattern was applied for each user.

Table 6.5.2-1: Assumed 2035 Future Demands

	ARJWS		Pioneer		Lavonia		Currahee		Hart Co.	
	MGD	cfs	MGD	cfs	MGD	cfs	MGD	cfs	MGD	cfs
Existing Acct Yield	29.89	46.252	-	-	0.155	0.241	-	-	2.21	3.42
New Request	16.05	24.833	5	7.736	3.00	4.642	0.50	0.773	-	-
2035 Total Demand	**45.94**	**71.085**	**5.00**	**7.736**	**3.16**	**4.882**	**0.50**	**0.773**	**2.21**	**3.420**

Hartwell pool conditions (Figure 6.4-1) and water accounting results (Figure 6.4-2, Figure 6.4-3, and Figure 6.4-4) for the future without project (run "AFWOP") are shown in the following figures. Each water accounting graph depicts one or more of the water storage accounts over the historical critical drought and recovery period from 1998-2003. The upper panels show the water account(s) maximum level and the modeled account drawdown. The lower panels show the water demand timeseries and modeled withdrawals. When the water account is empty or insufficient to meet the full demand, shortages can be observed in the lower panel, where the withdrawal is less than the demand.

This A2FWOP run demonstrates that future demands cannot be met without additional storage. ARJWS's and Lavonia's existing accounts could not sustain 2023 level demands. Water users without existing accounts (Pioneer and Currahee) would have to purchase water by other means. Figure 6.4-4 shows their demands but withdrawals are zero for each of them.

Each current account holder could withdraw their current account yield over the critical drought period, however, in less dry times, it is possible to withdraw much more from their current accounts without emptying them[4]. Since Hart County did not make an increased storage account request, its demand for the AFWOP run was assumed to be the critical yield. ARJWS and Lavonia, however, requested more storage, so their 2035 demands were modeled as much higher than their current critical yield. So, in the model run, ARJWS and Lavonia attempt to withdraw their full 2035 demands, to the extent possible given their current account sizes. In Figure 6.4-2 you can see that ARJWS is able to meet its full demand during 1998, which led up to the critical drought, and all the way into mid-2000. ARJWS's account did not empty until July of 2000, at which point it would no longer be able to meet its 2035 demand, nor would it be able to meet its current critical yield, because the higher 2035 demand drew the pool down faster than it would have under lesser demand. The ARJWS account begins to refill

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[4] Storage account holders also receive withdrawal permits from the states in conjunction with their account contracts. These typically match the withdrawal requested when the storage account is created. While it is possible for account holder to get permission to withdraw more, the states would typically consult with USACE to ensure further demand does not impact others. Thus, the model assumption of withdrawing the monthly yield pattern is reasonable.

during the recovery period, but refill is very slow, given that the demand is still high compared to the size of the account (and percentage of inflow). ARJWS's account is restored to full in early March 2003 when Hartwell's pool reaches the top of the Conservation Zone.

Figure 6.4-3 shows the current Lavonia storage account during the critical period with 2035 demands. Lavonia's current account is very small, only providing for about 0.24 cfs average annual critical yield, and the new request of 4.64 cfs is significantly higher, making the 2035 demands about 20x larger than the critical yield. The demand cannot typically be met with the current account, but like ARJWS, Lavonia's account becomes full when the Hartwell pool is at the top of conservation. The USACE reservoir operation aims to maintain a full conservation pool as much as possible. As long as the Hartwell pool is full, Lavonia would be able to meet its demand, even with an account sized much too small to sustain the withdrawal otherwise.

Figure 6.4-4 shows the water accounts for Pioneer, Currahee, and Hart County. As stated previously, Pioneer and Currahee do not have water storage accounts under the future without project condition, so their demands are not met in this model run. Hart County's demand is assumed to be the same as the yield for the current account. However, the impact of ARJWS and Lavonia attempting to meet the 2023 level of demand is that more water is withdrawn overall. Given that operational yield is impacted operations, Hart County's account is impacted by the greater usage in this scenario and would no longer be able to meet their current critical yield. A two-day shortage to Hart County's demand is shown in the figure in September 2002.

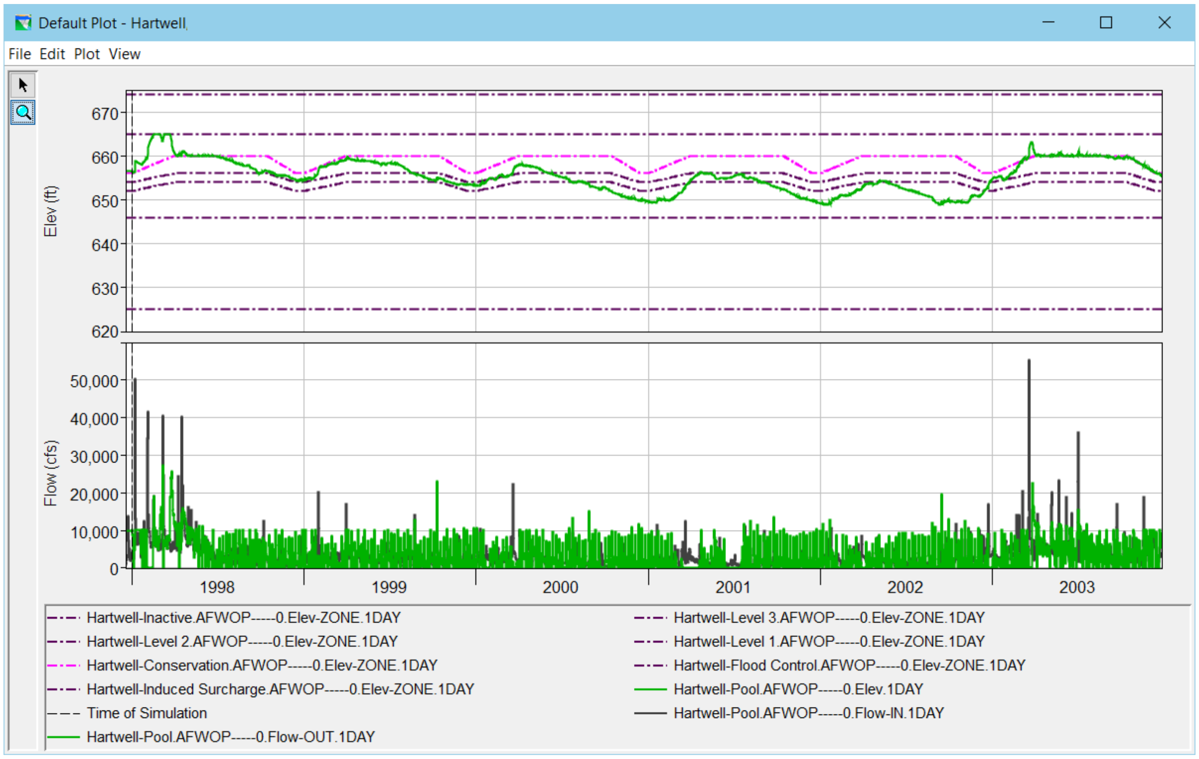


Figure 6.5.2-1: Hartwell Pool elevation, inflows, and outflows during critical drought

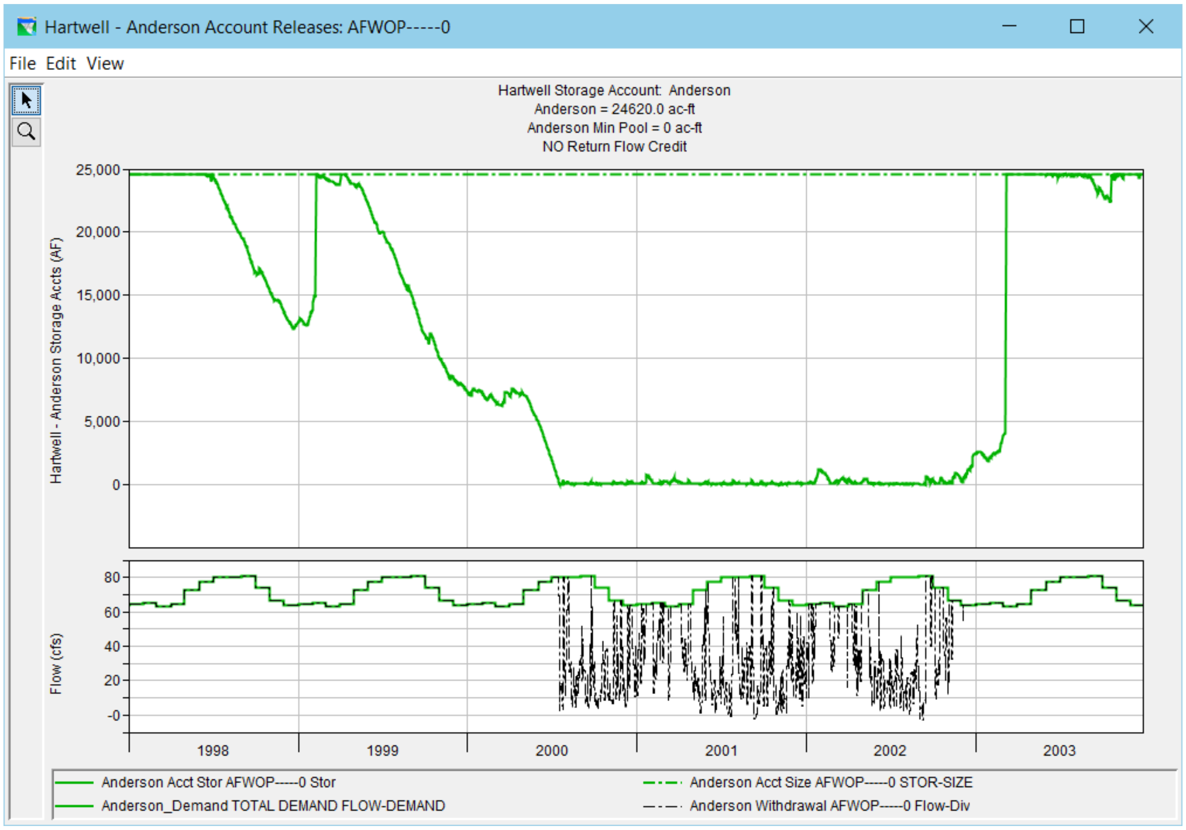


Figure 6.5.2-2: AFWOP run: ARJWS Storage account during the critical period

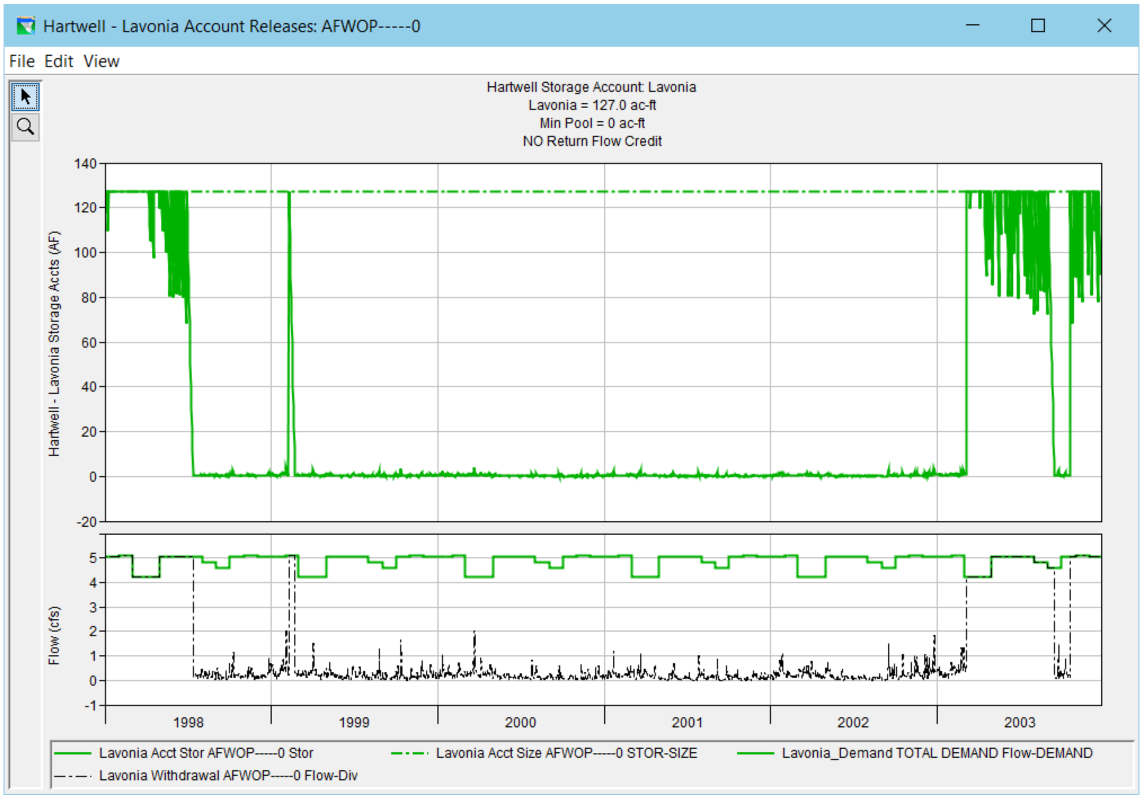


Figure 6.5.2-3: AFWOP run: Lavonia Storage account during critical period

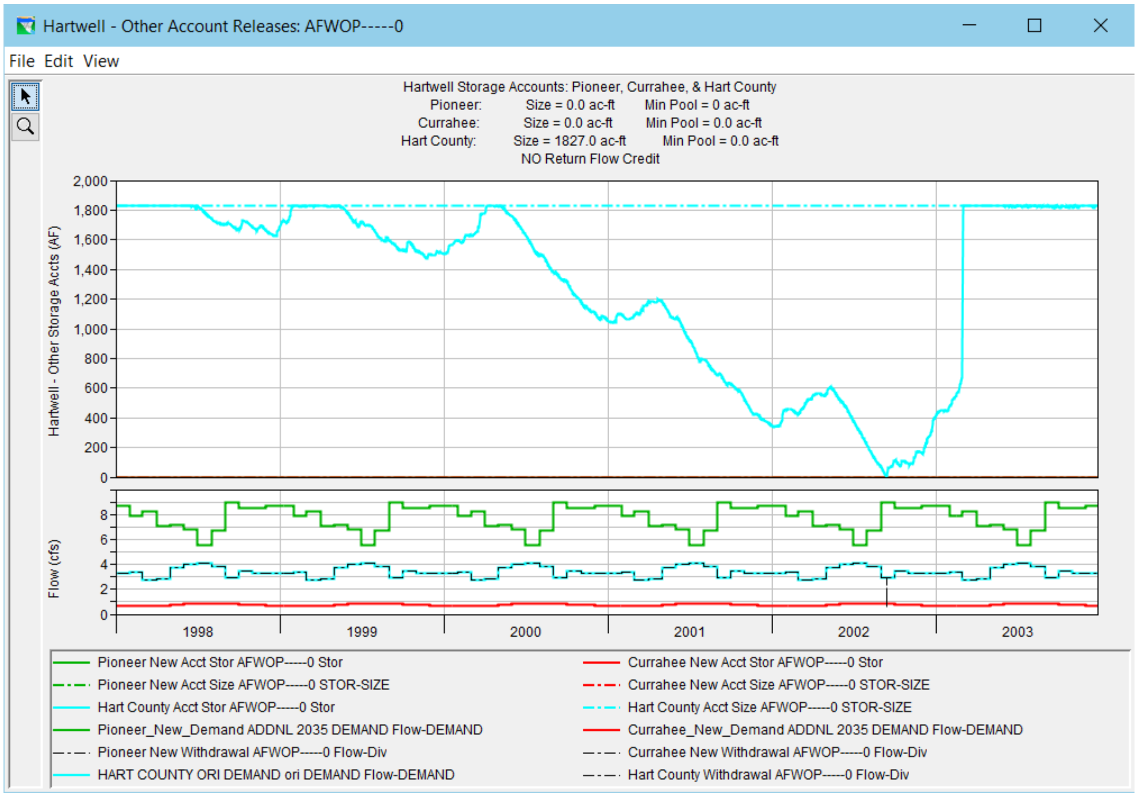


Figure 6.5.2-4: AFWOP run: Hart County account during critical period

6.5.3 Model Run “AFut0” Water Accounting Run: Future with Requested New Accounts

The “AFut0” model run is representative of PDT Alternative 2. The PDT alternative also includes Dependable Yield Mitigation (DYM) for any water account holders who are adversely affected by the new accounts. For the scripted water accounting ResSim model, no adjustments needed to be made to represent the DYMs. The model does not explicitly track Russell and Thurmond accounts. That is represented in the ResSim Yield Model.

The purpose of the AFut0 model run is to size the water storage accounts needed to meet the 2035 demands during the critical period. Similar modeling was done with the ResSim Yield model, but to compare across the alternatives with and without RFC scenarios, the modeling needed to also be done with the scripted water storage accounting model.

6.5.4 Model Run “AFut1” Water Accounting Run: Future with Requested New Accounts and Return Flow Credit

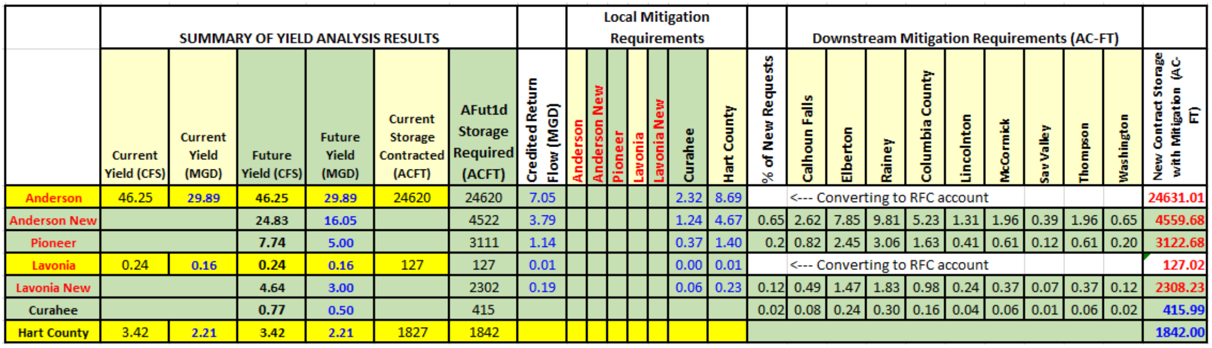
The “AFut1” model run is an intermediate modeling run with the addition of Return Flow Credit for ARJWS, Pioneer, and Lavonia.

The purpose of the AFut1 model run is to size the water storage accounts needed to meet the 2035 demands during the critical period under the conditions of full return storage credit. This modeling could not be done with the ResSim Yield model, because the ResSim inherent water accounting does not provide for return flow credit. This model run can be compared with the AFut0 to see the difference in account size needed with and without RFC.

6.5.5 Model Run “AFut1d” Water Accounting Run: Future with Requested New Accounts and Return Flow Credit and DYM for Hartwell Accounts

The “AFut1d” model run is representative of PDT Alternative 5, which meets future demands with Return Flow Credit accounting and applies Dependable Yield Mitigation (DYM) for impacts to accounts downstream and at Hartwell itself. This “AFut1d” model run uses the new Hartwell water storage account sizes calculated by “AFut1” and increases the size of existing Hartwell accounts that required DYMs due to the RFC water accounting. For the scripted water accounting ResSim model, no adjustments needed to be made to represent the downstream DYMs. The model does not explicitly track Russell and Thurmond accounts. Those DYMs were calculated and represented in the ResSim Yield Model.

