Appendix C

Summary of Climate Data and Future Operations on Water Resources

This page intentionally left blank.

SUMMARY OF CLIMATE DATA AND FUTURE OPERATIONS ON WATER RESOURCES

Bad Creek Pumped Storage Project
FERC Project No. 2740

Oconee County, South Carolina

February 2025

SUMMARY OF CLIMATE DATA AND FUTURE OPERATIONS ON WATER RESOURCES
BAD CREEK PUMPED STORAGE PROJECT
FERC PROJECT NO. 2740

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS

LIST OF FIGURES

TABLE OF CONTENTS

Section	Title	Page No.

Appendices

Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
Bad Creek or Project	Bad Creek Pumped Storage Station
Bad Creek II	Bad Creek II Power Complex
CHEOPS	Computerized Hydro Electric Operations Planning Software
Duke Energy or Licensee	Duke Energy Carolinas, LLC
FERC	Federal Energy Regulatory Commission
ft	feet/foot
ft msl	feet above mean sea level
KT Project	Keowee-Toxaway Hydroelectric Project
LIP	Low Inflow Protocol
ppm	parts per million
SCDNR	South Carolina Department of Natural resources
SEPA	Southeastern Power Administration
USACE	U.S. Army Corps of Engineers
UIF	unimpaired incremental flow

This page intentionally left blank.

1 Climate Change Summary and Future Operations on Water Resources

1.1 Introduction

Climate change refers to long-term shifts in weather patterns that define Earth's local, regional, and global climates (NASA 2023). The International Panel of Climate Change Sixth Assessment published in 2021 found that human emissions of heat-trapping gases have warmed the climate by nearly 2 degrees Fahrenheit (°F) or 1.1 degrees Celsius (°C) since pre-Industrial times (starting in 1750) (IPCC 2021). The global average temperature is expected to reach or exceed increases of 1.5°C within the next few decades and these changes will affect all areas of the planet (UNCA 2022). Figure 1-1 shows a climate model for temperature with and without anthropogenic forcing plotted against observed temperature.

Extreme climate-related weather events documented over the last 20 years include increased frequency and intensity of rainfall, flash flooding, prolonged periods of drought, and increased frequency and intensity of extreme weather events. In many instances, local climates are exhibiting trends that are inconsistent with regional patterns, resulting in a degree of uncertainty associated with predicting local climate change from global climate models. Scientists predict that temperature increases will continue, and severe weather associated with climate change will also increase and intensify in the future (NASA 2023).

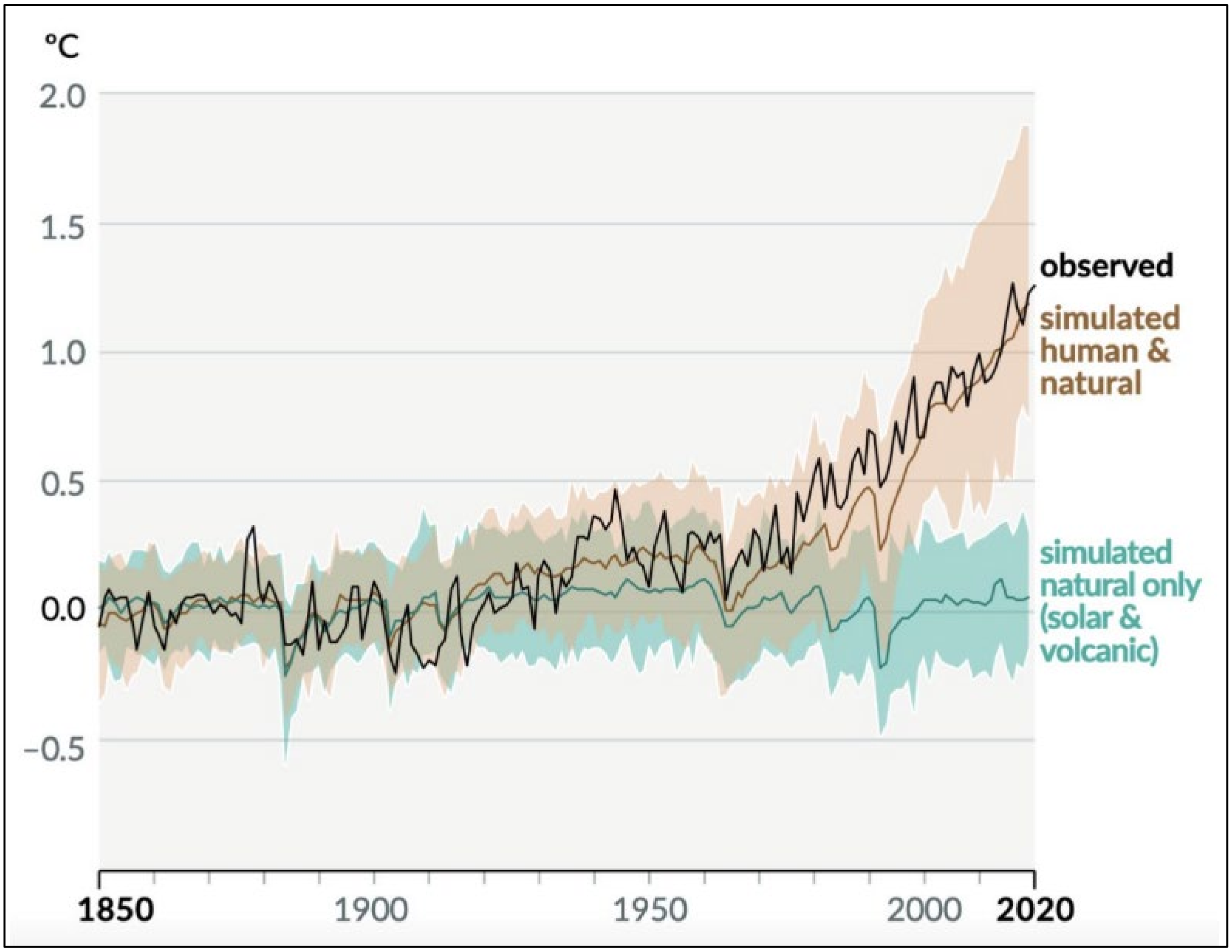


Figure 1-1. Simulated Temperatures with and without Anthropogenic Forcing Plotted against Observed Temperatures (IPCC 2021)

1.2 Objectives

This section of the Environmental Exhibit (Exhibit E) provides an overview of recent climate data, trends, and patterns in the state of South Carolina and potential climate related impacts relevant to Project operations. It was developed in response to stakeholder comments on the Pre-Application Document and Proposed Study Plan documents.

Operational models developed for the KT Project relicensing were developed with climate change scenarios in support of the 2014 Operating Agreement between Duke Energy, the U.S. Army Corps of Engineers (USACE), and Southeastern Power Administration (SEPA). Climate sensitivity assessments were evaluated to determine possible impacts of future temperature increases, basin inflow reduction, extended drought, and future water withdrawal demands. In 2023-2024, additional modeling (Computerized Hydro Electric Operations Planning Software [CHEOPS]) was carried out in support of Project relicensing to account for recent unit upgrades at the existing Project and increased operations from the proposed Bad Creek II Complex.

Recent modeling used the same parameters and climate sensitivities from the KT modeling studies. Bad Creek II operations will comply with the 2014 Operating Agreement and the proposed operating range of the Project and Bad Creek II is consistent with the operating range evaluated during the previous climate change analysis. For these reasons, the Commission stated in their Study Plan Determination, that results from the previous KT study should be sufficient in meeting stakeholder formal comments on the Pre-Application Document and Proposed Study Report regarding climate impacts on operations and water resources, and therefore did not recommend a new or expanded evaluation of the potential effects of climate change. FERC recommended that Duke Energy include a discussion of recent climate data, trends, and patterns in the license application and also recommended the study reports supporting climate change analyses in the KT relicensing be included with the application, therefore, Duke Energy has developed this section to provide an overview of (1) recent climate data and trends, (2) previous KT study methods and results, and (3) recent relicensing study results, and has included the following reports in Attachment 1:

- Operating Agreement executed by the United States of America acting by and through the Savannah District U.S. Army Corps of Engineers and the Southeastern Power Administration and Duke Energy Carolinas, LLC (October 10, 2014)
- Final Environmental Assessment of the New Operating Agreement Between the U.S. Army Corps of Engineers, Southeastern Power Administration, and Duke Energy Carolinas, LLC
- Keowee-Toxaway Final License Application – Exhibit E, Appendix E6: CE-Qual-W2 Model Results from WQ4 Operations Under Climate Change Scenarios
- Keowee-Toxaway Final License Application – Exhibit E, Appendix E6: Operations Model Study Savannah River Basin Model Logic and Verification Report

1.3 South Carolina Observed Climate Data and Trends

1.3.1 Temperature

South Carolina's annual average temperature varies from the mid-50s in the Upstate to the low-60s along the coast. Since the late-1800s, statewide annual average temperatures have experienced multiple periods of above and below normal temperatures. Despite the year-to-year variability, the overall pattern of average temperatures across South Carolina has increased since the mid-1970s driven largely by an increase in minimum temperatures (SCDNR 2022) (Figure 1-2). Most climate stations in the state report significant increases in maximum temperatures in winter, spring, and summer, along with a significant increase in minimum summer temperatures (SCOR 2023). Few climate stations exhibit maximum temperature trends during fall, or minimum temperature trends during winter, spring, or fall when considering records from the beginning of the early 20th century (SCOR 2023).

Statewide data provide a snapshot of general temperature trends over the last 125 years (Figure 1-2). The state experienced a relatively warm period from the mid-1920s to the mid-1950s, a cooler period during the next three decades, and an increase since the early 1980s. The warmest year on record for the state is 2017 with an average temperature of 65.1°F and seven of the top ten warmest years have occurred since 2010 (Table 1-1).

During summer, average temperatures range from the upper 60s in the Upstate to the mid-70s in the Lowcountry, though maximum temperatures can reach more than 100 degrees (SCDNR 2022). Heatwaves are common in the southeast and can worsen drought conditions, stress agriculture and water resources, and impact human health. South Carolina has experienced multiple heatwaves since 1895, including significant events in July 1952, the summer of 1954, July 1977, August 1983, July 1986, August 2007, and June – July 2012. The number of extremely hot days has been generally near average since 1980 following very high numbers in the early 1930s and early 1950s and a period of below average numbers from the late 1950s to the late 1970s; however, such days (i.e., below average) have been rare since 2014 (NOAA 2022). Statewide, very warm nights have generally been above average since 1980 with the highest 5-year average occurring during the 2010–2014 period. During winter, the average temperatures range from the mid-30s in the Upstate to the lower 50s near the coast, but there have been many instances of subzero temperatures in the climate record across the state. The number of freezing days has been below average since 1990.

Since 1895, South Carolina's average annual temperature has increased by approximately 1°F, which is lower than the average global increase of approximately 2°F. However, the rise during the past 60 years has matched or exceeded global increases and the past 30 years have been warmer than any other consecutive 30-year period (SCOR 2023). While determining a statistically significant trend over the entire dataset is difficult, there are some climate stations that provide clear statistically significant signals in temperature trends (see Figure 1-3 through Figure 1-6).

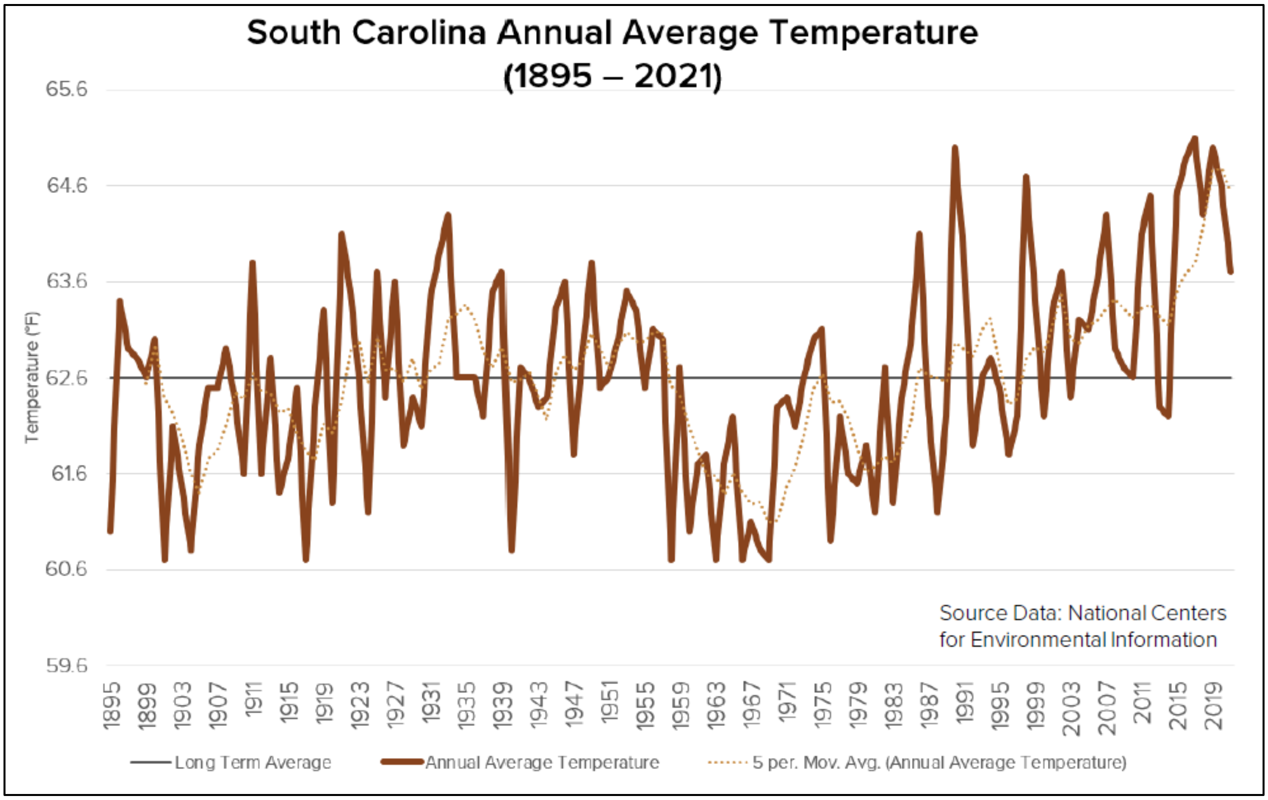


Figure 1-2. South Carolina Annual Average Temperatures (SCDNR 2022)

Table 1-1.Top Five Statewide Warmest and Coldest Years on Record

Year	Statewide Average Temperature	Departure from Long Term Average	Year	Statewide Average Temperatures	Departure from Long Term Average
2017	65.1°F	2.5°F	1901	60.7°F	-1.9°F
1990	65.0°F	2.4°F	1917	60.7°F	-1.9°F
2019	65.0°F	2.4°F	1958	60.7°F	-1.9°F
2016	64.9°F	2.3°F	1963	60.7°F	-1.9°F
1998	64.7°F	2.1°F	1966	60.7°F	-1.9°F

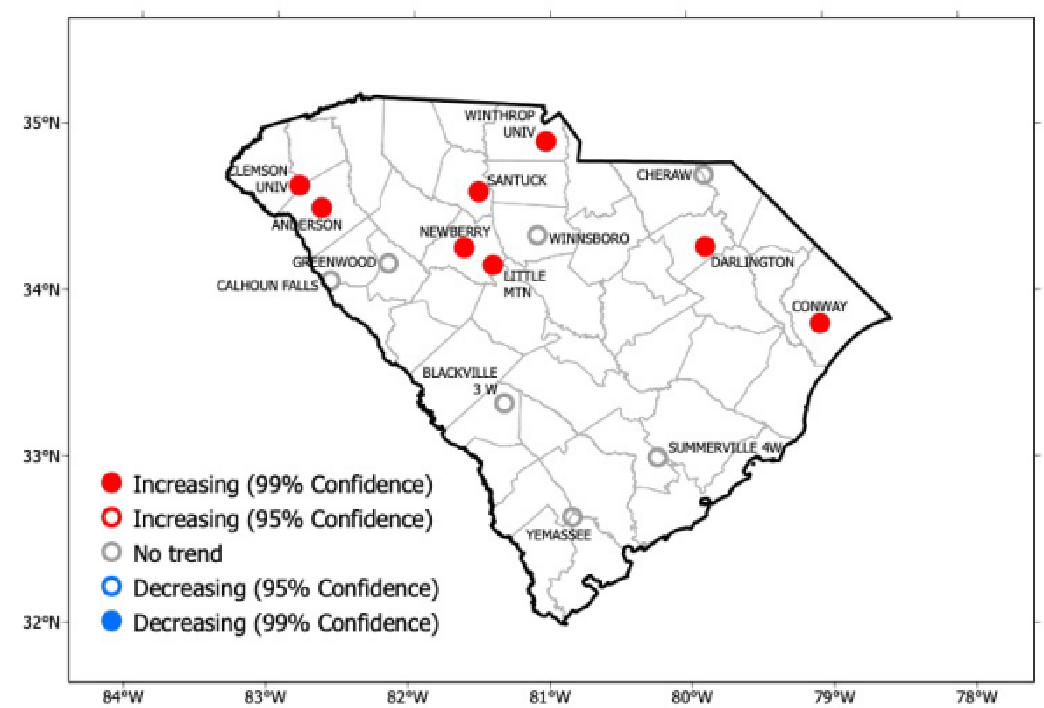


Figure 1-3. Spring Maximum Temperature Trends (1900-2020)

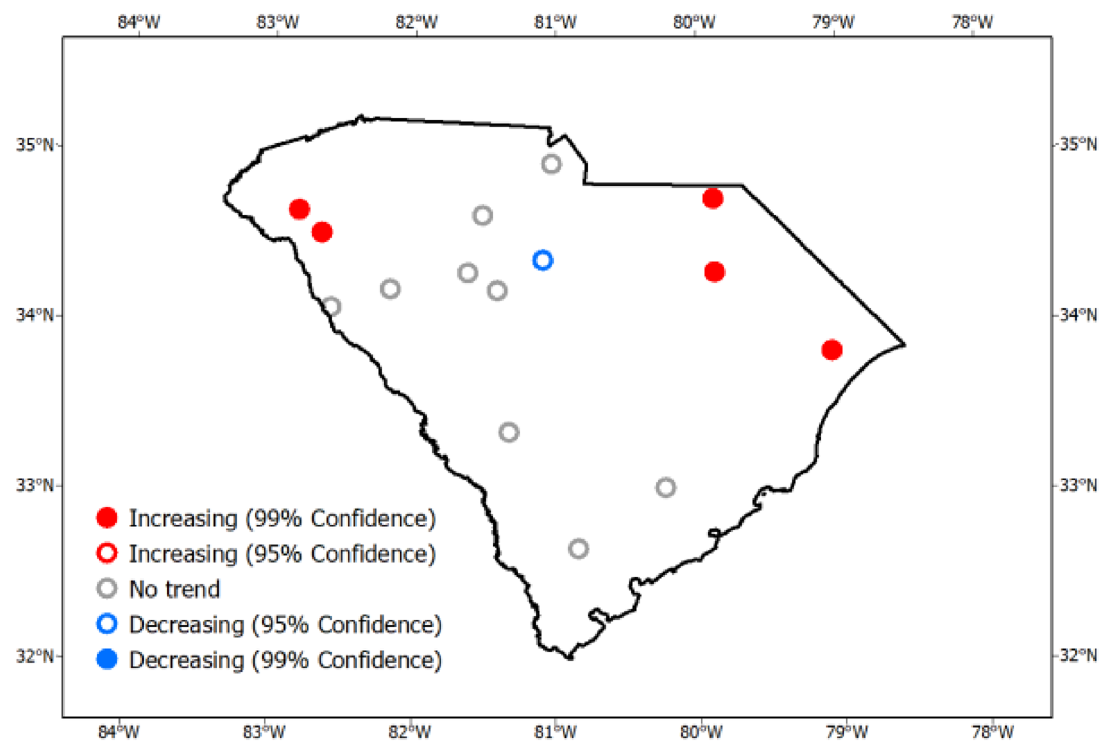


Figure 1-4. Summer Maximum Temperature Trends (1900-2020)

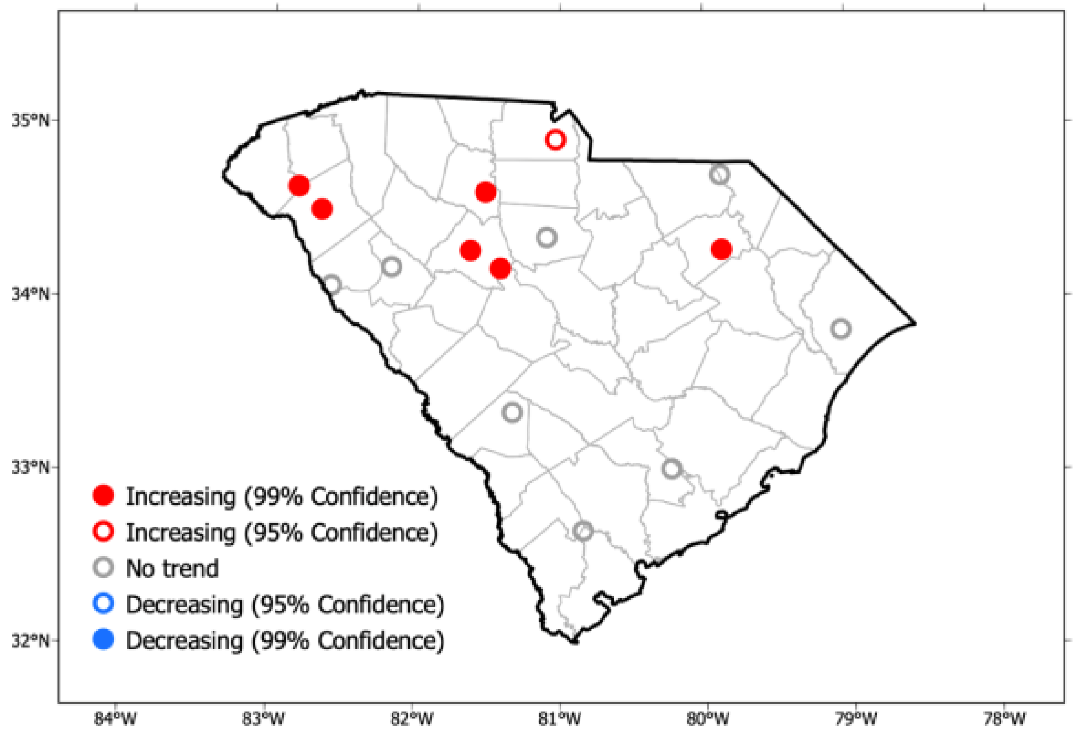


Figure 1-5. Winter Maximum Temperature Trends (1900-2020)

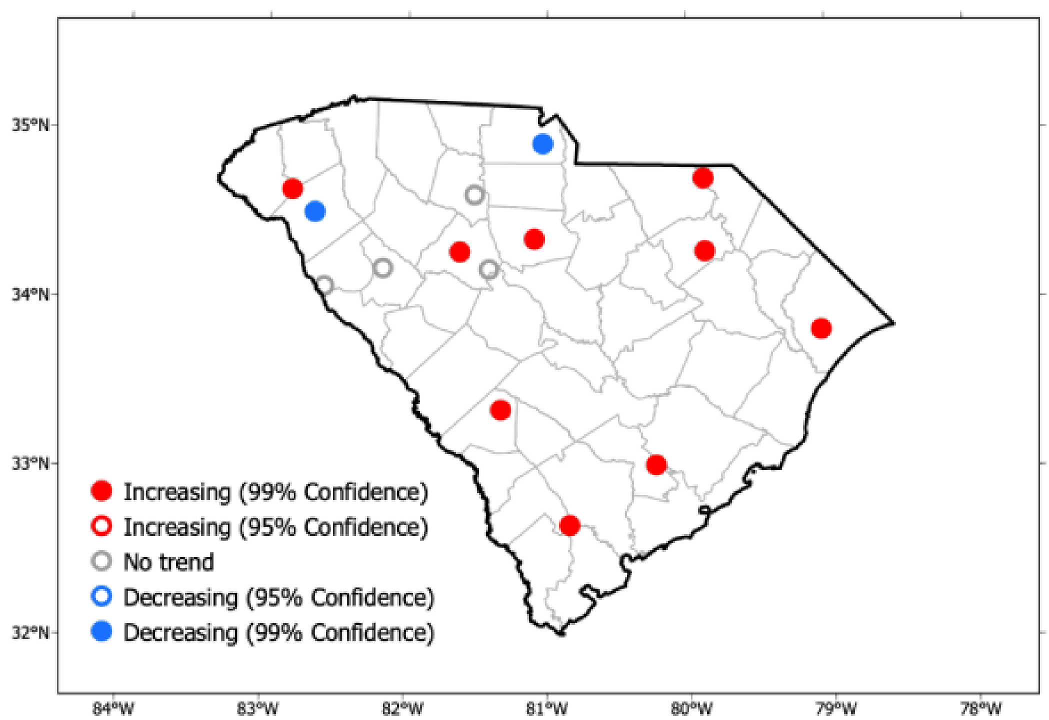


Figure 1-6. Summer Minimum Temperature Trends (1900-2020)

1.3.2 Precipitation

The geography of the state has an impact on the observed precipitation. The statewide annual rainfall average from 1895 –2021 is 45 to 50 inches (47.80 inches), though rainfall varies across the state (Figure 1-7). Annual rainfall ranges from less than 40 inches in the Sandhills region to over 80 inches in the higher elevations of the Upstate. While isolated mountain areas receive large precipitation amounts, average precipitation for most of the Upstate is 45 to 55 inches. There is no distinct dry season, and the rainfall is highly variable throughout the year.

There has been no significant change in average annual precipitation trends since the beginning of the 20th century. There are very few statistically significant long-term trends in heavy precipitation, though a few recent years (notably 2015, 2018, and 2020) have been very wet. Additionally, summer precipitation has decreased and the number of precipitation days in fall has increased, but few other statistically significant trends are found for seasonal or annual total precipitation or long-term trends in heavy precipitation (SCOR 2023). Between 2000 and 2015, the state experienced a below average number of 3-inch extreme precipitation events, but during the 2015–2020 period, the number was well above average. Of the last 21 years in South Carolina, 15 years have been characterized by warm-season drought conditions. The top five statewide wettest and driest years are included in Table 1-2 (SCDNR 2022).

As mentioned, there is a great deal of variation in annual precipitation totals; however, there are distinct periods of drier and wetter than normal conditions that can be seen in the overall pattern. From about the mid-1960s until the late 1990s, statewide precipitation totals were above-normal, though a few dry years were noted during the period. There was a shift in precipitation during the first part of the 21st century, and most of the 2000s and 2010s reported a decrease in the annual rainfall leading to long-term drought conditions (SCDNR 2022).

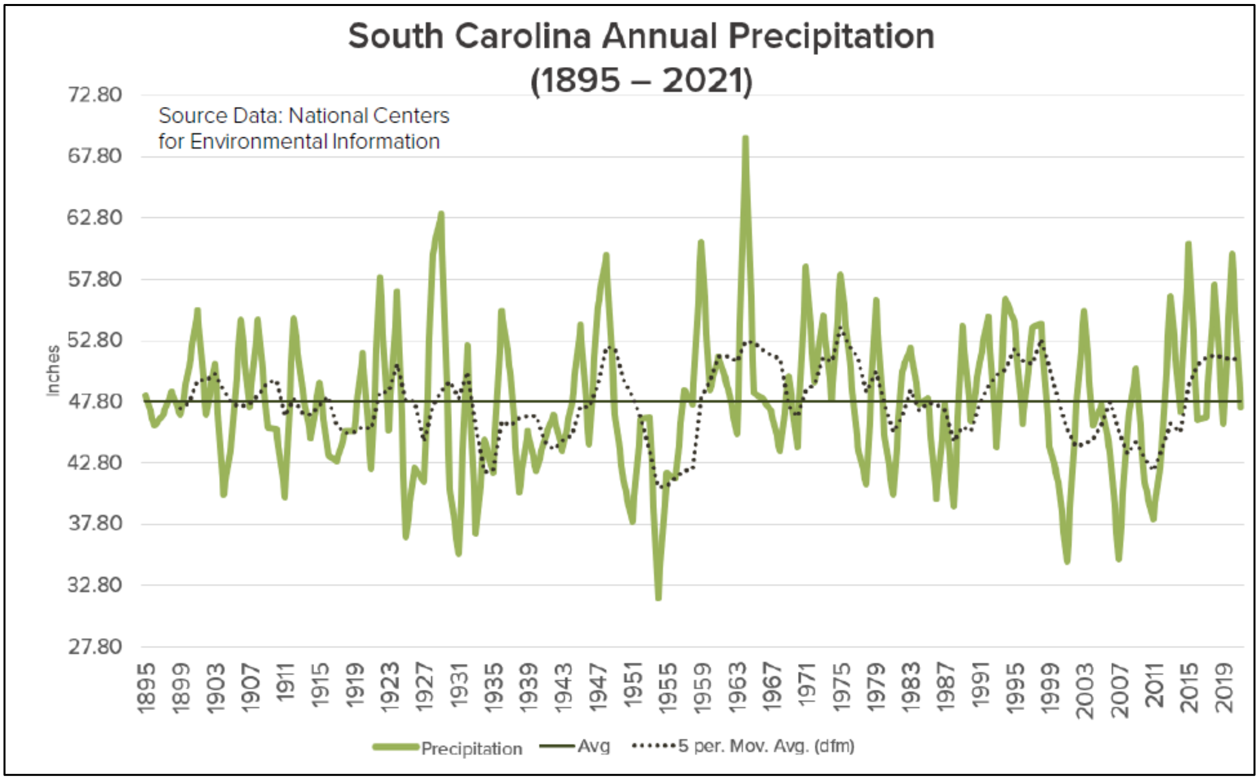


Figure 1-7. South Carolina Annual Precipitation

Table 1-2. Top Five Statewide Wettest and Driest Years on Record

Year	Statewide Average Precipitation Total	Departure from Long Term Average	Year	Statewide Average Precipitation Total	Departure from Long Term Average
1964	69.32”	21.52”	1954	31.72”	-16.08”
1929	63.14”	15.34”	2001	34.72”	-13.08”
1959	60.86”	13.06”	2007	34.90”	-12.90”
2015	60.66”	12.86”	1931	35.37”	-12.43”
1928	59.89”	12.09”	1925	36.37”	-11.07”

Precipitation has varied greatly on a yearly and decadal basis and there are few statistically significant trends in annual or seasonal precipitation record. One exception is that summer precipitation has decreased at all long-term stations and is statistically significant at two-thirds of the stations, most of these farther from the coast (Figure 1-8).

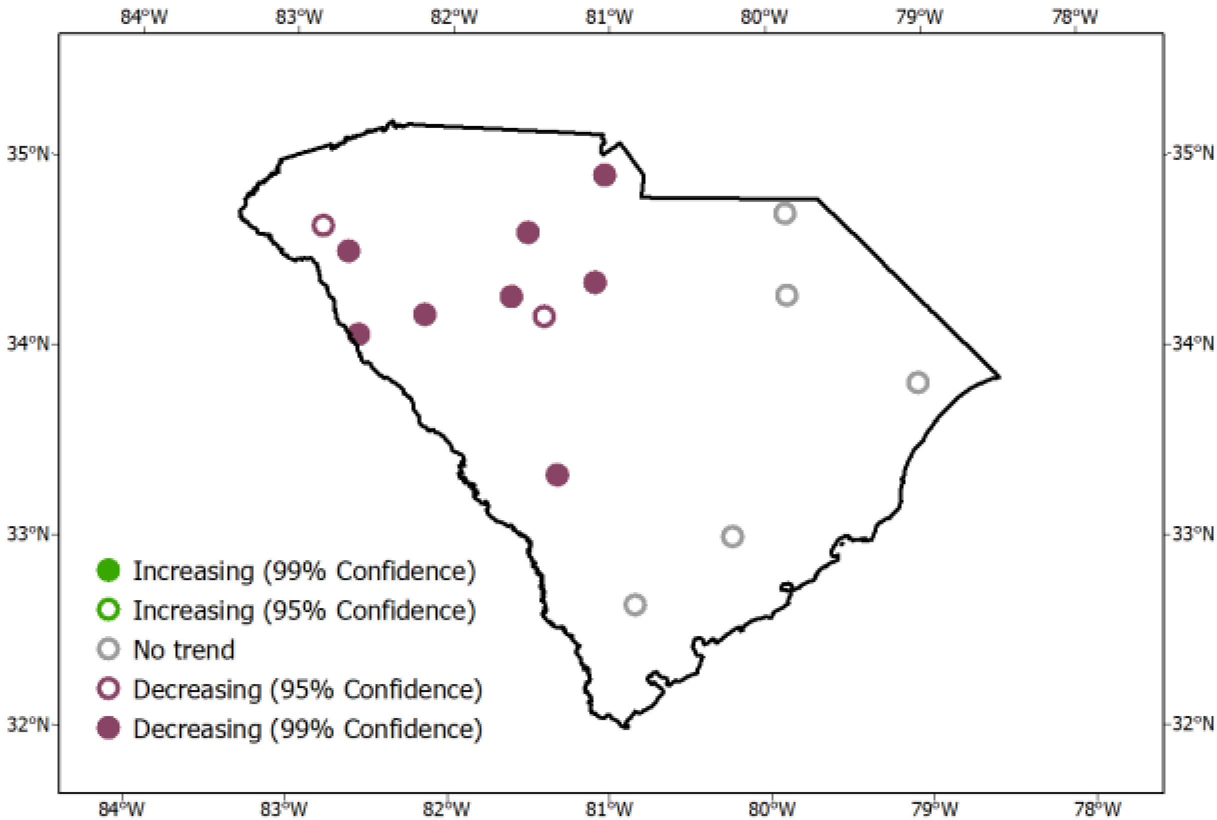


Figure 1-8. Summer Precipitation Trend 1900-2020

1.3.3 Severe Weather Events

Major storm threats for South Carolina include hurricanes and tropical storms, which occur in the summer and fall, and severe thunderstorms, which occur in the late winter and spring and are capable of producing tornadoes. The state ranks 23rd in the United States for annual tornado frequency, with an average of about 23 tornadoes confirmed each year between 2000 and 2019 (compared to Texas, ranked 1st, with an estimated 132 tornadoes each year) (SCDNR 2022). Strong and destructive tornadoes occur 2 to 4 times each year; some of the more impactful outbreaks occurred in November 1995, March 2008, and April 2020. There is no significant trend in tornadoes; through current climate projections predict that tornado alleys are shifting east (SCOR 2023).

Over the last decade, the state has experienced numerous billion-dollar disaster events involving severe storms, tornado outbreaks, hurricanes, and droughts. South Carolina ranks fifth among states that experience hurricanes, behind Florida, Texas, Louisiana, and North Carolina (SCOR 2023). Flooding associated with hurricanes is common and recent hurricanes (Matthew [2016], Florence [2018], and Dorian [2019]) each resulted in over 15 inches of rainfall resulting in widespread flooding in low lying areas. Frequency and intensity of hurricanes/tropical cyclones have been influenced by large-scale conditions including sea-surface temperature and wind shear; future scenarios are mixed with respect to the frequency of storms, but more consistently project greater intensity of wind and precipitation for those storms that do occur (SCOR 2023).

On average, there are between 45 and 70 thunderstorm days each year across the state (SCDNR 2022); these can cause damage in the form of hail and flooding.

Although South Carolina typically receives adequate precipitation, droughts can occur at any time of the year and last for several months to several years. South Carolina has experienced three major droughts in recent time (last 25 years). Drought conditions can also contribute to diminished water and air quality, increased public health and safety risks, and reduced quality of life and social well-being. Historical records of droughts across the state indicate periods of dry weather have occurred every decade since the late 19th century (see Figure 1-9). Some of the most severe droughts occurred in 1925, 1933, 1954, 1986, 1998 –2002, 2007 –2009, and 2010 – 2013. Figure 1-10 shows number of weeks in drought per year from 2000-2021 (SCDNR 2022).

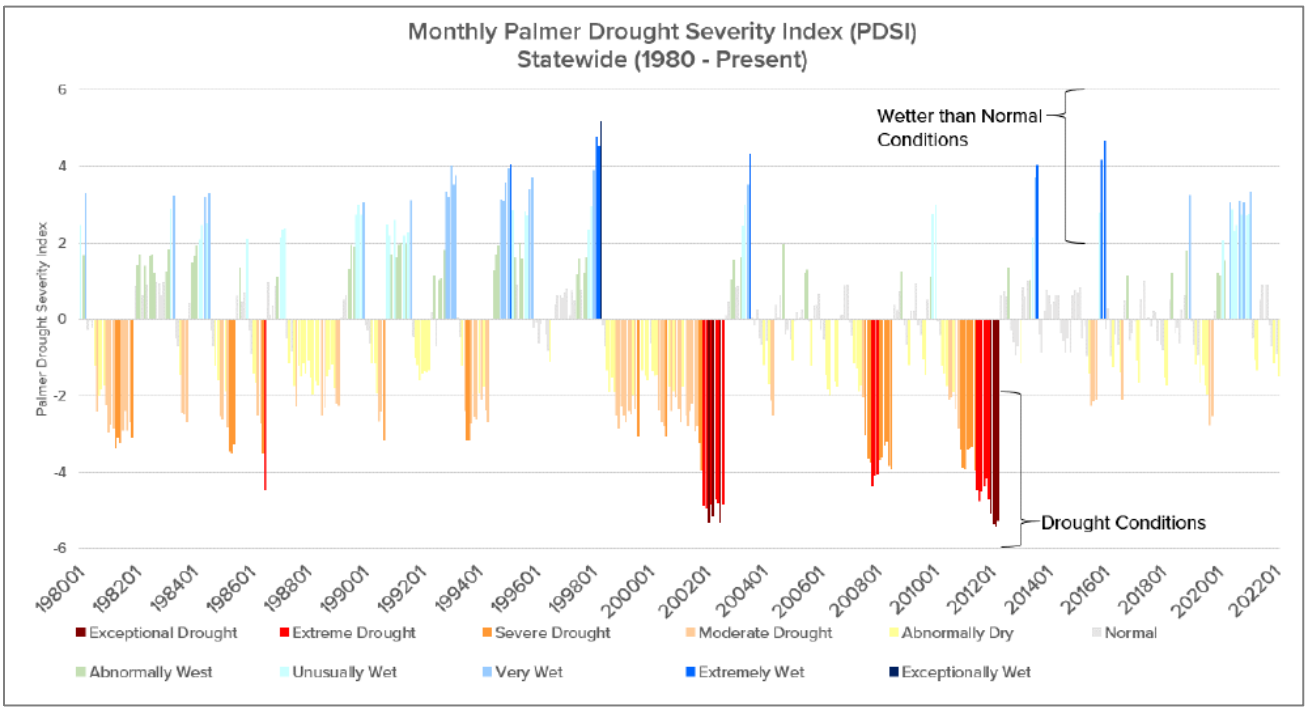


Figure 1-9. Monthly Palmer Drought Severity Index (1980-2022)

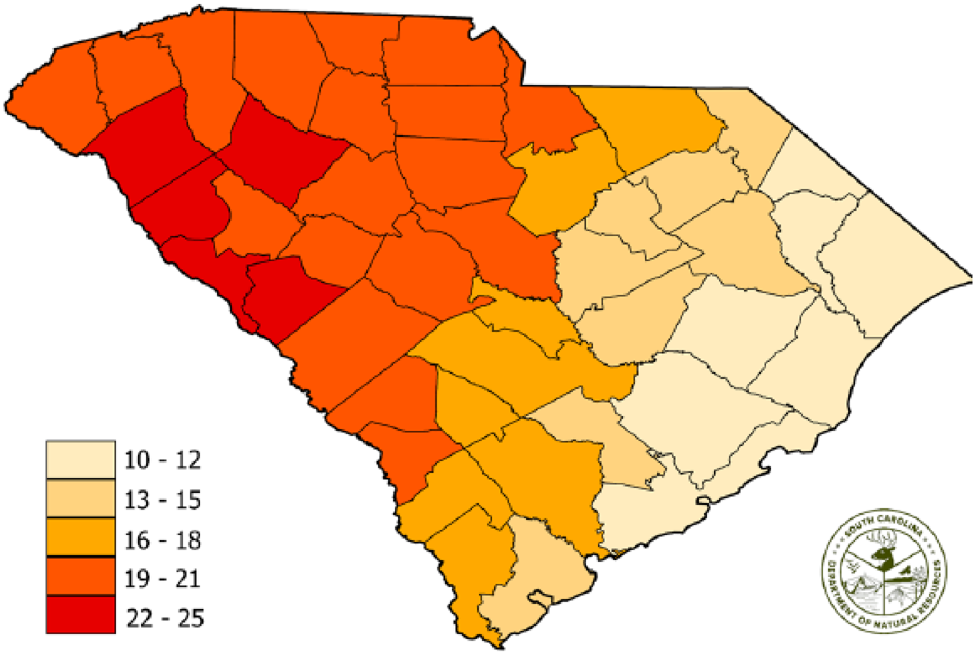


Figure 1-10. Weeks in Drought in South Carolina 2000-2021 (SCDNR 2022)

1.4 Oconee County Climate Data

Climate in the Upstate region of South Carolina is affected by factors such as the Blue Ridge Mountains, the state's location in the northern mid-latitudes, elevation, and the Atlantic Ocean (SCDNR 2022). The Blue Ridge Mountains protect the area from cold air derived from the northwest, keeping winter temperatures relatively mild.

Between March and May, temperatures in Upstate South Carolina range from highs of 62 to 80°F and lows of 39 to 57°F. From June to August, temperatures range from highs of 85 to 88°F to lows of 64 to 69 °F. Temperatures from September to November range from highs of 62 to 82°F to lows of 40 to 62°F. From December to February, high temperatures range from 50 to 54°F to lows of 31 to 33°F. The Upstate has no distinct wet or dry season (SCDNR 2022) and has typically more than 24 days of rain annually; however, only one to three days with precipitation includes measurable snowfall. During summer months thunderstorms are common but hail events are rare (SCDNR 2022). Between 1950 and 2009, two EF4 tornadoes occurred in the Upstate region. The Upstate region is generally unaffected by tropical cyclones, flooding, or other severe weather typically associated with coastal areas (SCDNR 2022).

County time series data are available from NOAA's National Center for Environmental Information. Oconee County monthly temperature data (average, maximum, and minimum) and precipitation and drought data (Palmer Drought Severity Index) are depicted for the last 50 years (1973-2023) on Figure 1-11 through Figure 1-15 and raw data are provided in Attachment 2.

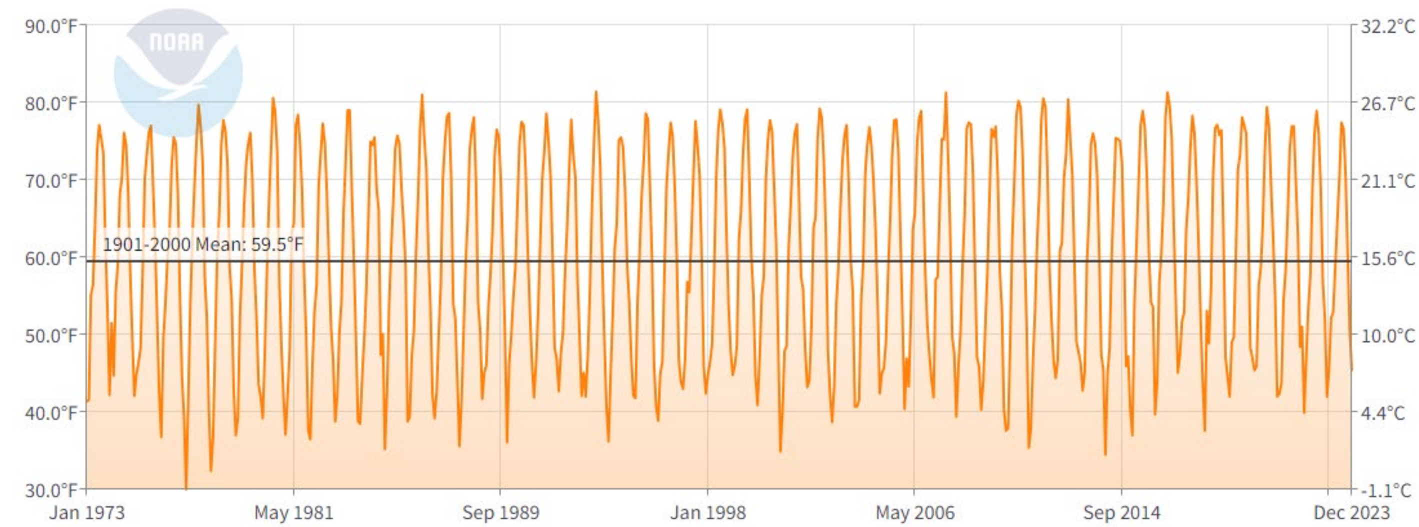


Figure 1-11. Oconee County Average Temperature Data (1973-2023)

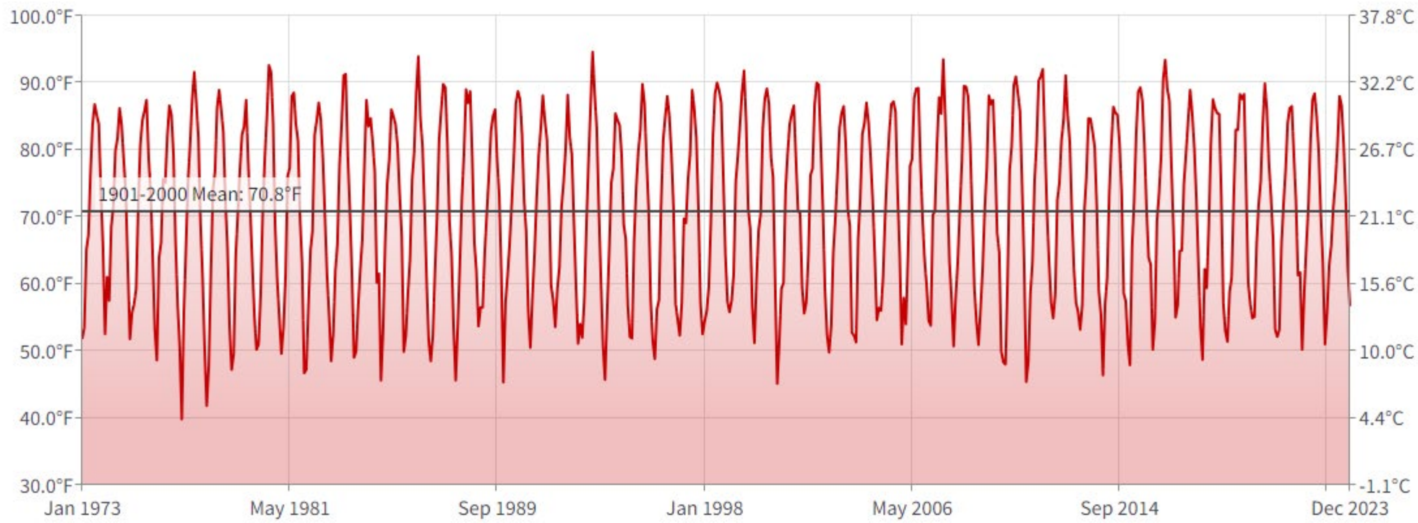


Figure 1-12. Oconee County Maximum Temperature Data (1973-2023)

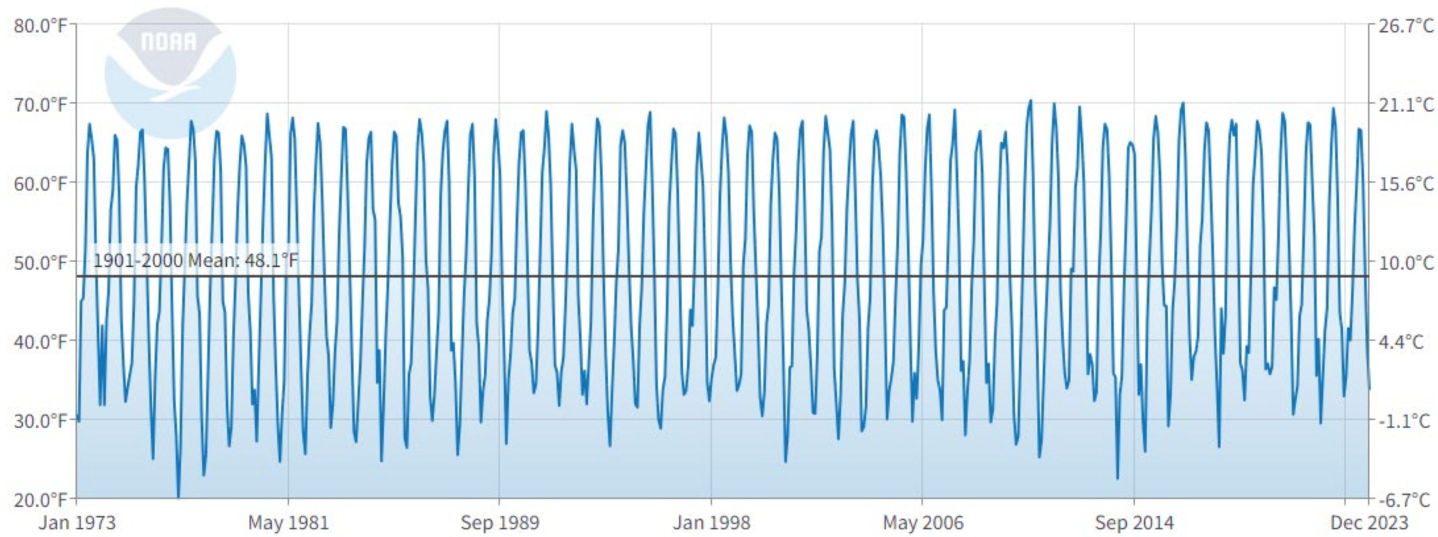


Figure 1-13. Oconee County Minimum Temperature Data (1973-2023)

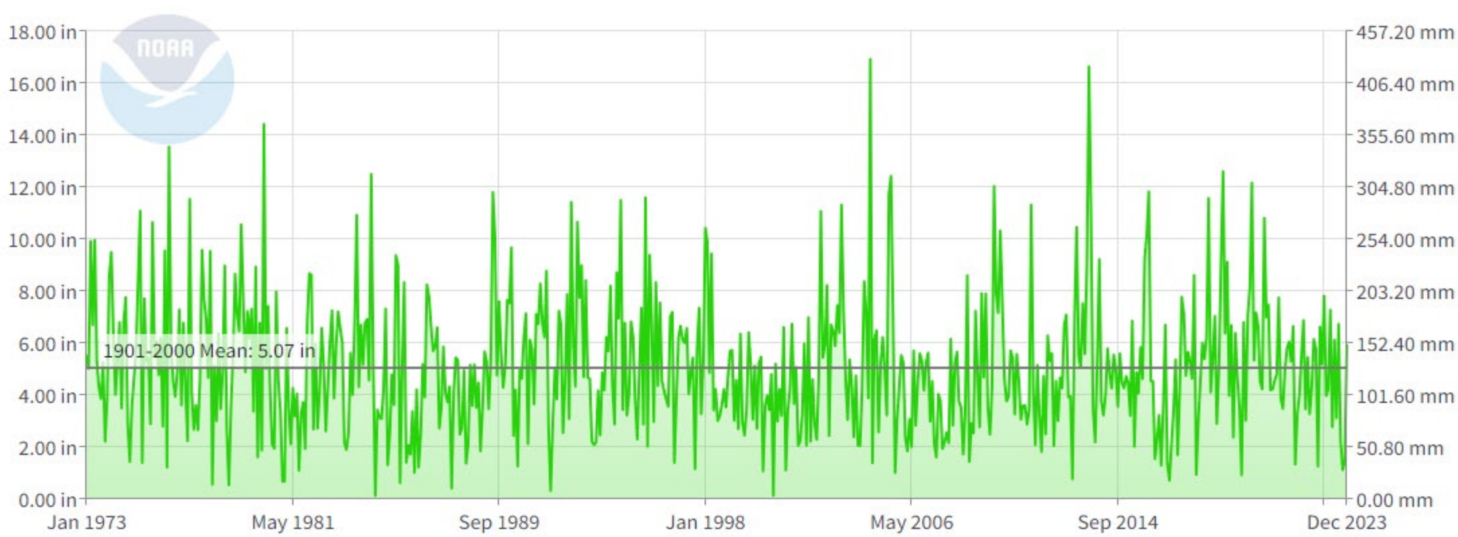


Figure 1-14. Oconee County Precipitation Data (1973-2023)

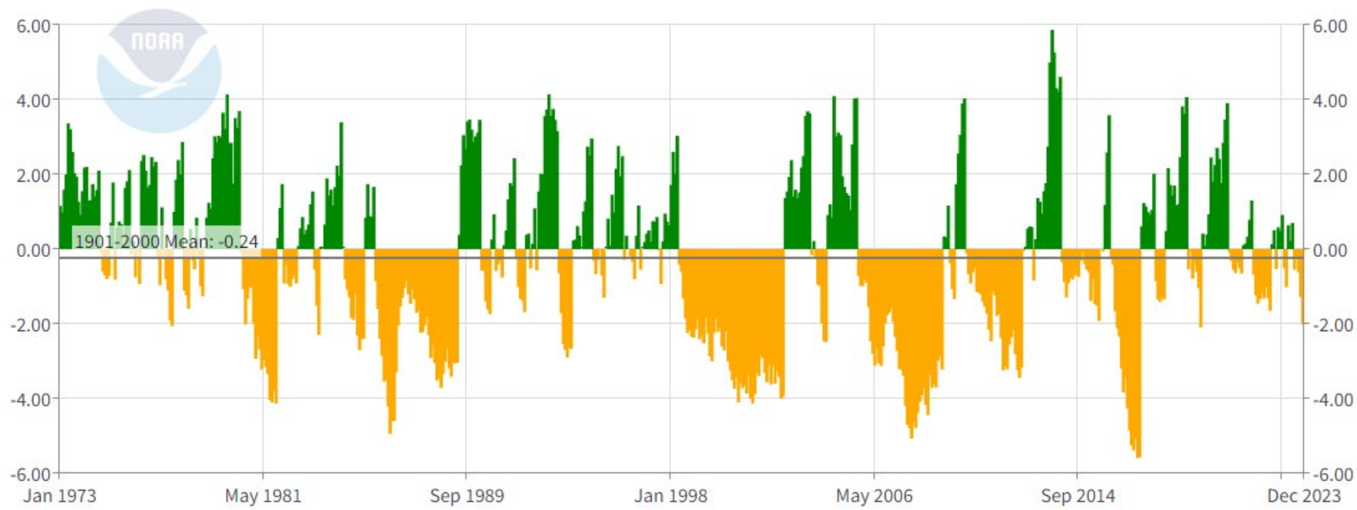


Figure 1-15. Oconee County Palmer Drought Severity Index (1973-2023)

2 Projected Climate Trends

2.1 South Carolina State Resilience Plan

The South Carolina Office of Resilience (SCOR) Strategic Statewide Resilience and Risk Reduction Plan identifies major risks and potential losses that could occur as a result of extreme weather events and provides strategies for local governments to implement resilience into their communities to mitigate potential flood risks. The resilience plan incorporates projected climate trends into their analysis in collaboration with the University of South Carolina, SC State Climatology Office and the SC Sea Grant Consortium and discusses climate variability, long-term changes, and project future changes in the state (SCOR 2023). This section summarizes major findings for future climate projections from the SC Resilience Plan; additional details regarding statistical methods and data sources are provided in the plan (SCOR 2023).

2.1.1 Temperature

Climate models project South Carolina temperature increases of 5° to 10°F by the year 2100, depending on future greenhouse gas emissions (SCOR 2023). Historic analysis documents maximum summer temperature increases across the state. Portions of the state are projected to experience up to 50 more days a year with temperatures above 95°F by the end of the century. Future temperature increases and more frequent and intense heat waves will likely cause the Southeast to experience a disproportionate health burden.

The degree of future changes in global temperature is dependent on greenhouse gases already emitted and those that will be emitted in future decades. Since future greenhouse gas emissions depend on unknown future energy technology and policies, different emission scenarios are typically considered. Two commonly-used scenarios include a “lower emissions” scenario (RCP4.5) and a “higher emissions” scenario (RCP8.5) and are dependent upon the amount of radiative forcing projected at the end of the century. To provide context, by 2100 the lower emissions (RCP4.5) scenario would lead to a CO_2 concentration of approximately 550 parts per million (ppm) (about double the pre-industrial value), and the higher emissions (RCP8.5) scenario would result in CO_2 concentration of about 900 ppm (more than triple the pre-industrial value) (SCOR 2023).

Per SCOR (2023), in a lower emission scenario, the average of all models projects an additional increased of 4°F from the 1991-2020 average by 2100; it ranges from an increase of approximately 3°F in a cooler model to 5°F in a warmer model. (This scenario assumes decreasing greenhouse gas emissions in the next decade and leveling CO_2 concentrations below 450 ppm by the end of the century. The high emissions scenario leads to 6°F, 8°F, and 10°F during the 21st century for the cooler model, ensemble average, and warmer model, respectively (Figure 2-1).

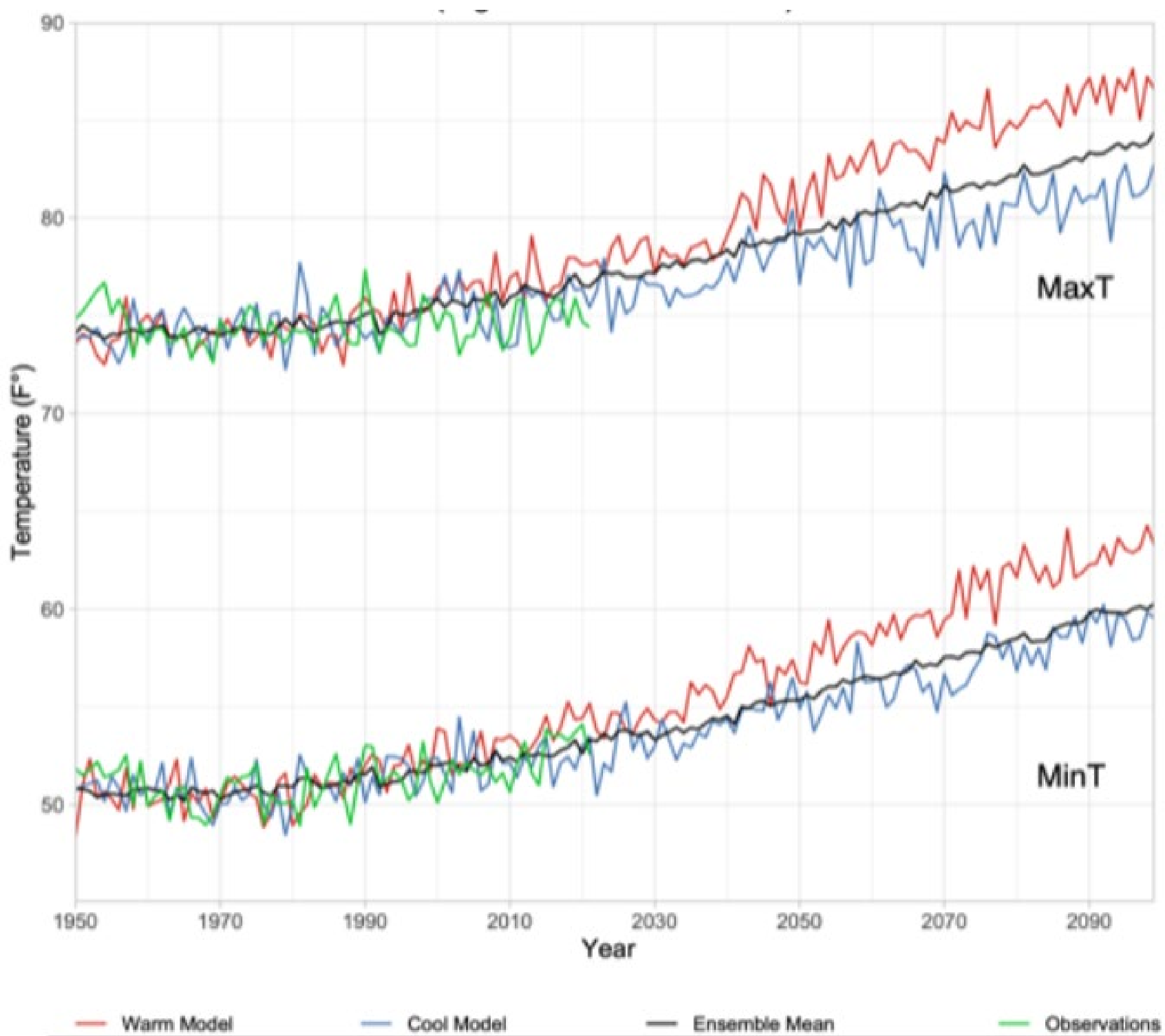


Figure 2-1. State Averaged Temperature Modeled vs. Observed under High Emissions

Projected changes in temperature extremes also vary by emissions scenario and individual model. By the end of the century, the number of days in which state averaged maximum temperature would exceed 95°F doubles in the lower emissions scenario, using output from a cooler model. In the higher emissions scenario with a warmer model, the number increases five-fold. Projections from a model ensemble average show changes in hot days across space and contrasts between emissions scenarios (Figure 2-2 and Figure 2-3). Such increases would likely have ecological impacts, as well as implications for human health and cooling costs during the warm season. Warm nights, as measured by state averaged minimum temperature above 75°F, also increase in future scenarios, from double to six times the number of days per year, depending on emissions scenario and model. Meanwhile, cold extremes, in this case defined by number of days in which the statewide average minimum temperature is cooler than 32°F, drop by half in the high emissions scenario by 2100.

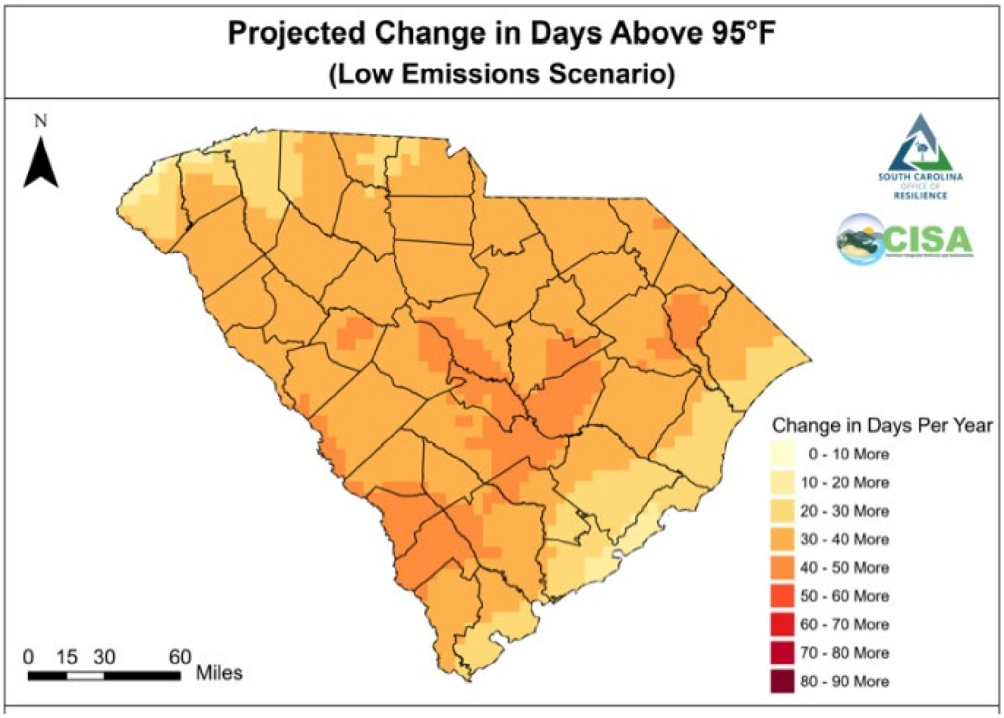


Figure 2-2. Projected increase in the number of days per year with maximum temperature above 95F (RCP 4.5 emissions scenario)

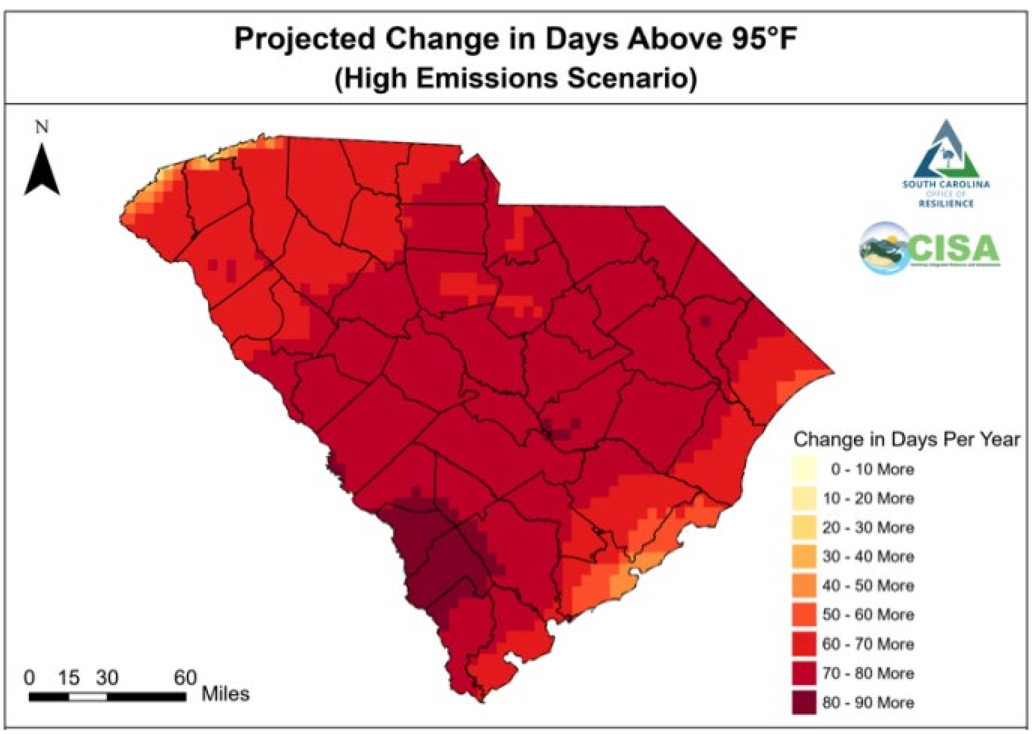


Figure 2-3. Projected increase in the number of days per year with maximum temperature above 95F (RCP 8.5 emissions)

2.1.2 Precipitation

Precipitation has varied greatly on a yearly and decadal basis and there are few statistically significant trends in annual or seasonal precipitation record. The number of precipitation days in fall has increased, however, overall, few other statistically significant trends are indicated for seasonal or annual total precipitation (SCOR 2023) and little change in total annual precipitation for the South Carolina is projected over this century (SCDNR 2022). However, increases in temperature will cause more rapid loss of soil moisture during dry spells, increasing the intensity of future droughts. The resulting decreases in water availability, exacerbated by population growth[1], will continue to increase competition for water.

Most future precipitation projections show modest increases through the 21st century, though there is a range among those models. One wetter model shows an average increase of about 10% with annual swings exceeding 40% of current average conditions. A drier model shows decreases of 10% and annual swings of 40% lower than current average conditions. The ensemble mean shows state-averaged precipitation increases of 5-10%. It is important to note that even if South Carolina's precipitation increases in the future, some of this increase would be offset by higher evaporation rates caused by warming. Under those conditions it is possible for precipitation to increase, but moisture availability in soils and watersheds to decrease because of higher evaporation rates. Moisture availability also depends on the nature of precipitation changes. If delivered in shorter, more intense bursts, precipitation runoff could increase, limiting soil moisture gains and increasing the risk of flooding (SCOR 2023).

Precipitation extremes potentially pose even greater social risks than changes in monthly, seasonal, or annual averages. Most measures of heavy precipitation have large interannual and interdecadal variability, even greater than that seen in monthly, seasonal, or annual total precipitation. While heavy precipitation has increased since the mid-1900s at many southeastern U.S. stations the picture is less consistent in South Carolina, where most stations do not exhibit significant long-term trends (Moraglia et al. 2022). Few stations in South Carolina, for example, have significant changes in the 1-day precipitation amounts expected with 50%, 10%, or 1% probability in any given year (often called 2-, 10-, and 100-year events, respectively). The large interannual and interdecadal variability, combined with the infrequency of extreme precipitation events, makes finding statistically significant long-term trends difficult (SCOR 2023).

The historical record reveals interannual and interdecadal variability in droughts, but no statistical trend. Rising temperatures in the 21st century will likely exacerbate agricultural and hydrologic drought. Projections of future meteorological drought in the state are mixed, though projections of drought measures that incorporate an evaporation component show a trend towards drier conditions in the Southeast (Ahmadalipour et al., 2017).

---

[1] South Carolina's population has increased to over 5.1 million people from an estimated 2.5 million people in 1970. Population growth is expected to continue with the population reaching 6.2 million people by 2035 (SCOR 2023).

2.2 Future Climate Sensitivities

Appendix E of the Operations Model Scenario Documentation Report contains the KT Climate Change Scenario Development Summary (Appendix A, Model Logic and Verification Report), which presents a summary of research and investigation into climate change and lays the foundation for defining climate change scenarios for incorporation into the CHEOPS model. The climate change summary presents overviews from the SCDNR State Climatology office, North Carolina State Climatologist Office, recent IPCC reporting, the Southeast Regional Assessment Project, the U.S. Global Change Research Program (Global Climate Change Impacts in the United States, and future changes in evaporation. The following is excerpted from the KT Climate Change Scenario Development Summary Report, Appendix E [Sept 19, 2012].

The precision of localized climate change projections for the Carolinas (and Georgia) based upon global models in questionable, due to an inability of the global models to correlate to past climate in this region. However, as there are few regionalized climate change projections available for the southeast, and as these regionalized climate change models are typically based upon larger global models, the use of global climate change models must be considered in developing climate change scenarios for studies related to the Savannah River Basin and relicensing the KT Project.

For the purposes of relicensing the KT Project, three climate change scenarios are proposed. Climate change modeling scenarios CC-01 and CC-02 are based on global climate change model projections (published by the USGCRP and IPCC) and are proposed for use as bookend scenarios representing the low end and high end of potential climate change in the Savannah River Basin, respectively. Alternately, proposed climate change modeling scenario CC-03 is based on a regionally downscaled climate change model (Multi-Model Ensembles) for the southeastern United States. This scenario seeks to provide a more localized and likely climate change scenario for the Savannah River Basen, which falls between the bookend projections of CC-01 and CC-02. It is believed that the implementation of these three scenarios will provide the most useful and accurate range of potential climate change effects to water supply in the Savannah River Basin, in the absence of more detail and definitive regionally based projections.

Two climate change sensitivities were developed during KT relicensing to represent future possible climate change conditions[2]. These two sensitivities are a simplification of possible future decreases in available water in the Savannah River basin as developed by the Operations Resource Committee and evaluated using the CHEOPS model. In the CHEOPS model, evaporation is based upon a monthly varying coefficient that defines the evaporative loss per reservoir. This evaporative loss represents the net change to inflows due to evaporation, direct precipitation to water surface, precipitation runoff, and changes to evapotranspiration losses.

[2] The same climate change sensitivities were also used for Project relicensing. See *Water Exchange Rates and Lake Jocassee Reservoir Levels Final Report* (Appendix D of Exhibit E).

2.2.1.1 Low Impact of Climate Change Sensitivity (CC-01 or ccLow)

The ccLow scenarios assumed a 3.0°F temperature increase, which was modeled as a 10 percent increase in natural surface evaporation applied uniformly over the entire 12 months of each year simulated. The application of the surface evaporation increase to the modeled net monthly evaporation coefficient included consideration of a positive or negative coefficient due to some months historically having more precipitation than evaporation. In the case of a negative monthly net evaporation coefficient, the adjustment was applied to always result in less water being available in that reservoir.

2.2.1.2 High Impact of Climate Change Sensitivity (CC-02 or ccHigh)

The ccHigh scenarios were simulated with the addition of a 6.0°F temperature rise and a 10 percent decrease in incremental inflows to each reservoir. The 6.0°F increase in temperature was modeled as a 20 percent increase in natural surface evaporation (see explanation of application of increased evaporation in Section 2.2.1.1). The 10 percent decrease in incremental inflow was applied to the Unimpaired Inflow (UIF) dataset for the period of record (January 1939 through December 31, 2011).

3 Climate Change and Project Impacts

3.1 Impacts to Operations

3.1.1 Operating Agreement Background and Model Development

In 1968, the USACE and SEPA entered into an Operating Agreement with Duke Power (a Duke Energy Carolinas, LLC predecessor company) regarding the water management between Duke Energy's Keowee-Toxaway Hydroelectric Project No. 2503 and the downstream USACE reservoirs existing at the time. The purpose of the 1968 Agreement was to ensure the Keowee-Toxaway Project operated such that the USACE and SEPA would be able to meet their hydropower generating requirements. The 1968 Agreement recognized a requirement for minimum flow releases form the USACE's most downstream project (J. Strom Thurmond Project) and other responsibilities, such as flood control, in connection with the USACE's Hartwell and J. Strom Thurmond Projects. The 1968 Agreement was based on equalizing the percentage of remaining usable storage in the USACE's Hartwell and J. Strom Thurmond Reservoirs with the percentage of remaining usable storage in Jocassee and Keowee Lakes on a weekly basis.

In 2014, the 1968 Operating Agreement was revised to reflect Duke Energy and USACE hydroelectric project operations and conditions in the basin at that time. Operational models (HEC-ResSim and CHEOPS) were developed and applied with climate change sensitivities to support the update of the Operating Agreement. See *Water Exchange Rates and Lake Jocassee Reservoir Levels Final Report* (Appendix D of Exhibit E). These climate change sensitivity assessments were simulated to evaluate possible impacts of future temperature increases, basin inflow reduction, extended drought, and future water withdrawal demands.

3.1.2 Updated CHEOPS Model

In support of Project relicensing, the CHEOPS Model was updated to reflect both mechanical and operational changes that have occurred since initial model development (i.e., since KT relicensing) and changes anticipated to occur during the term of the new Bad Creek license as discussed in the *Water Exchange Rates and Lake Jocassee Reservoir Levels Final Report* (Appendix D of Exhibit E).

3.1.3 Hydrology Data

The hydrologic dataset, Savannah River Unimpaired Flow 1939-2008 Time Series Extension Report (ARCADIS 2010), applied in the CHEOPS Model was provided by ARCADIS and prepared for Duke Energy, the Savannah District of the USACE, and the Georgia Environmental Protection Division. The study performed by ARCADIS developed UIF time series data (UIF database dated September 16, 2010) for the five hydroelectric developments on the Savannah River from Lake Jocassee to J. Strom Thurmond Lake. Due to the small size of the Bad Creek watershed, HDR developed the UIF to Bad Creek as a portioned one percent of the developed Jocassee UIF. As outlined in the Savannah River Unimpaired Flow 1939-2008 Time Series Extension Report released by ARCADIS on August 12, 2010, these data are suitable for the following purposes:

- Reservoir system operational modeling by Duke Energy and the USACE, with the USACE serving as a cooperating agency for the FERC relicensing of Duke Energy's KT Project
- Reservoir operational planning studies by the USACE
- Determination of desired flow regimes and consumptive water-use assessments for Georgia EPD

The 1939 through 2008 hydrologic dataset adopted by the Operations Resource Committee in August 2012 was used for KT model relicensing scenario development from September 2010 through December 2012. In the fall of 2012, Duke Energy, following a recommendation from the Operations Scenario Committee, funded an extension of the inflow dataset by three years. The inflow dataset was extended by ARCADIS using the same methodology developed to construct the original dataset expanding the period of record (POR) to 1939 through 2011. The final revised dataset was provided by ARCADIS on May 13, 2013, and extended the existing inflow hydrology files in the SR CHEOPS model as described in detail in the May 2013 Savannah River Unimpaired Flow Data Report (ARCADIS 2010, 2013).

3.1.4 Results

Minimum and maximum reservoir elevations and operating bands for all three hydrologic conditions are provided below (Normal, ccLow, and ccHigh). All simulated results presented in this report are based on the 15-minute model output, unless stated otherwise.

3.1.4.1 Baseline

Simulated reservoir elevations under all three hydrology conditions maintain reservoir elevations at Lake Keowee higher than the minimum operating levels for the existing municipal water intakes and Oconee Nuclear Station. Bad Creek and the KT Project were simulated to be in some stage of the LIP approximately 67 to 70% of the period of record depending on the hydrology (Table 2-1). Bad Creek simulated reservoir elevation duration curves and Keowee daily average flow releases for 1939-2011 are included in the relicensing study report.

Table 2-1. Minimum and Maximum Simulated Reservoir Elevations and Reservoir Operating Band for the Baseline Scenario (ft msl)

Hydrology	Bad Creek			
	Minimum	Median	Maximum	Band (ft)
Normal	2,246.1	2,259.5	2,280.0	33.9
ccLow	2,246.1	2,259.5	2,280.0	33.9
ccHigh	2,160.0	2,259.5	2,280.0	120.0
	Jocassee			
	Minimum	Median	Maximum	Band (ft)
Normal	1,084.1	1,107.0	1,110.0	25.9
ccLow	1,083.8	1,107.0	1,110.0	26.2
ccHigh	1,083.0	1,106.9	1,109.5	26.5
	Keowee			
	Minimum	Median	Maximum	Band (ft)
Normal	791.6	799.2	800.0	8.4
ccLow	791.6	799.2	800.0	8.4
ccHigh	792.0	799.1	800.0	8.0

3.1.4.2 Bad Creek II

As with the Baseline Scenario, the model results demonstrate minimum and maximum reservoir elevations for Bad Creek Reservoir, Lake Jocassee, and Lake Keowee meet the FERC license normal minimum and maximum reservoir elevations for both the Project as well as the KT Project under the three hydrology conditions (i.e., Normal, ccLow and ccHigh) (Table 2-2). As with the Baseline scenario, simulated reservoir levels for the Bad Creek Reservoir, Lake Jocassee, and Lake Keowee were generally comparable under Normal and ccLow hydrology, but additional Bad Creek Reservoir storage was accessed with the ccHigh hydrology. Simulated reservoir elevations under all three hydrology conditions maintain reservoir elevations at Lake Keowee higher than the minimum operating levels for the existing municipal water intakes and Oconee Nuclear Station. The Project and the KT Project were simulated to be in some stage of the LIP 81 to 87 percent of the period of record, depending on hydrology.

Table 2-2. Minimum and Maximum Simulated Reservoir Elevations for the Bad Creek II Scenario (ft msl)

Hydrology	Bad Creek			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	2,224.7	2,245.6	2,280.0	55.3
ccLow	2,224.7	2,245.6	2,280.0	55.3
ccHigh	2,151.6	2,245.3	2,280.0	128.4
	Jocassee			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	1,084.5	1,106.8	1,110.0	25.5
ccLow	1,084.2	1,106.8	1,110.0	25.8
ccHigh	1,080.0	1,106.7	1,109.9	29.9
	Keowee			
	Minimum	**Median**	**Maximum**	**Band (ft)**
Normal	791.6	799.2	800.0	8.4
ccLow	791.7	799.2	800.0	8.3
ccHigh	791.4	799.1	800.0	8.6

Model results for the Baseline and Bad Creek II scenarios were compared to identify potential differences in the effects of Bad Creek II as contrasted with existing license conditions. This comparison is focused primarily on reservoir elevation effects.

As demonstrated by the modeling results, the effects of Bad Creek II are constrained by Duke Energy's continued compliance with the existing KT Project FERC license including the KT LIP and the 2014 Operating Agreement. These requirements would not be modified with the relicensing of the Project or the construction and operation of Bad Creek II, so little to no effects to the downstream USACE hydroelectric projects were identified in the model results.

The relative size differences between the Bad Creek Reservoir, Lake Jocassee, and Lake Keowee directly affect how generation and pumping volumes affect reservoir levels within the three reservoirs. As a general guide and ignoring all other inflows, withdrawals, downstream flow releases, and evaporation, a change of 1.0 ft of reservoir storage at the Bad Creek Reservoir results in 0.05 ft (0.6 inches) of change in Lake Jocassee's water level. If the same volume of water was then moved upstream or downstream at Jocassee, Lake Keowee's level would change by 0.02 ft (0.25 inches).

There are very few differences in reservoir level-related measures when comparing the Baseline and Bad Creek II scenarios under all three hydrology conditions (Table 2-3, Table 2-4,Table 2-5). Both the Project and the KT Project normal minimum and normal maximum reservoir level limits in the existing Project license and the KT Project license would remain unchanged. As discussed above, reservoir elevations at Lake Keowee under the three hydrology conditions remain above the minimum reservoir operating levels for municipal water intakes and Oconee Nuclear Station, so no new effects to existing water intakes are anticipated.

Results demonstrate an additional 8.4 ft to 21.4 ft, depending on hydrology, of storage at the Bad Creek Reservoir would be accessed under the Bad Creek II scenario as compared to the Baseline scenario. Depending on hydrology, effects on minimum reservoir levels at Lake Jocassee and Lake Keowee are less pronounced

Table 2-3. Normal Hydrology Minimum Simulated Reservoir Elevations Compared to the Baseline Scenario (ft msl)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	2,246.1	1,084.1	791.6
Bad Creek II	2,224.7	1,084.5	791.6
Difference from Baseline	**-21.4**	**0.4**	**0.0**

Table 2-4. ccLow Sensitivity Minimum Simulated Reservoir Elevations Compared to the Baseline Scenario (ft msl)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	2,246.1	1,083.8	791.6
Bad Creek II	2,224.7	1,084.2	791.7
Difference from Baseline	**-21.4**	**0.4**	**0.1**

Table 2-5. ccHigh Sensitivity Minimum Simulated Reservoir Elevations Compared to the Baseline Scenario (ft msl)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	2,160.0	1,083.0	792.0
Bad Creek II	2,151.6	1,080.0	791.4
Difference from Baseline	**-8.4**	**-3.0**	**-0.6**

3.1.5 Lake Level Fluctuations and Shoreline Erosion

3.1.5.1 Fluctuation Rates

Model results in Table 2-6 demonstrate the maximum reservoir fluctuation over a 24-hour window during the period of record for both the Baseline and Bad Creek II scenarios. Typically, about 60% of the time, the Bad Creek II scenario results in an approximately 15-foot increase in 24-hour fluctuation at Bad Creek as compared with the Baseline scenario. In contrast, at Jocassee, about 97 percent of the time, the Bad Creek II scenario results in an approximately 0.4- to 0.2-ft decrease in 24-hour fluctuation as compared to the Baseline scenario. The decreased range in 24-hour fluctuations in Lake Jocassee is due to increased generation and pumping volumes associated with Bad Creek II. Both Bad Creek and Bad Creek II operations are synched with Jocassee Pumped Storage Station operations in the model such that both Bad Creek and Bad Creek II typically generate and pump when Jocassee generates and pumps. However, a larger volume of water moves between Bad Creek Reservoir and Lake Jocassee in the Bad Creek II scenario, offsetting more of the lake level fluctuation effects at Lake Jocassee caused by Jocassee Pumped Storage Station operations. The model indicates little to no difference in 24-hour fluctuations at Lake Keowee between the Bad Creek II scenario and the Baseline scenario (Table 2-6).

The reduction in Jocassee reservoir elevation fluctuations for the Bad Creek II scenario is demonstrated by the Performance Measures related to spawning success. Under all three hydrology conditions, reservoir elevations are within a tighter fluctuation band compared to the Baseline scenario. At Lake Keowee, there are no significant differences in the spawning fluctuation bands. In summary, when accounting for future climate change at the Project (and Bad Creek II), there are no adverse effects from operations identified in modeled results.

Table 2-6. Normal Hydrology Maximum Simulated Reservoir Fluctuation Over 24-hours Compared to the Baseline Scenario (ft)

Scenario	Bad Creek	Jocassee	Keowee
Baseline (Existing License)	33.1	4.3	2.3
Bad Creek II	52.6	4.5	2.3
Difference from Baseline	**19.2**	**0.2**	**0.0**

4 References

Ahmadalipour, A., Moradkhani, H., & Svoboda, M. 2017. Centennial drought outlook over the CONUS using NASA-NEX downscaled climate ensemble. International Journal of Climatology, 37(5), 2477–2491. https://doi.org/10.1002/joc.4859. Accessed September, 2024.

ARCADIS. 2010. Savannah River unimpaired flow 1939-2009 time series extension. Prepared for Duke Energy, the Savannah District of the U.S. Army Corps of Engineers, and the Georgia Environmental Protection Division. August 2010.

______. 2013. Savannah River Unimpaired Flow Data Report Revision 2 (May 2013): 2009 – 2011 Unimpaired Flow Extension. Prepared for Duke Energy. May 10, 2013.

Intergovernmental Panel on Climate Change (IPCC). 2021. Climate Change 2021: The Physical Science Basis, the Working Group I contribution to the Sixth Assessment Report, Cambridge University Press, Cambridge, UK. URL: https://www.ipcc.ch/report/ar6/wg1/. Accessed September, 2024.

Moraglia, G., Brattich, E., and Carbone, G. 2022. Precipitation trends in North and South Carolina. Journal of Hydrology Regional Studies 44: 101201.

National Aeronautics and Space Administration (NASA). 2023. Global Warming vs. Climate Change. Accessed January 2023. [URL]: https://climate.nasa.gov/global-warming-vs-climate-change/

National Oceanic and Atmospheric Administration National Centers for Environmental Information (NOAA). 2022. South Carolina State Climate Summary. [URL]: https://statesummaries.ncics.org/chapter/sc/. Accessed August 2024.

______. 2024. Climate at a Glance, County Time Series. [URL]: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/time-series. Accessed August 2024.

South Carolina Department of Natural Resources. 2022. Overview of South Carolina's Climate and Hazards. Prepared by South Carolina State Climatology Office Land, Water, and Conservation Division. [URL]: https://www.dnr.sc.gov/climate/sco/Publications/SCClimateOverview.pdf. Access August 2024.

United Nations Climate Action (UNCA). 2022. What is Climate Change. [URL]: https://www.un.org/en/climatechange/what-is-climate-change. Accessed January 2023.

South Carolina Office of Resilience (SCOR). 2023. Strategic Statewide Resilience and Risk Reduction Plan. URL: https://scor.sc.gov/resilience. Accessed September 2024.

Attachment 1

Keowee-Toxaway Relicensing Reports Relevant to Climate Change and Future Operations

This page intentionally left blank.

Rev Date: 10/10/2014

OPERATING AGREEMENT

executed by

THE UNITED STATES OF AMERICA

acting by and through the

SAVANNAH DISTRICT, U.S. ARMY CORPS OF ENGINEERS

and the

SOUTHEASTERN POWER ADMINISTRATION

and

DUKE ENERGY CAROLINAS, LLC

THIS OPERATING AGREEMENT, executed as of the last date noted on the signature pages, between the UNITED STATES OF AMERICA (hereinafter called the Government), acting by and through the SAVANNAH DISTRICT ENGINEER (hereinafter called the District Engineer), and the SOUTHEASTERN POWER ADMINISTRATOR (hereinafter called the Administrator), and DUKE ENERGY CAROLINAS, LLC (hereinafter called the Company), a limited liability company organized and existing under the laws of the State of North Carolina, with the District Engineer, the Administrator, and the Company hereinafter singularly called Party and collectively called the Parties;

0.1 WHEREAS the Company pursuant to the original 50-year license issued by the Federal Power Commission, predecessor to the Federal Energy Regulatory Commission (hereinafter called FERC), constructed on certain tributaries of the Savannah River a project known as the Keowee-Toxaway Hydroelectric Project, designated as FERC Project No. 2503 (hereinafter called the Keowee-Toxaway Project); and

0.2 WHEREAS the Keowee-Toxaway Project is composed of two adjoining developments, the most downstream of which is called the Keowee Development, which includes a reservoir (Lake Keowee) and a conventional hydroelectric station (Keowee Hydro Station), and the other the Jocassee Development, which includes a reservoir (Lake Jocassee) and a pumped storage hydroelectric station (Jocassee Pumped Storage Station); and

0.3 WHEREAS the Company also owns and operates the Bad Creek Pumped Storage Project, which includes the Bad Creek Reservoir and Bad Creek Pumped Storage Station, operated under a separate FERC license (Project No. 2740, hereinafter called the Bad Creek Project) on a tributary to Lake Jocassee in the Savannah River Basin; and

0.4 WHEREAS the Company operates the Keowee-Toxaway Project and the Bad Creek Project (hereinafter collectively called the Company Projects) in coordination with one another; and

0.5 WHEREAS the Government has three existing hydroelectric reservoir projects on the Savannah River downstream of the Keowee-Toxaway Project known as the J. Strom Thurmond (hereinafter called Thurmond), Richard B. Russell (hereinafter called Russell), and Hartwell projects (hereinafter collectively called the Federal Projects); and

0.6 WHEREAS the Federal Projects are operated and maintained by the District Engineer and the Administrator markets the available power and energy from the Federal Projects; and

0.7 WHEREAS Article 32 of the original FERC license for the Keowee-Toxaway Project required the Company to enter into an agreement with an authorized representative of the Chief of Engineers, Department of the Army, and an authorized representative of the Department of the Interior, assuring the Keowee-Toxaway Project would be operated so the capability of those downstream Federal Projects in existence at the time to meet power generating requirements would not be impaired, and further recognizing the requirement for water releases from Thurmond Lake (the most downstream reservoir) for low flow control and other responsibilities in connection with the Hartwell and Thurmond lakes, including flood control, and such agreement was executed in 1968 (hereinafter called the 1968 Agreement); and

0.8 WHEREAS the Company and 16 other organizations entered into a binding contract (hereinafter called the Relicensing Agreement) with an effective date of December 1, 2013, and which Relicensing Agreement includes among other things a Low Inflow Protocol (hereinafter called the LIP) specifying operating procedures for the Company Projects during periods of drought; and

0.9 WHEREAS the District Engineer instituted a Drought Plan (hereinafter called the DP) in 1989 to address operation of the Federal Projects during droughts and said DP was last updated in 2012; and

0.10 WHEREAS the Parties desire to enter into an Operating Agreement that is consistent with both the LIP and the DP; and

0.11 WHEREAS the District Engineer, the Administrator, and the Company are terminating the 1968 Agreement and simultaneously executing this Operating Agreement, developed after comprehensively assessing potential effects of this Operating Agreement and in conjunction with the FERC relicensing of the Keowee-Toxaway Project; and

0.12 WHEREAS the functions of the Administrator have been transferred from the Department of the Interior to the Department of Energy; and

0.13 WHEREAS the District Engineer and the Administrator have been authorized as representatives of the Department of the Army and the Department of Energy, respectively, to enter into the said Operating Agreement with the Company;

NOW, THEREFORE, the Parties hereto mutually covenant and agree as follows:

Section 1. Principle of Operation of the Company Projects in Conjunction with the Downstream Federal Projects

1.1 The principle of equalizing the percentage of combined remaining usable water storage in the Company Projects with the percentage of combined remaining usable water storage in the Federal Projects will be followed to determine the minimum weekly water release requirement from the Keowee Development, subject to the following provisions.

1.2 For purposes of this Operating Agreement, the usable storage in the respective projects is as defined by the reservoir elevation curves shown on Exhibit 1 with all reservoir elevations stated in feet above Mean Sea Level (AMSL) using National Geodetic Vertical Datum of 1929 (NGVD 29), attached hereto and by reference made a part hereof, and described as follows:

(a) Bad Creek Project. The volume in the Bad Creek Reservoir between elevation 2150 feet AMSL and 2310 feet AMSL.

(b) Jocassee Development. The volume in Lake Jocassee between elevation 1080 feet AMSL and 1110 feet AMSL. Note the elevation curves for the Jocassee Development also identify Stage Minimum Elevations for each Stage (i.e., Stage 0 through 4) of the LIP.

(c) Keowee Development. The volume in Lake Keowee between elevation 790 feet AMSL and 800 feet AMSL. Note the elevation curves for the Keowee Development also identify Stage Minimum Elevations for each Stage (i.e., Stage 0 through 4) of the LIP.

(d) Hartwell Project. The volume in Hartwell Lake between elevation 625 feet AMSL and the curve denoting top-of-power pool and minimum flood control pool.

(e) Russell Project. The volume in Russell Lake between elevation 470 feet AMSL and 475 feet AMSL.

(f) Thurmond Project. The volume in Thurmond Lake between elevation 312 feet AMSL and the curve denoting top-of-power pool and minimum flood control pool.

1.3 For purposes of this Operating Agreement, remaining usable storage at any time for the Company Projects is the sum of the volume of water contained between each reservoir's lowest elevation as described in subsection 1.2 and its actual reservoir elevation as measured in the forebay of each reservoir by the Company. The remaining usable storage for the Federal Projects at any time is the sum of the volume of water contained between each reservoir's lowest elevation as described in subsection 1.2 and the actual reservoir elevation as measured in the forebay of each reservoir by the District Engineer. The remaining usable storage for the Company Projects is expressed as a percentage of the sum of the total usable storage in the Company Projects. The remaining usable storage for the Federal Projects is expressed as percentage of the sum of the total usable storage in the Federal Projects.

Section 2. Determination of Minimum Weekly Water Release Requirement from the Keowee Development

2.1 The minimum weekly water release requirement from the Keowee Development will be calculated by the District Engineer as described below, subject to the concurrence of the other Parties. The minimum weekly water release requirement will be calculated based on the remaining usable water storage at each reservoir at midnight Tuesday and the water shall be released during the following seven days (i.e., Wednesday through Tuesday), unless the District Engineer requests a lesser amount.

2.2 For purposes of this Operating Agreement, water releases from the Keowee Development include hydroelectric generation flows, calculated flood gate releases, leakage through the Keowee Hydro Station and dam seepage, with such leakage and seepage estimated to total 650 acre-feet per week.

2.3 Whenever the remaining usable storage at the Federal Projects is 90 percent or above or the remaining usable storage at the Company Projects is an equal or lower percentage than the remaining usable storage at the Federal Projects at Tuesday midnight, there shall be no required minimum weekly water release from the Keowee Development during the following seven days. Further, if the remaining usable storage at the Federal Projects is below 90 percent for reasons other than reduced inflow to the Federal Projects, there shall be no required minimum weekly water release from the Keowee Development during the following seven days. If the Federal Projects are intentionally maintained at lower levels (e.g., to support maintenance situations), the Company shall not be required to provide a greater volume of minimum weekly water releases from the Keowee Development than would have otherwise been required.

2.4 Whenever the remaining usable storage at the Federal Projects is below 90 percent and equal to or greater than 85 percent (e.g., 88 percent) at Tuesday midnight, the minimum weekly water release requirement from the Keowee Development during the following seven days shall be calculated so the remaining usable storage at the Company Projects will be twice as many percentage points below 100 percent (e.g., 4 percent below or usable storage of 96 percent) as the remaining usable storage at the Federal Projects was below 90 percent on Tuesday midnight, except the minimum weekly water release required in the following seven days from the Keowee Development shall not exceed 25,000 acre-feet.

2.5 Whenever the remaining usable storage at the Federal Projects is below 85 percent and equal to or greater than 80 percent (e.g., 82 percent) at Tuesday midnight, the minimum weekly water release requirement from the Keowee Development during the following seven days shall be calculated so the remaining usable storage at the Company Projects will be twice as many percentage points below 100 percent as the remaining usable storage at the Federal Projects was below 90 percent on Tuesday midnight (e.g., 16 percent below, or usable storage of 84 percent), except the minimum weekly water release required in the following seven days from the Keowee Development shall not exceed 20,000 acre-feet.

2.6 Whenever the remaining usable storage at the Federal Projects is below 80 percent (e.g., 79 percent) or the DP is in Level 1 at Tuesday midnight, the minimum weekly water release requirement from the Keowee Development during the following seven days shall be determined so the remaining usable storage at the Company Projects will be the same percentage as the remaining usable storage at the Federal Projects was at Tuesday midnight (e.g., 79 percent), except the minimum weekly water release required in the following seven days from the Keowee Development shall not exceed 18,750 acre-feet.

2.7 Whenever the DP is in Level 2 at Tuesday midnight, the minimum weekly water release requirement from the Keowee Development during the following seven days shall be calculated so the remaining usable storage at the Company Projects will be the same percentage as the remaining usable storage at the Federal Projects was at Tuesday midnight, except the minimum weekly water release required in the following seven days from the Keowee Development shall not exceed 15,000 acre-feet.

2.8 Whenever the DP is in Level 3 and the remaining usable storage at the Federal Projects is at or above 25 percent at Tuesday midnight, the minimum weekly water release requirement from the Keowee Development during the following seven days shall be calculated so the remaining usable storage at the Company Projects will be the same percentage as the remaining usable storage at the Federal Projects was at Tuesday midnight, except the minimum weekly water release required in the following seven days from the Keowee Development shall not exceed 10,000 acre-feet.

2.9 Whenever the remaining usable storage at the Federal Projects is below 25 percent but greater than 12 percent at Tuesday midnight, the minimum weekly water release requirement from the Keowee Development during the following seven days shall be calculated so the remaining usable storage at the Company Projects will be the same percentage as the remaining usable storage at the Federal Projects was on Tuesday midnight, except the water release required in the following seven days from the Keowee Development shall not exceed 7,500 acre-feet.

2.10 Whenever the remaining usable storage at the Company Projects is at or below 12 percent at Tuesday midnight, Keowee Hydro Station leakage and dam seepage (estimated at 650 acre-feet per week) will be released from the Keowee Development, but no other releases will be required during the following seven days.

2.11 Notwithstanding the above Sections 2.3 through 2.10, prior to December 1, 2019, the Company shall not be required to provide any water releases from the Keowee Development that would cause the remaining usable storage in the Company Projects to drop below 71,408 acre-feet consistent with the LIP. This represents the volume of water in the Keowee Development between elevations 794.6 feet AMSL and 790.0 feet AMSL. The period prior to December 1, 2019, provides time for the Company to modify its Oconee Nuclear Station to allow its normal operation at Lake Keowee levels below 794.6 feet AMSL. In the event by June 1, 2018, both a new FERC license replacing the original FERC license referenced in Section 0.7 is issued and the identified modifications to the Oconee Nuclear Station are completed, Duke Energy will pursue written concurrence from the signatories to the Relicensing Agreement to modify the LIP to allow the full requirements for water releases from the Keowee Development to go into effect prior to December 1, 2019. If all the signatories to the Relicensing Agreement provide such written concurrence to a modification of the LIP, then Duke Energy will pursue the LIP revision process as described in the Relicensing Agreement, to revise the LIP and will implement such revised LIP when the required governmental approvals are received.

2.12 Notwithstanding the above Sections 2.3 through 2.10, the Company shall not be required to provide water releases from the Keowee Development that would cause the elevation of either Lake Jocassee or Lake Keowee to fall below its respective Stage Minimum Elevations as required by the LIP and as shown in Exhibit 1.

Section 3. <u>Operation of the Keowee-Toxaway Project during Floods and for Navigation</u>

3.1 The Company will operate the Company Projects during flood periods so as not to cause peak discharges downstream of the Keowee Development greater than those which would have occurred in the absence of the Company Projects, except due to Acts of God or other Force Majeure events, in accordance with ER 1110-2-241 and the Flood Control Act of 1944. During flood periods, close cooperation between the Company and the District Engineer will be exercised.

3.2 Except during floods or other Force Majeure events, the Company shall release water from the Keowee Development at such rate or such volume as the Secretary of the Army may prescribe in the interest of navigation in accordance with ER 1110-2-241 and the Flood Control Act of 1944, but only in so far as such operation and water releases are in compliance with the effective hydropower operating license issued by the FERC to the Company.

Section 4. <u>Exchange of Information</u>

On Wednesday of each week, the Parties hereto will exchange information on current and proposed water releases, pool elevations and other operating conditions pertinent to the operation of the Company Projects and the Federal Projects for the purpose of carrying out the provisions of this Operating Agreement. The Company will provide daily (midnight) reservoir elevation levels for the Company Projects and Keowee Development discharge volumes for the previous week to the District Engineer.

Section 5. <u>Protection of Water Supply</u>

5.1 The District Engineer will require any owner of a Large Water Intake (i.e., water intake with a maximum capacity greater than or equal to one million gallons per day) who is allocated water from the Federal Projects after the Effective Date of this Operating Agreement to implement coordinated water conservation measures when the DP is in effect similar to the water conservation measures required by the LIP for Large Water Intake owners on the Company Projects. Only that portion of the water allocated after the Effective Date of this Operating Agreement will be subject to the requirements of this subsection 5.1.

5.2 The Company will require owners of Large Water Intakes on the Company Projects to comply with the LIP.

5.3 The District Engineer and the Company will require whenever feasible that all Large Water Intakes used for municipal, industrial and power generation purposes that are constructed, expanded or rebuilt on the Company Projects and the Federal Projects after the Effective Date of this Operating Agreement be capable of operating at their permitted capacities at reservoir elevations as low as the applicable hydroelectric station can operate.

5.4 The District Engineer and the Company will encourage all water users withdrawing water from their respective reservoirs to conserve water in a coordinated manner when the DP is in effect similar to the water conservation measures required by the LIP on the Company Projects.

Section 6. <u>Term of Agreement</u>

This Operating Agreement shall become effective with the date of the last signature (the Effective Date of this Operating Agreement) and terminate with the expiration of the first non-annual FERC license for the Keowee-Toxaway Project issued after 2014.

Section 7. <u>Modification of Operating Agreement and Handling of New Data</u>

7.1 Any Party to this Operating Agreement can request modification of this Operating Agreement by notifying the other Parties in writing. Within 30 days following such written notice, the Party requesting the modification will convene a meeting of the Parties to discuss the proposed modification. Each Party shall use its best effort to reach timely agreement on the requested modification. This Operating Agreement can be modified only when all Parties agree with and sign the proposed modification.

7.2 As a minimum, the Parties shall meet to review this Operating Agreement and consider if modifications are needed if: (i) the LIP is modified in such a manner as to further restrict the Company's ability to make flow releases from the Keowee Development during droughts or (ii) the DP is modified in such a manner as to allow the District Engineer to make greater flow releases from the Thurmond Project during droughts. For the purposes of this subsection 7.2, short-term, modest increases in flow releases (e.g., releasing 3,800 cubic feet per second (cfs) instead of 3,100 cfs for three months while in DP Level 3) from the Thurmond Project as a result of implementing adaptive management requested by other state and / or federal agencies to improve water quality in Savannah Harbor will not trigger a need to review the Operating Agreement.

7.3 If the Company or the District Engineer acquires new data revising the usable water storage volumes or Keowee Hydro Station leakage and dam seepage rates used in implementing this Operating Agreement, these new data may be provided to the other Parties by written notice for review. If the Parties agree to use these new data in calculations required by this Operating Agreement, they shall formally modify (i.e., with signatures) this Operating Agreement.

Section 8. <u>Filing of Agreement</u>

Once it becomes effective, the Company shall file a copy of this Operating Agreement with the FERC.

Section 9. Miscellaneous Agreements

9.1 Notice. Each Party shall designate a representative for the receipt of notices and communicate its representative's contact information to the other Parties. All notices required to be given under this Operating Agreement shall be in writing and be given by personal delivery, overnight express service, or U.S. mail to each Party. The sender shall retain proof of posting or delivery, and notices shall be effective upon the date and time identified on the proof of posting or delivery. As designated representatives change over time, each Party shall be responsible for providing the other Parties with their updated contact information in a timely and accurate manner.

9.2 Human Health and Safety. Nothing in this Operating Agreement shall limit any Party's ability to take any and all lawful actions at its projects to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided nothing in this Operating Agreement obligates any Party to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. The Parties acknowledge such protection measures may be implemented without prior consultation or notification. In the event the Company takes such protective measures, the Company will consult with the District Engineer to determine how to best release any water in the amounts identified in Section 2 that was not released due to the Company's protective measures when such protective measures are no longer needed.

9.3 Protection of Legal Obligations. Nothing in this Operating Agreement shall require any Party to take actions inconsistent with its obligations under existing contracts (including but not limited to the Relicensing Agreement for the Company), licenses, other existing legal obligations, or Congressional authorizations. Each Party represents it possesses the requisite authority to enter into this Operating Agreement and to fulfill its requirements. If a Party subsequently determines a requirement of this Operating Agreement prevents compliance with an existing legal obligation, it may request modification of the Operating Agreement pursuant to Section 7.

9.4 Force Majeure. Force Majeure shall mean: (a) war, riots, insurrection, rebellion, floods, hurricanes, tornadoes, earthquakes, storms, and other natural calamities excluding drought; or (b) acts or inaction of any government authority which directly affect the operation of the Company Projects or its Oconee Nuclear Station. Such acts, events or conditions listed in (a) and (b) above shall only be deemed a Force Majeure to the extent they: (i) directly impact the Company's ability to release water to the Federal Projects while continuing to operate the Company Projects or its Oconee Nuclear Station in compliance with its operating licenses or the Relicensing Agreement and are beyond the reasonable control of the Company when claiming a delay or inability to perform, and (ii) are not the result of the willful misconduct or negligent act or omission of the Company. Any delays in performance, including the inability to perform, by the Company shall not constitute a default or breach hereunder if and to the extent such delays of performance, including the inability to perform, are caused by a Force Majeure event.

9.5 1968 Agreement is Terminated. The Parties agree and acknowledge the 1968 Agreement is hereby terminated and of no further force or effect coincident with the affixing of the last of the three Party's signatures on this Operating Agreement.

9.6 Mitigation. The Company will provide the mitigation identified in the Government's Finding Of No Significant Impact for this Agreement prior to December 1, 2019.

IN WITNESS WHEREOF, the Parties hereto have caused this Operating Agreement to be executed in several counterparts as of the day and year last written below.

UNITED STATES OF AMERICA

Department of the Army

By ________________________ 10/17/14
Thomas J. Tickner Date
Colonel, U.S. Army Corps of Engineers
District Engineer

Department of Energy

By ________________________ 10/17/14
Kenneth E. Legg Date
Administrator
Southeastern Power Administration
Elberton, Georgia 30635

DUKE ENERGY CAROLINAS, LLC

By ________________________ 10/17/14
Steven D. Jester, Vice-President Date
Water Strategy, Hydro Licensing, and
Lake Services
Duke Energy Carolinas, LLC
Charlotte, North Carolina 28201

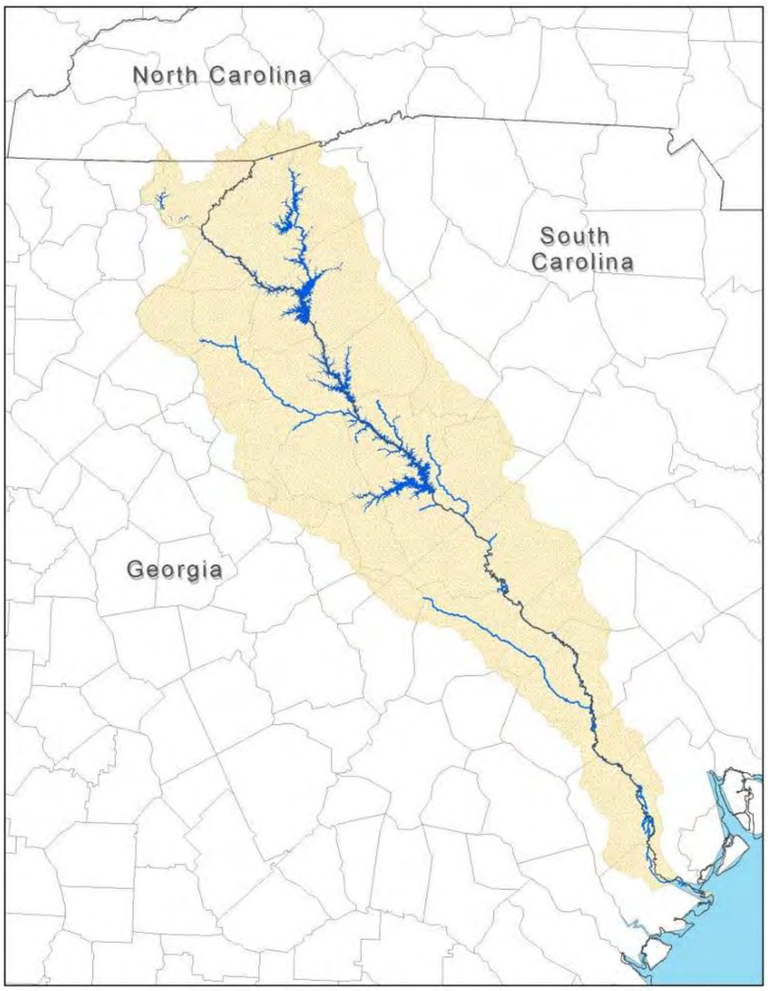
(SEAL)

ATTEST:

____
~~Secretary~~ Assistant Corporate Secretary

FINAL
ENVIRONMENTAL ASSESSMENT

NEW OPERATING AGREEMENT BETWEEN U.S. ARMY CORPS OF ENGINEERS, SOUTHEASTERN POWER ADMINISTRATION, AND DUKE ENERGY CAROLINAS, LLC



US Army Corps of Engineers
Savannah District
October 2014

FINAL ENVIRONMENTAL ASSESSMENT
NEW OPERATING AGREEMENT
BETWEEN U.S. ARMY CORPS OF ENGINEERS, SOUTHEASTERN POWER ADMINISTRATION, AND DUKE ENERGY

TABLE OF CONTENTS

Section	Title	Page No.

TABLE OF CONTENTS
(Continued)

Section	Title	Page No.

TABLE OF CONTENTS
(Continued)

Section	Title	Page No.

TABLE OF CONTENTS
(Continued)

Section	Title	Page No.

TABLE OF CONTENTS
(Continued)

Section	Title	Page No.

TABLE OF CONTENTS
(Continued)

Section	Title	Page No.

TABLE OF CONTENTS
(Continued)

Section **Title** **Page No.**

APPENDICES

LIST OF FIGURES

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure | **Title** | **Page No.**

LIST OF FIGURES
(Continued)

Figure **Title** **Page No.**

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF TABLES

Table **Title** **Page No.**

LIST OF TABLES
(Continued)

Table	Title	Page No.

LIST OF TABLES
(Continued)

Table	Title	Page No.

FINDING OF NO SIGNIFICANT IMPACT

Name of Action: New Operating Agreement between the U.S. Army Corps of Engineers, the Southeastern Power Administration, and Duke Energy Carolinas, LLC

1. Description of the Proposed Action

The proposed action (Alternative 3) consists of a new Operating Agreement between the U.S. Army Corps of Engineers, the Southeastern Power Administration, and Duke Energy Carolinas, LLC. Duke Energy would modify the Oconee Nuclear Station to allow operations to continue at Lake Keowee elevations down to 790 feet AMSL. A3 would modify the 1968 Agreement as follows:

- Incorporate additional storage capacity in Duke Energy's Bad Creek Reservoir and USACE's Richard B. Russell Reservoir into the calculations determining the remaining usable storage and weekly water release requirement from Lake Keowee. As a result, A3 equalizes the percentage of combined remaining usable storage capacity at USACE's Hartwell, RBR, and J. Strom Thurmond Reservoirs with the percentage of combined remaining usable storage capacity at Duke Energy's Bad Creek Reservoir and Lakes Jocassee and Keowee.
- Revise the Lake Keowee minimum elevation for calculating usable storage to elevation 790 feet AMSL (enabling a 10-foot drawdown of Lake Keowee).
- Lower the Lake Jocassee minimum reservoir elevation six feet (from 1086 feet AMSL to 1080 feet AMSL) and eliminate the allowance for pumping volume in the weekly water release calculation.
- Incorporate the USACE July 2012 Drought Plan operating protocols.
- Incorporate Duke Energy's Low Inflow Protocol (LIP) which provides rules for how they will operate their reservoirs during droughts, including minimum lake elevations and water use conservation for existing and future water intake owners located on Keowee-Toxaway Project Reservoirs.

A3 includes the following provisions to enhance drought tolerance in the Upper Savannah River Basin:

- Duke Energy will require owners of Large Water Intakes on the Duke Energy Projects to comply with its Low Inflow Protocol.
- USACE will require any owner of a Large Water Intake (i.e., water intake with a maximum capacity greater than or equal to one million gallons per day) who is allocated water from the USACE Projects after the effective date of the new Operating Agreement to implement coordinated water conservation measures when the USACE Drought Plan is in effect (similar to the water conservation measures required by the Low Inflow Protocol for Large Water Intake owners on the Duke Energy Projects).
- USACE and Duke Energy will encourage all water users withdrawing water from their respective reservoirs to conserve water in a coordinated manner when the USACE Drought Plan is in effect.

- USACE and Duke Energy will require (whenever feasible) that all Large Water Intakes used for municipal, industrial and power generation purposes that are constructed, expanded or rebuilt on their projects after the effective date of the new Operating Agreement be capable of operating at their permitted capacities at reservoir elevations as low as the applicable hydroelectric station can operate.
- Duke Energy would provide $438,000 in funding to support the next interim of the USACE Savannah River Basin Comprehensive Study (to evaluate reallocating existing storage or measures that could lead to better water management).
- Duke Energy would provide funding and/or in-kind services to USACE and other public entities to improve public boating access at Hartwell and Thurmond Reservoir facilities to fully mitigate for adverse impacts to recreational access to those reservoirs. Those impacts are presently estimated to be $2,938,000 (FY14 price levels) over a 50-year evaluation period.
- To avoid adverse impacts to dissolved oxygen levels in Savannah Harbor, USACE will discharge 200 cubic feet per second of water above that specified in the 2012 Drought Plan from Thurmond Dam for 11 days each year when the USACE reservoirs are in drought status during the summer months. At that time, Duke Energy will continue to release water from their projects to stay in balance with the USACE reservoirs in accordance with the USACE/SEPA/Duke Energy 2014 Operating Agreement.

Duke Energy would bear the estimated $2 Million cost to modify the Oconee Nuclear Station to enable its operations to continue down to a Lake Keowee elevation of 790 feet AMSL. Duke Energy would provide South Carolina with funds to support their participation in the next interim of the USACE Savannah River Basin Comprehensive Study. Duke Energy would provide funds and/or in-kind services to USACE and other public entities to improve public boating access at the Hartwell and Thurmond Reservoirs. USACE would manage those mitigation actions. USACE would continue to operate under the terms of its 2012 Drought Plan. Both organizations would implement the Low Inflow Protocol which describes how they will work with Large Water Intake owners within their reservoirs to conserve water during droughts.

2. Other Alternatives Considered

Alternatives to the Proposed Action were developed as part of the planning process. The alternatives that were considered include:

a. No Action Alternative: Duke Energy and USACE would operate in accordance with the 1968 Operating Agreement

b. Alternative 1: Duke Energy would modify its Oconee Nuclear Station to allow that facility to meet the flow requirements of the 1968 Agreement (i.e., ONS could operate down to a Lake Keowee elevation of 778 feet AMSL).

c. Alternative 2: Duke Energy would operate the Keowee-Toxaway Project as it has since the mid- to late-1990s during drought conditions.

d. Alternative 4 (evaluates how the Low Inflow Protocol in A3 affect reservoir levels and flow releases from the USACE Projects): Includes all features of A3 (same reservoir usable storage updates) except for the Low Inflow Protocol.

3. Coordination

Savannah District coordinated this action with Federal, State and local agencies and issued a Notice of Availability to solicit comments from the public on the Draft Environmental Assessment. Appendix Y contains the responses to each comment that was received.

4. Conclusions

Based on a review of the information contained in this Environmental Assessment (EA), I have determined that the preferred alternative is the best course of action. I have also determined that this new Operating Agreement with the Southeastern Power Administration and Duke Energy is not a major Federal action within the meaning of Section 102(2)(c) of the National Environmental Policy Act of 1969. Accordingly, the preparation of an Environmental Impact Statement is not required. My determination was made considering the following factors discussed in the EA to which this document is attached:

a. The proposed action would not have significant adverse effects on any threatened or endangered species.

b. The proposed action would not cause any significant long term adverse impacts to wetlands.

c. The proposed action would not have significant adverse impacts on cultural resources.

d. The proposed action would not cause or contribute to violations of SC or GA water quality standards.

e. The proposed action would not adversely impact air quality.

f. The proposed mitigation would fully compensate for adverse impacts to recreational users of the Federal reservoirs.

g. The proposed action would not significantly affect hydropower generation at the USACE dams on the Savannah River, or the distribution or sale of that hydropower by SEPA.

h. The proposed action would not result in unacceptable adverse cumulative or secondary impacts.

i. The proposed action complies with Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.”

5. Findings

The proposed action to enter into a new Operating Agreement with the Southeastern Power Administration and Duke Energy for the Savannah River Basin as described in Alternative 3 would result in no significant environmental impacts and is the alternative that represents sound natural resource management practices and environmental standards.

10 OCT 2014
Date

Thomas J. Tickner
Colonel, US Army
Commanding

EXECUTIVE SUMMARY

Background Information

In 1968, the U.S. Army Corps of Engineers (USACE) and the Southeastern Power Administration (SEPA) entered into an Operating Agreement (1968 Agreement) with Duke Energy Carolinas, LLC's (Duke Energy) predecessor company, Duke Power Company, regarding how water would be managed between Duke Energy's Keowee-Toxaway Hydroelectric Project No. 2503 (Keowee-Toxaway Project) and the downstream USACE reservoirs that existed at that time. The purpose of the 1968 Agreement was to ensure the Keowee-Toxaway Project is operated such that the USACE and SEPA will be able to meet their hydropower generating requirements.

The 1968 Agreement is based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell Lake and J. Strom Thurmond (JST) Lake with the percentage of combined remaining usable storage capacity at Duke Energy's Lake Jocassee and Lake Keowee during droughts.

There have been many changes in both the USACE and Duke Energy systems since 1968, but the 1968 Agreement has not been modified. The 1968 Agreement uses a minimum reservoir elevation at Lake Keowee of 778 feet above mean sea level (ft AMSL) (Full Pool Elevation is 800 ft AMSL), as described in the Federal Energy Regulatory Commission (FERC) license for the Keowee-Toxaway Project. During the 1970s, Duke Energy constructed Oconee Nuclear Station (ONS) on the shores of Lake Keowee. ONS relies on water stored in Lake Keowee to support station operations. As a result of the NRC requirements in the 1973 NRC license for the ONS, Duke would cease operation of the ONS facility if/when the Lake Keowee reservoir elevation drops below 793 ft AMSL (with certain other plant conditions). In addition, USACE and Duke Energy have constructed an additional reservoir and pumped storage facilities in the Savannah River Basin that affect operation of the Keowee-Toxaway, Hartwell, and JST Projects.

Those later facilities have not been incorporated into the operating rules between the USACE and Duke systems.

USACE modified its reservoir operations through implementation of a Drought Plan (DP) after the 1986-1989 drought. The original 1989 DP has been revised after subsequent droughts and the USACE is currently operating under the July 2012 DP. Duke Energy's FERC license for the Keowee-Toxaway Project expires in 2016 and future operations at the Keowee-Toxaway Project are expected to be modified with FERC relicensing. As part of their relicensing effort, Duke Energy has consulted with a diverse group of stakeholders including water suppliers and non-governmental organizations interested in the Keowee-Toxaway Project's ability to identify ways in which that project could better support future water supply needs in the region and address concerns about the impacts to water supply caused by the extended droughts of record.

As a result of these factors, USACE, SEPA and Duke Energy have worked together to develop a new Operating Agreement that would reflect the modified conditions discussed above. This Environmental Assessment identifies and evaluates the expected effects of a New Operating Agreement (NOA). USACE coordinated a draft of this document with the natural resource agencies and the public to obtain their comments, as required by the National Environmental Policy Act (NEPA). This document also serves as the NEPA analysis for the SEPA, who would also be a signatory to the NOA.

This EA evaluates potential environmental, engineering, and economic impacts associated with five alternatives as described on the following pages.

Alternatives Considered

No Action Alternative (NAA)

The No Action Alternative (NAA) represents operating in accordance with the 1968 Agreement. The 1968 Agreement is based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell Lake and JST Lake with the percentage of combined remaining usable storage capacity at Duke Energy's Lake Jocassee and Lake Keowee during droughts. Since the USACE's Richard B. Russell (RBR) Project and Duke Energy's Bad Creek Project were not constructed at the time of the 1968 Agreement, they are not included in the operating rules for determining flow release requirements from Lake Keowee under this alternative. The NAA assumes Duke Energy would draw down the Lake Keowee reservoir elevation below 793 ft AMSL when required. Such an action would require Duke to temporarily cease nuclear generation operations at the ONS, as specified in their license for that facility from the Nuclear Regulatory Commission. The NAA incorporates the most recent version (July 2012) of the USACE's DP operating protocols.

Alternative 1 (A1)

In Alternative 1, Duke Energy would modify the ONS to allow that facility to meet the flow requirements of the 1968 Agreement (i.e., ONS could continue to operate down to a Lake Keowee elevation of 778 ft AMSL). As with the NAA, A1 incorporates the USACE's July 2012 DP operating protocols. A1 is based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell Lake and JST Lake with the percentage of combined remaining usable storage capacity at Duke Energy's Lake Jocassee and Lake Keowee. A1 also includes the following provisions to enhance drought tolerance in the Upper Savannah River Basin:

- The USACE will require any owner of a Large Water Intake (i.e., water intake with a maximum capacity greater than or equal to one million gallons per day) who is allocated water from the USACE Projects after the Effective Date of the NOA to implement coordinated water conservation measures when the DP is in effect similar to the water conservation measures required by the LIP for Large Water Intake owners on the Duke Energy Projects. Duke Energy will require owners of Large Water Intakes on the Duke Energy Projects to comply with the LIP.

- The USACE and Duke Energy will encourage all water users withdrawing water from their respective reservoirs to conserve water in a coordinated manner when the DP is in effect similar to the water conservation measures required by the LIP on the Duke Energy Projects.
- The USACE and Duke Energy will require whenever feasible that all Large Water Intakes used for municipal, industrial and power generation purposes that are constructed, expanded or rebuilt on the Duke Energy Projects and the USACE Projects after the Effective Date of the NOA be capable of operating at their permitted capacities at reservoir elevations as low as the applicable hydroelectric station can operate.

Alternative 2 (A2)

Alternative 2 represents the manner in which Duke Energy has operated the Keowee-Toxaway Project since the mid- to late-1990s during extreme drought conditions. For A2, the methodology used to determine required weekly water releases from Lake Keowee is the same as in the NAA. However, no water release would be made from Lake Keowee if that release would result in a Lake Keowee elevation below 794.6 ft AMSL. As with the NAA, A2 incorporates the USACE's July 2012 DP operating protocols. A2 is also based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell Lake and JST Lake with the percentage of combined remaining usable storage capacity at Duke Energy's Lake Jocassee and Lake Keowee, subject to the NRC license requirements for the ONS. A2 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1.

Alternative 3 (A3)

While the NAA's overall concept of balancing the percentage of combined remaining usable storage between the Duke Energy and USACE Reservoirs is unchanged in Alternative 3, A3 incorporates additional storage facilities, updated storage volumes, coordinated drought response, measures to protect Upper Savannah River Basin water supply, and provisions expected to be included in FERC's 2016 operating license for the Keowee-Toxaway Project. As with the NAA, A3 incorporates the USACE's July 2012 DP operating protocols.

In A3, Duke Energy would modify the ONS to allow normal operations to continue when Lake Keowee elevations drop below the current NRC limitation of 794.6 ft AMSL. The Lake Keowee minimum elevation for calculation of usable storage would be revised to elevation 790 ft AMSL, which allows for a 10-foot drawdown of Lake Keowee during droughts. The Lake Jocassee minimum reservoir elevation would be lowered six feet (from 1086 ft AMSL to 1080 ft AMSL). A3 incorporates additional storage capacity created by the USACE and Duke Energy since the 1968 Agreement was executed with the addition of Bad Creek Reservoir and RBR Lake. These reservoirs increase the total storage volumes in the systems and A3 includes them in the calculation of usable storage and weekly water release requirements from Lake Keowee. Therefore, A3 is based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell, RBR, and JST Lakes with the percentage of combined remaining usable storage capacity at Duke Energy's Bad Creek Reservoir and Lakes Jocassee and Keowee. A3 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1. Duke Energy would implement the Keowee-Toxaway Low Inflow Protocol (LIP) which provides rules for how the Duke Energy Reservoirs are operated during periods of drought, including minimum reservoir elevations and water withdrawal reductions for varying levels of drought severity (and closely follows the USACE's July 2012 DP).

Alternative 4 (A4)

Alternative 4 was included to evaluate how LIP operations under A3 affect reservoir levels and flow releases from the USACE Projects. Accordingly, A4 includes the same reservoir usable storage updates as A3, but A4 does not include the Keowee-Toxaway Project LIP provisions contained in A3. As with the NAA, A4 incorporates the USACE's July 2012 DP operating protocols. As with A3, A4 uses the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell, RBR, and JST Lakes with that in Duke

Energy's Bad Creek Reservoir and Lakes Jocassee and Keowee. A4 also includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1.

Hydrologic Modeling

To identify and evaluate differences between the alternatives, the USACE's Hydrologic Engineering Center's Reservoir System Simulation (HEC-ResSim) hydrologic model was used to simulate reservoir elevations, usable storage, flow releases from, and hydroelectric energy production by all Duke Energy and USACE reservoirs in the Upper Savannah River Basin. HEC-ResSim model results were evaluated for each of the alternatives over a 73-year period of record (POR) (1939–2011). Two of the alternatives (NAA and A1) are the same from a reservoir modeling perspective and did not require separate model simulations, and are referred to as NAA/A1 in the modeling results.

Plan Comparison

During non-drought or wet hydrologic periods, there are only minimal differences in reservoir elevations, flow releases from, and hydroelectric energy production between alternatives. During drier or drought hydrological periods, there are some differences between alternatives. However, these differences are relatively small in magnitude, infrequent, and are not expected to result in significantly adverse environmental or socioeconomic impacts.

Socioeconomic Results

The Strom Thurmond Institute of Government and Public Affairs at Clemson University developed regional economic models for the counties surrounding Duke Energy's Lake Keowee and the USACE's Hartwell and JST Lakes. These models rely on three parameters as indicators of economic movement: recreational use at each reservoir, real estate transactions around each reservoir, and the sale of reservoir-related goods and services (e.g., sporting goods, bars, boating stores, etc.). The models are designed to evaluate regional economic conditions (both positive and negative) associated with every foot of water elevation change in these three reservoirs. The economic model results span 2001–2008, which includes the basin's 2008 drought of record.

For Lake Keowee, during the majority of the period modeled, differences between alternatives are within $2,000 of each other and three jobs over the eight-year study period. The largest differences between alternatives occur near the end of 2008 and are the result of extreme drought conditions. During that period, the NAA and A1 would result in the largest economic impact (a loss of $12,000 and 12 jobs) when Lake Keowee's elevation drops to 782 ft AMSL. A2 would result in the least economic impact (a loss of $4,000 and four jobs) because flow releases are not made if those releases would result in a Lake Keowee reservoir elevation below 794.6 ft AMSL. A3 and A4 are similar to each other and fall between A2 and NAA/A1 results (a loss of $6,000 and six jobs).

For Hartwell and JST Lakes, during the entire period modeled, economic and employment impacts are similar for all alternatives.

Hydropower Generation and ONS Impacts

HEC-ResSim model output identifies hydroelectric generation for each of the Duke Energy and USACE projects. Average annual net hydroelectric energy generation (in both dollars and MWHr) for each alternative over the 73-year POR for the Duke Energy and USACE systems is provided in Table ES-1. For the Duke Energy system, A4 produces the highest average annual net generation at $92.2 million, while NAA/A1, A2, and A3 are slightly lower ranging from $91.1 to $92.1 million. Except for A4, there is no difference in average annual net hydroelectric generation at the USACE Projects between the alternatives. A4 would result in slightly lower average annual net generation than the other alternatives. There is very little difference (<0.5%) in the value of the average annual net generation value between alternatives.

Table ES-1 Average Annual Net Hydroelectric Energy Generation (1939–2011)

Owner	Average Annual Net Hydroelectric Energy Generation[1] $ millions / MWh			
	NAA/A1	A2	A3	A4
Duke Energy[2, 3]	92.1 / (683,000)	91.1 / (635,000)	91.9 / (657,000)	92.2 / (660,000)
USACE	120.4 / 1,478,000	120.4 / 1,478,000	120.4 / 1,478,000	120.4 / 1,477,000
System	212.5 / 795,000	211.5 / 843,000	212.3 / 821,000	212.6 / 817,000

[1] Future water withdrawals with historic hydrology
[2] Average annual net generation for the Duke Energy system excludes generation impacts to ONS
[3] MWh for the Duke Energy system are negative due to pumping operations at Jocassee Pumped Storage Station and the Bad Creek Project.

Under the NAA, Lake Keowee reservoir levels would have fallen below 793 ft AMSL for a 348-day period in 2008-2009. The resulting forced outage at ONS would have resulted in energy replacement costs estimated at $913 million (assuming future water withdrawals and historic hydrology conditions). Costs to upgrade the existing electric transmission system to lessen the severity of grid reliability issues while ONS is off-line are estimated at $232 million. Under that alternative, actions to address those grid reliability issues should begin immediately to avoid those concerns.

A1 includes modification to the ONS station to allow its operation to continue down to a Lake Keowee elevation of 778 feet AMSL. An engineering alternatives study conducted by Enercon in 2011 estimates that capital costs for this design modification would reach at least $800 million, not including additional O&M costs. These costs are quite high when viewed in the context of the infrequent and relatively small benefits that would result.

Both A3 and A4 include modification to the ONS station to allow its operation to continue with Lake Keowee below 794.6 ft AMSL. Current capital cost estimates to modify ONS are up to $2 million. Modification of the ONS in A3 and A4 provides additional usable storage capacity in the Duke Energy system that helps maintain ONS operations (thus preventing expensive energy replacement costs and transmission system upgrade costs) and provides additional storage that can be used to support other water users in the Upper Savannah River Basin. Net USACE hydroelectric generation for A3 and A4 are similar to or greater than the other alternatives.

Pool Elevations

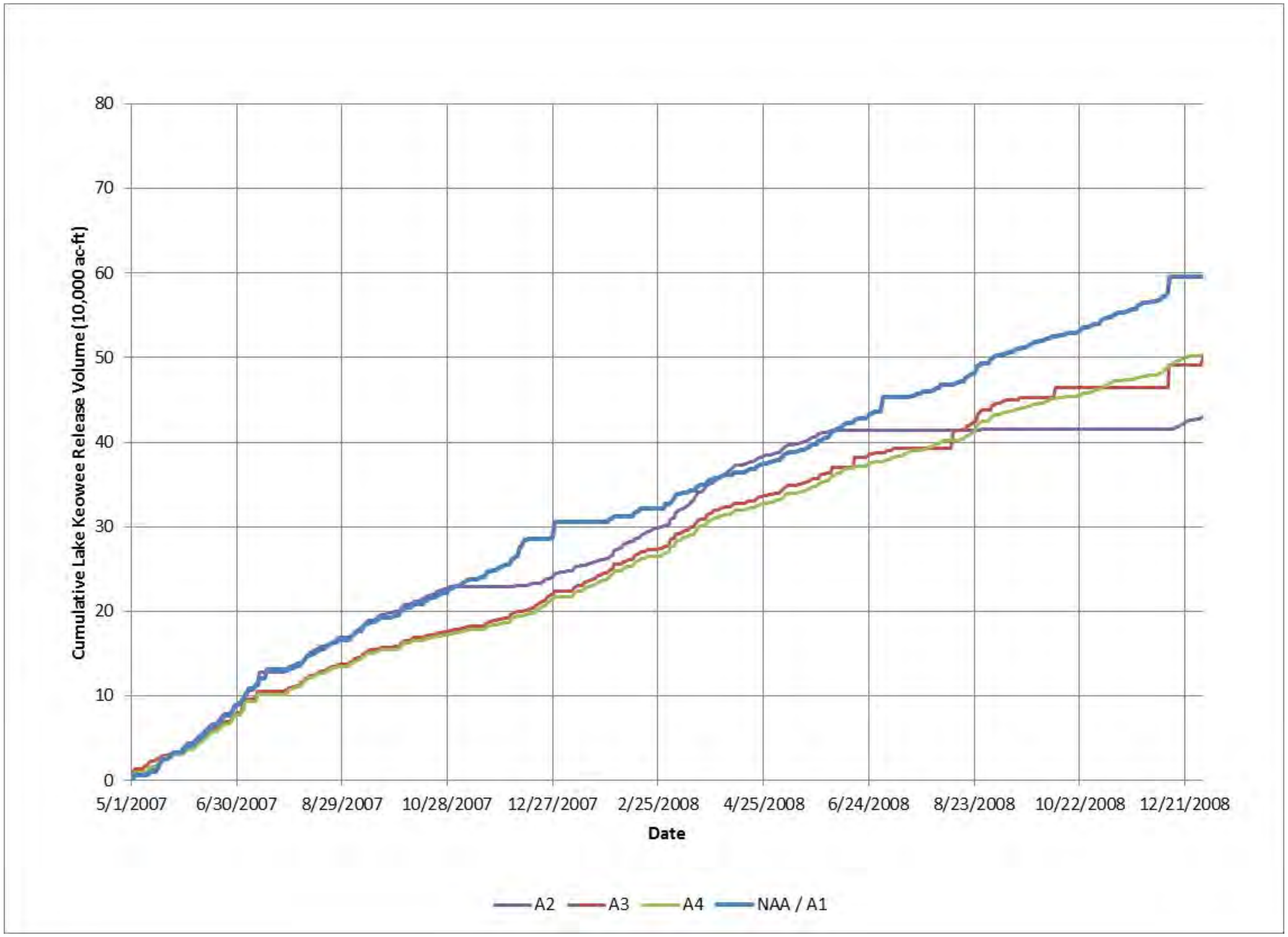
NAA and A1 would produce the lowest reservoir elevations in Duke Energy's Lakes Jocassee and Keowee. For those two lakes, A3 and A4 are almost identical and result in reservoir elevations higher than the NAA/A1, and A2 reservoir elevations for most of the POR (see Table ES-2). The only exceptions are during extreme drought conditions when the HEC-ResSim model logic tries to maintain Lake Keowee reservoir elevations at or above 794.6 ft AMSL in A2 and allows reservoir elevations down to 790 ft AMSL in A3 and A4.

The individual USACE reservoir elevations are similar for each alternative (see Table ES-2). Differences in USACE reservoir elevations occur infrequently and are relatively short in duration.

During drought conditions, A2 would maintain the highest Lake Keowee reservoir elevations. However, this is at the expense of Lake Jocassee, which would experience its lowest reservoir elevations under this alternative. During extreme drought periods, A2 would result in Lake Keowee elevations below 794.6 ft AMSL, which negatively impacts ONS operations. This would occur when Lake Jocassee storage capacity is depleted, making it harder to maintain Lake Keowee reservoir elevations above 794.6 ft AMSL which increases the risk of forced outages at ONS.

Figure ES-1 depicts Lake Keowee cumulative flow releases for each alternative during the 2007-2008 extreme drought. The HEC-ResSim model results presented in this figure assume the USACE implements its Drought Plan as written, reducing discharges from JST when a drought level is triggered. During the deepest part of the extreme drought (third quarter 2008), A3 and A4 flow releases would have been greater than A2 flow releases. This is due to Keowee-Toxaway Project operations continuing to provide generation flow releases to the USACE

Figure ES-1 Cumulative Lake Keowee Volume Released to the USACE System (Future Water Withdrawals with Historic Hydrology)



reservoir system under A3 that are not provided under A2. A2 would greatly reduce, and at times eliminate, flow releases from Keowee into the USACE Reservoirs during extreme droughts. NAA, A1, and A2 would also continue the vulnerability of the ONS to being shut down during extreme droughts.

The $2 million modification to ONS in A3 and A4 provides additional usable storage capacity in the Duke Energy system that can be used to support other water users in the Upper Savannah River Basin, and provides downstream flow releases to the USACE system during the deepest parts of drought periods. During less severe droughts, such as occurred at the end of 2006, A3 and A4 result in slightly lower reservoir elevations for Hartwell and JST Lakes (by approximately 0.7 feet and 0.5 feet, respectively) compared to NAA/A1 reservoir elevations. During extreme drought periods, there is very little difference in Hartwell and JST Reservoir elevations between A3 and A4 and NAA/A1. The minor differences in reservoir elevations are not expected to result in additional adverse effects to the biological communities in the USACE Reservoirs or result in substantial changes to social or socioeconomic resources in the Savannah River Basin.

Analysis of JST Project flow releases for the April through December when the system was in drought (i.e., those years where the USACE's DP was triggered) reveal there would be little difference in downstream flow releases between alternatives. Differences between A3/A4 and NAA/A1 are less than +/-5 percent on an annual basis. The larger negative differences (i.e., A3/A4 average flows are less than NAA/A1 flows) tend to occur during less severe drought years when average flows are well above 4,200 cfs. The larger positive differences tend to occur during recovery from extreme drought periods. JST flow releases under A3 and A4 are more similar to NAA/A1 than are the releases in A2.

As discussed in Section 3.3.3, state and/or federal regulatory agencies in Georgia and/or South Carolina may request implementation of adaptive management flow releases at the JST Project when JST flow releases fall below 3,800 cfs (i.e., during DP Levels 2, 3, and 4) to support downstream water quality. As a result, the small differences in April through December average

JST flow releases between A3/A4 and NAA/A1 (i.e., +/-5 percent) would be even smaller under adaptive management flow releases. As described in Section 3.4, Duke Energy can support adaptive management JST flow releases the majority of the time by scheduled weekly flow releases from Keowee Hydroelectric Station. During extreme drought periods when Duke Energy's remaining usable storage drops below 12 percent, a minimum of 650 ac-ft of water per week would continue to flow into Hartwell Lake via leakage and seepage from the Keowee Development. This water volume release to Hartwell Lake each week would help keep Duke Energy's system storage in balance with the USACE's system storage (within approximately 1 percent) during extreme drought periods. Therefore, in the event higher JST flow releases are needed for water quality purposes during extreme droughts, the remaining usable storage in the Duke Energy system under A3 and A4 could be used to support higher JST flow releases.

Under A3 and A4, adaptive management flow releases to address downstream water quality concerns during extreme drought conditions may result in slightly lower Hartwell and JST Lake elevations (by less than 0.4 feet in each reservoir). For A3, these slightly lower lake elevations are offset by Duke Energy's funding support for Phase 3 of the USACE's Comprehensive Study and public boating access improvements at Hartwell and JST Lakes. These funding measures are directly related to enhancing drought tolerance in the Upper Savannah River Basin and improving recreation opportunities on the USACE Reservoirs that would be affected by Keowee-Toxaway Project operations during drought periods. Similar funding measures are not included in A4.

For the Duke Energy system, A3 and A4 generally result in higher reservoir elevations throughout the 73-year POR for Lakes Jocassee and Keowee compared to the other alternatives. A3 and A4 provide additional usable storage in Lakes Jocassee and Keowee compared to A2. This is a result of deeper allowable maximum drawdowns (compared to A2) in Lakes Jocassee and Keowee and additional usable storage from the Bad Creek Project. This additional usable storage reduces the risk of forced outages at ONS during extreme drought periods (thus preventing expensive energy replacement costs and transmission system upgrade costs); provides additional storage that can be used to support other water users in the Upper Savannah River

Basin; and provides additional downstream flow releases to the USACE system (compared to current operating conditions) during the deepest parts of extreme drought periods.

In summary, A3 and A4 are better from a Duke Energy system operations perspective than NAA, A1 or A2. Adverse impacts to the USACE reservoir system during drought events are offset by the funding measures described above. A4 does not include the Keowee-Toxaway Project LIP (drought tolerance measure). For these reasons, Duke Energy believes A3 should be the Selected Alternative.

Recreation Impacts

The alternatives would affect the pool elevation in both the Duke Energy system and the USACE reservoir system. Those differences in pool levels would affect the usability of the boat ramps during droughts and, thus, the availability of the reservoirs to recreational users. In general, A2, A3, and A4 maintain higher pool levels in the Duke reservoirs when compared to NAA and A1. With A3 and A4, boat ramps in the Duke reservoirs would be available nearly every day over the period of analysis.

Pools in the USACE system would generally be higher during droughts with A2, but lower with A3, and A4, when compared to NAA and A1. Without mitigation, access to the USACE reservoirs would decline by 6.4 percent for A3 and 7.0 percent for A4. Mitigation is included in the alternatives to provide boating access and this mitigation would fully compensate for the expected impacts.

Releases Downstream of Thurmond Dam

Since USACE would continue to operate by its 2012 Drought Plan, all alternatives would produce similar discharge volumes from the JST Project to the lower Savannah River. The duration at which the reduced flows specified in the Drought Plan would occur would vary between alternatives. To avoid adverse impacts to dissolved oxygen levels in Savannah Harbor from A2 and A3, USACE and Duke Energy would discharge 200 cubic feet per second of water above that specified in the 2012 Drought Plan from their dams for 11 days each year when the USACE reservoirs are in drought status during the summer months.

Recommended Alternative

Alternative 3 is recommended because it best balances the competing interests of reservoir levels, downstream flow releases, hydroelectric generation, risks to ONS operations, social and biological communities, recreation, and economic costs. Tables ES-2 and ES-3 provide a summary of HEC-ResSim, economic, environmental and socioeconomic results.

USACE would continue to operate by its 2012 Drought Plan, resulting in similar discharge volumes from the JST Project to the lower Savannah River. The USACE system would be in a drought status for slightly longer periods than in the NAA.

Table ES-2 HEC-ResSim and Economic Results Summary (Future Water Withdrawals with Historic Hydrology)

Resource		Alternatives				
		NAA	A1	A2	A3	A4
Duke Energy Avg Reservoir Elevation (ft AMSL)	Lake Jocassee	1104.6	1104.6	1105.0	1106.4	1106.3
	Lake Keowee	797.7	797.7	797.9	798.4	798.4
USACE Avg Reservoir Elevation (ft AMSL)	Hartwell Lake	656.9	656.9	657.0	656.8	656.7
	RBR Lake	475.5	475.5	475.5	475.2	475.2
	JST Lake	327.1	327.1	327.1	327.1	327.0
Minimum Remaining Usable Storage (%)	Duke Energy	17	17	42	11	10
	USACE	16	16	20	13	13
Socioeconomic Loss ($ / Jobs)	Lake Keowee	12,000 / 12	12,000 / 12	4,000 / 4	6,000 / 6	6,000 / 6
	Hartwell Lake	30,000 / 25	30,000 / 25	28,000 / 24	30,000 / 26	31,000 / 27
	JST Lake	500,000 / 650	500,000 / 650	510,000 / 660	510,000 / 660	510,000 / 660
Average Annual Net Hydroelectric Generation ($ Million)	Duke Energy	92.1	92.1	91.1	91.9	92.2
	USACE	120.4	120.4	120.4	120.4	120.4
ONS Economic Impacts ($ Million)	Replacement Energy	913	n/a	n/a	n/a	n/a
	Transmission System Upgrades	232	n/a	n/a	n/a	n/a
	Station Modifications	n/a	>800	n/a	2	2
JST Project Avg Flow Releases (cfs)		6,074	6,074	6,076	6,082	6,078
Days in USACE Drought Status	Level 1	2,033	2,033	2,037	2,198	2,189
	Level 2	3,858	3,858	3,866	4,106	4,158
	Level 3	598	598	574	742	770
	Total	6,489	6,489	6,477	7,046	7,117

Table ES-3 Environmental and Socioeconomic Results Summary (Future Water Withdrawals with Historic Hydrology)

Resource		Modeling Parameter	Alternative Comparison with NAA / A1		
			A2	A3	A4
Water Supply	Water Intake Operation	Daily Average Drawdown Elevation	Little to no difference (<0.5 ft)	Little to no difference (<1 ft); smaller drawdowns for the Duke Energy System; alternative includes measures to reduce consumptive water uses at Keowee during droughts	Little to no difference (<1 ft); smaller drawdowns for the Duke Energy System
		Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)
Water Quality	Reservoir Temperature and DO Stratification	Daily Average Drawdown Elevation	Little to no difference (<0.5 ft)	Little to no difference (<1 ft); smaller drawdowns for the Duke Energy System	Little to no difference (<1 ft); smaller drawdowns for the Duke Energy System
	Lower Savannah River DO and Salinity	Average JST Flow Release	Little to no difference	Little to no difference	Little to no difference
Recreation	Public Boat-Launching Ramps	Daily Average Drawdown Elevation	Slight increase in annual usability	Small decrease (<2% of days) in annual usability; alternative includes measures to enhance boating facilities at Hartwell and JST	Small decrease (<2% of days) in annual usability; alternative includes measures to enhance boating facilities at Hartwell and JST
	Swimming		Small increase (<0.5 ft) in annual usability of swimming areas in USACE System during droughts	Small decrease (<1 ft) in annual usability of swimming areas in USACE System during droughts	Small decrease (<1 ft) in annual usability of swimming areas in USACE System during droughts
Biotic Communities - Reservoirs	Littoral Zone Fish and Mussel Habitat	Daily Average Reservoir Fluctuations	Little to no difference (< 0.01 ft)	Little to no difference (<0.01 ft)	Little to no difference (<0.01 ft)

Resource		Modeling Parameter	Alternative Comparison with NAA / A1		
			A2	A3	A4
	Pelagic Zone Fish Habitat	Mean September Drawdown Elevation	Little to no difference (infrequent larger drawdowns (<2 ft) at Lake Jocassee; studies find lake elevation alone is not a limiting factor to pelagic fisheries	Smaller drawdowns at Duke Energy System; Little to no difference at USACE System	Smaller drawdowns at Duke Energy System; Little to no difference at USACE System
	Aquatic Plants, Wetlands and Wildlife	Daily Average Drawdown Elevation	Little to no difference (<0.5 ft)	Little to no difference (<1 ft); smaller drawdowns at Lake Jocassee	Little to no difference (<1 ft); smaller drawdowns at Lake Jocassee
Biotic Communities-Lower Savannah River	Fish and Mussel Habitat	Average JST Flow Release	Higher mean monthly flows for late winter and critical summer species; lower mean monthly flows for spring spawning and fall juvenile fish outmigration	Higher mean monthly flows for late winter and critical summer species; lower mean monthly flows for spring spawning and fall juvenile fish outmigration	Higher mean monthly flows late winter and critical summer species; lower mean monthly flows for spring spawning and fall juvenile fish outmigration
	Aquatic Plants, Wetlands and Wildlife	Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)
	Savannah National Wildlife Refuge	Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)
	Protected Species	Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)
Environmental Justice and Protection of Children, Cultural Resources, Coastal Zone Consistency, Solid and Hazardous Waste Facilities, and Navigation	Human Health, Environmental Effects, and Economic Hardship, Historic Properties	Reservoirs - Daily Average Drawdown Elevation	Little to no difference (<0.5 ft)	Little to no difference (<1 ft); smaller drawdown for the Duke Energy System	Little to no difference (<1 ft); smaller drawdowns for the Duke Energy System
		Lower Savannah River - Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)

1.0 PURPOSE AND NEED FOR THE PROPOSED ACTION

1.1 Introduction

1.1.1 *History*

On October 1, 1968, the U.S. Army Corps of Engineers – Savannah District (USACE) and the Southeastern Power Administration (SEPA) entered into an Operating Agreement (1968 Agreement) with Duke Energy Carolinas, LLC's (Duke Energy) predecessor company, Duke Power Company regarding water releases from Duke Energy's Keowee-Toxaway Hydroelectric Project No. 2503 (Keowee-Toxaway Project). The 1968 Agreement was intended to describe how Duke Energy would operate its Keowee-Toxaway Project in a manner that did not impair the ability of USACE and SEPA to meet their hydropower generating requirements. The 1968 Agreement recognizes a requirement for minimum flow releases from the USACE's most downstream project (J. Strom Thurmond [JST Project]) and other responsibilities, including flood control, in connection with the USACE's Hartwell and J. Strom Thurmond Projects. The 1968 Agreement is based on equalizing the percentage of remaining usable storage in the USACE's Hartwell and JST Reservoirs with the percentage of remaining usable storage in Duke Energy's Jocassee and Keowee Lakes on a weekly basis.

The 1968 Agreement includes a minimum reservoir elevation at Lake Keowee of 778 feet above mean sea level (ft AMSL) (Full Pool Elevation is 800 ft AMSL) with an allowance for a pumping volume down to elevation 775 ft AMSL. This minimum elevation was stipulated by the Federal Power Commission (FPC) (present-day Federal Energy Regulatory Commission [FERC]) when Lake Keowee was originally constructed during the late 1960s.

During the 1970s, Duke Energy constructed the 2,538-megawatt (MW) Oconee Nuclear Station (ONS) on the shores of Lake Keowee. The ONS uses a once-through condenser circulating water (CCW) system to operate its three reactor units. This system relies on water stored in Lake Keowee to support normal station operations and emergency operating situations. As a result of Nuclear Regulatory Commission (NRC) regulations, the ONS plant safety margin is decreased if Lake Keowee's surface elevation drops below 793.7 ft AMSL. The plant is required to manage this increase in risk by minimizing the amount of time below this reservoir elevation and restricting certain maintenance activities. To allow for a small operating margin above 793.7 ft AMSL, Duke added an additional 0.9 ft in the minimum pool elevation, resulting in a minimum target reservoir elevation of 794.6 ft AMSL. Duke's commitments in the licensing of the ONS require it to temporarily cease operation of ONS if the reservoir elevation declines below 793 ft AMSL if certain plant system conditions exist. These additional operating limitations related to ONS effectively reduced the usable storage volume in Lake Keowee significantly.

Operation of the Keowee-Toxaway, Hartwell, and JST Projects has also been affected by the construction of additional hydroelectric facilities by both USACE and Duke. In 1985, USACE began operating the Richard B. Russell Project, a pumped storage station located between the Hartwell and JST Projects. In 1991, Duke Energy's Bad Creek Pumped Storage Station (Bad Creek Project) began operations on a tributary to Lake Jocassee. Construction of these hydroelectric developments changed the usable storage volume of the system, but this volume of water has not been incorporated into the remaining usable storage calculations. Operations have been further modified by the USACE implementation of its Drought Plan (DP) in 1989, an action it implemented after the 1986-1989 drought and further revised after subsequent droughts (1998-2002, 2007-2009, and 2011-2012).

Duke Energy's FERC license for the Keowee-Toxaway Project expires in 2016. Duke Energy has been coordinating a diverse group of stakeholders, including Federal, state and local government agencies, water suppliers, and non-governmental organizations interested in the Keowee-Toxaway Project's concerning relicensing of that facility. Duke and those stakeholders are attempting to identify how the Keowee-Toxaway Project can be operated for hydropower in the future while better supporting future water supply needs in the region. As a result of those discussions and the expected relicensing, it is likely that the Keowee-Toxaway Project will be operated differently in the future compared to when the 1968 Agreement was developed.

As a result, USACE, SEPA and Duke Energy have worked together to develop a New Operating Agreement (NOA) to reflect these changed conditions. This Environmental Assessment (EA) is part of USACE and SEPA's evaluation of such an agreement under the National Environmental Policy Act (NEPA).

1.1.2 *Objective*

The general objective of the proposed action is to update the 1968 Agreement to reflect current Duke Energy and USACE hydroelectric project operations, and current conditions in the basin.

1.2 Purpose and Need

The purpose and need for this proposed action is to update and revise the 1968 Operating Agreement to reflect conditions that have changed since the 1968 Agreement, including the addition of the USACE's Richard B. Russell Project, the Duke Energy's Bad Creek Pumped Storage Project, the Duke Energy's ONS, and the USACE Drought Plan.

1.2.1 *ONS Operational Constraint*

Currently, Duke Energy must maintain Lake Keowee at a reservoir elevation of 794.6 ft AMSL or higher (Full Pool Elevation is 800 ft AMSL) for it to continue to operate the ONS with no special limitations. That elevation allows a small amount of operating margin above the 793.7 ft AMSL elevation where the plant safety margin is decreased under certain conditions. To comply with the license for the ONS from the Nuclear Regulatory Commission (NRC), Duke would need to shut down the ONS when Lake Keowee is below an elevation of 793 ft AMSL if certain plant system conditions exist. A summary of reservoir elevation restrictions is as follows:

- Below 793.7 ft AMSL, plant safety risks relative to water availability are increased, but shutdown is not required. ONS is required to minimize risk by limiting the amount of time below this level and by restricting maintenance activities on certain systems.
- Below 793 ft AMSL, shutdown may be required, depending on the configuration of certain pumps and controls.
- Below 791 ft AMSL, shutdown is required within a short amount of time. In addition, fire protection water supply loses redundancy (i.e., only one pump available).

- Below 787 ft AMSL, Keowee Hydroelectric Station generators will have less than seven days of water supply for generation as the emergency power source for ONS.
- All levels mentioned above do not include measurement error. ONS is required to assume measurement error based in the worst-case direction (i.e., higher) for all reservoir elevation measurements. This requires adding 0.5 foot (ft) (e.g., 793.7 + 0.5 = 794.2 ft AMSL) when using control room computer indications. Adding 0.4 ft above 794.2 ft AMSL, Duke Energy's Hydro Operations uses 794.6 ft AMSL as its operating threshold to make sure Lake Keowee remains above 794.2 ft AMSL at all times, taking into account possible operator error, wind and wave conditions, etc. Consequently, Duke Energy maintains Lake Keowee above a reservoir elevation of 794.6 ft AMSL for ONS to continue operating with no special limitations.

Additional information related to reservoir elevation restrictions can be found on the following page in Table 1.2-1.

There are three important technical issues concerning Lake Keowee pool elevations and the ONS, as follows:

- Several pumps important to ONS safety have inadequate suction pressure below certain reservoir elevations (793 or 791 ft AMSL, depending on configuration). Most of the suction piping is underground or buried in the concrete floor of the Turbine Building basement.
- Water inventory in Lake Keowee must allow for at least seven days of Keowee Hydroelectric Station generation during certain emergency situations involving loss of normal alternating current (AC) power to ONS. This requires Lake Keowee to be at or above 787 ft AMSL.

Table 1.2-1 Lake Keowee Level Restrictions and Required Actions

Reservoir Elevation (ft AMSL)	Condition	Required Action
<793.7	Inadequate reservoir elevation to support CCW System gravity-induced reverse flow.	Shutdown not required. Track unavailability for Maintenance Rule performance monitoring and manage increase in plant risk (e.g., avoid planned maintenance on some systems/equipment).
<793	Inadequate suction head for Low Pressure Service Water (LPSW) pumps under some conditions (i.e., High Pressure Service Water [HPSW] pump B out of service or HPSW pump A set to automatically start before HPSW pump B).	Shutdown required within 12 hours if any LPSW pump is inoperable. Otherwise, shutdown may be required within 84 hours depending on HPSW pump alignment.
<791	Inadequate suction head for LPSW pumps and HPSW pump A under design basis accident conditions.	Shutdown required within 12 hours if any LPSW pump is inoperable. Otherwise, shutdown is required within 84 hours. Within 7 days, develop guidance for loss of redundancy in Fire Protection Water Supply System.
<790	Both control room ventilation system chillers are inoperable due to potential air de-entrainment in suction piping to Chiller Condenser Service Water pumps.	Shutdown required within 12 hours.
<789	Inadequate suction head for HPSW pump B.	Establish backup Fire Suppression Water Supply System within 24 hours or shut down within 36 hours.
<787	Inadequate water supply for Keowee Hydroelectric Station to operate for 7 days in an emergency.	Cease commercial power generation of Keowee Hydroelectric Station.
<787	Potential failure of CCW piping to Radwaste Equipment Cooling System could adversely affect Emergency CCW siphon headers.	Isolate supply to Radwaste Equipment Cooling System or declare Emergency CCW siphon headers to be inoperable. May require shutdown depending on number of operable siphon headers.
<786	Emergency CCW siphon headers are designed for reservoir elevation ≥786 ft AMSL. Therefore, all siphon headers are inoperable.	Shutdown within 12 hours.
<783	Keowee Oil Storage Room Water Spray System is inoperable.	Shutdown not required. Compensatory measures required by Fire Protection Program.
<780	Keowee Step-Up Transformer Fire Protection Water Supply System is inoperable.	Shutdown not required. Compensatory measures required by Fire Protection Program.

Source: Harris 2009

Note: To illustrate the effects of decreasing reservoir elevation, the required actions for each reservoir elevation in the table are intended to stand alone, without regard to the required actions at other reservoir elevations.

- The 793.7 ft AMSL restriction involves flow by gravity through underground piping (six 11-ft diameter pipes about 1,000 feet long and several feet underground) during certain ONS conditions. The limit is a function of the pipe elevation. Plant modifications are planned that will reduce the safety importance of this issue and provide more flexibility. These planned modifications are incorporated into Alternatives 3 and 4 (A3 and A4) analyzed in this report.

1.2.2 *Additional Hydroelectric Project Usable Storage*

Both Duke Energy and the USACE have constructed pumped storage facilities in the Upper Savannah River Basin since the 1968 Agreement. Duke Energy's Bad Creek Project is located on a tributary to Lake Jocassee and uses Lake Jocassee as its lower reservoir. The Bad Creek Project has affected Duke Energy's operation of the Jocassee Pumped Storage Station. The USACE's RBR Project is located immediately downstream of the Hartwell Project and uses JST Lake as its lower reservoir.

1.2.3 *USACE Drought Plan*

USACE implemented its Drought Plan in 1989 to address water management during periods of drought. The DP includes four stages, each of which results in successively reduced discharges from JST Dam when certain reservoir elevation trigger levels are reached at Hartwell Lake and JST Lake. The DP has been modified several times since it was implemented, with the most recent revision effective as of July 2012. The 1968 Agreement does not address the DP. All modeling described in this Comprehensive Report incorporates the July 2012 revision of the USACE's DP.

1.2.4 *Keowee-Toxaway FERC Relicensing*

The Keowee-Toxaway Project was licensed by the Federal Power Commission, the FERC's predecessor agency, in 1966 for 50 years. The Keowee-Toxaway Project consists of the Jocassee Pumped Storage Development and Keowee Hydroelectric Development, which are both located on the Keowee River tributary near the headwaters of the eastern arm of the Savannah River

Basin. Duke Energy is using the FERC's default relicensing process, known as the Integrated Licensing Process (ILP), to develop its application for new license. The current FERC license (Existing License) expires in 2016. In accordance with the FERC's relicensing requirements, Duke Energy must submit its license application no later than August 31, 2014.

In developing its license application, Duke Energy has consulted extensively with a Stakeholder Team comprised of state and Federal agencies (including USACE and SEPA), local governments, Native American tribes, non-governmental organizations, and citizen groups. As part of that consultation, Duke Energy shared with its stakeholders the analyses it had performed for the development of a NOA with USACE and SEPA. Those stakeholders identified additional reservoir operating scenarios that Duke had not considered. The feedback from those stakeholders has been incorporated into the alternatives evaluated in this EA.

In November 2013, Duke Energy and sixteen other organizations signed a Relicensing Agreement (RA), a legally binding contract, recommending how the Keowee-Toxaway Project reservoirs (Lakes Jocassee and Keowee) should be operated under a new license.

The operations protocols in the RA include a Low Inflow Protocol (LIP) specifying how Duke Energy will operate the Keowee-Toxaway Project during droughts. The LIP includes five stages based on specific triggers (i.e., remaining usable storage and DP levels, streamflows, and the U.S. Drought Monitor). The LIP also limits reservoir drawdowns and downstream flow releases from the Keowee Development based upon the specific LIP stage. Since those protocols were developed in 2013, they are not included in the 1968 Agreement.

1.3 Scope

This EA assesses the potential environmental, engineering, and economic impacts that would result from implementing five different alternatives. The analyses estimate outcomes resulting from various operating scenarios and use records of historical rainfall in the basin. Many uncertainties exist when one applies the operating scenario modeling inputs and historical records to the future. The analyses presented in this report are highly dependent on the assumptions made, but they comprise the best analysis that USACE, SEPA, and Duke could perform of future water management-related activities. The analyses do not address potential future changes in regulatory requirements, resource agency policies, environmental conditions (other than the specific climate change sensitivities modeled), or other changes that may occur during the 50-year period of evaluation. The timing and magnitude of the growth of consumptive water use may differ from the model inputs. Further, the computer modeling used to evaluate the effects of the operational scenarios is neither intended nor capable of predicting the timing of specific events. However, the analyses are well suited for comparing the likely effects of various alternate operational scenarios with each other and with those expected to result from application of the existing 1968 Operating Agreement in the future.

A brief summary of the five alternatives evaluated in this Environmental Assessment is provided below (a more detailed summary of each alternative is provided in Section 3.1):

No Action Alternative (NAA)

The NAA represents operating the USACE and Duke Energy systems in accordance with the 1968 Agreement with no changes. The 1968 Agreement is based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell and JST Reservoirs with the percentage of combined remaining usable storage capacity at Duke Energy's Lakes Jocassee and Keowee. On a weekly basis, USACE determines the required water releases (or non-release) from Hartwell, RBR, JST, and Keowee for the upcoming week. The NAA assumes ONS regulatory commitments would require the ONS to be shut down if the Lake Keowee reservoir elevation is below 793 ft AMSL. The NAA incorporates the most recent version (July 2012) of the USACE's DP operating protocols.

<u>Alternative 1 (A1)</u>

In Alternative 1, Duke Energy would modify the ONS to allow it to meet the flow requirements of the 1968 Agreement so that the ONS could continue to operate down to a Lake Keowee pool elevation of 778 ft AMSL. As with the NAA, A1 incorporates the USACE's July 2012 DP operating protocols. A1 is based on the concept of equalizing the percentage of remaining usable storage capacity at the USACE's Hartwell and JST Reservoirs with the percentage of remaining usable storage capacity at Duke Energy's Lakes Jocassee and Keowee. From a modeling perspective, A1 is identical to the NAA, and therefore, model results are referred to as NAA/A1. A1 also includes provisions to enhance drought tolerance in the Upper Savannah River Basin.

<u>Alternative 2 (A2)</u>

Alternative 2 represents how Duke has operated the Keowee-Toxaway Project since the mid- to late-1990s, particularly during extreme drought conditions. For A2, the overall methodology used to determine required weekly water releases from Lake Keowee would be the same as the NAA. However, no water would be released from Lake Keowee if that release would result in a Lake Keowee elevation below 794.6 ft AMSL. As with the NAA, A2 incorporates the USACE's July 2012 DP operating protocols. A2 is also based on the concept of equalizing the percentage of remaining usable storage capacity at the USACE's Hartwell and JST Reservoirs with the percentage of remaining usable storage capacity at Duke Energy's Lakes Jocassee and Keowee. A2 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1.

<u>Alternative 3 (A3)</u>

While the NAA's overall concept of balancing the percentage of combined remaining usable storage between the Duke Energy and USACE Reservoirs is unchanged in A3, A3 incorporates updated storage volumes, coordinated drought response, measures to protect Upper Savannah River Basin water supply, and provisions of the Keowee-Toxaway RA. As with the NAA, A3 incorporates the USACE's July 2012 DP operating protocols.

In A3, Duke Energy would modify the ONS to allow normal operations to continue at Lake Keowee elevations below the current 794.6 ft AMSL limitation, with the minimum elevation for Lake Keowee for calculating usable storage being revised to elevation 790 ft AMSL (allowing a 10-ft drawdown of Lake Keowee). The Lake Jocassee minimum reservoir elevation would be lowered six feet (from 1086 ft AMSL to 1080 ft AMSL) and the allowance for pumping volume would be eliminated in the weekly water release calculation. A3 incorporates the additional storage capacity created by USACE and Duke Energy since the 1968 Agreement was executed, (the Bad Creek and RBR Reservoirs) for determining the remaining usable storage and weekly water release from Lake Keowee. A3 is based on the concept of equalizing the percent of combined remaining usable storage capacity at the USACE Reservoirs (Hartwell, RBR, and JST) with the percent of combined remaining usable storage capacity at the Duke Energy Reservoirs[1] (Bad Creek Reservoir and Lakes Jocassee and Keowee). A3 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1.

<u>Alternative 4 (A4)</u>

A4 was included to evaluate how Duke's LIP operations under A3 affect reservoir levels and flow releases from the USACE JST Project. Accordingly, A4 includes the same reservoir usable storage updates as A3, but does not include the Keowee-Toxaway Project LIP provisions found in A3. As with the NAA, A4 incorporates the USACE's July 2012 DP operating protocols. A4 is also based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell, RBR, and JST Reservoirs with the percentage of combined remaining usable storage capacity at Duke Energy's Bad Creek Reservoir and Lakes Jocassee and Keowee. A4 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1.

[1] Duke Energy Reservoirs is defined as Bad Creek Reservoir, Lake Jocassee, and Lake Keowee and is used only when referring to A3 and/or A4 results and/or discussion.

1.4 Study Methodology

To evaluate the differences between the five alternatives from a water management perspective, the USACE's Hydrologic Engineering Center's Reservoir System Simulation (HEC-ResSim) model was used to develop four modeling scenarios. From a reservoir operations perspective, the NAA and A1 are identical, so one modeling scenario represents both of those alternatives. USACE developed a HEC-ResSim model for its three reservoir projects on the Savannah River (i.e., Hartwell, RBR, and JST). The USACE model setup originally included general features associated with Lakes Jocassee and Keowee such as drainage areas, reservoir volumes, general operating rules, and flow releases from each development. In order to model the four scenarios more accurately, Duke Energy refined the model for Lake Jocassee, Lake Keowee, and the Bad Creek Project. These refinements include updated water volumes calculated from updated bathymetry for Lakes Jocassee and Keowee, more detail on reservoir operating rules for high water management and water conservation modes of operation, additional logic on pumped storage operations at the Jocassee Pumped Storage Station and the Bad Creek Project, and derived unimpaired inflows to each reservoir. These refinements also include water withdrawals from each development, including existing (Year 2010) and projected future (2016-2066) water withdrawals from (and returns to) each development for all registered water use entities, including the cities of Greenville and Seneca, South Carolina. Appendix A summarizes the present and future water use projections that were used in this analysis.

USACE, SEPA, and Duke agreed to adopt and expand the unimpaired hydrologic dataset (UIF) being developed by ARCADIS for the Georgia Department of Natural Resources Environmental Protection Division (GA DNR-EPD). Duke first expanded the UIF to include the historic operations of its facilities from 1939-2008. The UIF for the entire Savannah River Basin was then expanded through 2011. Once the operations model was updated with the enhanced project information and outflows from the new UIF, the model was verified against available historic flow and generation records. The verification process ensured the model was an adequate representation of the Savannah River Basin from the Bad Creek Reservoir downstream to the outlet of the Thurmond Reservoir.

Results from the revised Savannah River HEC-ResSim model and inflow hydrology were then used to compare reservoir elevations, generation, and flow releases at the Duke Energy and USACE projects resulting from the four operating scenarios. Reservoir elevation results and simulated flow releases from the JST Project to the lower Savannah River from the HEC-ResSim model were also used to evaluate potential impacts to downstream environmental and economic issues.

When the Draft EA was released, the modeling analysis and results had not yet been thoroughly reviewed by all stakeholders. That review occurred through coordination of the Draft EA. During the Draft EA review period, USACE performed additional hydrologic modeling with an upgraded version of the Savannah River HEC-ResSim model. The results from using the updated model were shared with the hydraulic modelers in the natural resource agencies (regulating agencies). The results did not differ markedly from what was shown in the Draft EA, but the model performed more reliably and better reflected how the USACE water managers would operate their reservoirs. The differences between the model outputs did not warrant substitution of the updated model's performance numbers in this Final EA since the new numbers did not substantially alter the impacts identified or the plan selection. As a result of this additional modeling work and coordination, the natural resource agencies are comfortable with the reliability of the ResSim hydrologic model and the evaluations of potential environmental impacts of the alternatives in this EA.

2.0 AFFECTED ENVIRONMENT

2.1 Description of the Savannah River Basin

2.1.1 *Land Use Characteristics*

The Savannah River Basin has a total surface area of approximately 10,577 square miles. The total surface area is comprised of approximately 5,821 square miles in Georgia, 4,581 square miles in South Carolina, and 175 square miles in North Carolina. The study area, which extends from the headwaters of the Keowee-Toxaway Project downstream to Savannah Harbor and the Atlantic Ocean, drains portions of three physiographic provinces: the Blue Ridge, the Piedmont, and the Coastal Plain. Land use and land cover types vary, with evergreen forest, deciduous forest, and agriculture being the dominant land covers in the basin (Table 2.1-1).

Table 2.1-1 Savannah River Basin Land Cover and Use Statistics (1998 Data)

Land Cover Type	Percentage (%)
Beach	0.02
Water	3.88
Suburban	2.34
Commercial	1.81
Clearcut	7.66
Mines, rock outcrops	0.15
Deciduous forest	19.43
Evergreen forest	27.84
Mixed forest	8.70
Agriculture	19.46
Wetlands	8.71
Total	100.0

Source: Loeffler and Meyer 2010

2.1.2 *Drainage Basin Characteristics*

In the upper reaches of the Savannah River Basin, part of the flow is regulated by three reservoirs owned and operated by Duke Energy: Bad Creek Reservoir, Lake Jocassee, and Lake Keowee (Figure 2.1-1). These reservoirs drain approximately 435 square miles of the basin, approximately four percent of the overall Savannah River Basin drainage area.

The developments associated with Georgia Power Company's North Georgia Hydroelectric Project on the Tugaloo River drain about 473 square miles of the basin, approximately four percent of the overall Savannah River Basin drainage area. River flow is then regulated by three large, multipurpose USACE reservoirs (Hartwell, RBR, and JST) (Figure 2.1-1). These reservoirs are located along the border of Georgia and South Carolina and drain an incremental area of approximately 5,216 square miles of watershed, approximately 50 percent of the overall Savannah River Basin drainage area.

The lower Savannah River downstream of JST Dam drains the remaining 4,453 square miles, approximately 42 percent of the overall Savannah River Basin drainage area. Other impoundments/projects include the USACE's New Savannah Bluff Lock and Dam (NSBL&D), South Carolina Electric & Gas Company's (SCE&G) Stevens Creek Hydroelectric Project, and the reservoir created by the City of Augusta's Canal and Diversion Dam. Table 2.1-2 provides an overview of the hydroelectric projects in the Savannah River Basin.

Flow in the lower Savannah River (downstream of JST) varies considerably both seasonally and annually, even though it is largely controlled by flow releases from the Thurmond Dam, located approximately 20 miles northwest of Augusta, Georgia. Flows are typically high during the winter and early spring months, and lower during the summer and fall. Regulation by upstream reservoirs has reduced natural flow variations (USACE 2008a).

Figure 2.1-1 Savannah River Basin and Project Location

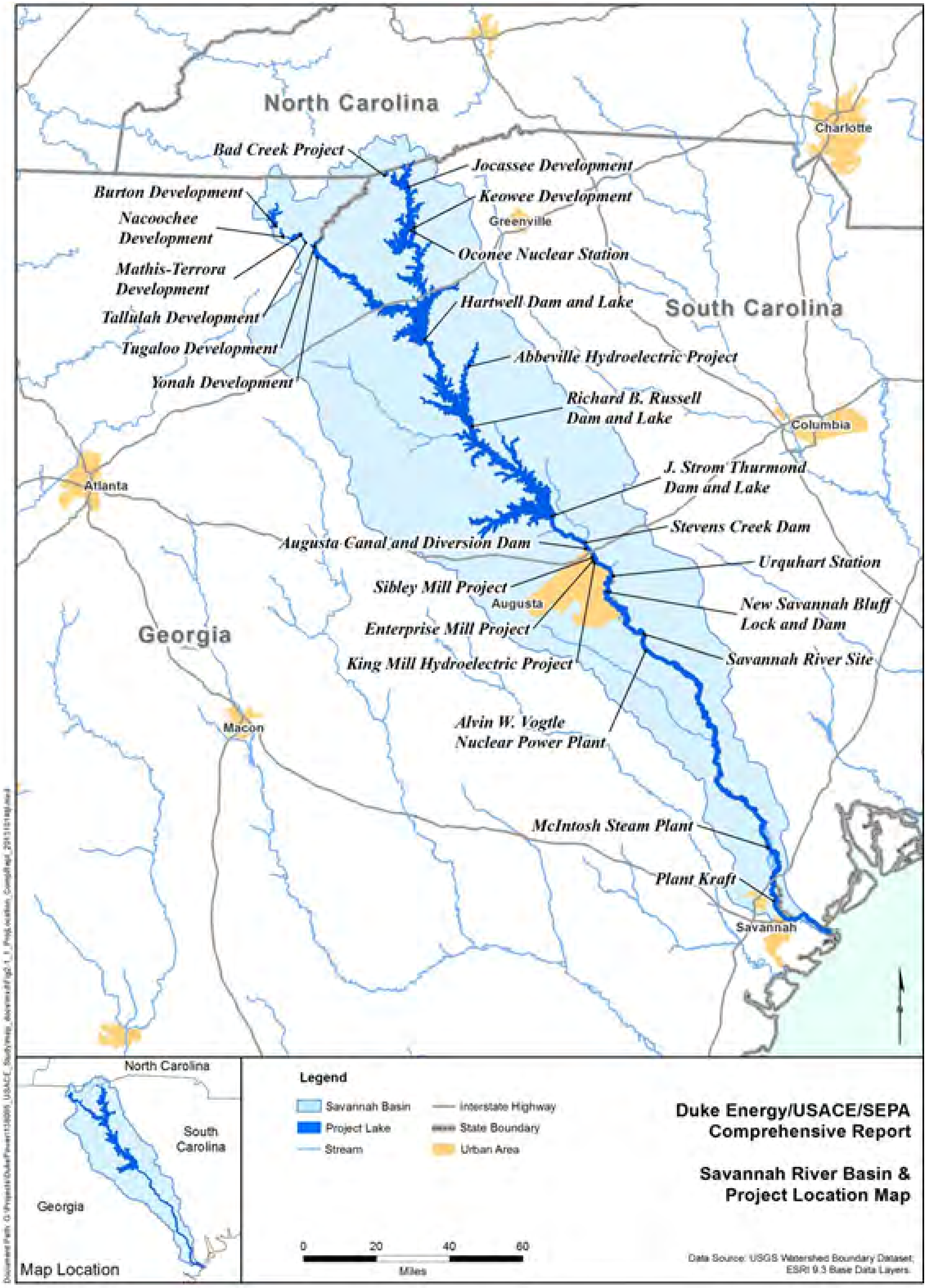


Table 2.1-2 Electrical Generating Facilities in the Savannah River Basin

Project Name	Owner / Operator	State	County	Waterbody	Usable Reservoir Storage Capacity (ac-ft)	Generating Capacity (MW)	Project Type[1]	License Expiration
Bad Creek	Duke Energy	SC	Oconee	Bad Creek	30,229	1,065	PS	2027
Jocassee	Duke Energy	NC, SC	Oconee, Pickens, Transylvania	Lake Jocassee	225,387	710.1	PS	2016
Oconee	Duke Energy	SC	Oconee	Lake Keowee	N/A	2,538	N	2033, 2034
Keowee	Duke Energy	SC	Pickens, Oconee	Lake Keowee	90,319[2]	157.5	H	2016
Hartwell	USACE	GA, SC	Hart, Franklin, Stephens Anderson, Oconee, Pickens	Hartwell Lake	1,415,500	422	H	N/A
Abbeville	City of Abbeville	SC	Abbeville, Anderson	Lake Secession	25,650	2.6	H	2037
John S. Rainey	Santee Cooper	SC	Anderson	Richard B. Russell	N/A	1100	O	N/A
Richard B. Russell	USACE	GA, SC	Elbert, Abbeville	Richard B. Russell Lake	126,864	660	PS	N/A
J. Strom Thurmond	USACE	GA, SC	Columbia, McCormick	J. Strom Thurmond Lake	1,044,908	380	H	N/A
New Savannah Bluff Lock and Dam[3]	USACE	GA, SC	Richmond, Aiken	Savannah River	N/A	N/A	O	N/A
Stevens Creek	South Carolina Electric & Gas Company	GA, SC	Columbia, McCormick, Edgefield	Stevens Creek, Savannah River	8,600	17.3	H	2025
Augusta Canal	City of Augusta	GA, SC	Richmond, Aiken	Augusta Canal	N/A	N/A	O	Pending
Sibley Mill	Avondale Mills Inc.	GA, SC	Richmond	Augusta Canal	N/A	2.46	H	2055
Enterprise Mill	Enterprise Mill Inc.	GA	Richmond	Augusta Canal	N/A	1.2	H	2055
King Mill	Augusta Canal Authority	GA	Richmond	Augusta Canal	N/A	2.25	H	2055
Urquhart	South Carolina Electric & Gas Company	SC	Aiken	Savannah River	N/A	650	O	N/A
Savannah River Site	DOE	SC	Aiken, Allendale, Barnwell	Savannah River	N/A	N/A	O	N/A
Vogtle	Southern Nuclear Operating Company	GA	Burke	Savannah River	N/A	2,400	N	2047, 2049
McIntosh	Southern Company	GA	Effingham	Savannah River	N/A	178	O	N/A
Kraft	Southern Company/Savannah Electric and Power Company	GA	Chatham	Savannah River	N/A	208	O	N/A
Burton	Georgia Power Company	GA	Rabun	Lake Burton	90,000	6.12	H	2036
Nacoochee	Georgia Power Company	GA	Rabun	Lake Seed	5,350	4.8	H	2036
Yonah	Georgia Power Company	GA/SC	Stephens, Oconee	Lake Yonah	6,000	22.5	H	2036
Mathis-Terrora	Georgia Power Company	GA	Rabun, Habersham	Lake Rabun	21,900	16	H	2036
Tallulah	Georgia Power Company	GA	Rabun	Tallulah Falls Lake	1,490	72	H	2036
Tugaloo	Georgia Power Company	GA, SC	Habersham, Oconee	Tugaloo Lake	14,000	45	H	2036
				Total	3,075,522	10,661		

[1] PS = Pumped Storage Hydroelectric, H = Conventional Hydroelectric, O = Other, N = Nuclear
[2] The usable capacity provided in this table is based on current 794.6 ft AMSL operating restriction at Lake Keowee. The storage capacity between full pond (800 ft AMSL) and the maximum drawdown listed in the 1968 Operating Agreement (778 ft AMSL) is 327,766 ac-ft. The storage capacity between full pond (800 ft AMSL) and the elevation Lake Keowee could operate down to with ONS modifications (790 ft AMSL) is 161,772 ac-ft.
[3] The NSBL&D does not include any hydropower generating facilities

2.1.3 *Shoreline Management*

2.1.3.1 *Duke Energy Projects*

Duke Energy is responsible for managing activities within the reservoir boundaries of Lakes Jocassee and Keowee in a manner that promotes safe public use and maintains environmental safeguards. For safety reasons, Duke Energy does not allow any access to the Bad Creek Reservoir. Duke Energy maintains a Shoreline Management Plan (SMP) for Lakes Jocassee and Keowee that classifies the respective shorelines and denotes where environmentally important habitats exist, where existing facilities and uses occur, and where future construction activities may be considered (Duke Energy 2010).

As part of its SMP, Duke Energy maintains Shoreline Management Guidelines, which, when used in combination with the SMP shoreline classifications, guide responsible reservoir use activities (e.g., construction, stabilization, and excavation activities) within the reservoir boundaries. Typical activities include construction of private piers, multi-slip marinas, and conveyances; dredging efforts; and shoreline stabilization efforts.

2.1.3.2 *North Georgia Hydroelectric Project*

The Georgia Power Company (Georgia Power) is responsible for preserving the scenic, environmental, and recreational value of its reservoirs and it maintains Shoreline Management Guidelines regarding shoreline development that comply with Federal, state, and local laws and regulations. The guidelines include construction permit requirements for dwellings and additions, seawalls, docks, dredging, and residential shoreline use (Georgia Power 2008).

2.1.3.3 *USACE Projects*

USACE is responsible for managing development activities around the shoreline of Hartwell and JST Lakes in a manner that promotes safe public use and maintains environmental safeguards. USACE maintains SMPs for Hartwell and JST Lakes, which provide guidance and information to the public, specific to the effective management of the Hartwell and JST Project shorelines (USACE 2010a). The types of private uses and activities that are permitted on the shorelines are described within the SMPs. Additionally, the plans address shoreline allocations, rules, regulations, and other information relevant to the Hartwell and JST Projects.

The USACE manages and protects the shoreline of RBR Lake via its Shoreline Management Policy. This policy establishes and maintains acceptable fish and wildlife habitat, aesthetic quality and natural environmental conditions, and promotes the safe use of RBR Lake shorelines for recreational purposes by the public. Considerations are given to possible conflicts of use between the general public and the owners of private property adjacent to the project. The policy of the Chief of Engineers is that private exclusive use[2] is not permitted on reservoirs constructed after December 1974 (i.e., RBR Lake). Therefore, privately-owned boat docks, launching ramps, driveways, gardens, buildings, developed walkways, vista clearings, under-brushing, mowing, and other private lakeshore uses are not permitted.

2.1.3.4 *Lower Savannah River Basin*

2.1.3.4.1 South Carolina

The South Carolina Department of Health and Environmental Control (SC DHEC) administers the Water Quality Certification program pursuant to Section 401 of the Clean Water Act, 33 U.S.C. Section 1341. SC DHEC Regulation 61-101 establishes procedures and policies for implementing state water quality certification requirements and directs the SC DHEC in processing applications for certification. Section 401 requires the State to issue certification for any activity requiring a Federal permit which may result in a discharge to State waters. The certification must state that applicable effluent limits and water quality standards will not be violated (SC DHEC 1995). During its review of applications for Section 401 Water Quality Certification, SC DHEC considers:

- Whether the activity is water dependent;
- The intended purpose of the activity;
- Whether there are feasible alternatives to the activity; and
- All potential water quality impacts associated with the project, both direct and indirect, over the life of the project, including impacts on existing and classified uses; physical,

[2] Private exclusive use is defined as use of public land by adjacent private property owners that would lead the public to believe public land is privately owned (USACE 2011).

chemical, and biological impacts, including cumulative impacts; the effect on circulation patterns and water movement; and the cumulative impacts of the proposed activity and reasonably foreseen similar activities of the applicant and others (SC DHEC 2010).

SC DHEC may waive, issue with conditions, or deny a 401 Water Quality Certification. Certification is denied if the activity will have permanent adverse effects on existing or designated uses.

Activities that result in a discharge of dredged or fill material to waters or wetlands of the United States (U.S.) such as dam, levee, infrastructure, and mining projects, require a Federal Section 404 Clean Water Act permit. Because these activities result in discharge to waters, SC DHEC must also take certification action on all Section 404 permit applications affecting waters of the state. A Federal Section 404 permit cannot be issued without the associated state action of a Section 401 Water Quality Certification and/or a Coastal Zone Consistency determination. U.S. Coast Guard permits and FERC regulations also require states to take Water Quality Certification action.

2.1.3.4.2 Georgia

The GA DNR-EPD administers the Water Quality Certification program pursuant to Section 401 of the Clean Water Act in Georgia in a similar manner to SC DHEC in South Carolina. GA DNR regulations establish the procedures and policies that EPD follow in implementing the water quality certification program in Georgia. EPD considers similar factors and has similar rights and responsibilities as it administers the Section 401 program in Georgia.

2.1.4 *Population Characteristics*

The Savannah River Basin includes portions of 28 counties in Georgia, 13 counties in South Carolina and 4 counties in North Carolina. Although the basin is predominantly rural, metropolitan areas within the basin are experiencing approximately 25 to 35 percent more growth and development compared to national population growth rates. The growth is occurring primarily in areas of Anderson, South Carolina, and Augusta and Savannah, Georgia, as well as many smaller cities and towns.

According to historical data, the overall U.S. population grew at an average annual rate of 1.05 percent from 1970 through 2000 (HDR 2012). During this 30-year period, South Carolina and Georgia experienced statewide average annual growth rates of 1.46 percent and 1.89 percent, respectively. South Carolina and Georgia counties in the Savannah River Basin experienced average annual growth rates of 1.30 percent and 1.42 percent, respectively over the same period, as described in the Water Supply Study (HDR 2012) (Appendix A). Population growth for the counties in the Savannah River Basin from 1970 through 2000 is displayed in Table 2.1-3. That table also provides population density estimates. North Carolina population data was not included because there are only a few small tributaries located in the Savannah River Basin in North Carolina, and the only water withdrawals are small and for agricultural use.

Table 2.1-3 Savannah River Basin Population Estimates

State	No. of Counties in Basin	Drainage Basin Area (sq mi)	1970 Population Estimate (No. of People)	2010 Population Estimate (No. of People)	2010 Population Density (No. of People/sq mi)
South Carolina	13	4,558	459,785	771,800	169
Georgia	28	5,746	768,851	1,353,973	236
Total	41	10,304	1,228,636	2,125,773	206

Source: HDR 2012.

2.2 Duke Energy Projects

2.2.1 *Bad Creek Project*

The 1,065 Megawatt Bad Creek Project is located in Oconee County, approximately 8 miles northwest of Salem and 35 miles northwest of Greenville, South Carolina. Duke Energy was issued a license to construct the project (FERC No. 2740) by the FERC on August 1, 1977; the license will expire on July 31, 2027. The Bad Creek Project was constructed after the 1968 Agreement went into effect, therefore, its influence on water storage, timing of flow releases, and hydroelectric generation was not factored into the 1968 Agreement.

Lake Jocassee serves as the lower reservoir for the Bad Creek Project. The upper reservoir impounds the Bad Creek and West Bad Creek tributaries of Howard Creek, approximately one-mile west of the Whitewater River arm of Lake Jocassee and within several thousand feet of the North Carolina state line. The upper reservoir typically operates between the elevations of 2,310 and 2,250 ft AMSL and has a maximum drawdown elevation of 2,150 ft AMSL. The upper reservoir has a surface area of approximately 318 acres and a usable storage capacity of approximately 30,229 acre-feet (ac-ft) at full pool.

The Bad Creek Project is operated to generate power in a pumped storage mode. The plant typically generates power to meet peak demands a few hours per day. During off-peak hours, water is pumped from Lake Jocassee (lower reservoir) to Bad Creek (upper reservoir).

2.2.2 *Keowee-Toxaway Project*

The Keowee-Toxaway Project, situated on the southeastern slope of the Blue Ridge escarpment, consists of two developments (Jocassee Pumped Storage Development and Keowee Hydroelectric Development) located in the Upper Savannah River Basin in Pickens and Oconee counties, South Carolina, and Transylvania County, North Carolina. Lake Jocassee was flooded in 1973 and serves as the upper reservoir for the Jocassee Pumped Storage Development and the lower reservoir for the Bad Creek Project.[3] Lake Keowee was formed in 1971 by constructing a dam on the Keowee River and a dam on the Little River. The two basins are connected by an excavated canal. In addition to providing water for the production of hydroelectric power, Lake Keowee also serves as the lower reservoir for the Jocassee Pumped Storage Development and as a source for cooling water for ONS. Keowee Hydroelectric Station also serves as the back-up power supply for ONS in the case of a loss of off-site power. The FERC license for the Keowee-

[3] Although the Bad Creek Project and the Keowee-Toxaway Project operate in tandem by both using Lake Jocassee as either a lower or upper reservoir, the two projects have separate FERC Licenses.

Toxaway Project was issued on September 1, 1966 and expires on August 31, 2016. Duke Energy is currently in the relicensing process to obtain a new FERC license (New License) for the Keowee-Toxaway Project.

2.2.2.1 *Jocassee Pumped Storage Development*

The 710.1 MW Jocassee Pumped Storage Development is the upstream development of the Keowee-Toxaway Project and includes the Jocassee Pumped Storage Station, Lake Jocassee, Jocassee Dam, and two saddle dikes. The Jocassee Pumped Storage Development occupies lands in the Upstate area of South Carolina primarily in Oconee and Pickens counties with a small portion of Lake Jocassee extending into Transylvania County, North Carolina. The development is located on the Keowee River approximately 20 miles north of Seneca, South Carolina. The full pool elevation is 1,110 ft AMSL. At full pool, the reservoir has approximately 7,980 surface acres, 92.4 miles of shoreline and a gross storage volume of 1,206,798 ac-ft. The drainage area is 145 square miles. Commercial operation of Units 1 and 2 began in 1973, and operation of Units 3 and 4 began in 1975. The Jocassee Pumped Storage Development releases water directly into Lake Keowee.

Duke Energy has historically operated the Jocassee Pumped Storage Development to meet system electrical demand. Lake Jocassee operates within a range of a normal high of 1,110 ft to a low of 1,080 ft AMSL, but is typically operated within a range of approximately 1,096 ft AMSL and 1,110 ft AMSL when drought conditions do not exist. Because of the nature of pumped-storage operations, Lake Jocassee generally fluctuates approximately 0.8 ft or less with approximately 88 percent of the daily fluctuations less than 1.5 feet and virtually all daily fluctuations less than 2.9 feet during high electricity demand periods. The usable storage capacity based on the water storage volume between the Normal Full Pool Elevation and 1,080 ft AMSL is 225,387 ac-ft.

2.2.2.2 *Keowee Development*

The 157.5 MW Keowee Development is the downstream development of the Keowee-Toxaway Project and includes the Keowee Hydroelectric Station, Lake Keowee, Little River Dam, Keowee Dam, and four saddle dikes. The Keowee Development is located on the Keowee River approximately eight miles north of Seneca, South Carolina, in Pickens and Oconee counties. The full pool elevation is 800 ft AMSL. At full pool, the reservoir has approximately 17,660 surface acres, 388 miles of shoreline and a gross storage volume of 869,338 ac-ft. The drainage area is 435 square miles. Commercial operation of Units 1 and 2 began in 1971. Water released from the Keowee Hydroelectric Station flows directly into Hartwell Lake.

Duke Energy has historically operated the Keowee Development to meet standby emergency power needs for ONS and to meet system electrical demand. Under the Existing License, Lake Keowee is allowed to be operated within a range from a normal high of 800 ft to a low of 775 ft AMSL, with pumped storage operations. Based on NRC requirements for certain systems at ONS and other operating margin considerations, Lake Keowee is currently maintained at or above 794.6 ft AMSL. The Keowee Development is typically operated within a range of approximately 799.5 ft AMSL and 794.6 ft AMSL. Because of the nature of pumped-storage operations at the Jocassee Development, Lake Keowee generally fluctuates about 0.6 feet or less with approximately 86 percent of the daily fluctuations less than 1.0 foot and almost all daily fluctuations less than 1.8 feet during high electricity demand periods. The Lake Keowee calculation of usable storage at elevation 778 ft AMSL allowing for storage up to elevation 800 ft AMSL is 327,766 ac-ft.

2.2.3 *Oconee Nuclear Station*

ONS is located on Lake Keowee in Seneca, South Carolina, eight miles north of Clemson, South Carolina. The facility has three 846-MW pressurized light water reactors with a total generating capacity of 2,538 MW. Construction of the facility began in 1967. Unit 1 began commercial operation in 1973 followed by Units 2 and 3 in 1974. On May 23, 2000, the NRC renewed the licenses for all three reactors for an additional 20 years. The licenses for Units 1 and 2 expire on February 6, 2033, and the license for Unit 3 expires on July 19, 2034.

2.3 North Georgia Hydroelectric Project (Georgia Power Company)

Georgia Power owns the North Georgia Project (FERC No. 2354), consisting of six hydroelectric developments in the Savannah River Basin on the Tallulah and Tugaloo Rivers, as shown on

Figure 2.1-1. The North Georgia Project's FERC license is scheduled to expire on September 30, 2036. Based on the location of the North Georgia Project in relation to the Duke Energy and USACE projects, there are no anticipated impacts to the North Georgia Project of the alternatives evaluated in this EA. Additional information on the North Georgia developments is provided in Appendix B.

2.4 USACE Projects

For the purposes of marketing the power output of the USACE projects in the Savannah River Basin, SEPA combines the three Savannah District projects with seven Mobile District projects to form the Georgia-Alabama-South Carolina system. Generally, if one project is unable to provide the power production needed or expected, another project can be used to make up the shortage. Savannah District exercises water control management at the USACE projects within the Savannah River Basin. The water management decisions are made within the broader context of the larger power network for the Southeastern U.S.

2.4.1 *Hartwell Dam and Lake Project*

The 422 MW Hartwell Dam and Lake Project (Hartwell Project) is located on the Savannah River seven miles downstream from the confluence of the Tugaloo and Seneca Rivers forming the Savannah River. Hartwell Lake is located in Georgia (Hart, Franklin, and Stephens counties) and South Carolina (Anderson, Oconee, and Pickens counties). The Hartwell Project includes the Clemson Upper and Lower Diversion Dams, which were completed in 1967 to protect lowlands at Clemson University. The project has 1,416,000 ac-ft of usable storage capacity at a full pool elevation of 660 ft AMSL. The surface area at 660 ft AMSL is approximately 56,000 acres with a 962-mile shoreline. Project construction occurred from 1955 through 1963 and the first generator went on-line on April 27, 1962.

The authorized purposes of the Hartwell Project are to provide flood control, fish and wildlife habitat, water quality enhancement, water supply, recreation, and hydroelectric power. The Hartwell Project includes 35 feet of conservation storage from elevation 625 to 660 ft AMSL and 5 feet of flood control storage operation from an elevation of 660 to 665 ft AMSL. During the spring and early summer, the project has limited additional flood control storage. During normal conditions, all flow releases are made through the turbine units. The water control manager coordinates weekly (or more frequent, if necessary) water control actions with SEPA. Power produced from the Hartwell Project is sold through SEPA to public entities and cooperatives in the Southeastern U.S. From there, the power is provided to customers of those entities.

2.4.2 *Abbeville Hydroelectric Project (City of Abbeville, SC)*

The 2.6 MW Abbeville Hydroelectric Project (FERC No. 11286) is located on Rocky River, a tributary to the Savannah River, situated in Anderson and Abbeville counties. The Project was constructed in 1940 by the City of Abbeville and was issued a 30-year license by the FERC on December 24, 1997. The project functions as a peaking facility with electrical energy used by the City to offset power purchases from electrical wholesalers. The project reservoir (Lake Secession) has a surface area of approximately 1,362 acres with 25,650 ac-ft of usable water storage at full pond (548 ft AMSL). The project tailrace is affected by backwater from RBR Lake.

2.4.3 *RBR Dam and Lake Project*

The 660 MW Richard B. Russell Dam and Lake Project (RBR Project) is located in the Piedmont region of Georgia and South Carolina on the middle Savannah River. The project is located in Abbeville County, South Carolina and Elbert County, Georgia, 30 miles downstream from Hartwell Dam and 37 miles upstream from the JST Dam. Construction of the RBR Project began in 1974 and it began operating in 1985. The power plant originally consisted of four conventional generators. Four pump-back units were added in 1992 and commercial operation of the pump-back units began in July 2002. The authorized purposes of the RBR Project include hydroelectric generation, incidental flood control, water supply, water quality enhancement, recreation, and fish and wildlife habitat. The RBR Project was constructed after the 1968 Agreement went into effect, so its influence on water storage, timing of flow releases, and hydroelectric generation is not factored into that 1968 Agreement.

The reservoir has a flood pool elevation of 480 ft AMSL and 126,800 ac-ft of usable storage capacity. RBR Lake has a surface area of approximately 26,650 acres and 540 miles of shoreline at a Normal Pool Elevation of 475 ft AMSL. RBR includes 5 feet of conservation storage from elevation 470 to 475 ft AMSL and 5 feet of flood control storage operation from an elevation of 475 to 480 ft AMSL.

There are several operational restrictions in place at the RBR Project to minimize fish entrainment and impacts to fishery habitat. The operational restrictions include:

- Pumped storage operations are limited to the hours beginning one hour before official sunrise to one hour after official sunset.
- Between March 1 and March 31, the RBR Project is limited to one-unit operation and no pumped storage operations occur between April 1 and April 30 (not applicable to Level 2 drought conditions or greater).
- There are no seasonal pumped storage operational restrictions when a Level 2 drought is declared.
- Between May 1 and May 31, pumped storage operations include a maximum of one-unit operation. In the event that a Level 1 drought is declared, pumped storage operations are increased to a maximum of two units between May 16 and May 31.
- From May 16 through September 30, the USACE conducts a minimum of six unit-hours of generation, of not less than 60 MW, within the 12 hours preceding any pumped-storage operation.

USACE is still monitoring the effects of four unit pumpback operation on fishery resources.

2.4.4 *John S. Rainey Generating Station*

The 1,100 MW John S. Rainey Generating Station (Rainey Station) is located in Starr, South Carolina. The first phase of the Rainey Generating Station, a 500 MW combined cycle unit, began commercial operation in January 2002, and by May 2002, two 150 MW simple-cycle combustion turbines were also in service. The Rainey Station is Santee Cooper's first facility with gas as its primary fuel source and is planned for service through 2066.

2.4.5 *JST Dam and Lake Project*

The 380 MW J. Strom Thurmond Dam and Lake Project (JST Project) is located on the Savannah River 22 miles upstream from Augusta, Georgia, and 239.5 miles upstream from the mouth of the Savannah River. JST Reservoir is located in Columbia, Lincoln and Elbert counties in Georgia; and McCormick and Abbeville counties in South Carolina. The reservoir extends 39.4 miles up the Savannah River, 29 miles up the Little River, 6.5 miles up the Broad River in Georgia, and 17 miles up the Little River in South Carolina. The project has 1,045,000 ac-ft of usable storage capacity, 1,200 miles of shoreline and approximately 71,000 surface acres of water at a normal pool elevation of 330 ft AMSL. The project was the first of the three USACE projects built in the Savannah River Basin and it was constructed from 1946 through 1954. Filling of JST began in July 1951 and was completed in October 1952. The power plant began commercial operation in November 1952.

The authorized purposes of the JST Project are to provide for flood control, fish and wildlife habitat, water quality enhancement, water supply, recreation, and hydroelectric power. The project has 18 feet of conservation storage from an elevation of 312 to 330 ft AMSL. The project has seasonal drawdowns of the conservation pool. Operations at the JST Project are similar to the operations at the Hartwell Project with the additional requirement of operating the gates at the NSBL&D. The power produced at the JST power plant is sold through SEPA. The JST power plant is operated primarily as a peaking plant to meet electric needs during peak demand hours.

The combined usable storage of Hartwell, RBR, and JST Lakes is 2,587,800 ac-ft.

2.5 Lower Savannah River Projects

The following projects are located on the Lower Savannah River in descending order between JST Dam and the Savannah Harbor as depicted in Figure 2.1-1 (with the exception of the NSBL&D Project, which is described in Section 2.57).

2.5.1 *Stevens Creek Project (South Carolina Electric & Gas Company)*

The 17.3 MW Stevens Creek Project (FERC No. 2535) is located at the confluence of Stevens Creek and the Savannah River in Edgefield and McCormick counties, South Carolina and Columbia County, Georgia. The project license was issued by the FERC on November 22, 1995 and expires on October 31, 2025. Stevens Creek is a run-of-river hydroelectric project, but it effectively functions as a re-regulating facility to smooth out the peaked flows discharged from the upstream JST Dam. The reservoir has a surface area of 2,400 acres and contains 23,700 ac-ft of water at full pool (187.5 ft AMSL) with 8,600 ac-ft of usable storage capacity. Construction of the project was completed in 1914.

SCE&G is required by Article 402 of the FERC license to operate the Stevens Creek Project to reach full pool in the Stevens Creek Reservoir by Friday evening and provide a continuous weekend discharge. Additional operational requirements include re-regulation of flow releases from the JST Dam (located upstream of the Stevens Creek Project) and releasing all JST Dam discharges on a weekly basis, and implementation of fish passage if/when they are effective at downstream dams. SCE&G is also required to obtain the predicted JST Dam discharge schedule from the USACE to limit reservoir fluctuations while maintaining the Stevens Creek Reservoir between elevations of 183 and 187 ft AMSL.

2.5.2 *Augusta Canal and Diversion Dam Project (City of Augusta, Georgia)*

The Augusta Canal Project (FERC No. 11810) has no hydroelectric generating facilities. On January 30, 2003, the City of Augusta, Georgia, filed an application with the FERC for a major license for the Augusta Canal Project. The License Application is still pending with the FERC. The South Carolina Department of Natural Resources (SC DNR) has requested the following seasonal aquatic-based flows (in cubic feet per second [cfs]) as part of the Water Quality Certification pursuant to § 401 of the Clean Water Act (Table 2.5-1).

Table 2.5-1 Seasonal Aquatic-Based Flows for Augusta Canal and Diversion Dam Project

Inflow (cfs)		Feb 1-Mar 31	Apr 1-30	May 1-15	May 16-31	Jun 1-Jan 31
Tier 1	≥5,400	3,300	3,300	2,500	1,900	1,900
Tier 2	4,500-5,399	2,300	2,200	1,800	1,800	1,500
Tier 3	3,600-4,499	2,000	2,000	1,500	1,500	1,500
Tier 4	<3,600	1,800	1,500	1,500	1,500	1,500

Source: SCDNR 2008.

The City of Augusta has indicated that it would comply with that request as best it could until a decision by FERC on the license. Natural resource agencies have also stated that the FERC license must include provision for fish passage if/when it is effective at the downstream dam.

The project currently provides hydro-mechanical power to pump raw drinking water to the City of Augusta's water treatment plant. The Augusta Canal also supplies water to the Sibley Mill, Enterprise Mill, and King Mill projects. Originally constructed in 1875, the project was modernized in 1979. The Augusta Diversion Dam is located at river mile (RM) 207.2 approximately 0.9 miles downstream from Stevens Creek Dam. The project impounds 190 surface acres at a Normal Pool Elevation of 160 ft AMSL. The dam operates in a run-of-river mode, with no usable storage capacity.

2.5.3 *Sibley Mill Project (Augusta Canal Authority.)*

The 2.457 MW Sibley Mill Project (FERC No. 5044) is located on the Augusta Canal approximately five miles downstream from the Augusta Diversion Dam in Richmond County, Georgia. The current license expires on October 31, 2055. Originally constructed in 1880, the project was converted from hydro-mechanical to hydroelectric power near the turn of the 20th Century. There is no dam or impoundment associated with the Sibley Mill Project. The project is owned and operated by the Augusta Canal Authority and withdraws up to 1,024 cfs of water from the Augusta Canal for discharge into an open concrete canal that flows into the Savannah River.

2.5.4 *Enterprise Mill Project (Melaver/Enterprise Mill, LLC)*

The 1.2 MW Enterprise Mill Project (FERC No. 2935) is located on the Augusta Canal approximately 0.5 miles downstream from the Sibley Mill Project in Richmond County, Georgia. The current license expires on October 31, 2055. There is no dam associated with the Enterprise Mill Project. The project operates in a run-of-river mode and withdraws approximately 560 cfs of water from the Augusta Canal when running at full capacity. Construction of the Enterprise Mill commenced in 1845 and was expanded in 1875. The existing turbines were installed in 1920. The Augusta Canal Authority operates the Enterprise Mill Project under an agreement with Melaver/Enterprise Mill, LLC.

2.5.5 *King Mill Project (Augusta Canal Authority.)*

The 2.25 MW King Mill Project (FERC No. 9988) is located on the Augusta Canal approximately 5.5 miles downstream from the Augusta Diversion Dam in Richmond County, Georgia. An application for a new license was filed with the FERC on May 1, 2007, and a 43-year, 4-month license (expiring on October 31, 2055) was issued effective August 3, 2012. The term of the new license was set to coincide with the FERC license expiration dates for the Sibley Mill and Enterprise Mill Projects.

There is no dam or impoundment associated with the King Mill Project. There are two generating units and approximately 881 cfs of water is withdrawn from the Augusta Canal when operating at full capacity. All flows return to the Savannah River approximately 5.5 miles downstream from the diversion dam. The King Mill Project is owned by the Augusta Canal Authority, but operated by Standard Textile Augusta Inc. Operations at the King Mill Project vary on a day-to-day basis, depending on the gravity flow and water levels of both the Augusta Canal and the Savannah River.

2.5.6 *Urquhart Station Project (South Carolina Electric & Gas Company)*

The 650 MW Urquhart Station Project is a five-unit coal and natural gas-fired power station located at Beach Island on the Savannah River near Augusta in Aiken County, South Carolina. The Urquhart Station Project began commercial operation in 1953 with two 75 MW units and one 100 MW unit. In 2002, two of the coal-fired units were converted to combined-cycle units fueled by natural gas. The project also has 50 MW of combustion turbine capacity. The project is operated by SCE&G.

2.5.7 *New Savannah Bluff Lock and Dam Project*

The NSBL&D Project is located approximately 33 miles downstream from the JST Dam and approximately 13 miles downstream from Augusta (Richmond County), Georgia and North Augusta (Aiken County), South Carolina. The NSBL&D Project consists of a lock chamber, operation building, and a 50-acre park and recreation area. The Project is no longer used for commercial navigation. The park is operated by the Augusta/Richmond County under a lease from USACE.

USACE has committed to construct a fish bypass at the NSBL&D as one of the mitigation features in the Savannah Harbor Expansion Project. The bypass design in the 2012 Final Environmental Impact Statement would pass river flows up to 8,000 cfs around the South Carolina side of the lock and dam. Flows over that amount would pass through the existing gates on the dam.