Table 6.5.25 DYM allocations for RFC scripted runs



	SUMMARY OF YIELD ANALYSIS RESULTS							Local Mitigation Requirements								Downstream Mitigation Requirements (AC-FT)									
	Current Yield (CFS)	Current Yield (MGD)	Future Yield (CFS)	Future Yield (MGD)	Current Storage Contracted (ACFT)	AFut1d Storage Required (ACFT)	Credited Return Flow (MGD)	Anderson	Anderson New	Pioneer	Lavonia	Lavonia New	Curahee	Hart County	% of New Requests	Calhoun Falls	Elberton	Rainey	Columbia County	Lincolnton	McCormick	Sav Valley	Thompson	Washington	New Contract Storage with Mitigation (AC-FT)
Anderson	46.25	29.89	46.25	29.89	24620	24620	7.05						2.32	8.69		<--- Converting to RFC account									24631.01
Anderson New			24.83	16.05		4522	3.79						1.24	4.67	0.65	2.62	7.85	9.81	5.23	1.31	1.96	0.39	1.96	0.65	4559.68
Pioneer			7.74	5.00		3111	1.14						0.37	1.40	0.2	0.82	2.45	3.06	1.63	0.41	0.61	0.12	0.61	0.20	3122.68
Lavonia	0.24	0.16	0.24	0.16	127	127	0.01						0.00	0.01		<--- Converting to RFC account									127.02
Lavonia New			4.64	3.00		2302	0.19						0.06	0.23	0.12	0.49	1.47	1.83	0.98	0.24	0.37	0.07	0.37	0.12	2308.23
Curahee			0.77	0.50		415									0.02	0.08	0.24	0.30	0.16	0.04	0.06	0.01	0.06	0.02	415.99
Hart County	3.42	2.21	3.42	2.21	1827	1842																			1842.00

6.6 Summary of Phase 2 Modeling Results

Table 6.4-5 summarizes the demand and account size information for the Phase 2 modeling scenarios. The ACur0 model run uses the current storage accounts sizes and the maximum demand that could be satisfied for those accounts during the critical period (i.e., critical yield). The AFWOP model run also uses the current account sizes but uses the 2035 demand timeseries. The ARJWS and Lavonia demands were shorted in this model run, demonstrating that the future without project (no action; no change in storage account sizes) scenario would not allow 2035 demands to be met. The AFut0 model run increases the storage account sizes for ARJWS and Lavonia to the size needed to fully meet the 2035 demands during the critical period. ARJWS required 13,140 additional ac-ft of storage, and Lavonia needed 2,437 ac-ft of additional storage to meet the 2035 demand. AFut1 included RFC for ARJWS, Pioneer, and Lavonia, which enabled them to hold smaller water accounts and still meet their 2035 demand during the critical period. However, granting RFC to those account holders reduced the portion of total inflow received by the other account holders, causing them to require larger accounts, as reflected in AFut1d, which is the same as AFut1, except it includes larger accounts for Currahee and Hart County. In all, granting RFC allows ARJWS, Pioneer, and Lavonia to need smaller accounts, by 8,618 ac-ft, 874 ac-ft, and 135 ac-ft, respectively. Currahee needed 4 ac-ft more to continue meeting the same level of demand during the critical period, and Hart County needed 15 ac-ft more.

Table 6.6-1: Comparison of Account Sizes needed for different model alternatives

			Accounts				
Model Alt			**Anderson**	**Pioneer**	**Lavonia**	**Currahee**	**Hart Co.**
Demand = Current Yield		MGD	29.89	-	0.16	-	2.21
		cfs	46.25	-	0.24	-	3.42
ACur0	*Current Storage (ac-ft)*		***24620***	***0***	***127***	***0***	***1827***
Demand = 2035 Demands		MGD	45.94	5.00	3.16	0.50	2.21
		cfs	71.08	7.74	4.88	0.77	3.42
AFWOP	*Current Storage (ac-ft)*		***24620***	***0***	***127***	***0***	***1827***
AFut0	*Account size needed (ac-ft)*		***37760***	***3985***	***2564***	***411***	***1827***
AFut1	*Account size needed (ac-ft)*		***29142***	***3111***	***2429***	***411***	***1827***
AFut1d	*Account size needed (ac-ft)*		***29142***	***3111***	***2429***	***415***	***1842***
Difference btw AFut0 and AFut1d (ac-ft)			8618	874	135	-4	-15

Account sizes listed in red were too small to meet full demand during the critical period.

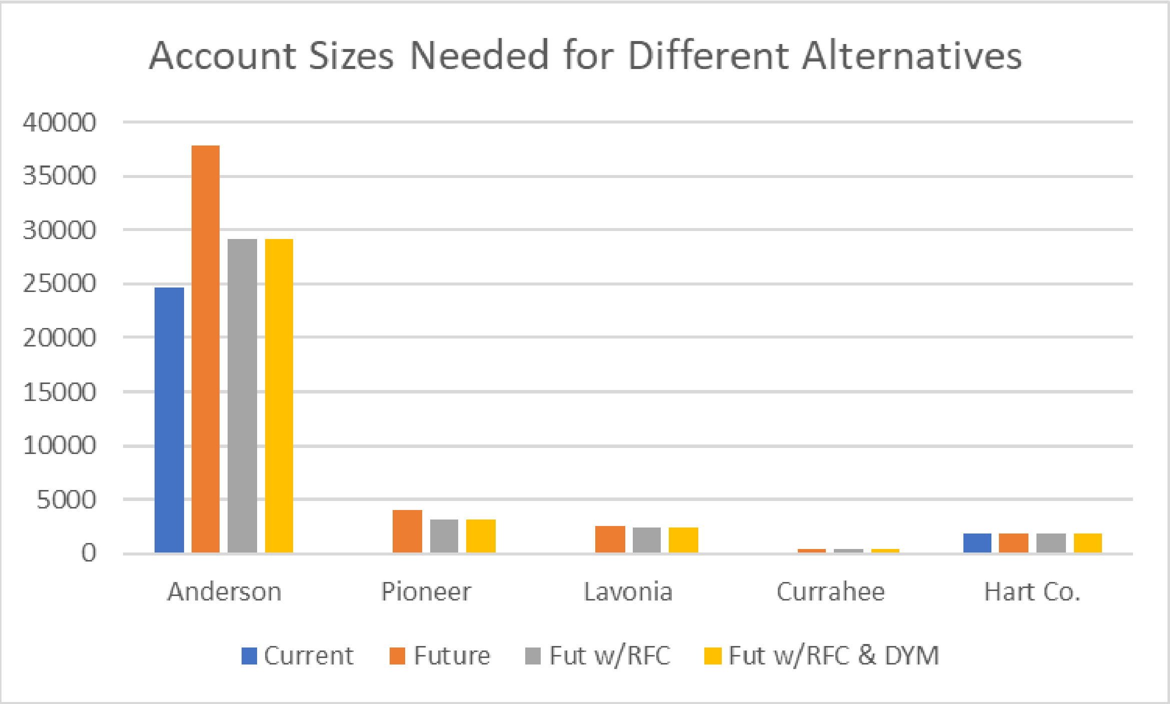


Figure 6.6-1: Account sizing for different alternatives

6.6.1 Phase 2 Model Results Compared with Yield Model Results

Since two different ResSim models were used in this study, and the yields calculated were slightly different between the two, below is a comparison of the yield and account sizing as calculated in the two different models.

As a reminder, the reason for using two different models was because RFC cannot be inherently calculated with the ResSim default yield. On the other hand, it would take significantly more time to completely script all the yield calculations. So, the two separate models were used, and their calculations were found to be comparable enough to accept both sets of results for drawing conclusions in this study. Using two separate models also offered the possibility of parallel work on each model, which saved time since both modeling efforts were time-intensive.

The first calculations done were to determine the current yield possible from each existing storage account. This was performed with ResSim's yield analysis feature. The resulting yields were used as the demands for the "Current Conditions" alternatives ("Current" in the Yield model and "ACur0" in the Scripted model).

Then the scripted model attempted to replicate the values found in the Yield model by setting demands=yield, using the current account sizes, and tracking the accounts over the period of record. It was found that due to slight differences in the logic behind the ResSim yield methodology and the scripted methodology, the scripted model showed shortages when attempting to use the Yield model yields as demands. So, the demands were reduced until the scripted model no longer shortages. The differences between the amounts yielded from each account in the Yield Model vs the Scripted model were small – between 0.10% and 0.62% and not more than 0.055 cfs (Table. 6.6.1-1). We think this is within the margin of error in the calculation of reservoir account yield.

Table. 6.6.1-1: Comparison of the Current Conditions yield calculated from the Yield Model vs. from the Scripted Model

Account	*Storage (ac-ft)*	Yield Model Yield[1]		Scripted Model Yield[2]		Difference btw Yield and Scripted Models		
		MGD	cfs	MGD	cfs	MGD	cfs	Percent
Anderson	***24620***	29.948	46.336	29.89	46.252	0.055	0.055	0.18%
Lavonia	***127***	0.157	0.2423	0.156	0.2408	0.001	0.001	0.62%
Hart Co.	***1827***	2.213	3.4244	2.211	3.4209	0.002	0.002	0.10%

[1] *Yield Model Alternative is called "Current"*

[2] *Scripted Model Alternative is called "ACur0"*

Since the yield calculated by the Yield Model was slightly different than that calculated from the Scripted Model, the Scripted Model used its calculated Yield as the demand time series instead of the yield calculated by the Yield model. The difference was small, but it enabled the Scripted model to have a Current Condition alternative that did not show shortages.

The current account demand timeseries were increased by the additional requests (stated in MGD/cfs). The Yield Model was then used to determine the necessary account size to meet the new requests. The Scripted Model also made this calculation. For the Yield Model Future Conditions alternative, yield for the new requests was calculated separately than the yield for the old accounts. For ease of comparison, and reporting purposes in the table below, the “ARJWS” and “ARJWS New” demands and account sizes were lumped. Likewise, the “Lavonia” and “Lavonia New” demands and account sizes were lumped.

The resulting account sizes can be seen in Table. 6.6.1-2. The account sizes calculated by the two models came within 0.31% of each other. The largest difference was seen in Pioneer, where the Yield Model indicated a needed account size of 10 acre-feet less than the Scripted Model showed.

Table. 6.6.1-2: Comparison of the Future Conditions (2035 Demands and New Accounts) account size calculated in the Yield Model vs. the Scripted Model

Account	Yield Model[1] 2035 Demands		Scripted Model[2] 2035 Demands		Demand Percent Difference	Yield Model Acct Size	Scripted Model Acct Size	Acct Size Difference	Acct Size Percent Difference
	MGD	cfs	MGD	cfs		ac-ft	ac-ft	ac-ft	
Anderson	46.162	71.423	45.94	71.085	0.47%	37767	37760	7	0.02%
Pioneer	5.001	7.737	5.00	7.736	0.01%	3975	3985	-10	-0.25%
Lavonia	3.157	4.884	3.16	4.882	0.03%	2556	2564	-8	-0.31%
Currahee	0.499	0.772	0.50	0.774	-0.15%	410	411	-1	-0.24%
Hart Co.	2.222	3.438	2.21	3.421	0.48%	1827	1827	0	0.00%

[1] *Yield Model Alternative is called "Future"*

[2] *Scripted Model Alternative is called "AFut0"*

6.7 Risk and Uncertainty Analysis

The ResSim models used to simulate and analyze different alternatives are not perfect reflections of reality. There are many assumptions and simplifications built into the modeling scenarios and approaches. For the purposes of this study, we believe these models suffice, with some caveats.

1. Hydrometeorologic Variability and Uncertainty

The critical drought on record is a unique event, which will not be repeated. Future hydrometeorological conditions cannot be known. We use the historical data as a representation of one set of conditions, through which we can compare and contrast different alternatives.

2. Operational Decisions and Judgement

The operation of the reservoirs within this system is done using guidelines set out in the Water Control Manuals, but human judgement also plays heavily into the operations.

The reservoirs in this watershed are operated together as a system. Any change at one reservoir can have impacts to the operation of the other reservoirs. It is not possible to completely isolate the changes caused by resizing water accounts. We minimize other differences by using the same operational sets for each model scenario.

3. Modeling Uncertainty and Error

Each model contains some uncertainty and error. The impacts are somewhat mitigated by comparing alternative scenarios run in the same model. For this study, we used two different models, so cross comparisons need to be interpreted carefully, however, the analysis made a point of keeping comparisons among alternatives run in the same model.

7.0 Model and Alternative Metric Comparison

The alternatives below (Table 7.0-1) were evaluated for relative differences in pool elevation, releases, days in drought zone, beach and boat ramp availability.

Table 7.0-1: Alternatives

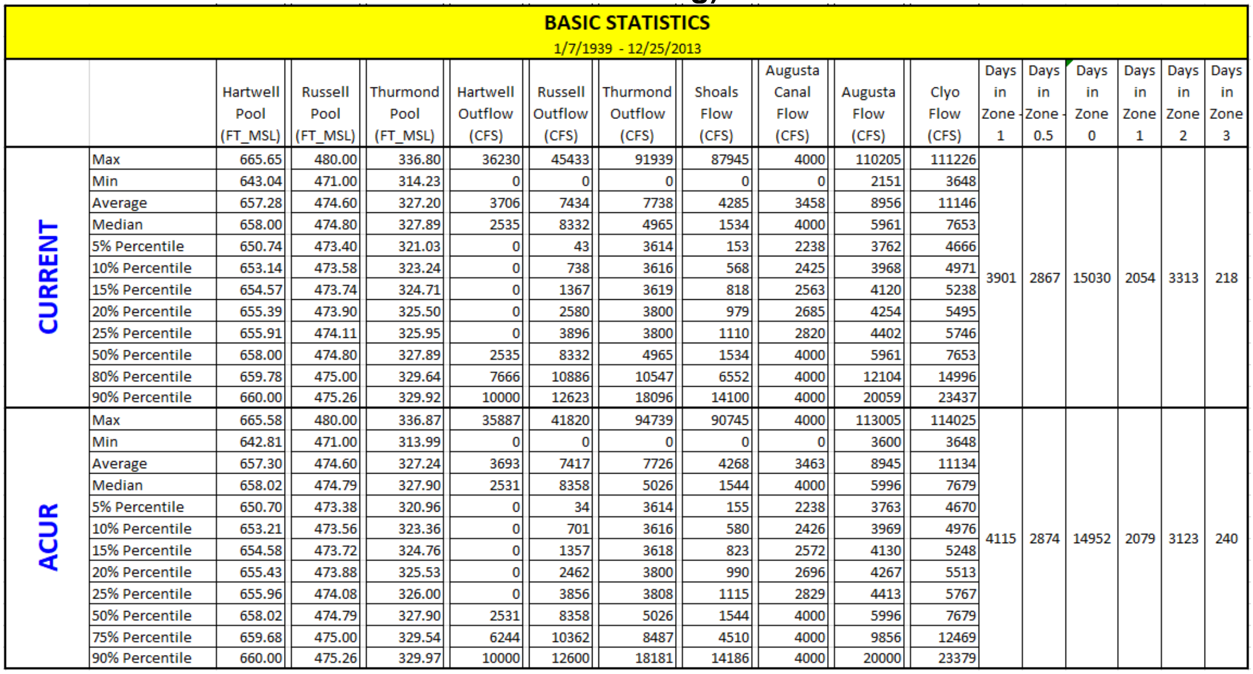
CURRENT	Current Water Accounts with default ResSim Water Accounting
ACUR	Current Water Accounts with scripted Water Accounting
AFUT0	Future Water Accounts with scripted Water Accounting (ALT2)
AFUT1	Future Water Accounts with scripted Accounting and RFC
AFUT1D	Future Water Accounts with scripted Accounting and RFC and DYM (ALT5)
AFWOP	Future Demands, scripted Water Accounting without any new water accounts

7.1 General Statistics

7.1.1 Default vs Scripted Alternative Comparison

Basic statistics for the Default ResSim Storage Accounting vs scripted ResSim Storage Accounting are found in Table 7.1-1 and Table 7.1-2, respectively. This information was used for initial comparison of ResSim default yield vs. scripted results. Comparison used to only validate scripting.

Table 7.1-1: Basic Statistics (Default Storage Accounting vs. Scripted Accounting)



BASIC STATISTICS

1/7/1939 - 12/25/2013

		Hartwell Pool (FT_MSL)	Russell Pool (FT_MSL)	Thurmond Pool (FT_MSL)	Hartwell Outflow (CFS)	Russell Outflow (CFS)	Thurmond Outflow (CFS)	Shoals Flow (CFS)	Augusta Canal Flow (CFS)	Augusta Flow (CFS)	Clyo Flow (CFS)	Days in Zone -1	Days in Zone -0.5	Days in Zone 0	Days in Zone 1	Days in Zone 2	Days in Zone 3
CURRENT	Max	665.65	480.00	336.80	36230	45433	91939	87945	4000	110205	111226	3901	2867	15030	2054	3313	218
	Min	643.04	471.00	314.23	0	0	0	0	0	2151	3648						
	Average	657.28	474.60	327.20	3706	7434	7738	4285	3458	8956	11146						
	Median	658.00	474.80	327.89	2535	8332	4965	1534	4000	5961	7653						
	5% Percentile	650.74	473.40	321.03	0	43	3614	153	2238	3762	4666						
	10% Percentile	653.14	473.58	323.24	0	738	3616	568	2425	3968	4971						
	15% Percentile	654.57	473.74	324.71	0	1367	3619	818	2563	4120	5238						
	20% Percentile	655.39	473.90	325.50	0	2580	3800	979	2685	4254	5495						
	25% Percentile	655.91	474.11	325.95	0	3896	3800	1110	2820	4402	5746						
	50% Percentile	658.00	474.80	327.89	2535	8332	4965	1534	4000	5961	7653						
	80% Percentile	659.78	475.00	329.64	7666	10886	10547	6552	4000	12104	14996						
	90% Percentile	660.00	475.26	329.92	10000	12623	18096	14100	4000	20059	23437						
ACUR	Max	665.58	480.00	336.87	35887	41820	94739	90745	4000	113005	114025	4115	2874	14952	2079	3123	240
	Min	642.81	471.00	313.99	0	0	0	0	0	3600	3648						
	Average	657.30	474.60	327.24	3693	7417	7726	4268	3463	8945	11134						
	Median	658.02	474.79	327.90	2531	8358	5026	1544	4000	5996	7679						
	5% Percentile	650.70	473.38	320.96	0	34	3614	155	2238	3763	4670						
	10% Percentile	653.21	473.56	323.36	0	701	3616	580	2426	3969	4976						
	15% Percentile	654.58	473.72	324.76	0	1357	3618	823	2572	4130	5248						
	20% Percentile	655.43	473.88	325.53	0	2462	3800	990	2696	4267	5513						
	25% Percentile	655.96	474.08	326.00	0	3856	3808	1115	2829	4413	5767						
	50% Percentile	658.02	474.79	327.90	2531	8358	5026	1544	4000	5996	7679						
	75% Percentile	659.68	475.00	329.54	6244	10362	8487	4510	4000	9856	12469						
	90% Percentile	660.00	475.26	329.97	10000	12600	18181	14186	4000	20000	23379						

Table 7.1-2: Basic Statistics (Scripted Storage Accounting)