2.5.8 *Alvin W. Vogtle Nuclear Power Plant (Southern Nuclear Operating Company-Operator)*

The 2,400 MW Alvin W. Vogtle Nuclear Power Plant is located along the Savannah River in Burke County, Georgia. The facility has two pressurized water reactors. Units 1 and 2 began commercial operation in 1987 and 1989, respectively. Cooling water requires the withdrawal of an average of 62 MGD (maximum of 74 MGD maximum) from the river. On August 15, 2006, Southern Nuclear formally applied for an Early Site Permit (ESP) for two additional units at the facility. In March 2008, Southern Nuclear filed a Combined Construction and Operating License (COL) application with the NRC for new units at the facility. In February 2012, the NRC approved the application for Vogtle Units 3 and 4. Commercial operation of the additional units is expected to begin in 2017 and 2018, respectively. Cooling for the two additional units would require withdrawal of an additional 74 MGD (maximum) from the river. GA DNR-EPD recently announced its intent to grant a water withdrawal permit for that additional withdrawal.

2.5.9 *McIntosh Steam Plant (Southern Company)*

McIntosh Steam Plant (also known as Effingham Steam Plant) is a 178 MW coal-fired power plant located in the City of Rincon, (Effingham County) Georgia. The plant began commercial operation in 1979.

2.5.10 *Plant Kraft (Southern Company/Savannah Electric and Power Company)*

Plant Kraft is a 208 MW coal-fired facility located along the Savannah River in Port Wentworth, Chatham County, Georgia. The plant has three units: Unit 1 (50 MW) was placed in service in 1958, followed by Unit 2 (54 MW) in 1961, and Unit 3 (104 MW) in 1965.

2.6 Water Supply

Water users in the Savannah River Basin that currently withdraw from, or return to, surface waters at an average rate of 0.1 million gallons per day (mgd) or greater are classified based on the following categories (information sources include SC DHEC and the Georgia Department of Natural Resources [GA DNR]):

- Public Water/Wastewater Utility
- Industrial
- Power
- Agricultural/Irrigation

Table 2.6-1 provides the number of Savannah River Basin water users identified by category and the estimated aggregate water use for 2010. The 2010 values are used as the current water use data since this data represents the most accessible and reliable water use information (HDR

2012). Table 2.6-2 presents future projected water use for 2066 from the Savannah River Basin. In order to develop reliable water withdrawal and return projections, users that withdraw or return from a surface water source an average daily rate of at least 100,000 gallons per day (or 0.1 mgd) from each reservoir watershed were included in the water supply analysis. Variations in total number of users from current to future values may be attributed to projected permit expirations, utility consolidations, and/or ownership changes.

Table 2.6-1 Savannah River Basin Current Water Use Information

Category	2010 Withdrawals		2010 Returns		2010 Net Withdrawals
	No.	Rate (mgd)	No.	Rate (mgd)	Rate (mgd)
Public Water/Wastewater Utility	35	201 (311 cfs)	54	108 (167 cfs)	93 (144 cfs)
Industrial	15	105 (162 cfs)	36	145 (225cfs)	-40 (-62 cfs)
Power	9	128 (199 cfs)	N/A[1]	N/A[1]	128 (199 cfs)
Agricultural/Irrigation Demand	N/A[2]	62 (96 cfs)	N/A[2]	N/A[3]	62 (96 cfs)
Total	59	496 (768 cfs)	90	253 (392 cfs)	243 (376 cfs)

Notes:
[1] Power withdrawals are net withdrawals (i.e., returns are accounted for in these values).
[2] Current agricultural/irrigation water use based on U.S. Geological Survey (USGS) data, which is aggregated by county.
[3] Agricultural/irrigation water use is assumed to be completely consumptive (i.e., no returns).

Table 2.6-2 Savannah River Basin Future Projected Water Use Information

Category	2066 Withdrawals		2066 Returns		2066 Net Withdrawals
	No.	Rate (mgd)	No.	Rate (mgd)	Rate (mgd)
Public Water/Wastewater Utility	34	511 (790 cfs)	54	223 (345 cfs)	288 (445 cfs)
Industrial	30	131 (203 cfs)	36	193 (299 cfs)	-62 (-96 cfs)
Power	20	305 (471 cfs)	N/A[1]	N/A[1]	305 (471 cfs)
Agricultural/Irrigation Demand	N/A[2]	62 (96 cfs)	N/A[2]	N/A[3]	62 (96 cfs)
Total	84	1,008 (1,560 cfs)	90	416 (644 cfs)	592 (916 cfs)

Notes:
[1] Power withdrawals are net withdrawals (i.e., returns are accounted for in these values).
[2] Projected agricultural/irrigation water use based on USGS data, which is aggregated by county.
[3] Agricultural/irrigation water use is assumed to be completely consumptive (i.e., no returns).

2.6.1 *Lake Jocassee*

There are no consumptive water withdrawals located on Lake Jocassee. The potential for future population growth around Lake Jocassee is limited due to its location in the Nantahala and Sumter National Forests, and the proximity of state parks and state-owned conservation land to the reservoir.

2.6.2 *Lake Keowee*

There are currently two municipal water withdrawal intakes on Lake Keowee: Greenville Water and Seneca Light & Water (Seneca). The area surrounding Lake Keowee has a moderate to high potential for residential growth, particularly to the south and southwest. Further, the area around the City of Greenville, South Carolina, which uses drinking water withdrawn from Lake Keowee, continues to grow. Given that the area around the Keowee-Toxaway Project continues to attract new development, Duke Energy anticipates the demand for water to support municipalities will continue to increase in the future. In addition, Duke Energy's ONS also withdraws water from Lake Keowee for cooling purposes.

The current (based on 2010 data) total water withdrawal from Lake Keowee is 65.6 mgd (101.5 cfs). Municipal and agricultural withdrawals account for 41.2 mgd (63.7 cfs) and net evaporative water use due to thermal cooling at ONS accounts for 24.5 mgd (37.9 cfs). Current total water returns in Lake Keowee are 1.5 mgd (2.4 cfs) from municipal sources (HDR 2012).

2.6.3 *Hartwell Lake*

Current total water withdrawals from Hartwell Lake and tributaries to Hartwell Lake (based on 2010 data) are 39.0 mgd (60.3 cfs), including withdrawals from ten municipal (public) raw water intakes. Current total water returns are 14.6 mgd (22.6 cfs). Hartwell Lake has three users holding water storage contracts that allow a total withdrawal of 26,574 ac-ft (or 53 percent) of the available 50,000 ac-ft of water supply storage authorized by Congress. These users are Lavonia, Georgia; Hart County, Georgia; and Anderson County, South Carolina.

USACE manages the amount of water that can be reallocated based on storage (in ac-ft) rather than yield (i.e., a particular withdrawal rate). As a result, the user (e.g., industry or municipality) must request a permanent reallocation of storage (in ac-ft) to support a given flow requirement (in cfs). The storage to support a particular yield is based on the drought of record at the time of the request. Based on the minimum reservoir levels that occurred during the 2007 through 2009 period, the USACE has deemed this period to be the worst drought on record. If a more severe drought occurs in the future, additional storage may need to be purchased (if available) to support the desired yield. The remaining storage at Hartwell Lake available for reallocation to water supply purposes is 23,426 ac-ft.

The permanent reallocation agreement is similar to a bank account of water that is debited by the user and credited based on a pro-rated apportionment of inflow coming into the reservoir. Debits and credits are determined on the first day of each month for the prior month. The amount of inflow coming into the reservoir is based on the net change in reservoir storage during the previous month plus the amount withdrawn by all users during the previous month (users must submit a monthly report to the USACE documenting their withdrawals). Debits for the prior month only occur if the reservoir the withdrawal is being made from is below guide curve on the first day of the current month.

During conservation operations (i.e., when the reservoir is below guide curve), USACE tracks each user's account on a monthly basis. The bank account of water is reset to the full reallocation purchased when the reservoir returns to guide curve, and is determined on the first day of each month.

2.6.4 *RBR Lake*

Current total water withdrawals from the RBR watershed (based on 2010 data) are 6.6 mgd (10.2 cfs), including withdrawals from two municipal raw water intakes. Current total water returns are 10.1 mgd (15.6 cfs) (HDR 2012). RBR Lake has the smallest discretionary limit for storage reallocations at 9,300 ac-ft. Water storage contracts for RBR Lake include Abbeville, Elberton, Georgia and Santee Cooper. These users account for 872 ac-ft (9 percent), leaving 8,428 ac-ft of the authorized storage reallocation.

2.6.5 *J. Strom Thurmond Reservoir*

Current total water withdrawals from the J. Strom Thurmond Reservoir (based on 2010 data) are 22.2 mgd (34.3 cfs), including withdrawals from eleven municipal raw water intakes. Current total water returns are 4.7 mgd (7.3 cfs) (HDR 2012). There are five users with permanent water storage contracts withdrawing from JST Lake: McCormick, South Carolina; Lincolnton, Georgia; Thomson, Georgia; Columbia County, Georgia; and Washington, Georgia. Of the 50,000 available ac-ft, these users account for 3,833 ac-ft (approximately 8 percent), leaving 46,167 ac-ft of the remaining available storage reallocation at JST.

2.6.6 *Lower Savannah River Basin*

Sixteen major municipal water withdrawal intakes are located downstream of JST Dam (USACE 2008a). The major municipal users extend from Augusta, Georgia, downstream to the coast at Savannah Harbor. The City of Augusta, Georgia withdraws water from the Augusta Canal (USACE 2008a). The City of North Augusta, South Carolina withdraws water from the pool upstream of the NSBL&D (RM 187.5) (USACE 2008a). The Beaufort-Jasper County Water Supply Authority withdraws water at RM 39.3. The City of Savannah's M&I Plant is located on Abercorn Creek, at approximately RM 29. The other major municipal users consist of Columbia County, Georgia and Edgefield County, South Carolina (USACE 2008a).

Industrial users with intakes in the NSBL&D pool include North Augusta, Mason's Sod, Kimberly Clark, Urquhart Station, PCS Nitrogen, Demand Side Management (DSM) Chemical and General Chemical, and SCE&G (USACE 2008a). Additional users downstream of NSBL&D include International Paper, Savannah River Site, Vogtle Nuclear Power Plant, Savannah Electric, Georgia-Pacific, and the Savannah National Wildlife Refuge (USACE 2008a). The total withdrawals in this area downstream of JST Dam are 363.6 mgd (562.5 cfs) and the total returns are 227.6 mgd (352.1 cfs) (HDR 2012).

2.7 Water Quality Standards

The Savannah River Basin is located within North Carolina, South Carolina, and Georgia. Most large headwater streams entering Lake Jocassee originate in North Carolina; all streams and rivers entering Lake Keowee fall under the jurisdiction of South Carolina. Both North and South Carolina have assigned state water quality standards commensurate with a designated use of a waterbody. Georgia classifies the waters of the state by designated use and has assigned water quality standards to each use classification.

North Carolina, South Carolina, and Georgia have similar categories of designated use; however, variations or sub-sets of general classifications differ between the states. Even though specific designations differ between the states, the states have distinguished between general use to maintain and support aquatic life and general contact recreation, trout habitats, and high value resource areas. Water use classifications and water quality standards for all three states are described in Appendix C.

2.7.1 *Duke Energy Projects*

Duke Energy monitored water quality after impoundment of Lakes Jocassee and Keowee, as required by the Atomic Energy Commission (AEC-predecessor to the NRC) for the licensing of ONS. This initial monitoring has continued with minor modifications.

Prior to 1981, ONS's thermal discharge was permitted under the authority of the NRC. Since that time, the ONS thermal discharge has been permitted under the National Pollutant Discharge Elimination System (NPDES) as authorized by SC DHEC. Pursuant to the Clean Water Act Section 316(a), three demonstrations have been successfully submitted to SC DHEC. The majority of the water quality data collected by Duke Energy on Lake Keowee, and presented in this document, was in support of ONS permitting. Details of Lake Keowee water quality sampling, water quality data analysis, and impact of once-through-cooling water in Lake Keowee are presented in the three Clean Water Act Section 316(a) demonstrations (Duke Power Company 1995 and Duke Energy 2007 and 2012).

Duke Energy water quality sampling on Lakes Jocassee and Keowee generally consisted of monthly[4] in situ sample collection for analysis of temperature, dissolved oxygen (DO), conductivity, and hydrogen ion concentration (pH) at several locations (Figures 2.7-1 and 2.7-2). This water quality monitoring program was designed to determine long-term water quality trends. Additionally, water samples were also collected at least semi-annually for analysis of nutrients, chlorophyll a, and primary anions and cations as well as various metals.

Various governmental agencies have also conducted water quality assessments of Lakes Jocassee and Keowee. The U.S. Environmental Protection Agency (EPA) conducted water quality surveys on Lake Keowee as part of the National Eutrophication Survey (US EPA 1975). EPA found Lake Keowee was mesotrophic and ranked it first in overall water quality compared to other South Carolina reservoirs.

The U.S. Fish and Wildlife Service (USFWS) (Oliver and Hudson 1987) conducted monthly temperature and oxygen profiling at 13 locations in Lake Keowee from 1971 to December 1982. The depression of the thermocline, expansion of the epilimnion, and increased vertical mixing of D.O. throughout the reservoir was the result of ONS pumping deep, cool water for condenser cooling from under a 67-foot deep skimmer wall. In addition, the USFWS noted a cold water plume in the northern portion of Lake Keowee as a result of Jocassee operations.

SC DHEC has consistently identified Lakes Jocassee and Keowee as among the cleanest South Carolina reservoirs based on 1980–1981, 1985–1986, and 1989–1990 data. DHEC has placed both reservoirs in the highest water quality classification and recommended preservation of existing conditions. Water quality in Lake Keowee is second only to Lake Jocassee, which DHEC considered excellent.

[4] Quarterly sampling occurred from 1984 to 1987.

Figure 2.7-1 Water Quality Monitoring Sites – Jocassee Watershed

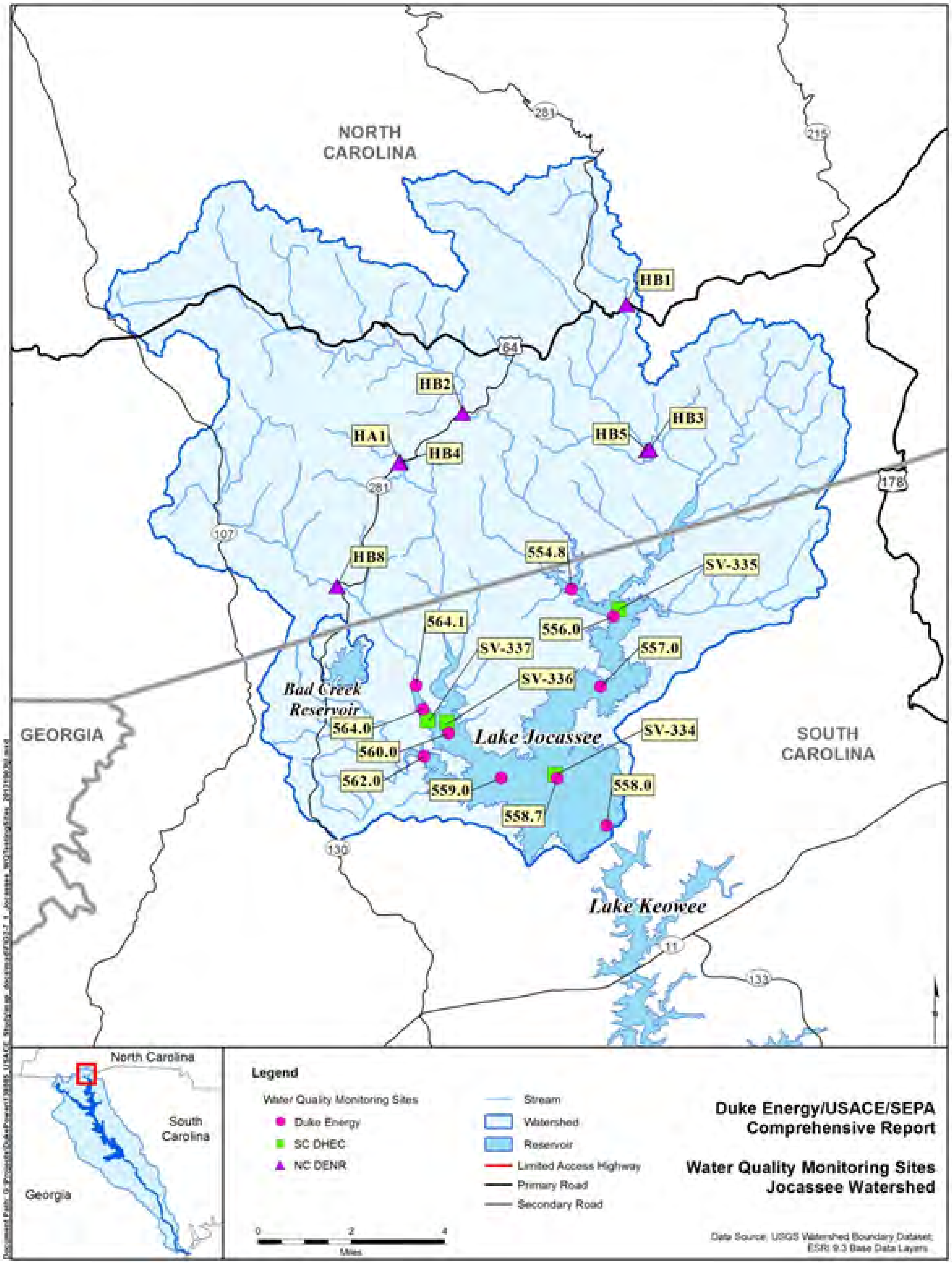
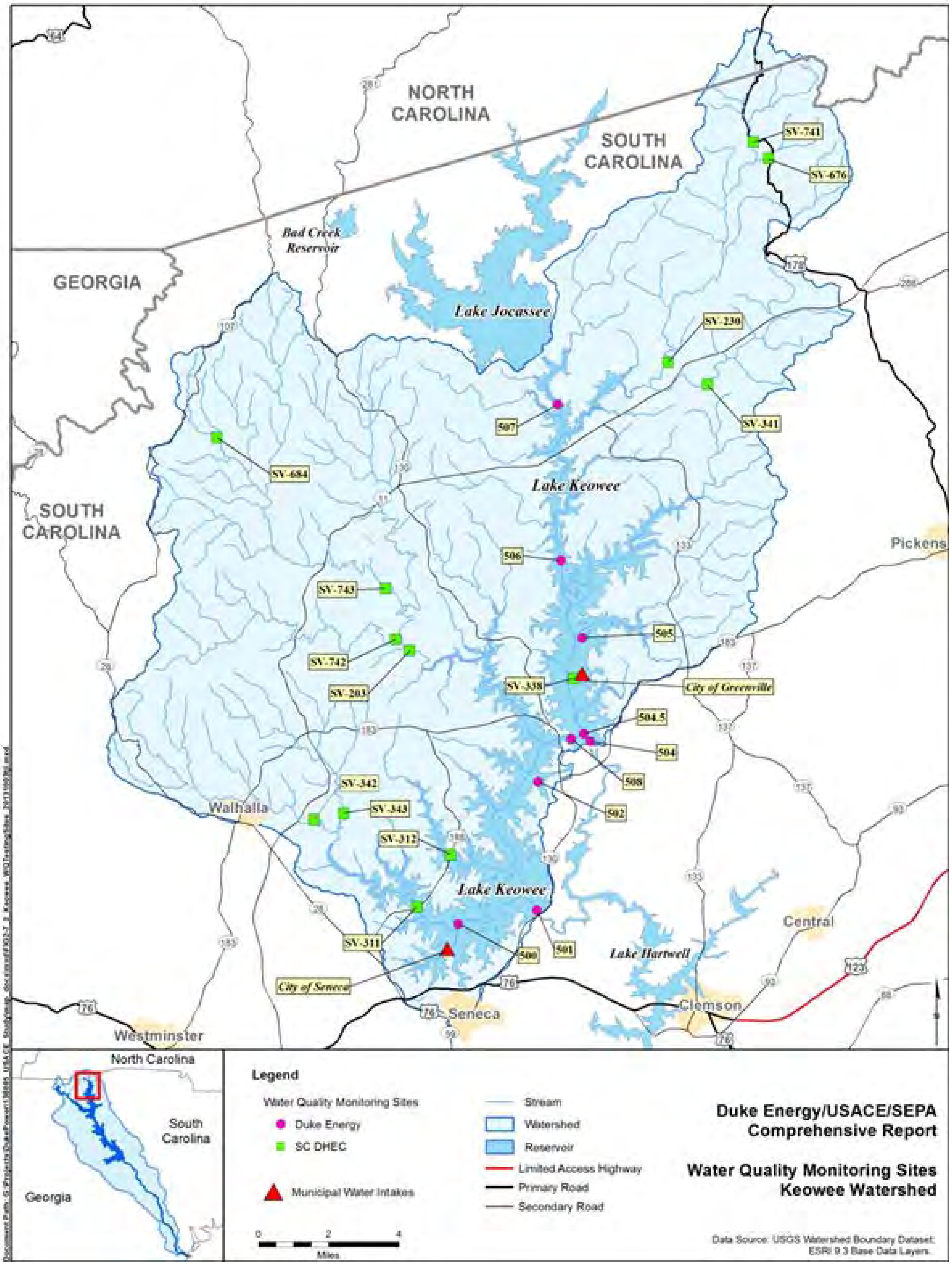


Figure 2.7-2 Water Quality Monitoring Sites – Keowee Watershed



2.7.1.1 *Lake Jocassee*

Lake Jocassee is one of only a few reservoirs in South Carolina that possesses the necessary combination of water temperatures and D.O. levels to ensure the survival of salmonid (trout) species year-round. Following impoundment of Lake Jocassee in the early 1970s, state fishery biologists from South Carolina introduced both rainbow and brown trout into the reservoir to diversify its fishery. The stocking of rainbow and brown trout has continued annually to present day, resulting in a productive combination of various gamefish for the avid fishery sportsman. Continued success of the trout fishery depends partly on the year-round availability of suitable pelagic habitat, as defined by specific thermal and D.O. limits.

Over the history of Jocassee Pumped Storage Station operations, the reservoir has experienced drawdowns of up to approximately 29 feet. Temperature and D.O. distributions within the reservoir during these large drawdown events have been compared to full pool and an intermediate level. The results of this comparison indicated that low water years exhibited deeper, stronger thermoclines. However, the overall thermal structure of the reservoir was maintained and D.O. concentrations throughout the water column were not impacted by the reduction of reservoir elevation. Rather, D.O. concentrations were primarily a function of the degree of the previous winter mixing. Colder winter temperatures resulted in deeper mixing within the reservoir, which in turn resulted in higher D.O. concentrations the following year (and vice versa).

In 2008, Duke Energy installed a water quality monitor to collect continuous temperature, D.O., conductivity, and water level data in the Jocassee tailwater area (i.e., upper end of Lake Keowee). Data from this monitoring location indicate that, as expected, Jocassee Pumped Storage Station releases cool water from deeper in the reservoir compared to the warmer surface water withdrawal at Keowee Hydroelectric Station. D.O. concentrations in the Jocassee tailwater area reflect the oxygen concentrations at the withdrawal depth and are relatively consistent given the relatively high exchange rates of similar water between the forebay and tailrace during generating and pumping cycles. During April to October 2012, temperature and D.O. data were collected in both the forebay and tailwater areas to evaluate the effects of Jocassee Pumped Storage Station operations on water quality. Throughout the 2008 - 2012 study period, D.O. and temperature from the forebay and the tailwater monitoring locations were similar, and both locations had higher D.O. levels than state water quality standards (up to 9 mg/L compared to the state standard of 5 mg/L). Details of the 2012 study are provided in Appendix C.

2.7.1.2 *Lake Keowee*

Unlike Lake Jocassee, Lake Keowee is a typical Southeastern monomictic reservoir with one stratified period and a long, fall-winter mixing period. Rather than having a single basin like Lake Jocassee, Lake Keowee has two basins (the Keowee Basin and the Little River Basin) connected by a man-made canal. Although connected, each basin exhibits slightly different patterns of temperature and oxygen stratification.

The seasonal patterns of temperature and D.O. in the two basins of Lake Keowee reflect similar heating and cooling with respect to the local seasonal patterns of meteorology, namely as the weather cools in the fall-winter period, heat is lost from the reservoir with the coolest reservoir temperatures observed in February and March. Unlike Lake Jocassee, both basins forming Lake Keowee mix completely every year (related to the relative shallow depth of Lake Keowee as compared to Lake Jocassee) and, consequently, Lake Keowee re-aerates every winter.

The Keowee Basin exhibited similar seasonal trends of temperature and D.O. changes as the Little River Basin. However, rather than developing one thermocline, two temperature gradients were observed, one at the depth of the Jocassee Pumped Storage Station pump-back intake and the other at the same depth as the Little River Basin. This pattern of stratification suggests that as Jocassee Pumped Storage Station releases water into the Keowee Basin, the cooler water (relative to the surface of Lake Keowee) from Lake Jocassee plunges to a depth commensurate with the water density of the cool water. Conversely, during the times of Jocassee Pumped Storage Station pump-back, warmer surface water from Lake Keowee is withdrawn from Keowee Basin and pumped into Lake Jocassee, thereby strengthening and maintaining the temperature gradient observed in Lake Jocassee. Even though the winter mixing re-established the initial temperature and oxygen conditions for the upcoming stratification period, the winter conditions, unlike Lake Jocassee, did not pre-determine hypolimnetic conditions at the height of stratification in Lake Keowee.

Duke Energy has monitored temperatures in the Keowee Hydroelectric Station forebay and tailrace on a daily basis since 2000. In 2008, Duke Energy installed a water quality monitor to collect water temperature, D.O., conductivity, and water level data in the tailrace area. The Keowee tailrace temperatures are indicative of the surface water withdrawal, but never exceeded 90ºF. Because Keowee Hydroelectric Station releases water at infrequent intervals (as compared to Jocassee Pumped Storage Station operations), there is greater variability in temperature and D.O. concentrations in the tailrace during these flow releases. The D.O. concentrations in the water released from Keowee Hydroelectric Station were above state water quality standards at all times. Details of this analysis are provided in Appendix C.

2.7.2 ***USACE Projects***

USACE conducts water quality monitoring on the Hartwell, RBR, and JST Reservoirs. The primary objectives of the monitoring program are to document water quality conditions (particularly temperature and D.O.) with emphasis on the influence of its operations (hydroelectric generation, pumped storage operations, and operation of oxygenation systems) on water quality. Past studies have examined reservoir and tailrace conditions in all three reservoirs. The current monitoring program does not include water quality sampling in Hartwell Lake, but data are still being collected in the Hartwell Project tailwater area.

Generally, water quality in the USACE Reservoirs meets or exceeds applicable state water quality standards. Similar to Duke Energy’s Lake Jocassee and Lake Keowee, the USACE Reservoirs experience thermal stratification during the late spring to late fall months. As a result, reservoir temperatures and D.O. concentrations are the primary water quality constituents of concern pertaining to this study.

2.7.2.1 *Hartwell Lake*

Thermal stratification begins in Hartwell Lake in late April and early May of each year. The thermocline is established at a depth of about 30 feet and is maintained at that depth through early August. The thermocline moves to a depth of about 40 feet in late August and early September and to about 50 feet in late September and early October. By late October or early November, Hartwell Lake starts to destratify due to cooler air temperatures and the thermocline moves to a depth of about 70 feet. Isothermal conditions exist by early December each year (USACE 1995).

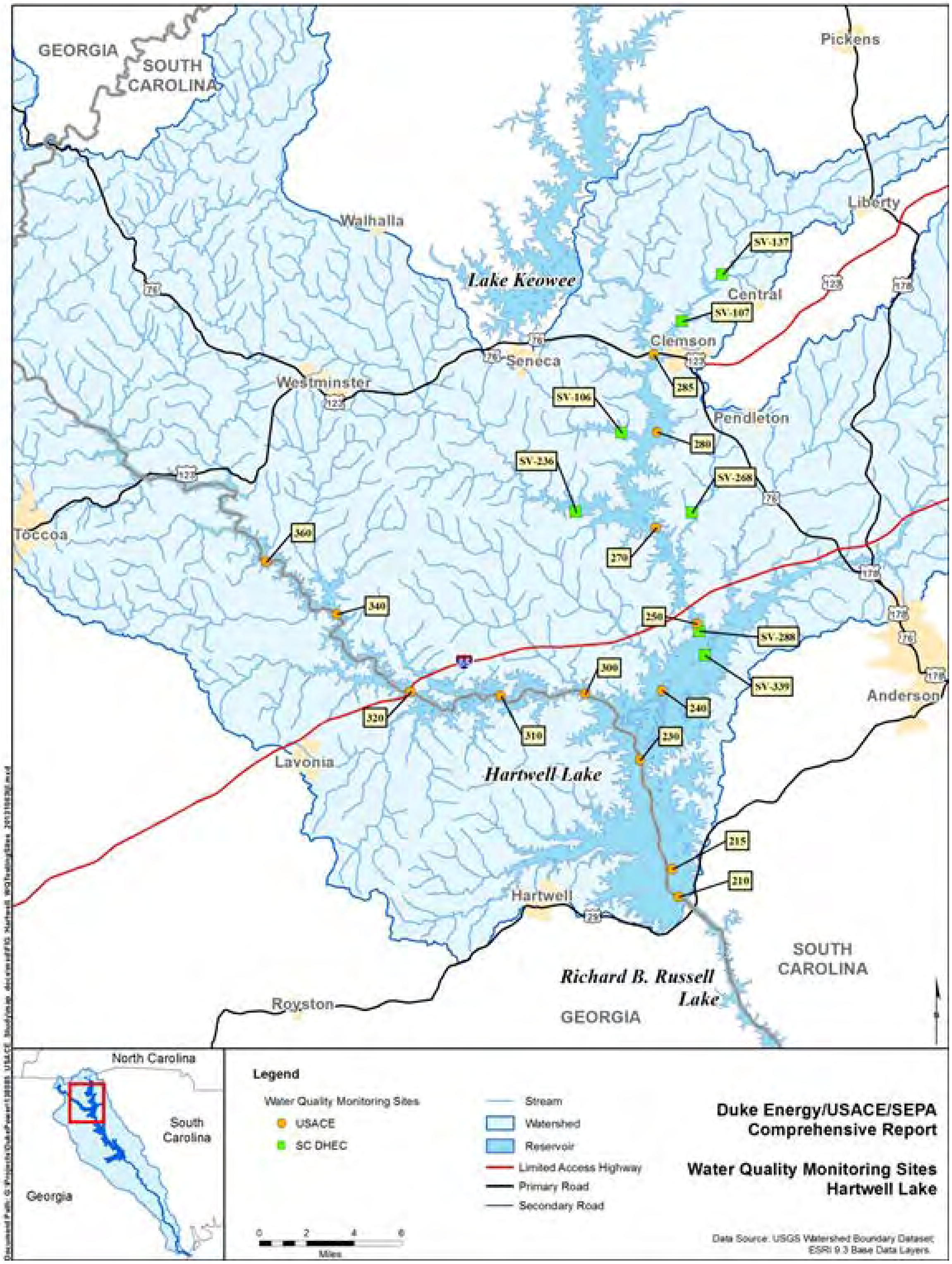
During stratified conditions, the D.O. in the epilimnion remains at a relatively constant concentration around 7 milligrams per liter (mg/L) while D.O. concentrations in the hypolimnion are much lower. The level of the maximum D.O. concentration gradient is established at a depth of about 30 feet in July, it moves to a depth of about 40 feet in August, and then it moves to a depth of 55 or 60 feet by late September. In early August, there is usually a 3 mg/L difference in D.O. levels between the upper and lower layers. By the middle of September, the D.O. in the hypolimnion can range between 0 and 2 mg/L. The water quality of the lower layer continues to deteriorate until the fall overturn occurs. As the water column destratifies, the level of the maximum D.O. concentration gradient falls to 80 feet in October and near the reservoir bottom in early December, after which the D.O. concentration is nearly the same at all levels until the following spring (USACE 1995). D.O. concentrations of water released from Hartwell Lake can be below 5 mg/L from late summer through early fall, with the lowest readings from August through September (USACE 2008a).

Based on the 1991–1992 comprehensive sampling study of Hartwell Lake, temporal and spatial gradients in D.O. were noted from the dam to the headwaters of both main embayments, particularly during the stratified period. Anoxic conditions were greater in the Seneca River arm than in the Tugaloo River arm potentially due to an increased amount of nutrients from greater organic material. Oxygen depletion was first observed in the mid reaches of both embayments in June. By early September, anoxic conditions were present and lasted until mid-October when re-aeration of the hypolimnion had occurred in both arms of the reservoir. Anoxic depletion in the upstream embayments was likely due to the summer flow releases from Hartwell Dam (Jabour 1993).

Since 2006, temperature, D.O., and specific conductance have been monitored continuously inside the penstock (upstream from the turbines) and in the immediate tailrace area. In general, tailrace D.O. concentrations are approximately 1.2 mg/L higher than the penstock D.O. concentrations. The increase in D.O. is the result of turbine venting and other reaeration effects in the tailrace area (USACE 2011). During the January through August 2009 monitoring period, penstock D.O. concentrations dropped below 5 mg/L in August, but tailrace D.O. concentrations remained above 5 mg/L. Monthly mean temperatures in the Hartwell Project tailrace ranged from 48ºF to 55ºF during the January through August 2009 monitoring period.

The 2012 South Carolina Section 303(d) list of impaired waters includes three locations in Hartwell Lake (Twelve-Mile Creek, Coneross Creek, and Lake Hartwell Dam area) that are listed as impaired for fish consumption due to high levels of polychlorinated biphenyls (PCBs) as well as two locations listed as impaired for aquatic life use due to the levels of total nitrogen, total phosphorus, and turbidity (Eighteen-Mile Creek) or pH (Lake Hartwell near Anderson City) (SC DHEC 2012). PCB levels have been elevated in the Eighteen-Mile Creek area as a result of contamination from an industrial site on the river, resulting in its designation as an EPA Superfund site. Work is presently underway to restore natural flows in that river to improve that environment.

Figure 2.7-3 Water Quality Monitoring Sites – Hartwell Lake



2.7.2.2 *RBR Lake*

RBR Lake backs up close to the tailwater of Hartwell Lake. As a result, water released from Hartwell Dam can affect water quality in RBR Lake, particularly during the summer months when low D.O. water can be released into the upper end of RBR Lake. From 1984 to 1988, a water quality sampling program was undertaken in RBR Lake to evaluate the impacts of project operations on water quality in the reservoir and immediate tailrace area.

During the 1984 to 1988 monitoring period, spatial patterns in thermal gradients were observed along the mainstem of the reservoir and thermal stratification was present from the dam to the headwaters. Stratification was evident in late March and a well-developed thermocline was present near a depth of 20 feet in mid-May. The thermocline remained between 20 and 26 feet and temperatures ranged from 53.6 to 82.4°F during the summer stratification period. The thermocline began to weaken with seasonal cooling in late-September to early-October and complete mixing was observed in late-October. Thermal regimes in the mainstem of the reservoir can be affected by the flows released from Hartwell Lake.

Temporal and spatial gradients in D.O. were apparent along the mainstem of the reservoir during stratification. Concentrations ranged from 8 to 10 mg/L in the epilimnion and gradually decreased in the hypolimnion. D.O. concentrations were higher at the surface (4 mg/L) in the mainstem and throughout the water column in the mid to upper stream region of the mainstem. Anoxic conditions were confined to the bottom waters and were established by mid-June. The anoxic conditions remained in the bottom 20 to 33 feet of the downstream end of the reservoir.

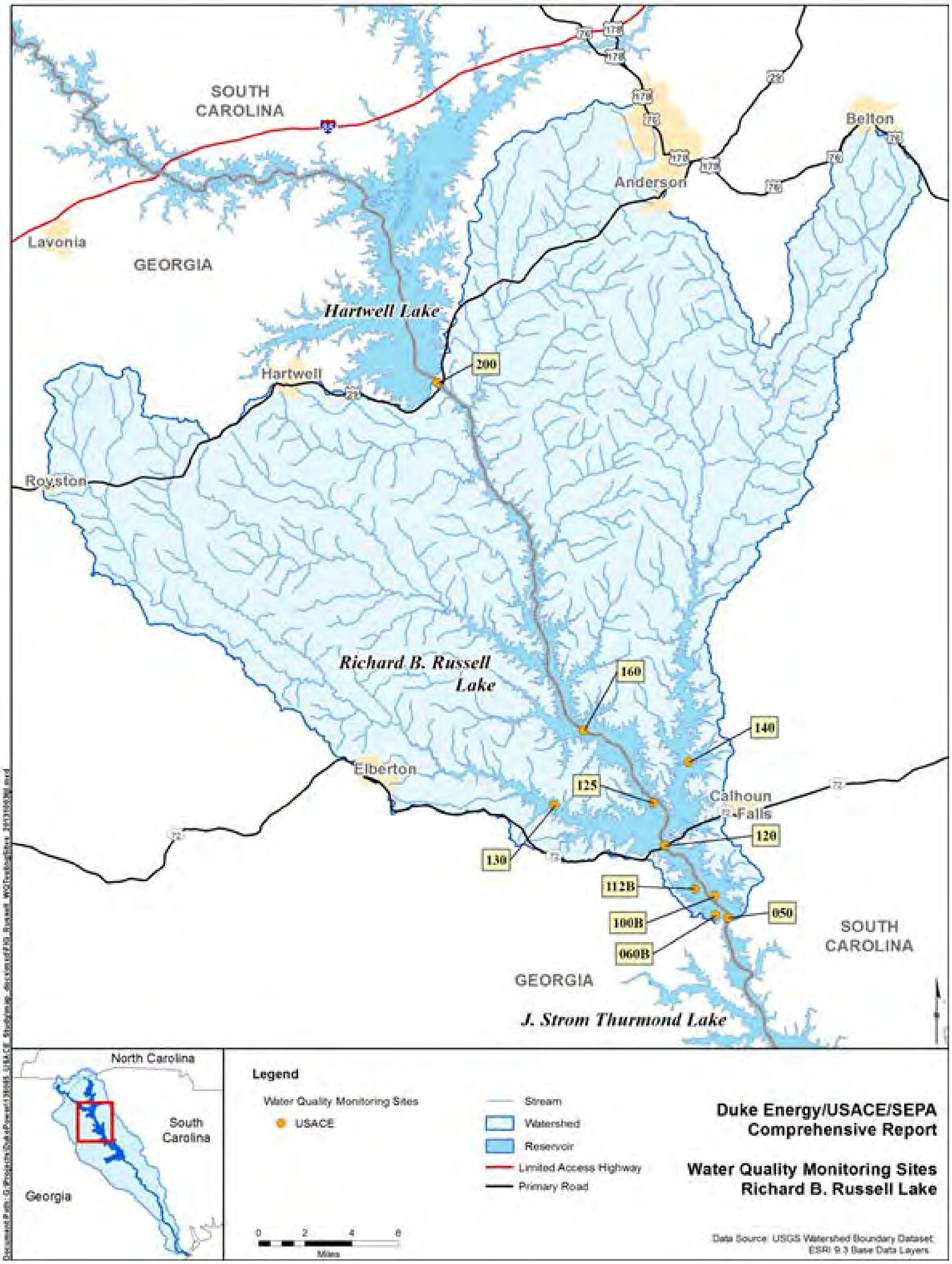
In 1988, the USACE began using a hypolimnetic oxygen injection system just upstream of the RBR Dam. Both the continuous and pulse injection systems operated during the stratified period with a combined capacity of 65 tons of oxygen per day. Delivery rates decrease as stratification decreases and typically end in early-November. This system is able to maintain the concentrations of D.O. near 6 mg/L at most depths in the forebay and within the turbine discharges. Concentrations below 6 mg/L have been noted in the RBR forebay at depths below 35 meters (m) (Ashby et al. 1994). Temperature and D.O. concentrations in the water discharges showed similar trends to those of the forebay. D.O. concentrations correlated with the operation of the oxygenation system and gradually returned to 8-12 mg/L during November and December (Ashby et al. 1994).

Beginning in 2006, the USACE's Engineer Research and Development Center (ERDC) monitored designated stations along the mainstem and major tributary embayments in RBR Lake (Figure 2.7-4). In situ measurements of temperature, D.O., and specific conductance are obtained monthly at these stations. The vertical and longitudinal patterns of temperature and D.O. in RBR Lake show substantial year-to-year and seasonal variation driven in large part by the volume of water flowing through the system (which in turn influences the volume of pumped storage in RBR Lake) and the seasonal patterns of vertical stratification (USACE 2009).

In addition to the monthly sampling program, temperature and D.O. are monitored continuously in the RBR Project penstock and immediate tailrace area (Station 050 on Figure 2.7-4) to determine when to operate the oxygen injection system. The oxygen injection system operates when low D.O. conditions are present. During 2009, the oxygen injection system ran the second half of June (average injection rate of 8 tons/day), the second half of July (average injection rate of 13 tons/day), and all of August (average injection rate of 26 tons/day). D.O. concentrations in the RBR discharges averaged 5.2 mg/L during the July through August 2009 period of system operation (USACE 2009).

The 2012 South Carolina Section 303(d) list of impaired waters includes three locations in RBR Lake listed as impaired for fish consumption due to high levels of mercury. These areas include RBR Lake near South Carolina Highway 181, Van Creek, and near the RBR Dam (SCDHEC 2012).

Figure 2.7-4 Water Quality Monitoring Sites – RBR Lake



2.7.2.3 *JST Lake*

The headwaters of JST Lake back up to the RBR Dam. As a result, water released from RBR Dam affect water quality in JST Lake. From 1984 to 1988, USACE conducted a water quality sampling program in both RBR and JST Lakes to evaluate the impacts of USACE project operations on water quality in the reservoir and immediate tailrace area.

Similar to RBR Lake, the 1984 to 1988 monitoring period showed temporal and spatial patterns in the mainstem of JST Lake with thermal stratification being present up to the headwater regions from April to September. Thermal stratification in the downstream region of the reservoir showed stratification beginning in late-April with the establishment of a thermocline (20-26 ft) in mid-May. Temperatures ranged from 57.2 to 86°F and the thermocline remained near a depth of 26 to 33 feet throughout the stratification period. The thermocline began to weaken in late-September when seasonal cooling began, until the reservoir conditions were almost completely isothermal by mid-October. Temporal regimes in the mainstem can be influenced by flow releases from Hartwell Lake and RBR Lake.

Similarly, temporal and spatial gradients of D.O. were observed in the mainstem of the reservoir during stratification (1984–1988 monitoring period). D.O. concentrations remained near 8 to 10 mg/L, gradually decreasing towards the downstream area of the reservoir. Anoxic conditions were established in the downstream hypolimnion area from mid-to-late August continuing until late October. Anoxic conditions remained within 33 feet of the surface. Concentrations of D.O. did not fall below 4 mg/L in the mid-region of the reservoir. The oxygenated waters during stratification can be attributed to the well-oxygenated flow releases from Hartwell Dam and RBR Dam. Anoxic conditions may also be the result of the proximity of major and secondary tributaries entering JST Lake. Temperature and D.O. concentrations in the water releases showed similar trends to those of the forebay. During fall mixing, D.O. levels were near 10 mg/L in the tailrace (Ashby et al. 1994).

From 2002 through 2007, the turbines at JST Dam were replaced as part of a major rehabilitation effort. The new turbines include a self-aspirating design that is a form of turbine venting. The new turbines now add as much as 3 mg/L of D.O. to the water as they pass through the dam.

Water released from JST Dam has D.O. concentrations of at least 3 mg/L throughout the year (USACE 2008a).

Since 2006, the ERDC has monitored designated stations along the mainstem and major tributary embayments in JST Lake (Figure 2.7-5). In situ measurements of temperature, D.O., and specific conductance are obtained monthly at these stations. Data from these discrete sampling locations is used to estimate the volume of available aquatic habitat on a monthly basis in the reservoir. Similar to RBR Lake, the vertical and longitudinal patterns of temperature and D.O. in JST Lake show substantial year-to-year and seasonal variation, driven in large part by the volume of water flowing through the system and the seasonal patterns of vertical stratification (USACE 2009). July and August are of particular interest in JST Lake because this is the period that puts the most severe limits of temperature and D.O. on habitat for striped bass in the reservoir. Since 2005, the ERDC has made quantitative estimates of available striped bass habitat during the critical summer periods. Minimum habitat typically occurs in July through August and into early-September, with between 20 percent and 40 percent of the reservoir volume categorized as available habitat during low flow years. Conditions improve during the fall, and a majority of the reservoir volume has suitable striped bass habitat by October. August 2007, with relatively low flow conditions, experienced the least available habitat (<20 percent) during the four-year period from 2006 to 2009 (USACE 2009).

In addition to the monthly sampling program, temperature and D.O. are monitored continuously in the JST penstock and immediate tailrace area (Station 10 on Figure 2.7-5) to determine when to operate the turbine venting system. In general, during the summer months, tailrace D.O. concentrations are approximately 2.7 mg/L higher than the penstock D.O. concentrations. During the summer 2009 monitoring period, penstock D.O. concentrations dropped to almost 0 mg/L in August, but tailrace D.O. concentrations remained above 3 mg/L due to the combined effects of turbine venting and other reaeration effects in the tailrace area (USACE 2009).

USACE began construction of an oxygen injection system (similar to the one at RBR Lake) in 2009 and the system began operating in June 2011. Unlike the oxygenation system at RBR Lake, which was designed for pumped storage operations, the system at JST Lake is located in the reservoir approximately 5 miles upstream of the dam. The system was designed to improve D.O. levels in the open waters of the reservoir to make large areas suitable to striped bass. The system has the capability to deliver 200 tons of oxygen per day and the ability to increase D.O. concentrations by an additional 1 to 3 mg/L in the tailrace. USACE operates this system on an as-needed basis during the June through September low D.O. periods. The D.O. concentrations of water released from JST Dam in 2013 are shown in the table below from the 2013 Annual Report of the Southeastern Natural Sciences Academy. The table shows mean monthly D.O. concentrations from JST to Savannah Harbor, with the data for River Mile 215 reflecting the quality of releases from the JST dam. The data shows that in 2013, the mean monthly D.O. levels in JST discharges were generally above 5 mg/l, but got as low as 3.99 mg/L.

Table 6. Monthly mean dissolved oxygen concentration (mg/L).

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RM215	ND	ND	ND	ND	ND	ND	ND	3.99	5.17	5.72	7.96	9.43
RM202	11.13	ND	10.83	10.24	9.50	8.92	8.75	8.59	8.67	8.69	9.59	10.31
RM190	ND	ND	10.77	10.01	9.06	7.98	ND	7.97	7.80	7.77	ND	10.03
Butler Creek	ND	9.97	9.25	7.13	5.91	4.52	4.67	4.77	6.19	7.43	ND	ND
RM148	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RM119	9.69	ND	9.13	7.92	7.50	6.95	5.74	5.95	6.68	7.18	8.20	8.89
RM61	ND	ND	ND	ND	ND	6.44	4.49	4.26	6.38	7.45	8.60	9.29
RM27	9.67	9.66	9.02	7.47	7.18	6.35	4.62	4.21	5.75	7.10	9.03	9.30
RM14	7.74	7.85	7.68	5.64	4.67	3.72	3.86	3.44	4.00	4.67	6.76	7.87

That same report shows D.O. levels at that location throughout 2013 to range as follows:

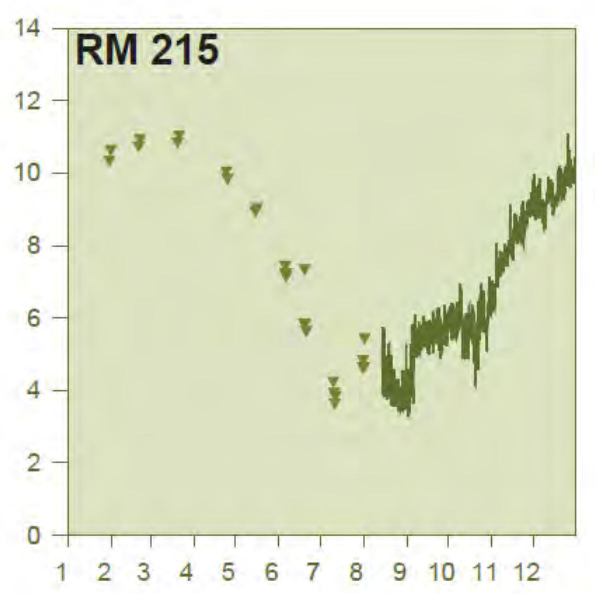
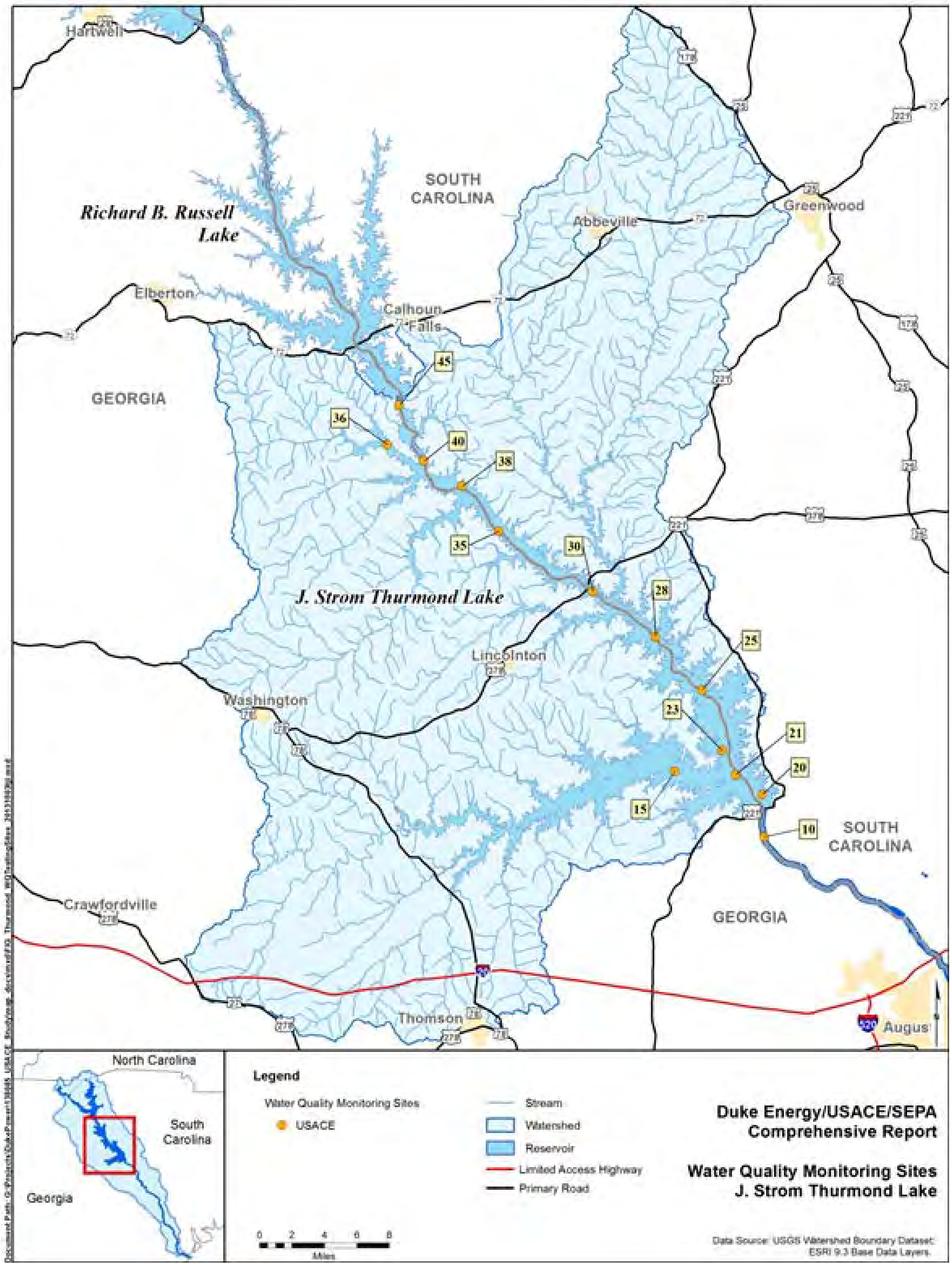


Figure 2.7-5 Water Quality Monitoring Sites – JST Lake



The 2012 South Carolina Section 303(d) list of impaired waters includes one location in JST (Long Cane Creek) that is listed as impaired for fish consumption due to high levels of mercury (SC DHEC 2012). Additionally, the JST Lake headwaters are listed as impaired for fish consumption due to mercury levels.

2.7.3 *Lower Savannah River Basin*

Along the Savannah River, water use classifications consist of Recreation, Drinking Water, and Coastal Fishing. Water use classifications along with the associated water quality standards of the mainstem of the Savannah River downstream of JST Dam are provided in Appendix C.

Portions of the lower Savannah River are listed as impaired on the 2012 Section 303(d) Lists of Impaired Waters for both South Carolina and Georgia. The 2012 South Carolina Section 303(d) list identifies numerous areas along the Savannah River as impaired for fish consumption due to mercury levels and aquatic life use due to turbidity and zinc levels. Reaches of the Savannah River listed as impaired for fish consumption include North Augusta State Park, Jackson Landing, Steel Creek, Little Hell Landing, Cohen's Bluff, Johnson's Landing, Stokes Bluff Landing, B&C Landing, Beck's Ferry, and Millstone Landing. Additionally, the Savannah River off B&C Landing off State Route S 27-201 is listed as impaired for aquatic life use (SC DHEC 2012). The 2012 Georgia 303(d) list includes a 59-mile stretch of the Savannah River from Brier Creek to Ebenezer Creek that is listed as impaired for fish consumption and drinking water due to mercury levels caused by nonpoint sources (GA DNR 2012).

The US EPA has prepared Total Maximum Daily Loads (TMDLs) for portions of the Savannah River as follows:

- Fecal coliform – Savannah River in Richmond County
- Lead – Savannah River between Butler and McBean Creeks
- Oxygen-depleting substances – Savannah River from the Seaboard Coastline Railroad Bridge (RM 27.4) to the coast

Seasonal D.O. sags occur in the summer months in the estuarine portion of the river. US EPA's 2006 TMDL called for zero discharge of oxygen-depleting substances from Augusta to the coast. Their 2010 revised Draft TMDL calls for a 30% reduction in oxygen-depleting substances in that reach. Georgia and South Carolina are working with point source dischargers along the river to develop a protocol to implement that reduction. After EPA finalizes that TMDL, the States will implement the requirements through their point source discharge permitting programs. The recently installed oxygen injection system in the forebay of JST Lake is expected to improve water quality below the JST Dam. Flows immediately below JST Dam are expected to contain at least 5 mg/L of D.O. throughout the year, which would meet both the Georgia and South Carolina standards for D.O.

The State of South Carolina uses the current Drought Plan Level 3 flow of 3,600 cfs (pers. comm., Larry Turner, SC DHEC) at the Savannah River Augusta gage for their wasteload assimilation calculations in permitting point source discharges in the Augusta area DHEC adjusts this flow upward as one moves down the river to account for the additional tributary inputs. The State of Georgia uses the 7Q10 values of 3,800 cfs at the Augusta gage, 4,160 cfs further downstream at the Millhaven U.S. Geological Survey (USGS) flow gaging station, and 4,710 cfs at the Clyo USGS gage in its decisions on the permitting of point source discharges (pers. comm., Paul Lamarre, GA DNR-EPD).

The Port of Savannah is the second-largest container port on the East Coast and the fourth-largest in the country. Savannah Harbor was deepened in the early 1990s and after continued growth in shipping volumes, the Georgia Ports Authority (GPA) requested the USACE conduct a reconnaissance study to determine the need to further deepen the harbor. In 1999, Congress authorized deepening the harbor, subject to some additional studies being conducted. The 2012 Final General Re-Evaluation Report (GRR) and the Final Environmental Impact Statement (FEIS) for the Savannah Harbor Expansion Project addresses the need for navigation improvements to the existing Savannah Harbor Navigation Project, Georgia and South Carolina as authorized by the Water Resources Development Act of 1999 (Public Law 106-53, Section 102(b)(9)). On October 26, 2012, USACE approved the Savannah Harbor Expansion Project via the signed Record of Decision. The Water Resources Reform and Development Act of 2014 (Public Law 113-121) authorized construction of the harbor deepening at a higher project cost.

The FEIS assessed the impacts expected to wetlands, fisheries, benthic communities, birds, marine mammals, endangered species, water quality, cultural resources, historic properties, and other environmental factors for each depth alternative. After avoiding and minimizing impacts where possible, USACE developed a mitigation plan to address the unavoidable adverse impacts to natural resources. The mitigation plan was designed to address both direct impacts to tidal brackish marshes that would occur as a result of dredging and unavoidable indirect impacts such as conversion of tidal freshwater marsh to brackish marsh. It is estimated the lower Savannah River area contains approximately 20 percent of all tidal freshwater marshes in Georgia and South Carolina. Therefore, the USACE considered this an important issue in its evaluation of potential impacts from harbor deepening.

The lower Savannah River estuary has been subjected to number alterations since the 1800s, and when coupled with sea level rise and subsidence, salinity levels have increase in the estuary, causing changes in the distribution of freshwater marsh, brackish marsh, and saltmarsh in the lower estuary.

The USGS report titled "Analysis of the Historical Data for the Lower Savannah River Estuary," contains data from a study conducted from 1990 through 1997. The USGS collected nine months of continuous salinity data from three stations before and after major system alterations. This data was analyzed to determine changes in salinity distribution resulting from these alterations. There were two types of analysis conducted under this study. The first analysis provides general statistical analysis of salinities, tides, and flows for each data period and compares that information with the data gathered post-alteration. This analysis did not account for the seasonal variation of flow and mean water levels.

Table 2.7-1 presents the maximum, mean, and minimum freshwater inflow measured on the Savannah River near Clyo, Georgia (RM 61) and Table 2.7-2 provides changes in Savannah Harbor salinity levels during the same period when system alterations were occurring.

Table 2.7-1 Savannah River Flows near Clyo, Georgia

Flow Statistics from the Savannah River near Clyo USGS Flow Gaging Station (02198500)				
Flow Range	1990	1992	1995	1996
Maximum	17,100 cfs	14,700 cfs	17,000 cfs	13,000 cfs
Mean	8,107 cfs	9,874 cfs	9,774 cfs	9,134 cfs
Minimum	5,700 cfs	6,490 cfs	6,540 cfs	6,760 cfs

Table 2.7-2 Savannah Harbor Salinity Levels

Savannah Harbor Salinity Levels (ppt)				
Port Wentworth, RM 21.7 (USGS 02198920)				
	1990	**1992**	**1995**	**1996**
Mean	1.83	0.58	1.13	1.25
Standard Deviation	1.86	1.16	1.78	2.05
Median	1.22	0.08	0.15	0.19
USFWS Dock, RM 22.0 (USGS 02198997)				
Mean	1.15	0.08	0.08	0.13
Standard Deviation	1.73	0.11	0.10	0.11
Median	0.24	0.05	0.05	0.07
Lucknow Canal, RM 25.36 (USGS 021989784)				
Mean	0.22	0.06	0.08	0.09
Standard Deviation	0.61	0.04	0.04	0.08
Median	0.08	0.05	0.07	0.05

The data between 1990 and 1996 in Table 2.7-2 show a significant change in the salinity conditions after decommissioning of the Tidegate and closure of the New Cut. It is also evident from the data there were minimal impacts from the channel deepening (1992 versus 1995 and 1996). The 0.5 parts per thousand (ppt) contour line is used to determine the threshold salinity value for brackish water. Table 2.7-3 shows the number of salinity events over 0.5 ppt during the alteration periods between June and September of each year.

Table 2.7-3 Occurrences of Salinity Levels >0.5 ppt in the Savannah Harbor

Number of Occurrences of Salinity > 0.5 ppt in the Lower Savannah River by Year and Location					
Location	**River Mile**	**1990**	**1992**	**1995**	**1996**
Port Wentworth (02198920)	21.7	58	25	27	38
USFWS Dock (02198997)	22.0	36	1	1	2
Lucknow Canal (021989784)	25.36	6	0	0	0

A multivariate analysis was developed in an attempt to correlate daily average flow values; daily maximum, mean, and median salinities; daily average mean water levels; and daily maximum tide ranges. In general, individual correlations between the dependent variable salinity and the independent variables showed fair to poor correlations. The best correlations were obtained by using a linear regression model with an independent variable and a one-to four-day lag applied to the flow data from Clyo, Georgia. Results of this analysis showed similar trends as those found in the raw data. For example, saltwater intrusion occurrences decreased 68 percent at Port Wentworth, 93 percent at USFWS Dock, and 73 percent at Lucknow Canal when the Tidegate was decommissioned versus small increases in salinity concentrations associated with deepening the Front River and the Little Back River during 1992 and subsequent years.

In the late 1990s, GPA funded a field monitoring program to document the salinity conditions within the Lower Savannah estuary at that time. A detailed report is provided in the report titled "Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, July-September 1997." The salinity data were collected as continuous in situ, discrete synoptic, and supplemental marsh data. There were 16 continuous monitoring stations positioned throughout the monitoring area from the Atlantic Ocean at RM -3.5 to the Lucknow Canal at RM 25.3. Surface and bottom concentrations were measured within the navigation channel while those stations outside of the channel recorded near bottom concentrations. The synoptic data was collected at 40 stations which were each monitored for a 12-hour period on August 13, 1997, September 9–10, 1997, and September 30, 1997. The supplemental marsh data was obtained by installing stations within and immediately outside of feeder channels attached to the Front, Middle, and Little Back Rivers, as well as two continuous gages, which recorded salinities entering and leaving the marshes at 15-minute intervals.

Review of historical data determined that subsequent to the decommissioning of the Tidegate, the maximum salinity intrusion along the Front River occurred primarily during neap tide[5] conditions. A possible reason for this is the reduction in velocities along the Front River above Fort Jackson during receding tides. As the tidal effect decreases, the salinity gradient is able to push further upstream. This is because a reduction in the tidal flow correlates to a reduction in turbulent mixing and stronger stratification within the water column. The stronger the stratification, the more the denser salinity is able to move upstream along the bottom of the river. Upstream saltwater intrusion is greatest during neap tide conditions and lowest during stronger spring tide conditions that create more turbulent flow conditions.

2.8 Recreation

During normal operating levels, the reservoirs of the Savannah River Basin provide many opportunities for water-based recreational activities, including boating and swimming. The following subsections provide details on public boat ramps and swimming areas.

2.8.1 ***Public Boat-Launching Ramps***

2.8.1.1 *Lakes Jocassee and Keowee*

Duke Energy provides nine public boat ramps on Lake Jocassee and twenty-four on Lake Keowee. On Lake Jocassee, six of the public boat ramps become unusable when reservoir elevations drop 25 ft (1,085 ft AMSL) below a full pool elevation of 1,110 ft AMSL and one boat ramp has recently been extended to accommodate boat launching even if the reservoir is at its maximum drawdown of 30 ft (1,080 ft AMSL). On Lake Keowee, concrete boat ramps begin to become unusable when the reservoir elevation drops approximately nine feet below a full pool elevation of 800 ft AMSL (pers. comm., Scott Jolley, Duke Energy, August 2013). Appendix D provides a detailed list of public boat ramps at Lake Jocassee and Lake Keowee and the reservoir elevation below which ramps may not be usable for most boats. The elevation below which

[5] A neap tide occurs just after the first and third quarters of the moon, when there is the least difference between high tide and low tide.

ramps may not be usable for most boats is presented as three feet above the top of the concrete ramp end elevation (pers. comm., Scott Jolley, Duke Energy, October, 2013).

2.8.1.2 *Hartwell Lake*

Hartwell Lake has approximately 111 public boat ramps located at 94 parks and marinas. From an elevation of 660 to 658 ft AMSL, all boat ramps are considered usable. If Hartwell Lake falls below 638 ft AMSL, all boat ramps are considered unusable. Appendix D provides a detailed list of public boat ramp locations (note some locations contain multiple ramps) at Hartwell Lake and the elevation below which ramps may not be usable for most boats. The elevation below which ramps may not be usable for most boats is presented as three feet above the top of the concrete ramp end elevation.

2.8.1.3 *RBR Lake*

RBR Lake has approximately 30 public boat ramps and launching sites. All of the sites become unusable at reservoir elevations below 466 ft AMSL. Lake levels typically do not drop more than five feet below the Normal Pool Elevation of 475 ft AMSL; therefore, boat ramps are likely to be usable at all times.

2.8.1.4 *JST Lake*

JST Lake has approximately 100 public boat ramps located at 81 parks and marinas. Boat ramps start to become unusable below a pool elevation of 326 ft AMSL (four feet below full pool of 330 ft AMSL). If JST Lake elevations fall below 306 ft AMSL, all boat ramps are considered unusable. Appendix D provides a detailed list of public boat ramp locations (note some locations contain multiple ramps) at JST Lake and the elevation below which ramps may not be usable for most boats. The elevation below which ramps may not be usable for most boats is presented as two feet above the top of the concrete ramp end elevation. These elevations are based on a comparison of the bottom of ramp elevations with the approximate lake elevation when launching becomes difficult using data available on Savannah District’s website for recreation on JST Lake.

2.8.1.5 *Lower Savannah River Basin*

There are approximately 55 public boat ramps with various owners in the Lower Savannah River Basin. Information is not readily available regarding the usability of the boat ramps at different water levels. Based on the location of the majority of the ramps, tidal influences would be the major contributing factor on the usability of these facilities. Appendix D provides a detailed list of the public boat ramps along the Savannah River downstream of JST Lake.

Currently the Augusta Canal prohibits motorized boating and public swimming, but there are several access areas available to canoeists and kayakers. These access areas can be found along a towpath that parallels the canal, starting at the headgates of Savannah Rapids Park and at the Eisenhower/Riverwatch Parkway Bridge. Take-out points are located downstream at Lake Olmstead, Broad Street, and 13th Street. The necessary flow for supporting recreation in the canal is 100 cfs, as shown in Table 2.8-1.

Table 2.8-1 Augusta Canal Recreation Flows

Name of Launch/Take-Out Points	Required Flow Level (cfs)
Manual Launch	
Headgates Savannah Park	100
Riverwatch Parkway Bridge	100
Take-Outs	
Lake Olmstead	100
Broad Street	100
13th Street	100

Source: FERC 2006

2.8.2 *Swimming*

2.8.2.1 *Lakes Jocassee and Keowee*

Swimming beaches at Lake Keowee are managed as part of the lease agreement Duke Energy has with Oconee and Pickens counties in South Carolina. Reservoir elevations affect the swimming beaches; however, Duke Energy does not decide when these areas are closed based on reservoir elevations. Each county determines when to close a swimming area based on the site's design. Oconee County does not designate any swimming areas at county parks and it does not supply lifeguards or roped off areas, but instead has "swim at your own risk" signage throughout the parks. As a result, there are no designated and managed swimming areas on Lake Jocassee and there are no criteria for swimming areas to be closed based on reservoir elevations. Pickens County has one public swimming area on Lake Keowee, but similar to Oconee County, it has no criteria for this area to be closed based on reservoir elevations.

2.8.2.2 *Hartwell Lake*

The USACE manages 22 swimming areas at 13 recreation areas on Hartwell Lake. When reservoir elevations drop to 657 ft AMSL, the swimming areas become less desirable, according to the USACE (2008a). At reservoir elevations of 654 ft AMSL and lower, all designated swimming areas are dry. When this happens swimming occurs outside of the designated areas, increasing the risk of injuries and fatalities to swimmers (USACE 2008a; USACE 2012a).

2.8.2.3 *RBR Lake*

There are no USACE-operated designated swimming areas on RBR Lake.

2.8.2.4 *JST Lake*

The USACE manages 18 swimming areas on JST Lake. When reservoir elevations drop to 327 ft AMSL, the swimming areas become shallower and less desirable (USACE 2008a). Below reservoir elevations of 324 ft AMSL, all designated swimming areas are dry. When this happens, swimming occurs outside of the designated areas, increasing the risk of injuries and fatalities to swimmers (USACE 2008a; USACE 2012a).

2.9 Biotic Communities

Common names for species are referenced throughout the main body of this EA. Appendix E contains tables that cross-reference the common names and scientific names for each species, as follows:

- Fish species Table E-1
- Aquatic plants Table E-2
- Wetland species Table E-3
- Wildlife species Tables E-4 through E-9

2.9.1 *Fisheries*

2.9.1.1 *Lake Jocassee*

Fishery resources in Lake Jocassee have been monitored since approximately 1974 using a variety of aquatic sampling techniques. In association with littoral fish populations in Lake Jocassee, electrofishing surveys were represented primarily by an assemblage of warmwater fish taxa in addition to the cool water and coldwater taxa. Estimated abundances ranged from 415 to 1,235 fish/3,000 m of shoreline, weighing from 18.9 to 49 kilograms (kg), in the lower reservoir area and from 746 to 1,429 fish/3,000 m of shoreline, weighing from 40.3 to 61.3 kg, in the upper portion of the reservoir. Total numbers of fish collected appeared to be similar in both areas, but total biomass appeared to be somewhat higher in the upper portion of the reservoir than the lower reservoir (Barwick et al. 1995).

In Lake Jocassee, gillnetting has been the primary technique used to sample littoral fish populations (Barwick and Geddings 1986). However, boat-mounted electrofishing (as described below for Lake Keowee) was implemented in 1996 and continues to the present day.

Overall, 26 fish species representing seven families and two hybrid complexes (sunfish and black bass) were collected in these surveys with 18 identical species and both hybrid complexes collected in each upper and lower portion of the reservoir (Barwick et al. 1995).

Littoral fish populations in Lake Jocassee gillnetting surveys were also represented primarily by an assemblage of warmwater fish taxa, but these surveys had higher contributions of both cool water and coldwater taxa than the electrofishing surveys. Common carp, flat bullhead, rainbow trout, brown trout, redeye bass, smallmouth bass, and largemouth bass dominated the catch in the surveys. Except for the rainbow trout and brown trout, which are stocked annually by the SC DNR, all other littoral fish taxa are indigenous or naturalized to the reservoir and are reproducing naturally (Barwick et al. 1995).

The entire reach of the Whitewater River in South Carolina and the Eastatoe Creek and its headwater tributaries (i.e., upstream of Lake Keowee) support an excellent wild rainbow trout population on the Jocassee Gorges property. SC DNR routinely stocks these areas with catchable trout along its length. In addition, these areas appear to be maintaining some larger holdover brown trout (SC DNR 2010a). Other headwater tributaries flowing into Lakes Jocassee and Keowee that support a thriving trout fishery are the Thompson River, Devils Fork, Howard Creek, Limberpole Creek, Corbin Creek, Wright Creek, Coley Creek, Cane Creek, and Laurel Fork (SC DNR 2010a).

Habitat in Lake Jocassee is similar to undeveloped North Carolina mountain reservoirs and is characterized by steep slopes with woody debris in the form of large stumps in some areas (Barwick et al. 2004). Rocky outcrops are the predominant habitat type and compose about 78 percent of the littoral zone. Other habitat types noted in the littoral zone are sand (8 percent), emergent vegetation/stream confluences (7 percent), residentially developed piers and riprap (4 percent), clay (3 percent), and cobble (1 percent).

Similar to many reservoir fisheries in the southeast, centrarchids (sunfish and bass) make up the majority of the littoral zone species abundance in Lake Jocassee. Woody debris and other instream structures (e.g., boulder riprap) are critical components for successful spawning and rearing and are likely the primary cover components in Lake Jocassee due to the lack of submerged vegetation. Sunfish species prefer shallow, low-velocity areas of the littoral zone where they construct nests/beds (small depressions) in mud, sand, and/or gravel substrates for spawning. Spawning is initiated in late winter/early spring (March-May) in South Carolina and typically extends for 4 to 6 weeks (USACE 2008a; Rohde et al. 2009). April is considered peak spawning in the Savannah impoundments for black bass. May to mid-June is considered peak spawning in the Savannah impoundments for sunfish.

Lake Jocassee is one of only a few reservoirs in South Carolina possessing the necessary combination of water temperatures and D.O. to allow the persistence of both a warmwater and a coldwater (trout) fishery year-round. Along with the effects on littoral zone fish spawning habitat in April, analysis of pelagic trout habitat in the critical summer month of September was of primary interest in Lake Jocassee. Although trout are stocked annually by the SC DNR, the sustainability of the trout fishery in Lake Jocassee is partially dependent on the availability of suitable pelagic habitat; specifically, a hypolimnion possessing water temperatures <20°C and D.O. >5 mg/L during the critical summer and fall months.

2.9.1.2 *Lake Keowee*

Fishery resources in Lake Keowee have been monitored since approximately 1973 using sampling techniques similar to those used in Lake Jocassee. Cove sampling with fish toxicants was the most frequently used technique in Lake Keowee during the early years of impoundment (Barwick et al. 1995). In the 1990s, due to the amount of residential development around the reservoir, sampling with fish toxicants was not used for future sampling of fish populations in this reservoir. Thus, the SC DNR and Duke Energy used boat-mounted electrofishing to monitor littoral fish populations. Boat-mounted electrofishing began in Lake Keowee in 1993 and continues to the present day (Barwick et al. 1995).

Littoral fish populations in the Lake Keowee electrofishing surveys consisted primarily of warmwater fish species with occasional cool water and coldwater species noted. Estimated abundances ranged from 319 to 1,981 fish/3,000 m of shoreline, weighing from 28.3 to 63.4 kg, in the lower portion of the reservoir, from 520 to 2,117 fish/3,000 m of shoreline, weighing from 18.9 to 71.4 kg, in the middle area of the reservoir, and from 232 to 2,064 fish/3,000 m of shoreline, weighing 29 to 51.5 kg, in the upper area of the reservoir. Total numbers of fish collected appeared to be similar in all areas, but total biomass was somewhat higher in the lower portion of the reservoir, in comparison to the total biomass noted in the middle and upper area of the reservoir (Barwick et al. 1995). Twenty-eight fish species representing eight families and two hybrid complexes (sunfish and black bass) were collected during surveys.

It appears the composition of the major fish species in Lake Keowee has remained generally similar over many years. Except for an occasional rainbow or brown trout, which are stocked in Lake Jocassee by the SC DNR and apparently enter Lake Keowee via operation of the Jocassee Pumped Storage Station or are stocked by the SC DNR in tributary streams, all other littoral species of fish are either indigenous or naturalized to the reservoir and are reproducing naturally (Barwick et al. 1995).

Lake Keowee's fishery is similar to Lake Jocassee except water quality characteristics do not support a sustainable year-round coldwater trout fishery. Sunfish and black bass represent the most critical management component, with littoral zone habitat loss and spawning success as the primary potential impact. Littoral fish habitat in Lake Keowee is similar to most residentially-developed Piedmont reservoirs in North Carolina and South Carolina. Since the reservoir bottom was completely cleared prior to impoundment, piers and riprap from residential development provide most (approximately 33 percent) of the subsurface and near surface habitats in the reservoir. The second most abundant habitat type is clay substrate, composing about 25 percent of the littoral zone. Other habitats include cobble (13 percent), emergent vegetation/stream confluences (12 percent), and sand (9 percent). Habitats in Lake Keowee are associated with relatively shallow or moderately sloping banks having little to no naturally-occurring woody debris.

2.9.1.3 *Hartwell Lake*

Hartwell Lake and its tailrace provide habitat for both warmwater and coldwater fisheries. The reservoir area supports a large warmwater fishery including such species as white and striped bass, hybrid bass, largemouth bass, bluegill, pumpkinseed, redear sunfish, yellow perch, walleye, and catfish. Non-game species found within the reservoir include blueback herring, common carp, longnose gar, redhorse and spotted sucker. The GA DNR and SC DNR both actively stock, on average, 500,000 to 1,000,000 total striped bass and hybrid bass in Hartwell Lake. The USACE fisheries management program supports a quality sportfish population in Hartwell Lake.

USACE's management activities are coordinated with state fishery agencies of both Georgia and South Carolina.

The Hartwell tailrace supports a coldwater trout fishery that is supported by stocking from both states. The waters are described as having no evidence of natural trout reproduction, but they are capable of supporting trout throughout the year. Striped bass and walleye are also found in this coldwater fishery (USACE 2008a). Study findings also indicate striped bass and blueback herring habitat becomes quite restricted during reservoir stratification due to the D.O. and temperature requirements of these cool water fish. The results of these stratification conditions are the congregation of herring in the penstock area and fish kills from entrainment; however, operational procedures are used to minimize this entrainment (USACE 2008a).

During each spawning season, the USACE closely monitors reservoir temperatures and levels. Bass and crappie spawn in the spring when water temperatures approach 70°F, which at Hartwell Lake generally occurs around the third week in April. Because the fish spawn in shallow water (i.e., 1 to 8 feet deep), special care is taken to ensure reservoir elevations do not fluctuate too much, leaving the eggs stranded. Therefore, from the time surface water temperatures reach 65°F until three weeks after the temperatures reach 70°F, which is the spawning period, the USACE limits reservoir elevation fluctuations to less than 6 inches to the extent practicable[6].

2.9.1.4 *RBR Lake*

The fishery resources of RBR Lake have been extensively studied. The USACE and the University of Georgia Cooperative Fish and Wildlife Research Unit (GA COOP) began baseline studies of fishery resources in RBR Lake in 1990. These studies included cove fish toxicant sampling, gill net sampling, electrofishing, and telemetry studies. SC DNR has conducted fisherman creel surveys on RBR since 1991. GA DNR has conducted fisherman creel surveys in the RBR tailrace since 1988 (USACE 2008a).

[6] Maintaining stable reservoir elevations during droughts may not be possible.

RBR Lake supports a variety of fish species including largemouth bass, spotted bass, redeye bass, threadfin shad, gizzard shad, blueback herring, bluegill, redear sunfish, channel catfish, brown bullhead, black crappie, yellow perch, white perch, spotted sucker, and common carp. Small numbers of hybrid bass and striped bass are caught each year in RBR Lake (USACE 2008a). Approximately 29,000 striped bass fingerlings were stocked in RBR in May 2004 in an attempt to establish a trophy striped bass fishery (GA DNR 2008). The GA DNR suggests larger striped bass caught in RBR Lake likely originated in Hartwell Lake. The reservoir water surface elevation fluctuates daily because of generation and pumping operations.

2.9.1.5 *JST Lake*

As with the other upstream impoundments, JST Lake is primarily a warmwater fishery. Largemouth bass, sunfish, and crappie make up the majority of important recreational species, as well as the stocked cool water striped bass. On average, 750,000 to 1,000,000 total striped and hybrid striped bass are stocked in JST Lake each year (USACE 2008a). Blueback herring are considered an important forage fish for striped bass and other predators.

The fishery resources of JST Lake have been extensively studied by the USACE, and the GA COOP began baseline studies of fishery resources in JST Lake in 1986. These studies included cove rotenone sampling, gillnet sampling, electrofishing, and telemetry. The Clemson University Cooperative Fish and Wildlife Research Unit (CU COOP) conducted a commercial creel estimate and a population estimate of blueback herring. SC DNR has conducted fisherman creel surveys on JST Lake since 1991 (USACE 2008a).

Common fish species in JST Lake include largemouth bass, bluegill, redear sunfish, hybrid bass, striped bass, black crappie, brown bullhead, channel catfish, flathead catfish, white perch, yellow perch, threadfin shad, gizzard shad, and blueback herring. SC DNR and GA DNR both actively stock hybrid bass and striped bass in JST Lake

The RBR tailrace supports a substantial fishery for striped and hybrid bass, and white perch. The tailrace makes up only 2 percent of the surface area of JST Lake, but accounts for approximately 10 percent of the total harvest of these species. Fish abundance in the RBR tailrace generally peaks in the summer and is lower in the winter. A commercial fishery for blueback herring exists in the RBR tailwaters. Blueback herring are used by fishermen as bait in both Georgia and South Carolina (USACE 2008a).

2.9.1.6 *Lower Savannah River Basin (Riverine Sections)*

Riverine fish habitats in the Savannah River Basin have been highly modified or converted to lacustrine habitat by construction of major dams and reservoirs inundating the upper half of the Savannah River Basin. This large-scale habitat conversion has changed the relative abundance and diversity of fish species from a system dominated by migratory diadromous fish to more localized riverine and lacustrine-dominated fish communities (USACE 2008a).

In the riverine portions of the Savannah River Basin downstream of JST Lake, a comprehensive fishery survey concluded the lower Savannah River riverine sections support an abundant and diverse fish community (Schmitt and Hornsby 1985). Based on numbers and weight collected, the most abundant gamefish found during the study were largemouth bass, chain pickerel, black crappie, yellow perch, redbreast sunfish, bluegill, redear sunfish, warmouth, and pumpkinseed.

Important non-game fish found during the study included longnose gar, bowfin, white catfish, channel catfish, common carp, spotted sucker, robust redhorse, striped mullet, and brown bullhead. The most important forage fish found during the study were gizzard shad and a number of minnow species. The diadromous fishes found to be inhabiting the lower Savannah River include striped bass, American shad, hickory shad, blueback herring, shortnose sturgeon, Atlantic sturgeon, and the catadromous American eel (USACE 2008a).

Although greatly reduced from former abundance, diadromous fish are an important component of the Savannah River's sport and commercial fisheries (USACE 2008a). American shad, blueback herring, and lesser numbers of striped bass and sturgeon migrate to the NSBL&D facility, which is the first major obstruction to fish passage on the river. A portion of the migratory fish population continues to migrate upstream to historical spawning grounds upstream of the facility (USACE 2008a). Some species pass upstream by swimming through fully opened dam gates at river flows of 16,000 cfs or higher, and by swimming through the navigation lock when it is operated in a manner suitable for fish passage (USACE 2008a). Additional fish movement is expected at the lock and dam when USACE constructs the fish bypass at that location as part of the Savannah Harbor Expansion Project. Shortnose sturgeon and other important species have been identified at gravel bars downstream of the NSBL&D (RM 179–190, 275–278, and 286) during spawning months of February and March (USACE 2008a). Research conducted in 1999–2000 indicated there was no observed increase in recruitment of shortnose sturgeon into the population over the previous eight years (USACE 2008a). However, an increased number of sturgeon have been observed in the river due to a SC DNR stocking enhancement program, which ended in 1992.

Presently, the lower Savannah River provides important striped bass habitat (USACE 2008a). Although the majority of the historical upstream spawning habitat for striped bass has been inundated by the reservoirs, some remaining rocky rapid habitats exist in the Augusta Shoals from just below the NSBL&D upstream to Stevens Creek Dam (USACE 2008a). After construction of the mainstem dams and prior to initiation of the 1977 Tidegate operation, the primary spawning area for striped bass in the Savannah River system was the tidal freshwater zone approximately 18 to 25 miles from the river mouth (i.e., Little Back River) (USACE 2008a). Salinity changes due to the Tidegate operation (1977–1991) reduced the extent of this tidal freshwater zone (USACE 2008a).

2.9.2 *Aquatic Plants*

There are limited aquatic plant populations in the Duke Energy and USACE reservoirs and in the Savannah River Basin in general. These aquatic plants or submerged aquatic vegetation (SAV) occur primarily in littoral zone habitats of reservoirs where ample sunlight penetrates the water column. Most of these species are non-native and/or invasive species introduced by humans. While certain aquatic plants or SAV are beneficial to fisheries, they can cause a loss of biodiversity, habitat degradation, loss of recreation, and other ecological consequences when they are not controlled or prevented. In addition, these species also threaten native species and their habitats by out-competing them for resources like sunlight, water, and nutrients (National Park Service and University of Georgia 2011).

The Duke Energy and USACE management goals for these species are to eliminate, reduce growth, and/or prevent the spread of invasive plants to other waterbodies. Several techniques are used to achieve these management goals, including winter drawdown, chemical treatment, and manual removal.

In support of the Keowee-Toxaway Project relicensing, a botanical resources inventory of the Keowee-Toxaway Project area was performed in 2012 and included an evaluation of aquatic plants in Lake Jocassee and Lake Keowee.

2.9.2.1 *Lake Jocassee*

Lake Jocassee has no native or exotic aquatic plant species populations, possibly due to bottom substrates and water level fluctuations within the reservoir preventing the establishment of most aquatic plants (Duke Energy 2011).

2.9.2.2 *Lake Keowee*

During the 2012 botanical resources study, aquatic coontail and parrot feather were found in Lake Keowee. Neither of these species is included on the state “noxious” aquatic weed list, but they are both invasive in the Piedmont of South Carolina. Additional information can be found in the 2012 Botanical Resources Final Study Report filed with FERC on January 18, 2013.

Hydrilla, an exotic invasive plant, was discovered in 1995, growing in scattered cove heads in the Cane Creek arm of Lake Keowee. Duke Energy and the SC DNR treated the approximately three hectares (7.4 acres) of hydrilla with approved chemicals and manually removed small shallow beds when they were observed. Hydrilla was last observed in Lake Keowee in 2002. Annual surveys for hydrilla continue in Lake Keowee, but no additional infestations have been observed (Duke Energy 2011). Hydrilla was not observed in Lake Keowee during the 2012 botanical resources study.

2.9.2.3 *Hartwell Lake*

Recent surveys on Hartwell Lake have shown aquatic plants have not become abundant in Hartwell Lake. No native species of aquatic plants were noted; however, two exotic and invasive species, hydrilla and water primrose, have been found. The water primrose was found in Eighteen-Mile Creek but it did not appear to have increased relative to previous studies (USACE 2008a). A small population of hydrilla was located between the Highway 93 Bridge and Highway 123 Bridge in Pickens County, South Carolina, but due to falling water levels, the hydrilla was exposed and appeared to have died due to desiccation. However, the USACE is concerned additional hydrilla will be moved from other waterbodies into Hartwell Lake (USACE 2008a). The overall aquatic plant growth in Hartwell Lake has not reached nuisance levels requiring treatment as stated in Executive Order 13112, which concludes federal agencies must prevent the introduction of invasive species and control populations of the species in a cost-effective and environmentally sound manner (USACE 2008a).

2.9.2.4 *RBR Lake*

Studies conducted on RBR Lake have been undertaken periodically to determine aquatic plant distribution and abundance. Hydrilla was discovered in RBR Lake during 2002, but apparently the populations died out and it has not been seen since that time (USACE 2008a). Approximately 8 hectares (20 acres) of Brazilian waterweed, a known invasive aquatic plant, was found in the Dry Fork Creek area and 2 miles downstream of Hartwell Dam. At present, the growth of the Brazilian waterweed in RBR Lake has not reached nuisance levels requiring treatment (USACE 2008a).

2.9.2.5 *JST Lake*

The USACE monitors and treats the hydrilla in JST Lake regularly (USACE 2008a). Hydrilla in JST Lake covers approximately 2,629 hectares (approximately 6,500 acres) and is found along approximately 863 km (536 miles) of JST Lake shoreline in Georgia and South Carolina (USACE 2008a). The USACE estimated in 2008 hydrilla populations occupied approximately 9.2 percent of the total reservoir surface at normal summer elevation (USACE 2008a). Infestations of hydrilla have been found in the following areas in JST Lake (Table 2.9-1).

Table 2.9-1 Location of Hydrilla Infestations in JST Lake

Location	County	State
Savannah River from Little River Subdivision to Savannah Lakes Marina	McCormick	SC
Benningsfield and Dordon Creeks	McCormick	SC
Hickory Knob State Park and Hickory Knob Subdivision	McCormick	SC
Soap Creek from Soap Creek Subdivision to Hwy 378 Bridge	Lincoln	GA
Wells Creek	Lincoln	GA
Mistletoe State Park / Cliett Creek	Columbia	GA

Source: USACE 2008a

2.9.2.6 *Lower Savannah River Basin*

Native and exotic aquatic plant populations in the lower Savannah River Basin are monitored periodically throughout the growing seasons. In addition to the species mentioned in Sections 2.9.2-1 through 2.9.2-5, water hyacinth, and fanwort were also identified in the drainage. None of the species appear to pose sufficient problems to operation of the NSBL&D or uses of the area to require treatment (USACE 2008a).

2.9.3 ***Wetlands***

2.9.3.1 *Lake Jocassee*

Generally, the terrain abutting Lake Jocassee is steep, which inhibits the formation of wetlands and riparian areas along the shoreline due to the existing slope and bedrock exposure. However, a review of existing information indicates wetlands exist at the confluences of streams and within various shallow cove areas (National Wetland Inventory [NWI] 2010; Dorcas 2009). The dominant vegetation within these wetlands includes black willow, red maple, hop hornbeam, American elm, box elder, buttonbush, elderberry, sensitive fern, and spotted lady's thumb (Nelson 1986).

One major type of wetland habitat (palustrine emergent [PEM]) is located adjacent to Lake Jocassee, (Cowardin et al. 1979). PEM habitats typical of those found adjacent to Lake Jocassee are characterized by a dominance of rushes, sedges, hydrophytic grasses such as reed canarygrass, various knotweed species such as tear thumb, halberd-leaved tear thumb, and painted lady's thumb (Nelson 1986).

Wetland delineation field surveys performed during the summer of 2012 identified four discrete wetland habitats on or adjacent to the Lake Jocassee reservoir, primarily consisting of PEM wetlands with very limited palustrine scrub-shrub (PSS) components. Approximately 48.2 acres of wetlands were identified on or adjacent to Lake Jocassee during the 2012 wetland study. Additional information can be found in Duke's Final Wetlands Study Report that it filed with FERC on January 25, 2013.

2.9.3.2 *Lake Keowee*

Like Lake Jocassee, the terrain abutting Lake Keowee is fairly steep which inhibits the formation of wetlands along the shoreline except at the confluences of streams and within various shallow cove areas (NWI 2010; Dorcas 2009). The dominant vegetation within these wetlands includes black willow, red maple, hop hornbeam, American elm, box elder, buttonbush, elderberry, sensitive fern, and spotted lady's thumb (Nelson 1986).

Palustrine emergent habitats typical of those found adjacent to Lake Keowee are characterized by a dominance of rushes, sedges, hydrophytic grasses such as reed canary grass, various knotweed species such as tear thumb, halberd-leaved tear thumb, and painted lady's thumb (Nelson 1986). PSS habitats are dominated by low to medium height trees and shrubs, generally with a diverse herbaceous strata (Cowardin et al 1979). Typical species found include spicebush, maleberry, common winterberry, hazel alder, red maple, and black willow (Nelson 1986). Palustrine forested habitats are dominated by mature tree species. These areas may not always have a well-developed understory or herbaceous layer depending on canopy density (Cowardin et al. 1979). Typical species found within the area include red maple, black willow, American elm, and swamp chestnut oak (Nelson 1986).

Wetland field surveys performed during the summer of 2012 identified 45 discrete wetland habitats on or adjacent to Lake Keowee, many of which are influenced by the active or relic presence of beaver, and are a mosaic of PEM and PSS, and to a lesser degree palustrine forested (PFO), habitats with pockets of open water interspersed throughout the wetland. Approximately 137.1 acres of wetlands were identified on or adjacent to Lake Keowee during the 2012 wetland study. Additional information can be found in Duke's Final Wetlands Study Report that it filed with FERC on January 25, 2013.

2.9.3.3 *Hartwell Lake*

There are approximately 676 acres of wetlands adjacent to Hartwell Lake (NWI 2010). Approximately 483 acres are classified as palustrine emergent wetland habitat, 48 acres as PSS wetland habitat, and 145 acres as palustrine forested wetland (NWI 2010).

2.9.3.4 *RBR Lake*

There are approximately 679 acres of various types of wetlands adjacent to RBR Lake. Approximately 38 acres are classified as palustrine emergent wetland habitat, 63 acres as PSS wetland habitat, and 578 acres as palustrine forested wetland (NWI 2010).

2.9.3.5 *JST Lake*

There are approximately 1,331 acres of various types of wetlands adjacent to JST Lake. Approximately 358 acres are classified as palustrine emergent wetland habitat, 187 acres as PSS wetland habitat, and 786 acres as estimated to be palustrine forested wetland (NWI 2010).

2.9.3.6 *Lower Savannah River Basin*

The majority of the wetland habitat in the riverine section of the Savannah River downstream of JST Lake is associated with the palustrine forested wetlands dominating the extensive alluvial plain of the Savannah River (USACE 2008a). The wetland habitats in the floodplain, such as swales, sloughs, and back swamps are dominated by bald cypress, water tupelo, and swamp tupelo. Slightly higher areas, which are usually flooded for much of the growing season, are often dominated by overcup oak and water hickory. A majority of the Savannah River floodplain consists of flats or terraces and these habitats tend to be flooded during most of the winter and early spring and one or two months during the growing season. Laurel oak is the dominant species on these flats and green ash, American elm, sweetgum, and sugarberry are often present. Swamp chestnut oak, cherrybark oak, and loblolly pine are found on the highest elevations of the floodplain, which are only flooded infrequently during the growing season (USACE 2008a).

On the lower Savannah River downstream of Interstate Highway 95, well into the coastal plain, tidal palustrine emergent wetlands become prevalent. Tidal palustrine emergent wetlands are flooded twice daily by tidal action. These marshes are vegetated with a diverse mixture of plants including giant cutgrass, spikerushes, and various other plant species adapted to the tidal flooding regime (USACE 2008a). The diverse tidal freshwater marsh located at the upper end of the estuary is particularly valuable, since it has substantially declined in acreage over the years.

2.9.4 *Wildlife*

Wildlife species can be found in various habitats within and immediately adjacent to the reservoirs. Habitats include open water; wetlands (emergent, shrub/scrub and forested); and uplands (forested, open/field, and disturbed). Some of these habitats can be affected by fluctuations in reservoir levels and others are likely to remain unaffected. Upland habitats are less likely to be impacted due to their distance from the reservoirs. In addition, wetland habitats not dependent on reservoir level as a source of hydrology are less likely to be impacted.

However, open water and wetland habitats dependent on reservoir level for hydrology and primary productivity, such as fringe wetlands, could be affected by reservoir fluctuations (e.g. 10 feet or more. Therefore, wildlife species using those habitats could potentially be affected.

Reptiles and amphibians use open water habitats of reservoirs. Species such as Eastern painted turtle, common musk turtle, snapping turtle, spiny softshell turtle, yellow-bellied slider, water snakes, newt, and frogs are predominantly associated with the shallow water areas of reservoirs. These species use the open water habitats for breeding, foraging, and hibernation.

Similar to reptiles and amphibians, birds use the shoreline and shallow open water habitats within reservoirs. These open water habitats are used as migration stopovers (resting habitat) for numerous species of ducks and geese as well as wading birds such as egrets, herons, and sandpipers. During the migration stopover, these species also use these areas for feeding prior to continuing their migration. Some of these migratory species use the reservoirs as overwintering habitat including Bonaparte’s and ring-billed gulls, common loons, and hooded mergansers.

In addition to the use of these habitats for feeding and overwintering by migratory species, resident avian species use open water for feeding. Examples of birds identified in the study area using the reservoir for feeding during the winter include belted kingfishers and great blue herons feeding in the shallow waters of the open water habitat.

Mammals commonly use open water habitats. Bats are one of the most common mammals to feed over the reservoirs. In addition, furbearers such as mink, American beaver, muskrats, and other semi-aquatic mammals use shallow water for feeding as a means of transportation to other habitats.

Reservoir Dependent Wetland (RDW) habitats are composed of emergent, shrub/scrub, and forested wetland habitats existing due to the water level in the reservoirs. As with the open-water habitat, RDW are widely used by wildlife during various parts of their life cycle. Reptiles and amphibians use RDW habitats near the shorelines of reservoirs. For example, a variety of turtles and snakes use RDW for feeding and basking, and numerous amphibians breed, lay eggs, forage, and undergo their aquatic larval stage in these habitats. Some species, such as the Eastern newt, could spend their entire life cycle in RDW habitats.

Avian species use RDW habitats adjacent to reservoirs as a migration stopover. Examples include numerous species of ducks and geese, as well as Neotropical migrants such as flycatchers, vireos, thrushes, and warblers. During the migration stopover, these species also use vegetated areas for feeding prior to continuing their migration. Some of these migratory species use RDW habitats as their overwintering habitat including swamp sparrows, yellow-rumped warblers, and Wilson's snipe.

In addition, RDW habitats also provide food and nesting for resident avian species. Song sparrows, yellow warblers, eastern kingbirds, mallard, wood duck, and Canada geese are a few examples of species that nest and raise their young in RDW habitats.

Some of the same mammals using open water habitats also use RDW habitats. Bats feed over the wetland habitats as they forage for flying insects such as midges and mosquitoes. In addition, the opossum, white-tailed deer, mink, American beaver, and other semi-aquatic mammals utilize RDW habitats for foraging and raising young.

2.9.4.1 *Lakes Jocassee and Keowee*

The wildlife species associated with Lakes Jocassee and Keowee include both aquatic (excluding fishes) and terrestrial species. Mussels, amphibian and reptiles, avian, and mammal species found in and adjacent to Lakes Jocassee and Keowee are included in this section.

2.9.4.1.1 Mussels

Mussel shell and live mussel collections were conducted during a major drawdown in Lake Jocassee in 2007 (Duke Energy 2011). Three mussel species were documented as extant in Lakes Jocassee and Keowee: paper pondshell, eastern floater, and the Florida pondhorn. In Lake Jocassee, the paper pondshell appears restricted to the northern portion of the reservoir, while the Florida pondhorn was noted only in the southern portion of the reservoir. The eastern floater was found only where the Toxaway River enters Lake Jocassee. Based on the total number of shells found, the paper pondshell (150 shells) was the most abundant mussel in Lake Jocassee followed by the six Florida pondhorns, and one eastern floater (Alderman 2009). In Lake Keowee, the paper pondshell and eastern floater were well distributed throughout the reservoir, with the eastern floater (80 shells) being somewhat more abundant than the paper pondshell (62 shells) based on the total number of shells and live specimens found. However, the Florida pondhorn appeared to be restricted to the middle portions of the reservoir and it was the least abundant (20 shells) of the mussels found in Lake Keowee (Alderman 2009). No Rare, Threatened, or Endangered (RTE) mussel species were collected during this study.

2.9.4.1.2 Amphibians

Thirty-seven species and subspecies of amphibians have been reported to occur in the watershed, of which 14 belong to the order Anura (frogs and toads) and 23 belong to the order Caudata (salamanders). The most common amphibian species in the vicinity of Lake Jocassee were salamanders, including the seal salamander, Ocoee salamander, three-lined salamander, and Southern gray-cheeked salamander. The Northern dusky salamander, Southern two-lined salamander, and spring salamander were also common (Dorcas 2009).

Salamanders were relatively less common around Lake Keowee, where the most abundant amphibians tended to be frogs, including the Northern cricket frog, spring peeper, bullfrog, and green frog. The American toad and the Eastern newt were abundant as well, while Cope's gray tree frog and the pickerel frog were common (Dorcas 2009).

2.9.4.1.3 Reptiles

The reptile fauna in the watershed included seven species of turtles (order Testudines). The Eastern painted turtle and common musk turtle were abundant in the area of Lake Keowee; the Eastern river cooter and Eastern box turtle were common as well. Other turtles observed near the reservoirs included the snapping turtle, spiny softshell turtle, and yellow-bellied slider (Dorcas 2009).

Fifteen species of snakes were documented from the Jocassee/Keowee watershed, based on the reference material available. Some of the species found were Northern water snake, black rat snake, Eastern garter snake, worm snake, black racer, ring-neck snake, Eastern kingsnake, Eastern milk snake, Northern rough green snake, pine snake, queen snake, brown snake, and red-bellied snake. Two species of the family Viperidae are found in the watersheds including the copperhead and timber rattlesnake (Dorcas 2009, Garton 2004; Kohlsaat et al. 2005; Duke Energy 2011).

Eight species of lizards were reported from the watersheds. The green anole was common in the vicinity of Lakes Jocassee and Keowee. Some of the species found were the Northern fence lizard, Eastern six-lined racerunner, five-lined skink; Southeastern five-lined skink; broad-headed skink; ground skink; and Southern coal skink (Dorcas 2009, Pitts 1997; Duke Energy 2011).

2.9.4.1.4 Birds

The Lake Jocassee and Lake Keowee watershed supports populations of at least 98 species of birds. Common species seen around the reservoirs include wild turkey, American woodcock, mourning dove, bobwhite quail, ruffed grouse, red-tailed, red-shouldered, and broad-winged hawks; Cooper's hawk; sharp-shinned hawk; Eastern screech-owl; and barred owl (Duke Energy 2011).

Additional common avian species known to occur in the Jocassee/Keowee watersheds are American crow, blue jay, blue-gray gnatcatcher, Carolina wren, downy woodpecker, Northern cardinal, red-eyed vireo, Summer Tanager, Tufted Titmouse, yellow-throated vireo, yellow-billed cuckoo, barn swallow, black-and-white warbler, brown-headed cowbird, common yellow-throat, Eastern bluebird, Eastern towhee, field sparrow, Northern mockingbird, white-eyed vireo, American goldfinch, and the yellow-breasted chat (Breeding Bird Atlas 1995). Some notable winter visitors to these reservoirs include common loons, pied-billed and horned grebes, and the bald eagle (Duke Energy 2011).

An avian study was performed in 2012 and consisted of surveys for avian resources through use of point counts at 52 established point count stations around Lake Keowee and Lake Jocassee in both South Carolina and North Carolina. During the 2012 avian study, 150 separate avian species were observed. The 2012 avian study also identified two great blue heron rookeries located at the Dodgins Creek and Eastatoe Creek areas on Lake Keowee. Additional information regarding the 2012 avian study can be found in the Final Avian Study Report filed with the FERC on February 22, 2013.

2.9.4.1.5 Mammals

Forty-eight species and subspecies of mammals have been reported to occur in the Jocassee/Keowee watershed. The area maintains one of the largest American black bear populations in the Southeast, and the mountainous regions of the watershed constitute a major portion of the quality black bear habitat in South Carolina. White-tailed deer and wild boar are abundant as well (Rankin et al. 1998; Duke Energy 2011). Larger predators found in the watershed include coyotes, bobcats, and gray and red foxes. Populations of smaller carnivores such as striped and Eastern spotted skunks, mink, and northern raccoons are also present (Rankin et al. 1998). At least nine species of bats have been reported including the big brown bat, red bat, and tricolored bat, as well as rare species such as Rafinesque's big-eared bat and the Eastern small-footed myotis (Duke Energy 2011). The watershed is also home to American beavers; muskrats; Virginia opossum; three species of cottontails; and several species of shrews, mice, and voles (Duke Energy 2011).

A comprehensive survey of the mammalian fauna of the Lake Keowee and Lake Jocassee area was conducted during three seasons (spring, summer, and autumn) in 2012. The 2012 survey documented 40 species of mammals within the study area, six of which are listed as rare, threatened, or endangered. Additional information regarding the 2012 mammalian survey can be found in Duke's Final Mammalian Study Report that it filed with the FERC in February 2013.

2.9.4.2 *Hartwell, RBR, and JST Reservoirs*

2.9.4.2.1 Mussels

No public information exists on mussel species in the USACE reservoirs. It is assumed that species similar to those found in Lakes Jocassee and Keowee also occur in the USACE impoundments.

2.9.4.2.2 Reptiles and Amphibians

The study area provides excellent habitat for a large number of reptiles and amphibians. Wetland habitats support many species of frogs including the bullfrog, green frog, southern leopard frog, several species of tree frogs, cricket frogs, and chorus frogs. Turtles found in the wetlands include the river cooter, Florida cooter, eastern chicken turtle, snapping turtle, and common musk turtle. Snakes found in the wetlands include the water snakes and eastern mud snake, (USACE 2008a).

2.9.4.2.3 Birds

Several of the most common bird species noted using Hartwell Lake or in the immediate vicinity of the reservoir include red-shouldered hawk, red-tailed hawk, ruby-throated hummingbird, Eastern kingbird, blue jay, American crow, Carolina chickadee, tufted titmouse, white-breasted nuthatch, American robin, Northern mockingbird, brown thrasher, Northern cardinal, red-winged blackbird, ring-necked duck, lesser scaup, and brown-headed cowbird (USACE 2008a and USACE 1981).

Additionally, some avian species commonly seen or heard in the surrounding uplands of Hartwell, RBR, and JST Lakes include: wild turkey, American bittern, great blue heron, osprey, red-tailed hawk, mourning dove, whip-poor-will, belted kingfisher, red-headed woodpecker, Eastern kingbird, blue jay, American crow, tufted titmouse, Eastern bluebird, American robin, gray catbird, Northern mockingbird, brown thrasher, Northern parula, Northern cardinal, red-winged blackbird, brown-headed cowbird, ring-necked duck, and lesser scaup (USACE 2008a and USACE 1981).

2.9.4.2.4 Mammals

Around Hartwell, RBR, and JST Lakes, furbearers and other mammals are an important component of these wetlands and include American beaver, muskrat, mink, northern river otter, and gray fox. White-tailed deer, and even black bear in the more isolated areas, use the bottomlands. Palustrine emergent wetlands also provide excellent habitat for furbearing mammals. Terrestrial species from surrounding areas often use the fresh marsh edge for shelter, food, and water. These include Northern raccoon, Virginia opossum, cottontails, nine-banded armadillo and coyote and bobcat (USACE 2008a and USACE 1981).

2.9.4.3 *Lower Savannah River Basin*

2.9.4.3.1 Mussels

In the portion of the Savannah River downstream of the USACE reservoirs, the wildlife associated with forested wetlands is numerous and diverse. In 2006, the USFWS studied freshwater mussels in the Savannah River to determine species composition and distribution of mussels (Savidge 2007). Twenty-six freshwater mussel species were identified during the survey efforts. With the exception of sites within the Augusta Shoals area, mussels were unevenly distributed in the surveyed areas, which is reflective of the distribution and quality of microhabitats within a particular river segment. In general, mussels were most abundant in the deepest part of the channel at the base of the river bank, and rare to absent in the shifting sand dominated runs in the center of the channel (USACE 2008a).

Atlantic pigtoe and Savannah lilliput were both observed in the 2006 mussel survey. Both of these species are experiencing range-wide declines. Atlantic pigtoe was found only in the Augusta Shoals area. This species has not been observed in any other Georgia or South Carolina rivers in many years. The population of Savannah lilliput upstream of Little Hell boat landing (Allendale County) may be the largest remaining population of this species (USACE 2008a Savidge 2007).

The flowing portion of the Savannah River is also reported to provide habitat for the Altamaha arc-mussel and Brother spike. The 2006 discovery of four species not previously known to occur in South Carolina demonstrates the incomplete knowledge regarding the mussel fauna of the Savannah River (Savidge 2007). The objective of the 2006 mussel survey was an attempt to estimate species composition and distribution in the Savannah River, but the surveyors primarily searched deepwater habitat in the river (USACE 2008a and Savidge 2007).

2.9.4.3.2 Reptiles and Amphibians

The study area provides excellent habitat for a large number of reptiles and amphibians. Wetland habitats support many kinds of frogs including the bullfrog, green frog, southern leopard frog, several species of tree frogs, cricket frogs, and chorus frogs. Turtles found in the wetlands include the river cooter, Florida cooter, eastern chicken turtle, snapping turtle, and common musk turtle. Snakes found in the wetlands include the water snakes, eastern mud snake, and eastern cottonmouth (USACE 2008a).

2.9.4.3.3 Birds

Palustrine emergent wetlands also provide habitat for many bird species. Resident, transient, and migrating birds of both terrestrial and aquatic origin use food and shelter found in this community. Some species use freshwater marshes for nesting and breeding. Waterfowl feed upon fresh marsh vegetation, mollusks, insects, small crustaceans, and fish found in the fresh marsh community. Wading birds such as the wood stork, great blue heron, little blue heron, green heron, and great egret also heavily use the tidal freshwater marsh. The lower Savannah River area is part of the Atlantic Flyway for migrating birds, and forested wetlands provide important wintering habitat for many waterfowl species and nesting habitat for wood ducks. Many species of Neotropical migratory birds, woodpeckers, hawks, and owls use the bottomlands and swamps (USACE 2008a). The extensive floodplain bottomland forest along the lower Savannah River also provides valuable habitat for species such as the swallow-tailed kite (USACE 2008a).

2.9.4.3.4 Mammals

As with the USACE reservoirs noted above in this document, furbearers and other mammals are an important component of these wetlands and include American beaver, muskrat, mink, northern river otter, gray fox, Northern raccoon, and Virginia opossum. White-tailed deer, and even black bear in the more isolated areas, use the bottomlands. Palustrine emergent wetlands also provide excellent habitat for furbearing mammals. Terrestrial species from surrounding areas often use the tidal and freshwater marsh edges for shelter, food, and water. These include cottontails, nine-banded armadillo, coyote, and bobcat (USACE 2008a).

2.9.5 *Protected Species*

Literature searches for potentially occurring endangered, threatened, and species of concern were completed using the databases of the USFWS, North Carolina Natural Heritage Program (NC NHP), SC DNR, GA DNR, and USACE. Based on this information, a list of potentially occurring state and federal endangered, threatened, and species of concern likely to occur in the Savannah River Basin study area was compiled. Information from counties bordering the Savannah River and associated reservoirs was used, but only listed species associated with habitats in or immediately adjacent to the reservoirs or within the Savannah River were included.

Upon compilation of the species list, federally listed threatened, endangered, proposed endangered, proposed threatened, and targeted federal species of concern were reviewed for distribution, habitat, and ecology to ascertain if there were species that could be found within the area of potential impacts within the study area. A summary of this information is provided in Appendix F. In addition, the bald eagle was reviewed due to its protection under the Bald and Golden Eagle Protection Act (BGEPA). Of those species reviewed, 11 species (Table 2.9-2) had the potential for impacts due to their distribution, habitat, or ecology within the study area.

Table 2.9-2 Federally Proposed and Protected Species Located in the Savannah River Basin Impact Study Area

Common Name	Federal Status	State Status
bald eagle	BGEPA	E (SC, GA)
manatee	E	E (GA)
wood stork	E	E (SC)
bluebarred pygmy sunfish	FSC*	N/A
shortnose sturgeon	E	E (SC, GA)
Atlantic sturgeon	PE	E (SC, GA)
robust redhorse	FSC*	N/A
American eel	PT	N/A
yellow lampmussel	FSC*	N/A
Savannah lilliput	FSC*	N/A
Atlantic pigtoe	FSC*	E (GA)
shoals spider-lily	FSC*	N/A
Altamaha arcmussel	FSC	N/A
Brother spike	FSC	N/A
Blueback herring	FSC	N/A

Source: NC NHP 2010, SC DNR 2006b, GA DNR 2007.

Notes: E = Endangered, T = Threatened, S/A= Similarity of Appearance, BGEPA = Bald & Golden Eagle Protection Act, PT = Proposed Threatened, PE = Proposed Endangered, FSC = Federal Species of Concern, N/A = Not Applicable,* = Target Species

2.9.6 *Special Biological Issues*

Approximately 150,000 acres of land surrounding Lake Jocassee is protected through public ownership. The lands are owned by the SC DNR, the U.S. Forest Service, the State of North Carolina, and the South Carolina Forestry Commission. Duke Energy owns land in the area for potential additional power generation and electric transmission facilities but has given up rights for other types of development through easements to the State of North Carolina and the SC DNR.

The Jocassee Gorges area was designated a State Important Bird Area based on the presence of a large portion of South Carolina's breeding populations of Swainson's warbler and worm-eating warbler, and on the availability of cove forest habitat and young Eastern hemlock stands, with which these birds are associated. Swainson's warbler was on the 2007 Watchlist of the National Audubon Society based on regional declines in numbers, potentially attributable to habitat loss (National Audubon Society 2010).

The tidal freshwater marsh of the SNWR in the lower Savannah River Basin supports a diverse plant community providing habitat for a wide variety of wildlife species. Tidal freshwater marshes are relatively scarce in the area due to past development and sea level rise, which have increased salinity levels in much of the estuary, reducing the amount of tidal freshwater marshes. According to the USFWS, the Savannah NWR contains only approximately 2,800 acres of the 6,000 acres of tidal freshwater marshes that once occurred in the estuary (USACE 2008a).

Prior to 1977, the Savannah River supported an important naturally-reproducing striped bass population, but production of striped bass in the Savannah River estuary declined by about 95 percent. There is currently an ongoing stocking program to improve this condition. Annual stocking efforts by the GA DNR have been very successful in increasing the number of striped bass in the lower Savannah River, and current population levels approach historic levels. After a 17-year closure, the striped bass fishery was re-opened in October 2005 (USACE 2008a).

The Savannah River estuary is considered essential fish habitat (EFH) by National Oceanic and Atmospheric Administration (NOAA). This stretch originates at the mouth of the Savannah River and extends upstream over 20 miles. This EFH encompasses approximately 8.2 square miles of the river and its associated estuaries. The groups covered by this EFH are the shrimp and the snapper/grouper complex (NOAA 2010).

Certain species of shrimp move into the estuaries as a result of nearshore tidal currents as the species spawn close to shore. Additionally, some shrimp species move into the estuary during late spring and early summer seasons. After shrimp enter the Savannah River estuaries, post-larval shrimp occupy nursery areas offering abundant food, suitable substrate, and shelter from predators. Smaller individuals of these shrimp species may remain in the estuary during winter months (NOAA 2010).

The species of the snapper/grouper complex typically use both the pelagic and benthic habitats during their lifecycles. The juveniles of some of the species could occur in the in-shore habitats of the Savannah River. Additionally, various combinations of habitats (including in-shore) may be used during daily feeding migrations and seasonal habitat shifts (NOAA 2010).

2.10 Socioeconomic Issues

2.10.1 *Reservoir Elevation Economic Impact Analysis*

The Strom Thurmond Institute of Public and Government Affairs (STI) at Clemson University conducted three analyses of the economic effects of reservoir levels on the surrounding communities. The analyses consisted of separate studies of the three reservoirs with the most potential for impacts associated with potentially large reservoir fluctuations: Lake Keowee, Hartwell Lake, and JST Lake.

The Institute conducted on analysis of the counties surrounding Hartwell Lake and reported their results in a document titled “The Hartwell Lake Economic Impact Analysis”. The study objective was to determine the incremental economic changes within the six counties from incremental changes in Hartwell Lake elevations. The counties all share a border with Hartwell Lake and include Pickens, Anderson, and Oconee Counties in South Carolina and Franklin, Hart, and Stephens Counties in Georgia. Information and data gathered and used in The Hartwell Lake Economic Impact Analysis included: county-level sales tax revenue according to industry classifications; 2007 estimates of total property value of lakefront real estate (segmented by county); residential and commercial development in relation to reservoir elevations (value and number of exchanges segmented by county); an estimation of economic impacts due to ancillary fees or loss of income related to real estate exchanges; and an assessment of the major roadways and potential development spots for increasing tourism and residential and commercial growth. In addition, information from Standard Industrial Classification (SIC) codes (including businesses and commercial concessionaires such as marinas, etc.) was incorporated into the Hartwell Lake economic assessment. The goal of the analysis was to identify a relationship between incremental reservoir levels and economic changes. The Institute used results from the USACE's HEC-ResSim model simulations for Hartwell Lake in their analysis.

Duke Energy retained STI to perform similar economic impact analyses based on reservoir levels at Lake Keowee and JST Lake. Similar to analysis for Hartwell Lake, these studies also developed a relationship between incremental reservoir levels and economic changes. The HEC-ResSim modeling results were also used in these two studies. A summary of findings is available in Section 4.5.1 and the full reports for the Hartwell, Keowee, and JST reservoirs are provided in Appendices P, R, and S, respectively.

2.10.2 *Environmental Justice*

Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations) was issued requiring every federal agency to consider environmental justice in its decisions by identifying and addressing the effects of all programs, policies, and activities on "minority and low income populations." Environmental justice consists of three fundamental principles:

- To avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority populations and low-income populations;
- To ensure the full and fair participation by all potentially affected communities in the transportation decision-making process; and
- To prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations (U.S. Department of Housing and Urban Development [HUD] 2010).

2.10.3 *Protection of Children*

Executive Order 13045, (Protection of Children from Environmental Health Risks and Safety Risks) requires each federal agency, to the extent possible, to:

- Make it a high priority to identify and assess environmental health and safety risks that may disproportionately affect children; and
- Ensure its policies, programs, activities, and standards address disproportionate risks to children resulting from environmental health or safety risks (White House Press Release 1997).

2.11 Coastal Zone Consistency

The 1972 Coastal Zone Management Act (CZMA) encourages coastal states to develop and implement coastal zone management programs. Pursuant to 16 U.S.C. 1456, "each Federal agency activity within or outside the coastal zone that affects any land or water use or natural resource of the coastal zone shall be carried out in a manner which is consistent to the maximum extent practicable with the enforceable policies of approved state management programs." Consultation with the relevant state agencies is required to determine if a consistency certification or determination is necessary prior to proceeding with any project falling under the jurisdiction of this Act.

There are four types of federal actions which fall under CZMA:

1. Federal agency actions including activities and developmental projects performed by a federal agency or a contractor on behalf of the federal agency;
2. Any non-federal entity actions requiring a federal license, permit, or other form of federal authorization (i.e., USACE 404 permits, NRC or FERC licenses);
3. Any project requiring approval from the Bureau of Ocean Energy Management, Regulation and Enforcement (formally Minerals Management Service) for an outer continental shelf plan; and
4. Any project by a state and local government receiving federal Assistance.

A consistency determination is a report, often part of an EA or an EIS, addressing the effects of a direct federal activity on enforceable policies of the state. A consistency certification is a statement certifying the federally permitted or funded project has been designated to meet all State and local laws and all necessary permits have been obtained.

Both the 1968 and a new Operating Agreement describe water management activities that would occur outside of the coastal zone of South Carolina and Georgia. However, changes in water flow patterns could extend downstream into the coastal zone, so an assessment of potential impacts to coastal resources is warranted.

2.12 Electric Generation

The Savannah River currently supports 26 power production facilities with a total combined generating capacity of 10,661 MW, which are described in detail in Sections 2.1.

The effects of the five alternatives on electric generation at Bad Creek Project, Jocassee Pumped Storage Station, Keowee Hydroelectric Station, and the USACE's Hartwell, RBR, and JST Projects were analyzed[7]. Under NAA, if Lake Keowee drops below 793 ft AMSL, Duke would have to shut down the ONS under certain situations. Under A1, A3, and A4, Duke would modify the ONS to enable it to continue operating. An evaluation of the potential impacts of the operating scenarios on electric generation is included in Section 4.7.

2.13 Electric Transmission

The Savannah River Basin and the electric generating facilities dependent upon it are part of the highly interconnected regional power transmission system. Loss of generation at ONS, the three USACE hydroelectric projects, and other generating stations in or near the Savannah River Basin could result in power grid reliability and stability issues throughout the region. As part of this

[7] The Bad Creek and RBR Projects were constructed after the 1968 Agreement went into effect. As a result, their influence on water storage, timing of flow releases, and hydroelectric generation has not been factored into the 1968 Agreement.

study, Duke Energy conducted an Electric Generation and Transmission Study focused on two primary areas of interest:

- A qualitative assessment of grid reliability and stability issues with no modifications to the transmission system
- A quantitative assessment related to costs of upgrading the transmission system to avoid grid reliability and stability problems during a three-unit forced outage at ONS

The results of that study are summarized in Section 4.8 and the Final Report is available in Appendix U.

2.14 Solid and Hazardous Waste Facilities

EPA lists six sites on their National Priorities List (NPL) of solid and hazardous waste facilities in the Savannah River Basin. Three of the sites are in South Carolina and three are in Georgia. Table 2.14-1 describes the general location of each listed facility within the study area.

Table 2.14-1 Solid and Hazardous Waste Facilities

EPA ID	Site Name	City	State
SCN000407714	Barite Hill/Nevada Goldfields	McCormack	SC
SCD003354412	Sangamo-Weston, Inc./Twelve-Mile Creek/Hartwell Lake	Pickens	SC
SC189000898	Savannah River Site	Aiken	SC
GAD001700699	Monsanto Corporation Augusta Plant	Augusta	GA
GAD033582461	Alternate Energy Resources, Inc.	Augusta	GA
GAN000407499	Peach Orchard Road PCE Ground Water Plume	Augusta	GA

None of the six listed sites directly adjoin Duke Energy or USACE reservoirs or the mainstem of the Savannah River. However, one of the sites (i.e., Sangamo-Weston, Inc.) is located along Twelve-Mile Creek, which is a tributary to Hartwell Lake. According to the EPA, construction of all physical structures necessary to achieve clean up goals has been completed with remedial actions continuing until all clean-up goals have been reached. The potentially responsible party (PRP) is currently leading site clean-up activities with oversight by EPA (USEPA 2010a).

An overview of the sites along with a map indicating the approximate location of each site is provided in Appendix H.

2.15 Cultural Resources

Evidence of human presence in the Savannah River Basin dates back to approximately 9,500 B.C. Numerous archaeological surveys have been conducted in the region including within the areas impounded by the Duke Energy and USACE reservoirs. Accordingly, a number of archaeological and historic sites are known to exist within the reservoirs and along the shoreline of the reservoirs. While most of these sites do not meet the criteria for inclusion in the National Register of Historic Places, some do and are afforded protection under the National Historic Preservation Act. Sites that are determined potentially eligible or requiring additional investigation are treated as though they are eligible until further work has determined concerning their National Register status. The National Historic Preservation Act requires federal agencies like the USACE and FERC to take into account the effects of their undertakings on historic properties, evaluate the effects of their actions on sites eligible for inclusion in the National Register of Historic Places, and provide the Advisory Council on Historic Preservation (ACHP) with a reasonable opportunity to comment on such proposed actions. In addition, Federal agencies are required to consult on the Section 106 process with State Historic Preservation Offices (SHPO), Tribal Historic Preservation Offices (THPO), Indian Tribes (to include Alaska Natives) [Tribes], and Native Hawaiian Organizations (NHO).

In 2006, the USACE issued the "Final Environmental Assessment, Finding of No Significant Impact, Drought Plan Update for the Savannah River Basin" (USACE 2006). In preparing the Drought Plan Update, the USACE reviewed the findings of previous archaeological surveys within the impounded areas of the JST, RBR and Hartwell reservoirs, associated upland areas, and downstream river reaches. USACE consulted with 19 Native American tribes about the proposed Drought Plan Update and a letter indicating concurrence with no adverse impacts was received from the Alabama-Quassarte Tribal Town. The Catawba Indian Nation stated they were opposed to illegal artifact hunting at times of low water but did not indicate any adverse effects. Limited archaeological surveys of areas affected by operation of the USACE projects had been conducted; however, the number of potentially significant prehistoric and historic resources within the fluctuation zone, riverbank or channel, and are adversely affected by changing pool elevations is not completely known.

USACE also consulted with the Augusta Canal Authority, Georgia, and South Carolina State Historic Preservation Officers (SHPO) and 18 Native American Tribes during the agency and public comment period for the 2006 FONSI. The Augusta Canal Authority indicated that flows <3,000 cfs would negatively affect the use of the Augusta Canal (designated by Congress as one of 18 National Heritage Areas in 1996) for recreational purposes, as well as operation of the Petersburg Tour Boats.

USACE performed similar evaluations and consultations for the 2011 Level 4 Drought Operations Study and the 2012 Drought Plan Update. The EA for the Level 4 Study identified the potential for impacts to archaeological and historic sites from extremely low pool levels and river flows. As a result, USACE included a Draft Programmatic Agreement (USACE PA) to identify and address those potential impacts in the Final 2011 Level 4 EA. The PA specifies USACE actions to assess the effects of reservoir operations and downstream flow release on archaeological and historic sites (USACE 2012a). In 2012, USACE consulted with the Georgia and South Carolina SHPOs, the Advisory Council on Historic Preservation (ACHP), and interested Native American tribes regarding potential impacts to historic properties associated with implementation of the updated Drought Plan. USACE drafted a PA which stipulates Savannah District and the Consulting Parties shall identify the need for and scope of, archeological surveys of areas that are affected by changes in lake elevations.

In 2007, FERC consulted with the Advisory Council on Historic Preservation and the South Carolina SHPO regarding potential effects to historic properties associated with implementation of Duke Energy's SMP at Lake Keowee. Duke Energy, the Catawba Nation, the Cherokee Nation of Oklahoma, and the Eastern Band of Cherokee Indians participated in the consultation and were invited to concur with a Programmatic Agreement (Duke Energy PA), which was executed on May 9, 2007. The agreement outlines stipulations including the acquisition of baseline data on historic properties and development of a predictive model for historic properties.

The PA also lists activities exempt from further review. The Duke Energy PA terminates with issuance of the next FERC License, at which point it will likely be replaced with a new Duke Energy PA requiring Duke Energy implement a Historic Properties Management Plan for the protection of historic properties included in its Application for New License.

Duke Energy surveyed the shoreline of Lake Jocassee, Lake Keowee, islands at both reservoirs, and Keowee-Toxaway access areas during implementation of the Duke Energy PA. Three archaeological sites that may be eligible for inclusion in the National Register of Historic Places were located along Lake Keowee shoreline (Duke Energy 2011). Management of these sites will be addressed in Duke Energy's Historic Properties Management Plan.

At this time, the effects that fluctuating water levels have already had on cultural resources, as well as potential impacts from future changes in water control management are not precisely known. However, the wording of the USACE PA and Duke Energy's PA are sufficiently broad that implementation of those agreements would adequately address such effects.

3.0 OPERATING ALTERNATIVES AND MODELING RESULTS

3.1 Operating Alternatives

During a series of Keowee-Toxaway Relicensing meetings between September 2012 and May 2013, the Stakeholder Team discussed and reviewed many potential reservoir operating regimes (or alternatives). Three of these alternatives and two additional operating alternatives are evaluated in this Environmental Assessment. The five alternatives (introduced in Section 1.3) are described in greater detail below. Note that some of the alternatives include provisions to enhance drought tolerance in the Upper Savannah River Basin. Those measures include enhanced coordinated drought response, measures to protect the Upper Savannah River Basin water supply, and provisions of the Keowee-Toxaway RA. Some of the drought tolerance measures are not captured in the HEC-ResSim model logic or results.

Several of these drought tolerance measures are based on Duke Energy's drought response experience in the Catawba-Wateree River Basin. For example, during the 2007 – 2009 drought of record, nearly two dozen Catawba-Wateree water partners and civic leaders in North and South Carolina issued a unified call for water conservation. Some of the water conservation measures were mandatory (e.g., Charlotte-Mecklenburg Utilities in North Carolina), while others were encouraged, but not mandatory. Regional water conservation efforts resulted in lower water usage and no communities in the basin ran out of water. Charlotte, North Carolina water users played a key role by lowering their water use by as much as 37 percent. Just as importantly, when drought restrictions were lifted in April 2009, water usage remained below pre-drought levels, indicating the communities learned from the experience and voluntarily adopted water conservation measures that extended after the drought measures were lifted. The drought response measures incorporated in A1, A2, A3, and A4 are based, in part, on drought responses measures used in the Catawba-Wateree River Basin.

To avoid adverse impacts to dissolved oxygen levels in Savannah Harbor, each action alternative includes a provision where USACE and Duke Energy would discharge 200 cubic feet per second of water above that specified in the 2012 Drought Plan from their dams for 11 days when the USACE reservoirs are in drought status during the summer months.

A detailed description of the five alternatives evaluated in this EA is provided below.

No Action Alternative (NAA)

The NAA represents the base condition from which the effects of potential changes are evaluated. In this case, the NAA consists of USACE and Duke operating in accordance with the 1968 Agreement (a legally binding document), with no changes. The 1968 Agreement uses the concept of equalizing the percent of combined remaining usable storage capacity at the USACE Hartwell and JST Lakes with the percentage of combined remaining usable storage capacity at Duke Energy's Lakes Jocassee and Keowee. Throughout the year, USACE calculates that storage on a weekly basis to determine required water releases (or non-release) from Lake Keowee for the upcoming week. The storage balance evaluation to determine the required water release from Lake Keowee is evaluated on a daily basis in the HEC-ResSim model resulting in a daily release representative of the actual weekly release volume requirement.

The 1968 Agreement is based on the reservoir storage between the minimum reservoir elevation and the rule curve for each reservoir. These elevations are provided in Table 3.1-1.

Table 3.1-1 Minimum Reservoir Elevation Levels

Reservoir	Minimum Elevation (feet AMSL)
Lake Jocassee (1)	1,086
Lake Keowee	778
Hartwell Lake	625
JST Lake	312

[1] Plus the volume reserved for pumping (41,000 ac-ft) per the 1968 Agreement, resulting in an operational minimum of 1,080 ft AMSL

The NAA assumes that if the pool elevation within Lake Keowee falls below 793 ft AMSL, Duke would cease to operate the ONS until the pool rises above that elevation. That assumption is based on NRC requirements for operation of the ONS. The NAA incorporates the July 2012 USACE Drought Plan operating protocols as described in Section 3.3.3.

Alternative 1 (A1)

For A1, Duke Energy would modify the ONS so they could operate that facility down to a Lake Keowee pool elevation of 778 ft AMSL. A1 incorporates the USACE July 2012 DP operating protocols. A1 is based on the concept of equalizing the percentage of combined remaining usable storage capacity at the USACE's Hartwell and JST Lakes with the percent of combined remaining usable storage capacity at Duke Energy's Lakes Jocassee and Keowee.

A1 includes the following provisions to enhance drought tolerance in the Upper Savannah River Basin:

- USACE will require any owner of a Large Water Intake (i.e., water intake with a maximum capacity greater than or equal to one million gallons per day) who is allocated water from the USACE Projects after the Effective Date of the NOA to implement coordinated water conservation measures when the DP is in effect similar to the water conservation measures required by the LIP for Large Water Intake owners on the Duke Energy Projects. Duke Energy will require owners of Large Water Intakes on the Duke Energy Projects to comply with the LIP.
- USACE and Duke Energy will encourage all water users withdrawing water from their respective reservoirs to conserve water in a coordinated manner when the DP is in effect similar to the water conservation measures required by the LIP on Duke Energy Projects.
- USACE and Duke Energy will require whenever feasible that all Large Water Intakes used for municipal, industrial and power generation purposes that are constructed, expanded or rebuilt on the USACE Projects and the Duke Energy Projects after the Effective Date of the NOA be capable of operating at their permitted capacities at reservoir elevations as low as the applicable hydroelectric station can operate.

A1 was not modeled because it is hydraulically identical to the NAA.

Alternative 2 (A2)

A2 represents how Duke Energy has operated the Keowee-Toxaway Project since the mid- to late-1990s during droughts. The overall methodology used to determine required weekly water releases from Lake Keowee remains the same as in the NAA. However, the operational minimum reservoir elevation at Lake Keowee would increase from 778 ft AMSL to 794.6 ft AMSL (resulting from the 1973 NRC requirements for continued operation of the ONS). The minimum reservoir elevation used in the weekly storage balancing calculations remains at 778 ft AMSL for Lake Keowee (as in the 1968 Agreement). Reservoir water withdrawals and evaporation may result in the Lake Keowee elevation falling below the operational minimum of 794.6 ft AMSL, but only to the extent there is minimal additional storage remaining in Lake Jocassee.

As with the NAA, A2 incorporates the July 2012 USACE Drought Plan operating protocols. A2 also equalizes the percent of combined remaining usable storage capacity at the USACE's Hartwell and JST Lakes with the percent of combined remaining usable storage capacity at Duke Energy's Lakes Jocassee and Keowee. A2 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1.

Alternative 3 (A3)

While the NAA's overall concept of balancing the percent of combined remaining usable storage between the Duke Energy and USACE Reservoirs is unchanged in A3, A3 incorporates updated storage volumes, coordinated drought response, measures to protect Upper Savannah River Basin water supply, and Duke's 2013 Keowee-Toxaway Relicensing Agreement. As with the NAA and A2, A3 incorporates the USACE July 2012 Drought Plan operating protocols.

For A3, Duke Energy would modify the ONS to enable them to continue to operate that facility when Lake Keowee elevations drop below 794.6 ft AMSL. With this alternative, the Lake Keowee minimum elevation for calculation of usable storage would be revised to 790 ft AMSL, which allows a 10-foot drawdown of Lake Keowee. The Lake Jocassee minimum reservoir elevation would be lowered six feet (from 1086 ft AMSL to 1080 ft AMSL) and the allowance for pumping volume would be eliminated in the weekly release calculation. A3 incorporates additional reservoir storage created by the USACE and Duke Energy since the 1968 Agreement, through the addition of the Bad Creek Reservoir and RBR Lake, for the purposes of determining the remaining usable storage and weekly water releases from Lake Keowee. Therefore, A3 would equalize the percent of combined remaining usable storage capacity at the USACE's Hartwell, RBR, and JST Lakes with the percentage of combined remaining usable storage capacity at Duke Energy's Bad Creek reservoir and Lakes Jocassee and Keowee.

Details of these changes to minimum reservoir elevations and additional storage capacity in A3 are:

- Addition of storage capacity in USACE's RBR Lake. The RBR storage is calculated as being from elevation 475 ft AMSL (top of conservation pool) to elevation 470 ft AMSL; 126,864 ac-ft of water.
- Addition of storage capacity in Duke Energy's Bad Creek Project. The Bad Creek storage is from elevation 2,310 ft AMSL to 2,150 ft AMSL; 30,229 ac-ft of water.
- Revising the Lake Keowee minimum elevation for calculating usable storage from elevation 778 ft AMSL to elevation 790 ft AMSL, based on Duke modifying the ONS so they can operate that facility down to a Lake Keowee at elevation 790 ft AMSL. The usable storage in Lake Keowee for the purpose of this Agreement would decrease from 327,766 ac-ft (at 778 ft AMSL in the 1968 Agreement) to 161,772 ac-ft (at 790 ft AMSL).

A3 includes the following provisions to enhance drought tolerance in the Upper Savannah River Basin:

- o The same drought tolerance provisions included in A1. Those provisions include Duke Energy implementing the Keowee-Toxaway LIP which describes how the Duke Energy Reservoirs would be operated during periods of drought, including minimum reservoir elevations and water use conservation for varying levels of drought severity (and closely follows the USACE's DP). Details of the Keowee-Toxaway LIP are provided below:
  - LIP Stage minimum elevations for Lake Jocassee and Lake Keowee (respectively)
    - Stage 0: 1,096 ft AMSL; 796 ft AMSL

- Stage 1: 1,092 ft AMSL; 795 ft AMSL
- Stage 2: 1,087 ft AMSL; 793 ft AMSL
- Stage 3: 1,083 ft AMSL; 792 ft AMSL
- Stage 4: 1,080 ft AMSL; 790 ft AMSL

- In LIP Stage 4, the Lake Keowee elevation is maintained at or above 791.5 ft AMSL until Duke Energy's remaining usable water storage drops to 12 percent, at which time non-emergency or non-ONS-related intentional flow releases are stopped and the minimum elevation is allowed to drop to the Stage 4 minimum elevation of 790 ft AMSL due to natural surface evaporation, on-lake water withdrawals, dam seepage, and hydro unit leakage. At least 650 ac-ft of water per week continues to be released via hydro unit leakage and dam seepage from the Keowee Development into Hartwell Lake.
- The LIP for this scenario allows Lake Keowee to move more quickly to a less severe drought level during the recovery process by eliminating the 2-foot recovery delay in the USACE's DP operating protocols. This does not impact the USACE's DP levels for Hartwell Lake and JST Lake.

- Duke Energy would provide $438,000 to support Phase 3 of the USACE's Savannah River Basin Comprehensive Study (i.e., consideration of reallocating flood storage).

A3 includes a provision to address adverse impacts to recreational users of the USACE reservoirs. Duke Energy would provide funding and/or in-kind services to USACE and other public entities to improve public boating access at Hartwell and Thurmond Reservoir facilities to fully mitigate for adverse impacts to recreational access to those reservoirs. Those impacts are presently estimated to be $2,938,000 (FY14 price levels) over a 50-year evaluation period.

A3 also includes the following provision to avoid adverse impacts to dissolved oxygen levels in Savannah Harbor: USACE and Duke Energy would discharge 200 cubic feet per second of water above that specified in the 2012 Drought Plan from their dams for 11 days when the USACE reservoirs are in drought status during the summer months.

Alternative 4 (A4)

A4 is included to evaluate how LIP operations (described in A3) affect Duke and USACE reservoir levels. A4 includes the same reservoir usable storage updates as A3 and requires Duke to modify the ONS so they could operate it down to a Lake Keowee elevation of 790 ft AMSL. A4 does not include the Keowee-Toxaway Project LIP provisions found in A3. The exclusion of those provisions in the Duke system in A4 is the only difference between A3 and A4.

As with the other alternatives, A4 incorporates the USACE July 2012 Drought Plan operating protocols. A4 equalizes the percent of combined remaining usable storage capacity at the USACE's Hartwell, RBR, and JST Lakes with the percent of combined remaining usable storage capacity at Duke Energy's Bad Creek reservoir and Lakes Jocassee and Keowee. A4 includes the same provisions to enhance drought tolerance in the Upper Savannah River Basin as A1. A4 includes Duke Energy's support of Phase 3 of the USACE's Savannah River Basin Comprehensive Study through $438,000, as well as the funding identified in A3 to address adverse impacts to recreational users of the USACE reservoirs.

3.2 Duke Energy System Water Availability

As described in Section 3.1, USACE calculates reservoir storage on a weekly basis for the USACE and Duke Energy systems and identifies the flow releases required from the Keowee Hydroelectric Station. Figure 3.2-1 provides a graphical representation of the volume of water available for use from the Keowee-Toxaway and Bad Creek Projects for each of the alternatives as the percentage of remaining storage in the USACE system declines (uses include municipal water withdrawals from Lake Keowee, ONS project uses, and flow releases to the USACE reservoirs). The volume of water available for use under the NAA and A1 is the same, thus they are represented by a single line in Figure 3.2-1. The volume of water available for use under A3 and A4 is also similar and is depicted by a single line.

The graphs shown in Figure 3.2-1 are conceptual and not based on HEC-ResSim model results. However, they provide insight as to how much water is available for use from the Duke Energy system based on USACE system storage levels. The results assume that inflows to the Duke

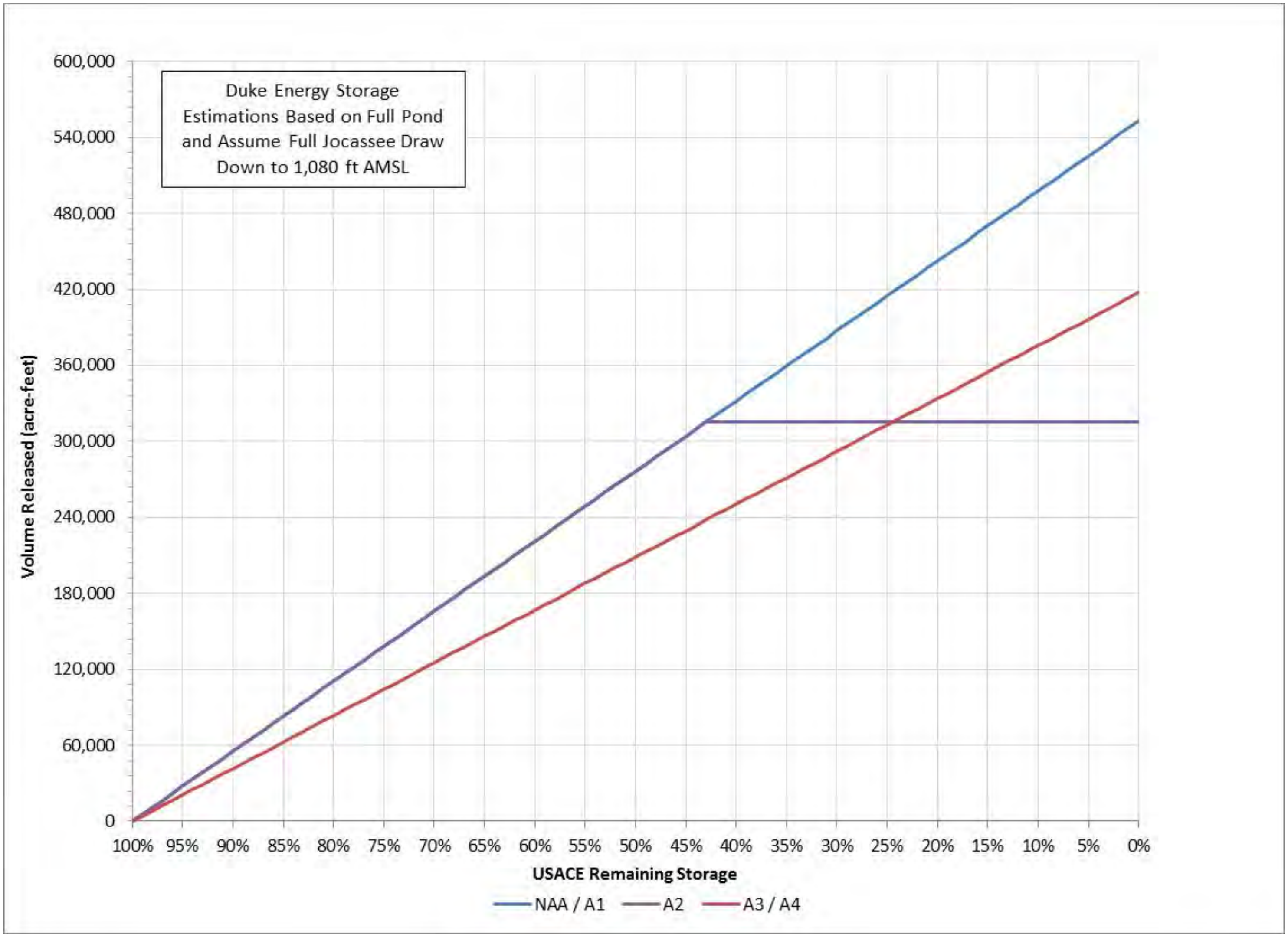
Energy system is enough to offset natural and forced evaporation, on-lake water withdrawals, dam and hydro unit leakage, and groundwater seepage at the three reservoirs in the Duke Energy system.

Among the five alternatives, the NAA and A1 have the largest volume of water available for use from Lake Keowee, since the reservoir elevation for these two alternatives is allowed to drop to 778 ft AMSL.

A2 assumes no flow release is made from Lake Keowee if that release would result in the reservoir dropping below 794.6 ft AMSL (results also assume Lake Jocassee is kept near 1086 ft AMSL and Bad Creek Project storage is not available). Figure 3.2-1 indicates no water is available to be released from the Duke Energy system in A2 once the USACE system storage drops below approximately 43 percent.

While less water is available for use in A3 and A4 when the USACE system storage is between 100 and 25 percent compared to the NAA, A1, and A2, more water is available for use than in A2 when USACE system storage levels drop below 25 percent during severe droughts. There would be less water available for use in A2, A3 and A4 when USACE system storage levels drop below 43 percent when compared to the NAA.

Figure 3.2-1 Duke Energy Cumulative Water Volume Used Based on USACE Percent Remaining Usable Storage



3.3 HEC-ResSim Model Development

For purposes of identifying and evaluating differences between the alternatives, Duke used the USACE HEC-ResSim model to simulate reservoir elevations and flow releases below JST Lake for each of the four alternatives over a 73-year period of record (POR) (1939–2011). Note that A1 is the same as the NAA for modeling purposes and does not require a separate hydrologic model simulation.

3.3.1 *HEC-ResSim Model Development*

USACE previously developed a HEC-ResSim model for its three reservoir projects on the Savannah River (i.e., Hartwell Lake, RBR Lake, and JST Lake). The original model setup included general features associated with Duke Energy's Lakes Jocassee and Keowee such as drainage areas, reservoir volumes, general operating rules, and flow releases from each development. In order to model the four alternatives more accurately and enable Duke to use the model in conjunction with their relicensing efforts for the Keowee-Toxaway Project, Duke Energy refined the model for Lakes Jocassee and Keowee, and added Bad Creek to the model logic. These refinements include more detail on reservoir operating rules for high water management and water conservation modes of operation, additional logic on pumped storage operations at Jocassee Pumped Storage Station, and derived UIF to each reservoir. These refinements also include known and calculated water withdrawals from each reservoir, including the estimated current (Year 2010) and projected future (Year 2066) water withdrawals from (and returns to) each reservoir for all registered water use entities. Appendix A summarizes the present water use volumes and future water use projections that were used in the analysis.

3.3.2 *Hydrology Development*

The UIF previously used in the HEC-ResSim model was developed by ARCADIS for the GA DNR-EPD (September 2010) and had a POR extending from 1939 through 2007. That UIF treated hydrology from the upper portions of the Savannah River Basin (i.e., the Duke Energy reservoir areas) as a lump sum. To refine the UIF to incorporate the historic operations of the Duke Energy facilities, historic hard copy reservoir operations records for Bad Creek, Lake

Jocassee, and Lake Keowee were digitized and incorporated into the 1939–2007 hydrology database. ARCADIS subsequently added 2008 hydrology to the UIF.

Duke revised and enhanced the HEC-ResSim model to support the evaluations in this EA. At the same time, they retained HDR Engineering (HDR) to develop a CHEOPS hydrologic model to support the Keowee-Toxaway Relicensing effort. To maintain consistency between the two hydrologic models, the PDT and the relicensing Stakeholder Team recommended using the same hydrology database developed by ARCADIS in both models. That stakeholder team provided advice during the development of the hydrologic modeling. During the analysis, ARCADIS extended the hydrology database through 2011, providing a 73-year POR (1939 – 2011).

3.3.3 *USACE Drought Plan*

Savannah District had developed a Short-Range Drought Water Management Strategy in 1986 to address the water shortage conditions in the Savannah River Basin at that time. This strategy served as a guide for using the remaining storage in the USACE-operated reservoirs and later became a timely foundation for a long-term strategy to deal with the 1988 drought and other severe droughts going forward (USACE 2012a). During the drought of 1988, JST and Hartwell Lakes dropped to almost 17 feet and 15 feet, respectively, below the top of their conservation pools (normal operating range). As a result, the USACE was not able to fully meet the authorized project purposes of hydropower and recreation. Subsequently, USACE developed the initial Drought Plan in 1989 to establish three reservoir elevation trigger levels (USACE 1989). The trigger levels are based on the reservoir elevations at both Hartwell and JST Lakes.

USACE developed the Savannah River Basin DP to help balance impacts to the authorized uses of its three reservoir projects during times of insufficient rainfall. To reduce the decline in pool elevations during the early stages of a drought, USACE reduces weekly average flow releases from the Hartwell and JST Projects. Once the DP has been activated, maximum flow amounts are reduced in a step-wise fashion from JST Lake. Reservoir elevations at the Hartwell and JST Projects are kept in balance during non-drought and the early levels of droughts.

In 2006, the DP was revised to include a fourth trigger level. The 2006 DP allowed the USACE to maintain higher pools at the reservoirs without further impacting water intakes upstream or downstream of the dams. Table 3.3-1 provides the flood control, conservation, and minimum conservation pool elevations for Hartwell, RBR, and JST Lakes.

Table 3.3-1 Flood Control, Conservation, and Minimum Conservation Pool Elevations for Hartwell, RBR, and JST Reservoirs

Pool Elevation	Hartwell Lake (feet AMSL)	RBR Lake (feet AMSL)	JST Lake (feet AMSL)
Top of Flood Control	665	480	335
Top of Conservation Pool (Summer/Winter)	660/656	475	330/326
Minimum Conservation Pool	625	470	312

Source: USACE 2010c

The 2012 revision to the DP reduced minimum flow releases below JST Lake and added a reservoir inflow trigger for the Broad River tributary (based on reported flows at the USGS Gage 02192000 Broad River near Bell, Georgia). Table 3.3-2 provides the seasonal trigger levels and management action (i.e., minimum required flow release from JST Lake).

Each drought level requires a minimum daily average flow release from JST Lake. The required flow release in the DP for Level 1 is 4,200 cfs when Broad River inflows, as reported by the USGS, are greater than 10 percent of the historical flow rate (calculated over a 28-day average); the required flow release drops to 4,000 cfs when Broad River inflows drop to less than or equal to 10 percent of the historical flow rate. The required flow release from JST for DP Level 2 is 3,600 cfs from November through January regardless of inflows. During the period February through October, the required flow release in DP Level 2 is 4,000 cfs when Broad River inflows are greater than 10 percent of the historical flow rate; the required flow release drops to 3,800 cfs when Broad River inflows are less than or equal to 10 percent of the historical flow rate.

Drought Levels 3 and 4 are not linked to inflows from the Broad River and are solely based on Hartwell and JST Lake elevations. Minimum required flow releases from JST for Levels 3 and 4 for the period February through October are 3,800 cfs and 3,600 cfs, respectively (and are reduced to 3,100 cfs from November through January). Those releases from JST would be continued during Level 4 for as long as possible; then they would be reduced to equal reservoir inflows.

Table 3.3-2 Hartwell and JST Lake Seasonal Trigger Levels

Trigger Level	1 Apr–15 Oct (feet AMSL)		15 Dec–1 Jan (feet AMSL)		Action
	Hartwell Lake	JST Lake	Hartwell Lake	JST Lake	
1	656	326	654	324	If Broad River inflows > 10% of historical flow rate, set JST Lake outflow to 4,200 cfs. If Broad River inflows <= 10% of historical flow rate, set JST Lake outflow to 4,000 cfs.
2	654	324	652	322	If Broad River inflows > 10% of historical flow rate, set JST Lake outflow to 4,000 cfs. If Broad River inflows <= 10% of historical flow rate, set JST Lake outflow to 3,800 cfs. Set JST Lake outflow to 3,600 cfs November through January.
3	646	316	646	316	Set JST Lake outflow to 3,800 cfs. Set JST Lake outflow to 3,100 cfs November through January.
4	625	312	625	312	Set JST Lake outflow to 3,600 cfs. Set JST Lake outflow to 3,100 cfs November through January. Continue release as long as possible, then outflow = inflow.

Note: Inflow is measured at the Broad River near Bell, Georgia USGS flow gaging station (#02192000)
Source: USACE 2012a

The 2012 DP includes the potential for adaptive management when USACE reduces flows from the JST Project during the months of November, December and January. As adaptive management, USACE would restore the 3,800/3,600 cfs release from the JST Project if requested by a state regulatory agency in Georgia and/or South Carolina to support downstream water quality, including in the Savannah Harbor. As a result, adaptive management flow releases could be implemented during DP Levels 2, 3, and/or 4.

If implemented, adaptive management flow releases would be made during the November to January timeframe and would involve increasing the JST flow release from the minimum allowed during those months. For example, if adaptive management were implemented during Level 3 conditions, the minimum JST Project flow release would be raised from 3,100 cfs, in an unspecified step-wise fashion, up to 3,800 cfs for the months of November, December and

January. The minimum required flow release for February through October would remain unchanged at 3,800 cfs.

3.3.4 *HEC-ResSim Model Verification*

Once Duke updated the HEC-ResSim model with more detailed information for its Projects, and the inflows from the extended UIF were incorporated, model results were verified using several different methods.

First, HEC-ResSim model output was compared to historical reservoir elevations, generation, and flow releases from each project. The results of this comparison are provided in Appendix I. Overall, the model outputs for each of the four scenarios, while not exact, offer a very good representation of reservoir elevations, generation, and flow releases from each project. As summarized in Appendix I, the HEC-ResSim model adequately represents the Savannah River Basin from Bad Creek downstream to the outlet of JST Lake.

Second, HEC-ResSim model output was compared to CHEOPS model output for the same period of record. The results of this comparison are provided in Appendix J. While there are some minor differences between the two models, they are within the accuracy range of complex hydrologic models.

3.3.5 *HEC-ResSim Model Sensitivity Analysis*

From a modeling perspective each operating scenario was run under a base set of water withdrawal and hydrology assumptions. The base set of assumptions includes projected future water withdrawals (as a constant throughout the POR) along with historic (i.e., unaltered) ARCADIS hydrology for the 1939–2011 POR. The model results using the base set of model assumptions are described in detail in Sections 3 and 4.

In addition, a set of model sensitivity analyses were performed using modified water withdrawal and hydrology assumptions. The first sensitivity analysis incorporated current water withdrawals (as a constant throughout the POR) along with the historic ARCADIS inflow hydrology dataset

(1939–2011 POR). The second set of sensitivity analyses incorporated projected future water withdrawals with climate change hydrology conditions (due to hypothetical climate change estimates) developed by HDR for the 1939–2011 POR. Results from the sensitivity analyses are briefly described in the main body of this document and detailed results are included in the appendices.

In brief, the three sets of water withdrawal and hydrology model assumptions are described below.

- Future water withdrawals (Year 2066) with historic hydrology
- Current water withdrawals (Year 2010) with historic hydrology
- Future water withdrawals (Year 2066) with climate change hydrology

The scenario titled "Future Water Withdrawals" consists of the expected water withdrawals by 2066 by presently-permitted users. To assess possible effects of adverse climatological changes on that issue, the hydrologic modelers considered (1) a 3 degree temperature rise (which would lead to a 10% increase in evaporation) and no reduction in inflows, and (2) a 6 degree temperature rise (which would lead to a 20% increase in evaporation) and a 10% reduction in inflows. The Climate Change hydrology scenario uses the larger changes -- a 6 degree temperature rise (which would lead to a 20% increase in evaporation) and a 10% reduction in inflows.

3.3.6 *Reservoir Sedimentation*

The HEC-ResSim model uses reservoir storage volume curves as input for both the Duke Energy and USACE reservoirs. Storage volumes for Lakes Jocassee and Keowee were based on 2010 bathymetry data; the original USACE reservoir storage capacities were reduced a small amount based on estimated sediment yields and deposition patterns since the reservoirs were constructed. Details regarding the 2010 reservoir storage curves for both the Duke Energy and USACE reservoirs are provided in Appendix L. The estimated reservoir storage capacity losses due to sedimentation through Year 2060 were less than 1 percent and, therefore, were not included in the model scenarios for future years.

3.4 USACE and Duke Energy Storage Balance Model Results

One objective of the HEC-ResSim model is to balance available storage between Duke Energy's reservoirs and the USACE's reservoirs on a daily basis (this is described in the 1968 Agreement on a weekly basis). Figures 3.4-1 through 3.4-4 compare USACE and Duke Energy system storage over the 73-year POR (future water withdrawals with historic hydrology) for the four operating scenarios. These graphs depict results from model runs that include the USACE's 2012 DP, but assume adaptive management (as described in Section 3.3.3) is not implemented. A summary of key points is provided below.

- Over the majority of the POR, all four model operating scenarios result in similar available storages (expressed in terms of percent remaining usable storage) between the USACE and Duke Energy reservoirs.
- The USACE and Duke Energy remaining usable storage is greater than 60 percent during the majority of the POR.
- The Duke Energy percent remaining usable storage is typically slightly lower than the USACE percent remaining usable storage over the POR. This is not the case during extreme drought conditions under NAA/A1 and A2 where USACE's remaining usable storage drops below that of Duke Energy's reservoirs. For example, under NAA/A1, the USACE's remaining usable storage drops to 16 percent while Duke Energy's remaining usable storage is slightly higher at 17 percent near the end of the 2007 – 2008 extreme drought. A2 results during this same extreme drought period show the USACE's remaining usable storage drops to 20 percent while Duke Energy's remaining usable storage is 42 percent. In A2, the Lake Keowee volume used in the weekly flow release calculation is the same as the NAA/A1, but no release beyond leakage and seepage is made if it would cause Lake Keowee's reservoir elevation to drop below 794.6 ft AMSL. This results in more Duke Energy remaining usable storage in A2 (compared to NAA/A1) as shown on Figures 3.4-1 and 3.4-2 at the end of the 2007 – 2008 extreme drought.

- Under A3, the USACE's and Duke Energy's remaining usable storage levels are 13 percent and 11 percent, respectively, near the end of the 2007 – 2008 extreme drought.
- Under A4, the USACE's and Duke Energy's remaining usable storage levels are 13 percent and 10 percent, respectively, near the end of the 2007 – 2008 extreme drought.
- While Duke Energy's remaining usable storage drops below 12 percent for a short period under both A3 and A4, a scheduled storage balance weekly release to the USACE system would not be required during this period because the USACE's remaining usable storage is greater than Duke Energy's remaining usable storage.

3.4.1 ***Remaining Usable Storage – Sensitivity Analysis***

Appendix K includes figures comparing the remaining usable storage for the USACE and Duke Energy reservoir systems for current water withdrawals with historic hydrology and future water withdrawals with climate change hydrology. Key points from the sensitivity analysis are:

- Overall, results of the sensitivity analysis are similar to those provided in Figures 3.4-1 through 3.4-4 for future water withdrawals with historic hydrology.
- For current water withdrawals with historic hydrology, the lowest USACE remaining usable storage is 24 percent under A2 (the corresponding lowest Duke Energy remaining usable storage is 44 percent under A2). This occurs at the end of the 2007 – 2008 extreme drought. A4 results in the lowest Duke Energy remaining usable storage at 19 percent, also at the end of 2008.
- For future water withdrawals with climate change hydrology, the minimum USACE remaining usable storage is 10 percent under both A3 and A4 (see Figures K-7 and K-8 in Appendix K). These two model scenarios also result in the lowest Duke Energy remaining usable storage at 10 percent and 7 percent for A3 and A4, respectively. Again, these results occur at the end of the 2007 – 2008 extreme drought. Since Duke Energy's remaining usable storage is equal to or less than the USACE's remaining usable storage, a scheduled storage balance weekly release from Keowee Hydroelectric Station would not be required.

Figure 3.4-1 Duke Energy and USACE Reservoir Storage Percentages – NAA/A1 (Future Water Withdrawals with Historic Hydrology (1939–2011))

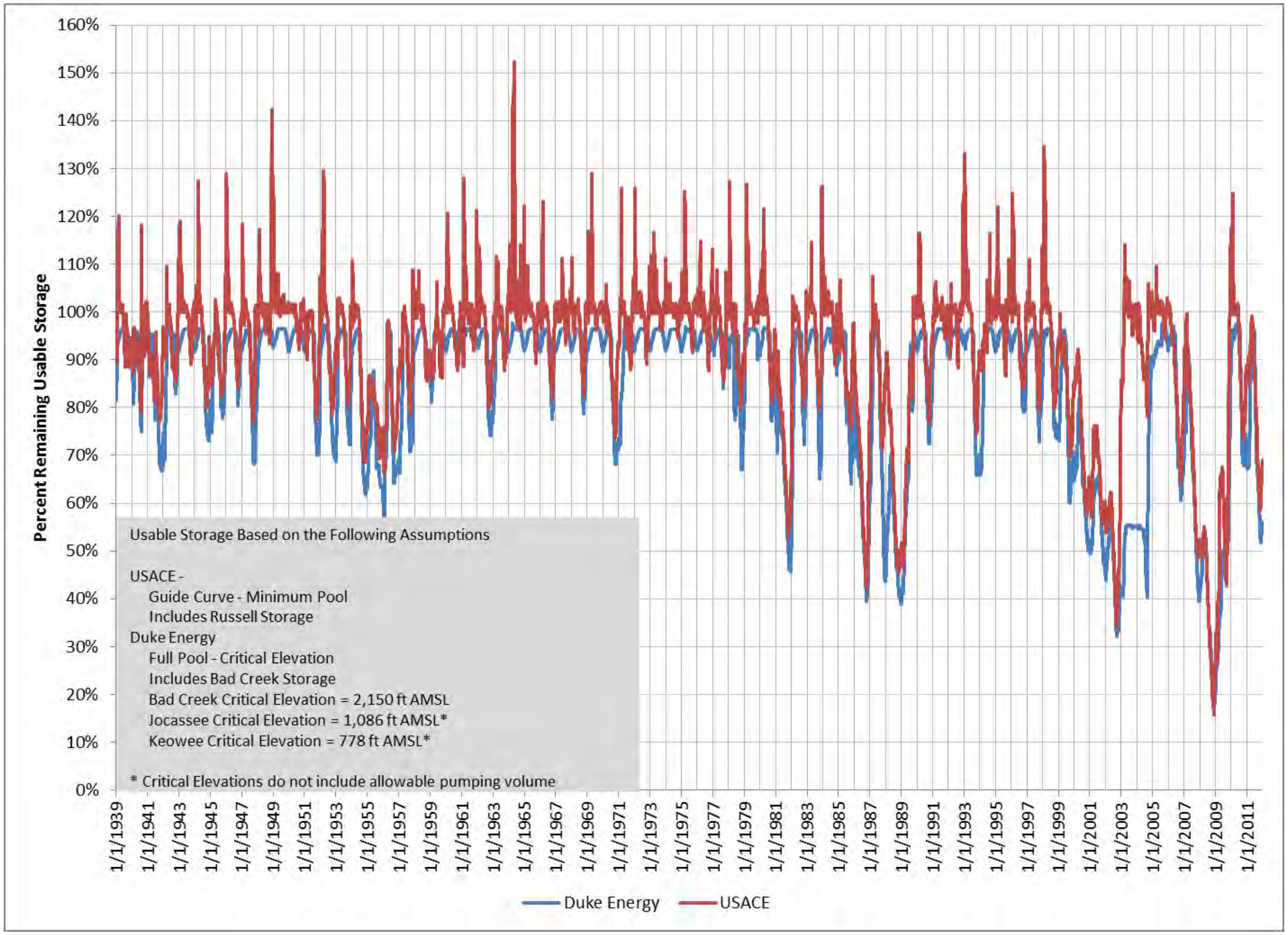


Figure 3.4-2 Duke Energy and USACE Reservoir Storage Percentages – A2

(Future Water Withdrawals with Historic Hydrology (1939–2011))

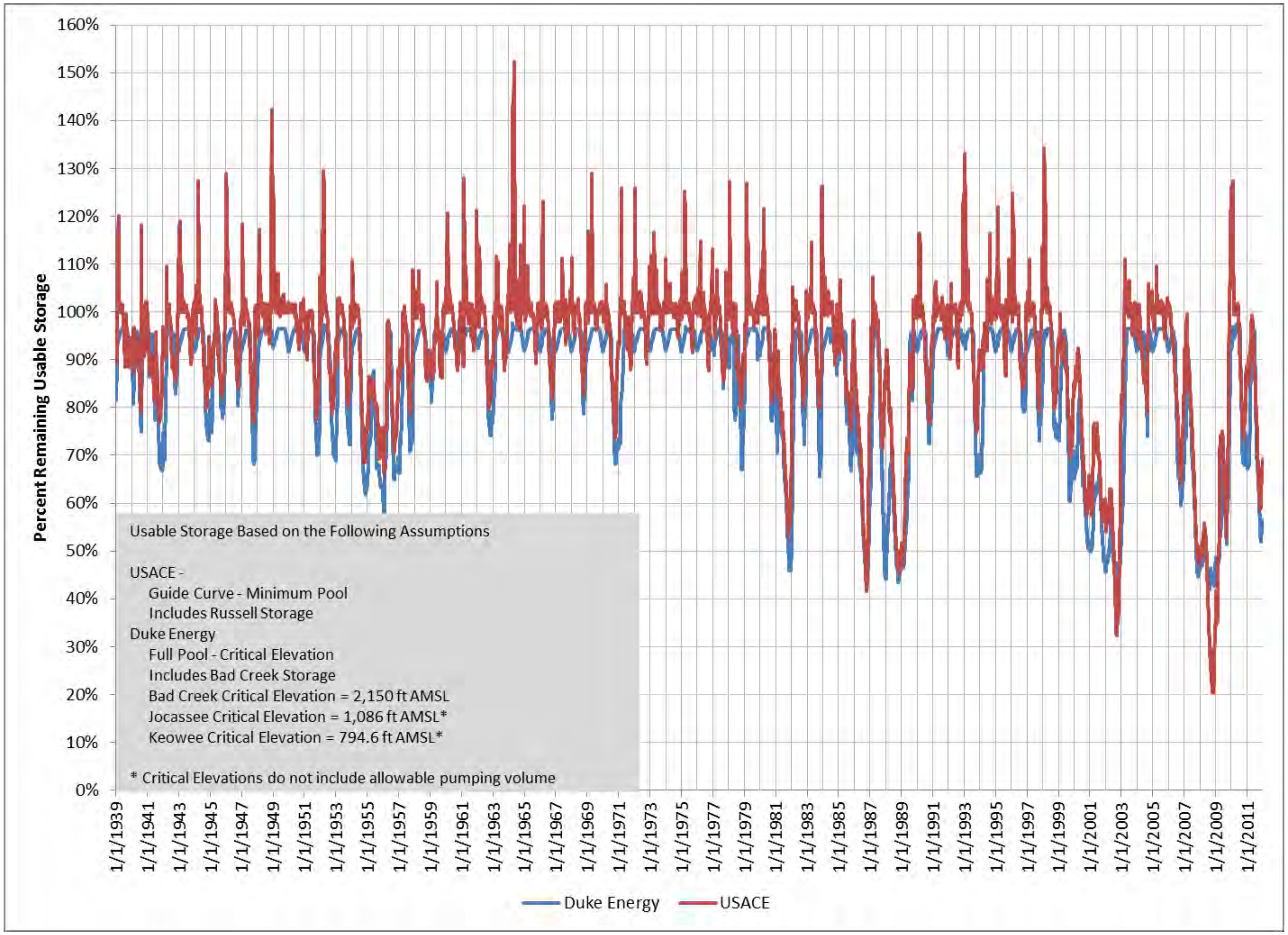


Figure 3.4-3 Duke Energy and USACE Reservoir Storage Percentages – A3

(Future Water Withdrawals with Historic Hydrology (1939–2011))

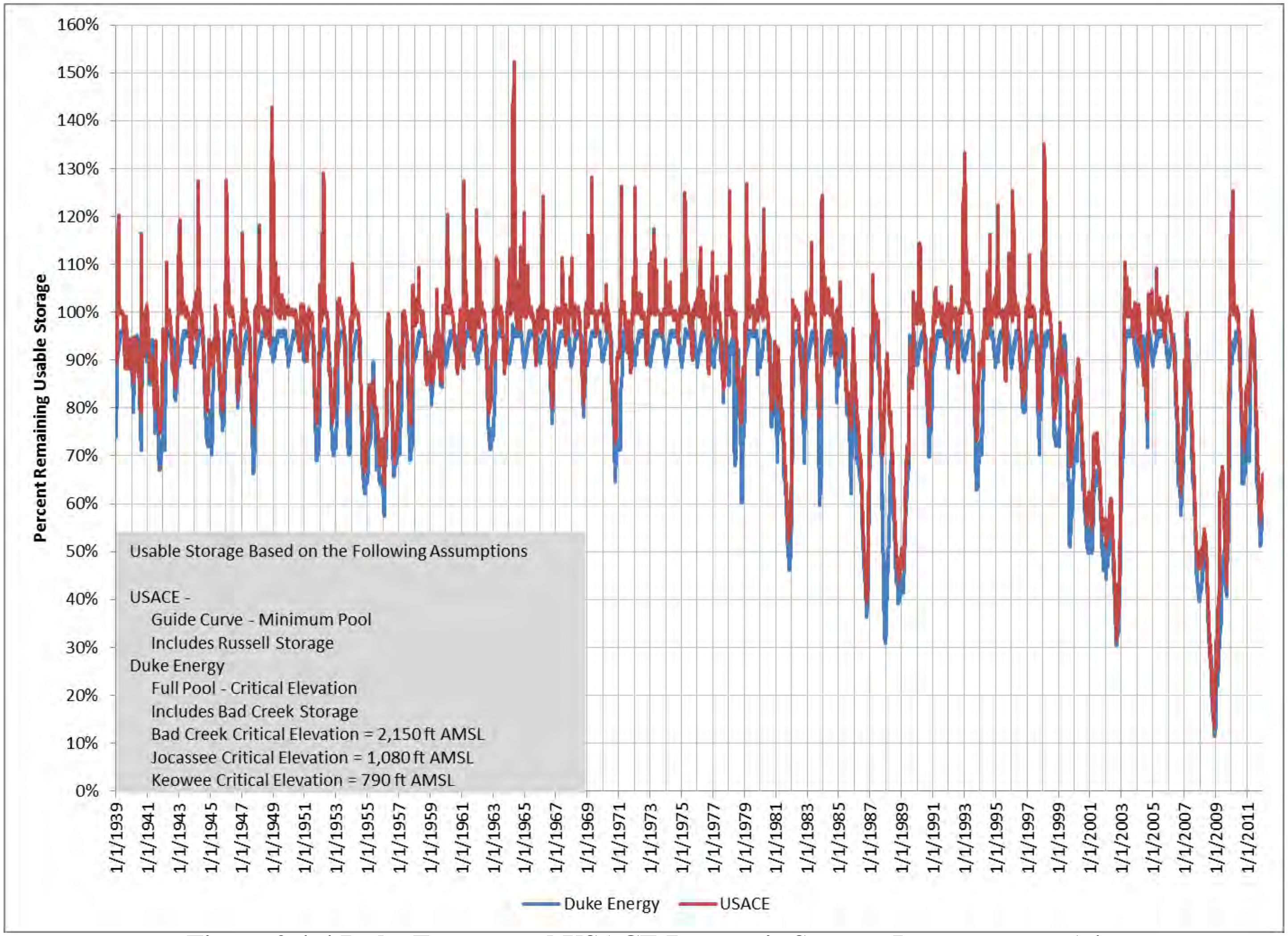
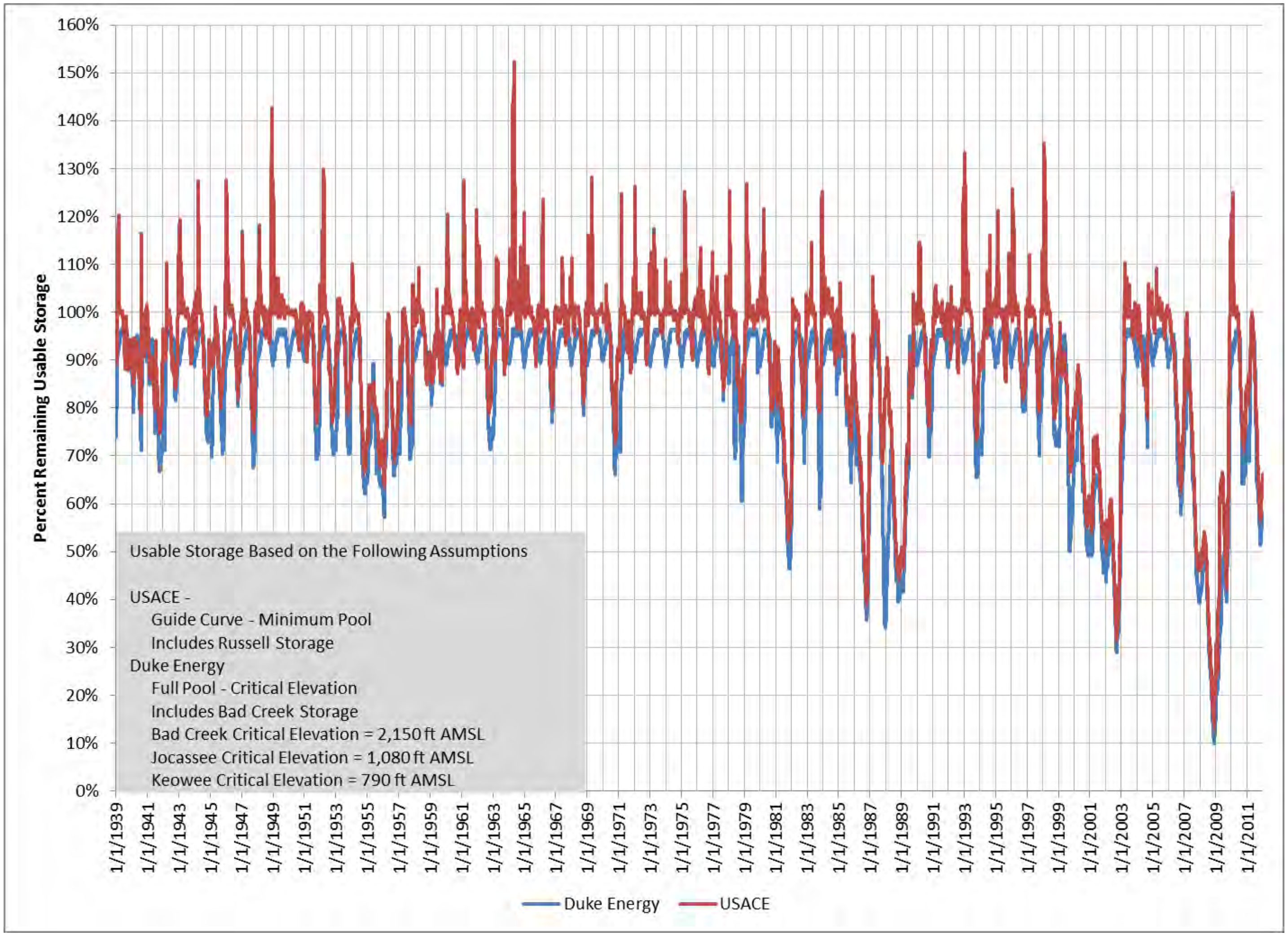


Figure 3.4-4 Duke Energy and USACE Reservoir Storage Percentages – A4

(Future Water Withdrawals with Historic Hydrology (1939–2011))



3.4.2 ***Remaining Usable Storage with Adaptive Management***

Figures 3.4-5 through 3.4-8 compare USACE and Duke Energy system storage over the 73-year POR (future water withdrawals with historic hydrology) for the four operating scenarios. These graphs show results from model runs that assume the USACE implements the 2012 DP adaptive management flow releases at the JST Project (as described in Section 3.3.3). The HEC-ResSim model logic was set to not allow JST Project flow releases less than 3,800 cfs during all Level 2 and 3 days (note a Level 4 was never reached in any model scenario or sensitivity analyses). In reality, the USACE could gradually bump the minimum required flow releases up to 3,800 cfs over time. Therefore, setting the minimum JST flow release at 3,800 cfs is a conservative assumption.

HEC-ResSim allows the input of only one storage relationship between the reservoirs (Appendix J), which influences simulated reservoir responses during the deepest part of the drought of 2007 – 2008. Since the USACE facilities are operated with winter drawdowns, the remaining usable storage percentages referenced or used in the HEC-ResSim model during the fall/winter drawdown (October 16 to March 31) are not reflective of the change in the Guide Curve. In other words, during those seasonal drawdowns, the USACE usable storage volume is smaller than the volume assumed by the model. Therefore, the percentage remaining usable storage calculated by the model during this period is smaller than it would be in practice. During normal hydrology periods this difference in storage balance percentages used in the model simulation is not considered significant, but during extended drought periods like 2007 – 2008 where remaining storage volumes are much smaller, this modeling assumption affects the accuracy of the simulated remaining usable storage percentages since the scenario would otherwise require higher releases for the Duke Energy Reservoirs during the October 16 to March 31 period.

A summary of key points is provided below.

- Since adaptive management flow releases only occur if/when JST releases fall below 3,800 cfs (i.e., during Level 2 and 3 droughts), the only differences in remaining usable storage between the USACE and Duke systems occur during extreme droughts (Figures 3.4-1 through 3.4-4).

- A3 and A4 would produce the lowest remaining usable storage for both the USACE and Duke Energy Reservoirs.
- For A3, Duke Energy's remaining usable storage would have fallen below 12 percent for a 44-day period (i.e., October 26 through December 8, 2008) at the deepest part of the 2007 – 2008 extreme drought. At its lowest point, Duke Energy's remaining usable storage would be 9.8 percent while the USACE's would be 8.7 percent. Since Duke Energy's remaining usable storage is less than 12 percent, no scheduled storage balance weekly release from Keowee Hydroelectric Station would occur. However approximately 650 ac-ft per week would be released from Keowee via seepage and leakage.
- For A3, there are five periods in the historical POR that simulate JST releases below 3,800 cfs. If winter adaptive management flow releases were made during these five periods (as described in Section 3.3.3), the resulting drop in reservoir elevation for Hartwell and JST Lakes would be less than 0.4 feet. This assumes the lake elevation decreases are based on equalizing stage change between these two reservoirs.
- For A4, USACE's lowest remaining usable storage was approximately 7 percent, while the lowest remaining usable storage for the Duke Energy System was approximately 5 percent. Since Duke Energy's remaining usable storage is less than the USACE remaining usable storage, no scheduled storage balance weekly release from Keowee would occur.

3.4.3 *Remaining Usable Storage with Adaptive Management - Sensitivity Analysis*

Appendix K contains figures comparing the remaining usable storage for the USACE and Duke Energy reservoir systems for current water withdrawals with historic hydrology and future water withdrawals with climate change hydrology. This sensitivity analysis also assumes winter adaptive management flow releases are made from the JST Project as described in Section 3.3.3.

Key points from the adaptive management sensitivity analysis are:

- For all alternatives, the USACE and Duke Energy reservoirs experience the lowest remaining usable storage percentages under the future water withdrawals with climate change hydrology model scenarios.
- Using climate change assumptions, A3 and A4 result in the lowest remaining usable storage for both the USACE and Duke Energy Reservoir systems. This occurred near the end of the 2007 – 2008 extreme drought (see Figure 3.4-9).
- For A3, there is a 56-day period (October 16 through December 10, 2008) where Duke Energy's remaining usable storage drops below 12 percent. At its lowest point, Duke Energy's remaining usable storage was 8.1 percent while the USACE's remaining usable storage was 7.5 percent. During this period, no scheduled storage balance weekly release from Keowee Hydroelectric Station would occur. However, roughly 650 ac-ft of water per week would continue to leak and seep from the Keowee Development into Hartwell Lake. The HEC-ResSim model does not account for such leakage and dam seepage. As a result, Duke Energy's remaining usable storage during this period may be somewhat less than 8.1 percent and the USACE's average remaining usable storage may be somewhat greater than 7.5 percent. As discussed above, USACE's remaining usable storage percentages calculated by the model for the period October 16 to March 31 may be lower than what would actually occur.
- For A4, the USACE's lowest remaining usable storage was approximately 6 percent, while that for Duke Energy's was approximately 4 percent. Since USACE's remaining usable storage percentage was greater than Duke Energy's during this extreme drought, a water release from the Duke Energy system would not occur under A4.
- Duke Energy's available storage is able to support the USACE's 2012 DP operations, including winter adaptive management flow releases to the lower Savannah River from the JST Project, even under worst case model sensitivity analysis including climate change assumptions.

Figure 3.4-5 Duke Energy and USACE Reservoir Storage Percentages with Minimum JST Flow Release set at 3,800 cfs – NAA/A1 (Future Water Withdrawals with Historic Hydrology (1939–2011))

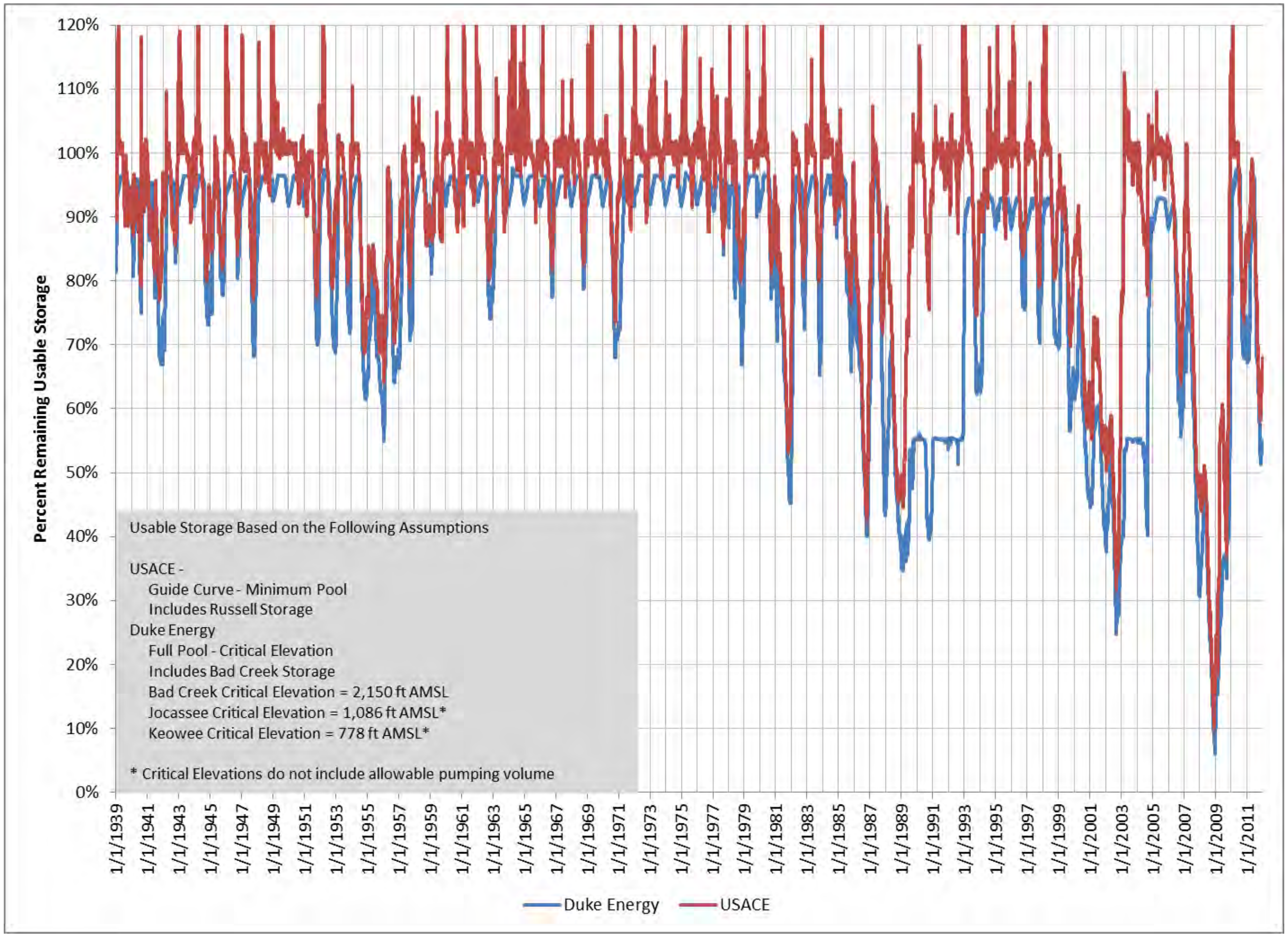


Figure 3.4-6 Duke Energy and USACE Reservoir Storage Percentages with Minimum JST Flow Release set at 3,800 cfs – A2 (Future Water Withdrawals with Historic Hydrology (1939–2011))

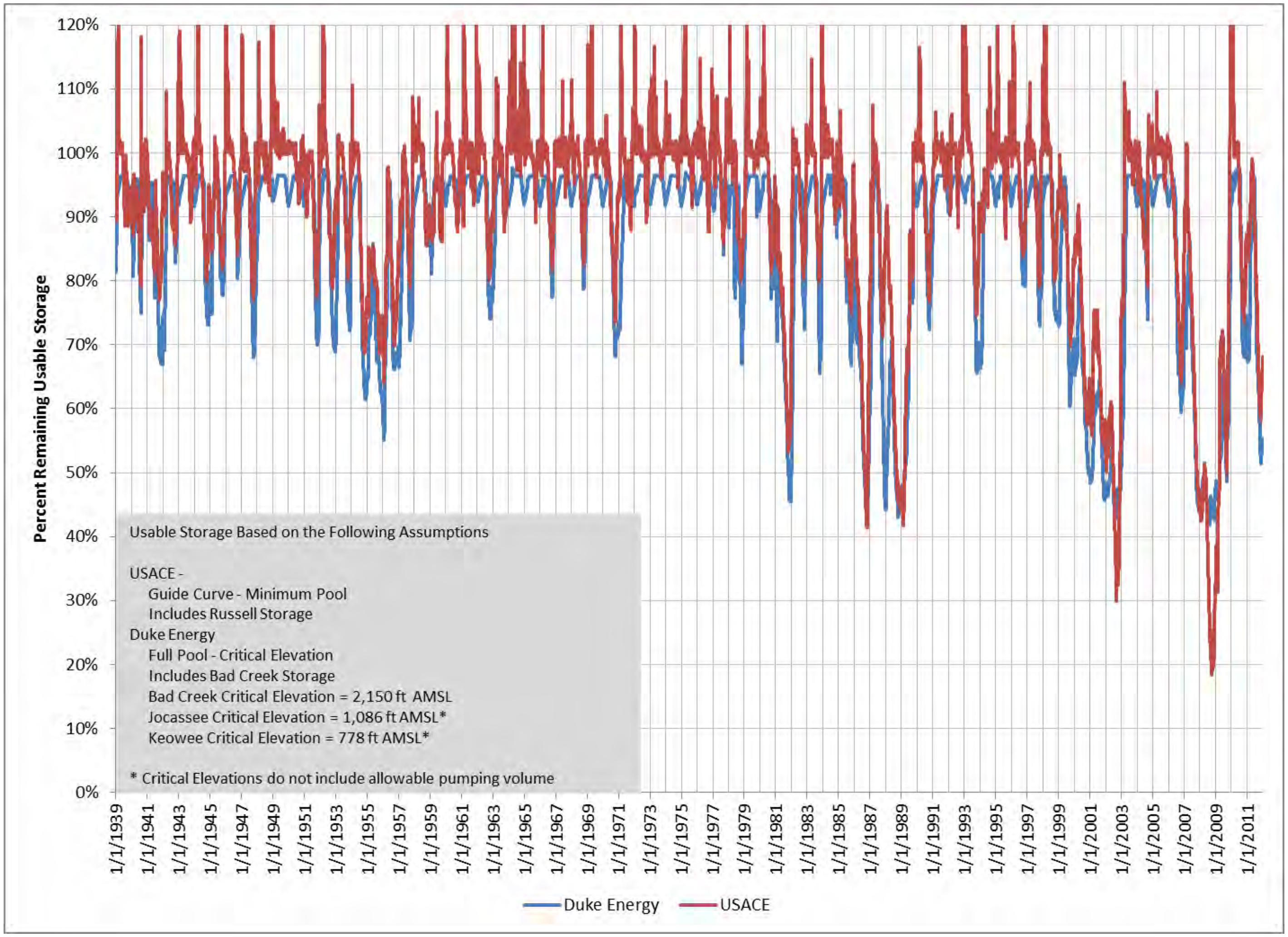


Figure 3.4-7 Duke Energy and USACE Reservoir Storage Percentages with Minimum JST Flow Release set at 3,800 cfs – A3 (Future Water Withdrawals with Historic Hydrology (1939–2011))

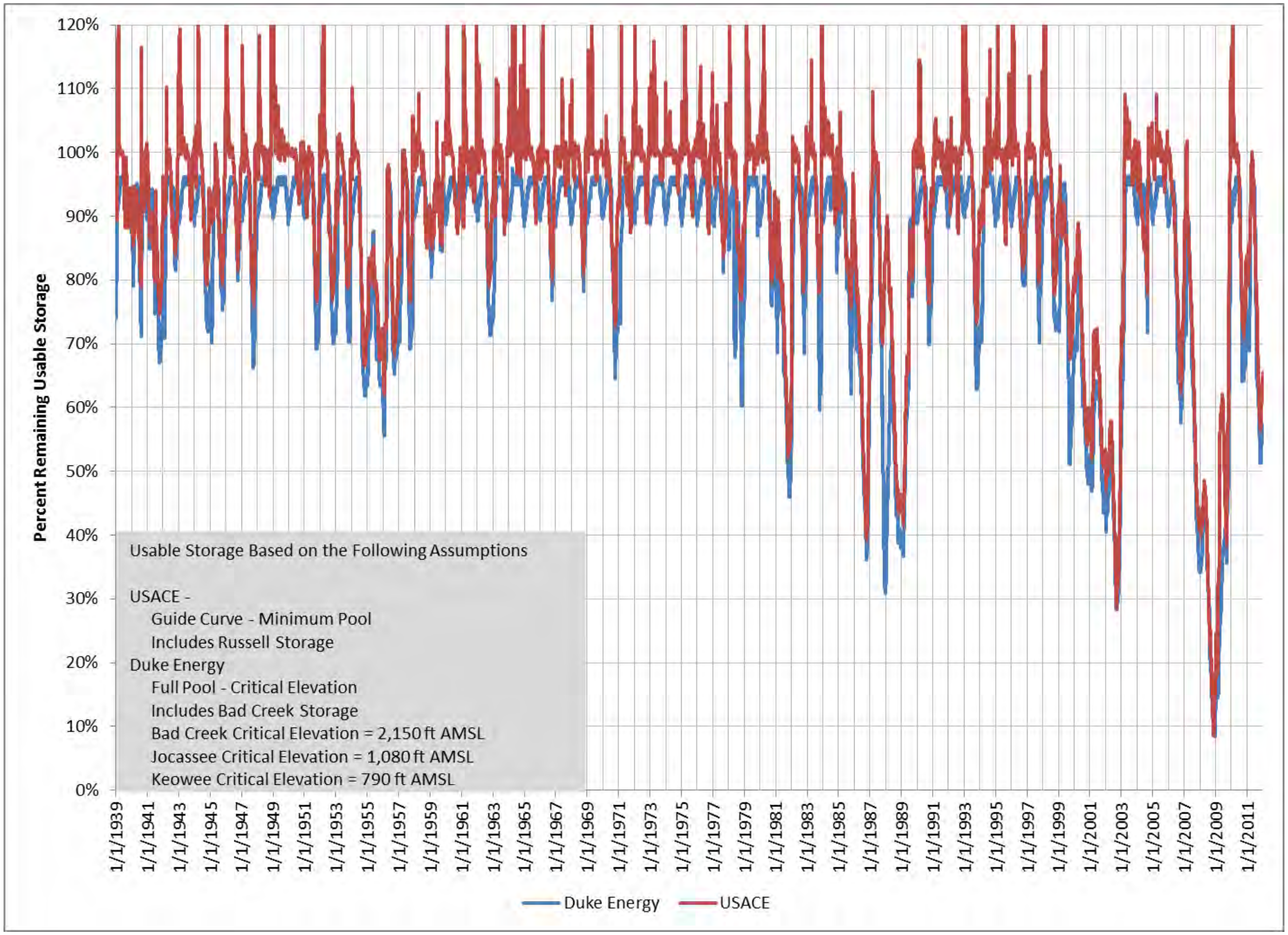


Figure 3.4-8 Duke Energy and USACE Reservoir Storage Percentages with Minimum JST Flow Release set at 3,800 cfs – A4 (Future Water Withdrawals with Historic Hydrology (1939–2011))

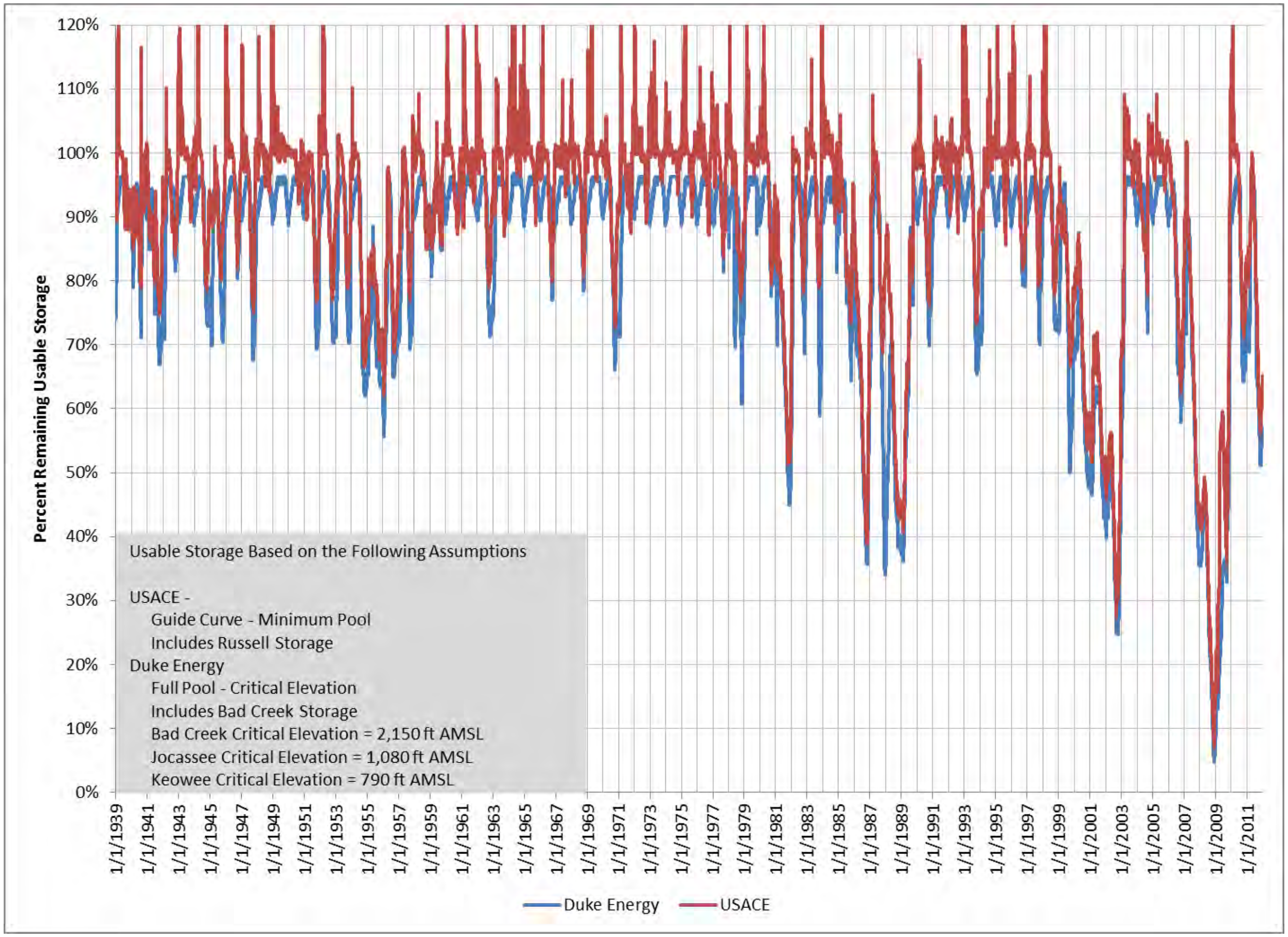
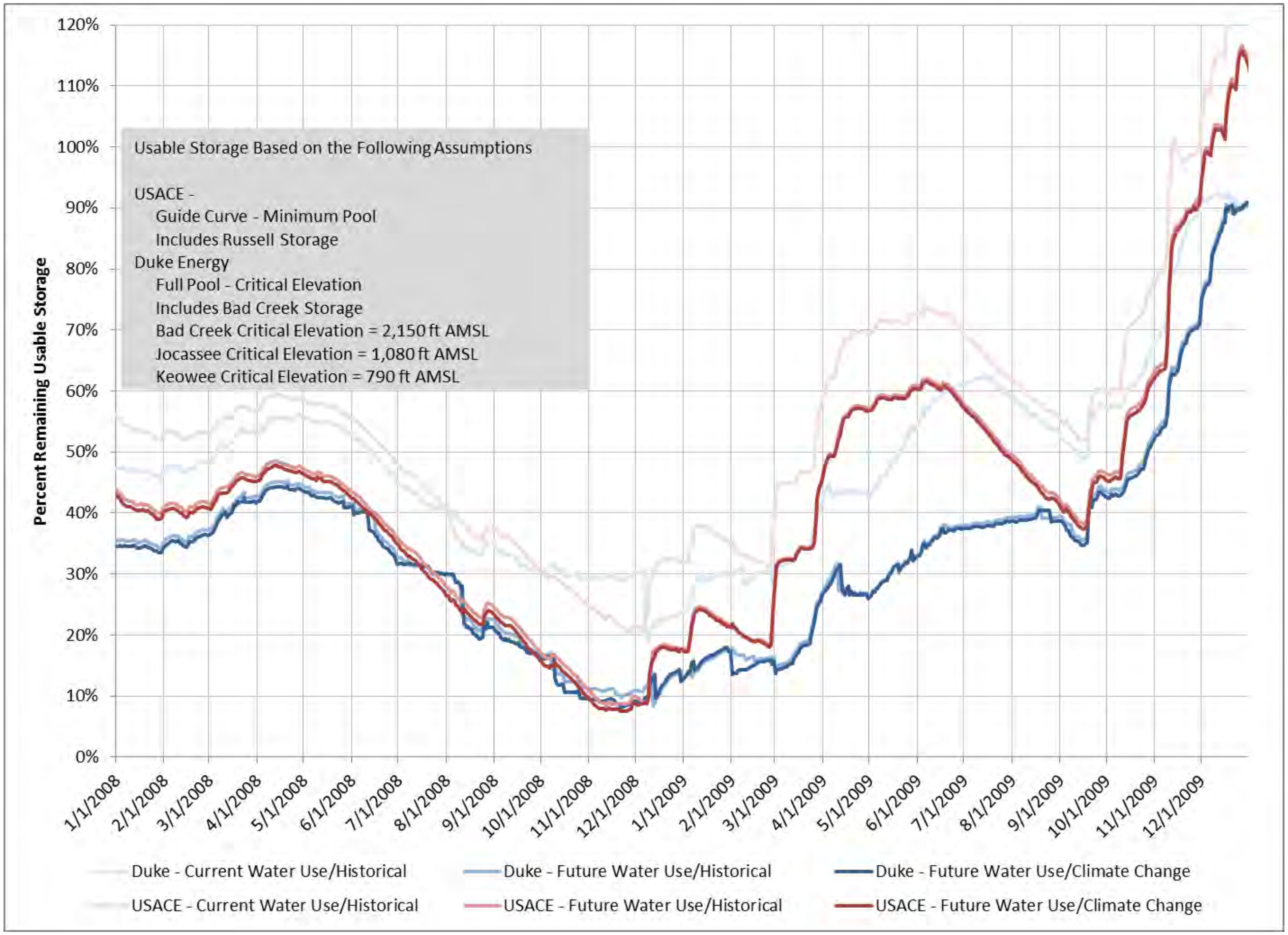


Figure 3.4-9 Duke Energy and USACE Reservoir Storage Percentages with Minimum JST Flow Release set at 3,800 cfs – A3 Summary (2008-2009)



3.5 Duke Energy Reservoir Elevation Results

HEC-ResSim model results for all four model scenarios for Duke Energy's Lakes Jocassee and Keowee are provided below. The results cover the 73-year POR for the future water withdrawal with historic hydrology conditions, as well as the sensitivity analyses described in Section 3.4.

3.5.1 *Future Water Withdrawals with Historic Hydrology*

Model results for Lakes Jocassee and Keowee assuming future water withdrawals with historic hydrology are provided in Figures 3.5-1 through 3.5-4. Figures 3.5-1 and 3.5-2 provide the 73-year POR results, while Figures 3.5-3 and 3.5-4 show a 6-year snapshot to aid in the results discussion.

Water stored in Lake Jocassee is used to help maintain required downstream flow releases to the USACE reservoirs, help maintain Lake Keowee levels at or above the required thresholds mandated by each scenario, and support operations at Bad Creek. As a result, Lake Jocassee experiences relatively large fluctuations in water surface elevation when compared to other reservoirs in the HEC-ResSim model (see Figure 3.5-1). Reservoir elevations in Lake Keowee are similarly affected as Jocassee Pumped Storage Station operations cycle water between Lakes Jocassee and Keowee, but to a lesser extent due to the required thresholds to maintain operations at the ONS (see Figure 3.5-2).

To get a sense of how the four model scenarios affect reservoir elevations in Lakes Jocassee and Keowee, the maximum difference between model scenarios was determined for each day in the 73-year POR. These maximum differences were then averaged over the 73-year POR. For Lake Jocassee the average difference in reservoir elevations between scenarios is 2.17 feet. For Lake Keowee, the average difference is 0.90 feet. This analysis indicates that while differences between model scenarios are relatively small over long periods, they are more pronounced for Lake Jocassee when compared to Lake Keowee.

When reviewing differences between model scenarios for both Lakes Jocassee and Keowee, A3 and A4 generally result in higher reservoir elevations. The additional storage capacity from the

Bad Creek Project along with a smaller usable storage capacity in Lake Keowee is the primary driver in keeping elevations higher in these two reservoirs. Minor differences between A3 and A4 are due to the LIP logic in A3.

For Lake Jocassee, there is little difference in reservoir elevation between the NAA/A1 and A2 model scenarios. In both cases, water stored in Lake Jocassee is used to maintain downstream flow releases below Lake Keowee (NAA/A1) and/or preserve Lake Keowee elevations to support ONS operations (A2). For NAA/A1, HEC-ResSim modeling for Lake Jocassee shows reservoir elevations near the minimum of 1,080 ft AMSL between August 2002 and August 2004 (see Figure 3.5-1). At the same time, Lake Keowee and all three USACE reservoirs are near full pool. This approximately two-year period of reservoir imbalance is an artifact of HEC-ResSim zone-boundary issues. In reality, Duke Energy would likely have more closely balanced usable storage in these two reservoirs. A3 and A4 produce different results from NAA/A1 and A2 because they assume a smaller usable volume for Lake Keowee and include storage from the Bad Creek Project. This assumption helps maintain Lake Keowee levels and thus, reduces the amount of water needed from Lake Jocassee. These incremental differences between scenarios for Lake Jocassee are shown in Figure 3.5-3.

While the 1968 Agreement uses elevation 1,086 feet AMSL as the lower reservoir limit for Lake Jocassee in the water storage balance calculations, the physical intake structure at Lake Jocassee allows reservoir operations down to 1,080 feet AMSL. The four alternatives result in reservoir drawdowns near this lower operational limit to help maintain water surface elevations as long as possible in Lake Keowee.

For Lake Keowee, there are minor differences between NAA/A1 and A2 as shown in Figure 3.5-4. NAA/A1 assumes Lake Keowee can be drawn down to elevation 778 feet AMSL and the modeling indicates that a maximum reservoir drawdown of 782 feet AMSL would be reached toward the end of the 2007–2008 drought period. A2 does not allow a non-emergency or non-ONS-related intentional flow release from Lake Keowee if that release would cause the reservoir elevation to drop below 794.6 feet AMSL. This assumption creates a 1-foot band of daily fluctuations in water surface elevations in Lake Keowee between 794 and 795 feet AMSL

(Figure 3.5-4). On those same days, a 2-foot band of daily fluctuating water surface elevations can be seen in the Lake Jocassee model results (Figure 3.5-3). These fluctuations are largely the result of HEC-ResSim model logic associated with pumped-storage operations at Jocassee Pumped Storage Station. When Lake Keowee is at or near 794.6 feet AMSL, model flow releases via the Keowee Hydro Station cease. However, daily operations continue at the Jocassee Pumped Storage Station. Daily generation and pump-back cycles modeled at the Jocassee Pumped Storage Station create these periods of fluctuating water surface elevations.

Figure 3.5-4 also indicates that while A3 and A4 generally result in higher reservoir elevations in Lake Keowee, a few exceptions would occur during extreme droughts. For example, toward the end of the 2007–2008 drought, A2 had higher reservoir elevations than A3 and A4. While A2 assumes the usable volume in Lake Keowee extends down to elevation 778 feet AMSL, a flow release is not made if it would cause the reservoir elevation to drop below 794.6 feet AMSL. This assumption results in higher Keowee reservoir elevations under A2 (compared to A3 and A4) for relatively short periods during extreme droughts. A3 and A4 result in similar reservoir elevations for both Lake Jocassee and Lake Keowee during extreme droughts.

None of the four reservoir operating scenarios result in Lake Jocassee elevations below its maximum drawdown of 1080 feet AMSL. For Lake Keowee, the NAA/A1 results in eight periods during the 73-year POR where the ONS would have been shut down due to Lake Keowee reservoir elevations below 793 feet AMSL (see Figure 3.5-2). The longest shutdown period was from June 20, 2008 to June 2, 2009, a span of 348 days. A2 results in relatively short periods below the current ONS operating threshold elevation of 794.6 feet AMSL, but would not result in an ONS shutdown. A3 and A4 do not result in Lake Keowee elevations below 790 feet AMSL.