BASIC STATISTICS

1/7/1939 - 12/25/2013

		Hartwell Pool (FT_MSL)	Russell Pool (FT_MSL)	Thurmond Pool (FT_MSL)	Hartwell Outflow (CFS)	Russell Outflow (CFS)	Thurmond Outflow (CFS)	Shoals Flow (CFS)	Augusta Canal Flow (CFS)	Augusta Flow (CFS)	Clyo Flow (CFS)	Days in Zone - 1	Days in Zone - 0.5	Days in Zone 0	Days in Zone 1	Days in Zone 2	Days in Zone 3
ACUR	Max	665.60	480.00	336.96	35953	41647	98338	94344	4000	116604	117624	4158	2924	14961	1884	3220	236
	Min	642.75	471.00	314.00	0	0	0	0	0	3600	3648						
	Average	657.33	474.61	327.26	3723	7410	7739	4279	3465	8957	11147						
	Median	658.04	474.80	327.91	2566	8361	5056	1548	4000	6034	7687						
	5% Percentile	650.80	473.40	321.05	0	34	3614	166	2234	3759	4665						
	10% Percentile	653.28	473.58	323.44	0	688	3616	578	2419	3963	4974						
	15% Percentile	654.61	473.74	324.79	0	1357	3618	827	2561	4119	5242						
	20% Percentile	655.48	473.90	325.58	0	2500	3797	992	2690	4260	5506						
	25% Percentile	655.98	474.10	326.00	0	3854	3800	1119	2829	4413	5759						
	50% Percentile	658.04	474.80	327.91	2566	8361	5056	1548	4000	6034	7687						
	80% Percentile	659.80	475.00	329.69	7668	10860	10639	6644	4000	12207	15120						
	90% Percentile	660.00	475.26	329.98	10000	12621	18152	14157	4000	20000	23339						
AFUT0	Max	665.58	480.00	336.87	35887	41820	94739	90745	4000	113005	114025	4115	2874	14952	2079	3123	240
	Min	642.81	471.00	313.99	0	0	0	0	0	3600	3648						
	Average	657.30	474.60	327.24	3693	7416	7726	4268	3463	8944	11134						
	Median	658.02	474.79	327.90	2532	8359	5025	1544	4000	5996	7679						
	5% Percentile	650.70	473.38	320.96	0	34	3614	155	2238	3763	4670						
	10% Percentile	653.21	473.56	323.36	0	697	3616	580	2426	3969	4976						
	15% Percentile	654.58	473.72	324.76	0	1356	3618	823	2572	4130	5248						
	20% Percentile	655.43	473.88	325.53	0	2462	3800	990	2696	4267	5513						
	25% Percentile	655.96	474.08	326.00	0	3857	3808	1115	2829	4413	5767						
	50% Percentile	658.02	474.79	327.90	2532	8359	5025	1544	4000	5996	7679						
	75% Percentile	659.68	475.00	329.54	6244	10362	8487	4510	4000	9855	12469						
	90% Percentile	660.00	475.26	329.97	10000	12598	18176	14181	4000	20000	23374						
AFUT1	Max	665.58	480.00	336.87	35887	41820	94739	90745	4000	113005	114025	4115	2874	14952	2079	3123	240
	Min	642.81	471.00	313.99	0	0	0	0	0	3600	3648						
	Average	657.30	474.60	327.24	3693	7417	7726	4268	3463	8945	11134						
	Median	658.02	474.79	327.90	2531	8358	5026	1544	4000	5996	7679						
	5% Percentile	650.70	473.38	320.96	0	34	3614	155	2238	3763	4670						
	10% Percentile	653.21	473.56	323.36	0	701	3616	580	2426	3969	4976						
	15% Percentile	654.58	473.72	324.76	0	1357	3618	823	2572	4130	5248						
	20% Percentile	655.43	473.88	325.53	0	2462	3800	990	2696	4267	5513						
	25% Percentile	655.96	474.08	326.00	0	3856	3808	1115	2829	4413	5767						
	50% Percentile	658.02	474.79	327.90	2531	8358	5026	1544	4000	5996	7679						
	75% Percentile	659.68	475.00	329.54	6244	10362	8487	4510	4000	9856	12469						
	90% Percentile	660.00	475.26	329.97	10000	12600	18181	14186	4000	20000	23379						
AFUT1D	Max	665.58	480.00	336.87	35887	41820	94739	90745	4000	113005	114025	4115	2874	14952	2079	3123	240
	Min	642.81	471.00	313.99	0	0	0	0	0	3600	3648						
	Average	657.30	474.60	327.24	3693	7417	7726	4268	3463	8945	11134						
	Median	658.02	474.79	327.90	2532	8359	5025	1544	4000	5996	7679						
	5% Percentile	650.70	473.38	320.96	0	34	3614	155	2238	3763	4670						
	10% Percentile	653.21	473.56	323.36	0	699	3616	580	2426	3969	4976						
	15% Percentile	654.58	473.72	324.76	0	1356	3618	823	2572	4130	5248						
	20% Percentile	655.43	473.88	325.53	0	2462	3800	990	2696	4267	5513						
	25% Percentile	655.96	474.08	326.00	0	3857	3808	1115	2829	4413	5767						
	50% Percentile	658.02	474.79	327.90	2532	8359	5025	1544	4000	5996	7679						
	75% Percentile	659.68	475.00	329.54	6244	10362	8487	4510	4000	9855	12469						
	90% Percentile	660.00	475.26	329.97	10000	12598	18181	14186	4000	20000	23379						
AFWOP	Max	665.59	480.00	336.83	35932	41697	93187	89194	4000	111454	112474	4110	2895	14964	1957	3222	235
	Min	642.94	471.00	314.10	0	0	0	0	0	3600	3648						
	Average	657.31	474.60	327.25	3707	7414	7737	4279	3463	8955	11145						
	Median	658.02	474.78	327.90	2557	8353	5028	1542	4000	6005	7688						
	5% Percentile	650.79	473.39	321.02	0	34	3614	167	2238	3764	4665						
	10% Percentile	653.28	473.57	323.42	0	686	3616	576	2426	3968	4974						
	15% Percentile	654.61	473.72	324.77	0	1357	3618	826	2567	4124	5245						
	20% Percentile	655.45	473.88	325.54	0	2509	3800	989	2692	4262	5506						
	25% Percentile	655.95	474.08	325.99	0	3882	3800	1116	2828	4412	5758						
	50% Percentile	658.02	474.78	327.90	2557	8353	5028	1542	4000	6005	7688						
	75% Percentile	659.67	475.00	329.54	6287	10330	8535	4551	4000	9846	12468						
	90% Percentile	660.00	475.26	329.98	10000	12622	18224	14228	4000	20000	23415						

7.1.2 Graphical Pool Comparison

- Graphical Pool Elevation Comparison (Hartwell)

All scripted alternatives provided Hartwell pool traces that were essentially the same with respect to pool elevation (Figure 7.1-1H).

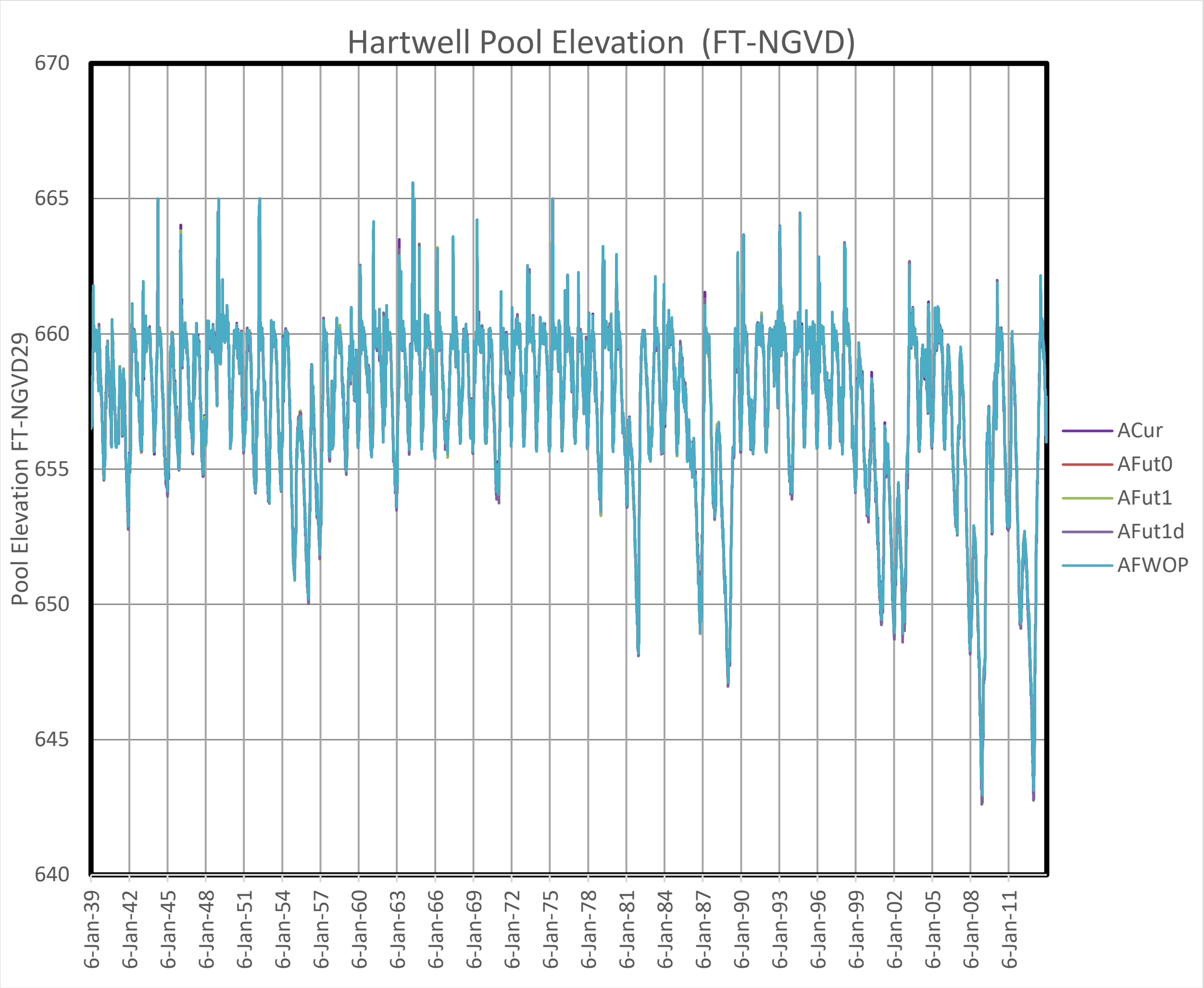


Figure 7.1.2-H: Period of Record Hartwell Pool Plot (Scripted Storage Accounting)

- Graphical Pool Elevation Comparison (Russell)

All alternatives vary a bit, likely due to subtle shifts in the timing and amount of pumping (Figure 7.5-1).

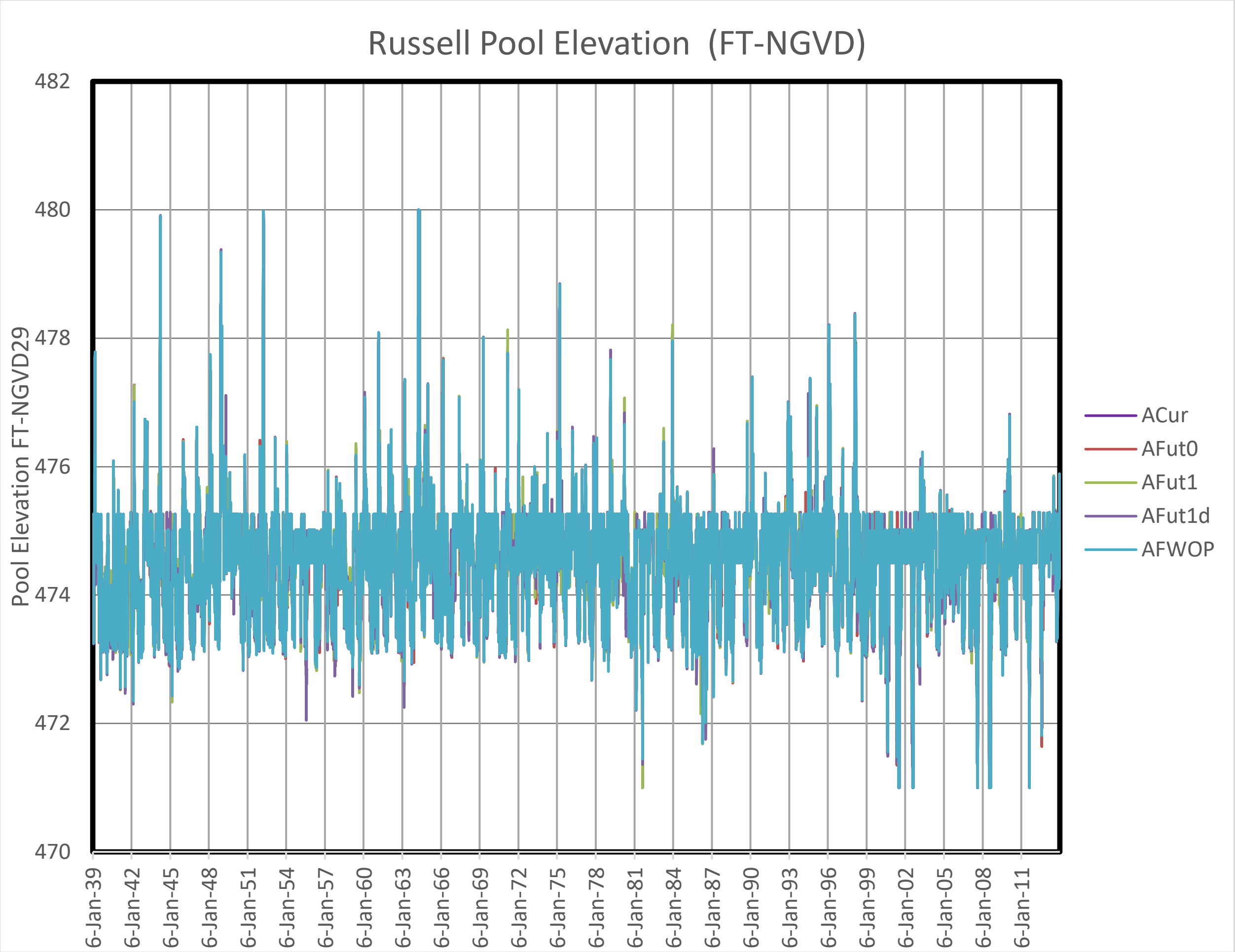


Figure 7.1.2-R: Period of Record Russell Pool Plot (Scripted Storage Accounting)

- Graphical Pool Elevation Comparison (Thurmond)

All alternatives provided Thurmond pool traces that were statistically the same with respect to pool elevation.

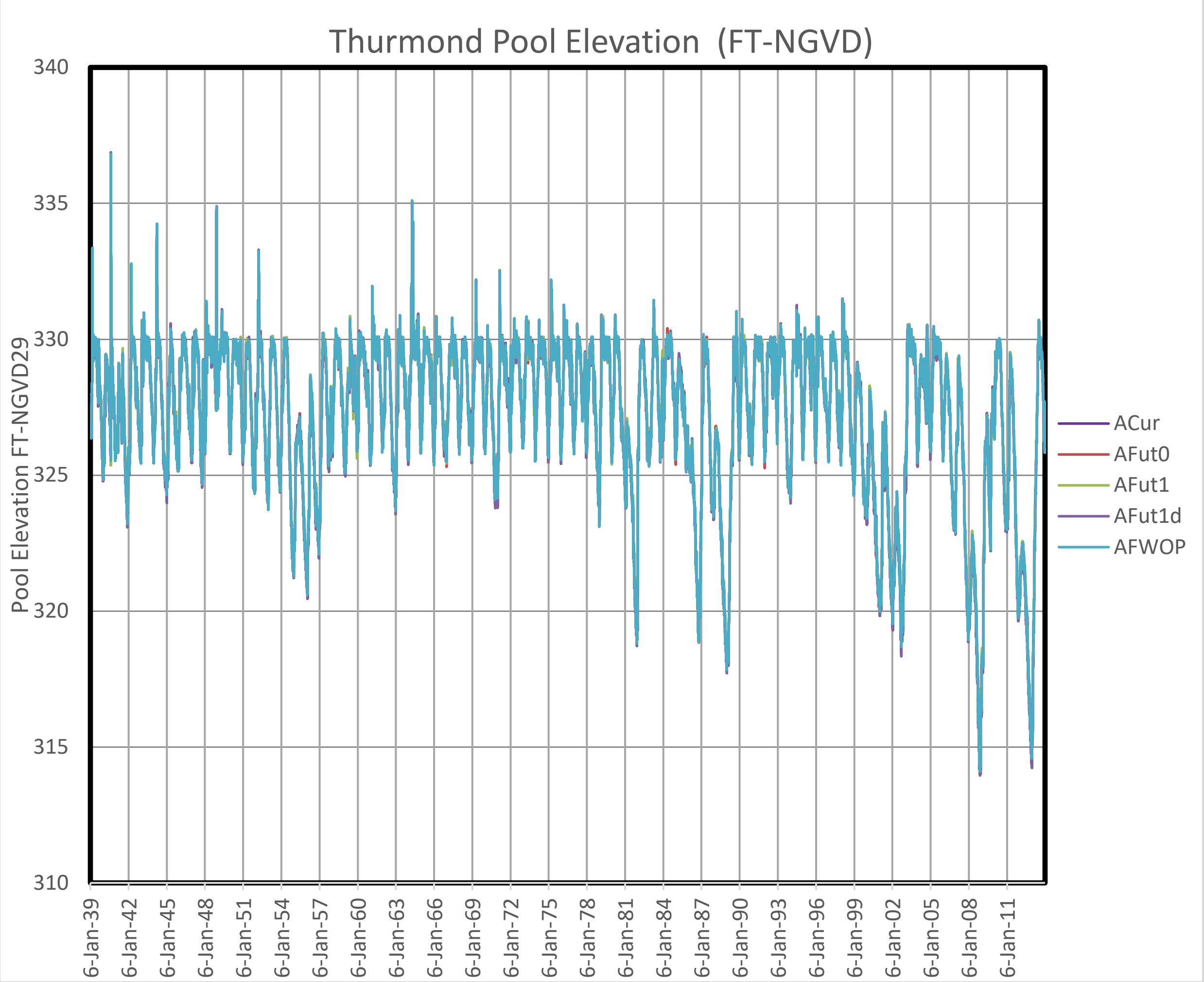


Figure 7.1.2-T: Period of Record Thurmond Pool Plot (Scripted Storage Accounting)

The scripted and default storage accounting methods yielded essentially identical results.

7.1.3 Percentile Pool Plots

Both Scripted and Non-Scripted storage accounting provided results that were statistically the same with respect to pool elevation validating scripting.

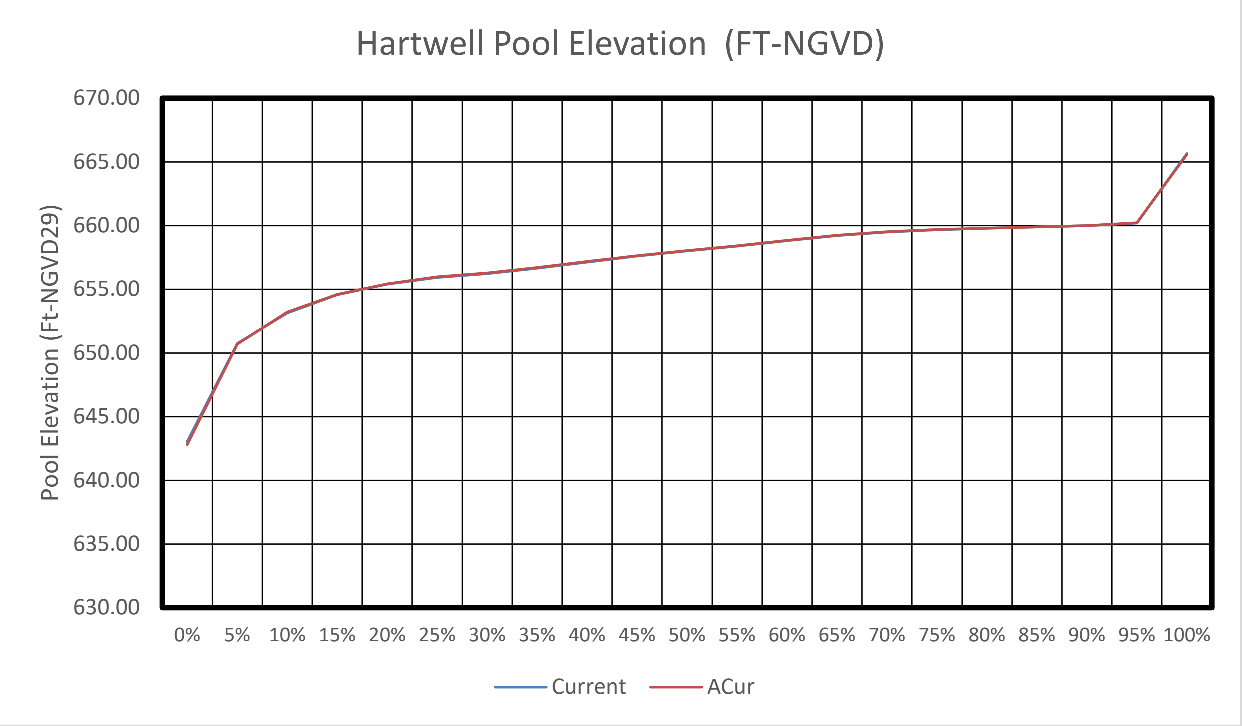


Figure 7.1-3: Hartwell Percentage Pool Plot (Default vs Scripted Storage Accounting)

All the alternatives shown in the following plots used scripted storage accounting. Alternatives AFut1 and AFut1d provided Return Flow Credits, AFut0 did not. Results were statistically the same with respect to pool elevation at all three reservoirs.

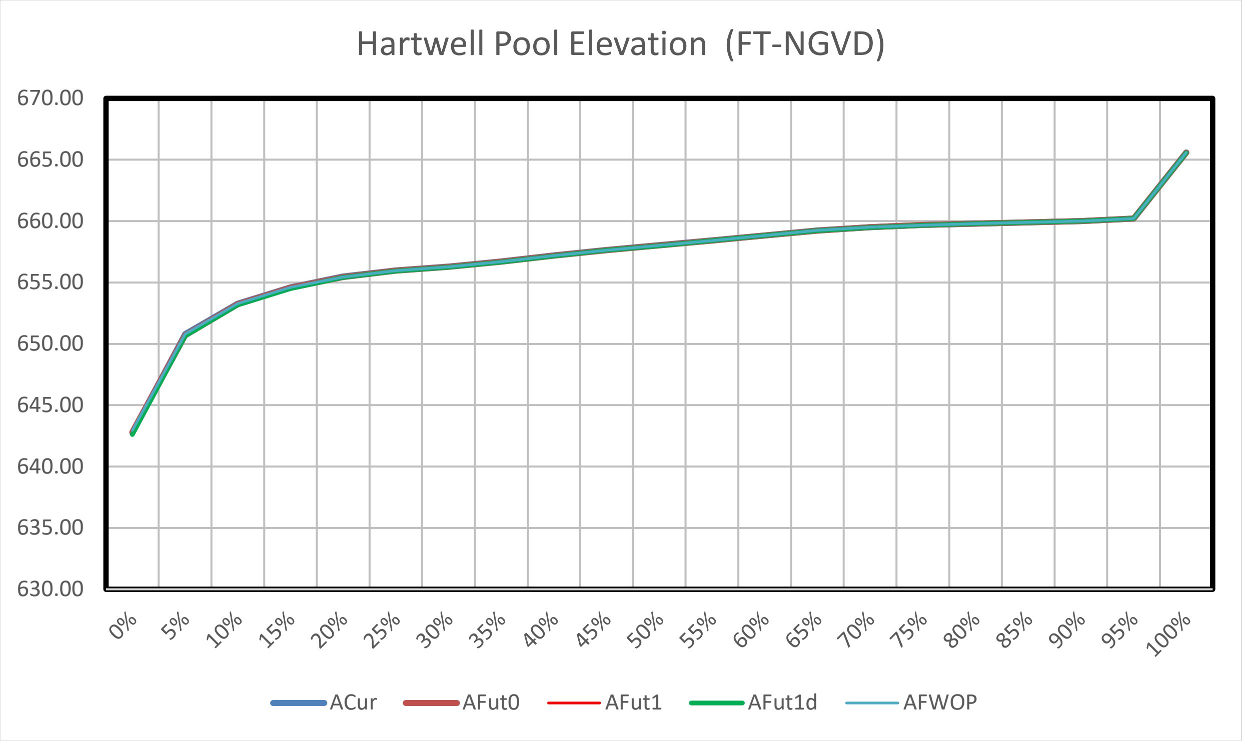


Figure. 7.1.3-H: Percentage Pool Plot (Alternative Comparison)

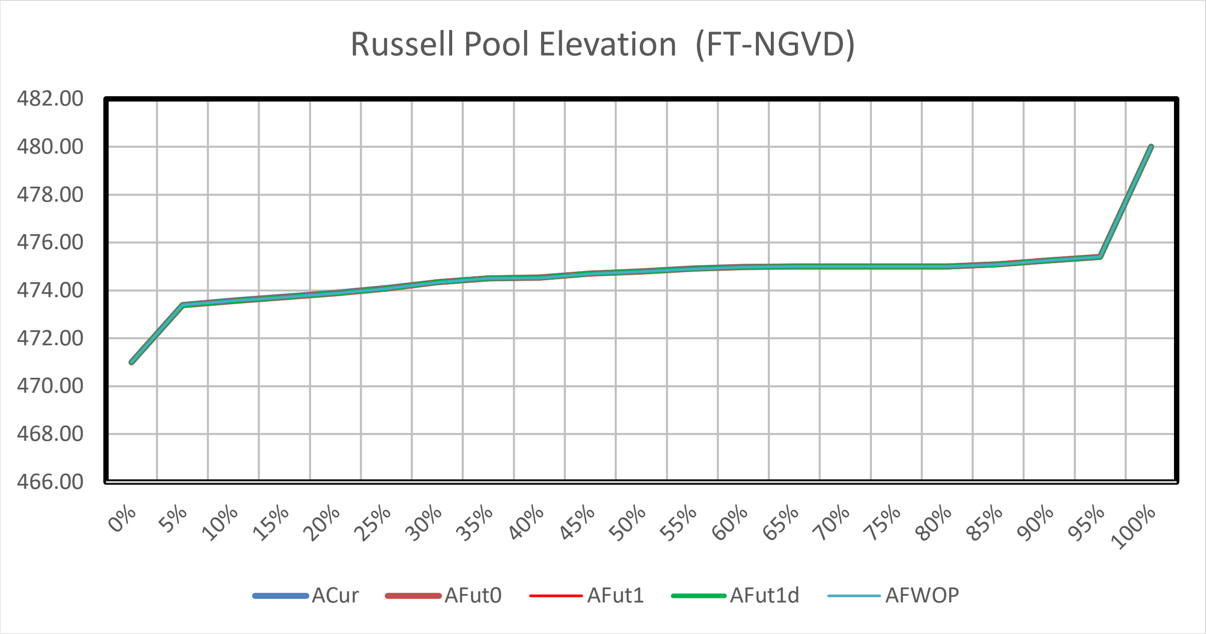


Figure. 7.1.3-R: Percentage Pool Plot (Scripted Storage Accounting)

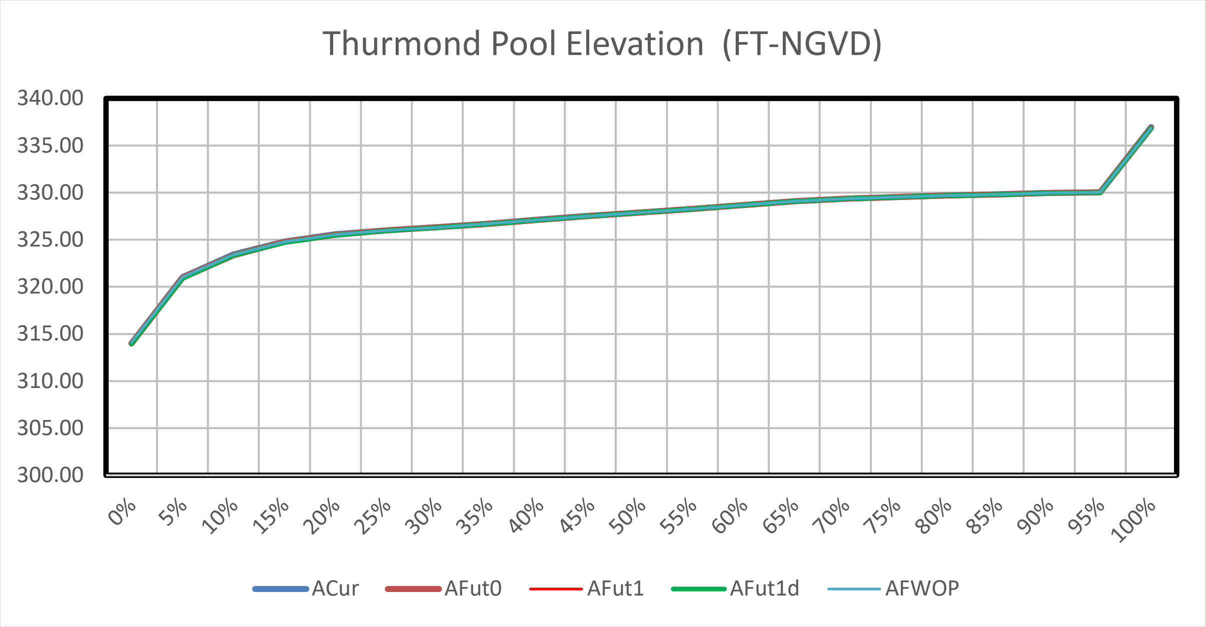


Figure. 7.1.3-T: Thurmond Percentage Pool Plot (Scripted Storage Accounting)

7.1.4 Tabular Pool Elevation Comparison

Table. 7.1.4-1H: Hartwell Pool Comparison (Scripted Storage Accounting)

Hartwell Pool Elevation (FT-NGVD)					
% of time at or below	**ACur**	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
0%	642.75	642.81	642.81	642.81	642.94
5%	650.80	650.70	650.70	650.70	650.79
10%	653.28	653.21	653.21	653.21	653.28
15%	654.61	654.58	654.58	654.58	654.61
20%	655.48	655.43	655.43	655.43	655.45
25%	655.99	655.96	655.96	655.96	655.95
30%	656.31	656.28	656.28	656.28	656.28
35%	656.72	656.70	656.70	656.70	656.69
40%	657.22	657.19	657.19	657.19	657.19
45%	657.65	657.63	657.63	657.63	657.64
50%	658.04	658.02	658.02	658.02	658.02
55%	658.43	658.41	658.41	658.41	658.41
60%	658.84	658.84	658.84	658.84	658.84

65%	659.24	659.23	659.23	659.23	659.24
70%	659.51	659.51	659.51	659.51	659.50
75%	659.68	659.68	659.68	659.68	659.67
80%	659.80	659.79	659.79	659.79	659.79
85%	659.91	659.89	659.89	659.89	659.89
90%	660.00	660.00	660.00	660.00	660.00
95%	660.21	660.21	660.21	660.21	660.21
100%	665.60	665.58	665.58	665.58	665.59
Average	657.33	657.30	657.30	657.30	657.31
Max	665.60	665.58	665.58	665.58	665.59
Min	642.75	642.81	642.81	642.81	642.94

Table. 7.1.4-2R: Russell Pool Comparison (Scripted Storage Accounting)

Russell Pool Elevation (FT-NGVD)					
% of time at or below	**ACur**	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
0%	471.00	471.00	471.00	471.00	471.00
5%	473.40	473.38	473.38	473.38	473.39
10%	473.58	473.56	473.56	473.56	473.57
15%	473.74	473.72	473.72	473.72	473.72
20%	473.90	473.88	473.88	473.88	473.88
25%	474.10	474.08	474.08	474.08	474.08
30%	474.35	474.35	474.35	474.35	474.33
35%	474.51	474.50	474.50	474.50	474.50
40%	474.54	474.53	474.53	474.53	474.52
45%	474.71	474.70	474.70	474.70	474.69
50%	474.80	474.79	474.79	474.79	474.78
55%	474.92	474.91	474.91	474.91	474.90
60%	474.98	474.98	474.98	474.98	474.98
65%	475.00	475.00	475.00	475.00	475.00
70%	475.00	475.00	475.00	475.00	475.00
75%	475.00	475.00	475.00	475.00	475.00
80%	475.00	475.00	475.00	475.00	475.00
85%	475.09	475.09	475.09	475.09	475.08
90%	475.26	475.26	475.26	475.26	475.26
95%	475.40	475.40	475.40	475.40	475.40
100%	480.00	480.00	480.00	480.00	480.00
Average	474.61	474.60	474.60	474.60	474.60
Max	480.00	480.00	480.00	480.00	480.00
Min	471.00	471.00	471.00	471.00	471.00

All alternatives provided elevations that were statistically the same with respect to pool elevation.

Table. 7.1.4-3T: Thurmond Pool Comparison (Scripted Storage Accounting)

Thurmond Pool Elevation (FT-NGVD)					
% of time at or below	**ACur**	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
0%	314.00	313.99	313.99	313.99	314.10
5%	321.05	320.96	320.96	320.96	321.02
10%	323.44	323.36	323.36	323.36	323.42
15%	324.79	324.76	324.76	324.76	324.77
20%	325.58	325.53	325.53	325.53	325.54
25%	326.00	326.00	326.00	326.00	325.99
30%	326.33	326.32	326.32	326.32	326.31
35%	326.71	326.68	326.68	326.68	326.69
40%	327.15	327.13	327.13	327.13	327.13
45%	327.55	327.53	327.53	327.53	327.53
50%	327.91	327.90	327.90	327.90	327.90
55%	328.28	328.27	328.27	328.27	328.26
60%	328.68	328.68	328.68	328.68	328.67
65%	329.07	329.07	329.07	329.07	329.07
70%	329.37	329.36	329.36	329.36	329.36
75%	329.54	329.54	329.54	329.54	329.54
80%	329.69	329.68	329.68	329.68	329.68
85%	329.82	329.81	329.81	329.81	329.81
90%	329.98	329.97	329.97	329.97	329.98
95%	330.02	330.02	330.02	330.02	330.03
100%	336.96	336.87	336.87	336.87	336.83
Average	327.26	327.24	327.24	327.24	327.25
Max	336.96	336.87	336.87	336.87	336.83
Min	314.00	313.99	313.99	313.99	314.10

7.1.5 Streamflow Comparison

Table. 7.1.5-1T: Thurmond Outflow Comparison (Scripted Storage Accounting)

Thurmond Outflow (CFS)					
	ACur	AFut0	AFut1	AFut1d	AFWOP
0%	0	0	0	0	0
5%	3614	3614	3614	3614	3614
10%	3616	3616	3616	3616	3616
15%	3618	3618	3618	3618	3618
20%	3797	3800	3800	3800	3800
25%	3800	3809	3809	3809	3800
30%	4000	4000	4000	4000	4000
35%	4000	4000	4000	4000	4000
40%	4200	4200	4200	4200	4200
45%	4552	4517	4517	4507	4528
50%	5056	5025	5026	5025	5028
55%	5587	5544	5545	5544	5553
60%	6099	6067	6067	6067	6090
65%	6674	6645	6645	6645	6669
70%	7400	7387	7387	7387	7398
75%	8537	8488	8488	8488	8536
80%	10639	10583	10583	10583	10629
85%	13834	13744	13744	13744	13825
90%	18155	18175	18190	18190	18227
95%	20000	20000	20000	20000	20000
100%	98338	94739	94739	93376	93187
Average	7739	7726	7727	7721	7737
Max	98338	94739	94739	94739	93187
Min	0	0	0	0	0

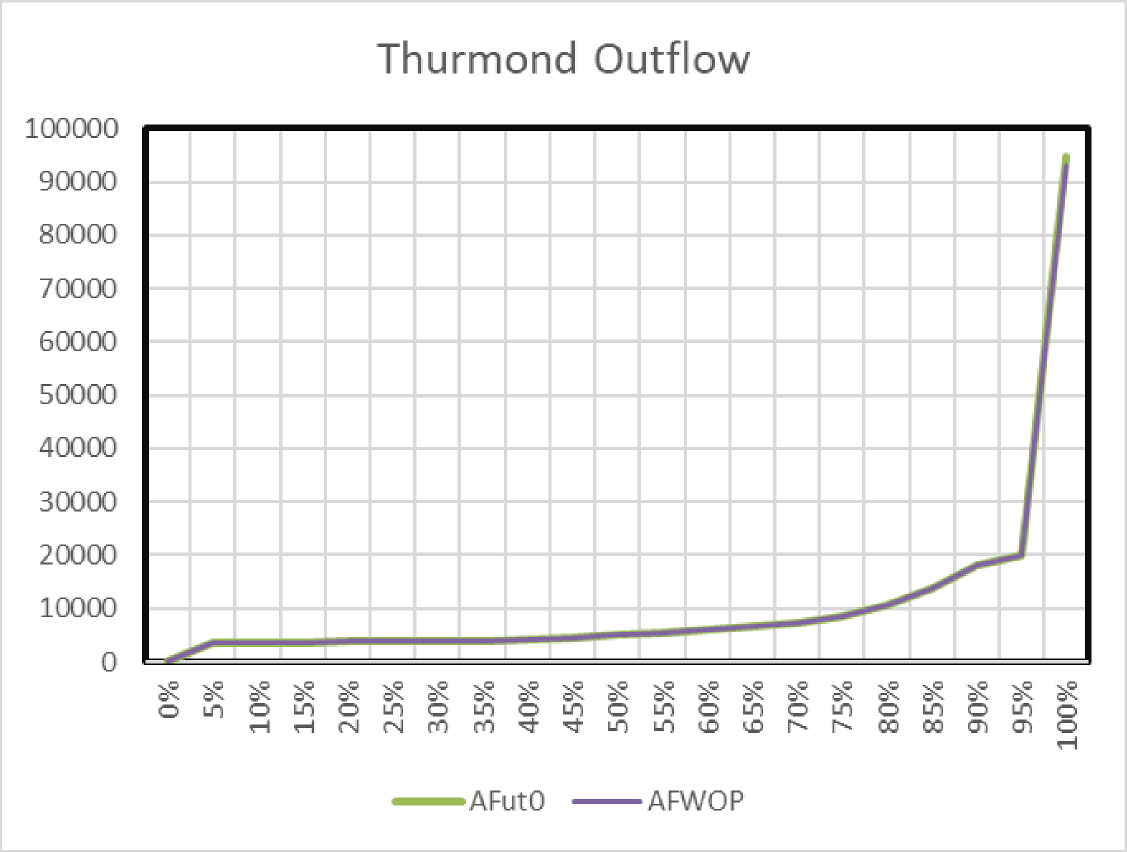


Figure. 7.1.5T: Thurmond Outflow Comparison

Table. 7.1.5-2A: Augusta Streamflow Comparison (Scripted Storage Accounting)