Figure 3.5-1 Lake Jocassee Modeled Reservoir Elevations(Future Water Withdrawals with Historic Hydrology [1939–2011])

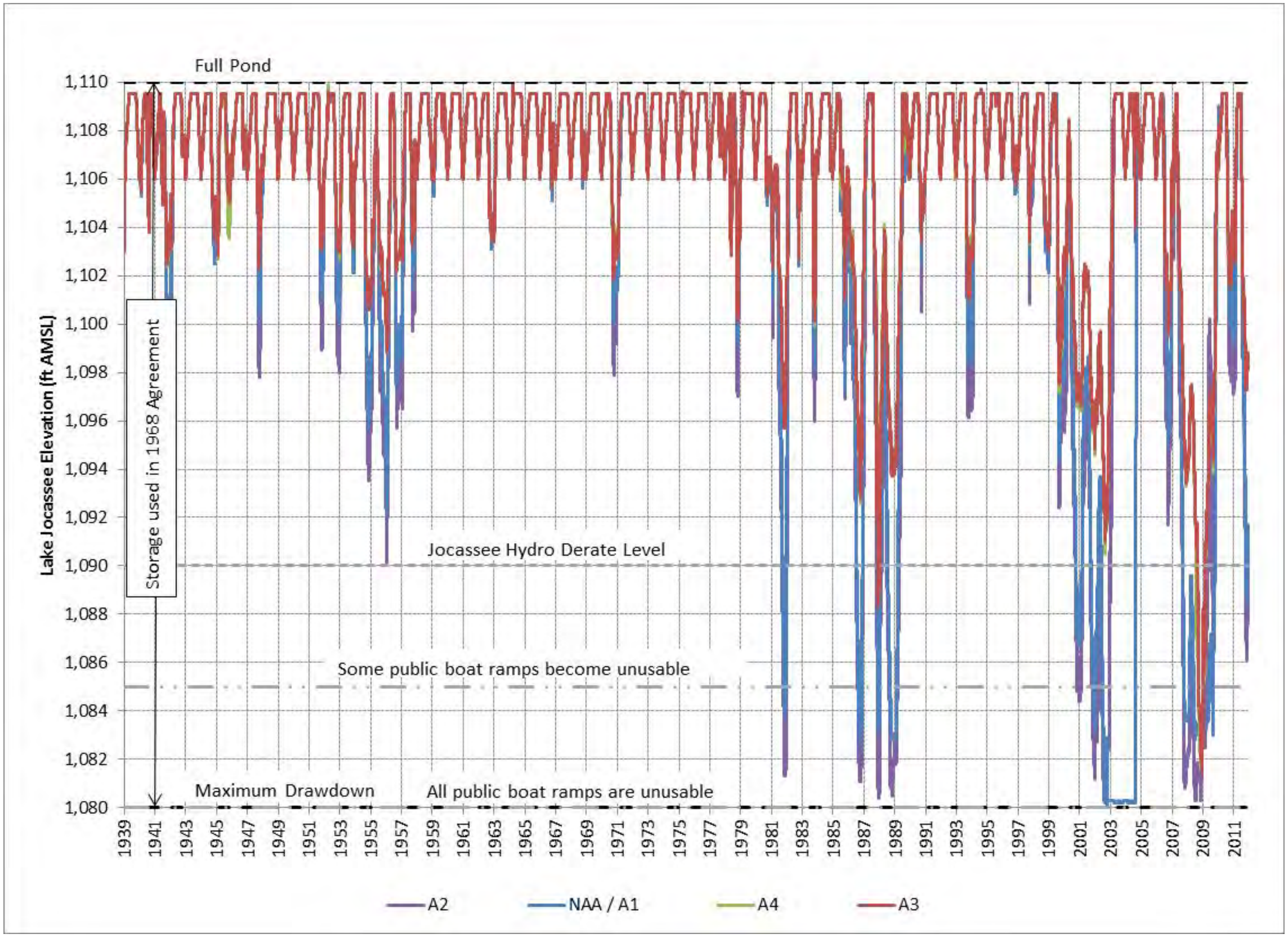


Figure 3.5-2 Lake Keowee Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [1939–2011])

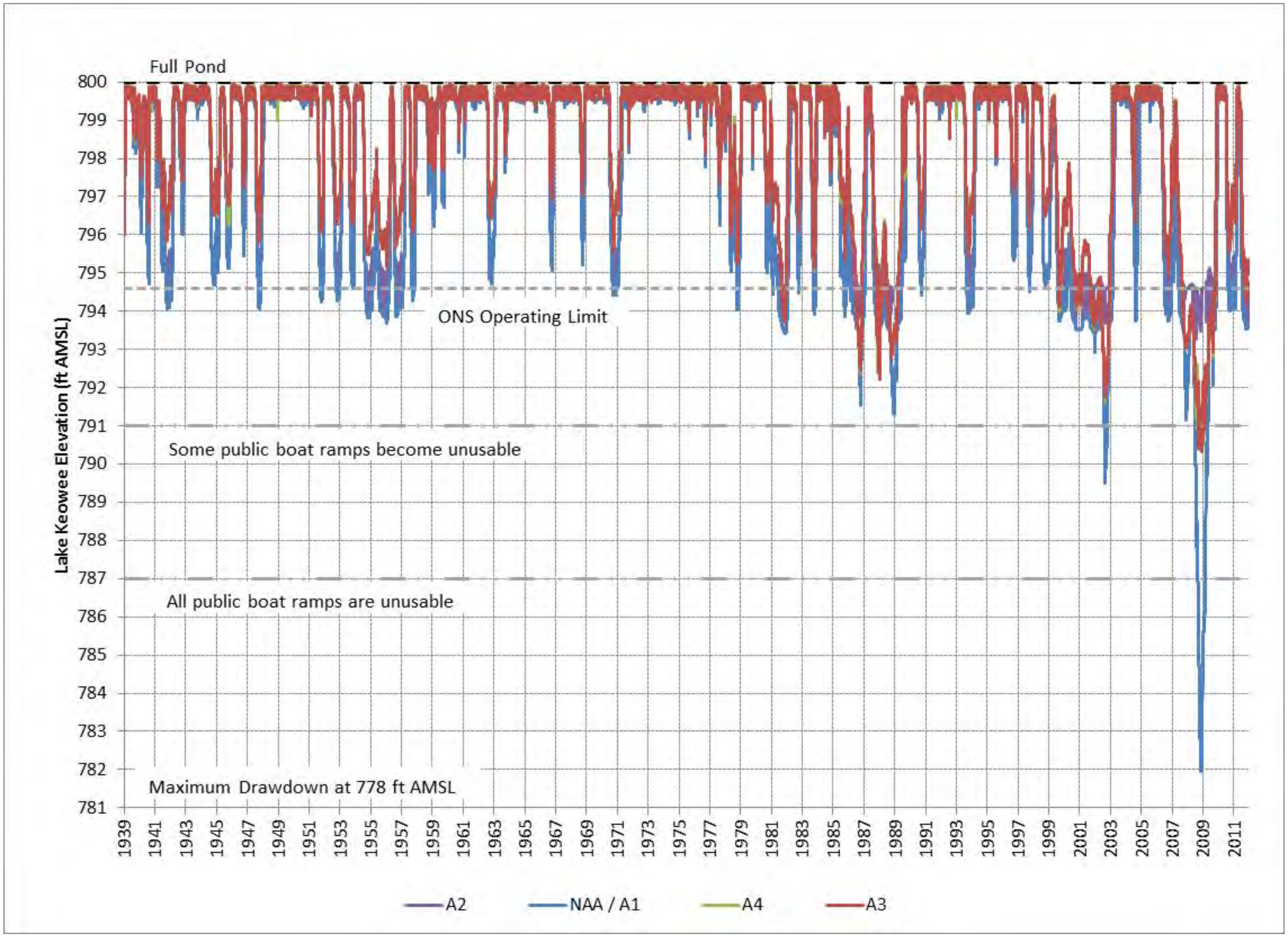


Figure 3.5-3 Lake Jocassee Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [2006–2011])

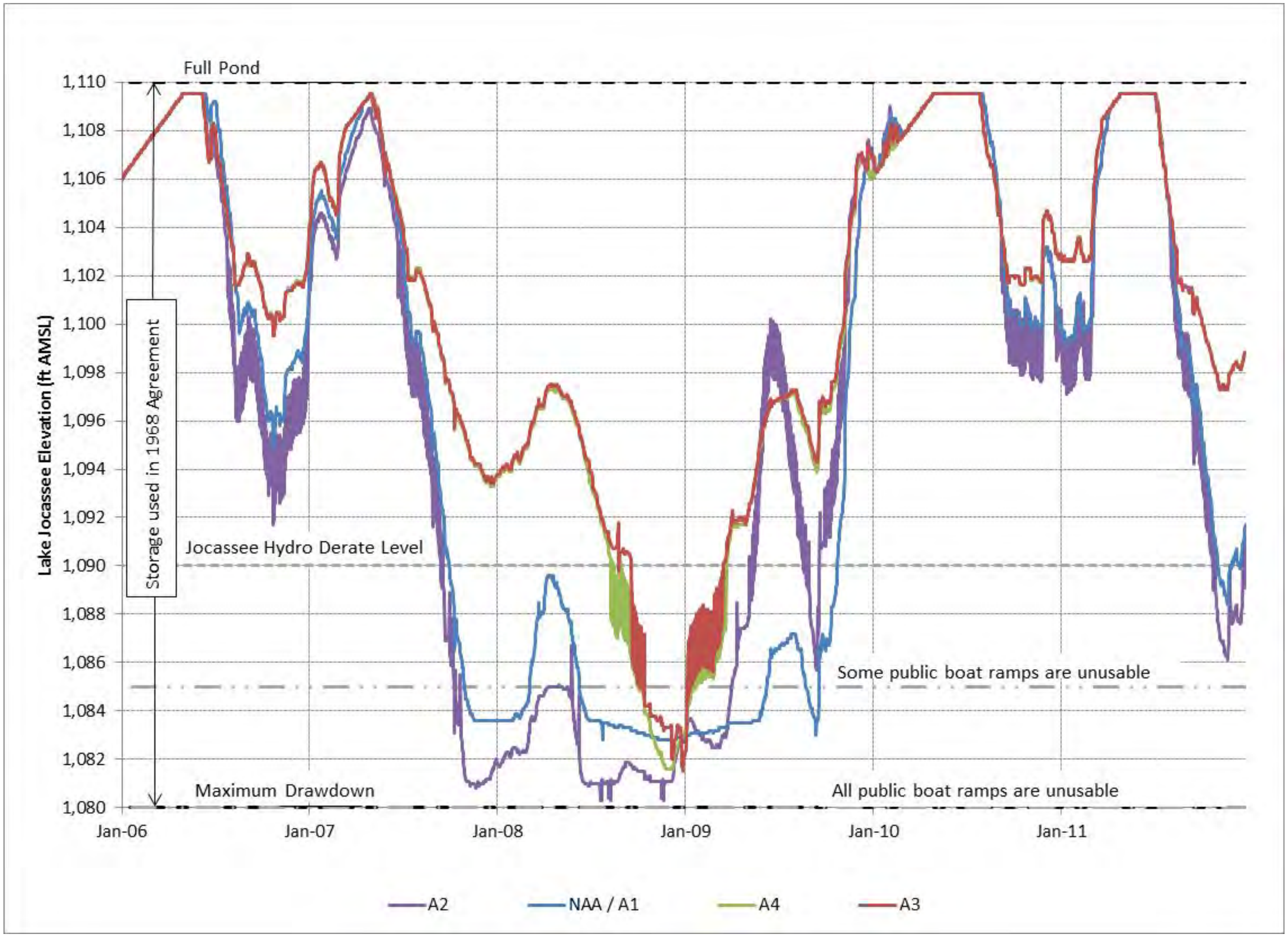
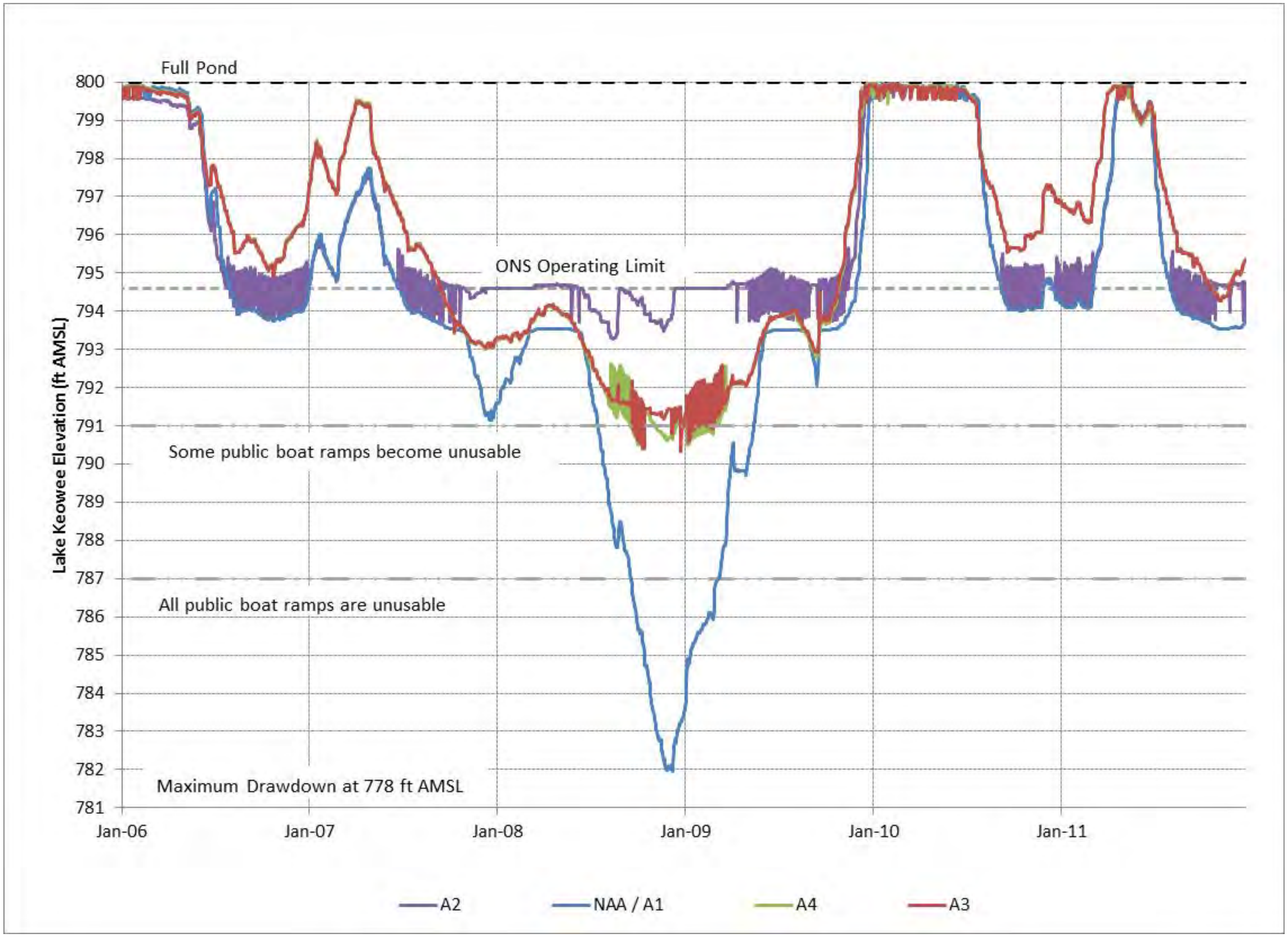


Figure 3.5-4 Lake Keowee Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [2006–2011])



3.5.2 *Hydrology and Water Withdrawal Sensitivity Analyses*

The results of the sensitivity analyses for Lakes Jocassee and Keowee are described below. Appendix M contains figures showing reservoir elevations over the 73-year POR for this sensitivity analysis.

3.5.2.1 *Current Water Withdrawals with Historic Hydrology*

Changing the water withdrawal assumption in the HEC-ResSim model from future levels to current levels does not alter the overall trends in the four operating scenarios over the 73-year POR, but the differences between scenarios are slightly smaller. This makes sense intuitively as less water is removed from the system for consumptive uses. For Lake Jocassee, the average difference between scenarios drops from 2.17 to 1.15 feet. As expected, this difference is larger during droughts. For example, during the 2007-2008 drought, the lowest reservoir elevation for A4 is 3 feet higher than it is under the future water withdrawal assumption. Similarly, for Lake Keowee, the average difference between scenarios drops from 0.90 to 0.73 feet.

3.5.2.2 *Future Water Withdrawals with Climate Change Hydrology*

Similarly, modifying the hydrology to simulate the potential effects of climate change conditions over the entire Savannah River Basin also does not alter the overall trends in the four operating scenarios over the 73-year POR, however, the differences between scenarios are slightly greater. Differences are not related to operations at the Keowee-Toxaway Project (i.e., they are related to climate change hydrologic conditions). This makes sense as accretion flows throughout the basin are reduced. For Lake Jocassee, the average difference between scenarios increases slightly from 2.17 to 2.23 feet. For Lake Keowee, the average difference between scenarios increases slightly from 0.90 to 0.95 feet.

3.6 USACE Reservoir Elevation Results

HEC-ResSim model results for all four model scenarios for USACE's Hartwell, RBR, and JST Reservoirs are provided below. The results cover the 73-year POR for the future water withdrawal and historic hydrology model assumptions as well as the sensitivity analyses described in Section 3.4.

3.6.1 *Future Water Withdrawals with Historic Hydrology*

Figures 3.6-1 through 3.6-6 show the model results for the Hartwell, RBR, and JST Reservoirs assuming future water withdrawals with historic hydrology. Figures 3.6-1 through 3.6-3 provide the 73-year POR results. Unlike Lakes Jocassee and Keowee, results for all four scenarios for the USACE reservoirs are almost identical over the entire modeled period. For example, over the 73-year POR, the average difference in reservoir elevation between scenarios for Hartwell Lake is 0.37 feet. For RBR, the average difference between scenarios is 0.35 feet and for JST the average difference is 0.30 feet. These differences are much smaller than those determined for Lakes Jocassee and Keowee (2.17 and 0.90 feet, respectively).

Figures 3.6-4 through 3.6-6 provide a 6-year snapshot for each of the USACE's reservoirs illustrating differences in pool elevations that are relatively infrequent and small in magnitude. During less severe droughts, such as occurred at the end of 2006, A3 and A4 result in slightly lower reservoir elevations for Hartwell and JST Lakes (by approximately 0.7 and 0.5 feet, respectively) compared to NAA/A1.

Overall, the four operating scenarios produce very similar results for the USACE's reservoirs. Differences are relatively small, occur infrequently, and are temporary.

Figure 3.6-1 Hartwell Lake Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [1939–2011])

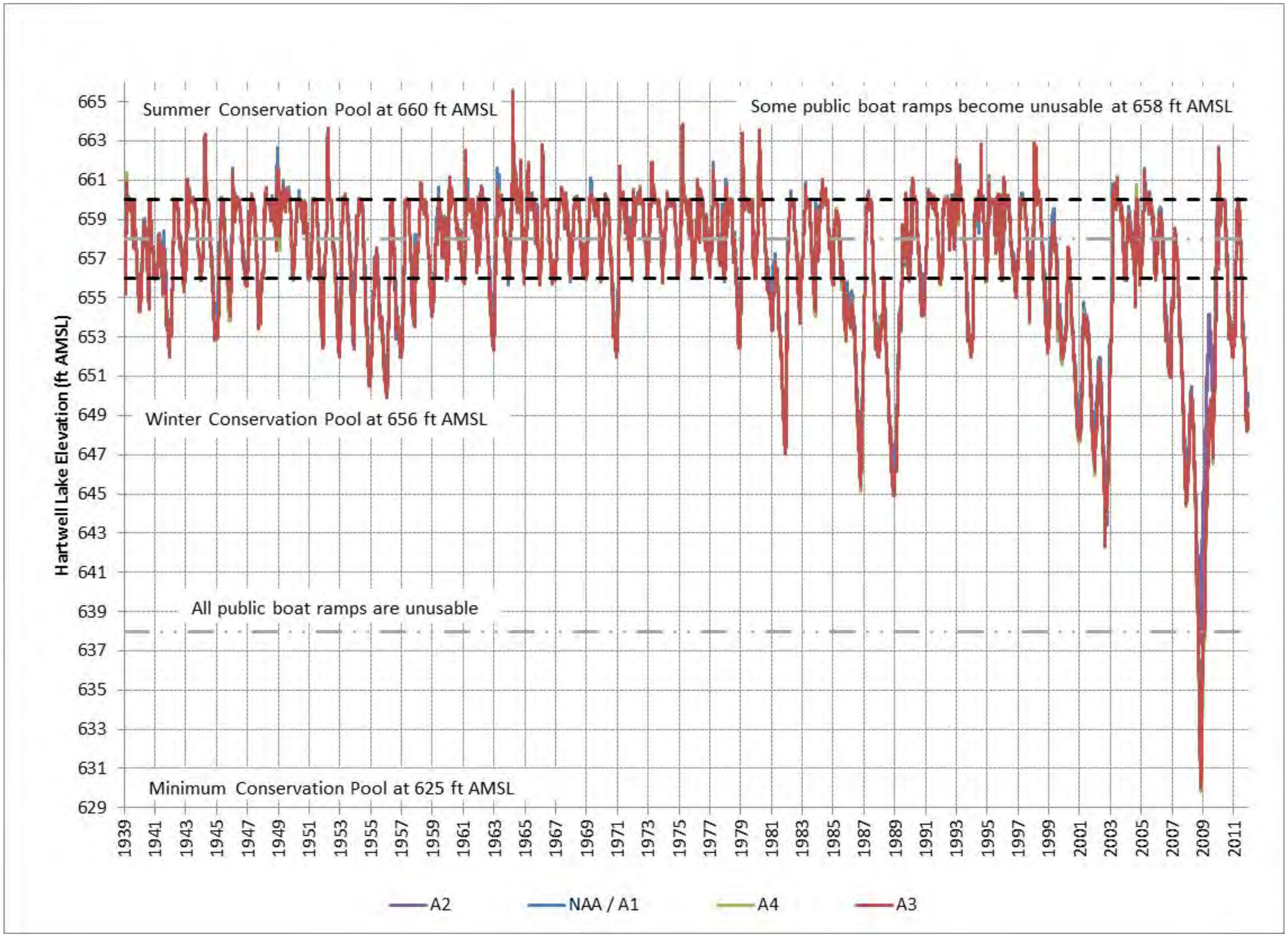


Figure 3.6-2 RBR Lake Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [1939–2011])

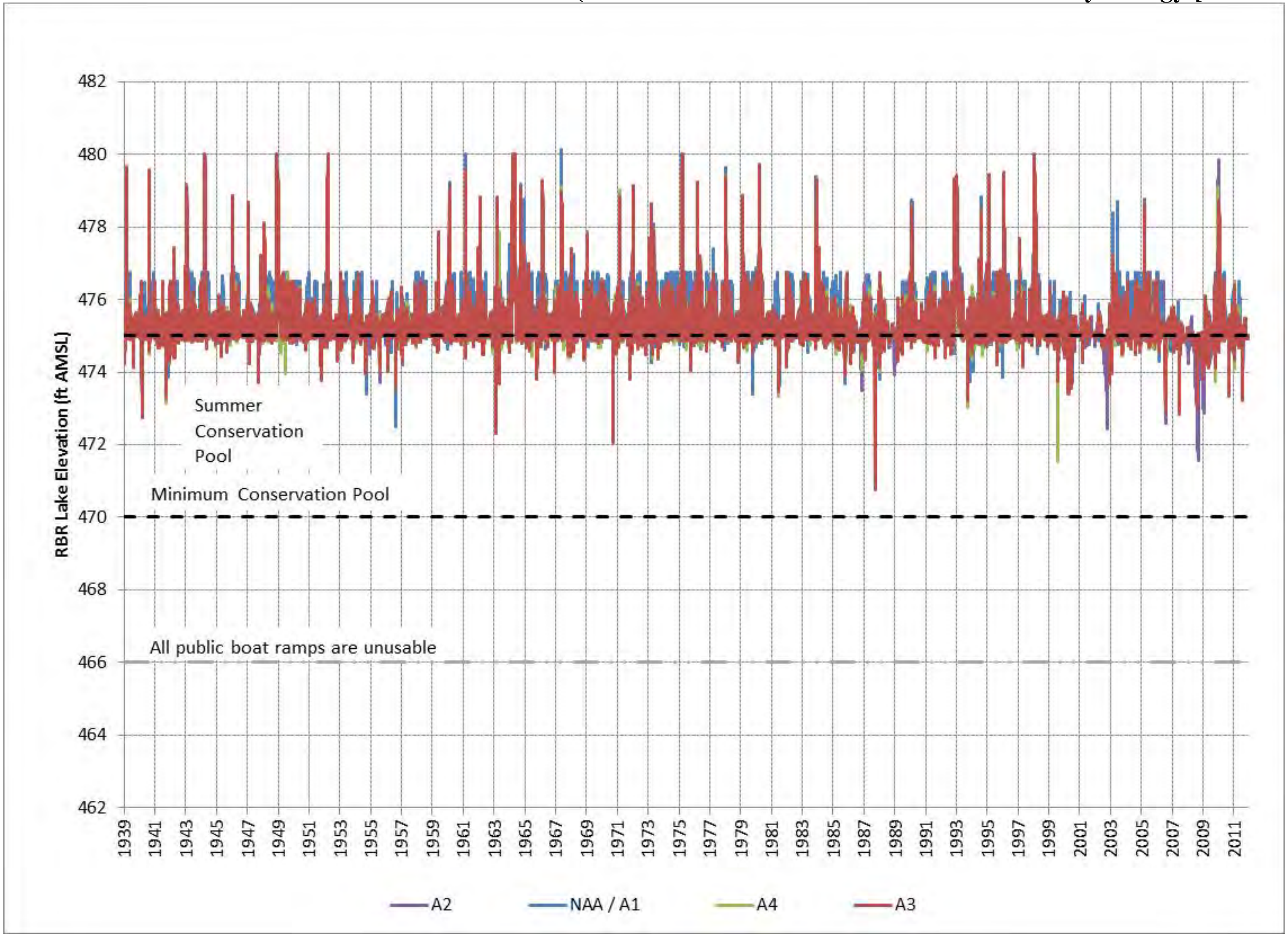


Figure 3.6-3 JST Lake Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [1939–2011])

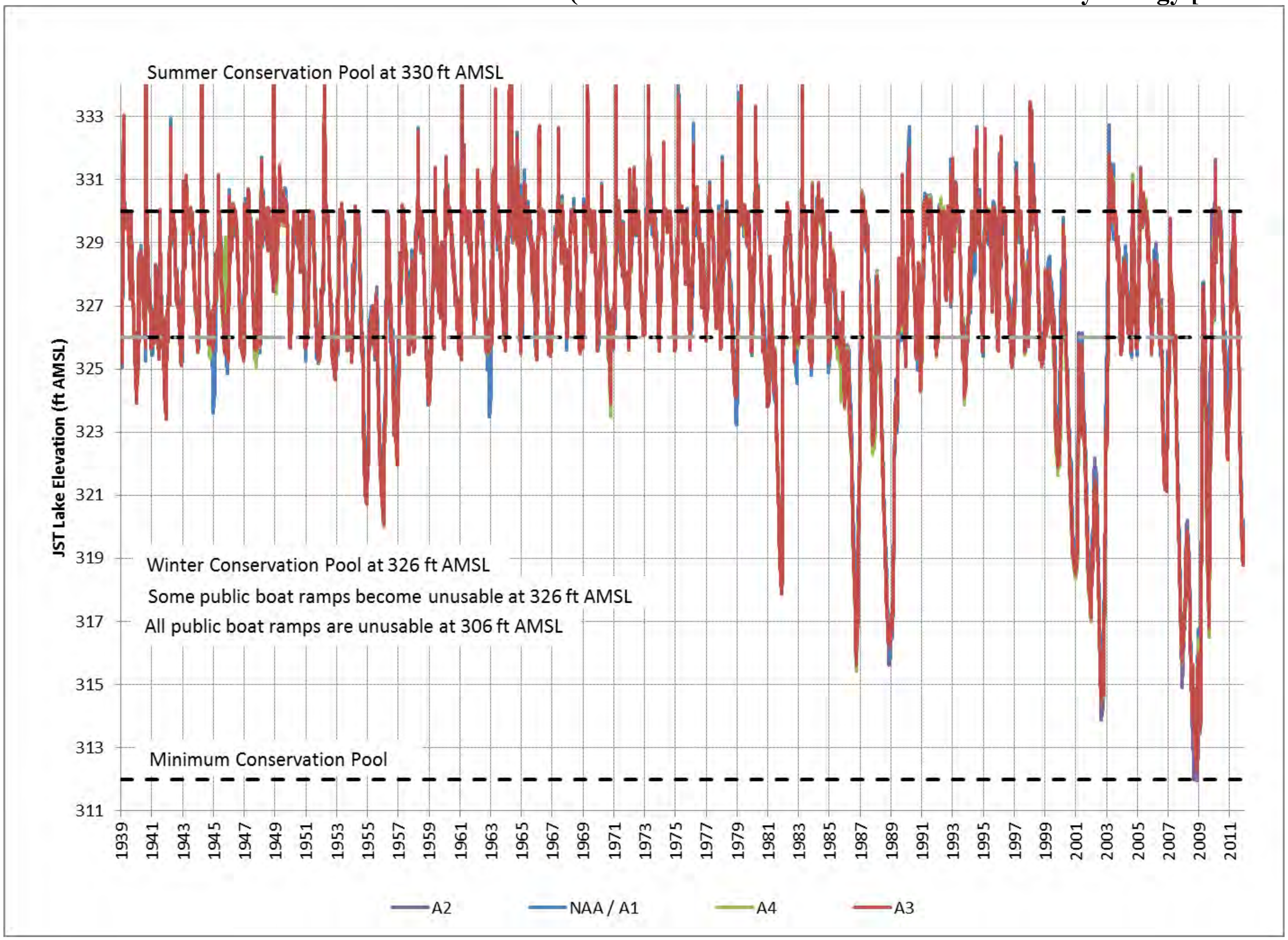


Figure 3.6-4 Hartwell Lake Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [2006–2011])

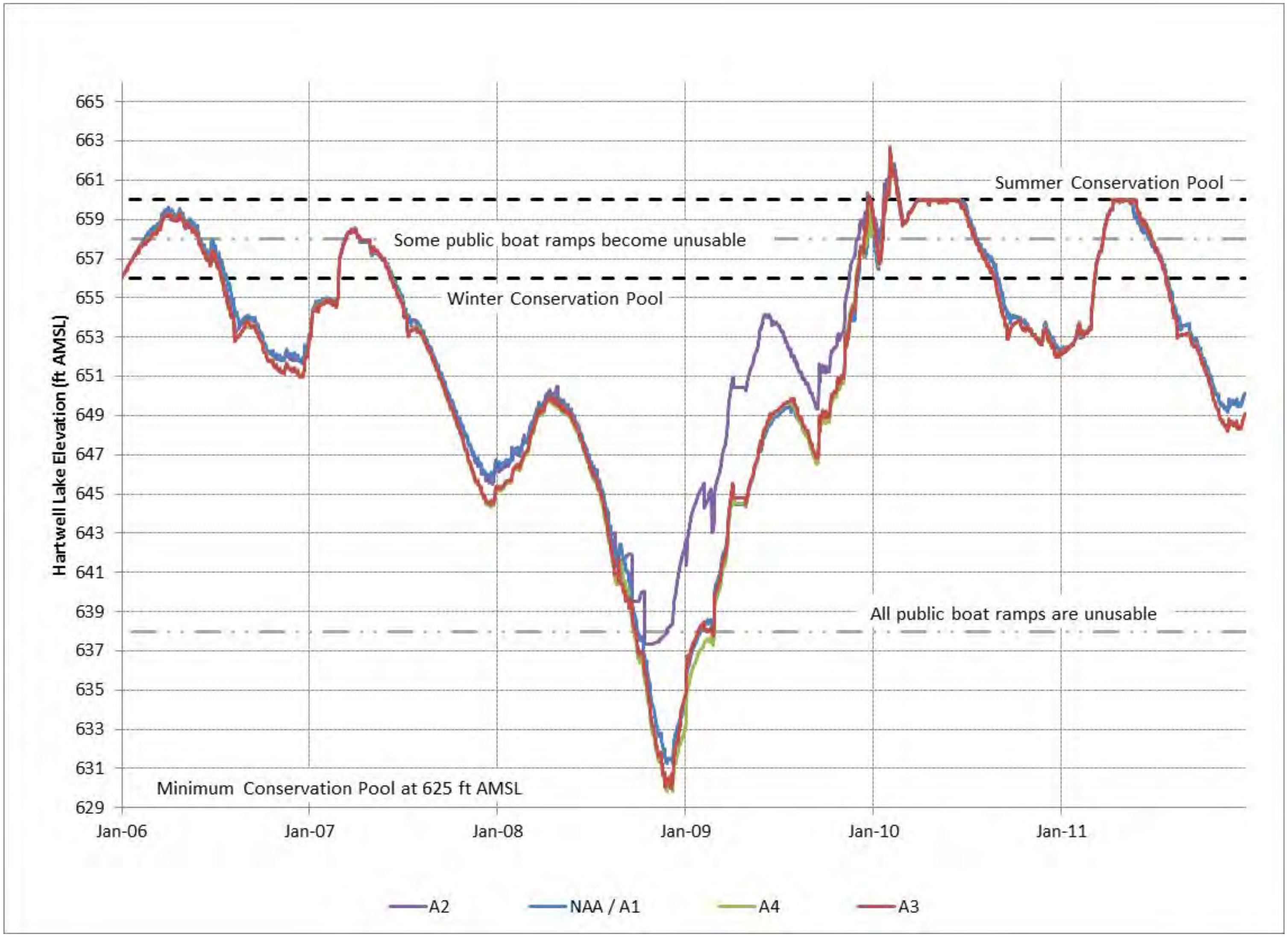
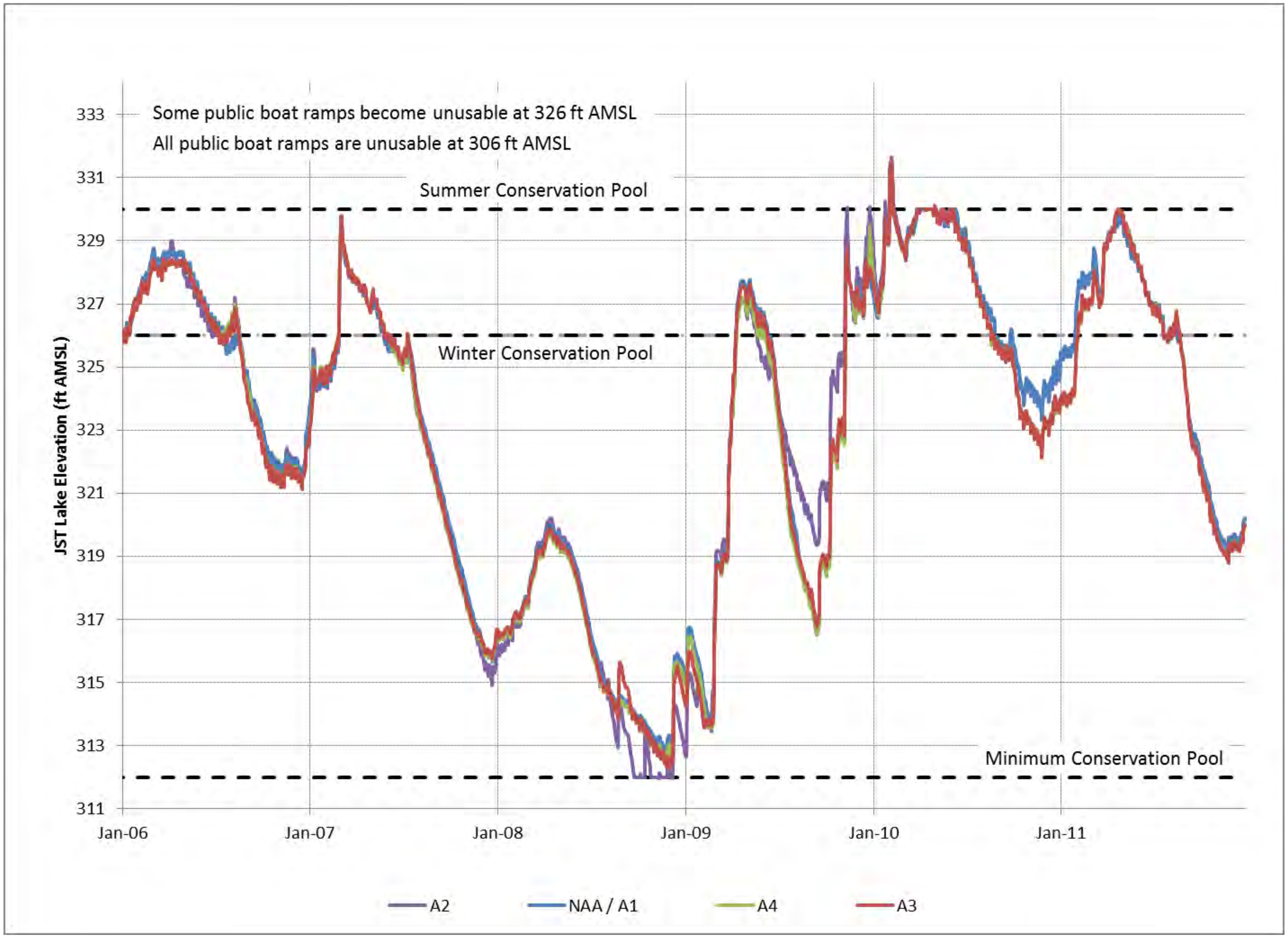


Figure 3.6-5 RBR Lake Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [2006–2011])

Figure 3.6-6 JST Lake Modeled Reservoir Elevations (Future Water Withdrawals with Historic Hydrology [2006–2011])



3.6.2 ***Hydrology and Water Withdrawal Sensitivity Analyses***

The results of the sensitivity analyses for reservoir levels are described below and summarized in Table 3.7-3. Appendix M contains figures showing reservoir elevations over the 73-year POR for the sensitivity analyses.

3.6.2.1 *Current Water Withdrawals with Historic Hydrology*

Similar to the Duke Energy reservoirs, limiting net water withdrawals to current levels resulted in smaller differences between the four scenarios for the USACE reservoirs. For Hartwell, the average difference between scenarios dropped from 0.37 to 0.22 feet. For RBR, the average difference between scenarios dropped from 0.35 to 0.34 feet, and for JST the difference dropped from 0.30 to 0.22 feet.

3.6.2.2 *Future Water Withdrawals with Climate Change Hydrology*

Similar to the effects observed in modeling of the Duke Energy reservoirs, reducing inflows to simulate basin-wide potential climate changes did not alter the overall reservoir elevation trends for the USACE reservoirs. However, the differences between scenarios are generally slightly larger when potential climate changes are included. For Hartwell, the average difference between scenarios increased from 0.37 to 0.40 feet. For RBR, the average difference increased from 0.35 to 0.36 feet, and for JST, there was no change in the average difference between scenarios (0.30 feet).

3.7 JST Lake Flow Release Results

3.7.1 ***Future Water Withdrawals with Historic Hydrology***

Reservoir elevations at Hartwell and JST Reservoirs have a direct influence on flow releases to the Savannah River downstream of JST. As described in Section 3.5, all four alternatives result in similar reservoir elevations over the 73-year POR for the USACE reservoirs. As a result, flow releases to the Savannah River downstream of JST are also similar between the four modeled scenarios.

To evaluate potential flow-related environmental impacts downstream from the JST Project, an analysis of average flows on a yearly basis was conducted. Only those years that triggered the

USACE's 2012 DP were used in the analysis because the Operating Agreement goes into effect when the system is experiencing a drought. The higher flow months of January through March were excluded from the analysis to better focus the analysis on lower flow release periods.

Based on HEC-ResSim model results, 51 of the 73 years in the POR trigger the USACE 2012 DP. Average JST flow releases (April through December) for each of those 51 years is provided in Table 3.7-1 for each alternative. The average flows from April through December for A2, A3, and A4 were compared to the NAA/A1 model scenario for each drought year. These differences are expressed as a percentage compared to the NAA/A1 on the right half of Table 3.7-1. A positive percentage indicates a given alternative's average flow is higher than the NAA/A1 average flow while a negative percentage indicates a given alternative's average flow is less than the NAA/A1 average flow.

Table 3.7-1 Annual Average JST Flow Releases April – December for Drought Years (Future Water Withdrawals with Historic Hydrology)

Year	Average Flow (cfs)				Percent Difference Compared to NAA/A1		
	NAA/A1	A2	A3	A4	A2	A3	A4
1940	6,976	6,976	6,920	6,914	0.0%	-0.8%	-0.9%
1941	5,626	5,625	5,539	5,538	0.0%	-1.6%	-1.6%
1942	5,991	5,992	6,029	6,022	0.0%	0.6%	0.5%
1944	7,894	7,894	7,746	7,755	0.0%	-1.9%	-1.8%
1945	6,240	6,240	6,244	6,223	0.0%	0.1%	-0.3%
1946	7,130	7,130	7,151	7,134	0.0%	0.3%	0.1%
1947	7,566	7,565	7,503	7,499	0.0%	-0.8%	-0.9%
1951	5,971	5,971	5,933	5,931	0.0%	-0.6%	-0.7%
1952	6,856	6,856	6,824	6,848	0.0%	-0.5%	-0.1%
1953	6,375	6,375	6,404	6,398	0.0%	0.5%	0.4%
1954	5,057	5,057	5,074	5,065	0.0%	0.3%	0.2%
1955	4,135	4,136	4,112	4,118	0.0%	-0.6%	-0.4%
1956	4,422	4,422	4,448	4,419	0.0%	0.6%	-0.1%
1957	6,525	6,522	6,764	6,719	0.0%	3.5%	2.9%
1958	6,340	6,340	6,388	6,387	0.0%	0.8%	0.7%
1959	6,781	6,781	6,764	6,765	0.0%	-0.2%	-0.2%
1962	6,701	6,701	6,531	6,527	0.0%	-2.6%	-2.7%
1963	7,630	7,630	7,632	7,631	0.0%	0.0%	0.0%
1966	6,220	6,220	6,248	6,220	0.0%	0.4%	0.0%

Year	Average Flow (cfs)				Percent Difference Compared to NAA/A1		
	NAA/A1	A2	A3	A4	A2	A3	A4
1968	6,506	6,506	6,512	6,512	0.0%	0.1%	0.1%
1970	5,260	5,258	5,264	5,258	0.0%	0.1%	0.0%
1971	7,106	7,107	7,245	7,237	0.0%	1.9%	1.8%
1978	5,633	5,632	5,598	5,583	0.0%	-0.6%	-0.9%
1979	9,638	9,638	9,712	9,713	0.0%	0.8%	0.8%
1980	8,172	8,172	8,187	8,188	0.0%	0.2%	0.2%
1981	4,027	4,026	4,088	4,081	0.0%	1.5%	1.3%
1982	6,296	6,266	6,323	6,322	-0.5%	0.4%	0.4%
1983	8,925	8,925	8,923	8,901	0.0%	0.0%	-0.3%
1985	5,093	5,055	5,072	5,084	-0.8%	-0.4%	-0.2%
1986	3,927	3,937	3,854	3,883	0.3%	-1.9%	-1.1%
1987	5,017	5,069	5,038	5,073	1.0%	0.4%	1.1%
1988	3,964	3,924	3,889	3,893	-1.0%	-1.9%	-1.8%
1989	6,392	6,459	6,587	6,595	1.0%	2.9%	3.1%
1990	5,700	5,700	5,727	5,741	0.0%	0.5%	0.7%
1993	6,734	6,735	6,562	6,555	0.0%	-2.6%	-2.7%
1994	9,341	9,368	9,469	9,457	0.3%	1.3%	1.2%
1996	6,859	6,859	6,928	6,879	0.0%	1.0%	0.3%
1997	7,110	7,126	7,093	7,094	0.2%	-0.2%	-0.2%
1998	8,266	8,266	8,250	8,250	0.0%	-0.2%	-0.2%
1999	4,454	4,454	4,379	4,432	0.0%	-1.7%	-0.5%
2000	4,225	4,223	4,182	4,143	-0.1%	-1.0%	-2.0%
2001	3,919	3,918	3,937	3,921	0.0%	0.5%	0.0%
2002	3,791	3,819	3,771	3,769	0.7%	-0.5%	-0.6%
2003	9,402	9,286	9,435	9,434	-1.2%	0.3%	0.3%
2004	7,085	7,453	7,394	7,394	4.9%	4.2%	4.2%
2006	4,226	4,242	4,160	4,146	0.4%	-1.6%	-1.9%
2007	4,024	4,011	4,015	4,027	-0.3%	-0.2%	0.1%
2008	3,717	3,177	3,711	3,711	-17.0%	-0.2%	-0.2%
2009	5,335	5,603	5,347	5,314	4.8%	0.2%	-0.4%
2010	4,970	4,970	5,015	5,013	0.0%	0.9%	0.9%
2011	4,246	4,245	4,283	4,271	0.0%	0.9%	0.6%
				Drought Year Average	**-0.1%**	**0.0%**	**0.0%**
				Drought Year Minimum	**-17.0%**	**-2.6%**	**-2.7%**
				Drought Year Maximum	**4.9%**	**4.2%**	**4.2%**

Key observations related to the JST flow releases shown in Table 3.7-1 are:

- The USACE 2012 DP is triggered 51 years out of the 73-year POR based on HEC-ResSim model results for A3 and A4.
- JST flow releases for A3 and A4 are more similar to NAA/A1 flow releases than they are to A2.
- Over the 51 drought years in the 73-year POR, A3 average flow releases are:
  - Less than NAA/A1 average flow releases for 22 years
  - Equal to or greater than NAA/A1 average flow releases for 29 years
- The differences between A3/A4 and NAA/A1 are less than 5 percent on an annual basis. The larger negative differences (i.e., 1962 and 1993) and larger positive differences (i.e., 1957, 1989, and 2004) tend to occur during less severe drought years when average flows are above 4,200 cfs.
- For A3 and A4, there are no consecutive extreme drought years where the average flow releases are less than the NAA/A1 average flow releases by more than 2 percent. For example, A3 average flows were 1.9 percent less than NAA/A1 average flow releases in 1988 followed by a 2.9 percent increase in 1989. During the 2007 – 2009 extreme drought, A3 average flows are less than NAA/A1 average flow releases by -0.2 percent, -0.2 percent, and +0.2 percent for 2007, 2008, and 2009, respectively.

As discussed in Section 3.3.3, state and/or federal regulatory agencies in Georgia and/or South Carolina may request implementation of adaptive management flow releases at the JST Project when JST flow releases fall below 3,800 cfs (i.e., during DP Levels 2, 3, and 4) to support downstream water quality. As a result, the small differences in April through December average JST flow releases presented in Table 3.7-1 would be even smaller if the adaptive management flow releases are implemented. As described in Section 3.4 (and shown in Figures 3.4-5 through 3.4-8), the Duke Energy system can support the adaptive management flows. This is still the case even under the worst case sensitivity analysis, which assumes future water withdrawals with climate change hydrology and adaptive management flow releases in every Level 2 and 3 day (note Level 4 conditions are never reached even in this worst-case scenario).

Average monthly flows (April through December) during drought years for each alternative are provided in Table 3.7-2.

Table 3.7-2 Monthly Average Flow Releases April 1 – December 31 for Drought Years (Future Water Withdrawals with Historic Hydrology)

Month	Average Flow (cfs)				Percent Difference Compared with NAA/A1		
	NAA/A1	A2	A3	A4	A2	A3	A4
April	9,041	9,055	9,082	9,083	0.2%	0.5%	0.5%
May	6,492	6,490	6,567	6,541	0.0%	1.1%	0.8%
June	5,276	5,279	5,258	5,269	0.1%	-0.3%	-0.1%
July	5,827	5,814	5,881	5,916	-0.2%	0.9%	1.5%
August	5,785	5,779	5,841	5,857	-0.1%	1.0%	1.2%
September	5,086	5,103	5,026	4,946	0.3%	-1.2%	-2.8%
October	4,794	4,806	4,740	4,741	0.2%	-1.1%	-1.1%
November	5,467	5,464	5,409	5,417	-0.1%	-1.1%	-0.9%
December	6,920	6,908	6,953	6,947	-0.2%	0.5%	0.4%
Drought Year Average					**0.0%**	**0.0%**	**-0.1%**
Drought Year Minimum					**-0.2%**	**-1.2%**	**-2.8%**
Drought Year Maximum					**0.3%**	**1.1%**	**1.5%**

Key observations from the JST monthly flow release data in Table 3.7-2 are:

- For A3, monthly average differences in JST flow releases (i.e., +1.1 percent to -1.2 percent) compared to NAA/A1 are smaller than the range of annual differences shown in Table 3.7-1 for A3 (i.e., +4.2 percent to -2.6 percent).
- Even during September when A3 has the largest negative difference (-1.2 percent) compared to NAA/A1, the A3 monthly average flows are still well above (e.g., 5,026 cfs) USACE 2012 DP flow release minimums (3,800 cfs to 4,200 cfs depending on drought level).

The number of days the USACE system is within each Drought Plan Level for each alternative is shown in the table on the following page.

Table 3.7-3 Days Within Drought Levels

Year	Drought Level 1				Drought Level 2				Drought Level 3				Total			
	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
1939	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1940	16	16	21	25	0	0	0	0	0	0	0	0	16	16	21	25
1941	130	130	60	60	0	0	91	92	0	0	0	0	130	130	151	152
1942	48	48	1	1	0	0	48	48	0	0	0	0	48	48	49	49
1943	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1944	72	72	105	102	0	0	0	0	0	0	0	0	72	72	105	102
1945	40	40	124	150	0	0	0	0	0	0	0	0	40	40	124	150
1946	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
1947	36	36	29	31	40	40	57	55	0	0	0	0	76	76	86	86
1948	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1951	89	89	102	102	0	0	0	0	0	0	0	0	89	89	102	102
1952	95	95	97	96	0	0	6	6	0	0	0	0	95	95	103	102
1953	89	89	89	89	0	0	30	40	0	0	0	0	89	89	119	129
1954	32	32	25	24	98	98	112	112	0	0	0	0	130	130	137	136
1955	69	67	47	50	235	235	248	249	0	0	0	0	304	302	295	299
1956	55	55	33	33	210	210	217	219	0	0	0	0	265	265	250	252
1957	79	79	84	84	63	63	59	59	0	0	0	0	142	142	143	143
1958	3	3	1	1	0	0	0	0	0	0	0	0	3	3	1	1
1959	18	18	19	19	0	0	0	0	0	0	0	0	18	18	19	19
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	80	80	113	113	0	0	0	0	0	0	0	0	80	80	113	113
1963	10	10	22	22	0	0	0	0	0	0	0	0	10	10	22	22
1964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1966	3	3	17	16	0	0	0	0	0	0	0	0	3	3	17	16
1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1968	1	1	5	5	0	0	0	0	0	0	0	0	1	1	5	5
1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1970	115	115	35	32	0	0	87	93	0	0	0	0	115	115	122	125
1971	25	25	1	1	0	0	33	35	0	0	0	0	25	25	34	36
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	78	78	99	97	0	0	0	0	0	0	0	0	78	78	99	97
1979	19	19	19	19	0	0	0	0	0	0	0	0	19	19	19	19
1980	5	5	30	29	0	0	0	0	0	0	0	0	5	5	30	29
1981	124	123	152	151	174	175	177	177	0	0	0	0	298	298	329	328
1982	24	24	67	67	33	32	33	33	0	0	0	0	57	56	100	100
1983	23	23	61	69	0	0	0	0	0	0	0	0	23	23	61	69
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	57	56	46	57	53	53	55	64	0	0	0	0	110	109	101	121
1986	104	110	115	60	245	236	189	242	0	0	56	58	349	346	360	360
1987	28	27	31	27	118	118	125	126	0	0	0	0	146	145	156	153
1988	0	0	0	0	352	322	312	313	14	44	54	53	366	366	366	366
1989	3	1	1	1	125	125	121	122	61	59	63	63	189	185	185	186
1990	33	33	91	91	0	0	0	0	0	0	0	0	33	33	91	91
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	27	27	28	29	84	84	92	91	0	0	0	0	111	111	120	120
1994	1	1	1	1	60	60	60	60	0	0	0	0	61	61	61	61
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	2	2	0	0	0	0	0	0	0	0	0	0	2	2
1997	29	29	40	42	0	0	0	0	0	0	0	0	29	29	40	42
1998	101	101	110	110	0	0	0	0	0	0	0	0	101	101	110	110
1999	56	56	54	58	119	119	130	127	0	0	0	0	175	175	184	185
2000	46	47	45	50	266	265	270	269	0	0	0	0	312	312	315	319
2001	0	0	0	0	365	365	365	365	0	0	0	0	365	365	365	365
2002	0	0	0	0	256	249	240	217	109	116	125	148	365	365	365	365
2003	1	1	1	1	57	64	64	64	0	0	0	0	58	65	65	65
2004	15	15	21	21	0	0	0	0	0	0	0	0	15	15	21	21
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	26	26	30	30	137	144	145	145	0	0	0	0	163	170	175	175
2007	76	80	72	69	157	151	139	136	23	30	42	45	256	261	253	250
2008	0	0	0	0	130	125	118	118	236	241	248	248	366	366	366	366
2009	1	1	4	1	180	232	175	173	155	84	154	155	336	317	333	329
2010	26	26	23	26	98	98	105	105	0	0	0	0	124	124	128	131
2011	25	25	24	24	203	203	203	203	0	0	0	0	228	228	227	227
Total	**2033**	**2037**	**2198**	**2189**	**3858**	**3866**	**4106**	**4158**	**598**	**574**	**742**	**770**	**6489**	**6477**	**7046**	**7117**

Key observations from data shown in Table 3.7-3 for the number of days the USACE reservoirs are in drought with the various alternatives are:

- A2 would decrease the number of days the USACE reservoirs are in a drought (12 days out of 6489) (0.2% decrease), when compared to the NAA/A1.
- A3 would increase the number of days the USACE reservoirs are in a drought (6489 plus 557 days) (8.6% increase), when compared to the NAA/A1.
- A4 would increase the number of days the USACE reservoirs are in a drought (6489 plus 628 days) (9.7% increase), when compared to the NAA/A1.
- All alternatives would increase the number of days the USACE reservoirs are in a drought Levels 1 and 2, when compared to the NAA/A1.
- A2 and A3 would increase the number of days the USACE reservoirs are in a drought Level 3, when compared to the NAA/A1.
- Since the USACE Drought Plan calls for reductions in flow releases from JST when the USACE system is in a drought status, downstream flow releases would be reduced more days with alternatives A2 and A3.

3.7.2 *JST Lake Flow Release Sensitivity Analyses*

The results of JST flow releases with the sensitivity analyses are provided in Table 3.7-3. Appendix M contains detailed April through December average flow releases for drought years (similar to Tables 3.7-1 and 3.7-4) for the sensitivity analyses.

Compared to future withdrawals with historic hydrology, current withdrawals result in smaller differences in JST releases for A2 (compared to NAA/A1). JST flow releases for A3 and A4 using current withdrawals are slightly lower on average (-0.2 percent) than NAA/A1 JST flow releases using future withdrawal assumptions (0.0 percent). The differences in monthly average JST flow releases are similar between current and future withdrawal assumptions for each alternative (compared to NAA/A1). Comparing current to future water withdrawal assumptions, A3 has same number of years (i.e., 22 years) where average JST flow releases are less than NAA/A1.

Compared to future withdrawals with historic hydrology, climate change hydrology results in similar differences in JST flow releases for A2, A3, and A4 (compared to NAA/A1). The differences in monthly average JST flow releases are similar between historic and climate change hydrology for each alternative (compared to NAA/A1). Using climate change hydrology assumptions, A3 results in four more years where average flows are less than NAA/A1 (26 years versus 22 years under historic hydrology).

Appendix M contains information showing the number of days the USACE reservoirs are in drought with the various alternatives under the sensitivity analyses. In general, that information indicates the following:

- The USACE reservoirs would be in drought fewer days under the scenario of Current Water Withdrawals and Historic Hydrology.
- The USACE reservoirs would be in drought more days under the scenario of Future Water Withdrawals and Climate Change Hydrology.

Table 3.7-4 Summary of JST Flow Release Statistics

	Base Plan	Sensitivity Analysis #1	Sensitivity Analysis #2
	Future Withdrawals with Historic Hydrology	**Current Withdrawals with Historic Hydrology**	**Future Withdrawals with Climate Change Hydrology**
Years DP Triggered over 73-year POR	51	44	52
Annual average difference[1] in JST flow releases compared to NAA/A1	A2: -0.1% A3: 0.0% A4: 0.0%	A2: 0.0% A3: -0.2% A4: -0.2%	A2: -0.3% A3: 0.0% A4: 0.0%
Range of annual differences[1] in JST flow releases compared to NAA/A1	A2: +4.9% to -17.0% A3: +4.2% to -2.6% A4: +4.2% to -2.7%	A2: +0.8% to -0.9% A3: +2.5% to -2.8% A4: +2.4% to -2.8%	A2: +4.9% to -22.0% A3: +4.3% to -2.2% A4: +4.3% to -2.5%
Range of monthly differences[1] in JST flow releases compared to NAA/A1	A2: +0.3% to -0.2% A3: +1.1% to -1.2% A4: +1.5% to -2.8%	A2: +0.1% to -0.3% A3: +1.7% to -2.0% A4: +1.8% to -2.0%	A2: +0.5% to -0.9% A3: +1.3% to -1.9% A4: +1.4% to -1.7%
Comparison of A3 to NAA/A1 average flow releases	A3 < NAA/A1 for 22 years A3 = NAA/A1 for 2 years A3 > NAA/A1 for 27 years	A3 < NAA/A1 for 22 years A3 = NAA/A1 for 4 years A3 > NAA/A1 for 18 years	A3 < NAA/A1 for 26 years A3 = NAA/A1 for 3 years A3 > NAA/A1 for 23 years

[1] Differences compared with NAA/A1 include only those years that triggered the USACE 2012 DP and the lower flow release time periods of April – December

4.0 ENVIRONMENTAL AND SOCIOECONOMIC CONSIDERATIONS

4.1 Water Supply

The HEC-ResSim modeling calculated reservoir elevations under the various alternatives. This allows identification of potential impacts to water intakes from the alternatives. The analyses indicate three Clemson University intakes on Hartwell Lake would be affected under some sensitivity analyses, but those intakes are not considered critical intakes because they are not used for drinking water. The City of Lavonia's intake on Hartwell Lake would be affected by A3 and A4. That intake is located at 636 feet AMSL, within the Hartwell Conservation Pool, so it is subject to periods of non-availability during droughts. The City is able to use water from the Crawford Creek reservoir if water from Hartwell is not available. The City plans to add another intake to their pipe in Hartwell and connect to the City of Toccoa's water system. Modeling on the availability of the Lavonia intake only considers the City's present withdrawal (one intake at 636 feet). With the NAA, that intake would not be useful 24 days during the 50-year period of analysis. With A3, the intake would be unavailable 43 days, and with A4 it would be unavailable 41 days. Since this intake is located within the Hartwell Conservation Pool that was designed to be fully drafted during droughts, these additional days on non-availability are deemed to be a minor impact. No other public water supply intake would become inoperable as a result of the alternatives considered. As a result, potential impacts to water supply from the four alternatives are considered negligible.

A2, A3 and A4 include measures to encourage coordinated responses by regional water suppliers during droughts to reduce their consumptive water use. Experience with these measures in the Catawba-Wateree River Basin during the 2007-2009 drought of record resulted in measureable reductions in water use when compared to long-term average.

Differences between alternatives in downstream flow releases from JST are small. No reduction would occur in flow volumes from JST on a given day because USACE would continue to operate under the conditions of its 2012 Drought Plan. As a result, there are no expected impacts to downstream water intakes, including the Savannah River Site, Beaufort-Jasper Water Authority, Vogtle Nuclear Plant, City of Savannah, City of Augusta, Georgia-Pacific Gypsum, Weyerhaeuser Port Wentworth Mill, Georgia Power Plants, International Paper's Augusta Plant, and South Carolina Electric and Gas Urquhart Station. Appendix A contains detailed water withdrawals and returns from a 2012 water supply study of the Savannah River Basin.

4.2 Water Quality

The HEC-ResSim model results provide information on how all four model scenarios affect reservoir drawdown levels and downstream flow releases. From a water quality perspective, reservoir drawdowns primarily impact temperature and D.O. stratification. Modeled reservoir drawdowns are more pronounced for Lakes Jocassee and Keowee and the differences between the alternatives are also more apparent for these two reservoirs. Differences between the alternatives are less pronounced for the USACE reservoirs and for flows released to the Savannah River from JST.

All D.O. data collected by Duke Energy in the Lake Keowee Hydro tailrace as part of the Keowee-Toxaway Project relicensing studies is in compliance with South Carolina water quality standards (daily average of 5.0 mg/L and a daily minimum of 4.0 mg/L). Flow releases from JST Dam generally contain at least 5 mg/L of D.O. This level meets both the Georgia and South Carolina D.O. standards for those waters. Since the flow volumes that USACE would release from JST would not change in any of the alternatives, instantaneous D.O. levels downstream of that site would not differ between alternatives. As a result, the proposed action will not cause or contribute to violations of SC or GA D.O. standards.

The Georgia Department of Natural Resources Environmental Protection Division (DNR-EPD) analyzed the potential effects on water quality in both the river and the Savannah estuary/harbor area associated with a proposed winter flow reduction to 3,100 cfs in 2008. The study concentrated on D.O. levels because the States of Georgia and South Carolina previously identified D.O. as a critical water quality parameter. For the river portion (JST to Clyo) of the basin, Georgia DNR-EPD used the RIV1 Model (one-dimensional dynamic hydraulic and water quality model) to identify potential point source discharge problems along the river if river flow was reduced. The riverine water quality model showed that the 5.0 mg/L D.O. standard would not be violated by a JST flow release of 3,100 cfs or 3,600 cfs. For the estuary/harbor portion of the basin (Clyo to ocean), Georgia DNR-EPD used the EFDC (Environmental Fluid Dynamics Code) and WASP (Water Quality Analysis Simulation Program) Models. The harbor water quality model showed that the 5.0 mg/L D.O. standard could be violated by a JST flow release of both 3,100 cfs and 3,600 cfs from April through December. This is the result of lower D.O. levels that are regularly experienced in the estuary during the warmer months.

As described in Section 3.3.3, the USACE Drought Plan includes provisions to increase JST flow releases during the winter months during droughts if the State of Georgia or South Carolina notifies USACE of unacceptable water quality conditions. USACE would then increase JST flow releases to as high as 3,800 cfs to address those observed unacceptable conditions.

To avoid adverse impacts to dissolved oxygen levels in Savannah Harbor, each action alternative includes a provision where USACE and Duke Energy would discharge 200 cubic feet per second of water above that specified in the Drought Plan from their dams for 11 days when the USACE reservoirs are in drought status during the summer months.

4.3 Recreation

The HEC ResSim model calculates reservoir elevations for operation under each of the alternatives. This section addresses potential impacts to recreation resources (i.e., boating and swimming) from changes in pool elevations. Daily reservoir elevations were evaluated for potential impacts to public boat ramps and swimming areas at both the Duke Energy and USACE reservoirs. The 73-year POR was separated into calendar quarters to identify the effect on reservoir elevations during specific times of the year.

4.3.1 *Public Boat-Launching Ramps on the Reservoirs*

4.3.1.1 *Duke Energy Reservoirs*

Duke Energy provides nine public boat ramps on Lake Jocassee and twenty-four public boat ramps on Lake Keowee. Six of the nine public boat ramps on Lake Jocassee become unusable when the reservoir elevation falls below 1,085 feet AMSL. All nine become unusable below 1,080 feet AMSL. The boat ramps on Lake Keowee are unusable at varying reservoir elevations. Two become unusable on Lake Keowee when the reservoir elevation falls below 791 feet AMSL, ten more (total of 12) become unusable below 790 feet AMSL, five more (total of 17) become unusable below 789 feet AMSL, four more (total of 21) become unusable below 788 feet AMSL, and three more (i.e., all 24) become unusable below 787 feet AMSL.

USACE used the ResSim model to calculate reservoir elevations over the 73-year Period of Record. Outputs from that modeling can be used to identify when pool levels would have declined to the point where a given boat ramp would not be available for use. Tables 4.3-1 and 4.3-2 provide the percentage of days and total days, respectively, when the boat ramps are unusable for the future water withdrawals and historic hydrology model runs. To evaluate potential seasonal differences, the table shows both quarterly and annual calculations of days where individual boat ramps are not usable.

For Lake Jocassee there is always at least one boat ramp open at Devils Fork State Park regardless of season or alternative. For Lake Keowee, NAA/A1 results in the most unusable days, although, the magnitude of the impact is small (e.g., an average of 1.41 percent of days in fourth quarter annually and an average of 0.93 percent of days on an annual basis). A3 and A4 result in a very small number of unusable days (e.g., an average of 0.02 percent) on an annual basis.

Sensitivity Analysis: Assuming current water withdrawals instead of future water withdrawals results in zero days where a boat ramp is not available on Lake Jocassee and the unusable days for NAA/A1 at Lake Keowee drop to 0.34 percent on an annual basis. See Tables N-1 and N-2 in Appendix N for detailed results.

Using climate change hydrology instead of historic hydrology results in five days where a boat ramp is not available on Lake Jocassee. For Lake Keowee, climate change hydrology conditions result in a slight increase of unusable days compared to historic hydrology. See Tables N-3 and N-4 in Appendix N for detailed results.

4.3.1.2 *USACE Reservoirs*

There are 111 public boat ramps on Hartwell Lake and 102 public boat ramps and marinas on JST Lake. Boat ramps at Hartwell Lake start becoming unusable at elevations below 658 feet AMSL and all boat ramps are unusable at elevations below 638 feet AMSL. In JST Lake, all boat ramps are usable until the reservoir falls below 326 feet AMSL. However, when the reservoir is at or below 306 feet AMSL, none of these boat ramps are available. At RBR Lake, none of the boat ramps are unusable under any of the alternatives considered.

Tables 4.3-3 and 4.3-4 provide the percentage of days and total days, respectively, when boat ramps would be unusable (with future water withdrawals with historic hydrology) at Hartwell Lake. On an annual basis, boat ramps are unavailable 0.16 - 52 percent of the time depending upon the ramp and the modeling scenario. The difference in number of days when individual boat ramps are unusable is typically in the one to two percent range for all modeled alternatives. In general, A4 results in the largest number of unusable days and A2 results in the fewest. On a quarterly basis, each season mimics the annual statistics in differences between model scenarios, however, the magnitude of differences changes seasonally. Again, A4 typically has the largest number of unusable days.

Tables 4.3-5 and 4.3-6 provide the percentage of days and total days, respectively, when boat ramps are unusable (with future water withdrawals with historic hydrology) at JST Lake. On an annual basis, boat ramps are unavailable up to 26.4 percent of the time depending upon the ramp and alternative. The differences in number of days when individual boat ramps are unusable on JST Lake are less than it is for Hartwell Lake and typically less than one percent. On a quarterly basis, only the months of October through December have results that differ slightly from the annual statistics. During the fourth quarter, differences between modeled scenarios are as large as 3 percent with A4 generally resulting in the largest number of unusable days.

Model Sensitivity Analysis: For Hartwell Lake, using current water withdrawals instead of future water withdrawals results in fewer unusable ramp days, with differences of unusable days between alternatives typically in the zero to two percent range. The October through December timeframe exhibits differences up to four percent for a few boat ramps. For both the annual and seasonal statistics, A4 typically results in the highest number of unusable days and NAA/A1 results in the lowest. However, differences between alternatives are minimal over the POR. See Tables N-5 and N-6 in Appendix N for detailed results.

For JST Lake, modeling current water withdrawals also results in fewer unusable ramp days with incremental differences between alternatives of less than one percent. See Tables N-7 and N-8 in Appendix N for detailed results.

Table 4.3-1 Percentage of Days Boat Ramps are Unusable on Lake Jocassee and Lake Keowee (With Future Water Withdrawals and Historic Hydrology) (1939 – 2011)

Development	Access Area Name	County	Not usable below elevation* (ft AMSL)	Percentage of days when ramp is not usable: Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Jocassee	Devils Fork State Park	Oconee	1080.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Keowee	Warpath	Pickens	789.0	1.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.82%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	0.87%	0.00%	0.00%	0.00%
	Cane Creek	Oconee	789.0	1.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.82%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	0.87%	0.00%	0.00%	0.00%
	Stamp Creek	Oconee	788.0	1.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.49%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	0.78%	0.00%	0.00%	0.00%
	Keowee Town	Oconee	790.0	1.37%	0.00%	0.00%	0.00%	0.38%	0.00%	0.00%	0.00%	1.01%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	1.03%	0.00%	0.00%	0.00%
	Fall Creek	Oconee	790.0	1.37%	0.00%	0.00%	0.00%	0.38%	0.00%	0.00%	0.00%	1.01%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	1.03%	0.00%	0.00%	0.00%
	Crow Creek	Pickens	788.0	1.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.49%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	0.78%	0.00%	0.00%	0.00%
	South Cove Park	Oconee	787.0	1.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	0.64%	0.00%	0.00%	0.00%
	High Falls Park	Oconee	791.0	1.37%	0.00%	0.24%	0.39%	0.68%	0.00%	0.00%	0.00%	1.44%	0.00%	0.06%	0.09%	1.77%	0.00%	0.24%	0.70%	1.32%	0.00%	0.14%	0.30%
	Mile Creek Park	Pickens	790.0	1.37%	0.00%	0.00%	0.00%	0.38%	0.00%	0.00%	0.00%	1.01%	0.00%	0.00%	0.00%	1.37%	0.00%	0.00%	0.00%	1.03%	0.00%	0.00%	0.00%

* The elevation below which ramps may not be usable for most boats is presented as three feet above the top of the concrete ramp end elevation.

Table 4.3-2 Number of Days Boat Ramps are Unusable on Lake Jocassee and Lake Keowee (With Future Water Withdrawals and Historic Hydrology) (1939 – 2011)

Development	Access Area Name	County	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable: Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Jocassee	Devils Fork State Park	Oconee	1080.0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Keowee	Warpath	Pickens	789.0	85	0	0	0	0	0	0	0	55	0	0	0	92	0	0	0	232	0	0	0
	Cane Creek	Oconee	789.0	85	0	0	0	0	0	0	0	55	0	0	0	92	0	0	0	232	0	0	0
	Stamp Creek	Oconee	788.0	82	0	0	0	0	0	0	0	33	0	0	0	92	0	0	0	207	0	0	0
	Keowee Town	Oconee	790.0	90	0	0	0	25	0	0	0	68	0	0	0	92	0	0	0	275	0	0	0
	Fall Creek	Oconee	790.0	90	0	0	0	25	0	0	0	68	0	0	0	92	0	0	0	275	0	0	0
	Crow Creek	Pickens	788.0	82	0	0	0	0	0	0	0	33	0	0	0	92	0	0	0	207	0	0	0
	South Cove Park	Oconee	787.0	67	0	0	0	0	0	0	0	12	0	0	0	92	0	0	0	171	0	0	0
	High Falls Park	Oconee	791.0	90	0	16	26	45	0	0	0	97	0	4	6	119	0	16	47	351	0	36	79
	Mile Creek Park	Pickens	790.0	90	0	0	0	25	0	0	0	68	0	0	0	92	0	0	0	275	0	0	0

* The elevation below which ramps may not be usable for most boats is presented as three feet above the top of the concrete ramp end elevation.

Table 4.3-3 Percentage of Days Boat Ramps are Unusable on Hartwell Lake (With Future Water Withdrawals and Historic Hydrology) (1939 – 2011)

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Sadler's Creek State Park	SC	1	658.0	58.32%	58.18%	59.27%	59.58%	18.09%	18.30%	19.06%	19.18%	49.57%	49.46%	51.01%	51.31%	81.40%	81.04%	82.01%	82.08%	51.91%	51.81%	52.90%	53.10%
Tugaloo State Park	GA	2	658.0	58.32%	58.18%	59.27%	59.58%	18.09%	18.30%	19.06%	19.18%	49.57%	49.46%	51.01%	51.31%	81.40%	81.04%	82.01%	82.08%	51.91%	51.81%	52.90%	53.10%
Jack's Landing	SC	1	658.0	58.32%	58.18%	59.27%	59.58%	18.09%	18.30%	19.06%	19.18%	49.57%	49.46%	51.01%	51.31%	81.40%	81.04%	82.01%	82.08%	51.91%	51.81%	52.90%	53.10%
Holder's Access	SC	1	658.0	58.32%	58.18%	59.27%	59.58%	18.09%	18.30%	19.06%	19.18%	49.57%	49.46%	51.01%	51.31%	81.40%	81.04%	82.01%	82.08%	51.91%	51.81%	52.90%	53.10%
Lakeshore	SC	1	658.0	58.32%	58.18%	59.27%	59.58%	18.09%	18.30%	19.06%	19.18%	49.57%	49.46%	51.01%	51.31%	81.40%	81.04%	82.01%	82.08%	51.91%	51.81%	52.90%	53.10%
Mountain Bay	SC	1	658.0	58.32%	58.18%	59.27%	59.58%	18.09%	18.30%	19.06%	19.18%	49.57%	49.46%	51.01%	51.31%	81.40%	81.04%	82.01%	82.08%	51.91%	51.81%	52.90%	53.10%
Reed Creek	GA	1	657.5	51.17%	51.00%	52.91%	52.88%	15.72%	15.76%	16.06%	16.27%	39.29%	39.07%	42.14%	42.56%	75.06%	74.76%	75.65%	75.73%	45.36%	45.20%	46.74%	46.91%
Rocky Ford	GA	1	657.5	51.17%	51.00%	52.91%	52.88%	15.72%	15.76%	16.06%	16.27%	39.29%	39.07%	42.14%	42.56%	75.06%	74.76%	75.65%	75.73%	45.36%	45.20%	46.74%	46.91%
Brown Road	SC	1	657.0	43.70%	43.62%	45.45%	45.45%	13.16%	13.22%	13.71%	13.83%	29.66%	29.44%	34.07%	34.46%	68.31%	67.91%	69.62%	69.72%	38.75%	38.59%	40.76%	40.92%
Hurricane Creek	SC	1	657.0	43.70%	43.62%	45.45%	45.45%	13.16%	13.22%	13.71%	13.83%	29.66%	29.44%	34.07%	34.46%	68.31%	67.91%	69.62%	69.72%	38.75%	38.59%	40.76%	40.92%
Seneca Creek	SC	1	657.0	43.70%	43.62%	45.45%	45.45%	13.16%	13.22%	13.71%	13.83%	29.66%	29.44%	34.07%	34.46%	68.31%	67.91%	69.62%	69.72%	38.75%	38.59%	40.76%	40.92%
Walker Creek	GA	1	657.0	43.70%	43.62%	45.45%	45.45%	13.16%	13.22%	13.71%	13.83%	29.66%	29.44%	34.07%	34.46%	68.31%	67.91%	69.62%	69.72%	38.75%	38.59%	40.76%	40.92%
Cove Inlet	SC	1	656.5	36.51%	36.48%	38.43%	38.59%	11.71%	11.71%	12.16%	12.34%	24.42%	24.51%	28.54%	28.96%	61.06%	60.80%	63.48%	63.47%	33.47%	33.42%	35.71%	35.89%
Durham	SC	1	655.7	25.32%	25.33%	26.96%	27.03%	10.12%	10.07%	10.28%	10.21%	19.33%	19.43%	22.41%	22.75%	41.91%	41.61%	47.24%	47.33%	24.20%	24.14%	26.76%	26.87%
South Union	SC	1	655.5	24.48%	24.56%	25.93%	26.12%	9.66%	9.57%	9.94%	9.80%	18.70%	18.78%	21.49%	21.74%	40.27%	39.94%	45.57%	45.99%	23.31%	23.24%	25.77%	25.95%
Bradberry	GA	1	655.0	22.47%	22.48%	24.30%	24.48%	8.93%	8.81%	9.26%	9.21%	17.24%	17.38%	19.43%	19.58%	36.55%	36.26%	41.86%	42.34%	21.32%	21.26%	23.75%	23.94%
Timberland	SC	1	654.0	16.36%	16.06%	18.99%	19.11%	7.38%	6.44%	7.39%	7.41%	13.59%	13.70%	15.38%	15.43%	29.59%	29.38%	34.58%	34.76%	16.76%	16.42%	19.12%	19.21%
Darvin Wright City Park	SC	1	653.0	11.57%	11.58%	12.83%	12.84%	4.95%	4.28%	5.19%	5.30%	9.81%	9.65%	10.33%	10.54%	20.48%	20.22%	25.39%	25.03%	11.72%	11.45%	13.46%	13.45%
Tillies	SC	1	653.0	11.57%	11.58%	12.83%	12.84%	4.95%	4.28%	5.19%	5.30%	9.81%	9.65%	10.33%	10.54%	20.48%	20.22%	25.39%	25.03%	11.72%	11.45%	13.46%	13.45%
White City	SC	1	653.0	11.57%	11.58%	12.83%	12.84%	4.95%	4.28%	5.19%	5.30%	9.81%	9.65%	10.33%	10.54%	20.48%	20.22%	25.39%	25.03%	11.72%	11.45%	13.46%	13.45%
Barton Mill	SC	1	653.0	11.57%	11.58%	12.83%	12.84%	4.95%	4.28%	5.19%	5.30%	9.81%	9.65%	10.33%	10.54%	20.48%	20.22%	25.39%	25.03%	11.72%	11.45%	13.46%	13.45%
Port Bass	SC	1	653.0	11.57%	11.58%	12.83%	12.84%	4.95%	4.28%	5.19%	5.30%	9.81%	9.65%	10.33%	10.54%	20.48%	20.22%	25.39%	25.03%	11.72%	11.45%	13.46%	13.45%
Seymour	GA	1	653.0	11.57%	11.58%	12.83%	12.84%	4.95%	4.28%	5.19%	5.30%	9.81%	9.65%	10.33%	10.54%	20.48%	20.22%	25.39%	25.03%	11.72%	11.45%	13.46%	13.45%
Payne's Creek (inner right)	GA	1	652.6	10.03%	10.08%	10.69%	10.82%	4.65%	3.97%	4.80%	4.85%	9.17%	8.89%	9.51%	9.56%	17.90%	17.71%	21.06%	21.07%	10.46%	10.18%	11.54%	11.60%
Payne's Creek (left)	GA	1	652.6	10.03%	10.08%	10.69%	10.82%	4.65%	3.97%	4.80%	4.85%	9.17%	8.89%	9.51%	9.56%	17.90%	17.71%	21.06%	21.07%	10.46%	10.18%	11.54%	11.60%
Big Oak (left lane)	GA	1	652.5	9.61%	9.62%	10.20%	10.32%	4.64%	3.84%	4.73%	4.70%	9.05%	8.68%	9.37%	9.43%	17.32%	16.99%	20.00%	20.03%	10.17%	9.80%	11.09%	11.14%
Tabor	SC	1	652.5	9.61%	9.62%	10.20%	10.32%	4.64%	3.84%	4.73%	4.70%	9.05%	8.68%	9.37%	9.43%	17.32%	16.99%	20.00%	20.03%	10.17%	9.80%	11.09%	11.14%
Townville	SC	1	652.3	8.33%	8.38%	9.17%	9.35%	4.47%	3.73%	4.59%	4.58%	8.71%	8.25%	9.11%	9.16%	16.41%	16.07%	18.35%	18.56%	9.50%	9.13%	10.33%	10.43%
Apple Island	SC	1	651.5	7.23%	7.18%	7.71%	7.76%	4.02%	2.88%	4.26%	4.25%	7.31%	6.60%	7.83%	7.85%	12.78%	12.35%	15.07%	15.06%	7.85%	7.26%	8.74%	8.74%
Poplar Spring (left ramp)	GA	1	651.5	7.23%	7.18%	7.71%	7.76%	4.02%	2.88%	4.26%	4.25%	7.31%	6.60%	7.83%	7.85%	12.78%	12.35%	15.07%	15.06%	7.85%	7.26%	8.74%	8.74%
Stephens Co.	GA	1	651.5	7.23%	7.18%	7.71%	7.76%	4.02%	2.88%	4.26%	4.25%	7.31%	6.60%	7.83%	7.85%	12.78%	12.35%	15.07%	15.06%	7.85%	7.26%	8.74%	8.74%
Broyles (East ramp)	SC	1	651.3	7.16%	7.09%	7.48%	7.56%	3.79%	2.60%	4.02%	4.05%	6.94%	6.21%	7.40%	7.64%	12.41%	11.93%	14.48%	14.50%	7.59%	6.97%	8.36%	8.45%
Friendship (left lane)	SC	1	651.0	6.98%	6.86%	7.33%	7.35%	3.42%	2.36%	3.72%	3.73%	6.60%	5.66%	7.00%	7.07%	12.15%	11.51%	13.57%	13.64%	7.30%	6.61%	7.92%	7.96%
Lawrence Bridge	SC	1	651.0	6.98%	6.86%	7.33%	7.35%	3.42%	2.36%	3.72%	3.73%	6.60%	5.66%	7.00%	7.07%	12.15%	11.51%	13.57%	13.64%	7.30%	6.61%	7.92%	7.96%

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
River Fork (right ramp)	SC	1	651.0	6.98%	6.86%	7.33%	7.35%	3.42%	2.36%	3.72%	3.73%	6.60%	5.66%	7.00%	7.07%	12.15%	11.51%	13.57%	13.64%	7.30%	6.61%	7.92%	7.96%
Broyles (West ramp)	SC	1	650.5	6.45%	6.24%	7.12%	7.12%	3.06%	2.05%	3.16%	3.19%	5.99%	4.90%	6.36%	6.39%	11.53%	11.14%	12.11%	12.30%	6.77%	6.09%	7.20%	7.26%
Jarrett	SC	1	650.0	6.06%	5.94%	6.63%	6.69%	2.91%	1.25%	3.01%	3.04%	5.61%	4.41%	5.85%	5.96%	10.57%	10.31%	11.38%	11.65%	6.30%	5.48%	6.73%	6.84%
Holcomb	GA	1	650.0	6.06%	5.94%	6.63%	6.69%	2.91%	1.25%	3.01%	3.04%	5.61%	4.41%	5.85%	5.96%	10.57%	10.31%	11.38%	11.65%	6.30%	5.48%	6.73%	6.84%
Cleveland	GA	1	649.5	5.75%	5.13%	6.03%	6.06%	2.32%	0.80%	2.48%	2.63%	5.33%	4.01%	5.20%	5.30%	9.14%	8.79%	10.62%	10.83%	5.64%	4.69%	6.09%	6.21%
Spring Branch	GA	1	649.0	4.33%	4.05%	5.59%	5.66%	1.90%	0.50%	1.78%	1.94%	4.35%	3.51%	4.54%	4.72%	7.59%	7.45%	9.83%	10.05%	4.55%	3.89%	5.44%	5.60%
Honea Path	SC	1	648.5	3.72%	3.60%	5.04%	5.13%	1.51%	0.33%	1.49%	1.49%	3.48%	2.92%	3.96%	4.05%	6.79%	6.60%	8.53%	8.73%	3.88%	3.37%	4.76%	4.86%
Twin Lakes (right ramp)	SC	1	648.0	3.57%	3.37%	4.14%	4.16%	1.22%	0.23%	1.25%	1.29%	2.89%	2.58%	3.26%	3.45%	5.29%	5.27%	7.10%	7.36%	3.24%	2.87%	3.95%	4.07%
Twin Lakes (left ramp)	SC	1	648.0	3.57%	3.37%	4.14%	4.16%	1.22%	0.23%	1.25%	1.29%	2.89%	2.58%	3.26%	3.45%	5.29%	5.27%	7.10%	7.36%	3.24%	2.87%	3.95%	4.07%
Fairplay (left lane)	SC	1	647.0	2.53%	1.97%	3.35%	3.42%	0.87%	0.08%	0.92%	0.93%	2.28%	2.22%	2.47%	2.61%	3.90%	3.93%	5.27%	5.51%	2.40%	2.06%	3.01%	3.12%
Twelve Mile (left lane)	SC	1	647.0	2.53%	1.97%	3.35%	3.42%	0.87%	0.08%	0.92%	0.93%	2.28%	2.22%	2.47%	2.61%	3.90%	3.93%	5.27%	5.51%	2.40%	2.06%	3.01%	3.12%
Twelve Mile (right lane)	SC	1	647.0	2.53%	1.97%	3.35%	3.42%	0.87%	0.08%	0.92%	0.93%	2.28%	2.22%	2.47%	2.61%	3.90%	3.93%	5.27%	5.51%	2.40%	2.06%	3.01%	3.12%
Clemson	SC	1	645.5	1.37%	0.91%	1.70%	1.73%	0.59%	0.00%	0.56%	0.57%	1.47%	1.38%	1.79%	1.82%	1.67%	2.00%	3.11%	3.08%	1.28%	1.08%	1.79%	1.80%
Milltown	GA	1	645.4	1.37%	0.88%	1.59%	1.62%	0.56%	0.00%	0.53%	0.56%	1.41%	1.35%	1.76%	1.80%	1.53%	1.94%	2.89%	2.92%	1.22%	1.05%	1.70%	1.73%
Carters Ferry	GA	1	645.0	1.37%	0.65%	1.37%	1.37%	0.44%	0.00%	0.44%	0.50%	1.10%	1.22%	1.52%	1.58%	1.37%	1.76%	2.43%	2.47%	1.07%	0.91%	1.44%	1.48%
Watsadler	GA	1	645.0	1.37%	0.65%	1.37%	1.37%	0.44%	0.00%	0.44%	0.50%	1.10%	1.22%	1.52%	1.58%	1.37%	1.76%	2.43%	2.47%	1.07%	0.91%	1.44%	1.48%
Big Oaks (right lane)	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Camp Creek	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Choestoea	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Coneross	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Double Spring	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Duncan Branch	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Fairplay (right lane)	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Friendship (right lane)	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Glenn Ferry	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Green Pond	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Hatton's Ford	SC	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Long Point	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
New Prospect	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Rock Spring	GA	1	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Gum Branch	GA	6	644.0	1.32%	0.30%	1.32%	1.35%	0.00%	0.00%	0.00%	0.00%	0.89%	0.89%	1.16%	1.25%	1.37%	1.44%	1.37%	1.40%	0.90%	0.66%	0.96%	1.00%
Poplar Spring (right ramp)	GA	1	643.6	1.29%	0.23%	1.31%	1.32%	0.00%	0.00%	0.00%	0.00%	0.83%	0.88%	0.95%	1.07%	1.37%	1.40%	1.37%	1.37%	0.87%	0.63%	0.91%	0.94%
Springfield	SC	1	643.6	1.29%	0.23%	1.31%	1.32%	0.00%	0.00%	0.00%	0.00%	0.83%	0.88%	0.95%	1.07%	1.37%	1.40%	1.37%	1.37%	0.87%	0.63%	0.91%	0.94%
Crawford Ferry	GA	1	643.3	1.29%	0.21%	1.29%	1.31%	0.00%	0.00%	0.00%	0.00%	0.76%	0.82%	0.94%	0.94%	1.37%	1.37%	1.37%	1.37%	0.86%	0.60%	0.90%	0.90%

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Asbury (camping)	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Denver	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Eighteen Mile Creek	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Elrod Ferry	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Jenkins Ferry	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Martin Creek	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Mary Ann Branch	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Oconee Point	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Paynes Creek (outer)	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Powder Bag Creek N	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Richland Creek	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
River Forks (left ramp)	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Singing Pines	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Weldon Island	SC	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Harbor Light Marina	GA	2	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Hartwell Marina	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Hart State Park	GA	2	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Portman Shoals	GA	1	643.0	1.28%	0.12%	1.29%	1.29%	0.00%	0.00%	0.00%	0.00%	0.76%	0.71%	0.91%	0.94%	1.37%	1.37%	1.37%	1.37%	0.85%	0.56%	0.89%	0.90%
Broyles (middle ramp)	SC	1	642.0	1.15%	0.02%	1.23%	1.26%	0.00%	0.00%	0.00%	0.00%	0.55%	0.63%	0.73%	0.74%	1.37%	1.34%	1.37%	1.37%	0.77%	0.50%	0.83%	0.84%
Tugaloo State Park (mega)	GA	6	642.0	1.15%	0.02%	1.23%	1.26%	0.00%	0.00%	0.00%	0.00%	0.55%	0.63%	0.73%	0.74%	1.37%	1.34%	1.37%	1.37%	0.77%	0.50%	0.83%	0.84%
Mullins Ford	SC	1	638.0	0.47%	0.00%	0.50%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	1.37%	0.64%	1.37%	1.37%	0.46%	0.16%	0.48%	0.59%
Big Water	SC	1	638.0	0.47%	0.00%	0.50%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	1.37%	0.64%	1.37%	1.37%	0.46%	0.16%	0.48%	0.59%
Bruce Creek	GA	1	638.0	0.47%	0.00%	0.50%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	1.37%	0.64%	1.37%	1.37%	0.46%	0.16%	0.48%	0.59%
Lake Hartwell State Park	SC	2	638.0	0.47%	0.00%	0.50%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	1.37%	0.64%	1.37%	1.37%	0.46%	0.16%	0.48%	0.59%
Lightwood Log Creek	GA	1	638.0	0.47%	0.00%	0.50%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	1.37%	0.64%	1.37%	1.37%	0.46%	0.16%	0.48%	0.59%
Sadlers Creek State Park #1	SC	2	638.0	0.47%	0.00%	0.50%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.09%	1.37%	0.64%	1.37%	1.37%	0.46%	0.16%	0.48%	0.59%

* The elevation below which ramps may not be usable for most boats is presented as three feet above the top of the concrete ramp end elevation.

Table 4.3-4 Number of Days Boat Ramps are Unusable on Hartwell Lake (With Future Water Withdrawals and Historic Hydrology) (1939 – 2011)

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Sadler's Creek State Park	SC	1	658.0	3,842	3,833	3,905	3,925	1,202	1,216	1,266	1,274	3,329	3,322	3,426	3,446	5,466	5,442	5,507	5,512	13,839	13,813	14,104	14,157
Tugaloo State Park	GA	2	658.0	3,842	3,833	3,905	3,925	1,202	1,216	1,266	1,274	3,329	3,322	3,426	3,446	5,466	5,442	5,507	5,512	13,839	13,813	14,104	14,157
Jack's Landing	SC	1	658.0	3,842	3,833	3,905	3,925	1,202	1,216	1,266	1,274	3,329	3,322	3,426	3,446	5,466	5,442	5,507	5,512	13,839	13,813	14,104	14,157
Holder's Access	SC	1	658.0	3,842	3,833	3,905	3,925	1,202	1,216	1,266	1,274	3,329	3,322	3,426	3,446	5,466	5,442	5,507	5,512	13,839	13,813	14,104	14,157
Lakeshore	SC	1	658.0	3,842	3,833	3,905	3,925	1,202	1,216	1,266	1,274	3,329	3,322	3,426	3,446	5,466	5,442	5,507	5,512	13,839	13,813	14,104	14,157
Mountain Bay	SC	1	658.0	3,842	3,833	3,905	3,925	1,202	1,216	1,266	1,274	3,329	3,322	3,426	3,446	5,466	5,442	5,507	5,512	13,839	13,813	14,104	14,157
Reed Creek	GA	1	657.5	3,371	3,360	3,486	3,484	1,044	1,047	1,067	1,081	2,639	2,624	2,830	2,858	5,040	5,020	5,080	5,085	12,094	12,051	12,463	12,508
Rocky Ford	GA	1	657.5	3,371	3,360	3,486	3,484	1,044	1,047	1,067	1,081	2,639	2,624	2,830	2,858	5,040	5,020	5,080	5,085	12,094	12,051	12,463	12,508
Brown Road	SC	1	657.0	2,879	2,874	2,994	2,994	874	878	911	919	1,992	1,977	2,288	2,314	4,587	4,560	4,675	4,682	10,332	10,289	10,868	10,909
Hurricane Creek	SC	1	657.0	2,879	2,874	2,994	2,994	874	878	911	919	1,992	1,977	2,288	2,314	4,587	4,560	4,675	4,682	10,332	10,289	10,868	10,909
Seneca Creek	SC	1	657.0	2,879	2,874	2,994	2,994	874	878	911	919	1,992	1,977	2,288	2,314	4,587	4,560	4,675	4,682	10,332	10,289	10,868	10,909
Walker Creek	GA	1	657.0	2,879	2,874	2,994	2,994	874	878	911	919	1,992	1,977	2,288	2,314	4,587	4,560	4,675	4,682	10,332	10,289	10,868	10,909
Cove Inlet	SC	1	656.5	2,405	2,403	2,532	2,542	778	778	808	820	1,640	1,646	1,917	1,945	4,100	4,083	4,263	4,262	8,923	8,910	9,520	9,569
Durham	SC	1	655.7	1,668	1,669	1,776	1,781	672	669	683	678	1,298	1,305	1,505	1,528	2,814	2,794	3,172	3,178	6,452	6,437	7,136	7,165
South Union	SC	1	655.5	1,613	1,618	1,708	1,721	642	636	660	651	1,256	1,261	1,443	1,460	2,704	2,682	3,060	3,088	6,215	6,197	6,871	6,920
Bradberry	GA	1	655.0	1,480	1,481	1,601	1,613	593	585	615	612	1,158	1,167	1,305	1,315	2,454	2,435	2,811	2,843	5,685	5,668	6,332	6,383
Timberland	SC	1	654.0	1,078	1,058	1,251	1,259	490	428	491	492	913	920	1,033	1,036	1,987	1,973	2,322	2,334	4,468	4,379	5,097	5,121
Darvin Wright City Park	SC	1	653.0	762	763	845	846	329	284	345	352	659	648	694	708	1,375	1,358	1,705	1,681	3,125	3,053	3,589	3,587
Tillies	SC	1	653.0	762	763	845	846	329	284	345	352	659	648	694	708	1,375	1,358	1,705	1,681	3,125	3,053	3,589	3,587
White City	SC	1	653.0	762	763	845	846	329	284	345	352	659	648	694	708	1,375	1,358	1,705	1,681	3,125	3,053	3,589	3,587
Barton Mill	SC	1	653.0	762	763	845	846	329	284	345	352	659	648	694	708	1,375	1,358	1,705	1,681	3,125	3,053	3,589	3,587
Port Bass	SC	1	653.0	762	763	845	846	329	284	345	352	659	648	694	708	1,375	1,358	1,705	1,681	3,125	3,053	3,589	3,587
Seymour	GA	1	653.0	762	763	845	846	329	284	345	352	659	648	694	708	1,375	1,358	1,705	1,681	3,125	3,053	3,589	3,587
Payne's Creek (inner right)	GA	1	652.6	661	664	704	713	309	264	319	322	616	597	639	642	1,202	1,189	1,414	1,415	2,788	2,714	3,076	3,092
Payne's Creek (left)	GA	1	652.6	661	664	704	713	309	264	319	322	616	597	639	642	1,202	1,189	1,414	1,415	2,788	2,714	3,076	3,092
Big Oak (left lane)	GA	1	652.5	633	634	672	680	308	255	314	312	608	583	629	633	1,163	1,141	1,343	1,345	2,712	2,613	2,958	2,970
Tabor	SC	1	652.5	633	634	672	680	308	255	314	312	608	583	629	633	1,163	1,141	1,343	1,345	2,712	2,613	2,958	2,970
Townville	SC	1	652.3	549	552	604	616	297	248	305	304	585	554	612	615	1,102	1,079	1,232	1,246	2,533	2,433	2,753	2,781
Apple Island	SC	1	651.5	476	473	508	511	267	191	283	282	491	443	526	527	858	829	1,012	1,011	2,092	1,936	2,329	2,331
Poplar Spring (left ramp)	GA	1	651.5	476	473	508	511	267	191	283	282	491	443	526	527	858	829	1,012	1,011	2,092	1,936	2,329	2,331
Stephens Co.	GA	1	651.5	476	473	508	511	267	191	283	282	491	443	526	527	858	829	1,012	1,011	2,092	1,936	2,329	2,331
Broyles (East ramp)	SC	1	651.3	472	467	493	498	252	173	267	269	466	417	497	513	833	801	972	974	2,023	1,858	2,229	2,254
Friendship (left lane)	SC	1	651.0	460	452	483	484	227	157	247	248	443	380	470	475	816	773	911	916	1,946	1,762	2,111	2,123
Lawrence Bridge	SC	1	651.0	460	452	483	484	227	157	247	248	443	380	470	475	816	773	911	916	1,946	1,762	2,111	2,123
River Fork (right ramp)	SC	1	651.0	460	452	483	484	227	157	247	248	443	380	470	475	816	773	911	916	1,946	1,762	2,111	2,123

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Broyles (West ramp)	SC	1	650.5	425	411	469	469	203	136	210	212	402	329	427	429	774	748	813	826	1,804	1,624	1,919	1,936
Jarrett	SC	1	650.0	399	391	437	441	193	83	200	202	377	296	393	400	710	692	764	782	1,679	1,462	1,794	1,825
Holcomb	GA	1	650.0	399	391	437	441	193	83	200	202	377	296	393	400	710	692	764	782	1,679	1,462	1,794	1,825
Cleveland	GA	1	649.5	379	338	397	399	154	53	165	175	358	269	349	356	614	590	713	727	1,505	1,250	1,624	1,657
Spring Branch	GA	1	649.0	285	267	368	373	126	33	118	129	292	236	305	317	510	500	660	675	1,213	1,036	1,451	1,494
Honea Path	SC	1	648.5	245	237	332	338	100	22	99	99	234	196	266	272	456	443	573	586	1,035	898	1,270	1,295
Twin Lakes (right ramp)	SC	1	648.0	235	222	273	274	81	15	83	86	194	173	219	232	355	354	477	494	865	764	1,052	1,086
Twin Lakes (left ramp)	SC	1	648.0	235	222	273	274	81	15	83	86	194	173	219	232	355	354	477	494	865	764	1,052	1,086
Fairplay (left lane)	SC	1	647.0	167	130	221	225	58	5	61	62	153	149	166	175	262	264	354	370	640	548	802	832
Twelve Mile (left lane)	SC	1	647.0	167	130	221	225	58	5	61	62	153	149	166	175	262	264	354	370	640	548	802	832
Twelve Mile (right lane)	SC	1	647.0	167	130	221	225	58	5	61	62	153	149	166	175	262	264	354	370	640	548	802	832
Clemson	SC	1	645.5	90	60	112	114	39	0	37	38	99	93	120	122	112	134	209	207	340	287	478	481
Milltown	GA	1	645.4	90	58	105	107	37	0	35	37	95	91	118	121	103	130	194	196	325	279	452	461
Carters Ferry	GA	1	645.0	90	43	90	90	29	0	29	33	74	82	102	106	92	118	163	166	285	243	384	395
Watsadler	GA	1	645.0	90	43	90	90	29	0	29	33	74	82	102	106	92	118	163	166	285	243	384	395
Big Oaks (right lane)	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Camp Creek	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Choestoea	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Coneross	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Double Spring	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Duncan Branch	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Fairplay (right lane)	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Friendship (right lane)	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Glenn Ferry	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Green Pond	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Hatton's Ford	SC	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Long Point	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
New Prospect	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Rock Spring	GA	1	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Gum Branch	GA	6	644.0	87	20	87	89	0	0	0	0	60	60	78	84	92	97	92	94	239	177	257	267
Poplar Spring (right ramp)	GA	1	643.6	85	15	86	87	0	0	0	0	56	59	64	72	92	94	92	92	233	168	242	251
Springfield	SC	1	643.6	85	15	86	87	0	0	0	0	56	59	64	72	92	94	92	92	233	168	242	251
Crawford Ferry	GA	1	643.3	85	14	85	86	0	0	0	0	51	55	63	63	92	92	92	92	228	161	240	241
Asbury (camping)	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Denver	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Eighteen Mile Creek	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Elrod Ferry	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Jenkins Ferry	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Martin Creek	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Mary Ann Branch	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Oconee Point	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Paynes Creek (outer)	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Powder Bag Creek N	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Richland Creek	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
River Forks (left ramp)	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Singing Pines	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Weldon Island	SC	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Harbor Light Marina	GA	2	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Hartwell Marina	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Hart State Park	GA	2	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Portman Shoals	GA	1	643.0	84	8	85	85	0	0	0	0	51	48	61	63	92	92	92	92	227	148	238	240
Broyles (middle ramp)	SC	1	642.0	76	1	81	83	0	0	0	0	37	42	49	50	92	90	92	92	205	133	222	225
Tugaloo State Park (mega)	GA	6	642.0	76	1	81	83	0	0	0	0	37	42	49	50	92	90	92	92	205	133	222	225
Mullins Ford	SC	1	638.0	31	0	33	58	0	0	0	0	0	0	2	6	92	43	92	92	123	43	127	156
Big Water	SC	1	638.0	31	0	33	58	0	0	0	0	0	0	2	6	92	43	92	92	123	43	127	156
Bruce Creek	GA	1	638.0	31	0	33	58	0	0	0	0	0	0	2	6	92	43	92	92	123	43	127	156
Lake Hartwell State Park	SC	2	638.0	31	0	33	58	0	0	0	0	0	0	2	6	92	43	92	92	123	43	127	156
Lightwood Log Creek	GA	1	638.0	31	0	33	58	0	0	0	0	0	0	2	6	92	43	92	92	123	43	127	156
Sadlers Creek State Park #1	SC	2	638.0	31	0	33	58	0	0	0	0	0	0	2	6	92	43	92	92	123	43	127	156

* The elevation below which ramps may not be usable for most boats is presented as three feet above the top of the concrete ramp end elevation.

Table 4.3-5 Percentage of Days Boat Ramps are Unusable on JST Lake (With Future Water Withdrawals and Historic Hydrology) (1939 – 2011)

Boat Ramp Name	State	No. of Lanes	Not usable below elevation * (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Hwy 28 Access Road	SC	1	326.0	23.42%	23.44%	21.30%	21.34%	11.38%	11.62%	11.15%	11.38%	21.19%	20.80%	22.77%	23.33%	49.34%	49.53%	45.05%	45.39%	26.39%	26.40%	25.12%	25.42%
Long Cane Creek Ramp	SC	1	325.7	18.61%	18.70%	17.27%	17.44%	10.06%	10.34%	9.92%	10.31%	18.02%	17.76%	17.97%	18.52%	38.42%	38.66%	36.35%	36.47%	21.32%	21.41%	20.42%	20.73%
Catfish Ramp	SC	1	325.5	16.09%	16.26%	15.98%	16.24%	9.11%	9.51%	9.15%	9.50%	15.99%	15.86%	15.74%	16.26%	32.70%	33.00%	31.94%	32.26%	18.51%	18.69%	18.24%	18.60%
Calhoun Falls Ramp	SC	1	325.0	13.46%	13.81%	14.19%	14.42%	7.69%	7.78%	7.59%	7.81%	13.70%	13.74%	14.03%	14.09%	25.81%	25.67%	26.66%	27.04%	15.19%	15.28%	15.64%	15.87%
Broad River Campground	GA	1	325.0	13.46%	13.81%	14.19%	14.42%	7.69%	7.78%	7.59%	7.81%	13.70%	13.74%	14.03%	14.09%	25.81%	25.67%	26.66%	27.04%	15.19%	15.28%	15.64%	15.87%
Cherokee Recreation Area	GA	5	324.7	12.25%	12.48%	12.93%	13.02%	6.83%	6.89%	6.83%	7.21%	13.22%	13.30%	13.64%	13.62%	23.93%	23.63%	24.80%	25.12%	14.09%	14.10%	14.58%	14.77%
Mistletoe State Park 1 & 2	GA	2	324.2	9.85%	10.09%	10.79%	11.02%	5.83%	5.61%	6.10%	6.26%	12.37%	12.37%	12.89%	12.94%	21.65%	21.27%	22.58%	22.87%	12.46%	12.37%	13.12%	13.30%
Soap Creek Park	GA	1	324.0	9.14%	9.24%	10.06%	10.23%	5.61%	5.36%	5.75%	5.90%	12.03%	12.05%	12.55%	12.63%	20.79%	20.42%	22.11%	22.41%	11.92%	11.80%	12.65%	12.82%
Little River Quarry Ramp	SC	1	324.0	9.14%	9.24%	10.06%	10.23%	5.61%	5.36%	5.75%	5.90%	12.03%	12.05%	12.55%	12.63%	20.79%	20.42%	22.11%	22.41%	11.92%	11.80%	12.65%	12.82%
Lakeside Subdivision Ramp	GA	1	324.0	9.14%	9.24%	10.06%	10.23%	5.61%	5.36%	5.75%	5.90%	12.03%	12.05%	12.55%	12.63%	20.79%	20.42%	22.11%	22.41%	11.92%	11.80%	12.65%	12.82%
Scotts Ferry (new ramp) 1 & 2	SC	2	323.8	8.65%	8.70%	9.56%	9.78%	5.24%	4.58%	5.40%	5.51%	11.61%	11.76%	12.24%	12.34%	20.04%	19.78%	21.59%	21.97%	11.42%	11.23%	12.23%	12.43%
Clay Hill Campground	GA	1	323.5	8.30%	8.33%	9.23%	9.47%	4.34%	3.84%	4.74%	4.86%	11.05%	10.96%	11.58%	11.78%	18.73%	18.44%	20.73%	21.28%	10.63%	10.42%	11.60%	11.88%
Winfield Subdivision	GA	1	323.1	7.95%	7.89%	8.74%	8.99%	3.55%	3.45%	3.78%	3.91%	10.08%	10.02%	10.54%	10.90%	17.11%	16.87%	18.99%	19.99%	9.70%	9.58%	10.54%	10.97%
Mt Pleasant Ramp	SC	1	322.4	7.39%	7.39%	7.56%	7.71%	3.06%	3.00%	3.13%	3.16%	8.80%	8.67%	9.17%	9.26%	15.53%	15.40%	16.32%	16.84%	8.72%	8.63%	9.07%	9.27%
Wildwood Park 5 & 6	GA	2	322.0	7.16%	7.16%	7.32%	7.33%	2.88%	2.68%	2.91%	2.94%	8.07%	7.80%	8.58%	8.73%	14.37%	14.37%	15.28%	15.40%	8.14%	8.02%	8.54%	8.62%
Morrahs Ramp	GA	1	321.5	7.00%	6.94%	7.01%	7.01%	2.48%	2.05%	2.83%	2.81%	7.16%	6.82%	7.58%	7.67%	12.75%	12.72%	13.55%	13.60%	7.36%	7.15%	7.76%	7.79%
Bussey Point	GA	1	321.0	6.80%	6.74%	6.91%	6.92%	1.90%	1.87%	2.03%	2.15%	6.39%	5.90%	6.80%	6.95%	11.84%	11.48%	12.15%	12.20%	6.74%	6.51%	6.99%	7.07%
Chamberlain Ferry Ramp	GA	1	321.0	6.80%	6.74%	6.91%	6.92%	1.90%	1.87%	2.03%	2.15%	6.39%	5.90%	6.80%	6.95%	11.84%	11.48%	12.15%	12.20%	6.74%	6.51%	6.99%	7.07%
Modoc Campground	SC	1	321.0	6.80%	6.74%	6.91%	6.92%	1.90%	1.87%	2.03%	2.15%	6.39%	5.90%	6.80%	6.95%	11.84%	11.48%	12.15%	12.20%	6.74%	6.51%	6.99%	7.07%
Murray Creek Ramp	GA	1	321.0	6.80%	6.74%	6.91%	6.92%	1.90%	1.87%	2.03%	2.15%	6.39%	5.90%	6.80%	6.95%	11.84%	11.48%	12.15%	12.20%	6.74%	6.51%	6.99%	7.07%
Parkway Ramp	GA	1	321.0	6.80%	6.74%	6.91%	6.92%	1.90%	1.87%	2.03%	2.15%	6.39%	5.90%	6.80%	6.95%	11.84%	11.48%	12.15%	12.20%	6.74%	6.51%	6.99%	7.07%
Cherokee Recreation Area 4	GA	1	321.0	6.80%	6.74%	6.91%	6.92%	1.90%	1.87%	2.03%	2.15%	6.39%	5.90%	6.80%	6.95%	11.84%	11.48%	12.15%	12.20%	6.74%	6.51%	6.99%	7.07%
Fishing Creek / Hwy 79 Ramp	GA	1	320.7	6.47%	6.39%	6.74%	6.75%	1.76%	1.76%	1.91%	1.93%	6.03%	5.43%	6.33%	6.40%	11.47%	11.23%	11.76%	11.78%	6.44%	6.21%	6.70%	6.73%
Wildwood Park 3 & 4	GA	2	320.0	5.98%	5.90%	6.13%	6.16%	1.61%	1.45%	1.67%	1.69%	5.20%	4.53%	5.54%	5.66%	10.51%	10.31%	11.08%	11.09%	5.84%	5.55%	6.12%	6.16%

Boat Ramp Name	State	No. of Lanes	Not usable below elevation * (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Maxim Subdivision Ramp	GA	1	320.0	5.98%	5.90%	6.13%	6.16%	1.61%	1.45%	1.67%	1.69%	5.20%	4.53%	5.54%	5.66%	10.51%	10.31%	11.08%	11.09%	5.84%	5.55%	6.12%	6.16%
Wells Creek Subdivision	GA	1	320.0	5.98%	5.90%	6.13%	6.16%	1.61%	1.45%	1.67%	1.69%	5.20%	4.53%	5.54%	5.66%	10.51%	10.31%	11.08%	11.09%	5.84%	5.55%	6.12%	6.16%
Leroys Ferry Campground	SC	1	319.5	5.63%	5.27%	5.83%	5.92%	0.99%	0.90%	1.19%	1.32%	4.78%	4.04%	5.09%	5.18%	9.31%	8.98%	10.10%	10.17%	5.19%	4.80%	5.56%	5.66%
Ridge Road Campground	GA	1	319.0	4.25%	3.79%	4.74%	5.04%	0.53%	0.51%	0.63%	0.74%	4.27%	3.45%	4.62%	4.82%	7.65%	7.45%	8.16%	8.56%	4.19%	3.81%	4.55%	4.80%
Cherokee Recreation Area 3	GA	1	318.7	3.57%	3.46%	3.93%	4.14%	0.45%	0.41%	0.50%	0.54%	3.86%	3.16%	4.21%	4.35%	7.18%	7.09%	7.40%	7.64%	3.77%	3.54%	4.02%	4.18%
Chamberlain Ferry Ramp	GA	1	318.3	3.23%	3.17%	3.38%	3.43%	0.33%	0.32%	0.38%	0.41%	3.32%	2.83%	3.80%	3.93%	6.18%	6.06%	6.75%	6.85%	3.27%	3.10%	3.59%	3.66%
Double Branches Ramp	GA	1	318.1	3.14%	3.13%	3.17%	3.19%	0.29%	0.27%	0.33%	0.36%	3.05%	2.65%	3.47%	3.65%	5.64%	5.58%	6.17%	6.33%	3.04%	2.91%	3.29%	3.39%
Soap Creek Marina	GA	1	318.0	3.11%	3.08%	3.13%	3.14%	0.26%	0.26%	0.30%	0.35%	2.93%	2.61%	3.37%	3.57%	5.41%	5.41%	5.82%	6.08%	2.93%	2.84%	3.16%	3.29%
Cherokee Recreation Area 2	GA	1	318.0	3.11%	3.08%	3.13%	3.14%	0.26%	0.26%	0.30%	0.35%	2.93%	2.61%	3.37%	3.57%	5.41%	5.41%	5.82%	6.08%	2.93%	2.84%	3.16%	3.29%
Amity Recreation Area	GA	1	317.9	3.08%	3.04%	3.10%	3.11%	0.24%	0.24%	0.29%	0.32%	2.84%	2.55%	3.20%	3.41%	5.26%	5.29%	5.63%	5.78%	2.86%	2.78%	3.06%	3.16%
Raysville Marina	GA	1	317.6	2.82%	2.78%	2.94%	3.05%	0.18%	0.18%	0.23%	0.26%	2.64%	2.43%	2.90%	3.01%	4.84%	5.09%	5.17%	5.29%	2.63%	2.63%	2.82%	2.91%
Elbert County Subdivision Ramp	GA	1	317.6	2.82%	2.78%	2.94%	3.05%	0.18%	0.18%	0.23%	0.26%	2.64%	2.43%	2.90%	3.01%	4.84%	5.09%	5.17%	5.29%	2.63%	2.63%	2.82%	2.91%
Modoc Ramp 2	SC	1	317.2	2.35%	2.43%	2.34%	2.43%	0.11%	0.11%	0.15%	0.18%	2.41%	2.26%	2.64%	2.72%	4.29%	4.56%	4.75%	4.85%	2.30%	2.34%	2.48%	2.55%
Soap Creek / Hwy 220 Ramp	GA	1	317.0	2.14%	2.28%	1.73%	1.85%	0.06%	0.06%	0.12%	0.14%	2.32%	2.23%	2.49%	2.62%	4.05%	4.17%	4.48%	4.65%	2.15%	2.19%	2.21%	2.32%
Landam Creek Ramp	SC	1	316.2	0.71%	1.18%	0.90%	0.77%	0.00%	0.00%	0.00%	0.00%	1.98%	2.05%	2.16%	2.17%	2.64%	3.04%	2.68%	2.77%	1.34%	1.58%	1.44%	1.44%
Dordon Creek Ramp	SC	1	316.2	0.71%	1.18%	0.90%	0.77%	0.00%	0.00%	0.00%	0.00%	1.98%	2.05%	2.16%	2.17%	2.64%	3.04%	2.68%	2.77%	1.34%	1.58%	1.44%	1.44%
Hickory Knob State Park	SC	1	316.2	0.71%	1.18%	0.90%	0.77%	0.00%	0.00%	0.00%	0.00%	1.98%	2.05%	2.16%	2.17%	2.64%	3.04%	2.68%	2.77%	1.34%	1.58%	1.44%	1.44%
Elijah Clark State Park 1, 2, & 3	GA	1	316.0	0.64%	0.96%	0.88%	0.71%	0.00%	0.00%	0.00%	0.00%	1.86%	1.97%	2.08%	2.10%	2.40%	2.70%	2.31%	2.61%	1.23%	1.41%	1.32%	1.36%
Holiday Park	GA	1	315.6	0.53%	0.88%	0.73%	0.59%	0.00%	0.00%	0.00%	0.00%	1.59%	1.79%	1.83%	1.91%	1.67%	2.17%	1.98%	2.06%	0.95%	1.22%	1.14%	1.14%
Ft. Gordon Recreation Area 1 & 2	GA	2	315.0	0.33%	0.65%	0.58%	0.46%	0.00%	0.00%	0.00%	0.00%	1.07%	1.43%	1.28%	1.47%	1.06%	1.79%	1.68%	1.59%	0.62%	0.97%	0.89%	0.89%
Plum Branch Yacht Club	SC	1	315.0	0.33%	0.65%	0.58%	0.46%	0.00%	0.00%	0.00%	0.00%	1.07%	1.43%	1.28%	1.47%	1.06%	1.79%	1.68%	1.59%	0.62%	0.97%	0.89%	0.89%
Wildwood Park 1 & 2	GA	2	315.0	0.33%	0.65%	0.58%	0.46%	0.00%	0.00%	0.00%	0.00%	1.07%	1.43%	1.28%	1.47%	1.06%	1.79%	1.68%	1.59%	0.62%	0.97%	0.89%	0.89%

Boat Ramp Name	State	No. of Lanes	Not usable below elevation * (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Bobby Brown State Park 1 & 2	GA	2	315.0	0.33%	0.65%	0.58%	0.46%	0.00%	0.00%	0.00%	0.00%	1.07%	1.43%	1.28%	1.47%	1.06%	1.79%	1.68%	1.59%	0.62%	0.97%	0.89%	0.89%
New Bourdeaux Subdivision Ramp	SC	1	315.0	0.33%	0.65%	0.58%	0.46%	0.00%	0.00%	0.00%	0.00%	1.07%	1.43%	1.28%	1.47%	1.06%	1.79%	1.68%	1.59%	0.62%	0.97%	0.89%	0.89%
Gill Point Ramp	GA	1	314.8	0.32%	0.59%	0.52%	0.36%	0.00%	0.00%	0.00%	0.00%	0.88%	1.31%	0.77%	1.09%	1.06%	1.68%	1.24%	1.30%	0.57%	0.90%	0.63%	0.69%
Cherokee Recreation Area 1	GA	1	314.6	0.29%	0.50%	0.49%	0.33%	0.00%	0.00%	0.00%	0.00%	0.73%	1.12%	0.51%	0.83%	1.04%	1.58%	1.09%	1.10%	0.52%	0.80%	0.52%	0.57%
Little River / Hwy 378	SC	1	314.5	0.29%	0.44%	0.47%	0.32%	0.00%	0.00%	0.00%	0.00%	0.60%	1.01%	0.45%	0.77%	1.04%	1.53%	1.07%	1.06%	0.48%	0.75%	0.50%	0.54%
Parksville Recreation Area	SC	1	314.5	0.29%	0.44%	0.47%	0.32%	0.00%	0.00%	0.00%	0.00%	0.60%	1.01%	0.45%	0.77%	1.04%	1.53%	1.07%	1.06%	0.48%	0.75%	0.50%	0.54%
Buffalo Creek Subdivision Ramp	SC	1	314.5	0.29%	0.44%	0.47%	0.32%	0.00%	0.00%	0.00%	0.00%	0.60%	1.01%	0.45%	0.77%	1.04%	1.53%	1.07%	1.06%	0.48%	0.75%	0.50%	0.54%
Dorn 1, 2, 5, & 6	SC	4	314.4	0.27%	0.36%	0.44%	0.32%	0.00%	0.00%	0.00%	0.00%	0.36%	0.92%	0.37%	0.61%	1.04%	1.49%	1.06%	1.06%	0.42%	0.70%	0.47%	0.50%
Amity Recreation Area 2	GA	1	314.3	0.26%	0.32%	0.39%	0.30%	0.00%	0.00%	0.00%	0.00%	0.25%	0.80%	0.33%	0.46%	1.04%	1.46%	1.06%	1.04%	0.39%	0.65%	0.45%	0.45%
Hamilton Branch State Park (Day Use)	SC	1	314.0	0.17%	0.23%	0.33%	0.26%	0.00%	0.00%	0.00%	0.00%	0.07%	0.64%	0.16%	0.16%	1.04%	1.25%	1.04%	1.04%	0.32%	0.53%	0.39%	0.37%
Hamilton Branch State Park 1 & 2	SC	2	314.0	0.17%	0.23%	0.33%	0.26%	0.00%	0.00%	0.00%	0.00%	0.07%	0.64%	0.16%	0.16%	1.04%	1.25%	1.04%	1.04%	0.32%	0.53%	0.39%	0.37%
Little River Marina 1	GA	1	314.0	0.17%	0.23%	0.33%	0.26%	0.00%	0.00%	0.00%	0.00%	0.07%	0.64%	0.16%	0.16%	1.04%	1.25%	1.04%	1.04%	0.32%	0.53%	0.39%	0.37%
Baker Creek State Park	SC	1	314.0	0.17%	0.23%	0.33%	0.26%	0.00%	0.00%	0.00%	0.00%	0.07%	0.64%	0.16%	0.16%	1.04%	1.25%	1.04%	1.04%	0.32%	0.53%	0.39%	0.37%
Tradewinds Marina	GA	1	314.0	0.17%	0.23%	0.33%	0.26%	0.00%	0.00%	0.00%	0.00%	0.07%	0.64%	0.16%	0.16%	1.04%	1.25%	1.04%	1.04%	0.32%	0.53%	0.39%	0.37%
Morrahs Ramp 2	GA	1	314.0	0.17%	0.23%	0.33%	0.26%	0.00%	0.00%	0.00%	0.00%	0.07%	0.64%	0.16%	0.16%	1.04%	1.25%	1.04%	1.04%	0.32%	0.53%	0.39%	0.37%
Amity Recreation Area 3	GA	1	313.8	0.02%	0.15%	0.11%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.01%	0.03%	0.91%	1.22%	0.98%	1.04%	0.23%	0.48%	0.28%	0.33%
Big Hart Recreation Area	GA	1	313.8	0.02%	0.15%	0.11%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.55%	0.01%	0.03%	0.91%	1.22%	0.98%	1.04%	0.23%	0.48%	0.28%	0.33%
Petersburg Campground	GA	1	313.7	0.00%	0.11%	0.06%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.52%	0.00%	0.01%	0.82%	1.21%	0.92%	0.95%	0.21%	0.46%	0.25%	0.26%
Mt. Carmel Picnic	SC	1	313.7	0.00%	0.11%	0.06%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.52%	0.00%	0.01%	0.82%	1.21%	0.92%	0.95%	0.21%	0.46%	0.25%	0.26%
Modoc Ramp 1	SC	1	313.5	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.00%	0.70%	1.13%	0.80%	0.82%	0.18%	0.42%	0.20%	0.21%
Clarks Hill Park	GA	1	313.5	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.00%	0.70%	1.13%	0.80%	0.82%	0.18%	0.42%	0.20%	0.21%
Hawe Creek Campground	SC	1	313.5	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.00%	0.70%	1.13%	0.80%	0.82%	0.18%	0.42%	0.20%	0.21%

Boat Ramp Name	State	No. of Lanes	Not usable below elevation * (ft AMSL)	Percentage of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Little River Subdivision Ramp	SC	1	313.5	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.00%	0.70%	1.13%	0.80%	0.82%	0.18%	0.42%	0.20%	0.21%
Mistletoe State Park Low Water Ramp	GA	1	313.5	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%	0.00%	0.70%	1.13%	0.80%	0.82%	0.18%	0.42%	0.20%	0.21%
Hesters Ferry Campground	GA	1	312.9	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.00%	0.06%	0.95%	0.51%	0.40%	0.02%	0.31%	0.13%	0.10%
Raysville Campground	GA	1	312.2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.12%	0.00%	0.00%	0.00%	0.83%	0.00%	0.00%	0.00%	0.24%	0.00%	0.00%
Winfield Campground	GA	1	311.7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Little River Marina 2	GA	1	311.3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mt. Carmel Campground	SC	1	311.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scotts Ferry Ramp	SC	1	310.7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Modoc Shores Subdivision Ramp	SC	1	310.4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Keg Creek Ramp	GA	1	309.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lake Springs Park 1, 2, & 3	GA	3	308.7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dorn 3 & 4	SC	2	308.4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Leathersville Ramp	GA	1	306.3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

* The elevation below which ramps may not be usable for most boats is presented as two feet above the top of the concrete ramp end elevation.

Table 4.3-6 Number of Days Boat Ramps are Unusable on JST Lake (With Future Water Withdrawals and Historic Hydrology) (1939 – 2011)

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Hwy 28 Access Road	SC	1	326.0	1,543	1,544	1,403	1,406	756	772	741	756	1,423	1,397	1,529	1,567	3,313	3,326	3,025	3,048	7,035	7,039	6,698	6,777
Long Cane Creek Ramp	SC	1	325.7	1,226	1,232	1,138	1,149	668	687	659	685	1,210	1,193	1,207	1,244	2,580	2,596	2,441	2,449	5,684	5,708	5,445	5,527
Catfish Ramp	SC	1	325.5	1,060	1,071	1,053	1,070	605	632	608	631	1,074	1,065	1,057	1,092	2,196	2,216	2,145	2,166	4,935	4,984	4,863	4,959
Calhoun Falls Ramp	SC	1	325.0	887	910	935	950	511	517	504	519	920	923	942	946	1,733	1,724	1,790	1,816	4,051	4,074	4,171	4,231
Broad River Campground	GA	1	325.0	887	910	935	950	511	517	504	519	920	923	942	946	1,733	1,724	1,790	1,816	4,051	4,074	4,171	4,231
Cherokee Recreation Area	GA	5	324.7	807	822	852	858	454	458	454	479	888	893	916	915	1,607	1,587	1,665	1,687	3,756	3,760	3,887	3,939
Mistletoe State Park 1 & 2	GA	2	324.2	649	665	711	726	387	373	405	416	831	831	866	869	1,454	1,428	1,516	1,536	3,321	3,297	3,498	3,547
Soap Creek Park	GA	1	324.0	602	609	663	674	373	356	382	392	808	809	843	848	1,396	1,371	1,485	1,505	3,179	3,145	3,373	3,419
Little River Quarry Ramp	SC	1	324.0	602	609	663	674	373	356	382	392	808	809	843	848	1,396	1,371	1,485	1,505	3,179	3,145	3,373	3,419
Lakeside Subdivision Ramp	GA	1	324.0	602	609	663	674	373	356	382	392	808	809	843	848	1,396	1,371	1,485	1,505	3,179	3,145	3,373	3,419
Scotts Ferry (new ramp) 1 & 2	SC	2	323.8	570	573	630	644	348	304	359	366	780	790	822	829	1,346	1,328	1,450	1,475	3,044	2,995	3,261	3,314
Clay Hill Campground	GA	1	323.5	547	549	608	624	288	255	315	323	742	736	778	791	1,258	1,238	1,392	1,429	2,835	2,778	3,093	3,167
Winfield Subdivision	GA	1	323.1	524	520	576	592	236	229	251	260	677	673	708	732	1,149	1,133	1,275	1,342	2,586	2,555	2,810	2,926
Mt Pleasant Ramp	SC	1	322.4	487	487	498	508	203	199	208	210	591	582	616	622	1,043	1,034	1,096	1,131	2,324	2,302	2,418	2,471
Wildwood Park 5 & 6	GA	2	322.0	472	472	482	483	191	178	193	195	542	524	576	586	965	965	1,026	1,034	2,170	2,139	2,277	2,298
Morrahs Ramp	GA	1	321.5	461	457	462	462	165	136	188	187	481	458	509	515	856	854	910	913	1,963	1,905	2,069	2,077
Bussey Point	GA	1	321.0	448	444	455	456	126	124	135	143	429	396	457	467	795	771	816	819	1,798	1,735	1,863	1,885
Chamberlain Ferry Ramp	GA	1	321.0	448	444	455	456	126	124	135	143	429	396	457	467	795	771	816	819	1,798	1,735	1,863	1,885
Modoc Campground	SC	1	321.0	448	444	455	456	126	124	135	143	429	396	457	467	795	771	816	819	1,798	1,735	1,863	1,885
Murray Creek Ramp	GA	1	321.0	448	444	455	456	126	124	135	143	429	396	457	467	795	771	816	819	1,798	1,735	1,863	1,885
Parkway Ramp	GA	1	321.0	448	444	455	456	126	124	135	143	429	396	457	467	795	771	816	819	1,798	1,735	1,863	1,885
Cherokee Recreation Area 4	GA	1	321.0	448	444	455	456	126	124	135	143	429	396	457	467	795	771	816	819	1,798	1,735	1,863	1,885
Fishing Creek / Hwy 79 Ramp	GA	1	320.7	426	421	444	445	117	117	127	128	405	365	425	430	770	754	790	791	1,718	1,657	1,786	1,794
Wildwood Park 3 & 4	GA	2	320.0	394	389	404	406	107	96	111	112	349	304	372	380	706	692	744	745	1,556	1,481	1,631	1,643
Maxim Subdivision Ramp	GA	1	320.0	394	389	404	406	107	96	111	112	349	304	372	380	706	692	744	745	1,556	1,481	1,631	1,643
Wells Creek Subdivision	GA	1	320.0	394	389	404	406	107	96	111	112	349	304	372	380	706	692	744	745	1,556	1,481	1,631	1,643
Leroys Ferry Campground	SC	1	319.5	371	347	384	390	66	60	79	88	321	271	342	348	625	603	678	683	1,383	1,281	1,483	1,509
Ridge Road Campground	GA	1	319.0	280	250	312	332	35	34	42	49	287	232	310	324	514	500	548	575	1,116	1,016	1,212	1,280
Cherokee Recreation Area 3	GA	1	318.7	235	228	259	273	30	27	33	36	259	212	283	292	482	476	497	513	1,006	943	1,072	1,114
Chamberlain Ferry Ramp	GA	1	318.3	213	209	223	226	22	21	25	27	223	190	255	264	415	407	453	460	873	827	956	977
Double Branches Ramp	GA	1	318.1	207	206	209	210	19	18	22	24	205	178	233	245	379	375	414	425	810	777	878	904
Soap Creek Marina	GA	1	318.0	205	203	206	207	17	17	20	23	197	175	226	240	363	363	391	408	782	758	843	878
Cherokee Recreation Area 2	GA	1	318.0	205	203	206	207	17	17	20	23	197	175	226	240	363	363	391	408	782	758	843	878
Amity Recreation Area	GA	1	317.9	203	200	204	205	16	16	19	21	191	171	215	229	353	355	378	388	763	742	816	843
Raysville Marina	GA	1	317.6	186	183	194	201	12	12	15	17	177	163	195	202	325	342	347	355	700	700	751	775
Elbert County Subdivision Ramp	GA	1	317.6	186	183	194	201	12	12	15	17	177	163	195	202	325	342	347	355	700	700	751	775
Modoc Ramp 2	SC	1	317.2	155	160	154	160	7	7	10	12	162	152	177	183	288	306	319	326	612	625	660	681
Soap Creek / Hwy 220	GA	1	317.0	141	150	114	122	4	4	8	9	156	150	167	176	272	280	301	312	573	584	590	619

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Ramp																							
Landam Creek Ramp	SC	1	316.2	47	78	59	51	0	0	0	0	133	138	145	146	177	204	180	186	357	420	384	383
Dordon Creek Ramp	SC	1	316.2	47	78	59	51	0	0	0	0	133	138	145	146	177	204	180	186	357	420	384	383
Hickory Knob State Park	SC	1	316.2	47	78	59	51	0	0	0	0	133	138	145	146	177	204	180	186	357	420	384	383
Elijah Clark State Park 1, 2, & 3	GA	1	316.0	42	63	58	47	0	0	0	0	125	132	140	141	161	181	155	175	328	376	353	363
Holiday Park	GA	1	315.6	35	58	48	39	0	0	0	0	107	120	123	128	112	146	133	138	254	324	304	305
Ft. Gordon Recreation Area 1 & 2	GA	2	315.0	22	43	38	30	0	0	0	0	72	96	86	99	71	120	113	107	165	259	237	236
Plum Branch Yacht Club	SC	1	315.0	22	43	38	30	0	0	0	0	72	96	86	99	71	120	113	107	165	259	237	236
Wildwood Park 1 & 2	GA	2	315.0	22	43	38	30	0	0	0	0	72	96	86	99	71	120	113	107	165	259	237	236
Bobby Brown State Park 1 & 2	GA	2	315.0	22	43	38	30	0	0	0	0	72	96	86	99	71	120	113	107	165	259	237	236
New Bourdeaux Subdivision Ramp	SC	1	315.0	22	43	38	30	0	0	0	0	72	96	86	99	71	120	113	107	165	259	237	236
Gill Point Ramp	GA	1	314.8	21	39	34	24	0	0	0	0	59	88	52	73	71	113	83	87	151	240	169	184
Cherokee Recreation Area 1	GA	1	314.6	19	33	32	22	0	0	0	0	49	75	34	56	70	106	73	74	138	214	139	152
Little River / Hwy 378	SC	1	314.5	19	29	31	21	0	0	0	0	40	68	30	52	70	103	72	71	129	200	133	144
Parksville Recreation Area	SC	1	314.5	19	29	31	21	0	0	0	0	40	68	30	52	70	103	72	71	129	200	133	144
Buffalo Creek Subdivision Ramp	SC	1	314.5	19	29	31	21	0	0	0	0	40	68	30	52	70	103	72	71	129	200	133	144
Dorn 1, 2, 5, & 6	SC	4	314.4	18	24	29	21	0	0	0	0	24	62	25	41	70	100	71	71	112	186	125	133
Amity Recreation Area 2	GA	1	314.3	17	21	26	20	0	0	0	0	17	54	22	31	70	98	71	70	104	173	119	121
Hamilton Branch State Park (Day Use)	SC	1	314.0	11	15	22	17	0	0	0	0	5	43	11	11	70	84	70	70	86	142	103	98
Hamilton Branch State Park 1 & 2	SC	2	314.0	11	15	22	17	0	0	0	0	5	43	11	11	70	84	70	70	86	142	103	98
Little River Marina 1	GA	1	314.0	11	15	22	17	0	0	0	0	5	43	11	11	70	84	70	70	86	142	103	98
Baker Creek State Park	SC	1	314.0	11	15	22	17	0	0	0	0	5	43	11	11	70	84	70	70	86	142	103	98
Tradewinds Marina	GA	1	314.0	11	15	22	17	0	0	0	0	5	43	11	11	70	84	70	70	86	142	103	98
Morrahs Ramp 2	GA	1	314.0	11	15	22	17	0	0	0	0	5	43	11	11	70	84	70	70	86	142	103	98
Amity Recreation Area 3	GA	1	313.8	1	10	7	15	0	0	0	0	0	37	1	2	61	82	66	70	62	129	74	87
Big Hart Recreation Area	GA	1	313.8	1	10	7	15	0	0	0	0	0	37	1	2	61	82	66	70	62	129	74	87
Petersburg Campground	GA	1	313.7	0	7	4	4	0	0	0	0	0	35	0	1	55	81	62	64	55	123	66	69
Mt. Carmel Picnic	SC	1	313.7	0	7	4	4	0	0	0	0	0	35	0	1	55	81	62	64	55	123	66	69
Modoc Ramp 1	SC	1	313.5	0	5	0	0	0	0	0	0	0	32	0	0	47	76	54	55	47	113	54	55
Clarks Hill Park	GA	1	313.5	0	5	0	0	0	0	0	0	0	32	0	0	47	76	54	55	47	113	54	55
Hawe Creek Campground	SC	1	313.5	0	5	0	0	0	0	0	0	0	32	0	0	47	76	54	55	47	113	54	55
Little River Subdivision Ramp	SC	1	313.5	0	5	0	0	0	0	0	0	0	32	0	0	47	76	54	55	47	113	54	55
Mistletoe State Park Low Water Ramp	GA	1	313.5	0	5	0	0	0	0	0	0	0	32	0	0	47	76	54	55	47	113	54	55
Hesters Ferry Campground	GA	1	312.9	0	4	0	0	0	0	0	0	0	14	0	0	4	64	34	27	4	82	34	27
Raysville Campground	GA	1	312.2	0	0	0	0	0	0	0	0	0	8	0	0	0	56	0	0	0	64	0	0
Winfield Campground	GA	1	311.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Boat Ramp Name	State	No. of Lanes	Not usable below elevation* (ft AMSL)	Number of days when ramp is not usable																			
				Jan - Mar (6,588 days)				Apr - Jun (6,643 days)				Jul - Sep (6,716 days)				Oct - Dec (6,715 days)				Total POR (26,662 days)			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Little River Marina 2	GA	1	311.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mt. Carmel Campground	SC	1	311.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scotts Ferry Ramp	SC	1	310.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Modoc Shores Subdivision Ramp	SC	1	310.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keg Creek Ramp	GA	1	309.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Springs Park 1, 2, & 3	GA	3	308.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dorn 3 & 4	SC	2	308.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leathersville Ramp	GA	1	306.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* The elevation below which ramps may not be usable for most boats is presented as two feet above the top of the concrete ramp end elevation.

Using climate change hydrology instead of historic hydrology results in more unusable ramp days at both Hartwell and JST Lakes. Differences between both the seasonal results and annual results mirror those of the future water withdrawals with historic hydrology model runs. See Tables N-9 through N-12 in Appendix N for detailed results for Hartwell Lake and JST Lake, respectively.

4.3.2 *Lower Savannah River Basin Public Boat-Launching Ramps*

There are approximately fifty-five known public boat ramps with various owners in the Lower Savannah River Basin. No information was available regarding the usability of the boat ramps at various river flows. However, since USACE would continue to discharge from JST Dam under the conditions of the 2012 Drought Plan under all of the alternatives, no changes would occur in the daily volume of flow released from JST. Therefore, no impacts to boat ramps in the Lower Savannah River Basin are expected from any alternative.

4.3.3 *Swimming*

There are no specific criteria for public swimming areas to be closed due to reservoir elevations on the Duke Energy reservoirs. Therefore, none of the operating scenarios are expected to impact swimming access at the Duke Energy facilities. When reservoir levels at Hartwell Lake drop to 657 feet AMSL, the swimming areas become less desirable (USACE 2008a), and at reservoir elevations of 654 feet AMSL and lower, all designated swimming areas are dry. Hartwell Lake drops below 657 feet AMSL annually and below 654 feet AMSL during most moderate and extreme droughts (Figure 3.5-1). There are only minor differences in the frequency and duration of such occurrences between the alternatives. At JST Lake, when elevations drop to 327 feet AMSL, the swimming areas become less desirable (USACE 2008a). When reservoir elevations drop to 324 feet AMSL, all designated swimming areas are dry (USACE 2008a). Like Hartwell Lake, swimming areas at JST have occurrences of limited access. However, only during moderate and extreme droughts (i.e., 1955-1956, 1982, 1987-1989, 2000-2003, and 2007-2009) do the swimming areas become completely dry (Figure 3.5-3). There are only minor differences in swimming access in JST Lake between the modeling alternatives.

4.3.4 *Mitigation for Impacts to Recreation*

The proposed alternatives would modify water levels in the Duke and USACE reservoirs during droughts, altering the availability of some boat ramps to recreational users. The following table shows the effects of the proposed alternatives on users of the boat ramps around the Duke Energy projects:

Table 4.4-7 Number of Days Boat Ramps Are Not Available

DUKE ENERGY PROJECT	ALTERNATIVES			
	NAA / A1	A2	A3	A4
Jocassee	1	0	0	0
Keowee	2,225	0	36	79
Total	2,226	0	36	79

Notes: (1) Number of days in the 26,662 day (73-year) period of record.
(2) These numbers include only boat ramps that are operated by Duke Energy

The boat ramps on the Duke Energy projects would be available more days with each of the proposed alternatives. No mitigation is needed for this beneficial effect.

Previous Corps documents reveal the following level of visitors at the USACE projects and those that use the recreation areas:

Table 4.3-8 Visitation at USACE Reservoirs

USACE PROJECT	TOTAL ANNUAL VISITATION	VISITATION TO RECREATION AREAS
Hartwell	10,085,193	2,318,568
Richard B. Russell	999,866	917,125
J. Strom Thurmond	5,692,851	1,950,967

Note: 10-year average from 2003-2012

In general, the alternatives would reduce pool levels in the USACE reservoirs and the availability of some boat ramps, leading to lower access to the water and a loss in recreational use of the reservoirs. Pool levels at RBR would not be noticeably affected by any of the alternatives, so no impacts to recreational users are expected at that project. For the Hartwell and JST Projects, USACE evaluated the value of the lost access and use by following the USACE Economic Guidance Memorandum, 14-03, Unit Day Values for Recreation for Fiscal Year 2014. Through procedures included in that document, unit day values can be developed for an average day of recreational use on the two USACE reservoirs. That value can then be multiplied by the number of days an alternative would impact users to produce an economic value for the lost recreational access and use. Savannah District used the following assumptions in its development of unit day values for recreational use on the Hartwell and JST reservoirs:

- Considered General Recreation
- Recreational experience
    - Several general activities; one high quality value activity
    - 16 points (out of 30 points)
- Availability of opportunity
    - Several within 1 hour travel time; a few within 30 minutes travel time
    - 3 points (out of 18 points)
- Carrying capacity
    - Optimum facilities to conduct activity at site
    - 11 points (out of 14 points)
- Accessibility
    - Good access, high standard road to site; good access within site
    - 18 points (out of 18 points)
- Environmental quality
    - High aesthetic quality; no factors exist that lower quality
    - 15 points (out of 20 points)

Appendix V contains the full USACE Economic Guidance Memorandum, 14-03, Unit Day Values for Recreation for Fiscal Year 2014. That document describes how points should be assigned and the criteria for assigning different values. Using the points described above, Savannah District believes the recreational value for use of the Hartwell and JST reservoirs has a total of 63 points. Using the information below from USACE Economic Guidance Memorandum 14-03, the economic value of that use would be $8.89 per day.

Table 4.3-9 Conversion of Points to Dollar Values

Point Values	General Recreation Values (1)	General Fishing and Hunting Values (1)	Specialized Fishing and Hunting Values (2)	Specialized Recreation Values other than Fishing and Hunting (2)
0	$ 3.84	$ 5.52	$ 26.90	$ 15.61
10	$ 4.56	$ 6.24	$ 27.62	$ 16.57
20	$ 5.04	$ 6.72	$ 28.10	$ 17.77
30	$ 5.76	$ 7.44	$ 28.82	$ 19.21
40	$ 7.20	$ 8.17	$ 29.54	$ 20.41
50	$ 8.17	$ 8.89	$ 32.42	$ 23.05
60	$ 8.89	$ 9.85	$ 35.30	$ 25.46
70	$ 9.37	$ 10.33	$ 37.46	$ 30.74
80	$ 10.33	$ 11.05	$ 40.35	$ 35.78
90	$ 11.05	$ 11.29	$ 43.23	$ 40.83
100	$ 11.53	$ 11.53	$ 45.63	$ 45.63

Based on a unit day value of $8.89 per day for recreation users of the USACE reservoirs, the effects of the alternatives on recreation are calculated as shown in the following two pages and summarized in Table 4.3-10.

J. Strom Thurmond

Boat Ramp Name	State	No. of Lanes	Not useable below elevation (ft AMSL)	Number of days when ramp is not useable					Percent of time that lane not available				Years	Number of days in 50 Years that Lanes not Available				Visitors per year	Total Revenue Lost				if positive, the location lost less than the NAA			
				Oct - Dec (6,715 days)	Total POR (26,662 days)								50										Delta Total Revenue Lost			
				A4	NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	days	NAA/A1	A2	A3	A4		NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Amity Recreation Area 3	GA	1	313.8	70	62	129	74	87	0.2%	0.5%	0.3%	0.3%	18250	42	88	51	60	49860.8	$ 51,538	$ 107,233	$ 61,513	$ 72,320	$ -	$ (55,695)	$ (9,975)	$ (20,782)
Baker Creek State Park	SC	1	314.0	70	86	142	103	98	0.3%	0.5%	0.4%	0.4%	18250	59	97	71	67	32269.7	$ 46,267	$ 76,395	$ 55,413	$ 52,723	$ -	$ (30,127)	$ (9,146)	$ (6,456)
Big Hart Recreation Area	GA	1	313.8	70	62	129	74	87	0.2%	0.5%	0.3%	0.3%	18250	42	88	51	60	34182.8	$ 35,333	$ 73,515	$ 42,171	$ 49,580	$ -	$ (38,182)	$ (6,839)	$ (14,247)
Bobby Brown State Park 1 & 2	GA	2	315.0	107	165	259	237	236	0.6%	1.0%	0.9%	0.9%	18250	113	177	162	162	32719.7	$ 90,006	$ 141,282	$ 129,282	$ 128,736	$ -	$ (51,276)	$ (39,275)	$ (38,730)
Broad River Campground	GA	1	325.0	1,816	4051	4074	4171	4231	15.2%	15.3%	15.6%	15.9%	18250	2773	2789	2855	2896	8416.3	$ 568,411	$ 571,638	$ 585,249	$ 593,667	$ -	$ (3,227)	$ (16,838)	$ (25,256)
Buffalo Creek Subdivision Ramp	SC	1	314.5	71	129	200	133	144	0.5%	0.8%	0.5%	0.5%	18250	88	137	91	99	400	$ 860	$ 1,334	$ 887	$ 960	$ -	$ (473)	$ (27)	$ (100)
Bussey Point	GA	1	321.0	819	1798	1735	1863	1885	6.7%	6.5%	7.0%	7.1%	18250	1231	1188	1275	1290	10748	$ 322,178	$ 310,890	$ 333,826	$ 337,768	$ -	$ 11,289	$ (11,647)	$ (15,589)
Calhoun Falls Ramp	SC	1	325.0	1,816	4051	4074	4171	4231	15.2%	15.3%	15.6%	15.9%	18250	2773	2789	2855	2896	13515.3	$ 912,782	$ 917,964	$ 939,821	$ 953,340	$ -	$ (5,182)	$ (27,039)	$ (40,558)
Catfish Ramp	SC	1	325.5	2,166	4935	4984	4863	4959	18.5%	18.7%	18.2%	18.6%	18250	3378	3412	3329	3394	300	$ 24,682	$ 24,927	$ 24,322	$ 24,802	$ -	$ (245)	$ 360	$ (120)
Chamberlain Ferry Ramp	GA	1	318.3	460	873	827	956	977	3.3%	3.1%	3.6%	3.7%	18250	598	566	654	669	25171.2	$ 366,351	$ 347,047	$ 401,181	$ 409,994	$ -	$ 19,304	$ (34,831)	$ (43,643)
Cherokee Recreation Area 1	GA	1	314.6	74	138	214	139	152	0.5%	0.8%	0.5%	0.6%	18250	94	146	95	104	87385.3	$ 201,046	$ 311,768	$ 202,503	$ 221,443	$ -	$ (110,721)	$ (1,457)	$ (20,396)
Clarks Hill Park	GA	1	313.5	55	47	113	54	55	0.2%	0.4%	0.2%	0.2%	18250	32	77	37	38	53296.5	$ 41,761	$ 100,405	$ 47,981	$ 48,870	$ -	$ (58,644)	$ (6,220)	$ (7,108)
Clay Hill Campground	GA	1	323.5	1,429	2835	2778	3093	3167	10.6%	10.4%	11.6%	11.9%	18250	1941	1902	2117	2168	6691.8	$ 316,282	$ 309,923	$ 345,066	$ 353,321	$ -	$ 6,359	$ (28,783)	$ (37,039)
Dordon Creek Ramp	SC	1	316.2	186	357	420	384	383	1.3%	1.6%	1.4%	1.4%	18250	244	287	263	262	17627.6	$ 104,916	$ 123,430	$ 112,850	$ 112,557	$ -	$ (18,515)	$ (7,935)	$ (7,641)
Dorn 3 & 4	SC	2	308.4	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	5708.6	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Double Branches Ramp	GA	1	318.1	425	810	777	878	904	3.0%	2.9%	3.3%	3.4%	18250	554	532	601	619	13445.3	$ 181,566	$ 174,169	$ 196,809	$ 202,637	$ -	$ 7,397	$ (15,243)	$ (21,071)
Elbert County Subdivision Ramp	GA	1	317.6	355	700	700	751	775	2.6%	2.6%	2.8%	2.9%	18250	479	479	514	530	200	$ 2,334	$ 2,334	$ 2,504	$ 2,584	$ -	$ -	$ (170)	$ (250)
Elijah Clark State Park 1, 2, & 3	GA	1	316.0	175	328	376	353	363	1.2%	1.4%	1.3%	1.4%	18250	225	257	242	248	81314.9	$ 444,655	$ 509,726	$ 478,546	$ 492,103	$ -	$ (65,071)	$ (33,891)	$ (47,448)
Fishing Creek / Hwy 79 Ramp	GA	1	320.7	791	1718	1657	1786	1794	6.4%	6.2%	6.7%	6.7%	18250	1176	1134	1223	1228	1000	$ 28,642	$ 27,625	$ 29,776	$ 29,909	$ -	$ 1,017	$ (1,134)	$ (1,267)
Ft. Gordon Recreation Area 1 & 2	GA	2	315.0	107	165	259	237	236	0.6%	1.0%	0.9%	0.9%	18250	113	177	162	162	81069.3	$ 223,007	$ 350,054	$ 320,320	$ 318,968	$ -	$ (127,047)	$ (97,312)	$ (95,961)
Gill Point Ramp	GA	1	314.8	87	151	240	169	184	0.6%	0.9%	0.6%	0.7%	18250	103	164	116	126	33428.9	$ 84,155	$ 133,756	$ 94,186	$ 102,546	$ -	$ (49,601)	$ (10,032)	$ (18,391)
Hamilton Branch State Park (Day Use)	SC	1	314.0	70	86	142	103	98	0.3%	0.5%	0.4%	0.4%	18250	59	97	71	67	56020	$ 80,319	$ 132,620	$ 96,197	$ 91,527	$ -	$ (52,301)	$ (15,877)	$ (11,207)
Hamilton Branch State Park 1 & 2	SC	2	314.0	70	86	142	103	98	0.3%	0.5%	0.4%	0.4%	18250	59	97	71	67	7743.3	$ 11,102	$ 18,331	$ 13,297	$ 12,651	$ -	$ (7,229)	$ (2,195)	$ (1,549)
Hawe Creek Campground	SC	1	313.5	55	47	113	54	55	0.2%	0.4%	0.2%	0.2%	18250	32	77	37	38	3632.2	$ 2,846	$ 6,843	$ 3,270	$ 3,331	$ -	$ (3,997)	$ (424)	$ (484)
Hesters Ferry Campground	GA	1	312.9	27	4	82	34	27	0.0%	0.3%	0.1%	0.1%	18250	3	56	23	18	3632	$ 242	$ 4,965	$ 2,059	$ 1,635	$ -	$ (4,723)	$ (1,817)	$ (1,393)
Hickory Knob State Park	SC	1	316.2	186	357	420	384	383	1.3%	1.6%	1.4%	1.4%	18250	244	287	263	262	103396.1	$ 615,391	$ 723,990	$ 661,934	$ 660,210	$ -	$ (108,598)	$ (46,542)	$ (44,818)
Holiday Park	GA	1	315.6	138	254	324	304	305	1.0%	1.2%	1.1%	1.1%	18250	174	222	208	209	14687.6	$ 62,196	$ 79,337	$ 74,440	$ 74,684	$ -	$ (17,141)	$ (12,243)	$ (12,488)
Hwy 28 Access Road	SC	1	326.0	3,048	7035	7039	6698	6777	26.4%	26.4%	25.1%	25.4%	18250	4815	4818	4585	4639	400	$ 46,914	$ 46,941	$ 44,667	$ 45,194	$ -	$ (27)	$ 2,247	$ 1,721
Keg Creek Ramp	GA	1	309.0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	30076.8	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Lake Springs Park 1, 2, & 3	GA	3	308.7	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	174425.8	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Lakeside Subdivision Ramp	GA	1	324.0	1,505	3179	3145	3373	3419	11.9%	11.8%	12.7%	12.8%	18250	2176	2153	2309	2340	500	$ 26,500	$ 26,216	$ 28,117	$ 28,500	$ -	$ 283	$ (1,617)	$ (2,001)
Landam Creek Ramp	SC	1	316.2	186	357	420	384	383	1.3%	1.6%	1.4%	1.4%	18250	244	287	263	262	6571.3	$ 39,111	$ 46,013	$ 42,069	$ 41,959	$ -	$ (6,902)	$ (2,958)	$ (2,848)
Leathersville Ramp	GA	1	306.3	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	10524.7	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Leroys Ferry Campground	SC	1	319.5	683	1383	1281	1483	1509	5.2%	4.8%	5.6%	5.7%	18250	947	877	1015	1033	5774.5	$ 133,142	$ 123,323	$ 142,769	$ 145,272	$ -	$ 9,820	$ (9,627)	$ (12,130)
Little River / Hwy 378	SC	1	314.5	71	129	200	133	144	0.5%	0.8%	0.5%	0.5%	18250	88	137	91	99	20056.1	$ 43,134	$ 66,874	$ 44,471	$ 48,149	$ -	$ (23,740)	$ (1,337)	$ (5,016)
Little River Marina 2	GA	1	311.3	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	24661.8	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Little River Quarry Ramp	SC	1	324.0	1,505	3179	3145	3373	3419	11.9%	11.8%	12.7%	12.8%	18250	2176	2153	2309	2340	400	$ 21,200	$ 20,973	$ 22,493	$ 22,800	$ -	$ 227	$ (1,294)	$ (1,600)
Little River Subdivision Ramp	SC	1	313.5	55	47	113	54	55	0.2%	0.4%	0.2%	0.2%	18250	32	77	37	38	400	$ 313	$ 754	$ 360	$ 367	$ -	$ (440)	$ (47)	$ (53)
Long Cane Creek Ramp	SC	1	325.7	2,449	5684	5708	5445	5527	21.3%	21.4%	20.4%	20.7%	18250	3891	3907	3727	3783	500	$ 47,381	$ 47,581	$ 45,389	$ 46,072	$ -	$ (200)	$ 1,992	$ 1,309
Maxim Subdivision Ramp	GA	1	320.0	745	1556	1481	1631	1643	5.8%	5.6%	6.1%	6.2%	18250	1065	1014	1116	1125	200	$ 5,188	$ 4,938	$ 5,438	$ 5,478	$ -	$ 250	$ (250)	$ (290)
Mistletoe State Park Low Water Ramp	GA	1	313.5	55	47	113	54	55	0.2%	0.4%	0.2%	0.2%	18250	32	77	37	38	73833	$ 57,853	$ 139,094	$ 66,470	$ 67,701	$ -	$ (81,241)	$ (8,616)	$ (9,847)
Modoc Campground	SC	1	321.0	819	1798	1735	1863	1885	6.7%	6.5%	7.0%	7.1%	18250	1231	1188	1275	1290	20810	$ 623,793	$ 601,936	$ 646,344	$ 653,977	$ -	$ 21,857	$ (22,551)	$ (30,184)
Modoc Ramp 1	SC	1	313.5	55	47	113	54	55	0.2%	0.4%	0.2%	0.2%	18250	32	77	37	38	25782.7	$ 20,203	$ 48,572	$ 23,211	$ 23,641	$ -	$ (28,369)	$ (3,009)	$ (3,439)
Modoc Shores Subdivision Ramp	SC	1	310.4	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	500	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Morrahs Ramp 2	GA	1	314.0	70	86	142	103	98	0.3%	0.5%	0.4%	0.4%	18250	59	97	71	67	19861.8	$ 28,477	$ 47,020	$ 34,106	$ 32,451	$ -	$ (18,543)	$ (5,629)	$ (3,974)
Mt Pleasant Ramp	SC	1	322.4	1,131	2324	2302	2418	2471	8.7%	8.6%	9.1%	9.3%	18250	1591	1576	1655	1691	4000	$ 154,980	$ 153,513	$ 161,248	$ 164,783	$ -	$ 1,467	$ (6,269)	$ (9,803)
Mt. Carmel Campground	SC	1	311.0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	14383.4	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Mt. Carmel Picnic	SC	1	313.7	64	55	123	66	69	0.2%	0.5%	0.2%	0.3%	18250	38	84	45	47	14383.4	$ 13,189	$ 29,495	$ 15,826	$ 16,546	$ -	$ (16,306)	$ (2,638)	$ (3,357)
Murray Creek Ramp	GA	1	321.0	819	1798	1735	1863	1885	6.7%	6.5%	7.0%	7.1%	18250	1231	1188	1275	1290	10323.3	$ 309,448	$ 298,605	$ 320,635	$ 324,421	$ -	$ 10,843	$ (11,187)	$ (14,973)
New Bourdeaux Subdivision Ramp	SC	1	315.0	107	165	259	237	236	0.6%	1.0%	0.9%	0.9%	18250	113	177	162	162	300	$ 825	$ 1,295	$ 1,185	$ 1,180	$ -	$ (470)	$ (360)	$ 355)
Parksville Recreation Area	SC	1	314.5	71	129	200	133	144	0.5%	0.8%	0.5%	0.5%	18250	88	137	91	99	45266.7	$ 97,353	$ 150,934	$ 100,371	$ 108,673	$ -	$ (53,582)	$ (3,019)	$ (11,320)
Parkway Ramp	GA	1	321.0	819	1798	1735	1863	1885	6.7%	6.5%	7.0%	7.1%	18250	1231	1188	1275	1290	300	$ 8,993	$ 8,678	$ 9,318	$ 9,428	$ -	$ 315	$ (325)	$ (435)
Petersburg Campground	GA	1	313.7	64	55	123	66	69	0.2%	0.5%	0.2%	0.3%	18250	38	84	45	47	74966.1	$ 68,740	$ 153,727	$ 82,487	$ 86,237	$ -	$ (84,987)	$ (13,748)	$ (17,497)
Plum Branch Yacht Club	SC	1	315.0	107	165	259	237	236	0.6%	1.0%	0.9%	0.9%	18250	113	177	162	162	41255	$ 113,485	$ 178,138	$ 163,006	$ 162,318	$ -	$ (64,652)	$ (49,521)	$ (48,833)
Raysville Campground	GA	1	312.2	0	0	64	0	0	0.0%	0.2%	0.0%	0.0%	18250	0	44	0	0	19676.7	$ -	$ 20,995	$ -	$ -	$ -	$ (20,995)	$ -	$ -
Raysville Marina	GA	1	317.6	355	700	700	751	775	2.6%	2.6%	2.8%	2.9%	18250	479	479	514	530	34653	$ 404,406	$ 404,406	$ 433,870	$ 447,736	$ -	$ -	$ (29,464)	$ (43,329)
Ridge Road Campground	GA	1	319.0	575	1116	1016	1212	1280	4.2%	3.8%	4.5%	4.8%	18250	764	695	830	876	19453.2	$ 361,938	$ 329,506	$ 393,073	$ 415,126	$ -	$ 32,432	$ (31,134)	$ (53,188)
Scotts Ferry Ramp	SC	1	310.7	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	35150.4	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Soap Creek / Hwy 220 Ramp	GA	1	317.0	312	573	584	590	619	2.1%	2.2%	2.2%	2.3%	18250	392	400	404	424	1500	$ 14,329	$ 14,604	$ 14,754	$ 15,480	$ -	$ (275)	$ (425)	$ (1,150)
Soap Creek Marina	GA	1	318.0	408	782	758	843	878	2.9%	2.8%	3.2%	3.3%	18250	535	519	577	601	63317.6	$ 825,487	$ 800,152	$ 889,879	$ 926,826	$ -	$ 25,335	$ (64,392	$ (101,339)
Soap Creek Park	GA	1	324.0	1,505	3179	3145	3373	3419	11.9%	11.8%	12.7%	12.8%	18250	2176	2153	2309	2340	400	$ 21,200	$ 20,973	$ 22,493	$ 22,800	$ -	$ 227	$ (1,294)	$ (1,600)
Tradewinds Marina	GA	1	314.0	70	86	142	103	98	0.3%	0.5%	0.4%	0.4%	18250	59	97	71	67	89186.9	$ 127,873	$ 211,139	$ 153,150	$ 145,716	$ -	$ (83,266)	$ (25,277)	$ (17,843)
Wells Creek Subdivision	GA	1	320.0	745	1556	1481	1631	1643	5.8%	5.6%	6.1%	6.2%	18250	1065	1014	1116	1125	300	$ 7,782	$ 7,407	$ 8,157	$ 8,217	$ -	$ 375	$ (375)	$ (435)
Wildwood Park 1 & 2	GA	2	315.0	107	165	259	237	236	0.6%	1.0%	0.9%	0.9%	18250	113	177	162	162	78183.2	$ 215,068	$ 337,592	$ 308,916	$ 307,613	$ -	$ (122,524)	$ (93,848)	$ (92,545)
Winfield Campground	GA	1	311.7	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	18250	0	0	0	0	34347.8	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Winfield Subdivision	GA	1	323.1	1,342	2586	2555	2810	2926	9.7%	9.6%	10.5%	11.0%	18250	1770	1749	1923	2003	700	$ 30,179	$ 29,817	$ 32,793	$ 34,147	$ -	$ 362	$ (2,614)	$ (3,968)

Hartwell

Boat Ramp Name	State	No. of Lanes	Not useable below elevation (ft AMSL)	Number of days when ramp is not useable Total POR (26,662 days)				Percent of time that lane not available				Years 50	Number of days in 50 Years that Lanes not Available				Visitors / year	Total Revenue Lost				Delta Total Revenue Lost			
				NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4	days	NAA/A1	A2	A3	A4		NAA/A1	A2	A3	A4	NAA/A1	A2	A3	A4
Apple Island	SC	1	651.5	2092	1936	2329	2331	7.8%	7.3%	8.7%	8.7%	18250	1432	1325	1594	1596	13032	$ 454,519	$ 420,625	$ 506,011	$ 506,445	$ -	$ 33,893	$ (51,492)	$ (51,926)
Asbury (camping)	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	22953	$ 86,865	$ 56,634	$ 91,074	$ 91,840	$ -	$ 30,231	$ (4,209)	$ (4,975)
Barton Mill	SC	1	653.0	3125	3053	3589	3587	11.7%	11.5%	13.5%	13.5%	18250	2139	2090	2457	2455	4811	$ 250,648	$ 244,873	$ 287,864	$ 287,704	$ -	$ 5,775	$ (37,216)	$ (37,056)
Big Oaks (right lane)	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	125793	$ 501,226	$ 371,201	$ 538,975	$ 559,947	$ -	$ 130,025	$ (37,749)	$ (58,721)
Big Water	SC	1	638.0	123	43	127	156	0.5%	0.2%	0.5%	0.6%	18250	84	29	87	107	16375	$ 33,579	$ 11,739	$ 34,671	$ 42,588	$ -	$ 21,840	$ (1,092)	$ (9,009)
Bradberry	GA	1	655.0	5685	5668	6332	6383	21.3%	21.3%	23.7%	23.9%	18250	3891	3880	4334	4369	16313	$ 1,546,121	$ 1,541,497	$ 1,722,082	$ 1,735,952	$ -	$ 4,623	$ (175,961)	$ (189,832)
Brown Road	SC	1	657.0	10332	10289	10868	10909	38.8%	38.6%	40.8%	40.9%	18250	7072	7043	7439	7467	29696	$ 5,115,186	$ 5,093,897	$ 5,380,549	$ 5,400,848	$ -	$ 21,289	$ (265,364)	$ (285,662)
Broyles (middle ramp)	SC	1	642.0	205	133	222	225	0.8%	0.5%	0.8%	0.8%	18250	140	91	152	154	43070	$ 147,200	$ 95,500	$ 159,407	$ 161,561	$ -	$ 51,700	$ (12,207)	$ (14,361)
Bruce Creek	GA	1	638.0	123	43	127	156	0.5%	0.2%	0.5%	0.6%	18250	84	29	87	107	15331	$ 31,438	$ 10,991	$ 32,460	$ 39,873	$ -	$ 20,447	$ (1,022)	$ (8,435)
Camp Creek	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	11062	$ 44,078	$ 32,643	$ 47,397	$ 49,242	$ -	$ 11,434	$ (3,320)	$ (5,164)
Carters Ferry	GA	1	645.0	285	243	384	395	1.1%	0.9%	1.4%	1.5%	18250	195	166	263	270	8219	$ 39,052	$ 33,297	$ 52,617	$ 54,125	$ -	$ 5,755	$ (13,565)	$ (15,073)
Choestoea	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	13484	$ 53,727	$ 39,789	$ 57,773	$ 60,021	$ -	$ 13,938	$ (4,046)	$ (6,294)
Clemson Marina	SC	1	645.5	340	287	478	481	1.3%	1.1%	1.8%	1.8%	18250	233	196	327	329	35103	$ 198,979	$ 167,962	$ 279,741	$ 281,497	$ -	$ 31,017	$ (80,762)	$ (82,518)
Cleveland	GA	1	649.5	1505	1250	1624	1657	5.6%	4.7%	6.1%	6.2%	18250	1030	856	1112	1134	13027	$ 326,854	$ 271,473	$ 352,698	$ 359,865	$ -	$ 55,381	$ (25,844)	$ (33,011)
Coneross	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	13610	$ 54,231	$ 40,163	$ 58,315	$ 60,584	$ -	$ 14,068	$ (4,084)	$ (6,353)
Cove Inlet	SC	1	656.5	8923	8910	9520	9569	33.5%	33.4%	35.7%	35.9%	18250	6108	6099	6516	6550	4811	$ 715,691	$ 714,648	$ 763,574	$ 767,505	$ -	$ 1,043	$ (47,884)	$ (51,814)
Crawford Ferry	GA	1	643.3	228	161	240	241	0.9%	0.6%	0.9%	0.9%	18250	156	110	164	165	11286	$ 42,898	$ 30,292	$ 45,156	$ 45,344	$ -	$ 12,606	$ (2,258)	$ (2,446)
Darvin Wright City Park	SC	1	653.0	3125	3053	3589	3587	11.7%	11.5%	13.5%	13.5%	18250	2139	2090	2457	2455	103920	$ 5,414,119	$ 5,289,378	$ 6,218,007	$ 6,214,542	$ -	$ 124,741	$ (803,888)	$ (800,423)
Denver	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	21873	$ 82,778	$ 53,970	$ 86,789	$ 87,518	$ -	$ 28,808	$ (4,011)	$ (4,741)
Double Spring	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	12423	$ 49,500	$ 36,659	$ 53,228	$ 55,299	$ -	$ 12,841	$ (3,728)	$ (5,799)
Duncan Branch	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	11063	$ 44,080	$ 32,645	$ 47,399	$ 49,244	$ -	$ 11,435	$ (3,320)	$ (5,164)
Durham	SC	1	655.7	6452	6437	7136	7165	24.2%	24.1%	26.8%	26.9%	18250	4416	4406	4885	4904	10854	$ 1,167,506	$ 1,164,792	$ 1,291,278	$ 1,296,525	$ -	$ 2,714	$ (123,772)	$ (129,019)
Eighteen Mile Creek	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	18243	$ 69,041	$ 45,013	$ 72,386	$ 72,995	$ -	$ 24,027	$ (3,346)	$ (3,954)
Elrod Ferry	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	35726	$ 135,204	$ 88,150	$ 141,755	$ 142,946	$ -	$ 47,053	$ (6,552)	$ (7,743)
Fairplay (right lane)	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	32403	$ 129,111	$ 95,618	$ 138,834	$ 144,237	$ -	$ 33,493	$ (9,724)	$ (15,126)
Friendship (right lane)	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	46169	$ 183,960	$ 136,238	$ 197,815	$ 205,512	$ -	$ 47,722	$ (13,855)	$ (21,552)
Glenn Ferry	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	11282	$ 44,955	$ 33,293	$ 48,340	$ 50,221	$ -	$ 11,662	$ (3,386)	$ (5,267)
Green Pond	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	27935	$ 111,309	$ 82,434	$ 119,692	$ 124,349	$ -	$ 28,875	$ (8,383)	$ (13,040)
Gum Branch	GA	6	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	13189	$ 52,552	$ 38,919	$ 56,509	$ 58,708	$ -	$ 13,633	$ (3,958)	$ (6,157)
Harbor Light Marina	GA	2	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	46787	$ 177,063	$ 115,442	$ 185,643	$ 187,203	$ -	$ 61,621	$ (8,580)	$ (10,140)

Hart State Park	GA	2	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	56238	$ 212,831	$ 138,762	$ 223,144	$ 225,019	$ -	$ 74,069	$ (10,313)	$ (12,189)
Hartwell Marina	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	43906	$ 166,162	$ 108,334	$ 174,214	$ 175,677	$ -	$ 57,827	$ (8,052)	$ (9,516)
Hatton's Ford	SC	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	27545	$ 109,753	$ 81,281	$ 118,019	$ 122,611	$ -	$ 28,471	$ (8,266)	$ (12,858)
Holcomb	GA	1	650.0	1679	1462	1794	1825	6.3%	5.5%	6.7%	6.8%	18250	1149	1001	1228	1249	15459	$ 432,716	$ 376,790	$ 462,354	$ 470,343	$ -	$ 55,926	$ (29,638)	$ (37,627)
Holder’s Access	SC	1	658.0	13839	13813	14104	14157	51.9%	51.8%	52.9%	53.1%	18250	9473	9455	9654	9690	4811	$ 1,109,990	$ 1,107,905	$ 1,131,245	$ 1,135,496	$ -	$ 2,085	$ (21,255)	$ (25,506)
Honea Path	SC	1	648.5	1035	898	1270	1295	3.9%	3.4%	4.8%	4.9%	18250	708	615	869	886	16060	$ 277,115	$ 240,434	$ 340,034	$ 346,728	$ -	$ 36,681	$ (62,920)	$ (69,613)
Hurricane Creek	SC	1	657.0	10332	10289	10868	10909	38.8%	38.6%	40.8%	40.9%	18250	7072	7043	7439	7467	37031	$ 6,378,565	$ 6,352,019	$ 6,709,470	$ 6,734,782	$ -	$ 26,546	$ (330,905)	$ (356,217)
Jack’s Landing	SC	1	658.0	13839	13813	14104	14157	51.9%	51.8%	52.9%	53.1%	18250	9473	9455	9654	9690	20901	$ 4,822,331	$ 4,813,271	$ 4,914,673	$ 4,933,141	$ -	$ 9,060	$ (92,342)	$ (110,810)
Jarrett	SC	1	650.0	1679	1462	1794	1825	6.3%	5.5%	6.7%	6.8%	18250	1149	1001	1228	1249	11024	$ 308,572	$ 268,691	$ 329,708	$ 335,405	$ -	$ 39,881	$ (21,135)	$ (26,832)
Jenkins Ferry	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	14635	$ 55,387	$ 36,111	$ 58,071	$ 58,559	$ -	$ 19,276	$ (2,684)	$ (3,172)
Lake Hartwell State Park	SC	2	638.0	123	43	127	156	0.5%	0.2%	0.5%	0.6%	18250	84	29	87	107	38365	$ 78,672	$ 27,503	$ 81,230	$ 99,779	$ -	$ 51,169	$ (2,558)	$ (21,107)
Lakeshore	SC	1	658.0	13839	13813	14104	14157	51.9%	51.8%	52.9%	53.1%	18250	9473	9455	9654	9690	6455	$ 1,489,316	$ 1,486,518	$ 1,517,834	$ 1,523,538	$ -	$ 2,798	$ (28,519)	$ (34,222)
Lawrence Bridge	SC	1	651.0	1946	1762	2111	2123	7.3%	6.6%	7.9%	8.0%	18250	1332	1206	1445	1453	16795	$ 544,878	$ 493,358	$ 591,078	$ 594,438	$ -	$ 51,520	$ (46,200)	$ (49,560)
Lightwood Log Creek	GA	1	638.0	123	43	127	156	0.5%	0.2%	0.5%	0.6%	18250	84	29	87	107	16313	$ 33,453	$ 11,695	$ 34,540	$ 42,428	$ -	$ 21,758	$ (1,088)	$ (8,975)
Long Point	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	37949	$ 151,208	$ 111,982	$ 162,596	$ 168,922	$ -	$ 39,225	$ (11,388)	$ (17,715)
Martin Creek	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	16062	$ 60,788	$ 39,632	$ 63,733	$ 64,269	$ -	$ 21,155	$ (2,946)	$ (3,481)
Mary Ann Branch	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	8854	$ 33,507	$ 21,846	$ 35,130	$ 35,425	$ -	$ 11,661	$ (1,624)	$ (1,919)
Milltown	GA	1	645.4	325	279	452	461	1.2%	1.0%	1.7%	1.7%	18250	222	191	309	316	3981	$ 21,570	$ 18,517	$ 29,999	$ 30,597	$ -	$ 3,053	$ (8,429)	$ (9,026)
Mountain Bay	SC	1	658.0	13839	13813	14104	14157	51.9%	51.8%	52.9%	53.1%	18250	9473	9455	9654	9690	4751	$ 1,096,147	$ 1,094,088	$ 1,117,137	$ 1,121,335	$ -	$ 2,059	$ (20,990)	$ (25,188)
Mullins Ford	SC	1	638.0	123	43	127	156	0.5%	0.2%	0.5%	0.6%	18250	84	29	87	107	8377	$ 17,178	$ 6,005	$ 17,736	$ 21,786	$ -	$ 11,172	$ (559)	$ (4,609)
New Prospect	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	13059	$ 52,033	$ 38,535	$ 55,952	$ 58,129	$ -	$ 13,498	$ (3,919)	$ (6,096)
Oconee Point	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	9818	$ 37,156	$ 24,225	$ 38,957	$ 39,284	$ -	$ 12,931	$ (1,801)	$ (2,128)
Paynes Creek (outer)	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	8084	$ 30,594	$ 19,947	$ 32,076	$ 32,346	$ -	$ 10,647	$ (1,483)	$ (1,752)
Poplar Spring (left ramp)	GA	1	651.5	2092	1936	2329	2331	7.8%	7.3%	8.7%	8.7%	18250	1432	1325	1594	1596	39738	$ 1,385,933	$ 1,282,585	$ 1,542,944	$ 1,544,269	$ -	$ 103,349	$ (157,011)	$ (158,336)
Poplar Spring (right ramp)	GA	1	643.6	233	168	242	251	0.9%	0.6%	0.9%	0.9%	18250	159	115	166	172	39738	$ 154,362	$ 111,300	$ 160,325	$ 166,287	$ -	$ 43,062	$ (5,962)	$ (11,925)
Port Bass	SC	1	653.0	3125	3053	3589	3587	11.7%	11.5%	13.5%	13.5%	18250	2139	2090	2457	2455	4753	$ 247,647	$ 241,941	$ 284,418	$ 284,259	$ -	$ 5,706	$ (36,771)	$ (36,612)
Portman Shoals	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	143551	$ 543,266	$ 354,200	$ 569,591	$ 574,378	$ -	$ 189,066	$ (26,326)	$ (31,112)
Powder Bag Creek N	GA	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	11024	$ 41,721	$ 27,201	$ 43,742	$ 44,110	$ -	$ 14,520	$ (2,022)	$ (2,389)
Reed Creek	GA	1	657.5	12094	12051	12463	12508	45.4%	45.2%	46.7%	46.9%	18250	8278	8249	8531	8562	4811	$ 970,028	$ 966,579	$ 999,625	$ 1,003,234	$ -	$ 3,449	$ (29,597)	$ (33,206)
Richland Creek	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	14674	$ 55,533	$ 36,207	$ 58,224	$ 58,714	$ -	$ 19,327	$ (2,691)	$ (3,180)
River Forks (left ramp)	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	37251	$ 140,975	$ 91,913	$ 147,807	$ 149,049	$ -	$ 49,062	$ (6,831)	$ (8,073)
Rock Spring	GA	1	644.0	239	177	257	267	0.9%	0.7%	1.0%	1.0%	18250	164	121	176	183	14562	$ 58,024	$ 42,972	$ 62,394	$ 64,822	$ -	$ 15,052	$ (4,370)	$ (6,798)
Rocky Ford	GA	1	657.5	12094	12051	12463	12508	45.4%	45.2%	46.7%	46.9%	18250	8278	8249	8531	8562	9604	$ 1,936,447	$ 1,929,562	$ 1,995,530	$ 2,002,735	$ -	$ 6,885	$ (59,083)	$ (66,288)
Sadlers Creek State Park #1	SC	2	638.0	123	43	127	156	0.5%	0.2%	0.5%	0.6%	18250	84	29	87	107	40116	$ 82,262	$ 28,758	$ 84,938	$ 104,333	$ -	$ 53,504	$ (2,675)	$ (22,070)
Seneca Creek	SC	1	657.0	10332	10289	10868	10909	38.8%	38.6%	40.8%	40.9%	18250	7072	7043	7439	7467	25957	$ 4,471,154	$ 4,452,546	$ 4,703,107	$ 4,720,849	$ -	$ 18,608	$ (231,953)	$ (249,696)
Seymour	GA	1	653.0	3125	3053	3589	3587	11.7%	11.5%	13.5%	13.5%	18250	2139	2090	2457	2455	17408	$ 906,918	$ 886,022	$ 1,041,577	$ 1,040,997	$ -	$ 20,895	$ (134,659)	$ (134,079)
Singing Pines	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	53740	$ 203,378	$ 132,599	$ 213,233	$ 215,025	$ -	$ 70,779	$ (9,855)	$ (11,647)
South Union	SC	1	655.5	6215	6197	6871	6920	23.3%	23.2%	25.8%	26.0%	18250	4254	4242	4703	4737	4795	$ 496,862	$ 495,423	$ 549,307	$ 553,224	$ -	$ 1,439	$ (52,444)	$ (56,362)
Spring Branch	GA	1	649.0	1213	1036	1451	1494	4.5%	3.9%	5.4%	5.6%	18250	830	709	993	1023	15745	$ 318,405	$ 271,944	$ 380,878	$ 392,166	$ -	$ 46,461	$ (62,474)	$ (73,761)

Springfield	SC	1	643.6	233	168	242	251	0.9%	0.6%	0.9%	0.9%	18250	159	115	166	172	18975	$ 73,709	$ 53,146	$ 76,556	$ 79,403	$ -	$ 20,563	$ (2,847)	$ (5,694)
Stephens Co.	GA	1	651.5	2092	1936	2329	2331	7.8%	7.3%	8.7%	8.7%	18250	1432	1325	1594	1596	71408	$ 2,490,520	$ 2,304,802	$ 2,772,668	$ 2,775,049	$ -	$ 185,718	$ (282,148)	$ (284,529)
Tabor	SC	1	652.5	2712	2613	2958	2970	10.2%	9.8%	11.1%	11.1%	18250	1856	1789	2025	2033	11016	$ 498,086	$ 479,904	$ 543,267	$ 545,470	$ -	$ 18,182	$ (45,180)	$ (47,384)
Tillies	SC	1	653.0	3125	3053	3589	3587	11.7%	11.5%	13.5%	13.5%	18250	2139	2090	2457	2455	4780	$ 249,017	$ 243,280	$ 285,992	$ 285,832	$ -	$ 5,737	$ (36,974)	$ (36,815)
Timberland	SC	1	654.0	4468	4379	5097	5121	16.8%	16.4%	19.1%	19.2%	18250	3058	2997	3489	3505	4811	$ 358,367	$ 351,228	$ 408,817	$ 410,742	$ -	$ 7,138	$ (50,450)	$ (52,375)
Townville	SC	1	652.3	2533	2433	2753	2781	9.5%	9.1%	10.3%	10.4%	18250	1734	1665	1884	1904	13901	$ 587,047	$ 563,871	$ 638,034	$ 644,523	$ -	$ 23,176	$ (50,987)	$ (57,476)
Tugaloo State Park (mega)	GA	6	642.0	205	133	222	225	0.8%	0.5%	0.8%	0.8%	18250	140	91	152	154	93552	$ 319,732	$ 207,436	$ 346,246	$ 350,925	$ -	$ 112,296	$ (26,514)	$ (31,193)
Twelve Mile (right lane)	SC	1	647.0	640	548	802	832	2.4%	2.1%	3.0%	3.1%	18250	438	375	549	569	84793	$ 904,730	$ 774,675	$ 1,133,740	$ 1,176,149	$ -	$ 130,055	$ (229,010)	$ (271,419)
Twin Lakes (right ramp)	SC	1	648.0	865	764	1052	1086	3.2%	2.9%	3.9%	4.1%	18250	592	523	720	743	120293	$ 1,734,744	$ 1,532,190	$ 2,109,770	$ 2,177,957	$ -	$ 202,554	$ (375,026)	$ (443,212)
Walker Creek	GA	1	657.0	10332	10289	10868	10909	38.8%	38.6%	40.8%	40.9%	18250	7072	7043	7439	7467	11062	$ 1,905,465	$ 1,897,535	$ 2,004,316	$ 2,011,878	$ -	$ 7,930	$ (98,851)	$ (106,412)
Watsadler	GA	1	645.0	285	243	384	395	1.1%	0.9%	1.4%	1.5%	18250	195	166	263	270	14907	$ 70,830	$ 60,392	$ 95,435	$ 98,169	$ -	$ 10,438	$ (24,604)	$ (27,338)
Weldon Island	SC	1	643.0	227	148	238	240	0.9%	0.6%	0.9%	0.9%	18250	155	101	163	164	9090	$ 34,400	$ 22,428	$ 36,067	$ 36,370	$ -	$ 11,972	$ (1,667)	$ (1,970)
White City	SC	1	653.0	3125	3053	3589	3587	11.7%	11.5%	13.5%	13.5%	18250	2139	2090	2457	2455	16432	$ 856,090	$ 836,366	$ 983,202	$ 982,654	$ -	$ 19,724	$ (127,112)	$ (126,564)

Table 4.3-10 Economic Value of Recreation Impacts

USACE PROJECT	ANNUAL VISITATION TO RECREATION AREAS	# UNAVAILABLE RAMP DAYS	RAMP-DAY IMPACTS (DAYS)	TOTAL VALUE OF IMPACT (50 YEARS)	PRESENT WORTH OF ANNUAL IMPACT
NAA / A1					
Hartwell	2,171,405	171,374	---	---	---
J. Strom Thurmond	1,805,742	60,869	---	---	---
Alternative 2					
Hartwell	2,171,405	166,104	-5,270	-$2,955,567*	
J. Strom Thurmond	1,805,742	61,605	736	$910,744	
				-$2,044,823*	-$898,370*
Alternative 3					
Hartwell	2,171,405	182,410	11,036	$4,718,945	
J. Strom Thurmond	1,805,742	63,411	2,542	$964,568	
				$5,683,512	$2,937,573
Alternative 4					
Hartwell	2,171,405	183,555	12,181	$5,199,358	
J. Strom Thurmond	1,805,742	64,485	3,616	$1,371,134	
				$6,570,492	$3,626,374

Note: Impacts based on comparing ramp day availability to that in the No Action Alternative
Annual Value of Impact = Annual Visitation x % Ramp-Day Impacts x Unit-Day Value
Negative impacts at Hartwell mean that higher pools would increase recreational use
Present worth based on 50-year period of analysis and interest rate of 3.5%

To address these impacts to recreation users of the USACE reservoirs, Duke Energy would provide funding, in-kind services, contractor services or combinations of the same to USACE and other public entities that operate public boat launching facilities on Hartwell and Thurmond Reservoirs ("Public Boat Ramp Operators") to improve public boat launching facilities.

USACE will oversee the mitigation program to ensure the adverse impacts to recreational users of the USACE reservoirs are fully addressed. The mitigation would be implemented in several locations on each reservoir to address the impacts that are distributed around those lakes. At present, the improvements are expected to be provided at ramps on Hartwell and Thurmond. The mitigation may include extending existing ramps so they provide access when the reservoirs are lower, constructing new ramps, improving access at existing ramps, improving parking at existing ramps, etc.

If funding is provided to USACE, Duke will provide the estimated cost prior to the work being performed. USACE will provide Duke with an accounting of the expenditures and return any amount that was not used for that specific purpose.

Duke Energy would contribute an amount equal to the estimated adverse effects identified to recreational users on Hartwell and Thurmond Reservoirs. That amount would fully compensate for the expected impacts identified to recreational users.

4.4 Biotic Communities

Common names for species are referenced throughout the main body of this EA. Cross-reference tables that provide both the common names and scientific names for each species are provided in Appendix E as follows:

- Fish species Table E-1
- Aquatic plants Table E-2
- Wetland species Table E-3
- Wildlife species Tables E-4 through E-9

4.4.1 *Fish and Mussel Critical Habitat and Seasons*

Detailed descriptions of the fish and mussel resources in the Savannah River reservoirs and the mainstem Savannah River downstream from JST are provided in Section 2.9. Reservoir elevation results for the entire 73-year POR were analyzed for potential impacts to fish and mussel communities. Critical habitats and time periods, including reservoir littoral zone fish spawning habitat (April, May, and June), reservoir pelagic cool water/forage fish habitat (September), and reservoir littoral zone mussel habitat (annual) were assessed to evaluate differences between modeled reservoir operating scenarios. Differences in daily lake level fluctuations were the basis for the littoral zone assessment, while mean September reservoir elevations were analyzed for pelagic habitats. Similarly, critical time periods during the year were analyzed for the lower Savannah River downstream from JST Lake. These included riverine spawning (February-May), outmigration (May-August), summer low flow (August-November), and overwintering (November-February) periods. JST mean monthly flows were used for this assessment. HEC-ResSim model results for all four model scenarios are provided below for each critical time period in the Duke Energy and USACE reservoirs, as well as the lower Savannah River.

4.4.1.1 *Duke Energy Reservoir Littoral Zone Fish Habitat*

Similar to many reservoir fisheries in the southeastern U.S., centrarchids (e.g., sunfish and largemouth bass) make up the majority of the littoral zone species abundance in the Duke Energy Reservoirs. Many of these species create nests in littoral zone habitats where potential for nest/egg exposure can occur with reservoir level fluctuations. Unlike the USACE Reservoirs, there is currently no guideline for Duke Energy to maintain reservoir elevations during spring black bass spawning, which typically peaks in April. Sunfish spawning typically peaks in May and June. The average and range of daily reservoir fluctuations during the spawning months of April, May, and June are provided in Tables 4.4-1, 4.4-2, and 4.4-3, respectively.

Future Water Withdrawals with Historic Hydrology

During spawning months in Lakes Jocassee and Keowee, there is very little (0.01 feet) to no difference in average daily fluctuations between the alternatives. In Lake Jocassee, the maximum rise and fall of A2 daily fluctuations is 2 – 3 feet greater than the other model scenarios. Although a daily drop in reservoir elevation of 2 feet could cause nests to become exposed, pump-back operations often result in a similar increase the following day. Such large daily pool variations make those sites unsuitable for spawning by littoral zone fish. Five years of littoral zone electrofishing (1996, 1999, 2002, 2005, and 2008) conducted by Duke Energy found increasing numbers and weights of centrarchids (10 species combined) during two extreme drought periods (i.e., 1998 – 2002 and 2007 – 2008). Rodriguez (2009) suggests fish populations in Lake Jocassee are more limited by nutrient inputs than reservoir elevations. It is also likely that centrarchids have acclimated to the daily reservoir elevation fluctuations in Lake Jocassee and they have selected deeper spawning sites, as have been observed in other pumped storage reservoirs (Estes 1971).

Model Sensitivity Analyses

Modeling current water withdrawals had little effect on the average daily fluctuations in the Duke Energy Reservoirs. A2 produced the greatest daily maximum and minimum fluctuation (0.1 to 1.3 feet) in both Lakes Jocassee and Keowee.

Modeling climate change hydrologic conditions results in the same daily average fluctuation for all alternatives, but with greater (0.1 to 1.5 feet) maximum declines in pool levels during April. Similar to the future water withdrawals with historic hydrology scenario, these differences in the sensitivity analyses are unlikely to affect littoral zone fish spawning success.

4.4.1.2 *USACE Reservoir Littoral Zone Fish Habitat*

State natural resource agencies have identified largemouth bass spawning as a high priority for all of the USACE impoundments on the Savannah River. SC DNR personnel indicate that largemouth bass initiate spawning in the USACE reservoirs when water temperatures reach 18°C (65°F) and cease spawning when water temperatures reach 21°C (70°F) (USACE 2008a). With peak spawning likely occurring in April, USACE targets stable pool levels to prevent exposed and/or abandoned centrarchids nests and eggs. The USACE limits the lowering of reservoir elevations to 6 inches or less during the spawning period unless high inflows and/or drought conditions exist. The average and range of daily reservoir fluctuations during the spawning months of April, May, and June are provided in Tables 4.4-1, 4.4-2, and 4.4-3, respectively.

Future Water Withdrawals with Historic Hydrology

As discussed in Section 3.5, model results for the USACE reservoirs are very similar for all four alternatives, including April-June reservoir elevations. During the spawning months in Hartwell, RBR, and JST Lakes, there is very little (0.01 foot) to no difference in average daily fluctuations between the alternatives. As expected, there are rare instances when the maximum rise and fall of daily fluctuations exceeds the 6-inch rule, with the greatest of these instances occurring in RBR Lake. However, these differences occur very infrequently (5 percent or less of the time during spawning months) and the magnitudes of these differences are similar between scenarios. Overall, such minor and infrequent differences between scenarios would not have a negative effect on littoral zone spawning in the USACE reservoirs.

Model Sensitivity Analyses

Modeling current water withdrawals and climate change hydrologic conditions had very little (0.01 foot) to no effect on the average daily fluctuations in the USACE Reservoirs when compared to the future water withdrawals with historic hydrology. Modeling sensitivity analyses result in minor differences in maximum rise and fall. For example, A2's maximum fall in Hartwell Lake is less (by approximately 1 foot) for both sensitivity analyses than the future water withdrawals with historic hydrology. The effects of all four alternatives on littoral zone fish spawning are expected to be similar.

4.4.1.3 *Duke Energy Reservoir Littoral Zone Mussel Habitat*

Although mussel populations are not abundant in the Duke Energy reservoirs, reservoir elevation fluctuations could lead to exposure and mortality of mussels in the littoral zone. The severity of the impact would be related to the rate, frequency, and magnitude of daily reservoir fluctuations. Seasonal and meteorological influences may delay (i.e., cool, wet weather) or exacerbate (i.e., hot, dry weather) mortality of mussels during short periods of exposure. However, dewatering during even brief periods under survivable conditions make mussels more susceptible to predation by birds and/or small mammals (Devine Tarbell and Associates 2008). The average and range of daily reservoir fluctuations during the full POR is provided in Table 4.4-4.

Future Water Withdrawals with Historic Hydrology

Similar to littoral zone fish spawning, an analysis of daily reservoir fluctuations was performed to assess potential impacts to littoral zone mussel communities/habitats. All months in the 73-year POR were considered in this mussel habitat analysis (as opposed to only April-June fluctuations for fish). In Lakes Jocassee and Keowee, there is no difference in average daily fluctuations between the alternatives. In Lake Jocassee, the maximum rise and fall of A2 daily fluctuations is 1-2 feet larger (compared to the other three reservoir operating scenarios). As a result, A2 would result in greater potential impacts to mussels.

Model Sensitivity Analyses

Modeling current water withdrawals had no effect on the average daily fluctuations in the Duke Energy reservoirs, but some minimal differences in maximum rise and fall. For example, all alternatives in both reservoirs showed increases in the maximum rise (0.5-3.5 feet) and fall (0.7-1.7 feet). The magnitude of this change was similar between alternatives.

Modeling climate change hydrologic conditions results in the same average daily fluctuation for all alternatives, but with some larger differences in maximum rise and fall. Similar to the current water withdrawal scenario, all alternatives show increases in maximum rise (0.7-4.5 feet) and fall (0.2-2.9 feet). A short-term impact to some individuals would be expected with a 4.4 foot daily drop in elevation (NAA/A1 maximum drop under the future water withdrawals with climate change hydrologic conditions). However, the magnitudes are similar between alternatives.

4.4.1.4 *USACE Reservoir Littoral Zone Mussel Habitat*

No information on mussel communities in the USACE reservoirs was available for this report. However, similar to effects on mussels in the Duke Energy reservoirs, exposure and mortality of mussels could occur in littoral zone areas as a result of daily reservoir fluctuations. The average and range of daily reservoir fluctuations during the full POR are provided in Table 4.4-4.

Future Water Withdrawals with Historic Hydrology

There is no difference in the average daily reservoir fluctuation over the POR between the alternatives for all three of the USACE reservoirs, and little to no difference between maximum rise (0.1-0.3 feet) and fall (0.01-0.4 feet) in the entire POR, particularly for RBR and JST Reservoirs. There were some differences in the maximum daily rise in Hartwell Lake, with A2 producing the greatest rise (1.0 foot). However, a sudden rise in reservoir elevation would not impact mussel populations (only sudden drops). The effects of all four alternatives on mussel populations in the USACE reservoirs are similar.

Model Sensitivity Analyses

Modeling current water withdrawals and climate change hydrologic conditions had no effect on the average daily fluctuations in the USACE reservoirs, but some minor differences in maximum rise and fall are observed. Similar to the sensitivity analysis for littoral zone spawning, all alternatives show increases in the maximum rise (0.1-2.0 feet) and fall (0.3-2.0 feet) under the current water withdrawal with historic hydrology. However, the magnitudes between alternatives are similar. With climate change hydrology, differences in maximum rise also increase for all alternatives, but at a similar magnitude. The effects of all four alternatives on mussel populations in the USACE reservoirs are similar.

Table 4.4-1 Duke Energy and USACE Reservoir Daily Fluctuations in April for the 73-Year POR (1939–2011)

Model Setup	Parameter (feet)	Jocassee				Keowee				Hartwell				RBR				JST			
		NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4
Future Water Withdrawals with Historic Hydrology	Max Rise	2.00	4.00	2.10	2.10	1.23	1.23	0.83	1.02	0.66	0.66	0.69	0.66	1.69	1.69	1.65	1.50	0.72	0.72	0.73	0.73
	Max Fall	-1.60	-2.60	-0.90	-0.90	-0.37	-1.16	-0.37	-0.37	-2.10	-2.10	-2.11	-2.08	-1.74	-1.74	-2.25	-2.25	-1.67	-1.67	-1.67	-1.68
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	0.00	0.00	0.02	0.02	0.02	0.02
Current Water Withdrawals with Historic Hydrology	Max Rise	1.30	3.70	1.10	0.90	0.40	1.13	0.47	0.46	0.89	0.89	0.75	0.75	2.63	2.63	2.42	1.30	0.69	0.69	0.69	0.68
	Max Fall	-1.50	-3.10	-0.80	-0.80	-0.75	-1.19	-0.48	-0.48	-1.01	-0.99	-1.05	-1.05	-2.21	-2.21	-2.00	-2.00	-2.39	-2.39	-2.92	-2.91
	Average	-0.03	-0.04	-0.03	-0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Future Water Withdrawals with Climate change Hydrology	Max Rise	1.50	3.60	0.90	0.90	0.42	1.19	0.43	0.42	0.68	0.68	0.89	0.84	2.23	2.23	1.98	2.17	0.69	0.69	0.69	0.69
	Max Fall	-1.70	-3.20	-1.50	-1.50	-1.49	-1.57	-0.50	-0.47	-1.29	-1.29	-1.12	-1.12	-1.56	-1.56	-2.04	-2.03	-2.39	-2.39	-2.91	-2.91
	Average	-0.03	-0.03	-0.03	-0.03	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00

Table 4.4-2 Duke Energy and USACE Reservoir Daily Fluctuations in May for the 73-Year POR (1939–2011)

Model Setup	Parameter (feet)	Jocassee				Keowee				Hartwell				RBR				JST			
		NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4
Future Water Withdrawals with Historic Hydrology	Max Rise	1.30	2.90	1.40	1.60	1.13	1.20	0.63	0.53	0.59	0.59	0.88	0.88	3.02	3.02	1.50	1.50	0.61	0.61	0.75	0.75
	Max Fall	-1.40	-2.50	-1.30	-1.30	-0.67	-1.19	-0.44	-0.50	-0.70	-0.70	-1.08	-1.22	-3.77	-3.77	-4.03	-3.95	-1.93	-1.84	-1.82	-1.82
	Average	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.00	0.01	0.01	0.01	0.02	0.02
Current Water Withdrawals with Historic Hydrology	Max Rise	1.80	4.10	2.10	2.20	1.25	1.25	0.87	0.99	0.87	0.87	0.74	0.89	1.69	1.68	1.60	1.61	0.72	0.72	0.72	0.72
	Max Fall	-0.70	-3.80	-0.40	-0.40	-0.45	-1.13	-0.54	-0.54	-2.11	-2.11	-2.10	-2.08	-2.04	-2.04	-1.76	-2.03	-1.67	-1.67	-1.68	-1.69
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	0.00	0.00	0.02	0.02	0.01	0.02
Future Water Withdrawals with Climate change Hydrology	Max Rise	2.10	4.00	2.20	2.10	1.23	1.23	0.83	0.84	0.75	0.75	0.69	0.69	1.76	1.76	1.65	1.61	0.73	0.73	0.73	0.73
	Max Fall	-1.70	-2.70	-0.90	-0.80	-0.37	-1.14	-0.37	-0.37	-2.10	-2.10	-2.11	-2.11	-1.89	-1.89	-2.25	-2.25	-1.67	-1.67	-1.67	-1.67
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	-0.02	-0.02	0.00	0.00	0.02	0.02	0.02	0.02

Table 4.4-3 Duke Energy and USACE Reservoir Daily Fluctuations in June for the 73-Year POR (1939–2011)

Model Setup	Parameter (feet)	Jocassee				Keowee				Hartwell				RBR				JST			
		NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4
Future Water Withdrawals with Historic Hydrology	**Max Rise**	1.30	2.90	1.40	1.60	1.13	1.13	0.92	0.91	0.37	0.41	0.59	0.63	2.00	2.02	1.58	1.58	0.61	0.62	0.52	0.52
	Max Fall	-1.40	-2.40	-1.30	-1.30	-0.67	-1.19	-0.45	-0.50	-0.91	-0.91	-1.08	-1.22	-1.91	-1.94	-1.79	-1.93	-1.93	-1.84	-1.82	-1.82
	Average	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.02	0.02	0.02	0.02
Current Water Withdrawals with Historic Hydrology	**Max Rise**	1.50	3.60	0.80	0.80	1.06	1.12	1.24	1.23	0.58	0.67	0.42	0.44	3.01	3.01	1.51	1.53	0.56	0.56	0.75	0.74
	Max Fall	-1.30	-2.50	-1.30	-1.30	-0.67	-1.11	-0.53	-0.52	-1.26	-1.26	-1.15	-1.16	-3.88	-3.88	-4.02	-4.23	-1.58	-1.61	-1.59	-1.60
	Average	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02
Future Water Withdrawals with Climate change Hydrology	**Max Rise**	1.40	3.50	1.70	1.60	0.82	1.13	0.50	0.53	0.85	0.85	0.88	0.88	3.02	3.01	1.52	1.50	0.62	0.62	0.74	0.74
	Max Fall	-1.00	-2.60	-1.20	-1.30	-0.67	-1.16	-0.44	-0.50	-1.28	-0.65	-1.06	-1.06	-3.74	-3.74	-4.02	-3.92	-2.02	-1.93	-1.82	-1.82
	Average	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.02	0.02	0.02	0.02

Table 4.4-4 Duke Energy and USACE Reservoir Year-Round Daily Fluctuations for the 73-Year POR

Model Setup	Parameter (feet)	Jocassee				Keowee				Hartwell				RBR				JST			
		NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4	NAA / A1	A2	A3	A4
Future Water Withdrawals with Historic Hydrology	**Max Rise**	1.40	3.70	0.90	0.90	0.43	1.17	0.43	0.42	0.68	0.68	0.89	0.84	2.23	2.23	2.11	2.11	0.69	0.69	0.69	0.69
	Max Fall	-1.70	-3.20	-1.40	-1.50	-1.48	-1.48	-0.50	-0.51	-1.22	-1.22	-1.12	-1.13	-2.43	-2.43	-2.04	-2.03	-2.38	-2.38	-2.92	-2.90
	Average	-0.03	-0.03	-0.03	-0.03	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Current Water Withdrawals with Historic Hydrology	**Max Rise**	5.00	4.30	3.10	3.20	1.68	1.68	1.66	1.77	0.91	2.69	1.03	0.91	3.35	2.42	3.35	3.37	0.76	0.76	0.75	0.76
	Max Fall	-2.80	-4.40	-3.10	-2.80	-2.33	-2.18	-2.18	-2.14	-2.93	-2.93	-2.93	-2.93	-3.88	-2.75	-4.02	-4.23	-3.89	-3.89	-4.01	-4.04
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Future Water Withdrawals with Climate change Hydrology	**Max Rise**	4.40	4.40	2.80	2.70	1.67	1.67	1.64	1.67	0.92	3.14	1.12	1.63	3.02	2.51	3.65	4.18	0.76	0.76	0.76	0.76
	Max Fall	-4.40	-3.50	-4.10	-4.10	-1.64	-1.78	-1.59	-1.61	-2.80	-2.73	-2.81	-2.82	-3.74	-2.74	-4.02	-4.50	-3.82	-3.82	-3.36	-3.17
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.4.1.5 *Duke Energy Reservoir Pelagic Zone Fish Habitat*

Blueback herring and trout are important cool water forage and game fish, respectively, in the Duke Energy reservoirs. Although populations of these species are supplemented through stocking, pelagic habitat during hot and dry summer conditions can limit populations. The optimal temperature for blueback herring is 20°C (68°F) to 25°C (77°F), with D.O. > 4.0 mg/L (Nestler et al. 2002).

The pelagic trout fishery is unique to Lake Jocassee and its sustainability is partially dependent on the availability of suitable pelagic habitat; specifically, a hypolimnion that possesses water temperatures <20°C (68°F) with D.O. >5 mg/L during the critical summer and fall months. During extreme droughts, Lake Jocassee can experience periods of relatively low reservoir elevations. However, reservoir elevations alone have not been found to influence the amount of pelagic trout habitat. Therefore, the Lake Jocassee trout fishery is not expected to be negatively affected by any of the alternatives (William Foris, Duke Energy, Personal Communication, October 15, 2013). Pelagic habitats were further assessed by comparing mean September reservoir elevations. The mean September reservoir elevations for the 73-year POR are provided in Figures 4.4-1 and 4.4-2.

There is an increased risk of fish entrainment associated with pumping operations at the Bad Creek Project when Lake Jocassee reservoir elevations fall below 1,096 feet AMSL (Barwick et al 1994). Over the 73-year POR, Lake Jocassee daily reservoir elevations drop below 1,096 feet AMSL 12 percent of the time for the NAA/A1 and A2, and 4 percent of the time for A3 and A4. So A3 and A4 would reduce the risk of fish entrainment at the Bad Creek Project.

Future Water Withdrawals with Historic Hydrology

As discussed in Section 3.4 for the Duke Energy Reservoirs, A3 and A4 generally result in higher reservoir elevations compared to NAA/A1 and A2. A3 and A4 produce the highest mean September reservoir elevations (approximately 5-14 feet higher than NAA/A1 and A2) in Lake Jocassee. Differences between the alternatives in mean September elevations occur during 23 years for Lake Jocassee and 46 years for Lake Keowee over the POR. The greatest differences occur in Lake Jocassee between NAA/A1 and A2 compared to A3 and A4. For example, in

September 1988, NAA/A1 and A2 are 12 feet lower than A3 and A4. NAA/A1 and A2 Lake Jocassee elevations were 10 feet lower than A3 and A4 during the 2001 extreme drought year.

Lake Keowee reservoir elevations follow the same general pattern as Lake Jocassee (differences in elevations occur between NAA/A1 and A2 compared to A3 and A4). On occasion, NAA/A1 results in lower reservoir elevations (by up to 5 feet) compared to A2 (2008). Although some of the differences between alternatives are relatively large during certain drought periods, they are infrequent and would not be expected to have an effect on the long term sustainability of cool water forage and predator fish populations in the Duke Energy reservoirs. Reservoir elevations alone have not been found to influence the amount of pelagic trout habitat in Lake Jocassee. Therefore, the Lake Jocassee trout fishery should not be negatively affected by any of the alternatives.

Model Sensitivity Analyses

Modeling current water withdrawals result in slightly higher September mean elevations in both reservoirs, which under favorable meteorological conditions, would increase pelagic cool water fish habitat under all alternatives compared to the future water withdrawal with historic hydrology. Reducing water withdrawals also results in smaller differences between scenarios. For example, differences between A3 and A4 compared to A2 for Lake Jocassee range from 2-10 feet (instead of 5-14 feet).

Climate change hydrologic conditions result in similar differences between scenarios compared to future water withdrawals with historic hydrology model assumptions. A3 and A4 result in higher mean elevations. When the reservoirs are strongly stratified, lower lake elevations could “squeeze” preferred habitats into a smaller zone and potentially compress species into less preferred habitats. Based on the model results, these conditions would likely affect Lake Keowee more than Lake Jocassee. However, the infrequent nature of these events is not expected to have long-term consequences on pelagic fish populations in the Duke Energy reservoirs.