	Streamflow at Augusta (CFS)				
	ACur	AFut0	AFut1	AFut1d	AFWOP
0%	3600	3600	3600	3600	3600
5%	3759	3763	3763	3762	3764
10%	3963	3969	3969	3969	3968
15%	4119	4130	4130	4130	4124
20%	4260	4267	4267	4267	4262
25%	4413	4413	4413	4413	4412
30%	4619	4612	4612	4612	4612
35%	4872	4856	4856	4856	4856
40%	5189	5166	5166	5166	5176
45%	5593	5566	5566	5566	5570
50%	6034	5996	5996	5996	6005
55%	6507	6473	6473	6473	6491
60%	7017	7003	7004	7003	7025
65%	7675	7639	7639	7639	7660
70%	8544	8524	8524	8524	8535
75%	9869	9856	9857	9856	9848
80%	12208	12134	12134	12134	12191
85%	15445	15411	15411	15411	15514
90%	20000	20000	20000	20000	20000
95%	24186	24267	24271	24271	24254
100%	116604	113005	113005	113005	111454
Average	8958	8945	8945	8945	8955
Max	116604	113005	113005	113005	111454
Min	3600	3600	3600	3600	3600

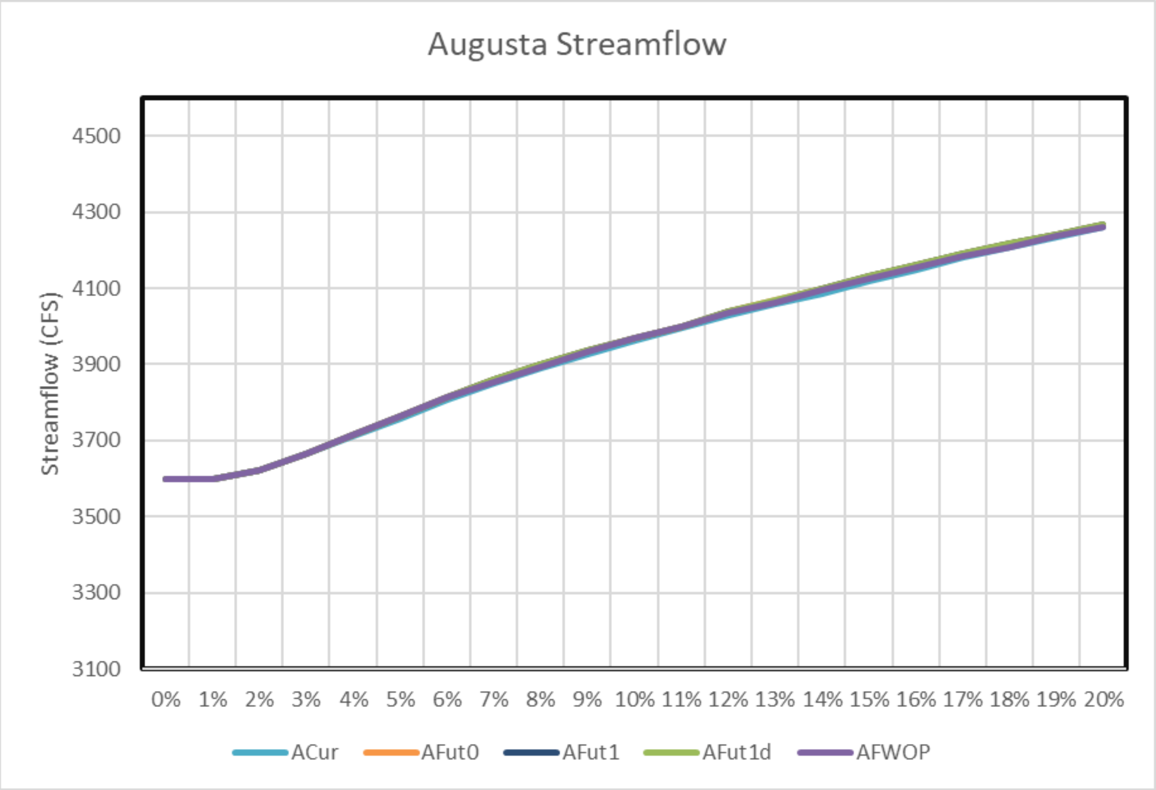


Table. 7.1.5A: Augusta Streamflow Comparison (Scripted Storage Accounting)

Figure 7.1.5-1A illustrates a comparison between Alt-5 (A2Fut1d), the Proposed Reallocation, and the Future Without Project alternative (A2FWOP). Both output datasets are based on future water demands. There is a very small decrease in stream flow at Augusta due to the proposed reallocation.

7.2 Beach Impacts

7.2.1 Year Round

Table 7.2.1-1 Beach Impacts, Year-Round (Scripted Storage Accounting)

Beach Impacts - Days closed due to elevation (01/07/1939 - 12/25/2013) Jan1 - Dec31						
Number of Beaches	**Beach Closure Elevation**	**Alternative**				
		ACur	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
23 Beaches	**654**	**HARTWELL**				
Days Closed		3352	3439	3439	3439	3359
Beach Days Closed		77096	79097	79097	79097	77257
Max Possible Beach Days		627670	627670	627670	627670	627670
Percent of Time Closed		12.3%	12.6%	12.6%	12.6%	12.3%
2 Beaches	**469**	**RUSSELL**				
Days Closed		0	0	0	0	0
Beach Days Closed		0	0	0	0	0
Max Possible Beach Days		54580	54580	54580	54580	54580
Percent of Time Closed		0.0%	0.0%	0.0%	0.0%	0.0%
64 Beaches	**324**	**THURMOND**				
Days Closed		3210	3303	3303	3303	3230
Beach Days Closed		205440	211392	211392	211392	206720
Max Possible Beach Days		1746560	1746560	1746560	1746560	1746560
Percent of Time Closed		11.8%	12.1%	12.1%	12.1%	11.8%
		ACur	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
Combined Days Closed		282536	290489	290489	290489	283977
Rank (Lower is Better)		1	3	3	3	2

7.2.2 Memorial Day to Labor Day

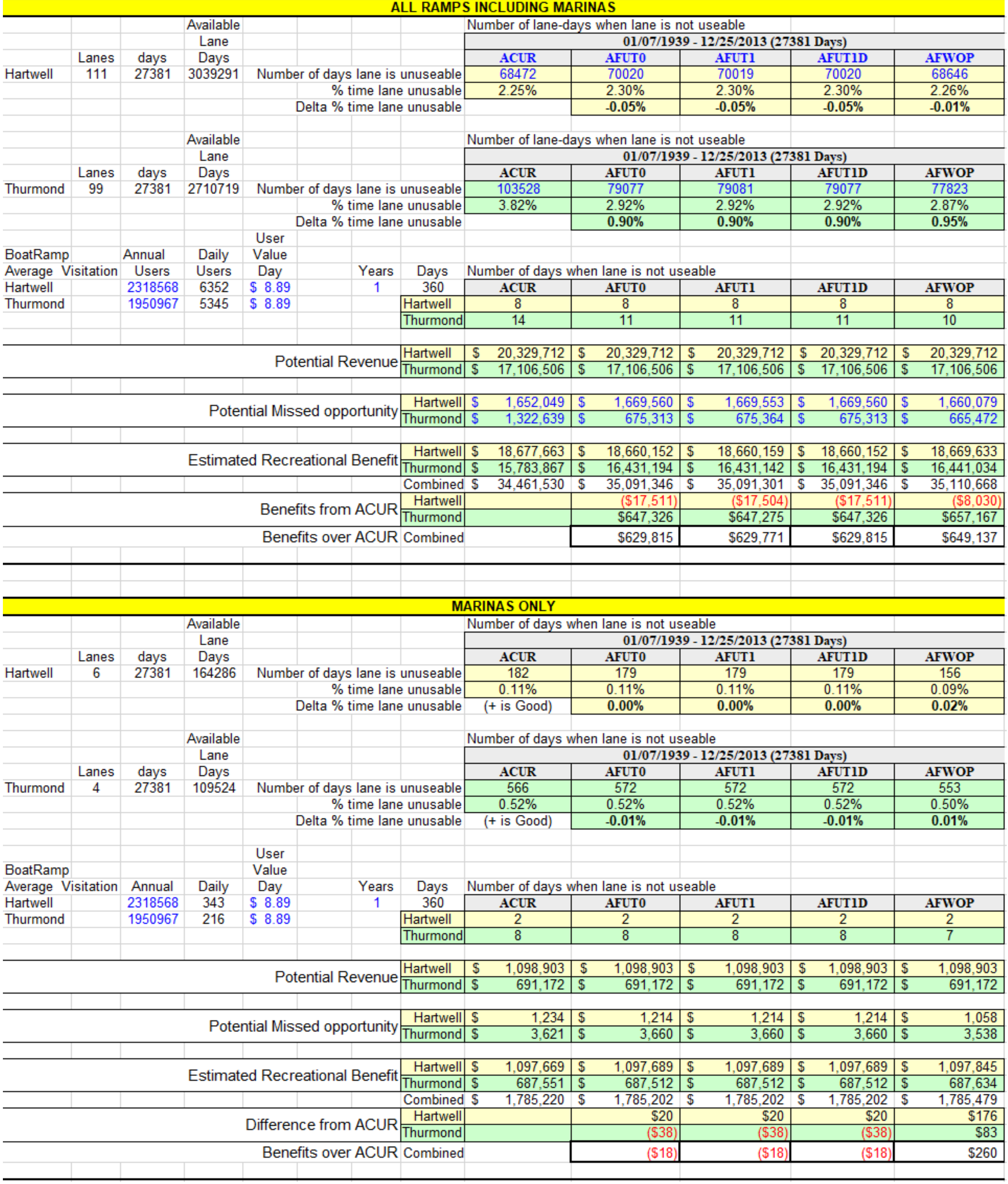
Table 7.2.2-1 Beach Impacts, Summer (Scripted Storage Accounting)

Beach Impacts - Days closed due to elevation (01/07/1939 - 12/25/2013) Memorial Day to Labor Day						
		Alternative				
Number of Beaches	**Beach Closure Elevation**	**ACur**	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
23 Beaches	**654**	**HARTWELL**				
Days Closed		489	514	514	514	495
Beach Days Closed		11247	11822	11822	11822	11385
Max Possible Beach Days		162150	162150	162150	162150	162150
Percent of Time Closed		6.9%	7.3%	7.3%	7.3%	7.0%
2 Beaches	**469**	**RUSSELL**				
Days Closed		0	0	0	0	0
Beach Days Closed		0	0	0	0	0
Max Possible Beach Days		54580	10944	10944	10944	10944
Percent of Time Closed		0.0%	0.0%	0.0%	0.0%	0.0%
64 Beaches	**324**	**THURMOND**				
Days Closed		497	516	516	516	503
Beach Days Closed		31808	33024	33024	33024	32192
Max Possible Beach Days		451200	451200	451200	451200	451200
Percent of Time Closed		7.0%	7.3%	7.3%	7.3%	7.1%
		ACur	**AFut0**	**AFut1**	**AFut1d**	**AFWOP**
Combined Days Closed		43055	44846	44846	44846	43577
Rank (Lower is Better)		1	3	3	3	2

7.3 Boat Ramp Impacts

Ramp impacts are based on ramp availability due to low pool levels. User spending estimated are based on assumption that a specific percentage of visitors go boating and use the available ramps. The estimated recreational benefits are just an assumption. It is the difference between alternatives that sets them apart.

Table 7.3-1 Boat Ramp Analysis (Scripted Storage Accounting)



ALL RAMPS INCLUDING MARINAS											
			Available				Number of lane-days when lane is not useable				
			Lane				01/07/1939 - 12/25/2013 (27381 Days)				
	Lanes	days	Days				ACUR	AFUT0	AFUT1	AFUT1D	AFWOP
Hartwell	111	27381	3039291	Number of days lane is unuseable			68472	70020	70019	70020	68646
				% time lane unusable			2.25%	2.30%	2.30%	2.30%	2.26%
				Delta % time lane unusable				-0.05%	-0.05%	-0.05%	-0.01%
			Available				Number of lane-days when lane is not useable				
			Lane				01/07/1939 - 12/25/2013 (27381 Days)				
	Lanes	days	Days				ACUR	AFUT0	AFUT1	AFUT1D	AFWOP
Thurmond	99	27381	2710719	Number of days lane is unuseable			103528	79077	79081	79077	77823
				% time lane unusable			3.82%	2.92%	2.92%	2.92%	2.87%
				Delta % time lane unusable				0.90%	0.90%	0.90%	0.95%
				User							
BoatRamp		Annual	Daily	Value							
Average	Visitation	Users	Users	Day	Years	Days	Number of days when lane is not useable				
Hartwell		2318568	6352	$ 8.89	1	360	ACUR	AFUT0	AFUT1	AFUT1D	AFWOP
Thurmond		1950967	5345	$ 8.89		Hartwell	8	8	8	8	8
						Thurmond	14	11	11	11	10
				Potential Revenue		Hartwell	$ 20,329,712	$ 20,329,712	$ 20,329,712	$ 20,329,712	$ 20,329,712
						Thurmond	$ 17,106,506	$ 17,106,506	$ 17,106,506	$ 17,106,506	$ 17,106,506
				Potential Missed opportunity		Hartwell	$ 1,652,049	$ 1,669,560	$ 1,669,553	$ 1,669,560	$ 1,660,079
						Thurmond	$ 1,322,639	$ 675,313	$ 675,364	$ 675,313	$ 665,472
				Estimated Recreational Benefit		Hartwell	$ 18,677,663	$ 18,660,152	$ 18,660,159	$ 18,660,152	$ 18,669,633
						Thurmond	$ 15,783,867	$ 16,431,194	$ 16,431,142	$ 16,431,194	$ 16,441,034
						Combined	$ 34,461,530	$ 35,091,346	$ 35,091,301	$ 35,091,346	$ 35,110,668
				Benefits from ACUR		Hartwell		($17,511)	($17,504)	($17,511)	($8,030)
						Thurmond		$647,326	$647,275	$647,326	$657,167
				Benefits over ACUR		Combined		$629,815	$629,771	$629,815	$649,137
MARINAS ONLY											
			Available				Number of days when lane is not useable				
			Lane				01/07/1939 - 12/25/2013 (27381 Days)				
	Lanes	days	Days				ACUR	AFUT0	AFUT1	AFUT1D	AFWOP
Hartwell	6	27381	164286	Number of days lane is unuseable			182	179	179	179	156
				% time lane unusable			0.11%	0.11%	0.11%	0.11%	0.09%
				Delta % time lane unusable			(+ is Good)	0.00%	0.00%	0.00%	0.02%
			Available				Number of days when lane is not useable				
			Lane				01/07/1939 - 12/25/2013 (27381 Days)				
	Lanes	days	Days				ACUR	AFUT0	AFUT1	AFUT1D	AFWOP
Thurmond	4	27381	109524	Number of days lane is unuseable			566	572	572	572	553
				% time lane unusable			0.52%	0.52%	0.52%	0.52%	0.50%
				Delta % time lane unusable			(+ is Good)	-0.01%	-0.01%	-0.01%	0.01%
				User							
BoatRamp				Value							
Average	Visitation	Annual	Daily	Day	Years	Days	Number of days when lane is not useable				
Hartwell		2318568	343	$ 8.89	1	360	ACUR	AFUT0	AFUT1	AFUT1D	AFWOP
Thurmond		1950967	216	$ 8.89		Hartwell	2	2	2	2	2
						Thurmond	8	8	8	8	7
				Potential Revenue		Hartwell	$ 1,098,903	$ 1,098,903	$ 1,098,903	$ 1,098,903	$ 1,098,903
						Thurmond	$ 691,172	$ 691,172	$ 691,172	$ 691,172	$ 691,172
				Potential Missed opportunity		Hartwell	$ 1,234	$ 1,214	$ 1,214	$ 1,214	$ 1,058
						Thurmond	$ 3,621	$ 3,660	$ 3,660	$ 3,660	$ 3,538
				Estimated Recreational Benefit		Hartwell	$ 1,097,669	$ 1,097,689	$ 1,097,689	$ 1,097,689	$ 1,097,845
						Thurmond	$ 687,551	$ 687,512	$ 687,512	$ 687,512	$ 687,634
						Combined	$ 1,785,220	$ 1,785,202	$ 1,785,202	$ 1,785,202	$ 1,785,479
				Difference from ACUR		Hartwell		$20	$20	$20	$176
						Thurmond		($38)	($38)	($38)	$83
				Benefits over ACUR		Combined		($18)	($18)	($18)	$260

7.4 Weekly Energy Surplus

The Savannah System targets a monthly varying weekly target of total Generation (MW-HR) for the three projects. The weekly target is the marketed amount of energy contracted by SEPA to its customers. When the Savannah system is short of the target, SEPA has to provide replacement energy to its customers from purchases on the open market or from other sources. When the system is in flood management, the target will be exceeded with a focus on flood damage reduction.

Table 7.4-1 System Power Weekly Surplus

System Power Weekly Surplus (MW-HR)					
% of time less than	ACur	AFut0	AFut1	AFut1d	AFWOP
0%	0	0	0	0	0
5%	65	86	86	86	83
10%	171	222	222	222	209
15%	334	436	436	436	412
20%	730	860	860	860	797
25%	1443	1700	1700	1700	1550
30%	2288	2544	2547	2544	2346
35%	3331	3652	3652	3652	3453
40%	4733	5058	5058	5058	4706
45%	6340	6741	6741	6741	6238
50%	8335	8955	8955	8955	8330
55%	10389	11075	11075	11075	10410
60%	12801	13304	13304	13304	12725
65%	15662	16088	16088	16088	15770
70%	19099	19545	19545	19545	19317
75%	23334	24121	24121	24121	23636
80%	28409	28794	28794	28794	28781
85%	34940	35147	35147	35147	35179
90%	42980	43655	43655	43655	42969
95%	57083	57074	57074	57074	57126
100%	115974	115856	115856	115856	115942

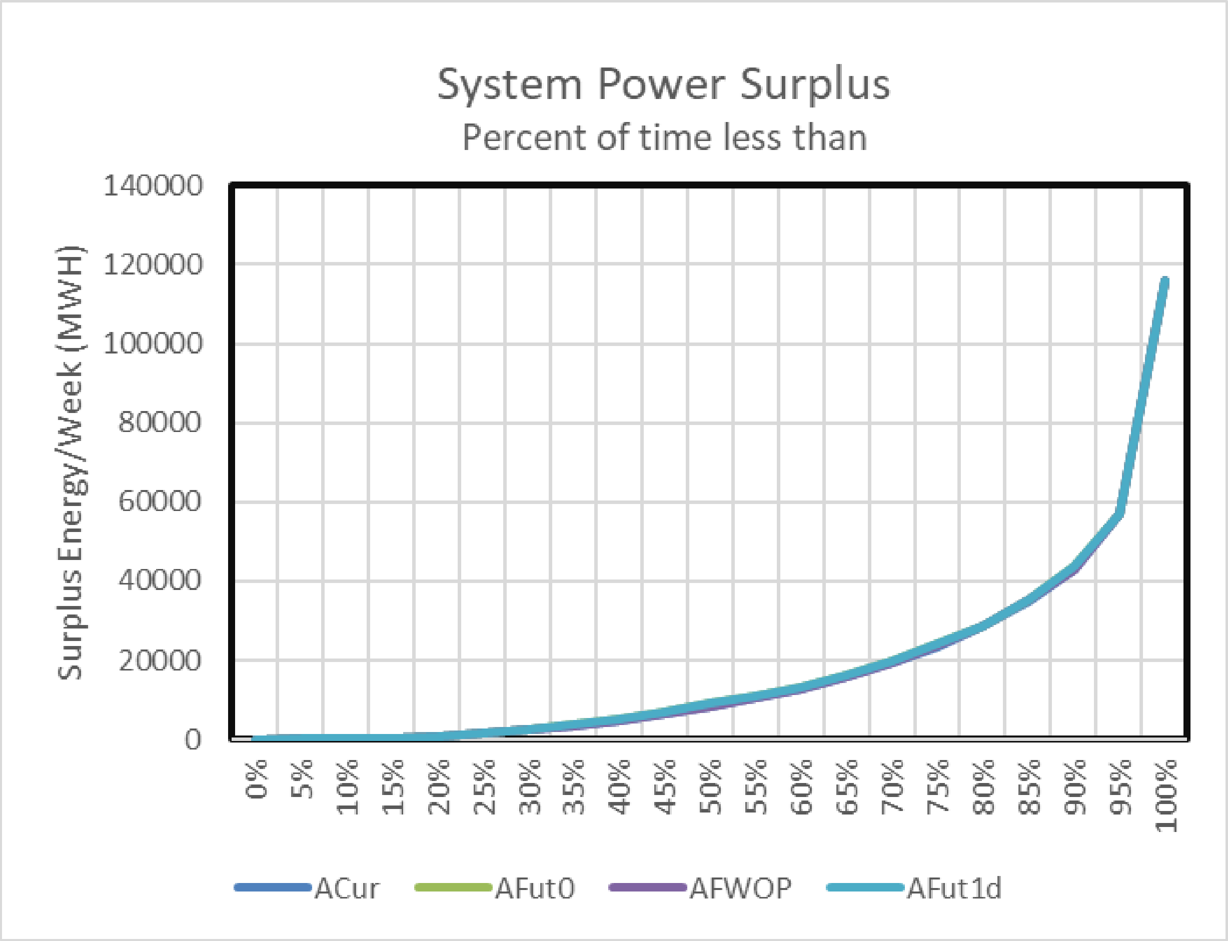


Figure 7.4-1 System Power Weekly Surplus

7.5 Weekly Pump Hours

SEPA has marketed a seasonally varying amount of pumping, typically 40-80 unit-hours of pumping/week. During drought periods, the Russell Project may pump well beyond the normal 80 unit-hours, up to the full night-time window - 2 hours in an attempt to meet the weekly system energy requirement. Pumping restrictions are reduced with severity in drought level.

Table 7.5-1 Weekly Pump Hours

Weekly Pump Hours					
% of time less than	ACur	AFut0	AFut1	AFut1d	AFWOP
0%	0	0	0	0	0
5%	0	0	0	0	0
10%	0	0	0	0	0
15%	0	0	0	0	0
20%	11	11	11	11	11
25%	23	23	23	23	23
30%	46	46	46	46	46
35%	57	57	57	57	57
40%	80	75	75	75	69
45%	80	80	80	80	80
50%	80	80	80	80	80
55%	80	80	80	80	80
60%	80	80	80	80	80
65%	80	80	80	80	80
70%	80	80	80	80	80
75%	80	80	80	80	80
80%	80	81	81	81	80
85%	108	109	109	109	109
90%	135	136	136	136	135
95%	161	162	162	162	161
100%	248	252	252	252	252

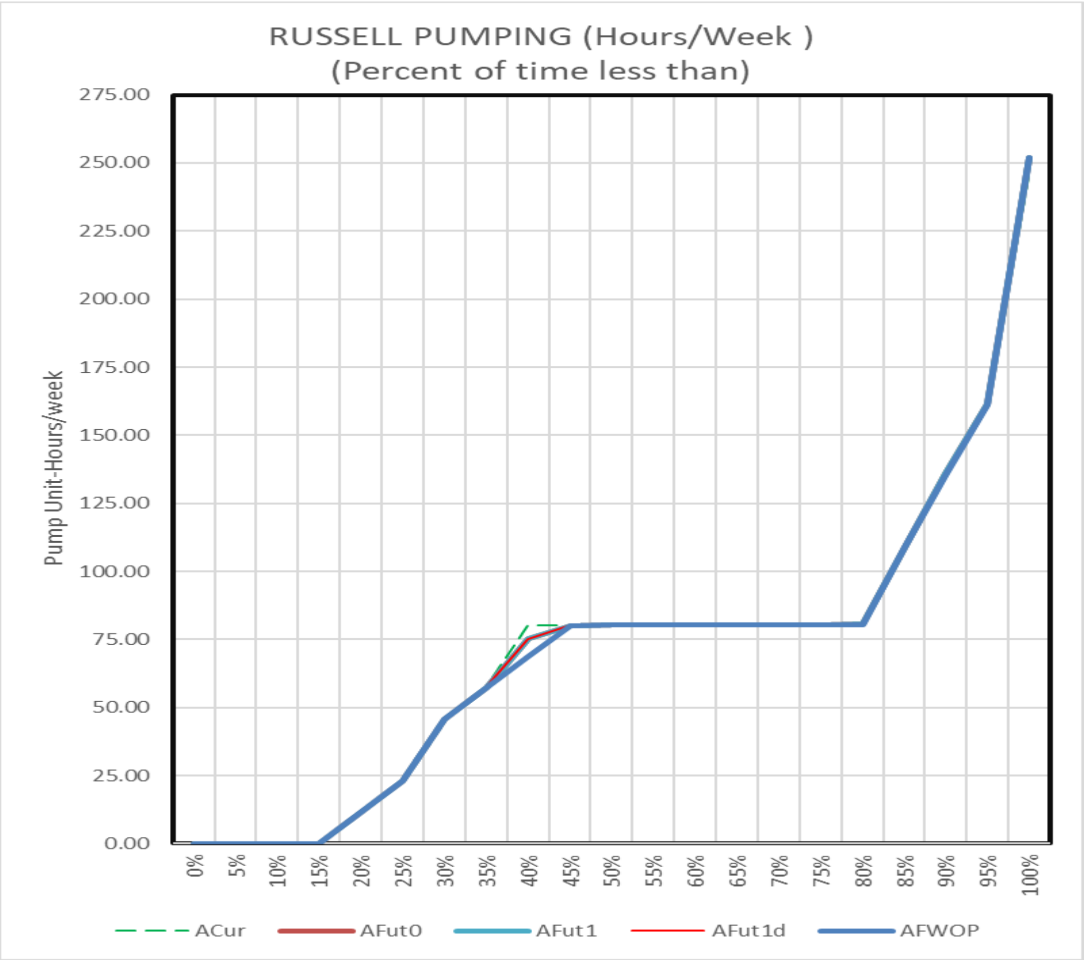


Figure 7.5-1 Weekly Pump Hours (Percent time less than)

The Hydropower analysis by HAC will pick up the economics associated with variations in pumping.

7.6 Weekly Energy Shortages

Table 7.6-1 Weekly Energy Shortages (Percent time less than)

System Power Weekly Shortage (MW-HR)					
% of time less than	ACur	AFut0	AFut1	AFut1d	AFWOP
0%	0	0	0	0	2
5%	10	20	20	20	14
10%	12	23	23	23	18
15%	14	25	25	25	19
20%	15	27	27	27	21
25%	16	28	28	28	22
30%	17	29	29	29	23
35%	18	30	30	30	24
40%	19	31	31	31	25
45%	21	32	32	32	26
50%	22	34	34	34	27
55%	24	35	35	35	28
60%	24	35	35	35	29
65%	25	37	37	37	30
70%	26	38	38	38	31
75%	27	40	40	40	33
80%	29	41	41	41	35
85%	30	42	42	42	36
90%	31	43	43	43	39
95%	39	51	51	51	48
100%	7438	7406	7406	7406	7489

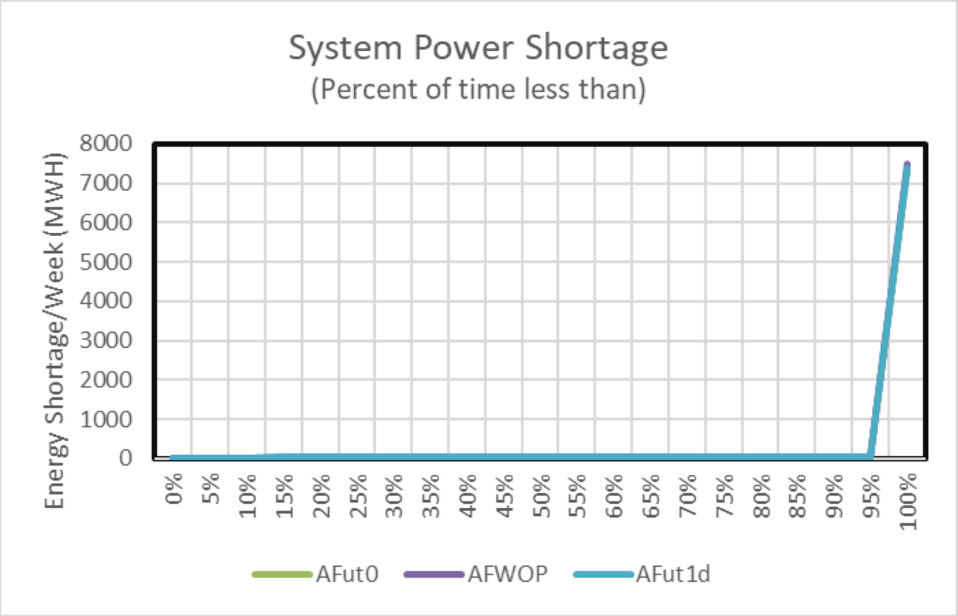


Figure 7.6-1 Weekly Energy Shortages (Percent time less than)

8.0 Conclusions

The following conclusions were made from this engineering work:

- Comparison between scripted and default storage accounting resulted in Hartwell and Thurmond Pool Elevations that were statistically indifferent.
- The difference in the minimum pool elevation between the proposed alternative and the without project were insignificant, 0.13 ft for Hartwell and 0.11 ft for Thurmond, about 0.5% of the depth of the conservation pool depth at each project..
- Addition of Return Flow Credits did not visibly change the statistics of Hartwell and Thurmond pool elevations
- The greatest variations between the alternatives can best be seen in the max and min statistics, and in the number of days spent in drought zones. Table 6.6.1.2.
- The proposed reallocation of storage for water supply in Hartwell does not change any of the regulating rules associated with operation of the three-project system. The operating rules associated with the Drought, Flood Management, and standard operations including hydropower generation and minimum flow requirements from the projects remain unchanged. Should the operational rules change in the future, they may impact the calculated yield for the account holders.
- Since this study use operational yield rather than firm yield to determine account sizes, any change in operational strategy could impact the account size needed to provide the desired yield.

- This analysis was based on a daily time step and does not accurately reflect hourly inflow and outflow peaks that you would typically expect to see during high flow events.
- It is important to keep in mind that while this analysis simulates actual operation using the best available datasets defining inflow and outflow parameters, it is not a perfect reflection of reality.

9.0 Water Storage Accounting Script

The water storage accounting script used for the Phase 2 modeling was adapted from the ResSim Allatoona water accounting script which was previously used to compare different storage accounting approaches, including return flow credit.

The script is a ResSim State Variable script called “Accounting”. The main body of the “Accounting” script is broken into sections and explained here. In order to ensure the correct variation of the script was described in this report, the text was reproduced directly from the model network that produced the results in this report. Note that this version of the script has some unusual numbering and unnecessary or incomplete sections that do not affect computations.

9.1 Beginning of script

- Imports
- Comments
- Descriptions of variables

```
from hec.model import RunTimeStep
from hec.hecmath import DSS

# 31Dec2022 version
# Also calculates several other variables.

        # Partial list of names, variables
        # ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
        # Anderson
        # Anderson New
        # Pioneer New
        # Lavonia
        # Lavonia New
        # Currahee New
        # Hart County
        # Hart_And_acct = Anderson existing storage account in Hartwell, volume (AF)
        # Hart_AndNew_acct = Anderson New storage account in Hartwell, volume (AF)
        # Hart_PioNew_acct = Anderson New storage account in Hartwell, volume (AF)
        # Hart_Lav_acct = Lavonia existing storage account in Hartwell, volume (AF)
        # Hart_LavNew_acct = Lavonia New storage account in Hartwell, volume (AF)
        # Hart_CrhNew_acct = Currahee New storage account in Hartwell, volume (AF)
        # Hart_HCo_acct = Hart County storage account in Hartwell, volume (AF)
        #~ Hart_USACE_acct = USACE storage account in Hartwell, volume (AF)

        # QHart_And = Hartwell's release for Anderson(cfs)
        # QHart_AndNew = Hartwell's release for Anderson New (cfs)
        # QHart_PioNew = Hartwell's release for Pioneer (cfs)
        # QHart_Lav = Hartwell's release for Lavonia (cfs)
        # QHart_LavNew = Hartwell's release for Lavonia New (cfs)
        # QHart_CrhNew = Hartwell's release for Currahee New (cfs)
        # QHart_HCo = Hartwell's release for Hart County (cfs)
        #~ QHart_USACE = Hartwell's release for USACE (cfs)
```

```
# Get the name of the current alternative
# -----------------------------------------
curAlt = currentVariable.getSystem().getAlternative().getName()

# Strip the current alternative name to just the base part.
# This will work for trials and nontrials
pos = curAlt.rfind(":")
TheCurAlt = curAlt[pos+1:]

# set up previous runtimestep
prevRTS = RunTimeStep(currentRuntimestep)
prevRTS.setStep(currentRuntimestep.getPrevStep())
# also, tho silly, make variable for the timestep before the previous one
# this is needed to initialize on first timestep
# b/c many calculations happen on the previous
prevprevRTS = RunTimeStep(currentRuntimestep)
prevprevRTS.setStep(prevRTS.getPrevStep())

# This portion of code checks to see whether it is the FIRST time it has been run,
# if so, it would get the lookback value of these variables and store them to a variable
# each time the script is run, it must get the value from the variable.
tw=network.getRssRun().getCurrentComputeBlockRunTimeWindow()
numLBsteps=tw.getNumLookbackSteps()
firsttimestep = numLBsteps + 1

if currentRuntimestep.getStep() == firsttimestep :
        currentVariable.varPut("RunOnce", int(1))
        setStorLookback = 1
else : setStorLookback = 0


# USE LOOKBACK VALUES to SET SOME KEY VARIABLES:

 # AcctingSettings - 0 = old USACE accting
 #                   1 = New USACE accting
  # fullReturnCredit - 1 = Eligible Account(s) get full credit to its account for return flow
  #                  - 0 = return flows are distributed as part of total inflow
  # AcctVarInf - 1 Hartwell inflow % to accounts varies according to seasonally varying Con pool volume
  #            - 0 Hartwell inflow % to accounts constant based on SUMMER Con pool volume
  # ResetCon - 1 Hartwell 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
  # QRecycle - 1 When a storage account does not need its complete portion of inflow to fill, offer the
rest to other accounts
  #          - 0 When a storage account does not need its complete portion of inflow to fill, the rest
goes to USACE/Other account
  # AllowOD - 1 for allowing accounts to be overdrafted
  #         - 0 for limited withdrawals to the amount in the account

  # Hart_USACE_acct_size
  # Hart_And_acct_size
  # Hart_AndNew_acct_size
  # Hart_PioNew_acct_size
  # Hart_Lav_acct_size
  # Hart_LavNew_acct_size
  # Hart_CrhNew_acct_size
  # Hart_HCo_acct_size
```

9.2 Get Lookback Settings

The lookback values of state variables can be defined per alternative and were used to set various values for different alternatives.

9.2.1 Get Lookback: Accounting Approach Settings

The lookback value of the “_acct_settings” state variable is used to define the accounting approach.

Only settings 0 and 1 are used in this study, because the only accounting setting that changed was whether or not to grant RFC. Many more subsettings are defined or semi-defined but not used.

```
# ---------------------------------------------------------------------------------------
# (0) GET LOOKBACK SETTINGS from lookback tab
# ---------------------------------------------------------------------------------------
# (0a) ~~~~ Get Allatoona Accounting Settings ~~~~
# -------------------------------------------------------
#AcctingSettings = 0
AcctingSettings = network.getStateVariable("_Acct_Settings").getTimeSeries().getValue(1)
network.getStateVariable("_Acct_Settings").setValue(currentRuntimestep, AcctingSettings)

#
if AcctingSettings == 0: #Aset = [0,1,0,0,0]
  fullReturnCredit = 0
  AcctVarInf = 1
  ResetCon = 1
  QRecycle = 0
  HartOD = 0
  AndRT = 0
  LavRT = 0
  PioRT = 0
  AndoRT = 0
  LavoRT = 0
#
elif AcctingSettings == 1:
  fullReturnCredit = 1
  AcctVarInf = 1
  ResetCon = 1
  QRecycle = 0
  HartOD = 0
  AndRT = 1
  LavRT = 1
  PioRT = 1
  AndoRT = 1
  LavoRT = 1
#
elif AcctingSettings == 2:
  fullReturnCredit = 0
  AcctVarInf = 1
  ResetCon = 1
  QRecycle = 0
  HartOD = 1
  AndRT = 0
  LavRT = 1
  PioRT = 0
  AndoRT = 1
  LavoRT = 1
#
elif AcctingSettings == 3:
  fullReturnCredit = 1
  AcctVarInf = 1
  ResetCon = 1
  QRecycle = 0
  HartOD = 0
  AndRT = 1
  LavRT = 1
  PioRT = 1
  AndoRT = 1
  LavoRT = 1
#
elif AcctingSettings == 4:
  fullReturnCredit = 1
```

```
  AcctVarInf = 1
  ResetCon = 1 #1
  QRecycle = 0
  HartOD = 0
  AndRT = 1
  LavRT = 1
  PioRT = 0
  AndoRT = 1
  LavoRT = 1
```

9.2.2 Get Lookback: Storage Account Sizes

The water storage account sizes used in each run were defined using the state variable lookback. For example, the table below shows the lookback values for the storage accounts at Hartwell for the A2Cur alternative (Current conditions). It sets the Anderson, Lavonia, and Hart County accounts to their current size in AF. It sets the USACE account to the value of summer storage in the conservation pool minus the volumes of the three existing accounts.

Note that there are options to model new accounts for Anderson and Lavonia for alternatives in which they receive new storage, however, ultimately the scripting model lumped Anderson’s existing and new demands together as one instead of having two separate demands and two separate storage accounts; likewise with Lavonia.