Figure 4.4-1 Lake Jocassee Mean September Elevation for Future Water Withdrawals with Historic Hydrology

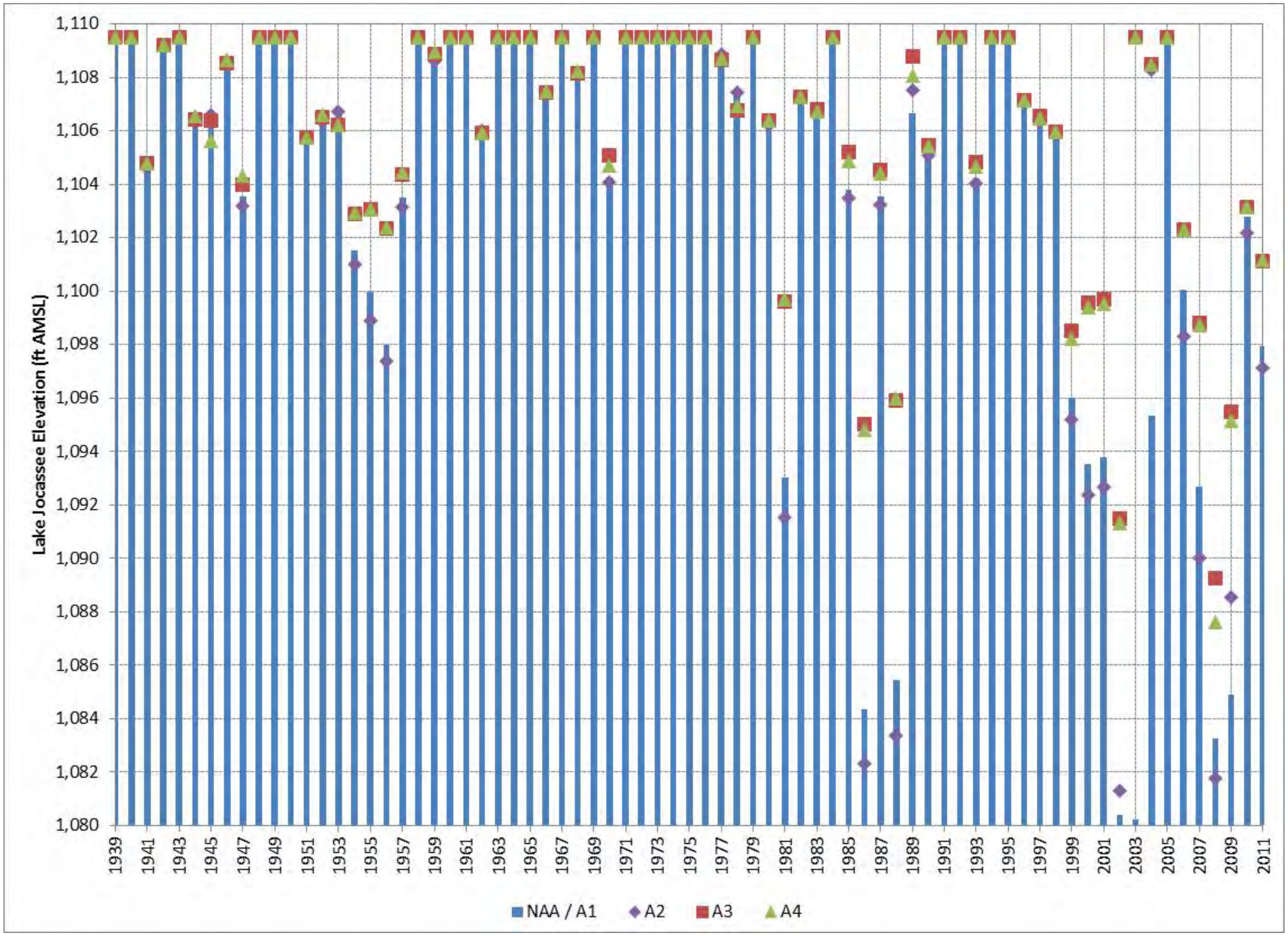
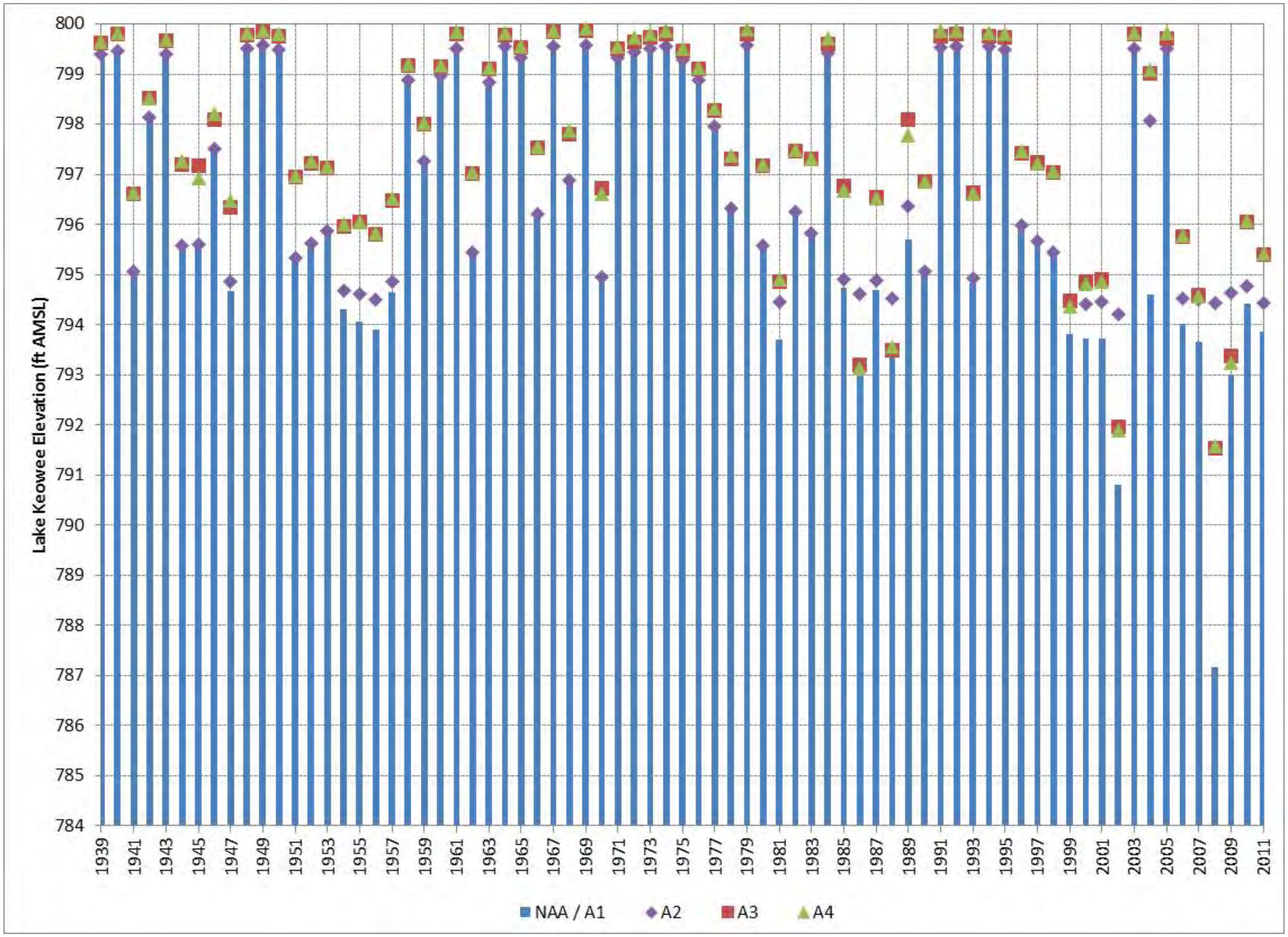


Figure 4.4-2 Lake Keowee Mean September Elevation for Future Water Withdrawals with Historic Hydrology



Appendix O provides the mean September reservoir elevation graphs for the HEC-ResSim model sensitivity analyses for the Duke Energy reservoirs.

4.4.1.6 *USACE Reservoir Pelagic Zone Fish Habitat*

Blueback herring and temperate bass are important forage and game fish, respectively, in the USACE reservoirs. Although populations of striped bass are supplemented through stocking, pelagic habitat during hot and dry summer conditions can limit populations for these species. Similar optimal water quality conditions as those reported for the Duke Energy reservoirs are also required for summer survival within the USACE reservoirs. Varying lake elevations from year to year could shift the location of preferred habitat in each USACE reservoir, which could result in a smaller volume of preferred habitat. However, because the differences in reservoir elevation between alternatives are small, it is expected that all four alternatives would have similar effects on the amount of preferred habitat in each reservoir. The mean September reservoir elevations are provided in Figures 4.4-3, 4.4-4, and 4.4-5.

Future Water Withdrawals with Historic Hydrology

There is very little to no difference (< 1 foot) between mean September elevations for the alternatives in all three USACE reservoirs. These small and infrequent differences are not expected to impact pelagic fish habitat in these reservoirs.

Model Sensitivity Analyses

Modeling current water withdrawals resulted in slightly higher September mean elevations for all three USACE reservoirs, but differences between alternatives are still very small (< 1 foot).

Modeling climate change hydrologic conditions results in no difference or only slightly lower September mean reservoir elevations in all three USACE reservoirs compared to historic hydrologic conditions. For the most part, differences between alternatives are very small (< 1 foot) in all three USACE reservoirs. However there are two years at RBR Lake where the differences were slightly greater than 1 foot (i.e., 1969 and 1979). The infrequent nature of these events and small differences in reservoir elevations between alternatives is not expected to affect pelagic fish populations in the USACE reservoirs.

Appendix O provides the mean September reservoir elevation graphs for the HEC-ResSim model sensitivity analyses for the USACE reservoirs.

Figure 4.4-3 Hartwell Lake Mean September Elevation (Future Water Withdrawals with Historic Hydrology)

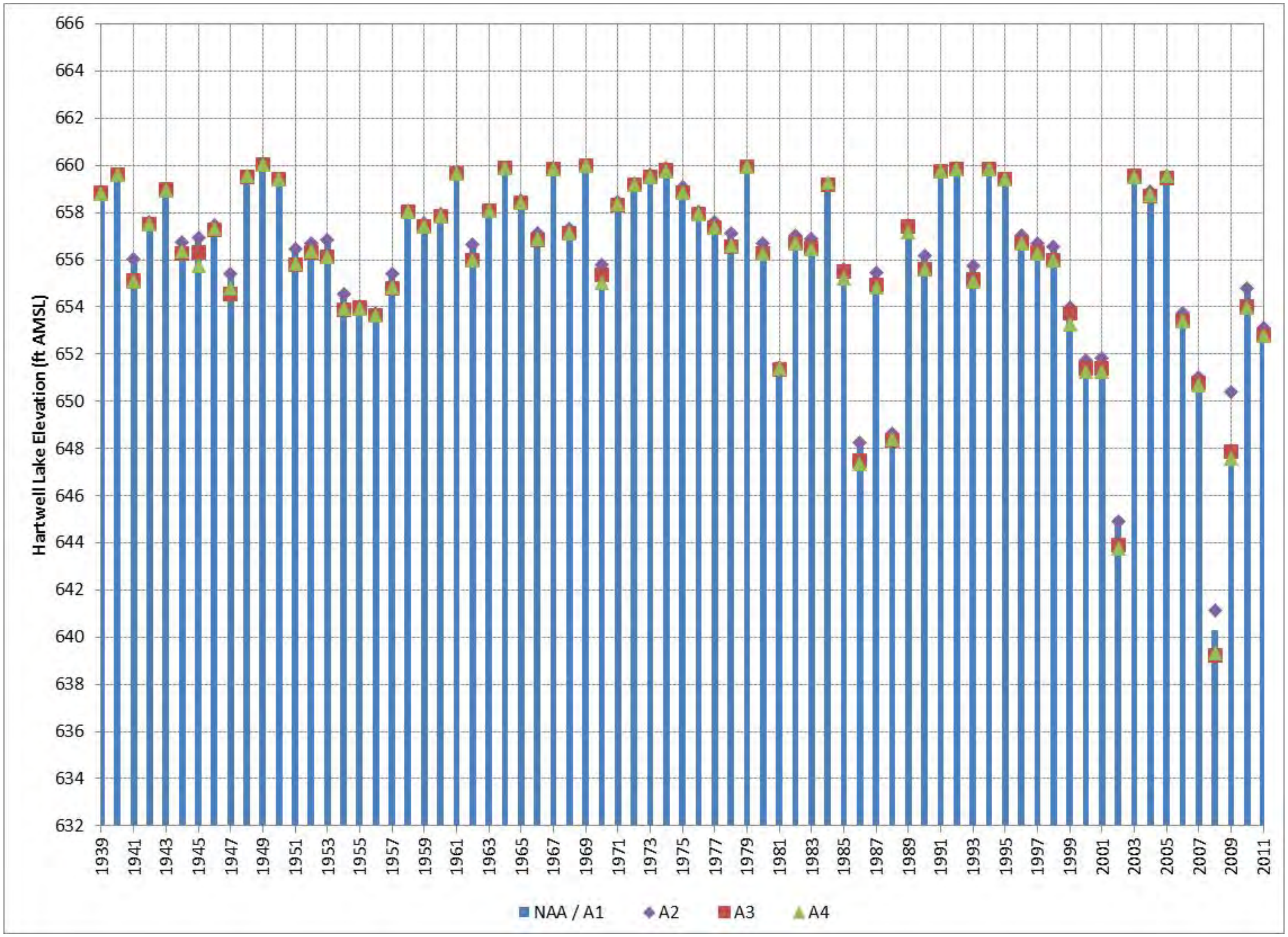


Figure 4.4-4 RBR Lake Mean September Elevation (Future Water Withdrawals with Historic Hydrology)

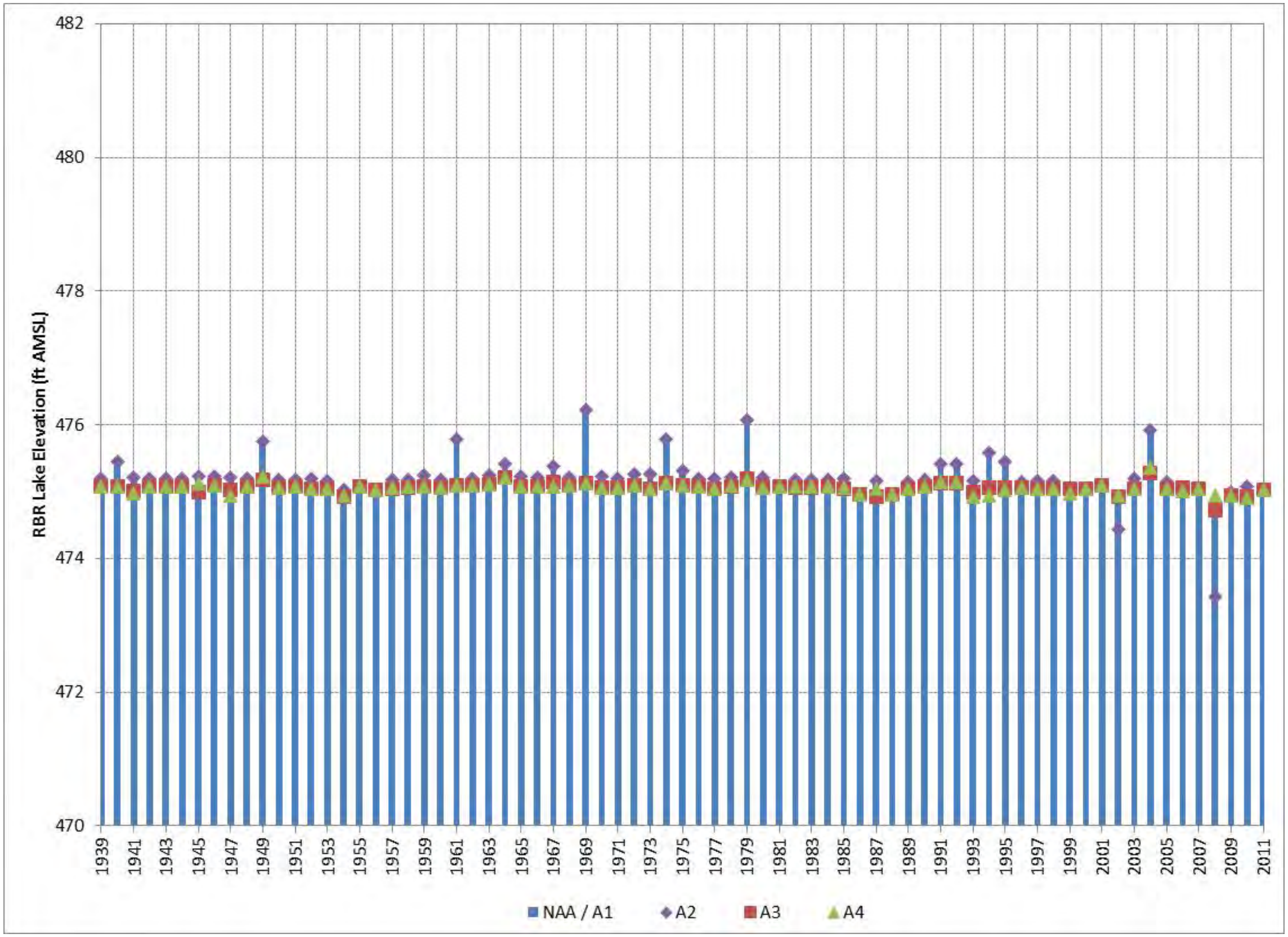
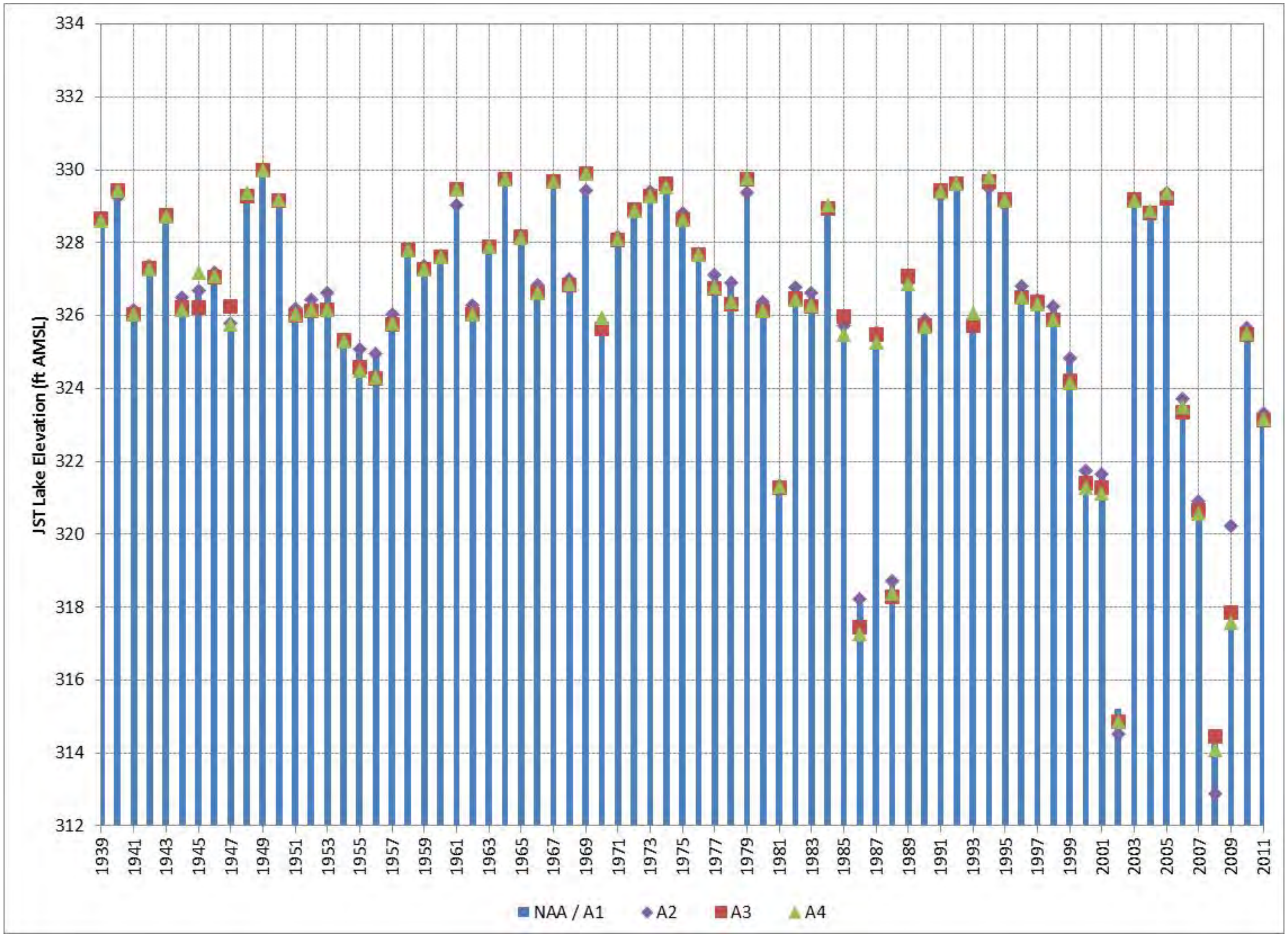


Figure 4.4-5 JST Lake Mean September Elevation (Future Water Withdrawals with Historic Hydrology)



4.4.1.7 *Lower Savannah River Fish and Mussel Habitats*

As mentioned in Section 2.9.1.6, the Savannah River downstream from JST Reservoir supports an abundant and diverse fish community including resident freshwater, euryhaline, and diadromous species. Augusta Shoals and other gravel bars downstream from JST are known spawning habitats for many fish species including striped bass, shad, endangered sturgeon, suckers, and other riverine species (Duncan et al. 2003). Sufficient river flows during spawning runs, larval drift and juvenile outmigration, and overwintering are important for completion of diadromous and resident fish life cycles. Summer low flow periods, particularly during drought years can reduce wetted perimeters and limit instream habitats. These periods create stressful conditions for fish and mussel species and during extreme circumstances can result in fish and mussel mortalities. Mean monthly flows were used to assess potential effects on critical time periods for fish and mussel communities in the lower Savannah River downstream from JST Lake. Figures 4.4-6 through 4.4-17 provide monthly mean flow data (January through December). Similar to mean flow data presented in Section 3.7, differences between alternatives are minor.

Future Water Withdrawals with Historic Hydrology

All four alternatives result in similar reservoir elevations for the USACE reservoirs. As a result, flow releases to the lower Savannah River downstream from JST are also similar. Where there are differences, they typically occur during higher flow periods when monthly average JST flow releases are well above 10,000 cfs. Monthly average differences in flows released from JST were not as evident during drought conditions, and in particular extreme drought conditions. For example, during the extreme drought in 2008, there was little to no difference in average monthly JST releases between alternatives. Therefore, the effects of all four alternatives on lower Savannah River fish and mussel populations are expected to be similar.

Model Sensitivity Analysis

Current water withdrawals result in slightly higher monthly releases from JST compared to future water withdrawals. There is little to no difference in JST releases between current water withdrawal model scenarios. Where there are differences in monthly average JST flow releases, they typically occur during high flow events (i.e., in excess of 10,000 cfs). As a result, any effects to lower Savannah River fish and mussel populations are expected to be similar for the four current water withdrawal modeling scenarios.

Modeling climate change hydrologic conditions results in similar mean monthly releases from JST compared to historic hydrologic conditions. The effects of all four alternatives on lower Savannah River fish and mussel populations are expected to be similar.

Appendix O provides the monthly mean flow figures (January-December) for the Savannah River model sensitivity analyses.

Figure 4.4-6 Mean January JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

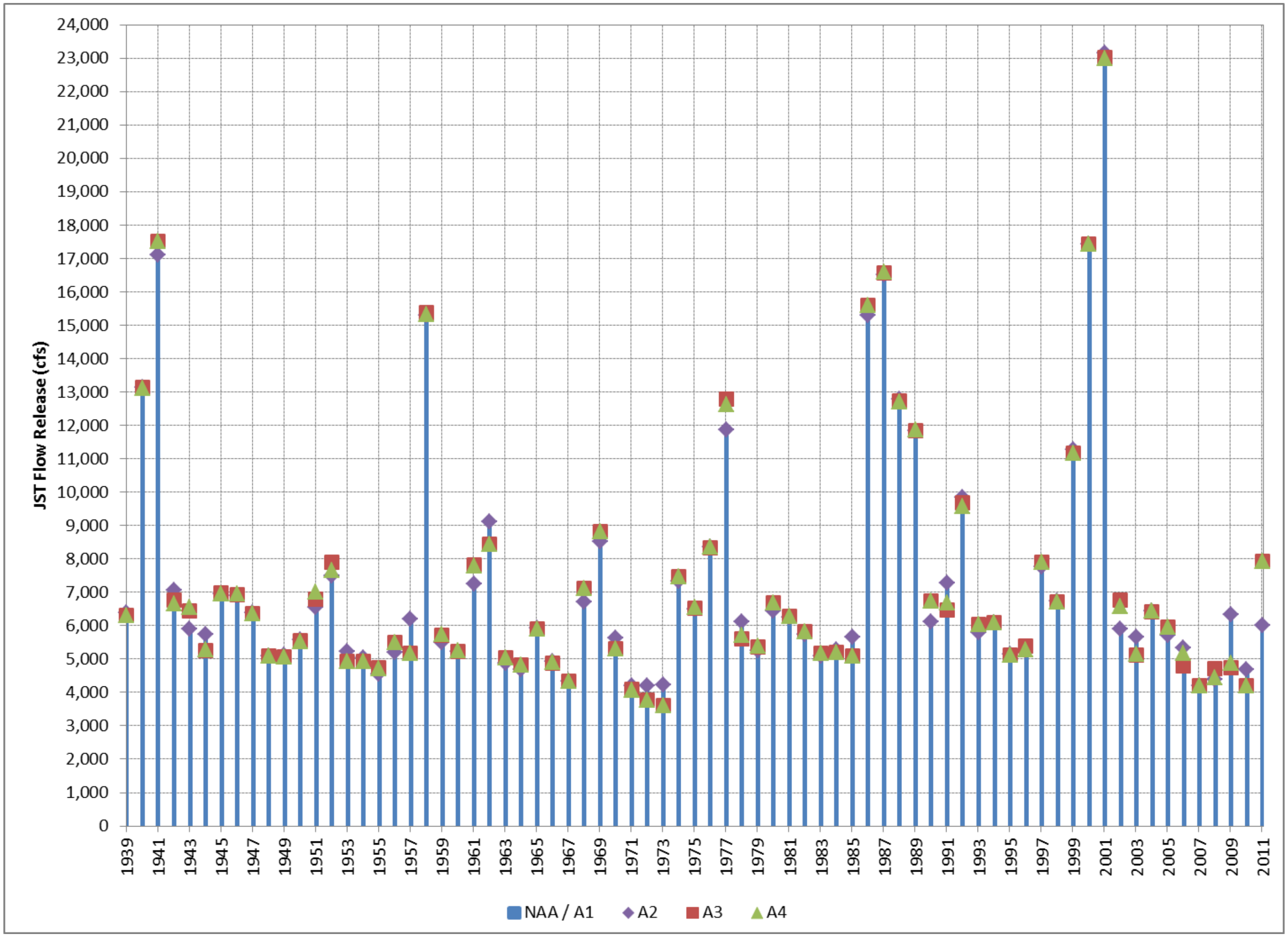


Figure 4.4-7 Mean February JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

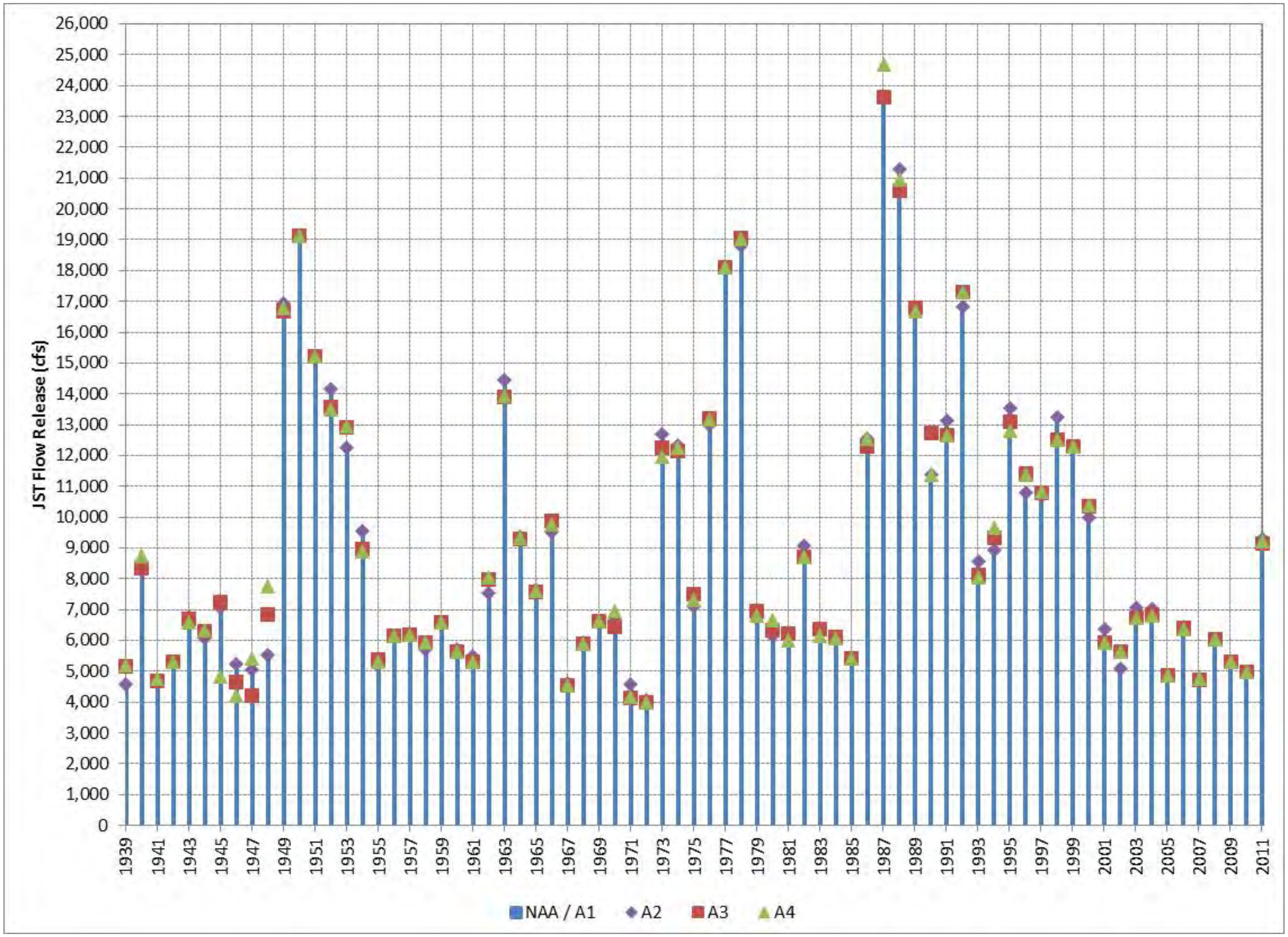


Figure 4.4-8 Mean March JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

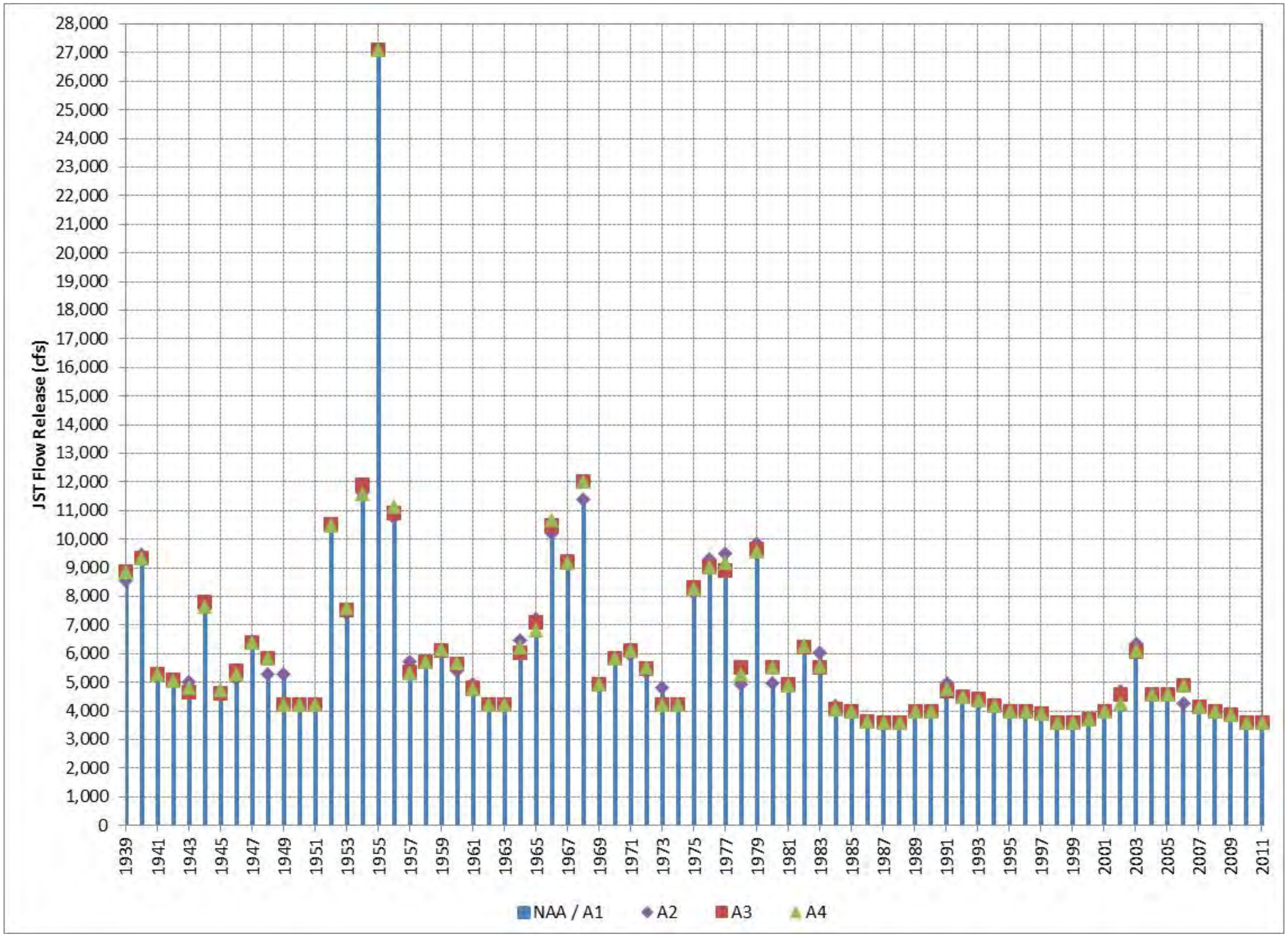


Figure 4.4-9 Mean April JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

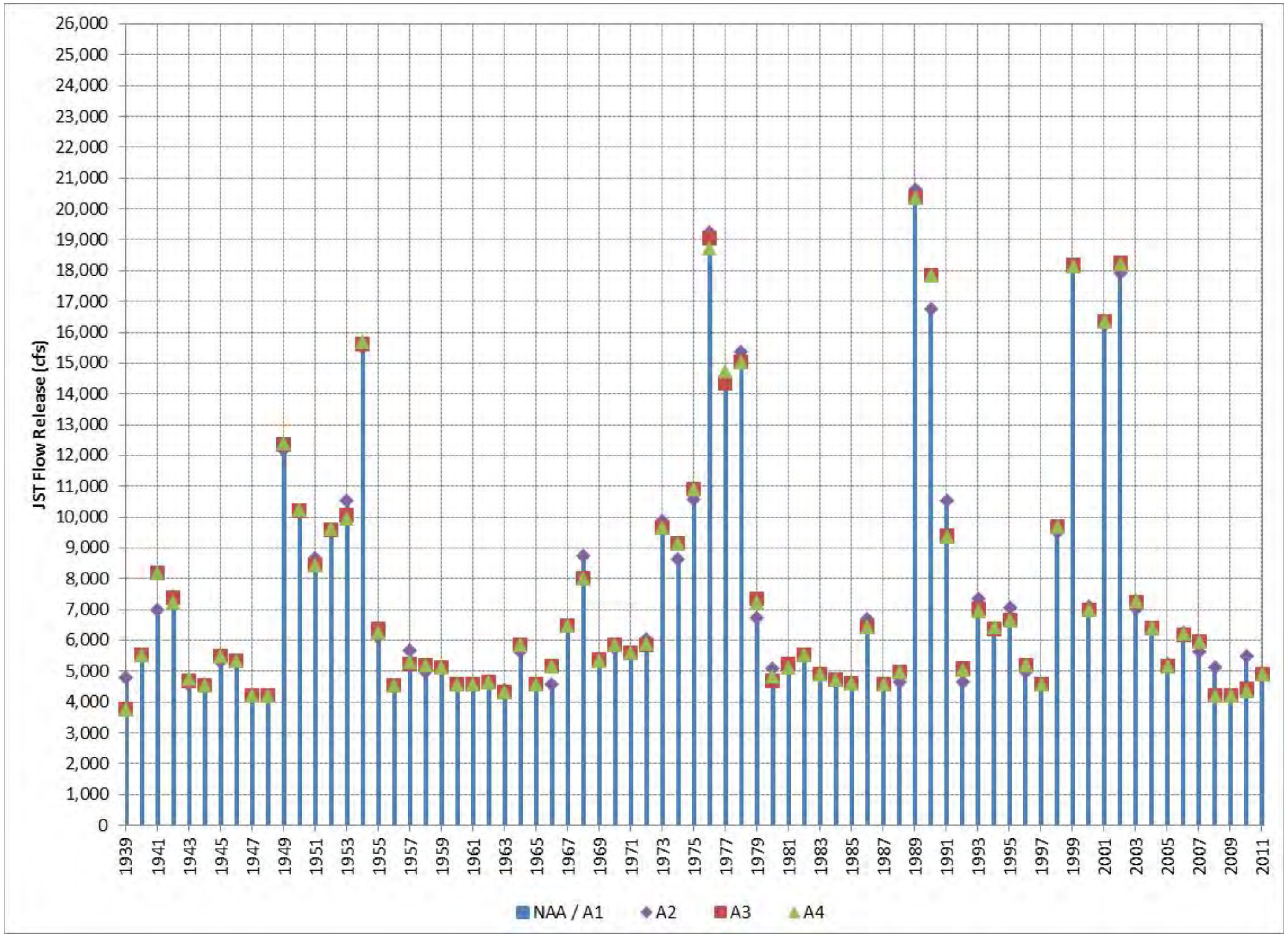


Figure 4.4-10 Mean May JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

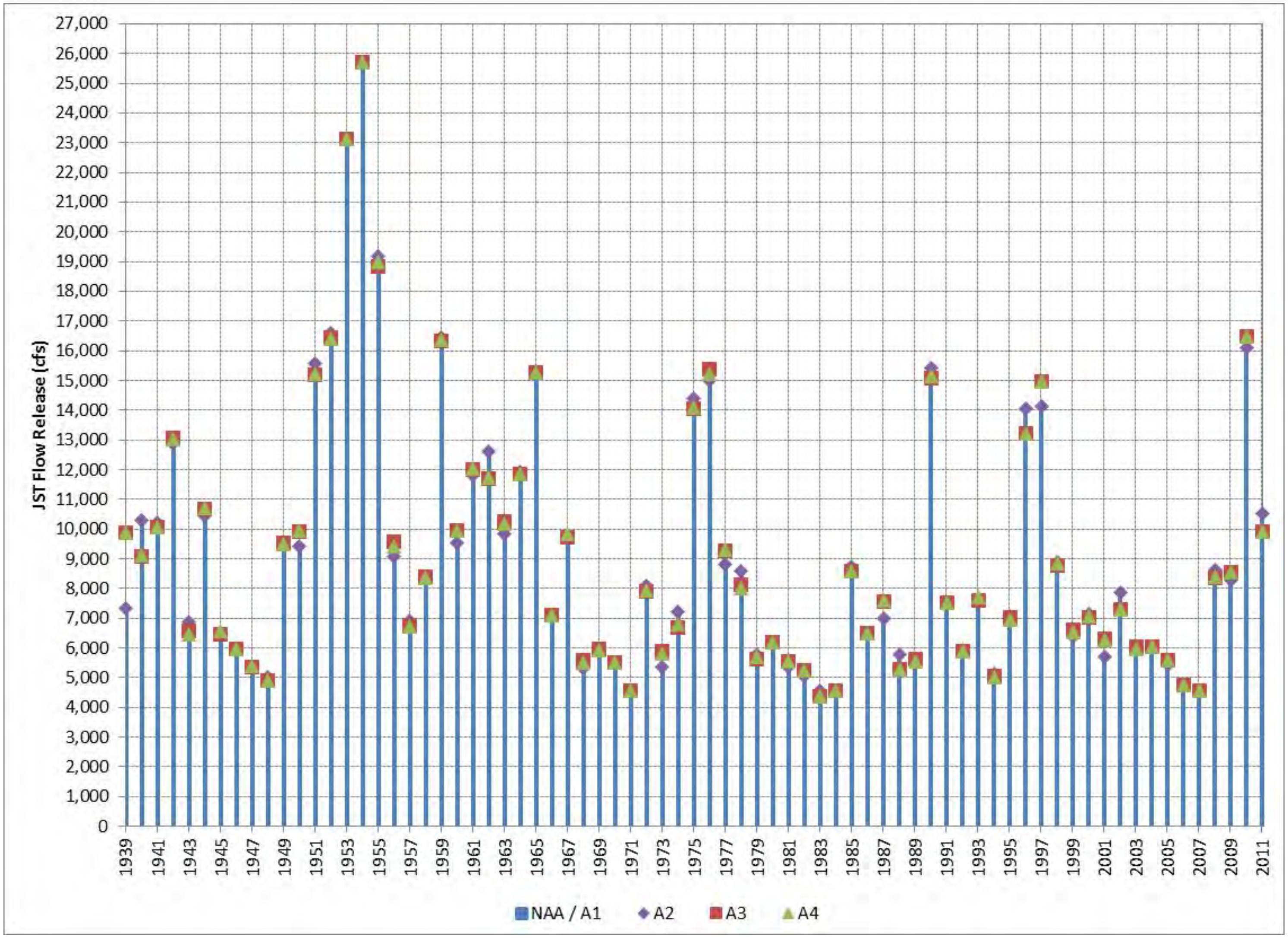


Figure 4.4-11 Mean June JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

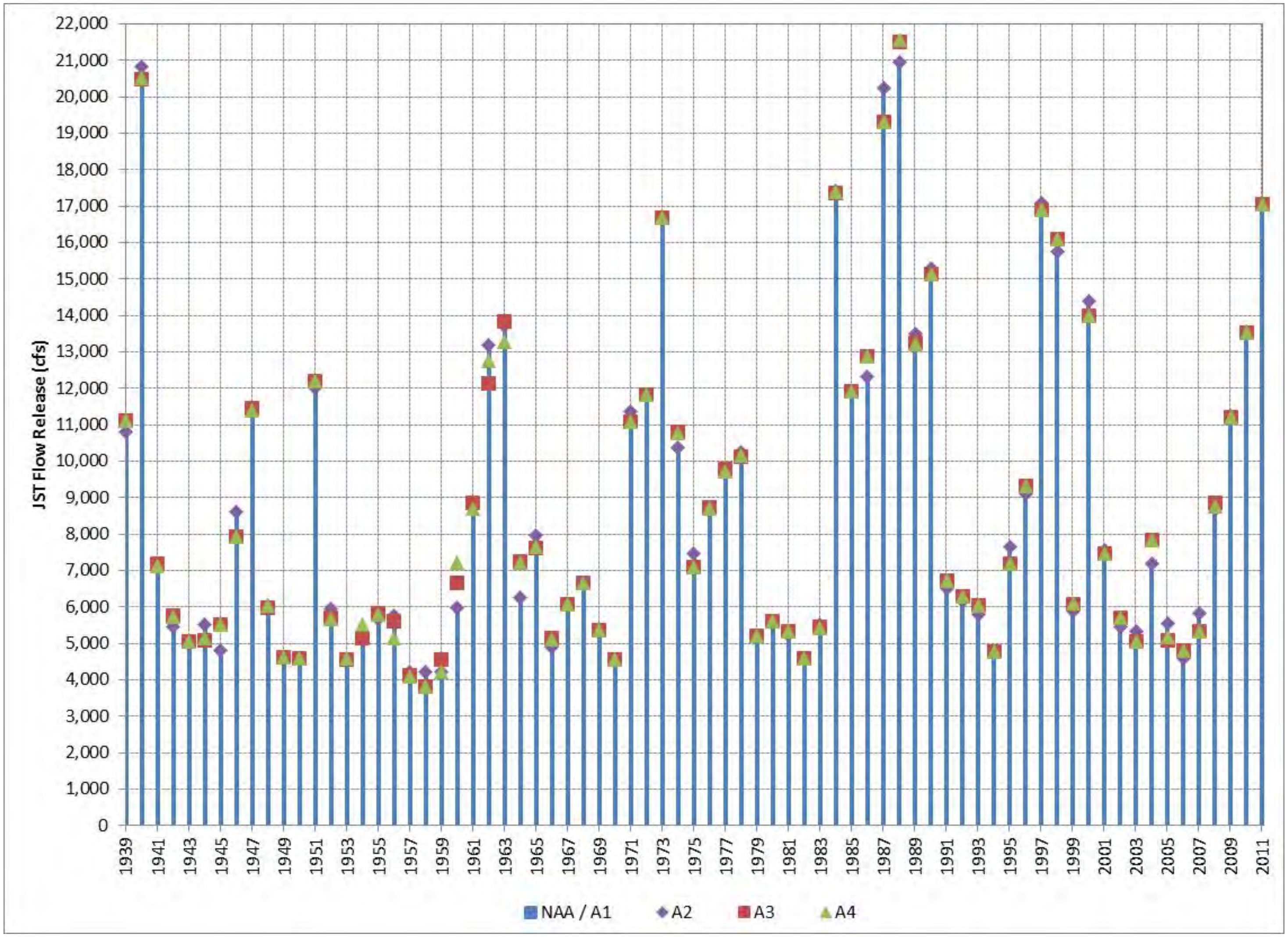


Figure 4.4-12 Mean July JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

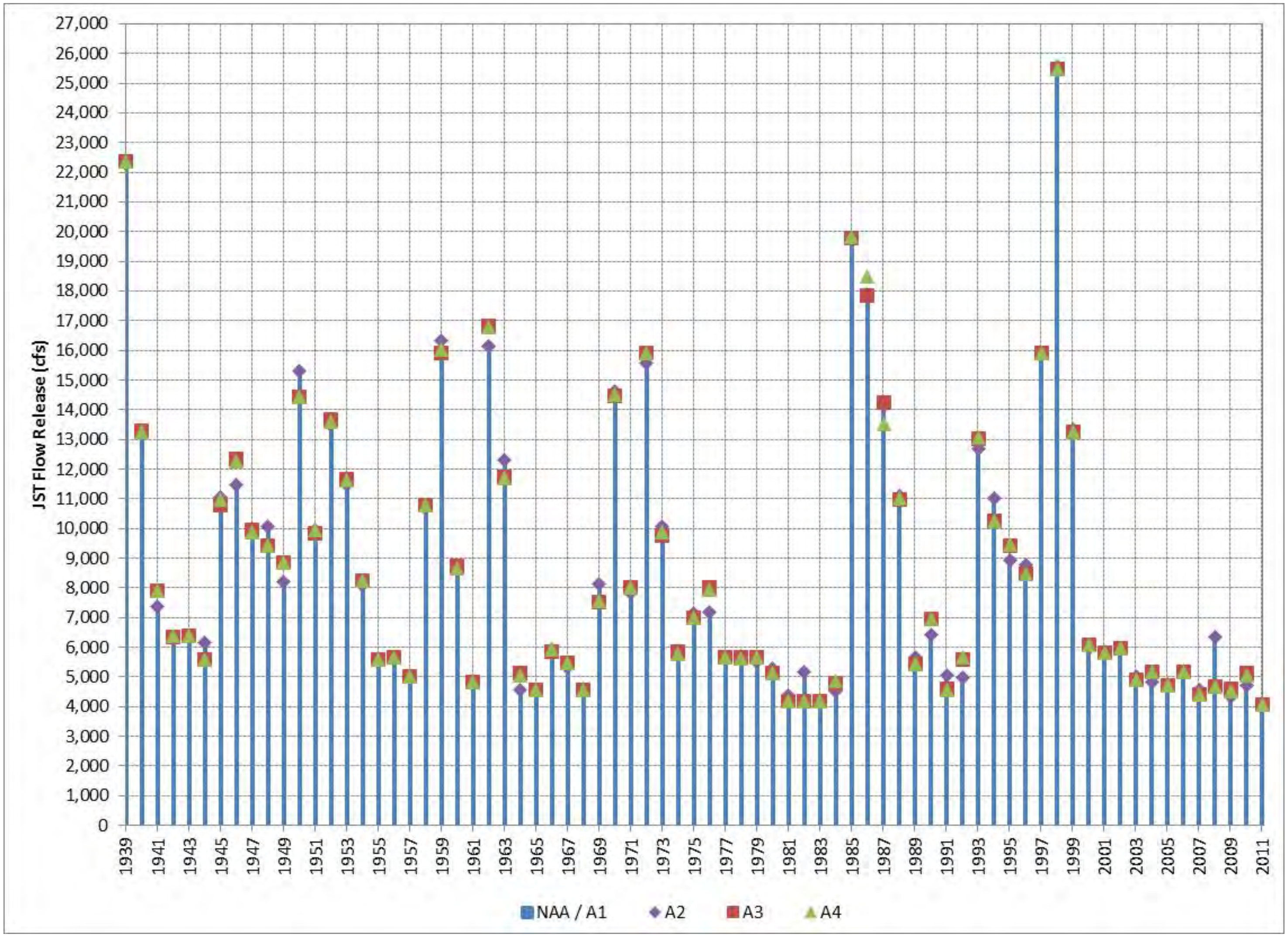


Figure 4.4-13 Mean August JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

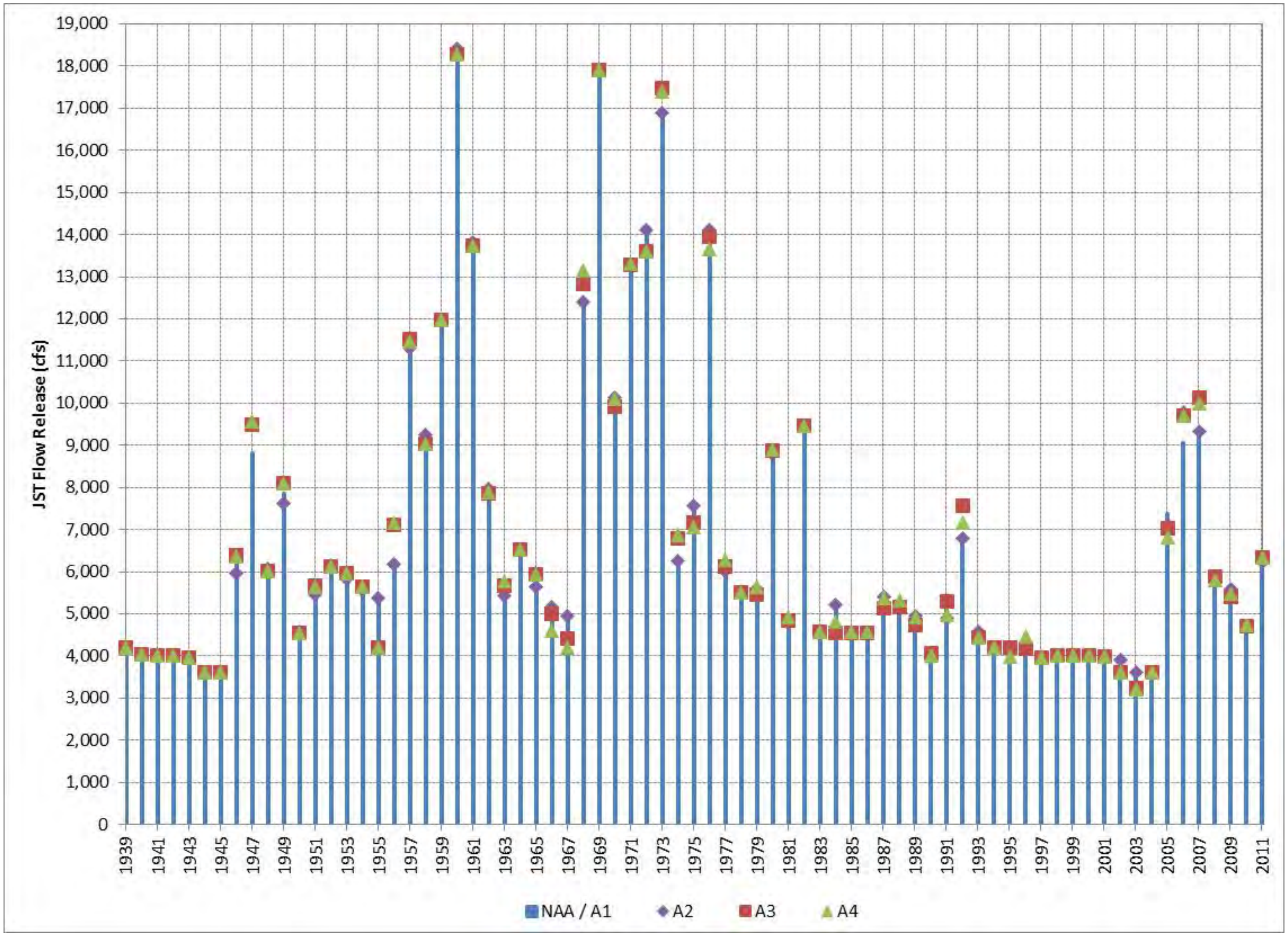


Figure 4.4-14 Mean September JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

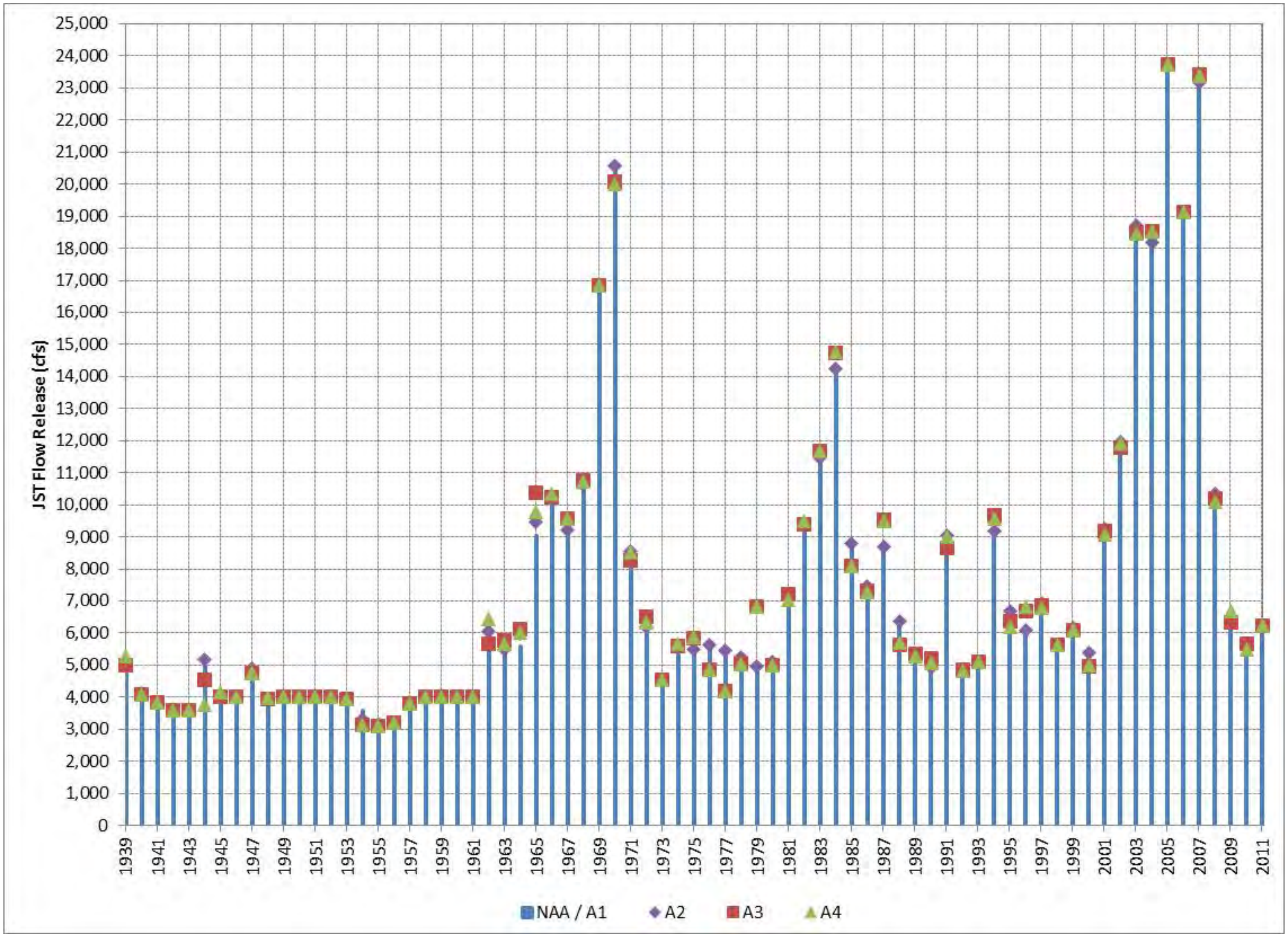


Figure 4.4-15 Mean October JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

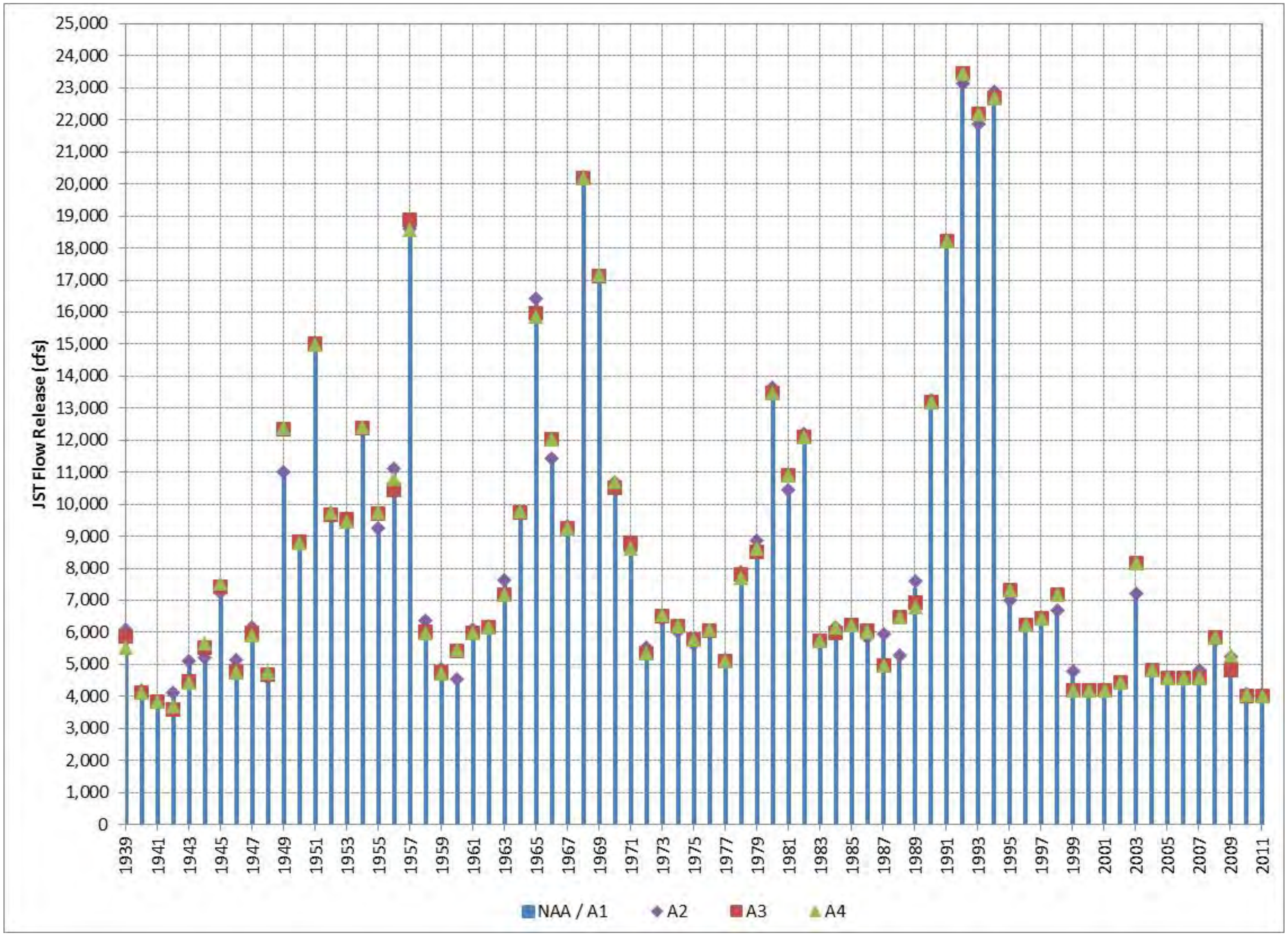


Figure 4.4-16 Mean November JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)

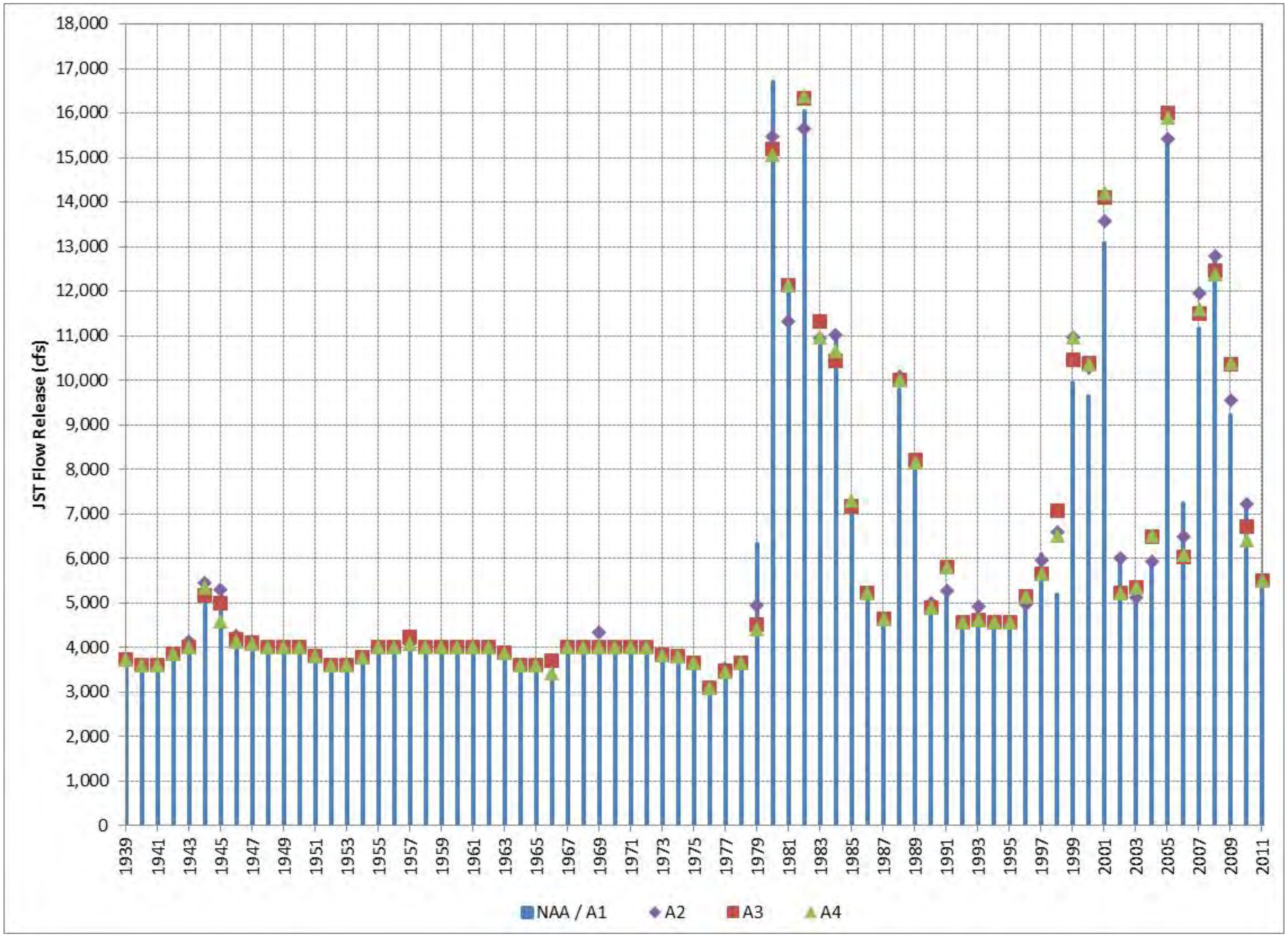
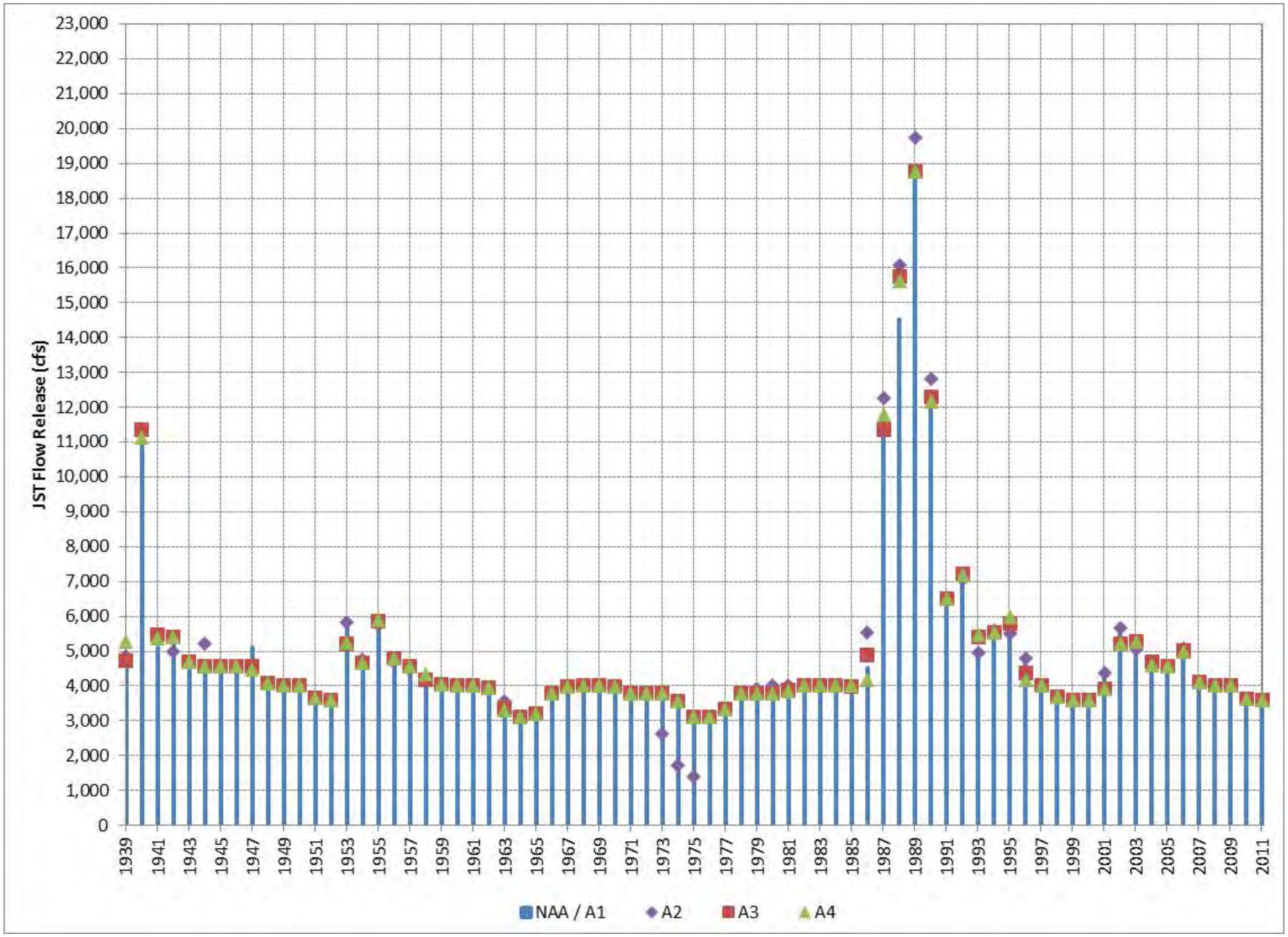


Figure 4.4-17 Mean December JST Lake Flow Release (Future Water Withdrawals with Historic Hydrology)



4.4.1.8 *Rare, Threatened, Endangered Fish and Mussel Habitats*

No federally-protected endangered or threatened fish or mussel species occur in Savannah River impoundments. The redeye bass and blackbanded darter, both of which are considered rare in South Carolina, have been collected in the Duke Energy reservoirs. No state-listed species occur in the USACE reservoirs. As mentioned in Section 2.9.5, there are several federally-listed fish species, including those classified as endangered, threatened, species of concern, or candidates for listing that occur in the lower Savannah River below JST. These include the shortnose sturgeon, Atlantic sturgeon, American eel, robust redhorse, bluebarred pygmy sunfish, and blueback herring. Three mussel species recently collected in the lower Savannah River (the Atlantic pigtoe, Savannah lilliput, and yellow lampmussel) are considered federal species of concern. The Altamaha arc-mussel and brother spike are two other federal species of concern. Blueback herring is an important forage fish in the USACE reservoirs. Varying lake elevations from year to year could shift the location of preferred habitat in each reservoir, which could result in a smaller volume of preferred habitat. However, because the differences in reservoir elevation between alternatives are small, it is expected that all four alternatives would have similar effects on the amount of preferred habitat for herring in each reservoir. Sufficient river flows during fish spawning runs, larval drift and juvenile outmigration, and overwintering are important for the completion of diadromous and resident fish life cycles. Summer low flow periods, particularly during drought years can reduce wetted perimeters and limit in-stream habitats. These periods can create stressful conditions for rare fish and mussel species, and during extreme circumstances can result in fish and mussel mortalities.

Future Water Withdrawals with Historic Hydrology

Analysis of critical time periods for the rare fish species in the lower Savannah River are identified in Section 4.4.1 and further discussed in Section 4.4.1.7. As discussed, small differences in mean monthly flows between alternatives occur infrequently. In addition, USACE will continue to release flows from JST dam in accordance with the USACE Drought Contingency Plan, which specifies the discharge rate for each drought level. As a result, the effects of all alternatives on rare lower Savannah River fish and mussel populations are expected to be minimal.

Model Sensitivity Analysis

Appendix O provides the HEC-ResSim model sensitivity analysis for monthly mean flow releases to the lower Savannah River. The same analysis and conclusions included in Section 4.4.1.7 also apply to the rare fish and mussel species in the lower Savannah River. Differences between alternatives are generally minor. Therefore, the effects of all alternatives on rare fish and mussel species in the lower Savannah River are expected to be minimal.

4.4.2 *Aquatic Plants*

Reservoir elevation model results (Sections 3.4 and 3.5) were reviewed to determine potential impacts to submerged aquatic vegetation (SAV) in the Duke Energy and USACE reservoirs and the lower Savannah River. SAV is occurs in the littoral zone, or upper 10 feet of a reservoir, with a primary growing season from March 1 to October 31 (the average date of the first killing frost to the last killing frost), with a peak growing season of typically May through September.

4.4.2.1 *Duke Energy Reservoirs*

Although Lake Jocassee has the largest pool drawdowns and largest differences between alternatives (as described in Section 3.4), little to no SAV occurs in Lake Jocassee and it is not considered a vital source of cover for littoral zone fishes (Rodriguez 2009). As a result, regardless of the alternative or model setup assumptions, no negative impacts to SAV are anticipated within Lake Jocassee.

The only SAV known to occur in Lake Keowee are hydrilla, parrot feather and coontail -- non-native invasive species. The hydrilla was chemically and manually treated until the infestation was eliminated. While there are small differences between NAA/A1, A2, A3, and A4 during droughts, similar to Lake Jocassee, no impacts to SAV in Lake Keowee are anticipated. This is also the case for the sensitivity analyses.

4.4.2.2 *USACE Reservoirs*

For the future water withdrawals with historic hydrology model runs, reservoir elevations for all four alternatives for Hartwell and RBR Reservoirs are similar and no effects on SAV during the growing season are expected. Invasive SAV, such as hydrilla, have not become abundant in

Hartwell and RBR Lakes. Brazilian waterweed, an invasive plant, is present in RBR, but it has not reached nuisance levels requiring treatment. Hydrilla is abundant in JST and USACE monitors its presence and treats infestations. While droughts may help in the overall control of hydrilla in JST by drying it out, differences between the four alternatives are not likely to impact the hydrilla population.

Similar to the future water withdrawals with historic hydrology model runs, differences in USACE reservoir elevations for the model sensitivity runs are minimal and not expected to affect SAV in Hartwell, RBR, or JST Reservoirs.

4.4.2.3 *Lower Savannah River Basin*

As described in Section 3.7, differences in flows released from JST are small and only occur during droughts. The effects of all four alternatives on lower Savannah River Basin SAV populations are expected to be similar.

4.4.3 ***Wetlands***

Detailed descriptions of the wetland communities in the Savannah River reservoirs and the mainstem Savannah River downstream from JST Lake are provided in Section 2.9. Wetlands contribute to the overall health of the environment by providing important functions such as floodwater and stormwater detention, nutrient cycling, exporting organic carbons, maintaining plant communities, and providing fish and wildlife habitats (USDA 2005). Wetland functions for reservoir-dependent, or fringe, wetlands and open water areas could decrease due to the lowering of the adjacent water table. In addition, disturbances to the dynamics of water movement and volume in a wetland can change the distribution and richness of plant species (Duke Energy 2005).

Reservoir elevation model results (Sections 3.4 and 3.5) were reviewed to identify potential impacts to palustrine emergent or fringe wetland communities in the Duke Energy and USACE reservoirs and lower Savannah River. Fringe wetlands are considered to occur in the upper 10 feet of the reservoir, with a primary growing season from March 1 to October 31 (the average date of the first killing frost to the last killing frost), and with a peak growing season of May through September.

4.4.3.1 *Duke Energy Reservoirs*

Future Water Withdrawals with Historic Hydrology

During most years, Duke Energy reservoirs are at or near (i.e., within 2 feet of) full pool during the peak growing season for all four alternatives, which supports overall wetland productivity. Impacts to fringe wetlands primarily occur during droughts when low lake elevations reduce the water table's connectivity to these habitats. During extreme droughts, all four reservoir operating scenarios result in elevations below the upper 10 feet for both Lakes Jocassee and Keowee (see Section 3.5.1, Figures 3.5-1 and 3.5-2). At these relatively low reservoir elevations, fringe wetlands would be similarly impacted regardless of the overall magnitude of the drawdown.

Differences between alternatives when reservoir elevations are in the upper 10 feet of their operating range are also of interest. For example, during the moderate drought that extended from 1997 to 1999, A3 and A4 maintain higher overall Lake Jocassee reservoir elevations than NAA/A1 and A2. Droughts resulting in moderate reservoir drawdowns (i.e., < 10 feet) have occurred approximately 14 years (i.e., 1941, 1942, 1945, 1946, 1954, 1959, 1963, 1978, 1980, 1983, 1991, 1997, 1998, and 1999) over the 73-year POR. During each of these years, A3 resulted in higher Jocassee reservoir elevations -- and would have had a smaller effect on wetlands -- than the other three alternatives.

Model results show Lake Keowee may experience drawdowns close to 10 feet during extreme droughts, which could potentially impact fringe wetlands under all alternatives. A3 and A4 typically result in higher overall reservoir elevations compared to the other alternatives and (approximately 1 – 2 feet higher than NAA/A1 and A2). Overall, A3 and A4 would result in fewer impacts to fringe wetlands than NAA/ A1 and A2. However, any impacts to fringe wetlands based on differences between alternatives would likely be minimal and short-term.

Model Sensitivity Analyses

Modeling current water withdrawals results in similar overall lake elevations within the upper 10 feet of each reservoir compared to future water withdrawals model scenarios. As a result, no incremental impacts are anticipated during the growing season. The only differences occur during extreme droughts (> 10 foot drawdowns) when differences between scenarios are not meaningful from a fringe wetland perspective.

The climate change scenario (instead of historic hydrologic conditions) results in reservoir elevations near full pool during the growing season most years in both Duke Energy reservoirs. There would be a lower frequency of moderate droughts, which cause both reservoirs to experience drawdowns up to 10 feet (approximately 12 years[8] over the 73-year POR, or roughly 16 percent of the time). A3 and A4 result in higher reservoir elevations (compared to NAA/A1 and A2) during these droughts, which could benefit wetland functions during these events. See Appendix M for detailed results.

4.4.3.2 *USACE Reservoirs*

Future Water Withdrawals with Historic Hydrology

Similar to the Duke Energy reservoirs, USACE reservoirs would generally be at or near (i.e., within 2 feet of) full pool during the peak growing season in all four alternatives, which supports overall wetland productivity. As described in Section 3.6, results for all four alternatives for the USACE reservoirs are almost identical over the entire modeled period. Therefore, no impacts to wetlands are likely during the growing season for any of the four modeled scenarios.

Model Sensitivity Analyses

For Hartwell, RBR, and JST Reservoirs, modeling current water withdrawals results in only minor changes to reservoir elevations within the upper 10 feet of each reservoir. As a result, no effects on wetlands are anticipated for the USACE reservoirs.

[8] For this comparison, drought events included Years 1939, 1940, 1941, 1945, 1946, 1959, 1963, 1978, 1981, 1983, 1998, and 1999.

Modeling climate change hydrologic conditions results in less than 0.35 feet differences (as described in Section 3.6) between modeled scenarios, which are not likely to result in any additional impacts to wetland productivity. See Appendix M for detailed results.

4.4.3.3 *Lower Savannah River Basin*

As described in Sections 3.7 and 4.1.1.7, relatively minor, infrequent differences occur between scenarios in monthly mean flows released downstream from JST. These small differences could create short-term differences in wetted perimeter and wetland connectivity. However, they are not expected to have long-term consequences on lower Savannah River wetland communities.

4.4.4 ***Wildlife***

Potential impacts to wildlife were reviewed for each reservoir based on the HEC-ResSim model results. This evaluation focused on identifying differences between alternatives affecting habitat (i.e., nest cover) and food sources associated with lowering reservoir elevations. The analysis included both the full POR and the reproductive season of March 1 through July 31 (i.e., breeding period until the young are fledged or weaned).

4.4.4.1 *Duke Energy Reservoirs*

Future Water Withdrawals with Historic Hydrology

During most years, Duke Energy reservoirs are at or near (i.e., within 2 feet of) full pool during the breeding season for all four alternatives, which supports wildlife productivity by creating habitat for nesting and foraging activities. Average differences in daily reservoir elevation between the four alternatives are relatively small, averaging 2.17 and 0.90 feet for Lakes Jocassee and Keowee, respectively (Section 3.5). For the Duke Energy Reservoirs, A3 and A4 generally result in higher reservoir elevations compared to NAA/A1 and A2 (see Section 3.5.1, Figures 3.5-1 and 3.5-2). For Lake Keowee, the only exception is during extreme droughts (i.e., near the end of 2008) when A2 results in higher elevations than A3 and A4.

Overall, for both Lakes Jocassee and Keowee, A3 and A4 would provide a small benefit compared to NAA/A1 and A2 during wildlife breeding seasons, given the higher reservoir elevations.

Model Sensitivity Analyses

As previously discussed in Section 3.5, modeling current water withdrawals results in higher reservoir elevations, with small differences between the four alternatives.

Modeling climate change hydrologic conditions results in Duke Energy reservoir elevations at or near full pool during the breeding season. As expected, differences between scenarios are larger than when using historic hydrology. A3 and A4 result in higher reservoir elevations (compared to NAA/A1 and A2), which would benefit wildlife habitat during droughts. See Appendix M for more detailed model sensitivity analyses results.

4.4.4.2 *USACE Reservoirs*

Similar to the Duke Energy reservoirs, the USACE reservoirs are generally at or near (i.e., within 2 feet of) full pool during the peak breeding season for all four alternatives, which supports wildlife productivity. Differences in reservoir elevations between the four alternatives are relatively minor, with an average daily difference of 0.37 feet at Hartwell, 0.35 feet at RBR, and 0.30 feet at JST (see Section 3.6). Since there are only minor differences in reservoir elevations between operating scenarios, the effects on wildlife habitat or breeding around the USACE reservoirs are expected to be similar.

Model Sensitivity Analyses

Modeling current water withdrawals or assuming climate change hydrologic conditions, does not result in USACE reservoir elevation differences that negatively impact the breeding season. Therefore, the effects of all four alternatives on wildlife around the USACE reservoirs are expected to be similar. See Appendix M for detailed results.

4.4.4.3 *Lower Savannah River Basin*

As described in Section 3.7, relatively minor, infrequent differences occur between alternatives for monthly mean flows released from JST. Monthly mean flows (provided in Section 4.4.1.7) were also reviewed to evaluate potential impacts during the breeding season. While there are some small differences between alternatives in flows released from JST, impacts to nesting or foraging are expected to be similar for all four alternatives, would be short-term, and not expected to have long-term consequences on wildlife in the lower Savannah River.

4.4.5 *Protected Species*

As stated in Section 2.9.5 and Table 2.9-2, federally-listed threatened, endangered, proposed endangered, proposed threatened, and targeted federal species of concern were reviewed and 12 species have the potential for impacts within the study area and include the bald eagle, manatee, wood stork, shoals spider-lily, shortnose sturgeon, Atlantic sturgeon, robust redhorse, American eel, yellow lampmussel, Savannah lilliput, the Atlantic pigtoe, and the bluebarred pygmy sunfish. As described in Section 3, Duke Energy and USACE reservoir elevation differences for the four alternatives are similar with their differences being evident during droughts. The differences in reservoir elevation are unlikely to affect the bald eagle due to its mobility and adaptability near the reservoirs. Flows released to the lower Savannah River from JST also exhibit only minor differences in timing and duration between alternatives. As a result, it is unlikely differences in alternatives would affect manatee, wood stork, or shoals spider-lily habitat. In addition, flows released downstream of JST would generally not drop below 3,100 cfs regardless of alternative, which provides baseline habitat for aquatic and terrestrial species in the lower Savannah River reach. The remaining species listed are fish and mussels; potential impacts to fish and mussels were previously addressed in Section 4.4.1.8.

4.4.6 *Special Biological Issues*

Lake Jocassee is surrounded by SC DNR's James Timmerman Natural Resources Area at the Jocassee Gorges (Jocassee Gorges) and other natural areas. The primary objectives for the Jocassee Gorges are to maintain the natural character of the area and maintain and restore or enhance noteworthy plant, fish, and wildlife communities and their habitats (there are 171 known occurrences of rare, threatened, or endangered species over 32,000 acres) (SC DNR 2010b). Since the Jocassee Gorges is not directly affected by the water fluctuations of the reservoir, none of the alternatives are expected to adversely impact natural areas within the region.

As described in Section 3.7, flows released downstream of JST are similar between the four alternatives since USACE will continue to follow its 2012 Drought Plan. Since the USACE reservoir system would be in drought for a longer period with the four alternatives (described in Section 4.3.4), the Corps would implement the smaller releases from JST Dam for longer periods. Wetlands and wildlife at the Savannah National Wildlife Refuge would experience low river flows during droughts for longer durations. This would extend the adverse effects of a drought on those resources over a longer period of time.

As described in Section 2.9.6, EFH exists in the Savannah River from its mouth to just upstream of the Houlihan Bridge. This includes estuarine areas and habitat for species for which Management Plans have been prepared by the South Atlantic Fishery Management Council. Potential influences to these areas from JST flow releases include salinity levels and saltwater intrusion. Oligohaline areas (< 8 ppt of salinity) would be most affected by reductions in river flow and greater intrusion of saltwater. Continuous recording water quality gages operate in the Savannah River estuary. When requested by state natural resource agencies, USACE may perform additional monitoring during severe droughts to better define the extent of the salinity intrusion. Average JST flow releases (April through December) for each of the 51 years which would trigger the USACE 2012 Drought Plan are provided in Tables 3.7-1 and 3.7-2. Differences between A3 and A4, compared to NAA/A1, are less than 5 percent on an annual basis. Instances where A3 and A4 flow releases are less than NAA/A1 flow releases tend to occur during less severe droughts (i.e., 1962 and 1993) when average flows are well above 4,200 cfs. As a result, the effects of all four alternatives on EFH in the Savannah River estuary are expected to be similar.

HEC-ResSim model sensitivity analyses results using current water withdrawals or climate change hydrology are similar to flow releases from JST using future water withdrawals and historical hydrology. Differences in average flow releases between scenarios for each sensitivity analyses are minor. As a result, the effects of all four alternatives sensitivity analyses on EFH in the Savannah River estuary are expected to be similar.

4.5 Socioeconomic Issues

4.5.1 *Economic Impact Analysis*

4.5.1.1 *Hartwell Lake Economic Impact Model and Analysis*

In November 2010, STI released a report entitled "An Economic Analysis of Low Water Levels in Hartwell Lake" (see Appendix P), which analyzed the effects of low water levels at the reservoir on the regional economy. The report, commissioned by USACE and the county governments adjacent to Hartwell Lake, examined the 21-month drought period from April 2007 to December 2008. During this period, reservoir elevations stayed well below the summer full pool elevation of 660 feet AMSL. Many in the region hypothesized this would have a measurable, negative impact on the economies of Franklin, Hart, Stephens, Anderson, Oconee, and Pickens Counties. Anecdotal evidence and a study focusing on the drought of 1998 also suggested the impact on the regional economy would be significant (STI. 2010).

The economic analysis was intended to identify whether changing water levels in Hartwell Lake have a measurable effect on the economy and property values in surrounding counties. The study examined selected reservoir, real estate, and economic data over an 11-year period from 1998 to 2009, which includes the two most extreme droughts on record (1999–2002 and 2007–2008).

Several statistical analysis techniques were combined to identify the strength of the relationship between lake elevations and economic activity in the surrounding counties. Standard statistical techniques were used to identify the relationships between reservoir elevations and real estate sales, property sales prices, and gross retail sales. Real estate data included the number of monthly transactions (including sales price and property attributes) on all parcels in the counties. Economic data included monthly gross retail sales in selected sectors plus other measures of the local and regional economy. Gross retail sales included, among others, retail trade, general merchandise, groceries, gas, boating stores, restaurants, sporting goods stores, bars, and liquor store sales. Economic and population data were collected from a variety of local, state, and federal government secondary source materials. These variables captured both resident and non-resident economic activity from people buying homes on the reservoir, purchasing goods and services on or near the reservoir, and visiting reservoir sites for recreation purposes.

The Regional Dynamics (REDYN) input-output model was then used to estimate the total economic impact of different Hartwell pool levels on the six-county region. The REDYN model produced estimates of the marginal changes in the value of goods and services in selected industry sectors as a result of changing reservoir levels. The model generates estimated economic impacts for four measures: (1) employment, (2) output, (3) disposable income, and (4) net government revenue.

Study results described economic impacts of reduced reservoir levels in Hartwell Lake as being negative and measurable. However, the reservoir is not a "primary economic driver" of the region. The total economic impact of lower reservoir elevations on the six-county region was determined to be less than one-tenth of one percent. To place the economic impact in context, the total economic output for the region during the study period was $30.2 billion, while the negative impact of the drought on output was estimated to be $18.8 million, a decline of 0.06 percent. Anderson County showed the largest decline at -0.16 percent followed by Franklin County (-0.07 percent), Hart County (-0.07 percent), and Pickens County (less than -0.01 percent). Both Stephens and Oconee Counties showed economic gains of 0.09 percent and 0.08 percent, respectively.

Three parameters were measured as indicators of economic movement: recreational use at the reservoir, real estate transactions around the reservoir, and the sale of reservoir-related goods and services (e.g., sporting goods, bars, boating stores, etc.). For every foot of pool elevation change, the number of monthly visitors to USACE recreational sites on Hartwell rose or fell by approximately 21,200. There were 56 fewer (3.4 percent) real estate transactions for parcels with reservoir access during the study period. The impact of the real estate decline was not distributed evenly throughout the six counties, but rather estimated lost transactions due to drought were a larger share of total activity in those counties with fewer total real estate transactions. The sale of retail goods and services showed variable correlations with reservoir elevations, depending on the sector. Sectors such as general merchandise, bars, boating stores, and sporting goods stores had a statistically significant relationship with reservoir elevations (STI. 2010).

The study showed that Oconee and Stephens Counties experienced positive economic growth during the study period. In the case of Oconee County, STI reports this may be the result of Lake Keowee being in direct competition with Hartwell as a recreation destination. Water levels at Lake Keowee are generally more stable, suggesting that as pool elevations decrease at Hartwell, recreational users tend to select Lake Keowee as an alternative destination. As for Stephens County, economic evidence suggests as reservoir-related activity slows down, other business sectors such as restaurants located away from the reservoir see increased activity.

4.5.1.2 *Application of Hartwell Lake Model to Daily Reservoir Levels*

In April 2014, STI ran the same economic model with the HEC-ResSim model output of daily reservoir elevations at Hartwell for each of the four alternatives to identify any regional economic impact of the alternatives on the six counties bordering the reservoir. Since the REDYN economic model only provides information dating back to 2001, the regional economic model simulations specific to the Hartwell Lake analysis cover the HEC-ResSim lake elevation results from 2001 to 2008. Economic modeling results were prepared for each operating scenario (NAA/A1, A2, A3, and A4) relative to differences from the summer conservation level, so forecasted changes in economic measures could be estimated.

Assuming future (i.e., Year 2066) water withdrawals with historical hydrology, Figure 4.5-1 depicts the forecasted economic effect of pool elevation changes in terms of overall dollar impact. Likewise, Figure 4.5-2 provides the forecasted impact on employment.

The STI analysis indicates that all four alternatives would produce similar economic and employment impacts around Hartwell Lake. Only minor differences were identified between the NAA and the other alternatives.

Figure 4.5-1 Hartwell Lake Economic Impacts (With Future Water Withdrawals and Historic Hydrology)

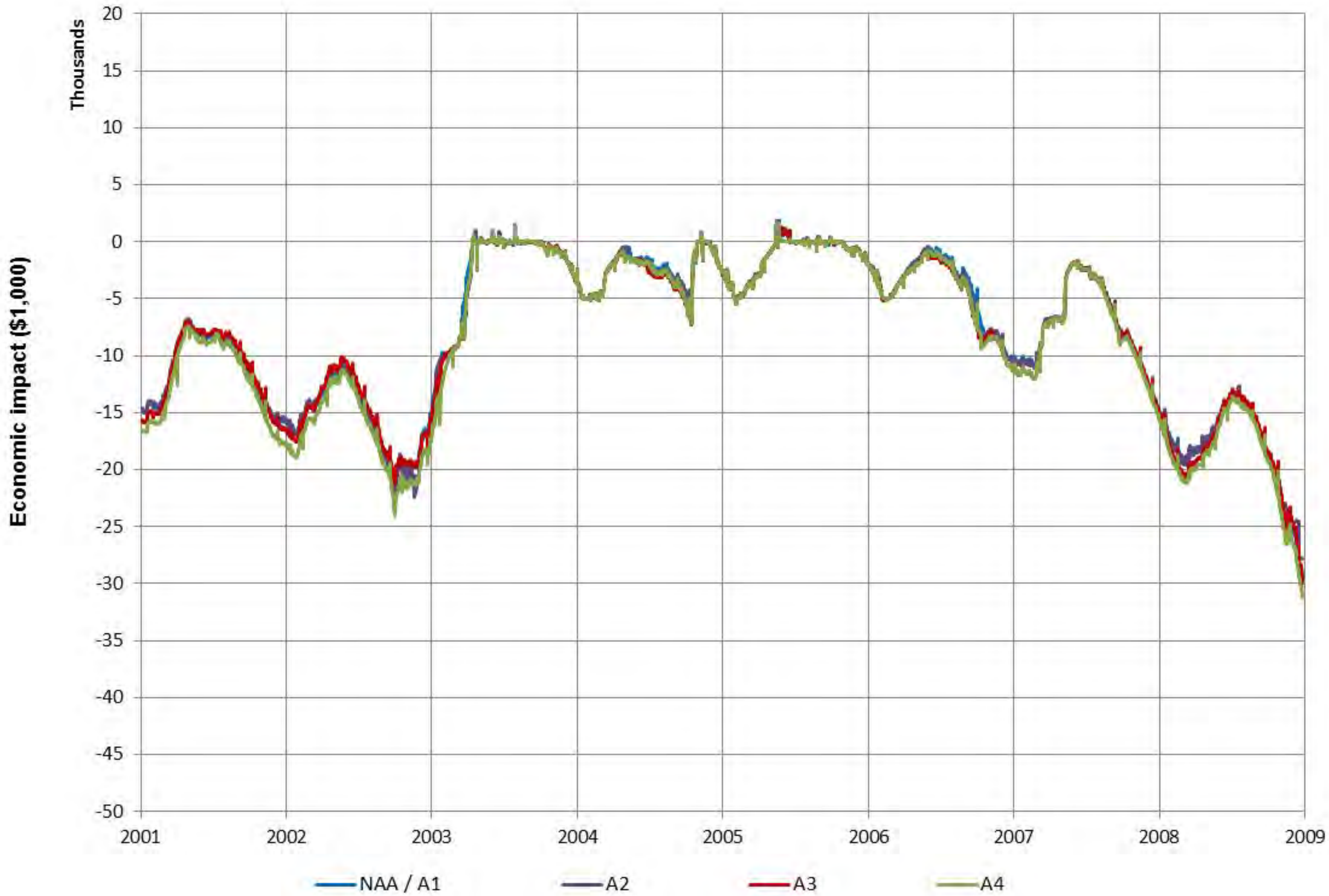
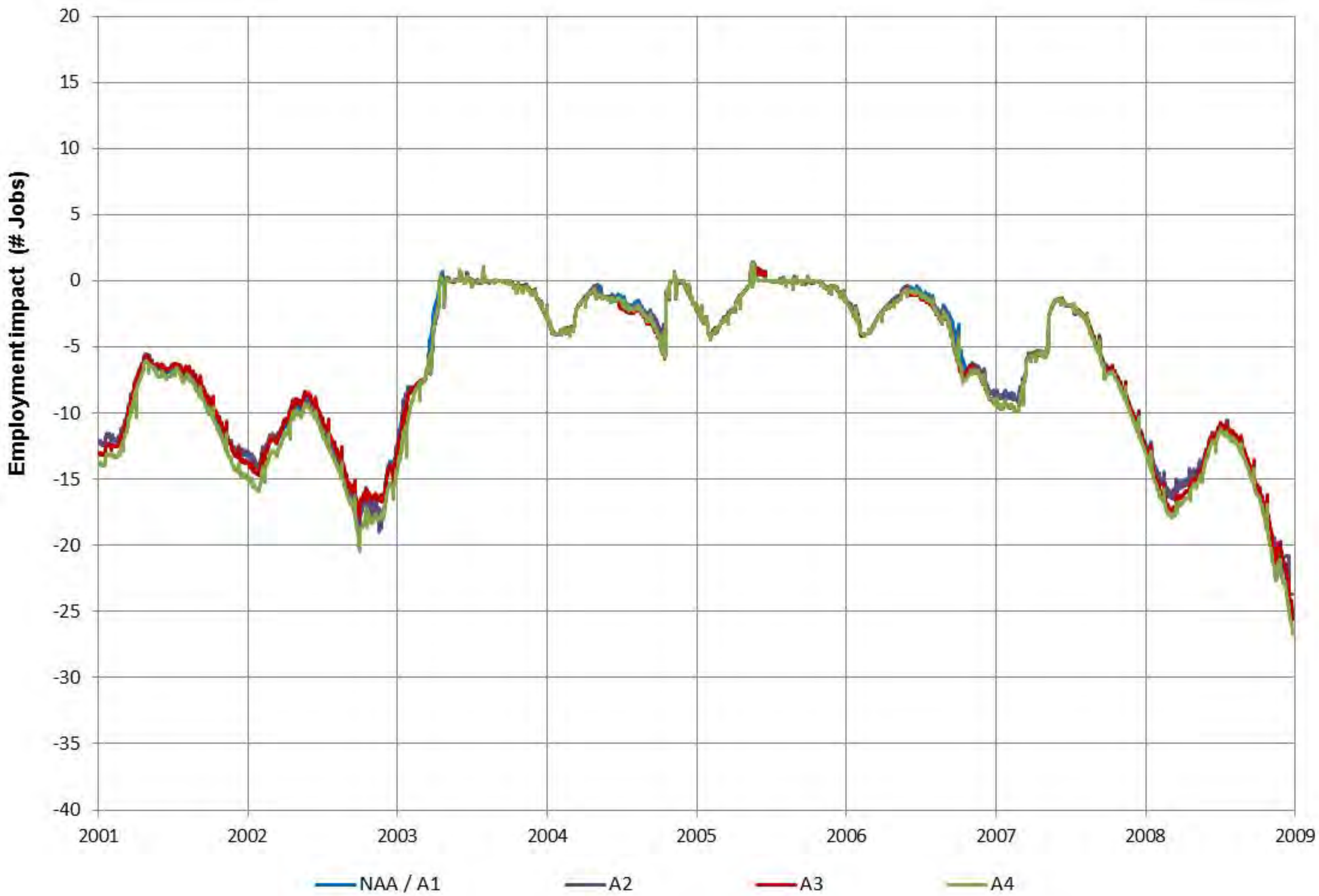


Figure 4.5-2 Hartwell Lake Employment Impacts (With Future Water Withdrawals and Historic Hydrology)



Model Sensitivity Analysis

Using current (i.e., Year 2010) water withdrawals results in smaller, yet similar economic impacts for all alternatives compared to future (i.e., Year 2066) water withdrawals. There would be no expected difference in output, disposable income, government revenue, or number of jobs regardless of reservoir operations. See Figures Q-1 and Q-2 in Appendix Q for detailed results.

Modeling climate change instead of historic hydrologic conditions results in larger economic and employment impacts. However, all four alternatives produce similar results. See Figures Q-3 and Q-4 in Appendix Q for detailed results.

4.5.1.3 *Application of Economic Impact Model to Lake Keowee Daily Reservoir Levels*

Subsequent to the RTI completing its study on Hartwell, it developed a similar economic model for Lake Keowee to examine the economic impacts of the four alternatives on counties (Oconee and Pickens) surrounding that lake (see Appendix R). Economic and employment impacts on Lake Keowee counties using the future water withdrawals with historical hydrology model assumptions are provided in Figures 4.5-3 and 4.5-4, respectively.

During the majority of the 2001-2008 modeling period, differences between alternatives are within $2,000 and 3 jobs of each other. The largest differences occurred near the end of 2008 during an extreme drought. As expected, NAA/A1 produces the largest economic impact as Lake Keowee's elevation drops to 782 feet AMSL. A2 results in the least economic impact for counties surrounding Lake Keowee because pool elevations are not allowed to drop below 794.6 feet AMSL. A3 and A4 results are similar to each other and fall between A2 and NAA/A1 results.

Figure 4.5-3 Lake Keowee Economic Impacts (With Future Water Withdrawals and Historic Hydrology)

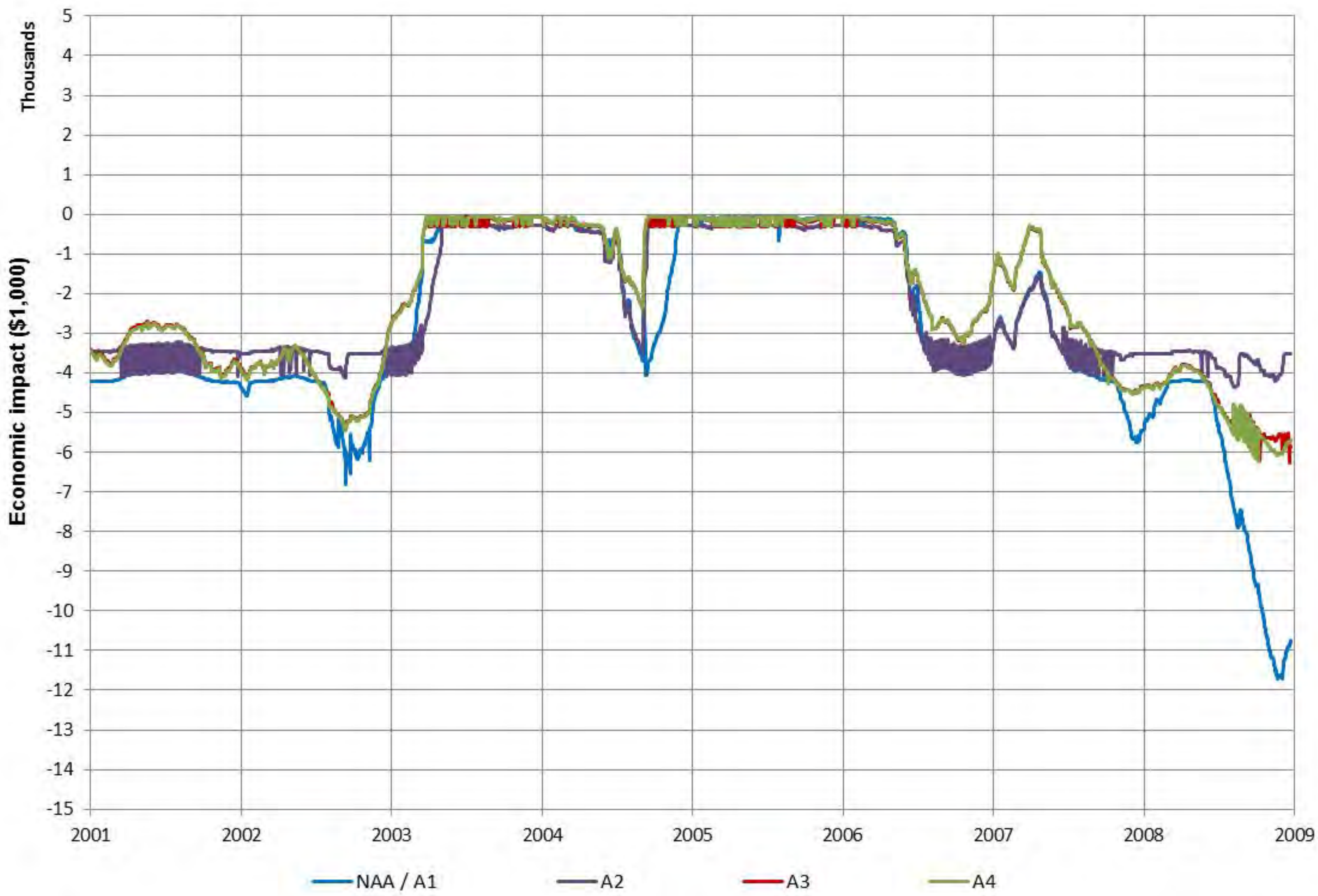
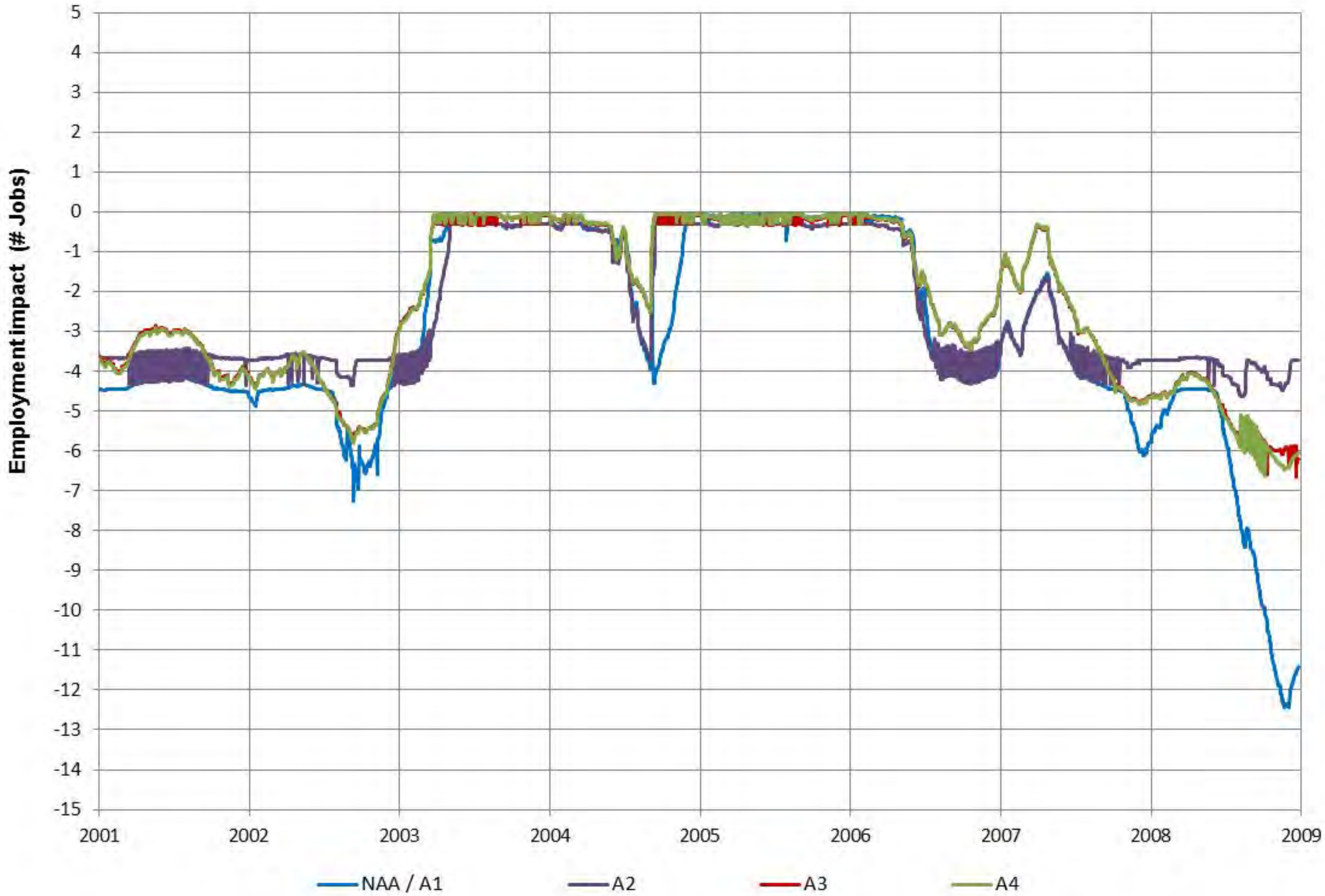


Figure 4.5-4 Lake Keowee Employment Impacts (With Future Water Withdrawals and Historic Hydrology)



Model Sensitivity Analysis

The magnitude of impacts to the regional economy from A2, A3, and A4 is similar when current water withdrawals are compared to future water withdrawals. The regional economic and employment model results are approximately 28 percent lower for NAA/A1 when using future water withdrawals with historic hydrology model results. See Figures Q-5 and Q-6 in Appendix Q for detailed results. That is a substantial difference that state water managers may want to consider as they make decisions in the future.

Using climate change hydrology instead of historic hydrologic conditions produces similar results from the economic model for all four alternatives. See Figures Q-7 and Q-8 in Appendix Q for detailed results.

4.5.1.4 *JST Reservoir Regional Economic Model*

During 2011, STI developed a regional economic model for JST Reservoir and its surrounding region (Appendix S). They drew upon the models they had previously developed for Hartwell and Lake Keowee to produce a model of the South Carolina and Georgia counties surrounding JST (McCormick, Columbia, Elbert, Lincoln, McDuffie, and Wilkes).

Economic and employment impacts on JST counties from the NAA and the four alternatives using the future water withdrawals with historical hydrology are provided in Figures 4.5-5 and 4.5-6, respectively.

During most of the modeled period (2001 – 2008), economic and employment impacts resulting from the four alternatives are almost identical (i.e., differences are less than $20,000 and fewer than 20 jobs between alternatives).

Figure 4.5-5 JST Lake Economic Impacts (With Future Water Withdrawals and Historic Hydrology)

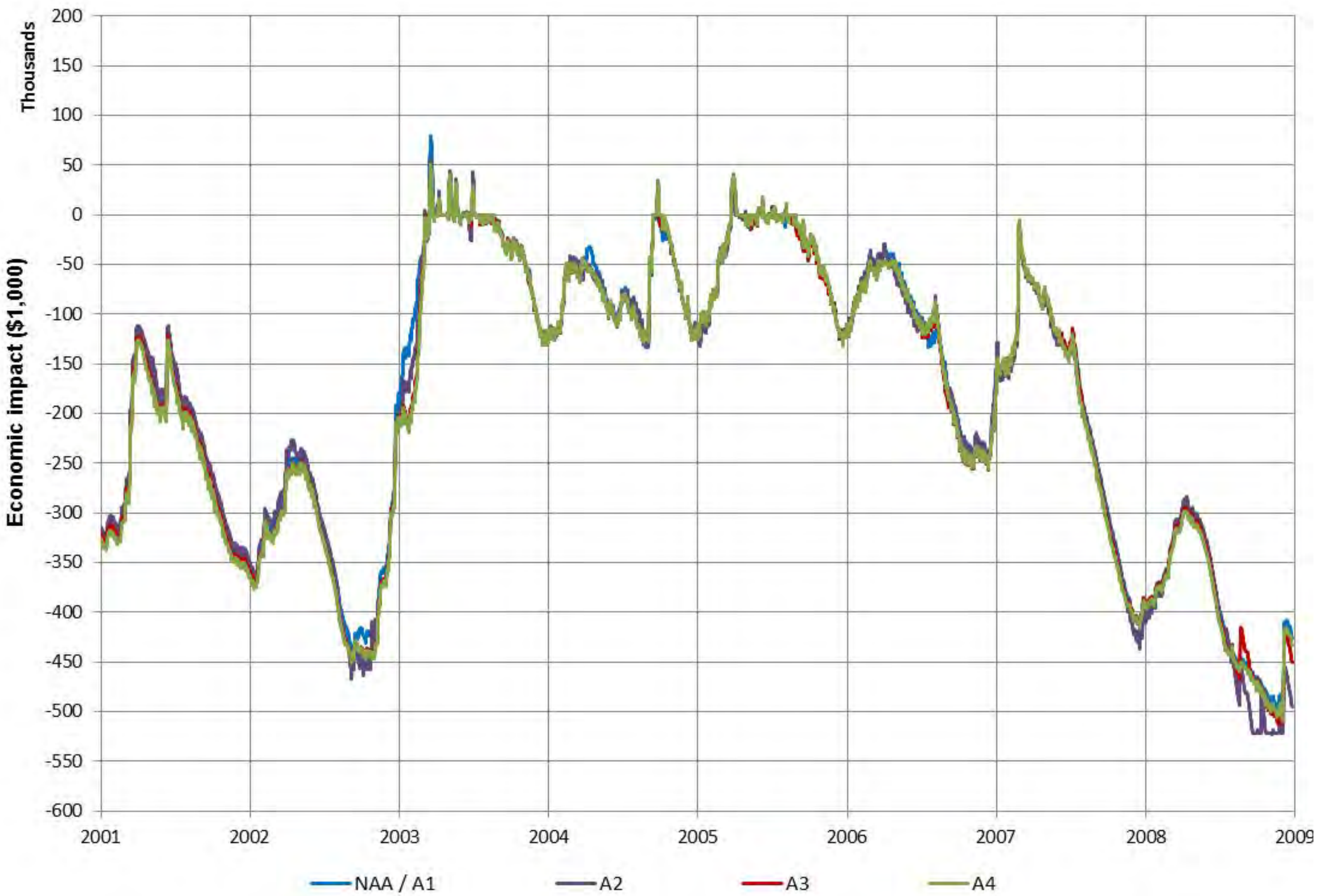
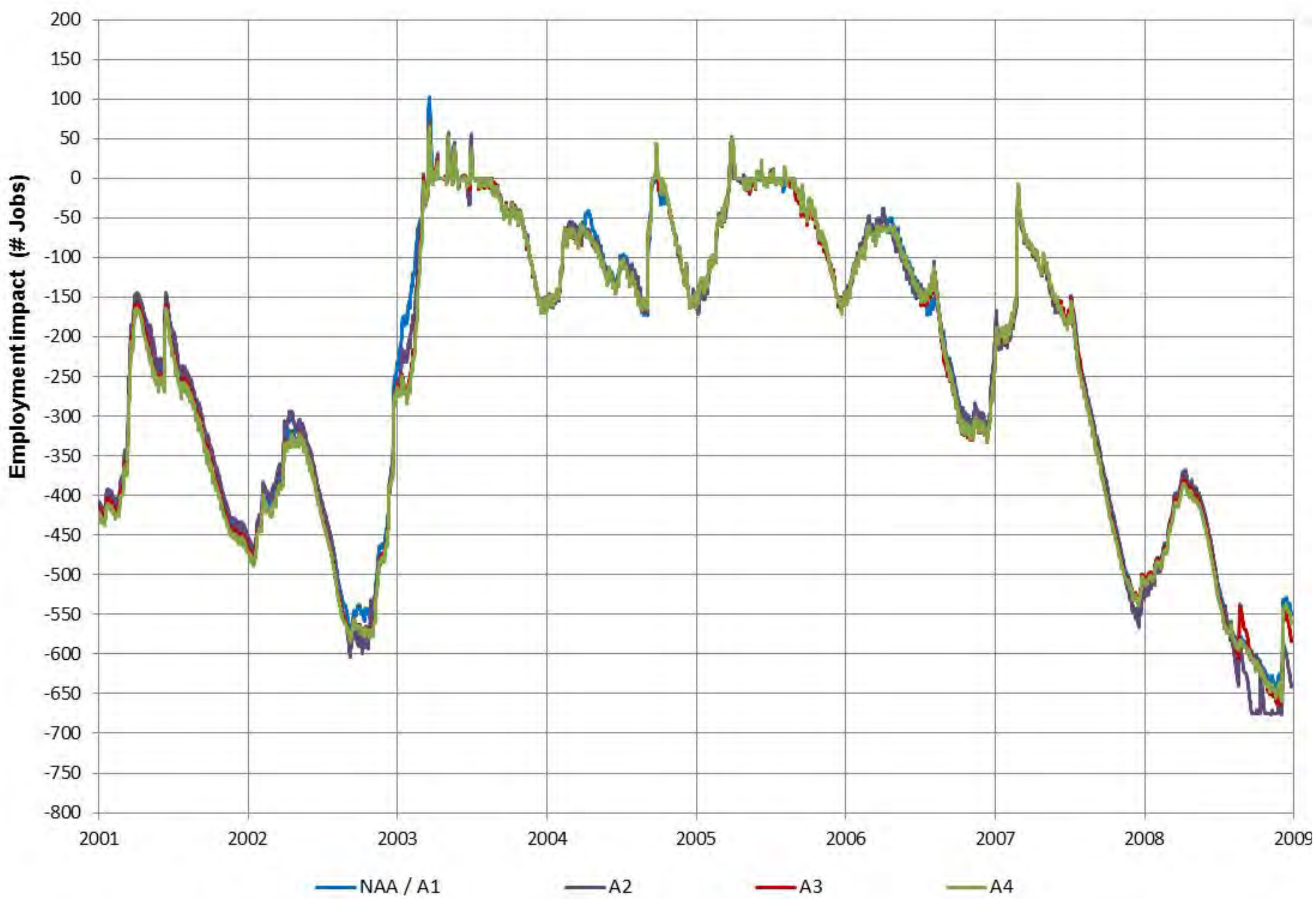


Figure 4.5-6 JST Lake Employment Impacts (With Future Water Withdrawals and Historic Hydrology)



Model Sensitivity Analysis

Using current water withdrawals instead of future water withdrawals results in similar impacts for each of the four alternatives. The economic and employment impacts are approximately 20 percent less than the impacts associated with the future water withdrawals with historical hydrology model assumptions, which is an expected outcome of the lower present volume of withdrawals. The 20 percent difference is substantial and state water managers may want to consider it as they make decisions in the future. See Figures Q-9 and Q-10 in Appendix Q for detailed results.

Using climate change hydrology instead of historic hydrologic conditions produces similar results from the economic model for all four alternatives. See Figures Q-11 and Q-12 in Appendix Q for detailed results.

Regional Economic Model Summary

Overall, regional economic impacts for each of the three reservoirs studied by STI are similar between the four alternatives. The region surrounding JST exhibited the largest economic impacts, by magnitude, followed by the Hartwell and Lake Keowee. However, all alternatives would produce comparable results in each of the three regional economic models. The Lake Keowee economic model was the only one that showed differences between alternatives near the end of the 2008 extreme drought. For Lake Keowee, A2 had the least impact (-$4,000 and four jobs lost) as no downstream releases are made if the release would cause Lake Keowee elevations to drop below 794.6 feet AMSL. NAA/A1 had the largest economic impact (-$12,000 and 12 jobs lost) as the reservoir level dropped to 782 feet AMSL. A3 and A4 results are similar to each other and fall between A2 and NAA/A1 results (-$6,000 and six jobs lost). The models identify the expected growth of water withdrawals in the future as producing the largest effects on the regional economy of the factors considered.

4.5.2 *Environmental Justice and Protection of Children*

The concept of environmental justice is based on the premise that no segment of the population should bear a disproportionate share of adverse human health or environmental effects. To address these concerns, Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority and Low Income Populations" was issued in 1994.

The concept of protecting children arises out of scientific evidence that demonstrates children may suffer disproportionately from environmental health and safety risks. To address these concerns, Executive Order 13045, "Protection of Children from Environmental Health Risks and Safety Risks" was issued in 1997.

The alternatives under consideration could alter reservoir elevations in the Upper Savannah River Basin and flows released from the JST Project to the lower Savannah River. Therefore, populations around those reservoirs and along the Savannah River downstream of JST could be affected. The HEC-ResSim modeling described in Section 3 reveals there would be only minor differences in reservoir elevations and downstream flow releases between the alternatives. These differences occur only during droughts.

NAA/A1 results in the lowest reservoir elevations for Duke Energy's Jocassee and Keowee Lakes. This alternative also produces economic impacts related to forced outages at the ONS (see Sections 4.7.2 and 4.8) which result in energy replacement costs and/or transmission system upgrades of approximately $913 million and $232 million, respectively. A2 requires modifications of the ONS costing at least $800 million. These costs would likely be passed on to electric ratepayers in the Duke Energy service area and potentially other electric consumers. Because of the large number of Duke Energy customers, the impact to each individual customer would be relatively small. However, the increase would likely be felt more by those with low incomes.

The four alternatives exhibit similar minor results at the USACE reservoirs and downstream along the Savannah River. Since waterfront property is generally more expensive, residents that surround the Duke and USACE reservoirs would typically not be considered low-income. Therefore, impacts to pool levels from the alternatives would not be considered as affecting Low Income Populations. No impacts to minority and low-income populations are expected from the four alternatives. No environmental health and safety risks are expected from the four alternatives.

4.6 Coastal Zone Consistency

Under the NAA and all four alternatives, USACE would continue to implement its 2012 Drought Plan which defines how it would release water from JST Dam during droughts. That Plan was previously determined to be consistent with the Coastal Management Programs of both South Carolina and Georgia. Since that Plan would continue to be followed in each of the alternatives considered in this EA, no adverse impacts are expected to environmental resources in the coastal zone from implementation of any of the alternatives.

4.7 Electric Generation

4.7.1 *Hydroelectric Energy Generation*

To evaluate the differences in energy production between the alternatives, an energy impact assessment was conducted for the Bad Creek Project, Jocassee Pumped Storage Station, Keowee Hydro Station, Hartwell Project, RBR Project, and JST Project. While USACE's RBR Project and Duke Energy's Bad Creek Project were not constructed at the time of the 1968 Agreement, and are therefore not included in the present rules for determining flow releases from Lake Keowee, these two plants have been incorporated into the HEC-ResSim model.

Output from the HEC-ResSim model for each alternative included daily gross generation (in MWh) for all Duke Energy and USACE facilities, as well as average daily flow rates for each of the pumped-storage plants. The generation/pumping amounts were converted from MWh to dollars using monthly average energy values provided by SEPA (see Table 4.7-1).

Table 4.7-1 Average Energy Values for Power Purchase

Month	Average Energy Values ($/MWh)	
	On-Peak	Off-Peak
January	$77.60	$43.48
February	$68.62	$42.76
March	$79.01	$36.53
April	$69.71	$35.70
May	$66.79	$26.84
June	$91.81	$36.72
July	$90.39	$35.77
August	$87.37	$41.56
September	$64.71	$32.86
October	$60.82	$35.84
November	$57.15	$37.01
December	$73.19	$41.37

Source: Email from Douglas Spencer (SEPA) to Ed Bruce (Duke Energy) and Jason Ward (USACE) on 6/13/2011. Table compiled from SEPA's energy purchase records since Fiscal Year 2006.

The pumping flow rates were converted to dollars by first converting the average daily average flow (in cfs) to MWh using the pump performance curve for each pumped-storage plant. Once the MWh for each facility were determined, pumping energy was converted to dollars using average energy values provided in Table 4.7-1. Off-peak energy values were used for pump-back operations because those operations occur at night and on weekends when energy values are lower. Table 4.7-2 provides summary generation results for each of the alternatives as average annual net energy generation.

For the future water withdrawals with historic hydrology model results, there are minor differences in generation between alternatives for the Duke Energy system. The small differences in generation are the result of differences in available storage between alternatives. A2 has the smallest amount of available storage and the lowest generation, while A4 results in the most generation value. The difference between A4 and A2 is approximately $1.1 million each year. Net generation value for NAA/A1 and A3 is bracketed by A2 and A4 for the Duke Energy system.

There are only minimal differences between alternatives on a monthly basis for the USACE system (Figure 4.7-1). Figure 4.7-2 provides cumulative USACE generation along with cumulative Lake Keowee flow releases over the 73-year POR, and shows only minor differences between alternatives. Figure 4.7-3 provides a zoom-in of 2006-2011 to better illustrate the magnitude of differences between the alternatives. While there are differences between alternatives in the amount of flow released from Lake Keowee, these minor differences do not affect USACE system generation, as shown in the figure.

Table 4.7-2 Average Annual Net Energy Generation (1939–2011)

Owner	Average Annual Net Energy Generation							
	NAA/A1		A2		A3		A4	
	$ million	MWh	$ million	MWh	$ million	MWh	$ million	MWh
Future Water Withdrawals with Historic Hydrology								
Duke Energy[1,2]	92.1	(683,000)	91.1	(635,000)	91.9	(657,000)	92.2	(660,000)
USACE	120.4	1,478,000	120.4	1,478,000	120.4	1,478,000	120.4	1,477,000
System	212.5	795,000	211.5	843,000	212.3	821,000	212.6	817,000
Current Water Withdrawals with Historic Hydrology								
Duke Energy[1,2]	93.3	(667,000)	91.2	(619,000)	90.9	(620,000)	91.0	(620,000)
USACE	125.9	1,552,000	125.9	1,552,000	126.0	1,552,000	126.0	1,551,000
System	219.2	885,000	217.1	933,000	216.9	932,000	217.0	931,000
Future Water Withdrawals with Climate change Hydrology								
Duke Energy[1,2]	91.7	(684,000)	91.2	(636,000)	92.1	(661,000)	92.4	(663,000)
USACE	119.8	1,470,000	119.8	1,470,000	119.9	1,470,000	119.8	1,469,000
System	211.5	786,000	211.0	834000	212.0	809,000	212.2	806,000

[1] Average annual net generation for the Duke Energy system excludes generation impacts to ONS.
[2] MWh for the Duke Energy system are negative due to pumping operations at Jocassee Pumped Storage Station and the Bad Creek Project.

Figure 4.7-1 Monthly USACE Generation (Future Water Withdrawals with Historic Hydrology [1939–2011])

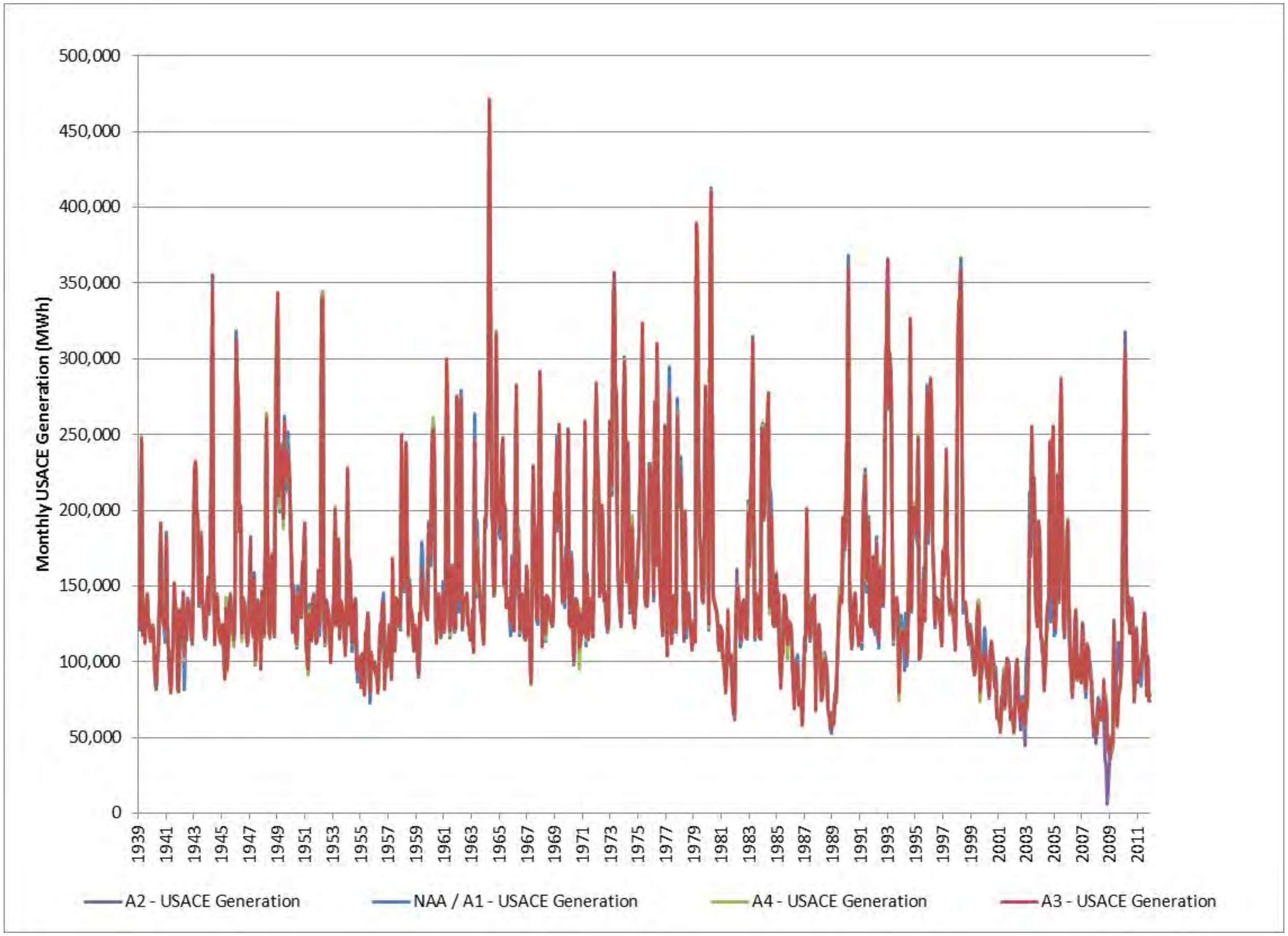


Figure 4.7-2 Total USACE Generation and Lake Keowee Release Volume (Future Water Withdrawals with Historic Hydrology [1939–2011])

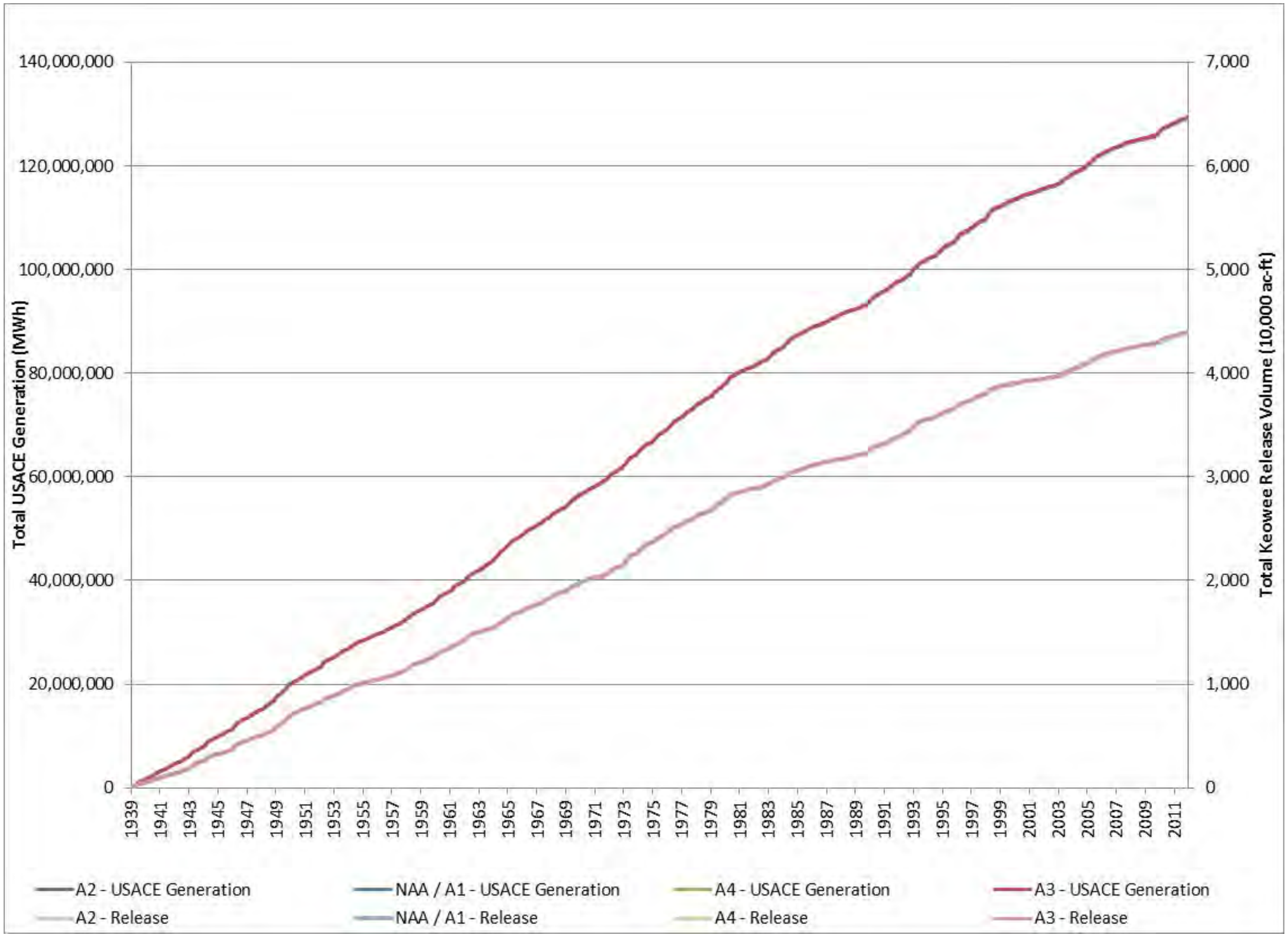
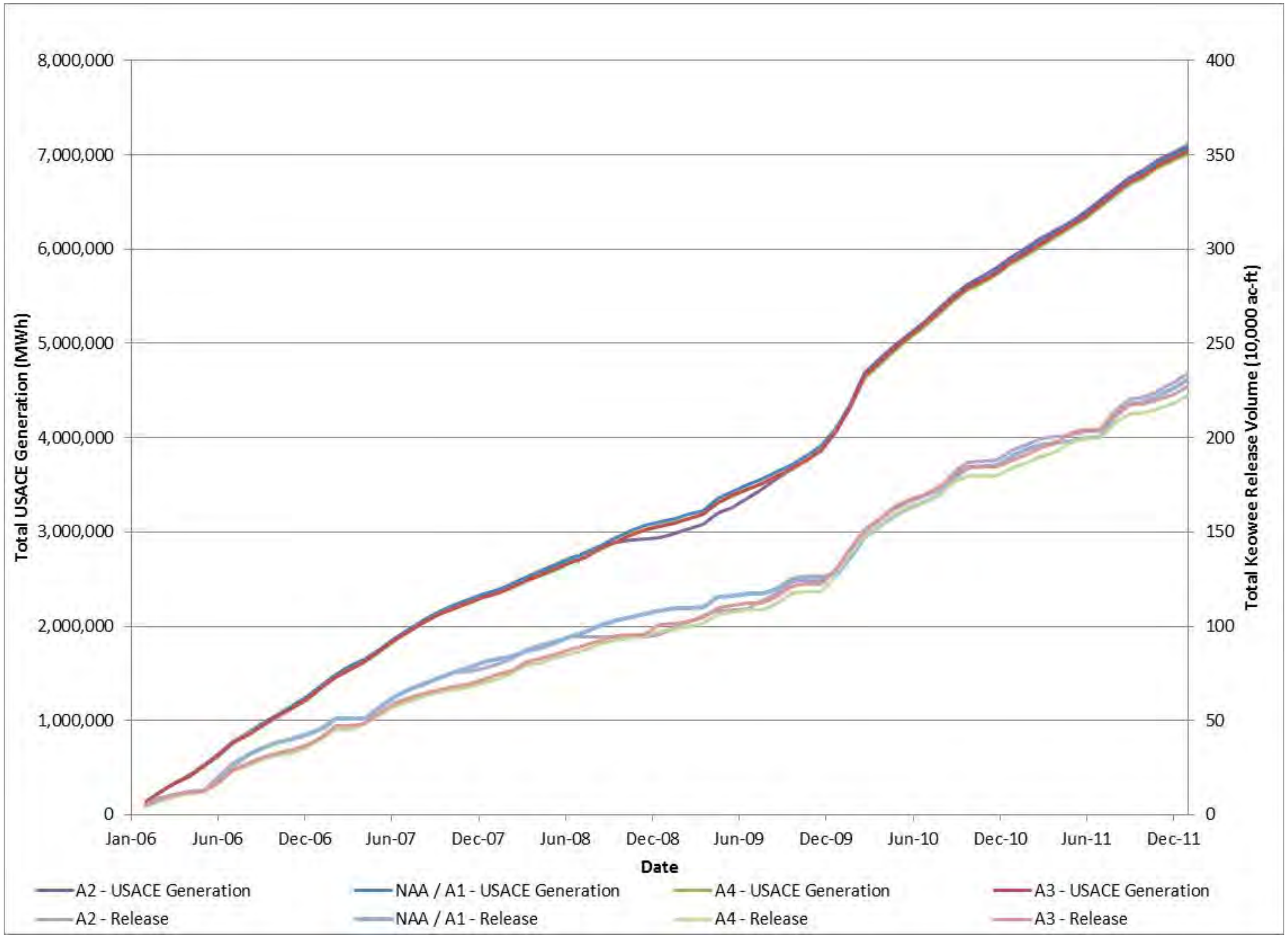


Figure 4.7-3 Total USACE Generation and Lake Keowee Release Volume (Future Water Withdrawals with Historic Hydrology [2006–2011])



Model Sensitivity Analysis

Using current water withdrawals instead of future water withdrawals results in a modest increase in generation for the Duke Energy system for two of the alternatives (NAA/A1 and A2), but shows a slight decrease in generation for A3 and A4. This is due to a decrease in generation at the Jocassee Pumped Storage Station resulting from the LIP logic, which keeps reservoir elevations higher and makes less water volume available for pump-back operations during drought periods (i.e., 2007) for A3. Added storage capacity from the Bad Creek Project along with a smaller usable storage capacity in Lake Keowee keeps Duke pool elevations higher in A4. The USACE system shows an annual average increase in generation of approximately $5.6 million for each alternative in this sensitivity analysis. Similar to the future water withdrawals with historic hydrology results, there are minor differences in USACE system generation (see Figures 4.7-4 through 4.7-6). The zoom-in of the 2006 – 2011 period in Figure 4.7-6 shows no difference in USACE system generation between alternatives and only minor differences between scenarios in Lake Keowee flow releases.

Figure 4.7-4 Monthly USACE Generation (Current Water Withdrawals with Historic Hydrology [1939–2011])

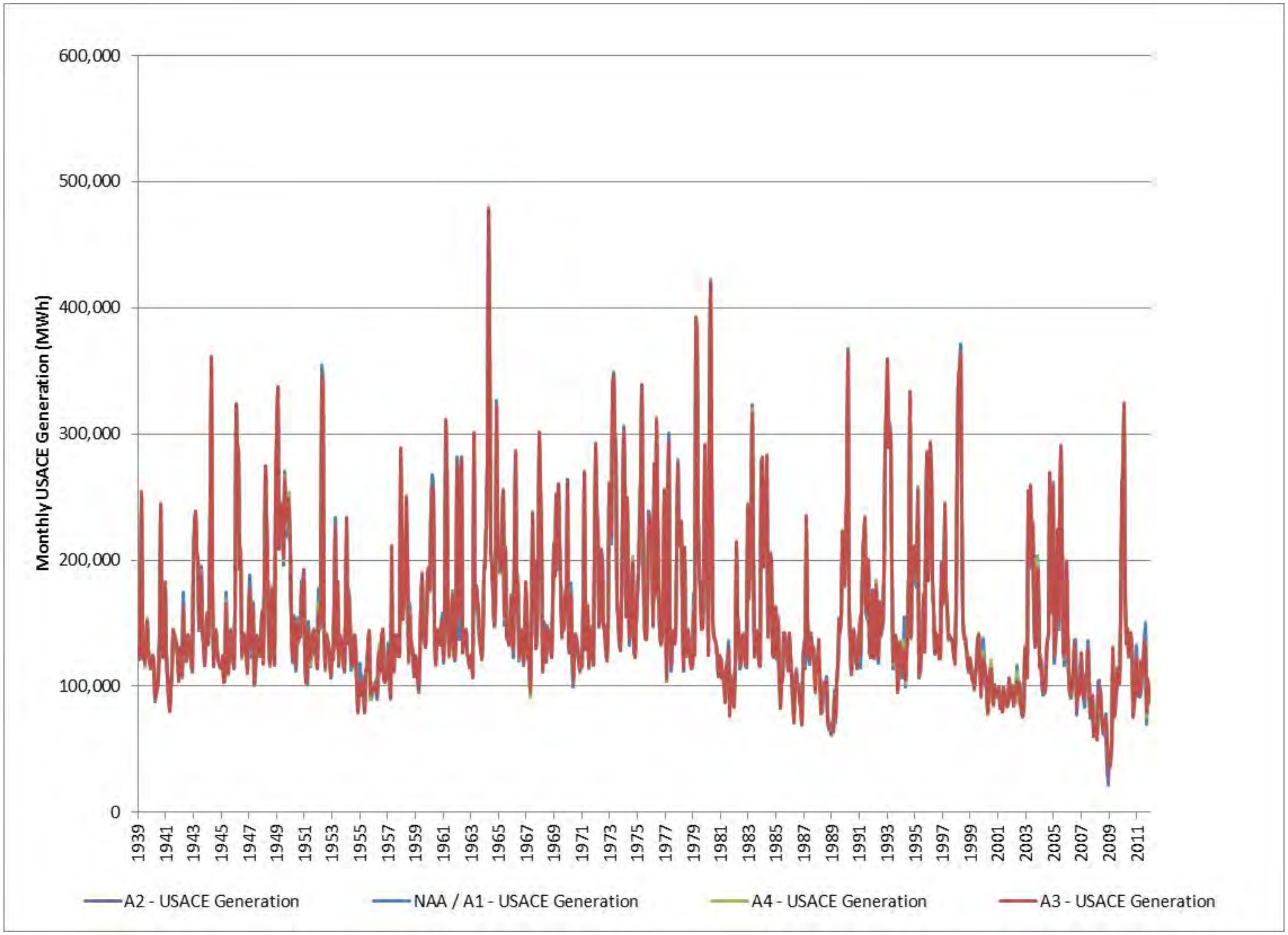


Figure 4.7-5 Total USACE Generation and Lake Keowee Release Volume (Current Water Withdrawals with Historic Hydrology [1939–2011])

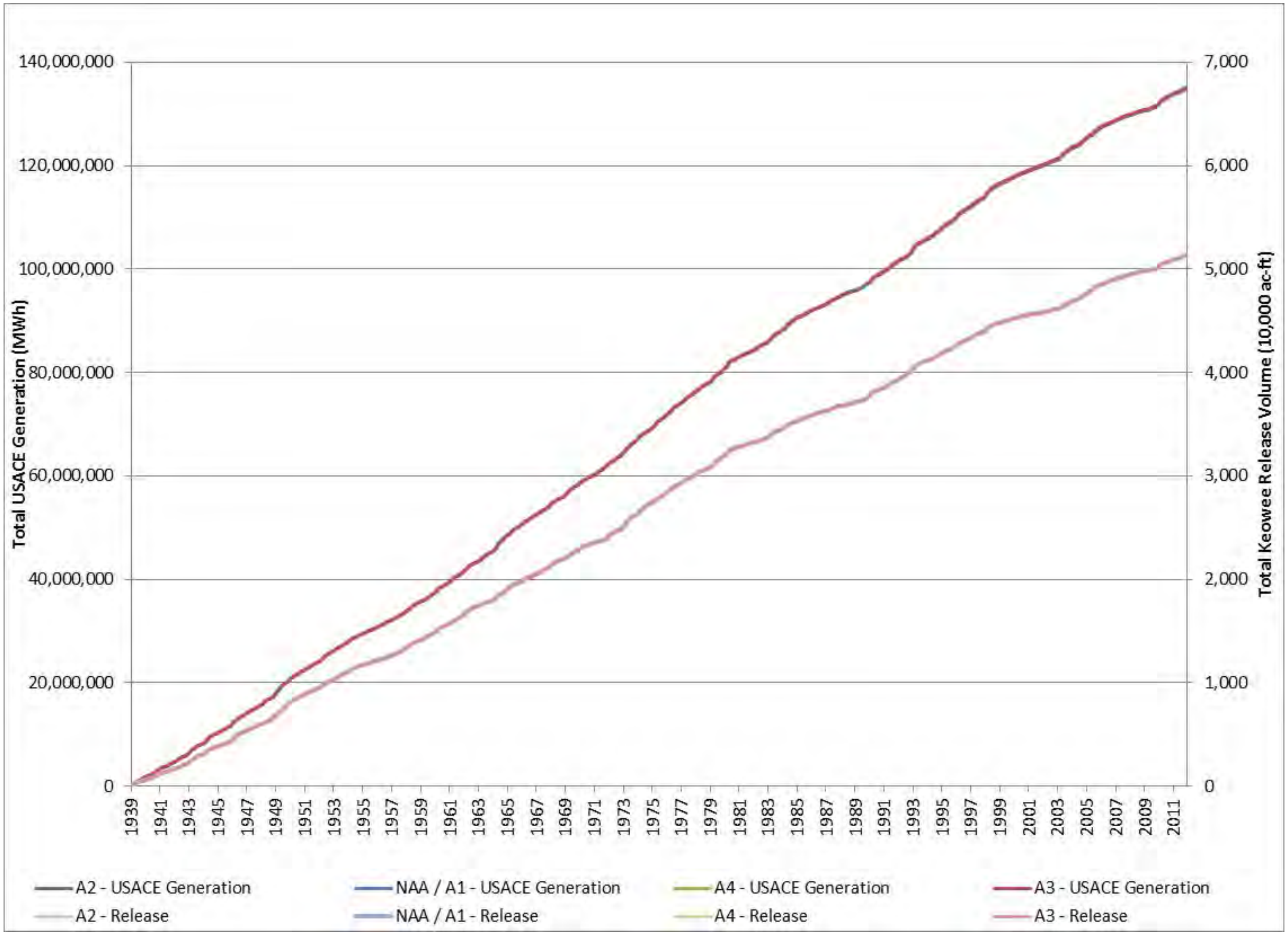
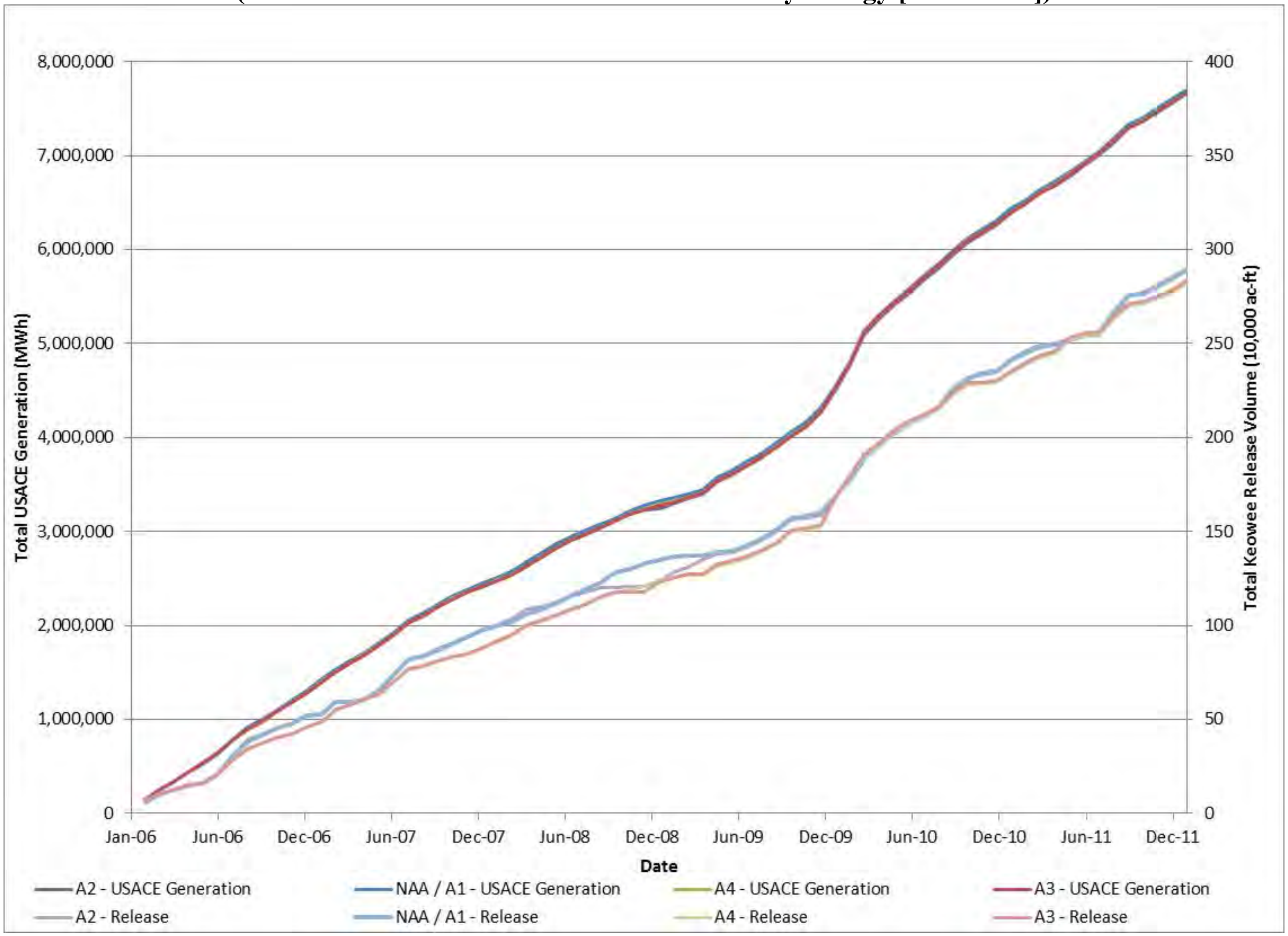


Figure 4.7-6 Total USACE Generation and Lake Keowee Release Volume (Current Water Withdrawals with Historic Hydrology [2006–2011])



Using climate change hydrology instead of historic hydrology results in less electric generation under NAA/A1 for both the Duke Energy and USACE systems. Electric generation would increase slightly in the Duke Energy system under A2, A3, and A4, while it would decrease slightly in the USACE's system. Under climate change hydrology, storage balance requirements for the Duke Energy system increase generation at the Jocassee Pumped Storage Station. Generation increases in A3 and A4 are also influenced by the inclusion of available storage at the Bad Creek Project. As a result, more water is available for pump-back and generation in A3 and A4. The USACE system experiences a decrease in annual average generation of approximately $600,000 for all model scenarios in the climate change scenarios.

Appendix T provides annual energy generation from the HEC-ResSim model results for all alternatives and sensitivity analyses.

4.7.2 *Oconee Nuclear Station Replacement Power*

Under NAA/A1, Duke Energy must shut down the ONS if Lake Keowee drops below 793 feet AMSL. During these periods, Duke would need to purchase replacement power to continue to serve its customers. 2,487 MW of generating capacity would need to be replaced for all months except April and November, which are typically outage months when one of the three ONS units is off-line for refueling. For these two months, only 1,658 MW of generation capacity would need to be replaced.

Over the 73-year POR, there was one extended period where Lake Keowee would have dropped below 793 feet AMSL (with the future water withdrawals and historical hydrology). This occurred during the extreme drought in 2008 and 2009. For NAA/A1, Lake Keowee dropped below 793 feet AMSL from June 20, 2008, through June 2, 2009, a total of 348 days. Using the monthly on-peak and off-peak energy values from Table 4.7-1 and an assumption that each week is comprised of 80 hours of on-peak energy and 88 hours of off-peak energy, the ONS replacement energy would cost approximately $913 million. This calculation includes the avoided cost of energy needed to power electrical systems during generation at the ONS.

Using current water withdrawals instead of future water withdrawals, replacement energy would be needed from July 28, 2008, through March 24, 2009, a total of 240 days. The resulting energy replacement cost is approximately $641 million, or $272 million less than with future water withdrawals.

Using climate change hydrology, replacement energy would be needed from June 11, 2008 through June 15, 2009, a total of 370 days. The resulting energy replacement cost is approximately $985 million, or $72 million more than with historic hydrology.

4.7.3 *Engineering Scenarios for Oconee Nuclear Station*

Enercon completed a conceptual level design study in April 2011 (Appendix G) that identified the feasibility and cost of modifications needed for the ONS to operate at Lake Keowee elevations lower than 793.7 feet AMSL (note this elevation does not include the additional operating margin of 0.9 ft used in the HEC-ResSim model runs). Modifications to the ONS to allow it to operate down to a Lake Keowee elevation of 777.1 ft AMSL are included in A1.

Options considered in the study included:

- Upgrades to the CCW system pumps, discharge valves, and associated motors and controls to allow plant operation at a Lake Keowee level of 787 ft AMSL (Part 1 Option 1a)
- Reducing flow of the LPSW and HPSW systems (by reducing or eliminating non-essential loads during loss of offsite power events) to reduce these systems' required net positive suction head (NPSH) (Part 1 Option 1b)
- Upgrades to the CCW pumps, discharge valves, and their associated motors and controls to allow plant operation at a Lake Keowee level of 787 ft AMSL (Part 1 Option 1c)
- Upgrades to the CCW pumps, discharge valves, and their associated motors and controls to allow plant operation at a Lake Keowee level of 777.1 ft AMSL (Part 2 Option 1)
- Upgrades to the CCW pumps, discharge valves, and their associated motors and controls to allow plant operation at a Lake Keowee level of 777.1 ft AMSL (Part 2 Option 2)

Enercon thoroughly investigated each option via plant walkdowns, site personnel interviews, document research, and hydraulic analyses. They prepared conceptual designs for each option and evaluated them for feasibility, plant impact, and licensing basis impact. They developed cost estimates for each option and included design costs, procurement costs, implementation costs, and annual operations and maintenance (O&M) costs.

Enercon's study concluded that all of the options considered are potentially feasible and can meet their stated target reduction in Lake Keowee elevation. The study did not attempt to make a recommendation, but rather it provided a detailed evaluation of the feasibility of plant modifications that would reduce required Lake Keowee reservoir elevations and developed cost estimates for each option. Table 4.7-3 summarizes the estimated capital cost and annual O&M costs for each option they considered. (See Figure 4.7-7)

Since Enercon completed the feasibility/conceptual design study in April 2011, Duke Energy has further reviewed potential design modifications allowing the ONS operations at Lake Keowee elevations below 794.6 feet AMSL. These design modifications would use some elements of the modifications outlined in some of the options in Table 4.7-3, but other plant specific design and system considerations will require costs in addition to the costs specified in Table 4.7-3. Design modifications are currently scheduled to be implemented by November 30, 2019.

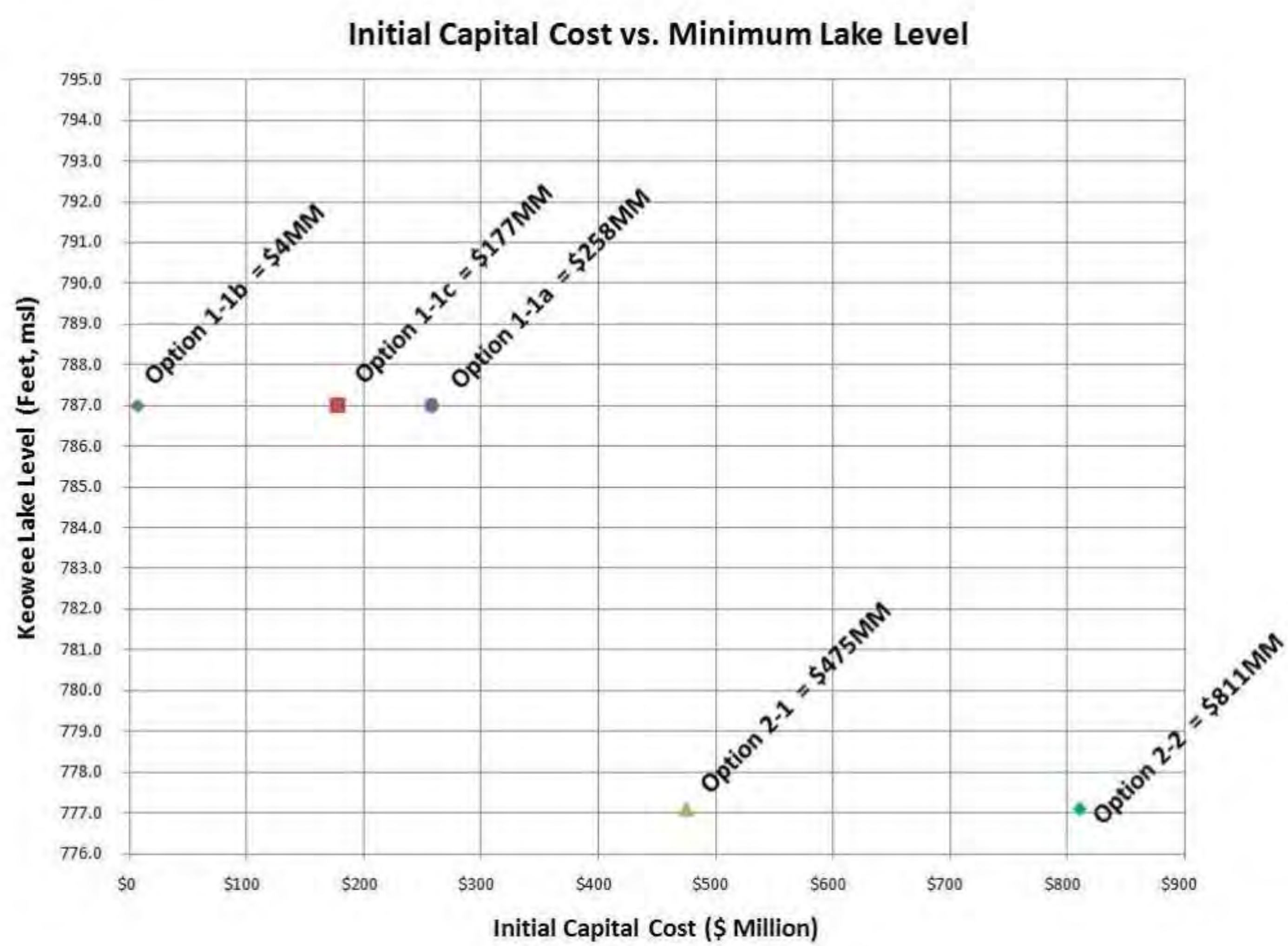
Table 4.7-3 Project Cost Estimates and Minimum Reservoir Elevations

Option	Capital Cost	Annual O&M Cost	Reduced Lake Level (ft msl)
1-1a- Upgrade twelve CCW pumps / motors and CCW discharge valves / motors to QA1, and power from SR DGs	$257,553,509	$434,248	787
1-1b- Reduce required NPSH for LPSW and HPSW pumps. This option consists of LPSW flow reduction option L1 (component cooler isolation modification), option L5 (analytically accounting for isolation of the non-essential LPSW header), reduction of HPSW flow to 5400 gpm, and addition of booster pump to increase NPSH available to CCSW pumps	$3,660,335	$36,400	787
1-1c- Add sufficient safety related conductors and transformer capacity to allow use of Keowee Hydro power for CCW pumps / motors and CCW discharge valves / motors upgraded to QA1.	$177,016,658	$106,600	787

Option	Capital Cost	Annual O&M Cost	Reduced Lake Level (ft msl)
2-1- Replace underground SR power supply from Keowee Hydro with SR DGs sufficient in size to power emergency loads (including CCW) during a site wide LOOP and a LOCA on one unit or power the PSW loads.	$475,094,105	$710,924	777.1
2-2- Replace underground SR power supply and overhead non-SR power supply from Keowee Hydro with DGs sufficient to power emergency loads (including CCW) during site wide LOOP and LOCA on one unit or power the PSW load; additionally power non-SR BOP loads currently powered from Keowee Hydro overhead line.	$810,656,722	$1,418,473	777.1

Note: Elevations do not include any operating margins
Source: Enercon 2011.

Figure 4.7-7 Initial Capital Cost Versus Minimum Reservoir Elevation



Source: Enercon 2011.

4.8 Electric Transmission

At USACE's request, Duke Energy assessed potential impacts to electric transmission system from shutdown of all three ONS generating units under the NAA/A1 under extreme drought conditions. It focused on grid stability and reliability issues. The study identified overloaded transmission lines and/or transformers that would need to be rebuilt or replaced and construction activities that should be accelerated under NAA/A1. The study provides a cost basis for comparison of the action alternatives to the No Action Alternatives.

Duke investigated generator instability issues. Instabilities can arise from the unplanned tripping of a transmission line. Depending on a number of factors, this can cause a generator to be tripped. Under worst case conditions, this could cause a total loss of the transmission grid. A stability study uses a computer program whose initial conditions are set to generate and load data for the particular "peak" or "valley" period being studied. The program systematically trips each transmission line (one line for each computer run) and analyzes the effect on each generator. This approach is standard industry practice and was used for the load scenarios being investigated. The analysis concluded that ONS shutdowns would not result in transmission system stability concerns throughout the southern region. Therefore, grid stability is not a major concern.

Transmission line and transformer overloads were investigated. The actual generation and loading data for 2010 (including seasonal "peaks" and "valleys" but excluding the ONS units), were used as the baseline. These baseline conditions were then increased by projected growth factors for years 2013, 2017, and 2021. These years were selected based on current transmission planning models and generation scenarios. Model results were evaluated to identify overloaded transmission lines and transformers. Only the overloads created by the absence of the ONS units were included in the analysis. Based on the results of a previous study, the overloads driven by this type of event would most likely occur during the summer peak. This study focused only on summer peak load levels, but recommended that 10 percent be added to the total cost to account for the winter peak, fall peak, and fall valley periods that were not considered in this analysis.

For the summer peak scenario, an estimated cost was determined to rebuild or replace each overloaded line and/or transformer. This analysis included generators from Duke Energy, Tennessee Valley Authority (TVA), South Carolina Electric and Gas (SCEG), and Southern Company (SOCO). The estimated cost to address transmission line and transformer overloads in the NAA is $232 million. Major transmission system components (i.e., conductors and transformers) would need to be upgraded to address reliability concerns. Due to long lead times associated with these upgrades, planning activities would need to begin as soon as possible and upgrade costs would extend for many years.

The complete study is included in Appendix U. Summary estimated cost results are provided in Table 4.8-1.

Table 4.8-1 Transmission Impacts Related to Potential ONS Shutdowns

Season Load Level	Line / Transformer Upgrades	Capital Costs (2012 dollars)		
		Non-Duke	Duke	Total
Summer Peak (B)	31 / 5	$60,800,000	$149,900,000	$210,700,000
Overall with 10% Added	34 / 6	$66,900,000	$164,900,000	$231,800,000

4.9 Solid and Hazardous Waste Facilities

The average flow releases below JST remain at or above 3,100 cfs for all four alternatives. Therefore, it is unlikely any of the alternatives will impact solid and hazardous waste facilities located in South Carolina and Georgia and all modeled scenarios would have comparable effects.

4.10 Cultural Resources

As described in Section 2.15, during the droughts of 2006, 20011 and 2012, USACE evaluated potential effects on cultural and historic resources listed in or eligible for inclusion in the NRHP resulting from varying pool levels. The evaluations included consultation with Native American tribes, the ACHP, the South Carolina and Georgia SHPOs, the Augusta Canal Authority, and other appropriate parties. The Augusta Canal Authority indicated flows in the Savannah River less than 3,000 cfs would negatively affect the use of the Augusta Canal National Heritage Area for recreational purposes, as well as operation of the Petersburg Tour Boats. No other parties identified concerns regarding the potential effects of flow rates in the USACE Drought Plan on historic properties downstream of its reservoirs. For each of the four alternatives, average flows released downstream from the JST Project would be at or above 3,100 cfs, the minimum flow required to avoid adverse effects to the Augusta Canal National Heritage Area.

At this time, USACE has not fully documented the effects that fluctuating water levels have had on cultural resources within its USACE reservoirs. As such, it is not certain how the management of reservoir elevations is impacting these resources. The proposed alternatives would reduce pool elevations in the USACE reservoirs during severe droughts, but would not empty the USACE Conservation Pools. The original design of the USACE reservoirs was to have them decline to the bottom of their Conservation Pools during the worst drought. Since the minimum pool levels would still be above the bottom of the Conservation Pool with the proposed alternatives, they would not expose any submerged lands that were not intended to be exposed during severe droughts. However, comprehensive cultural resource surveys were not performed before the Hartwell and Thurmond reservoirs were flooded. As a result, the locations of all significant historic or cultural resources on the bottom of the reservoirs, along their shorelines, and on the adjacent Federal uplands are not completely known. With substantial water depths in many locations, such surveys are quite difficult to perform.

In 2011 as part of the Level 4 Drought Operations EA, USACE developed and agreed to implement a Programmatic Agreement, and survey inundated areas that are affected by changes in Level 4 drought operations to identify and evaluate properties eligible for the National Register of Historic Places. It would also identify and evaluate alternatives to avoid and/or mitigate adverse effects on those properties. The Programmatic Agreement was updated slightly in the 2012 Drought Plan and that document contains the same commitments to protect cultural resources. USACE would continue to follow the 2012 Drought Plan in each of the alternatives considered in this EA and incorporates the 2012 Programmatic Agreement into this document by reference. Implementation of the Programmatic Agreement will increase understanding of the effects of fluctuating water levels on archaeological sites within the project area.

As discussed in Section 2.15, FERC executed a Programmatic Agreement with the South Carolina SHPO in 2007 for managing historic properties potentially affected by implementation of the Shoreline Management Plan for the Keowee-Toxaway Project. Duke consulted with Indian tribes, the North and South Carolina SHPOs, and other appropriate parties to identify, assess, and resolve adverse effects on historic properties potentially affected by relicensing the Keowee-Toxaway Project. Since no historic properties have been located at Lake Jocassee, no impacts to historic properties are expected at that site. Three archaeological sites that may be eligible for the National Register have been located at Lake Keowee. None of the proposed alternatives are expected to affect those properties.

All alternatives would have minor and similar effects on cultural resources.

4.11 Navigation

Although navigation is one of the Congressionally-authorized purposes of the USACE reservoirs, USACE does not set aside any reservoir storage or identify any pool elevation to support downstream navigation. Similarly, no minimum flow requirements have been established to support navigation in the lower Savannah River. Since USACE would continue to implement the minimum releases from JST identified in its 2012 Drought Plan in each alternative, none of the alternatives would affect downstream navigation.

5.0 CONCLUSIONS

As summarized below, there are only minor differences in environmental, socioeconomic, and hydroelectric generation effects between the alternatives. Although the changes from the alternatives would only result in small changes in USACE pool elevations, those changes under A3 and A4 would result in substantial losses in recreational use over the 50-year period of analysis. Mitigation would be included in those two alternatives to fully compensate for those impacts. All action alternatives eliminate the substantial energy replacement and transmission system upgrade costs resulting from temporary shutdowns of the ONS during extreme droughts (approximately $913 million and $232 million, respectively) associated with NAA. A1 includes substantial costs associated with modifying the ONS to meet the requirements of the 1968 Agreement ($800 million in capital costs, without additional O&M costs). Such costs would likely be passed on to electric ratepayers in the region, make the NAA and A1 undesirable alternatives from an economic perspective. A2, A3, and A4 are very similar with respect to reservoir elevation, generation, and socioeconomic effects.

Duke Energy System Water Volume Available for Downstream Flow Releases

Reservoir storage calculations are completed on a weekly basis for the USACE and Duke Energy systems and required flow releases from Keowee Hydroelectric Station are determined. Figure 3.2-1 showed the volume of water available for use from the Keowee-Toxaway and Bad Creek Projects as the percent of remaining usable storage in the USACE system declines (uses include municipal water withdrawals from Lake Keowee, ONS uses, and flow releases to the USACE reservoirs, in addition to natural surface evaporation).

Among the five alternatives, NAA and A1 have the largest volume of water available for use from Lake Keowee as the pool would be allowed to decline to 778 feet AMSL. However, making this volume of water available requires a substantial cost to Duke Energy either through a shutdown of the ONS in NAA or through expensive modifications to the ONS in A1. Neither of those two alternatives is consistent with Duke's 2014 stakeholder agreement for relicensing of the Keowee-Toxaway Project.

A2 assumes no flow release is made from Lake Keowee if that release would result in the reservoir level dropping below 794.6 feet AMSL. With this alternative, Duke Energy would not release water from its system once the USACE system storage drops below approximately 43 percent if inflows are not sufficient to meet all on-reservoir water use demands for the Keowee-Toxaway Project.

While less water is available for use in A3 and A4 when the USACE system storage is between 100 and 25 percent (compared to NAA, A1, and A2), more water would be available for use (compared to A2) when the USACE system storage level drops below 25 percent during severe droughts.

Hydrologic Modeling

USACE's HEC-ResSim hydrologic model was used to simulate reservoir elevations, usable storage, and flow releases from the Duke Energy and USACE reservoirs in the Upper Savannah River Basin, including flow releases from JST Reservoir. Two alternatives (NAA and A1) are the same from a reservoir modeling perspective and did not require separate model simulations. The analyses use future water withdrawals and historic hydrology. Additional analyses were performed to identify the sensitivity of the results to an alternate assumption in (A) water withdrawals (current rather than future), and (B) climate (climate change rather than historic hydrology).

Differences between alternatives are only evident during droughts. Those differences are usually small in magnitude (particularly for the USACE reservoirs and the lower Savannah River Basin), infrequent (only occurring during droughts), and are not expected to have long-term effects on environmental conditions.

For Lakes Jocassee and Keowee, A3 and A4 are almost identical and result in reservoir elevations higher than NAA/A1 and A2. The only time A2 maintains higher Lake Keowee reservoir elevations is during extreme droughts. The available storage in Lake Jocassee is used during droughts to help maintain Lake Keowee pools as long as possible to support operation of the ONS.

For the USACE reservoirs, differences in pool elevations are observed during extreme droughts. The differences in pool elevation occur infrequently (only during extreme droughts) and are relatively short in duration (i.e., 2 to 3 months).

The USACE and Duke Energy remaining usable storage is greater than 60 percent during the majority of the POR. All alternatives would result in similar amounts of available storage. With A3 and A4, the usable storage would drop below 12 percent in both the USACE and Duke Energy reservoirs under extreme drought near the end of 2008. When that occurs, Duke Energy would not be required to provide a weekly scheduled storage balance release from the Keowee Hydroelectric Station. However approximately 650 ac-ft per week is released continuously via seepage and leakage through the Keowee Development, so some inflow would continue to occur to the USACE reservoirs.

USACE would continue to release the minimum flows from JST during droughts that were identified in USACE's July 2012 Drought Plan. This means that the volume of water USACE discharges through JST would be the same in the NAA and the action alternatives. However, those discharges would be reduced for longer periods of time with the action alternatives because the USACE pools would be lower and USACE would operate the system under the Drought Plan for more days.

Environmental Effects

The HEC-ResSim modeled differences in reservoir elevations and downstream flow releases might affect water supply; water quality; recreation opportunities; and aquatic, wetland, and wildlife resources for the five alternatives. During non-drought and wet hydrologic periods, there were no differences between model scenarios in reservoir elevations or flows released from the JST Project. As a result, during these periods, the effects of all alternatives on water supply, water quality, recreation opportunities, or natural resources in the Savannah River Basin are comparable.

During drought conditions, there were some differences between alternatives that could affect environmental conditions and natural resources. Most, if not all, of the differences are relatively minor, infrequent (i.e., only occur during the most severe parts of the droughts), and short-lived. As described above, these differences were the greatest at Lakes Jocassee and Keowee. A3 and A4 generally result in Lake Jocassee and Lake Keowee reservoir elevations higher than they are under NAA/A1 and A2, which could generally benefit environmental conditions and natural resources.

- Effects Associated with Lake Jocassee Reservoir Elevations: The effects of large reservoir drawdowns at Lake Jocassee have been the subject of a water quality and fish habitat monitoring program (undertaken by Duke Energy) which identified no long-term detrimental impacts to fish or biota living in or using the reservoir. Recreation opportunities on Lake Jocassee likely diminish during large reservoir drawdowns, but access to the reservoir is still available. A3 and A4 maintain higher reservoir elevations compared to NAA/A1 and A2 and would result in the least impacts to environmental conditions and natural resources. Recreational users of the reservoir would benefit from the higher pool levels in A3 and A4.

- Effects Associated with Lake Keowee Reservoir Elevations: For Lake Keowee, only NAA/A1 results in reservoir drawdowns greater than 10 feet, which occur twice during the 73-year POR. All public boat ramps become unusable at drawdowns greater than 13 feet; that is a lower elevation than observed in any alternative, except during the most severe drought in the 73 year period of record. Municipal water supply intakes on Lake Keowee are below the largest modeled drawdown (i.e., 782 feet AMSL) and would not be affected. Most alternatives maintain reservoir elevations within the upper five feet of the reservoir, with only small differences occurring between alternatives. Therefore, differences between the alternatives in effects to water quality and aquatic, wetland, and wildlife resources are minimal.

- Effects Associated with USACE Reservoir Elevations: For the USACE reservoirs, small differences in reservoir elevations between alternatives occur during droughts. In general, those impacts are only 2 - 3 months in duration. Water intakes (and supply) are not expected to be impacted by any of the alternatives. Reservoir drawdowns during droughts result in periods where public boat ramps are unusable. A2 would reduce the number of days boat ramps would be unavailable, while the number of days would increase in A3 and A4. The expected effects on recreation would be as follows: A2 - $898,000 benefit per year; A3 - $2,938,000 adverse impact per year; and A4 - $3,626,000 adverse impact per year. The adverse impacts would be fully compensated by mitigation that would increase recreational access to the USACE reservoirs. The effect on natural resources from changes in the drawdown during droughts would be similar for all four alternatives.

- Effects Associated with JST Flow Releases: Differences in environmental effects between the alternatives are negligible in the lower Savannah River. As droughts become more severe, HEC-ResSim model results indicate downstream average flow releases become more similar between alternatives. Since USACE would continue to follow the conditions of its 2012 Drought Plan, the average daily volume of water released from JST would be the same under all alternatives. Since the USACE pools would drop lower during droughts in A3 and A4, the reduced flow levels identified in the Drought Plan would occur for a longer duration with A3 and A4. The number of additional days varies by drought level (see Section 3.7.1). To avoid adverse impacts to dissolved oxygen levels in Savannah Harbor, the action alternatives include the following provision: USACE and Duke Energy will discharge 200 cubic feet per second of water above that specified in the Drought Plan from their dams for 11 days when the USACE reservoirs are in drought status during the summer months.

Hydropower Generation

HEC-ResSim model calculates hydropower generation expected at each of the Duke Energy and USACE Projects. Differences in average annual net energy generation in the Duke system between alternatives are relatively minor (Table 4.7-2). A4 results in the highest net annual generation for the Duke Energy system at $92.2 million and NAA/A1, A2, and A3 are slightly lower ranging from $91.1 - $92.1 million. As a result, the maximum difference between scenarios for the Duke Energy system is $1.1 million ($92.2 - $91.1 million) on an annual basis. There is no difference in net hydroelectric generation between alternatives for the USACE system (Table 4.7-2).

Oconee Nuclear Station Economic Impacts

Under the NAA, Lake Keowee reservoir levels would fall below 793 feet AMSL for a 348-day period in 2007–2008. The resulting forced outage at the ONS would have resulted in energy replacement costs estimated at $913 million. In addition, costs to upgrade the existing electric transmission system to lessen the severity of grid reliability issues while the ONS is off-line are estimated at $232 million. Implementation of those transmission system upgrades would have to begin immediately to avoid grid reliability issues in the future (under this alternative).

Duke Energy evaluated options that would allow it to continue to operate the ONS at lower pool elevations. Those modifications include upgrades to the CCW system (i.e., pumps, discharge valves, and associated motors and controls) and reductions in the flow of the low-pressure and high-pressure service water systems by reducing or eliminating non-essential loads during loss of offsite power events. Duke Energy identified the most cost effective modifications that would allow it to operate the ONS at various elevations of Lake Keowee below 794.6 ft AMSL. No modifications to the ONS are included in the NAA.

Under A1, Duke Energy would modify the ONS so that its operations are not tied to Lake Keowee elevations. From a water management perspective, A1 decouples the ONS from the Keowee Hydroelectric Station through installation of diesel generators that would serve as the primary backup power supply. Duke estimates the cost of installing those diesel generators to be at least $800 million, not including O&M costs.

No modifications to the ONS are included in A2. Duke Energy's cost to modify the ONS in A3 and A4 is approximately $2 million.

Socioeconomic Impacts

Regional Economic Models

The Strom Thurmond Institute developed regional economic models for the counties surrounding Duke Energy's Lake Keowee and the USACE Hartwell and JST Reservoirs. These models rely on three parameters as indicators of economic change: recreational use at each reservoir, real estate transactions around each reservoir, and the sale of reservoir-related goods and services (e.g., sporting goods, bars, boating stores, etc.). The models evaluated regional economic conditions (both positive and negative) associated with every foot of water elevation change in these three reservoirs. The economic model results span 2001–2008, which includes the drought of record in 2008. The impacts of the proposed alternatives were found to be minor at each reservoir.

For Lake Keowee, during the majority of the period modeled, differences between alternatives are within $2,000 of each other and three jobs over the eight-year study period (see Figures 4.5-3 and 4.5-4). The largest differences occur near the end of 2008 and are the result of the extreme drought. During this period, NAA/A1 results in the largest economic impact to the region (a loss of $12,000 and 12 jobs) as Lake Keowee's reservoir elevation drops to 782 feet AMSL. A2 results in the least impact (a loss of $4,000 and four jobs) because flow releases would not be made if they would result in Lake Keowee dropping below 794.6 feet AMSL. A3 and A4 are similar to each other and fall between A2 and NAA/A1 results (a loss of $6,000 and six jobs).

For Hartwell and JST Lakes, during the entire period modeled, economic and employment impacts are similar for all alternatives. See Figures 4.5-1 and 4.5-2 for Hartwell Lake results and Figures 4.5-5 and 4.5-6 for JST Lake results.

The sensitivity analyses indicate that economic effects from drought-induced reservoir drawdowns increase substantially over the NAA with expected future increases in water withdrawals and with the Climate Change scenario.

Environmental Justice and Protection of Children

The analysis considered potential impacts to populations of minorities, low income households, and children (who may suffer disproportionately from environmental health and safety risks) and would most likely be affected by differences in reservoir elevations and flows released from the JST Project to the lower Savannah River. Based on the HEC-ResSim model results, those differences would be small in both the reservoir and downstream. These differences occur during extreme drought and are widespread. As a result, negligible impacts are expected to minority and low-income populations, or environmental health and safety.

Overall Summary of Results

Tables 5.0-1 and 5.0-2 provide a summary of HEC-ResSim, economic, environmental and socioeconomic results.

Table 5.0-1 HEC-ResSim Model and Economic Results Summary (Future Water Withdrawals with Historic Hydrology)

Resource		Alternatives				
		NAA	A1	A2	A3	A4
Duke Energy Avg Reservoir Elev (ft AMSL)	Lake Jocassee	1104.6	1104.6	1105.0	1106.4	1106.3
	Lake Keowee	797.7	797.7	797.9	798.4	798.4
USACE Avg Reservoir Elev (ft AMSL)	Hartwell Lake	656.9	656.9	657.0	656.8	656.7
	RBR Lake	475.5	475.5	475.5	475.2	475.2
	JST Lake	327.1	327.1	327.1	327.1	327.0
Minimum Remaining Usable Storage (%)	Duke Energy	17	17	42	11	10
	USACE	16	16	20	13	13
JST Project Avg Flow Releases (cfs)		6,074	6,074	6,076	6,082	6,078
Approximate Largest Socioeconomic Loss ($ / Jobs)	Lake Keowee	12,000 / 12	12,000 / 12	4,000 / 4	6,000 / 6	6,000 / 6
	Hartwell Lake	30,000 / 25	30,000 / 25	28,000 / 24	30,000 / 26	31,000 / 27
	JST Lake	500,000 / 650	500,000 / 650	510,000 / 660	510,000 / 660	510,000 / 660
Average Annual Net Hydroelectric Generation ($ Million)	Duke Energy	92.1	92.1	91.1	91.9	92.2
	USACE	120.4	120.4	120.4	120.4	120.4
ONS Economic Impacts ($ Million)	Replacement Energy	913	n/a	n/a	n/a	n/a
	Transmission System Upgrades	232	n/a	n/a	n/a	n/a
	Station Modifications	n/a	>800	n/a	2	2

Table 5.0-2 Environmental and Socioeconomic Results Summary

<table>
<tr><th colspan="2" rowspan="2">Resource</th><th rowspan="2">Modeling Parameter</th><th colspan="3">Alternative Comparison with NAA / A1</th></tr>
<tr><th>A2</th><th>A3</th><th>A4</th></tr>
<tr><td rowspan="2">Water Supply</td><td rowspan="2">Water Intake Operation</td><td>Daily Average Drawdown Elevation</td><td>Little to no difference (<0.5 ft)</td><td>Little to no difference (<1 ft); Smaller drawdowns for the Duke Energy System; Alternative includes measures to reduce consumptive water uses at Keowee during droughts</td><td>Little to no difference (<1 ft); Smaller drawdowns for the Duke Energy System</td></tr>
<tr><td>Average JST Flow Release</td><td>Little to no difference (<2 cfs)</td><td>Minor increase (~8 cfs)</td><td>Little to no difference (<4 cfs)</td></tr>
<tr><td rowspan="2">Water Quality</td><td>Reservoir Temperature and D.O. Stratification</td><td>Daily Average Drawdown Elevation</td><td>Little to no difference (<0.5 ft)</td><td>Little to no difference (<1 ft); Smaller drawdowns for the Duke Energy System</td><td>Little to no difference (<1 ft); Smaller drawdowns for the Duke Energy System</td></tr>
<tr><td>Lower Savannah River D.O. and Salinity</td><td>Average JST Flow Release</td><td>Little to no difference; No difference in volume of daily minimum release</td><td>Little to no difference; No difference in volume of daily minimum release</td><td>Little to no difference; No difference in volume of daily minimum release</td></tr>
<tr><td rowspan="2">Recreation</td><td>Public Boat-Launching Ramps</td><td rowspan="2">Daily Average Drawdown Elevation</td><td>Increase of less than 2% of days in annual usability; Increase of 4,497 ramp days at USACE reservoirs</td><td>Decrease of less than 6% of days in annual usability; Decrease of 13,484 ramp days at USACE reservoirs; Measures included to retain boating access</td><td>Decrease of less than 7% of days in annual usability; Decrease of 15,701 ramp days at USACE reservoirs; Measures included to retain boating access</td></tr>
<tr><td>Swimming</td><td>Little to no difference (<0.5 ft); Swimming areas become dry during droughts in USACE System</td><td>Little to no difference (<1 ft); Swimming areas become dry during droughts in USACE System</td><td>Little to no difference (<1 ft); Swimming areas become dry during droughts in USACE System</td></tr>
</table>

Resource		Modeling Parameter	Alternative Comparison with NAA / A1		
			A2	**A3**	**A4**
Biotic Communities - Reservoirs	Littoral Zone Fish and Mussel Habitat	Daily Average Reservoir Fluctuations	Little to no difference (< 0.01 foot)	Little to no difference (<0.01 foot)	Little to no difference (<0.01 foot)
	Pelagic Zone Fish Habitat	Mean September Drawdown Elevation	Little to no difference (infrequent larger drawdowns) (<2 foot) at Lake Jocassee; Studies indicate depth alone is not a limiting factor to pelagic fisheries	Smaller drawdowns at Duke Energy System; Little to no difference at USACE System	Smaller drawdowns at Duke Energy System; Little to no difference at USACE System
	Aquatic Plants, Wetlands and Wildlife	Daily Average Drawdown Elevation	Small difference (<0.5 foot)	Small difference (<1 foot); Smaller drawdowns at Lake Jocassee	Small difference (<1 foot); Smaller drawdowns at Lake Jocassee
Biotic Communities- Lower Savannah River	Fish and Mussel Habitat	Average JST Flow Release	Higher mean monthly flows for late winter and critical summer species; Lower mean monthly flows for spring spawning and fall juvenile fish outmigration	Higher mean monthly flows for late winter and critical summer species; Lower mean monthly flows for spring spawning and fall juvenile fish outmigration	Higher mean monthly flows for late winter and critical summer species; Lower mean monthly flows for spring spawning and fall juvenile fish outmigration
	Aquatic Plants, Wetlands and Wildlife	Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)
	Savannah National Wildlife Refuge	Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)
	Protected Species	Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)

Resource		Modeling Parameter	Alternative Comparison with NAA / A1		
			A2	A3	A4
Environmental Justice and Protection of Children, Cultural Resources, Coastal Zone Consistency, Solid and Hazardous Waste Facilities, and Navigation	Human Health, Environmental Effects, and Economic Hardship, Historic Properties	Reservoirs - Daily Average Drawdown Elevation	Little to no difference (<0.5 foot)	Minor difference (<1 foot); Smaller drawdowns for the Duke Energy System; Larger drawdowns for the USACE System	Minor difference (<1 foot); Smaller drawdowns for the Duke Energy System; Larger drawdowns for the USACE System
		Lower Savannah River - Average JST Flow Release	Little to no difference (<2 cfs)	Minor increase (~8 cfs)	Little to no difference (<4 cfs)

The tables show that differences between the alternatives for the USACE reservoirs are generally small. The largest differences are in impacts to boating access at the USACE reservoirs as a result of changes in pool elevations during droughts. Those impacts vary from a positive $40,896 per year with A2 to a loss of $131,409 per year with A4. A1 would have the same effect on recreation as the NAA. A3 would result in somewhat less adverse impacts than A4 (loss of $113,670 per year). Duke Energy would mitigate those losses (A3 and A4) by providing funding and/or in-kind services to USACE and other public entities to improve public boating access at Hartwell and JST Reservoir facilities. The amount of funding would equal the expected adverse impacts (present worth of $2,938,000 with A3). A3 and A4 result in slightly higher reservoir elevations for Lakes Jocassee and Keowee compared to NAA, A1, and A2. As a result, environmental effects associated with A3 and A4 will likely be the same or a slight improvement for Lakes Jocassee and Keowee compared to the other alternatives. Changes in releases from the JST Project would be minimal because USACE would continue to follow its 2012 Drought Plan in the NAA and all alternatives. Therefore, environmental effects associated with all five alternatives will be very similar in the lower Savannah River. Only negligible differences were identified between the NAA and alternatives for other environmental resources.

From a socioeconomic perspective, there are no substantial differences were identified in the economy of the region between the alternatives.

No major differences were identified for the USACE system between alternatives in hydroelectric generation. A4 would result in slightly more generation for the Duke Energy system than the other alternatives. The NAA would require substantial replacement energy (approximately $913 million) and transmission system upgrade costs (approximately $232 million). Similarly, A1 would require ONS modification costs in excess of $800 million. Because of these large costs, neither of those two alternatives is preferred. A3 and A4 include much lower ONS modification capital costs, estimated at approximately $2 million.

Rationale for Recommended Alternative

The performance of the No Action Alternative and four action alternatives were evaluated over the 73-year Period Of Record. The alternatives would have resulted in similar USACE reservoir elevations and JST Project flow releases to the lower Savannah River. Differences between the alternatives occur infrequently, during droughts.

A3 and A4 include additional storage from the Bad Creek Project in the Duke Energy system. Those alternatives also include additional storage from the Richard B. Russell Project in the USACE system. This additional usable storage in the Duke Energy system reduces the risk of forced outages at the ONS during extreme droughts (thus preventing expensive energy replacement costs and transmission system upgrades); and provides additional storage that can be used to support other water users in the Upper Savannah River Basin.

NAA and A1 result in lower reservoir elevations for Lakes Jocassee and Keowee. During droughts, A2 maintains the highest Lake Keowee pool elevations. However, that is at the expense of Lake Jocassee, which experiences its lowest reservoir elevations with this alternative. During extreme droughts, A2 results in Lake Keowee elevations below 794.6 feet AMSL, which would negatively impact Duke's operation of the ONS. This would occur when the Lake Jocassee storage capacity is depleted, making it harder to maintain Lake Keowee reservoir elevations above 794.6 feet AMSL, increasing the risk of forced outages at the ONS.

A3 and A4 generally result in higher reservoir elevations for Lakes Jocassee and Keowee compared to the other alternatives. During less severe droughts, such as occurred at the end of 2006, A3 and A4 result in slightly lower elevations in Hartwell and JST Reservoirs (by approximately 0.7 feet and 0.5 feet, respectively) compared to the NAA and A1. During extreme droughts, there is little difference in Hartwell and JST Lake elevations between A3 and A4 and NAA/A1. The minor differences in reservoir elevations are not expected to result in additional adverse effects to the biological communities in the USACE Reservoirs or negatively impact social or socioeconomic resources in the Savannah River Basin.

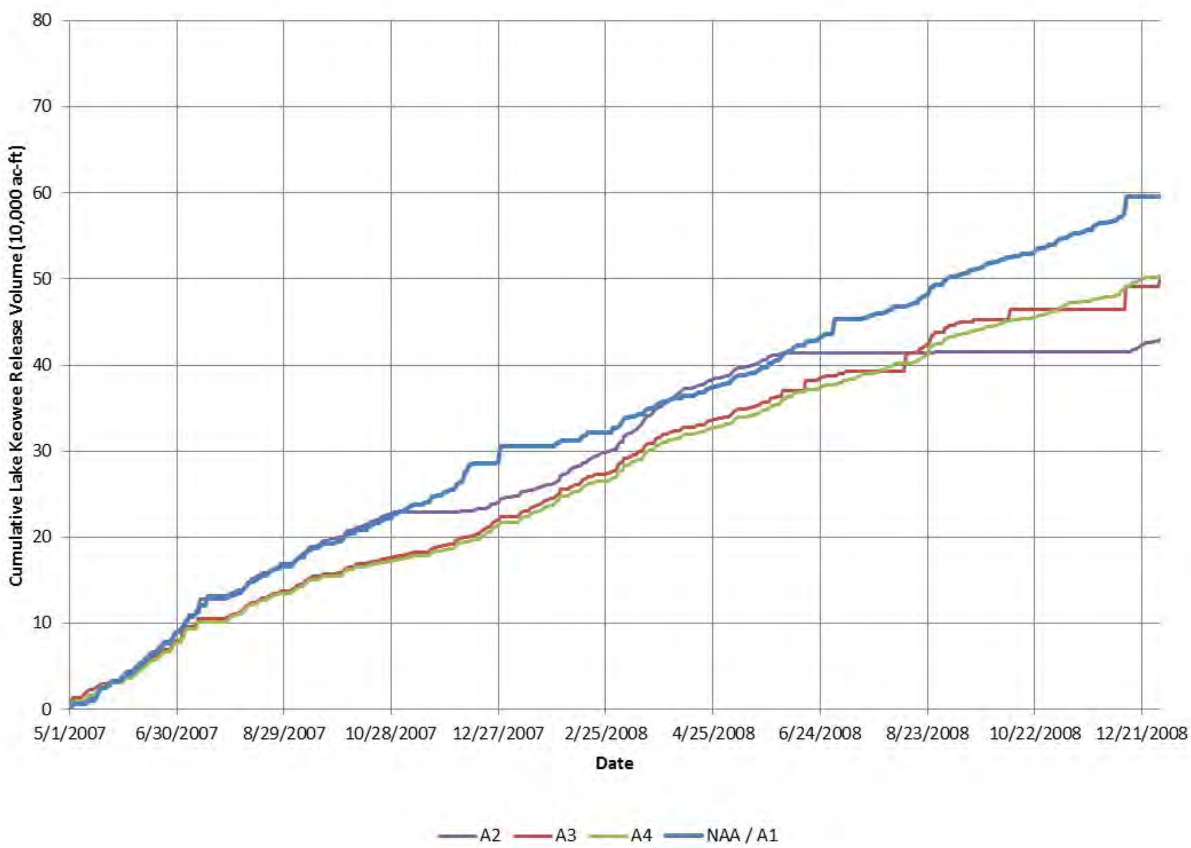
An analysis of flow releases from the JST Project for the April through December periods of drought (i.e., those years where the USACE's Drought Plan was triggered) reveals little difference in downstream flow releases between alternatives. Differences between A3/A4 and NAA/A1 are less than +/-5 percent on an annual basis. The larger negative differences (i.e., A3/A4 average flows are less than NAA/A1 flows) tend to occur during less severe droughts when average flows are well above 4,200 cfs. The larger positive differences tend to occur during recovery from extreme droughts. JST flow releases under A3 and A4 are more similar to NAA/A1 than are the A2 flow releases.

Figure 6.0-1 shows the releases from Lake Keowee to the USACE System toward the end of the drought of record (2007-2008). During this extreme drought, discharges from the Duke Energy system to the USACE system would be higher with the NAA and A1 than the other three alternatives. Flows with A3 and A4 would exceed those of A2 at the deepest part of the extreme drought (third quarter 2008), when releases would cease under A2 because of the limitations in Lake Keowee to enable the ONS to continue to operate.

During extreme droughts when the remaining usable storage in the Duke Energy system drops below 12 percent, Duke would cease to release water from Lake Keowee. However, an estimated 650 ac-ft of water per week would continue to flow into Hartwell Lake via leakage and seepage from the Keowee Development. This water volume would help keep Duke Energy's system storage within approximately 1 percent of the USACE's system storage in extreme droughts.

Net USACE hydroelectric generation results for A3 and A4 are similar to the other alternatives.

Figure 6.0-1 Cumulative Lake Keowee Volume Released to the USACE System (With Adaptive Management Winter Flows) (Future Water Withdrawals with Historic Hydrology)



NAA requires ONS energy replacement costs of approximately $913 million and potential transmission system upgrade costs of up to $232 million. A1 requires ONS station modification costs of at least $800 million. The high costs of A1 and A2 are not justified by the benefits to USACE reservoirs or downstream areas. Adverse impacts to users of the USACE reservoirs could be mitigated by improving access at public ramps on those reservoirs.

The $2 million modification to the ONS in A3 and A4 provides additional usable storage capacity in the Duke Energy system that helps maintain ONS operations (thus preventing expensive energy replacement costs and transmission system upgrades); provides additional storage that can be used to support other water users in the Upper Savannah River Basin; and provides downstream flow releases to the USACE system during the deepest parts of drought periods.

Under A3 and A4, adaptive management flow releases to address downstream water quality concerns during extreme droughts may result in slightly lower Hartwell and JST Lake elevations (by less than 0.4 feet in each reservoir). Duke Energy would offset the effects of these lower lake elevations by providing funding for Interim #3 of the USACE's Savannah River Basin Comprehensive Study and public boating access improvements at Hartwell and JST Lakes. These funding measures are directly related to enhancing drought tolerance in the Upper Savannah River Basin and improving recreation opportunities on the USACE Reservoirs that would be affected by operation of the Duke Energy system during droughts.

In summary, A3 and A4 are better from a Duke Energy system operations perspective than NAA, A1 or A2. These two alternatives result in minor impacts to the USACE reservoir system during extreme droughts. These impacts are offset by drought tolerance and funding measures. A4 does not include the Low Inflow Protocol (drought tolerance measure) similar to what it included in its 2013 Relicensing Agreement for the Keowee-Toxaway Project. Duke Energy prefers A3 and that alternative has been accepted by Duke Energy's stakeholders through their concurrence in the 2013 Relicensing Agreement.

6.0 RECOMMENDED ALTERNATIVE

A3 is the Recommended Alternative because it best balances the competing interests of reservoir levels, risks to operation of the ONS, downstream flow releases, hydroelectric generation, social and biological communities, recreation, and economic costs. Under A3, Duke Energy would modify the ONS to allow operations to continue at Lake Keowee elevations down to 790 feet AMSL. Duke Energy would bear the estimated $2 million cost of those modifications to provide additional operating margin and risk mitigation. The modification costs are significantly lower than the costs associated with forced outages of the ONS (both replacement power and transmission system upgrades) or ONS engineering modifications that would allow operations at Lake Keowee reservoir elevations down to 778 feet AMSL (as required by the 1968 Agreement). Duke would implement these station modifications by November 30, 2019.

Duke Energy expects to modify operations of the Keowee-Toxaway Project as a result of its ongoing FERC relicensing of that facility. A3 conforms to the Relicensing Agreement that Duke and its stakeholders signed on November 20, 2013. As such, the effects of A3 have already been reviewed by Duke's stakeholders and found to be acceptable.

In general, A3 would modify the 1968 Agreement as follows:

- Incorporate additional storage capacity in Duke Energy's Bad Creek Reservoir and USACE's RBR Reservoir into the calculations determining the remaining usable storage and weekly water release requirement from Lake Keowee. As a result, A3 equalizes the percentage of combined remaining usable storage capacity at USACE's Hartwell, RBR, and JST Reservoirs with the percentage of combined remaining usable storage capacity at Duke Energy's Bad Creek Reservoir and Lakes Jocassee and Keowee.
- Revise the Lake Keowee minimum elevation for calculation of usable storage to elevation 790 feet AMSL (which allows for a 10-foot drawdown of Lake Keowee).
- Lower the Lake Jocassee minimum reservoir elevation six feet (from 1086 feet AMSL to 1080 feet AMSL) and eliminate the allowance for pumping volume in the weekly water release calculation.
- Incorporate the USACE July 2012 Drought Plan operating protocols.

- Incorporate Duke Energy's Low Inflow Protocol (LIP) which provides rules for how they will operate their reservoirs during droughts, including minimum lake elevations and water use conservation for existing and future water intake owners located on Keowee-Toxaway Project Reservoirs.

A3 also includes the following provisions to enhance drought tolerance in the Upper Savannah River Basin:

- Duke Energy will require owners of Large Water Intakes on the Duke Energy Projects to comply with its Low Inflow Protocol.
- USACE will require any owner of a Large Water Intake (i.e., water intake with a maximum capacity greater than or equal to one million gallons per day) who is allocated water from the USACE Projects after the effective date of the new Operating Agreement to implement coordinated water conservation measures when the USACE Drought Plan is in effect (similar to the water conservation measures required by the Low Inflow Protocol for Large Water Intake owners on the Duke Energy Projects).
- USACE and Duke Energy will encourage all water users withdrawing water from their respective reservoirs to conserve water in a coordinated manner when the USACE Drought Plan is in effect (similar to the water conservation measures required by the LIP on Duke Energy Projects).
- USACE and Duke Energy will require (whenever feasible) that all Large Water Intakes used for municipal, industrial and power generation purposes that are constructed, expanded or rebuilt on their projects after the effective date of the new Operating Agreement be capable of operating at their permitted capacities at reservoir elevations as low as the applicable hydroelectric station can operate.
- Duke Energy would provide $438,000 in funding to support the next interim of the USACE Savannah River Basin Comprehensive Study (to evaluate reallocating existing storage or measures that could lead to better water management).
- Duke Energy would provide funding and/or in-kind services to USACE and other public entities to improve public boating access at Hartwell and JST Reservoir facilities to fully

mitigate for adverse impacts to recreational access to those reservoirs. Those impacts are presently estimated to be $2,938,000 (FY14 price levels).

To avoid adverse impacts to dissolved oxygen levels in Savannah Harbor, A3 contains the following provision: USACE and Duke Energy will discharge 200 cubic feet per second of water above that specified in the Drought Plan from their dams for 11 days when the USACE reservoirs are in drought status during the summer months.

7.0 REFERENCES

Alderman, J. M. 2009. Freshwater Mussel Survey of Lake Keowee in SC and Lake Jocassee in NC/SC. Duke Energy.

Ashby, S. L., R. H. Kennedy, J. H. Carroll, and J. J. Hains. 1994. "Water quality studies: Richard B. Russell and J. Strom Thurmond Lakes; Summary Report," Miscellaneous Paper EL-94-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Barwick, D. H. and W. R. Geddings. 1986. Relative abundance of fish in two South Carolina reservoirs during the first nine years of pumped storage hydroelectric operation. 1986 Proceedings.

Barwick, D. H., T. C. Folsom, L. E. Miller, and S. S. Howie. 1994. Assessment of Fish Entrainment at the Bad Creek Pumped Storage Station. Final Report. Duke Power Company, Huntersville, NC.

Barwick, D. H., L. E. Miller, W. R. Geddings, and D. M. Rankin. 1995. Fish Biomass and angler harvest from a South Carolina cooling reservoir. Proceedings Annual Conference.

Barwick, D. H., J. W. Foltz, and D. M. Rankin. 2004. Summer habitat use by rainbow trout and brown trout in Jocassee Reservoir. North American Journal of Fisheries Management 24:735-740.

Breeding Bird Atlas. 1995. South Carolina Department of Natural Resources. [Online] URL: http://water.dnr.state.sc.us/wild/bbatlas/bba.html.

Bunch, M. S. and A. Dye. 1999. Monitoring and Status Surveys of Rare Species in the Jocassee Gorges Area. E-1-21 Project Final Report. South Carolina Department of Natural Resources. Columbia, SC.

Camp, J. L. 2004. Use of a Landscape Ecosystem Classification Model to Determine Avian-Habitat Relationships in the Mountains of South Carolina. Master's Thesis. Clemson University. Clemson, SC.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Dept. of Interior, Fish and Wildlife Service. FWS/OBS-79/31. 131pp.

Devine Tarbell and Associates. 2008. Aquatic resources assessment. Claytor Hydroelectric Project (FERC No.739). Prepared for Appalachian Power Company, Roanoke, Virginia. 517 pp.

DeWoody, J. A., D. E. Fletcher, S. D. Wilkins, W. S. Nelson, and J. C. Avise. 2000. Genetic monogamy and biparental care in an externally fertilizing fish, the largemouth bass (Micropterus salmoides). Proceedings of the Royal Society of London B 267:2431-37.

Dorcas, M. E. 2009. Herpetological Inventory of Lake Keowee, South Carolina and Lake Jocassee, North Carolina/South Carolina. Final Report to Duke Energy Corporation.

Duke Energy. 2007. Oconee Nuclear Station 316(a) Demonstration Report. Duke Energy Corporation, Charlotte, NC.

Duke Energy. 2012. Oconee Nuclear Station, 316(a) Demonstration Report. Duke Energy Corporation, Charlotte, NC.

Duke Energy Carolinas, LLC. 2005. Wetlands Mapping and Characterization Study Report of the Catawba-Wateree Project. FERC No. 2232.

Duke Energy Carolinas, LLC. 2008. Selected ONS License Commitments Manual Section 16.9.7.

Duke Energy Carolinas, LLC. 2011. Pre-Application Document for the Keowee-Toxaway Hydroelectric Project.

Duke Energy Carolinas, LLC. 2010. Shoreline Management Plan. [Online] URL: http://www.duke-energy.com/environment/water-quality/shoreline-management.asp (Accessed June 2010).

Duke Engineering & Services, Inc., Ichthyological Associates, Inc., and Woodlot Alternatives, Inc. 2001. The Effects of Water Level Fluctuation on Aquatic and Terrestrial Habitats and Biota in Lake St. Lawrence. Prepared for the New York Power Authority.

Duke Power Company. 1995. Oconee Nuclear Station 316(A) Demonstration Report.

Duncan, W. W., M. C. Freeman, C. A. Jennings, and J. T. McLean. 2003. Considerations for flow alternatives that sustain Savannah River fish populations. Proceedings of the 2003 Georgia Water Resources Conference. University of Georgia. April 23-24, 2003. 4 pp.

Enercon. 2011. Study Report for Lake Keowee Water Level Reduction. Prepared for Duke Energy, Oconee Nuclear Station Units 1, 2, and 3.

ENTRIX, Inc. 2002. Savannah River Instream Flow Study for the Augusta Canal Hydropower Project. FERC No.11810. September 2002.

Estes, R. D. 1971. The effects of the Smith Mountain Pump Storage Project on the fishery of the lower reservoir, Leesville, Virginia. Ph.D. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 151 pp.

Federal Energy Regulatory Commission. 2006. Final Environmental Assessment for the Augusta Canal Project, P-11810-004. Issued September 2006.

Federal Register. 2010. 50 CFR Part 224. Endangered and Threatened Wildlife and Plants; Proposed Listings for Two Distinct Population Segments of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) in the Southeast. Vol. 75, No.193. October 6, 2010. pp 61904–61929.

Foris, W. J. 2009. Jocassee Reservoir pelagic trout habitat: Year 2009. Duke Energy. November 2010. 12 pp.

Garton, J. 2004. Many species of snakes inhabit Jocassee Gorges. Jocassee Journal 5(2): 6-7. Publication of the South Carolina Department of Natural Resources. Columbia, SC.

Georgia Department of Natural Resources. 2007. Known Occurrences of Special Concern Plants, Animals and Natural Communities in Savannah River Watershed HUC (Accessed June 2010).

Georgia Department of Natural Resources. 2008. [Online] URL: http://www.probass.net/presslease.php?content_id=44 (Accessed December 2010).

Georgia Department of Natural Resources, Environmental Protection Division. 2012. Water Quality in Georgia 2010-2011.

Georgia Ports Authority. 1998. Environmental Impact Statement: Savannah Harbor Expansion Feasibility Study. July 1998

Georgia Power. 2008. Shoreline Management Guidelines. Georgia Power Lakes.

Grabowski, T. B. and J. J. Isely. 2006. Seasonal and Diel Movements and Habitat Use of Robust Redhorses in the Lower Savannah River, Georgia and South Carolina, Transactions of the American Fisheries Society, 135:5, pp 1145–1155.

Grunden, R. 2007. Cultural Resources Survey of the Lake Jocassee Shoreline, Oconee and Pickens Counties, South Carolina, and Transylvania County, North Carolina, January 2007. August2007.

Harris, R. 2009. Personal Communication (presentation) generated in support of the February 26, 2009 Project Delivery Team meeting for the development of the Comprehensive Environmental, Engineering, and Economic Analysis Impact Report.

HDR. 2010. Savannah River Basin Preliminary Water Use Evaluation. Identification of Current Water Users and Water Use. Technical Memorandum No.1, March 18, 2010.

HDR. 2012. Water Supply Study Final Report. October 31.2012.

Holling, J. 2010. Personal communication (email) with J. Holling of South Carolina Department of Natural Resources on 5 March 2010, containing SCDNR lists of rare, threatened and endangered species in the Jocassee Gorges, Laurel Fork Heritage Preserve, Eastatoe Creek Heritage Preserve, and Wadakoe Mountain Heritage Preserve.

Huckabee, A. E. 2001. Breeding Birds of an Oak-Hickory Forest in the Blue Ridge Escarpment of South Carolina. Master's Thesis. Clemson University. Clemson, SC.

Huffstetler, C. J., J. H. Carroll, and W. E. Jabour. 1993. Water quality studies: Hartwell Lake 1992 summary report. U.S. Army Corps of Engineers Miscellaneous Paper EL-93-21. October 1993.

Hutchinson, G. E. 1957. A Treatise on Limnology, Vol. 1, Part 1 - Geography and Physics of Lakes, pp. 540, John Wiley and Sons, New York.

Jabour, W. E., and Carroll, J. H. 1993. Water quality studies: Hartwell Lake 1991 summary report. Miscellaneous Paper EL-93-20, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Jenkins, R. E. and N. M. Burkhead. 1993. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Jolley, S. 2010. Personal communication (email) with S. Jolley of Duke Energy on February 17, 2010, and June 14, 2010, pertaining to public boat ramps on Lakes Jocassee and Keowee.

Kasul, R. L. and K. E. Conley. 1992. Distribution and abundance of fish above Hartwell Dam during a period of entrainment. U.S. Army Corps of Engineers Technical Report EL-92-20. May 1992.

Kilpatrick, J. M. 2003. Habitat use, movements, and exploitation of striped bass and hybrid striped bass in Claytor Lake, Virginia. Master's Thesis. Virginia Polytechnic Institute and State University.

Kohlsaat, T., L. Quattro, and J. Rinehart. 2005. South Carolina Comprehensive Wildlife Conservation Strategy 2005-2010. South Carolina Department of Natural Resources. Columbia, SC.

Loeffler, G. and J. L. Meyer. 2010. Savannah River Basin. [Online] URL: http://www.rivercenter.uga.edu/education/k12resources/basinsofga5.htm (Accessed June 2010).

Mathur, D. 1973a. Some aspects of life history of the blackbanded darter, Percina nigrofasciata, (Agassiz), in Halawakee Creek, Alabama. Transactions of the American Fisheries Society 89:381-93.

Mathur, D. 1973b. Food habits and feeding chronology of the blackbanded darter, Percina nigrofasciata, (Agassiz), in Halawakee Creek, Alabama. Transactions of the American Fisheries Society 102:48-55.

Montenucci, R. R. 2006. A review of the amphibians of the Jim Timmerman Natural Resources Area, Oconee and Pickens Counties, South Carolina. Southeastern Naturalist 5, Monograph 1:1-58.

National Audubon Society. 2010. Information on the Important Bird Areas Program and National Audubon Society Watchlist [Online] URL: http://www.audubon.org/bird/IBA. (Accessed March 2010).

National Oceanic and Atmospheric Administration. 2010. Essential Fish Habitat South Atlantic Council. [Online] URL: http://www.nmfs.noaa.gov/habitat/habitatprotection /efh/GIS_inven.htm (Accessed June 2010).

National Park Service and University of Georgia. 2011. Invasive Plant Atlas of the United States. [Online] URL: http://www.invasiveplantatlas.org/index.html (Accessed June 2011).

National Wetlands Inventory. 2010. U.S. Fish & Wildlife Service, National Wetland Inventory. [Online] URL: http://wetlandswms.er.usgs.gov/imf/imf.jsp?site=extract_tool (Accessed March 2010).

Nelson, J. B. 1986. The Natural Communities of South Carolina; Initial Classification and Description. S.C. Wildlife and Marine Resources Department.

Nestler, J. M., R. A. Goodwin, T. M. Cole, D. Degan, and D. Dennerline. 2002. Simulating movement patters of blueback herring in a stratified southern impoundment. Transactions of the American Fisheries Society 131:55-69.