State Variable	Description	Lookback Value
_Hart_And_acct_size	Anderson existing	24,620
_Hart_AndNew_acct_size	Anderson new	-
_Hart_PioNew_acct_size	Pioneer new	-
_Hart_Lav_acct_size	Lavonia existing	127
_Hart_LavNew_acct_size	Lavonia new	-
_Hart_CrhNew_acct_size	Currahee new	-
_Hart_HCo_acct_size	Hart County	1,827
_Hart_USACE_acct_size	USACE default	1,388,926

```
# -------------------------------------------------------
# (0b) ~~~~ Get Storage Account Sizes from Lookback values ~~~~
# -------------------------------------------------------
# Get the account size from the state variable's lookback tab.
# This is run at every timestep (just like many other values that are taken from a timeseries)
HartUSACE_size = network.getStateVariable("_Hart_USACE_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_USACE_acct_size").setValue(currentRuntimestep, HartUSACE_size)
HartAnd_size = network.getStateVariable("_Hart_And_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_And_acct_size").setValue(currentRuntimestep, HartAnd_size)
HartAndNew_size = network.getStateVariable("_Hart_AndNew_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_AndNew_acct_size").setValue(currentRuntimestep, HartAndNew_size)
HartPioNew_size = network.getStateVariable("_Hart_PioNew_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_PioNew_acct_size").setValue(currentRuntimestep, HartPioNew_size)
HartLav_size = network.getStateVariable("_Hart_Lav_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_Lav_acct_size").setValue(currentRuntimestep, HartLav_size)
HartLavNew_size = network.getStateVariable("_Hart_LavNew_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_LavNew_acct_size").setValue(currentRuntimestep, HartLavNew_size)
HartCrhNew_size = network.getStateVariable("_Hart_CrhNew_acct_size").getTimeSeries().getValue(1)
network.getStateVariable("_Hart_CrhNew_acct_size").setValue(currentRuntimestep, HartCrhNew_size)
HartHCo_size = network.getStateVariable("_Hart_HCo_acct_size").getTimeSeries().getValue(1)
```

```
network.getStateVariable("_Hart_HCo_acct_size").setValue(currentRuntimestep, HartHCo_size)

Hart_SumAccts_size = HartAnd_size + HartAndNew_size + HartPioNew_size + HartLav_size + HartLavNew_size
+ HartCrhNew_size + HartHCo_size

# Set lookback for USACE acct because it may start during low con pool
Hart_stor_ts = network.getTimeSeries("Reservoir","Hartwell", "Pool", "Stor")
Hart_stor_prev = Hart_stor_ts.getPreviousValue(currentRuntimestep)
HartTopCon_stor_ts = network.getTimeSeries("Reservoir","Hartwell", "Conservation", "Stor-ZONE")
HartTopCon_stor_prev = HartTopCon_stor_ts.getPreviousValue(currentRuntimestep)
HartTopInactive_stor_ts = network.getTimeSeries("Reservoir","Hartwell", "Inactive", "Stor-ZONE")
HartTopInactive_stor_prev = HartTopInactive_stor_ts.getPreviousValue(currentRuntimestep)
Hart_StorMinusInact_prev = Hart_stor_prev - HartTopInactive_stor_prev
HartAcctVol_SV = network.getStateVariable("aHart_StorMinusInact")
HartAcctVol_SV.setValue(prevRTS, Hart_StorMinusInact_prev)

#print HartTopCon_stor_prev-HartTopInactive_stor_prev
#sdfds
Hart_stor_prevprev = Hart_stor_ts.getPreviousValue(prevRTS)
HartTopCon_stor_prevprev = HartTopCon_stor_ts.getPreviousValue(prevRTS)
HartTopInactive_stor_prevprev = HartTopInactive_stor_ts.getPreviousValue(prevRTS)


if setStorLookback == 2 :
  HartUSACE_stor_LB_prev = Hart_stor_prev - Hart_SumAccts_size - HartTopInactive_stor_prev
  HartUSACE_stor_LB_prevprev = Hart_stor_prevprev - Hart_SumAccts_size - HartTopInactive_stor_prevprev
  network.getStateVariable("aHart_USACE_acct").setValue(prevRTS, HartUSACE_stor_LB_prev)
  network.getStateVariable("aHart_USACE_acct").setValue(prevprevRTS, HartUSACE_stor_LB_prevprev)
  network.getStateVariable("aHart_And_acct_int").setValue(prevRTS, HartAnd_size)
  network.getStateVariable("aHart_And_acct_int").setValue(prevprevRTS, HartAnd_size)
  network.getStateVariable("aHart_AndNew_acct_int").setValue(prevRTS, HartAndNew_size)
  network.getStateVariable("aHart_AndNew_acct_int").setValue(prevprevRTS, HartAndNew_size)
  network.getStateVariable("aHart_PioNew_acct_int").setValue(prevRTS, HartPioNew_size)
  network.getStateVariable("aHart_PioNew_acct_int").setValue(prevprevRTS, HartPioNew_size)
  network.getStateVariable("aHart_Lav_acct_int").setValue(prevRTS, HartLav_size)
  network.getStateVariable("aHart_Lav_acct_int").setValue(prevprevRTS, HartLav_size)
  network.getStateVariable("aHart_LavNew_acct_int").setValue(prevRTS, HartLavNew_size)
  network.getStateVariable("aHart_LavNew_acct_int").setValue(prevprevRTS, HartLavNew_size)
  network.getStateVariable("aHart_CrhNew_acct_int").setValue(prevRTS, HartCrhNew_size)
  network.getStateVariable("aHart_CrhNew_acct_int").setValue(prevprevRTS, HartCrhNew_size)
  network.getStateVariable("aHart_HCo_acct_int").setValue(prevRTS, HartHCo_size)
  network.getStateVariable("aHart_HCo_acct_int").setValue(prevprevRTS, HartHCo_size)
```

9.3 Initializing Script Variables

```
# ------------------------------------------------------------------------------------
# (1) INITIALIZE and SET UP
# ------------------------------------------------------------------------------------
# (1a) ~~~~ Set up CONSTANTS ~~~~
# ---------------------------------------------------
# Total Storage Account Volumes (in AF)
#~ Hartwell Storage Accts (as defined in the alternative Lookback tab.  Does not include inactive pool)
Hart_USACE_acctFULL = HartUSACE_size
Hart_And_acctFULL = HartAnd_size
Hart_AndNew_acctFULL = HartAndNew_size
Hart_PioNew_acctFULL = HartPioNew_size
Hart_Lav_acctFULL = HartLav_size
Hart_LavNew_acctFULL = HartLavNew_size
Hart_CrhNew_acctFULL = HartCrhNew_size
Hart_HCo_acctFULL = HartHCo_size

HartTotAcctVol = HartUSACE_size + Hart_SumAccts_size   #this is true unless you hit the if block later
# vol at Top of Con (AF)
HartCon_stor_prev= HartTopCon_stor_prev - HartTopInactive_stor_prev
HartCon_stor_SV = network.getStateVariable("aHart_Con_Stor_size")
HartCon_stor_SV.setValue(prevRTS, HartCon_stor_prev)
```

```
# Fraction of Storage belonging to each account holder
USACE_Hfrac = HartUSACE_size/HartTotAcctVol
And_Hfrac = HartAnd_size/HartTotAcctVol
AndNew_Hfrac = HartAndNew_size/HartTotAcctVol
PioNew_Hfrac = HartPioNew_size/HartTotAcctVol
Lav_Hfrac = HartLav_size/HartTotAcctVol
LavNew_Hfrac = HartLavNew_size/HartTotAcctVol
CrhNew_Hfrac = HartAndNew_size/HartTotAcctVol
HCo_Hfrac = HartHCo_size/HartTotAcctVol

# Conversion Factor: cfs-days to AF
cfs2AF = 1.9835
```

9.4 Get previous inflow and outflow

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 Hartwell) finishes, the diversion 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.

```
# -------------------------------------------------------
# (1b) ~~~~ Get previous timestep INFLOW to Hartwell. ~~~~
#  also the previous OUTFLOW from Hartwell
# -------------------------------------------------------

QHart_in_ts = network.getTimeSeries("Reservoir", "Hartwell", "Pool", "Flow-IN")
QHart_in_prev = QHart_in_ts.getPreviousValue(currentRuntimestep)
QHart_in_cur = QHart_in_ts.getCurrentValue(currentRuntimestep)
#~
QHart_out_ts = network.getTimeSeries("Reservoir","Hartwell", "Pool", "Flow-OUT")
QHart_out_prev = QHart_out_ts.getPreviousValue(currentRuntimestep)

#~
#QRT_Hart_And_ts = network.getTimeSeries("Reservoir", "Dummy_abv_Dawsonville", "Cartv_ReturnQ_Dummy",
"", 1)
#QRT_Hart_And_cur = QRT_Hart_And_ts.getCurrentValue(currentRuntimestep)
#QRT_Hart_And_cur = QRT_Hart_And_ts.getCurrentValue(currentRuntimestep)

#QRT_Hart_AndNew_ts = network.getTimeSeries("Reservoir", "Dummy_abv_Dawsonville",
"Cartv_ReturnQ_Dummy", "", 1)
#QRT_Hart_AndNew_cur = QRT_Hart_AndNew_ts.getCurrentValue(currentRuntimestep)

#QRT_Hart_PioNew_ts = network.getTimeSeries("Reservoir", "Dummy_abv_Dawsonville",
"Cartv_ReturnQ_Dummy", "", 1)
#QRT_Hart_PioNew_cur = QRT_Hart_PioNew_ts.getCurrentValue(currentRuntimestep)
#~
```

```
# -------------------------------------------------------
# (1c) ~~~~ Get previous ELEVATION/STORAGE for determining current total storage. ~~~~
# -------------------------------------------------------
# ---- for the resetting of accounts depends on elevation of 840 (or the elev of the GC)
Hart_elev_ts = network.getTimeSeries("Reservoir","Hartwell", "Pool", "Elev")
Hart_elev_prev = Hart_elev_ts.getPreviousValue(currentRuntimestep)
```

```
# --------------------------------------------------------
# (1d) ~~~~ Get EVAPORATION ~~~~
# --------------------------------------------------------
QHart_evap_ts = network.getTimeSeries("Reservoir","Hartwell", "Pool", "Flow-EVAP")
QHart_evap_prev= QHart_evap_ts.getPreviousValue(currentRuntimestep)
QHart_evap_cur = QHart_evap_ts.getCurrentValue(currentRuntimestep)

# the first timestep evap is a large negative number.  reset that
if QHart_evap_prev < -999 : QHart_evap_prev = 0
```

```
# --------------------------------------------------------
# (1e) ~~~~ Get DEMANDS ~~~~
# --------------------------------------------------------
# Hartwell demands are external timeseries read in thru a dummy IF Block at Bad Creek.

Qdemand_And_ts = network.getTimeSeries("Reservoir","Bad Creek", "AndersonOriginal_Qdemand", "",1)
Qdemand_And = Qdemand_And_ts.getCurrentValue(currentRuntimestep)
Qdemand_AndNew_ts = network.getTimeSeries("Reservoir", "Bad Creek", "AndersonNew_Qdemand", "", 1)
Qdemand_AndNew = Qdemand_AndNew_ts.getCurrentValue(currentRuntimestep)
Qdemand_PioNew_ts = network.getTimeSeries("Reservoir", "Bad Creek", "PioneerNew_Qdemand", "", 1)
Qdemand_PioNew = Qdemand_PioNew_ts.getCurrentValue(currentRuntimestep)
Qdemand_Lav_ts = network.getTimeSeries("Reservoir", "Bad Creek", "LavoniaOriginal_Qdemand", "", 1)
Qdemand_Lav = Qdemand_Lav_ts.getCurrentValue(currentRuntimestep)
Qdemand_LavNew_ts = network.getTimeSeries("Reservoir", "Bad Creek", "LavoniaNew_Qdemand", "", 1)
Qdemand_LavNew = Qdemand_LavNew_ts.getCurrentValue(currentRuntimestep)
Qdemand_CrhNew_ts = network.getTimeSeries("Reservoir", "Bad Creek", "CurraheeNew_Qdemand", "", 1)
Qdemand_CrhNew = Qdemand_CrhNew_ts.getCurrentValue(currentRuntimestep)
Qdemand_HCo_ts = network.getTimeSeries("Reservoir", "Bad Creek", "HartCounty_Qdemand", "", 1)
Qdemand_HCo = Qdemand_HCo_ts.getCurrentValue(currentRuntimestep)
```

```
# --------------------------------------------------------
# (1f) ~~~~ Initialize STORAGE ACCOUNTS ~~~~
# --------------------------------------------------------
# ~~~~ Get previous interim values for Hartwell's STORAGE ACCOUNT balances ~~~~
Hart_And_accti_SV = network.getStateVariable("aHart_And_acct_int")
Hart_And_acct_prev = Hart_And_accti_SV.getPreviousValue(currentRuntimestep)
Hart_AndNew_accti_SV = network.getStateVariable("aHart_AndNew_acct_int")
Hart_AndNew_acct_prev = Hart_AndNew_accti_SV.getPreviousValue(currentRuntimestep)
Hart_PioNew_accti_SV = network.getStateVariable("aHart_PioNew_acct_int")
Hart_PioNew_acct_prev = Hart_PioNew_accti_SV.getPreviousValue(currentRuntimestep)
Hart_Lav_accti_SV = network.getStateVariable("aHart_Lav_acct_int")
Hart_Lav_acct_prev = Hart_Lav_accti_SV.getPreviousValue(currentRuntimestep)
Hart_LavNew_accti_SV = network.getStateVariable("aHart_LavNew_acct_int")
Hart_LavNew_acct_prev = Hart_LavNew_accti_SV.getPreviousValue(currentRuntimestep)
Hart_CrhNew_accti_SV = network.getStateVariable("aHart_CrhNew_acct_int")
Hart_CrhNew_acct_prev = Hart_CrhNew_accti_SV.getPreviousValue(currentRuntimestep)
Hart_HCo_accti_SV = network.getStateVariable("aHart_HCo_acct_int")
Hart_HCo_acct_prev = Hart_HCo_accti_SV.getPreviousValue(currentRuntimestep)

#~
Hart_USACE_acct_SV = network.getStateVariable("aHart_USACE_acct")
# dont need an interim value for USACE.
Hart_USACE_acct_prev = Hart_USACE_acct_SV.getPreviousValue(prevRTS)
```