North Carolina Division of Parks and Recreation. 2010. [Online] URL: http://www.ncparks.gov/Visit/parks/gorg/ecology.php (Accessed February 25, 2010).

North Carolina Natural Heritage Program. 2010. County Element Search Results Transylvania County NC NHP database updated on Friday, April 23rd, 2010. [Online] URL: http://www.ncnhp.org/Pages/heritagedata.html.

Oliver, James L., Hudson, Patrick L. 1987. Thermal and Dissolved Oxygen Characteristics of a South Carolina Cooling Reservoir.

Pitts, I. 1997. Field notes taken 9 September 1997 at Keowee-Toxaway State Natural Area. Unpublished data.

Pitts, I. 1999. Field notes taken 21 April 1999 at Keowee-Toxaway State Natural Area. Unpublished data.

Pitts, I. 2000. Field notes taken 14 January 2000 for Midwinter Eagle Assessment at Devils Fork State Park and Lake Jocassee. Unpublished data.

Pitts, I. 2003. Field notes taken 10 June 2003 at Keowee-Toxaway State Natural Area. Unpublished data.

Rankin, D. M., P. A. Sandifer, and W. B. Conrad. 1998. Resource Management Plan for Jocassee Gorges Property, Oconee and Pickens Counties, South Carolina. [Online] URL: http://www.dnr.sc.gov/managed/wild/jocassee/management.htm (Accessed February 23, 2010).

Rodriguez, M. S. 2009. Assessment of the Pelagic Forage Fish Populations of Lake Jocassee, North and South Carolina. Prepared for Duke Energy Carolinas, LLC. December 2009.

Rohde, F. C., R. G. Arndt, J.W. Foltz, and J.M. Quattro. 2009. Freshwater fishes of South Carolina. The University of South Carolina Press. Columbia, South Carolina.

Savidge, T. W. 2007. Freshwater Mussel Surveys The Savannah River from Augusta to Savannah: South Carolina & Georgia. Prepared for International Paper & U. S. Fish and Wildlife Service. The Catena Group.

Schmitt, D. N. and J. H. Hornsby, 1985. A Fisheries Survey of the Savannah River. Georgia Department of Natural Resources Final Report for Project Number F-30-12. Atlanta, Georgia. 91 pp.

Schwartzman, E. 2010. Personal communication (email) with E. Schwartzman of North Carolina Department of Environment and Natural Resources, North Carolina Natural Heritage Program on 9 March 2010, containing North Carolina Natural Heritage Program lists of rare, threatened and endangered species for the North Carolina portion of the Lake Jocassee watershed.

South Carolina Department of Health and Environmental Control. 1995. R.61-101, Water Quality Certification. Effective Date: June 23, 1995. [Online] URL: http://www.scdhec.gov/environment/water/regs/r61-101.doc (Accessed June 2010).

South Carolina Department of Health and Environmental Control. 2010. 401 Water Quality Certification. [Online] URL: http://www.scdhec.gov/environment/water/401.htm (Accessed June 2010).

South Carolina Department of Health and Environmental Control. 2012. State of South Carolina Integrated Report for 2012, Part I: Section 303(d) List of Impaired Waters.

South Carolina Department of Natural Resources. 2006b. South Carolina Rare, Threatened, & Endangered Species Inventory [Online] URL: https://www.dnr.sc.gov/pls/heritage/county_species.select_county_map (Accessed June 2010).

South Carolina Department of Natural Resources. 2008. Public Notice # DHEC 06-C-001, Augusta Canal 401.

South Carolina Department of Natural Resources. 2009. DNR reducing wild hog population on Jocassee Gorges. Jocassee Journal 10(1):3. Publication of the South Carolina Department of Natural Resources. Columbia, SC.

South Carolina Department of Natural Resources. 2010. South Carolina Trout Fishing. SCDNR, Columbia, SC. (Accessed online June 2010).

South Carolina Department of Natural Resources. 2010b. Jocassee Gorges. SCDNR, Columbia, SC [Online] URL: http://www.dnr.sc.gov/managed/wild/jocassee/indexfull.htm (Accessed June 2010 and December 2013).

Swanson, M. 2008. Keowee-Toxaway Hydroelectric Project Historic Context Oconee and Pickens Counties, South Carolina and Transylvania County, North Carolina FERC ProjectNo.2503. May2008.

U.S. Army Corps of Engineers. 1981. Mitigation Report and Supplement to the Final Environmental Impact Statement, Richard B. Russell Dam and Lake. Savannah District USACE. April 1981.

U.S. Army Corps of Engineers. 1989. Corps of Engineers' Drought Management of Savannah River Projects.

U.S. Army Corps of Engineers. 2002. Potential Methods for Reducing Shoaling in Harbors and Navigation Channels. ERDC/CHL CHETN-XIV-6. June 2002.

U.S. Army Corps of Engineers. 1995. Hartwell Major Rehabilitation Program Evaluation Report. U.S. Army Corps of Engineers, Savannah District.

U.S. Army Corps of Engineers. 2008a. Draft Environmental Assessment and Finding of No Significant Impact, Temporary Deviation Drought Contingency Plan Savannah River Basin. Savannah District.

U.S. Army Corps of Engineers. 2008b. Threatened and Endangered Species of the Upper Savannah River Basin, Protected Species Manual. Savannah District USACE. September 2008.

U.S. Army Corps of Engineers. 2009. Engineer Research and Development Center. Water Quality in Richard B. Russell and J. Strom Thurmond Lakes. Summary Report #84. September 29, 2009.

U.S. Army Corps of Engineers. 2010a. Concept of the Savannah River Drought Contingency Plan. [Online] URL: http://water.sas.usace.army.mil/drought/DCP.CFM (Accessed August 12, 2010).

U.S. Army Corps of Engineers. 2010a. Richard B. Russell Lake Shoreline Management Policy. 2010a. [Online] URL: http://www.sas.usace.army.mil/lakes/russell/rsmp.htm (Accessed June 2010).

U.S. Army Corps of Engineers. 2010b. Shoreline Management Program. [Online] URL: http://corpslakes.usace.army.mil/employees/gets.cfm?Id=shoreline (Accessed June 2010).

U.S. Army Corps of Engineers. 2010c. Water Management Page for the Savannah River Projects.[Online] URL: http://water.sas.usace.army.mil/home/indexDU.htm (Accessed August 11, 2010).

U.S. Army Corps of Engineers. 2011. Final Environmental Assessment and Finding of No Significant Impact Level 4 Drought Operations Savannah River Basin. Savannah District. USACE. October 2011.

U.S. Army Corps of Engineers. 2012a. Final Environmental Assessment and Finding of No Significant Impact Drought Plan Revision. Savannah River District. USACE. July 2012.

U.S. Army Corps of Engineers. 2012b. Savannah River Basin Drought Management Plan. Savannah River District. USACE. September 2012.

U.S. Department of Agriculture. 2005. Wetland Functions Fact Sheet. [Online] URL: http://www.nrcs.usda.gov/programs/compliance/WC-files/SWAMP-WetFctns-2005.pdf (Accessed December 8, 2010)

U.S. Department of Housing and Urban Development. 2010. Executive Order 12898. [Online] URL: http://www.hud.gov/offices/fheo/FHLaws/EXO12898.cfm (Accessed June 2, 2010).

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey: Report on Lake Keowee, Oconee and Pickens County, South Carolina. EPA Region IV. Working Paper No. 433.

U.S. Environmental Protection Agency. 2010a. Region 4 Superfund Sangamo Weston, Inc./Twelve-Mile Creek/Lake Hartwell PCB Contamination. [Online] URL: http://www.epa.gov/region4/waste/npl/nplsc/sangamsc.html (Accessed August 11, 2010).

U.S. Fish and Wildlife Service. 1983. Northern states Bald Eagle recovery plan. Department of the Interior. Denver, CO. 116 pp.

White House Press Release. 1997. Protection of Children from Environmental Health Risks and Safety Risks. The White House. Office of the Press Secretary. [Online] URL:

http://www.health.gov/environment/TaskForce/whouseprenv.html (Accessed June 2, 2010).

Zohary, T., Ostrovsky, I. 2011. Ecological impacts of excessive water level fluctuations in stratified freshwater lakes. Inland Waters, 1:47-59.

APPENDICES

Appendix E6:

Final Study Reports

This appendix contains the final study reports and the addenda to the final study reports, organized by Resource Committee as follows.

Aquatic Resources

- Fish Community Assessment Study Plan Final Report, January 7, 2013
- Fish Community Assessment Study – FERC Required Fish Entrainment Modification, October 2013

Cultural Resources

- NRHP Evaluation of the Keowee-Toxaway Hydroelectric Development, October 2012

Recreation Resources

- Recreation Use and Needs Study, March 2013

Shoreline Management

- Lake Keowee & Lake Jocassee Shoreline Erosion Study Final Report, January 14, 2013

Water Quality

- Jocassee Forebay and Tailwater Water Quality Report, February 2013
- Keowee Reservoir Water Quality Modeling Study Report, March 2013
- Keowee Reservoir Water Quality Modeling Study Addendum: CE-QUAL-W2 Water Quality Model Results from WQ4 Operations Under Climate Change Scenarios, May 2014

Water Quantity and Hydro Operations

- Reservoir Level and Project Flow Releases Study for the Keowee-Toxaway Relicensing Project, November 2012
- Operations Model Study Savannah River Basin Model Logic and Verification Report, May 1, 2014
- Operations Model Scenario Documentation Report, May 1, 2014
- Water Supply Study Report, Keowee-Toxaway Relicensing Project, May 1, 2014

Wildlife and Botanical Resources

- Final Avian Study Report for the Keowee-Toxaway Relicensing Project Area, February 18, 2013
- Botanical Resources Study, October 2013
- Mammalian Survey for Keowee-Toxaway Relicensing Project, March 2013

- Wetlands Study Final Report, January 17, 2013

Keowee Reservoir

Water Quality Modeling Study Addendum:

KEOWEE-TOXAWAY PROJECT
(FERC PROJECT NO. 2503)

CE-QUAL-W2 Model Results from WQ4 Operations Under Climate Change Scenarios

Prepared for

Duke Energy Carolinas, LLC

Prepared by

Reservoir Environmental Management, Inc.

Andy F. Sawyer, Richard J. Ruane, and Jon C. Knight,

May 2014

Reservoir Environmental Management, Inc.

TABLE OF CONTENTS

Section	Title	Page No.

LIST OF FIGURES

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure	**Title**	**Page No.**

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF TABLES

Table	Title	Page No.

Executive Summary

The Keowee-Toxaway Project (Project) relicensing Water Quality Resource Committee (WQRC) evaluated the impact of potential future climate change on temperature and dissolved oxygen (DO) in the Keowee Hydro Station tailrace. The evaluation included both a low- and high-impact climate change assessment and was consistent with a similar operational assessment made by the Operations Model Study Team.

The calibrated Lake Keowee CE-QUAL-W2 (W2) water quality model initially applied to evaluate water quality under Project operational and nutrient management scenarios was utilized to assess potential effects of climate change on water quality of Keowee Hydro Station releases. This report summarizes the impact on climate change on the water quality of the water released from Keowee Hydro Station using the updated WQ4 operational protocol.

Both 1998 and 2008 were characterized by air temperatures exceeding a 42-year (1968 to 2009) annual average air temperature. Consistent with water quantity modeling efforts, low-impact and high-impact climate changes were simulated by adding 3 °F and 6 °F, respectively, to air temperatures in the W2 model meteorological input data. Additionally, a local inflow reduction was applied to the CHEOPS high-impact climate change simulation. Also, as it became evident that actual 2012 Jocassee Pumped Storage Station generation release temperatures were the warmest on record, Jocassee release thermal data from 2012 (with some comparatively warmer 2008 temperatures substituted) were utilized as model inputs in all the 2008 WQ4 scenarios to provide an even more rigorous test of climate change conditions on water quality. Model settings and input variables were otherwise representative of the baseline conditions described in the Keowee Reservoir Water Quality Modeling Study Report (Sawyer et al., 2013).

Modeling climate change scenarios resulted in Keowee Hydro Station generation release temperatures no more than 3.0 °F (monthly means) greater than those under the baseline conditions (i.e., scenarios without air temperature adjustments), and differences were usually less.

Modeled dissolved oxygen (DO) concentrations were marginally impacted by the climate change scenarios. As water temperatures increased in both climate change scenarios, oxygen solubility decreased and microbial activity increased resulting in a predicted decrease of 0.1 to 0.2 milligrams per liter (mg/L) in DO. This decrease in DO was predicted to occur throughout the depths of Lake Keowee, including the water released from Keowee Hydro Station. Regardless, DO concentrations at the Keowee Hydro Station tailrace consistently remained well above the state water quality standard of a daily average 5.0 mg/L. Furthermore, at no time were the predicted DO concentrations in the Keowee Hydro Station tailrace less than 6 mg/L.

In conclusion, the modeled low- and high-impact climate change meteorology (increased air temperatures with modified inflows) had minimal effect compared to baseline conditions on predicted water temperatures and DO concentrations in Lake Keowee or the water released during Keowee Hydro Station generation. While the modeled years 1998 and 2008 both represented warmer than average air temperatures, the year 2011, from which actual lake and tailrace water quality data were used to calibrate the W2 model, would have ranked as the second warmest among the 42-year (1968-2009) historical record. In comparison, 2011 summer temperatures exceeded the low-impact (+3 °F) 1998 and 2008 modeled climate change scenarios, and were only exceeded by the high-impact (+6 °F) scenarios. It is noteworthy that the actual 2011 air temperatures, combined with the record high temperatures utilized for Jocassee releases to Lake Keowee, clearly represented a meteorological extreme and, similar to the modeled 1998 and 2008 climate change scenarios, produced minimal effect compared to baseline conditions on predicted or observed water temperatures and DO concentrations.

In a separate pair of W2 model scenarios utilizing 2008 hydrology and (2011) calibration settings, Project operations under the WQ4 scenario had little, if any, impact on the previously modeled (WQ3) water temperatures and DO concentrations, either in the Lake Keowee forebay, or the water released during Keowee Hydro Station generation.

Initial climate change scenario W2 water quality modeling efforts were conducted using the WQ3 operational conditions and were documented in a report addendum to the original *Keowee Reservoir Water Quality Modeling Study* (Sawyer et al., 2013), entitled *W2 Results from Climate*

Change Scenarios Using 1998 and 2008 Duke Energy Trail Balloon (WQ3) Conditions (Sawyer et al., 2014a). After the final proposed WQ4 operational scenario was developed, an additional modeling addendum report was prepared. That report, entitled *W2 Model Results Comparing Water Quality Predicted Under Duke Energy Trial Balloon (WQ3) and Revised (WQ4) Operational Conditions* (Sawyer et al., 2014b) applied year 2011 W2 model calibration settings for the low-inflow year 2008, and documented that even under adverse conditions from a standpoint of hydrology, WQ3 and WQ4 operations resulted in negligible comparative differences in modeled Keowee Hydro generation release water quality. A new series of W2 modeling scenarios described in the present report repeats both the climate change and WQ3/WQ4 scenario addendum study objectives, but incorporates updated WQ4 water quantity inputs, derived from modified CHEOPS output data made available in March 2014. The W2 water quality model results documented in the present report thereby correct W2 model output for known CHEOPS water quantity input errors inherent in earlier model runs. This report, therefore, supersedes the two earlier water quality addendum reports.

Section 1
Introduction

The Existing License for the Keowee-Toxaway Project (Project) was issued in 1966 and will expire on August 31, 2016. Duke Energy Carolinas, LLC (Duke Energy) is using the Federal Energy Regulatory Commission's (FERC's) Integrated Licensing Process (ILP) to relicense the Project. As part of this process, Duke Energy formed a Water Quality Resource Committee (WQRC) comprised of representatives of federal and state resource agencies, along with local and regional stakeholders. This WQRC is responsible for identifying studies within its resource area, providing technical input, drafting study plans, identifying participants for the Study Teams, and synthesizing the findings of the Study Teams for review and consideration by the Stakeholder Team.

The Keowee Reservoir Water Quality Modeling Study applied the CE-QUAL-W2 (W2) model to investigate water quality in the Keowee Hydro Station tailrace under Project operational scenarios. The study was completed in late 2012, and the final report was completed in March 2013 (Sawyer et al., 2013). However, after the completion of the study, the Operations Model Study Team (OMST) and Operations Scenarios Committee (OSC) developed low- and high-impact climate change scenarios to evaluate the effects of Project operations on reservoir levels, downstream flow releases, future water withdrawals, and hydropower generation using CHEOPS, a hydroelectric operational model. The WQRC subsequently requested similar climate change scenarios be evaluated using the calibrated W2 model to predict the effect of comparable climate change assumptions on water temperature and DO concentrations in the Keowee Hydro Station tailrace.

Climate change scenarios were modeled using the WQ3 operational scenario and were presented in Sawyer et al., 2014a. However, through the efforts of the relicensing Stakeholder Team, a new operational scenario, WQ4, was ultimately developed as the final proposed Project operational scenario, resulting in a new revised CHEOPS output. Further refinement of the WQ4 output was made in 2014 (HDR Engineering, Inc., 2014a), including adjustments to modeled future Project withdrawals. This addendum report presents the results of the application of the W2 model to revised and updated CHEOPS-modeled climate change scenarios. Additionally, a controlled case comparison where the previous WQ3 and revised WQ4 operational conditions were modeled for the exceptionally low inflow year 2008 are presented. Together, the results presented in this addendum report supersede the two formerly issued Keowee modeling addendum reports, Sawyer et al., 2014a, and 2014b.

Section 2
Objective and Methods

2.1 Objective

The objective of this portion of the Keowee Reservoir Water Quality Modeling Study was to apply the calibrated W2 water quality model to the revised WQ4, low- and high-impact climate change scenarios to evaluate the impact on water quality (temperature and DO) of the Keowee Hydro Station generation releases.

2.2 Methods

The approach taken in assessing low and high climate change impacts in the CHEOPS model was to add 3 °F and 6 °F, respectively, to the monthly average air temperatures of historical meteorological data. Subsequent increased evaporation estimates based upon these increased air temperatures were then applied to the CHEOPS model, along with an inflow reduction to the high-impact climate impact scenario. The results of the CHEOPS modeling were used to evaluate water availability and allocation. Since the W2 water quality model calculates heat exchange and evaporation from inputted meteorological data, i.e., air temperature, dew point, barometric pressure, cloud cover, wind speed and direction, etc., the WQRC recommended that only the air temperature should be adjusted to for the climate change analyses.

The years 1998 and 2008 were chosen by the WQRC to evaluate the impact of climate change on Lake Keowee water quality by comparing results from prior defined scenarios which evaluated lake water quality (see Appendix D, Table 4, Sawyer et al., 2013). Those modeled scenarios provided a “baseline” for comparing the low- and high-impact climate change effects for the same years. Sawyer et al. (2013) selected 2008 to represent an extreme year with below-average precipitation and warmer-than-average summer water temperatures. Year 1998 was selected to represent a year with increased winter and spring inflows related to above-average precipitation, and the potential impact of increased watershed nutrient loading on DO concentrations in the reservoir and tailrace. For these years, hourly station operations for the Jocassee Pumped

Storage Station and Keowee Hydro Station and hourly Keowee lake levels were obtained from the WQ4 CHEOPS model and integrated into the W2 water quality model. W2 modeling for all tested scenarios utilized one of the 3 distinct sets of CHEOPS input:

(avg) corresponding to baseline WQ4 operations;

(cc low) corresponding to the CHEOPS WQ4 low-impact climate change scenario, and

(cc high) corresponding to the CHEOPS WQ4 high-impact climate change scenario.

A summary of the W2 modeling scenarios using revised WQ4 CHEOPS inputs is shown below.

1. **WQ4 Baseline scenarios for 1998 and 2008:**
    a. 1998 WQ4 (avg) using 1998 air temperature
    b. 2008 WQ4 (avg) using 2008 air temperature
2. **WQ4 Low Climate Change for 1998 and 2008:**
    a. 1998 WQ4 (cc low) using 1998 air temperature + 3 ^{o}F
    b. 2008 WQ4 (cc low) using 2008 air temperature + 3 ^{o}F
3. **WQ4 High Climate Change for 1998 and 2008:**
    a. 1998 WQ4 (cc high) using 1998 air temperature + 6 ^{o}F and a reduction in local inflow
    b. 2008 WQ4 (cc high) using 2008 air temperature + 6 ^{o}F and a reduction in local inflow
4. **WQ4 Applying Observed (2011) air temperatures for 1998 and 2008:**
    a. 1998 WQ4 (avg) using 2011 air temperature
    b. 2008 WQ4 (avg) using 2011 air temperature

Important W2 modeling assumptions used for the W2 Climate Change modeling include:

Keowee Hydro Releases and Lake Levels: Hourly Keowee releases for all scenarios came directly from the "DischFlow" column of the Keowee output spreadsheet from the correspondingly named CHEOPS run. Keowee lake level came from the "EnEl" (i.e., end-of-hour elevation) column of the respective CHEOPS output spreadsheets.

Jocassee Hydro Releases: Hourly Jocassee releases for all scenarios came directly from the "DischFlow" column of the Jocassee output spreadsheet from the correspondingly named CHEOPS run.

Jocassee Pumpage: Hourly pumpage for all scenarios came directly from the "PumpFlow" column of the Jocassee output spreadsheet from the correspondingly named CHEOPS run.

Local Inflow: The data in the "accr" (i.e., accretion flow) column in the CHEOPS output was not used for the W2 modeling since the CHEOPS outputs include periodic negative values (an artifact indicative of flow from lake to streams) and frequent instances of fluctuating, unnatural daily variability. This approach was consistent with all previous W2 modeling since the CHEOPS derived "accr" values were never used in W2 scenarios (see Sawyer and Ruane, 2012).

For W2, local inflow was calculated by prorating the flows measured from adjacent watersheds gaged by the USGS in the same years as the scenario (i.e., 1998 or 2008). Flow was prorated based on the drainage area of the gaged watersheds to each of the individual watersheds of the inflows used in the W2 model. These local inflows were adjusted, when necessary, to closely match the Keowee lake level data in the "EnEl" column from the corresponding Keowee CHEOPS output spreadsheet.

Oconee Nuclear Station (ONS) Operations: As in previous W2 scenarios**,** 2011 ONS operations were used for all Baseline and Climate Change scenarios.

Evaporation: The W2 water quality model is capable of modeling evaporation from the lake surface. Since heat exchange (water temperature derivation) is important in the Keowee water quality model, the evaporation calculated from W2 was employed for all the Keowee scenarios modeled in 2012 and 2013 (i.e., 2011 Calibration, 2008 Actual Hydrology, and the 2007 Validation). Remaining consistent, W2-calculated evaporation was employed for all W2 scenarios rather than utilizing the monthly values of estimated evaporation used by CHEOPS.

Meteorology: Other than air temperature, all meteorological inputs into the W2 model (i.e., wind speed, wind direction, cloud cover, and dew-point temperature) for the Baseline and Climate Change scenarios were used as previously for the 2011 W2 calibration.

Temperature and Water Quality of Local Inflows to the Model: For all Baseline and Climate Change scenarios, the temperature and water quality constituent concentrations in all local inflows to the model were the same as used in the 2011 Calibration.

Jocassee Release Temperature: For all the 2008 WQ4 scenarios, the water temperature dataset representing the releases from Jocassee Hydro into Lake Keowee was a combination of 2008 and 2012 temperatures observed in the Jocassee tailrace. These two years exhibited the warmest Jocassee release temperatures on record. See Sawyer and Ruane (2012) for a thorough explanation of how this dataset was developed. For all the 1998 WQ4 scenarios, the Jocassee observed 2011 generation water temperatures were used as the W2 model input representing the temperature of the releases from Jocassee.

A summary of these input variables employed in W2 for the climate change assessment is presented in Table 1.

Table 1. Summary of CE-QUAL-W2 Input Data Used in the WQ4 Baseline and Climate Change Scenarios.

Model Scenario Name (CHEOPS scenario abbreviation)	**Meteor-ology** [1]	**Air Temp Year**	**Keowee Lake Level** (EnEl ft)	**Source of Flows Used in Model**					**Source of Water Temps for Model Inputs**		
				Jocassee Releases (Disch Flow)	Jocassee Pumpback (Pump Flow)	Keowee Releases	ONS CCW	Local Inflow to the Reservoir (accretion flow between Jocassee Dam and Keowee Dam)	Jocassee Releases	ONS Dis-charge [2]	Local Inflow to the Reservoir
2008 WQ4 (avg) with 2008 Air Temperature - Baseline	2011	2008	CHEOPS (2008 avg Keowee)	CHEOPS (2008 avg Jocassee)	CHEOPS (2008 avg Jocassee)	CHEOPS (2008 avg Keowee)	2011	Back-calculated USGS flows to match the observed surface elevation for each WQ4 CHEOPS scenario.	2012 [3]	2011	2011 Observed in Eastatoe Creek, Little River and Cane Creek [4]
2008 WQ4 (cc low) with 2008 Air Temperature + 3 °F Low Climate Change		2008 + 3 °F	CHEOPS (2008 cc low Keowee)	CHEOPS (2008 cc low Jocassee)	CHEOPS (2008 cc low Jocassee)	CHEOPS (2008 cc low Keowee)					
2008 WQ4 (cc high) with 2008 Air Temperature + 6 °F High Climate Change		2008 + 6 °F	CHEOPS (2008 cc high Keowee)	CHEOPS (2008 cc high Jocassee)	CHEOPS (2008 cc high Jocassee)	CHEOPS (2008 cc high Keowee)					
2008 WQ4 (avg) with 2011 Air Temperature - Observed		2011	CHEOPS (2008 avg Keowee)	CHEOPS (2008 avg Jocassee)	CHEOPS (2008 avg Jocassee)	CHEOPS (2008 avg Keowee)					
1998 WQ4 (avg) with 1998 Air Temperature-Baseline	2011	1998	CHEOPS (1998 avg Keowee)	CHEOPS (1998 avg Jocassee)	CHEOPS (1998 avg Jocassee)	CHEOPS (1998 avg Keowee)	2011	Back-calculated USGS flows to match the observed surface elevation for each WQ4 CHEOPS scenario.	2011	2011	2011 Observed in Eastatoe Creek, Little River and Cane Creek [4]
1998 WQ4 (cc low) with 1998 Air Temperature + 3 °F Low Climate Change		1998 + 3 °F	CHEOPS (1998 cc low Keowee)	CHEOPS (1998 cc low Jocassee)	CHEOPS (1998 cc low Jocassee)	CHEOPS (1998 cc low Keowee)					
1998 WQ4 (cc high) with 1998 Air Temperature +6 °F High Climate Change		1998 + 6 °F	CHEOPS (1998 cc high Keowee)	CHEOPS (1998 cc high Jocassee)	CHEOPS (1998 cc high Jocassee)	CHEOPS (1998 cc high Keowee)					
1998 WQ4 (avg) with 2011 Air Temperature - Observed		2011	CHEOPS (1998 avg Keowee)	CHEOPS (1998 avg Jocassee)	CHEOPS (1998 avg Jocassee)	CHEOPS (1998 avg Keowee)					

Notes:
1 Meteorological inputs include dew point temp, wind speed, wind direction, and cloud cover.
2 Delta T between the observed intake temperature and the discharge temperature.
3 Based on primarily on the warmer 2012 Jocassee tailrace data, supplemented with warm 2008 release temperatures.
4 2011 observed temperatures in the creeks were the best data available to use for inflow temperatures. Sensitivity runs showed that varying local inflow temperature within the limits within a range that could be expected had very little to no effect on temperatures in Lake Keowee.

.

Water Withdrawals and Returns: The initial calibration of the W2 water quality model only included the actual withdrawals obtained from the Greenville (daily data) and Seneca (monthly data) water treatment plants. However, the subsequent W2 Baseline and Climate Change scenarios runs with the updated CHEOPS WQ4 operational protocol used water withdrawals and water returns projected to occur in 2066 (HDR Engineering, Inc. 2014b; Table 2). These projections were included in the W2 water quality scenarios by inputting the CHEOPS hydrology. Withdrawal and return flows were held constant for each month in both the CHEOPS and W2 simulations, although the W2 model included only the net flows for the Greenville and Seneca water supplies. The W2 water quality scenarios for the climate change assessment also incorporated the Keowee Key wastewater flows as a return flow. Pertinent water quality information on the Keowee Key wastewater discharge needed for model input was obtained from South Carolina Department of Health and Environmental Control (SCDHEC) NPDES Permit # SC0022322.

Table 2. Monthly Return and Withdrawal Flows Used in the W2 Climate Change Models

Facility	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	W2 Modeling Assumptions
Year 2066 Water RETURNS - Projected flow rate in cubic feet per second (cfs)													
City of Seneca - Seneca City WTP	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	These monthly values were subtracted from the gross withdrawal yielding a net withdrawal from the existing Seneca facility
Greenville Water - Witty Adkins WTP	7.9	6.4	5.0	6.5	6.3	7.8	7.0	7.3	7.6	6.4	5.7	7.1	These monthly values were subtracted from the gross withdrawal yielding a net withdrawal from the existing Greenville facility
Keowee Key Utility Systems, Inc.	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	This return was added as a tributary inflow in the model segment closest to the location provided by SCDHEC. Water quality concentrations in the return were used as the simulated sewage inflow in the modeled nutrient scenarios.
Year 2066 Water WITHDRAWALS - Projected flow rate in cubic feet per second (cfs)													
Facility	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**W2 Modeling Assumptions**
City of Seneca - Seneca City WTP	20.9	20.3	19.7	21.7	24.1	26.4	27.6	27.0	25.4	23.1	21.5	20.6	The same monthly values (minus the return flow) were used for all WQ4 scenarios to yield the net withdrawal from the existing Seneca facility.
Greenville Water - Witty Adkins WTP	147.7	143.4	144.4	157.6	174.7	194.3	182.0	178.2	180.5	171.5	155.6	150.2	The same monthly values (minus the return flow) were used for all WQ4 scenarios to yield the net withdrawal from the existing Greenville facility.
New Future Industry (placeholder)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	This withdrawal was added to the W2 model in an adjacent segment to the Seneca WTP withdrawal at the same elevation as the Seneca facility. Monthly values were used for all WQ4 scenarios.
Agriculture-Irrigation Demand	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	This withdrawal was added to the W2 model in an adjacent segment to the Greenville WTP withdrawal at the same elevation as the Greenville facility. Monthly values were used for all WQ4 scenarios.

Data from 2014 Keowee-Toxaway Water Supply Study (HDR Engineering, Inc. 2014b)

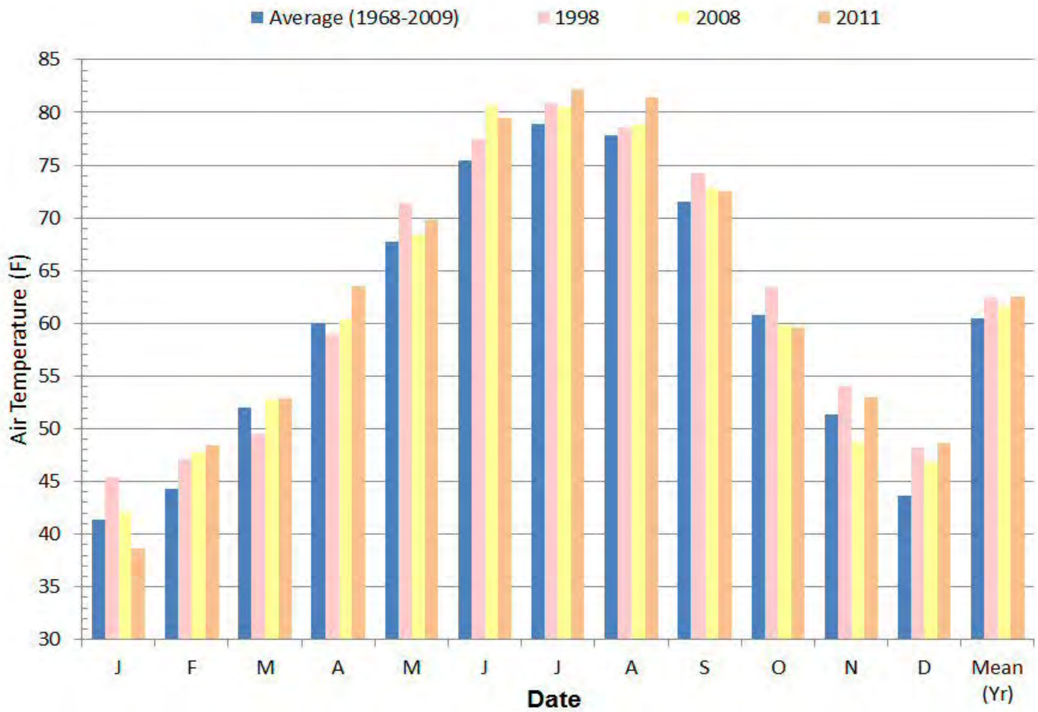
Section 3

Results and Discussion

3.1 Historical Air Temperatures

Monthly mean air temperatures recorded at Greenville-Spartanburg Airport (NOAA 2013) revealed the years chosen for the W2 scenarios, 2008 and 1998, were on the average 1.2 and 2.0 °F warmer, respectively, than annual mean temperature recorded between 1968-2009 (Figure 1). Year 2011 was 2.1 °F warmer than the mean for that 42-year period. Summertime (June-August) air temperatures for 1998, 2008, and 2011 were 1.9, 2.2, and 3.0 °F warmer than the respective long-term means. Therefore, the 2 years chosen to evaluate potential climate change, especially with 3 °F and 6 °F added to the observed air temperatures, represent extreme temperature conditions. Lastly, since 2011 had the second-highest summertime temperature compared to the 42-year period, establishing a modified base case with 2011 meteorological data (apart from air temperature) also represented an approach consistent with producing extreme climate scenarios desired for this evaluation.

Figure 1. Greenville-Spartanburg Monthly and Annual Average Air Temperatures for the 1968 - 2009 Period, and Modeled Years 1998, 2008, and 2011



3.2 Water Column Temperature and DO Concentrations

Predicted vertical profiles of temperature and DO concentrations during the summer at the Keowee Hydro Station forebay (Location 504.5) exhibited similar seasonal changes for both 2008 and 1998 scenarios with increasing air temperatures (see Figures 2-17). Surface temperatures increased throughout the summer reaching maxima in September. Hypolimnetic (deep water column) temperatures increased slightly throughout the summer with the maximum bottom temperatures predicted in September. Compared to baseline conditions, modeled increased air temperatures yielded hypolimnetic temperature differences that typically varied by less than 1 °F throughout the summer. Metalimnetic (middle depth) temperatures under both the low- and high-impact climate scenarios were similar to the baseline temperatures in June and July (see Figures 2 and 4). The metalimnetic temperatures gradually increased in response to elevated air temperatures in the latter half of the summer; but by no more than 2 °F (see Figures 6 and 8). Temperatures in the near-surface isothermal (epilimnetic) layer and slightly deeper, to the elevation of the submerged weir located immediately upstream of Keowee Hydro Station, typically demonstrated a 1 to 2 °F increase for the climate change scenarios compared to baseline temperatures. By September, the lake had begun to cool as evidenced by slightly lower metalimnetic temperatures compared to August.

As anticipated, patterns in modeled DO concentrations were the reverse of the modeled temperature changes. Increases in water temperatures decrease the solubility of oxygen as well as increase the biological metabolic rates for oxygen-consuming decomposers. Differences in DO between the W2 air temperature scenarios were most consistently observed in the near-surface waters and the hypolimnion throughout the summer, reflecting the respective water column strata responding most to the modeled air temperature changes. However, differences in modeled DO concentrations were generally less than 0.2 mg/L. At no time did modeled DO concentrations approach the state water quality standard of 5.0 mg/L as a daily average, and concentrations were consistently modeled to exceed 6 mg/L in both the low- or high-impact climate change scenarios.

Figure 2. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, June 15, 2008

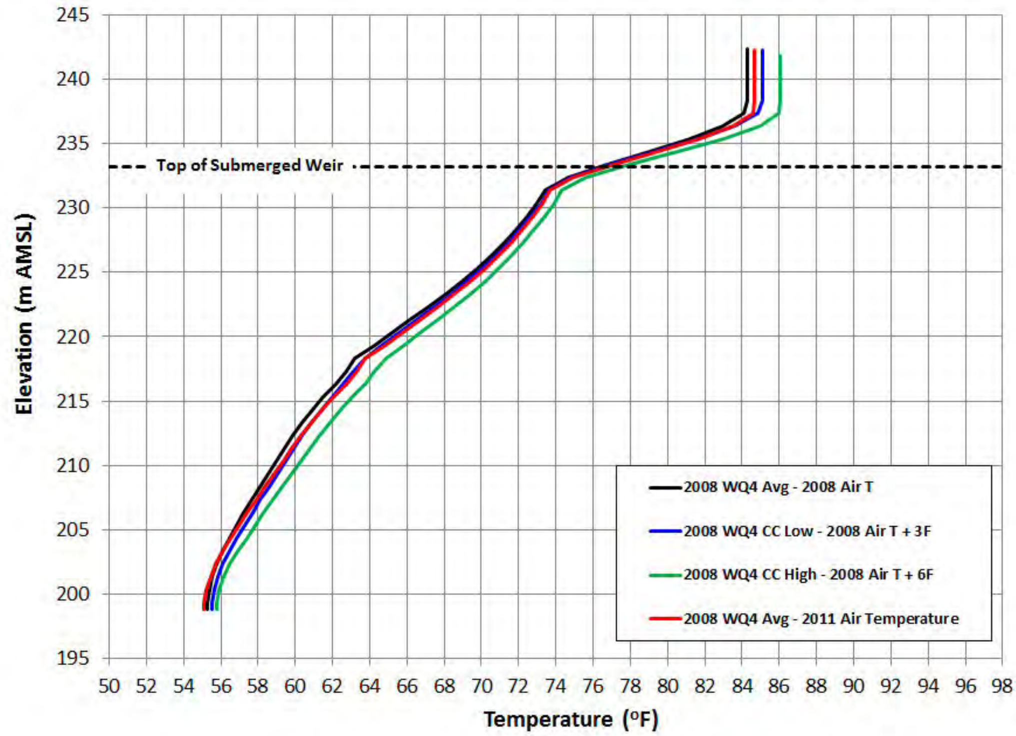


Figure 3. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, June 15, 2008

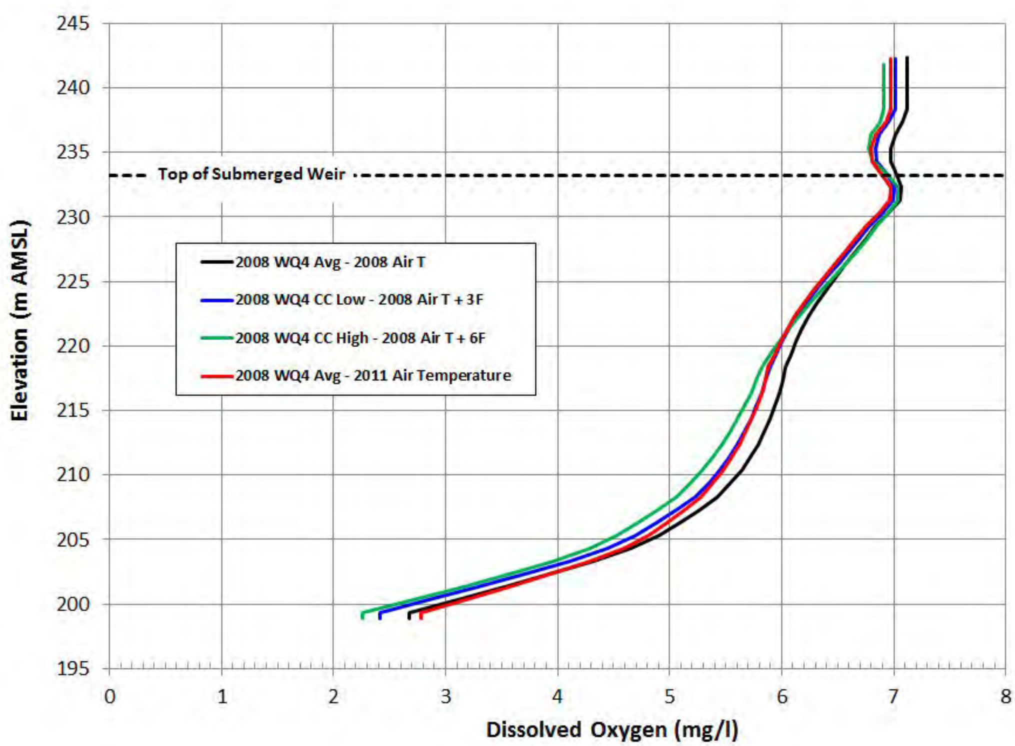


Figure 4. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, July 15, 2008

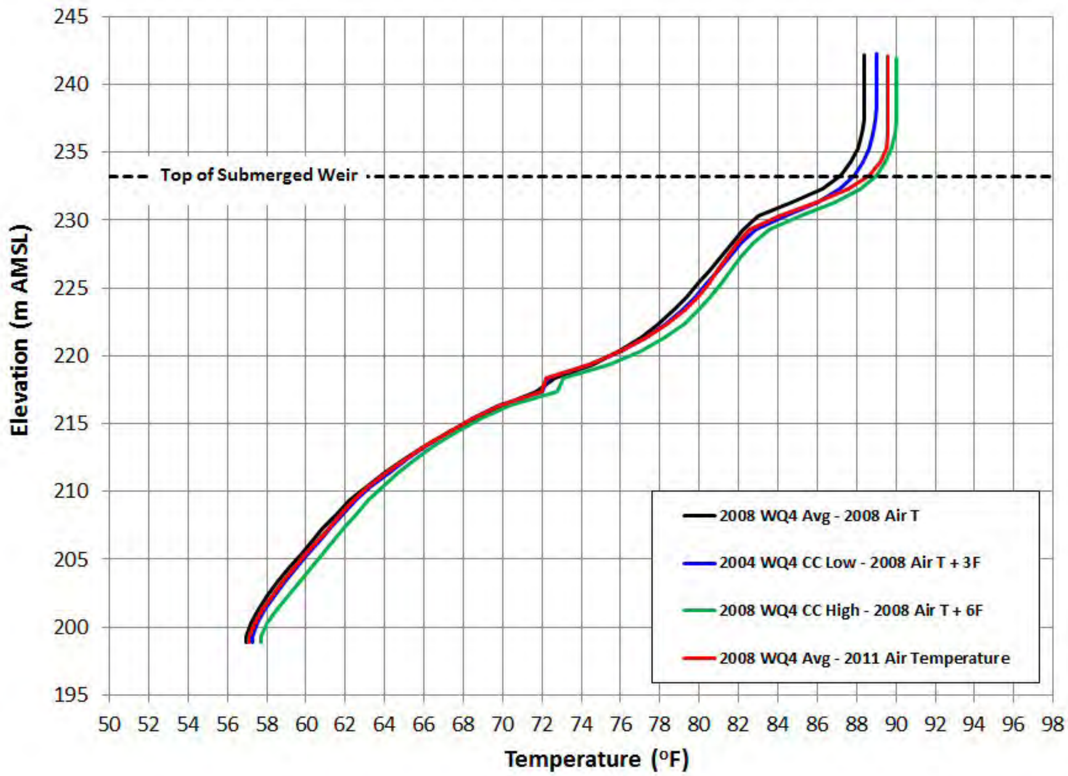


Figure 5. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, July 15, 2008

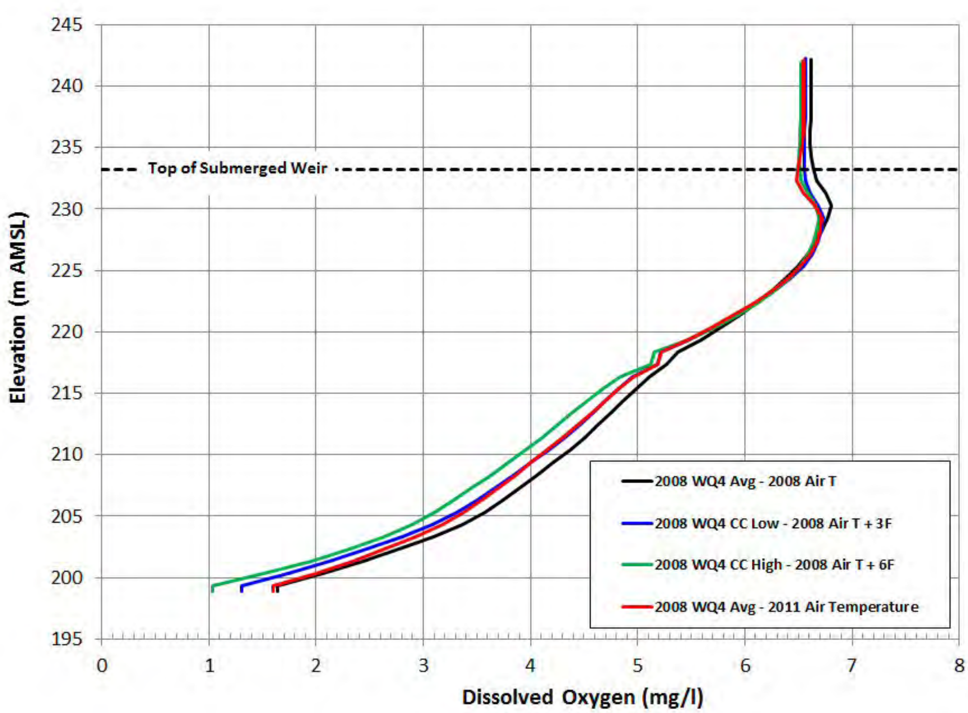


Figure 6. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, August 15, 2008

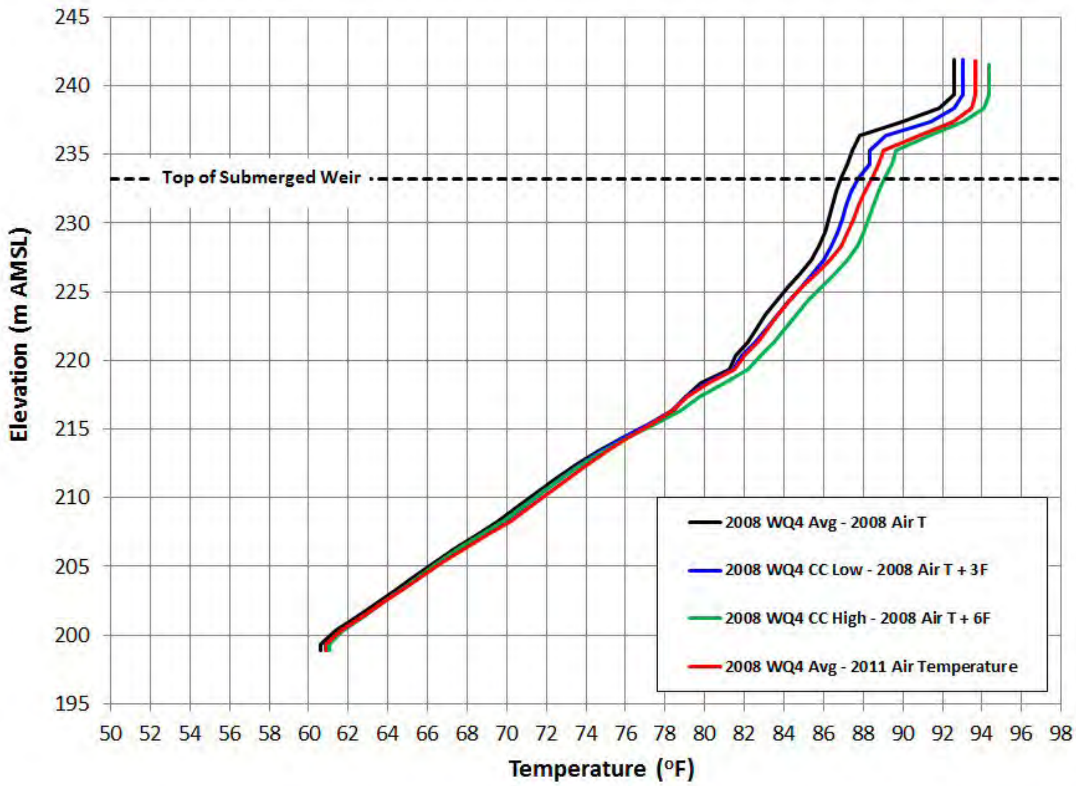


Figure 7. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, August 15, 2008

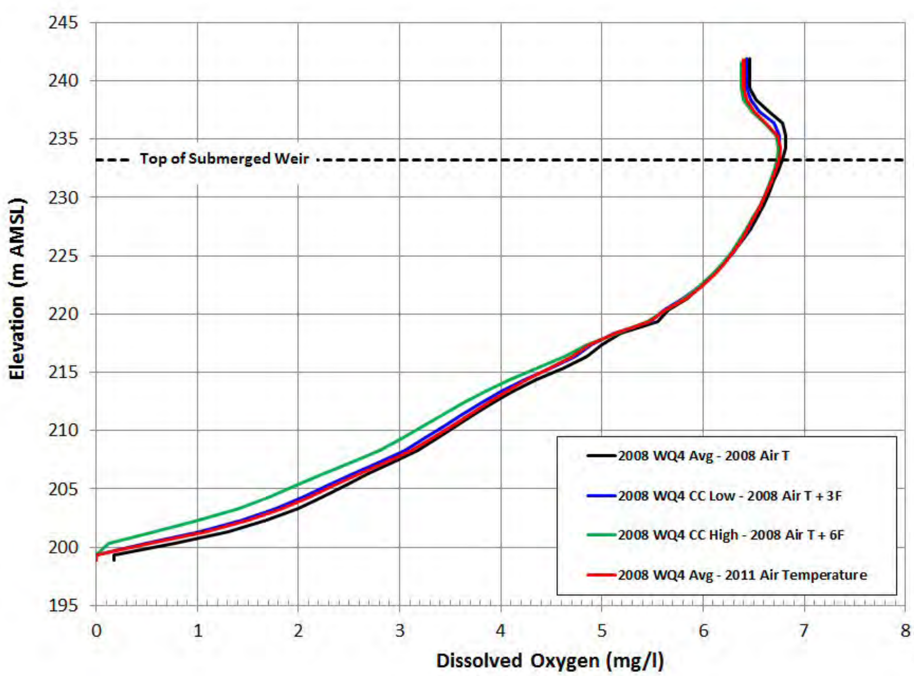


Figure 8. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, September 15, 2008

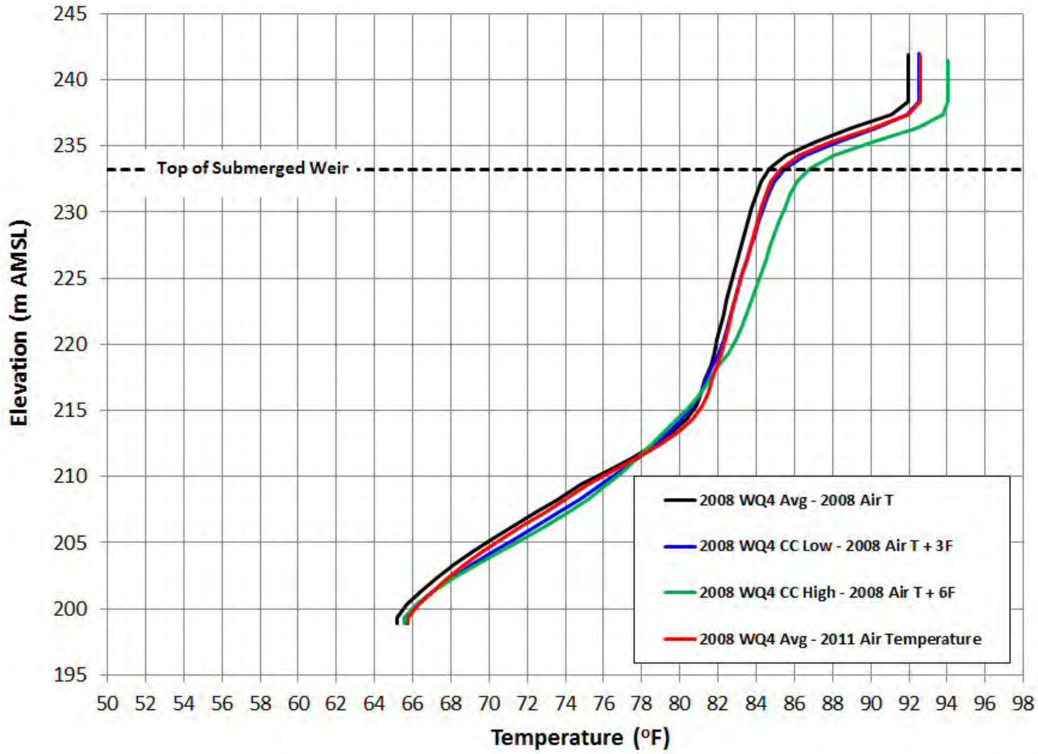


Figure 9. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, September 15, 2008

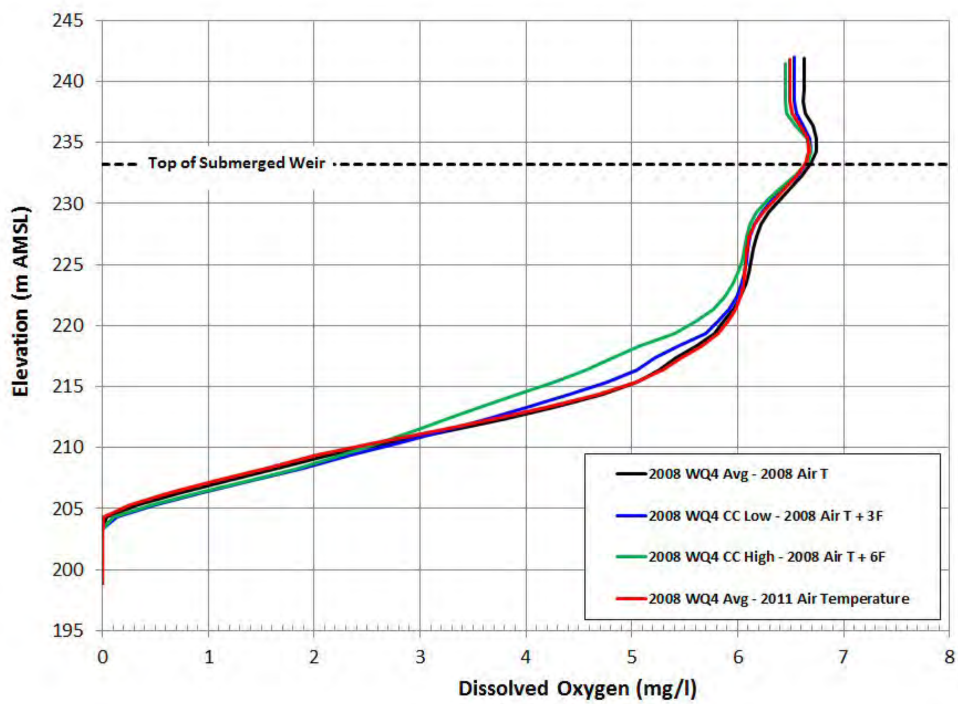


Figure 10. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, June 15, 1998

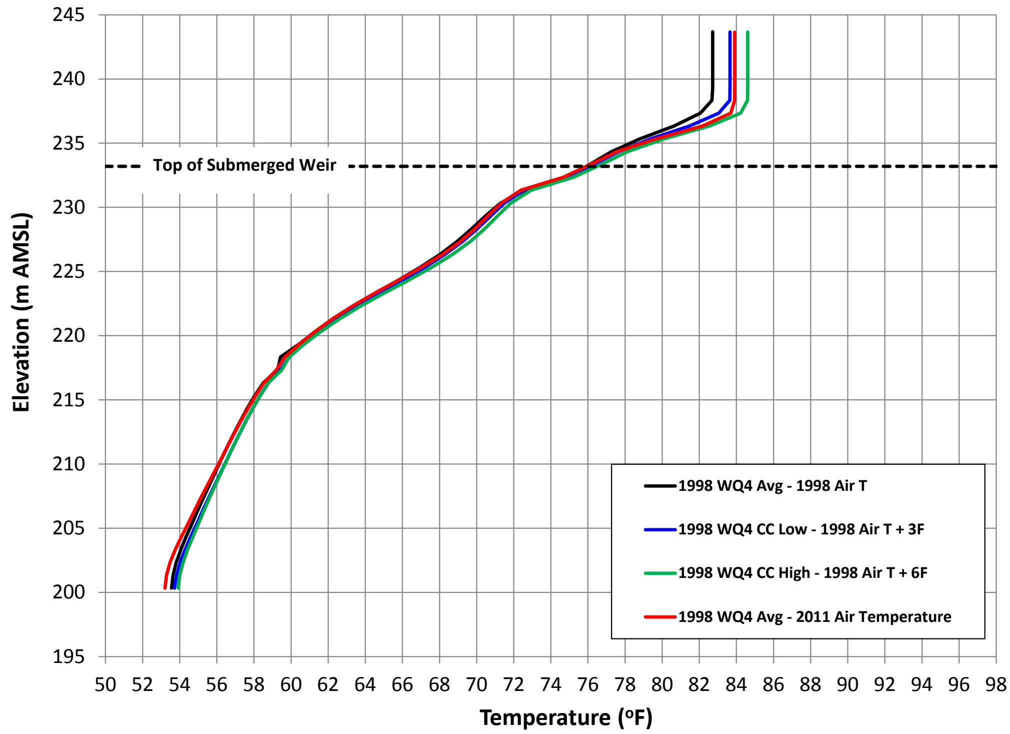


Figure 11. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, June 15, 1998

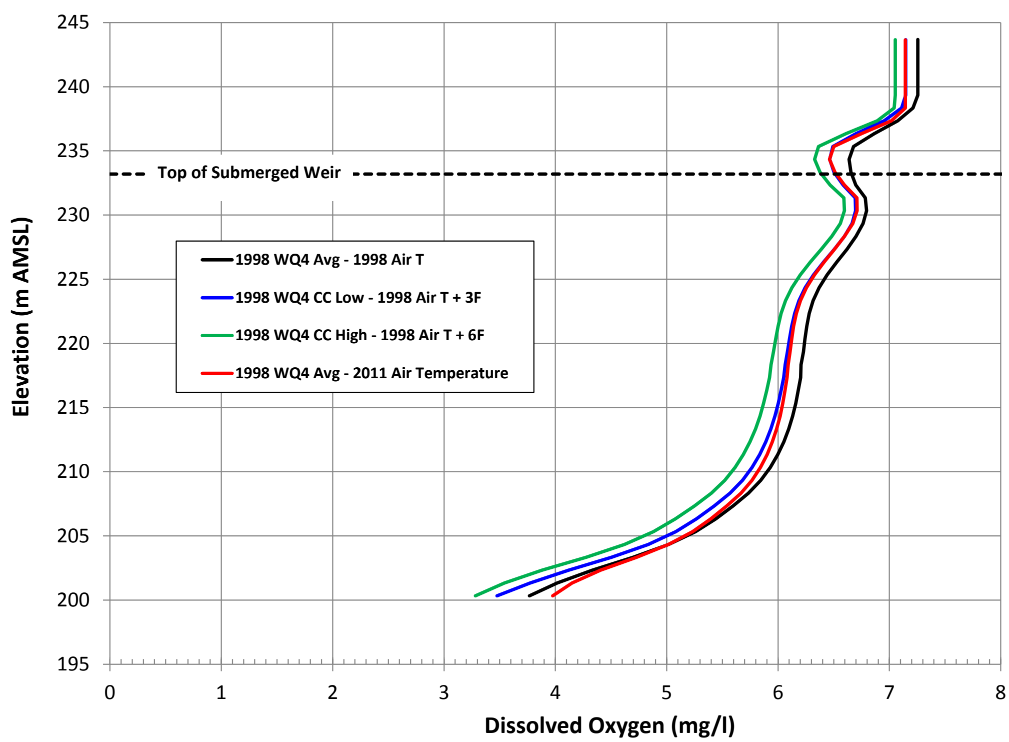


Figure 12. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, July 15, 1998

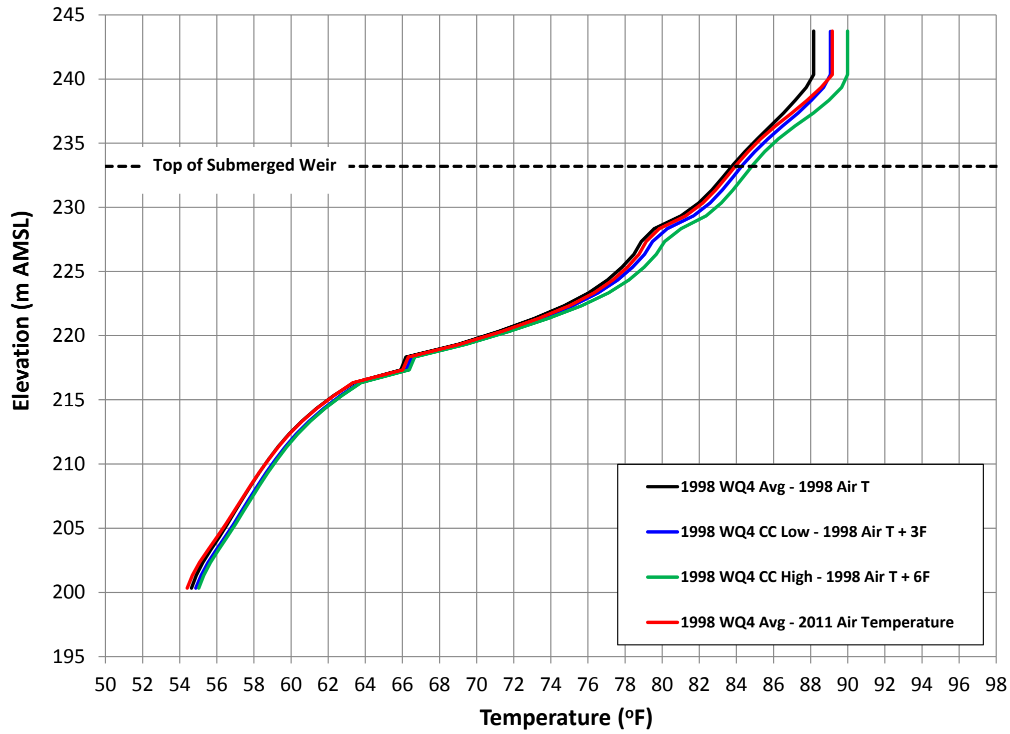


Figure 13. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, July 15, 1998

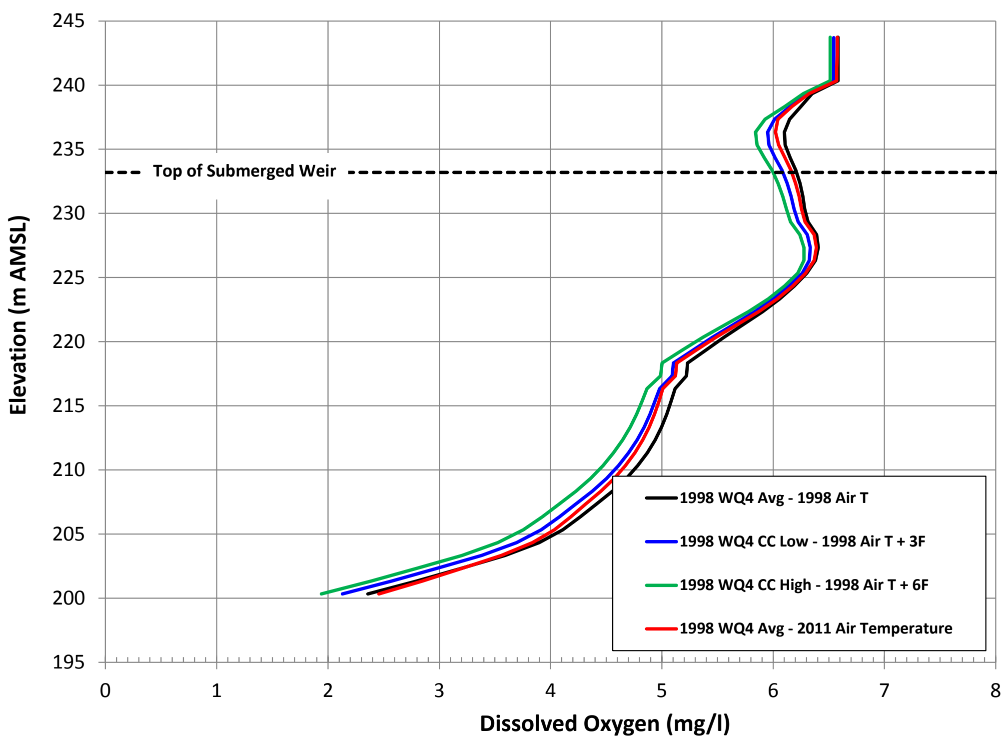


Figure 14. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, August 15, 1998

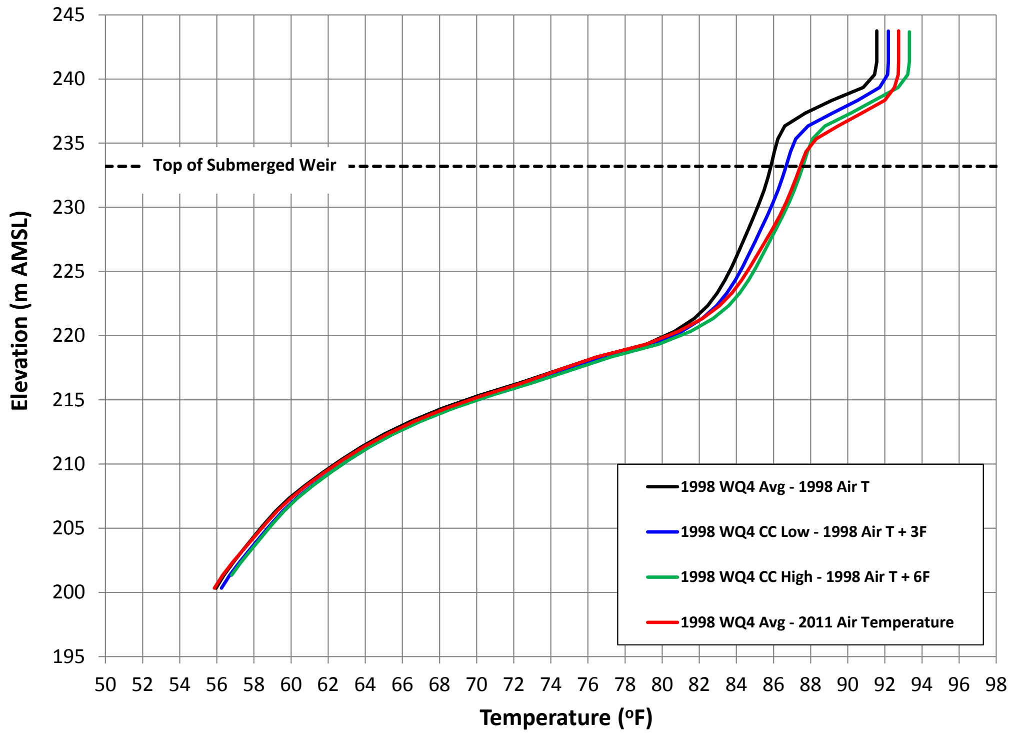


Figure 15. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, August 15, 1998

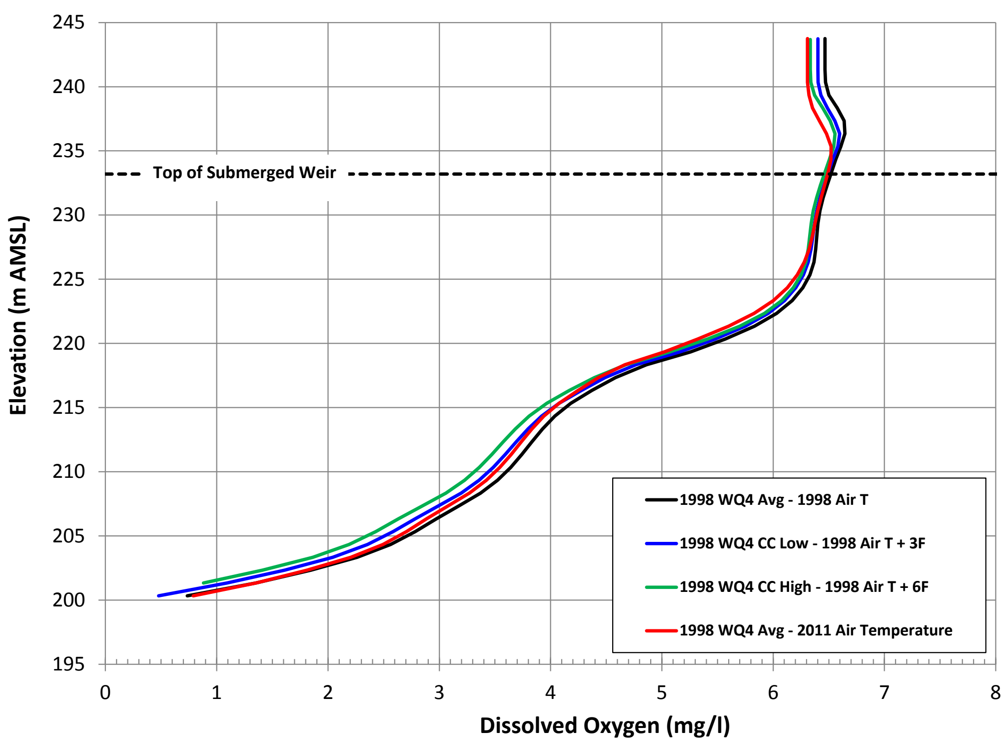


Figure 16. Keowee Hydro Station Forebay Temperature Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, September 15, 1998

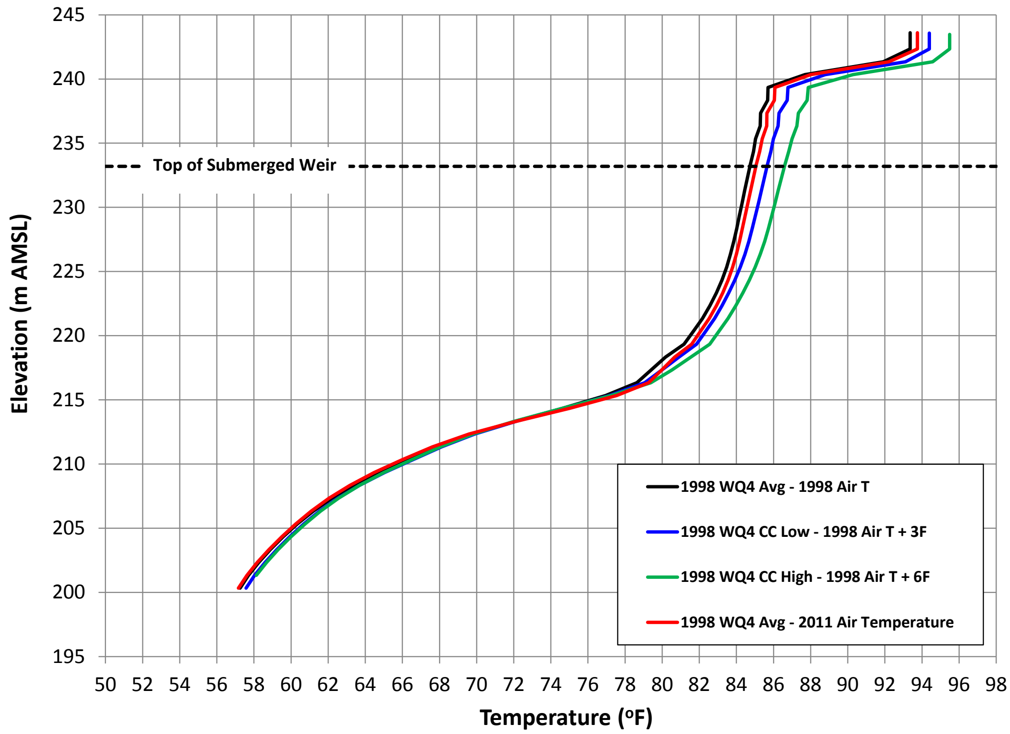
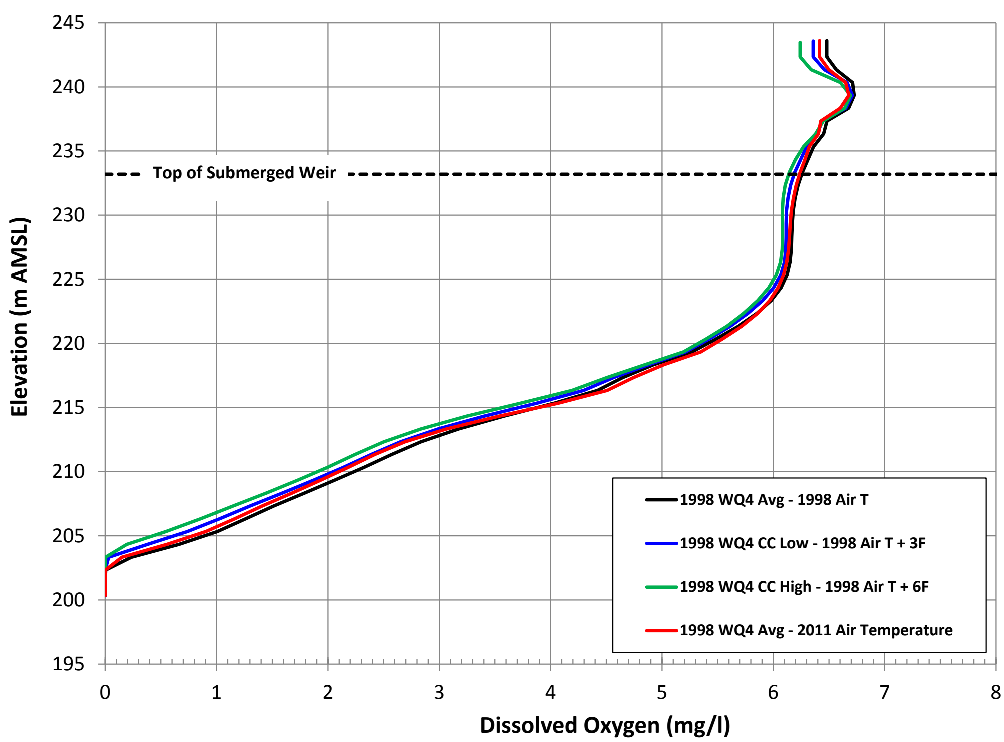


Figure 17. Keowee Hydro Station Forebay DO Profiles Modeled for WQ4 Baseline and Climate Change Scenarios, September 15, 1998



3.3 Keowee Hydro Station Release Temperatures and DO Concentrations

As discussed in the original report (Sawyer, et al., 2013), the water released from Keowee Hydro Station during generation was modeled as an integrated flow originating from the upper portion of the water column where water can pass above the submerged weir located immediately upstream of the hydro station intake. The W2 model calculated the withdrawal zone water quality based on the model's determination of the proportion of released water originating from each depth stratum (i.e., model layer) above the submerged weir. The net result was a modeled temperature and DO concentration based on a flow-weighted average of each parameter at each depth. These calculations were made for each time step in the model and provided time-dependent temperatures and DO concentrations for Keowee Hydro Station releases.[1]

The above calculations were made for Keowee Hydro Station generation releases for each climate scenario for each year, January through December. The 2008 and 1998 modeled temperatures and DO concentrations in the hydro releases revealed a similar pattern as described for the water column data, i.e., release temperatures increased marginally in concert with increased air temperatures, whereas DO concentrations decreased slightly (see Figures 18-21). Although somewhat variable day to day, a 3 °F air temperature rise resulted in a 1 to 2 °F rise in Keowee Hydro Station release water temperatures, whereas a 6 °F air temperature increase resulted in a 2 to 3 °F increase in release water temperatures, as compared to release water temperatures in the baseline (Figures 22 and 23).

DO concentrations similarly exhibited day-to-day variability and decreased slightly with increased temperatures. The modeled DO decrease averaged 0.1 to 0.2 mg/L for the low-impact climate change scenario (+3 °F air temperatures) and 0.2 to 0.3 mg/L for the high-impact climate change scenario (+6 °F air temperatures). At no time did the DO concentration drop below 6 mg/L in the Keowee Hydro Station tailrace.

[1] Tailrace temperature and DO concentrations during periods of non-generation were not modeled and therefore could not be calculated.

A more detailed examination of summer generation release temperatures modeled for the climate change scenarios (see Figures 22 and 23) revealed considerable variability. Despite the short-term variability in the modeled thermal data, the general trends remain apparent, with baseline temperatures lower than those predicted using a 3 °F air temperature increase which, in turn, were lower than temperatures predicted using a 6 °F increase.

As mentioned previously, because the year 2011 would have been ranked as the second-highest average summertime temperature when contrasted to the 1968 - 2009 period of record, inclusion of meteorology for that year (which happened to coincide with the W2 calibration year) also represents an approach to evaluate climate change scenarios even without artificially increasing air temperatures. For modeling and comparative purposes, actual measurements of lake and tailrace temperature and DO were available for the year 2011. Both the 1998 and 2008 scenarios using the 2011 air temperature input data modeled Keowee Hydro Station release temperatures were higher than the low-impact climate impact scenario but slightly less than the high-impact climate change scenario (see Figures 22 and 23). The actual temperature and DO data recorded in 2011 (Knight et al., 2013) were similar to the modeled values presented in Figures 22 and 23. Actual 2011 summertime maximum generation release temperatures approached 91 °F, whereas the modeled maximum temperatures using the 2008 WQ4 flows reached approximately 93 °F. The input of warmer 2012/2008 Jocassee Hydro generation release temperatures likely contributed to this small comparative increase in the model's thermal output. While actual 2011 DO concentrations in the water released from Keowee Hydro Station reached a summertime minimum slightly below 6 mg/L, the modeled minimum DO using the WQ4 flows remained above 6 mg/L (see Figures 19 and 21). In neither case did minimum DO concentrations approach the water quality standard of 5.0 mg/L as a daily average.

Figure 18. Modeled Temperature in Keowee Hydro Station Generation Releases[2] for 2008 under WQ4 Baseline and Climate Change Scenarios

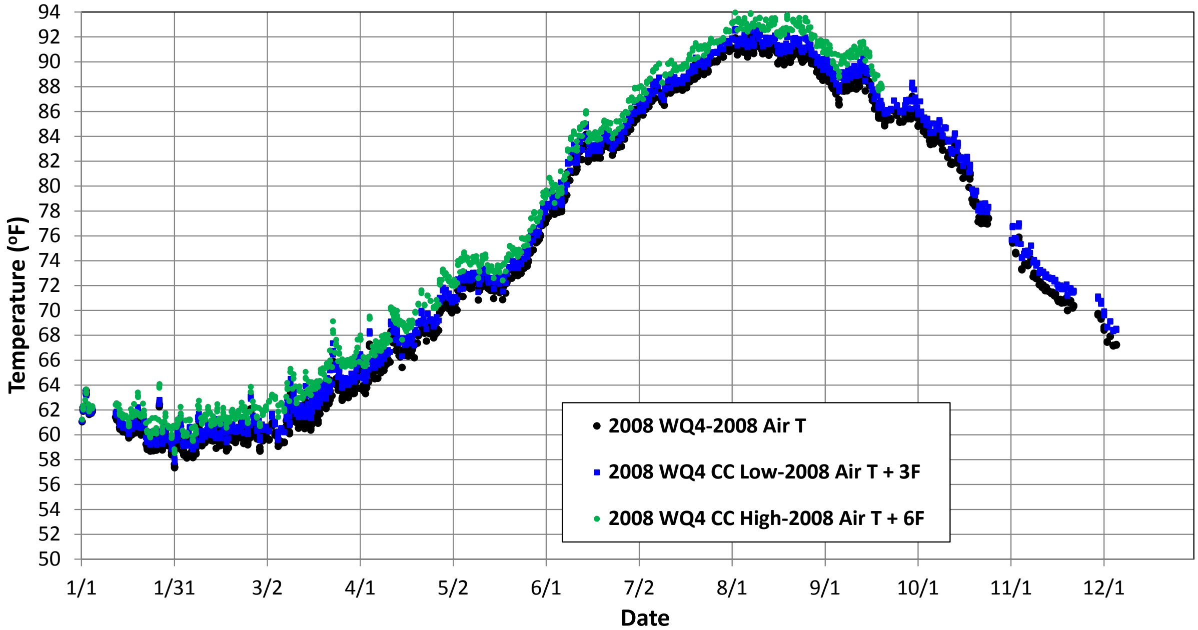
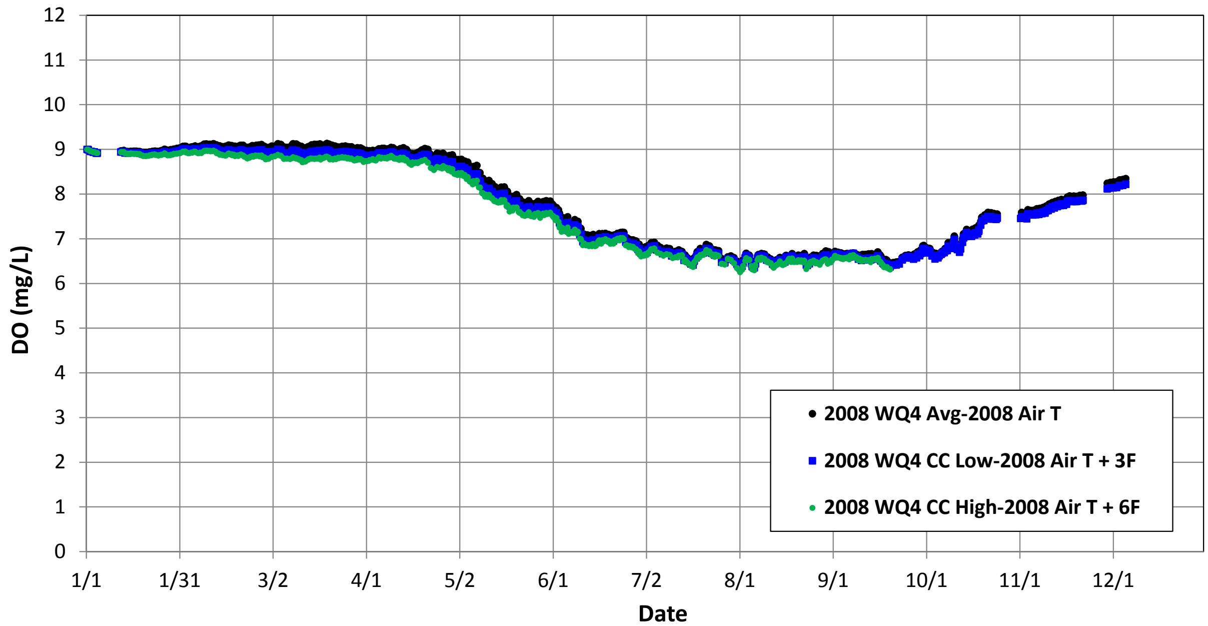


Figure 19. Modeled DO in Keowee Hydro Station Generation Releases for 2008 under WQ4 Baseline and Climate Change Scenarios



[2] Model output data gaps in Figures 18 through 23 correspond to periods without Keowee Hydro generation.

Figure 20. Modeled Temperature in Keowee Hydro Station Generation Releases for 1998 under WQ4 Baseline and Climate Change Scenarios

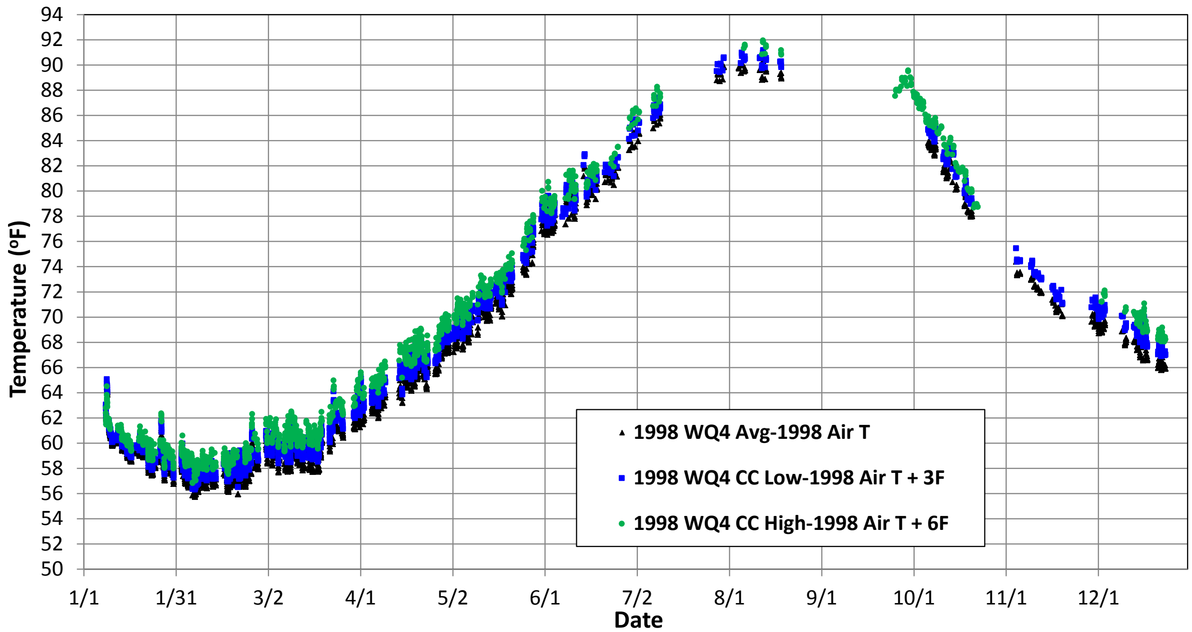


Figure 21. Modeled DO in Keowee Hydro Station Generation Releases for 1998 under WQ4 Baseline and Climate Change Scenarios

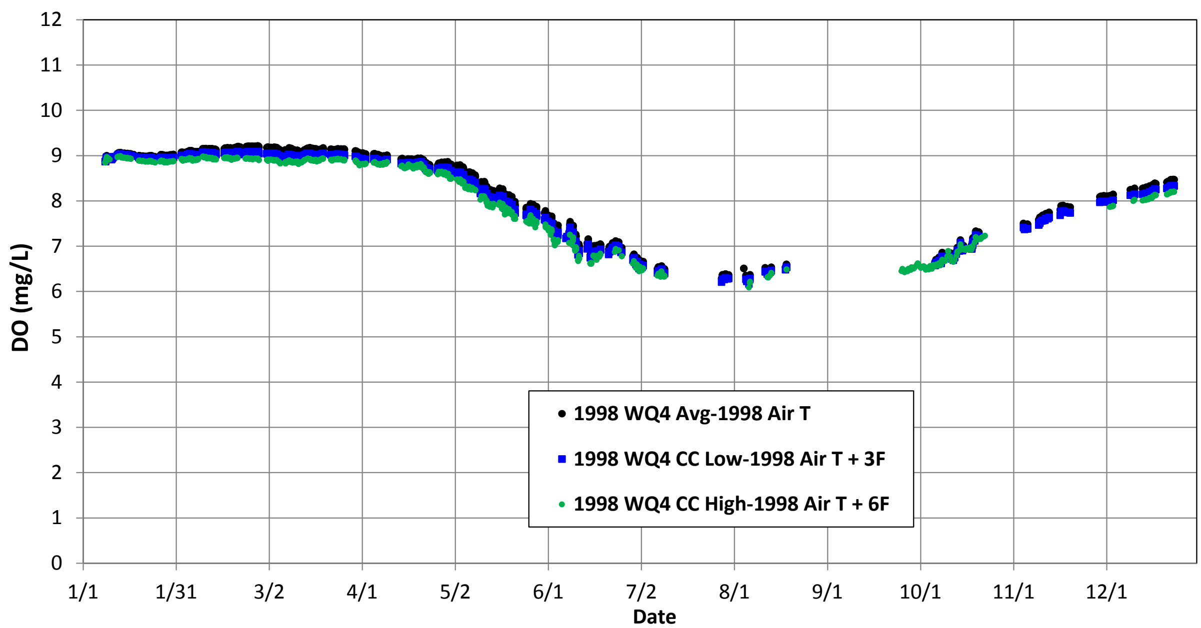


Figure 22. Modeled Keowee Hydro Station Generation Release Water Temperatures - July through September 2008 – WQ4 Baseline and Climate Change Scenarios

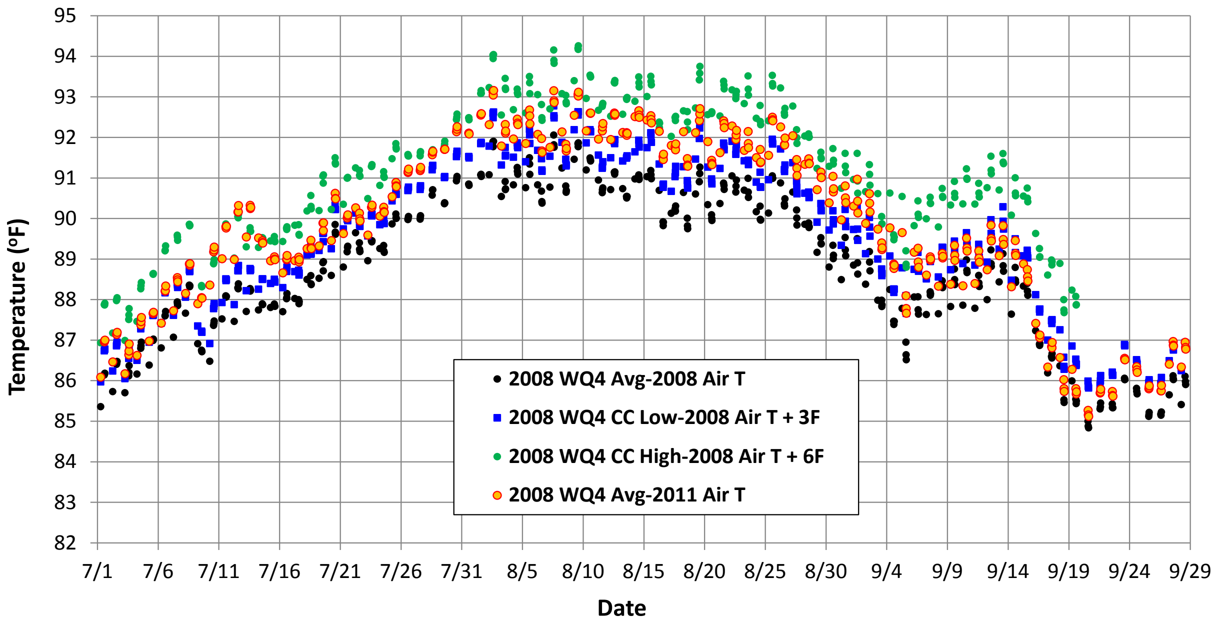
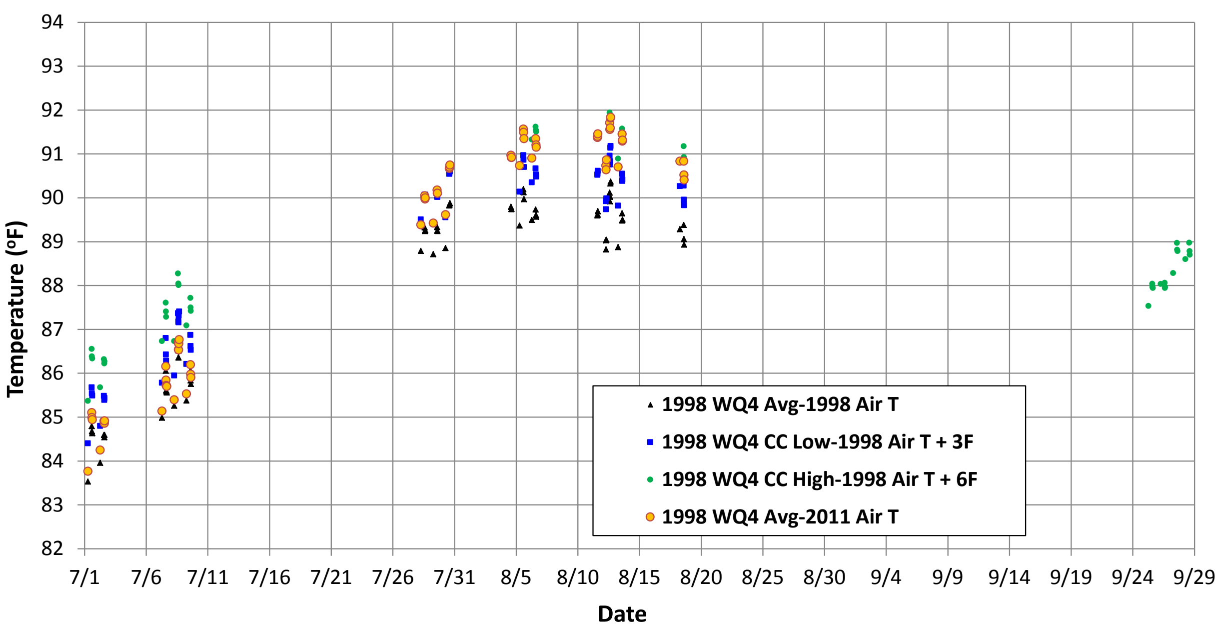


Figure 23. Modeled Keowee Hydro Station Generation Release Water Temperatures - July through September 1998 – WQ4 Baseline and Climate Change Scenarios



3.4 Descriptive Statistics for Climate Change Scenarios

Table 3 provides descriptive statistics (e.g., mean, minimum, and maximum) of the modeled summer temperatures and DO concentrations for the Keowee Hydro Station generation releases for each of the scenarios evaluated in this addendum report. Modeling of the low-impact climate change scenarios (3 °F air temperature increase) resulted in both monthly mean and monthly maximum water temperatures in the Keowee release ≤ 1 °F higher than the baseline scenarios.

The 2008 scenarios modeled with the observed 2011 air temperatures and with high-impact climate change (+6 °F air temperatures) exhibited the greatest water temperature changes compared to baseline conditions, with mean temperature differences of ≤ 1.4 °F and ≤ 3.0 °F, respectively (Table 3). The maximum hydro release temperature increases relative to the 2008 baseline were predicted to be ≤ 1.5 °F for the scenario using 2011 temperatures, and ≤ 2.3 °F for the scenario using high-impact climate change conditions.

The W2 model results for 1998 using the WQ4 operational scenario were less conclusive because generation water releases for Keowee Hydro were limited to only 9 days[3], producing minimal output for the four climate scenarios (see Figure 23 and Table 3 for hours of operation.) Using the low-impact climate change air temperatures (+3 °F), Keowee Hydro generation release temperatures were on average ≤ 1.0 °F higher than the baseline generation release temperatures. However, under the high-impact climate change scenario (+6 °F air temperatures), the 1998 WQ4 scenario, on average, yielded lower Keowee Hydro Station generation water release temperature increases than either the low-impact climate change scenario or the scenario that utilized observed 2011 air temperatures (Table 3). This apparent discrepancy was the result of a significant reduction in the total hours of Keowee Hydro generation during the summer months. In 1998 the total hours of WQ4 releases from Keowee Hydro Station for the high-impact climate

[3] Comparatively few days of Keowee Hydro generation occurred under WQ4 in the summer of 1998 relative to the drought year 2008, primarily because ample storage maintained in US Army Corp Reservoirs downstream of the Project following the relatively wet first half of 1998 avoided triggering a requirement for Keowee Hydro to pass water downstream.

change (+6 °F air temperatures) were about half that of the other 1998 scenarios, and perhaps more importantly, those releases did not correspond to the same time as the other 1998 scenarios. This temporal 'mis-match' of the limited Keowee Hydro releases severely constrained any ability to make temperature comparisons for the 1998 WQ4 scenarios.

As with the Keowee Hydro Station generation release temperature comparisons between the 1998 WQ4 scenarios, data available for comparisons of modeled DO concentrations in the Keowee tailwater were likewise sparse. However, the averaged modeled DO results appeared less affected by short-term temporal 'mis-matching' of output among the scenarios, and monthly mean and minimum DO concentrations resulting from the model predictions were very similar from one scenario to another. Collectively, all climate change scenarios yielded consistently no more than a 0.2 mg/L decrease with respect to baseline DO concentrations, with most values decreased by 0.1 mg/L. As mentioned previously, DO concentrations consistently exceeded 6 mg/L, well above state water quality standards even under the most challenging climate change scenario.

Table 3. Descriptive Statistics of Modeled Keowee Hydro Station Tailrace Temperatures and DO Concentrations for Baseline and Climate Change Scenarios

Model Scenario Name	Monthly Statistics for the Keowee Hydro Station Generation Releases During Generation														
	Mean Temperature (˚F)			Maximum Temperature (˚F)			Hours of Keowee Generation			Mean DO (mg/L)			Minimum DO (mg/L)		
	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
2008 WQ4 (avg) with 2008 Air Temperature - Baseline	88.3	90.6	87.1	91.0	92.0	89.5	56	61	53	6.7	6.6	6.6	6.5	6.4	6.4
2008 WQ4 (cc low) with 2008 Air Temperature + 3°F Low Climate Change	88.9	91.4	88.0	91.7	92.8	90.3	56	61	53	6.6	6.5	6.6	6.4	6.3	6.4
2008 WQ4 (cc high) with 2008 Air Temperature + 6°F High Climate Change	90.0	92.8	90.1	92.6	94.3	91.6	49	61	38	6.6	6.5	6.5	6.3	6.2	6.3
2008 WQ4 (avg) with 2011 Air Temperature - Empirical	89.3	92.0	87.9	92.3	93.2	91.0	56	61	53	6.6	6.5	6.6	6.4	6.3	6.4
1998 WQ4 (avg) with 1998 Air Temperature - Baseline	86.2	89.6	No gen [4]	89.9	90.4	No gen.	22	14	0	6.5	6.5	No gen.	6.3	6.3	No gen.
1998 WQ4 (cc low) with 1998 Air Temperature + 3°F Low Climate Change	87.2	90.5	No gen.	90.6	91.2	No gen.	20	13	0	6.4	6.4	No gen.	6.2	6.2	No gen.
1998 WQ4 (cc high) with 1998 Air Temperature + 6°F High Climate Change	86.8	91.4	88.5	88.3	91.9	89.6	12	7	10	6.4	6.3	6.5	6.3	6.1	6.4
1998 WQ4 (avg) with 2011 Air Temperature - Empirical	86.6	91.2	No gen.	90.7	91.8	No gen.	22	14	0	6.5	6.3	No gen.	6.2	6.1	No gen.

[4] A 'No gen.' entry means that no Keowee Hydro generation occurred for the month under the modeled scenario.

3.5 Comparison of W2 Model Water Quality Predictions under the Revised WQ4 Operational Scenario to Predictions Obtained from the WQ3 Operational Scenario

Originally, the climate change scenarios and other water quality scenarios were modeled using the WQ3 operational scenario and reported in early 2013 (Sawyer et al., 2014b). However, after the finalization of the report, the relicensing Stakeholder Team finalized its proposed Project operations. These operations are incorporated into the WQ4 scenario, resulting in a new revised CHEOPS output reflecting future withdrawals and higher Keowee lake levels. This section compares the modeled Lake Keowee water quality of the WQ3 scenario to the water quality modeled using the WQ4 protocol.[5]

Lake Levels and Operations

For Lake Keowee, the most noticeable difference between the modeled 2008 WQ3 and WQ4 scenarios was higher lake levels (Figure 24) resulting from the WQ4 scenario. Lake Keowee started 2008 at 6 feet below full pond for the WQ3 test and 4.5 feet below full pond (800 ft-AMSL) for the WQ4 scenario. By May, the lake levels under the two scenarios had converged. Lake Keowee, with minor exceptions in the latter part of the year, remained above 792 ft AMSL for the WQ4 scenario, while the lake was pulled down an additional 1-2 feet in November and December for the WQ3 scenario. Under the WQ4 scenario, Lake Jocassee levels were higher in the winter and spring and similar throughout the summer and early fall relative to WQ3. Beginning in November 2008, Lake Jocassee levels modeled under the WQ4 scenario were lowered to maintain Lake Keowee levels, as water scarcity increased and the Project's Low Inflow Protocol ultimately reached Level 4. (Figure 26).

The amount of water released from Keowee Hydro was less (~5%) under the WQ4 scenario compared to WQ3 (see Figure 25). By August, the WQ4 scenario required about 5% more water

---

[5] The comparative W2 water quality model results presented here, based respectively on the WQ3 and updated WQ4 operational scenario (HDR Engineering, Inc., 2014a) supersede the previously issued report, Sawyer et al., 2014b.

from Jocassee Pumped Storage Station to maintain Keowee lake levels (Figure 27). Annual cumulative water usage for hydroelectric generation at both Keowee and Jocassee Hydros was greater under both the 2008 WQ3 and WQ4 operational protocols compared to actual 2008 cumulative generation releases. This probably was the result of more water stored in Lake Jocassee (lake level was higher) in both modeled operational scenarios compared to actual conditions.

Figure 24. Modeled Lake Keowee Reservoir Elevations for 2008 WQ3 and WQ4 Scenarios (CHEOPS Output)

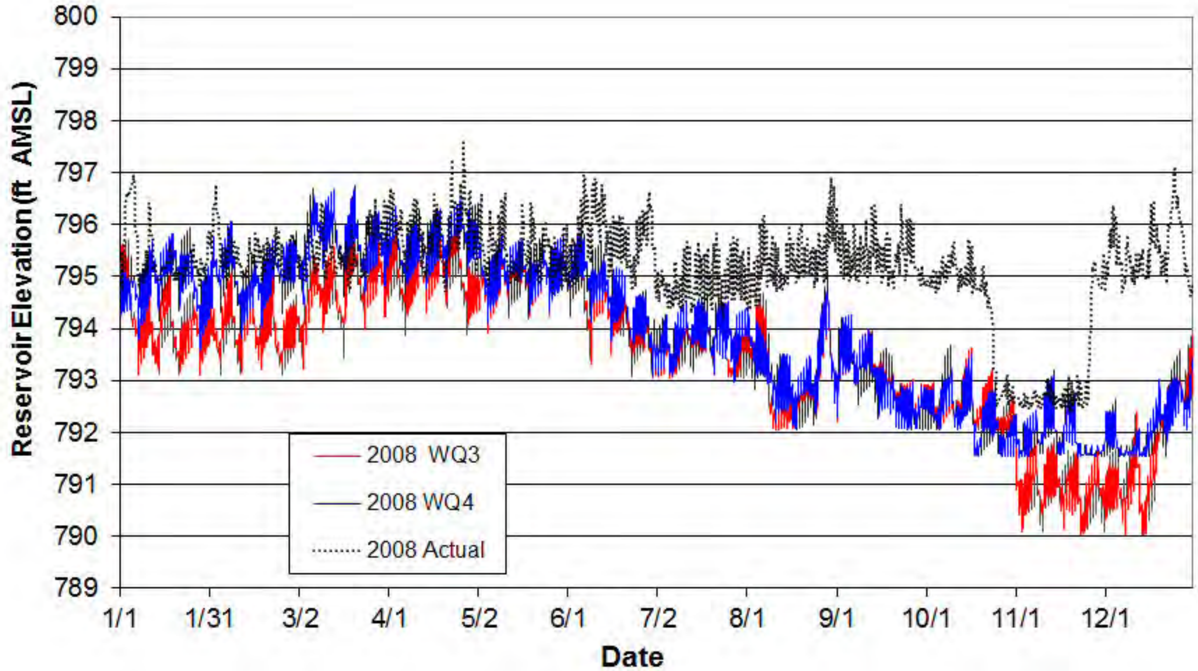


Figure 25. Modeled Keowee Hydro Station Cumulative Water Used for Electrical Generation for 2008 WQ3 and WQ4 Scenarios

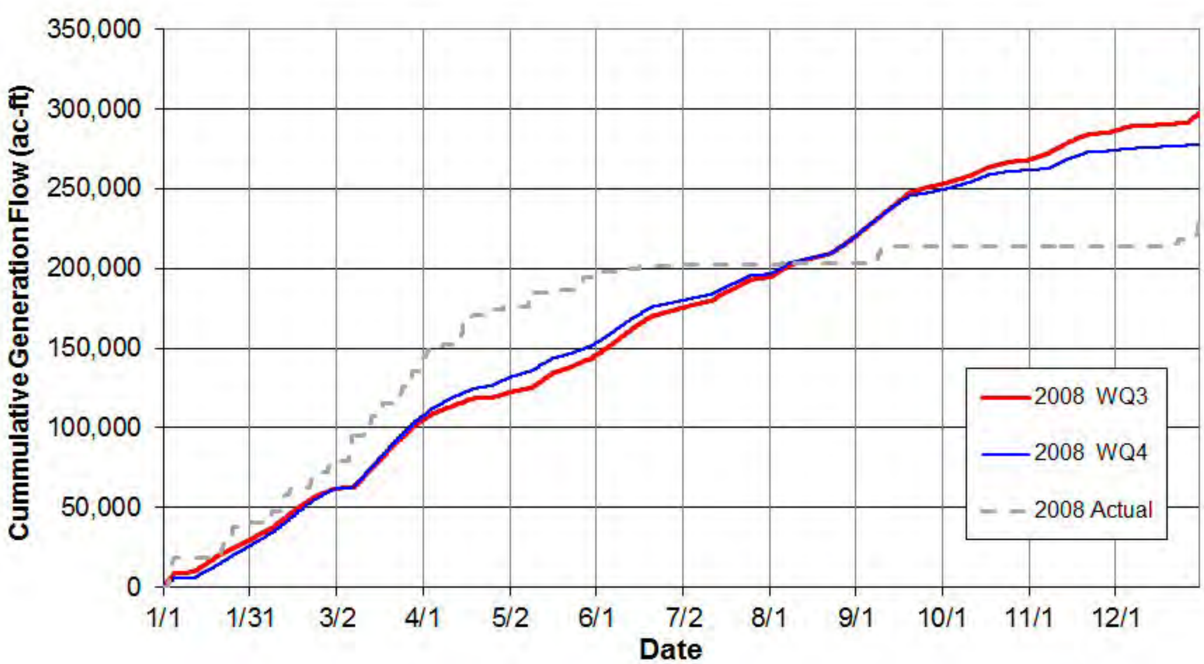


Figure 26. Modeled Lake Jocassee Reservoir Elevations for 2008 WQ3 and WQ4 Scenarios (CHEOPS Output)

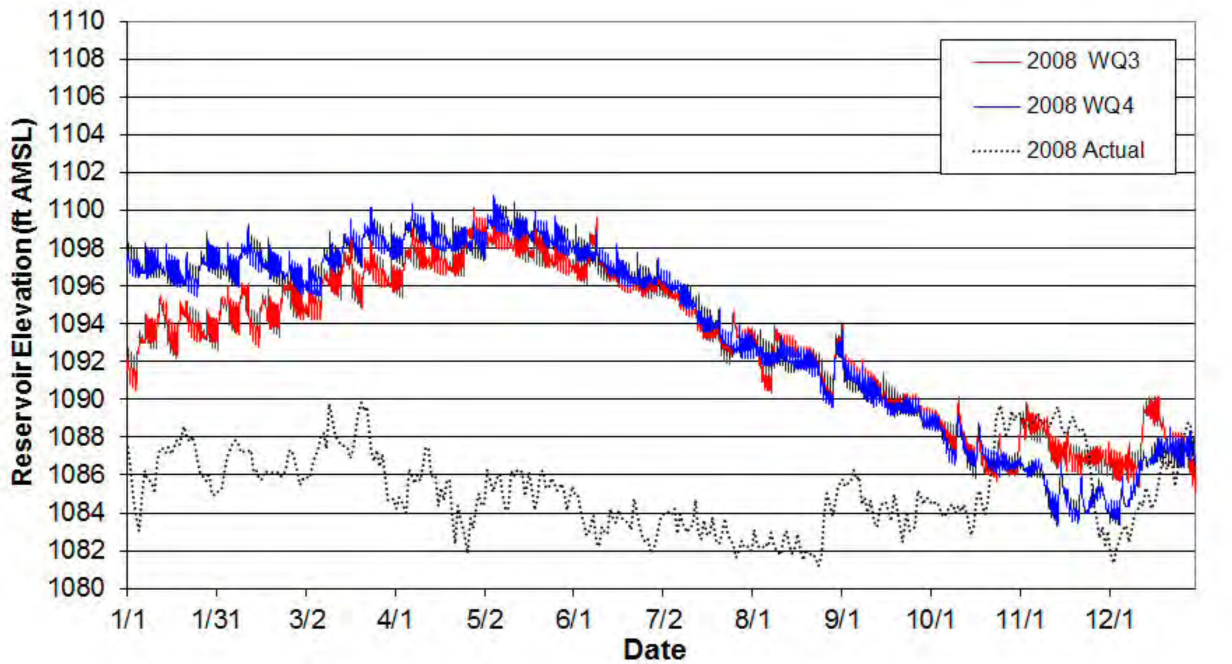
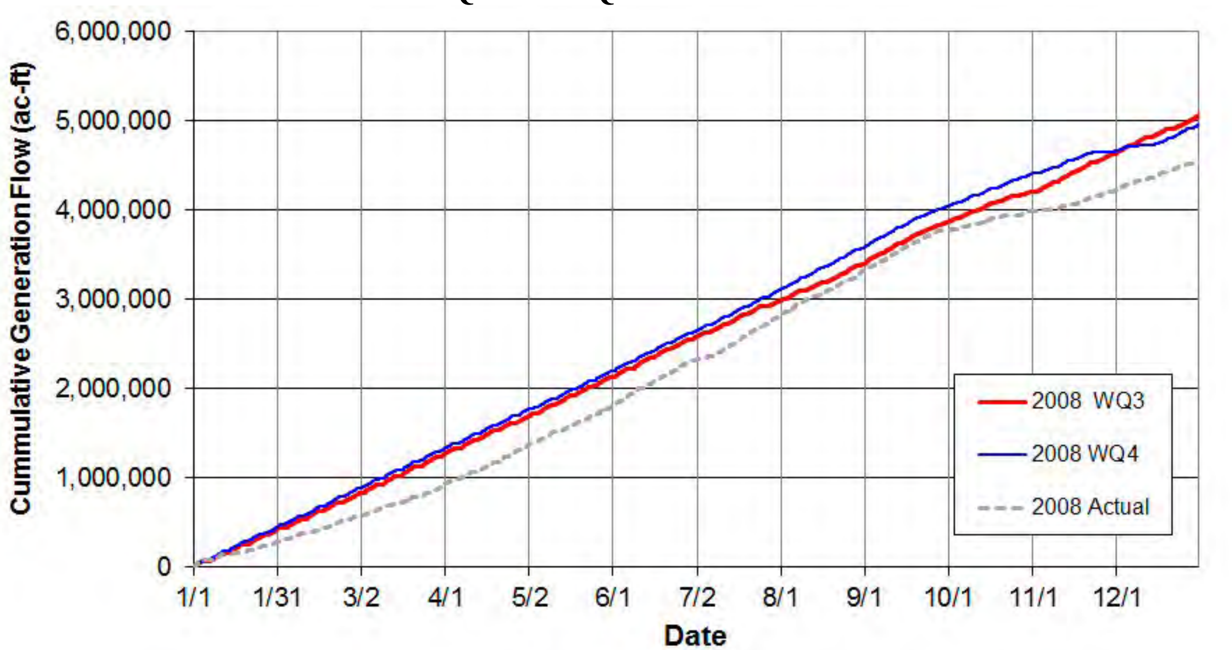


Figure 27. Modeled Jocassee Pumped Storage Station Cumulative Water Used for Electrical Generation for 2008 WQ3 and WQ4 Scenarios



Keowee Hydro Station Release Temperature and DO Concentrations

The temperatures and DO concentrations in the Keowee Hydro generation releases were highly similar between the WQ3 and WQ4 scenarios for the 2008 model runs (Figures 28 and 29). Consistent with the previously modeled Keowee Hydro Station vertical DO profiles, generation release DO concentrations consistently exceeded the water quality standard of 5.0 mg/L, measured as a daily average. Further, modeled results for both scenarios showed that at no time did the DO concentration drop below 6 mg/L in the Keowee Hydro tailrace.

A more detailed examination of summer temperatures modeled for each scenario revealed appreciable variability of the hour-to-hour water temperatures (Figure 30). In August and September the WQ3 scenario generation release temperatures were slightly higher (by approximately 1 to 1.5 °F) than those modeled for the WQ4 scenario.

Figure 28. Modeled Keowee Hydro Station 2008 Generation Release Temperatures for the WQ3 and WQ4 Scenarios

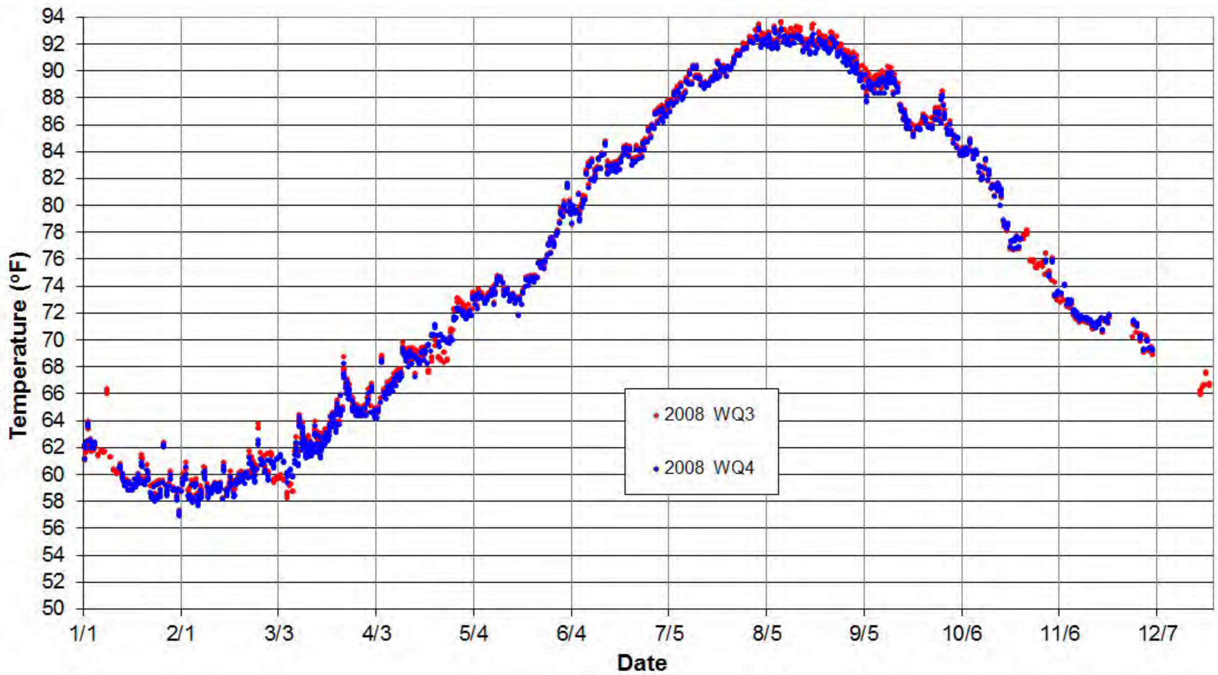


Figure 29. Modeled Keowee Hydro Station 2008 Summer Generation Release DO Concentrations - June through September 2008 – WQ3 and WQ4 Scenarios

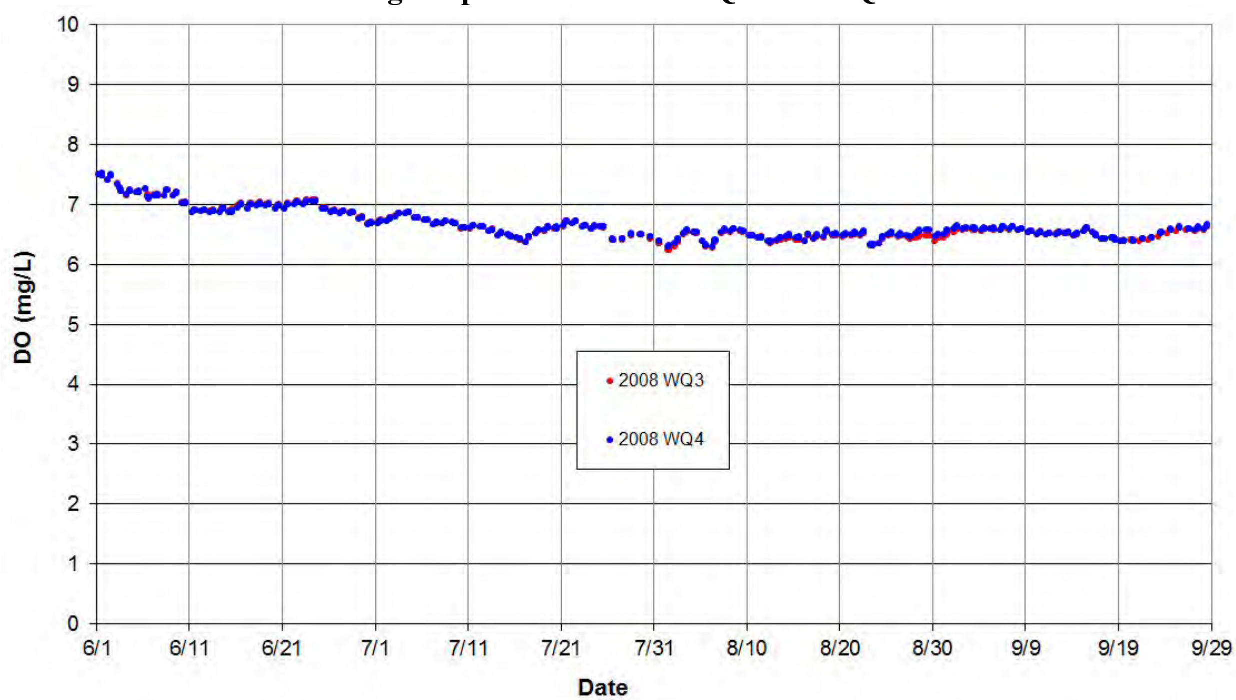
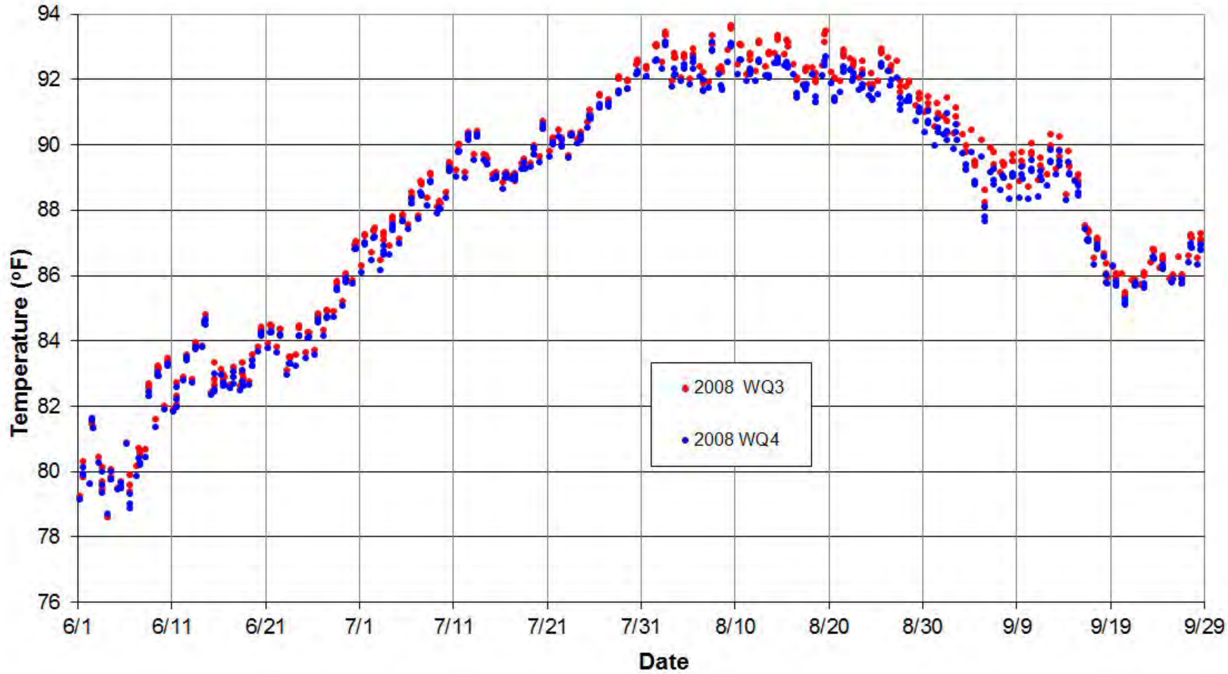


Figure 30. Modeled Keowee Hydro Station Generation Release Water Temperatures - June through September 2008 – WQ3 and WQ4 Scenarios



Monthly Summer Statistics

Monthly summertime mean and maximum predicted temperatures and mean and minimum DO concentrations for the Keowee Hydro Station generation releases for the 2008 WQ3 and WQ4 operational scenarios were similar (Table 4). Mean water temperatures in the releases were slightly less for the WQ4 scenario than those for the WQ3 scenario. The WQ4 operational scenario also resulted in slightly lower monthly maximum temperatures; 0.3, 0.4, and 0.5 °F cooler in July, August, and September, respectively.

Monthly mean and minimum DO concentrations resulting from the WQ3 and WQ4 operational scenarios were virtually identical. The minor exceptions of modeled minimum DO concentrations for July and August indicated only a ±0.1 mg/L differential under WQ4 operations relative to WQ3 (see Table 4). As mentioned previously, under both scenarios DO was consistently greater than 6 mg/L and well above state water quality standard of 5.0 mg/L as a daily average. These modeled results, obtained from applying the two operational scenarios to the low inflow year of 2008, confirm that previously modeled and reported (Sawyer et al., 2013) water quality results obtained by applying the WQ3 operational scenario are still closely predictive of water quality results that would be anticipated if the WQ4 operational conditions had been applied.

Table 4. Summer Monthly Keowee Hydro Station Generation Release Temperature and DO Statistics Calculated from Model Results from 2008 WQ3 and WQ4 Operational Scenarios

Model Scenario Name	Mean Temperature (°F)			Maximum Temperature (°F)			Mean DO (mg/L)			Minimum DO (mg/L)		
	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
2008 WQ3 (avg) with 2011 Air Temperature	89.5	92.4	88.1	92.6	93.6	91.5	6.6	6.5	6.5	6.3	6.2	6.4
2008 WQ4 (avg) with 2011 Air Temperature	89.3	92.0	87.9	92.3	93.2	91.0	6.6	6.5	6.6	6.4	6.3	6.4

Section 4

Summary

The previously calibrated CE-QUAL-W2 water quality model (Sawyer et al., 2013) was employed to evaluate potential climate change effects on water quality of Keowee Hydro Station releases using the WQ4 operational scenario for years 2008 and 1998. Potential climate change effects were evaluated separately by adding 3 °F and 6 °F to the air temperatures in the meteorological input data file, consistent with the operational (CHEOPS) modeling approach. Otherwise, model inputs were similar to the baseline conditions described in the water quality modeling study report (Sawyer et al., 2013).

For the low-impact climate change scenarios (air temperatures increased 3 °F), the Keowee Hydro generation release temperatures were, on average, less than 1 °F warmer than both the 1998 and 2008 baseline temperatures. When the air temperatures were modeled for the high-impact climate change scenario (+6 °F air temperatures), the 2008 tailrace temperatures were approximately 2 to 3 °F higher than baseline conditions. When the actual 2011 air temperatures were applied to the 2008 model, the resultant water temperatures released from Keowee Hydro Station were modeled to be between the low- and high-impact climate change scenarios. Temperature comparisons for the 1998 climate change scenarios were less conclusive due to extremely limited Keowee hydro generation occurring for that year under the modeled WQ4 operational conditions.

DO concentrations responded slightly to increased water temperatures resulting from the climate change scenarios. As water temperatures increased, oxygen solubility decreased and microbial activity increased resulting in a predicted 0.1 to 0.2 mg/L decrease in oxygen throughout the water column and the Keowee Hydro Station releases. Modeled DO concentrations at the Keowee Hydro Station tailrace consistently remained well above the state daily average water quality standard of 5.0 mg/L, and at no time were DO concentrations less than 6 mg/L.

In conclusion, the low- and high-impact climate change scenarios had minimal impact on modeled water temperatures and DO concentrations in Lake Keowee and water released during Keowee Hydro Station generation.

An additional W2 model comparison evaluating the differences in water quality results derived under 2008 WQ3 and WQ4 operational scenarios indicated negligible temperature, and virtually no DO differences for Keowee Hydro generation release water quality. The high degree of similarity between the two scenarios confirms that earlier water quality results obtained under the WQ3 operational scenario would be representative of results anticipated using the proposed WQ4 operational scenario.

Section 5

References

HDR Engineering, Inc. 2014a. Final Scenario Documentation Report. Keowee-Toxaway Project, FERC Project No. 2303. May, 2014. Duke Energy, Charlotte, NC.

__________. 2014b. Water Supply Study Final Report. Keowee-Toxaway Project, FERC Project No. 2303. May, 2014. Duke Energy, Charlotte, NC.

Knight, J.C., A.F. Sawyer, and R.J. Ruane. 2013. 2011 Lake Keowee and Keowee Tailrace Data, Appendix B - Keowee Reservoir Water Quality Modeling Study Report, FERC Project No. 2303. February, 2013. Duke Energy, Charlotte, NC.

[NOAA] National Oceanic and Atmospheric Administration 2013. National Climatic Data Center, State of the Climate: National Overview for August 2011. Accessed August 23, 2013 from http://www.ncdc.noaa.gov/sotc/national/2011/8.

Sawyer, A.F., and R.J. Ruane. 2013. Keowee Reservoir Water Quality Modeling Study Report, Appendix D. Keowee-Toxaway Project, FERC Project No. 2303. March, 2013. Duke Energy, Charlotte, NC.

Sawyer, A.F., R.J. Ruane, and J.C. Knight. 2013. Keowee Reservoir Water Quality Modeling Study Report, Keowee-Toxaway Project, FERC Project No. 2303. March, 2013. Duke Energy, Charlotte, NC.

__________. 2014a. Addendum to Keowee Reservoir CE-QUAL-W2 Water Quality Modeling Study Report: W2 Model Results from Climate Change Scenarios Using 1998 and 2008 Duke Energy Trial Balloon (WQ3) Conditions. Keowee-Toxaway Project, FERC Project No. 2303. January, 2014. Duke Energy, Charlotte, NC.

__________. 2014b. Addendum to Keowee Reservoir CE-QUAL-W2 Water Quality Modeling Study Report: W2 Model Results Comparing Water Quality Predicted Under Duke Energy Trial Balloon (WQ3) and Revised (WQ4) Operational Conditions. Keowee-Toxaway Project, FERC Project No. 2303. January, 2014. Duke Energy, Charlotte, NC.

RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY FOR THE KEOWEE-TOXAWAY RELICENSING PROJECT (FERC PROJECT NO. 2503)

Prepared for:
DUKE ENERGY CAROLINAS, LLC
Charlotte, North Carolina

Prepared by:
HDR ENGINEERING, INC. OF THE CAROLINAS
Charlotte, North Carolina

FINAL - NOVEMBER 2012

RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY FOR THE KEOWEE-TOXAWAY RELICENSING PROJECT (FERC PROJECT NO. 2503)

TABLE OF CONTENTS

RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY FOR THE KEOWEE-TOXAWAY RELICENSING PROJECT (FERC PROJECT NO. 2503)

TABLE OF CONTENTS

Section **Title** **Page No.**

RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY FOR THE KEOWEE-TOXAWAY RELICENSING PROJECT (FERC PROJECT NO. 2503)

LIST OF TABLES

Table	Title	Page No.

RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY FOR THE KEOWEE-TOXAWAY RELICENSING PROJECT (FERC PROJECT NO. 2503)

LIST OF FIGURES

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

LIST OF FIGURES
(Continued)

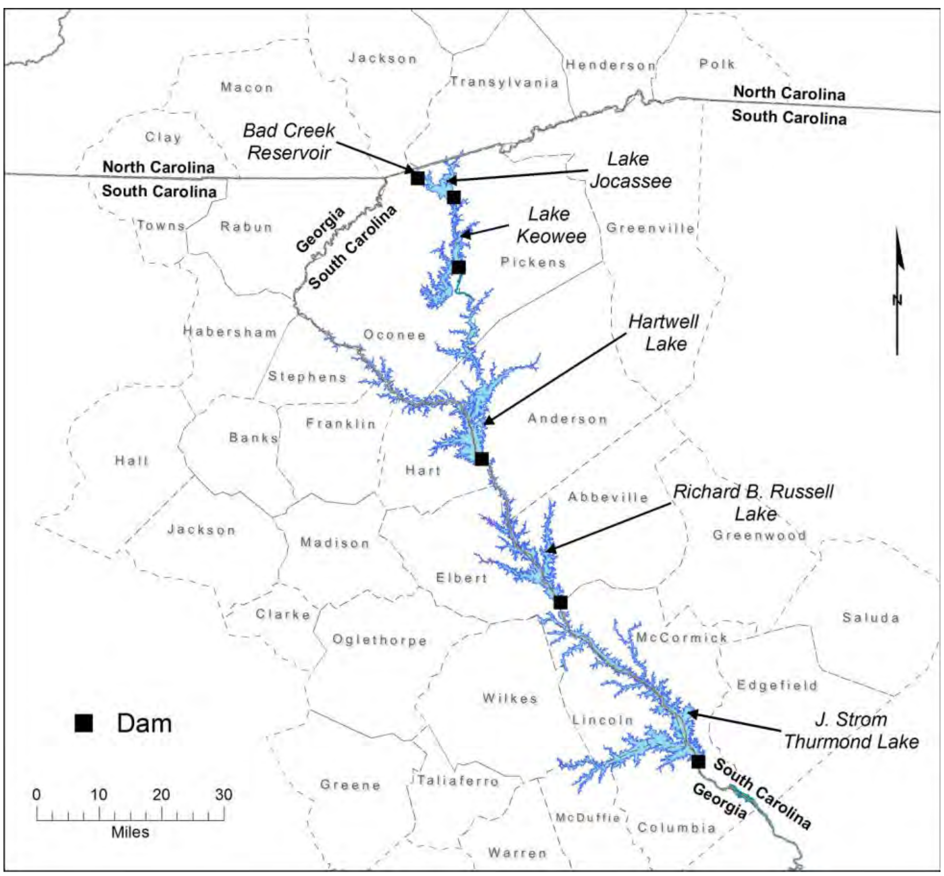
Figure	Title	Page No.

Section 1
Introduction and Background

1.1 Project Location

Duke Energy Carolinas, LLC (Duke Energy) is the Licensee of the Keowee-Toxaway Hydroelectric Project (FERC No. 2503), hereafter referred to as the Project. The Project is located at the headwaters of the Savannah River Basin (see Figure 1.1-1) in the upstate area of South Carolina primarily in Oconee County and Pickens County with a small portion of Lake Jocassee extending into Transylvania County, North Carolina. The Project consists of two developments: the Jocassee Development and the Keowee Development. The Keowee Development is downstream of the Jocassee Development.

FIGURE 1.1-1
RESERVOIR LOCATIONS IN THE SAVANNAH RIVER BASIN



1.2 Project Overview

Lake Keowee is formed by the Keowee Dam, which impounds the Keowee River, and the Little River Dam, which impounds the Little River. Lake Keowee is the larger of the Project's two reservoirs with a surface area of approximately 17,610 acres at Normal Full Pond Elevation, which is 800 feet above mean sea level (ft AMSL). Keowee Hydroelectric Station (see Figure 1.2-1), with an installed generating capacity of 157.5 Megawatts (MW), releases directly into Hartwell Lake, a United States Army Corps of Engineers (USACE) reservoir. Lake Keowee functions as the lower reservoir for the Jocassee Pumped Storage Station and as the cooling pond for Oconee Nuclear Station (ONS), which is a nuclear powered thermal electric generating station. Lake Keowee contains water intakes of Greenville Water and Seneca Light & Water.

FIGURE 1.2-1
KEOWEE HYDROELECTRIC STATION
WITH ONS IN BACKGROUND

Lake Jocassee is formed by the Jocassee Dam, which impounds the Keowee River. Lake Jocassee is the smaller of the two Project reservoirs with a surface area of approximately 7,980 acres at Normal Full Pond Elevation, which is 1,110 ft AMSL. The Jocassee Pumped Storage Station (see Figure 1.2-2), with an installed generating capacity of 710.1 MW, releases directly into Lake Keowee. Lake Jocassee functions as the upper reservoir for the Jocassee Pumped Storage Station and as the lower reservoir for the Bad Creek Pumped Storage Project (FERC Project No. 2740).

FIGURE 1.2-2
JOCASSEE PUMPED STORAGE STATION
WITH LAKE KEOWEE IN FOREGROUND

Table 1.2-1 provides relevant water surface elevation data for the Keowee and Jocassee Developments.

TABLE 1.2-1
PROJECT RESERVOIR ELEVATIONS

Reservoir Level	Lake Keowee	Lake Jocassee
Normal Full Pond (point of incipient overflow)	800.0	1,110.0
ONS's Operating Restriction on Lake Keowee	794.6	N/A
Level at which fish entrainment at Bad Creek Pumped Storage Station noticeably increases	N/A	1,096.0
Level at which deepest public boat ramp becomes unusable	790.0	1,080.0
Maximum drawdown per the current FERC license	775.0	1,080.0
Greenville Water critical intake elevation	770.0	N/A

All elevations in table are in units of ft-AMSL.

The Project was initially licensed in 1966 by the Federal Power Commission (FPC) – the predecessor agency to the Federal Energy Regulatory Commission (FERC). The current license expires on August 31, 2016.

A chronology of Savannah River Basin events that affect, or could affect, the operation of the Project is shown in Table 1.2-2.

TABLE 1.2-2
PROJECT OPERATION CHRONOLOGY

Event	Year
Year when existing Operating License was issued by the FPC	1966
Duke Energy/Southeastern Power Administration/USACE Operating Agreement signed	1968
Year of Keowee Hydroelectric Station commercial operation – all units	1971
Year of ONS commercial operation – all units	1974
Year of Jocassee Pumped Storage Station commercial operation – all units	1975
Richard B. Russell Pumped Storage Project begins limited commercial operation	January 1985
Institution of USACE Savannah River Drought Contingency Plan	March 1989
Year of Bad Creek Pumped Storage Project commercial operation – all units	1991
Year when Keowee Hydroelectric Station operations were modified to accommodate ONS's Operating Restriction on Lake Keowee	1995
Keowee-Toxaway Fishery Resources Memorandum of Understanding between Duke Energy and the South Carolina Department of Natural Resources on Fish Entrainment at the Bad Creek Pumped Storage Station	December 1996
Revision 1 of USACE Savannah River Drought Contingency Plan	September 2006
Revision 2 of USACE Savannah River Drought Contingency Plan	August 2012
Year when existing FERC Operating License expires	2016

Section 2
Description of Study

Duke Energy is relicensing the Project using the FERC's Integrated Licensing Process (ILP) as described in Parts 5.1 through 5.31 of Title 18 of the Code of Federal Regulations. Under the ILP, Duke Energy formed a Stakeholder Team comprised of federal and state agency representatives and local and regional stakeholders. The Resource Committees and Study Teams are involved with the identification, development, and implementation of studies associated with the relicensing effort. This report was prepared under the guidance of the Reservoir Level and Project Flow Releases Study Team in support of the Water Quality and Operations Resource Committee.

The study area for the Reservoir Level and Project Flow Releases Study is the area within the Project Boundary. The objective of the study is to organize historic reservoir flow release data for Keowee Hydroelectric Station and reservoir elevation data for Lake Keowee and Lake Jocassee into a computer-accessible database. The database includes all available reservoir elevation and flow release data from the developments' commercial operation dates (all units available) through the end of 2011.

The reservoir elevation data plots included in this report have been used to identify potential seasonal operating elevation bands for Lake Keowee and Lake Jocassee based on historical operations. Flow release data for the Keowee Hydroelectric Station can be used to identify changes in historic volumetric release patterns in and out of drought periods. Lake Keowee release and reservoir elevation data also show the influence of the 1968 Operating Agreement between Duke Energy, the Savannah District of the USACE, and the Southeastern Power Administration (SEPA), as well as the changes to Lake Keowee's operations due to ONS's limits on Lake Keowee drawdowns which began in 1995.

Section 3
Methodology

Daily and hourly operations data were obtained from Duke Energy for the Keowee and Jocassee Developments. A database of daily time series data was developed for each development starting from its commercial operation date (all units available) through the end of 2011. Lake Keowee data covers the period from April 17, 1971, through December 31, 2011, the 40-year period of record for the Keowee Development (Keowee POR). Lake Jocassee data covers the period from May 1, 1975, through December 31, 2011, the 37-year period of record for the Jocassee Development (Jocassee POR). Similarly, a database of hourly time series data was developed for each development from 1995 through the end of 2011 (pre-1995 hourly data were not available digitally). The post-2008 daily values were computed from hourly data for both developments. The computed daily release values are the average of 24 hourly values, and daily reservoir elevation values are the midnight readings. These computations are consistent with pre-2008 daily data sets. The reservoir elevation plots for both developments and the Lake Keowee release volume plots were produced from the daily data.

The hourly time series data are sortable by day, and the daily time series data are sortable by week, month, and quarter. For Lake Keowee, a continuous daily time series of releases was developed and used to create time series data for weekly, monthly, and quarterly releases. For the Lake Keowee and Lake Jocassee elevation data, statistical plots were developed including histograms, cumulative frequency curves, and exceedance curves. Hayes charts were produced for Lake Keowee and Lake Jocassee daily elevations. These statistical plots and Hayes charts were part of the Study Team's consultations to determine maximum drawdown elevations as described in Section 4.5.

Hartwell Lake and J. Strom Thurmond Lake (JST Lake) daily elevation records were downloaded from the USACE website, and drought period start and stop dates were determined using current USACE definitions of Level 1, Level 2, and Level 3 droughts. These drought period start and stop dates were part of the Study Team's consultations to define drought periods as described in Section 4.4. A time series of Richard B. Russell Lake (RBR Lake) daily elevations was plotted, and a Hayes chart was developed for RBR Lake daily elevations.

In addition to computing the daily values above, the 1995 through 2011 hourly reservoir elevation data for Lake Keowee and Lake Jocassee were used to prepare statistical plots. Daily reservoir level ranges were displayed in histograms and cumulative frequency curves to assess intra-day pond fluctuations.

Section 4
Results

The databases and plots listed in this section are the results of this study. The data plots are presented and explained individually. In Section 5, the data plots are analyzed and discussed in relation to one another, and trends and conclusions are presented.

4.1 Reference Databases

The first results of the study effort are a number of databases from which all of the charts and tables are constructed. These databases include the time series of Project releases and reservoir water surface elevations listed below:

1. Keowee Development powerhouse and gate daily release volumes expressed in acre-feet per day (ac-ft/day) covering the Keowee POR.
2. Keowee Development powerhouse and gate hourly releases expressed in acre-feet per hour (ac-ft/hr) for the years 1995 through 2011.
3. Lake Keowee daily reservoir elevations expressed in ft AMSL at the end of each day for the Keowee POR.
4. Lake Keowee hourly reservoir elevations (ft AMSL at the end of each hour) for the years 1995 through 2011.
5. Lake Jocassee daily reservoir elevations (ft AMSL at the end of each day) for the Jocassee POR.
6. Lake Jocassee hourly reservoir elevations (ft AMSL at the end of each hour) for the years 1995 through 2011.

These results have been made available to the Study Team.

4.2 Lake Keowee Releases

Daily, and some hourly, release volume data are available in the databases. The daily time series database of Lake Keowee releases was used to generate the figures in this section. Because the density of data was so large when daily releases were plotted, the chart showed a solid mass of blue lines in which no patterns were discernible. Therefore, weekly release volumes are plotted.

Figure 4.2-1 shows the weekly release volumes from Keowee Hydroelectric Station for the Keowee POR. The weekly volumes are the sum of the daily volumes of the seven preceding days. Release volumes include the estimated continuous leakage of 50 cubic ft per second (cfs). Units on the left vertical axis are ac-ft per week in thousands. The units on the right vertical axis are cfs. The average flow rates on the right axis are the weekly release volumes divided by the amount of time in a week. These values are useful indicators of the inflow rate into the Project, but they are not indicative of the flow rate through the powerhouse at any given time. The red line on the chart shows the average of all weekly releases in the Keowee POR.

Figure 4.2-2 is the same as Figure 4.2-1, except the time scale is restricted to July 1, 2006, through December 31, 2009, which includes the drought of record for the region. The red line is the same Keowee POR average shown in Figure 4.2-1. See Section 5 for a discussion of Lake Keowee release patterns and drought periods.

Figure 4.2-3 is similar to Figure 4.2-1 except it shows quarterly release volumes, which are the sum of the daily release volumes for the three months preceding April 30, June 30, September 30, and December 31 each year. Units on the left vertical axis are ac-ft per quarter in thousands. The units on the right vertical axis are cfs. The average flow rates on the right axis are the quarterly release volumes divided by the amount of time in a quarter. A four-quarter moving average of the quarterly volumes is represented by the dashed green line. The red line on the chart shows the average of all quarterly releases in the Keowee POR.

FIGURE 4.2-1
LAKE KEOWEE WEEKLY RELEASE VOLUMES
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

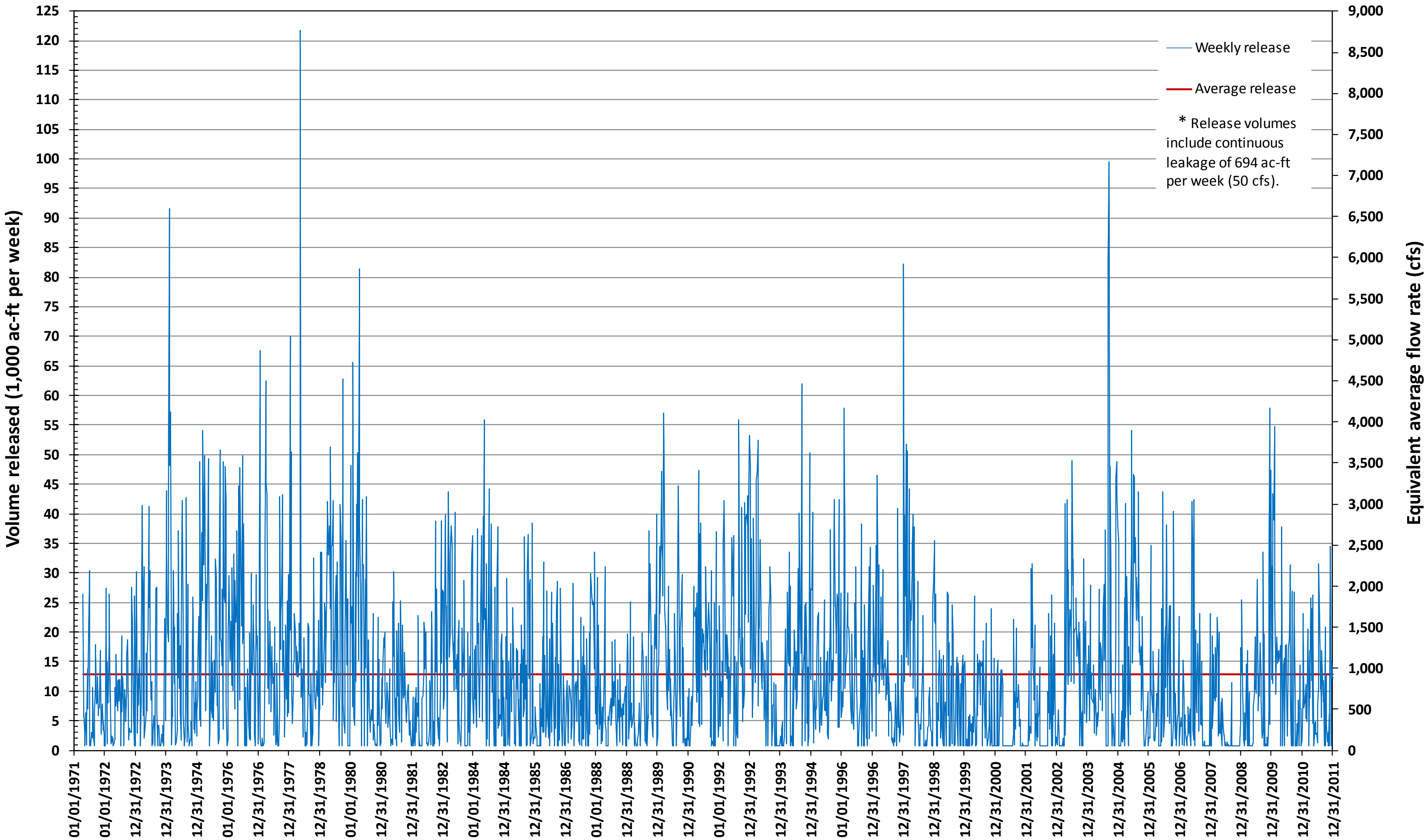


FIGURE 4.2-2
LAKE KEOWEE WEEKLY RELEASE VOLUMES*
JULY 1, 2006, THROUGH DECEMBER 31, 2009

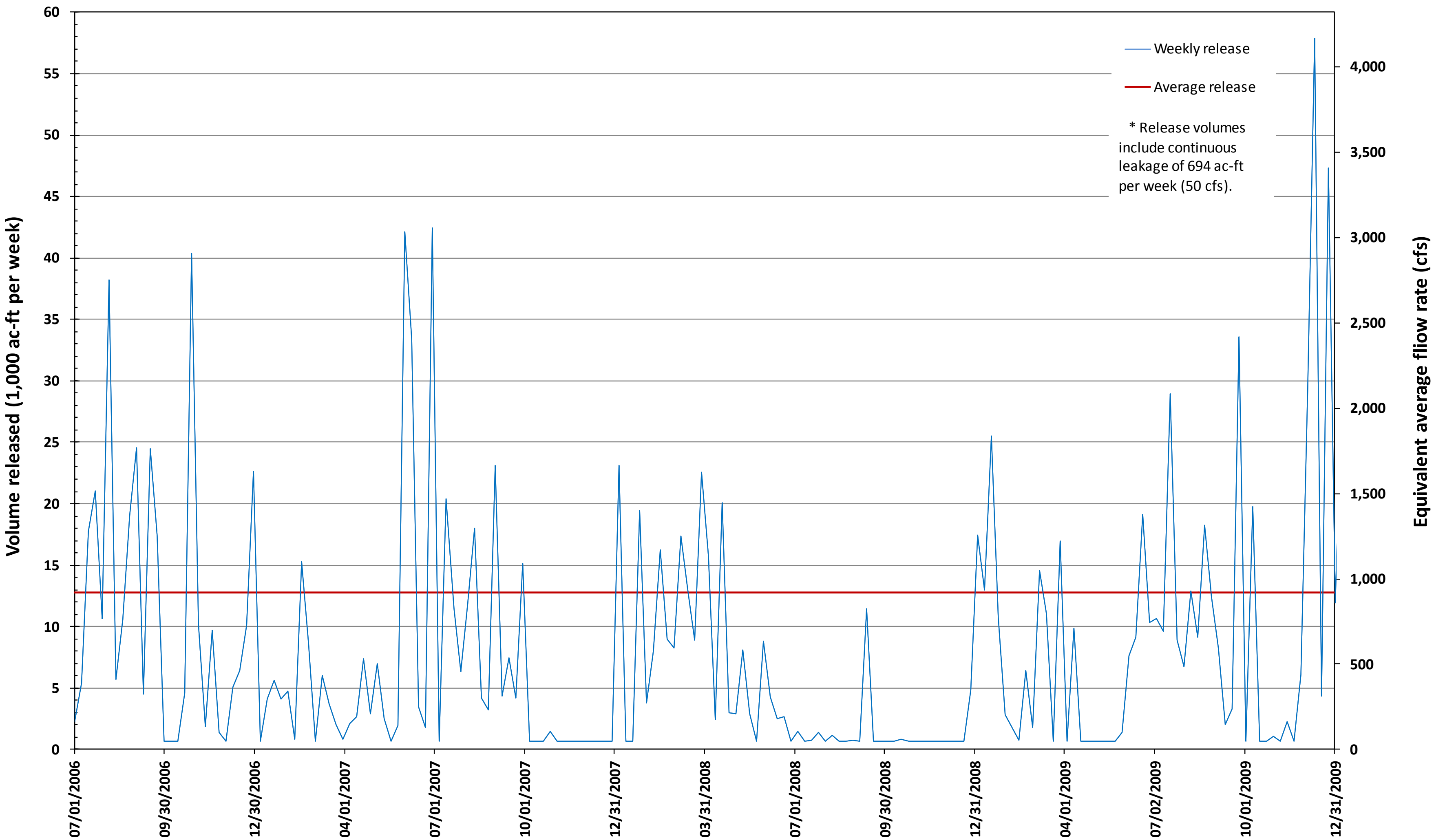
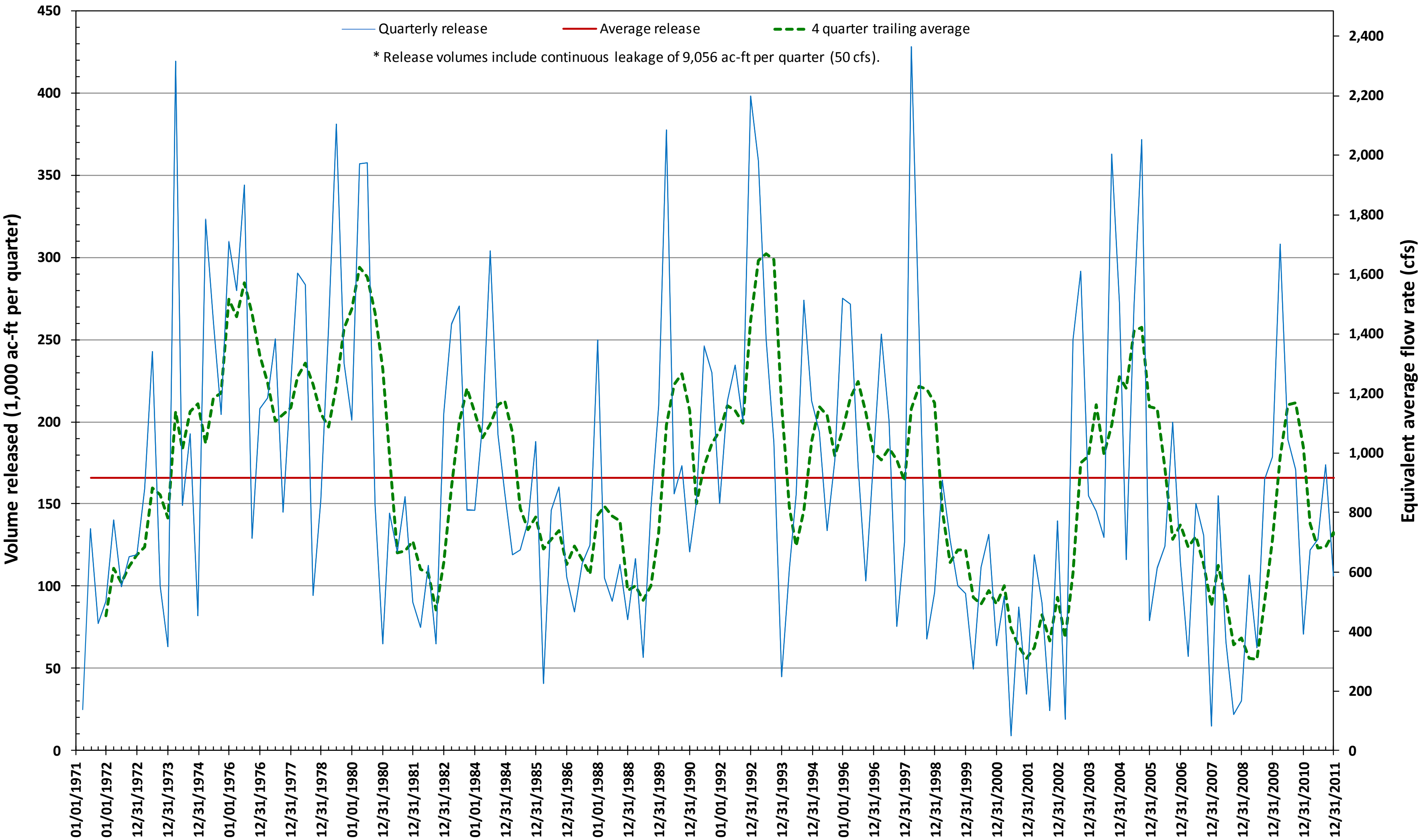


FIGURE 4.2-3
LAKE KEOWEE QUARTERLY RELEASE VOLUMES*
APRIL 17, 1971, THROUGH DECEMBER 31, 2011



4.3 Reservoir Levels

4.3.1 Lake Keowee Level Charts

Figure 4.3-1 shows daily reservoir elevations for Lake Keowee for the Keowee POR. The turbines and spillway gates are operated so the reservoir elevation never exceeds the Normal Full Pond Elevation of 800 ft AMSL. In addition to the daily time series plot, the significant operating levels from Table 1.2-1 are shown on the chart. The vertical scale used on this chart has the same range in feet as the vertical scale used to plot the reservoir elevations for Lake Jocassee in Figure 4.3-6. Using the same range for the vertical scales on both plots facilitates comparison of the reservoir operations of the two developments. These plots are presented together on the same chart in Figure 4.3-11. Except for drought periods and the four drawdowns in the fall of 2005, 2006, 2007, and 2008 to support ONS outages, Lake Keowee generally stayed above an elevation of 795 ft AMSL. See Section 5 for a discussion of the coordinated operation of Lakes Keowee and Jocassee.

Figure 4.3-2(a) shows a Hayes chart developed using all daily reservoir elevation data for the Keowee POR. Daily reservoir elevations for Lake Keowee for each year are superimposed in the Hayes chart. A high density of lines appears at the reservoir elevations that occur most frequently. Daily median and mean reservoir elevations are also plotted on the Hayes chart. For example, the July 4 mean elevation is the average of all of the July 4 daily elevations for the 40-year POR.

Figure 4.3-2(b) contains a Hayes chart similar to Figure 4.3-2(a), except the daily reservoir elevations plotted are restricted to those from non-drought periods – specifically periods for which there would have been no drought level declared in accordance with the current United States Army Corps of Engineers (USACE) Savannah River Basin Drought Contingency Plan (DCP) (see Section 4.4 for the definition of drought levels).

FIGURE 4.3-1
LAKE KEOWEE WATER SURFACE ELEVATIONS
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

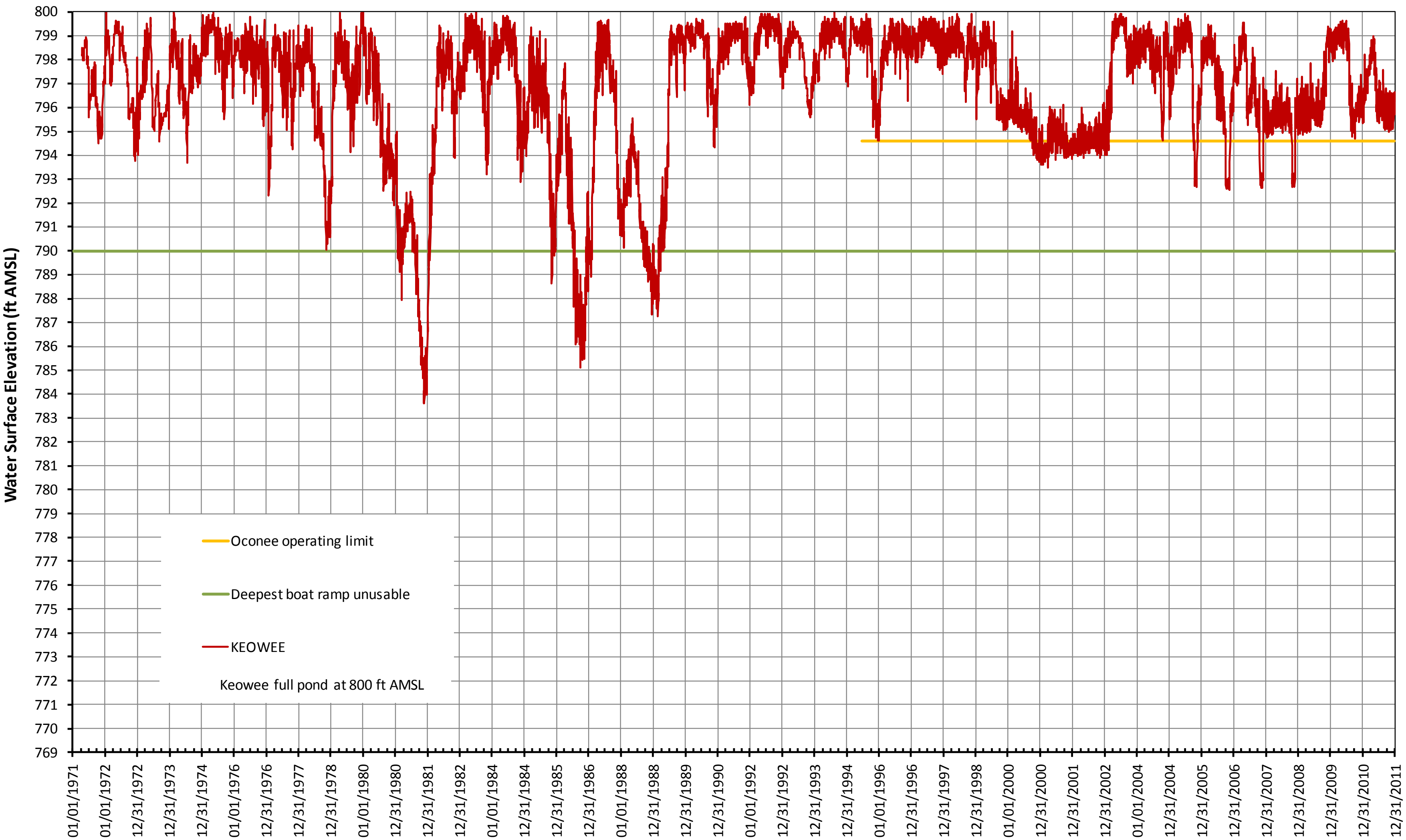


FIGURE 4.3-2(a)
HAYES CHART OF ALL LAKE KEOWEE DAILY WATER SURFACE ELEVATIONS
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

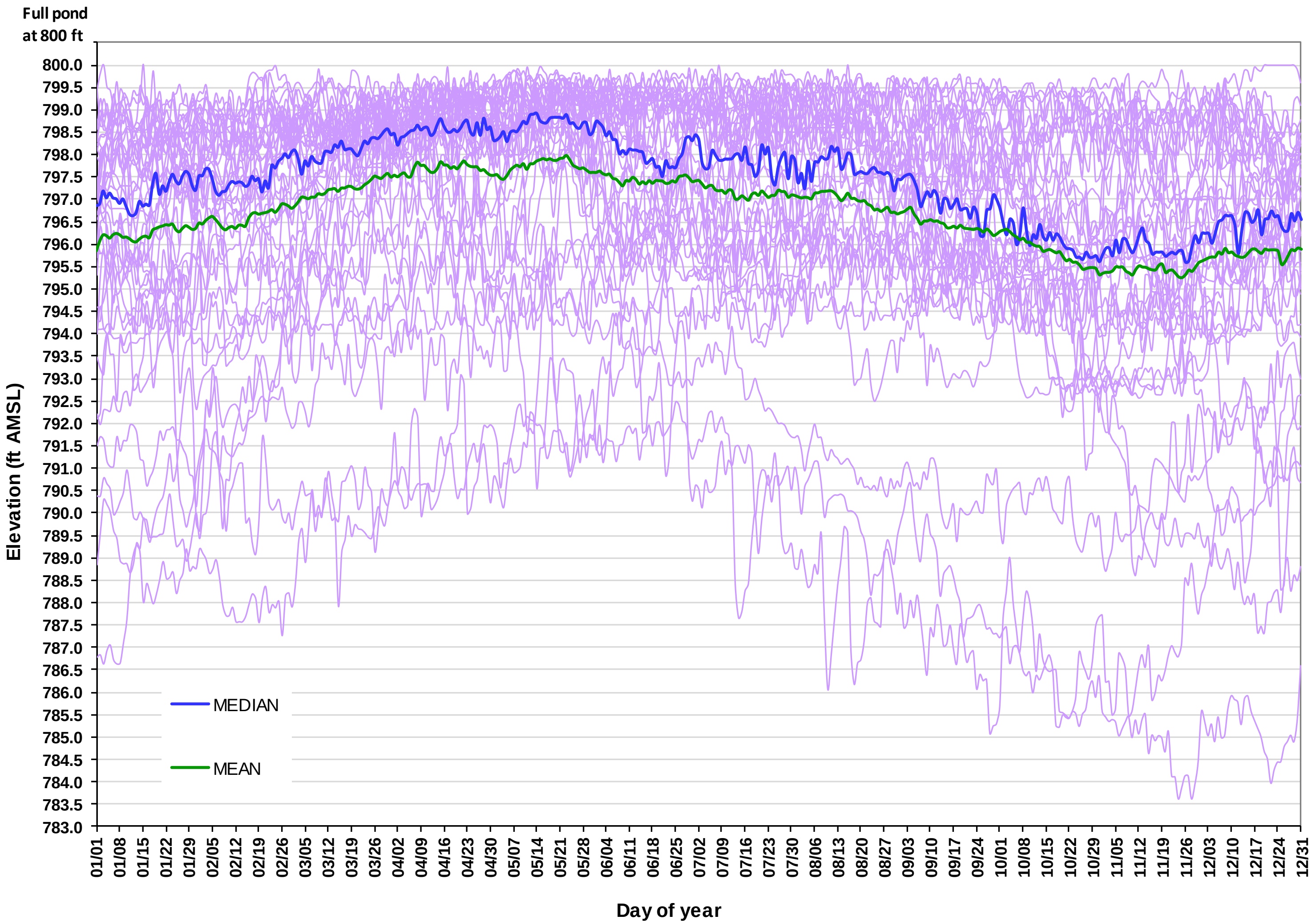
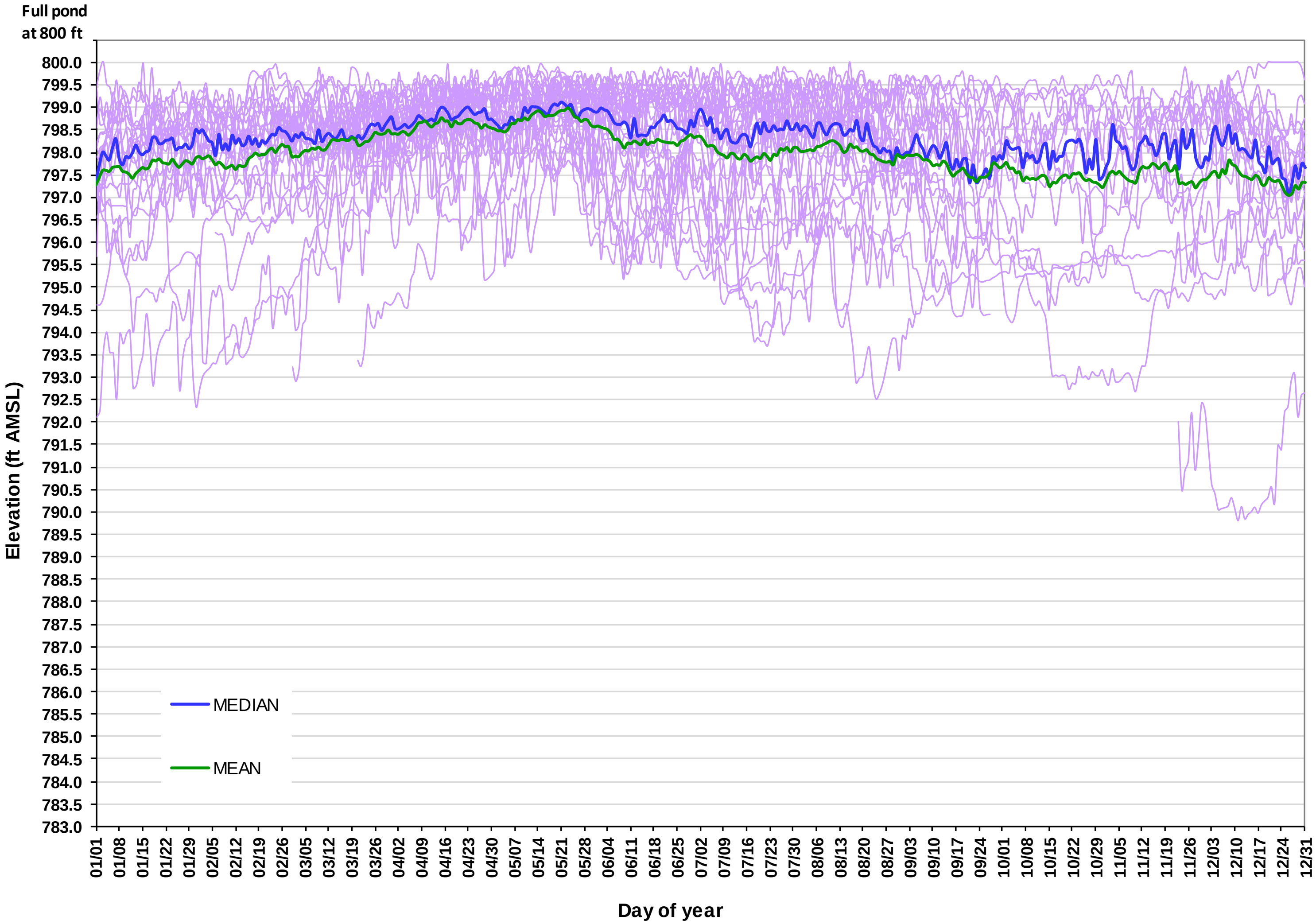


FIGURE 4.3-2(b)
HAYES CHART OF NON-DROUGHT LAKE KEOWEE DAILY WATER SURFACE ELEVATIONS
APRIL 17, 1971, THROUGH DECEMBER 31, 2011



Figures 4.3-1, 4.3-2(a), and 4.3-2(b) were used in the Study Team's discussions of the proposed operating range for Lake Keowee elevations summarized in Section 4.5.

Figure 4.3-3 shows a histogram of Lake Keowee elevations. The blue bars of the histogram account for all 14,869 days in the Keowee POR. The bars are produced by sorting the daily reservoir elevations into bins. The height of each bar graphically represents the number of daily elevation values in each bin, and the number is displayed at the top of each bar. For example, there were 1,134 daily elevations between 798.75 and 799.00 ft AMSL. This number can also be read on the left vertical axis. A cumulative frequency curve for the reservoir elevation values is shown in red, and the percent value can be read on the right vertical axis. For example, 84 percent of the daily reservoir elevations were at or below 799.00 ft AMSL.

Monthly Figures 4.3-3(a) through 4.3-3(l) are the same as Figure 4.3-3 with each of the 12 figures providing a histogram of Lake Keowee pond elevations for one month of the year. For example, all July data for every year in the Keowee POR was collected, processed, and displayed in Figure 4.3-3(g). These monthly histograms are included in Appendix A (Supplemental Figures) at the end of this report.

Figure 4.3-4 shows the exceedance curve for Lake Keowee elevations derived from the histogram. The exceedance curve is based on the 14,869 daily reservoir elevations in the Keowee POR. The vertical axis shows the daily reservoir elevation, and the horizontal axis shows the percent of the elevation readings with a higher value than the daily value on the vertical axis. For example, 16 percent of all reservoir elevation readings were higher than 799 ft AMSL. Specific elevations of interest are shown as horizontal lines. This figure shows the deepest boat ramp (790 ft AMSL) was available 96 percent of the time.

Monthly Figures 4.3-4(a) through 4.3-4(l) are the same as Figure 4.3-4 with each of the 12 figures showing a monthly exceedance curve. For example, Figure 4.3-4(g) contains only July data for all of the years in the Keowee POR. Figures 4.3-4(a) through 4.3-4(l) are located in Appendix A at the end of this report.

FIGURE 4.3-3
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

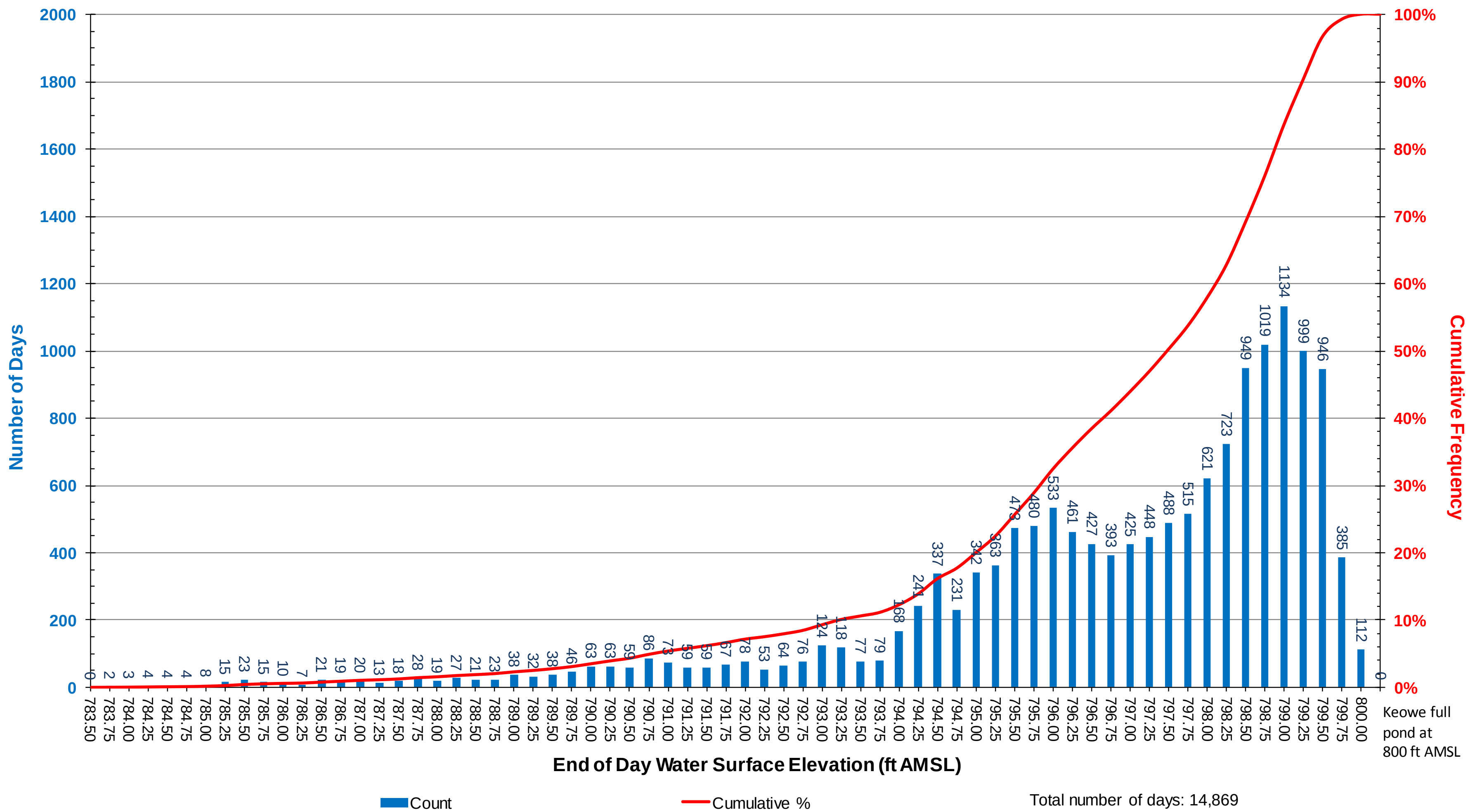
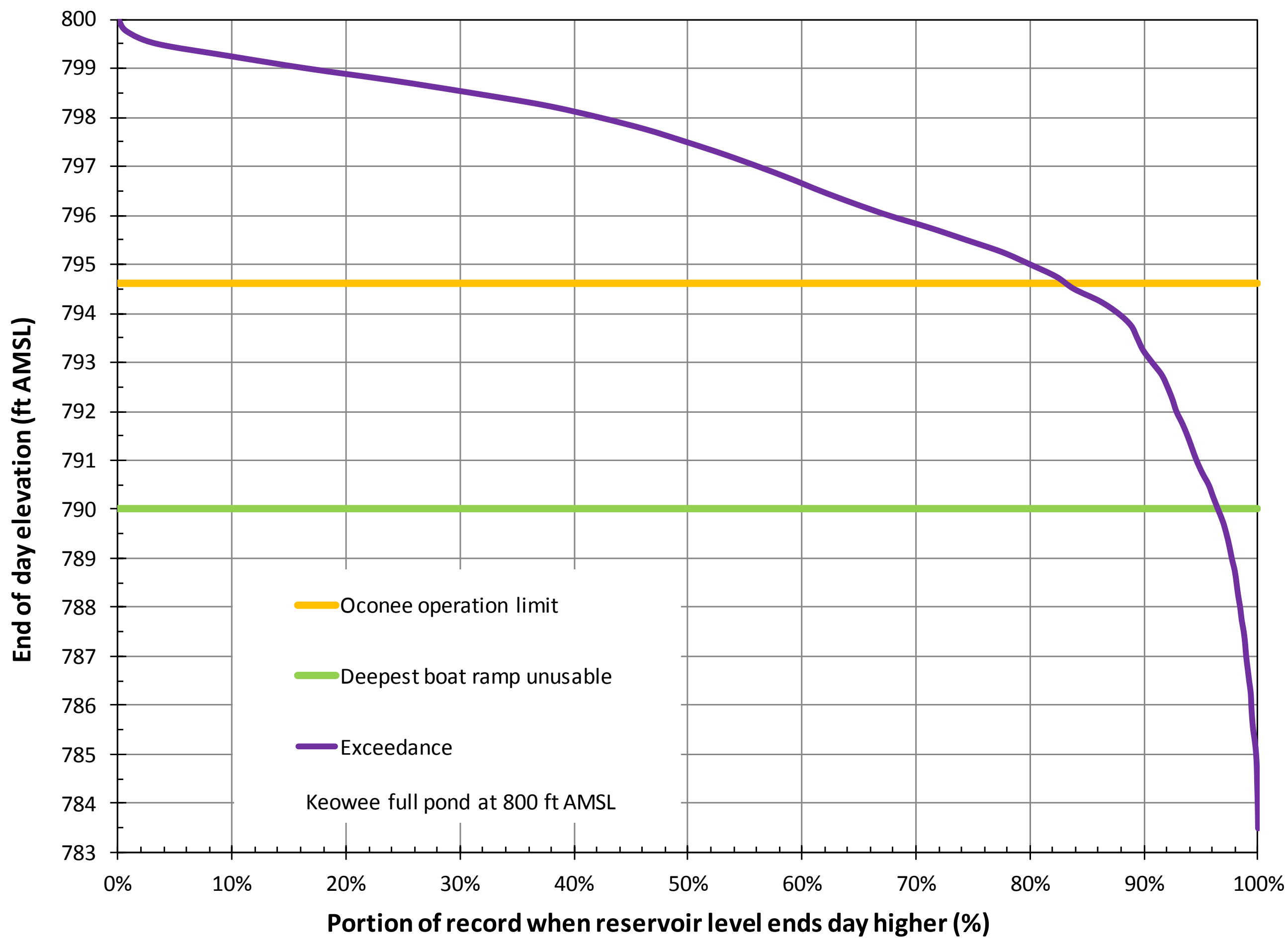
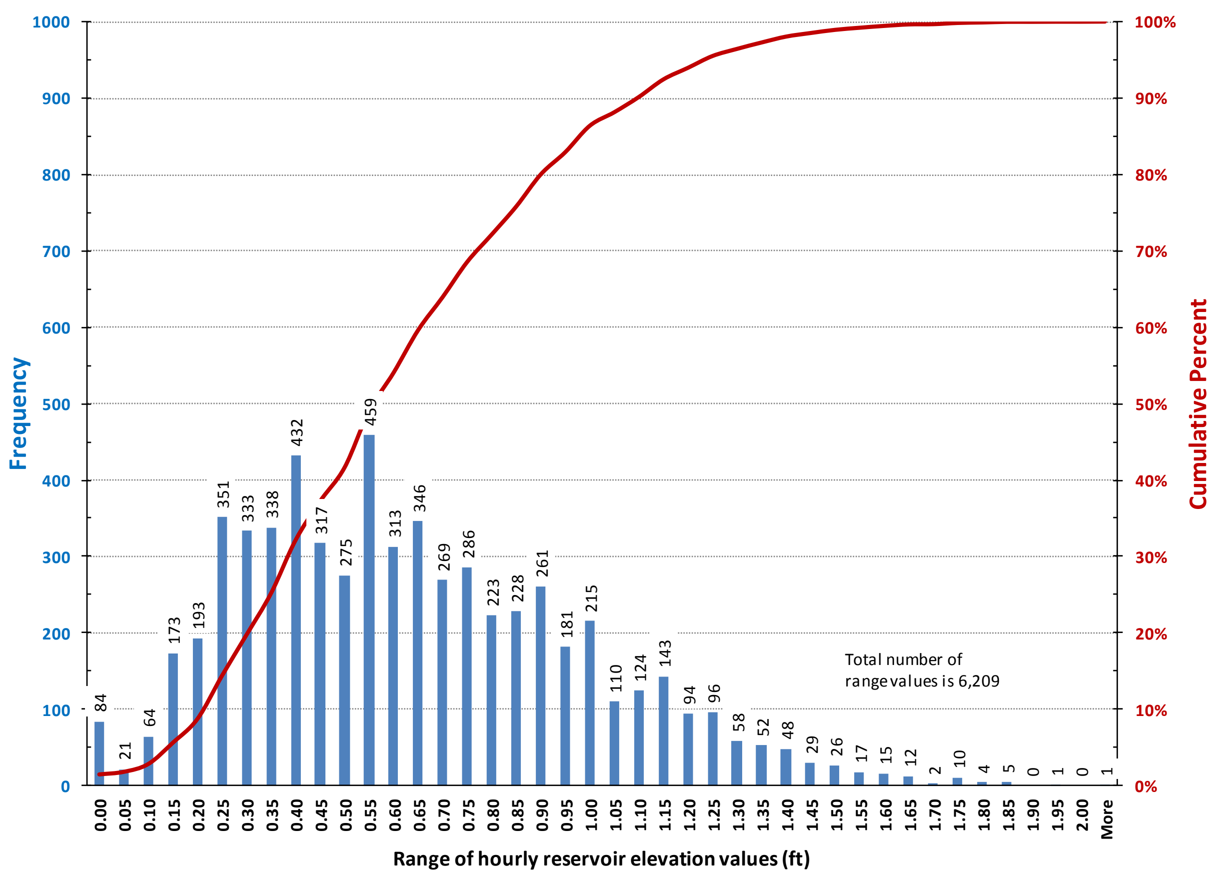


FIGURE 4.3-4
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
APRIL 17, 1971, THROUGH DECEMBER 31, 2011



Figures 4.3-1 through 4.3-4 were developed from the Lake Keowee daily elevations database. In contrast, Figure 4.3-5 was developed from the Lake Keowee hourly database. Figure 4.3-5 can be used to gain insight into how much the Lake Keowee elevation changed during the course of a single day. The histogram and cumulative frequency curve in this figure show the distribution of daily differences between the highest and lowest reservoir elevations (i.e., the daily range of reservoir elevations) during the period 1995 through 2011. From the cumulative percent curve in Figure 4.3-5, the median (50 percent exceedance) daily fluctuation is about 0.55 ft with approximately 86 percent of the daily fluctuations less than 1.0 ft and almost all daily fluctuations less than 1.8 ft.

FIGURE 4.3-5
HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
FOR DAILY RANGE OF LAKE KEOWEE HOURLY ELEVATIONS
JANUARY 1, 1995, THROUGH DECEMBER 31, 2011



4.3.2 Lake Jocassee Level Charts

Figure 4.3-6 shows daily reservoir elevations for Lake Jocassee covering the Jocassee POR. The Normal Full Pond Elevation for Lake Jocassee is 1,110 ft AMSL. Like the Keowee Development, the Jocassee Development's turbines and gated spillway are operated so the reservoir elevation never exceeds the Normal Full Pond Elevation. The significant operating levels from Table 1.2-1 are shown on Figure 4.3-6. The elevation of the deepest boat ramp is indicated by a solid green line. All boat ramps are unusable when the reservoir elevation drops below 1,080 ft AMSL.

Figures 4.3-7(a) and 4.3-7(b) are Hayes charts showing Lake Jocassee elevations for the Jocassee POR. The charts are constructed exactly as described for Figures 4.3-2(a) and 4.3-2(b) with one chart for the entire POR and the other restricted to data from non-drought periods.

Figure 4.3-8 shows the histogram of all 13,394 reservoir elevations in the Jocassee POR. The histogram and cumulative frequency curve are prepared as described for Figure 4.3-3. Due to the greater fluctuation of Lake Jocassee levels, the horizontal axis for the Lake Jocassee histogram is presented in 0.50 ft increments, and the horizontal axis for the Lake Keowee histogram is presented in 0.25 ft increments. Figure 4.3-8 can be interpreted the same way as Figure 4.3-3. For example, there were 1,041 daily elevations between 1,107.5 and 1,108.0 ft AMSL at Lake Jocassee. This number can also be read on the left vertical axis. The cumulative frequency value for the reservoir elevations is read on the right vertical axis. For example, 81 percent of daily reservoir elevations were at or below 1,108.0 ft AMSL.

FIGURE 4.3-6
LAKE JOCASSEE WATER SURFACE ELEVATIONS
MAY 1, 1975, THROUGH DECEMBER 31, 2011

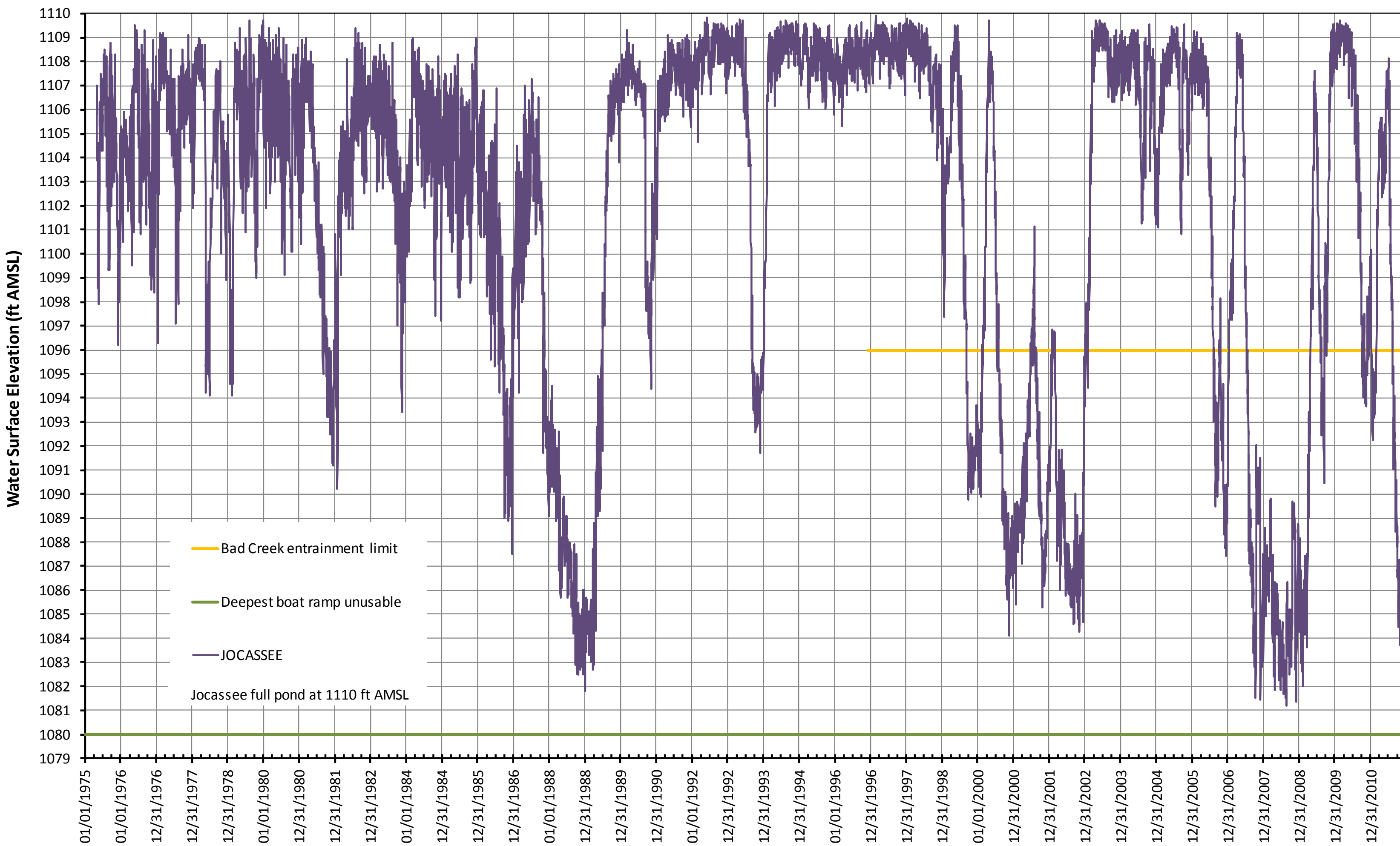


FIGURE 4.3-7(a)
HAYES CHART FOR ALL LAKE JOCASSEE DAILY WATER SURFACE ELEVATIONS
MAY 1, 1975, THROUGH DECEMBER 31, 2011

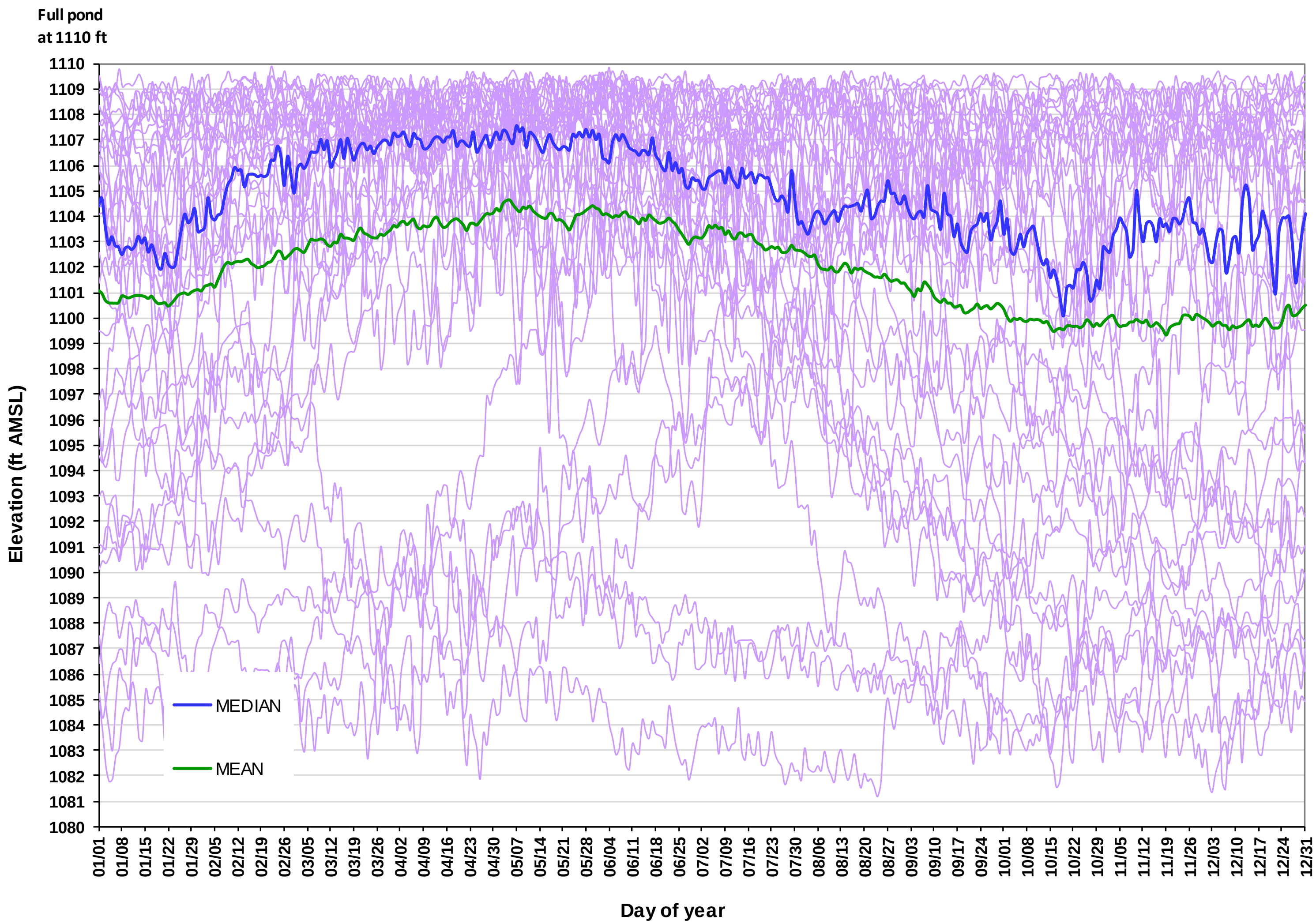


FIGURE 4.3-7(b)
HAYES CHART FOR NON-DROUGHT LAKE JOCASSEE DAILY WATER SURFACE ELEVATIONS
MAY 1, 1975, THROUGH DECEMBER 31, 2011

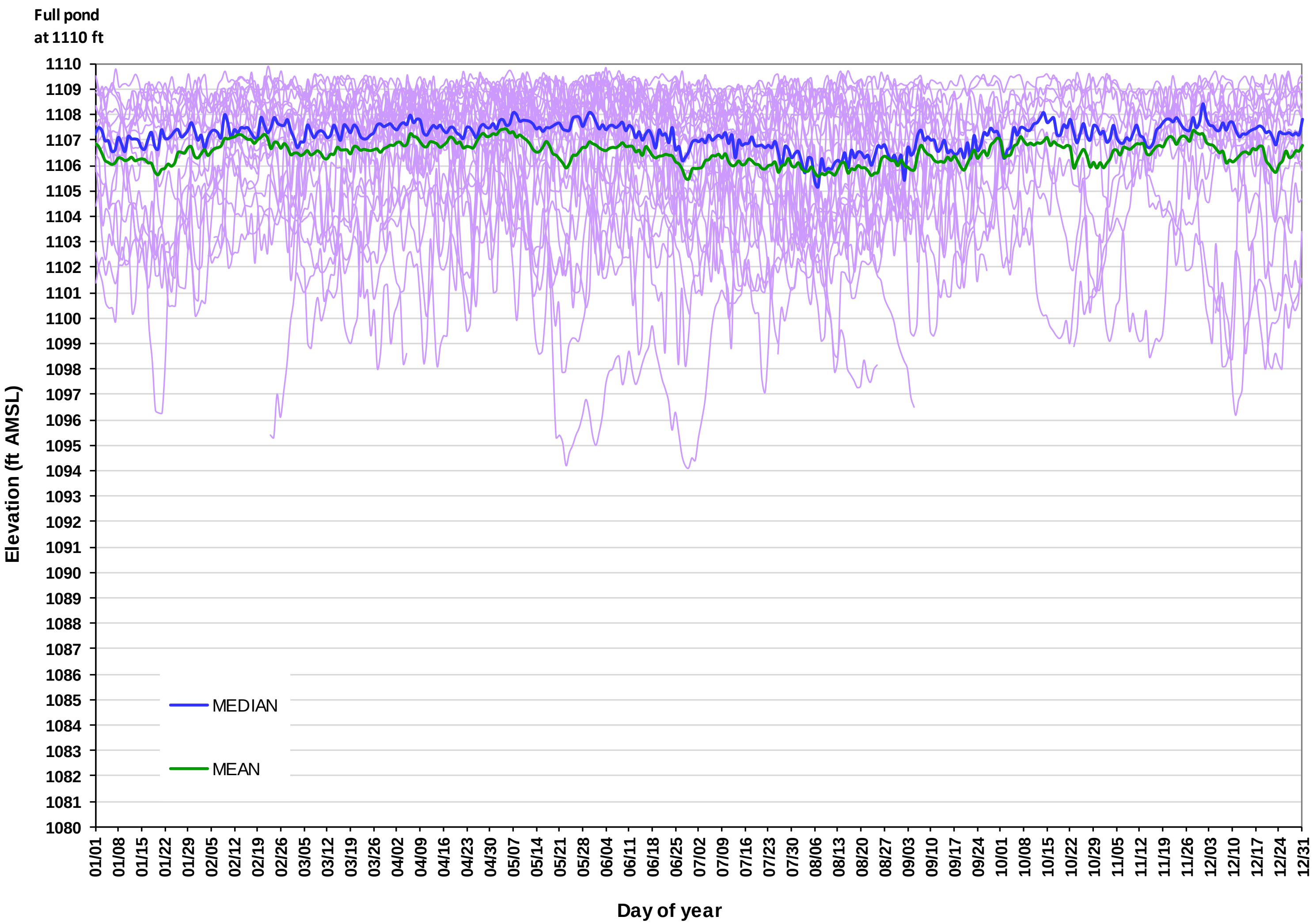
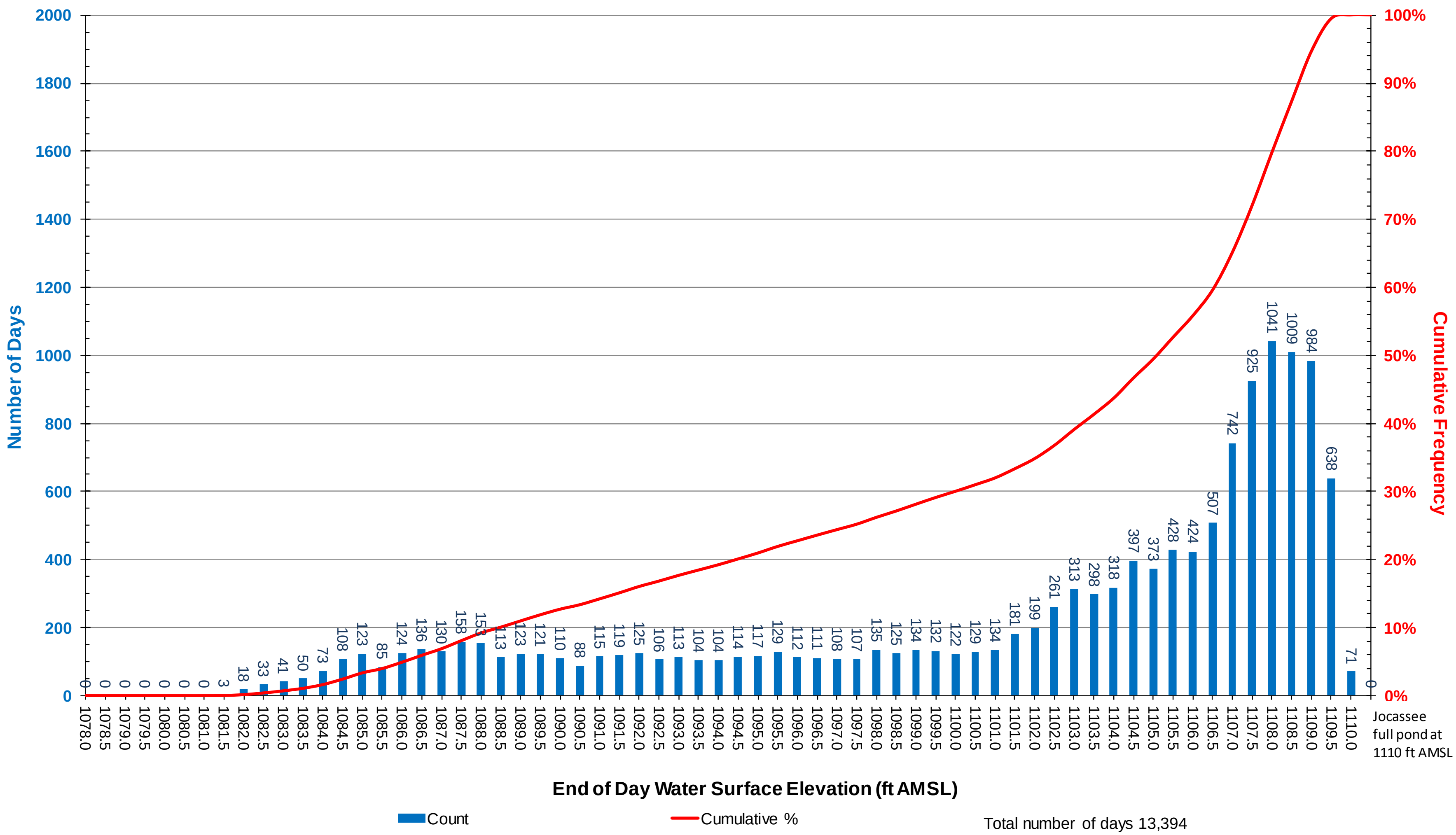


FIGURE 4.3-8
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
MAY 1, 1975, THROUGH DECEMBER 31, 2011



Monthly Figures 4.3-8(a) through 4.3-8(l) show 12 histograms and cumulative frequency curves in the same format as Figure 4.3-8. These monthly histograms appear in Appendix A at the end of this report.

Figure 4.3-9 shows the exceedance curve for the 13,394 reservoir elevations in the Jocassee POR. This figure can be read in the same way as Figure 4.3-4. For example, 19 percent of all reservoir elevation readings were higher than 1,108 ft AMSL. This figure shows the deepest boat ramp (1,080 ft AMSL) was available 100 percent of the time.

Monthly Figures 4.3-9(a) through 4.3-9(l) are the 12 exceedance curves prepared as described for Figures 4.3-4(a) through 4.3-4(l). These monthly exceedance curves appear in Appendix A at the end of this report.

Figure 4.3-10 was developed from the Lake Jocassee hourly elevation database in the same way that Figure 4.3-5 was developed from the Lake Keowee hourly database. Note the difference in the x-axis. The Keowee chart has bin increments of 0.05 ft, and the Jocassee chart has bin increments of 0.10 ft. The Jocassee histogram and cumulative frequency curve in Figure 4.3-10 show the distribution of daily differences between the highest and lowest reservoir elevations (i.e., the daily range of reservoir elevations) during the period for which hourly data was available – 1995 through 2011. From the cumulative percent curve in Figure 4.3-10, the median (50 percent exceedance) daily fluctuation is about 0.8 ft with approximately 88 percent of the daily fluctuations less than 1.5 ft and virtually all daily fluctuations less than 2.9 ft.

4.3.3 Combined Lake Keowee and Lake Jocassee Chart

Figure 4.3-11 shows daily reservoir elevations for Lake Keowee and Lake Jocassee for the Jocassee POR (the shorter POR for the two developments) on the same graph. Reservoir elevations are presented in ft AMSL. See Section 5 for a discussion of the influence of the ONS restrictions on Lake Keowee's operation.

FIGURE 4.3-9
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
MAY 1, 1975, THROUGH DECEMBER 31, 2011

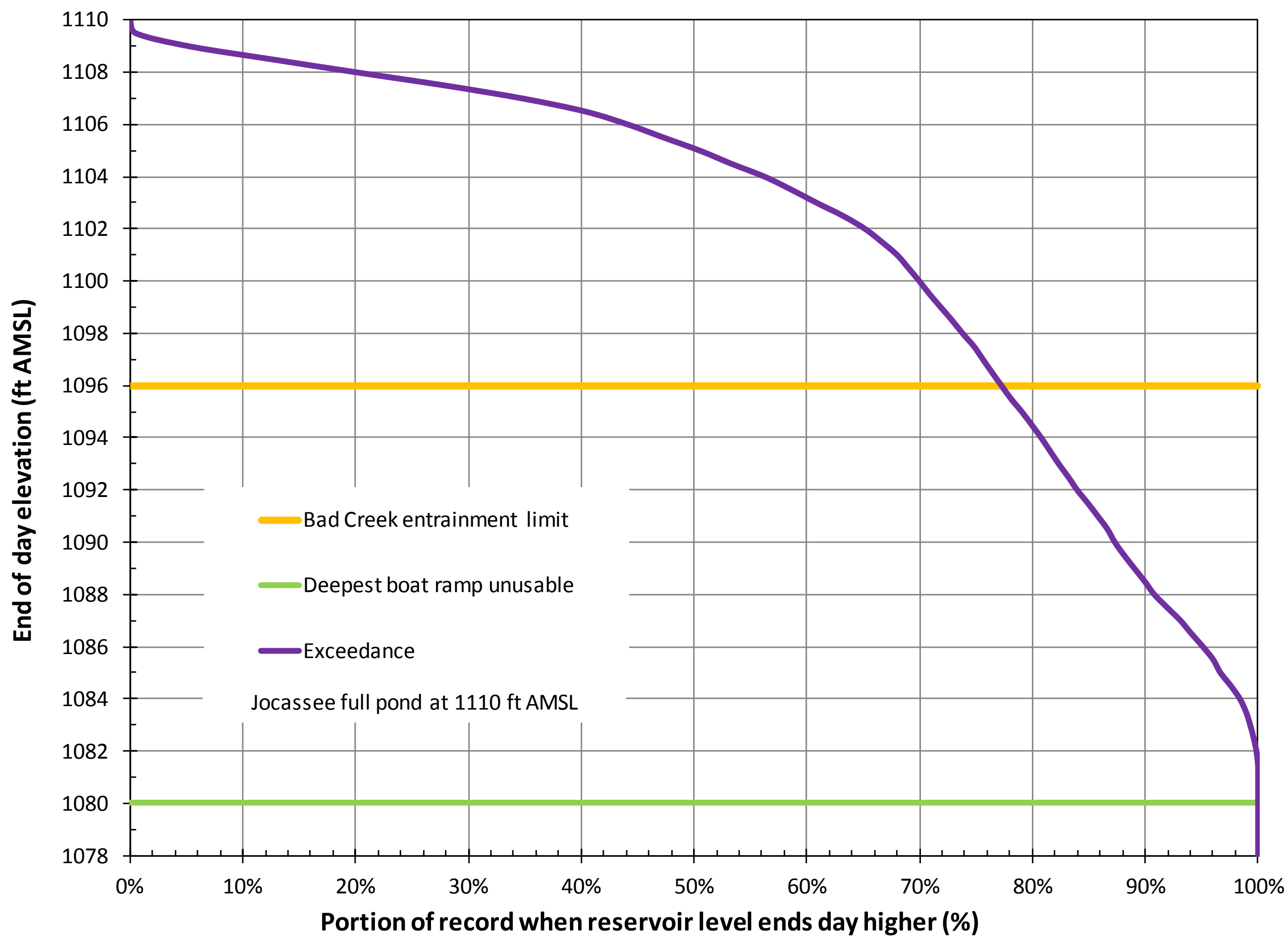


FIGURE 4.3-10
HISTOGRAM AND CUMULATIVE FREQUENCY CURVE SHOWING FOR DAILY RANGE OF LAKE JOCASSEE HOURLY ELEVATIONS JANUARY 1, 1995, THROUGH DECEMBER 31, 2011

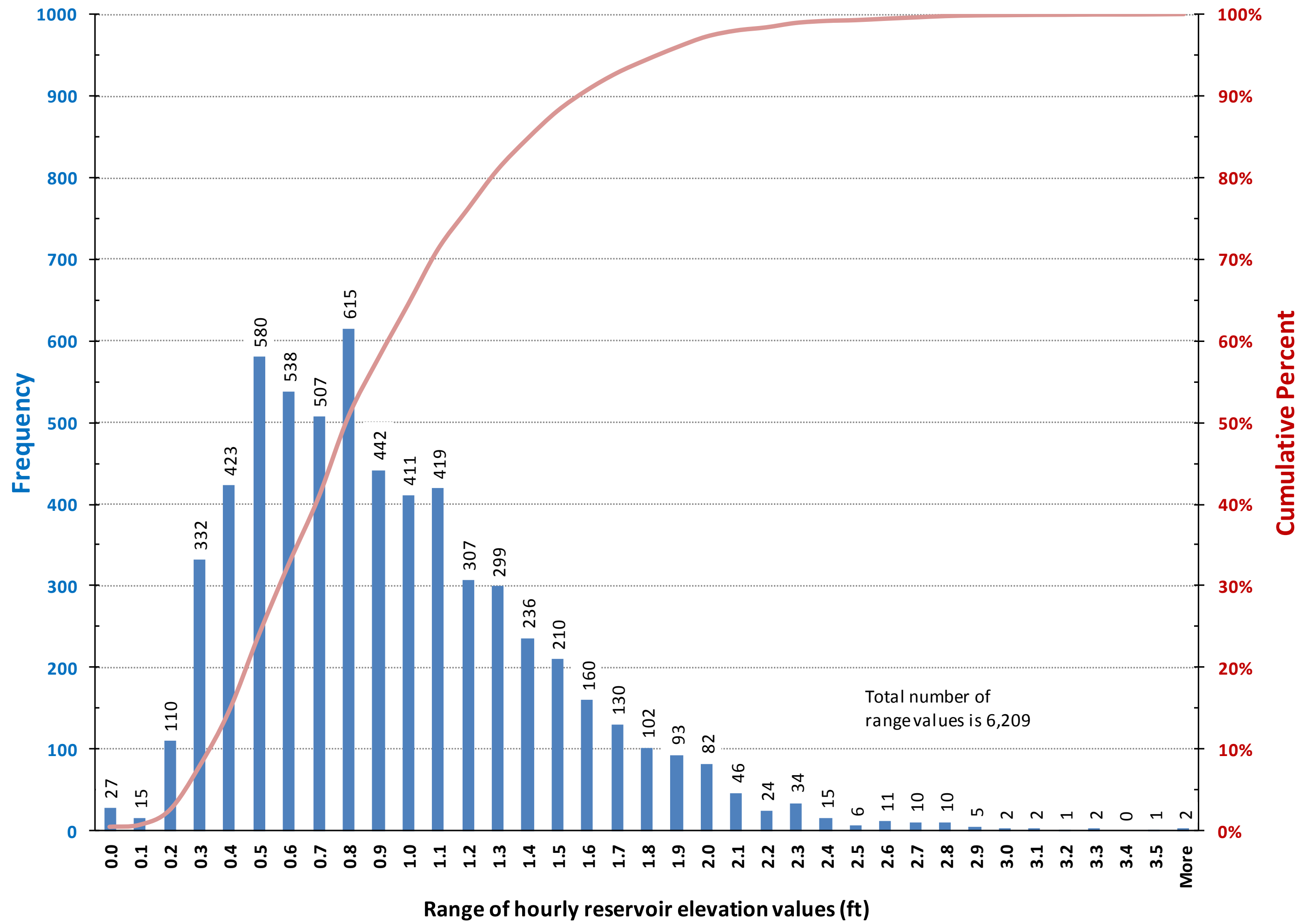
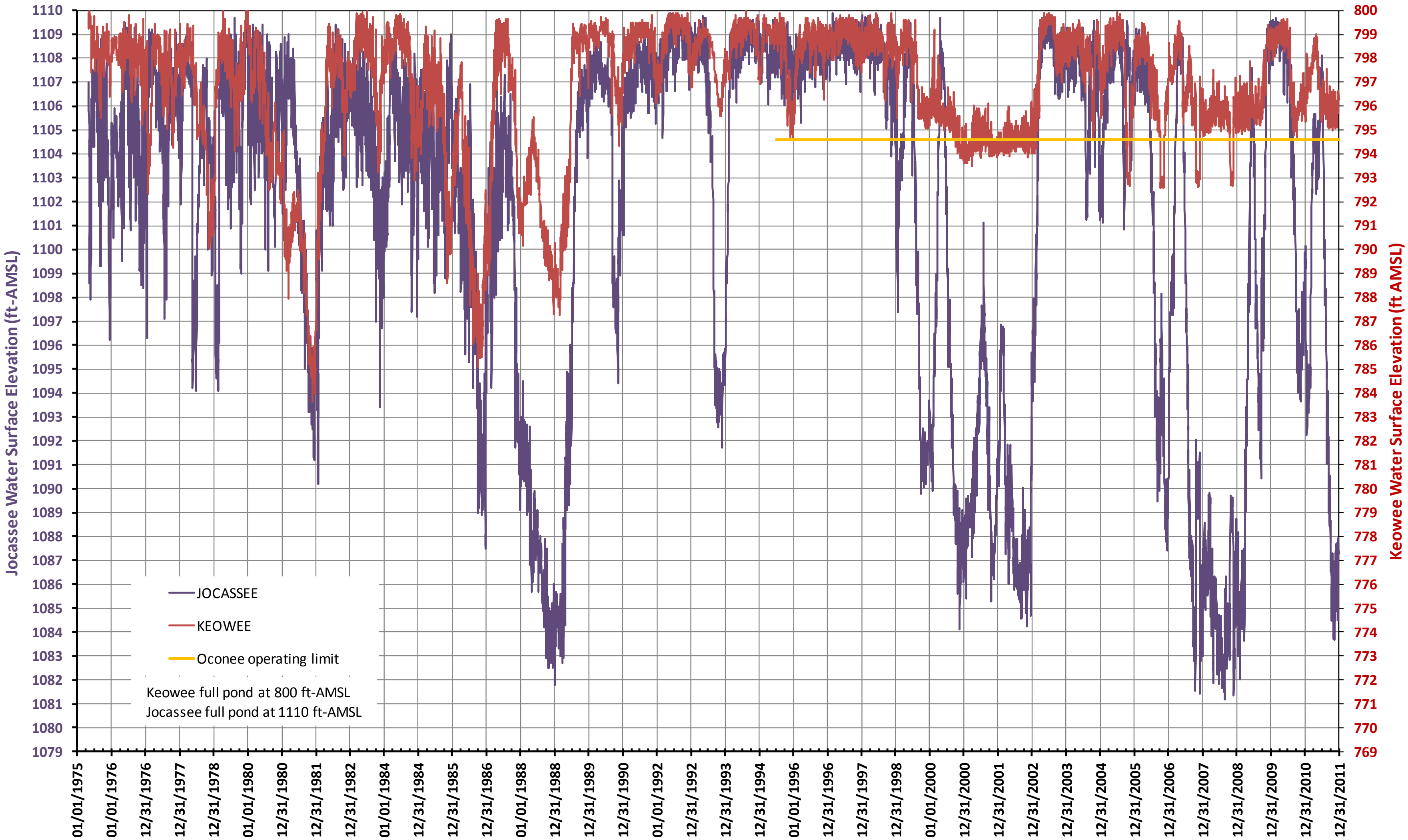


FIGURE 4.3-11
LAKE KEOWEE AND LAKE JOCASSEE WATER SURFACE ELEVATIONS
MAY 1, 1975, THROUGH DECEMBER 31, 2011



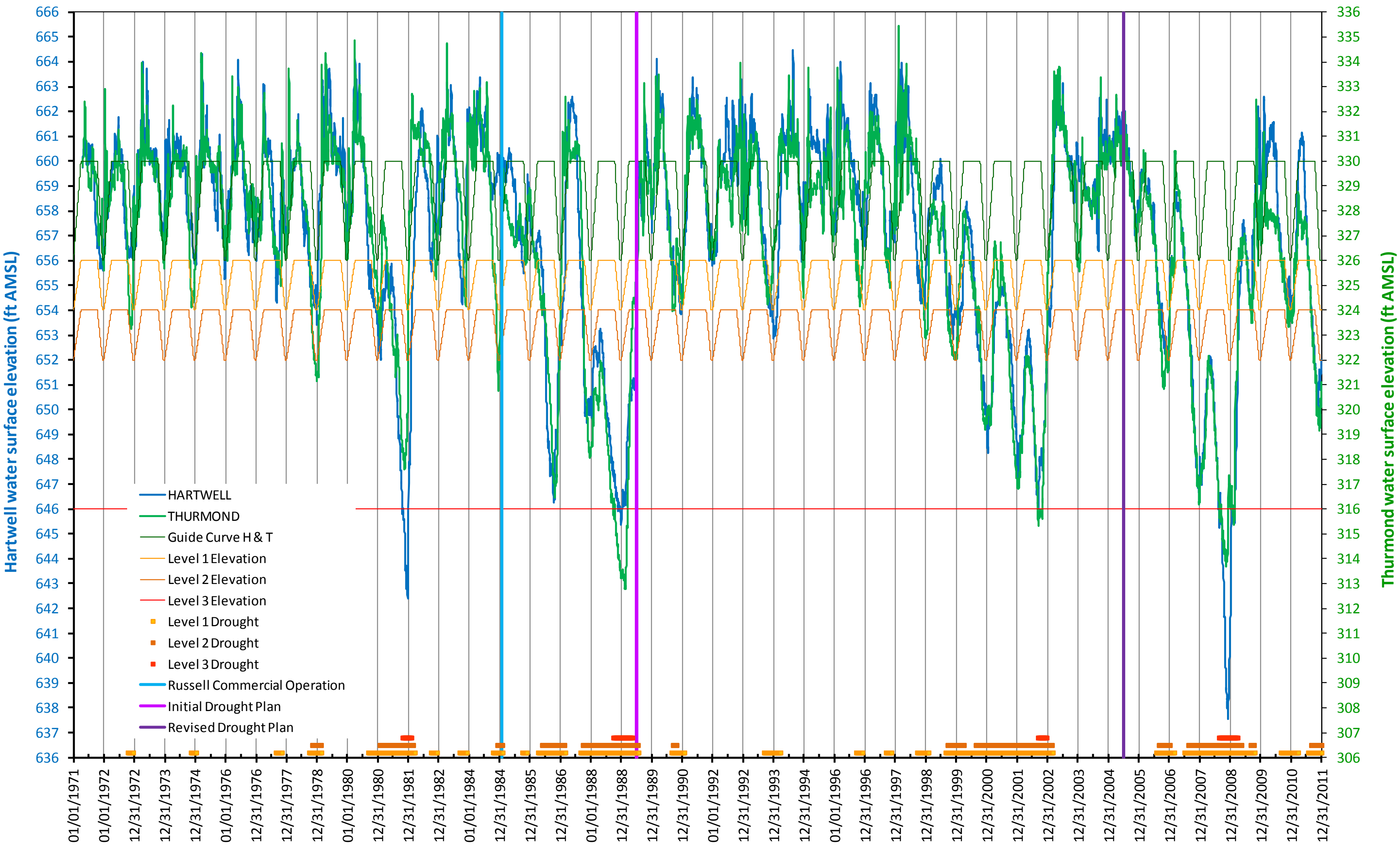
4.4 Upper Savannah River Basin Drought Periods

Figure 4.4-1 shows hypothetical drought levels as if the USACE's definition of drought as set forth in its Savannah River Basin DCP (revised in 2006) had been applied to the entire Keowee POR rather than just for the period after 2006. Guide curves and drought level elevation curves are plotted for each reservoir. The guide curves and drought level elevation curves for Hartwell Lake and JST Lake have the same shape, so they can be shown on their respective axis on the same chart. Hartwell Lake and JST Lake elevations are read on the left and right vertical axes respectively. To facilitate reading this figure in more detail, the data in Figure 4.4-1 was divided into two time periods and charted individually in Figures 4.4-1(a) and 4.4-1(b). Figure 4.4-1(a) covers the period from April 17, 1971, through June 30, 1991, and Figure 4.4-1(b) covers the period from July 1, 1991, through December 31, 2011. Figures 4.4-1(a) and 4.4-1(b) are included in Appendix A at the end of this report.

The Study Team identified drought periods for the Upper Savannah River Basin, including the Keowee and Jocassee Developments, as those periods for which the USACE would have declared a Level 1 drought or higher (i.e., more severe) based on the reservoir elevations at Hartwell Lake and JST Lake. Under the current DCP, a Level 1 drought period starts when either reservoir elevation drops below its Level 1 drought threshold and ends when the reservoir elevations for both reservoirs rise two feet above their Level 1 drought thresholds. The resulting Level 1 drought periods are indicated by horizontal orange bars at the bottom of the figure, just above the x-axis. See Table 4-1 for Level 1 drought initiation and termination dates.

Level 2 and 3 drought conditions are determined in a similar way based on the Level 2 and 3 drought threshold elevations. The resulting Level 2 and 3 drought periods are shown as horizontal brown and red bars at the bottom of Figure 4.4-1, with brown Level 2 bars above the orange Level 1 bars and red Level 3 bars above the brown Level 2 bars. See Tables 4.4-2 and 4.4-3 for Level 2 and Level 3 drought initiation and termination dates.

FIGURE 4.4-1
HARTWELL LAKE AND JST LAKE WATER SURFACE ELEVATIONS
APRIL 17, 1971 THROUGH DECEMBER 31, 2011



Three dates of interest from Table 1.2-2 are shown graphically on Figure 4.4-1. The limited commercial operation date of the RBR Pumped Storage Project is displayed as a vertical teal line set at September 15, 1985. The initiation of the Savannah River Basin DCP is displayed as a vertical magenta line set at March 15, 1989. The revision of the DCP currently in use is displayed as a vertical purple line set at September 15, 2006.

Level 1 drought conditions are the least severe drought conditions. The durations of Level 1 drought periods include the durations of any imbedded Level 2 and Level 3 drought periods. Level 2 drought conditions are more severe than Level 1 drought conditions, shorter in duration, and occur less frequently than Level 1 drought conditions. The durations of Level 2 droughts include any imbedded Level 3 drought periods. Similarly, Level 3 drought conditions are more severe than Level 2 drought conditions. Level 3 drought periods are shorter in duration and occur less frequently compared to Level 2 drought conditions. Tables 4.4-1, 4.4-2, and 4.4-3 list the start and end dates of the Level 1, 2, and 3 drought periods shown in Figure 4.4-1.

Tables 4.4-1 through 4.4-3 show that, in the April 17, 1971, through December 31, 2011, study period, about half of the Level 1 drought periods progressed to Level 2 and about one third of the Level 2 drought periods progressed to Level 3. There were no Level 4 drought periods. This smaller number of droughts progressing to Level 3 is explained by the larger reservoir elevation drop from Level 2 to Level 3 compared to the drop from Level 1 to Level 2. This larger drop is evident in Figure 4.4-1.

TABLE 4.4-1
PERIODS OF DROUGHT LEVEL 1 OR GREATER
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

Period	Start Date	End Date	Days
1	10/13/1972	12/18/1972	66
2	11/09/1974	01/13/1975	65
3	08/24/1977	11/06/1977	74
4	09/28/1978	02/23/1979	148
5	09/06/1980	03/21/1982	561
6	09/28/1982	12/12/1982	75
7	09/07/1983	12/05/1983	89
8	10/12/1984	02/06/1985	117
9	09/28/1985	11/23/1985	56
10	04/06/1986	03/01/1987	329
11	08/27/1987	07/26/1989	699
12	08/24/1990	01/27/1991	156
13	09/06/1993	03/25/1994	200
14	09/16/1996	12/03/1996	78
15	09/08/1997	11/15/1997	68
16	09/18/1998	02/04/1999	139
17	08/26/1999	03/06/2003	1,288
18	07/27/2006	03/03/2007	219
19	06/30/2007	10/23/2009	846
20	08/30/2010	03/28/2011	210
21	07/24/2011	After 12/31/2011	161+

TABLE 4.4-2
PERIODS OF DROUGHT LEVEL 2 OR GREATER
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

Period	Start Date	End Date	Days
1	11/03/1978	02/19/1979	108
2	01/21/1981	03/01/1982	404
3	12/03/1984	02/02/1985	61
4	05/24/1986	02/18/1987	270
5	09/25/1987	07/18/1989	662
6	09/10/1990	10/25/1990	45
7	09/19/1999	04/03/2000	197
8	08/22/2000	02/23/2003	915
9	08/28/2006	01/09/2007	134
10	08/16/2007	05/17/2009	640
11	09/02/2009	10/14/2009	42
12	08/15/2011	After 12/31/2011	139+

TABLE 4.4-3
PERIODS OF DROUGHT LEVEL 3 OR GREATER
APRIL 17, 1971, THROUGH DECEMBER 31, 2011

Period	Start Date	End Date	Days
1	10/23/1981	02/07/1982	107
2	09/25/1988	05/13/1989	230
3	09/07/2002	12/21/2002	105
4	08/18/2008	03/31/2009	225

In Table 4.4-4, the durations of the Level 1 through 4 droughts are totaled for three periods of interest:

Period 1 – the entire Lake Keowee POR

Period 2 – after the March 1989 initiation of the first Savannah River Basin DCP

Period 3 – after the 1995 establishment of the ONS-based drawdown limits on Lake Keowee

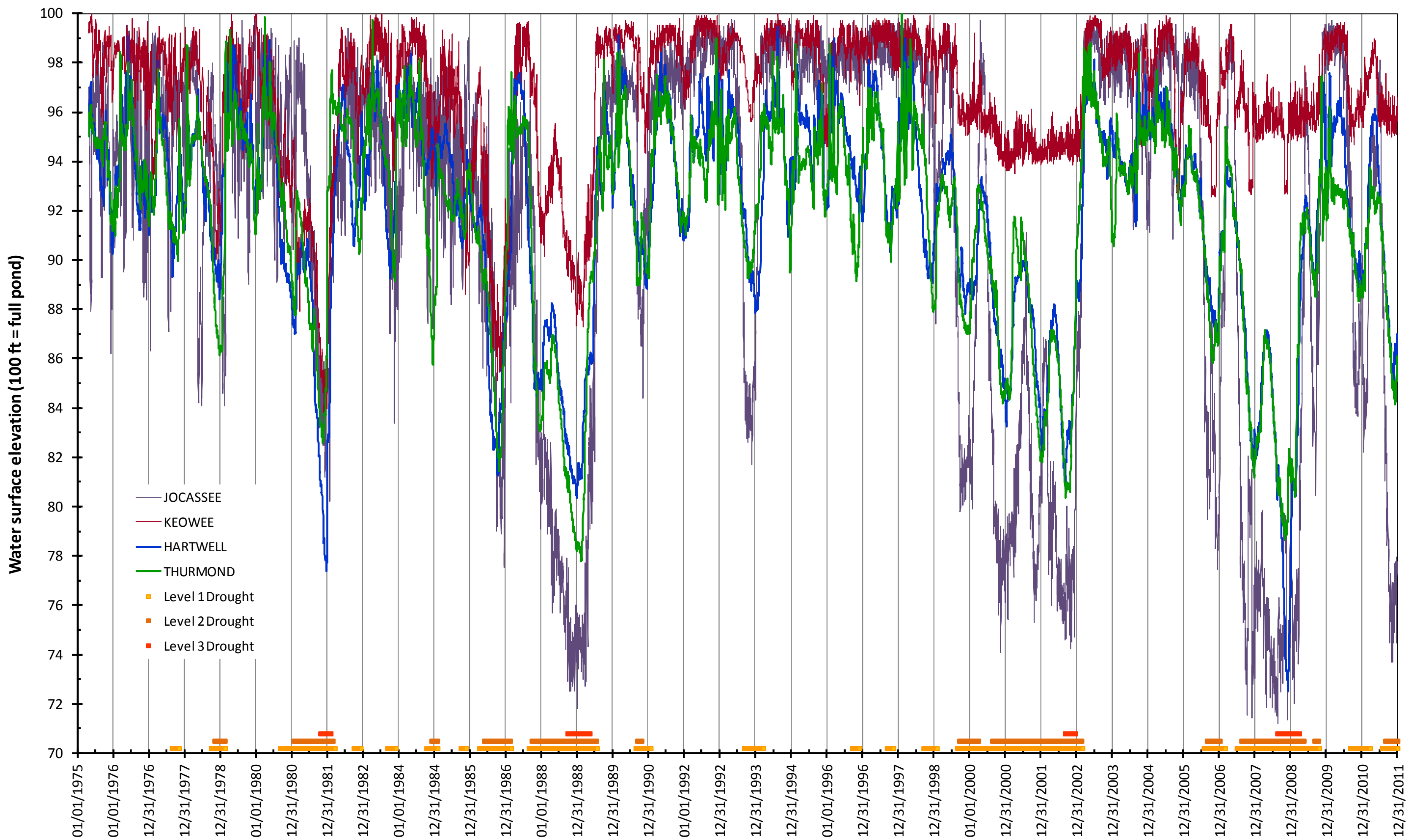
TABLE 4.4-4
NUMBER OF DROUGHT DAYS IN VARIOUS PERIODS OF INTEREST

USACE Drought Level	Period 1 April 17, 1971 through 2011		Period 2 March 1989 through 2011		Period 3 January 1995 through 2011	
	Days	Percent	Days	Percent	Days	Percent
All Days in Period	14,869	100.0	8,341	100.0	6,209	100.0
Level 1 or Greater	5,644	38.0	3,365	40.3	3,009	48.5
Level 2 or Greater	3,617	24.3	2,112	25.3	2,067	33.3
Level 3 or Greater	667	4.5	330	4.0	330	5.3
Level 4	0	0.0	0	0.0	0	0.0

Although the number of days in each drought level decreases going from Period 1 to Period 3, the percentage of drought days increases. This is a reflection of the longer and more severe droughts in more recent years.

Figure 4.4-2 shows reservoir elevations of the Duke Energy reservoirs and the USACE reservoirs along with the USACE drought designations from 1975 through 2011. Figure 4.4-2 is a combination of Figure 4.3-11 and Figure 4.4-1 without guide curves and drought level elevation curves plotted. In order to plot all four reservoir elevations in the same figure, the elevations were converted to a common local datum. In Figure 4.4-2, the top of the flood pool for USACE reservoirs and the top of the operating range (point of incipient spill) for the Duke Energy reservoirs are defined as 100 ft (local datum), which corresponds to 335 ft for JST Lake, 665 ft for Hartwell Lake, 800 ft for Lake Keowee, and 1,110 ft for Lake Jocassee. The start date is May 1, 1975, which is the most recent commercial operation date of the four developments.

FIGURE 4.4-2
USACE AND DUKE ENERGY RESERVOIR SURFACE ELEVATIONS
MAY 1, 1975 THROUGH DECEMBER 31, 2011



Although the reservoir elevations for RBR Lake do not play a direct role in determining the Savannah River Basin drought level, the data were plotted to analyze seasonal patterns. Figure 4.4-3 displays daily reservoir elevations for RBR Lake from January 1, 1985, through December 31, 2011. Figure 4.4-4 is a Hayes chart based on these daily elevations.

FIGURE 4.4-3
RBR LAKE WATER SURFACE ELEVATIONS
JANUARY 1, 1985, THROUGH DECEMBER 31, 2011

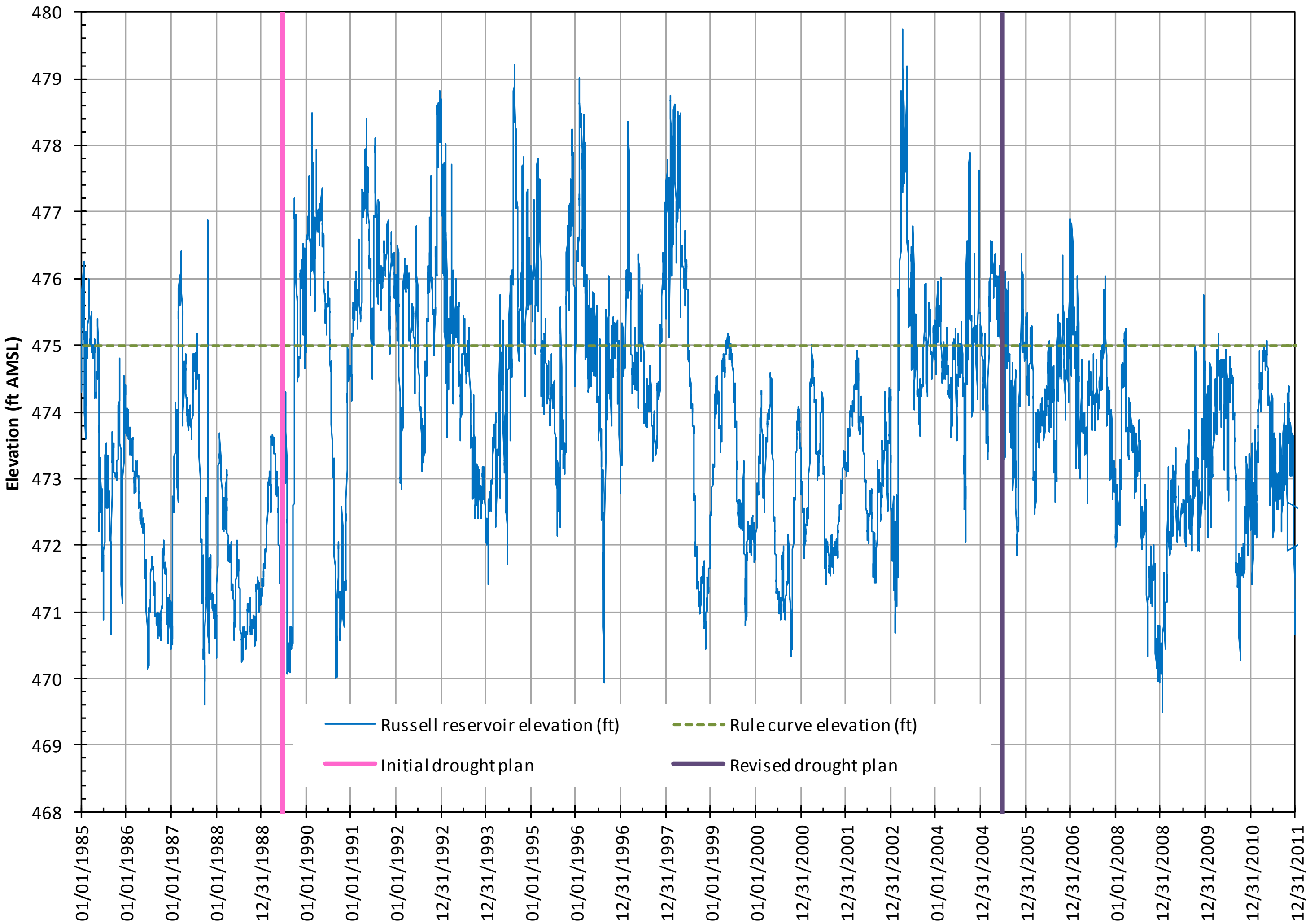
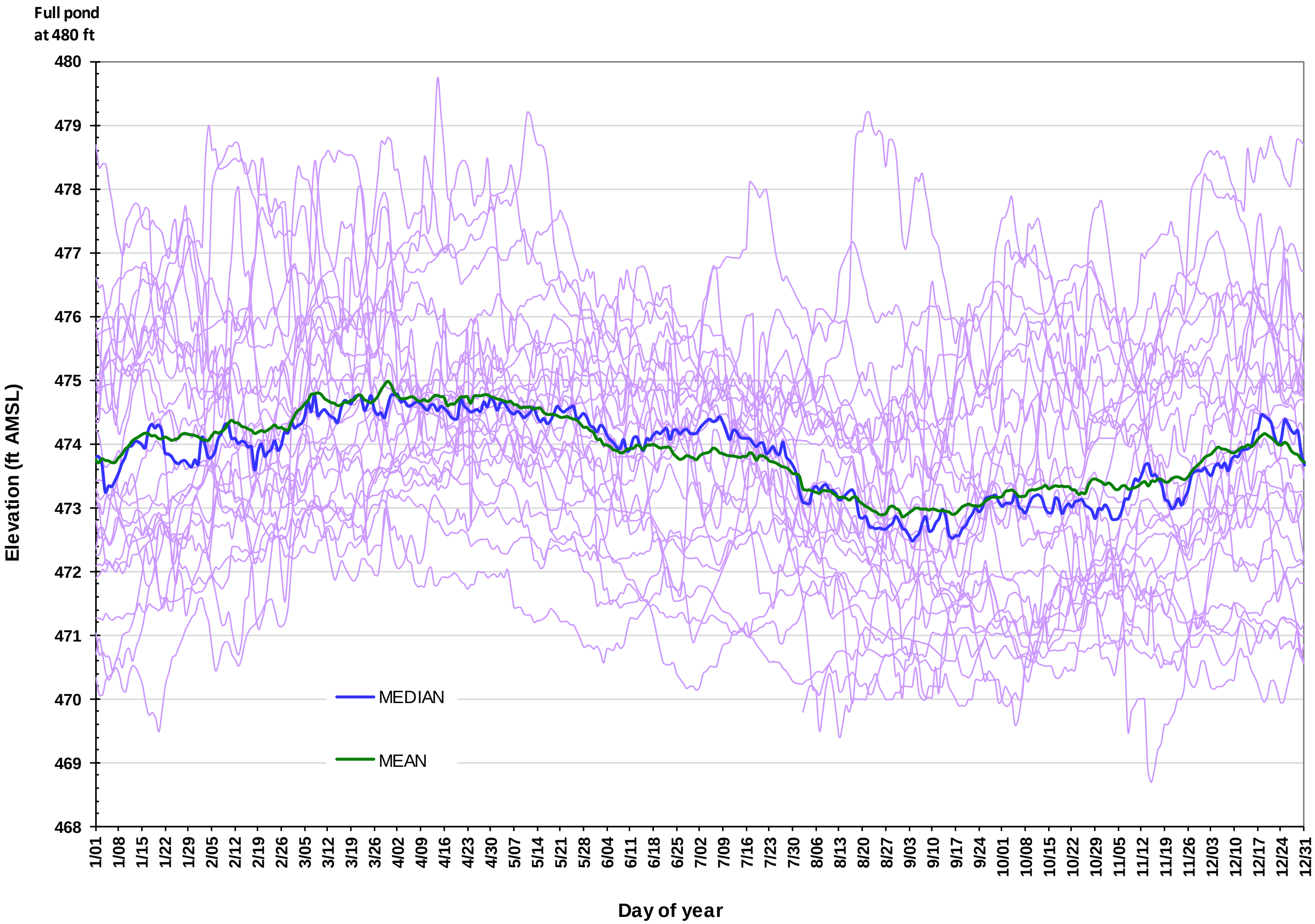


FIGURE 4.4-4
HAYES CHART OF RBR LAKE DAILY WATER SURFACE ELEVATIONS
JANUARY 1, 1985, THROUGH DECEMBER 31, 2011



4.5 Potential Reservoir Operating Ranges

4.5.1 Normal Operating Conditions

The Study Team used Figure 4.4-1 and Figure 4.3-11 to reach a consensus that drought periods for the upper Savannah River Basin could be most clearly defined as periods when the USACE would have declared a Level 1 drought based on its DCP as revised in 2006. Using this definition of drought period, Hayes charts were developed for non-drought (normal) periods at Lake Keowee and Lake Jocassee. These Hayes charts are shown in Figure 4.3-2(b) and in Figure 4.3-7(b), respectively. Based on these figures and the corresponding Figures 4.3-2(a) and 4.3-7(a) for the entire PORs of each development, the Study Team proposed a maximum normal drawdown of 5 feet to an elevation of 795 ft AMSL for Lake Keowee and a maximum normal drawdown of 14 feet to an elevation of 1,096 ft AMSL for Lake Jocassee. These elevations are compatible with the levels shown for ONS and Bad Creek in Table 1.2-1. When looking at the entire POR for each development, Figure 4.3-4 shows Lake Keowee exceeding an elevation of 795 ft AMSL approximately 80 percent of the time, and Figure 4.3-9 shows Lake Jocassee exceeding an elevation of 1,096 ft AMSL approximately 78 percent of the time.

4.5.2 Drought Operating Conditions

On July 26, 2012, the Study Team discussed potential drought operations after viewing a number of drought drawdown scenarios. All scenarios are based on the assumption that both reservoirs start the drought period at the bottom of the Normal Operating Ranges proposed in Section 4.5.1 (i.e., Lake Jocassee at 1,096 ft AMSL and Lake Keowee at 795 ft AMSL). In these drought drawdown scenarios, the maximum drought drawdown at Lake Jocassee was assumed to be 1,080 ft AMSL, and a potential maximum drought drawdown of 790 ft AMSL was arbitrarily chosen for Lake Keowee.

Table 4.4-5 shows the normal and drought storage volumes above each elevation in the Lake Keowee operating range. Table 4.4-6 shows the normal and drought storage volumes above each elevation in the Lake Jocassee operating range.

TABLE 4.4-5
LAKE KEOWEE VOLUME AVAILABLE

Reservoir Elevation (ft AMSL)	Incremental Volume (ac-ft)	Volume Above Elevation (ac-ft)	
		Normal Operation	Drought Operation
800	17,362	0	- - -
799	17,032	17,362	- - -
798	16,750	34,394	- - -
797	16,492	51,144	- - -
796	16,249	67,636	- - -
795	16,015	83,885	0
794	15,787	99,900	16,015
793	15,565	115,687	31,802
792	15,345	131,252	47,367
791	15,130	146,597	62,712
790	14,921	161,727	77,842
789	14,715	176,648	92,763
788	14,512	191,363	107,478

TABLE 4.4-6
LAKE JOCASSEE VOLUME AVAILABLE

Reservoir Elevation (ft AMSL)	Incremental Volume (ac-ft)	Volume Above Elevation (ac-ft)	
		Normal Operation	Drought Operation
1110	7,967	0	- - -
1109	7,937	7,967	- - -
1108	7,905	15,905	- - -
1107	7,873	23,809	- - -
1106	7,841	31,682	- - -
1105	7,811	39,524	- - -
1104	7,780	47,334	- - -
1103	7,750	55,114	- - -
1102	7,719	62,864	- - -
1101	7,690	70,583	- - -
1100	7,660	78,273	- - -
1099	7,631	85,933	- - -
1098	7,602	93,564	- - -
1097	7,572	101,165	- - -
1096	7,543	108,738	0
1095	7,515	116,281	7,543
1094	7,486	123,796	15,058
1093	7,457	131,281	22,544
1092	7,417	138,738	30,000
1091	7,372	146,154	37,417
1090	7,335	153,526	44,788
1089	7,299	160,861	52,123
1088	7,264	168,159	59,422
1087	7,231	175,424	66,686
1086	7,198	182,655	73,918
1085	7,166	189,853	81,116
1084	7,135	197,019	88,282
1083	7,105	204,154	95,417
1082	7,077	211,259	102,522
1081	7,051	218,336	109,599
1080	7,025	225,387	116,649

There are many possible drought operation scenarios based on the relative drawdown rates of Lake Jocassee and Lake Keowee. Scenarios based on several hypothetical relative drawdown rates were discussed by the Study Team. In addition, there was a general discussion of a fundamental operating principle applicable to multiple reservoirs.

In a system of stair-stepped reservoirs with no-upstream pumping capabilities, it is preferred to hold storage longer in the most upstream reservoirs. In addition, in no-upstream pumping systems, it is important to consider available inflow from the incremental drainage area for each reservoir relative to its working volume, as these influence refill time. The storage in a reservoir with higher refill time should ideally be conserved longer. The Project, however, is not a no-upstream-pumping system, but rather a pumped-storage system. The turbines in the Jocassee powerhouse are capable of reversing to pump water from Lake Keowee to Lake Jocassee; therefore, any runoff from the drainage area upstream of Lake Keowee is available to Lake Jocassee as well. Consequently, these rules of thumb for reservoirs with no-upstream pumping capabilities do not apply to the Project.

The four scenarios below provide a series of potential examples of how Lake Keowee and Lake Jocassee might be operating together during droughts. All of the scenarios assume that, as a drought event begins, both reservoirs are at their respective normal minimum elevation. In all scenarios, the total volume released from both reservoirs is 194,492 ac-ft.

Scenario 1 – Draw Lake Jocassee down 1 ft below elevation 1,096 ft AMSL for each 1 ft Lake Keowee is drawn down below elevation 795 ft AMSL – a Jocassee to Keowee drawdown ratio of 1:1.

- When Lake Keowee reaches its hypothetical maximum drought drawdown of 5 ft, it has released 77,842 ac-ft of water, and Lake Jocassee is at 1,091 ft AMSL having released 37,417 ac-ft of water.
- Lake Keowee is no longer drawn down, and Lake Jocassee continues to draw down 11 more feet to release another 79,233 ac-ft of water.

Scenario 2 – Draw Lake Jocassee down 2 ft for each 1 ft Lake Keowee is drawn down – a Jocassee to Keowee drawdown ratio of 2:1.

- When Lake Keowee reaches its hypothetical maximum drought drawdown of 5 ft, it has released 77,842 ac-ft of water, and Lake Jocassee is at 1,086 ft AMSL having released 73,918 ac-ft of water.
- Lake Keowee is no longer drawn down, and Lake Jocassee continues to draw down 6 more feet to release another 43,732 ac-ft of water.

In this scenario, the volumetric rates of drawdown (e.g., ac-ft per day) are close to equal. In fact, the volumetric drawdown rates are exactly equal when Lake Jocassee is drawn down 2.1 ft for each 1 ft Lake Keowee is drawn down – a Jocassee to Keowee drawdown ratio of 2.1:1.

Scenario 3 – Draw Lake Jocassee down 3 ft for each 1 ft Lake Keowee is drawn down – a Jocassee to Keowee drawdown ratio of 3:1.

- When Lake Keowee reaches its hypothetical maximum drought drawdown of 5 ft, it has released 77,842 ac-ft of water, and Lake Jocassee is at 1,081 ft AMSL having released 109,599 ac-ft of water.
- Lake Keowee is no longer drawn down, and Lake Jocassee continues to draw down 1 more foot to release another 7,051 ac-ft of water.

In this scenario, the volumes of both reservoirs are exhausted at very close to the same time. In fact, the volumes of both reservoirs are used up at exactly the same time when Lake Jocassee is drawn down 3.2 ft for each 1 ft Lake Keowee is drawn down – a Jocassee to Keowee drawdown ratio of 3.2:1.

Scenario 4 – Draw Lake Jocassee down 4 ft for each 1 ft Lake Keowee is drawn down – a Jocassee to Keowee drawdown ratio of 4:1.

- When Lake Jocassee reaches its maximum drought drawdown of 30 ft, it has released 116,649 ac-ft of water, and Lake Keowee is at 791 ft AMSL having released 62,712 ac-ft of water.
- Lake Jocassee is no longer drawn down, and Lake Keowee continues to draw down 1 more foot to release another 15,130 ac-ft of water.

In this scenario, the drought storage volume of Lake Jocassee is exhausted before that of Lake Keowee.

In addition to the four scenarios presented, two others were discussed briefly by the Study Team: one scenario in which Lake Keowee is drawn down to its minimum elevation of 790 ft AMSL before drawing down Lake Jocassee below its normal minimum elevation of 1,096 ft AMSL, and another scenario in which Lake Jocassee is drawn down to its minimum elevation of 1,080 ft AMSL before drawing down Lake Keowee below its normal minimum elevation of 795 ft AMSL. These two extreme scenarios were determined by the Study Team to not represent reasonable potential operating scenarios.

From these scenarios, certain observations can be made.

- All scenarios ultimately result in the same amount of water being released.
- Scenarios 1 and 2 tend to maintain storage volume in Lake Jocassee, thereby, drawing down Lake Keowee early and holding it at a lower elevation through the later drought stages. This could cause Lake Keowee to be at its maximum drawdown longer than Lake Jocassee is at its maximum drawdown.
- Scenario 3 exhausts the storage volume of both reservoirs at almost the same time causing both reservoirs to be at their maximum drawdowns for about the same amount of time.
- Compared to Scenarios 1 and 2, Scenario 4 tends to maintain storage volume in Lake Keowee, thereby, drawing down Lake Jocassee early and holding it at lower elevations in

later drought stages. This could cause Lake Jocassee to be at its maximum drawdown longer than Lake Keowee is at its maximum drawdown.

Multiple drawdown scenarios will be further evaluated using the CHEOPS model developed for the relicensing effort. This will allow relicensing participants to consider the relative effects of different operating scenarios under modeled assumptions for the New License period.

Section 5
Discussion and Analysis

Lake Keowee releases tend to decrease as drought periods are prolonged. This is evident in Figure 4.2-1 and is shown in more detail in Figure 4.2-2 with gradually smaller releases until the release is reduced to leakage at the end of prolonged dry periods. The four-quarter trailing average line in Figure 4.2-3 clearly shows the drought periods throughout the Keowee POR.

As the Project makes releases greater than net inflow during drought periods, reservoir elevations decline. This is evident in the time series plots in Figures 4.3-1 and 4.3-6, which illustrate the decline in reservoir elevations for Lake Keowee and Lake Jocassee, respectively. Lake Keowee and Lake Jocassee elevations are plotted together in Figure 4.3-11. The effects of the ONS reservoir level operating restrictions on Lake Keowee are evident from the mid-1990s to the present with Lake Jocassee being drawn down more often to help preserve Lake Keowee elevations.

The differences between Lake Keowee and Lake Jocassee operating patterns are evident in the Hayes charts. Figures 4.3-2(a) and 4.3-7(a) show more frequent and deeper drawdowns at Lake Jocassee than at Lake Keowee. For both developments, the medians plotted on the Hayes charts in Figures 4.3-2(a) and 4.3-7(a) show generally higher historical reservoir elevations in May and lower historical reservoir elevations near the end of October. When reservoir elevation data from drought periods is excluded in Figures 4.3-2(b) and 4.3-7(b), this pattern is reduced, and the operations of the reservoirs appear to be more similar.

The cumulative frequency curves in Figures 4.3-3 and 4.3-8, which include all data, show a difference between reservoir operations. The broader histogram plot for Lake Jocassee reflects the greater fluctuations in reservoir level as seen in the Hayes charts. Figure 4.3-3 shows the influence of the ONS drawdown limit on Lake Keowee with the secondary concentration of reservoir levels near an elevation of 795 ft AMSL, coinciding with the ONS operating limit.

The potential Normal Operating Ranges for Lake Jocassee and Lake Keowee discussed in Section 4.5 are based on the historical reservoir levels in the POR data set. However, the POR reservoir levels do not take into account potential changes in Project operations nor do they account for future changes in water withdrawals at the Project as identified in the Water Supply Study being conducted for Project relicensing. Accordingly, these potential Normal Operating Ranges should be further evaluated using the CHEOPS model.

Based on the Normal Operating Ranges and the maximum drawdown assumptions discussed in Section 4.5, a number of scenarios for operating during droughts were explored. These scenarios provide a starting point for discussions on how to operate during a drought, but the drawdown strategy can only be finalized when the maximum drawdown for Lake Keowee has been determined and the effect on Project operations has been assessed using the CHEOPS model.

Section 6
References

Duke Energy Carolinas, LLC and SC Department of Natural Resources. 1996. Memorandum of Understanding, Keowee-Toxaway Fishery Resources. Duke Energy Legal Document, Charlotte, North Carolina.

——. 2010. Pre-Application Document for the Keowee-Toxaway Hydroelectric Project.

——. 2011. Comprehensive Environmental, Engineering, and Economic Analysis Impact Report for Revising the 1968 Operating Agreement for the Keowee-Toxaway Project

HDR. 2010. Savannah River Basin Preliminary Water Use Evaluation. Identification of Current Water Users and Water Use. Technical Memorandum No.1, March 18, 2010.

U.S. Army Corps of Engineers. 1989. Corps of Engineers' Drought Management of Savannah River Projects

——. 2010a. Concept of the Savannah River Drought Contingency Plan. [Online] URL: http://water.sas.usace.army.mil/drought/DCP.cfm

——. 2010b. Water Management Page for the Savannah River Projects.[Online] URL: http://water.sas.usace.army.mil/home/indexDU.htm

——. 2012a. Water Management Page for the Savannah River Projects.[Online] URL: http://water.sas.usace.army.mil/lakes/russell/history.htm

——. 2012b. Water Management Page for the Savannah River Projects.[Online] URL: http://water.sas.usace.army.mil/cf/DataQuery/DataQuery.cfm

Appendix A

Supplemental Figures

LAKE KEOWEE AND LAKE JOCASSEE ELEVATIONS
MONTHLY HISTOGRAMS AND EXCEEDANCE CURVES

HARTWELL LAKE AND JST LAKE DROUGHT LEVELS
SEMIANNUAL PLOTS

FIGURE 4.3-3(a)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
JANUARY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

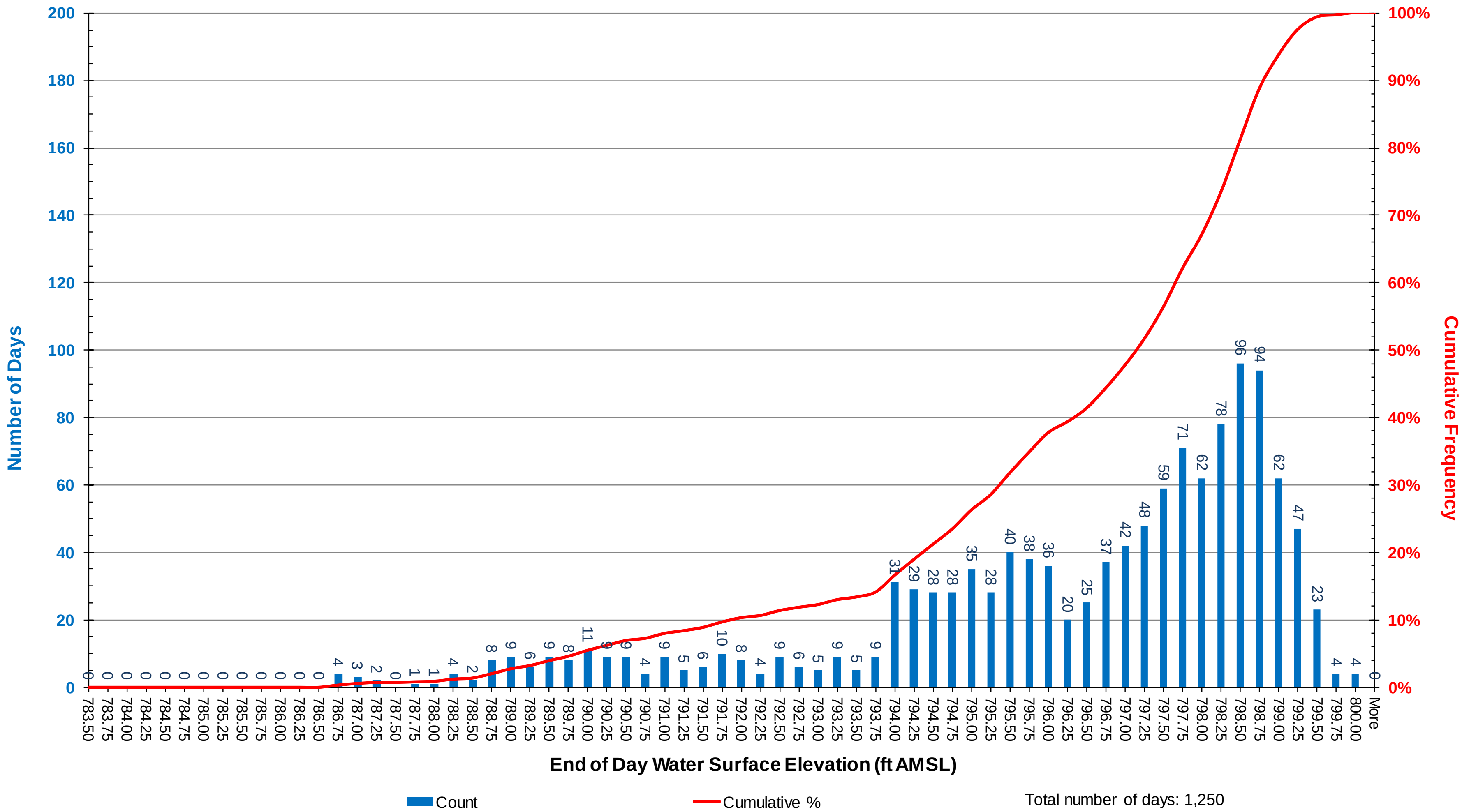


FIGURE 4.3-3(b)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
FEBRUARY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

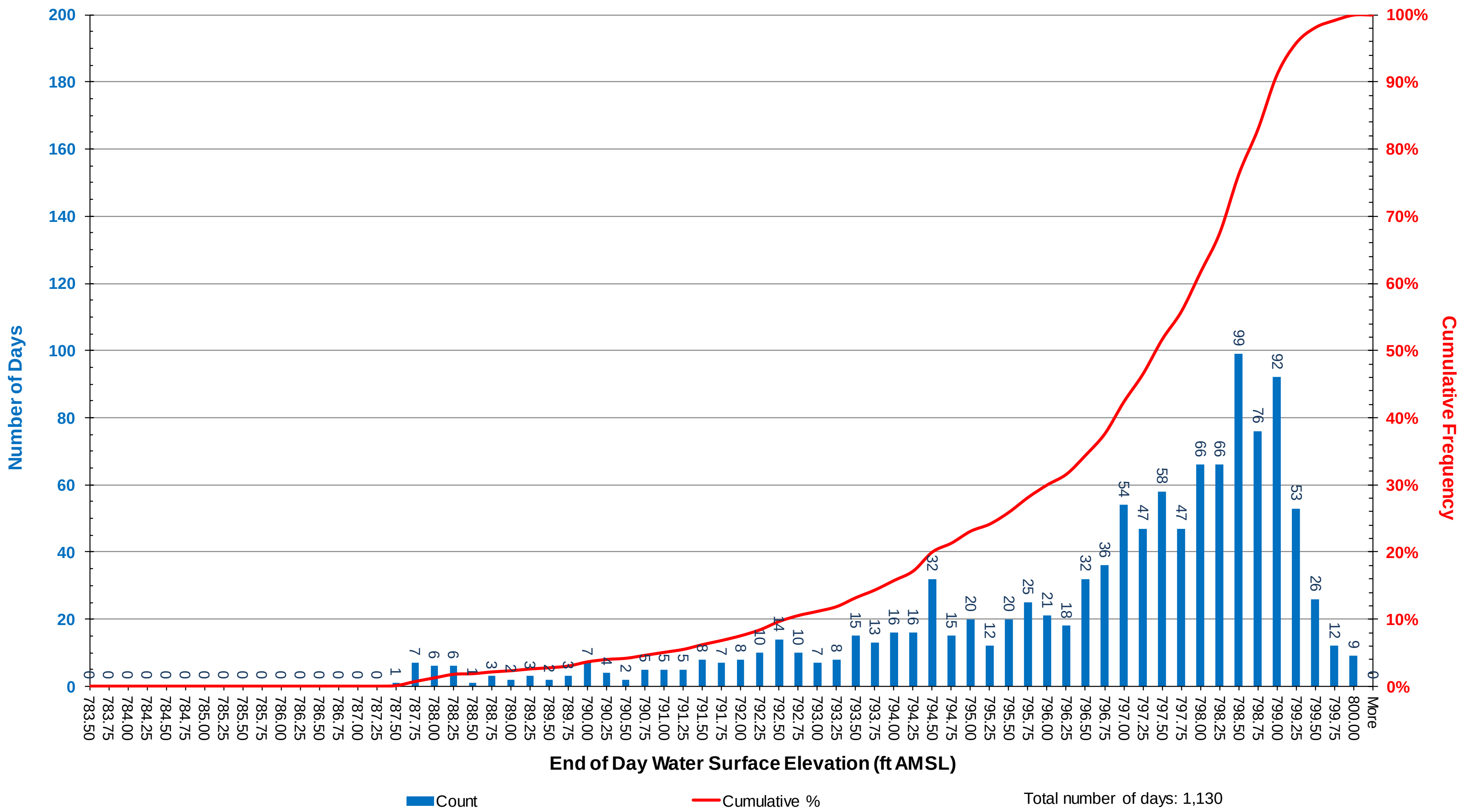


FIGURE 4.3-3(c)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
MARCH DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

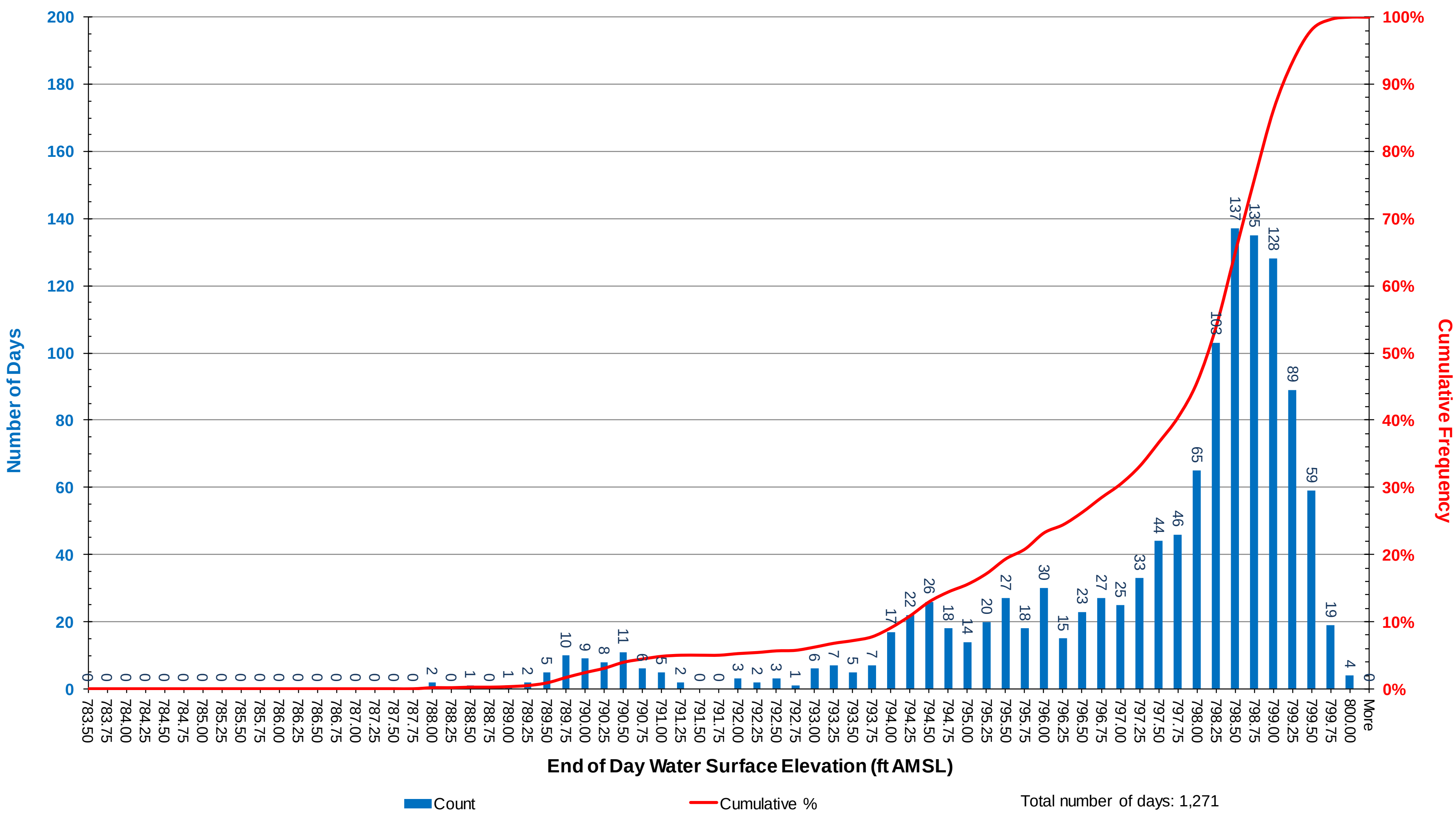


FIGURE 4.3-3(d)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
APRIL DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

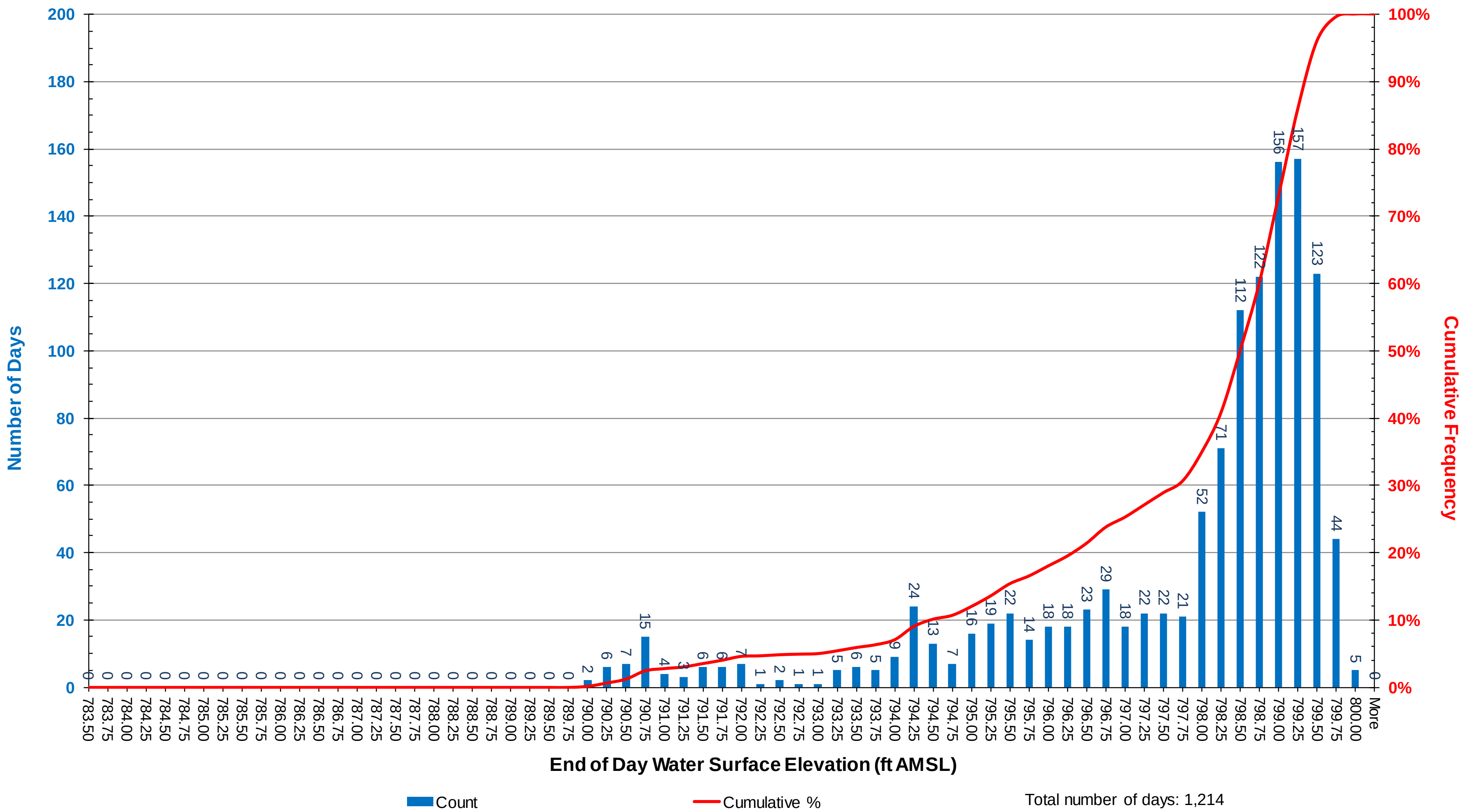


FIGURE 4.3-3(e)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
MAY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

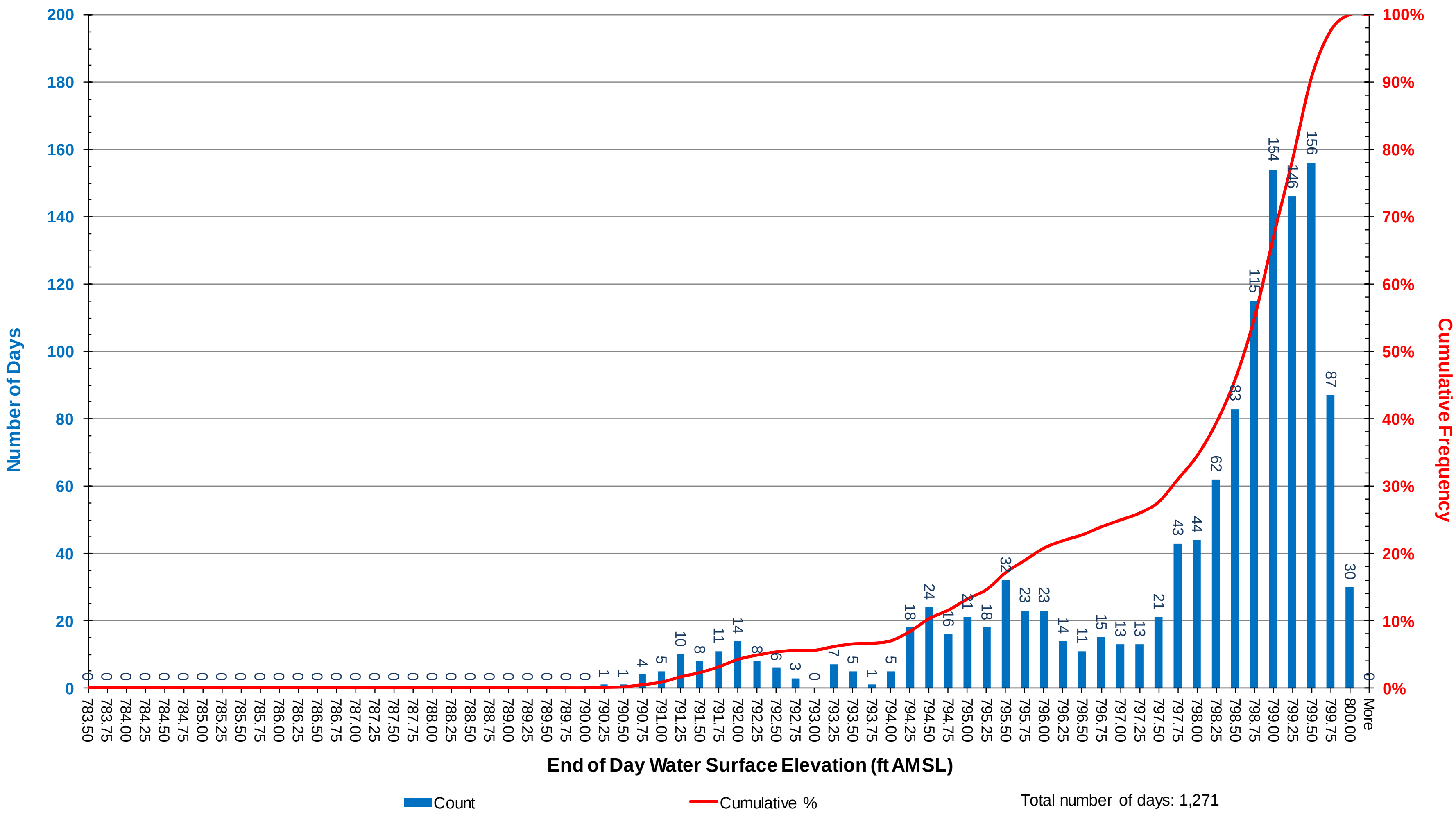


FIGURE 4.3-3(f)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
JUNE DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

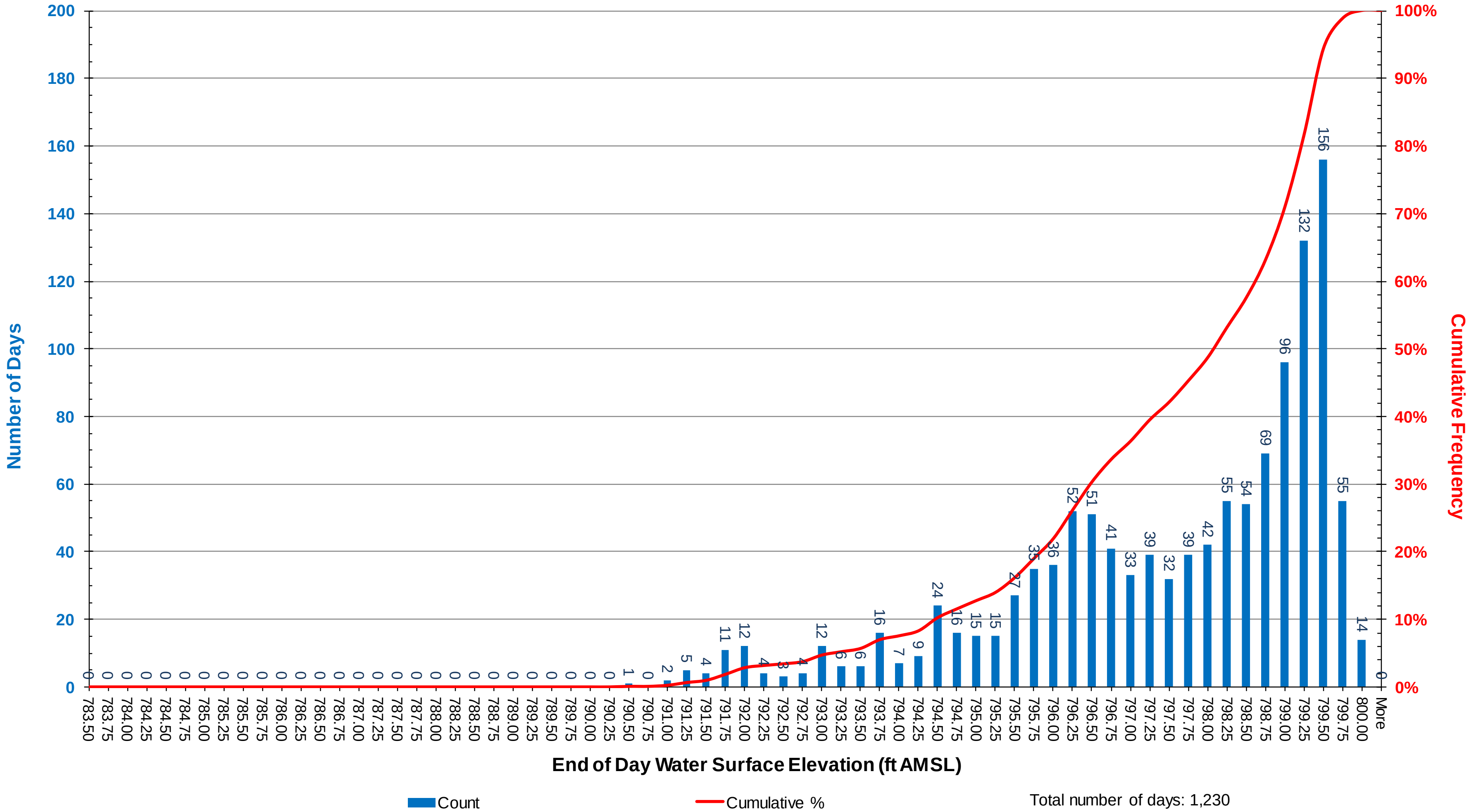


FIGURE 4.3-3(g)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
JULY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

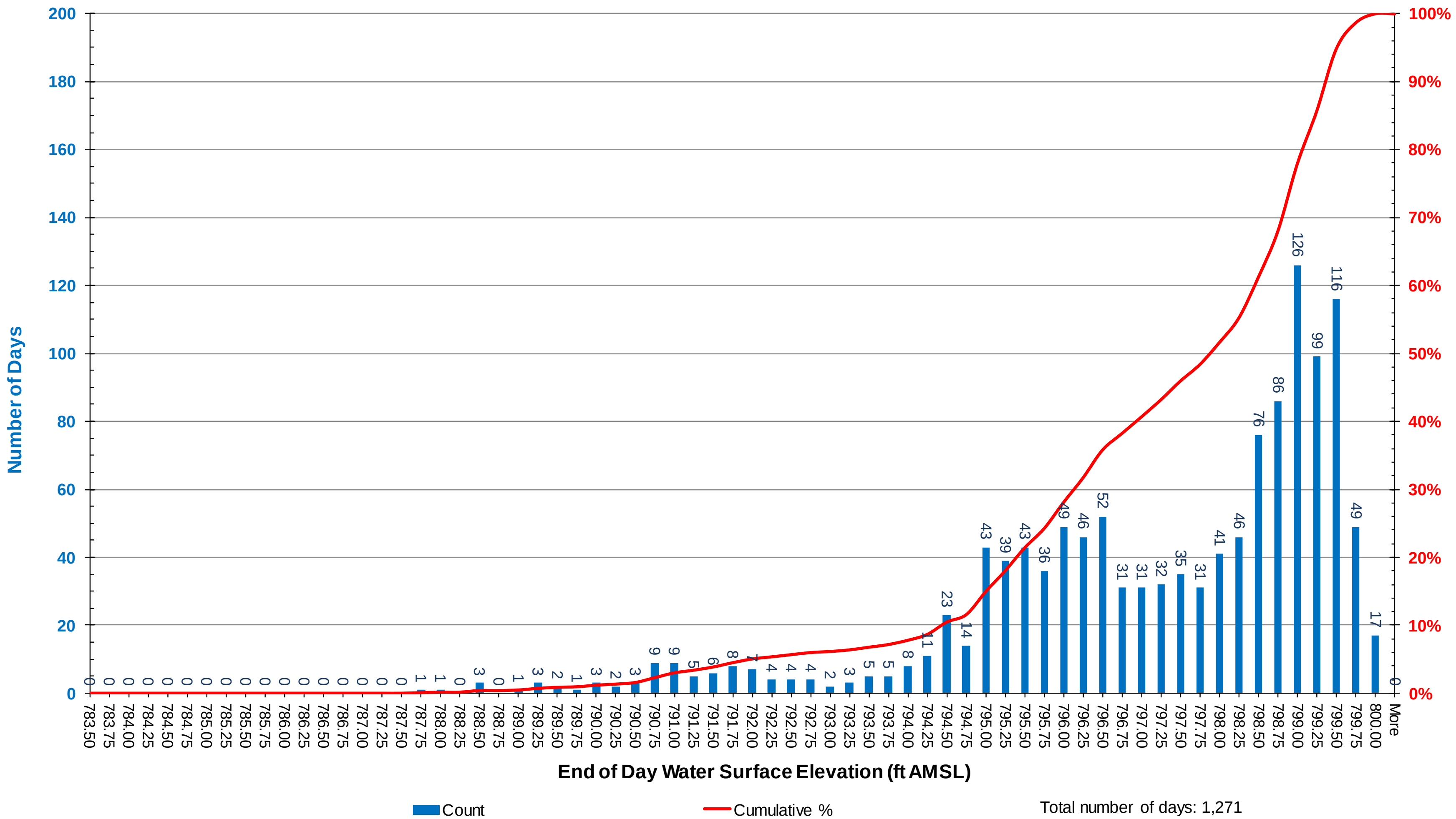


FIGURE 4.3-3(h)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
AUGUST DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

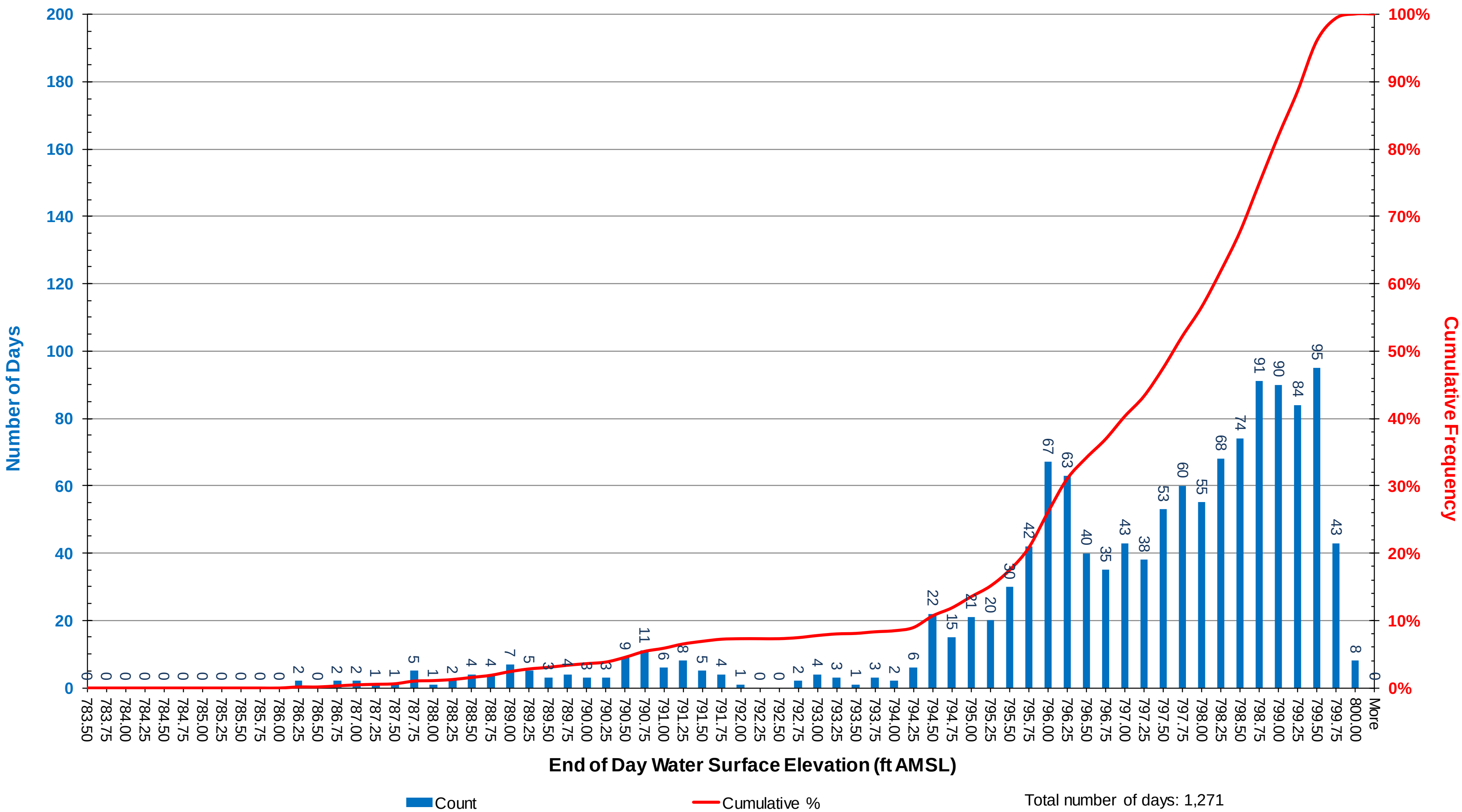


FIGURE 4.3-3(i)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
SEPTEMBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

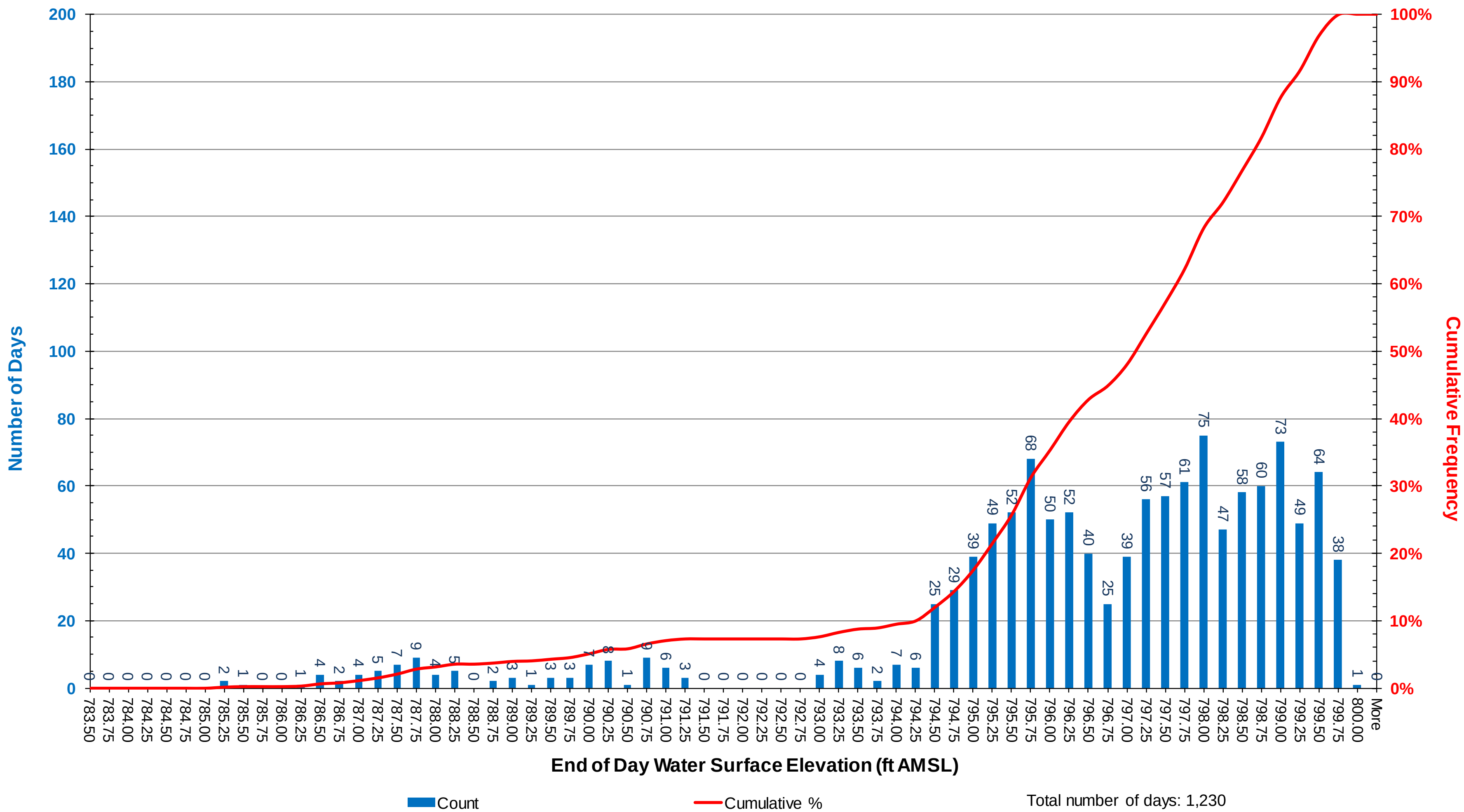


FIGURE 4.3-3(j)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
OCTOBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

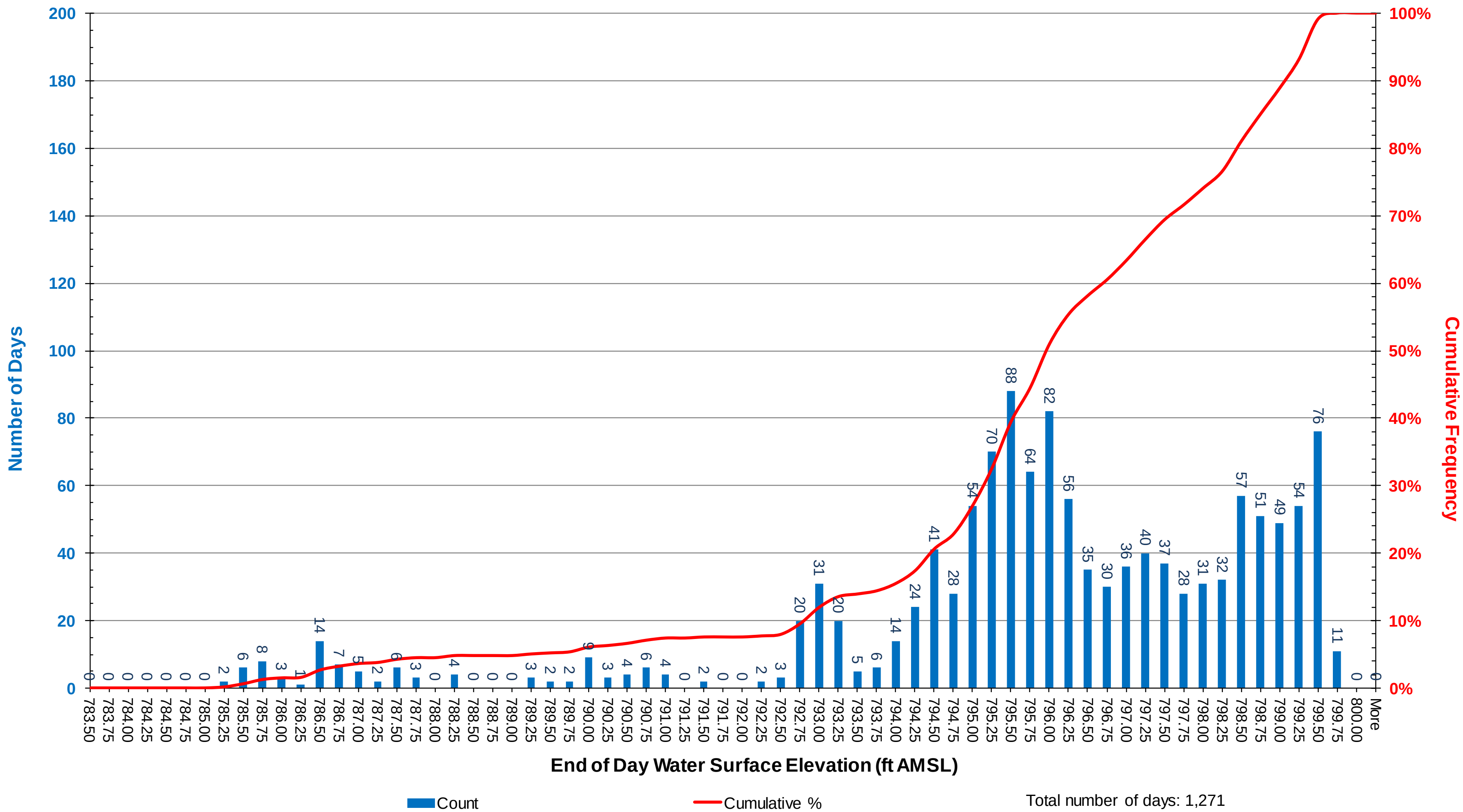


FIGURE 4.3-3(k)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
NOVEMBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

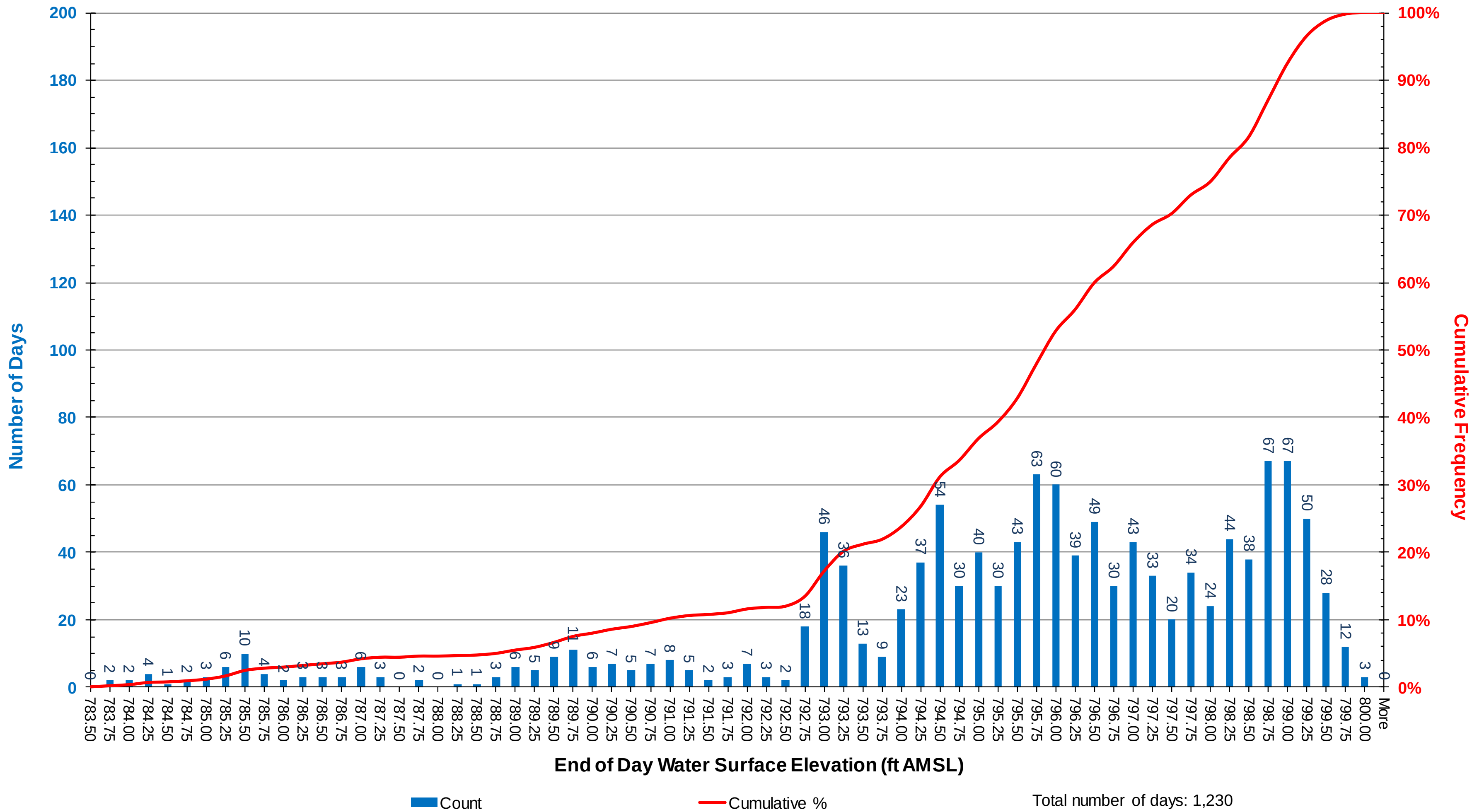


FIGURE 4.3-3(l)
LAKE KEOWEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
DECEMBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

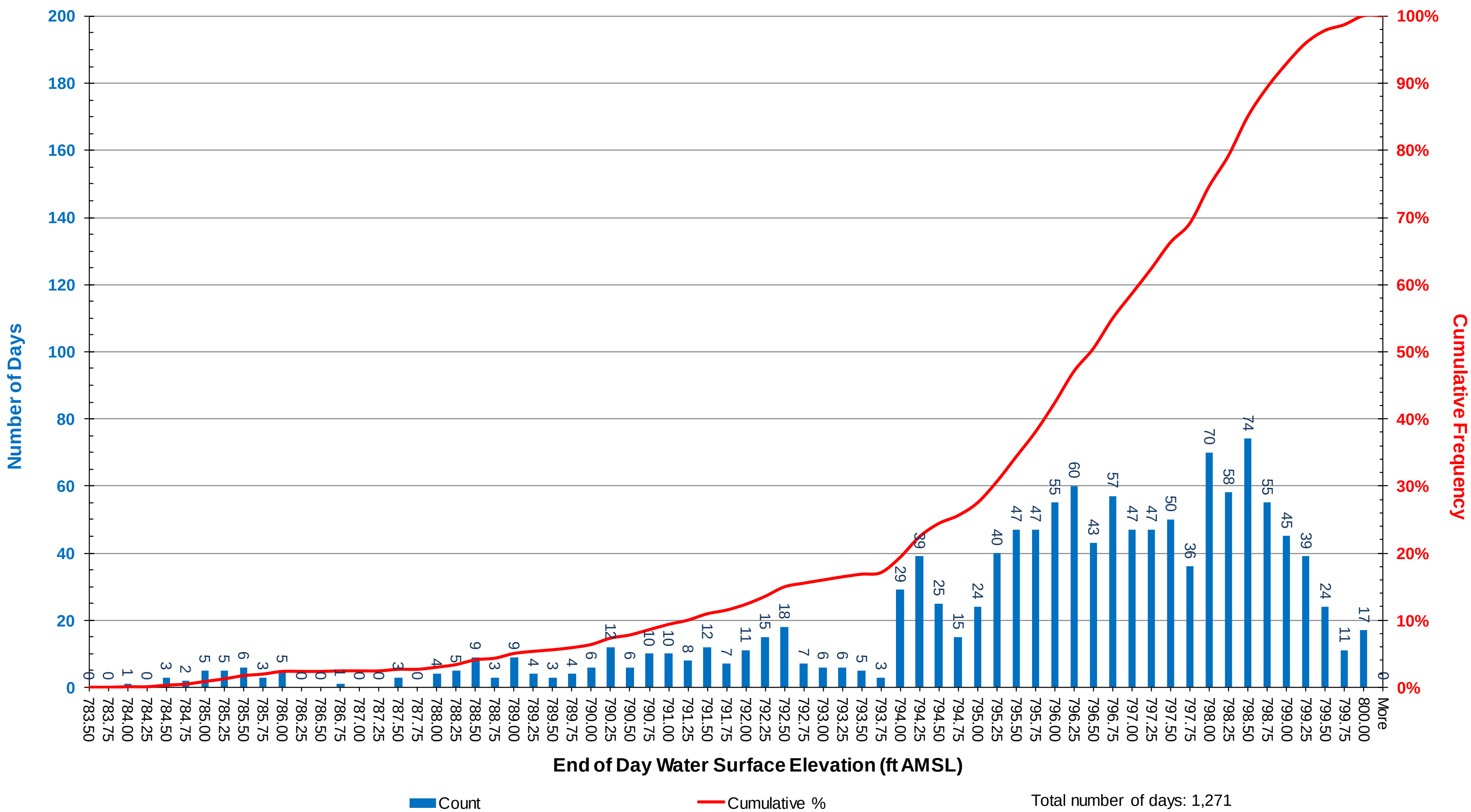


FIGURE 4.3-4(a)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
JANUARY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

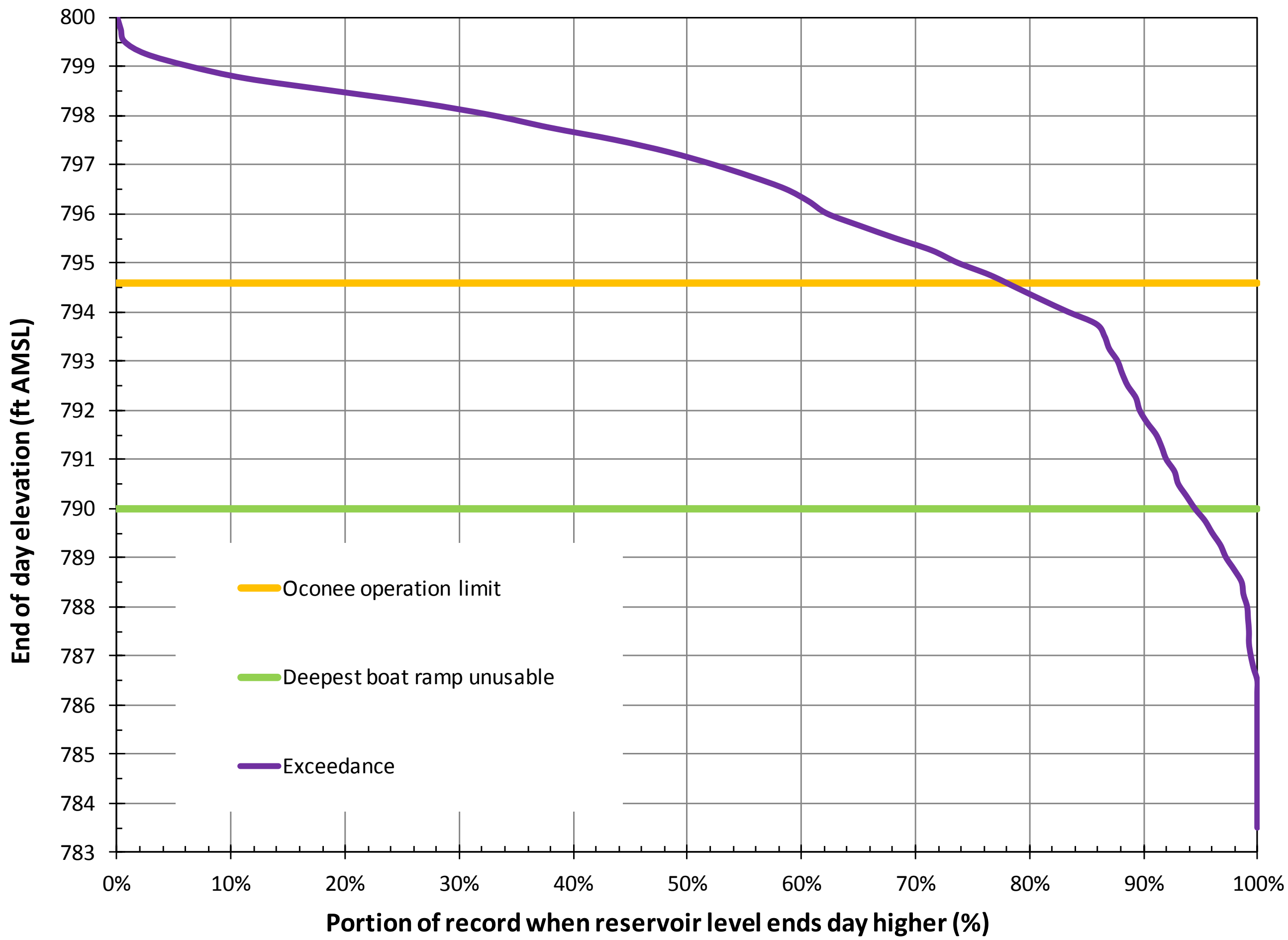


FIGURE 4.3-4(b)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
FEBRUARY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

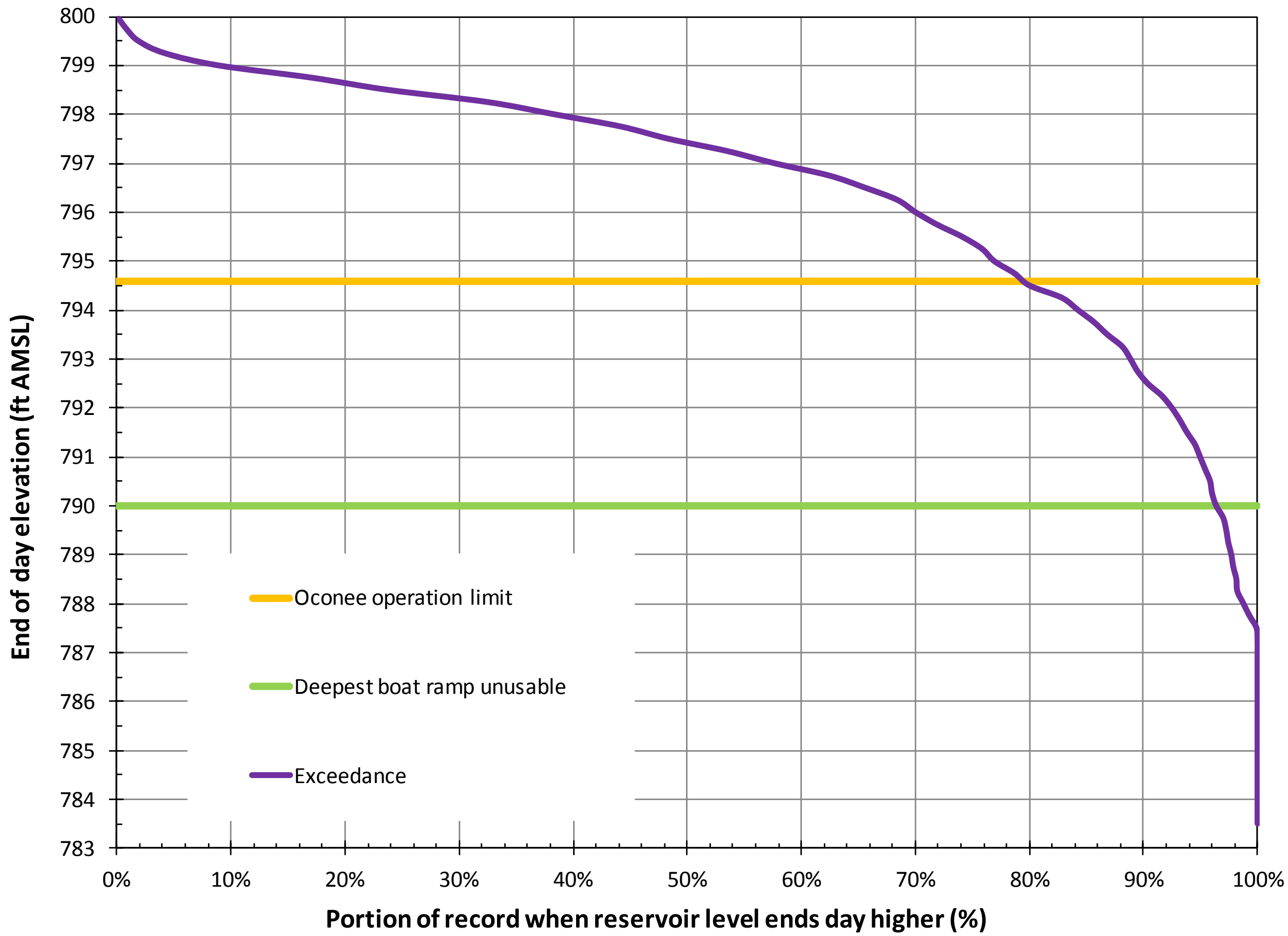


FIGURE 4.3-4(c)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
MARCH DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

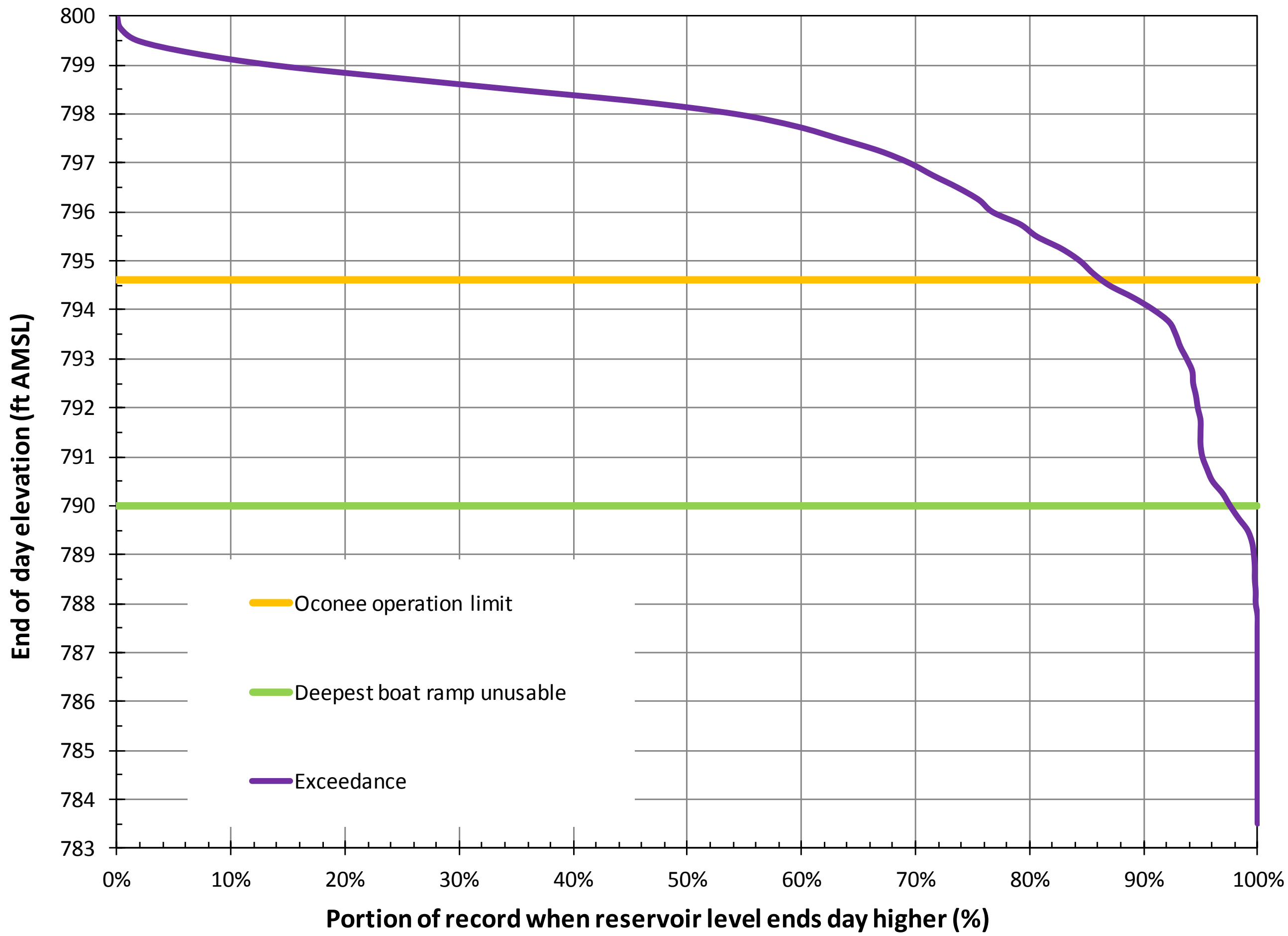


FIGURE 4.3-4(d)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
APRIL DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

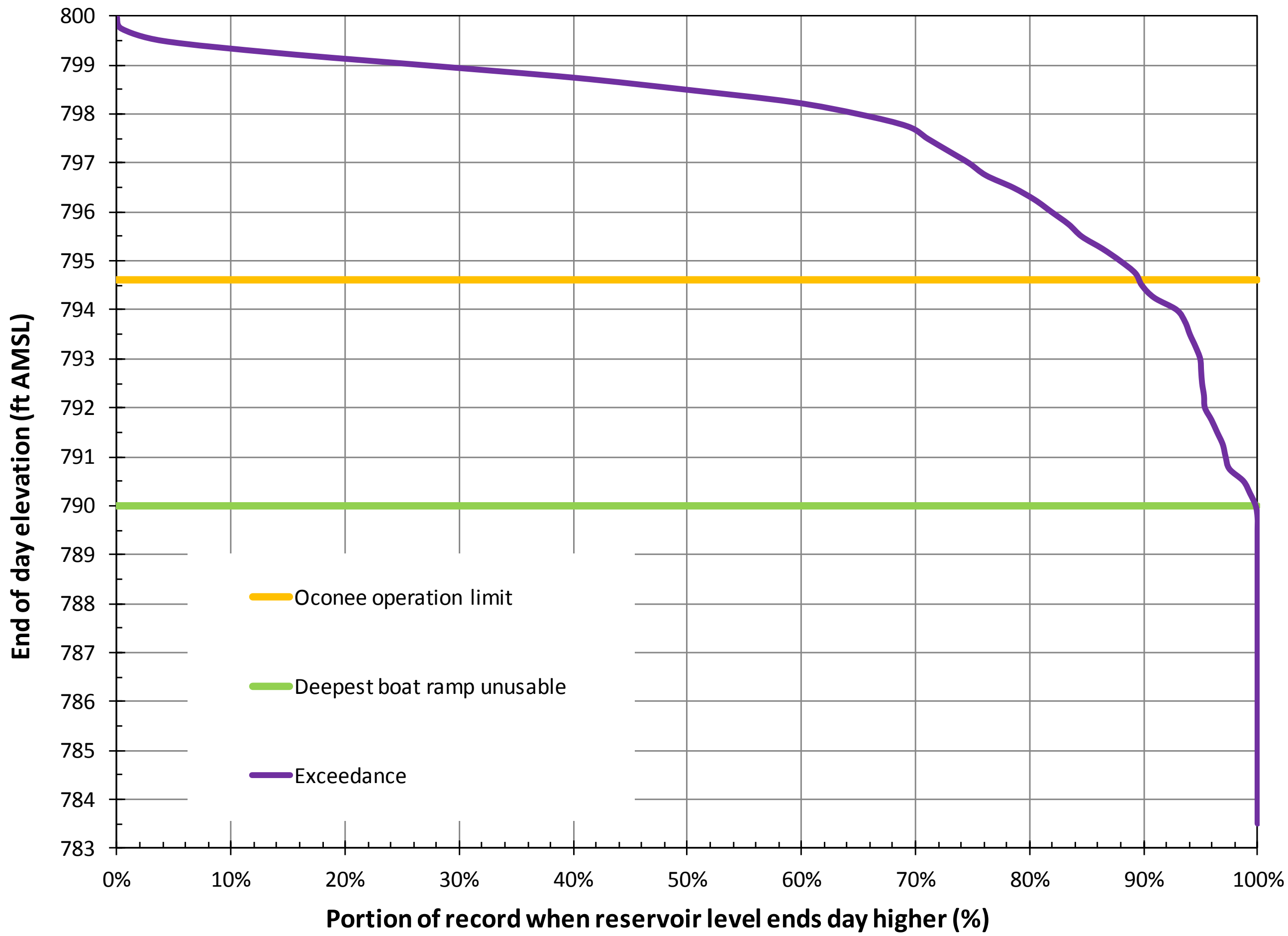


FIGURE 4.3-4(e)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
MAY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

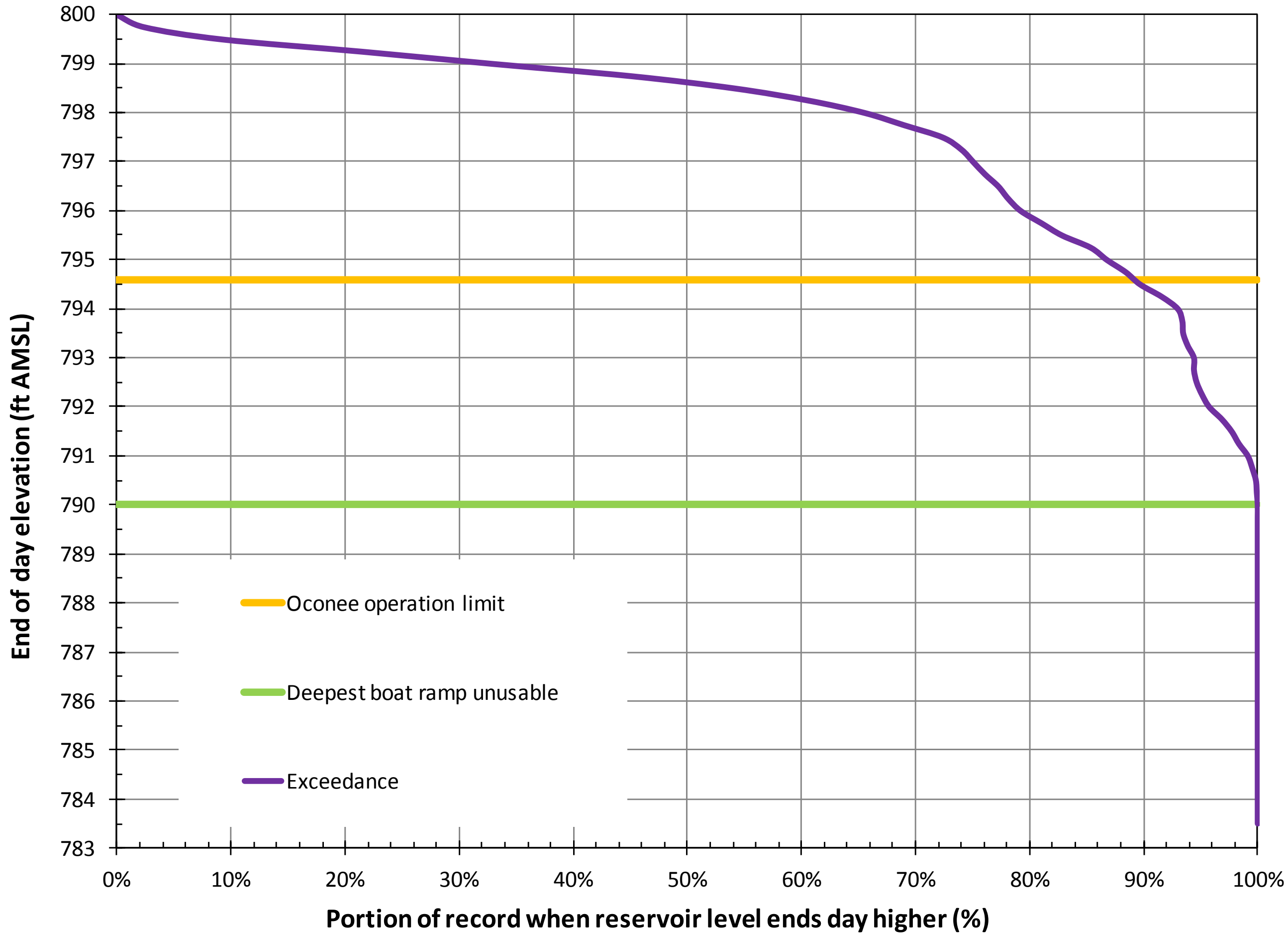


FIGURE 4.3-4(f)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
JUNE DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

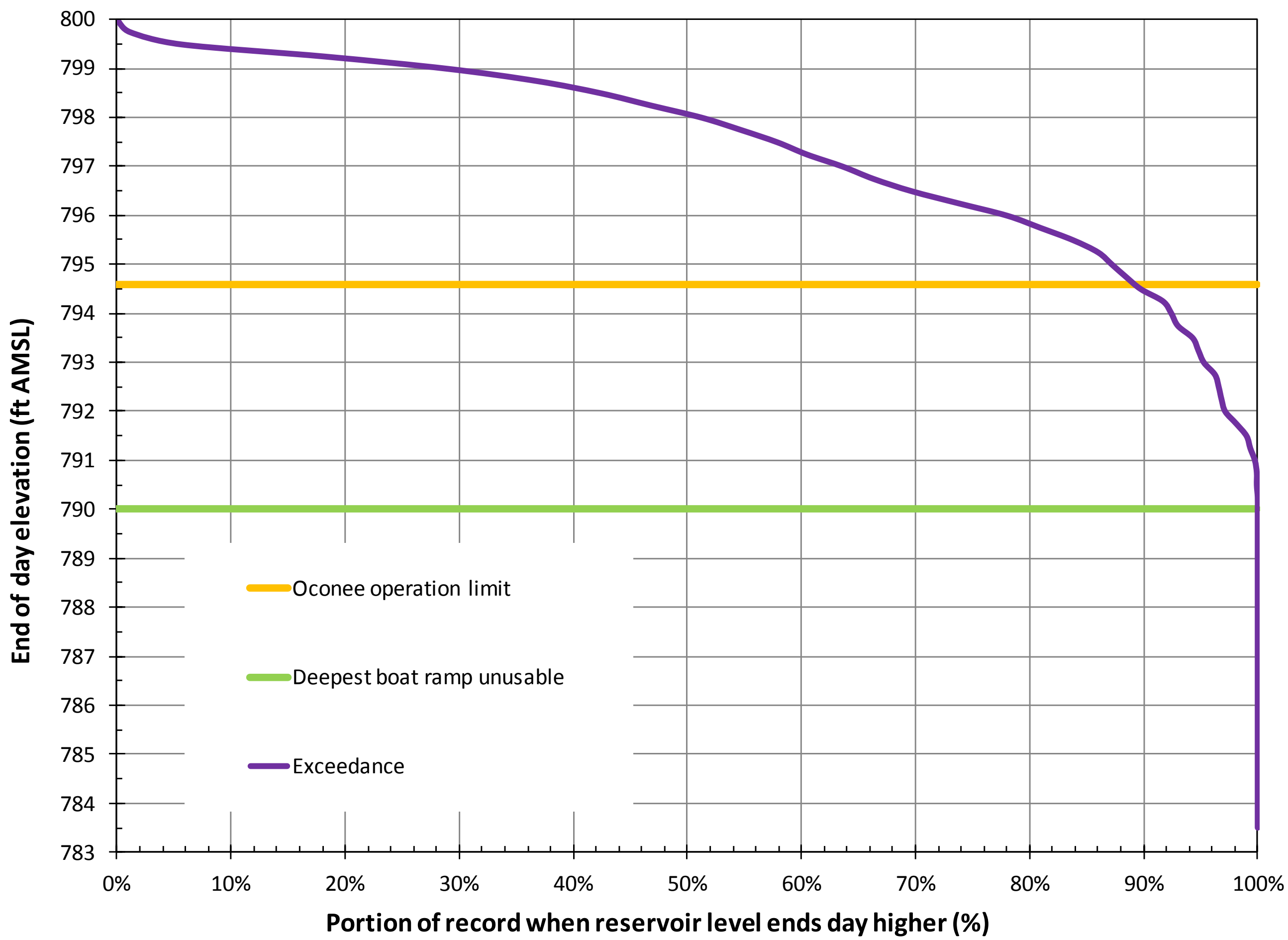


FIGURE 4.3-4(g)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
JULY DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

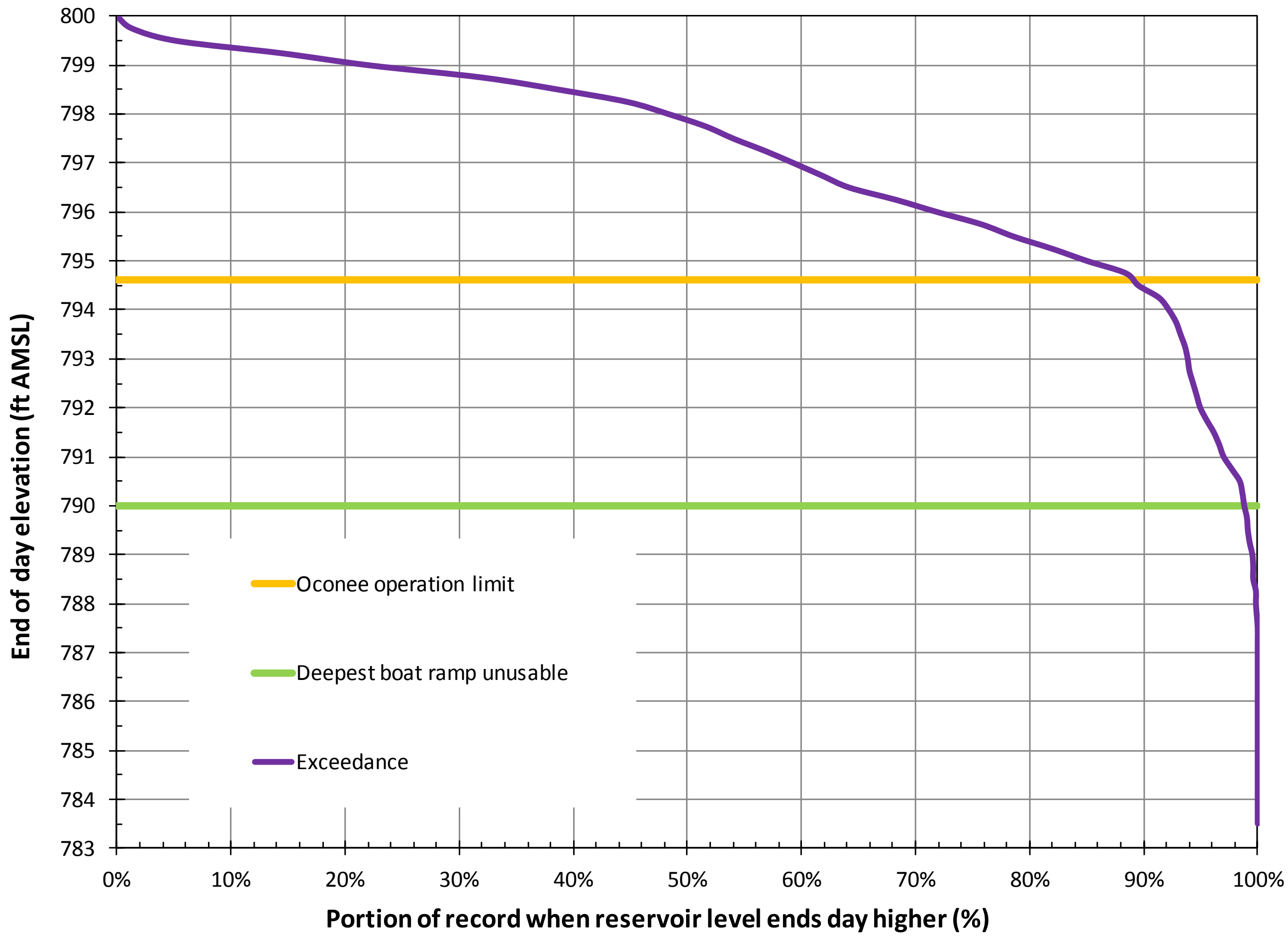


FIGURE 4.3-4(h)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
AUGUST DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

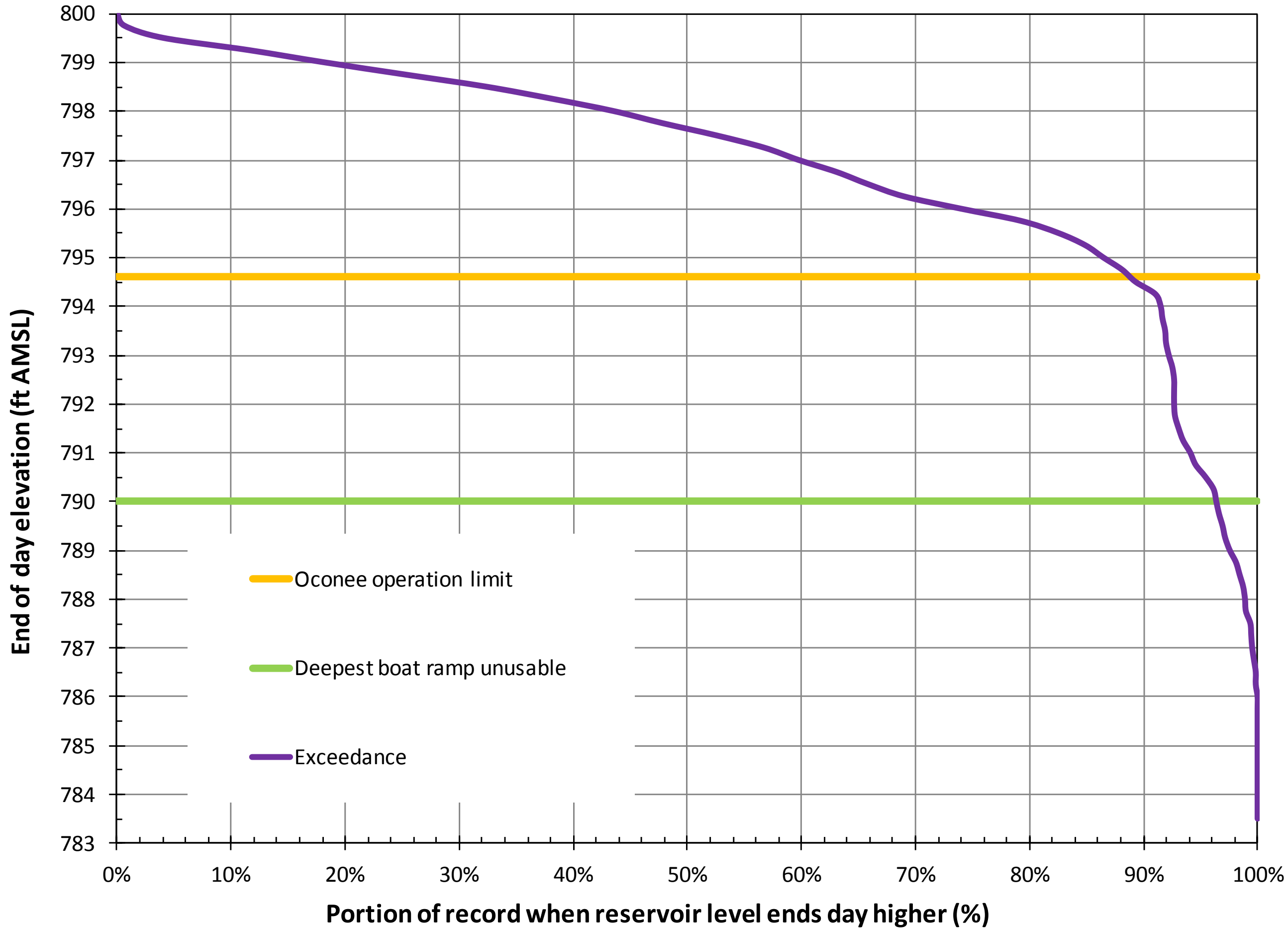


FIGURE 4.3-4(i)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
SEPTEMBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

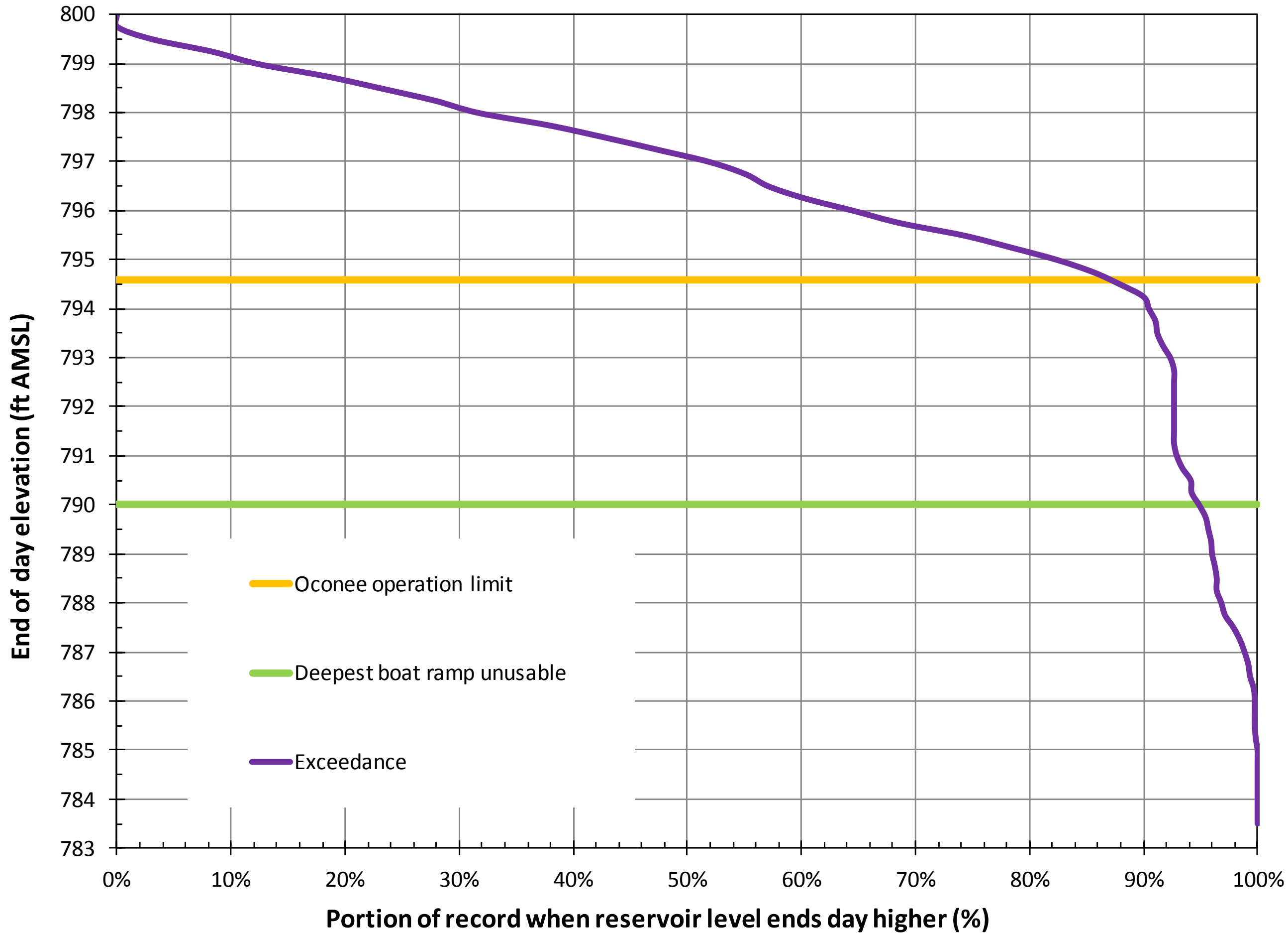


FIGURE 4.3-4(j)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
OCTOBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

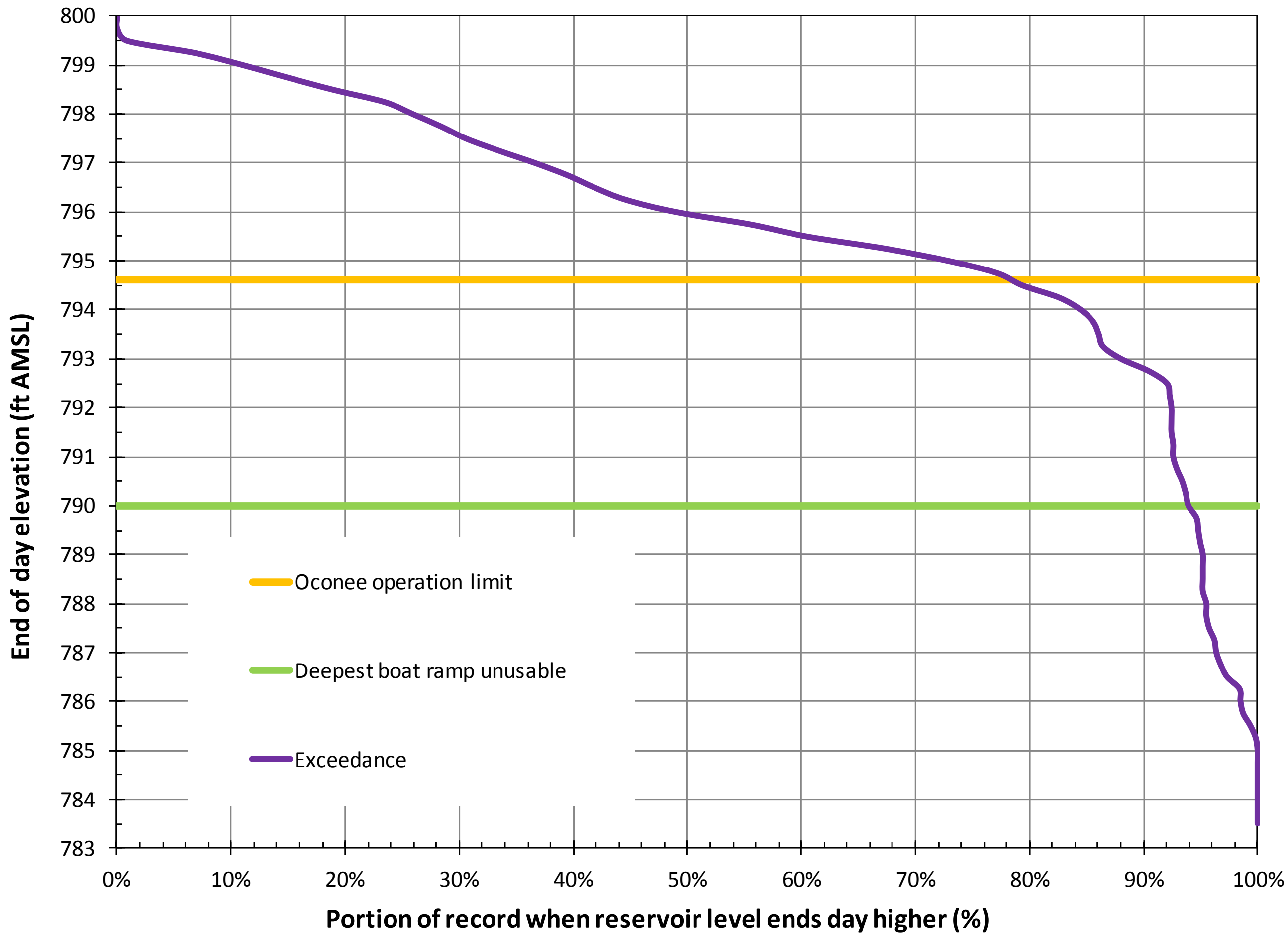


FIGURE 4.3-4(k)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
NOVEMBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

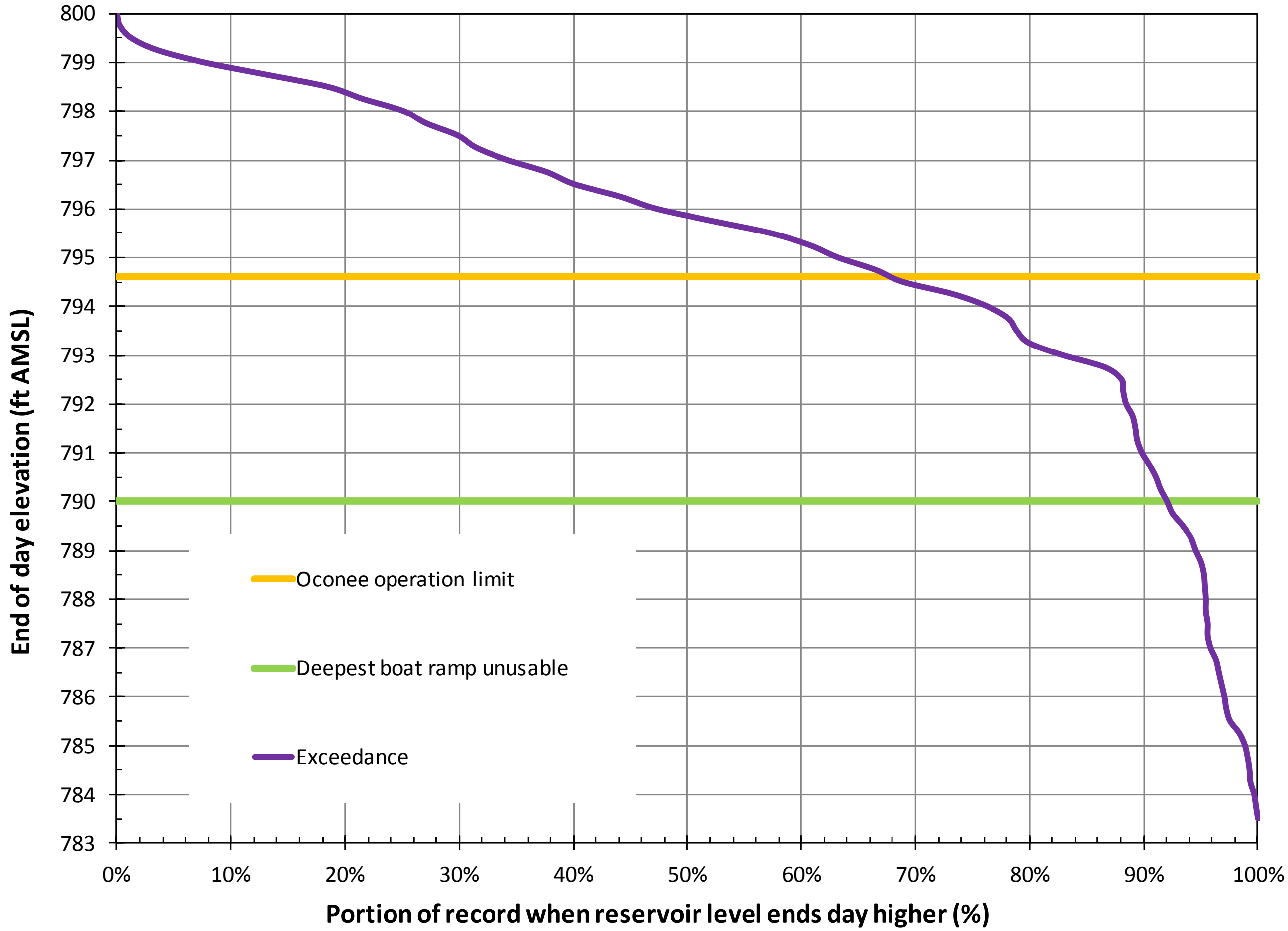


FIGURE 4.3-4(l)
LAKE KEOWEE LEVELS EXCEEDANCE CURVE
DECEMBER DATA FROM APRIL 17, 1971, THROUGH DECEMBER 31, 2011

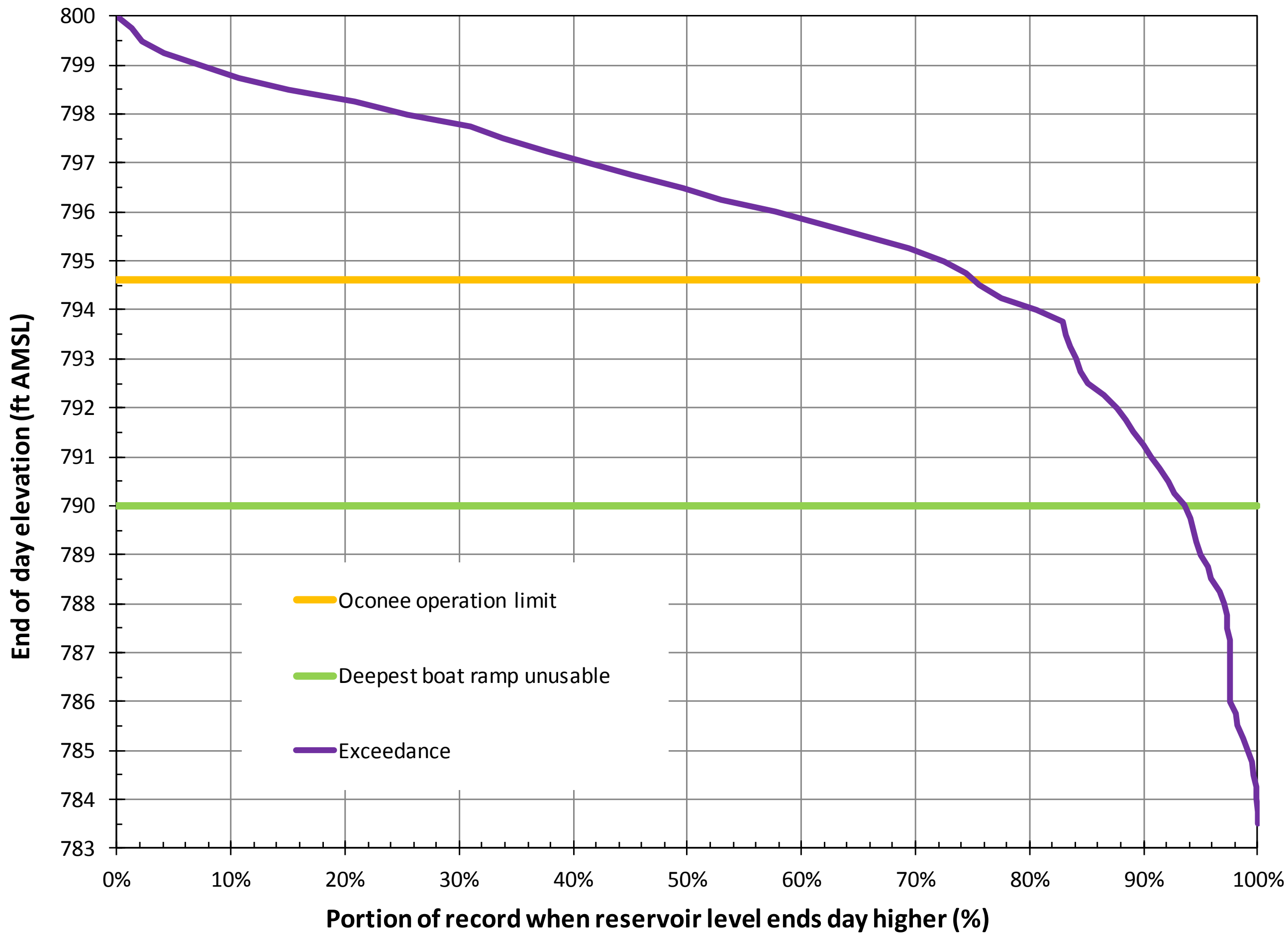


FIGURE 4.3-8(a)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
JANUARY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

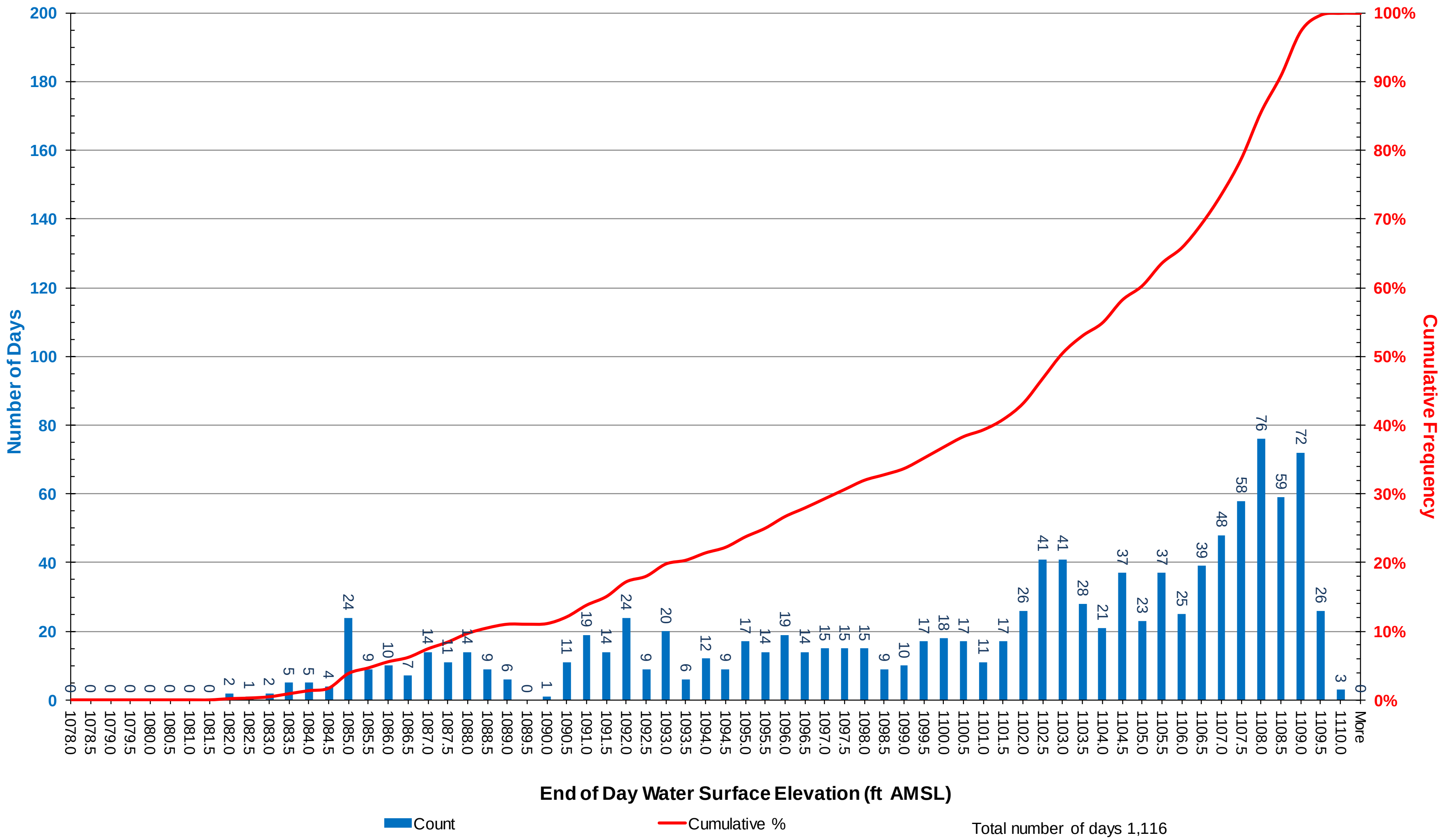


FIGURE 4.3-8(b)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
FEBRUARY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

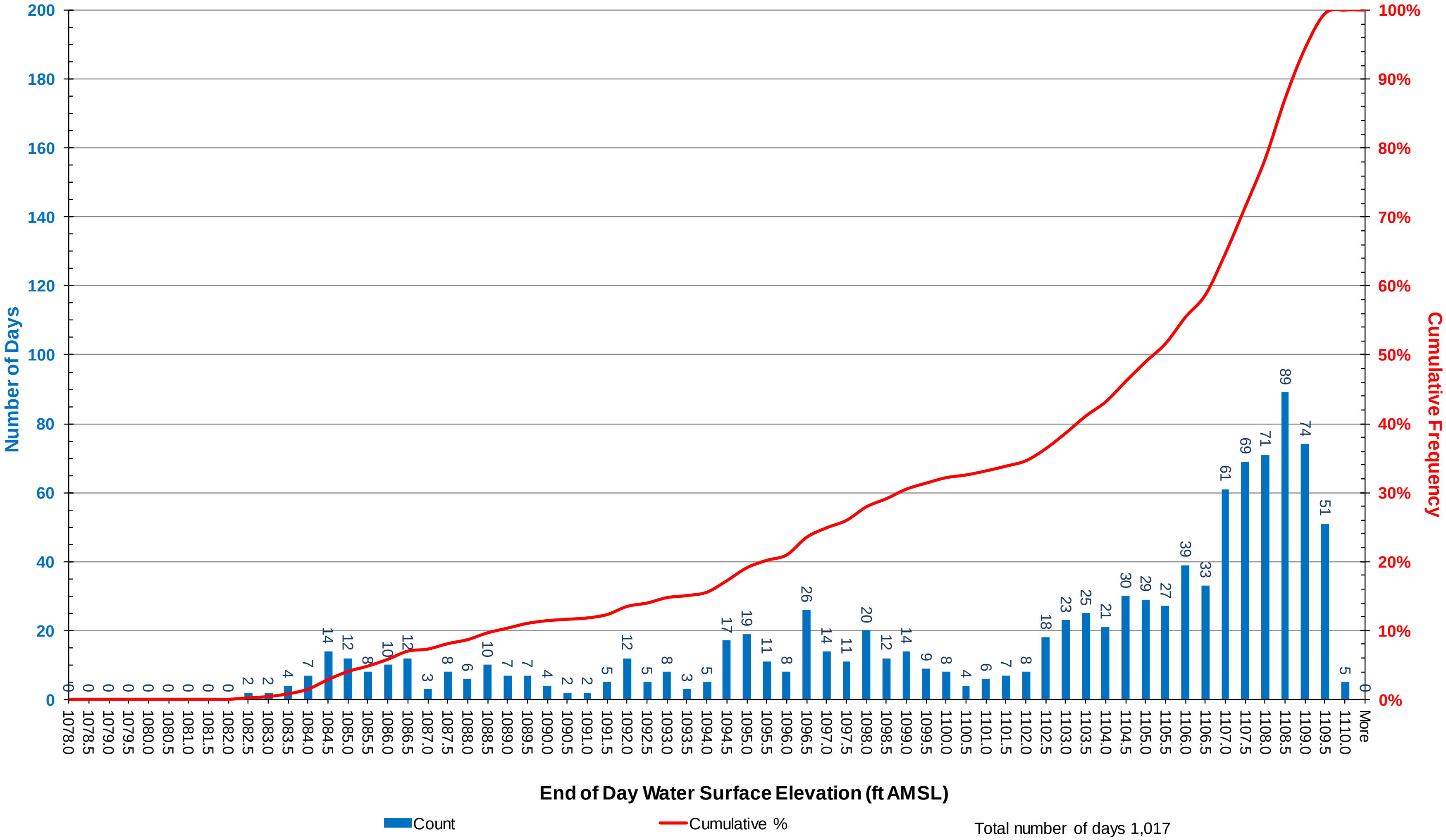


FIGURE 4.3-8(c)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
MARCH DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

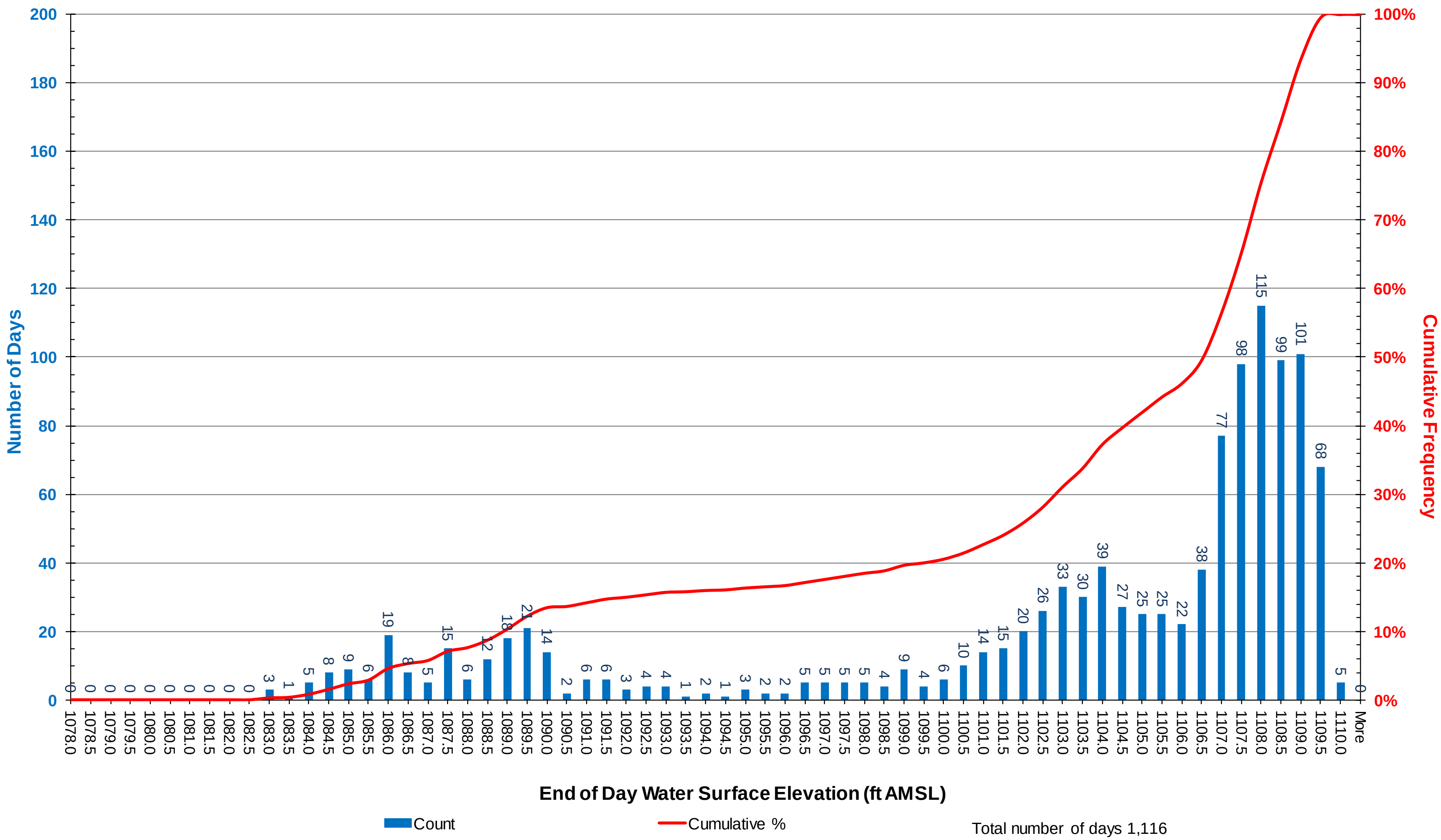


FIGURE 4.3-8(d)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
APRIL DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

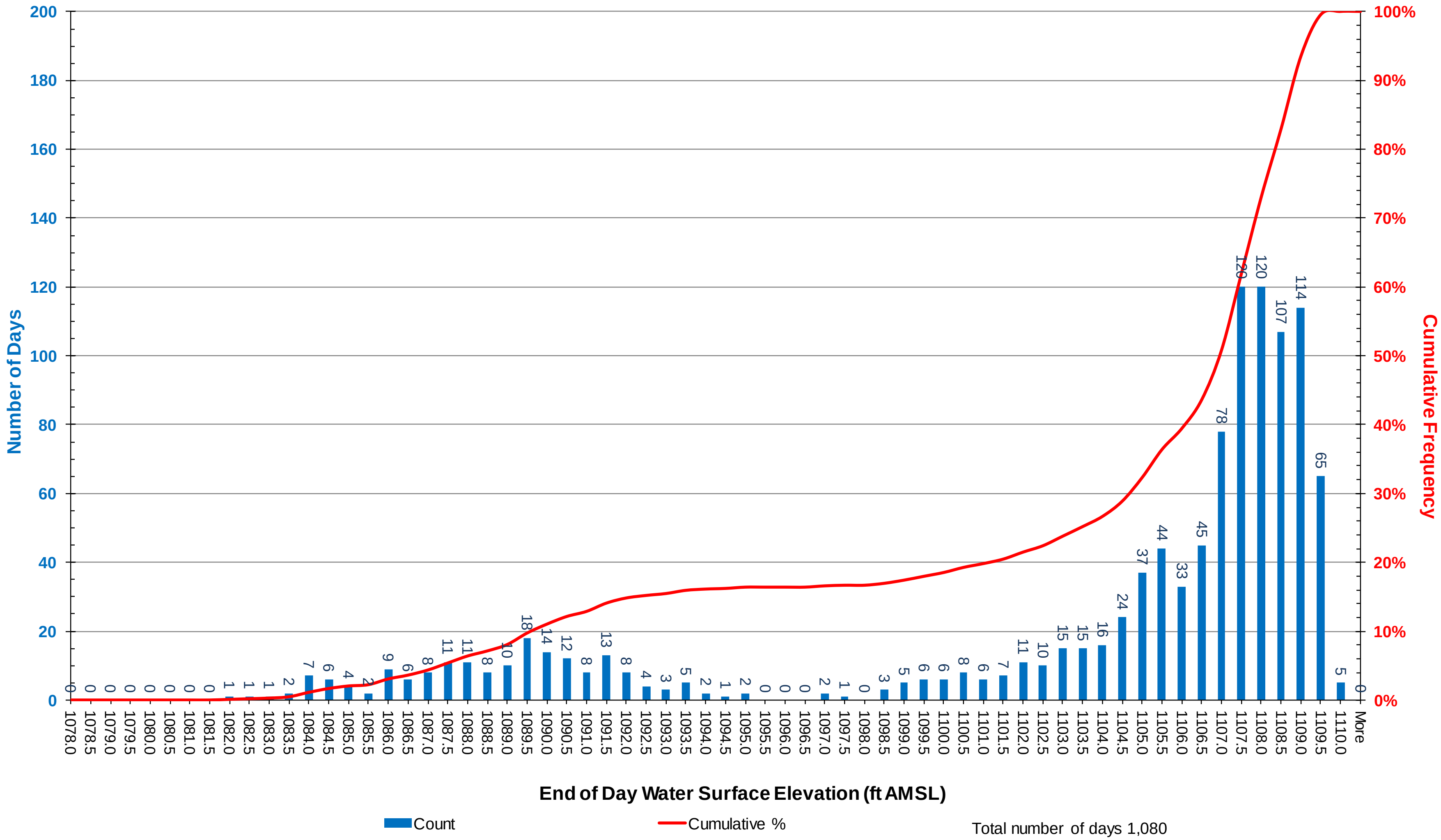


FIGURE 4.3-8(e)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
MAY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

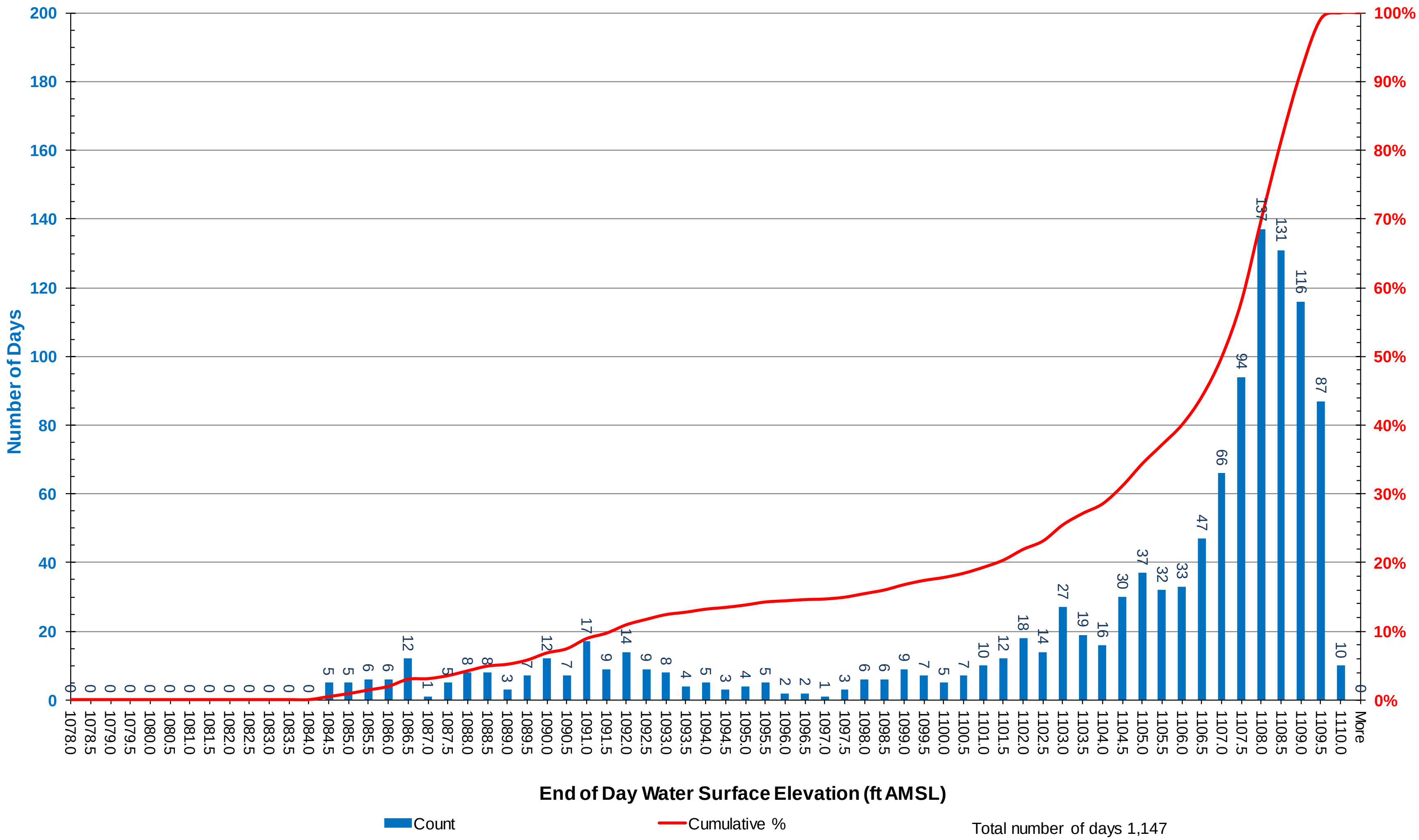


FIGURE 4.3-8(f)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
JUNE DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

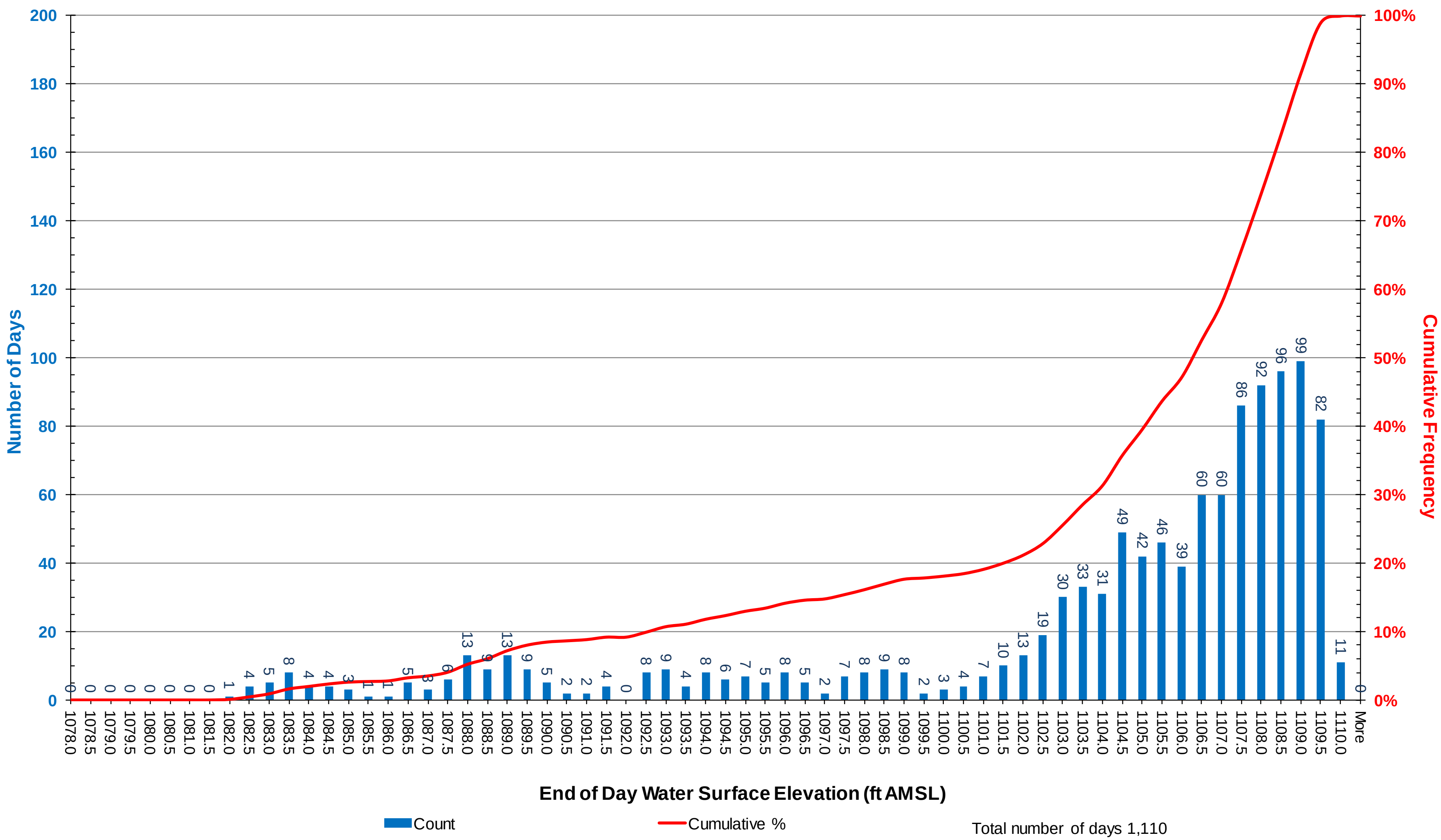


FIGURE 4.3-8(g)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
JULY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

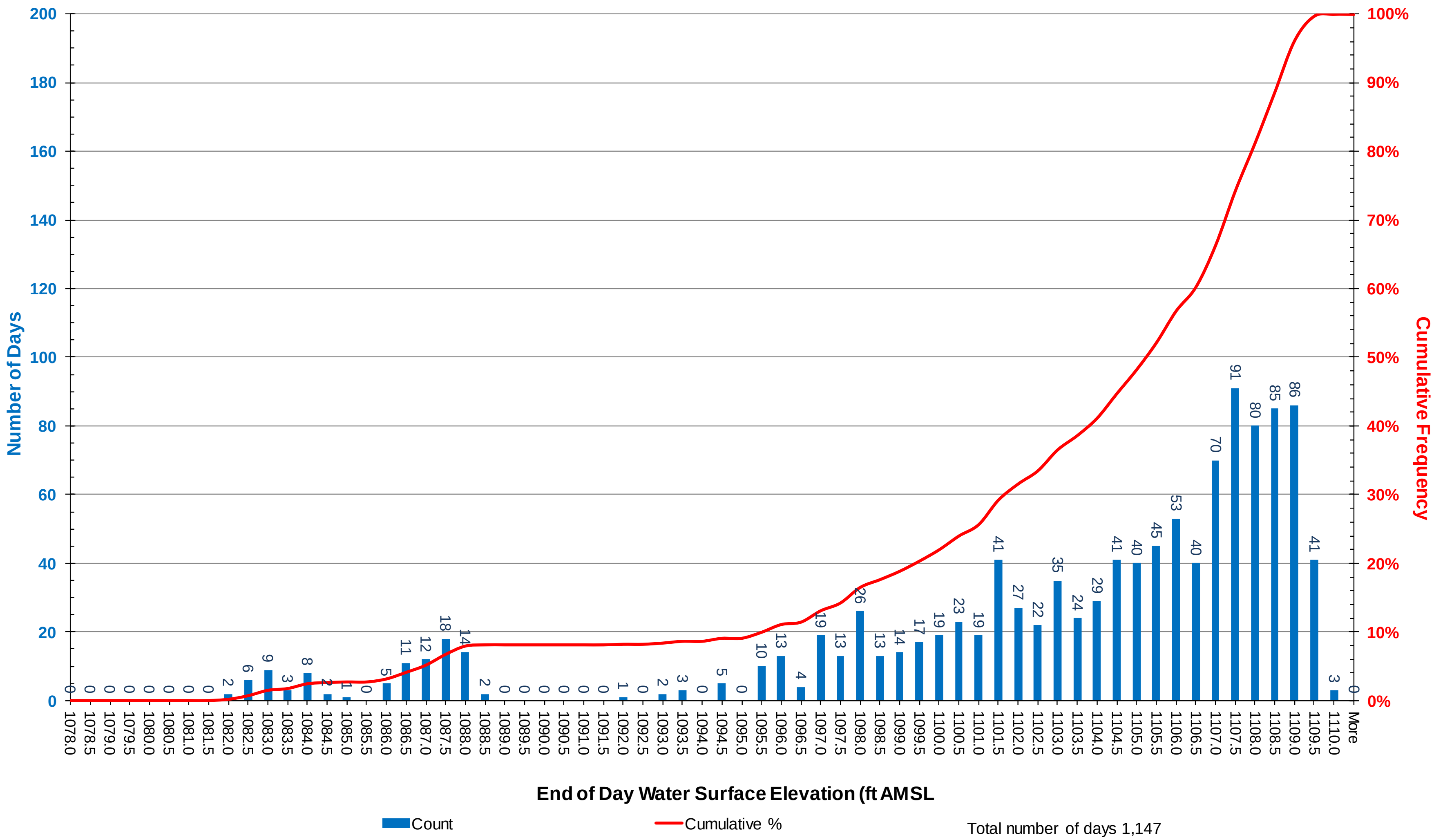


FIGURE 4.3-8(h)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
AUGUST DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

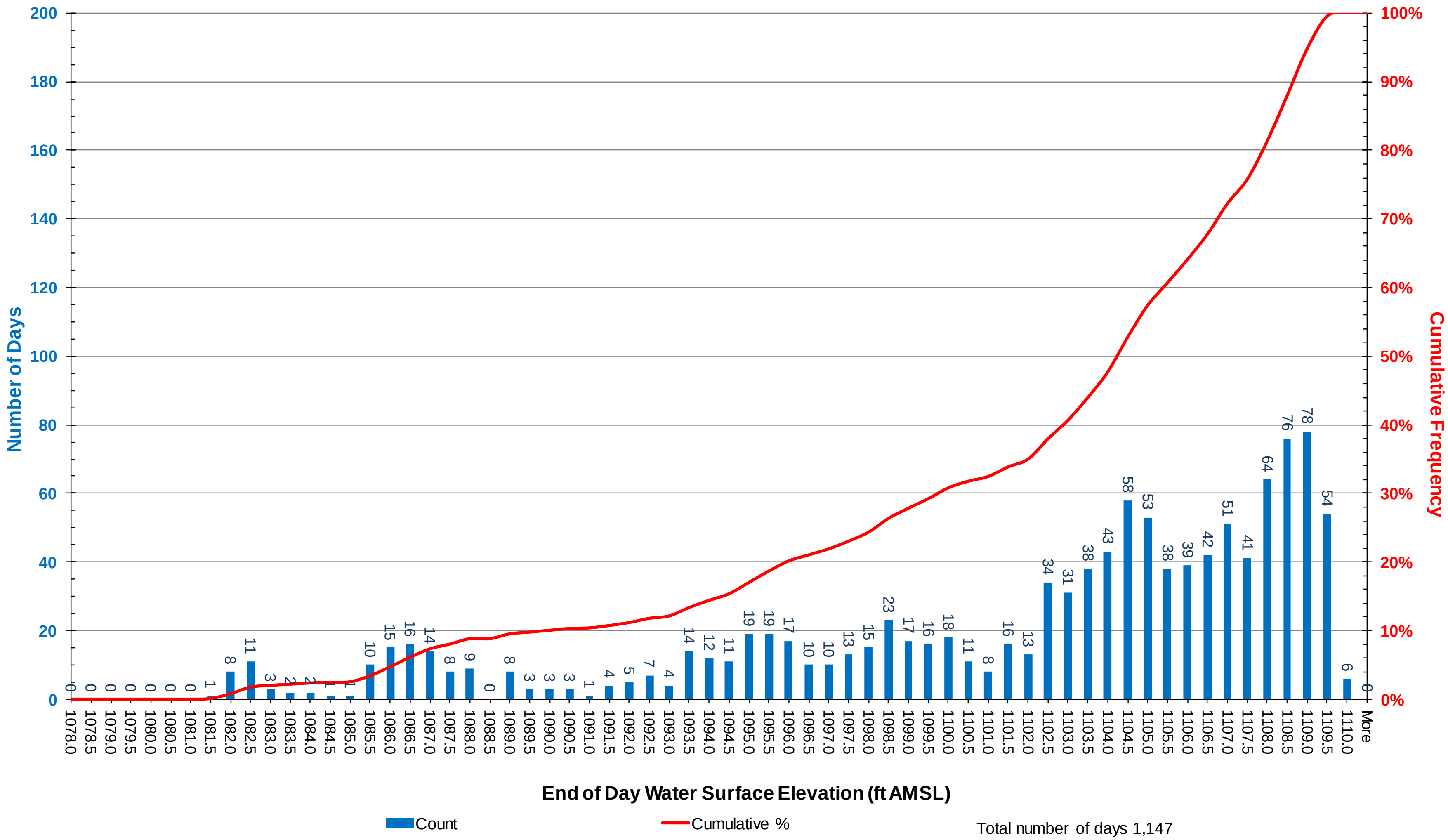


FIGURE 4.3-8(i)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
SEPTEMBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

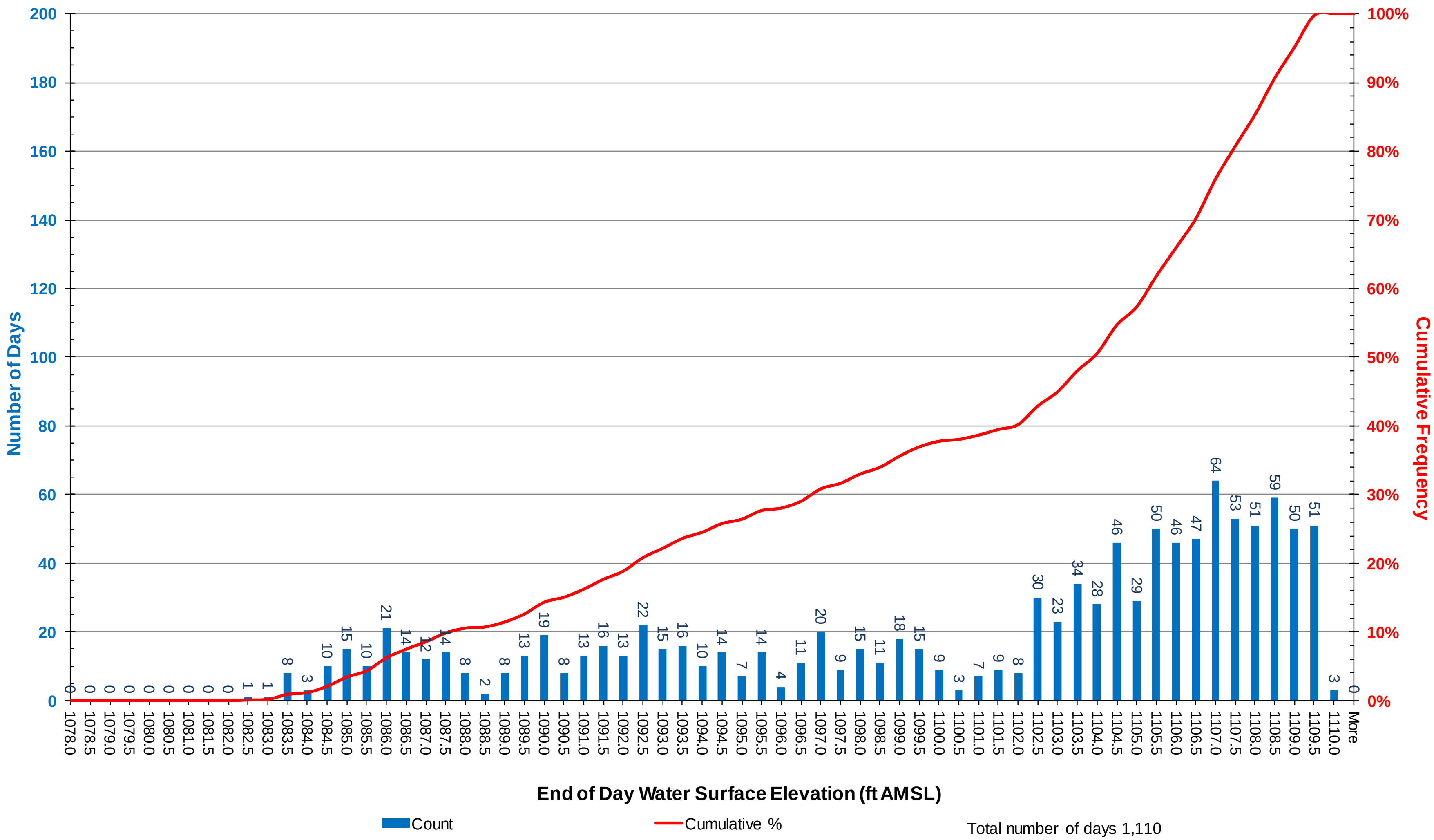


FIGURE 4.3-8(j)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
OCTOBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

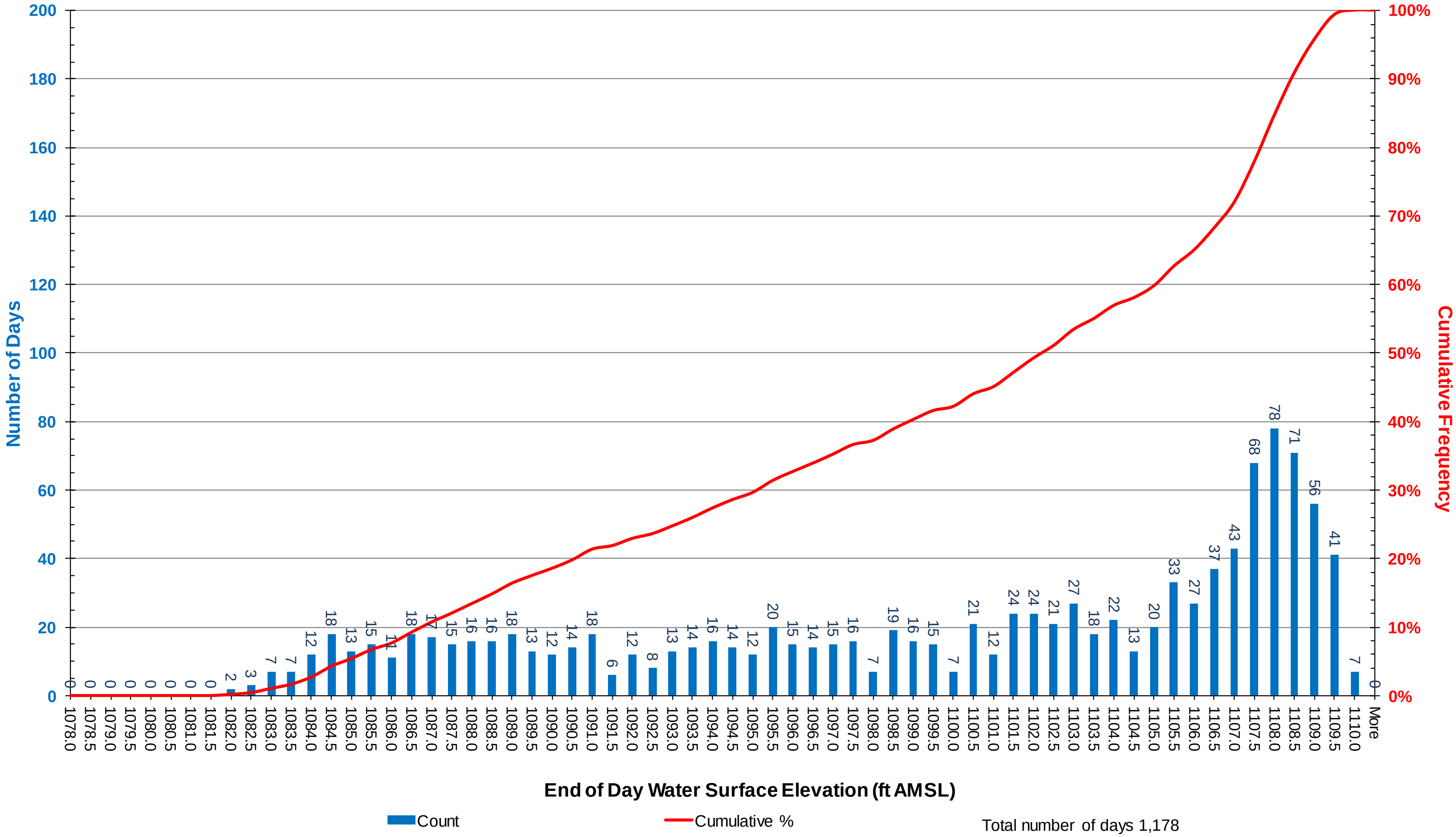


FIGURE 4.3-8(k)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
NOVEMBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

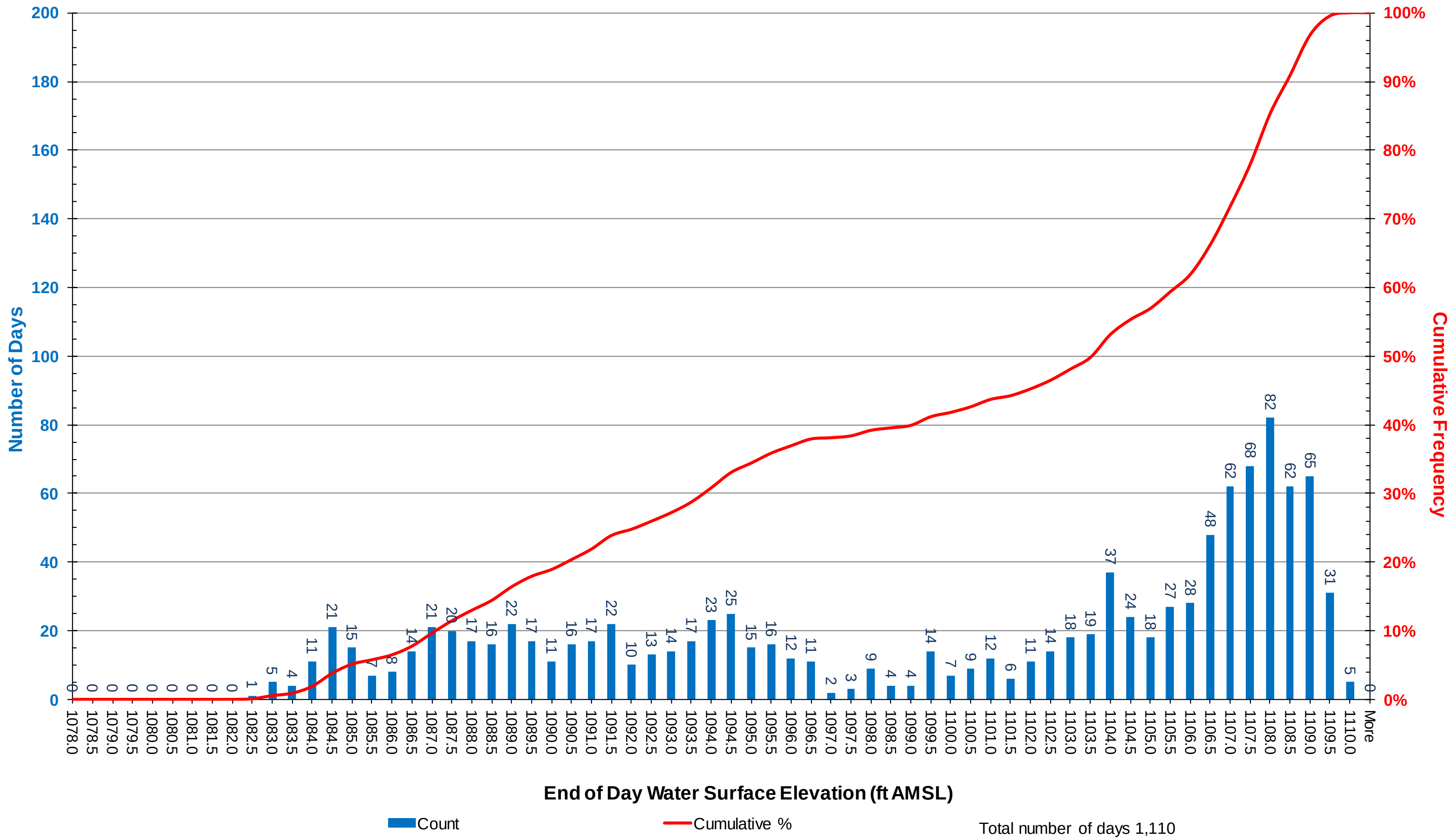


FIGURE 4.3-8(l)
LAKE JOCASSEE LEVELS HISTOGRAM AND CUMULATIVE FREQUENCY CURVE
DECEMBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

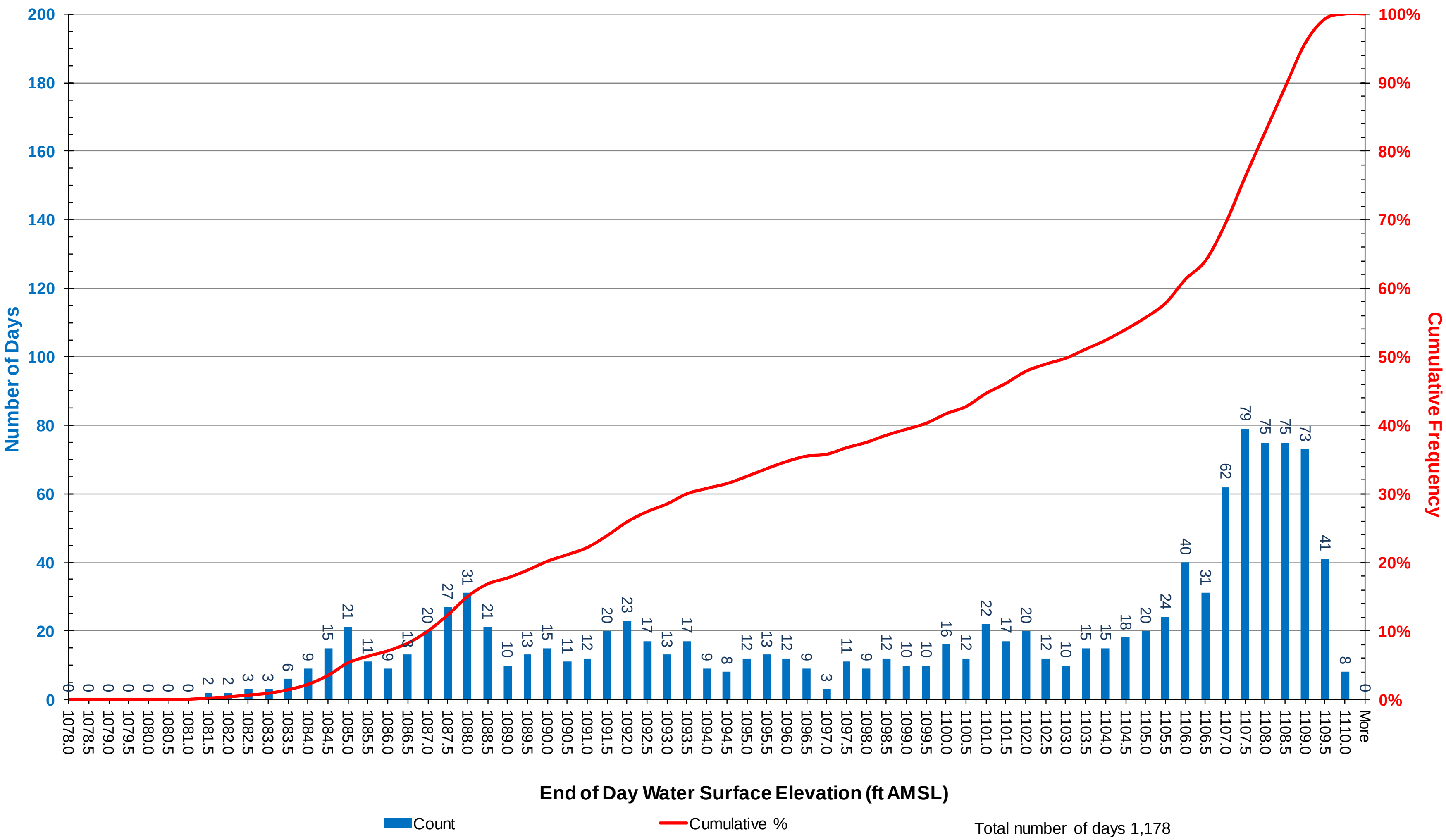


FIGURE 4.3-9(a)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
JANUARY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

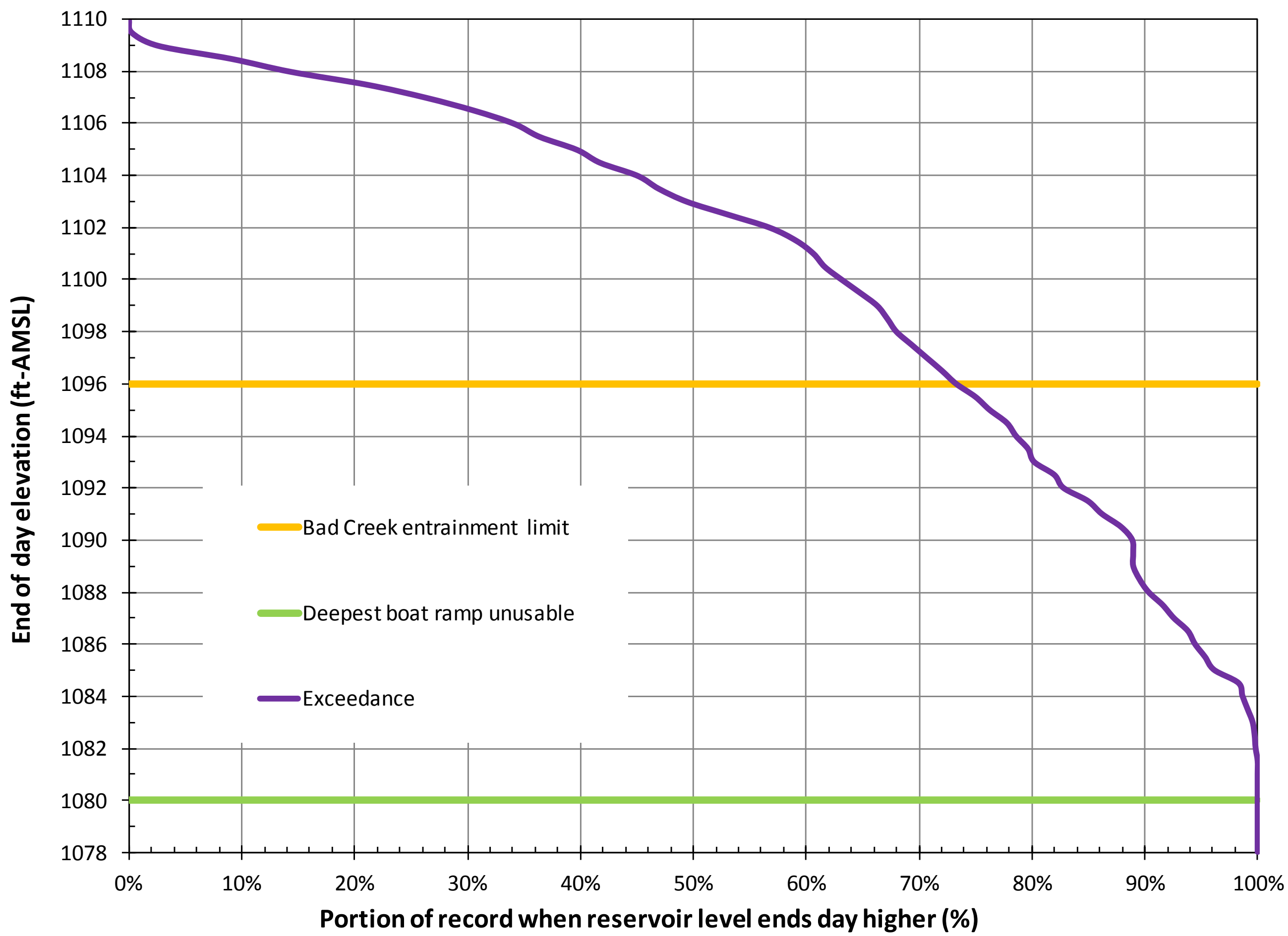


FIGURE 4.3-9(b)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
FEBRUARY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

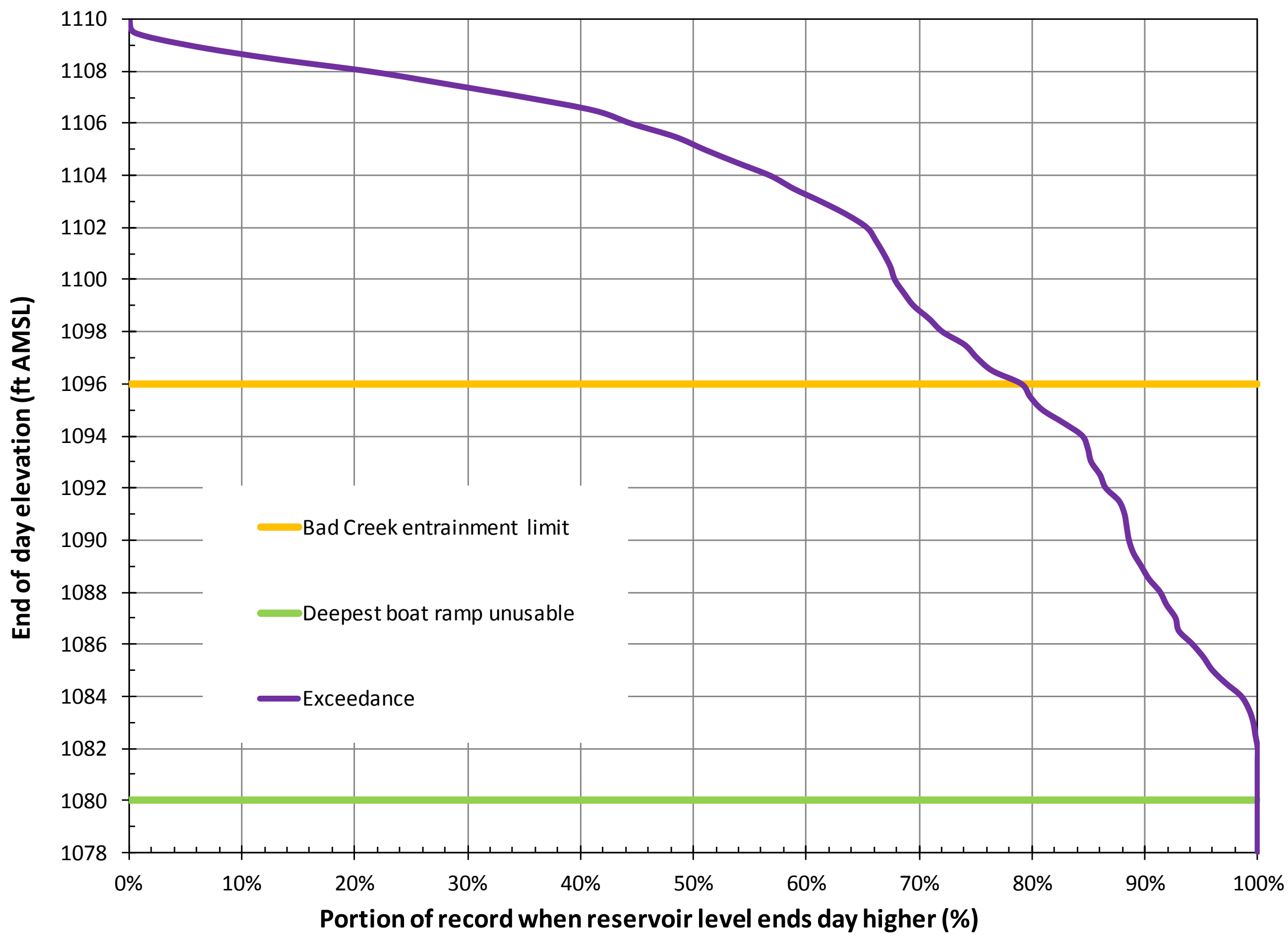


FIGURE 4.3-9(c)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
MARCH DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

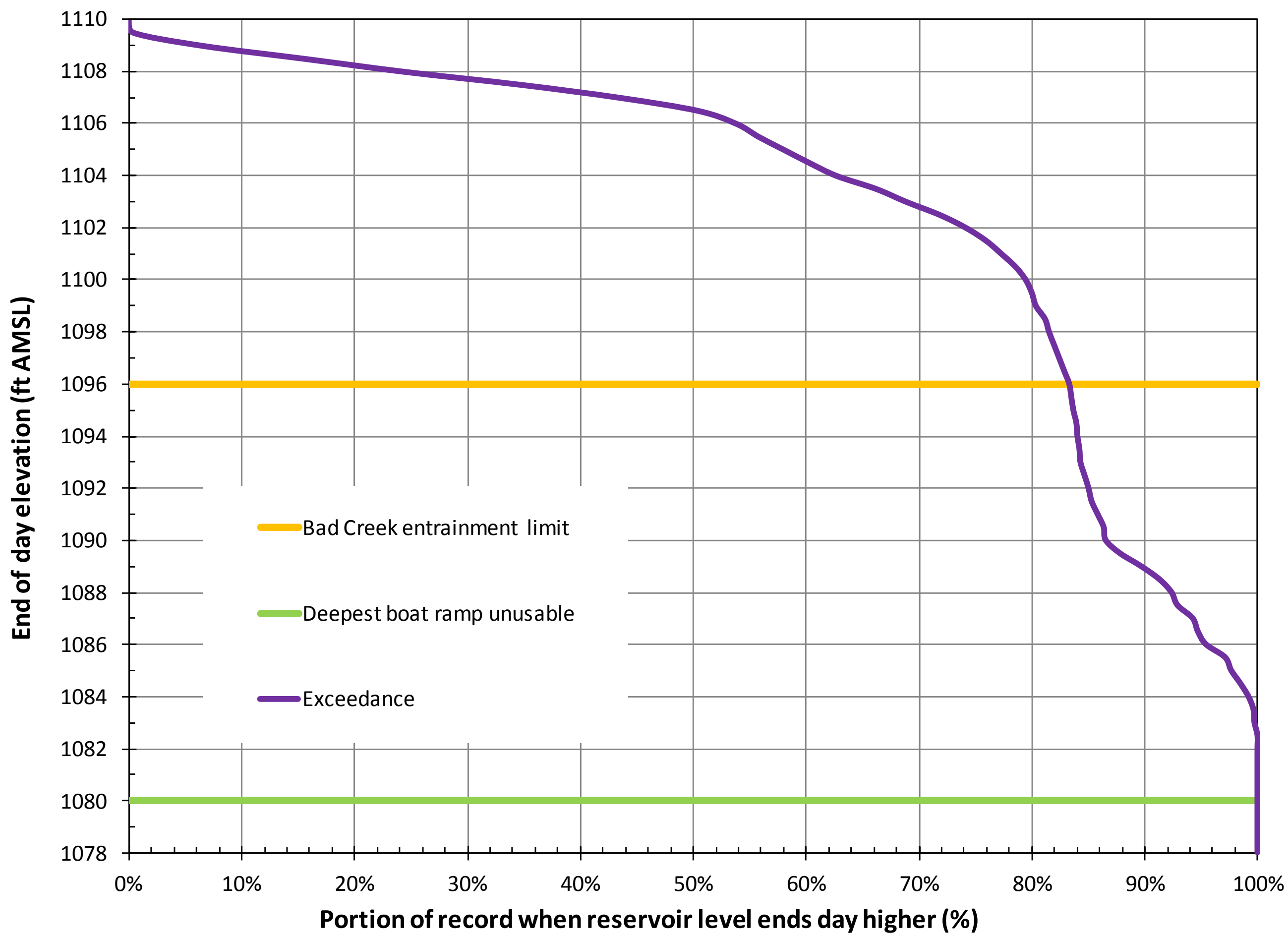


FIGURE 4.3-9(d)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
APRIL DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

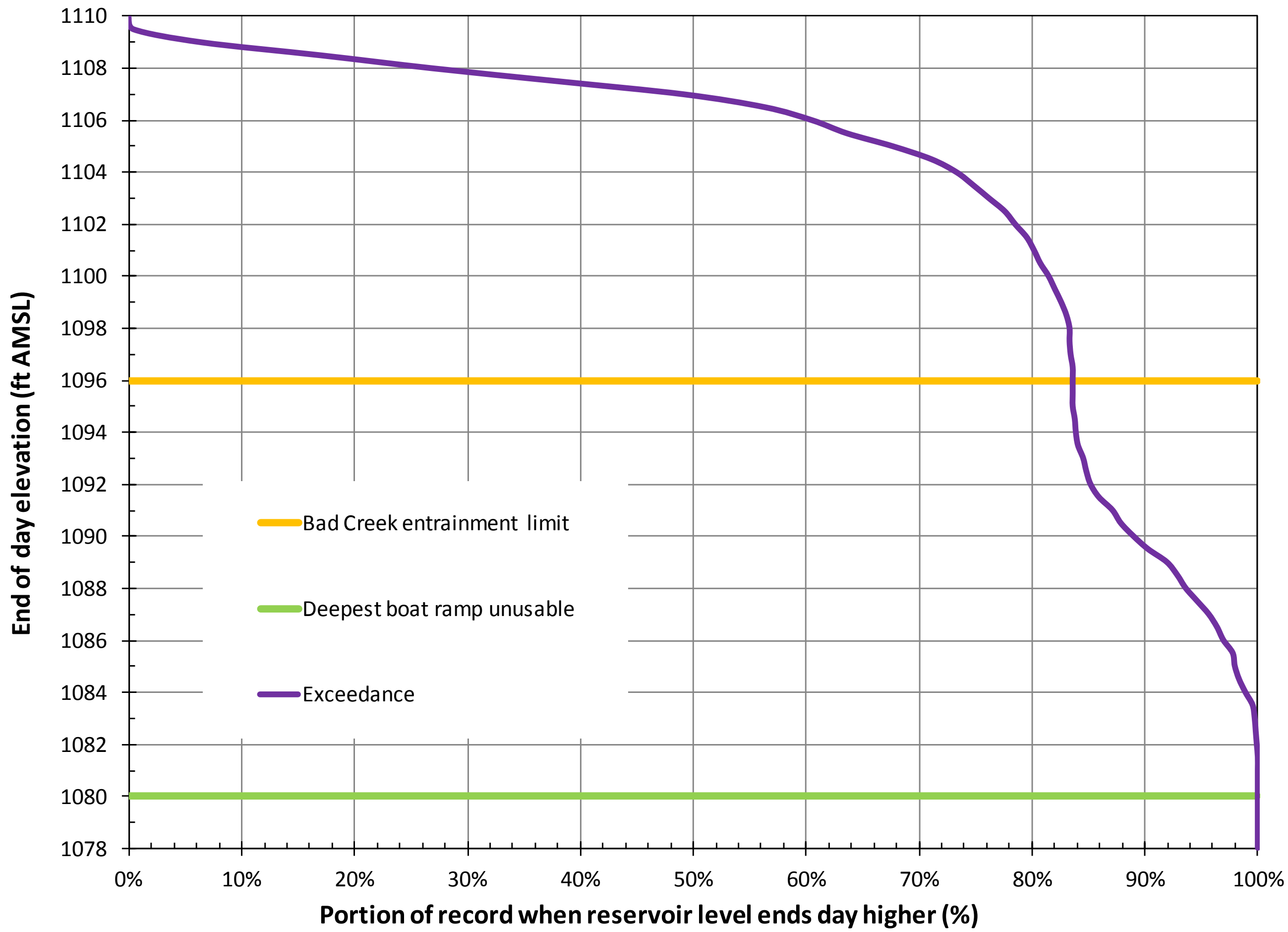


FIGURE 4.3-9(e)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
MAY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

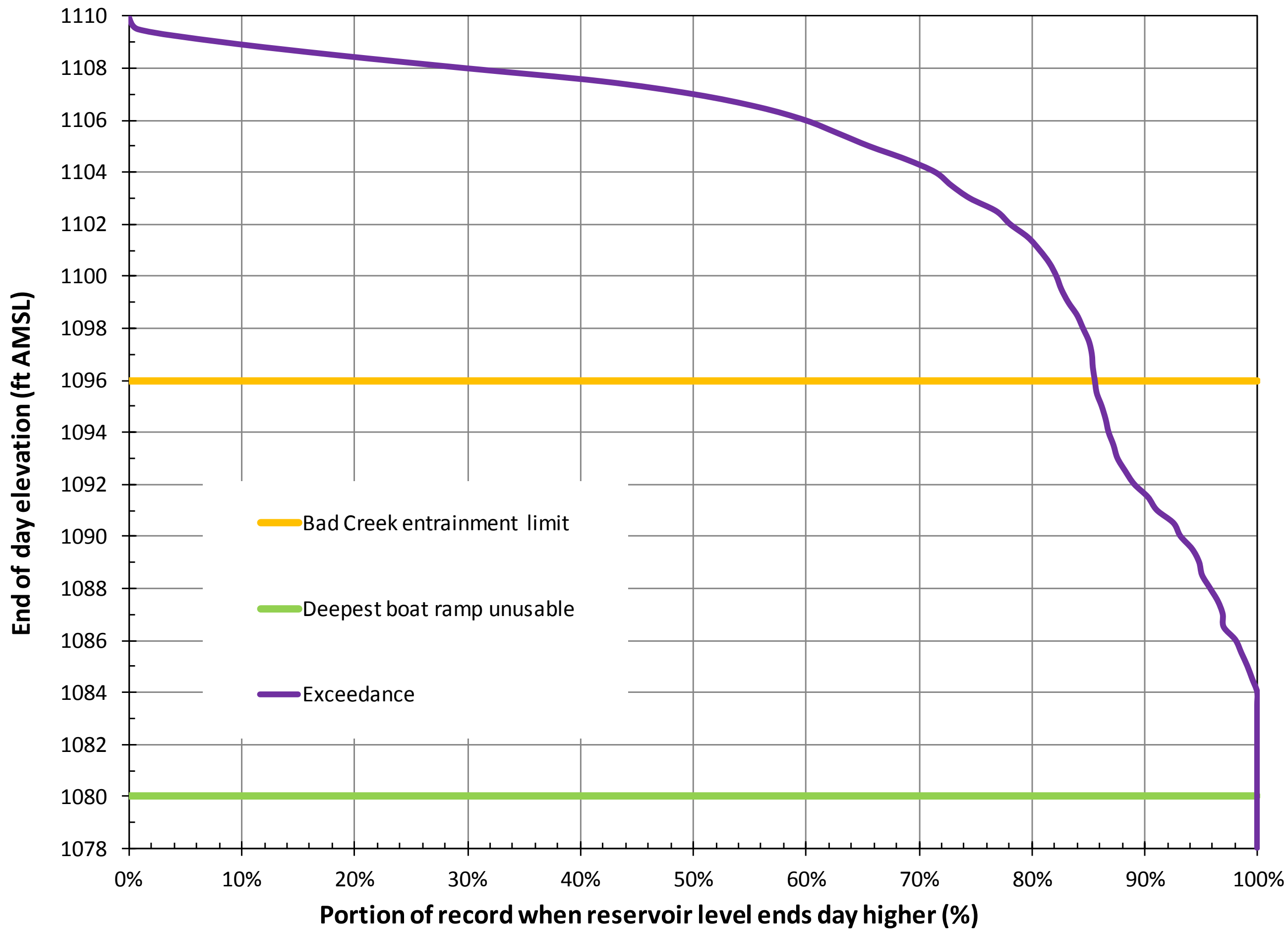


FIGURE 4.3-9(f)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
JUNE DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

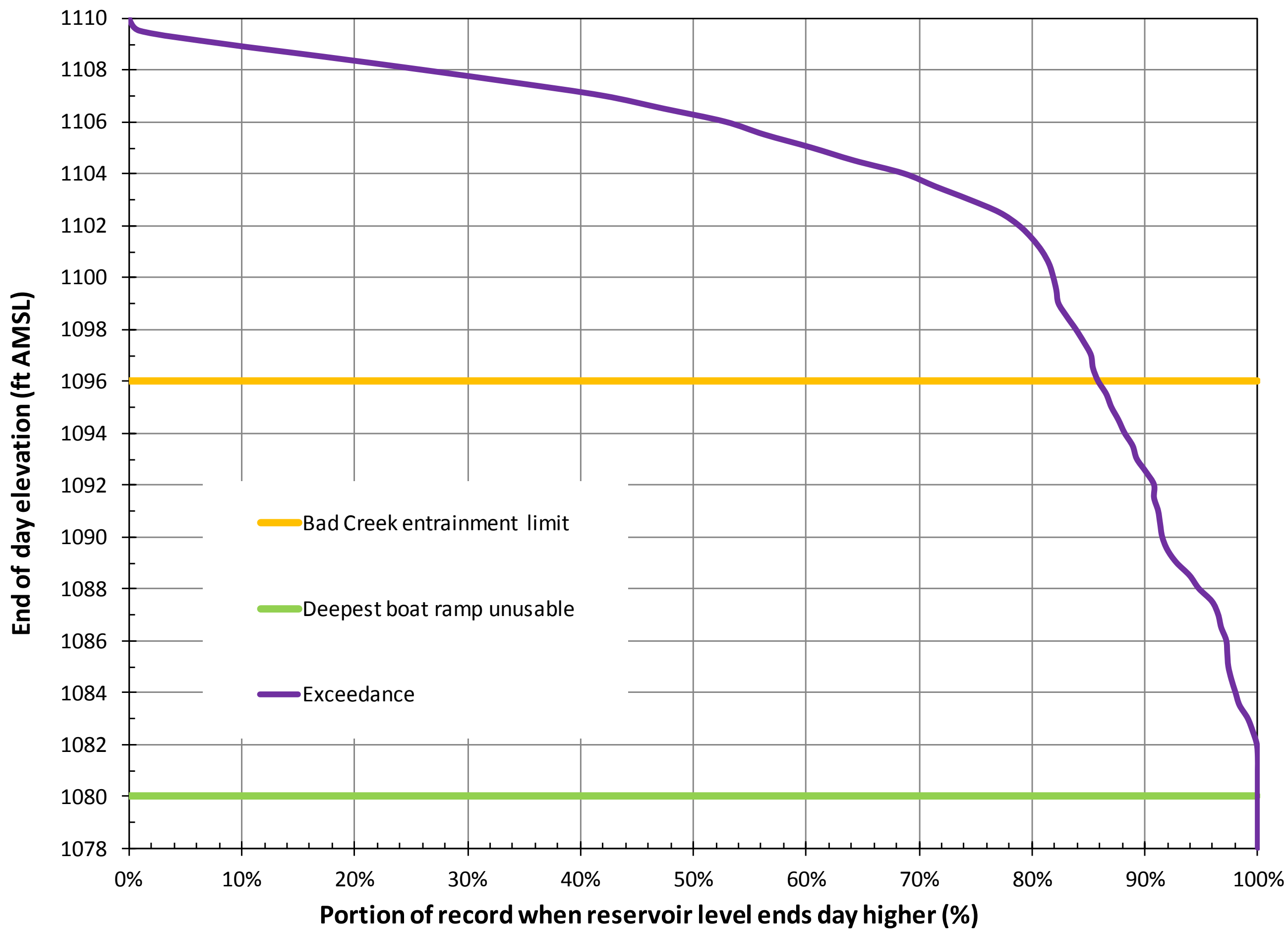


FIGURE 4.3-9(g)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
JULY DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