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.

```
# --------------------------------------------------------
# (1g) ~~~~ Update Hartwell USACE ACCOUNT ~~~~
```

```
# because it is not known until the next timestep, after release decisions have been made.
# -------------------------------------------------------

# Hartwell account withdrawals
QHart_And_SV = network.getStateVariable("aQHart_And")
QHart_And_prev = QHart_And_SV.getPreviousValue(currentRuntimestep)
QHart_AndNew_SV = network.getStateVariable("aQHart_AndNew")
QHart_AndNew_prev = QHart_AndNew_SV.getPreviousValue(currentRuntimestep)
QHart_PioNew_SV = network.getStateVariable("aQHart_PioNew")
QHart_PioNew_prev = QHart_PioNew_SV.getPreviousValue(currentRuntimestep)
QHart_Lav_SV = network.getStateVariable("aQHart_Lav")
QHart_Lav_prev = QHart_Lav_SV.getPreviousValue(currentRuntimestep)
QHart_LavNew_SV = network.getStateVariable("aQHart_LavNew")
QHart_LavNew_prev = QHart_LavNew_SV.getPreviousValue(currentRuntimestep)
QHart_CrhNew_SV = network.getStateVariable("aQHart_CrhNew")
QHart_CrhNew_prev = QHart_CrhNew_SV.getPreviousValue(currentRuntimestep)
QHart_HCo_SV = network.getStateVariable("aQHart_HCo")
QHart_HCo_prev = QHart_CrhNew_SV.getPreviousValue(currentRuntimestep)

QHart_USACE_SV = network.getStateVariable("aQHart_USACE")
#QAlla_USACE_prev = QAlla_USACE_SV.getPreviousValue(currentRuntimestep)
QHart_USACE_prev = QHart_out_prev - QHart_And_prev - QHart_AndNew_prev - QHart_PioNew_prev -
QHart_Lav_prev - QHart_LavNew_prev - QHart_CrhNew_prev - QHart_HCo_prev

Hart_USACE_acct_prev = Hart_USACE_acct_prev - QHart_USACE_prev*cfs2AF
```

```
# -----------------------------------------------------------------------------------------
# (2)  STORAGE ACCOUNTING - BEGINNING OF TIMESTEP  ~~~~
# -----------------------------------------------------------------------------------------
# At this step we are accounting for yesterday's inflow.
# The last step is to take away today's outflow.
# This approach allows us to add in the actual values of inflow & evaporation,
# since they are undetermined until after the state variable is calculated.
# Use the interim account storage value to calculate the beginning of timestep storage.
# Releases for water accounts are considered at end of period, but general releases from the main
# part of the reservoir should be considered here.  Subtract previous time period releases.
# ----------------------------------------------
# -------------------------------------------------------
# (2a) calculate CURRENT BEGINNING STORAGE in Hartwell accounts
# HARTWELL REFILL - end of previous period
# -------------------------------------------------------
# Evap is taken out of inflow (not just Corps account)
# Evap is not stored as a negative unless precip exceeds evap.
Hart_acct_refill = (QHart_in_prev - QHart_evap_prev)*cfs2AF


# refill Hartwell's accounts based on:
# INvol - total inflow from previous period in AF
# STORaccts - a list of each storage account in the reservoir
# MAXaccts - a list of the maximum storage in each of the accounts
# dists - a list of the fraction of inflow that goes to each account
# fullReturnCredit - if 1, then CCM gets full credit for return flow
#     subtract return flow out of the inflow and distribute to the accounts.
#     then do the regular inflow distribution.

# AndNew, PioNew, LavNew storage accounts gets full credit for its return flow, so take care of that
first
if fullReturnCredit == 1:
  # Anderson New
  if AndRT :
    Qrt_Hart_AndNew_SV = network.getStateVariable("aQrt_Hart_AndNew")
    Qrt_Hart_AndNew_prev = Qrt_Hart_AndNew_SV.getPreviousValue(currentRuntimestep)
    if setStorLookback == 1 : Qrt_Hart_AndNew_prev = 0

    Hart_AndNew_acct_prev = Hart_AndNew_acct_prev + Qrt_Hart_AndNew_prev*cfs2AF
    Hart_acct_refill = Hart_acct_refill - Qrt_Hart_AndNew_prev*cfs2AF

  if AndoRT :
```

```
    Qrt_Hart_And_SV = network.getStateVariable("aQrt_Hart_And")
    Qrt_Hart_And_prev = Qrt_Hart_And_SV.getPreviousValue(currentRuntimestep)
    if setStorLookback == 1 : Qrt_Hart_And_prev = 0

    Hart_And_acct_prev = Hart_And_acct_prev + Qrt_Hart_And_prev*cfs2AF
    Hart_acct_refill = Hart_acct_refill - Qrt_Hart_And_prev*cfs2AF

  # Pioneer New
  if PioRT :
    Qrt_Hart_PioNew_SV = network.getStateVariable("aQrt_Hart_PioNew")
    Qrt_Hart_PioNew_prev = Qrt_Hart_PioNew_SV.getPreviousValue(currentRuntimestep)
    if setStorLookback == 1 : Qrt_Hart_PioNew_prev = 0

    Hart_PioNew_acct_prev = Hart_PioNew_acct_prev + Qrt_Hart_PioNew_prev*cfs2AF
    Hart_acct_refill = Hart_acct_refill - Qrt_Hart_PioNew_prev*cfs2AF

  # Lavonia New
  if LavRT :
    Qrt_Hart_LavNew_SV = network.getStateVariable("aQrt_Hart_LavNew")
    Qrt_Hart_LavNew_prev = Qrt_Hart_LavNew_SV.getPreviousValue(currentRuntimestep)
    if setStorLookback == 1 : Qrt_Hart_LavNew_prev = 0

    Hart_LavNew_acct_prev = Hart_LavNew_acct_prev + Qrt_Hart_LavNew_prev*cfs2AF
    Hart_acct_refill = Hart_acct_refill - Qrt_Hart_LavNew_prev*cfs2AF

  if LavoRT :
    Qrt_Hart_Lav_SV = network.getStateVariable("aQrt_Hart_Lav")
    Qrt_Hart_Lav_prev = Qrt_Hart_Lav_SV.getPreviousValue(currentRuntimestep)
    if setStorLookback == 1 : Qrt_Hart_Lav_prev = 0

    Hart_Lav_acct_prev = Hart_Lav_acct_prev + Qrt_Hart_Lav_prev*cfs2AF
    Hart_acct_refill = Hart_acct_refill - Qrt_Hart_Lav_prev*cfs2AF
# ~~~~~~~
# Refill, but if any account is too full to accept their share of the inflow, just give the excess to
USACE (other)
def refill_Hart_NOrecycle(INvol, STORaccts, MAXaccts, dists):
# INvol = volume of water coming into reservoir in prev timestep
# STORaccts = volume of storage in each account in prev timestep
# MAXaccts = volume of storage in each account when full
# dists = fraction of inflow that is given to each account for prev timestep

  recycleVol = 0
  dists_sum = sum(dists)

  for i, dist in enumerate(dists):
    #print i, STORaccts[i], dist, dists_sum
    STORaccts[i] += INvol * (dist / dists_sum)
    if STORaccts[i] >= MAXaccts[i]: #if there's more vol than can be held in the acct
      recycleVol += STORaccts[i] - MAXaccts[i] #increase the available inflow vol to include the
overflow
      STORaccts[i] = MAXaccts[i] #set the storage in that account to maximum

  STORaccts[0] = STORaccts[0] + recycleVol
  # Return the new bucket quantities, and any excess input.
  return STORaccts #, INvol


def refill_Hart(INvol, STORaccts, MAXaccts, dists, recycle):
# INvol = volume of water coming into reservoir in prev timestep
# STORaccts = volume of storage in each account in prev timestep
# MAXaccts = volume of storage in each account when full
# dists = fraction of inflow that is given to each account for prev timestep

  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, storVol in enumerate(STORaccts):
```

```
      if storVol >= MAXaccts[i]: #if there's more vol than can be held in each acct
        full_count += 1
        dists[i] = 0 #don't give it any more water.
        INvol += storVol - MAXaccts[i] #increase the available inflow vol to include the overflow
        STORaccts[i] = MAXaccts[i] #set the storage in that account to maximum

    # 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):
      #print i, STORaccts[i], dist, dists_sum
      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

# ~~~~~~~
# -----------------
if AcctVarInf == 1 :

  # Fraction of Storage belonging to each account holder changes with changing guide curve
  varHartTotAcctVol = HartTopCon_stor_prev - HartTopInactive_stor_prev
  varHartUSACE_size = varHartTotAcctVol - Hart_SumAccts_size
  USACE_Hfrac = varHartUSACE_size/varHartTotAcctVol
  And_Hfrac = HartAnd_size/varHartTotAcctVol
  AndNew_Hfrac = HartAndNew_size/varHartTotAcctVol
  PioNew_Hfrac = HartPioNew_size/varHartTotAcctVol
  Lav_Hfrac = HartLav_size/varHartTotAcctVol
  LavNew_Hfrac = HartLavNew_size/varHartTotAcctVol
  CrhNew_Hfrac = HartCrhNew_size/varHartTotAcctVol
  HCo_Hfrac = HartHCo_size/varHartTotAcctVol

# first param selects desired function based on the Qrecyc variable
RefilledStorAccts = (refill_Hart if QRecycle else refill_Hart_NOrecycle)(Hart_acct_refill,
[Hart_USACE_acct_prev,Hart_And_acct_prev,Hart_AndNew_acct_prev, \

Hart_PioNew_acct_prev,Hart_Lav_acct_prev,Hart_LavNew_acct_prev,Hart_CrhNew_acct_prev,Hart_HCo_acct_prev
], \

[Hart_USACE_acctFULL,Hart_And_acctFULL,Hart_AndNew_acctFULL,Hart_PioNew_acctFULL,Hart_Lav_acctFULL,Hart
_LavNew_acctFULL,Hart_CrhNew_acctFULL,Hart_HCo_acctFULL], \
 [USACE_Hfrac,And_Hfrac,AndNew_Hfrac,PioNew_Hfrac,Lav_Hfrac,LavNew_Hfrac,CrhNew_Hfrac,HCo_Hfrac])

# -----------------

Hart_USACE_acct = RefilledStorAccts[0]
Hart_And_acct = RefilledStorAccts[1]
Hart_AndNew_acct = RefilledStorAccts[2]
Hart_PioNew_acct = RefilledStorAccts[3]
Hart_Lav_acct = RefilledStorAccts[4]
Hart_LavNew_acct = RefilledStorAccts[5]
Hart_CrhNew_acct = RefilledStorAccts[6]
Hart_HCo_acct = RefilledStorAccts[7]
```

```
# --------------------------------------------------------
# Reset the Hartwell accounts if Hartwell is full
 # if ResetCon = 0, then "Full" is at top of SUMMER (Max) con pool
 # if ResetCon = 1, then "Full" is at top of CURRENT con pool
```

```
# -------------------------------------------------------
if ResetCon == 0 :
  Hart_Con_Max = currentVariable.varGet("HartMaxGCelev")
  if Hart_elev_prev >= Hart_Con_Max :
        Hart_And_acct = Hart_And_acctFULL
        Hart_AndNew_acct = Hart_AndNew_acctFULL
        Hart_PioNew_acct = Hart_PioNew_acctFULL
        Hart_Lav_acct = Hart_Lav_acctFULL
        Hart_LavNew_acct = Hart_LavNew_acctFULL
        Hart_CrhNew_acct = Hart_CrhNew_acctFULL
        Hart_HCo_acct = Hart_HCo_acctFULL
        Hart_USACE_acct = Hart_stor_prev - Hart_And_acct - Hart_AndNew_acct - Hart_PioNew_acct -
Hart_Lav_acct - Hart_LavNew_acct - Hart_CrhNew_acct - Hart_HCo_acct - HartTopInactive_stor_prev
else :
  Hart_Con_TS = network.getTimeSeries("Reservoir","Hartwell", "Conservation", "Elev-ZONE")
  Hart_Con_prev = Hart_Con_TS.getPreviousValue(currentRuntimestep)
  if Hart_elev_prev >= Hart_Con_prev :
        Hart_And_acct = Hart_And_acctFULL
        Hart_AndNew_acct = Hart_AndNew_acctFULL
        Hart_PioNew_acct = Hart_PioNew_acctFULL
        Hart_Lav_acct = Hart_Lav_acctFULL
        Hart_LavNew_acct = Hart_LavNew_acctFULL
        Hart_CrhNew_acct = Hart_CrhNew_acctFULL
        Hart_HCo_acct = Hart_HCo_acctFULL
        Hart_USACE_acct = Hart_stor_prev - Hart_And_acct - Hart_AndNew_acct - Hart_PioNew_acct -
Hart_Lav_acct - Hart_LavNew_acct - Hart_CrhNew_acct - Hart_HCo_acct -HartTopInactive_stor_prev
```

```
# -------------------------------------------------------
# (2d) set account values for END of PREVIOUS TIMESTEP (BEGINNING OF CURRENT)
# -------------------------------------------------------
Hart_And_acct_SV = network.getStateVariable("aHart_And_acct")
Hart_And_acct_SV.setValue(prevRTS, Hart_And_acct)
Hart_AndNew_acct_SV = network.getStateVariable("aHart_AndNew_acct")
Hart_AndNew_acct_SV.setValue(prevRTS, Hart_AndNew_acct)
Hart_PioNew_acct_SV = network.getStateVariable("aHart_PioNew_acct")
Hart_PioNew_acct_SV.setValue(prevRTS, Hart_PioNew_acct)
Hart_Lav_acct_SV = network.getStateVariable("aHart_Lav_acct")
Hart_Lav_acct_SV.setValue(prevRTS, Hart_Lav_acct)
Hart_LavNew_acct_SV = network.getStateVariable("aHart_LavNew_acct")
Hart_LavNew_acct_SV.setValue(prevRTS, Hart_LavNew_acct)
Hart_CrhNew_acct_SV = network.getStateVariable("aHart_CrhNew_acct")
Hart_CrhNew_acct_SV.setValue(prevRTS, Hart_CrhNew_acct)
Hart_HCo_acct_SV = network.getStateVariable("aHart_HCo_acct")
Hart_HCo_acct_SV.setValue(prevRTS, Hart_HCo_acct)

#~
Hart_USACE_acct_SV = network.getStateVariable("aHart_USACE_acct")
if setStorLookback == 1 :
        x = Hart_stor_prev - Hart_And_acct - Hart_AndNew_acct - Hart_PioNew_acct - Hart_Lav_acct -
Hart_LavNew_acct - Hart_CrhNew_acct - Hart_HCo_acct  - HartTopInactive_stor_prev
        Hart_USACE_acct_SV.setValue(prevRTS, x)
else :
        Hart_USACE_acct_SV.setValue(prevRTS, Hart_USACE_acct)

# ---------------------------------------------------------------------------------------
# END STORAGE ACCOUNTING - BEGINNING OF TIMESTEP
# ---------------------------------------------------------------------------------------
```

```
# ---------------------------------------------------------------------------------------
# (5)  CALCULATE WITHDRAWALS FROM HARTWELL'S STORAGE ACCOUNTS ~~~~
# ---------------------------------------------------------------------------------------
# -------------------------------------------------------
# (5a) calculate Hartwell's releases for Accounts
```

```
# -------------------------------------------------------
QHart_And = min(Qdemand_And, Hart_And_acct/cfs2AF)
QHart_AndNew = min(Qdemand_AndNew, Hart_AndNew_acct/cfs2AF)
QHart_PioNew = min(Qdemand_PioNew, Hart_PioNew_acct/cfs2AF)
QHart_Lav = min(Qdemand_Lav, Hart_Lav_acct/cfs2AF)
QHart_LavNew = min(Qdemand_LavNew, Hart_LavNew_acct/cfs2AF)
QHart_CrhNew = min(Qdemand_CrhNew, Hart_CrhNew_acct/cfs2AF)
QHart_HCo = min(Qdemand_HCo, Hart_HCo_acct/cfs2AF)



# -------------------------------------------------------
# (8) calculate storage account OVERDRAW
# -------------------------------------------------------
# overdraw (if allowed to overdraw)
#if TheCurAlt in AltGroup_AllaUnlimited :
if HartOD == 1 :
        QHart_And = Qdemand_And
        QHart_AndNew = Qdemand_AndNew
        QHart_PioNew = Qdemand_PioNew
        QHart_Lav = Qdemand_Lav
        QHart_LavNew = Qdemand_LavNew
        QHart_CrhNew = Qdemand_CrhNew
        QHart_HCo = Qdemand_HCo

Hart_And_overdraw = min(0,Hart_And_acct - QHart_And*cfs2AF)
#Hart_AndNew_overdraw = max(0,Hart_AndNew_acct - QHart_AndNew*cfs2AF)
Hart_PioNew_overdraw = min(0,Hart_PioNew_acct - QHart_PioNew*cfs2AF)
Hart_Lav_overdraw = min(0,Hart_Lav_acct - QHart_Lav*cfs2AF)
#Hart_LavNew_overdraw = Hart_LavNew_acct - QHart_LavNew*cfs2AF
Hart_CrhNew_overdraw = min(0,Hart_CrhNew_acct - QHart_CrhNew*cfs2AF)
Hart_HCo_overdraw = min(0,Hart_HCo_acct - QHart_HCo*cfs2AF)
```

```
# ----------------------------------------------------------------------------------------
# (9)  CALCULATE RETURN FLOWS  ~~~~
# ----------------------------------------------------------------------------------------
# Calculate Return flows to Hartwell
# frac of flow

frac_QRTHart_And = 0.236
frac_QRTHart_AndNew = 0.236
frac_QRTHart_PioNew = 0.227
frac_QRTHart_Lav = 0.0616
frac_QRTHart_LavNew = 0.0616

if Qdemand_And > 0:
  frac_demand_met_Hart_And = QHart_And/Qdemand_And
  Qreturn_Hart_And = frac_demand_met_Hart_And*frac_QRTHart_And*QHart_And             #QRT_Hart_And_cur
else : Qreturn_Hart_And = 0

if Qdemand_AndNew > 0:
  frac_demand_met_Hart_AndNew = QHart_AndNew/Qdemand_AndNew
  Qreturn_Hart_AndNew = frac_demand_met_Hart_AndNew*frac_QRTHart_AndNew*QHart_AndNew     #QRT_Hart_And_
New
else : Qreturn_Hart_AndNew = 0

if Qdemand_PioNew > 0:
  frac_demand_met_Hart_PioNew = QHart_PioNew/Qdemand_PioNew
```

```
  Qreturn_Hart_PioNew = frac_demand_met_Hart_PioNew*frac_QRTHart_PioNew*QHart_PioNew
#QRT_Hart_Pioneer New
else : Qreturn_Hart_PioNew = 0

if Qdemand_Lav > 0:
  frac_demand_met_Hart_Lav = QHart_Lav/Qdemand_Lav
  Qreturn_Hart_Lav = frac_demand_met_Hart_Lav*frac_QRTHart_Lav*QHart_Lav     #QRT_Hart_Lavonia
else : Qreturn_Hart_Lav = 0

if Qdemand_LavNew > 0:
  frac_demand_met_Hart_LavNew = QHart_LavNew/Qdemand_LavNew
  Qreturn_Hart_LavNew = frac_demand_met_Hart_LavNew*frac_QRTHart_LavNew*QHart_LavNew
#QRT_Hart_Lavonia New
else : Qreturn_Hart_LavNew = 0

#print "XXXXXX", QAlla_Cartv_Qreturn, QCartvfrac, QRT_Cartv_cur, currentRuntimestep.dateTimeString()
```

```
# ---------------------------------------------------------------------------
# (10)  INTERIM STORAGE ACCOUNTING  ~~~~
# ---------------------------------------------------------------------------------------
# -------------------------------------------------
# STORAGE ACCOUNTING - interim calc based on what is known
# at end of time period (w/current releases, but not yet counting current inflows)
# -------------------------------------------------
# this just takes care of the amount that has been released from the accounts.

Hart_And_acct_int = Hart_And_acct - QHart_And*cfs2AF
Hart_AndNew_acct_int = Hart_AndNew_acct - QHart_AndNew*cfs2AF
Hart_PioNew_acct_int = Hart_PioNew_acct - QHart_PioNew*cfs2AF
Hart_Lav_acct_int = Hart_Lav_acct - QHart_Lav*cfs2AF
Hart_LavNew_acct_int = Hart_LavNew_acct - QHart_LavNew*cfs2AF
Hart_CrhNew_acct_int = Hart_CrhNew_acct - QHart_CrhNew*cfs2AF
Hart_HCo_acct_int = Hart_HCo_acct - QHart_HCo*cfs2AF
```

```
# ------------------
# (11) STORE STATE VARIABLES
# ------------------
# store other vars for access in simulation.dss file

# Interim storage accounts
# SV are already set at the top of the script
Hart_And_accti_SV.setValue(currentRuntimestep, Hart_And_acct_int)
Hart_AndNew_accti_SV.setValue(currentRuntimestep, Hart_AndNew_acct_int)
Hart_PioNew_accti_SV.setValue(currentRuntimestep, Hart_PioNew_acct_int)
Hart_Lav_accti_SV.setValue(currentRuntimestep, Hart_Lav_acct_int)
Hart_LavNew_accti_SV.setValue(currentRuntimestep, Hart_LavNew_acct_int)
Hart_CrhNew_accti_SV.setValue(currentRuntimestep, Hart_CrhNew_acct_int)
Hart_HCo_accti_SV.setValue(currentRuntimestep, Hart_HCo_acct_int)



# Hartwell account withdrawals
QHart_And_SV.setValue(currentRuntimestep, QHart_And)
QHart_AndNew_SV.setValue(currentRuntimestep, QHart_AndNew)
QHart_PioNew_SV.setValue(currentRuntimestep, QHart_PioNew)
QHart_Lav_SV.setValue(currentRuntimestep, QHart_Lav)
QHart_LavNew_SV.setValue(currentRuntimestep, QHart_LavNew)
QHart_CrhNew_SV.setValue(currentRuntimestep, QHart_CrhNew)
QHart_HCo_SV.setValue(currentRuntimestep, QHart_HCo)
#~
QHart_USACE_SV.setValue(prevRTS, QHart_USACE_prev)


# Total return flow at Hartwell_IN
Qrt_Hart_And_SV = network.getStateVariable("aQrt_Hart_And")
```

```
Qrt_Hart_And_SV.setValue(currentRuntimestep, Qreturn_Hart_And)
Qrt_Hart_AndNew_SV = network.getStateVariable("aQrt_Hart_AndNew")
Qrt_Hart_AndNew_SV.setValue(currentRuntimestep, Qreturn_Hart_AndNew)
Qrt_Hart_PioNew_SV = network.getStateVariable("aQrt_Hart_PioNew")
Qrt_Hart_PioNew_SV.setValue(currentRuntimestep, Qreturn_Hart_PioNew)
Qrt_Hart_Lav_SV = network.getStateVariable("aQrt_Hart_Lav")
Qrt_Hart_Lav_SV.setValue(currentRuntimestep, Qreturn_Hart_Lav)
Qrt_Hart_LavNew_SV = network.getStateVariable("aQrt_Hart_LavNew")
Qrt_Hart_LavNew_SV.setValue(currentRuntimestep, Qreturn_Hart_LavNew)

# Total overdrafts
if HartOD :
  network.getStateVariable("aHart_And_overdraw").setValue(currentRuntimestep, Hart_And_overdraw)
  network.getStateVariable("aHart_PioNew_overdraw").setValue(currentRuntimestep, Hart_PioNew_overdraw)
  network.getStateVariable("aHart_Lav_overdraw").setValue(currentRuntimestep, Hart_Lav_overdraw)
  network.getStateVariable("aHart_CrhNew_overdraw").setValue(currentRuntimestep, Hart_CrhNew_overdraw)
  network.getStateVariable("aHart_HCo_overdraw").setValue(currentRuntimestep, Hart_HCo_overdraw)
```

```
# ----------------------------------------------------------------------------------------
# GET Global Variables
# ----------------------------------------------------------------------------------------
usingGlobalVariables = 0
if usingGlobalVariables == 1:
  HMaxTotAcct_GV = network.getGlobalVariable("MaxTotAcctVol")
  HTotAcct_GV = network.getGlobalVariable("HartTotAcctStor")
  HAndAcctPerc_GV = network.getGlobalVariable("HartAndAcctPercFull")
  HAndNewAcctPerc_GV = network.getGlobalVariable("HartAndNewAcctPercFull")
  HPioNewAcctPerc_GV = network.getGlobalVariable("HartPioNewAcctPercFull")
  HLavAcctPerc_GV = network.getGlobalVariable("HartLavAcctPercFull")
  HLavNewAcctPerc_GV = network.getGlobalVariable("HartLavNewAcctPercFull")
  HCrhNewAcctPerc_GV = network.getGlobalVariable("HartCrhNewAcctPercFull")
  Test_GV =  network.getGlobalVariable("Test2")
  Test3_GV =  network.getGlobalVariable("Test3")
  HMaxTotAcct_GV.setCurrentValue(prevRTS, HartTopCon_stor_prev - HartTopInactive_stor_prev)
  HTotAcct_GV.setCurrentValue(prevRTS, Hart_stor_prev - HartTopInactive_stor_prev)
  HAndAcctPerc_GV.setCurrentValue(prevRTS, Hart_And_acct/HartAnd_size)
  HAndNewAcctPerc_GV.setCurrentValue(prevRTS, Hart_AndNew_acct/HartAndNew_size)
  HPioNewAcctPerc_GV.setCurrentValue(prevRTS, Hart_PioNew_acct/HartPioNew_size)
  HLavAcctPerc_GV.setCurrentValue(prevRTS, Hart_Lav_acct/HartLav_size)
  HLavNewAcctPerc_GV.setCurrentValue(prevRTS, Hart_LavNew_acct/HartLavNew_size)
  HCrhNewAcctPerc_GV.setCurrentValue(prevRTS, Hart_CrhNew_acct/HartCrhNew_size)
  Test_GV.setCurrentValue(prevRTS, 5.55)
  Test3_GV.setCurrentValue(prevRTS, 5.55)

placeholder_var = 0


# For all alternatives, set this variable, which is a dummy variable - never actually used.
currentVariable.setValue(currentRuntimestep, placeholder_var)
```

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