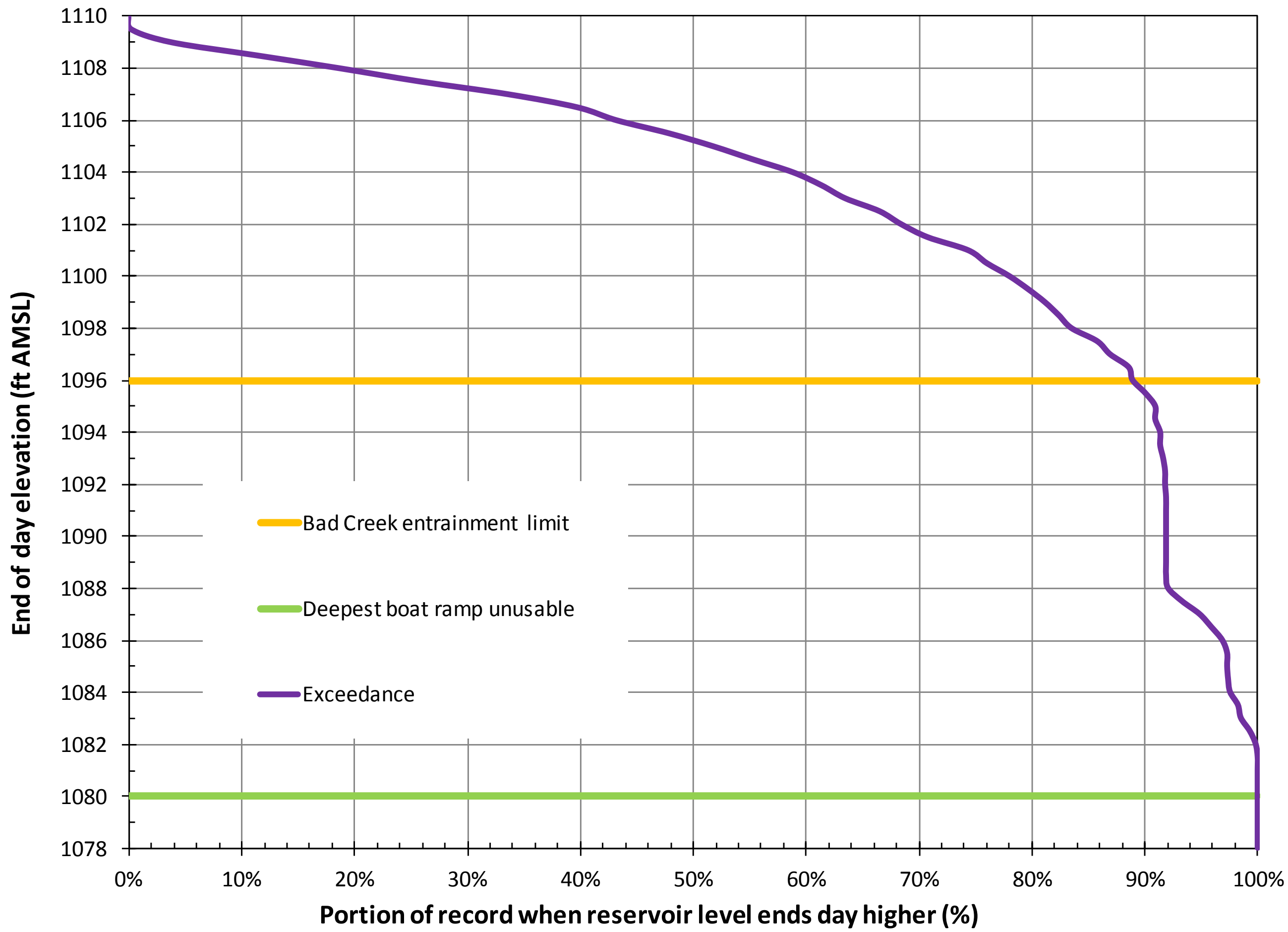


FIGURE 4.3-9(h)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
AUGUST DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

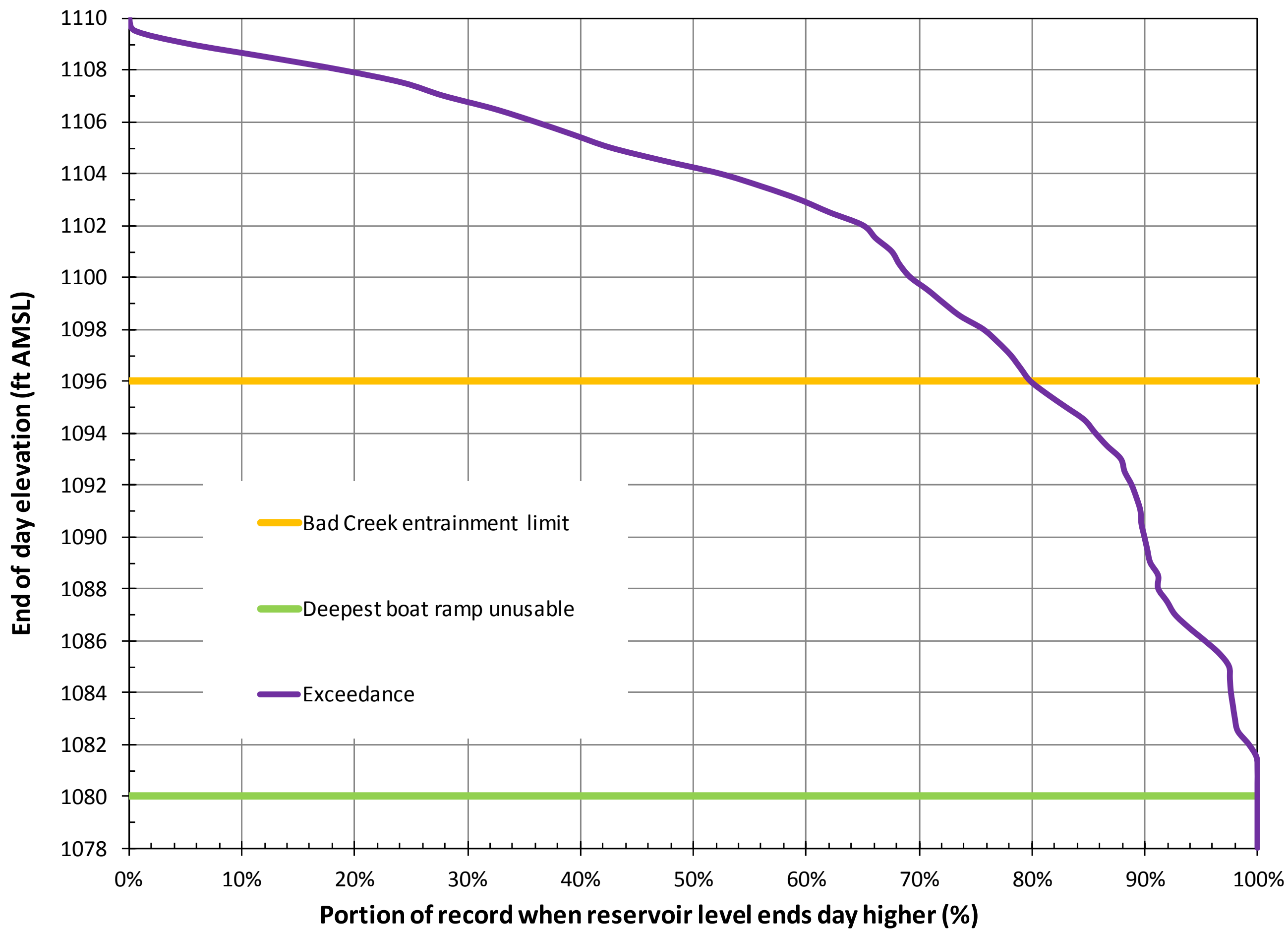


FIGURE 4.3-9(i)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
SEPTEMBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

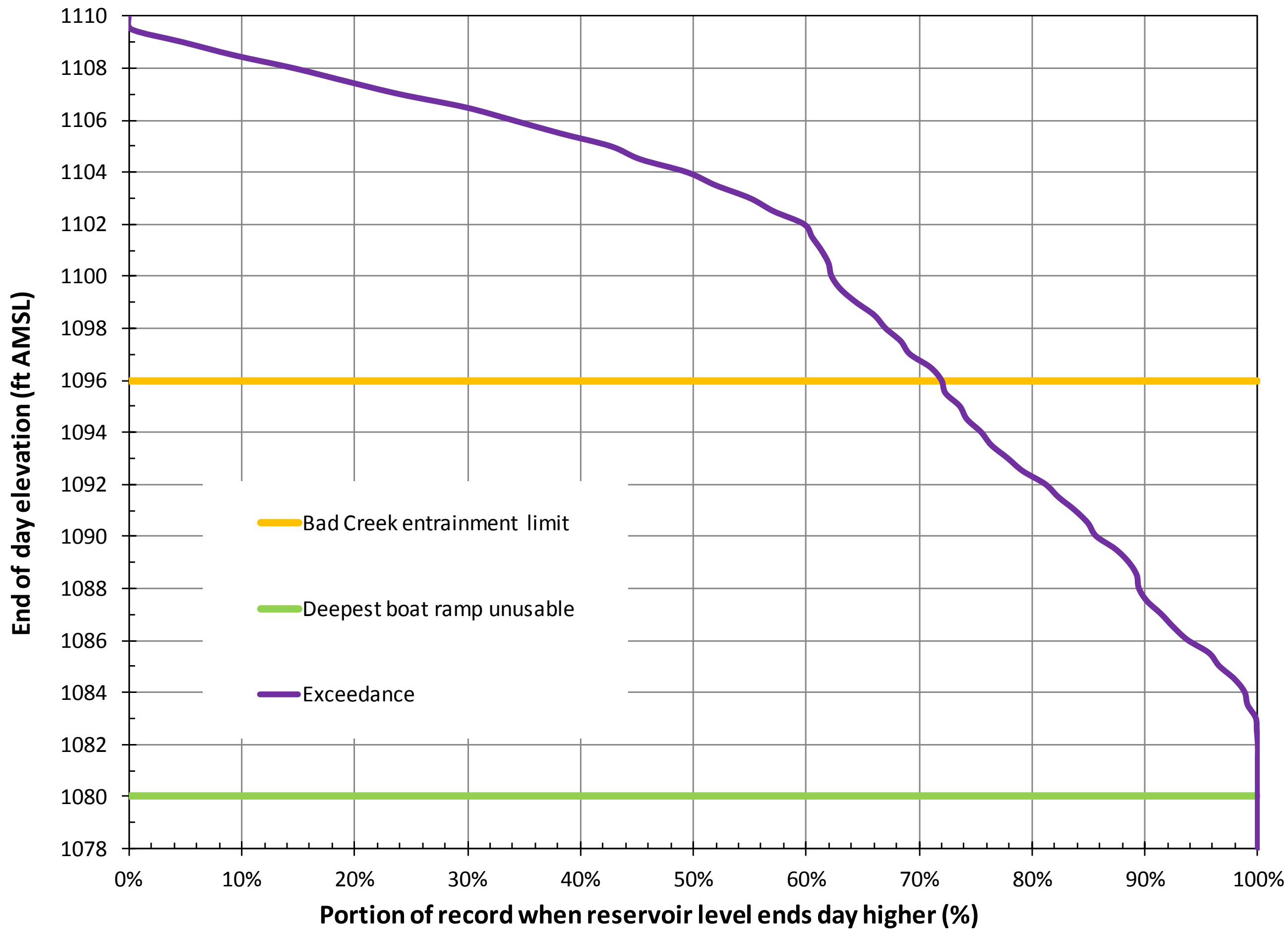


FIGURE 4.3-9(j)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
OCTOBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

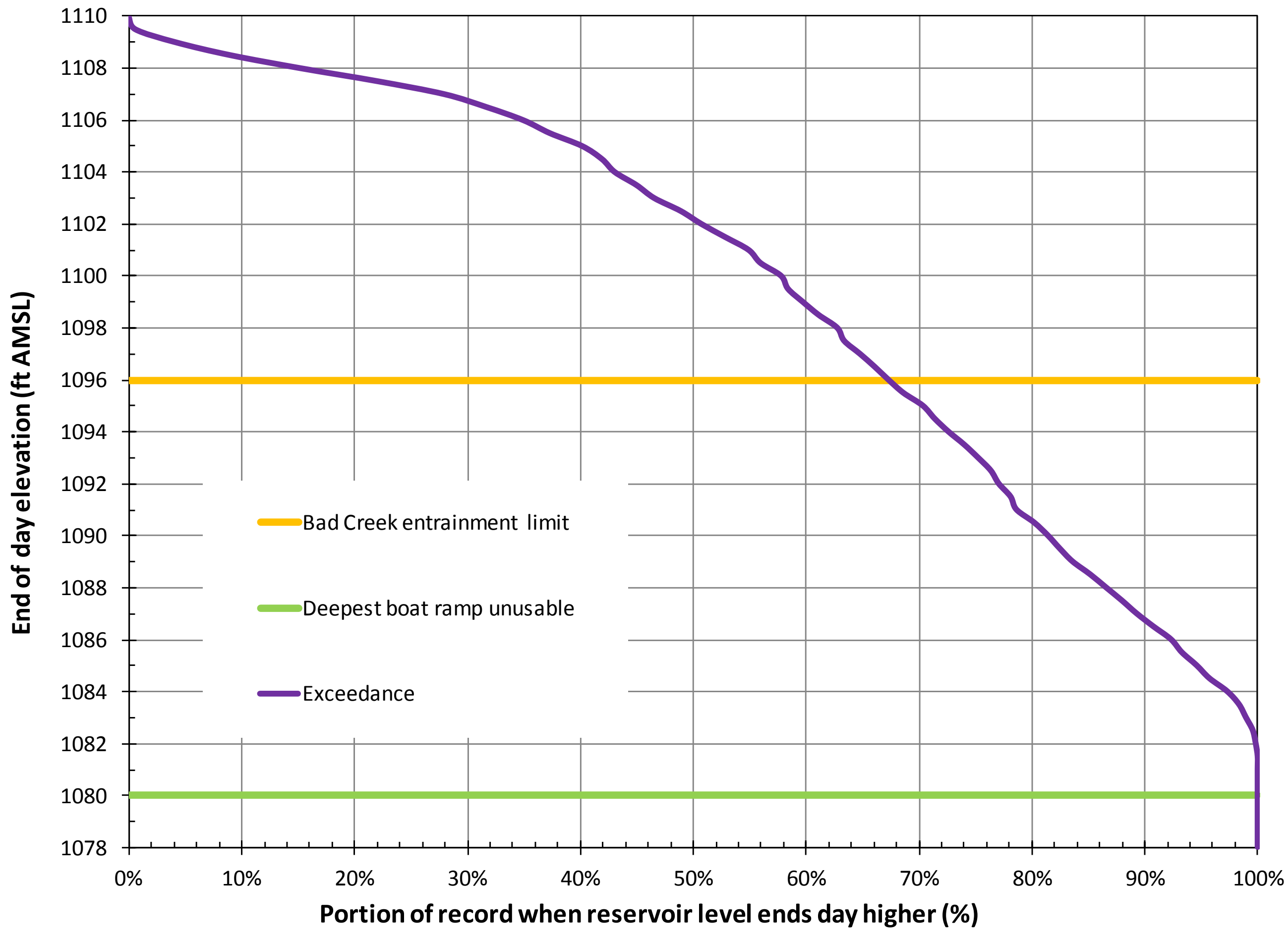


FIGURE 4.3-9(k)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
NOVEMBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

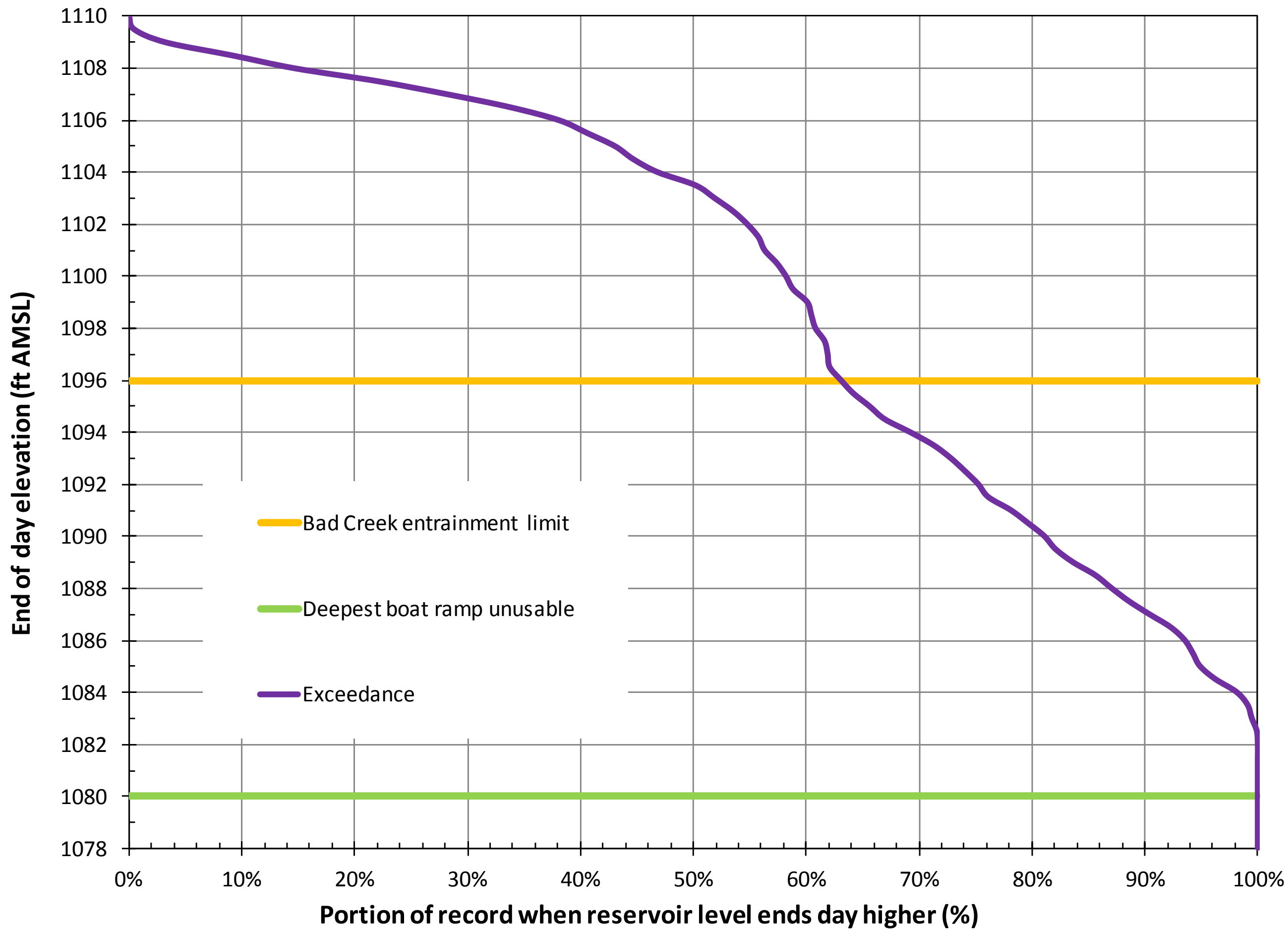


FIGURE 4.3-9(l)
LAKE JOCASSEE LEVELS EXCEEDANCE CURVE
DECEMBER DATA FROM MAY 1, 1975, THROUGH DECEMBER 31, 2011

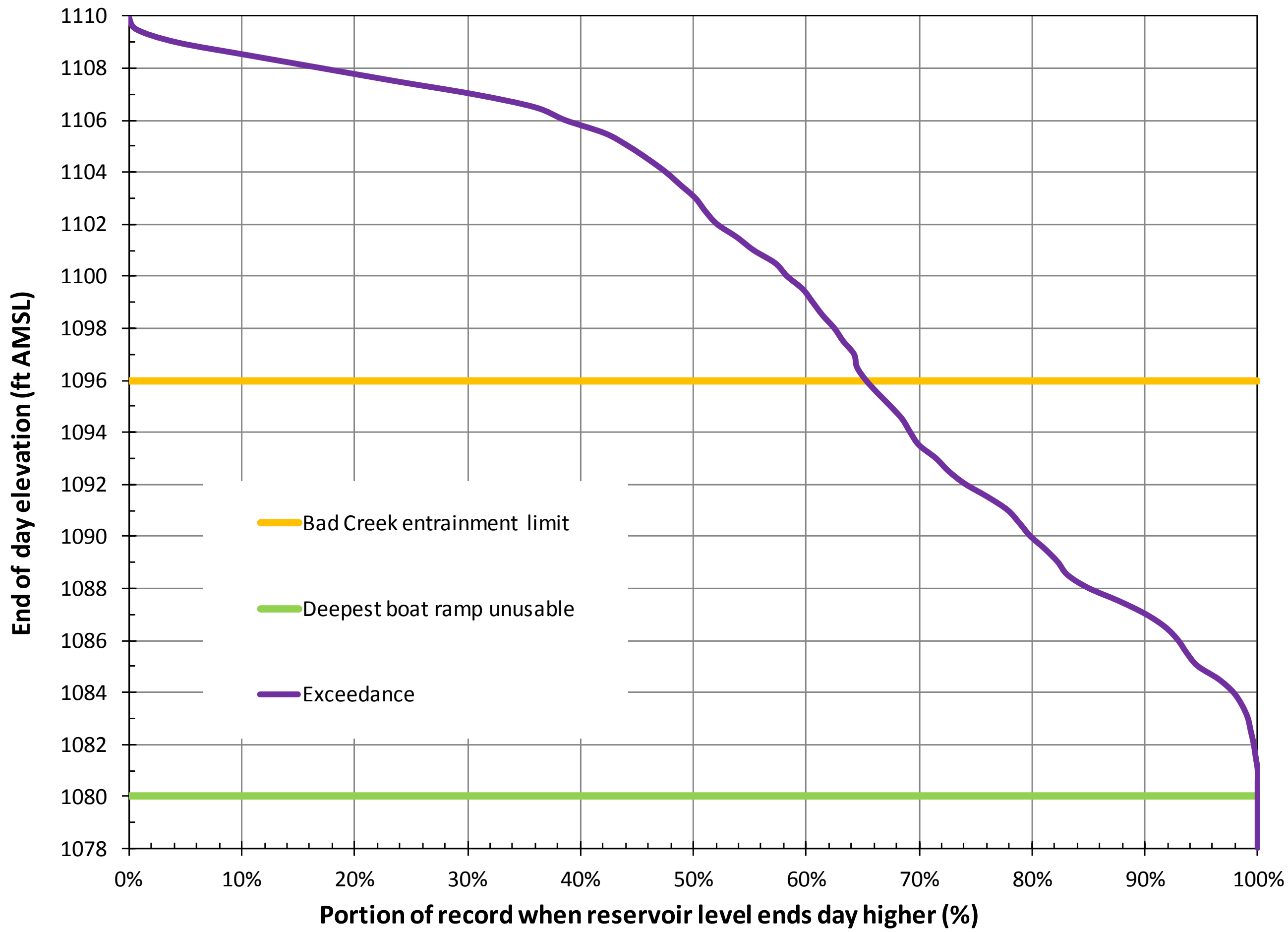


FIGURE 4.4-1(a)
HARTWELL LAKE AND JST LAKE WATER SURFACE ELEVATIONS
APRIL 17, 1971 THROUGH JUNE 30, 1991

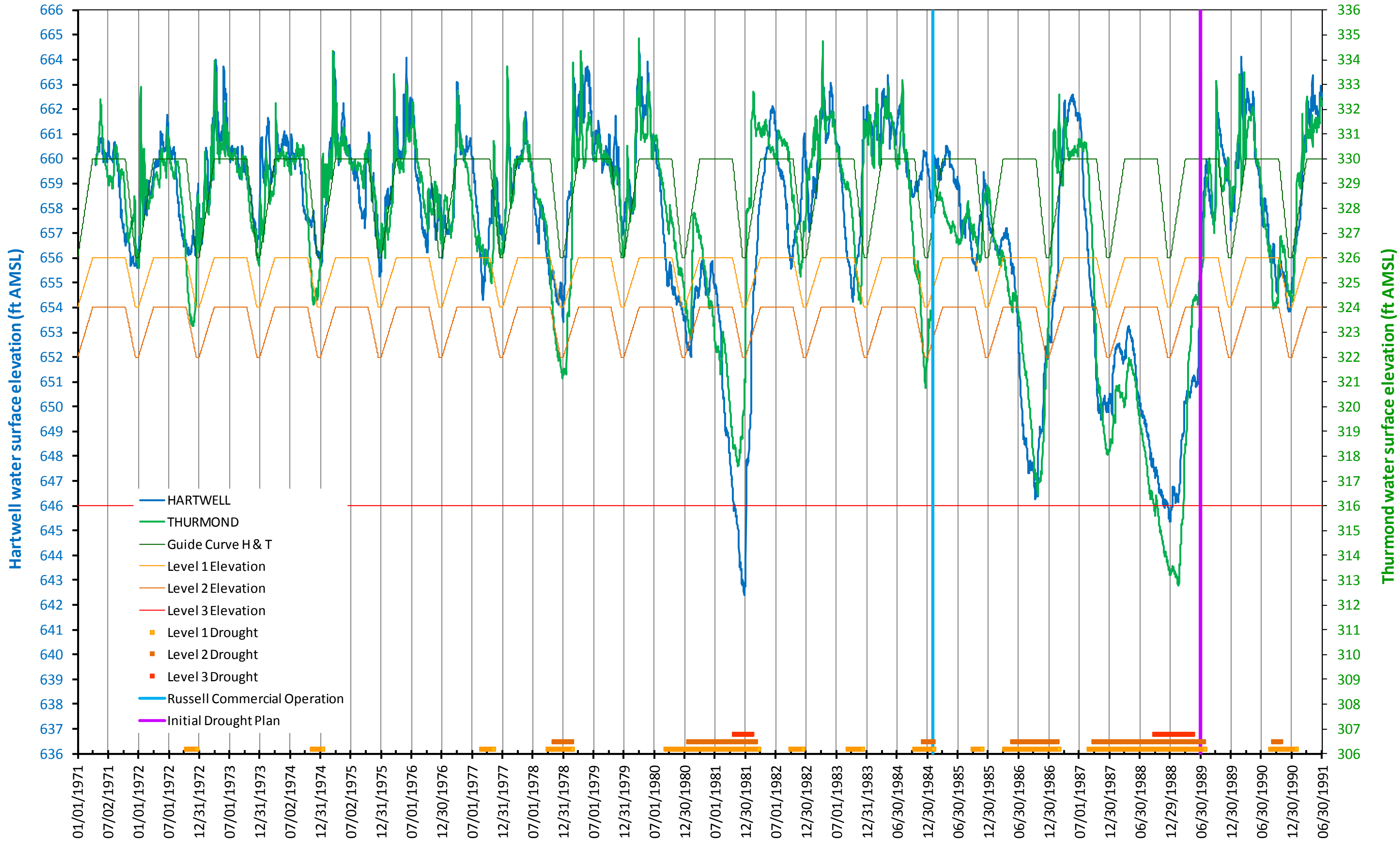
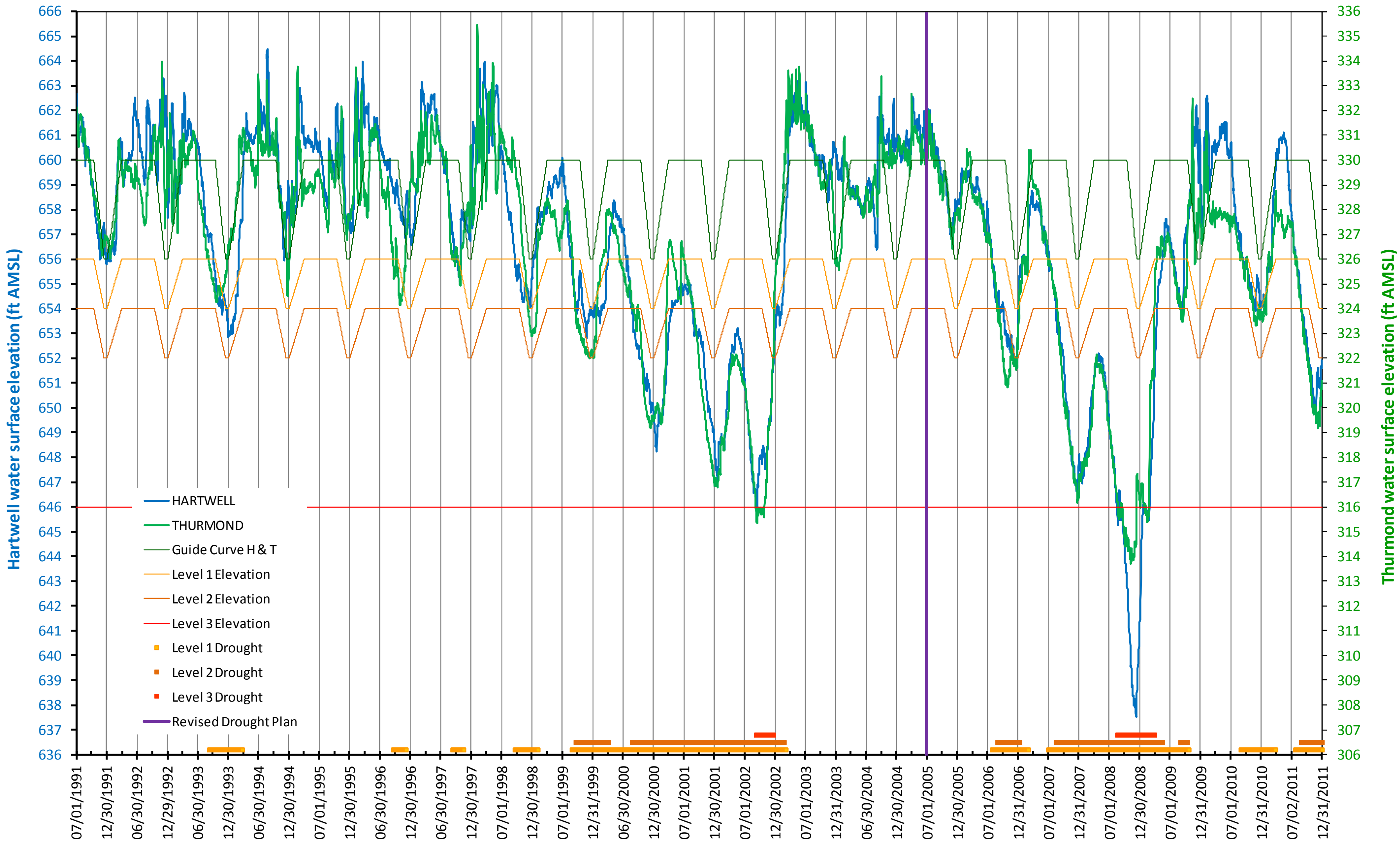


FIGURE 4.4-1(b)
HARTWELL LAKE AND JST LAKE WATER SURFACE ELEVATIONS
JULY 1, 1991 THROUGH DECEMBER 31, 2011



Appendix B
Consultation Record

Keowee -Toxaway Hydro Relicensing

(FERC Project No 2503)

MEETING OF RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY TEAM

Monday, February 27, 2012

10:00 AM – 12 Noon

Via Live Meeting Conference Call

AGENDA

10:00 AM	**Introduction**		
10:05 AM	**Agenda Review**		
10:10 AM	**Schedule**		
		February 2012	Initial Analysis and Study Team Meeting
		March-April 2012	Rough Draft Report Prepared
		April 2012	Meeting of Study Team to Review Draft Report
		April 2012	Study Team Identifies Potential Lake Level Bands
			Revised Draft Report
			Comment Period
			Final Report
10:15 AM	**Brief Review of Objectives and Methods of Study Plan**		
10:30 AM	**Preliminary Analysis**		

- Chronology of Important Events
- Overview of Data Collected
- Lake Levels
  - Daily Time Series Plots
  - Hayes Charts
  - Histograms
  - Exceedance Curves
- Releases
  - Weekly Time Series Plots
  - Quarterly Time Series Plots

11:30 AM **Next Steps**

- Defining Droughts
- Preparation of Rough Draft Report
- Next Meeting of Study Team – Week of April 16-20

11:50 AM **Other Discussion**

12 Noon **Adjourn**

APPENDIX H

RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY PLAN

KEOWEE-TOXAWAY RELICENSING PROJECT
FERC NO. 2503

December 2011

Prepared by:
Duke Energy Carolinas, LLC
Charlotte, NC

1.0 INTRODUCTION

1.1 General Description of the Keowee-Toxaway Project

Duke Energy Carolinas, LLC (Duke Energy) is the Licensee of the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) (Project). The Project consists of two developments – the Jocassee Development and the Keowee Development. The Project is located in the Upstate area of South Carolina primarily in Oconee County and Pickens County with a small portion of Lake Jocassee extending into Transylvania County, North Carolina.

The Jocassee Development is the upstream development and includes Jocassee Pumped Storage Station, Lake Jocassee, Jocassee Dam, and two saddle dikes. The Full Pond Elevation is 1,110 feet above mean sea level (AMSL). At Full Pond, the reservoir has approximately 7,980 surface acres with approximately 92 miles of shoreline. Jocassee Pumped Storage Station's installed generating capacity is 710.1 MW. The Jocassee Development releases water directly into Lake Keowee.

The Keowee Development includes Keowee Hydro Station, Lake Keowee, the Little River Dam, the Keowee Dam, and four saddle dikes. The Full Pond Elevation is 800 feet AMSL. At Full Pond, the reservoir has approximately 17,660 surface acres with approximately 388 miles of shoreline. Keowee Hydro Station's installed generating capacity is 157.5 MW. Water released from Keowee Hydro Station flows directly into Hartwell Lake, a US Army Corps of Engineers reservoir.

1.2 Relicensing Process

The Existing License for the Keowee-Toxaway Project was issued in 1966 and will expire on August 31, 2016. Duke Energy is using the Integrated Licensing Process (ILP) as promulgated by the Federal Energy Regulatory Commission (FERC) regulations issued August 25, 2003 (68 FR 51070), codified at 18 CFR Part 5 to relicense the Project. Duke Energy has elected to form a Stakeholder Team comprised of representatives of local, state, and federal agencies, Native

American tribes, and non-governmental organizations to assist in the implementation of the relicensing process. This Stakeholder Team is charged with supporting the implementation of the ILP, ensuring that information flows between Duke Energy and organizations affected by continued operation of the Project, and developing a comprehensive Relicensing Agreement for inclusion with the Application for New License Duke Energy will submit by August 29, 2014.

Two types of teams, separate from the Stakeholder Team, will be involved with the identification, development, and implementation of studies to support the relicensing effort. Resource Committees (RC) are charged with identifying studies within their resource areas, drafting the study plans, identifying participants for the Study Teams, and synthesizing the findings of the Study Teams for consideration by the Stakeholder Team. The RCs are: Aquatics, Cultural Resources, Recreation, Shoreline Management, Water Quality, Water Quantity & Operations, and Wildlife & Botanical Resources.

Study Teams are comprised of technical experts who actually conduct the various studies. Study Teams typically include representatives from resource agencies, Native American tribes, Duke Energy, and consultants retained by Duke Energy. The members of each Study Team are identified in the study plan.

During the process, information needs will be identified as they relate to Project relicensing. In association with this interest, the following study plan has been prepared that addresses each of the required seven FERC study plan criteria provided in 18 CFR § 5.9(b). Any information or study request must address the following:

(1) *Describe the goals and objectives of each study and the information to be obtained (§ 5.9(b)(1)):* This section describes what the study is intended to accomplish, the goals and objectives of the study, and specific information to be obtained. The goals of the study should clearly relate to the need to evaluate the effects of the project on a particular resource. The objectives are the specific information needs to be gathered to allow achievement of the study goal. This section provides the context for why the study is being requested.

(2) *If applicable, explain the relevant resource management goals of the agencies or Indian tribes with jurisdiction over the resource to be studied (§ 5.9(b)(2)):* This discussion should clearly establish the connection between the study request and the management goals of the requesting agency or tribe. A statement by an agency connecting its study request to a legal, regulatory, or policy mandate is entitled to appropriate consideration. However, it is much easier to understand the relationship of an information need to a specific management goal than to broadly stated mandates established in law or regulation. Where such mandates are integral to the need for the information, the requester needs to thoroughly explain how the mandate relates to the study request and, in turn, project impacts.

(3) *If the requester is not a resource agency, explain any relevant public interest considerations in regard to the proposed study (§ 5.9(b)(3))*: This discussion should clearly establish the connection between the study request and the resource of interest. The requester needs to thoroughly explain how its resource interest relates to the study request and, in turn, project impacts.

(4) *Describe existing information concerning the subject of the study proposal, and the need for additional information (§ 5.9(b)(4)):* The purpose of this discussion is to highlight the gap in existing data, giving full consideration to what has been provided in the PAD or is known from other information sources relevant to the project. This discussion should clearly explain why the existing information is inadequate and the need for additional information.

(5) *Explain any nexus between project operation and effects (direct, indirect, and/or cumulative) on the resource to be studied, and how the study results would inform the development of license requirements (§ 5.9(b)(5)):* This discussion should clearly draw the connection between project operations and the effects (direct, indirect, and/or cumulative) on the applicable resource. Just as important, this discussion should explain how the requester will use the information to develop protection, mitigation, and enhancement measures, including those related to an agency's mandatory conditioning authority under 401 of the Clean Water Act (CWA) or sections 4(e) and 18 of the Federal Power Act.

(6) *Explain how any proposed study methodology (including any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration) is consistent with generally accepted practices in the scientific community or, as appropriate, considers relevant tribal values and knowledge (§ 5.9(b)(6)):* Study requests should be as detailed as possible. It is important to relay to the applicant expectations on the scope and methods so an adequate study plan can be developed. The requester may describe the proposed methodology by outlining specific methods to be implemented (e.g. study area, study sites, data collection methods, etc.) or simply by referencing an approved and established study protocol or methodology (e.g. Henderson 1999, or Missouri State Water Quality Sampling Protocols for Lead, 1999). If providing a detailed methodology, the requester should demonstrate how the requested methodology is consistent with generally accepted practice within the scientific community or, as appropriate, considers relevant tribal values and knowledge. The requested study must be generally accepted in the context of how it is being used.

(7) *Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs (§ 5.9(b)(7)):* This section should describe expectations of the level of effort and costs associated with the development and implementation of the requested study. This would be used to provide the applicant with a better understanding of expectations for the completion of the study. Within this section, requesters should also provide a justification as to why any proposed alternative studies would not be sufficient to meet the stated information needs. Proposed alternative studies could be studies being proposed by the applicant in the PAD or those being requested by other parties.

2.0 GOALS AND OBJECTIVES

The objective of this study is to organize historic lake level data for both Lake Keowee and Lake Jocassee and flow release data for Keowee Hydro Station into a database format to allow easy computer access and analysis. The data will include all available reservoir level and flow release data for the entire available record, including both drought and non-drought times.

The lake level data will be used to identify potential seasonal operating elevation bands for Lake Keowee, based on historical operation under all conditions. However, because Lake Jocassee's full usable storage volume is expected to be used as needed during droughts, only its historic levels during non-drought periods will be used to identify potential normal seasonal operating elevation bands for Lake Jocassee.

The Keowee Hydro Station flow release data will be used as a reference to observe the historic volumetric release patterns in relation to the beginning and ending of drought periods. Since flow releases from Keowee Hydro Station are largely controlled by the provisions of the 1968 Operating Agreement between Duke Energy, the Savannah District of the US Army Corps of Engineers, and the Southeastern Power Administration, an analysis of the distribution of the release volumes in relation to drought periods will provide useful observations of the relationship of the Project storage with the storage in the downstream federal projects.

3.0 STUDY AREA

The study area is limited to the Project Boundary.

4.0 BACKGROUND AND EXISTING INFORMATION

4.1 Existing Data

Duke Energy has access to the following data for use in this study:

- Historical lake level information (daily midnight readings) dating back to initial operation of both facilities, and hourly lake level data dating back to 1995:
  - Jocassee Pumped Storage Station began operation in 1973
  - Keowee Hydro Station began operation in 1971
- Current operating elevations for Lake Keowee used as guidelines
- Critical lake level data for steam power plant and municipal water intake operations
- Lake levels at which Project boat ramps become unusable

- Daily and weekly cyclical lake level fluctuations
- Daily and weekly generation data for Keowee Hydro Station to estimate water volume releases from Keowee Hydro Station
- Weekly storage level data for Hartwell Lake and J. Strom Thurmond Lake
- Data compiled for development of the inflow dataset for the Project

4.2 Resource Discussion

Lake Keowee is formed by the Keowee Dam impounding the Keowee River and the Little River Dam impounding the Little River. These two rivers join just downstream of the Lake Keowee dams within Hartwell Lake and their confluence forms the Seneca River, a tributary of the Savannah River. Lake Keowee is used as cooling water for Oconee Nuclear Station. Greenville Water and Seneca Light & Water currently are the only two public water system water withdrawers at Lake Keowee. Lake Keowee is also the lower reservoir from which the Jocassee Pumped Storage Station pumps water into Lake Jocassee.

5.0 PROJECT NEXUS

Project operations have a direct effect on both reservoir levels and flow releases. This study is expected to assist in the development of license terms because the New License for the Project could require seasonally varying operating elevation bands for Lake Keowee. Also, Duke Energy may decide to establish Normal Target Elevations or Normal Operating Ranges for Lake Keowee. The Study Team will review whether Normal Target Elevations or Normal Operating Ranges also need to be identified for Lake Jocassee for non-drought conditions. An assessment of alternative seasonal reservoir levels is required to evaluate the impacts of any proposed changes in operations on environmental and other resources. The results of this study will be used to assist in balancing the often conflicting demands on water stored in the Project reservoirs by providing insight into historical ranges and frequency of reservoir level fluctuations.

6.0 METHODOLOGY

The methods for conducting the study described above in the goals and objectives are as follows:

6.1 Data Analysis

The historical lake level data will be assembled in a database. Lake level data will extend from the original operation dates through December 31, 2011. Daily midnight readings will be used from the beginning of hydro operations until 1995. Beginning in 1995, hourly lake level information will be used. The data will be analyzed to determine both the frequency and time duration of a particular lake level band on each lake.

Weekly average flow releases from Keowee Hydro Station will be calculated and assembled in a database. The data will begin with the earliest date for which data are available and extend through December 31, 2011. In the analysis, particular interest will be paid to flow releases during periods of drought.

6.2 Identification of Potential Operating Ranges

Duke Energy, in consultation with Study Team Members and the larger Stakeholder Team, will identify potential Normal Operating Ranges for Lakes Keowee and Jocassee under non‐drought conditions. In addition, potential operating ranges for Lake Keowee under drought conditions will also be identified. These potential operating ranges will then be analyzed using the operations models developed for relicensing (see the Operations Model Development Study Plan).

6.3 Data Reporting

Draft and Final technical reports on the results and recommendations will be prepared for this study and will include the following elements:

a) Project Introduction and Background (including a discussion of the availability of Project boat ramps at different lake levels)
b) Study area
c) Methodology
d) Discussion and Analysis
e) Results (including discussions of Project effects and recommendations)
f) Any agency correspondence and or consultation
g) Literature citations

7.0 SCHEDULE

The schedule for the conduct of this study follows.

1. Study planning and data compilation begins: February 2, 2012
2. Data compilation and analysis complete: April 2, 2012
3. Potential lake level bands identified: August 1, 2012
4. Draft report provided to Study Team: December 31, 2012
5. Comments on draft report due from Study Team: January 31, 2013
6. Final study report submitted to Study Team: April 1, 2013

8.0 BUDGET

The approximate budget for the study is $50,000.

9.0 DISCUSSION OF ALTERNATIVE APPROACHES

The proposed methods for this study are consistent with professional practices. The overall approach is commonly used in relicensing proceedings, is consistent with generally accepted methods for conducting reservoir level data studies, and follows the generally accepted techniques used by federal and state agencies. In addition, the proposed methods for this study are consistent with FERC study requirements under the ILP. No alternative approaches to this study are necessary.

10.0 STUDY TEAM MEMBERS

Phil Fragapane, Duke Energy, Study Team Lead

George Galleher, Duke Energy

Ed Bruce, Duke Energy

Bob Faires, Seneca Light & Water

Ben Turetzky, FOLKS

Frank Eskridge, Greenville Water

Chuck Gorman, SCDHEC

Scott Harder, SCDNR

Andy Wachob, SCDNR

Chronology of Important Events

Keowee -Toxaway Hydro Project

Existing License Issued by the Federal Power Commission	1966
Duke/SEPA/USACE Operating Agreement Signed	1968
Keowee Hydro Station Commercial Operation of Last Unit	17 April 1971
Oconee Nuclear Station Commercial Operation of Last Unit	1974
Jocassee Pump Storage Station Commercial Operation of Last Unit	1 May 1975
Institution of USACE Drought Contingency Plan	1989
Bad Creek Pumped Storage Project Commercial Operation	1991
Keowee Hydro Station Operation Modified to Accommodate Oconee Nuclear Station	1995
Keowee -Toxaway Fishery MOU on Bad Creek Entrainment Signed	1997
Existing License Expires	2016

Overview of Data Collected

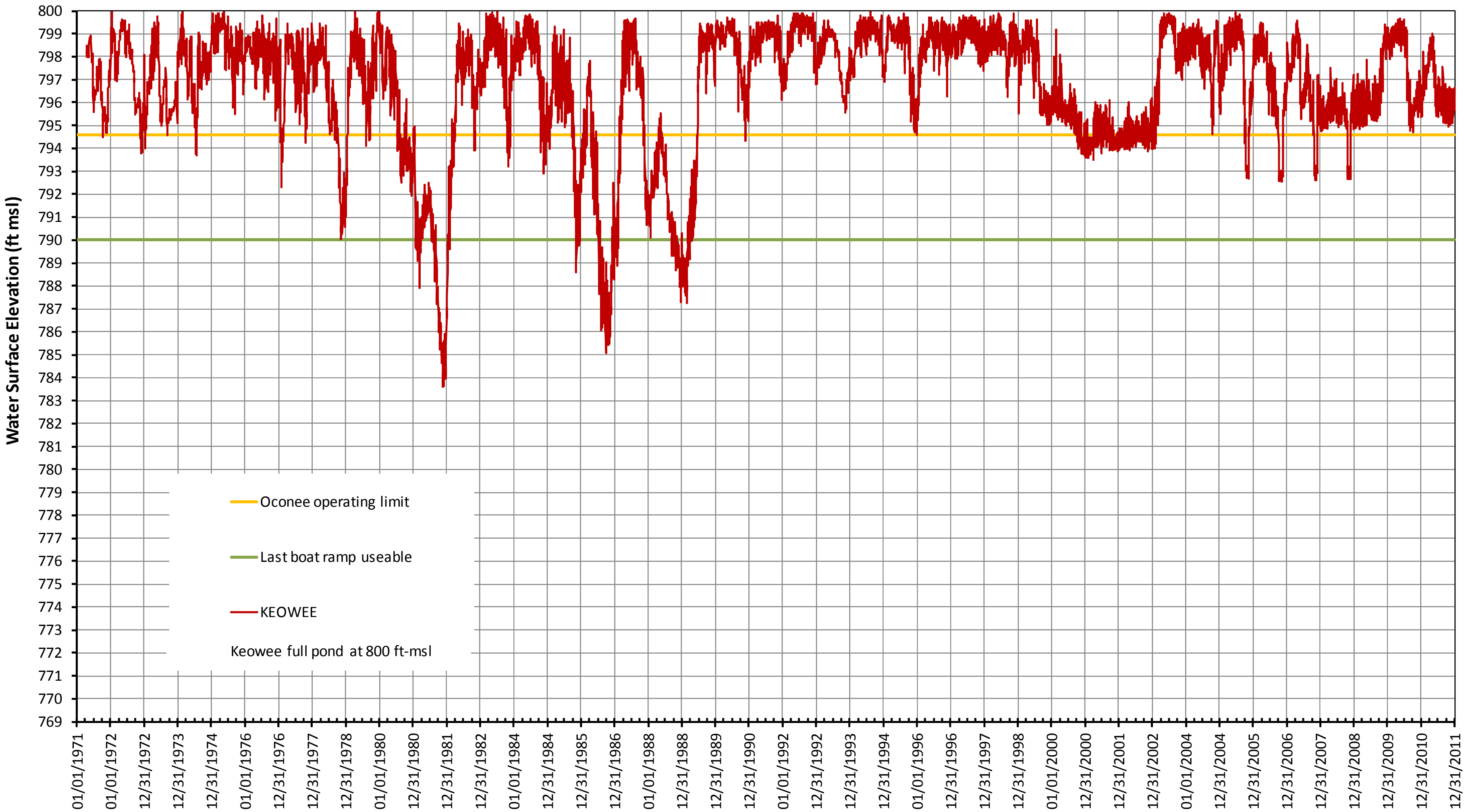
Keowee (April 17, 1971 through December 31, 2011 - levels and discharges)

- Daily data from 1971 through 2011
- Hourly data from 1995 through 2011

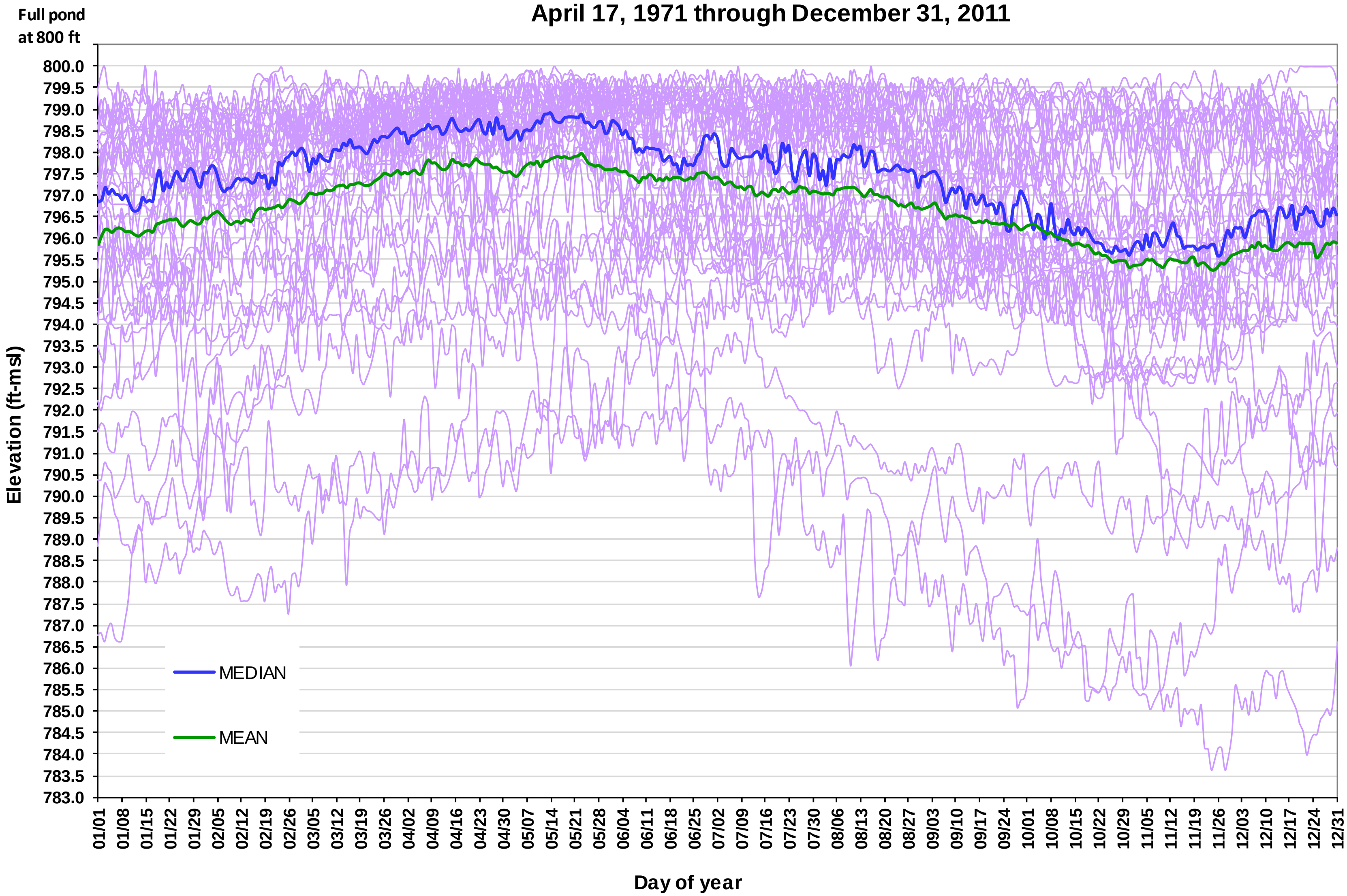
Jocassee (May 1, 1975 through December 31, 2011 - levels only)

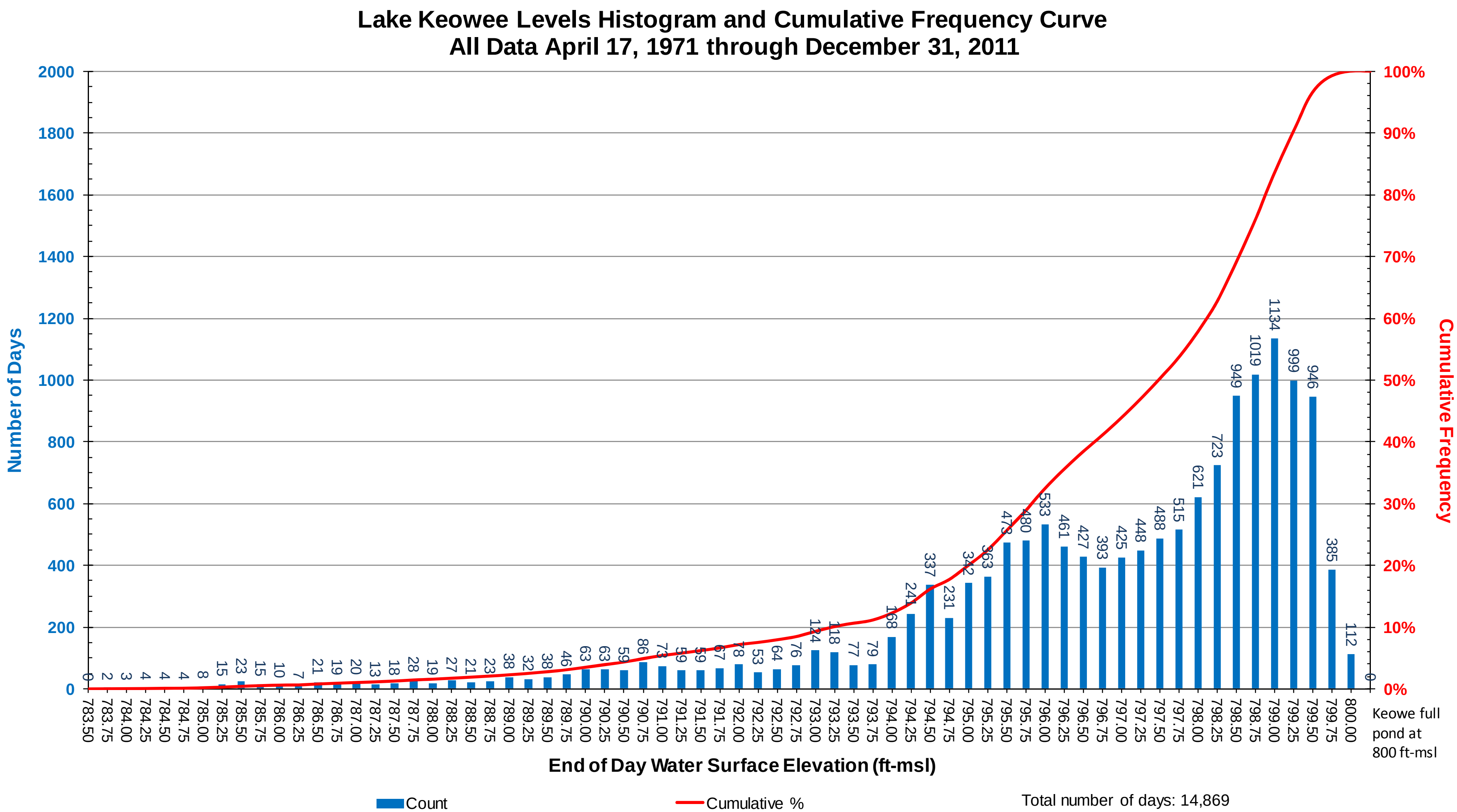
- Daily data from 1975 through 2011
- Hourly data from 1995 through 2011

Lake Keowee Water Surface Elevations
April 17, 1971 through December 31, 2011

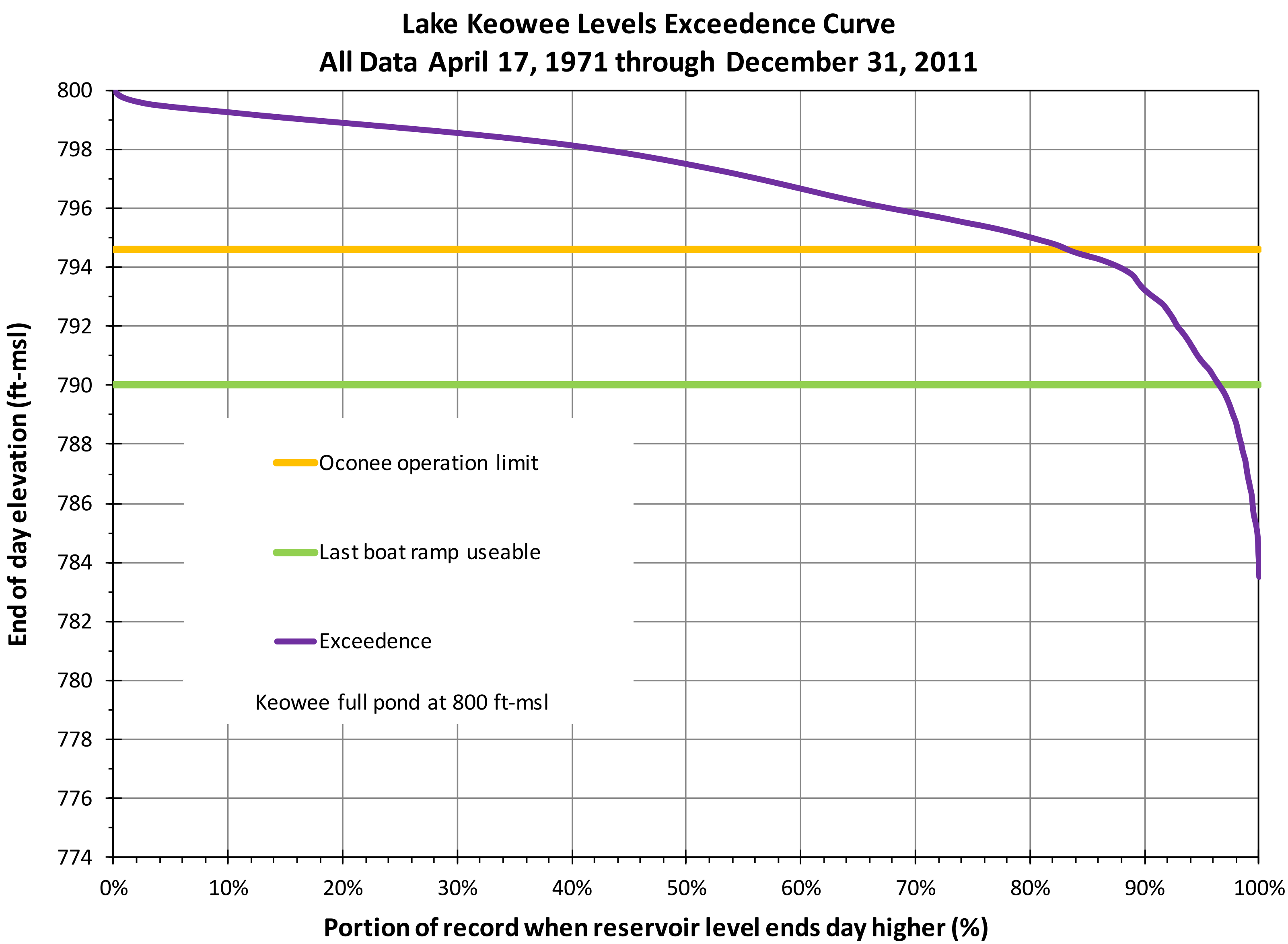


Hayes Chart of Lake Keowee Daily Water Surface Elevations
April 17, 1971 through December 31, 2011

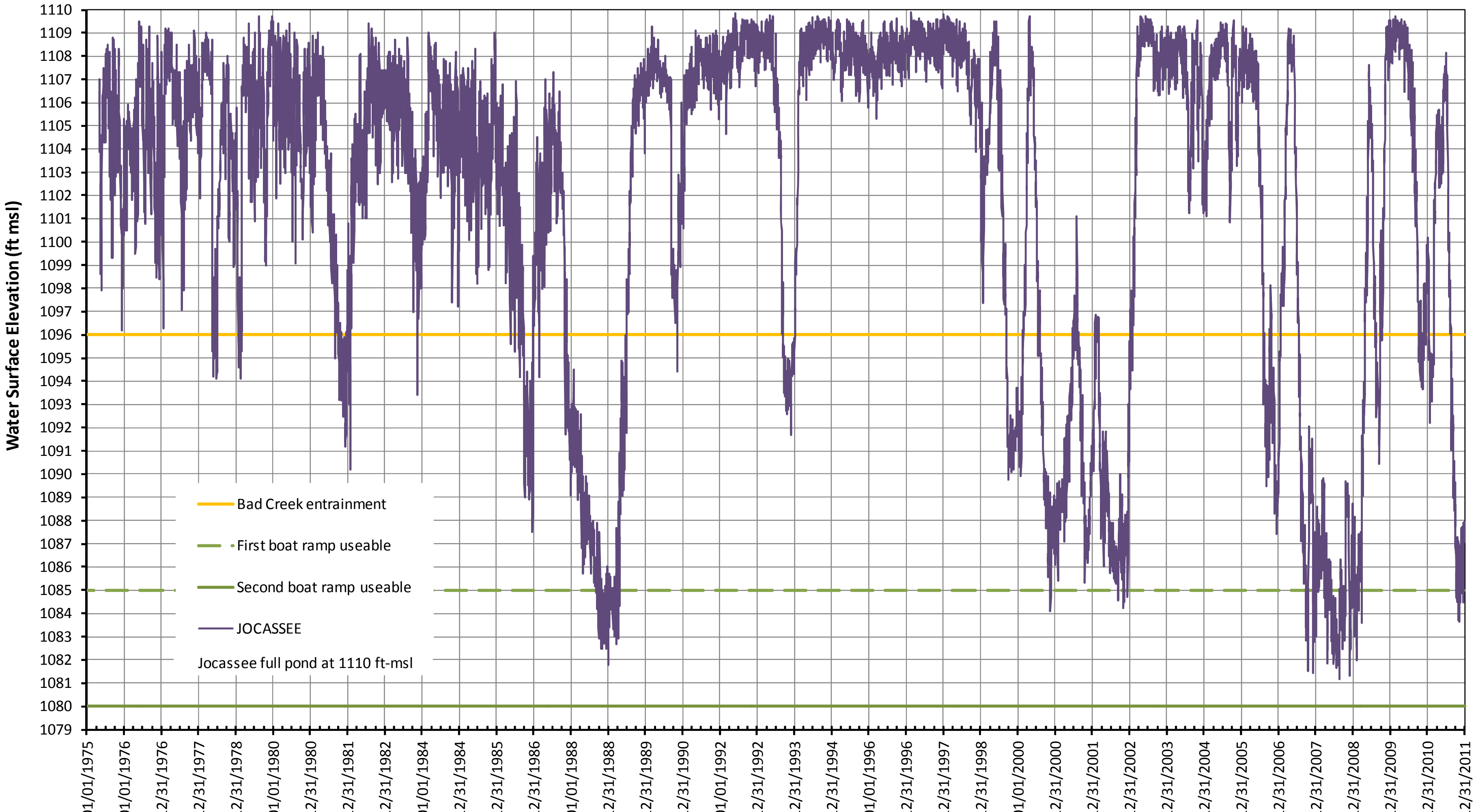




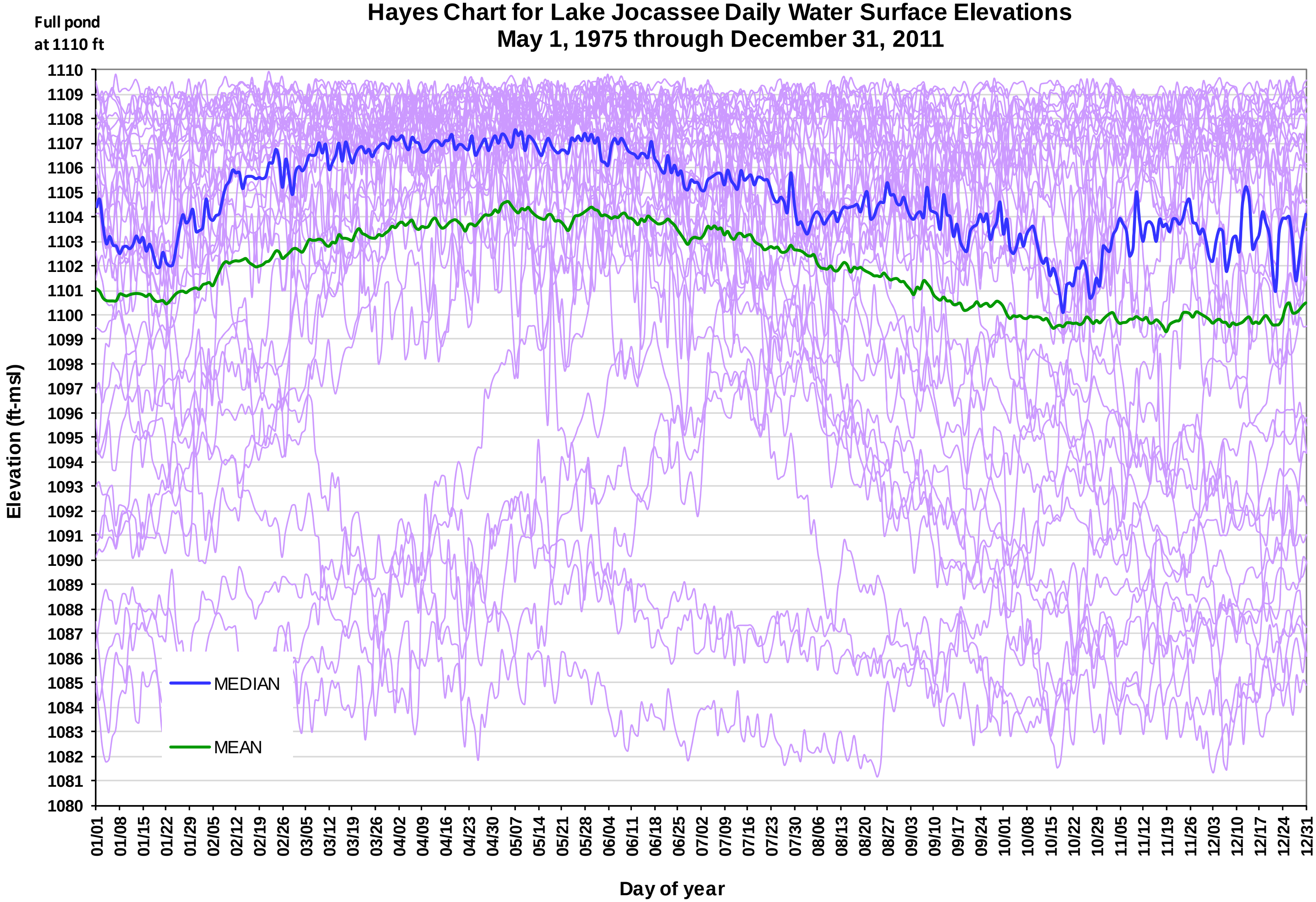
Lake Keowee Levels Histogram and Cumulative Frequency Curve
All Data April 17, 1971 through December 31, 2011
Number of Days
Cumulative Frequency
End of Day Water Surface Elevation (ft-msl)
Count
Cumulative %
Total number of days: 14,869
Keowe full pond at 800 ft-msl


Lake Keowee Levels Exceedence Curve
All Data April 17, 1971 through December 31, 2011
800
798
796
794
792
790
788
786
784
782
780
778
776
774
End of day elevation (ft-msl)
Oconee operation limit
Last boat ramp useable
Exceedence
Keowee full pond at 800 ft-msl
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Portion of record when reservoir level ends day higher (%)

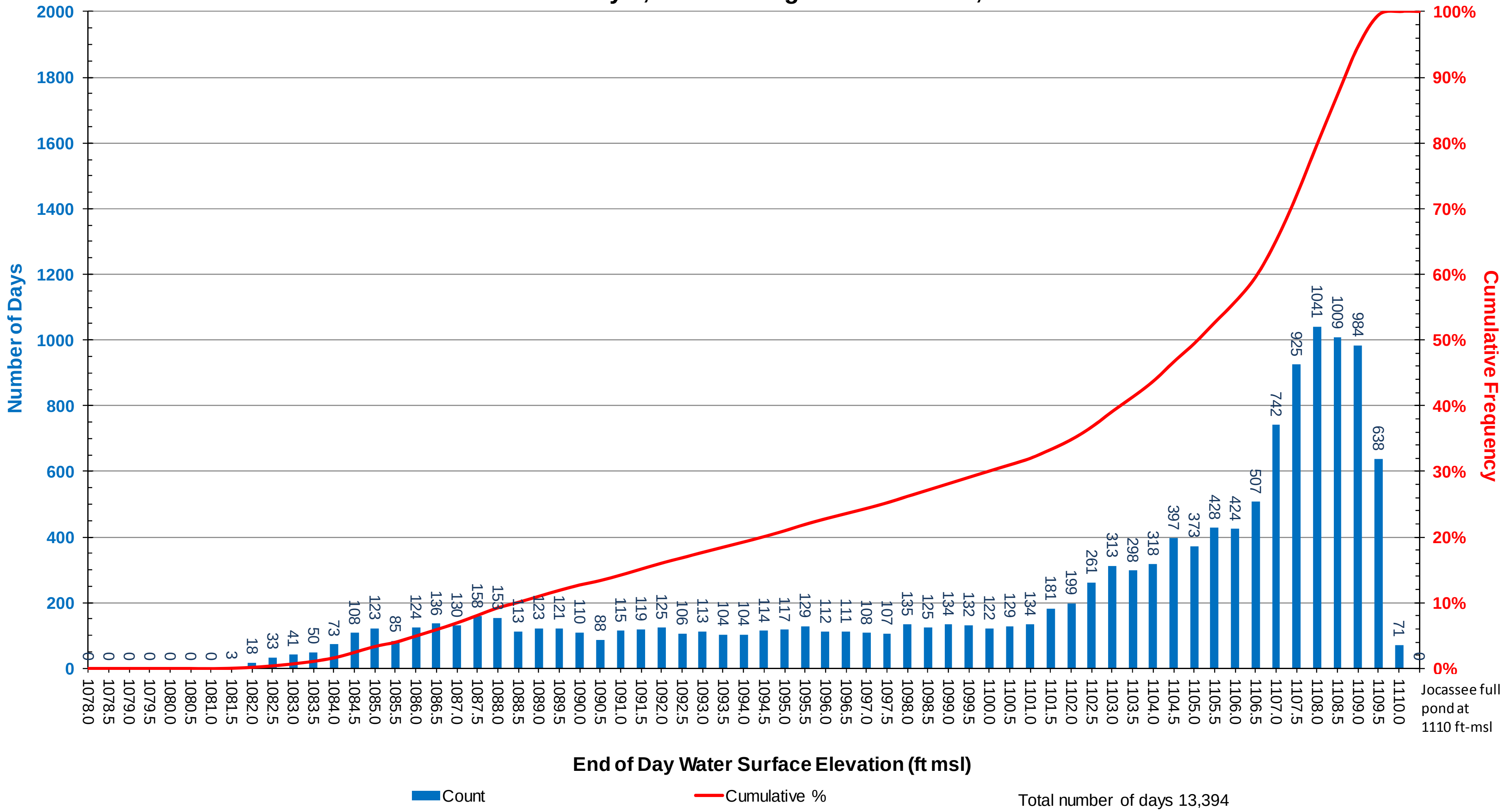
Lake Jocassee Water Surface Elevations
May 1, 1975 through December 31, 2011



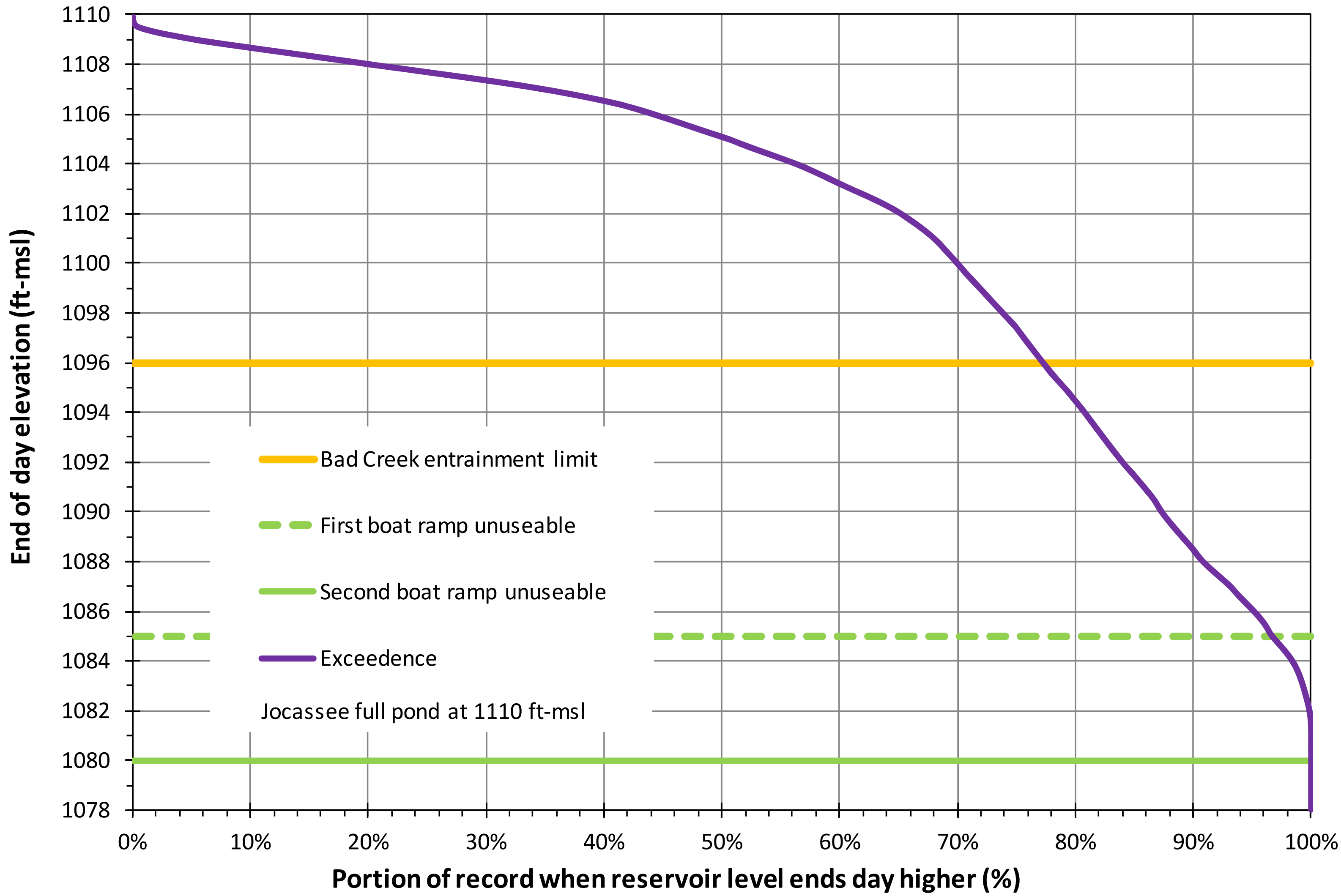
Hayes Chart for Lake Jocassee Daily Water Surface Elevations
May 1, 1975 through December 31, 2011



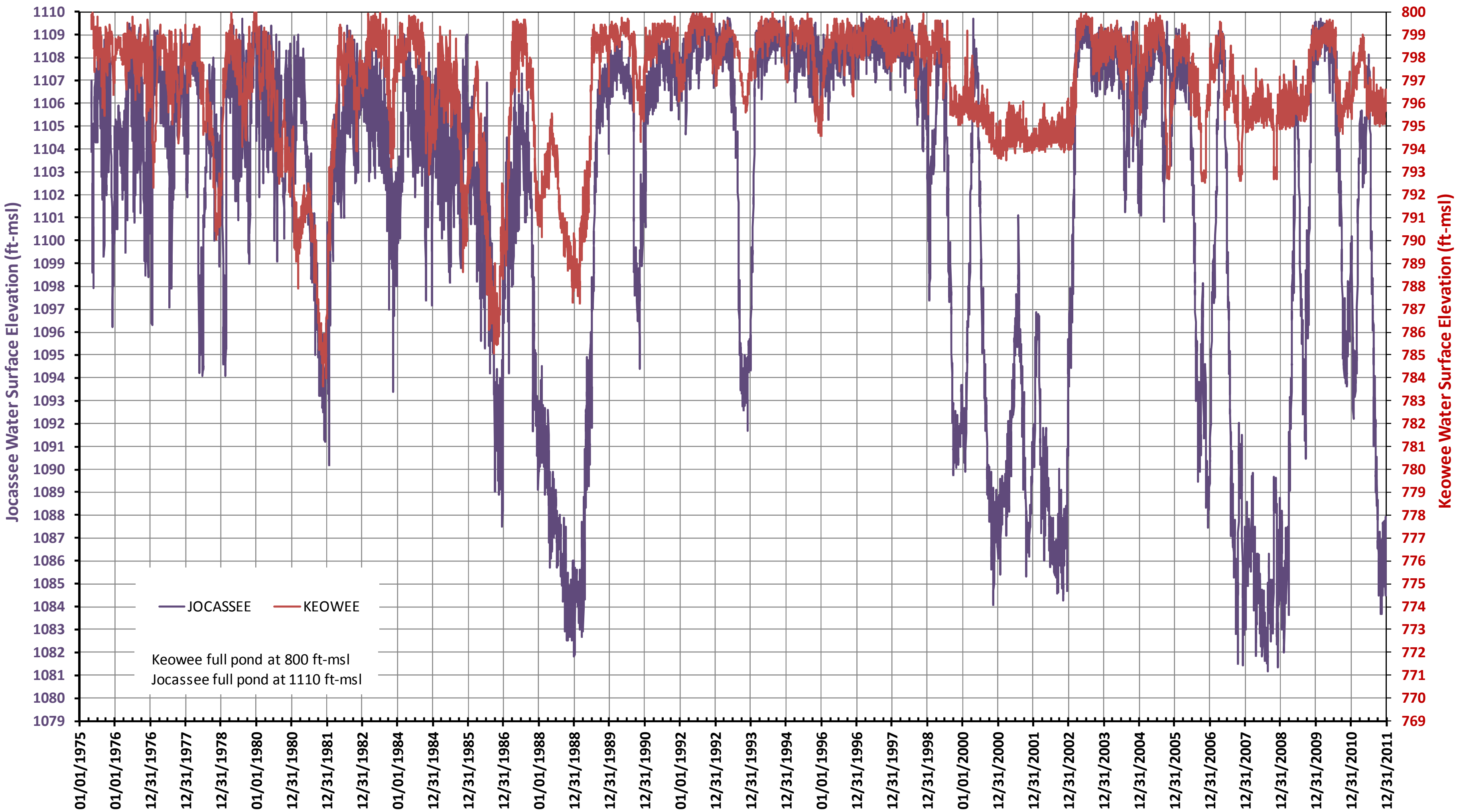
Lake Jocassee Levels Histogram and Cumulative Frequency Curve
All Data May 1, 1975 through December 31, 2011



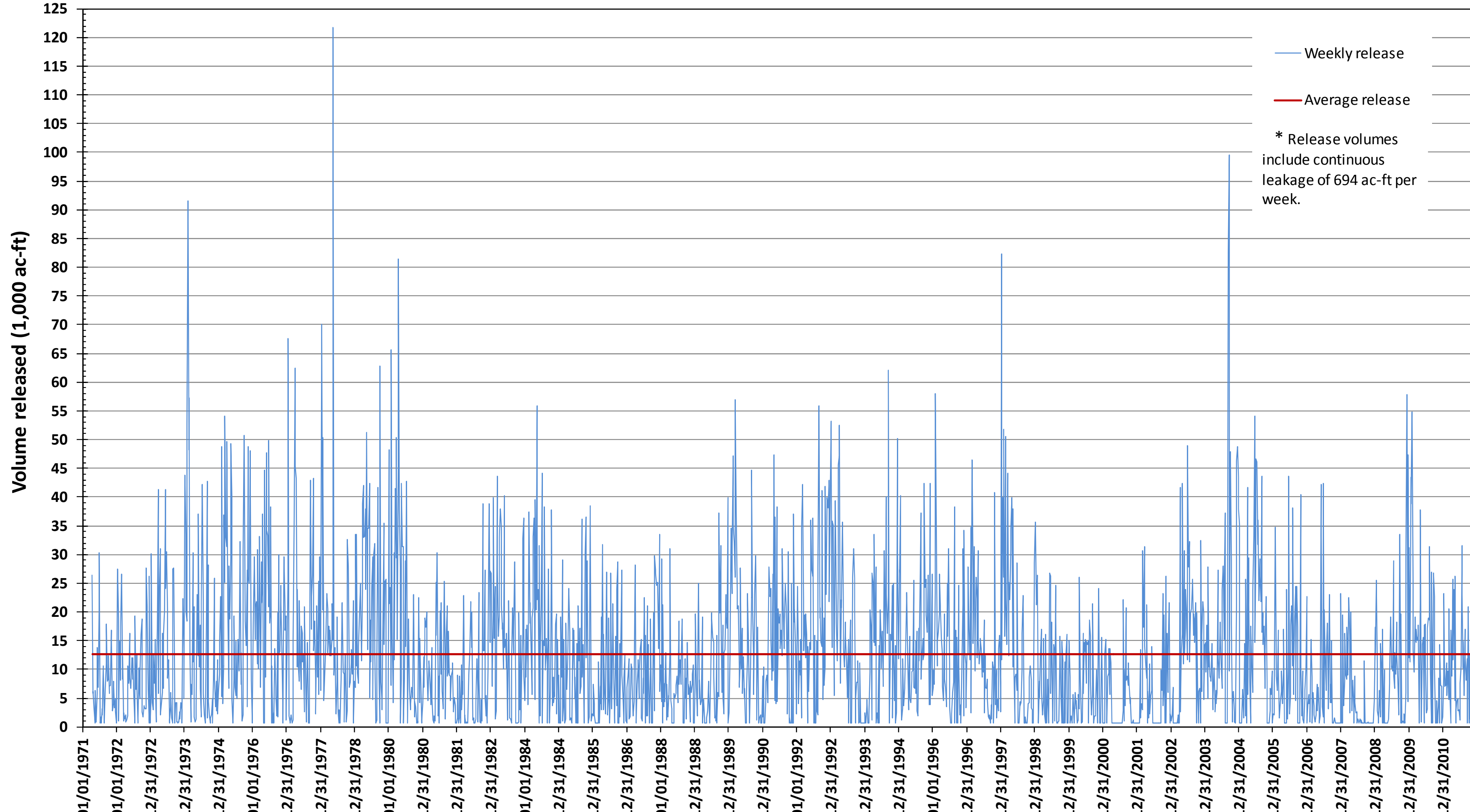
Lake Jocassee Levels Exceedence Curve
All Data May 1, 1975 through December 31,2011

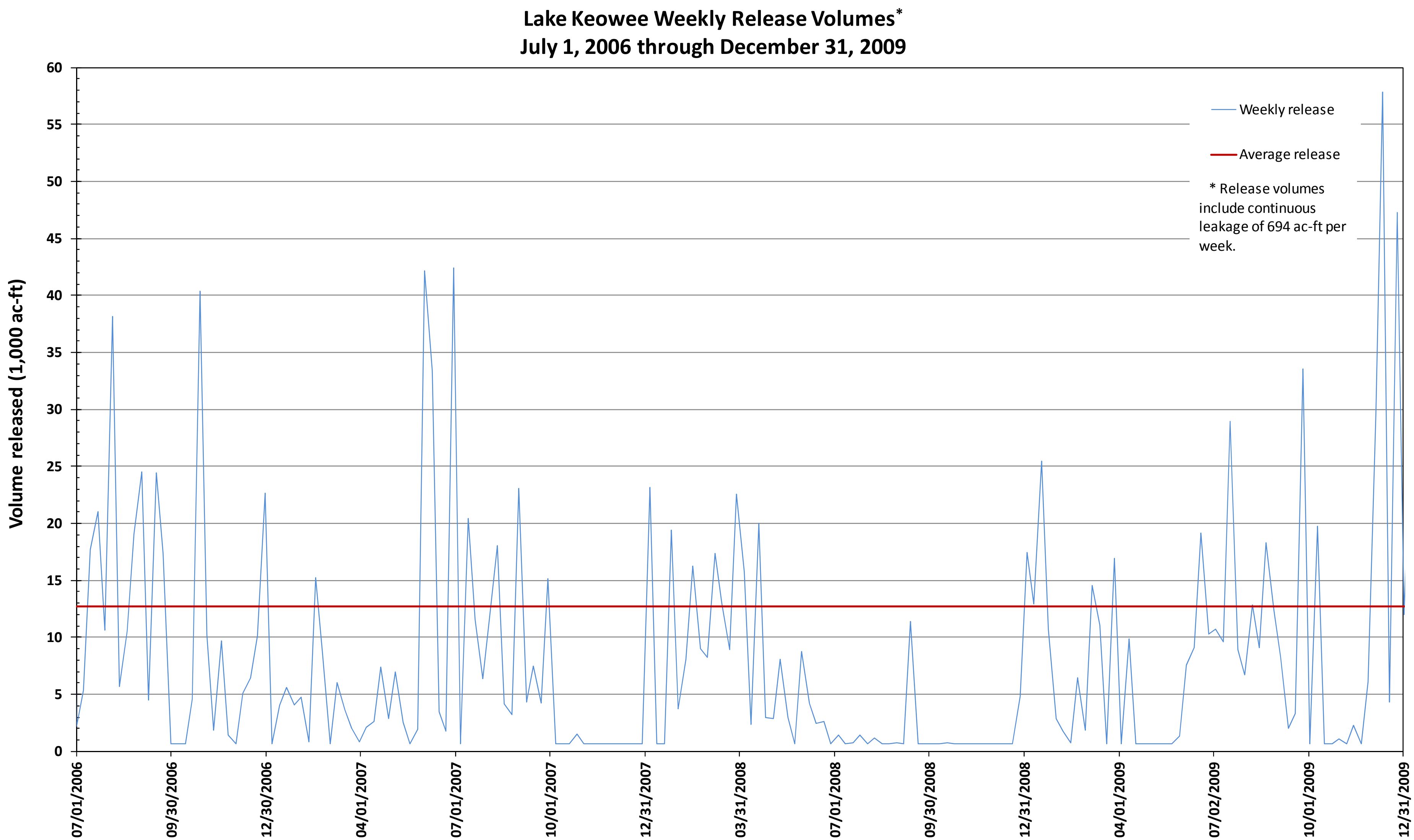


Lake Kewoee and Lake Jocassee Water Surface Elevations
May 1, 1975 through December 31, 2011



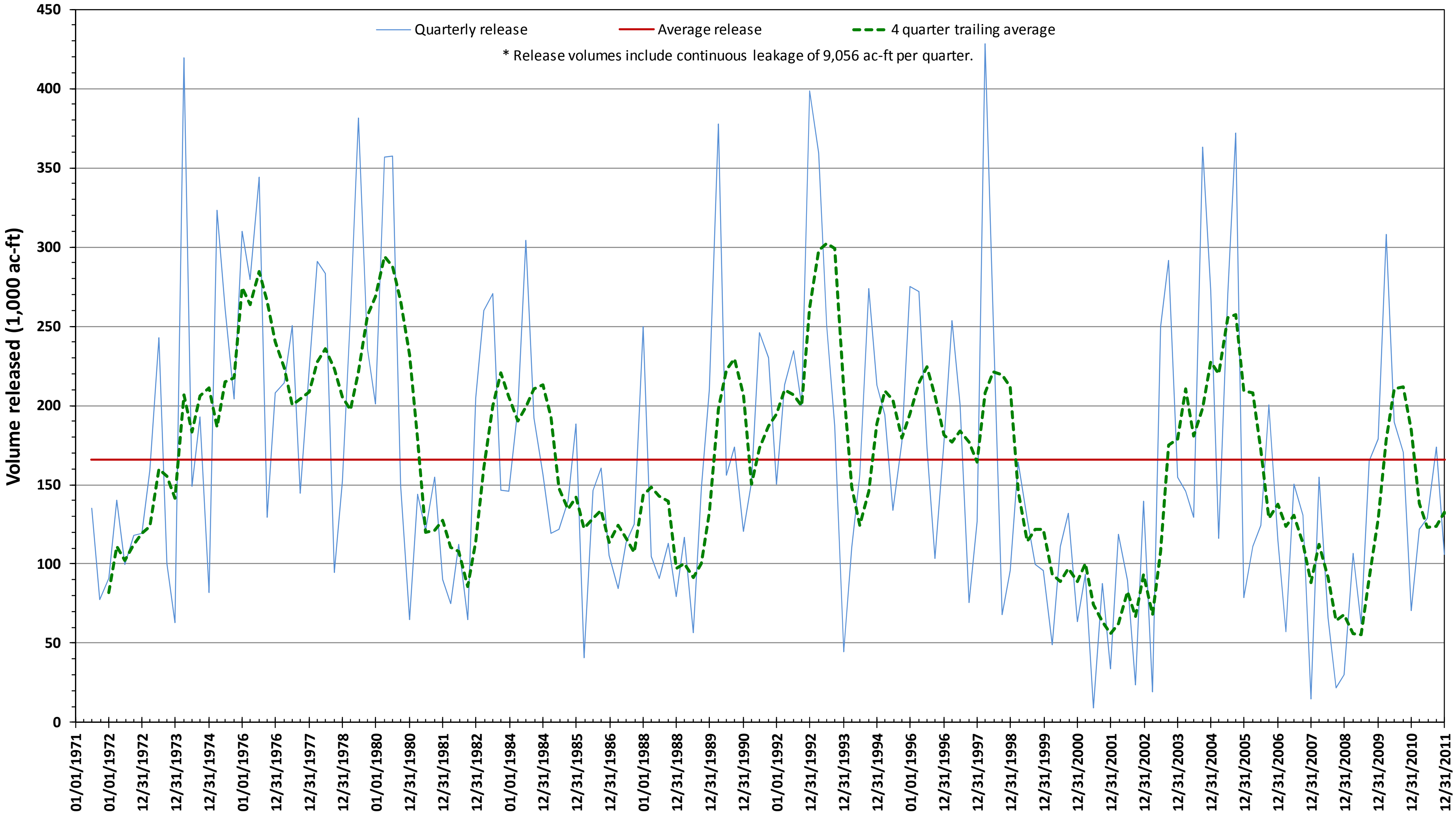
Lake Keowee Weekly Release Volumes*
April 17, 1971 through December 31, 2011



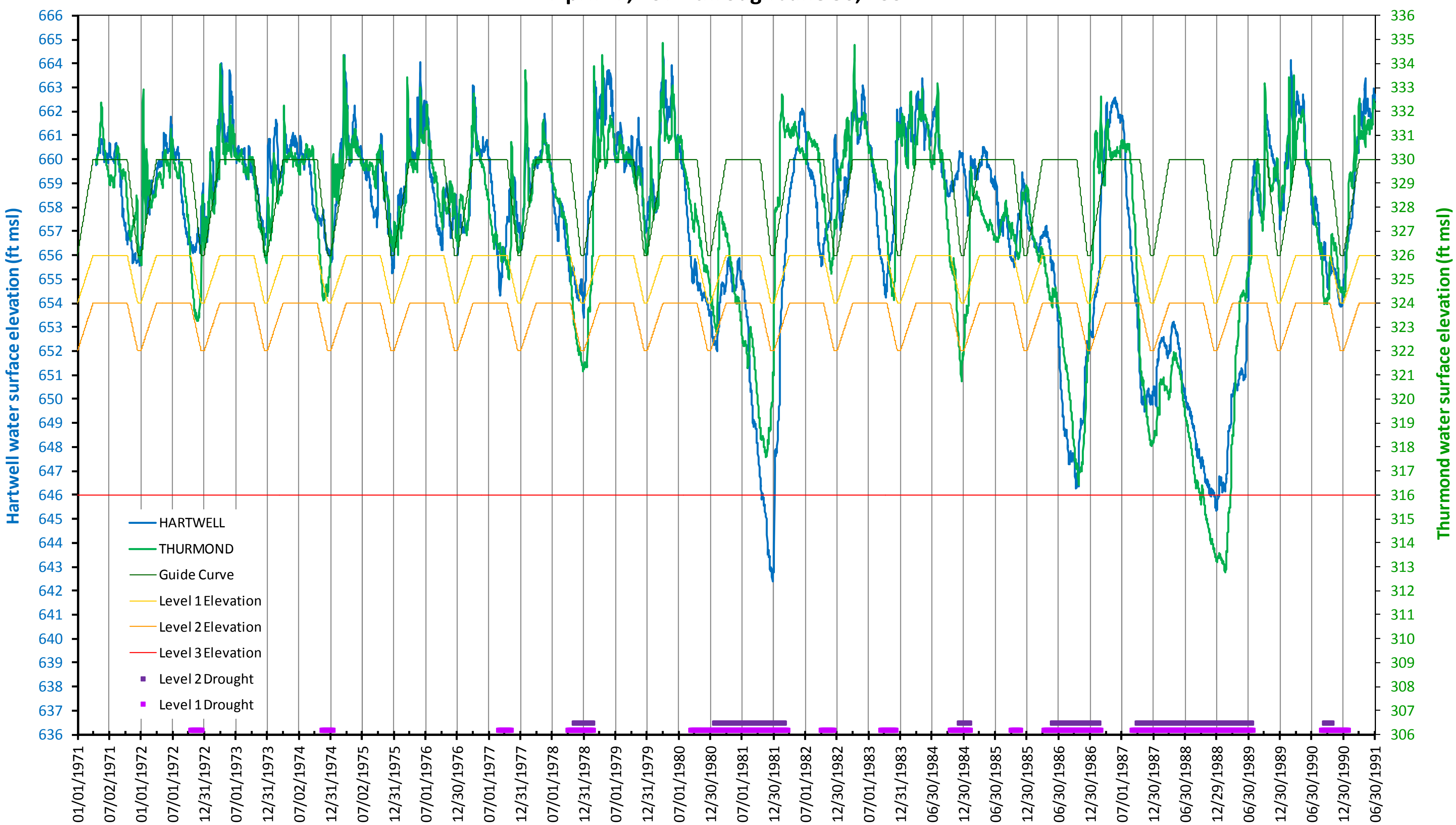


Lake Keowee Weekly Release Volumes*
July 1, 2006 through December 31, 2009
Volume released (1,000 ac-ft)
60
55
50
45
40
35
30
25
20
15
10
5
0
07/01/2006
09/30/2006
12/30/2006
04/01/2007
07/01/2007
10/01/2007
12/31/2007
03/31/2008
07/01/2008
09/30/2008
12/31/2008
04/01/2009
07/02/2009
10/01/2009
12/31/2009
Weekly release
Average release
* Release volumes include continuous leakage of 694 ac-ft per week.

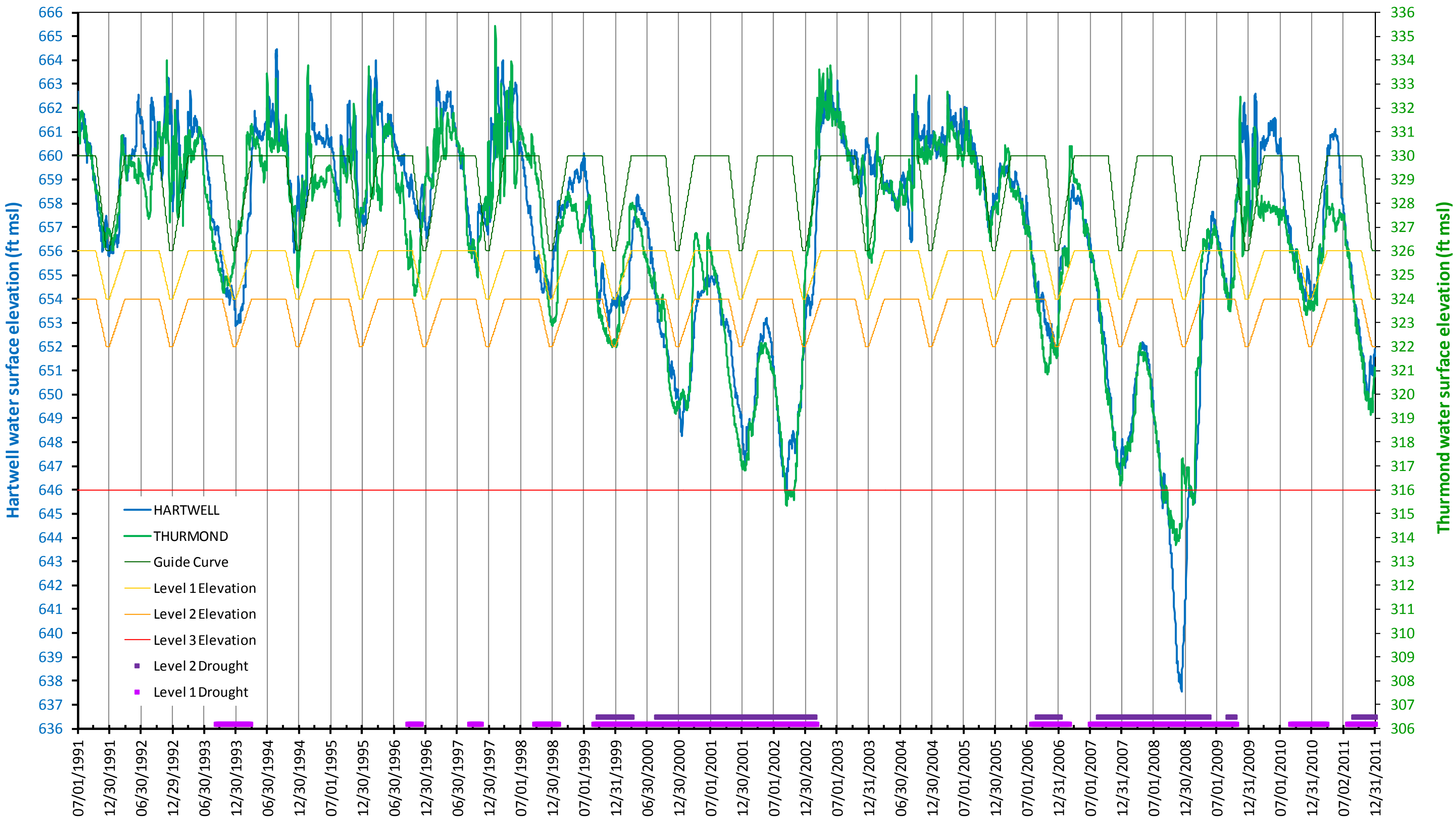
Lake Keowee Quarterly Release Volumes*
April 17, 1971 through December 31, 2011



Lake Hartwell and Lake Thurmond Water Surface Elevations
April 17, 1971 through June 30, 1991



Lake Hartwell and Lake Thurmond Water Surface Elevations
July 1, 1991 through December 31, 2011



Periods of Drought Level 1 or Greater from April 17, 1971 through December 31, 2011

Defined According to USACE Drought Contingency Plan

Period	Starting Date	Ending Date	Days Duration
1	10/14/1972	12/18/1972	66
2	11/10/1974	01/13/1975	65
3	08/25/1977	11/06/1977	74
4	09/29/1978	02/23/1979	148
5	09/07/1980	03/21/1982	561
6	09/29/1982	12/12/1982	75
7	09/08/1983	12/05/1983	89
8	10/13/1984	02/06/1985	117
9	09/29/1985	11/23/1985	56
10	04/07/1986	03/01/1987	329
11	08/28/1987	07/26/1989	699
12	08/25/1990	01/27/1991	156
13	09/07/1993	03/25/1994	200
14	09/17/1996	12/03/1996	78
15	09/09/1997	11/15/1997	68
16	09/19/1998	02/04/1999	139
17	08/27/1999	03/06/2003	1288
18	07/28/2006	03/03/2007	219
19	07/01/2007	10/23/2009	846
20	08/31/2010	03/28/2011	210
21	07/25/2011	After 12/31/2011	162+

The durations of these 21 periods total to 5,645 days of the 14,490 days in the April 17, 1971 through December 31, 2001 period.

Periods of Drought Level 2 or Greater from April 17, 1971 through December 31, 2011

Defined According to USACE Drought Contingency Plan

Period	Starting Date	Ending Date	Days Duration
1	11/03/1978	02/19/1979	108
2	01/21/1981	03/011982	404
3	12/03/1984	02/02/1985	61
4	05/24/1986	02/18/1987	270
5	09/25/1987	07/18/1989	662
6	09/10/1990	10/25/1990	45
7	09/19/1999	04/03/2000	197
8	08/22/2000	02/23/2003	915
9	08/28/2006	01/09/2007	134
10	08/16/2007	05/17/2009	640
11	09/02/2009	10/14/2009	42
12	08/15/2011	After 12/31/2011	126+

The durations of these 12 periods total to 3,604 days of the 14,490 days in the April 17, 1971 through December 31, 2001 period.

Next Steps

Preparation of Rough Draft Report

Next Meeting (Possibly April 16- 20)

Other Discussion

Adjourn

Keewee -Toxaway Hydro Relicensing

(FERC Project No 2503)

MEETING OF RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY TEAM

Monday, February 27, 2012

10:00 AM – 12 Noon

Via Live Meeting Conference Call

Summary of Meeting

Live Meeting Participants

Ed Bruce	Duke Energy	Jennifer Huff	Duke Energy
Bob Faires	Town of Seneca, SC	Nancy Jessen	Duke Energy
Phil Fragapane	Duke Energy	George McMahon	Arcadis
Gary Freeman	Arcadis	KC Price	Greenville Water
Steve Gaffney	HDR	Heather Rizzuti	SCDHEC
George Galleher	Duke Energy	Bob Swank	FOLKS
David Graves	SCDHEC	Ben Turetzky	FOLKS
Scott Harder	SCDNR	Larry Turner	SCDHEC
Earl Hayter	FOLKS	Andy Wachob	SCDNR

Summary

Phil Fragapane began meeting with greeting, introductions, review of the agenda and schedule for the study. He then reviewed the sections of the final version of the Reservoir Level and Project Flow Releases Study Plan titled “2.0 Goal and Objectives” and “6.1 Data Analysis”.

Steve Gaffney presented the data collected and the preliminary analysis prepared for Study Team review.

On review of the analysis, the following action points were suggested by the Study Team:

- All lake level and project releases data used in developing the preliminary analyses will be posted to the KTREL website at www.ktrel.com. The files will be under the “Water Quan RC” tab and in the folders titled “Reservoir Level and Project Flow Releases Study/Data - Reservoir Level and Project Releases”
- In the next draft of the analysis, monthly plots of reservoir elevations will be provided for the months of May through September at a minimum.
- A trend line will be added in the next draft for the Lake Keowee Quarterly Project Releases plot.

Next Steps

- In April, a rough draft of the study report will be prepared and distributed for Study Team review.
- A key component of the Study Team's review of the rough draft will be to begin to identify potential operating bands for Lake Keowee and Lake Jocassee under normal conditions, set criteria for defining "drought" periods, and identify operating bands for Lake Keowee during drought periods.
- The next meeting of the Study Team will be held on April 17 from 10 AM - 12 Noon most likely in Greenville, SC.

Keowee -Toxaway Hydro Relicensing

(FERC Project No 2503)

MEETING OF RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY TEAM

Tuesday April 17, 2012

10:00 AM – 12 Noon

Greenville Water Stovall Filtration Plant

50 Pleasant Retreat Rd.
Travelers Rest, SC 29690
Telephone: (864) 241-7830

AGENDA

10:00 AM **Introduction**

10:05 AM **Agenda Review**

10:10 AM **Schedule**

February 2012	Initial Analysis and Study Team Meeting
April 2012	Rough Draft Report Prepared
April 17, 2012	Meeting of Study Team to Review Draft Report and Identify Potential Lake Level Bands
May 4, 2012	Study Team Provides Comments on Rough Draft
July 9, 2012	Revised Draft Distributed to Study Team
July 2012	Meeting or Live Meeting of Study Team (If Necessary)
August 9, 2012	Study Team Provides Comments on Revised Draft
September 9, 2012	Final Draft of Report Prepared

10:15 AM **Review of Minutes of February 27, 2012 Study Team Meeting**

10:20 AM **Presentation of Rough Draft of Study Report**

10:50 AM **Review of Interim Low Inflow Protocol**

Defining Drought Periods for Study Analysis

11:10 AM **Discussion on Identifying Normal Operating Bands for Lake Keowee and Lake Jocassee**

Identification of Potential Normal Minimum Elevation for Each Lake

12 Noon **Lunch**

Keowee -Toxaway Hydro Relicensing

(FERC Project No 2503)

MEETING OF RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY TEAM

Tuesday, April 17, 2012

10:00 AM – 12 Noon

Greenville Water Stovall Filtration Plant

Summary of Meeting

Meeting Participants

Ed Bruce	Duke Energy	George McMahon	Arcadis
Bob Faires	Seneca Light & Water	KC Price	Greenville Water
Phil Fragapane	Duke Energy	Chris Starker	Upstate Forever
Steve Gaffney	HDR	Tami Styer	Duke Energy
George Galleher	Duke Energy	Bob Swank	FOLKS
Jennifer Huff	Duke Energy	Larry Turner	SCDHEC

Summary

Phil Fragapane began meeting with greeting, introductions, review of the agenda and a tentative schedule for the study.

Minutes of the February 27, 2012 Live Meeting were reviewed. There were no comments and the minutes were approved.

Steve Gaffney presented the rough draft of the study report. A number of revisions/additions were suggested by the Team. These are summarized in the action points.

KC Price asked whether we should follow the Corp's current "+2 ft" rule for coming out of a drought level. It was decided that this would be addressed in the modeling study by possibly running scenarios to assess the impacts.

The deadline for members of the Study Team to submit written comments to Duke Energy on the rough draft of the study report was set for May 4, 2012.

Ed Bruce presented a brief description of how Duke Energy operates Lake Keowee and Lake Jocassee in accordance with the 1968 Operating Agreement between Duke Energy, Southeastern Power Administration (SEPA) and the US Army Corps of Engineers (USACE). He also explained how the Interim

Low Inflow Protocol (ILIP) for the Keowee-Toxaway River Basin defines drought in a similar way as the 1968 Operating Agreement. He then facilitated a discussion on defining drought for purposes of the study.

Ed Bruce proposed a definition of a drought period as any time that the USACE has declared Level 1, Level 2, or Level 3 as defined in its Drought Contengency Plan (DCP) for the Upper Savannah Basin. After discussion, it was decided that for the purposes of the study, drought will be defined as proposed.

Ed Bruce facilitated a discussion of setting operating bands for lake levels for Lake Keowee and Lake Jocassee for normal (non-drought) periods.

Ed Bruce proposed that during normal periods, the upper limits for both lakes be the full pond elevations, and that the lower limits be 1096 ft above mean sea level (14 feet below full pond) for Lake Jocassee and 795 feet above mean sea level (five feet below full pond) for Lake Keowee. The Lake Jocassee limit corresponds to the level at which an increase in fish entrainment during pumping from Lake Jocassee to Bad Creek Reservoir has been observed.

After discussion, the Study Team agreed that the proposed limits are reasonable for normal periods.

There was no discussion of limits during drought periods because of the on-going analysis and discussions related to the minimum level at Lake Keowee that can sustain operation of the Oconee Nuclear Station. This minimum level is expected to be known in May 2012.

Action Points

The following action points were identified during the meeting:

Study Report Rough Draft

- Figure A-3 is missing the linear trend line. Replace with figure showing linear trend line.
- In Figure C-1, correct typo in Figure C-1 title. It should be "…through June 30, 1991".
- Make an additional figure by combining Figures C-1 and C-2 into a continuous time line from 1971 through 2011.
- In Figures C-1, C-2 and additional figure, graphically show dates (years) for commercial operation of Russell, initial 1989 USACE drought plan, and revised 2005(please verify date) USACE drought plan.
- In Figures C-1, C-2 and additional figure, determine Level 3 drought periods and add Level 3 bar at bottom of chart. Prepare new Table 4.4-3 showing Level 3 dates.
- Prepare two new figures showing reservoir elevations for Russell – one a simple time series and the other a Hayes chart.
- Finalize the internal Jocassee Hayes chart for "normal" periods for inclusion in next draft report.
- Prepare new Keowee Hayes chart for "normal" periods.

General

- The Keowee-Toxaway ILIP will be posted to the "Water Quan RC/Reservoir Level and Project Flow Releases Study/Data and Other Documents"
- The Study Team will provide any written comments on the rough draft of the study report to **Phil Fragapane** by May 4, 2012.

Next Steps

- In May, the results of the study to identify the lowest lake level which will allow operation of Oconee Nuclear Station will be completed
- In July, a revised draft of the study report will be prepared, incorporating all Study Team comments received on the rough draft
- The Study Team's review of the revised draft will include identification of potential operating bands for Lake Keowee under normal and drought conditions[BED1]
- The next meeting of the Study Team will likely be held in July[SRG2], 2012

Keewee -Toxaway Hydro Relicensing

(FERC Project No 2503)

MEETING OF RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY TEAM

Thursday July 26, 2012

10:00 AM – 12 Noon

Wenwood Operations Center

425 Fairforest Way

Greenville, SC 29607

AGENDA

10:00 AM **Introductions**

10:05 AM **Agenda Review**

10:10 AM **Schedule**

February 2012	Initial Analysis and Study Team Meeting
April 2012	Rough Draft Report Prepared
April 17, 2012	Meeting of Study Team to Review Draft Report and Identify Potential Lake Level Bands
May 4, 2012	Study Team Provides Comments on Rough Draft
July 17, 2012	Revised Draft Made Available to Study Team
July 26, 2012	Meeting or Live Meeting of Study Team
August 9, 2012	Study Team Provides Comments on Revised Draft
September 9, 2012	Final Draft of Study Report Prepared
October 9, 2012	Study Team Provides Comments on Final Draft (last chance for comments)
November 9, 2012	Final Study Report Completed

10:15 AM **Review and Approval of Minutes of April 17, 2012 Study Team Meeting**

10:20 AM **Presentation of Revised Draft of Study Report**

11:10 AM **Discussion of Conceptual Operating Approaches During Droughts**

How Might the Two Lakes Be Operated During a Drought?

12 Noon **Lunch Provided**

Review of Study Results

Report highlights and
opportunity to ask questions

Background information: Key reservoir elevations (ft AMSL)

Reservoir Level	**Lake Keowee**	**Lake Jocassee**
Normal Full Pond (point of incipient overflow)	800.0	1,110.0
ONS's Operating Restriction	794.6	- - -
Bad Creek Pumped Storage Operating Restriction	- - -	1,096.0
Deepest public boat ramp becomes unusable	790.0	1,080.0
Maximum drawdown per current FERC license	775.0	1,080.0
Greenville municipal water intake elevation	765.0	- - -

Reference: Table 1-1, *Reservoir Level and Project Flow Releases Study for the Keowee-Jocassee Relicensing Project,* FERC Project No. 2503, Revised Draft, July 2012

Background information: Key years during project's operation

Event	**Year**
Year when existing Operating License was issued by the FPC	1966
Duke Energy/Southeastern Power Administration/USACE Operating Agreement signed	1968
Year of Keowee Hydroelectric Station commercial operation – all units	1971
Year of ONS commercial operation – all units	1974
Year of Jocassee Pumped Storage Station commercial operation – all units	1975
Richard B. Russell Pumped Storage Project begins commercial operation	1985
Institution of USACE Savannah River Drought Contingency Plan	1989
Year of Bad Creek Pumped Storage Project commercial operation – all units	1991
Oconee Nuclear Station's Operating Restriction on Lake Keowee	1995
Keowee-Toxaway Fishery Resources Memorandum of Understanding – Bad Creek	1996
Revision of USACE Savannah River Drought Contingency Plan	2006
Year when existing FERC Operating License expires	2016

Reference: Table 1-2, *Reservoir Level and Project Flow Releases Study for the Keowee-Jocassee Relicensing Project,* FERC Project No. 2503, Revised Draft, July 2012

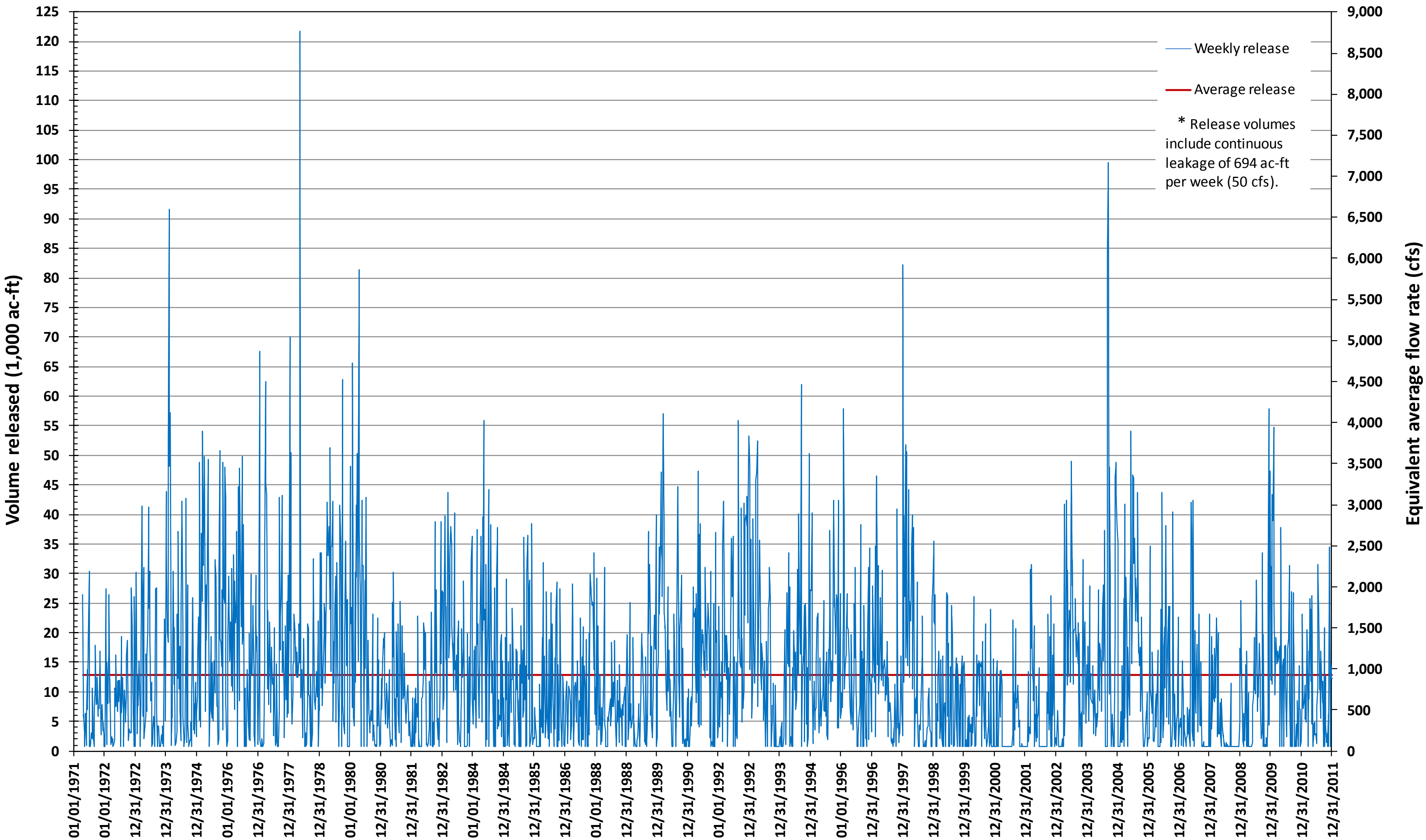
RESULTS

Section 4.1 Digital databases of reservoir operations

		Start	End
RELEASES:			
Lake Keowee:			
	Daily	April 17, 1971	December 31, 2011
	Hourly	January 1, 1995	December 31, 2011
ELEVATIONS:			
Lake Keowee:			
	Daily	April 17, 1971	December 31, 2011
	Hourly	January 1, 1995	December 31, 2011
Lake Jocassee:			
	Daily	May 1,1975	December 31, 2011
	Hourly	January 1, 1995	December 31, 2011

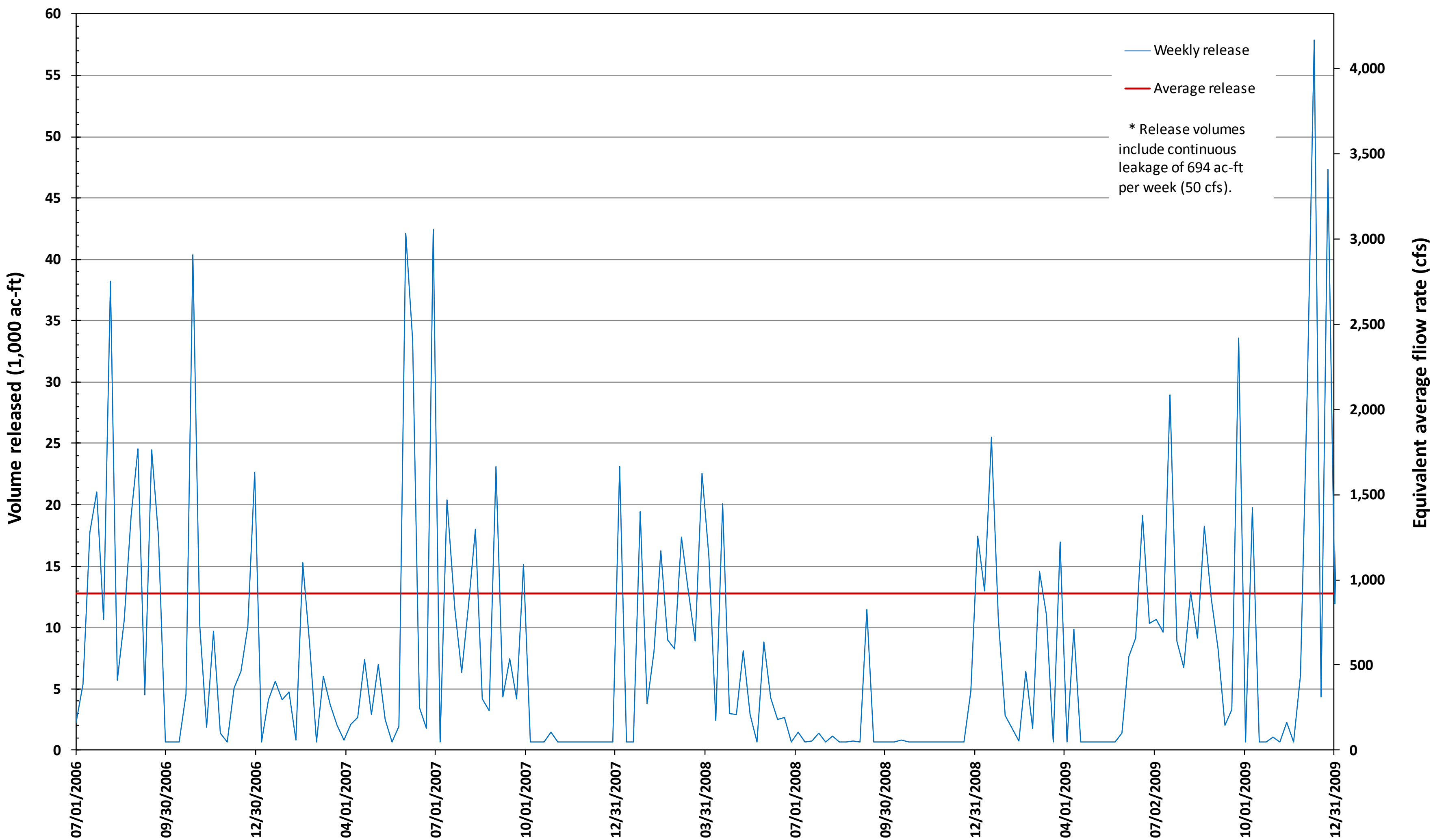
Section 4.2 Plots of Lake Keowee releases

Figure 4.2-1 Lake Keowee Weekly Release Volumes
April 17, 1971, through December 31, 2011



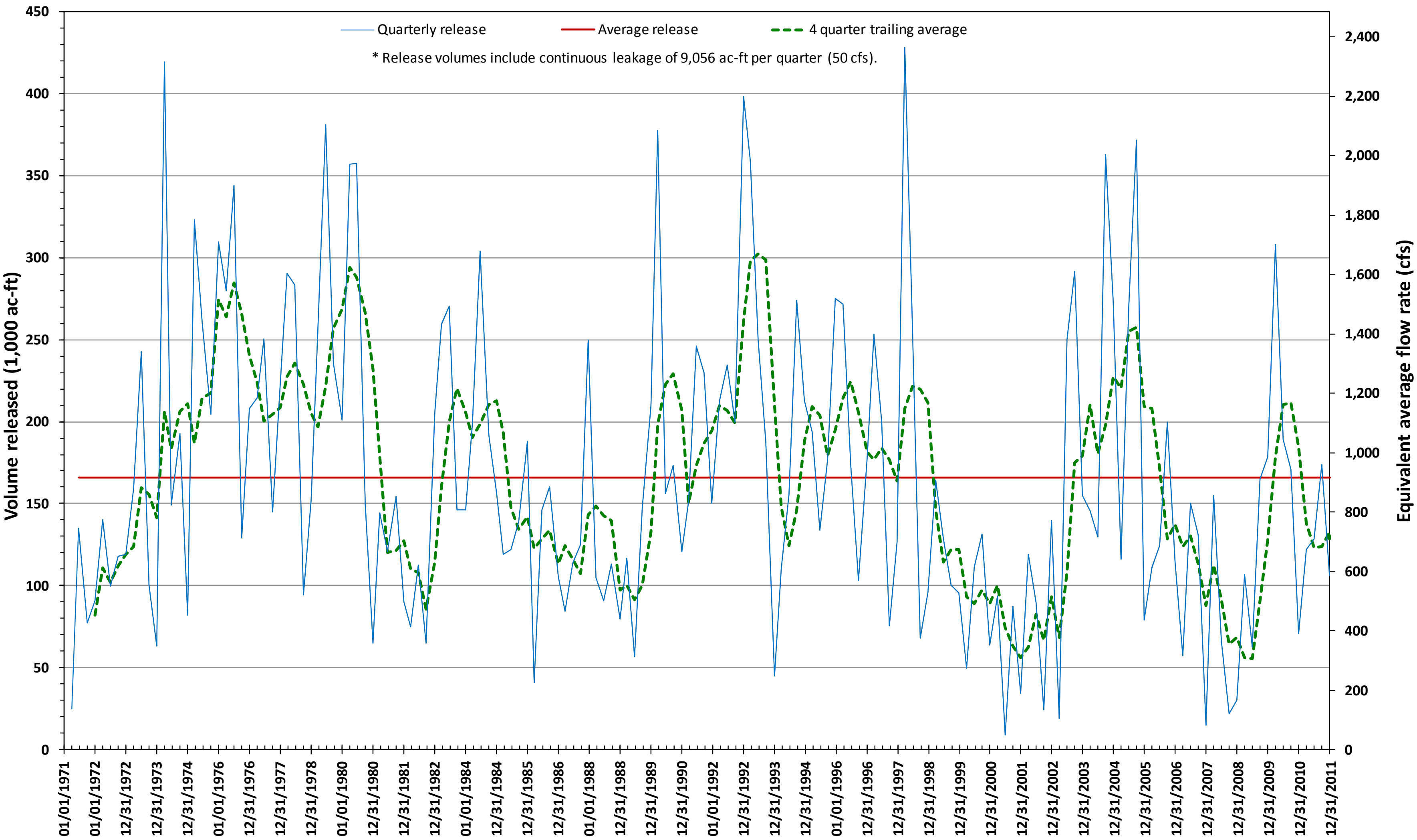
Section 4.2 Plots of Lake Keowee releases

Figure 4.2-2 Lake Keowee Weekly Release Volumes July 1, 2006, through December 31, 2009



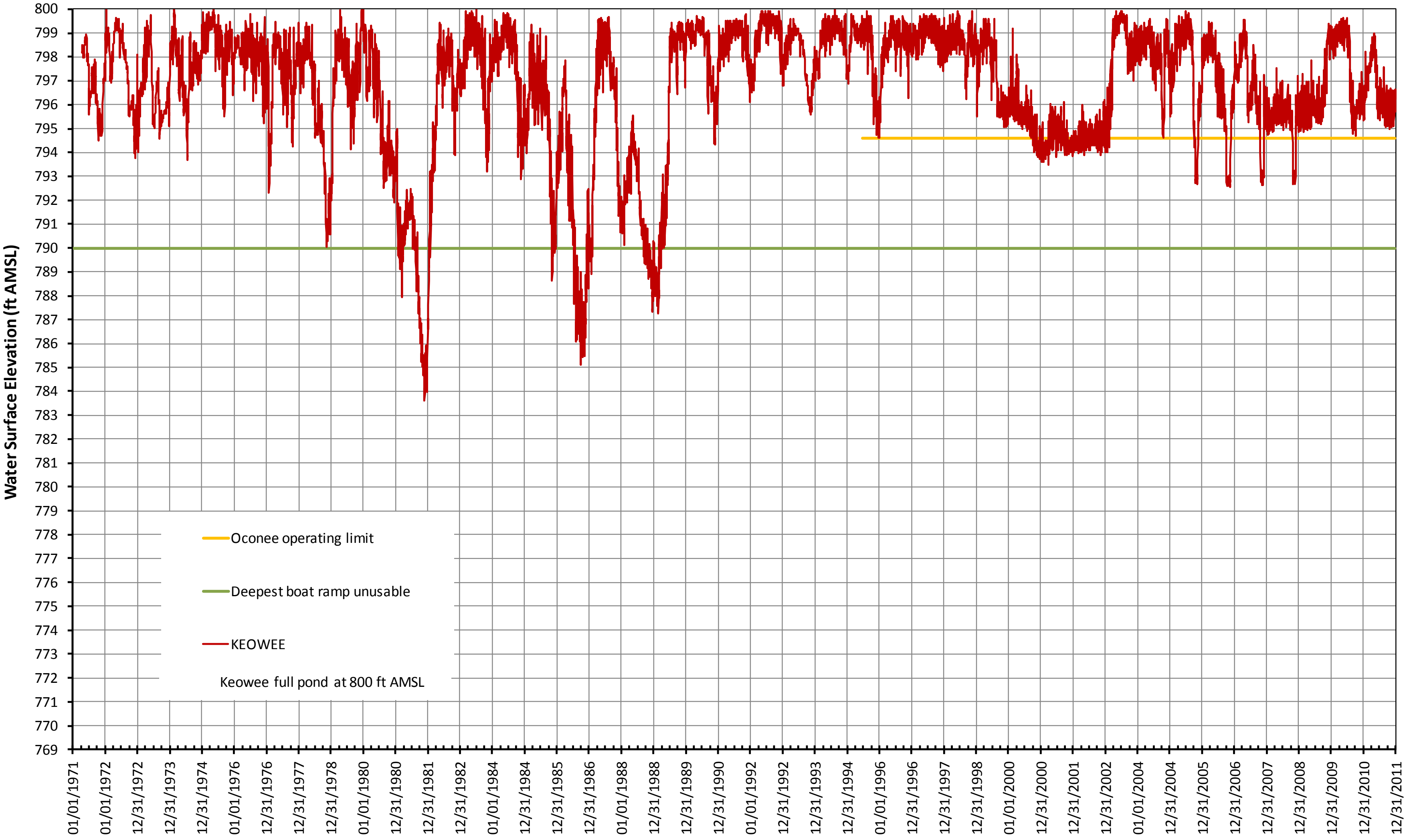
Section 4.2 Plots of Lake Keowee releases

Figure 4.2-3 Lake Keowee Quarterly Release Volumes
April 17, 1971, through December 31, 2011



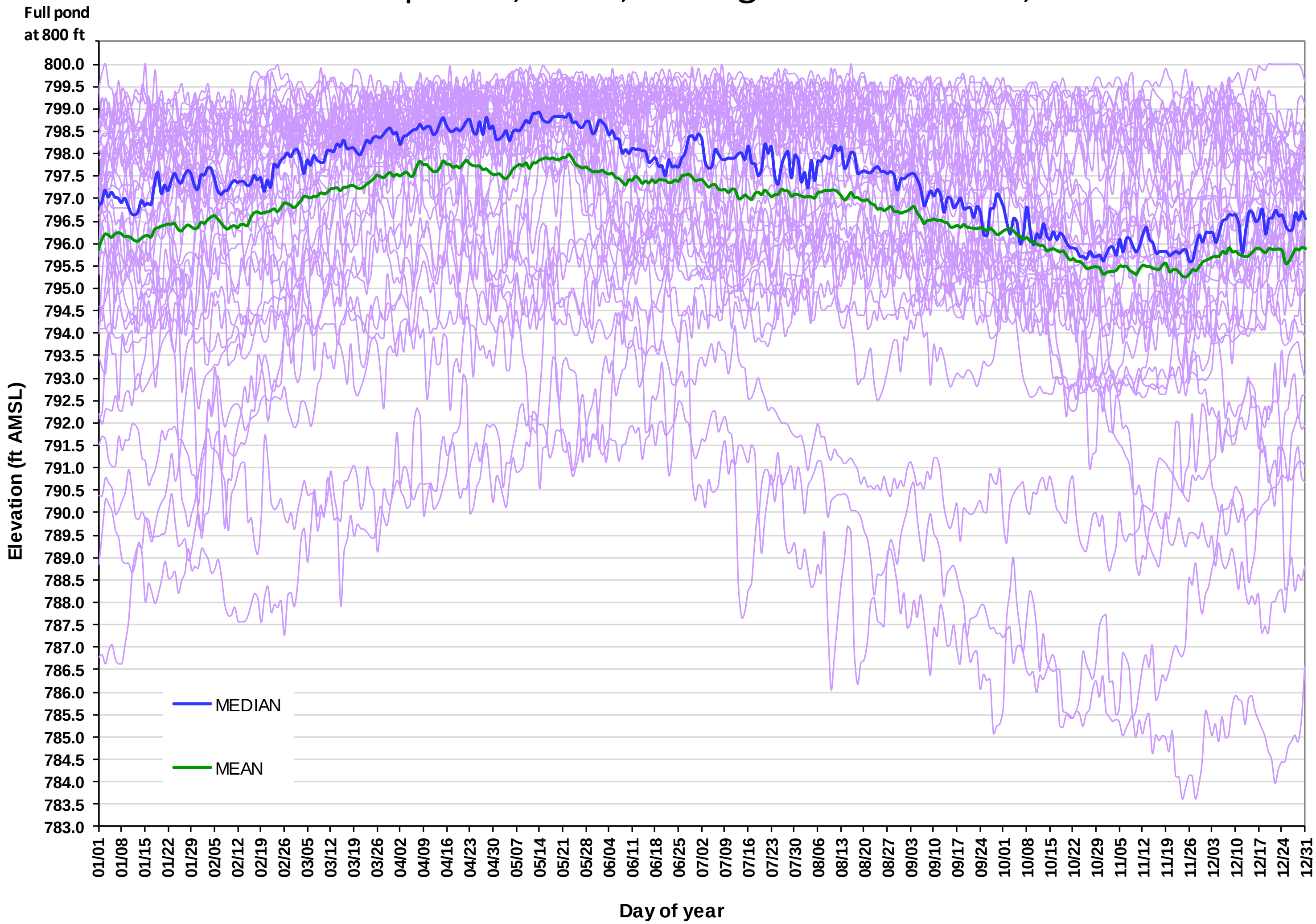
Section 4.3.1 Plots of Lake Keowee reservoir elevations

Figure 4.3-1 Lake Keowee Water Surface Elevations
April 17, 1971, through December 31, 2011



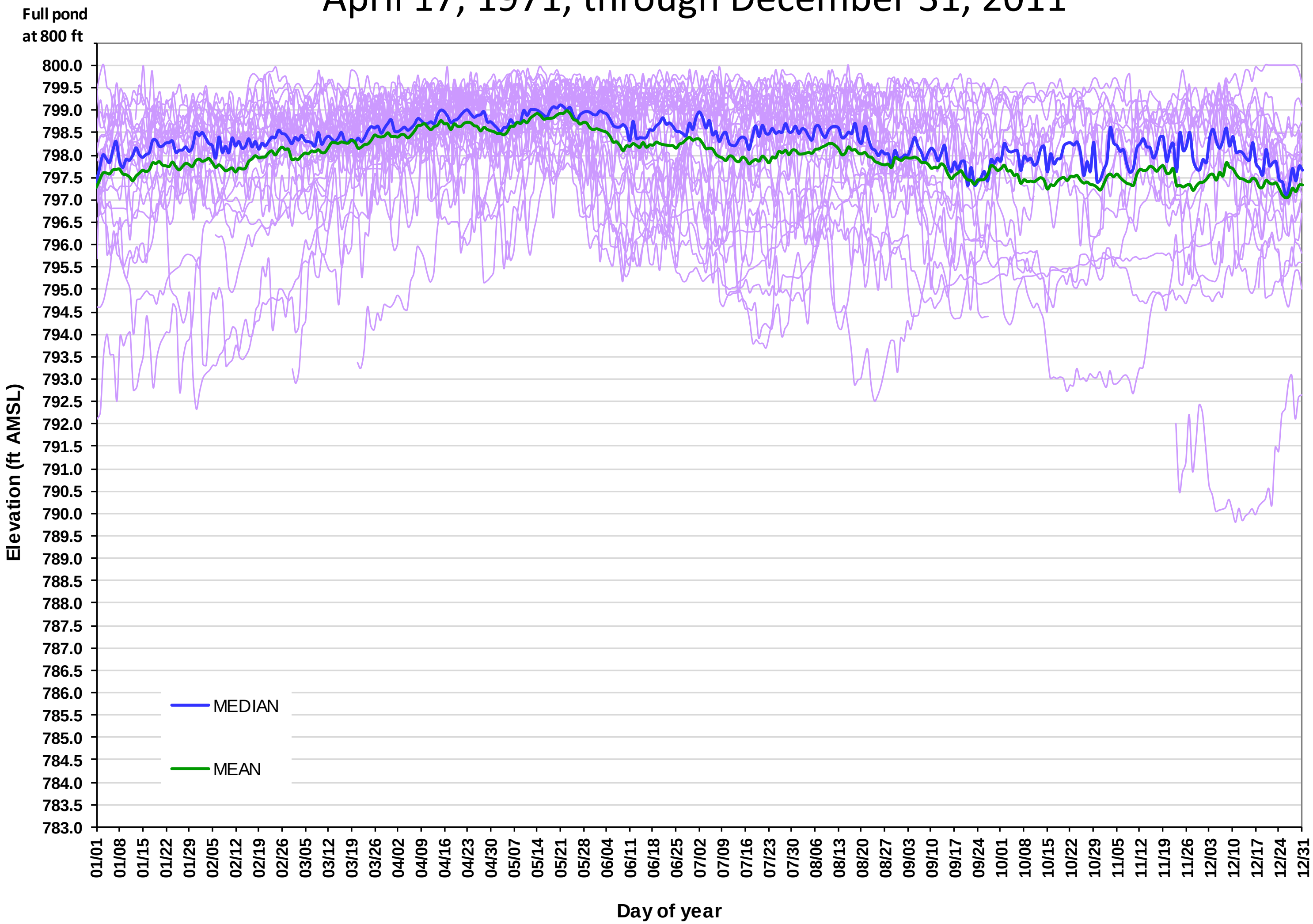
Section 4.3.1 Plots of Lake Keowee reservoir elevations

Figure 4.3-2(a) Hayes Chart of All Lake Keowee Water Surface Elevations April 17, 1971, through December 31, 2011



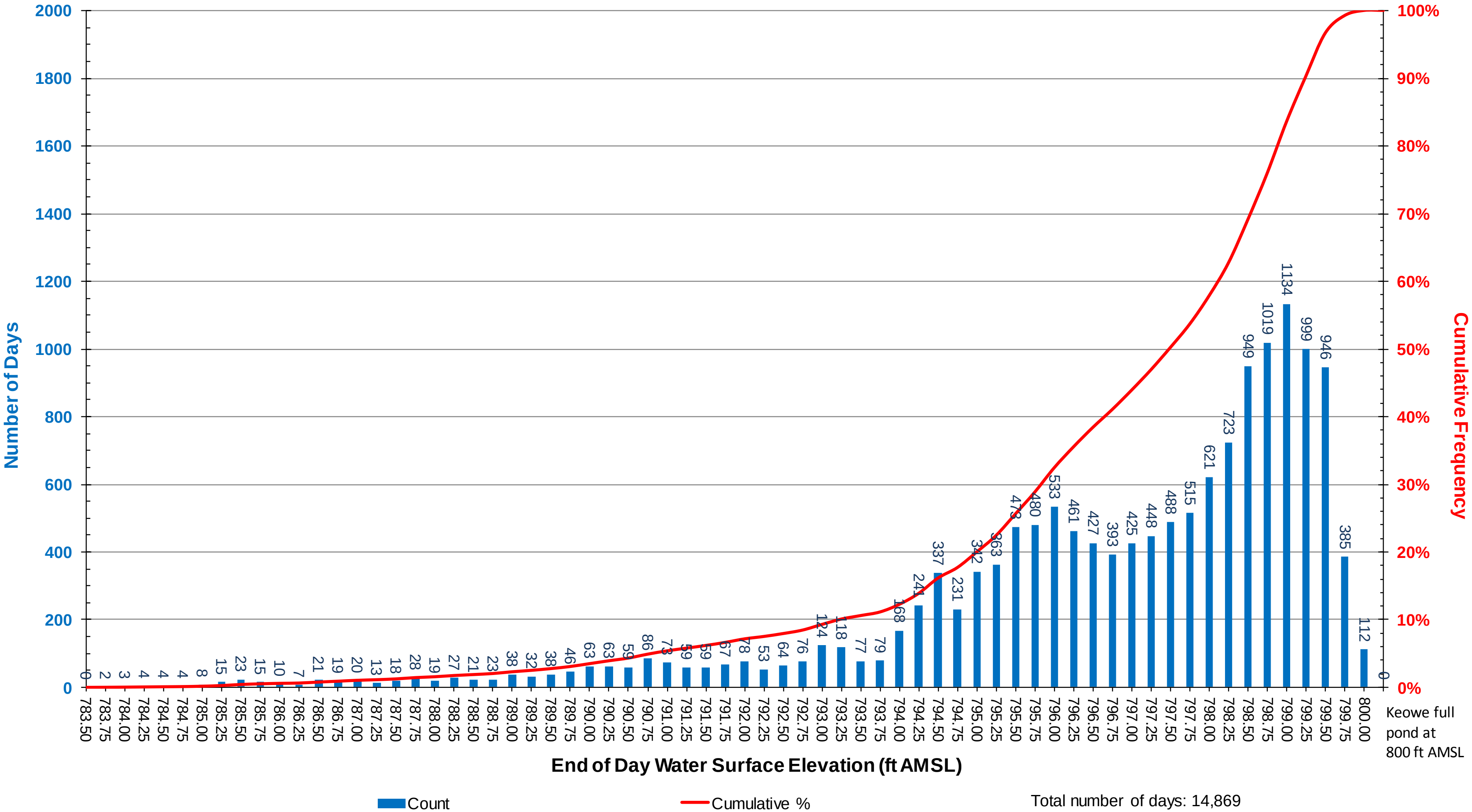
Section 4.3.1 Plots of Lake Keowee reservoir elevations

Figure 4.3-2(b) Hayes Chart of Non-Drought Lake Keowee Water Surface Elevations April 17, 1971, through December 31, 2011



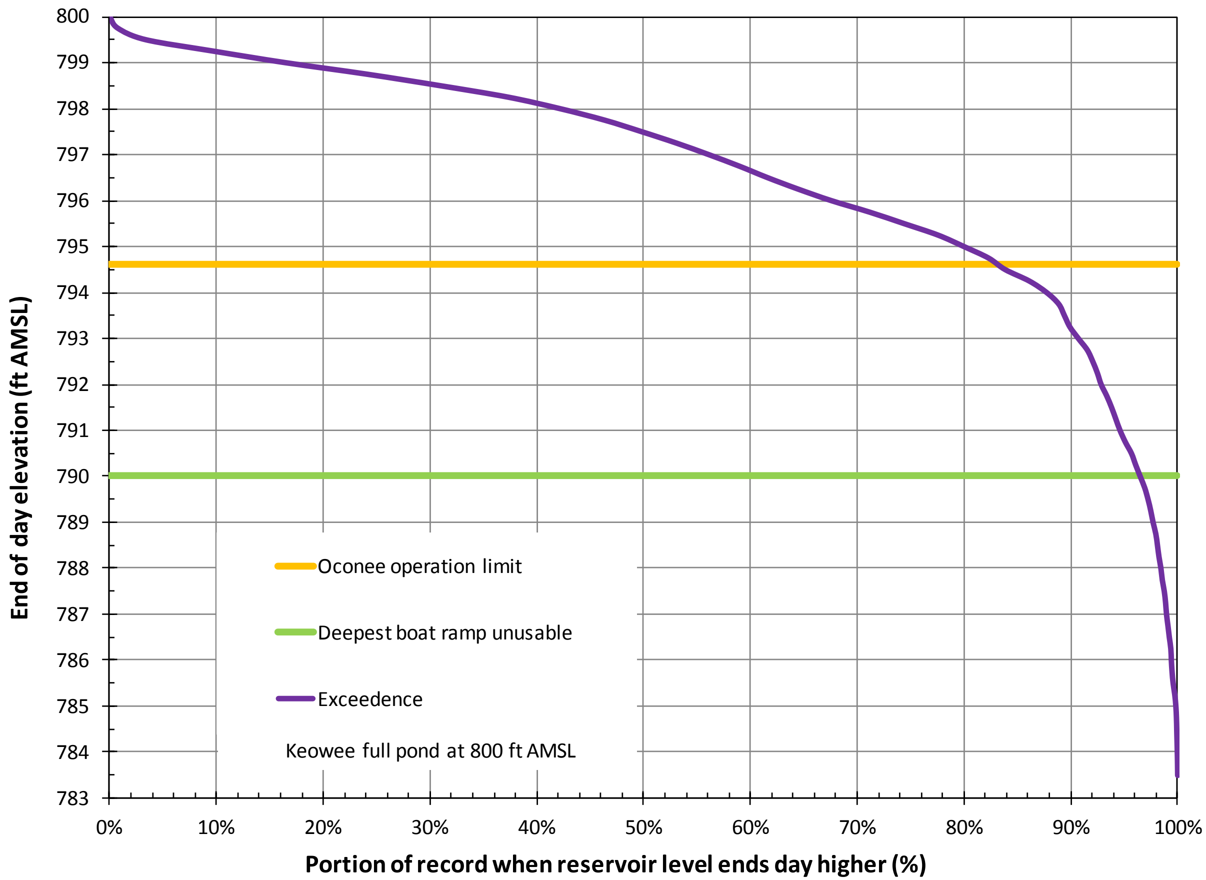
Section 4.3.1 Plots of Lake Keowee reservoir elevations

Figure 4.3-3 Lake Keowee Water Levels Histogram and Cumulative Frequency Curve April 17, 1971, through December 31, 2011



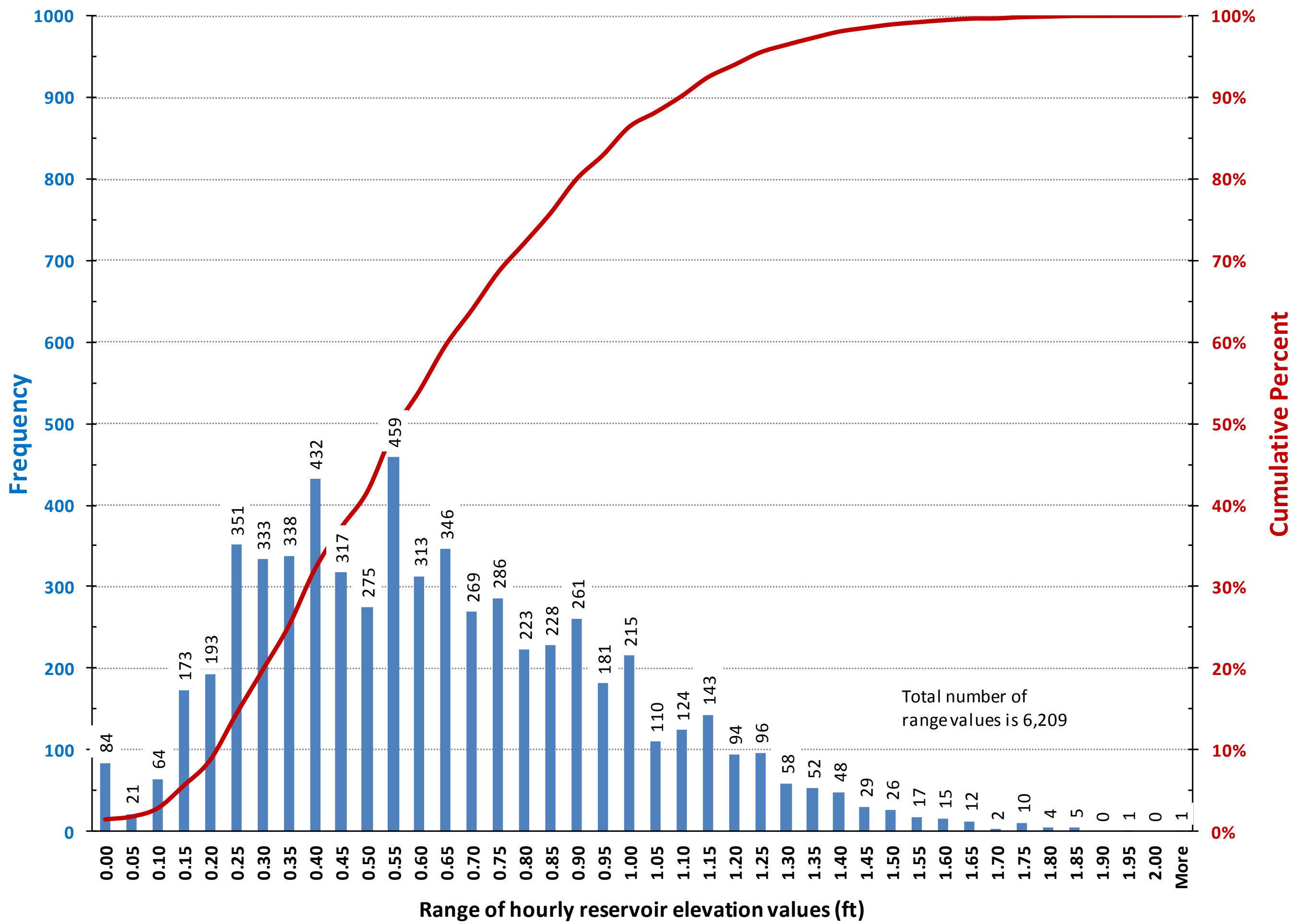
Section 4.3.1 Plots of Lake Keowee reservoir elevations

Figure 4.3-4 Lake Keowee Levels Exceedance Curve
April 17, 1971, through December 31, 2011



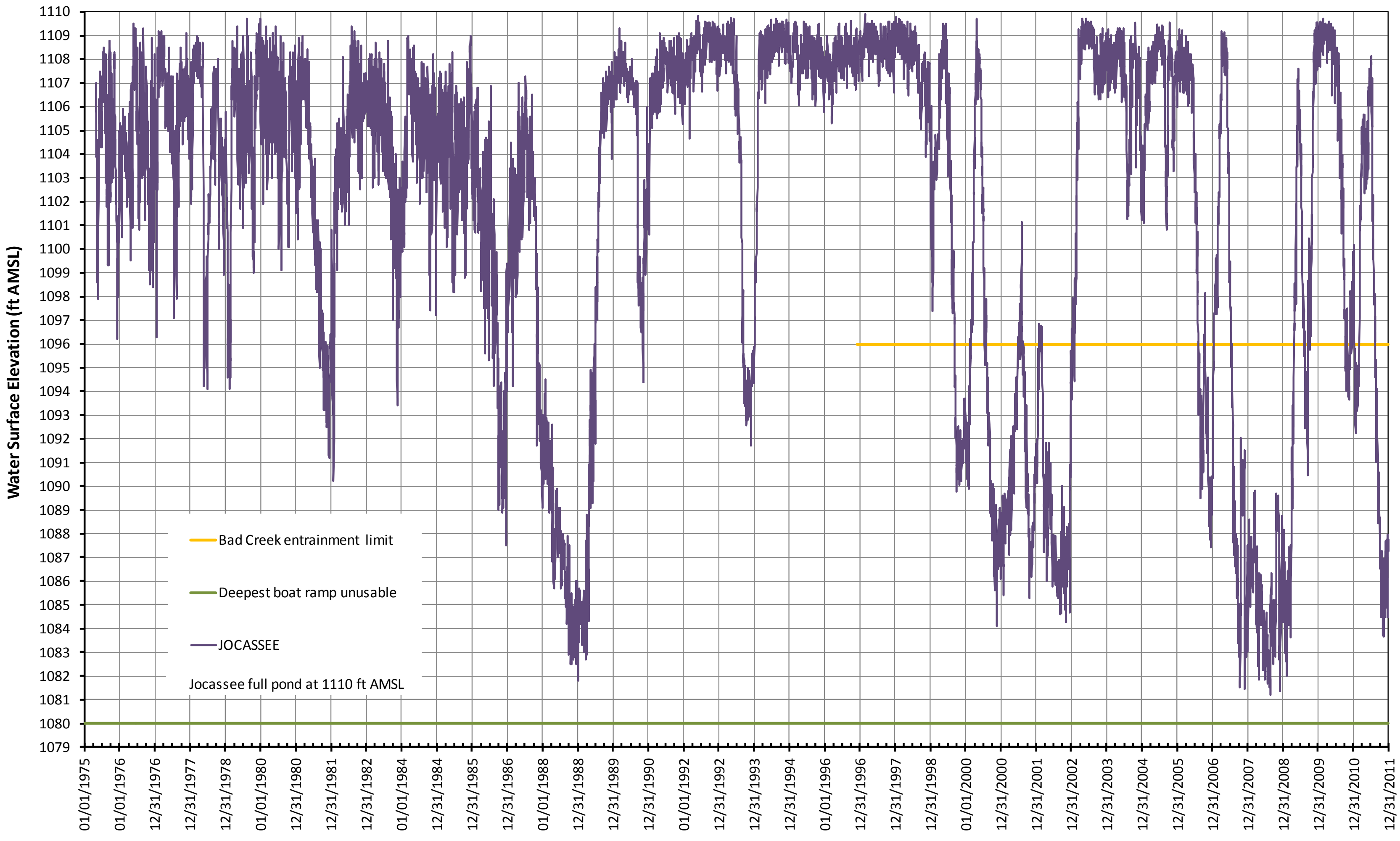
Section 4.3.1 Plots of Lake Keowee reservoir elevations

Figure 4.3-5 Histogram and Cumulative Frequency Curve
Daily Range of Lake Keowee Elevations from Hourly Data
January 1, 1995, through December 31, 2011



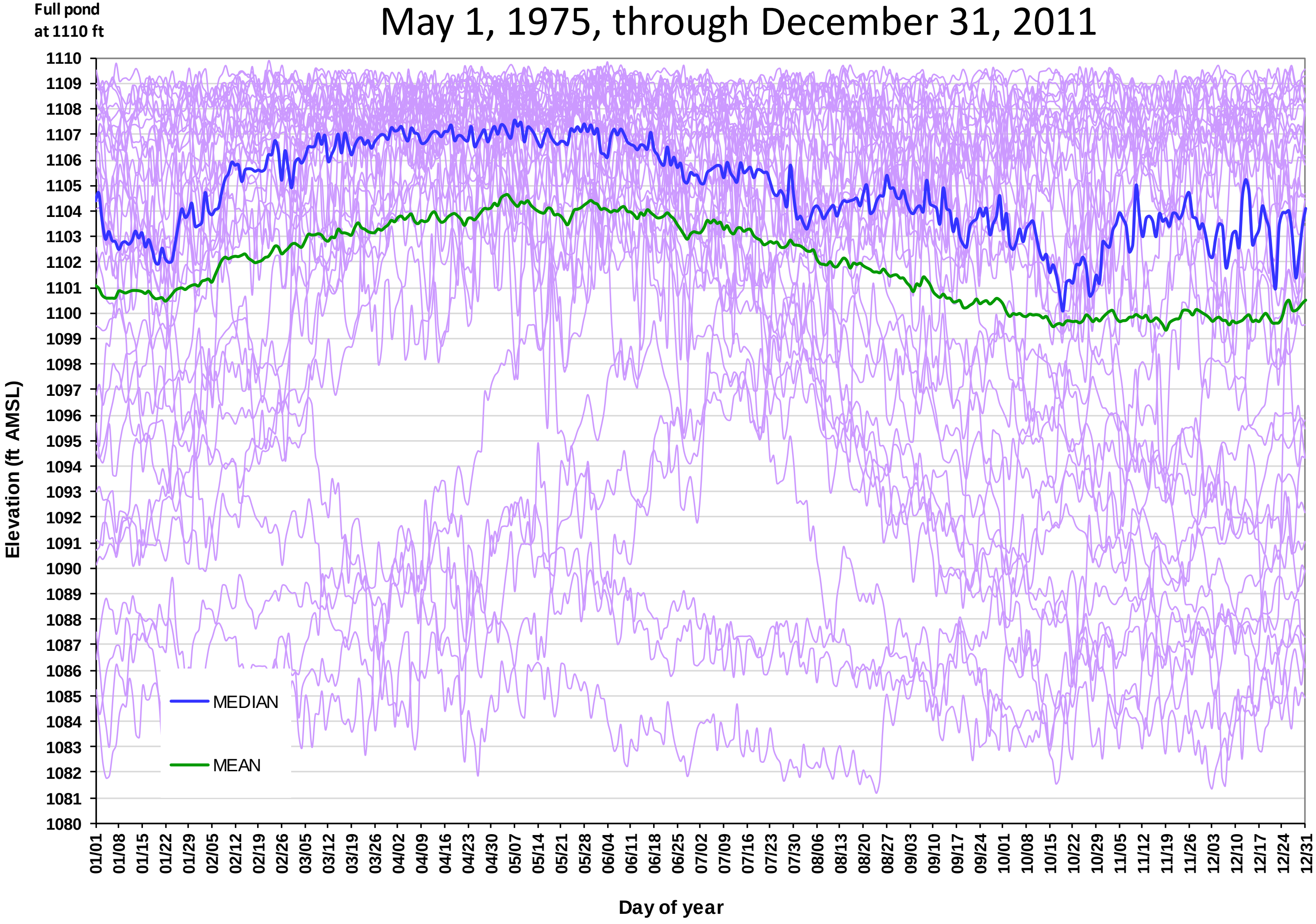
Section 4.3.2 Plots of Lake Jocassee reservoir elevations

Figure 4.3-6 Lake Jocassee Water Surface Elevations
May 1, 1975, through December 31, 2011



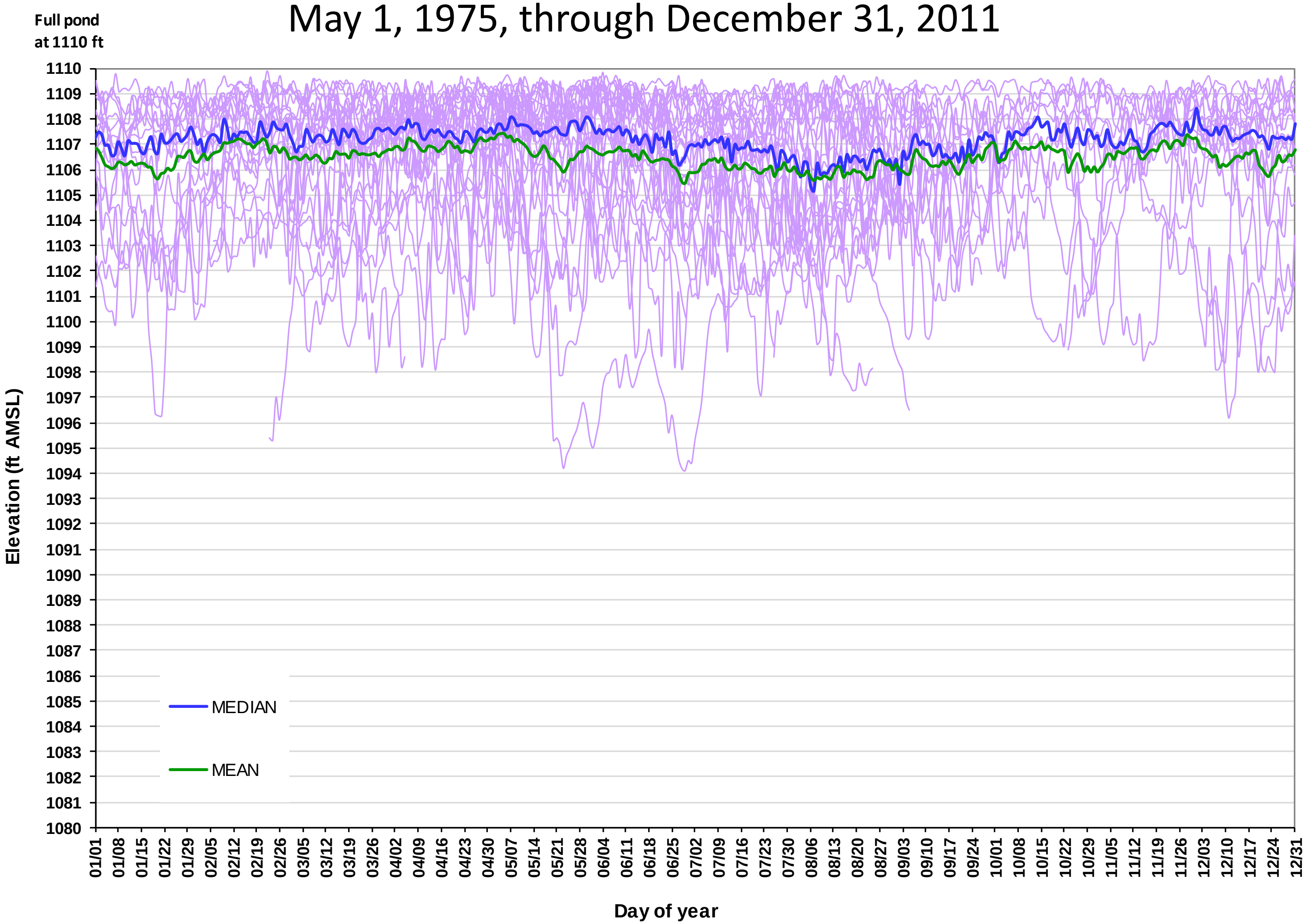
Section 4.3.2 Plots of Lake Jocassee reservoir elevations

Figure 4.3-7(a) Hayes Chart of All Lake Jocassee Water Surface Elevations May 1, 1975, through December 31, 2011



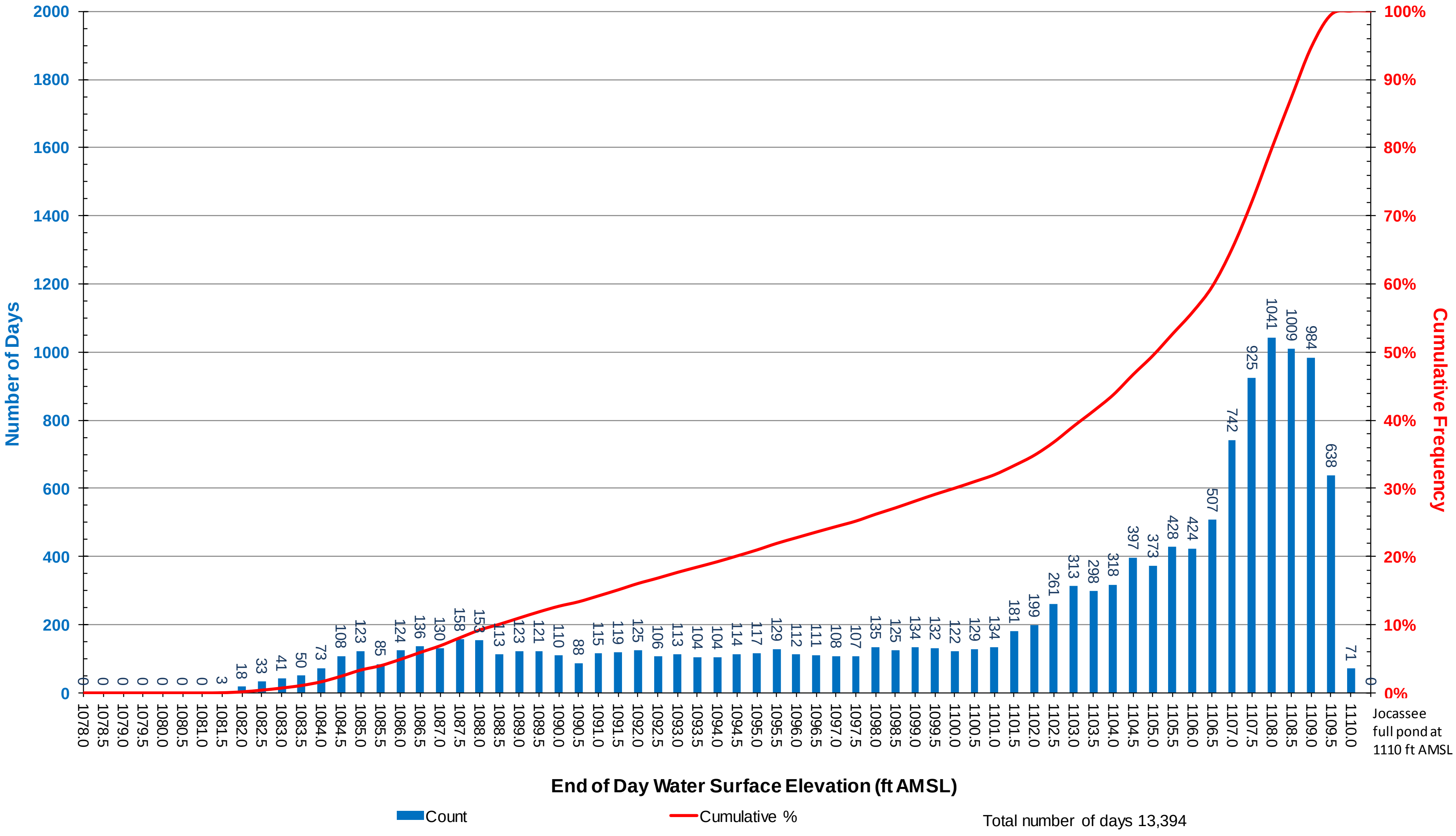
Section 4.3.2 Plots of Lake Jocassee reservoir elevations

Figure 4.3-7(b) Hayes Chart of Non-Drought Lake Jocassee Water Surface Elevations May 1, 1975, through December 31, 2011



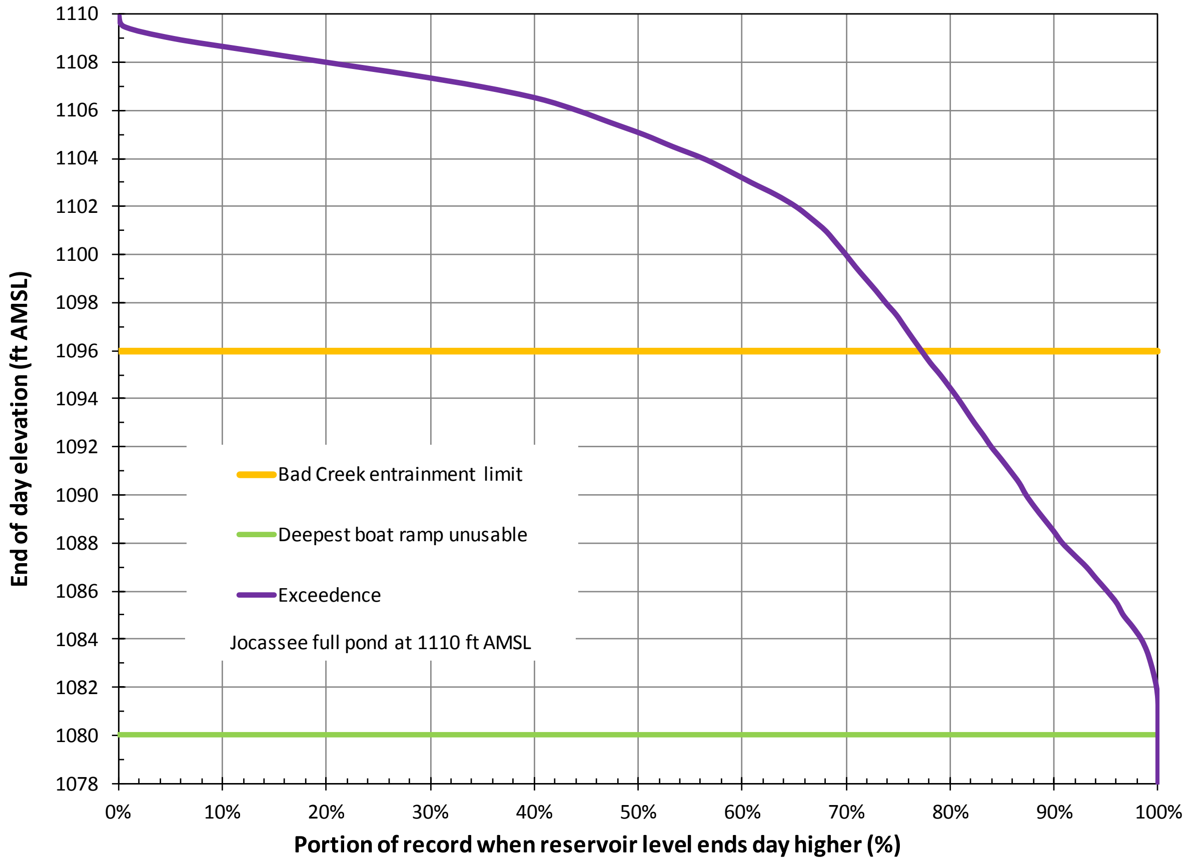
Section 4.3.2 Plots of Lake Jocassee reservoir elevations

Figure 4.3-8 Lake Jocassee Water Levels Histogram and Cumulative Frequency Curve
May 1, 1975, through December 31, 2011



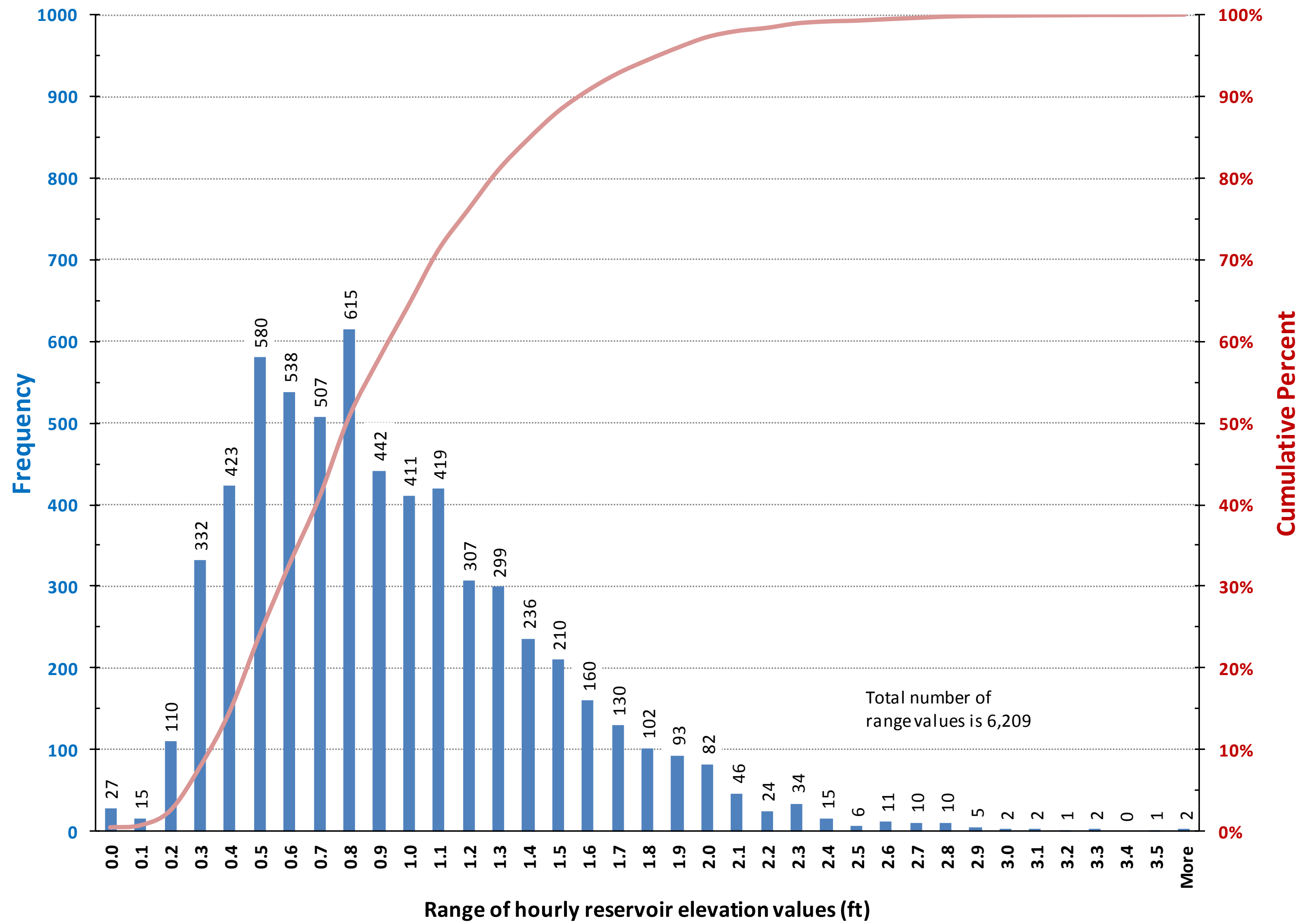
Section 4.3.2 Plots of Lake Jocassee reservoir elevations

Figure 4.3-9 Lake Jocassee Levels Exceedance Curve
May 1, 1975, through December 31, 2011



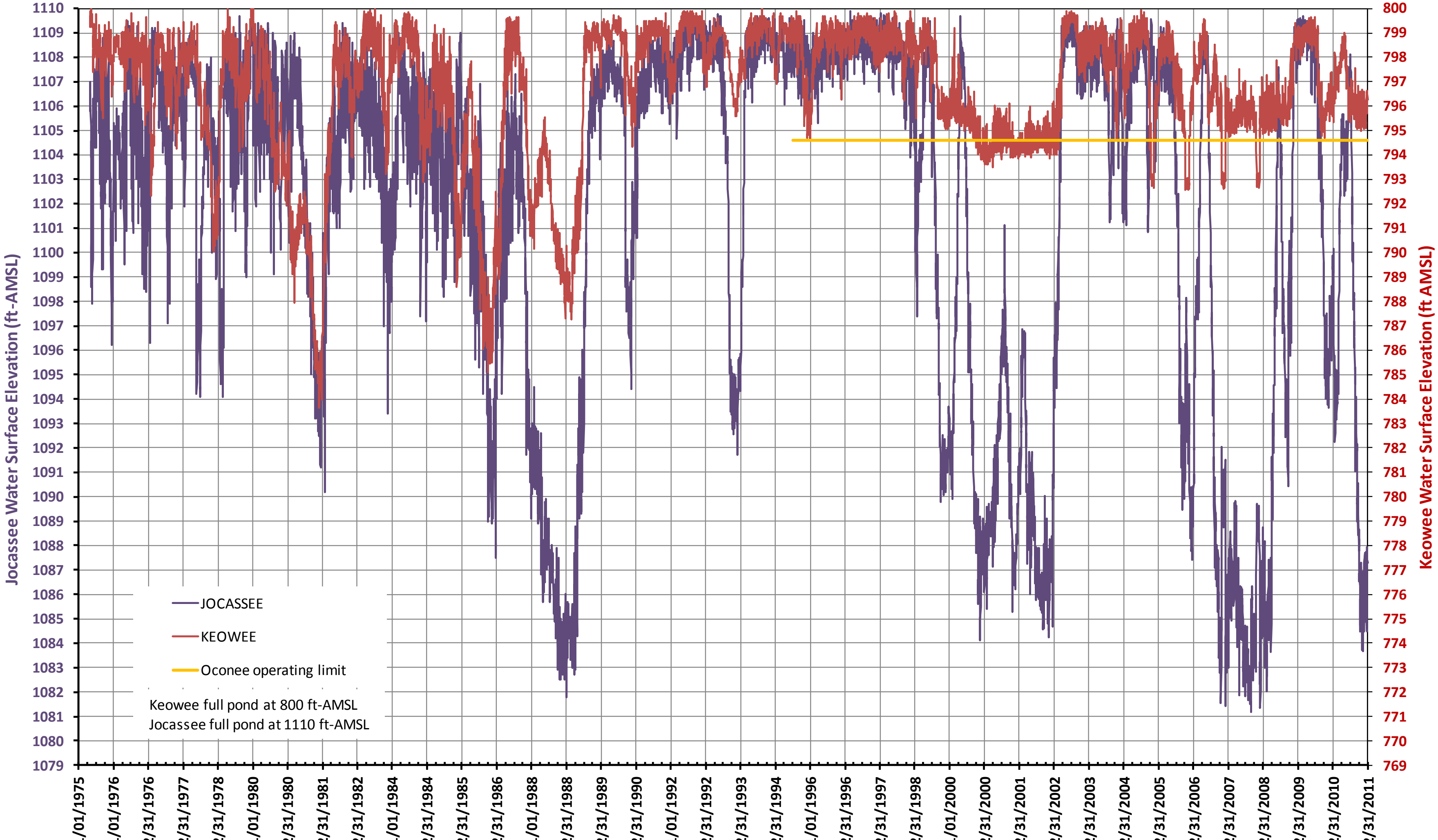
Section 4.3.2 Plots of Lake Jocassee reservoir elevations

Figure 4.3-10 Histogram and Cumulative Frequency Curve
Daily Range of Lake Jocassee Elevations from Hourly Data
January 1, 1995, through December 31, 2011



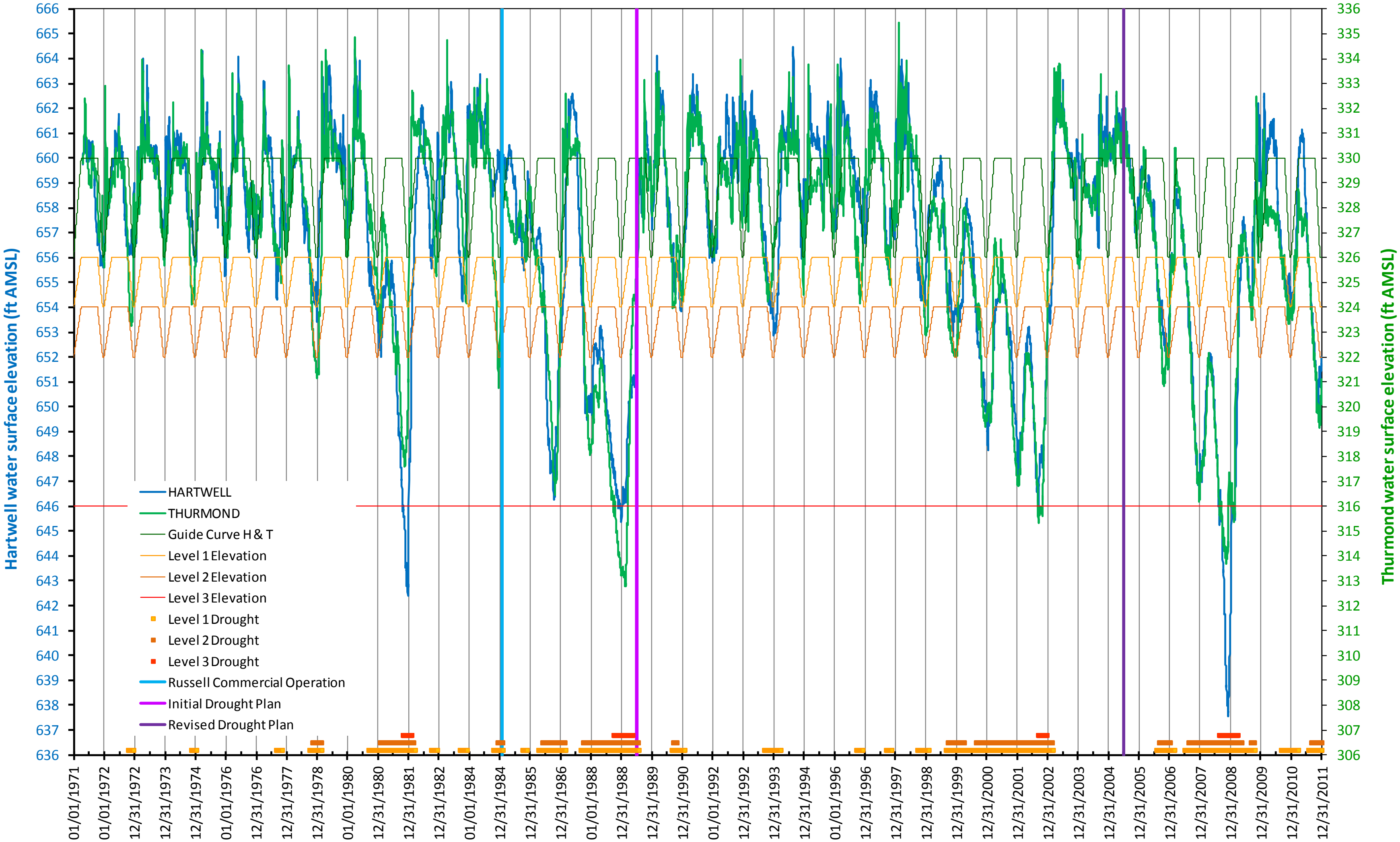
Section 4.3.3 Plot of Lake Keowee and Lake Jocassee reservoir elevations

Figure 4.3-11 Lake Keowee and Lake Jocassee Water Surface Elevations May 1, 1975, through December 31, 2011



Section 4.4 Upper Savannah River Basin drought periods

Figure 4.4-1 Hartwell Lake and JST Lake Water Surface Elevations April 17, 1971, through December 31, 2011



Section 4.4 Upper Savannah River Basin drought periods

Periods of drought Level 1 or greater, April 17, 1971, through December 31, 2011

Period	Start Date	End Date	Days
1	10/14/1972	12/18/1972	66
2	11/10/1974	01/13/1975	65
3	08/25/1977	11/06/1977	74
4	09/29/1978	02/23/1979	148
5	09/07/1980	03/21/1982	561
6	09/29/1982	12/12/1982	75
7	09/08/1983	12/05/1983	89
8	10/13/1984	02/06/1985	117
9	09/29/1985	11/23/1985	56
10	04/07/1986	03/01/1987	329
11	08/28/1987	07/26/1989	699
12	08/25/1990	01/27/1991	156
13	09/07/1993	03/25/1994	200
14	09/17/1996	12/03/1996	78
15	09/09/1997	11/15/1997	68
16	09/19/1998	02/04/1999	139
17	08/27/1999	03/06/2003	1,288
18	07/28/2006	03/03/2007	219
19	07/01/2007	10/23/2009	846
20	08/31/2010	03/28/2011	210
21	07/25/2011	After 12/31/2011	162+

Reference: Table 4.4-1, *Reservoir Level and Project Flow Releases Study for the Keowee-Jocassee Relicensing Project,* FERC Project No. 2503, Revised Draft, July 2012

Section 4.4 Upper Savannah River Basin drought periods

Figure 4.4-2 RBR Lake Water Surface Elevations
January 1, 1985, through December 31, 2011

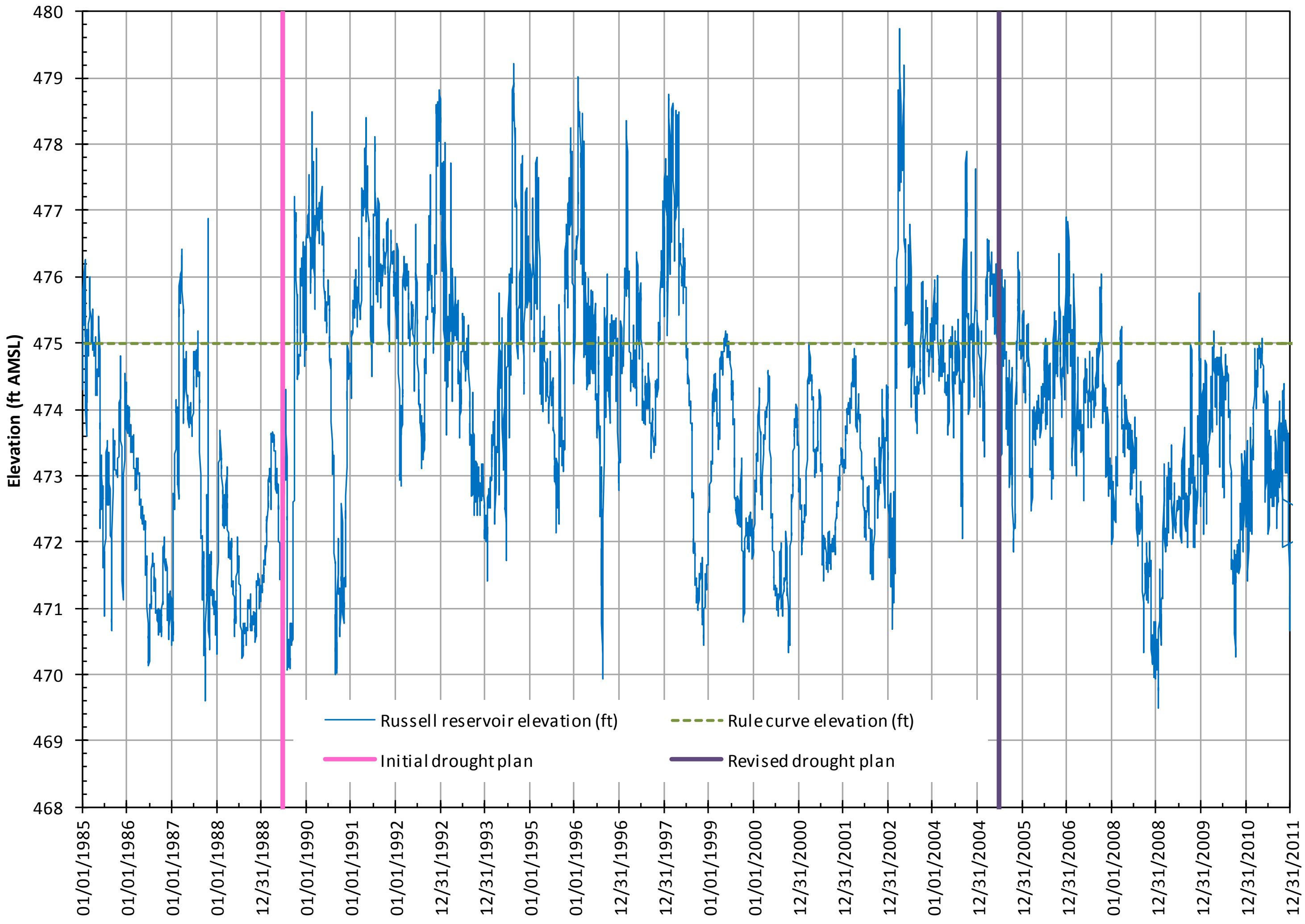
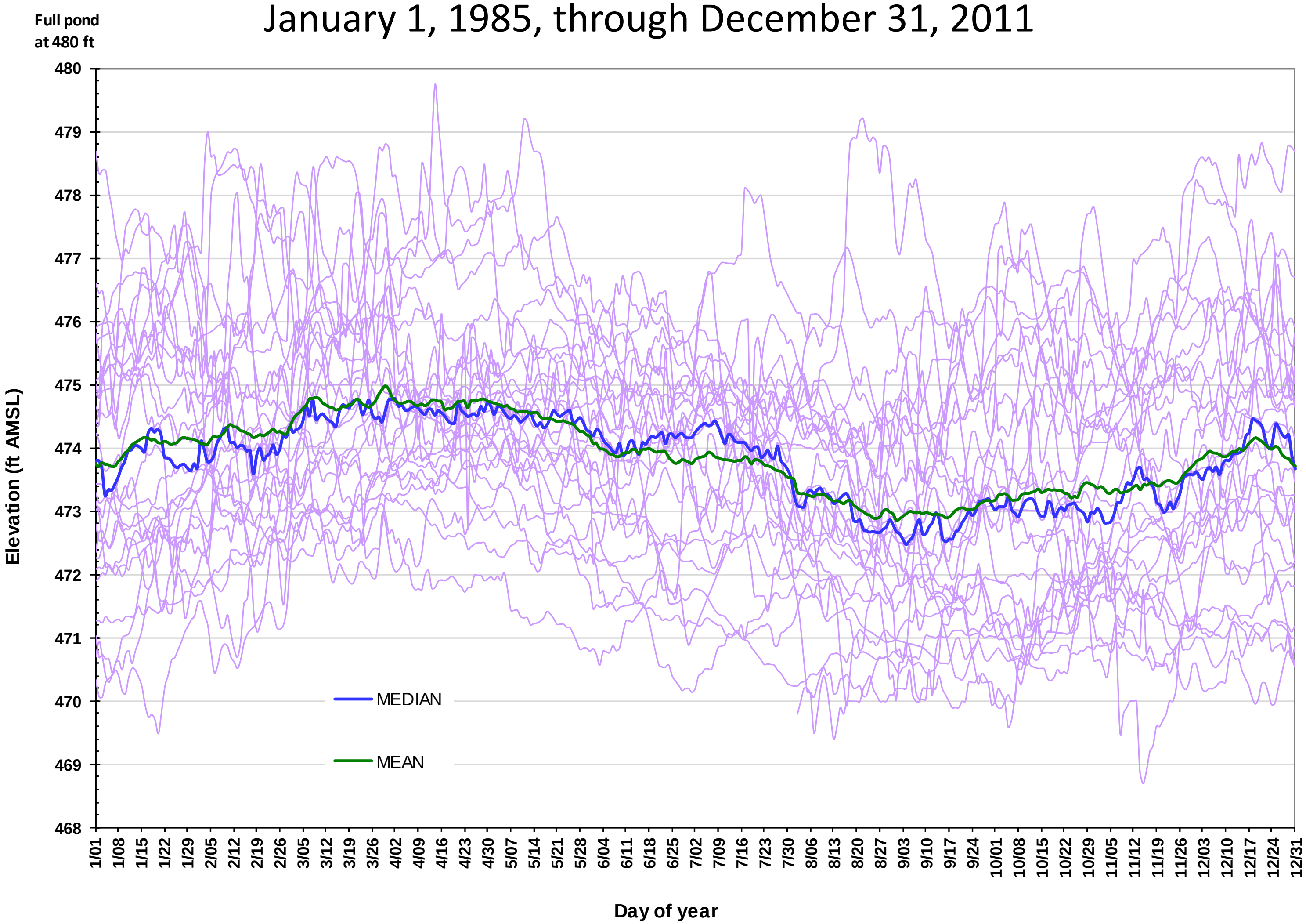


Figure 4.4-3 Hayes Chart of RBR Lake Water Surface Elevations January 1, 1985, through December 31, 2011



Consensus reached by Team

1. Drought periods for the upper Savannah River basin are defined to be periods when the Corps of Engineers' drought level is 1 or higher. All other periods will be described as normal.

2. Normal operating ranges for the Keowee-Toxaway Project are:

Lake Keowee	800 to 795 ft AMSL
Lake Jocassee	1110 to 1096 ft AMSL

3. Operating principles for drought periods will be discussed after the break.

QUESTIONS

Drought Period Operations

Explore operating principles to be applied during drought periods

This presentation considers some of the potential drought operating conditions that are combinations of the following two variables:

Hypothetical increase in Lake Keowee drawdown:

- 795 case – the null case – current condition where maximum drawdown remains 794.6 ft AMSL
- 792 case – maximum drawdown extended to 792 ft AMSL
- 790 case – maximum drawdown extended to 790 ft AMSL
- 788 case – maximum drawdown extended to 788 ft AMSL

Hypothetical ratio of Lake Jocassee to Lake Keowee drawdowns:

- 1-to-1 ratio – 1 ft drawdown at Lake Jocassee to 1 ft at Lake Keowee
- 2-to-1 ratio – 2 ft drawdown at Lake Jocassee to 1 ft at Lake Keowee
- 4-to-1 ratio – 4 ft drawdown at Lake Jocassee to 1 ft at Lake Keowee
- 8-to-1 ratio – 8 ft drawdown at Lake Jocassee to 1 ft at Lake Keowee

Later in this presentation, the drawdown ratios are illustrated for the 790 case.

Physical description of Lake Jocassee and Lake Keowee

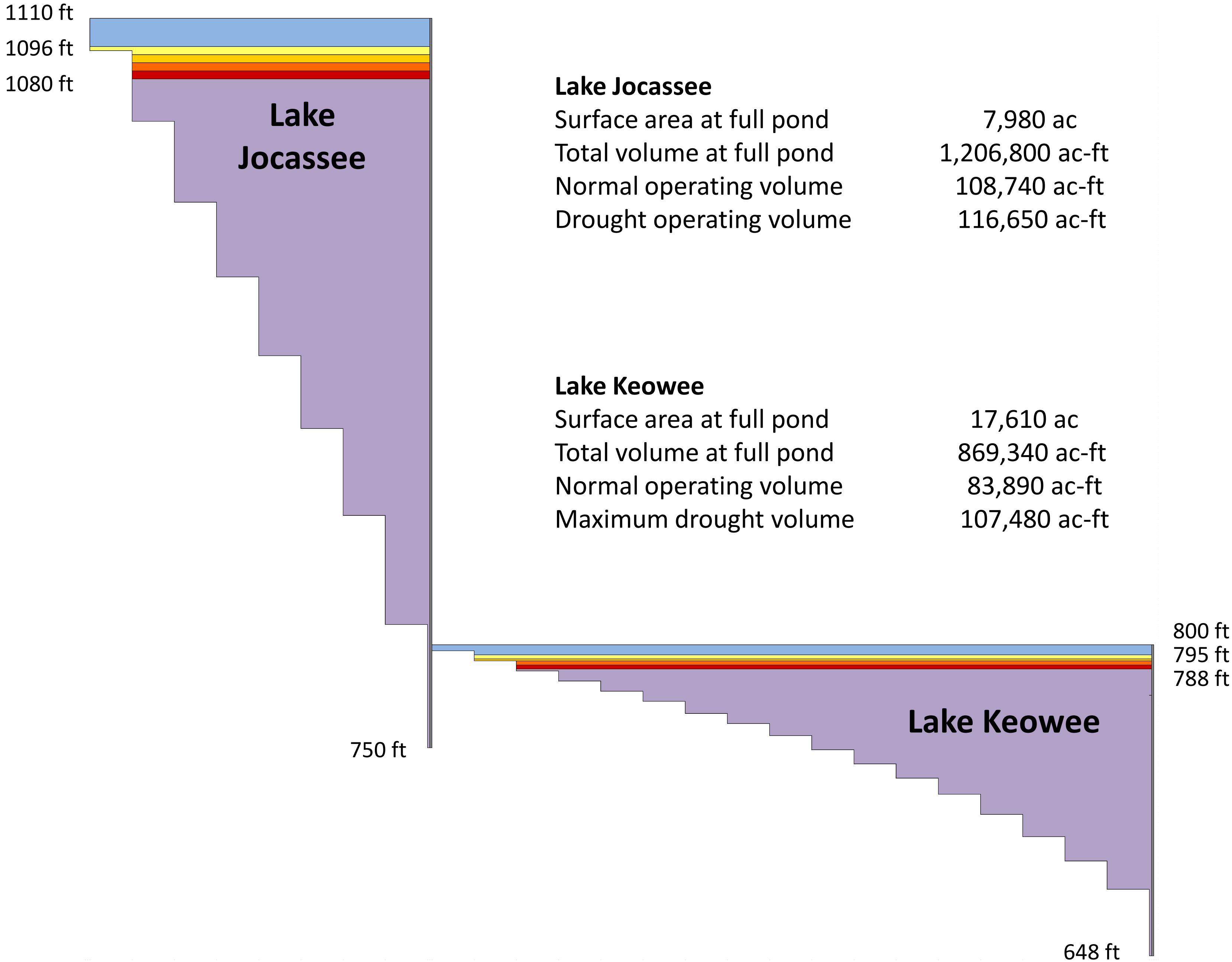
Key elevations for Lake Jocassee:

1110 ft	Full pond – top of normal operating range
1096 ft	Bottom of normal operating range
1080 ft	Maximum drawdown per current FERC license

Key elevations for Lake Keowee

800 ft	Full pond – top of normal operating range
795 ft	Bottom of normal operating range
794.6 ft	Current operating limit
792 ft	Hypothetical future operating limit
790 ft	Hypothetical future operating limit
788 ft	Maximum drawdown based on Keowee Hydro providing emergency power for ONS

Physical description of Lake Jocassee and Lake Keowee



Lake Jocassee	
Surface area at full pond	7,980 ac
Total volume at full pond	1,206,800 ac-ft
Normal operating volume	108,740 ac-ft
Drought operating volume	116,650 ac-ft

Lake Keowee	
Surface area at full pond	17,610 ac
Total volume at full pond	869,340 ac-ft
Normal operating volume	83,890 ac-ft
Maximum drought volume	107,480 ac-ft

Table of available volume above specified elevations: Volume used for normal operations is shown in blue.
Volume used during drought periods is shown in orange.

		LAKE JOCASSEE				LAKE KEOWEE			
Draw-down (ft)	Local elevation 100 ft = full pond	Elevation (ft AMSL)	Incremental volume (ac-ft)	Volume above elevation (ac-ft)	Volume above elevation (ac-ft)	Elevation (ft AMSL)	Incremental volume (ac-ft)	Volume above elevation (ac-ft)	Volume above elevation (ac-ft)
0	100	1110	7,967	0		800	17,362	0	
1	99	1109	7,937	7,967		799	17,032	17,362	
2	98	1108	7,905	15,905		798	16,750	34,394	
3	97	1107	7,873	23,809		797	16,492	51,144	
4	96	1106	7,841	31,682		796	16,249	67,636	
5	95	1105	7,811	39,524		795	16,015	83,885	
6	94	1104	7,780	47,334		794	15,787	99,900	16,015
7	93	1103	7,750	55,114		793	15,565	115,687	31,802
8	92	1102	7,719	62,864		792	15,345	131,252	47,367
9	91	1101	7,690	70,583		791	15,130	146,597	62,712
10	90	1100	7,660	78,273		790	14,921	161,727	77,842
11	89	1099	7,631	85,933		789	14,715	176,648	92,763
12	88	1098	7,602	93,564		788	14,512	191,363	107,478
13	87	1097	7,572	101,165					
14	86	1096	7,543	108,738					
15	85	1095	7,515	116,281	7,543				
16	84	1094	7,486	123,796	15,058				
17	83	1093	7,457	131,281	22,544				
18	82	1092	7,417	138,738	30,000				
19	81	1091	7,372	146,154	37,417				
20	80	1090	7,335	153,526	44,788				
21	79	1089	7,299	160,861	52,123				
22	78	1088	7,264	168,159	59,422				
23	77	1087	7,231	175,424	66,686				
24	76	1086	7,198	182,655	73,918				
25	75	1085	7,166	189,853	81,116				
26	74	1084	7,135	197,019	88,282				
27	73	1083	7,105	204,154	95,417				
28	72	1082	7,077	211,259	102,522				
29	71	1081	7,051	218,336	109,599				
30	70	1080	7,025	225,387	116,649				

Lake Keowee's volumes are smaller than Lake Jocassee's volumes:

Lake Keowee's normal operating volume is 77% of Lake Jocassee's.

Lake Keowee's drought volume at the 788 ft AMSL drawdown limit is 92% of Lake Jocassee's.

... at 790 ft AMSL is 67%

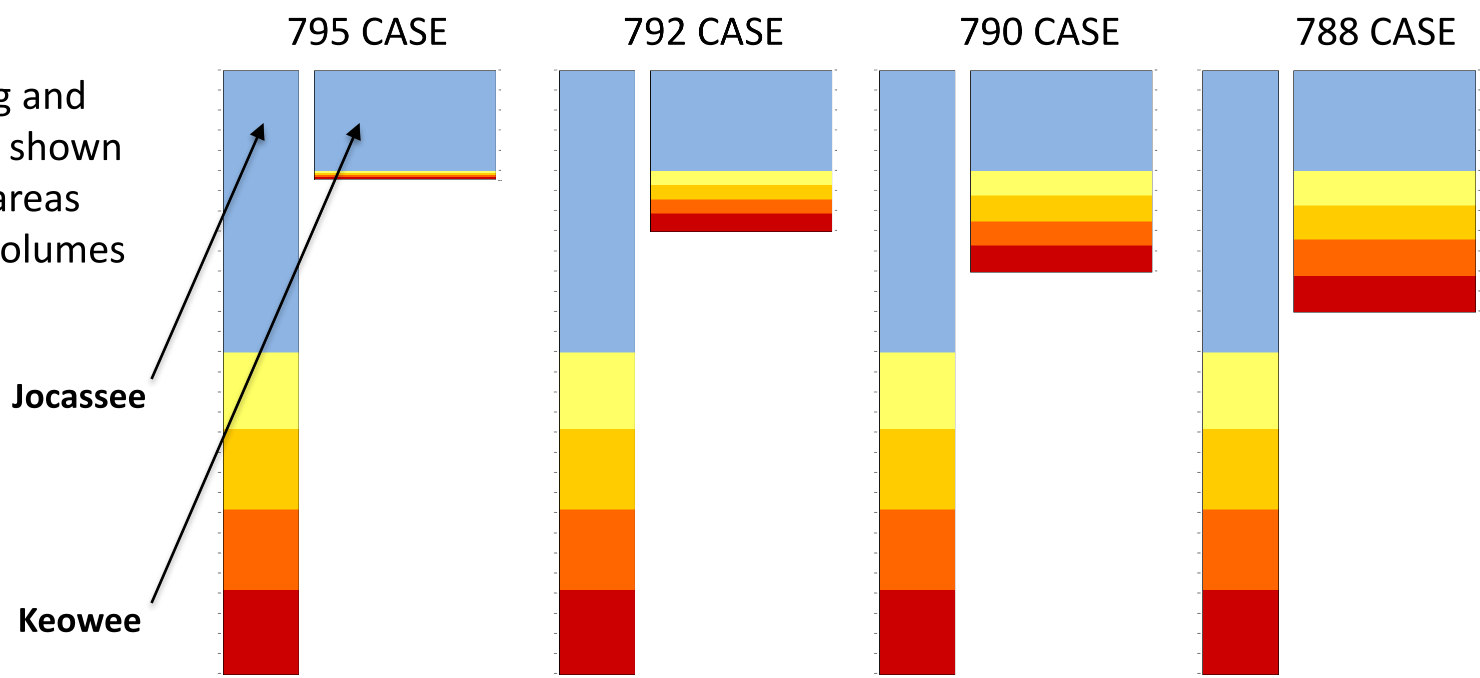
... at 792 ft AMSL is 41%

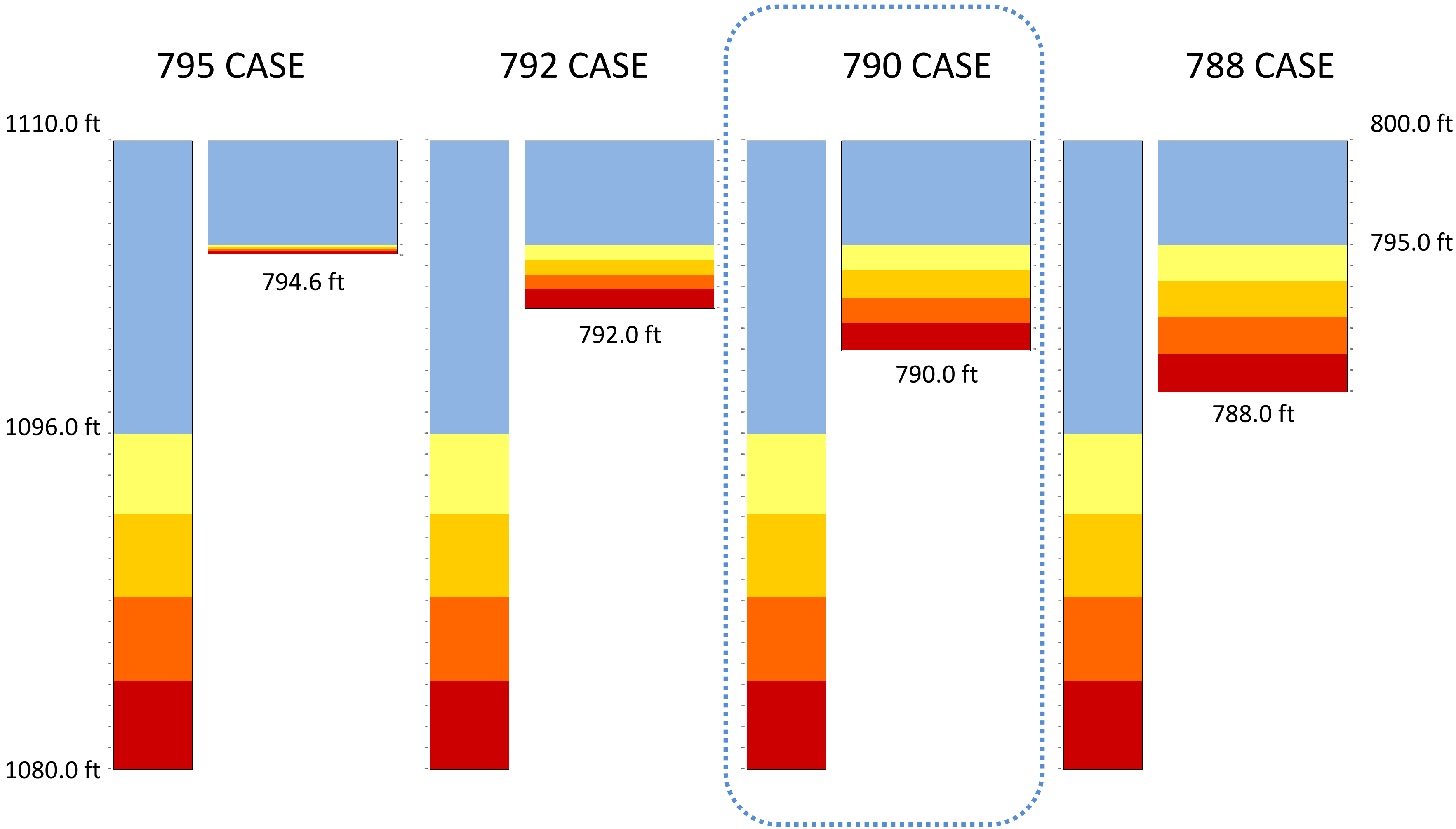
Drought volumes for each drawdown case divided into equal-volume segments

LAKE	JOCASSEE		KEOWEE							
CONDITION	"ALL"		"795"		"792"		"790"		"788"	
OPERATING RANGE	ELEVATION* (ft AMSL)	VOLUME (ac-ft)	ELEVATION* (ft AMSL)	VOLUME (ac-ft)	ELEVATION* (ft AMSL)	VOLUME (ac-ft)	ELEVATION* (ft AMSL)	VOLUME (ac-ft)	ELEVATION* (ft AMSL)	VOLUME (ac-ft)
FULL	1110.0		800.0		800.0		800.0		800.0	
		108,738		83,885		83,885		83,885		83,885
NORM	1096.0		795.0		795.0		795.0		795.0	
		28,509		1,602		11,842		19,461		26,869
Q1	1092.2		794.9		794.3		793.8		793.3	
		29,453		1,602		11,842		19,461		26,869
Q2	1088.2		794.8		793.6		792.5		791.6	
		28,887		1,602		11,842		19,461		26,869
Q3	1084.2		794.7		792.8		791.3		789.8	
		29,801		1,602		11,842		19,461		26,869
Q4	1080.0		794.6		792.0		790.0		788.0	
TOTAL		116,649		6,406		47,367		77,842		107,478

* Elevations are estimated to the nearest 1/10 ft.

Normal operating and drought volumes shown graphically with areas proportional to volumes

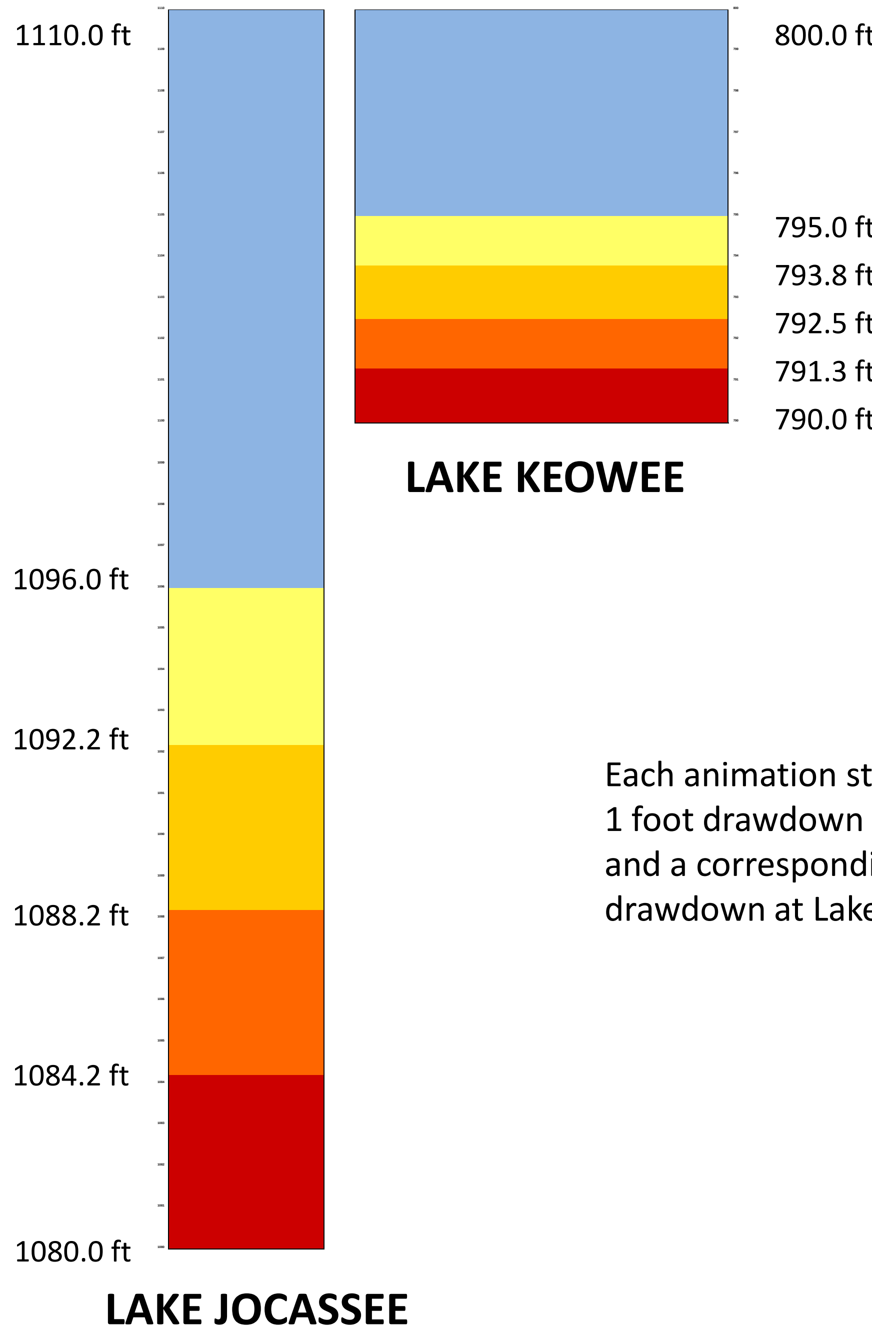




The 790 case is selected to demonstrate the effect of four drawdown ratios: 1-to-1, 2-to-1, 4-to-1, and 8-to-1.

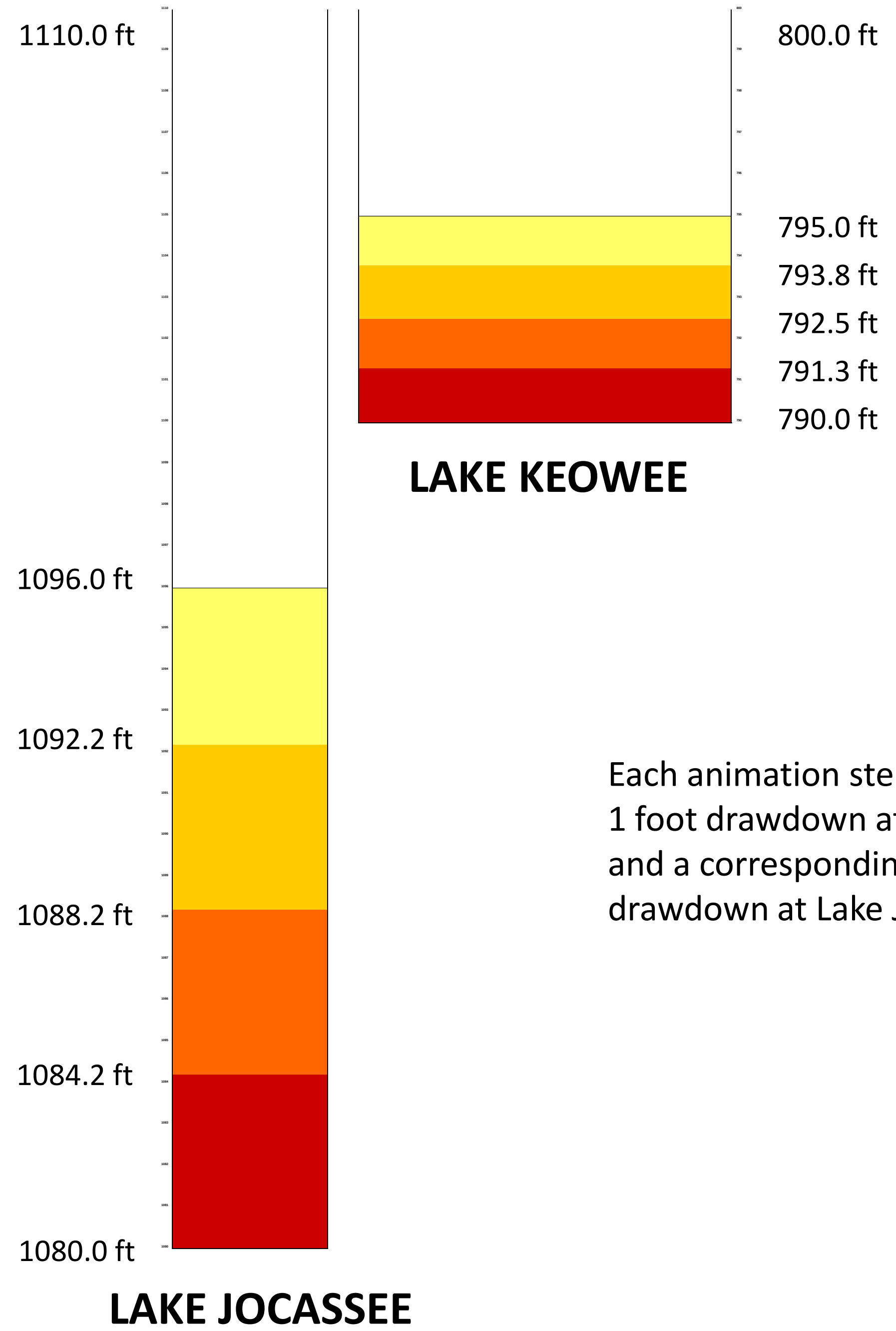
Animation and summary graphs are shown for each ratio.

1-to-1 Drawdown Ratio



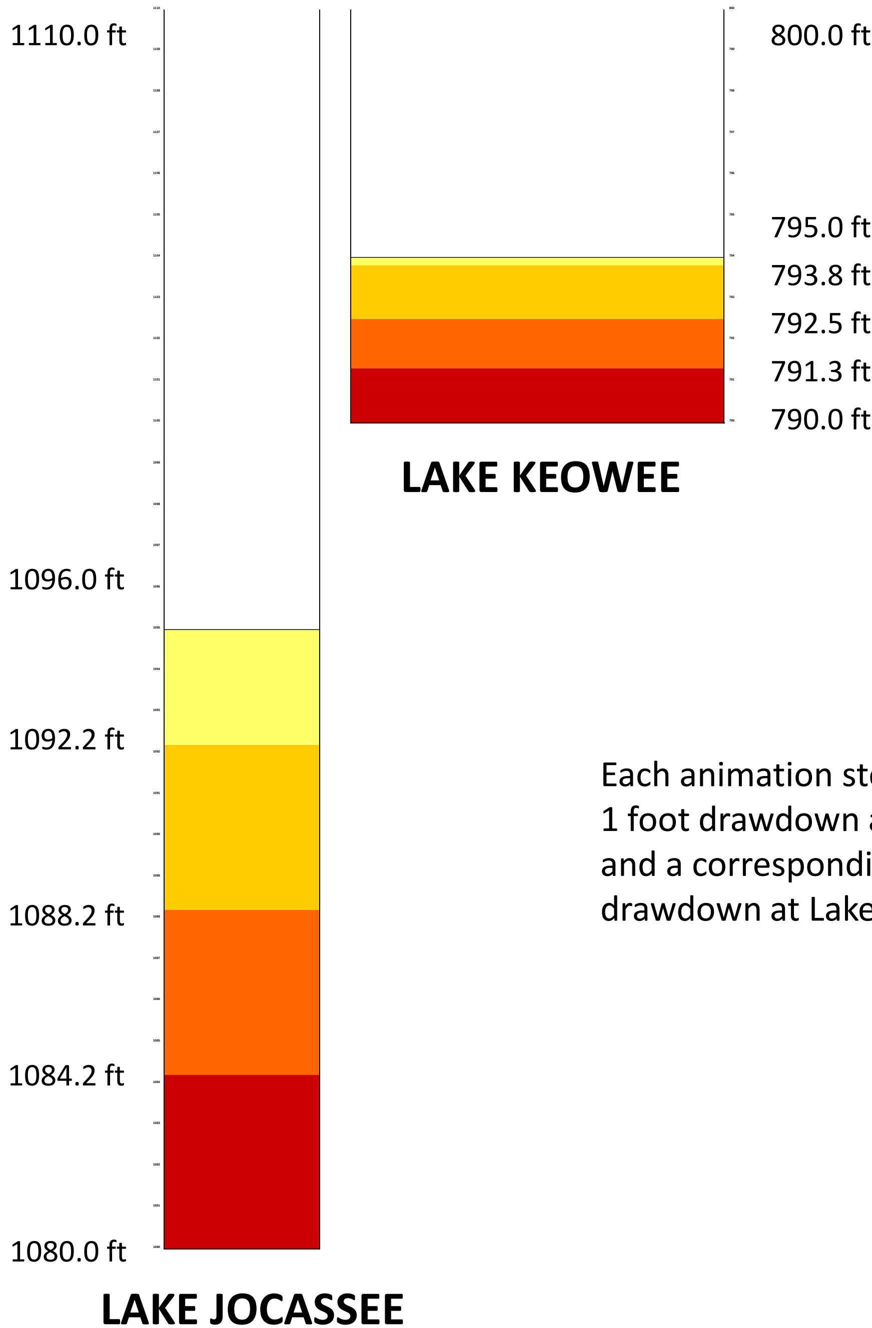
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



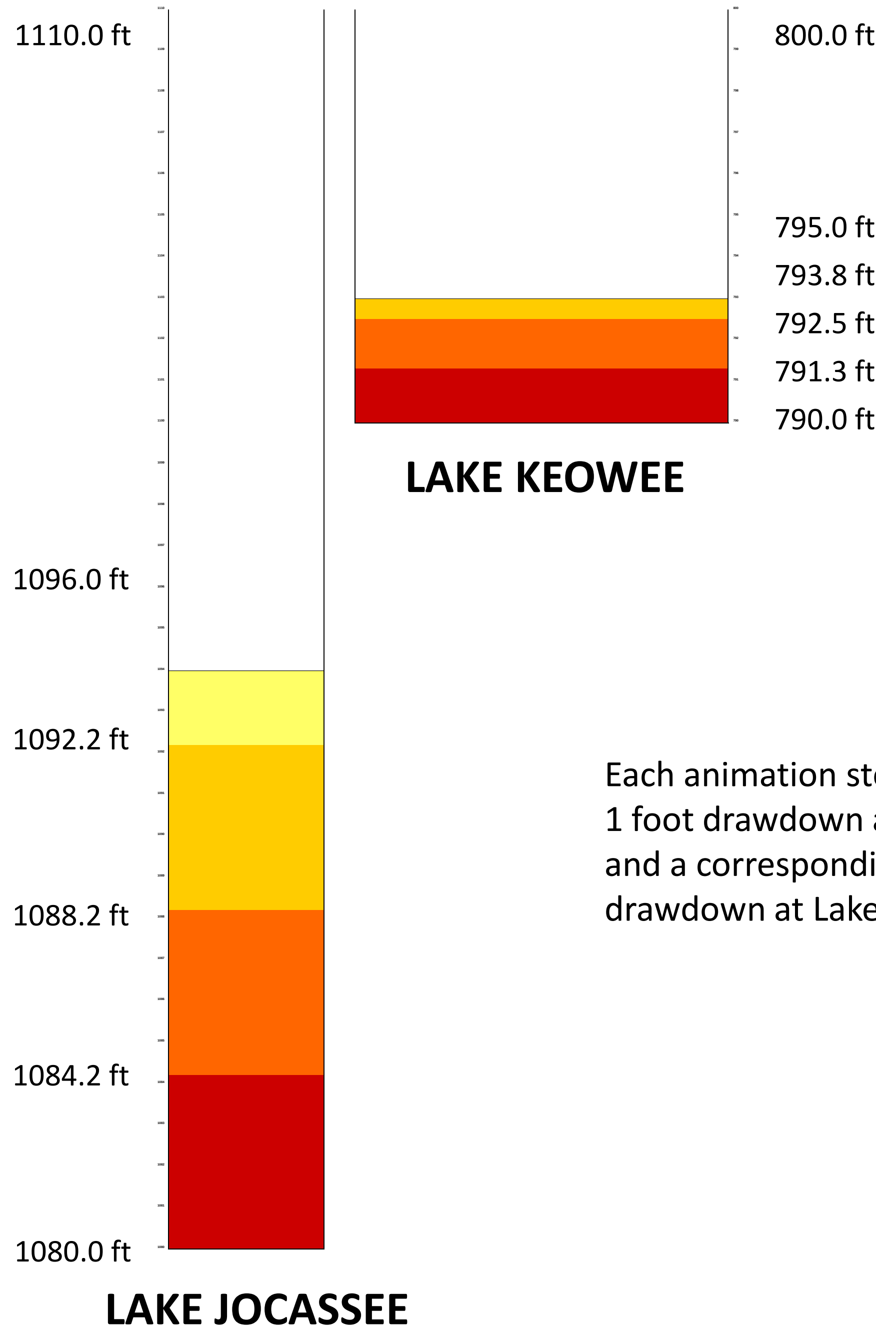
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



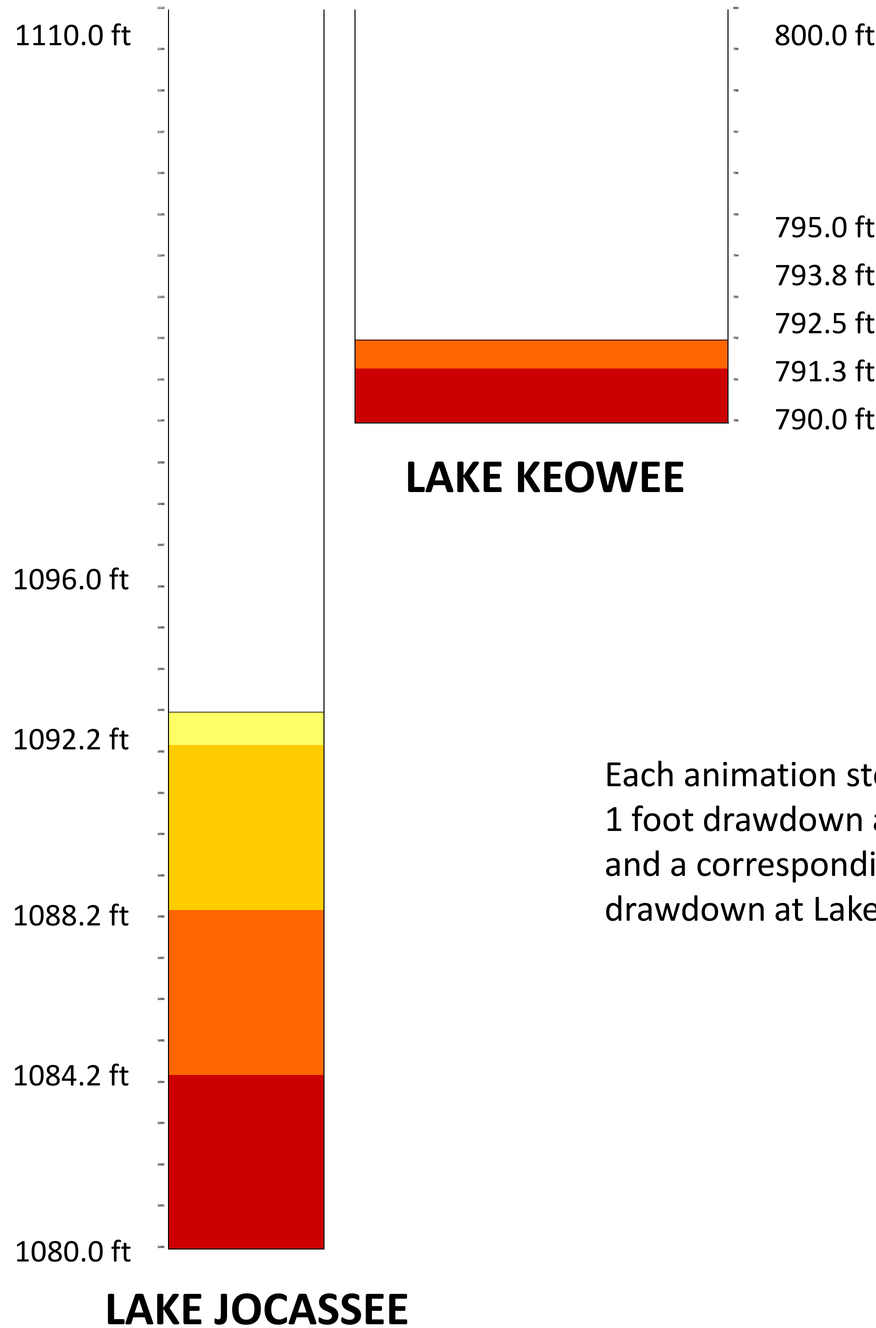
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



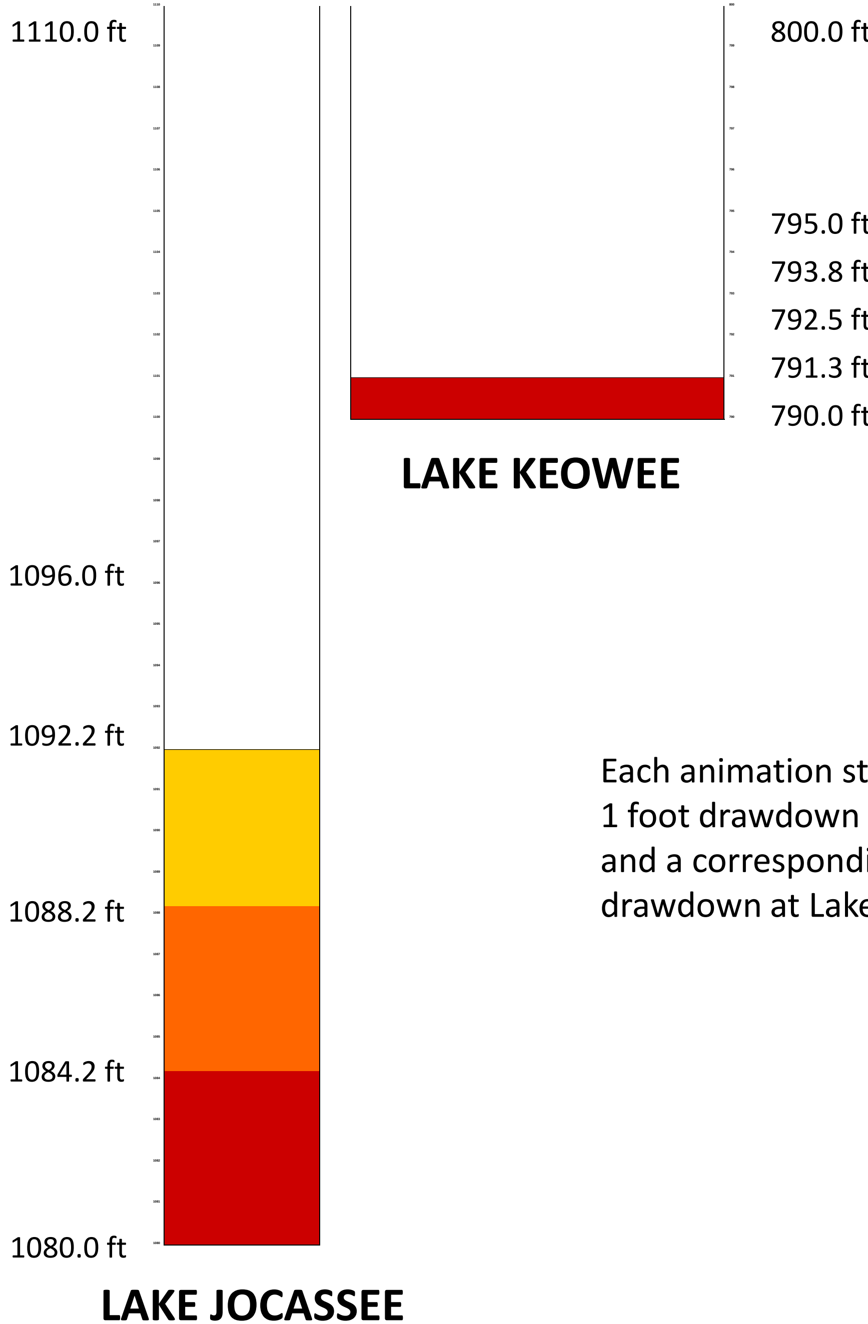
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



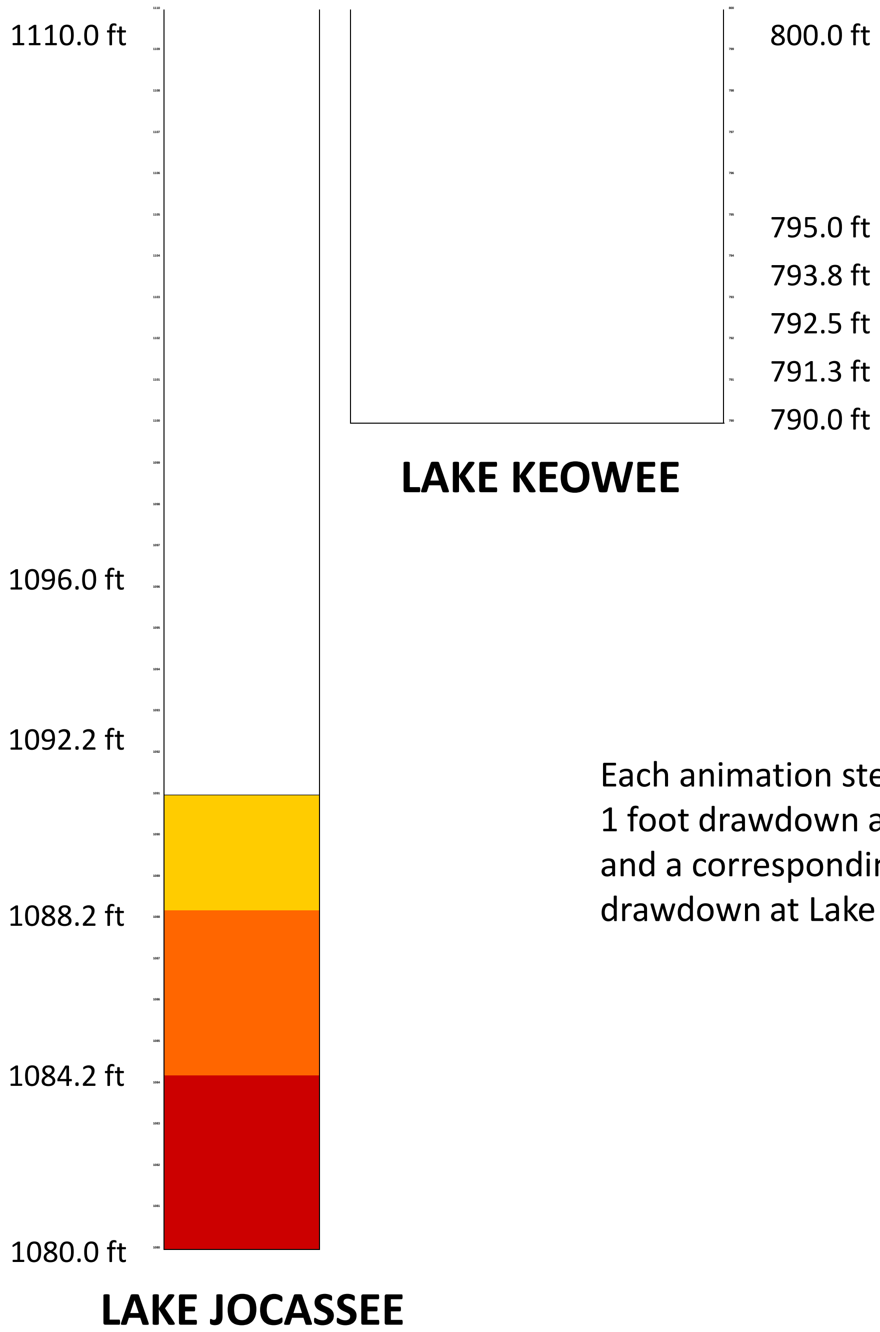
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



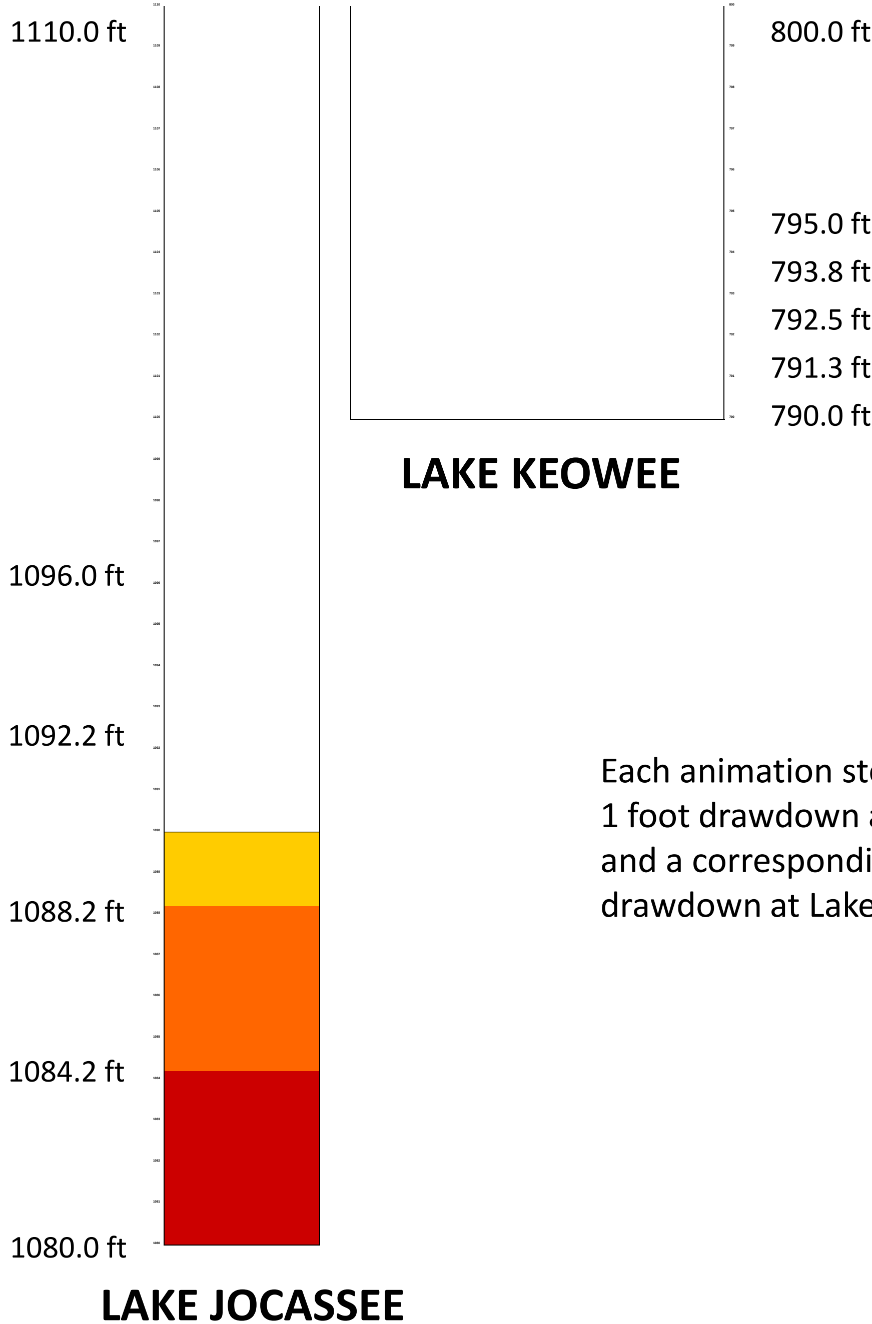
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



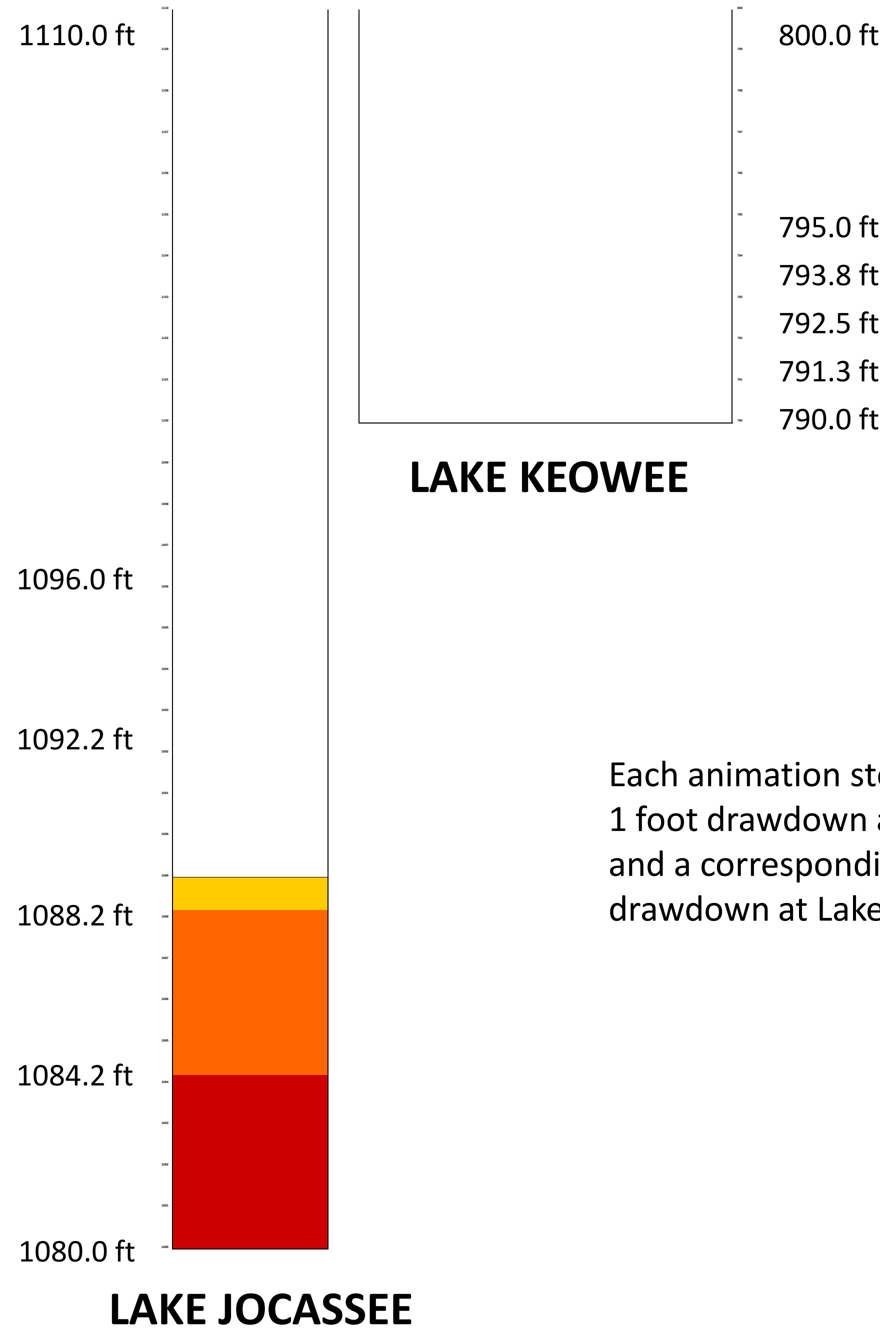
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



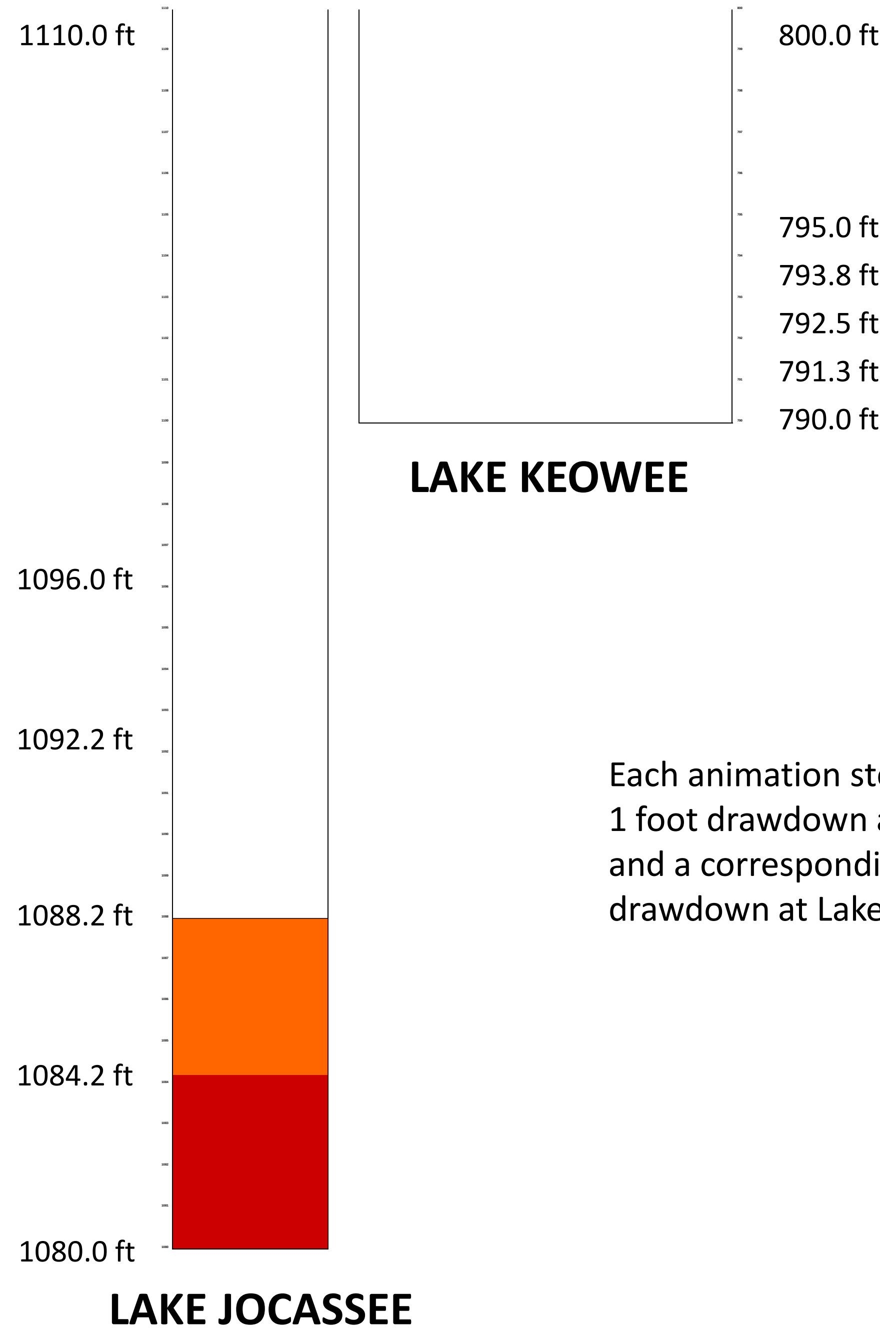
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



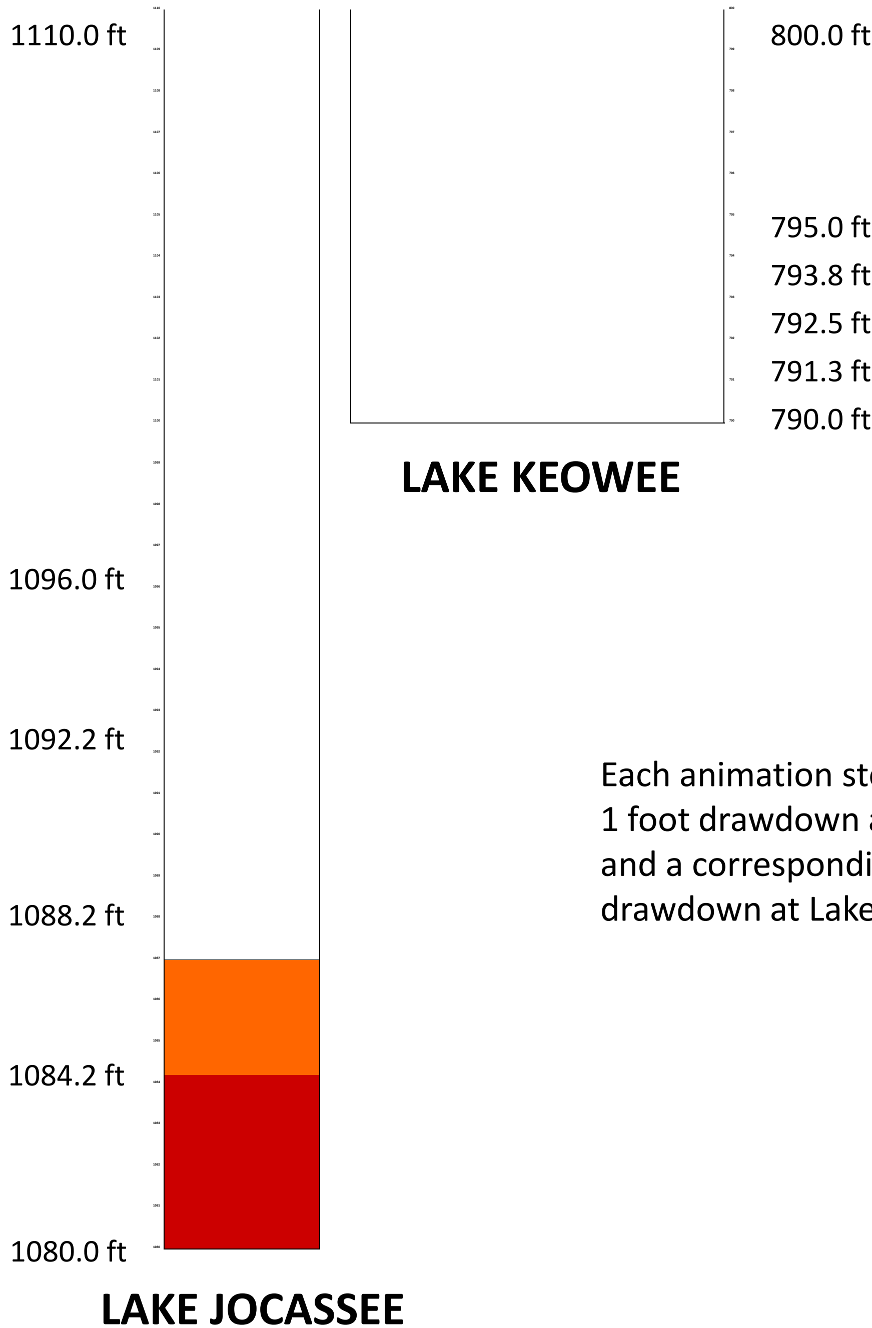
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



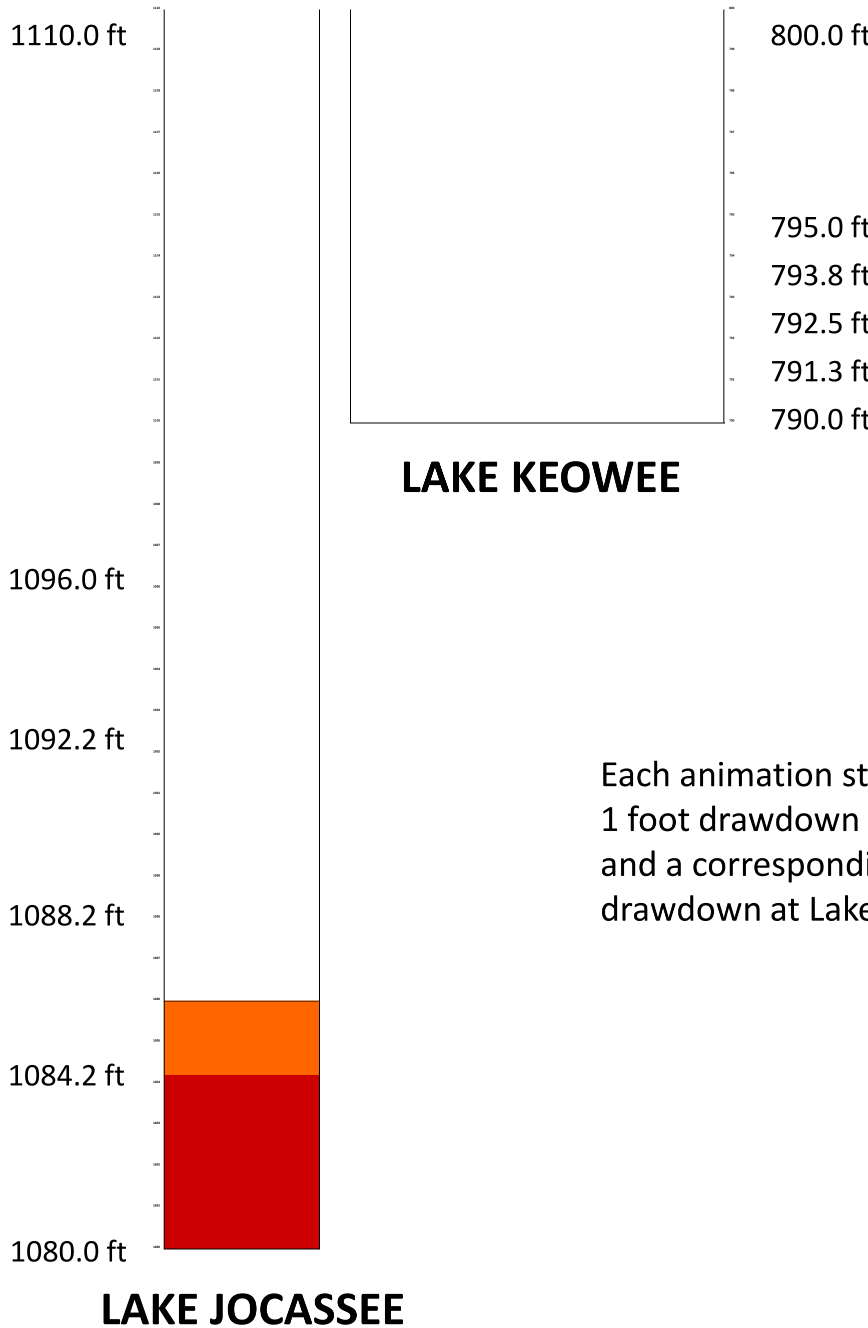
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



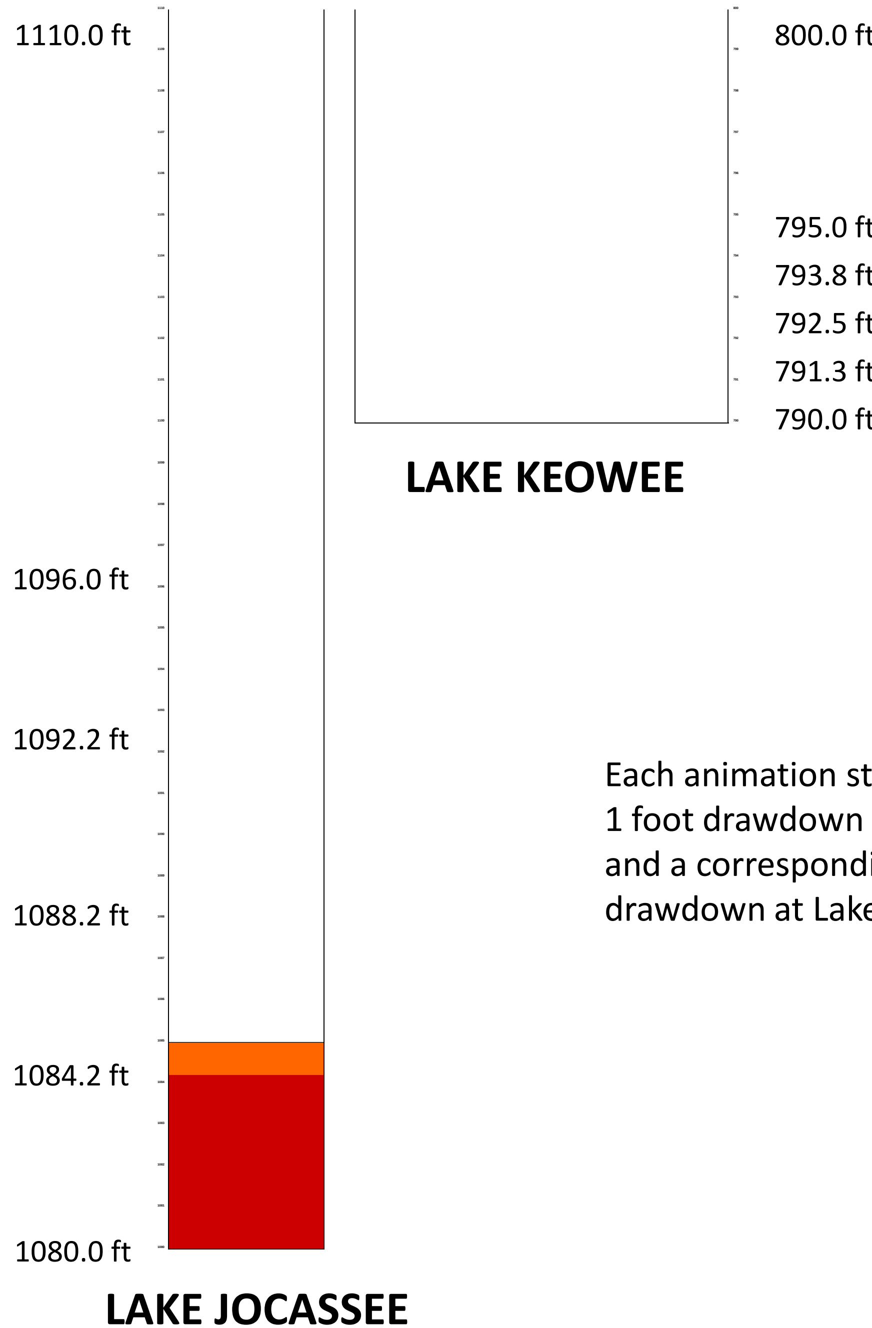
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



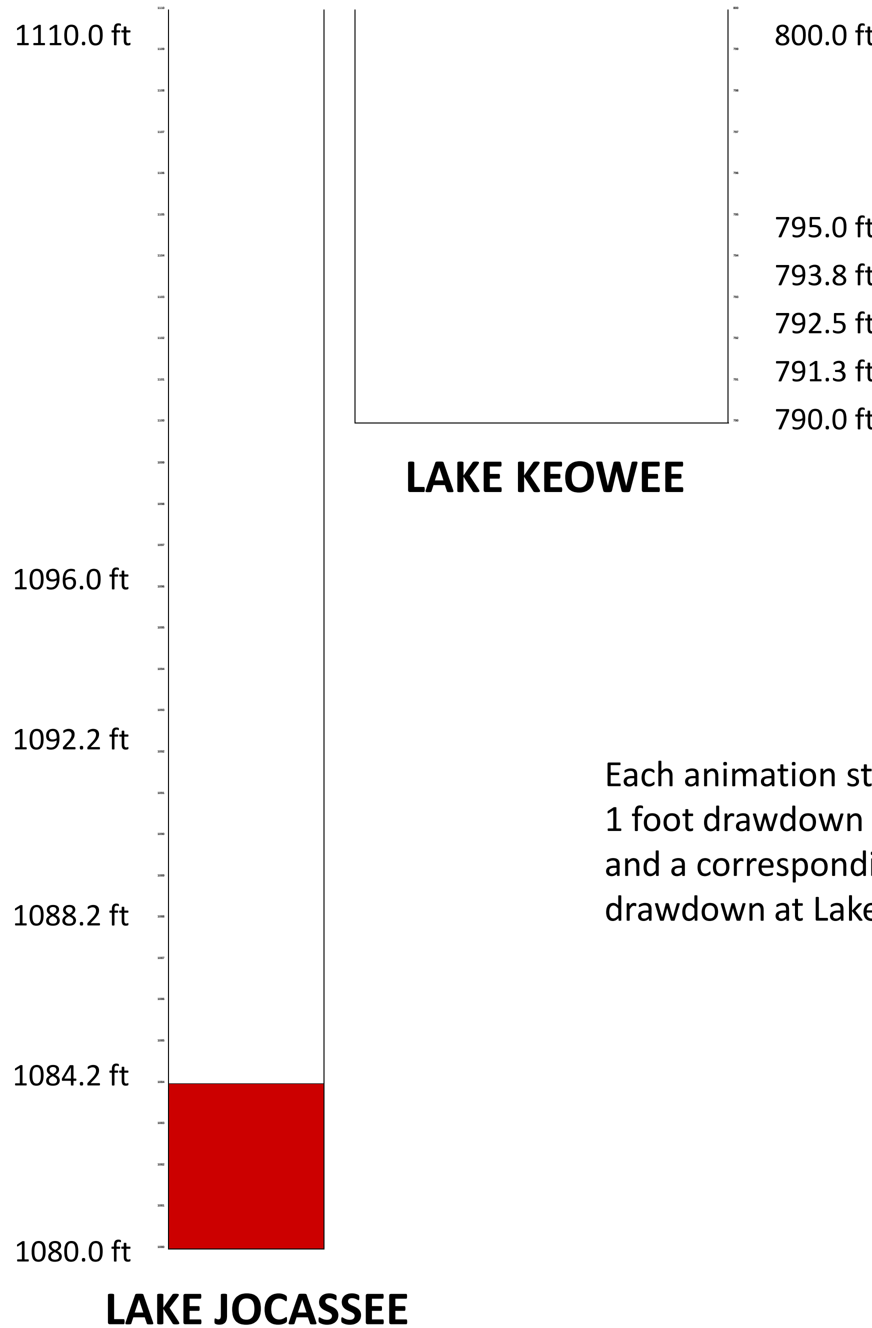
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



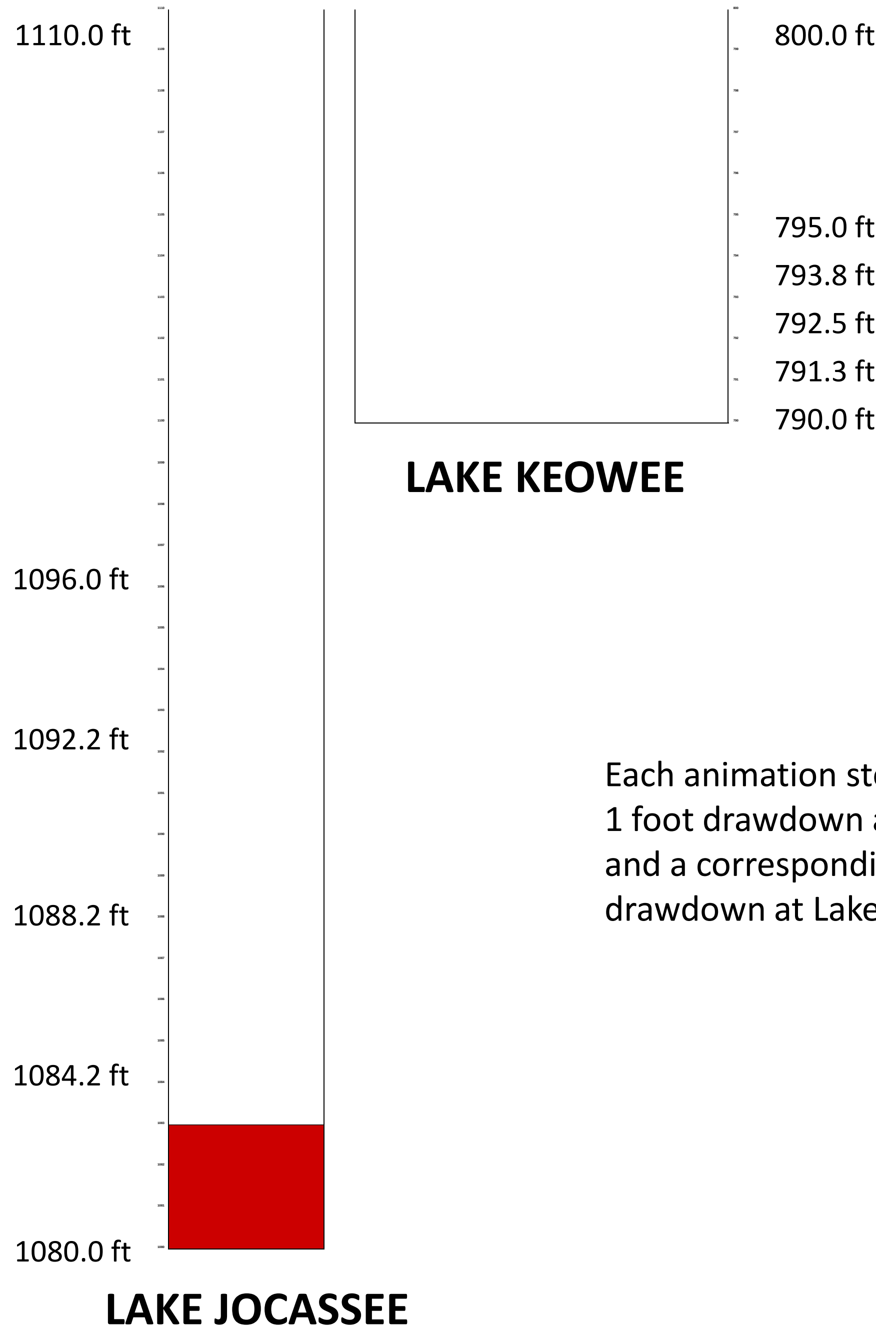
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



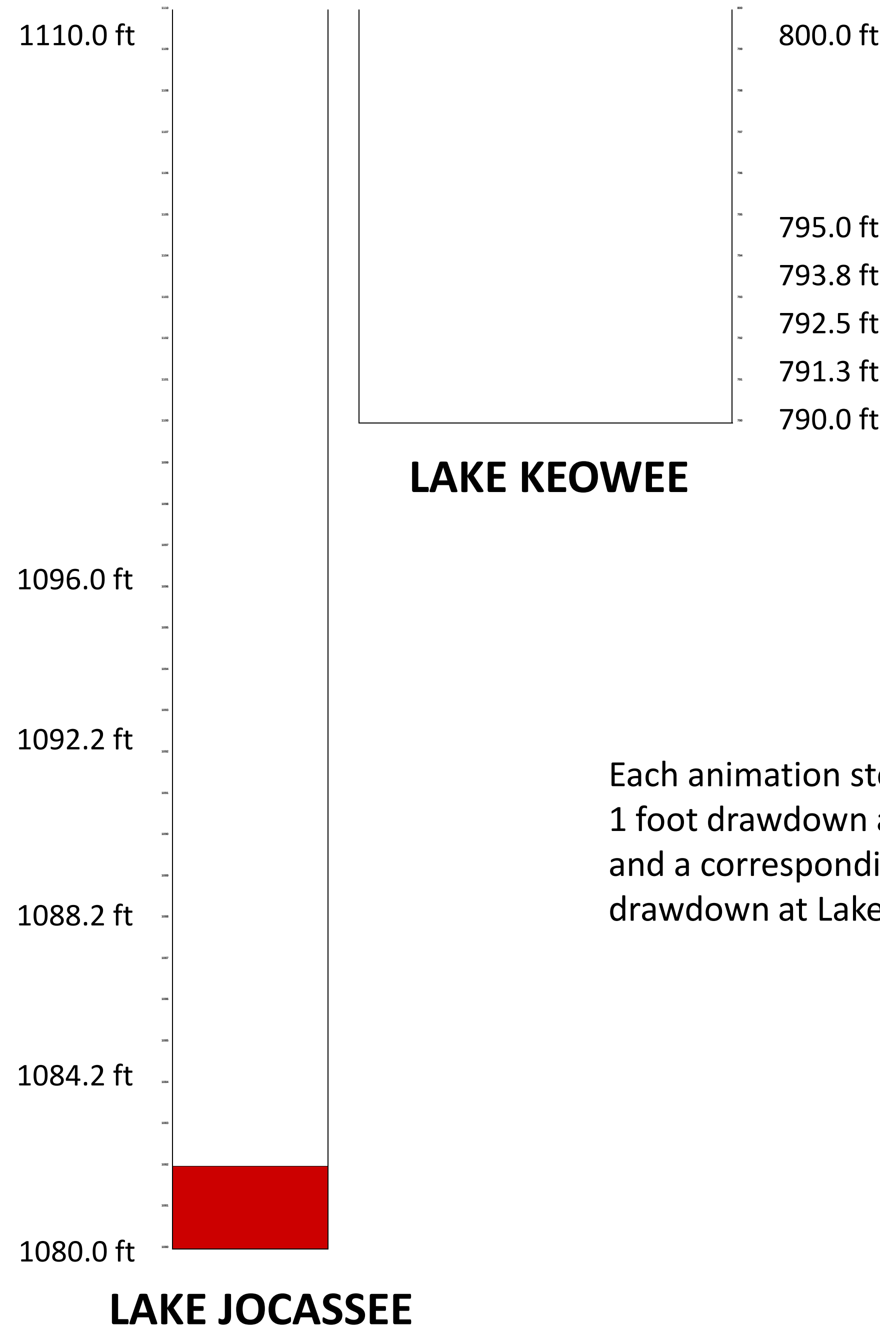
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



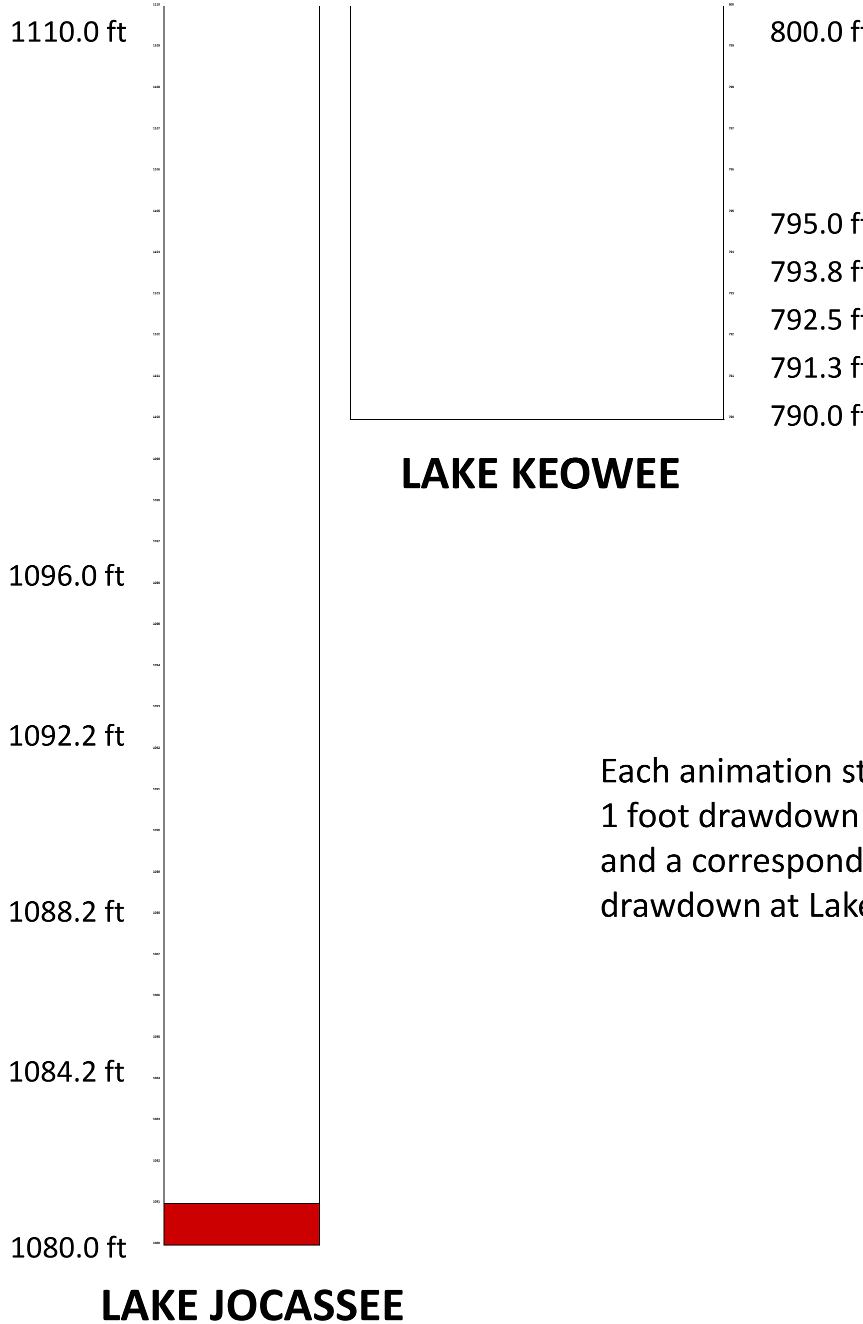
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



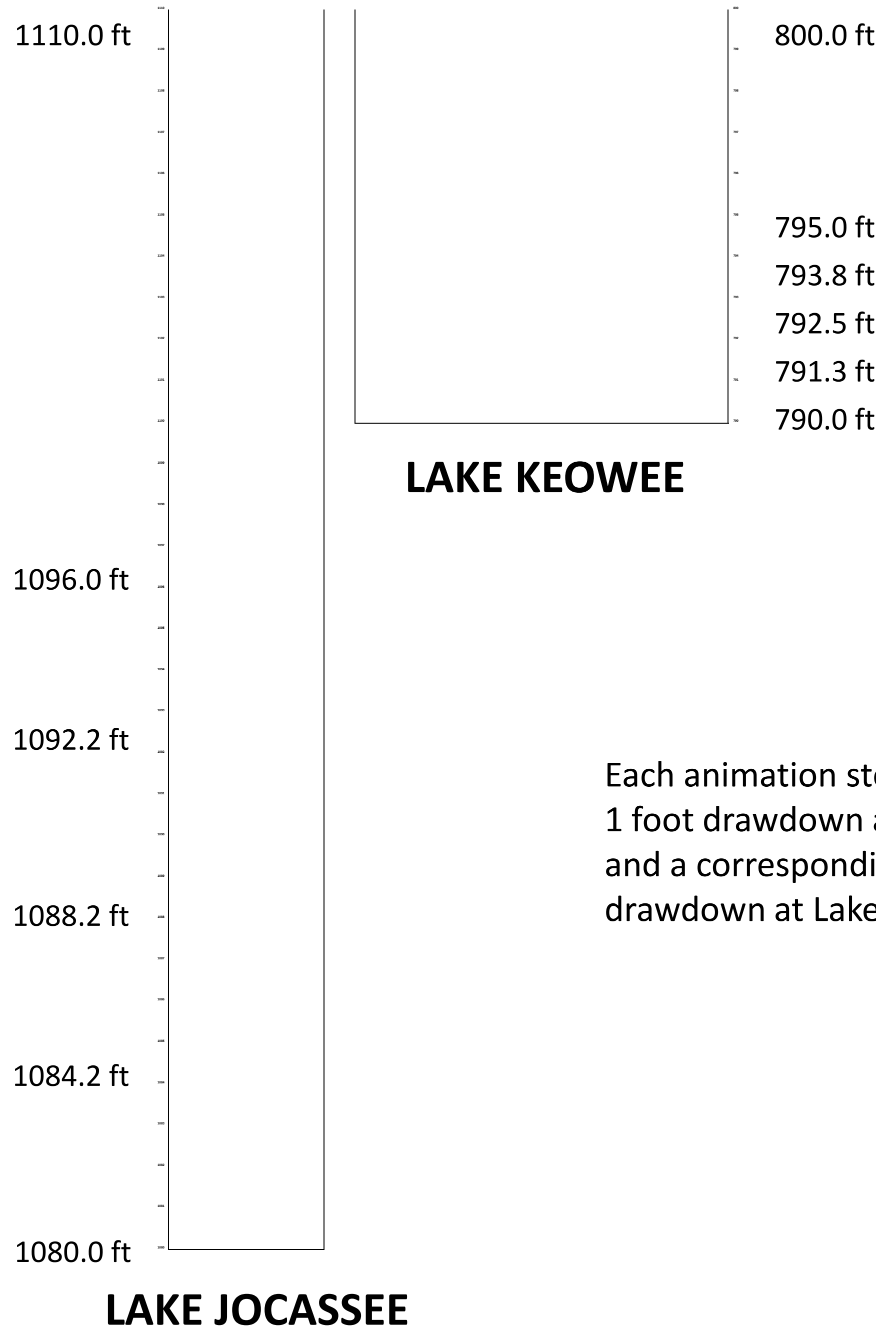
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



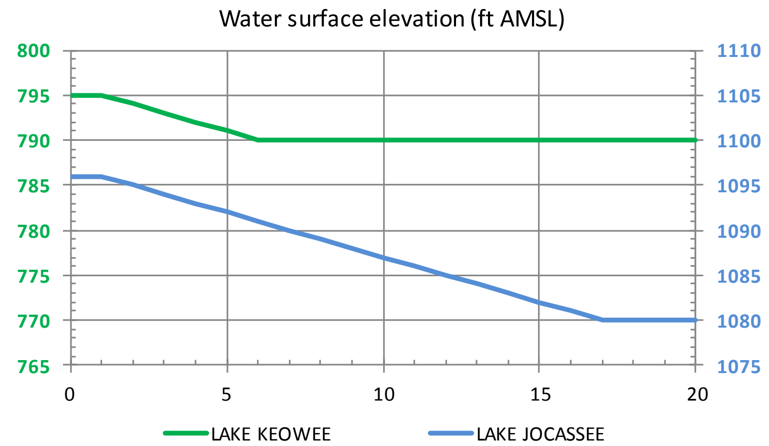
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

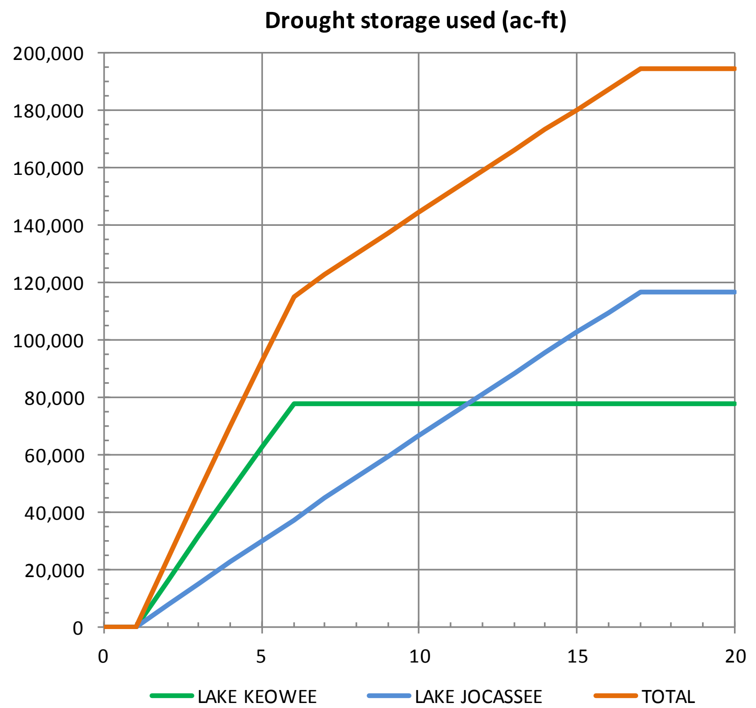
1-to-1 Drawdown Ratio



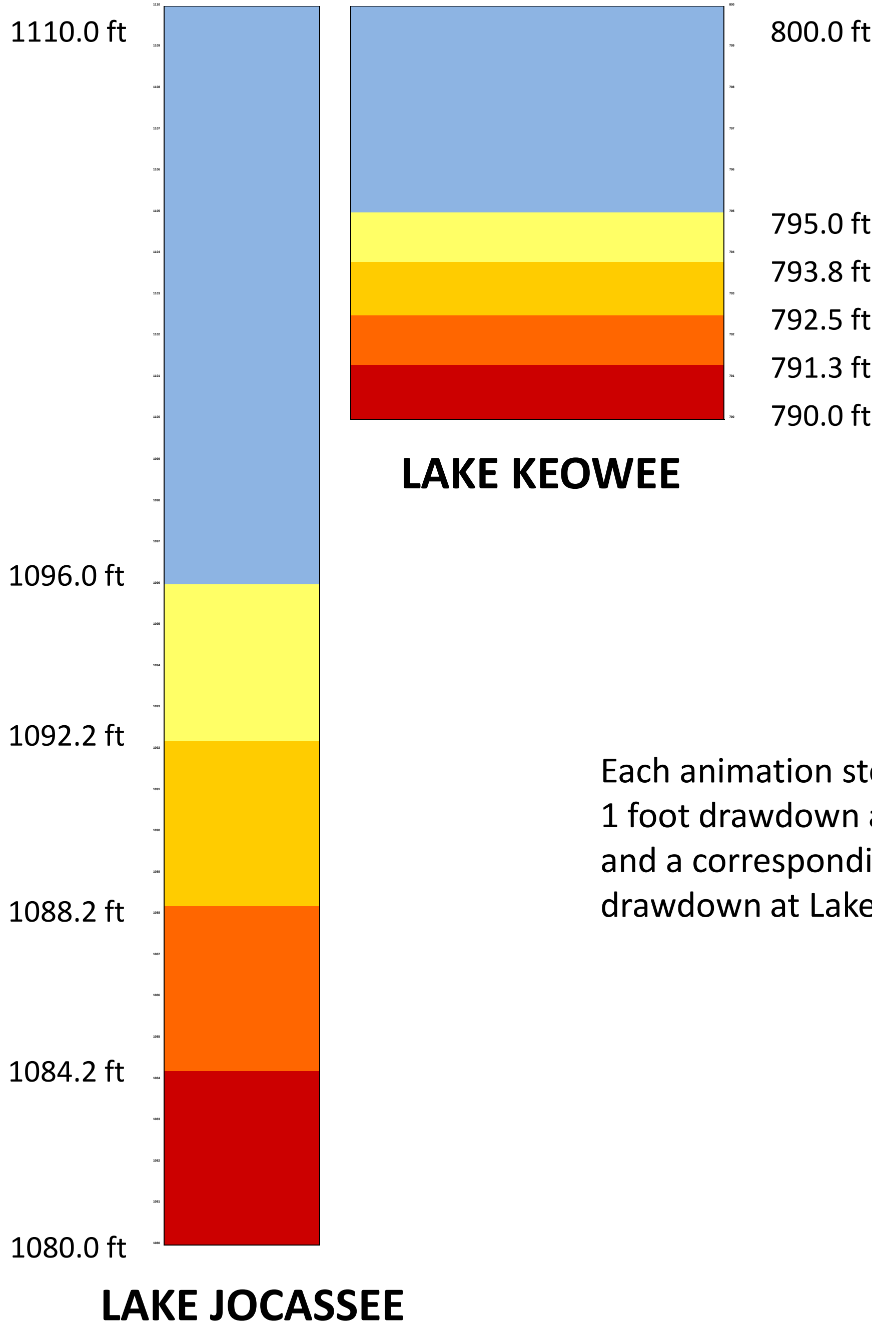
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 1 foot drawdown at Lake Jocassee.

1-to-1 Drawdown Ratio



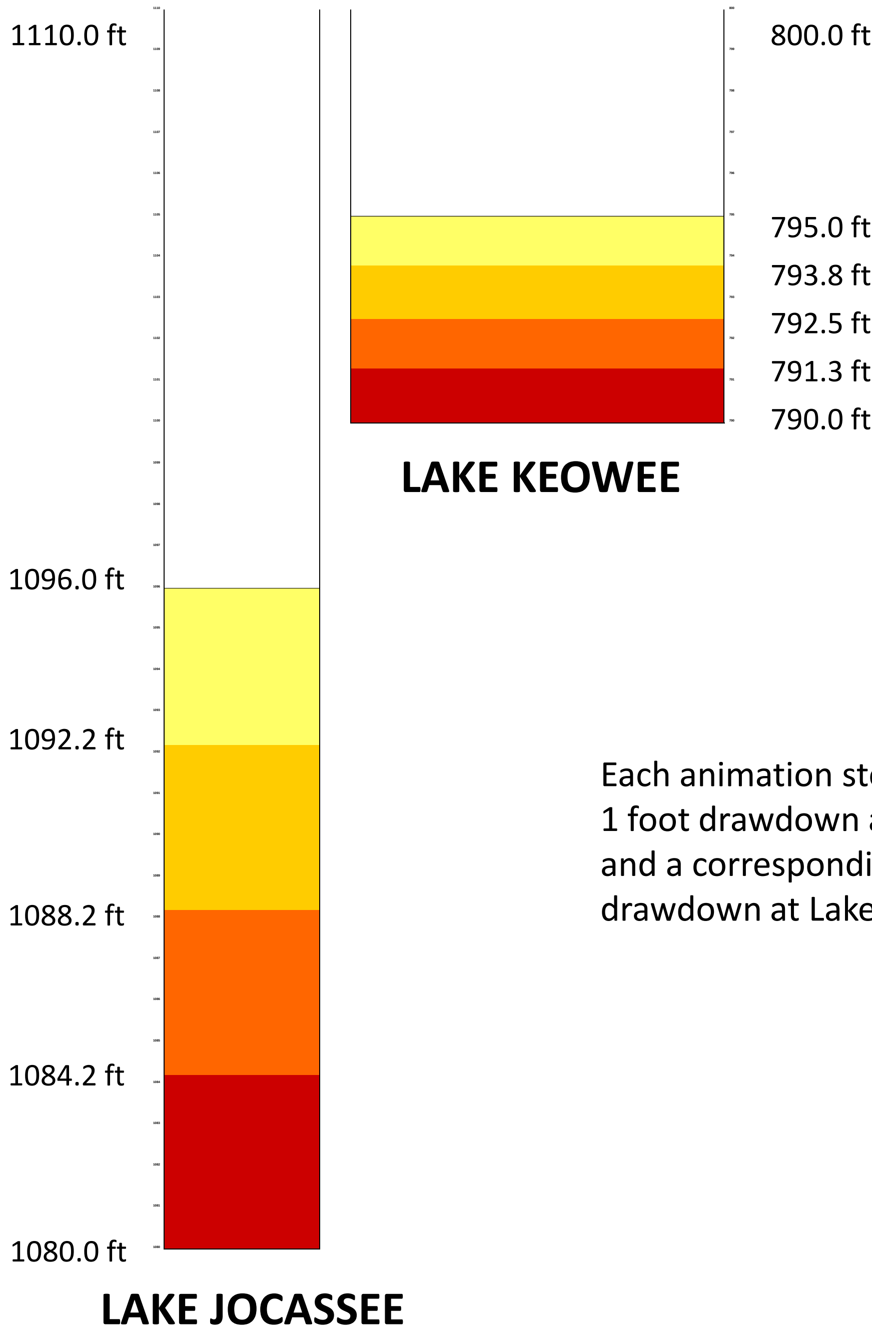


2-to-1 Drawdown Ratio



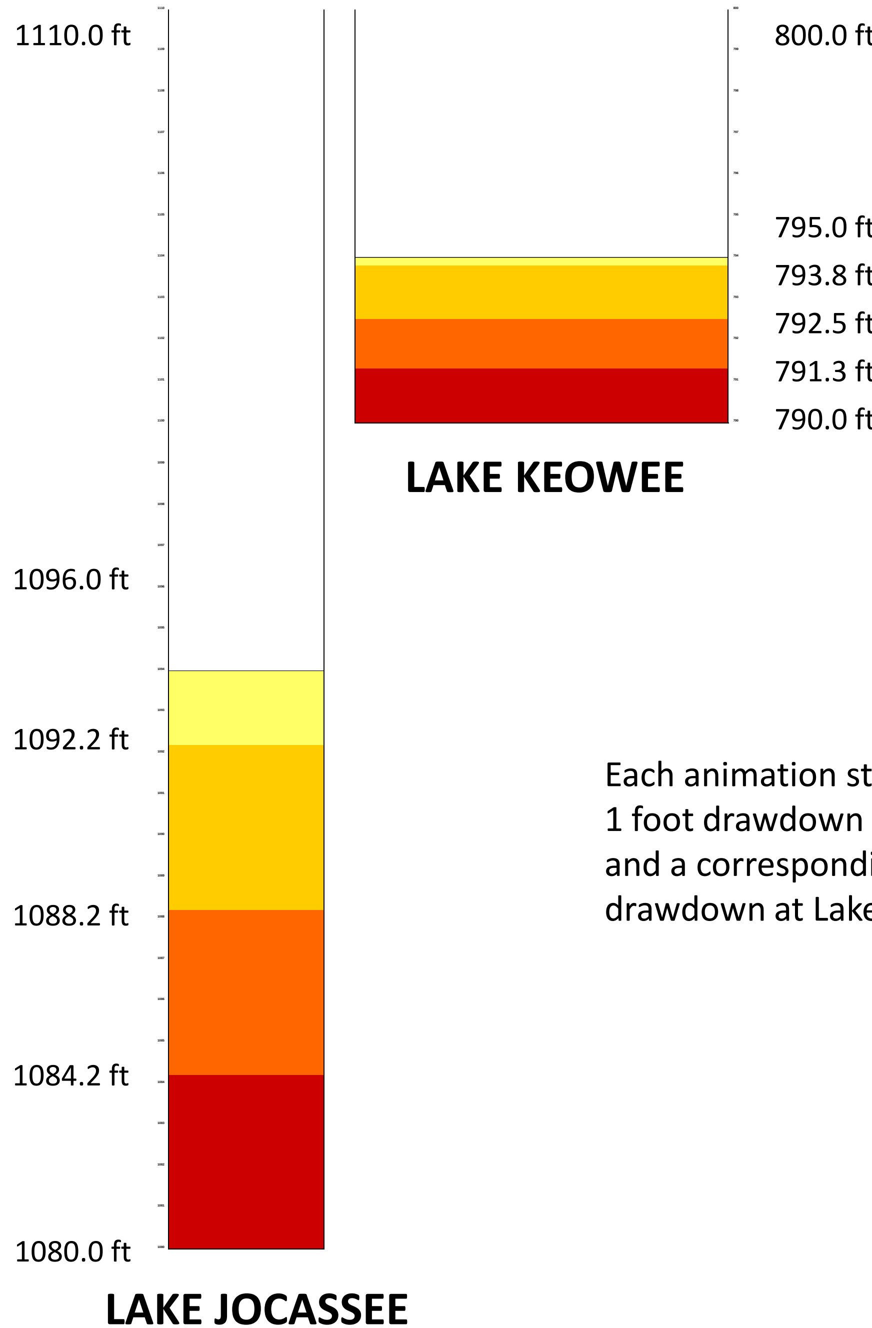
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



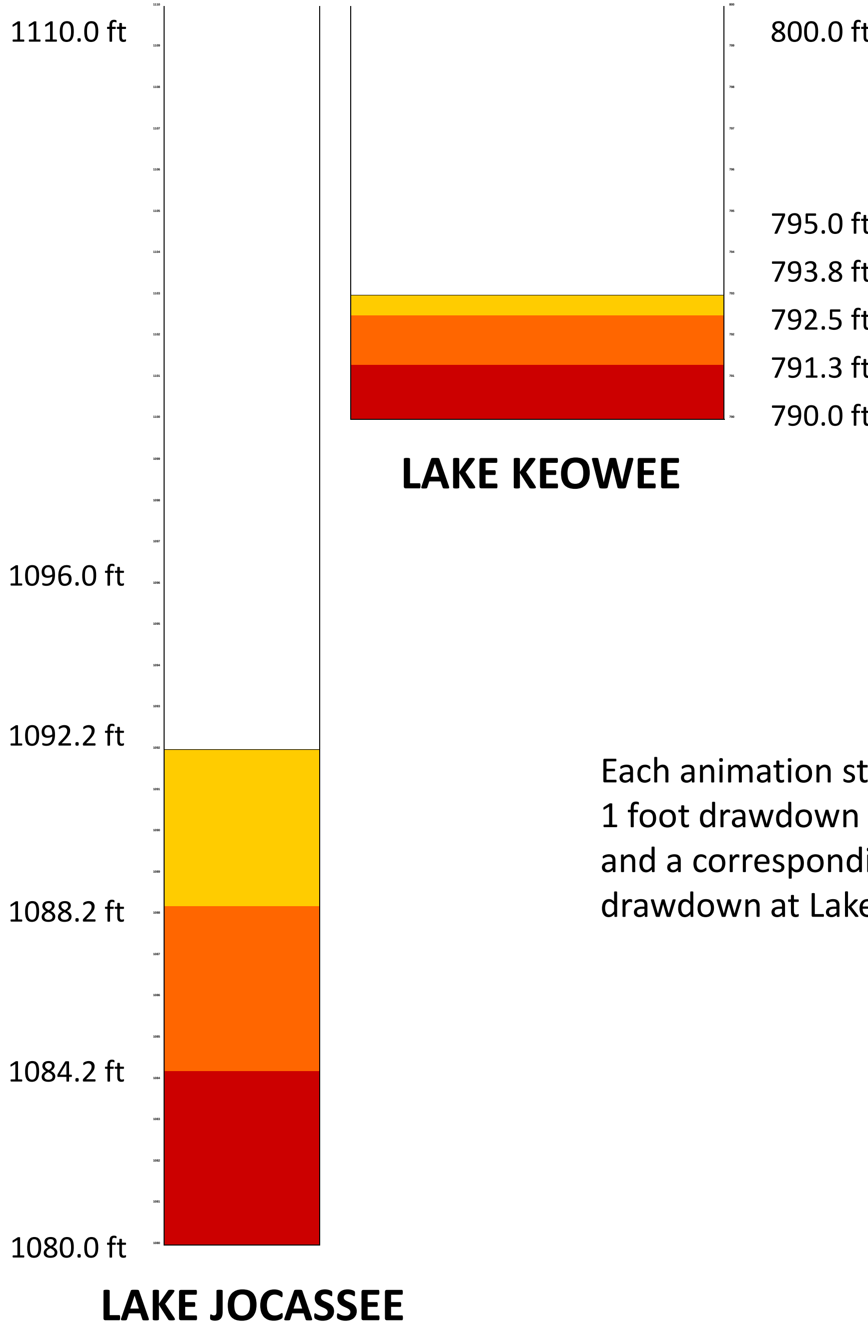
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



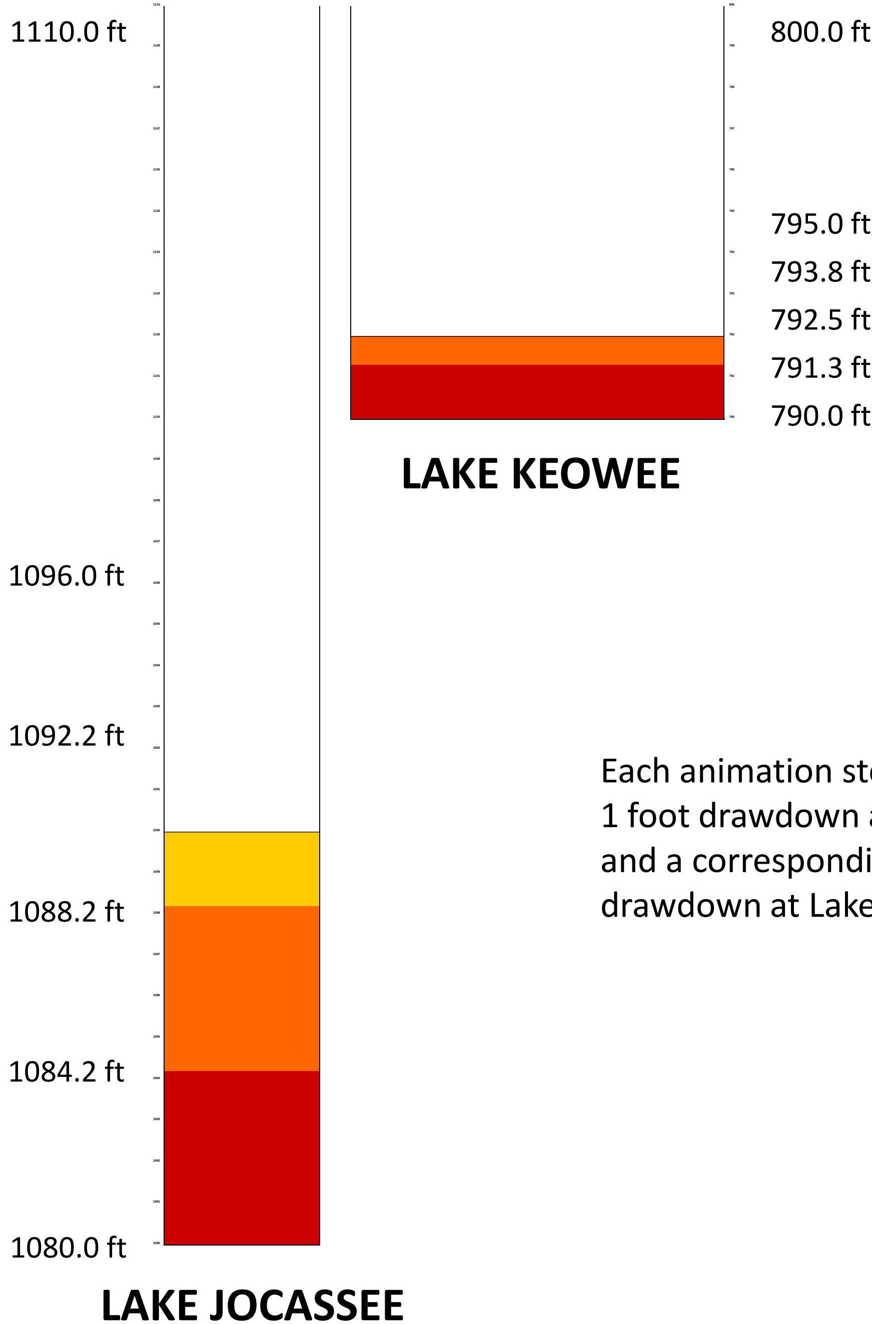
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



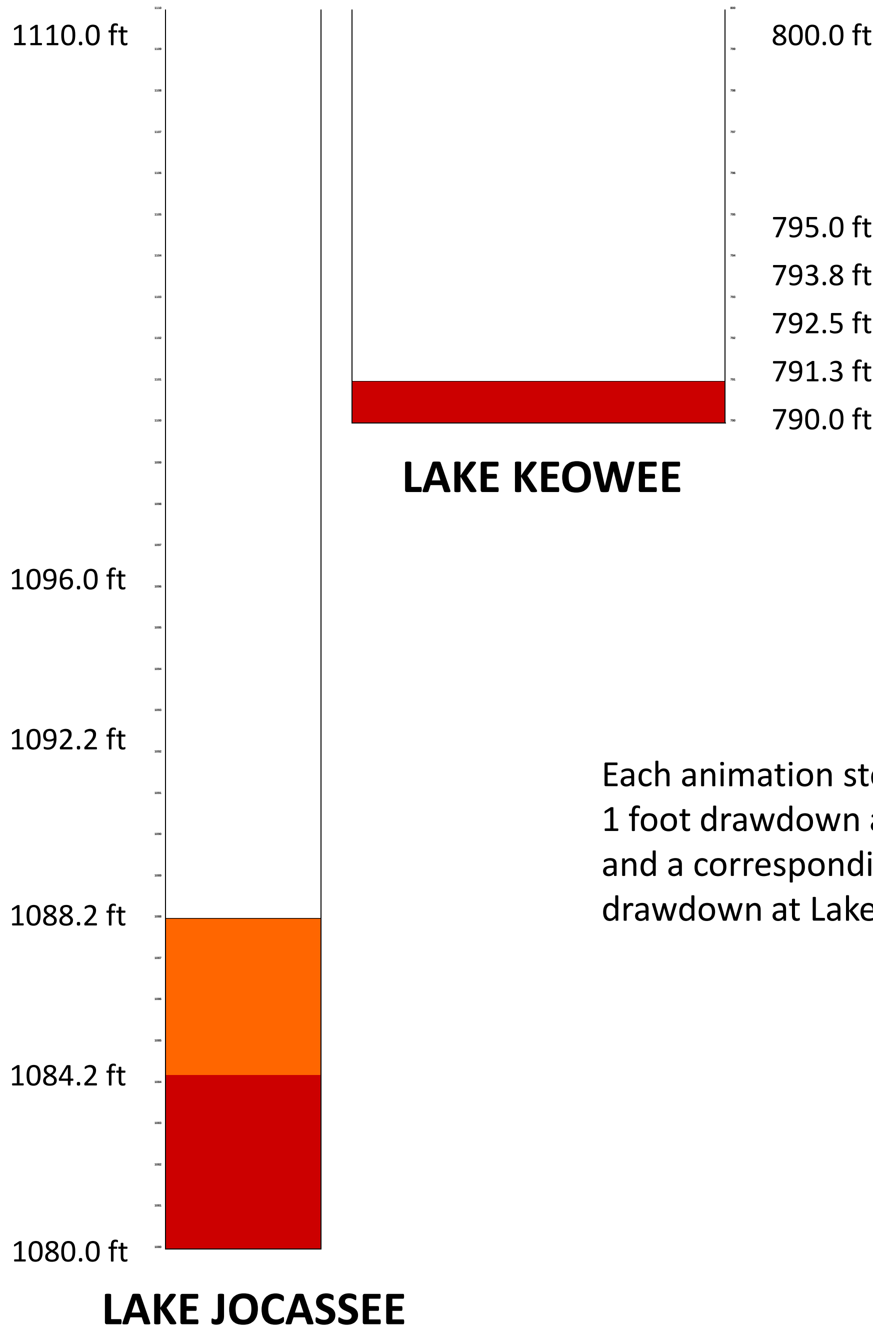
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



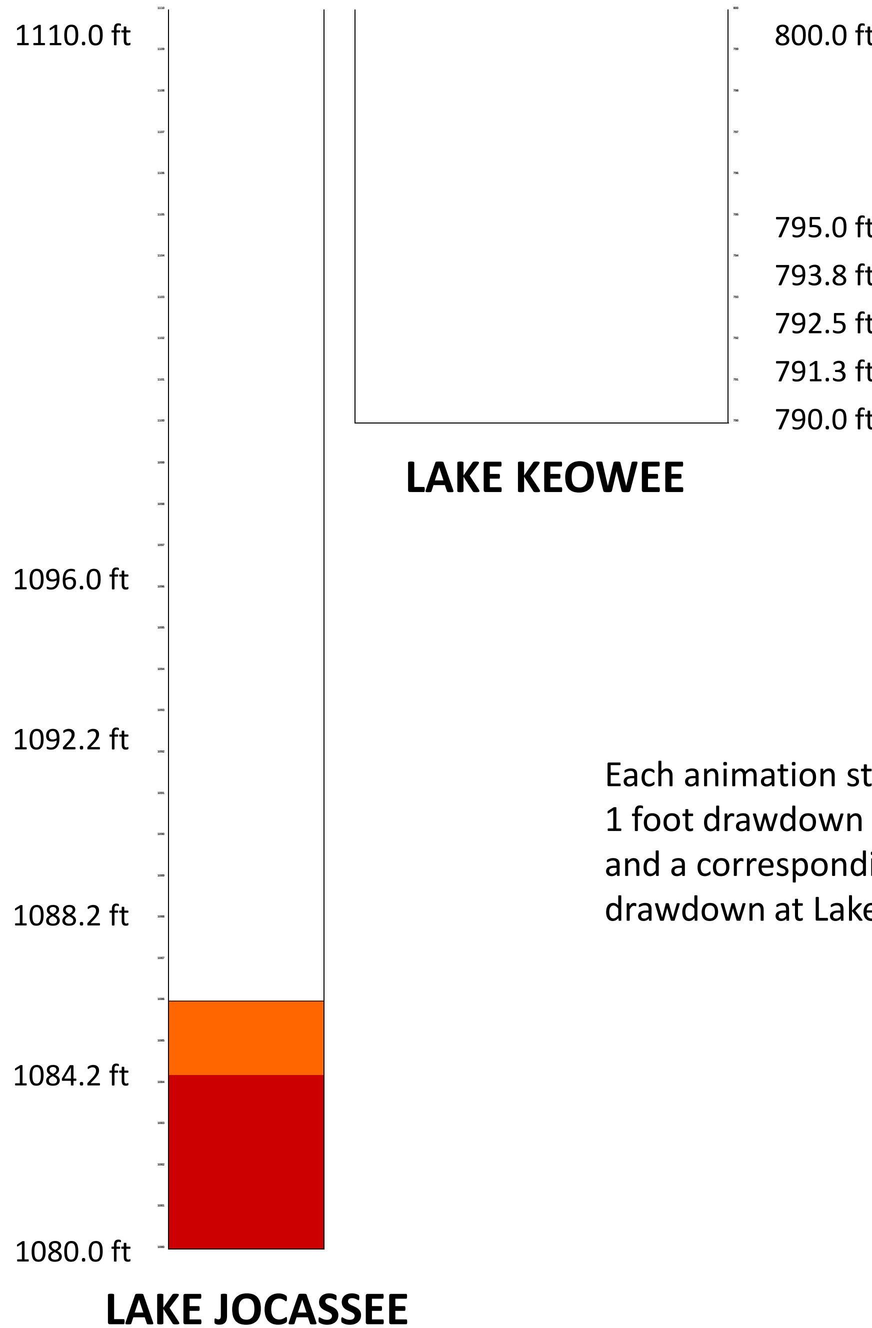
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



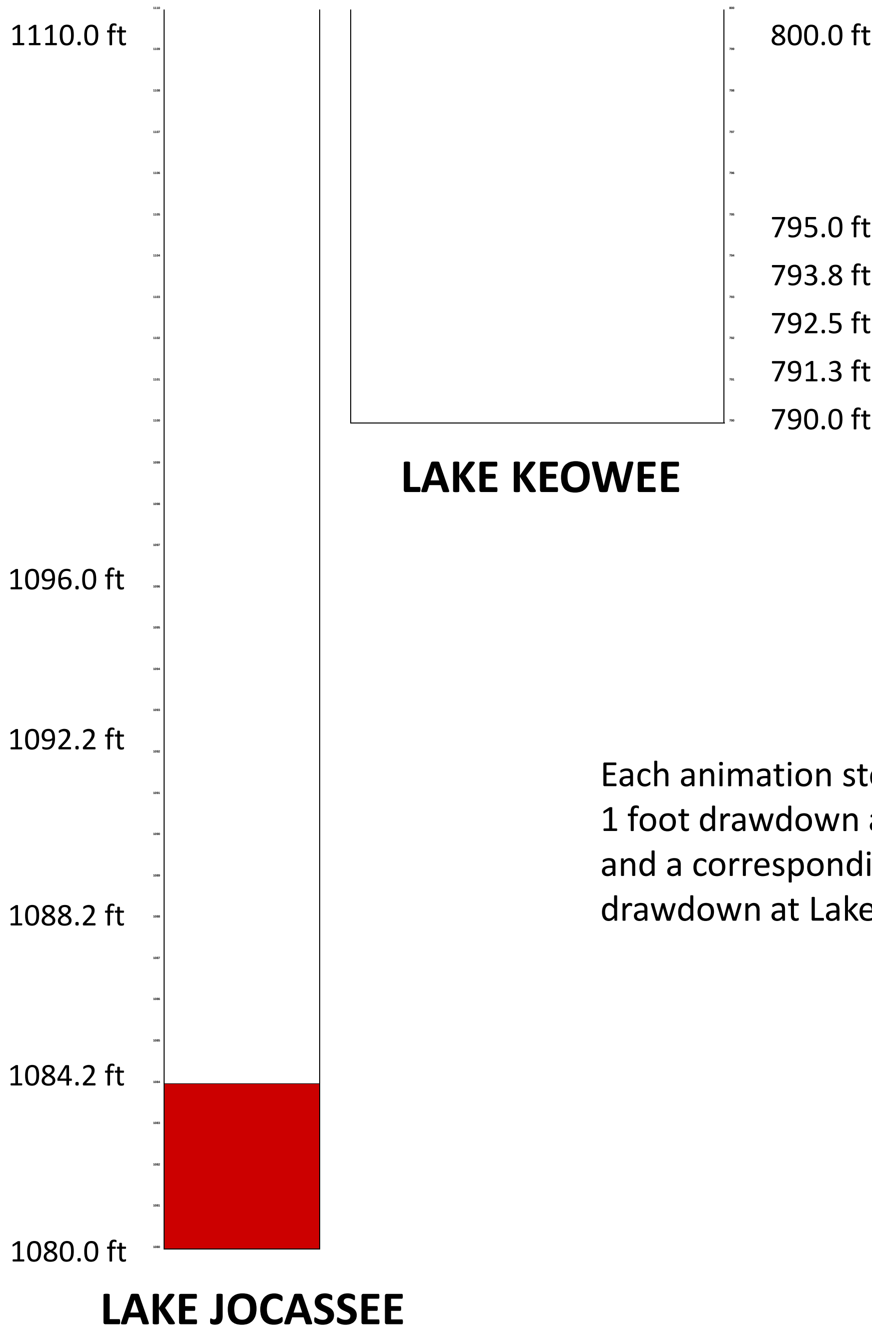
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



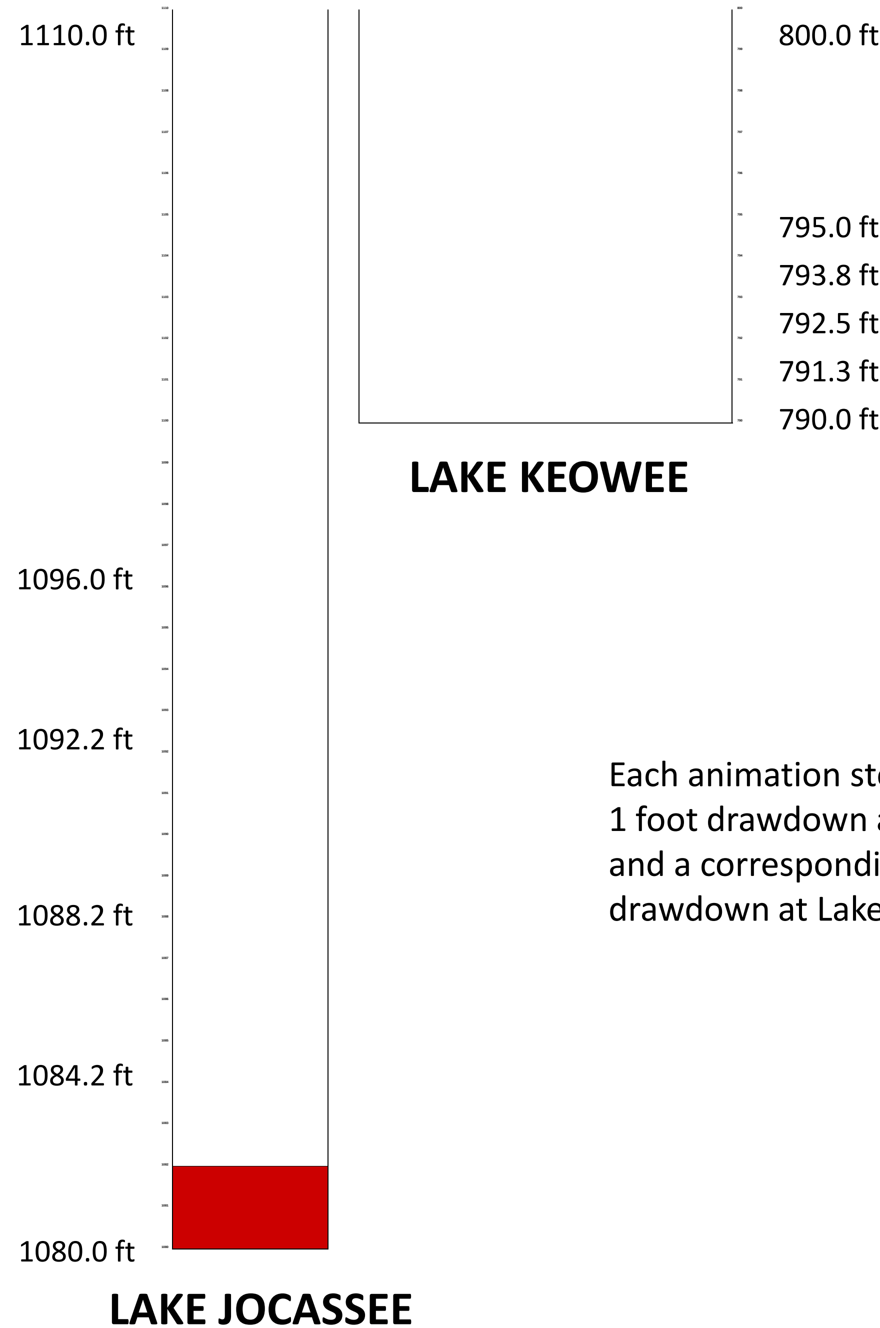
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



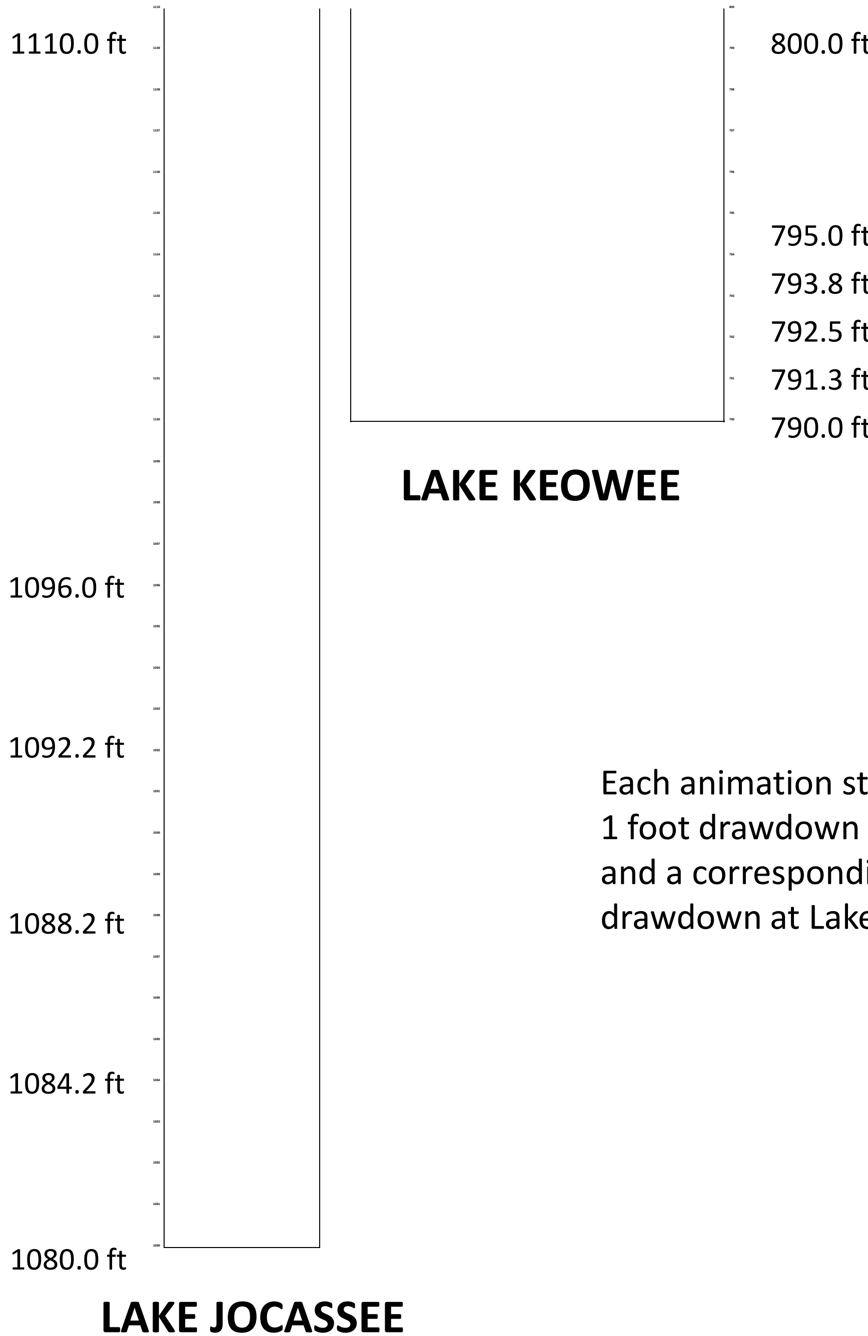
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



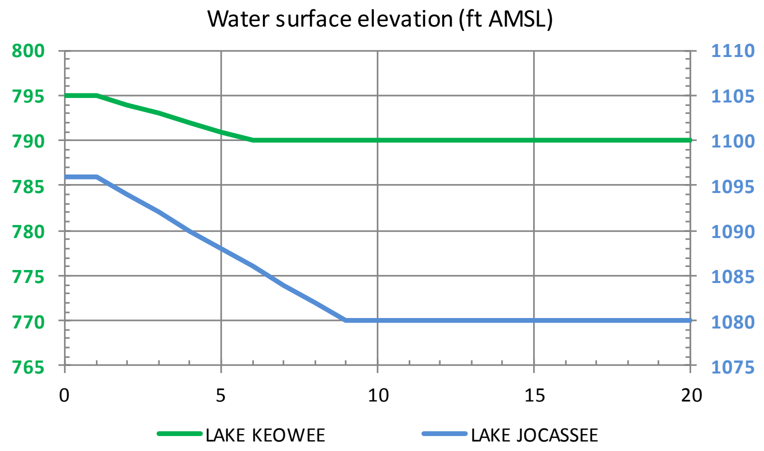
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

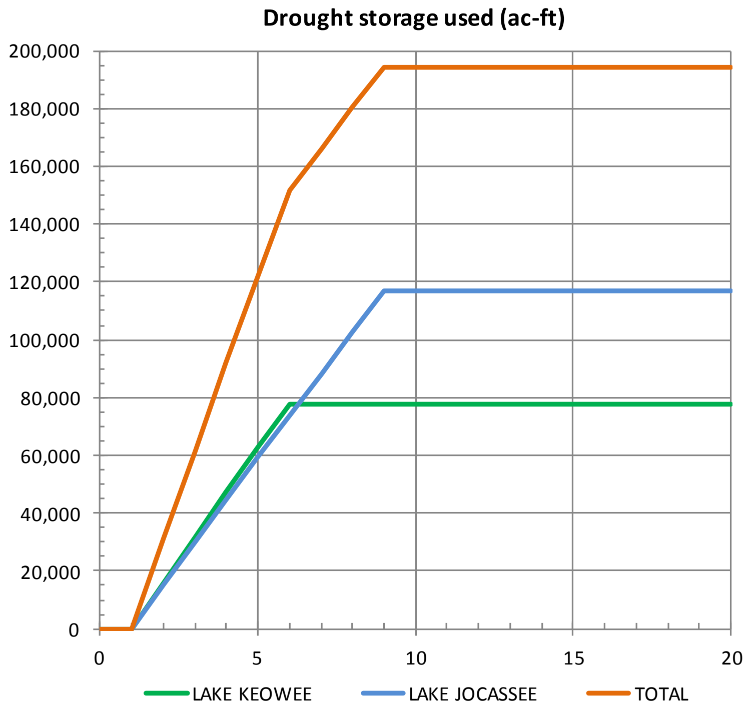
2-to-1 Drawdown Ratio



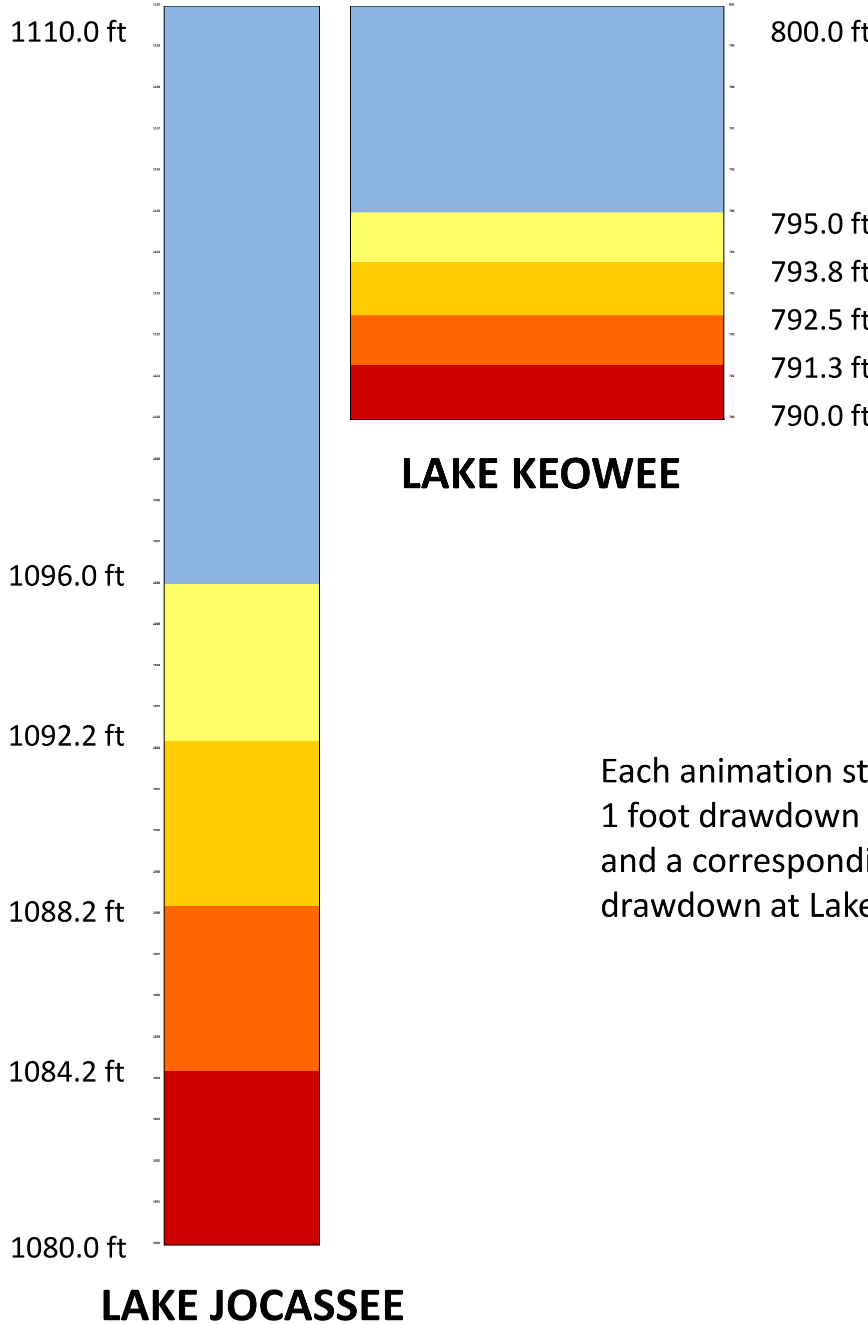
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 2 foot drawdown at Lake Jocassee.

2-to-1 Drawdown Ratio



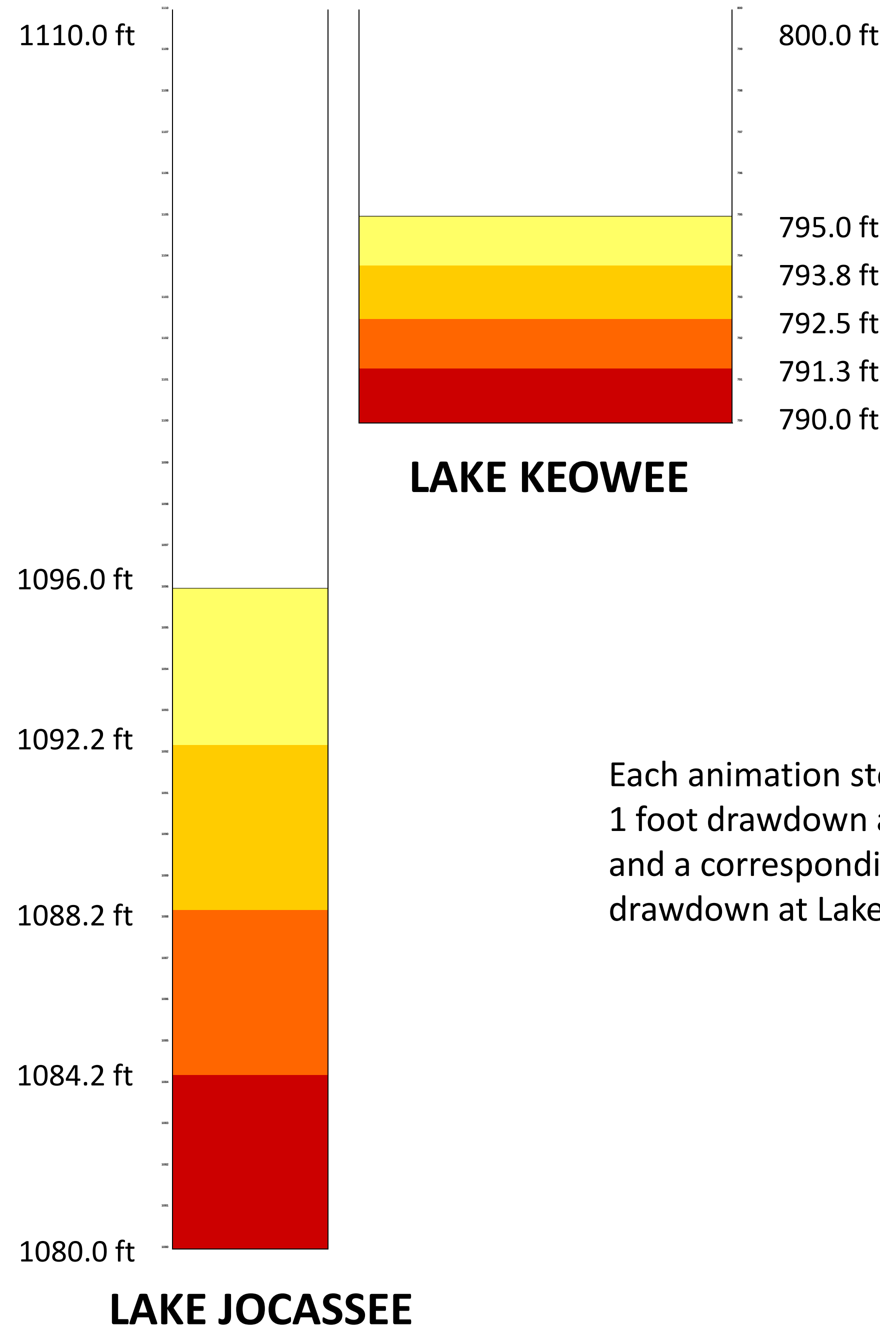


4-to-1 Drawdown Ratio



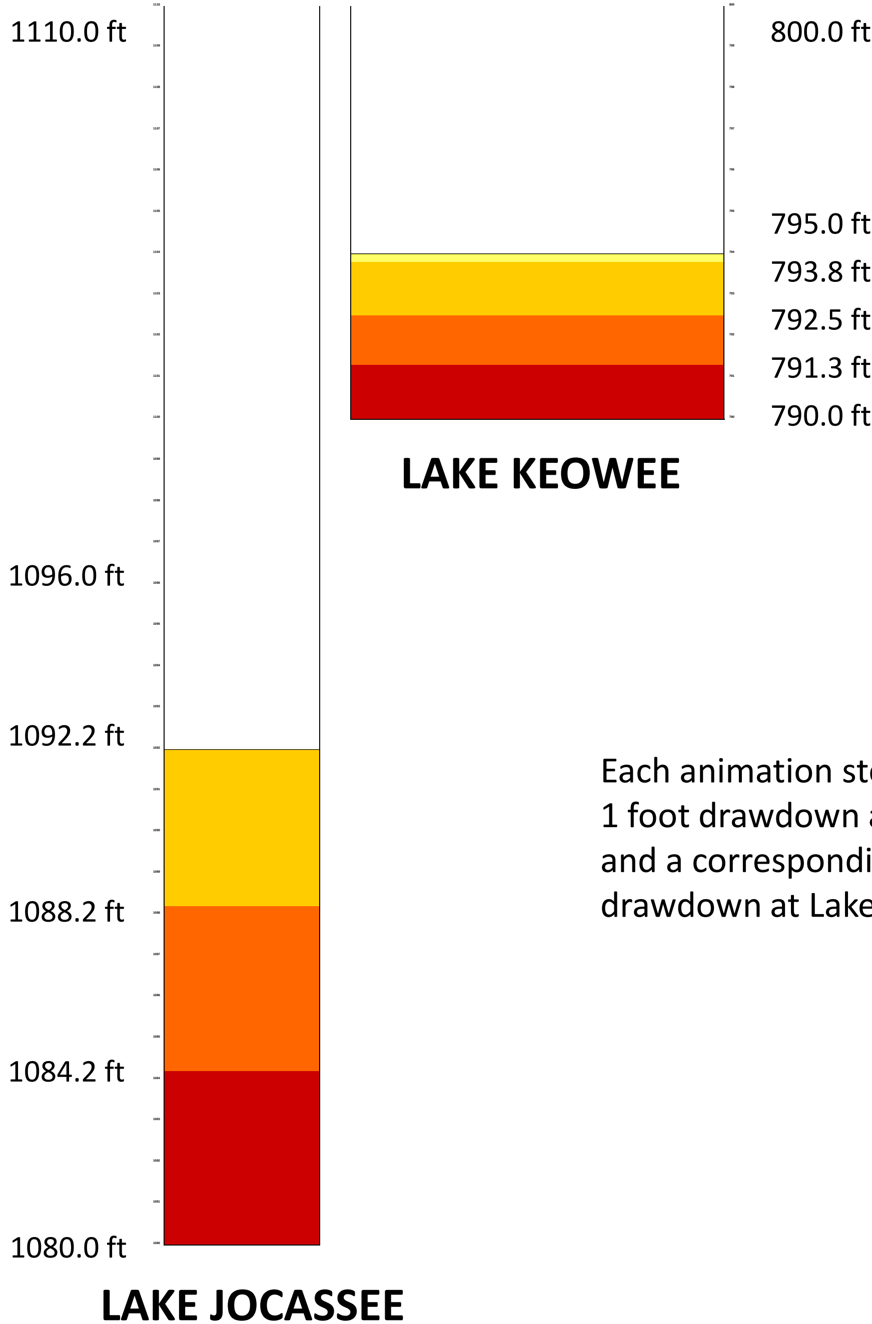
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.

4-to-1 Drawdown Ratio



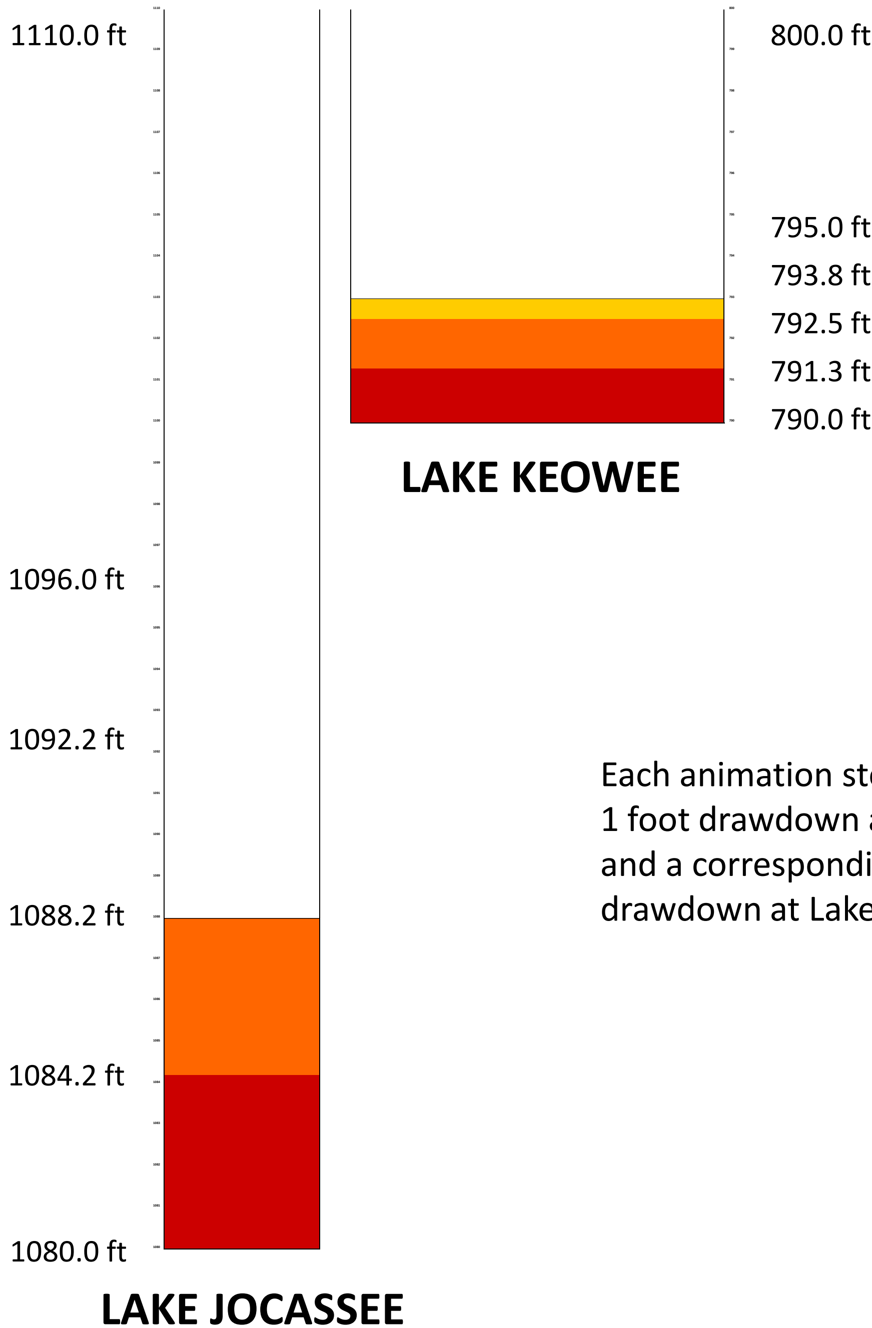
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.

4-to-1 Drawdown Ratio



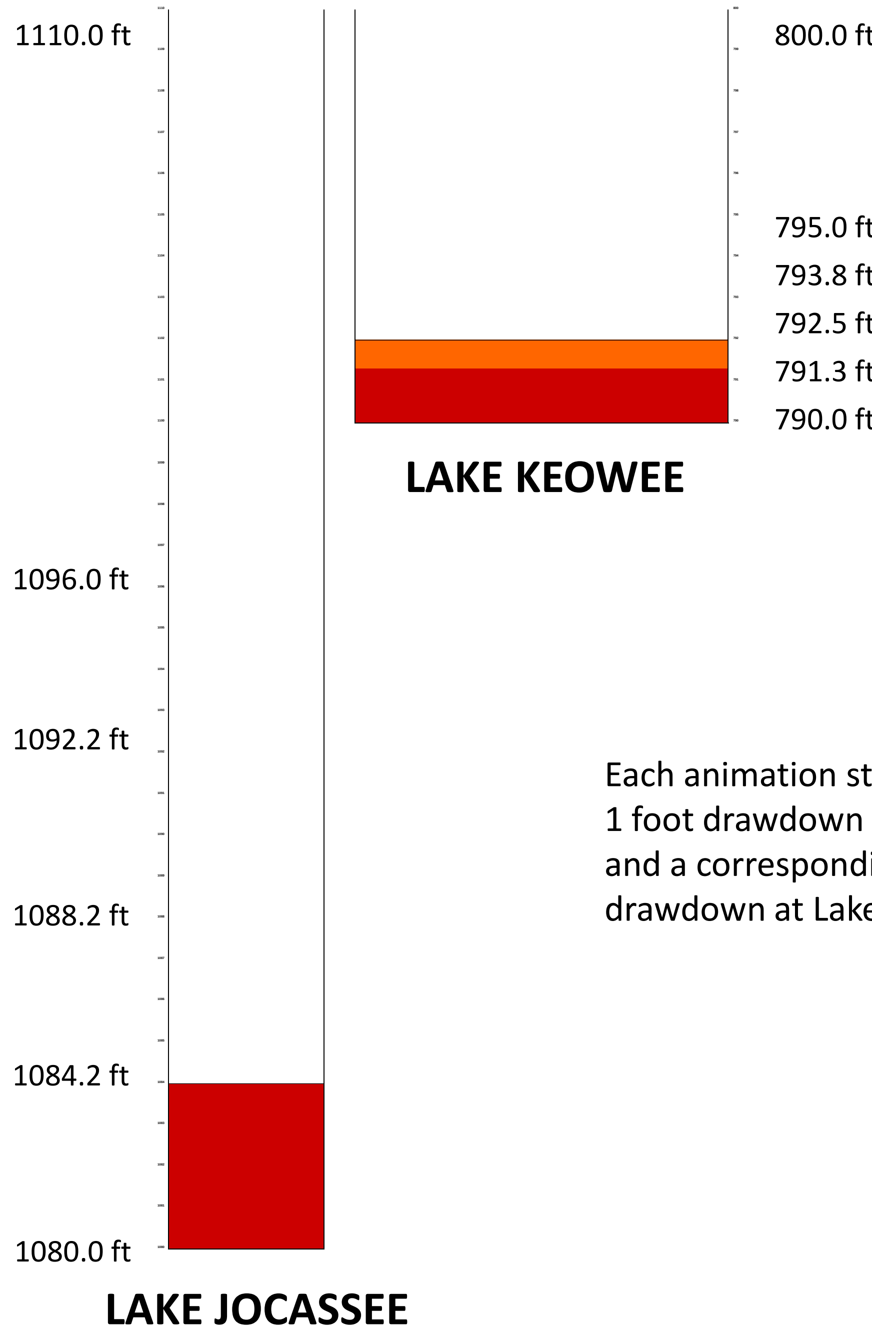
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.

4-to-1 Drawdown Ratio

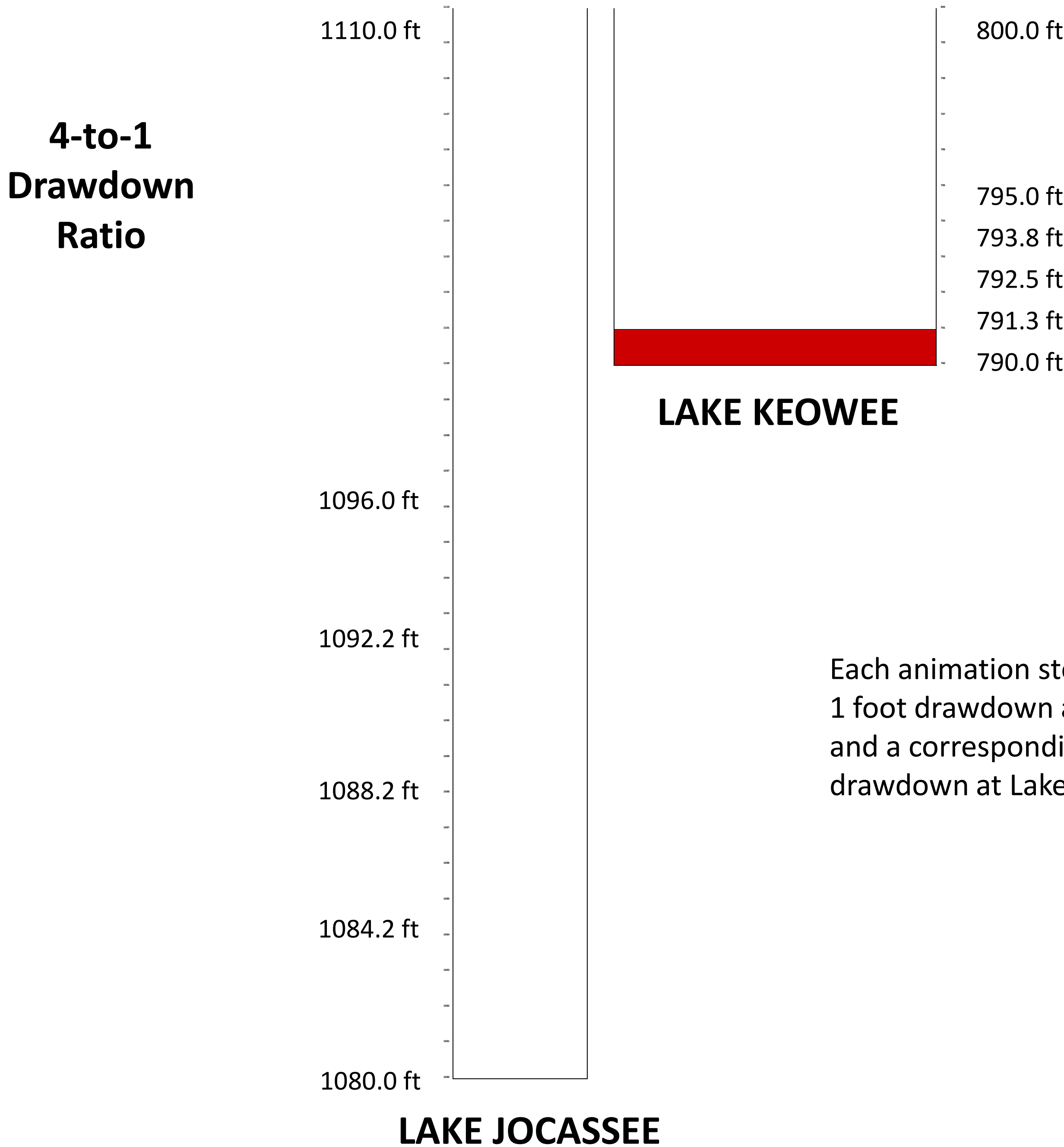


Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.

4-to-1 Drawdown Ratio

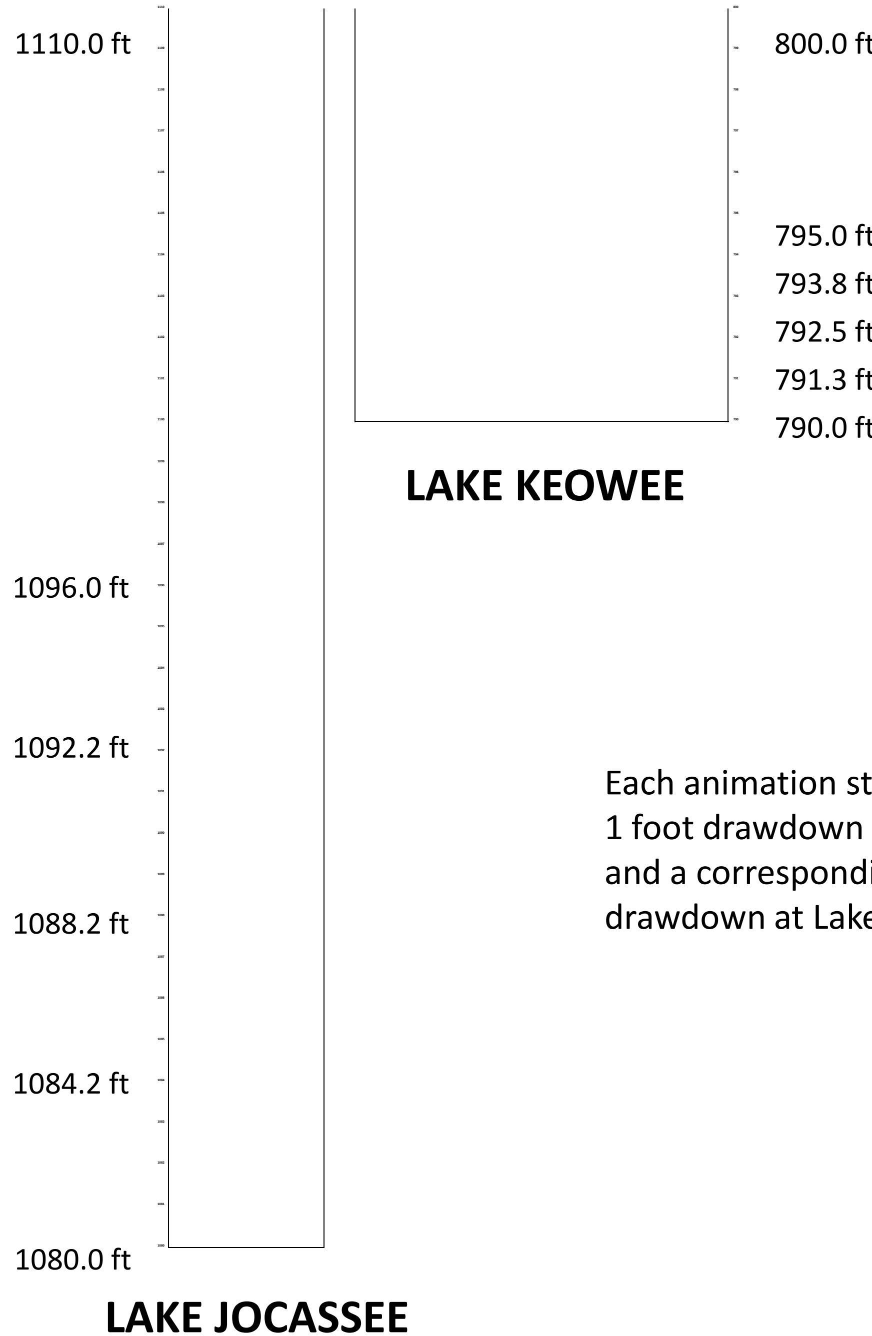


Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.



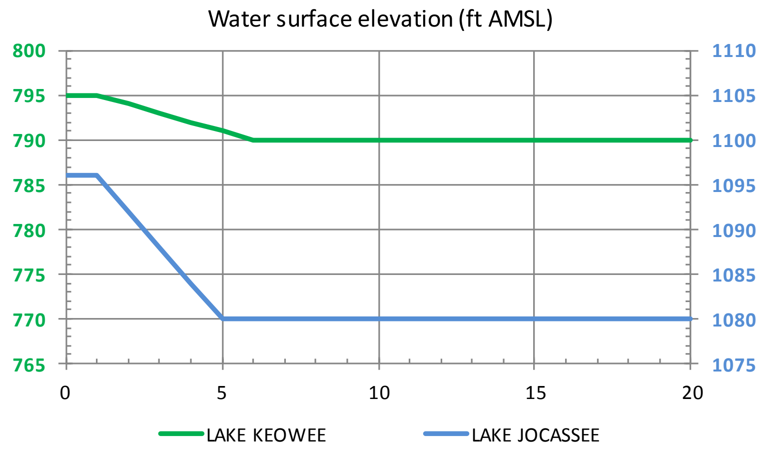
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.

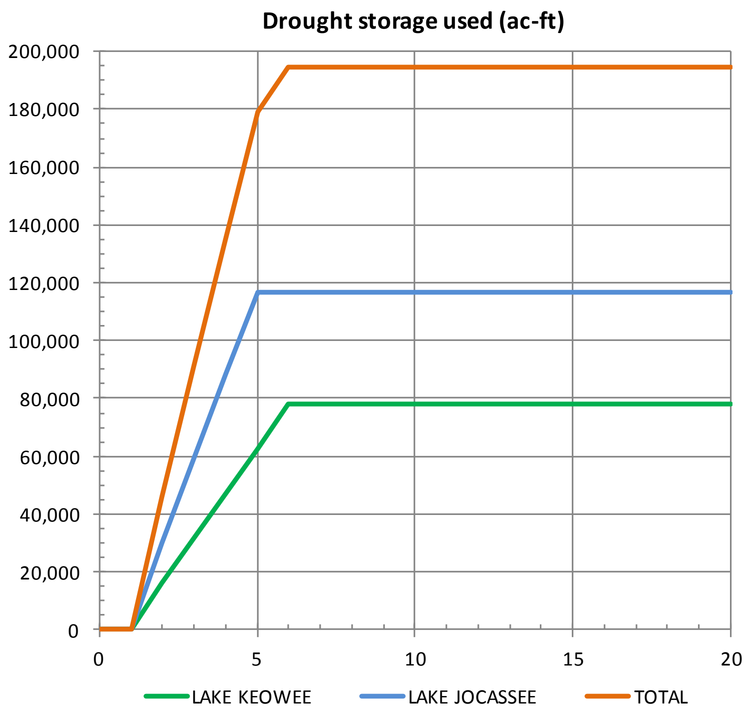
4-to-1 Drawdown Ratio



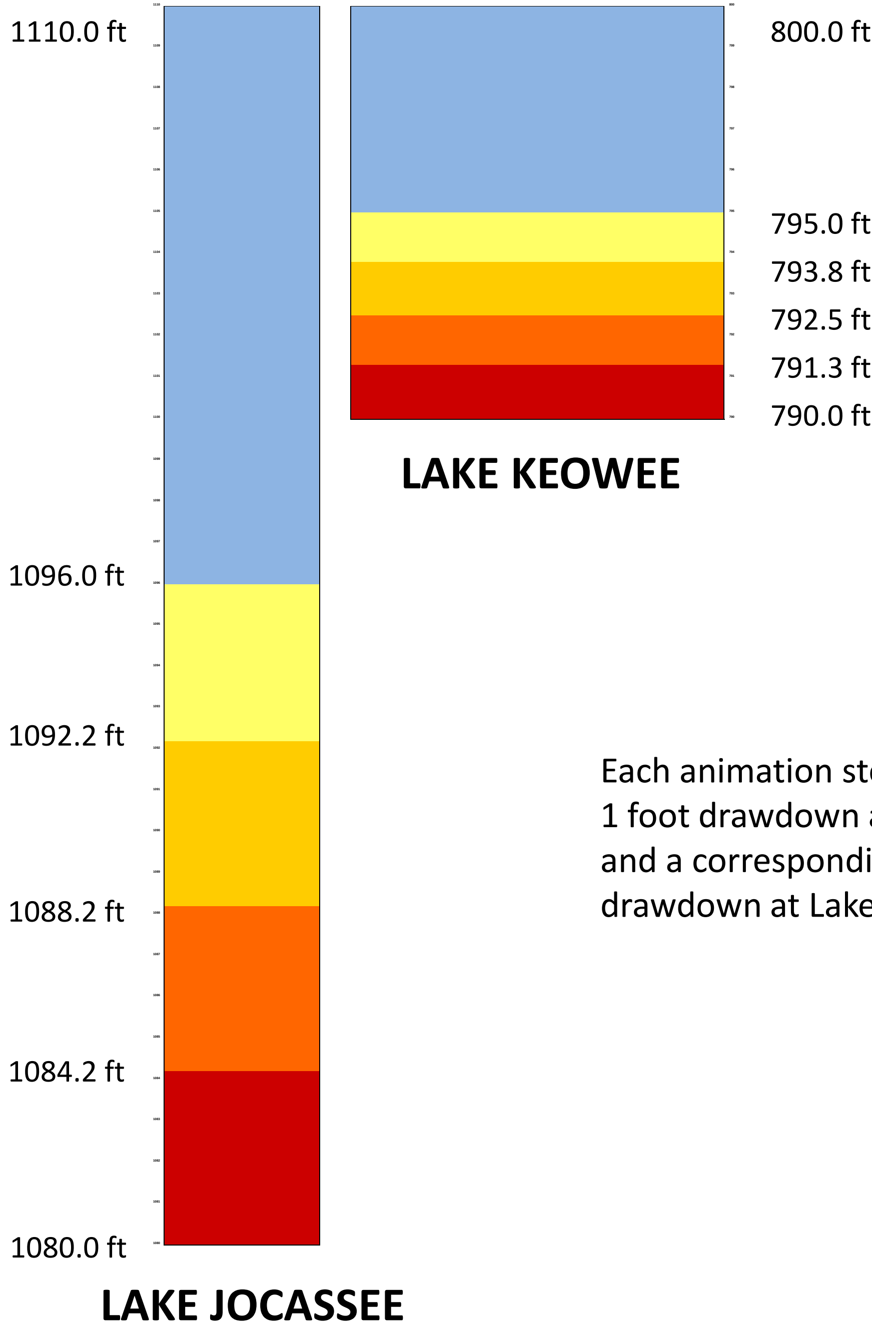
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 4 foot drawdown at Lake Jocassee.

4-to-1 Drawdown Ratio



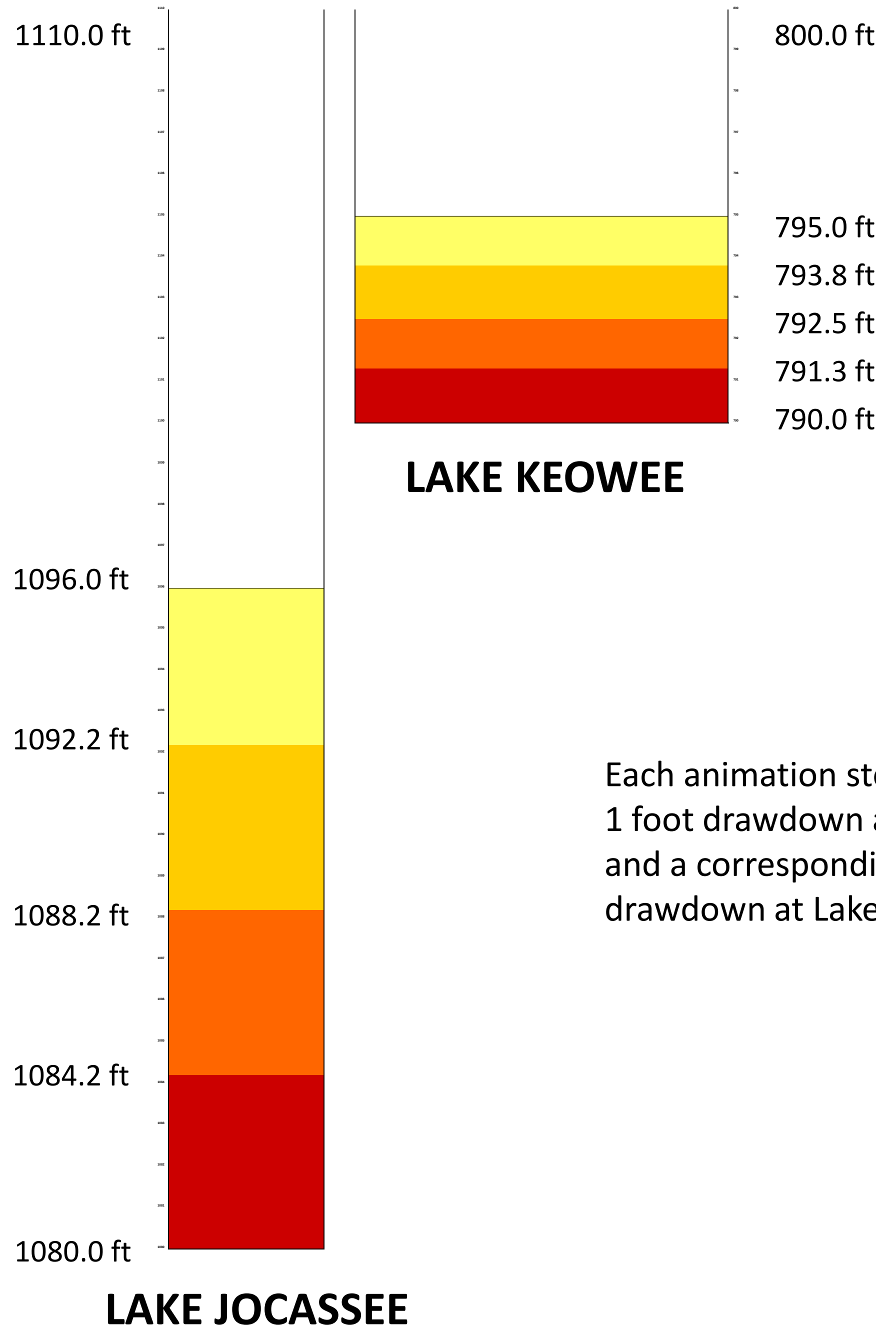


8-to-1 Drawdown Ratio



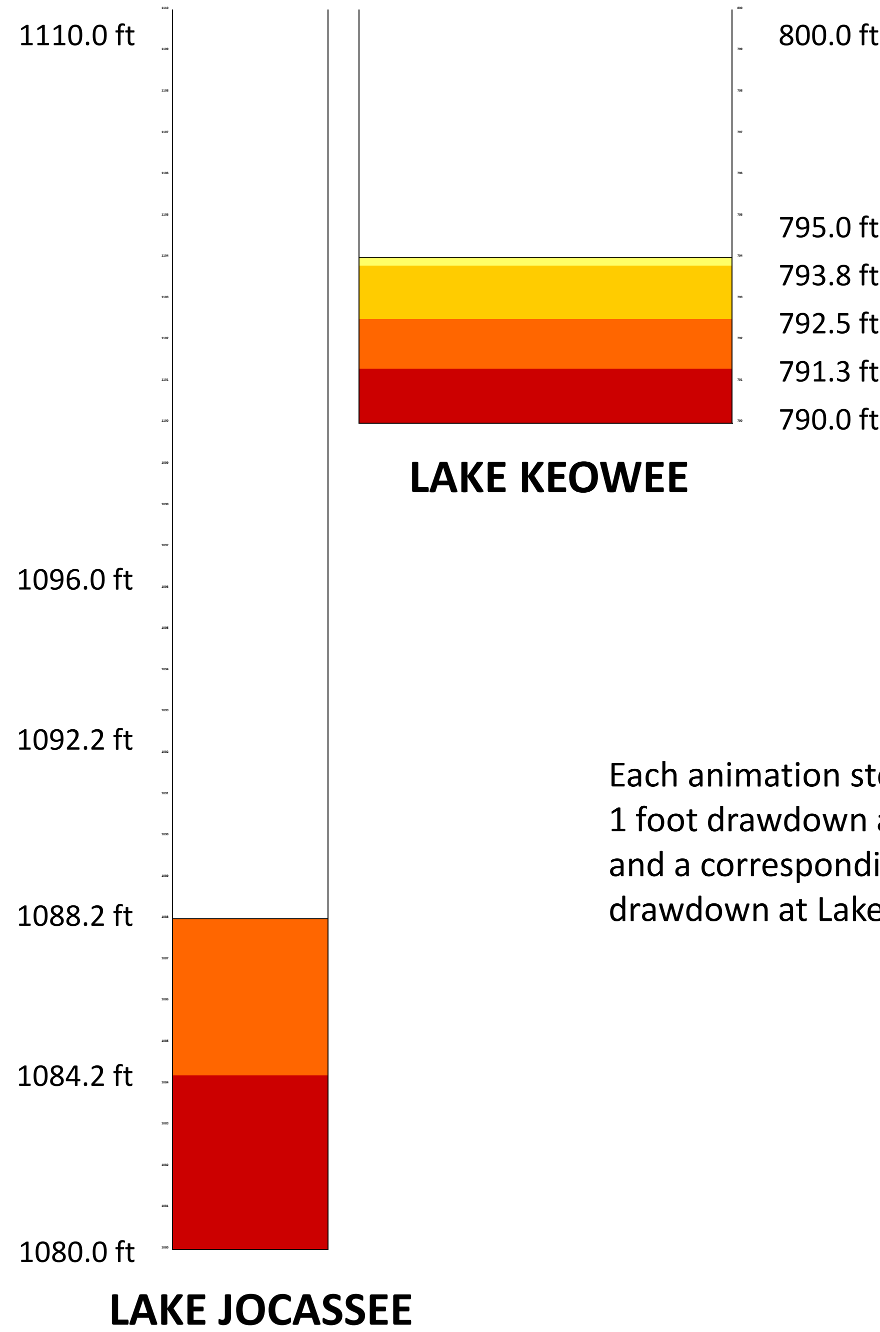
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

8-to-1 Drawdown Ratio



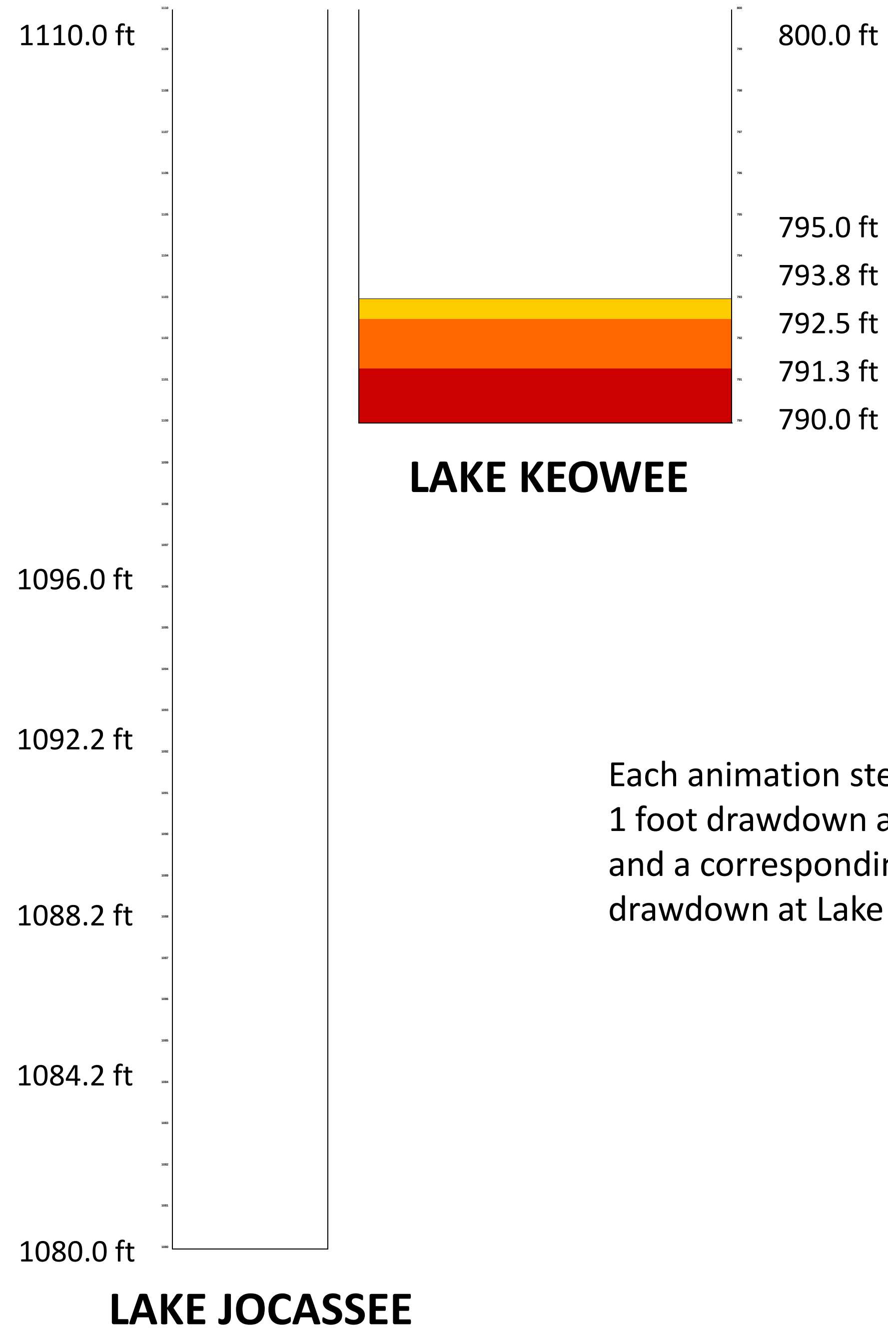
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

8-to-1 Drawdown Ratio



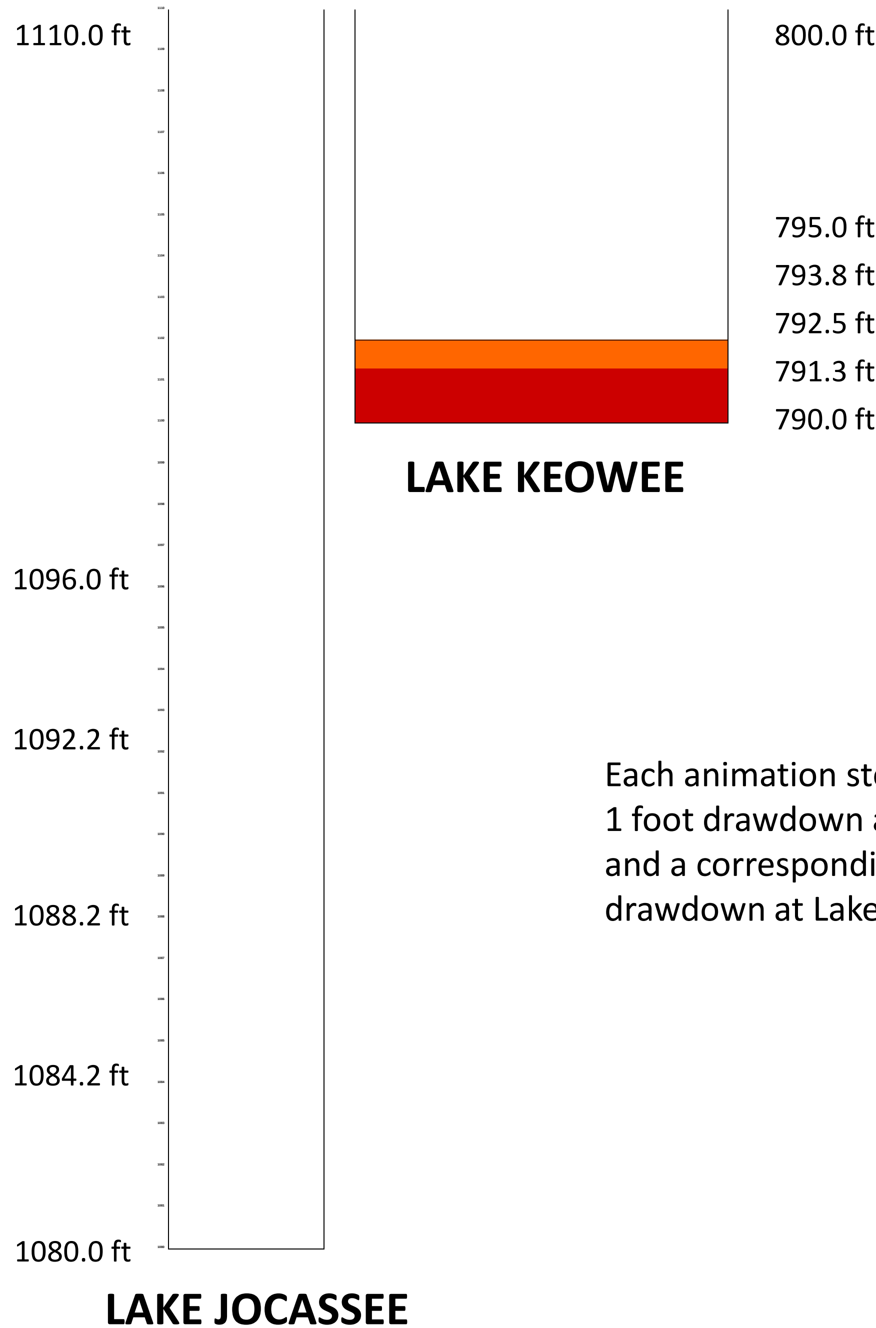
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

8-to-1 Drawdown Ratio



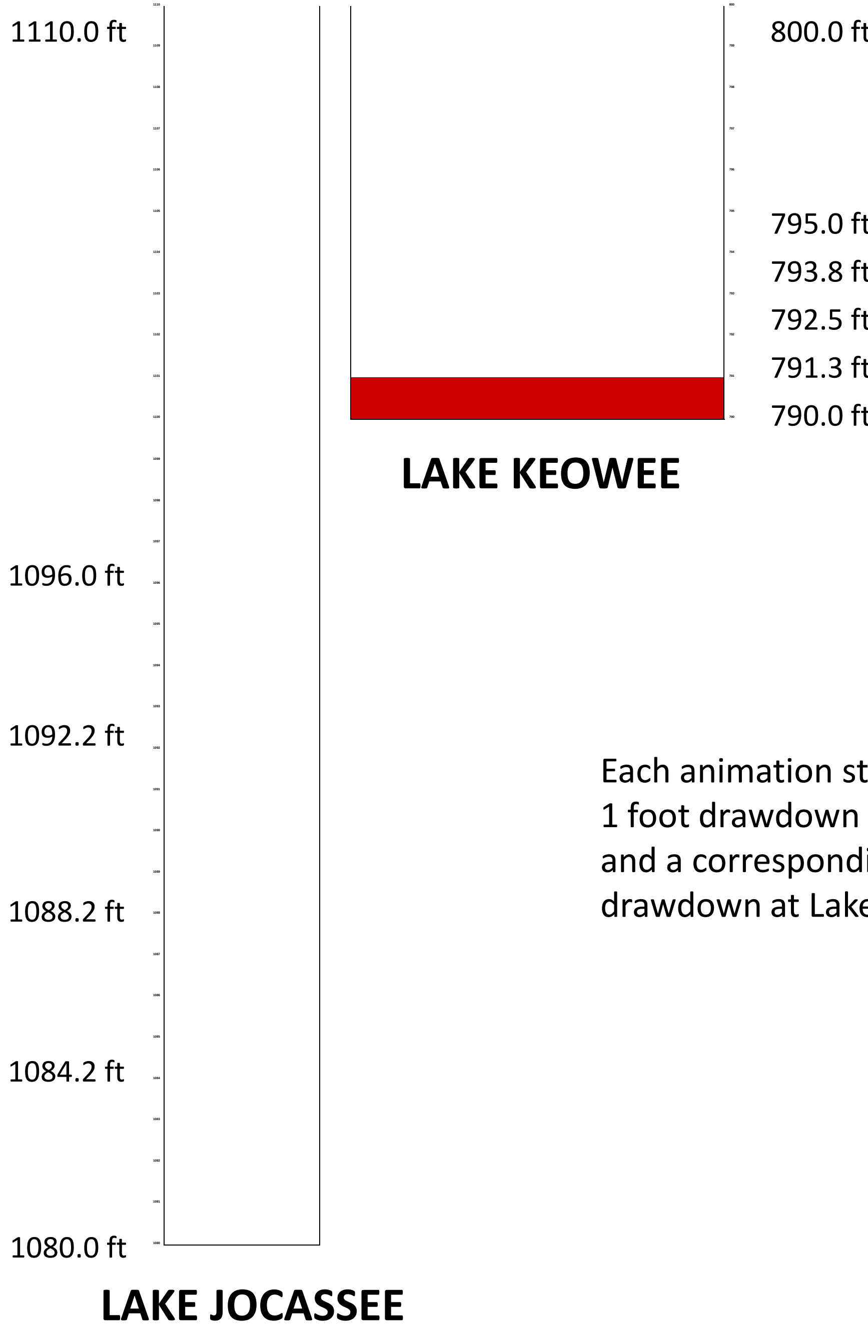
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

8-to-1 Drawdown Ratio



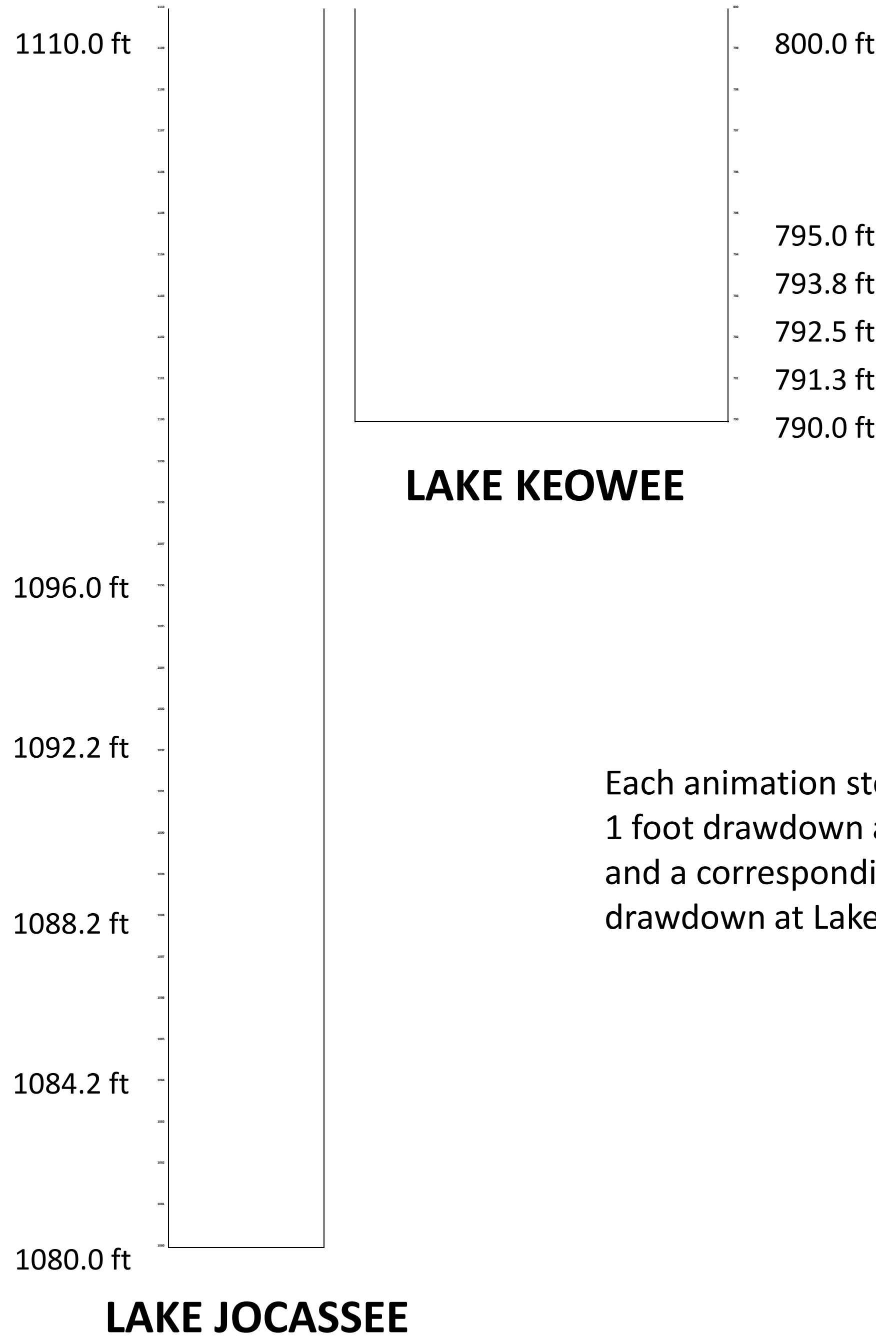
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

8-to-1 Drawdown Ratio



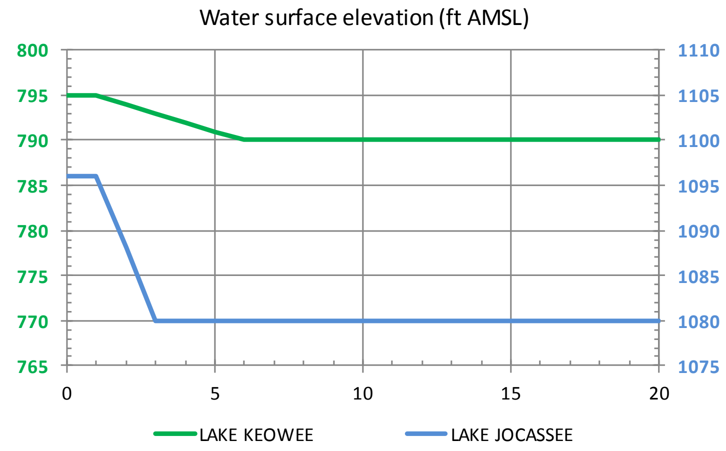
Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

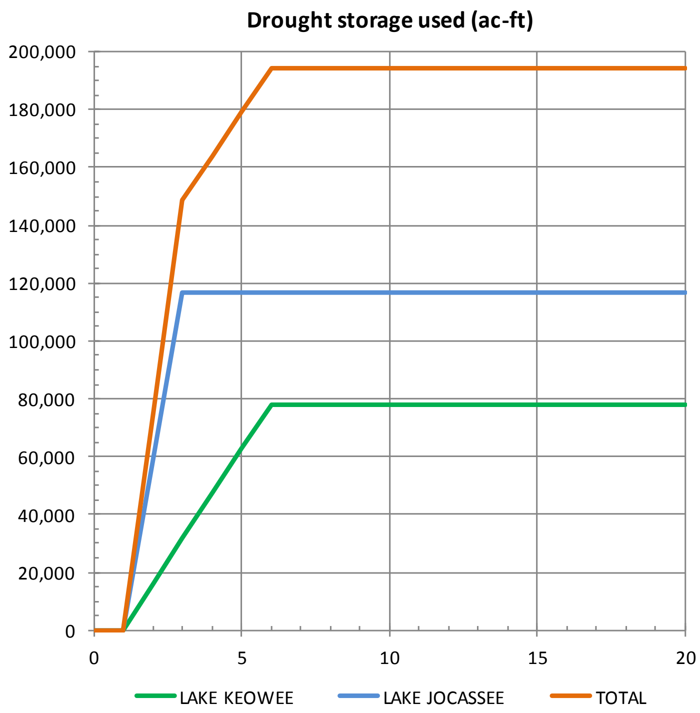
8-to-1 Drawdown Ratio



Each animation step represents a 1 foot drawdown at Lake Keowee and a corresponding 8 foot drawdown at Lake Jocassee.

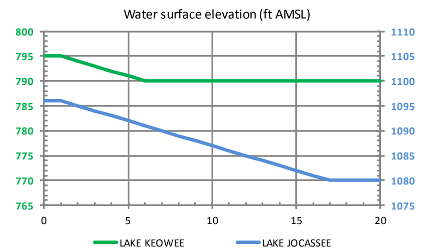
8-to-1 Drawdown Ratio

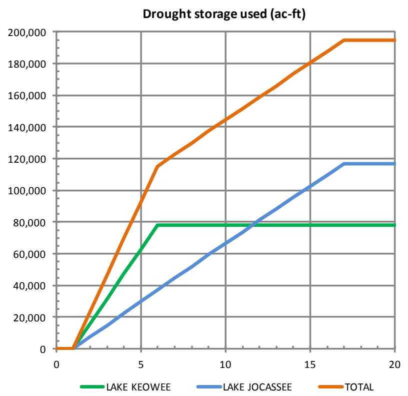




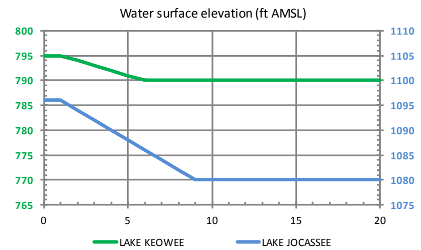
Summary of 790 ft maximum drawdown case with various drawdown ratios

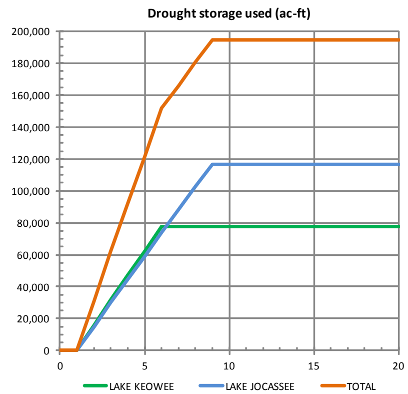
1-to-1



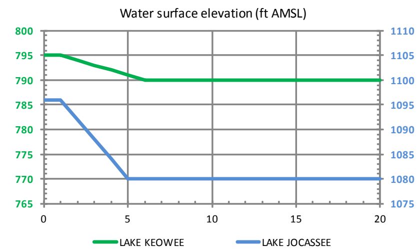


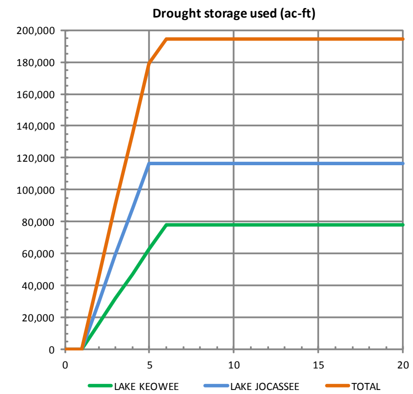
2-to-1



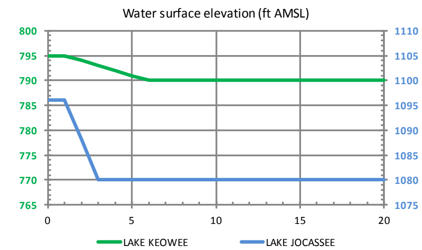


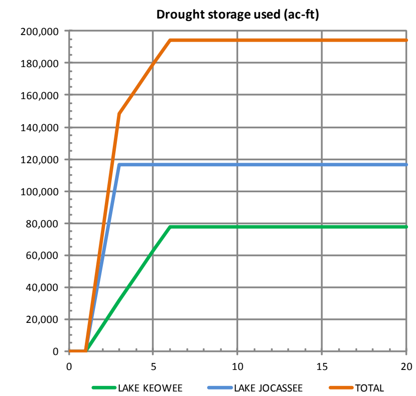
4-to-1





8-to-1





1-to-1	Quickest drawdown for Lake Keowee; Keowee's storage depleted 11 steps before Jocassee's
2-to-1	Similar storage use rates based on volume; Keowee's storage depleted 3 steps before Jocassee's
4-to-1	Similar storage use rates based on percent of drought storage ; Jocassee's storage depleted 1 step before Keowee's
8-to-1	Slowest drawdown for Lake Keowee; Jocassee's storage depleted 3 steps before Keowee's

Make your own combination...

Choose one from Column A and one from Column B.

Column A Lake Keowee drought storage volume available down to elevation (ft AMSL)	**Column B** Lake Jocassee to Lake Keowee drawdown ratio (ft:ft)
	1-to-1
792.0	
	2-to-1
790.0	
	4-to-1
788.0	
	8-to-1

There are many more than these 12 combinations when other drought storage volumes and drawdown ratios are considered.

DISCUSSION

Keowee -Toxaway Hydro Relicensing

(FERC Project No. 2503)

MEETING OF RESERVOIR LEVEL AND PROJECT FLOW RELEASES STUDY TEAM

Thursday July 26, 2012

10:00 AM – 12 Noon

Wenwood Operations Center

Greenville, SC

Summary of Meeting

Meeting Participants

Ed Bruce	Duke Energy	Jennifer Huff	Duke Energy
Bob Faires	Seneca Light & Water	George McMahon	Arcadis
Phil Fragapane	Duke Energy	KC Price	Greenville Water
Steve Gaffney	HDR	Heather Rizzuti (Phone)	SCDHEC
Tamela Hammond	Duke Energy	Chris Starker	Upstate Forever
Scott Harder	SCDNR	Bob Swank	FOLKS

Introduction, Agenda Review and Study Schedule

Phil Fragapane began meeting with greetings, introductions, review of the agenda and a review of the schedule for the study. He informed the Study Team the study is progressing slightly ahead of the schedule identified in the study plan.

Review and Approval of Minutes of April 17, 2012 Study Team Meeting

Minutes of the April 17, 2012 meeting were reviewed. There were no comments and the minutes were approved.

Presentation of Revised Draft of Study Report

Steve Gaffney presented the revised draft of the study report. Revisions and additions to the previous version of the document were highlighted.

No specific changes to the document were suggested during the meeting.

Bob Swank offered to publish portions of the final study report in *The Sentinel* newsletter to help raise public awareness of how the lakes are operated.

It was announced comments on the revised draft are due by August 9, 2012.

Discussion of Conceptual Operating Approaches During Droughts

Phil Fragapane stated the Study Team has now addressed all of the objectives in the study plan except identifying potential operating level bands for Lake Keowee during droughts and how Lake Keowee and Lake Jocassee would be lowered during droughts. He said it will only be possible to address this objective conceptually because the lower operating limit of Lake Keowee to sustain safe operation of the Oconee Nuclear Station, expected to be between 788 ft and 794.6 ft, has not yet been identified.

Steve Gaffney reviewed the physical descriptions of Lake Jocassee and Lake Keowee pointing out the large difference in surface areas and storage volume versus depth. He then presented a series of animated slides showing conceptually how the lakes might be drawn down during a severe drought by assuming that both lakes begin the drought at the Study recommended Normal Minimum Elevations of 795 ft for Lake Keowee and 1096 ft for Lake Jocassee. For the purposes of the animations, a lower operating limit of 790 ft for Lake Keowee was assumed. Scenarios were depicted for four drawdown ratios: a 1-foot drawdown in Lake Jocassee for every 1-foot drawdown in Lake Keowee, a 2-foot drawdown in Lake Jocassee for every 1-foot drawdown in Lake Keowee, a 4-foot drawdown in Lake Jocassee for every 1-foot drawdown in Lake Keowee, and an 8-foot drawdown in Lake Jocassee for every 1-foot drawdown in Lake Keowee. Summary charts were presented showing that, if both reservoirs were drawn down at the same volumetric rate, Keowee would reach its 790 ft drawdown limit before Jocassee would reach its 1080 ft drawdown limit, and the drawdown ratio would be just over 2:1. If both reservoirs were to be drawn down to their maximum limits (1080 ft and 790 ft) at the same time, the drawdown ratio would be something less than 4:1 – possibly around 3.5:1.

Chris Starker asked why 790 ft was chosen for the theoretical drawdown limit for Lake Keowee instead of 788 ft. Steve answered the choice of 790 was arbitrarily chosen as it was in between the lowest and highest possible lower elevations.

Bob Swank stated he tentatively thought that somewhere between a 2:1 and 5:1 ratio of Lake Jocassee drawdown to Lake Keowee drawdown might seem reasonable.

DRAFT

Scott Harder stated that he thought the 2:1 and 4:1 scenarios seemed more reasonable than the other two scenarios, but it will be important to first identify the minimum operating elevation of Lake Keowee.

Chris Starker said it's important to consider the impacts of lake drawdowns and that it might make sense to consider varying the drawdown ratio at different levels of drought severity.

George McMahon said in general it is better to hold storage upstream during drought. **Ed Bruce** pointed out the Project is not a typical case since it involves pumped-storage operations with the ability to pump water upstream.

George McMahon suggested considering inflow as an additional "check" on balancing storage between reservoirs.

Next Steps

- The Study Team will provide any written comments on the revised draft of the study report by August 9, 2012.
- Comments will be addressed and the Final Draft Study Report will be provided to the Study Team for review with a target date of September 9, 2012.
- The Study Team will provide comments on the Final Draft Study Report with a target date of October 9, 2012.

DRAFT

Fragapane, Phil

From: Chris Starker [cstarker@upstateforever.org]
Sent: Thursday, August 09, 2012 4:20 PM
To: Fragapane, Phil
Cc: Ken Kearns; Huff, Jennifer R
Subject: Comments on the June 2012 Draft study report for Res. Levels and Proj. Flow Releases

Dear Phil Fragapane,

I wanted to take a minute to submit a few comments on the Reservoir Level and Project Flow Releases Study (draft, July 2012). Most of the report is straight forward includes details about the background and history of the project and study, the methodology used, and some basic observations on the resulting data as it pertains to flows and reservoir levels.

However, one observation I wanted to point out is in section 4.4 (Upper Savannah Drought Periods), in which I noticed that during the Period of Record, when the Basin is in a drought, it almost always ends up in a Level 2 drought. Of the 14,490 days in the Keowee POR, 39% of those days were in level 1 drought or greater; but of those 5,645 days, over half are in level 2 drought (2937 days) and more than level 1 and level 3 drought days combined (2708 days). In other words, when the reservoir enters into drought level 1, which happened 21 times since 1971 (see Figure 4.4-1), there is roughly a 50% chance that it will progress to a level 2 drought.

These data are provided when the USAC drought conditions are applied to the Keowee POR, however, I would also like to see similar data for periods of drought when applied to Lake Jocassee, which experiences deeper drawdowns than Lake Keowee. I think a comparison of drought conditions between the two reservoirs is useful when determining operating bands for the Project.

Furthermore, it might be useful to look at the drought contingency plans and the Interim LIP protocol to see if there isn't any additional measures that can help thwart these conditions in the future and still provide sufficient flows downstream.

In section 4.5 (Potential Reservoir Operating Ranges), the draft Study Report proposes normal drawdowns of 5 feet for Lake Keowee and 14 feet for Lake Jocassee, a ratio of nearly 1:3 feet. I would like to propose further that in order to maintain storage at the uppermost reservoir that for every foot that Keowee is lowered, Jocasse be lowered three, and that the Keowee Reservoir take the lead deductions so that Keowee is the first to drop and Jocassee would follow until Keowee is down 5 feet and Jocassee down 14 feet. At that point, I recommend that the ratio of drawdowns be 1:2 so that for every foot of elevation drop in Keowee, Jocassee drops 2 feet, which will help preserve storage at the uppermost reservoir. This ratio should be maintained until Keowee reaches its maximum drawdown, at which point Jocassee will have to provide the remainder of the relief.

Finally, in section 5 (Discussion and Analysis), the second paragraph states that the elevations of Lakes Keowee and Jocassee are reasonably correlated until the end of 1987. I would like to see some discussion included in this section that attempts to explain why such a deviation occurred. For example, the last sentence of that paragraph explains that ONS restrictions are easily observed in Lake Keowee elevations beginning in the mid-1990's. Lake Russell began operating in 1985 and the initial drought contingency plan was implemented in 1989, but how are these events related to the sudden lack of correlation in Jocassee and Keowee reservoir levels in the late 1980's? Or is there a different explanation?

I appreciate the opportunity to provide comments on the study. Please don't hesitate to contact me if you have any questions about my comments.

Sincerely,
Chris Starker

--
Chris Starker
Project Associate
Clean Air & Water Program

Upstate Forever
507 Pettigru St.
Greenville, SC 29601-3116
864-250-0500 ext 15
cstarker@upstateforever.org

Upstate Forever's mission is to promote sensible growth and to protect special places in the Upstate region of South Carolina. Please join us! To become a member, visit http://join.upstateforever.org. Thank you for your support!

You can now follow Upstate Forever on Twitter!
http://twitter.com/UpstateForever

Fragapane, Phil

From: Chris Starker [cstarker@upstateforever.org]
Sent: Wednesday, August 22, 2012 12:55 PM
To: Fragapane, Phil
Cc: Huff, Jennifer R
Subject: Re: Comments on the June 2012 Draft study report for Res. Levels and Proj. Flow Releases

Phil,

I know it's a bit after the fact, but it just dawned on me that I think it would be very useful to see the same data presented in section 4.4 Upper Savannah Drought Periods for the period from March
1989 to the present, which is when the Drought Contingency Plan was implemented. It would also be useful to compare this data to the overall drought period data in this section.

Similarly, I would like to see the data for just the period from 1995 to the present, which is the period when the ONS restrictions were implemented and lake levels on Keowee generally stabilized at that level.

And of course, as I mentioned in my email on the 9th, comparisons with Jocassee would be useful, especially given the minimum drawdown on Keowee due to ONS restrictions.

Sorry this is coming so late, but like I said it was an after-thought.
Hopefully it is not too late for this request?

Regards,
Chris

On Thu, Aug 9, 2012 at 4:19 PM, Chris Starker <cstarker@upstateforever.org> wrote:
> Dear Phil Fragapane,
>
> I wanted to take a minute to submit a few comments on the Reservoir
> Level and Project Flow Releases Study (draft, July 2012). Most of the
> report is straight forward includes details about the background and
> history of the project and study, the methodology used, and some basic
> observations on the resulting data as it pertains to flows and
> reservoir levels.
>
> However, one observation I wanted to point out is in section 4.4
> (Upper Savannah Drought Periods), in which I noticed that during the
> Period of Record, when the Basin is in a drought, it almost always
> ends up in a Level 2 drought. Of the 14,490 days in the Keowee POR,
> 39% of those days were in level 1 drought or greater; but of those
> 5,645 days, over half are in level 2 drought (2937 days) and more than
> level 1 and level 3 drought days combined (2708 days). In other
> words, when the reservoir enters into drought level 1, which happened
> 21 times since 1971 (see Figure 4.4-1), there is roughly a 50% chance
> that it will progress to a level 2 drought.
>
> These data are provided when the USAC drought conditions are applied
> to the Keowee POR, however, I would also like to see similar data for
> periods of drought when applied to Lake Jocassee, which experiences

> deeper drawdowns than Lake Keowee. I think a comparison of drought
> conditions between the two reservoirs is useful when determining
> operating bands for the Project.
>
> Furthermore, it might be useful to look at the drought contingency
> plans and the Interim LIP protocol to see if there isn't any
> additional measures that can help thwart these conditions in the
> future and still provide sufficient flows downstream.
>
> In section 4.5 (Potential Reservoir Operating Ranges), the draft
> Study Report proposes normal drawdowns of 5 feet for Lake Keowee and
> 14 feet for Lake Jocassee, a ratio of nearly 1:3 feet. I would like
> to propose further that in order to maintain storage at the uppermost
> reservoir that for every foot that Keowee is lowered, Jocasse be
> lowered three, and that the Keowee Reservoir take the lead deductions
> so that Keowee is the first to drop and Jocassee would follow until
> Keowee is down 5 feet and Jocassee down 14 feet. At that point, I
> recommend that the ratio of drawdowns be 1:2 so that for every foot of
> elevation drop in Keowee, Jocassee drops 2 feet, which will help
> preserve storage at the uppermost reservoir. This ratio should be
> maintained until Keowee reaches its maximum drawdown, at which point
> Jocassee will have to provide the remainder of the relief.
>
> Finally, in section 5 (Discussion and Analysis), the second paragraph
> states that the elevations of Lakes Keowee and Jocassee are reasonably
> correlated until the end of 1987. I would like to see some discussion
> included in this section that attempts to explain why such a deviation
> occurred. For example, the last sentence of that paragraph explains
> that ONS restrictions are easily observed in Lake Keowee elevations
> beginning in the mid-1990's. Lake Russell began operating in 1985 and
> the initial drought contingency plan was implemented in 1989, but how
> are these events related to the sudden lack of correlation in Jocassee
> and Keowee reservoir levels in the late 1980's? Or is there a
> different explanation?
>
> I appreciate the opportunity to provide comments on the study. Please
> don't hesitate to contact me if you have any questions about my
> comments.
>
> Sincerely,
> Chris Starker
>
> --
> Chris Starker
> Project Associate
> Clean Air & Water Program
>
> Upstate Forever
> 507 Pettigru St.
> Greenville, SC 29601-3116
> 864-250-0500 ext 15
> cstarker@upstateforever.org
>
> Upstate Forever's mission is to promote sensible growth and to protect
> special places in the Upstate region of South Carolina. Please join
> us! To become a member, visit http://join.upstateforever.org. Thank
> you for your support!

>
> You can now follow Upstate Forever on Twitter!
> http://twitter.com/UpstateForever

--
Chris Starker
Project Associate
Clean Air & Water Program

Upstate Forever
507 Pettigru St.
Greenville, SC 29601-3116
864-250-0500 ext 15
cstarker@upstateforever.org

Upstate Forever's mission is to promote sensible growth and to protect special places in the Upstate region of South Carolina. Please join us! To become a member, visit http://join.upstateforever.org. Thank you for your support!

You can now follow Upstate Forever on Twitter!
http://twitter.com/UpstateForever

Responses to Chris Starkers comments of August 9 and August 22, 2012

Comment	Response
1. In section 4.4, when the Basin is in a drought, it almost always ends up in a Level 2 drought. In other words, when the reservoir enters into drought level 1, which happened 21 times since 1971 (see Figure 4.4-1), there is roughly a 50% chance that it will progress to a level 2 drought.	Tables 4.4-1, 4.4-2, and 4.4-3 and acompanying discussion were added showing drought period duration for the period of record for each drought level according to USACE drought levels.
2. Provide a comparison of drought conditions at both reservoirs to assist in determining operating bands for the Project.	Figure 4.4-2 and accompanying discussion was added which compares levels of Lake Keowee, Lake Jocasse, Hartwell Lake, and Thurmond Lakes for 1975 to the present. Drought periods are also shown on this figure.
3. Review the drought contingency plans and the Interim LIP for additional measures to minimize future drawdowns and still provide sufficient flows downstream	This issue is not within the scope of the Reservoir Levels and Project Releases Study. The identification and assessment of potential improvements to the Interim LIP is part of the scope of the Water Supply Study.
4. For every foot Keowee is lowered, Jocasse should be lowered three, and Lake Keowee should be lowered first with Jocassee following until Keowee is down 5 feet and Jocassee down 14 feet. At that point, the ratio of drawdowns should be 1:2 (i.e. 1 foot of elevation in Keowee: 2 feet Jocassee). Maintain this ratio until Keowee reaches its maximum drawdown, then Jocassee declines to its maximum drawdown.	The scenario described is the same as Scenario 2 (the 2:1 scenario) for lake elevations below minimum normal elevations. The details to be included in the license application regarding how lakes are to be operated during droughts will be developed during the stakeholder process. Pumped-storage operations allow water to be moved upstream which will be an important consideration during this process.
5. In section 5, the second paragraph states the elevations of Lakes Keowee and Jocassee are reasonably correlated until the end of 1987. Provide additional discussion to explain why such a deviation occurred. Explain how the ONS restrictions, operations of the Richard B. Russell Project, and implementation of the USACE's drought contingency plans relate to lack of correlation in Jocassee and Keowee reservoir levels in the late 1980s.	The passage stating the elevations of Lake Keowee and Lake Jacassee "reasonably correlate with each other until the end of 1987" was removed because it is subjective. In general, it is difficult to draw broad cause-and-effect conclusions regarding lake levels. Though it is clear the ONS operating limit had an effect on the operations of Lake Keowee and Lake Jocassee beginning in the mid-1990s, it is not clear from the data that the beginning of Lake Russell operations nor the initialization of the USACE drought contingency plan had significant impacts on the operation of Lake Keowee and Lake Jocassee.
6. Present data in section 4.4 Upper Savannah Drought Periods for the period from March 1989 to the present, which is when the Drought Contingency Plan was implemented. Compare these data to the overall drought period data in this section.	Table 4.4-4 with acompanying discussion was added, comparing a number of different time periods of interest. Table 4.4-4 includes a March 1989 to the present time period.
7. Provide data for just the period from 1995 to the present, which is the period when the ONS restrictions were implemented and lake levels on Keowee generally stabilized at that level.	Table 4.4-4 with acompanying discussion was added comparing a number of different time periods of interest. Table 4.4-4 includes a 1995 to the present time period.

Appendix E6:

Final Study Reports

This appendix contains the final study reports and the addenda to the final study reports, organized by Resource Committee as follows.

Aquatic Resources

- Fish Community Assessment Study Plan Final Report, January 7, 2013
- Fish Community Assessment Study – FERC Required Fish Entrainment Modification, October 2013

Cultural Resources

- NRHP Evaluation of the Keowee-Toxaway Hydroelectric Development, October 2012

Recreation Resources

- Recreation Use and Needs Study, March 2013

Shoreline Management

- Lake Keowee & Lake Jocassee Shoreline Erosion Study Final Report, January 14, 2013

Water Quality

- Jocassee Forebay and Tailwater Water Quality Report, February 2013
- Keowee Reservoir Water Quality Modeling Study Report, March 2013
- Keowee Reservoir Water Quality Modeling Study Addendum: CE-QUAL-W2 Water Quality Model Results from WQ4 Operations Under Climate Change Scenarios, May 2014

Water Quantity and Hydro Operations

- Reservoir Level and Project Flow Releases Study for the Keowee-Toxaway Relicensing Project, November 2012
- Operations Model Study Savannah River Basin Model Logic and Verification Report, May 1, 2014
- Operations Model Scenario Documentation Report, May 1, 2014
- Water Supply Study Report, Keowee-Toxaway Relicensing Project, May 1, 2014

Wildlife and Botanical Resources

- Final Avian Study Report for the Keowee-Toxaway Relicensing Project Area, February 18, 2013
- Botanical Resources Study, October 2013
- Mammalian Survey for Keowee-Toxaway Relicensing Project, March 2013

- Wetlands Study Final Report, January 17, 2013

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

FERC NO. 2503

OPERATIONS MODEL STUDY

SAVANNAH RIVER BASIN

MODEL LOGIC AND VERIFICATION REPORT

Prepared for:
DUKE ENERGY CAROLINAS, LLC
Charlotte, North Carolina

Prepared by:
HDR ENGINEERING, INC. OF THE CAROLINAS
Charlotte, North Carolina

MAY 1, 2014

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

TABLE OF CONTENTS

Section **Title** **Page No.**

TABLE OF CONTENTS
(Continued)

Section | **Title** | **Page No.**

TABLE OF CONTENTS
(Continued)

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

TABLE OF CONTENTS
(Continued)

Section	Title	Page No.

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

LIST OF FIGURES

Figure	Title	Page No.

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

Figure	Title	Page No.

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

LIST OF FIGURES
(Continued)

Figure **Title** **Page No.**

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

(FERC NO. 2503)

OPERATIONS MODEL STUDY

SAVANNAH RIVER BASIN

MODEL LOGIC AND VERIFICATION REPORT

LIST OF TABLES

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

LIST OF TABLES
(Continued)

OPERATIONS MODEL STUDY
SAVANNAH RIVER BASIN
MODEL LOGIC AND VERIFICATION REPORT

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

EXECUTIVE SUMMARY

The Keowee-Toxaway Hydroelectric Project (FERC No. 2503) (Project), owned and operated by Duke Energy Carolinas, LLC (Duke Energy) is located in the upper Savannah River Basin and consists of two developments: Jocassee and Keowee. As part of the Federal Energy Regulatory Commission (FERC) relicensing of the Project, Duke Energy contracted with HDR Engineering, Inc. of the Carolinas (HDR) to develop an operations model of six hydroelectric facilities within the Savannah River Basin. The operations model developed includes the Duke Energy-owned Bad Creek Project, the Jocasse Development, and Keowee Development as well as three downstream U.S. Army Corps of Engineers (USACE) projects (Hartwell, Richard B. Russell, and J. Strom Thurmond). The six aforementioned Duke Energy and USACE hydro facilities are collectively referred to as "the system." The model is intended to be used as a tool to assist in evaluating various Stakeholder interests and reevaluation of the 1968 Operating Agreement (1968 Agreement) between Duke Energy, the USACE, and the Southeastern Power Administration (SEPA) (Duke Power Company 1968). This was performed by reviewing relative change between proposed operational modifications at the Keowee and Jocassee developments as outlined in the Operations Model Study Plan (Duke Energy 2011).

Two existing operations model platforms have been customized to the appropriate characteristics of the system. CHEOPS™ (Computerized Hydro Electric Operations Planning Software) is a proprietary software model owned by HDR and HEC-ResSim (Hydrologic Engineering Center's Reservoir System Simulation) is a product of the USACE. Both platforms are capable of modeling reservoir operations in the basin and of providing the needed water balance assessments. This report characterizes the development and verification of the customized CHEOPS and HEC-ResSim Models by loading the physical and operational parameters specific to the Project and, as appropriate, the USACE-owned Hartwell, Richard B. Russell, and J. Strom Thurmond Projects into the models. The operating logic for six reservoirs has been added into each model based on existing and future station operating plans in accordance with information provided by Duke Energy and the USACE. Operating logic is a single set of rules per scenario and does not account for changes in external conditions for a single model run. A model calibration and validation process has been developed using a mass balance approach over the period of 1998-2008 applying the basic law of mass continuity between the reservoirs. The period was selected based on the completion of all reservoirs and the best available records of constant plant operation and reservoir elevations. Both models were calibrated and validated using a similar procedure and dataset. A significant portion of the work for the operation model development included the reconstruction of annual inflow hydrology for the Savannah River (SR) Basin. The unimpaired inflow (UIF) data for the SR Basin was generated from existing hourly and/or daily reservoir elevations, generation, spillage and other operations data. The simulation models are decision support tools and are not intended to simulate or predict exact future conditions on a daily or annual basis. The models were constructed to compare different scenarios. Both models use historic inflows (i.e., UIF) to simulate likely future conditions, as if the inflow will occur in the same pattern in the future as occurred in the past.

The description of the two models and the verification results are presented in this report in two separate sections. The CHEOPS model is described in Sections 3 and 4, and the ResSim model in Sections 5 and 6. Description of common inputs has been repeated for each model. This report supersedes the previously submitted February 2012 CHEOPS Model Operations/Verification Report and January 2013 Addendum (HDR 2012, 2013).

Development of the Savannah River CHEOPS Model (SR CHEOPS Model) was based on input and physical characteristics of each facility previously developed for the same river basin as part of the Savannah River ResSim Model (SR ResSim Model) and updated over time as information became available (HDR 2014). The SR ResSim Model was originally developed by the USACE and has since been updated to assist in the reevaluation of the 1968 Agreement between Duke Energy and the USACE (Duke Power Company 1968). In conjunction with the SR ResSim Model, the SR CHEOPS Model, described in this report, was used throughout the FERC relicensing process for the Project (HDR 2014). The SR ResSim Model has been developed and verified using Version 3.1 RC3 Revision 3.1.7.157 Build 3.1.7.157R June 2011 of the USACE HEC-ResSim software (Build 157) (USACE 2007).

Using average daily inflow as input, the SR CHEOPS and SR ResSim Models simulate operations to budget water to ensure that all constraints (physical, environmental, and operational) are met while maximizing peak period hydro turbine energy as a lower priority objective. These models provide for user-defined customization of specific constraints within the system, such as flow requirements, target reservoir elevations, powerhouse equipment constraints, and reservoir storage balancing between hydro development operators.

The purpose of this report is to document inputs and assumptions used in the development of the two models, to demonstrate that the models reasonably characterize operations of the three Duke Energy and three USACE facilities modeled, and to demonstrate the models are adequate for use in evaluating the effects of alternative operating scenarios.

Model verification is intended to validate the input data and ability of the programmed logic in simulating daily hydroelectric and reservoir operations. HDR performed model verification of both the SR CHEOPS and SR ResSim Models using comparisons of actual and model-estimated generation and total discharge. The verification simulations were completed for recent hydrologic years with best available historical reservoir operations over a wide range of hydrologic and reservoir operations conditions.

The SR CHEOPS and SR ResSim Models are coded to run day-to-day operations based on a single set of operating conditions or rules. Actual project operations generally follow the operating rules; however, human intervention periodically deviates from the general operating rules to accommodate day-to-day realities such as equipment failure and maintenance, changing hydrologic conditions, power demands, and other factors.

The verification for the SR CHEOPS and SR ResSim Models was performed using historical operations data provided by Duke Energy and the USACE. Verification scenarios were developed to test the facility operation rules, provided by Duke Energy and the USACE, in an attempt to replicate daily human decision making with respect to typical operating requirements of the system. Verification of the SR CHEOPS and SR ResSim Models was completed using two different scenarios (model runs). For consistency between the SR CHEOPS and SR ResSim Models, the first model run performs a verification of the model input data, logic, and conditions of the Historical Baseline scenario for calendar years 1998 through 2008. In addition to the Historical Baseline scenario, a second verification scenario (v2007) was developed using the SR CHEOPS and SR ResSim Models to simulate the detailed operations for calendar year 2007.

In the opinion of HDR, verification results show the two operations models and the hydrologic inputs compare favorably to historical data, reasonably characterize system operations, and are appropriate for use in evaluating the effects of alternative operating scenarios on generation, reservoir levels, and outflows. The CHEOPS and ResSim software and the Savannah River operations models are tools that, as this report demonstrates, can be successfully used to evaluate the relative sensitivity and response of the system modeled to changing operational constraints. As with any model, accuracy is highly dependent on input data; consequently, model results should be viewed in a relative, rather than an absolute, context.

1.0 INTRODUCTION

The Keowee-Toxaway Hydroelectric Project (FERC No. 2503) (Project), owned and operated by Duke Energy Carolinas, LLC (Duke Energy) is located in the upper Savannah River Basin and consists of two developments: Jocassee and Keowee. As part of the Federal Energy Regulatory Commission (FERC) relicensing of the Project, Duke Energy contracted with HDR Engineering, Inc. of the Carolinas (HDR) to develop an operations model of six hydroelectric facilities within the Savannah River Basin. The operations model developed includes the Duke Energy-owned Bad Creek Project, the Jocassee Development, and Keowee Development as well as three downstream U.S. Army Corps of Engineers (USACE) projects (Hartwell, Richard B. Russell, and J. Strom Thurmond). The six aforementioned Duke Energy and USACE hydro facilities are collectively referred to as "the system." Two operations models were developed for this system: one model utilized HDR's proprietary Computer Hydro Electric Operations and Planning Software (CHEOPS) and incorporated the six aforementioned facilities along the main stem of the Savannah River Basin, and the other model utilized Version 3.1 RC3 Revision 3.1.7.157 Build 3.1.7.157R June 2011 of the USACE Hydrologic Engineering Center's Reservoir System Simulation (HEC-ResSim) software (Build 157) (USACE 2007).

CHEOPS is specifically designed to evaluate the effects of operational changes and physical modifications at multi-development hydroelectric projects. CHEOPS has been applied to evaluate the physical and operational changes considered during the FERC relicensing of more than 25 projects. The Savannah River CHEOPS Model (SR CHEOPS Model), in conjunction with the Savannah River ResSim Model (SR ResSim Model) of the system (HDR 2014) developed to reevaluate the 1968 Operating Agreement (1968 Agreement) between Duke Energy and the USACE (Duke Power Company 1968), was applied throughout the FERC relicensing process for the Project (Duke Energy 2011).

HDR created the CHEOPS hydropower system simulation model as a tool for evaluating a wide range of physical changes (e.g., turbine upgrades) and operational constraints (e.g., minimum flows) associated with relicensing or upgrading single and multiple development hydro systems. One of the many strengths of the CHEOPS model is the degree of customization each individual model contains. The model is tailored to meet the demands of the particular system being modeled. The unique CHEOPS program architecture provides a platform for investigating project-specific features as defined by stakeholder interests, represented by the Operating Scenario Committee (OSC) for the FERC relicensing of the Project. The SR CHEOPS Model was custom-configured for the system based on the specific system constraints such as flow requirements, target reservoir elevations, powerhouse equipment constraints, and reservoir storage balancing between hydro development operators.

The original USACE Savannah River ResSim Model was based on Version 3.1 Beta III Revisions 3.1.4.36 Build 3.1.4.36R October 2008 of the USACE HEC-ResSim software. The USACE model contained minimal logic for the operation of the Jocassee and Keowee Developments and did not include the Bad Creek Project. As previously stated, the SR ResSim Model has since been updated. The SR ResSim Model includes a definition of the physical pumping and generation capabilities at Jocassee Station, physical generation capabilities at Keowee Station, as well as operational logic to reflect actual reservoir operations at both developments. The updated model also includes Bad Creek reservoir operations and physical pumping and generation capabilities. The newer "Build" of the ResSim software provides additional logic support for the system storage balance rule, which is a significant operational driver in this system.

The two models utilize daily flows, plant-generating characteristics, and operating criteria of the system to simulate operation, allocate flow releases, and calculate energy production within the system. The SR CHEOPS Model calculates headwater elevation, headlosses, net head, turbine discharge and spill, and power generation in 15-minute increments. The SR ResSim Model uses a daily time step to perform similar operations calculations. Both models are designed for long-term analysis of the effects of operational and physical changes made to the modeled hydro-system.

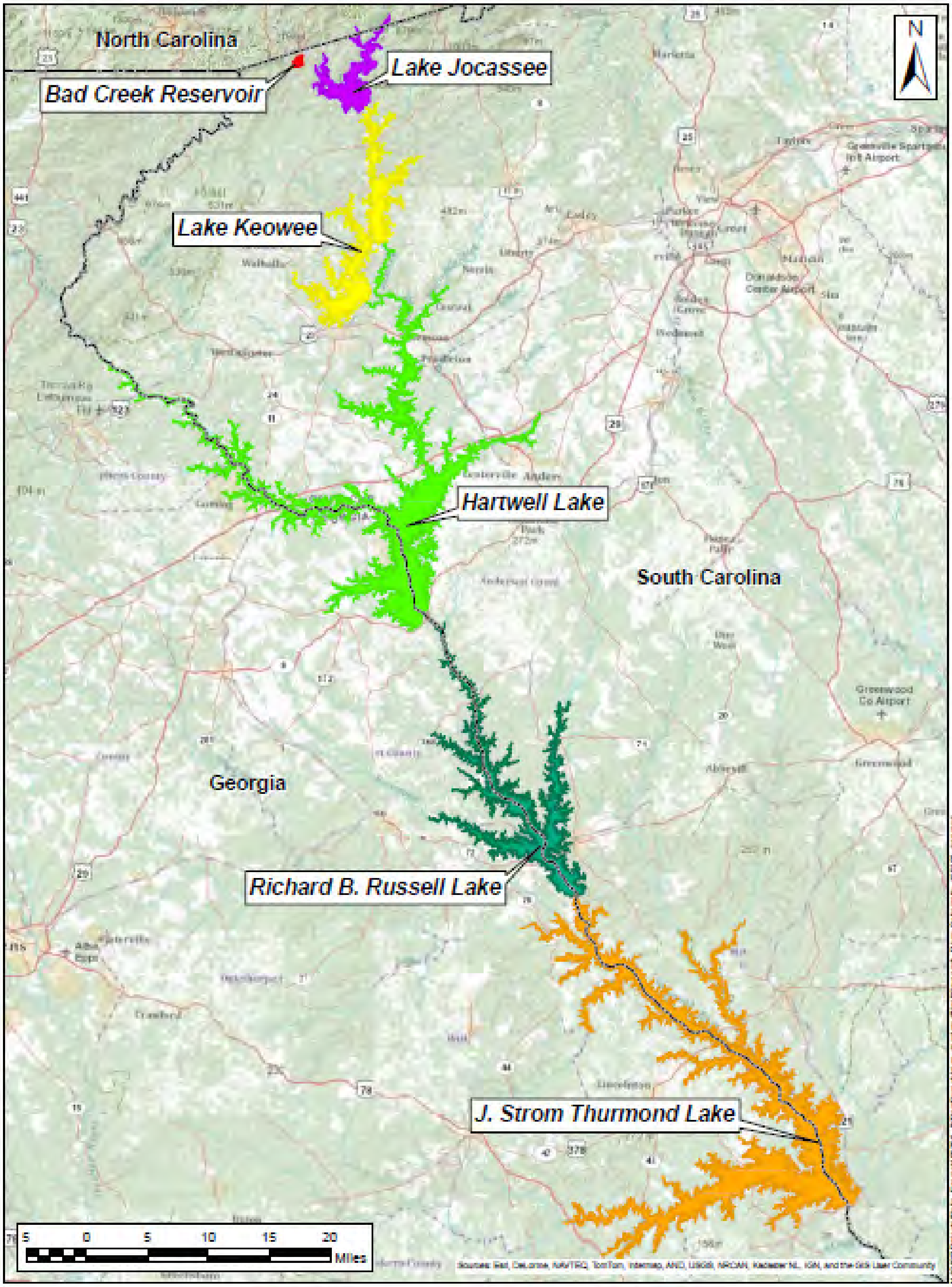
Model verification is intended to validate the input data and ability of the programmed logic in simulating daily hydroelectric and reservoir operations. A "Baseline" scenario was established following the current system-wide operation rules outlined in the model verification process. The Baseline scenario does not include historical USACE drought operations (J. Strom Thurmond Project flow requirements), and historical water use or flow requirements (historical operations) applied in the verification scenarios. The Baseline scenario is used as the baseline or starting point (operating rules and settings) for all subsequent analyses. HDR performed model verification using comparisons of actual and model-estimated generation and total discharge. The verification simulations were completed for recent hydrologic years with best available historical reservoir operations over a wide range of hydrologic and reservoir operations conditions. The purpose of this report is to document inputs and assumptions used in the development of the SR CHEOPS and SR ResSim Models, to demonstrate the models reasonably characterizes operations of the six facilities modeled, and to demonstrate the models are adequate for use in evaluating the effects of alternative operating scenarios.

The SR CHEOPS and SR ResSim Models are coded to run day-to-day operations based on a single set of operating conditions or rules. Actual project operations generally follow the operating rules; however, human intervention periodically deviates from the general operating rules to accommodate day-to-day realities such as equipment failure and maintenance, changing hydrologic conditions, power demands, and other factors. In addition to differences between modeled operations versus actual operations that include human interventions, there are also inherent discrepancies due to input data inaccuracies (e.g., differences in calculated hydrology data, turbine or generator efficiencies, or reservoir storage curves). It is important to understand model results will never completely match historical or future operations due to these differences between actual operating conditions and modeled conditions.

The SR CHEOPS and SR ResSim Models include a definition of the physical pumping and generation capabilities at the Bad Creek, Jocassee, and Richard B. Russell facilities, and physical generation capabilities at the Keowee, Hartwell, and J. Strom Thurmond facilities, as well as operational logic to reflect reservoir operations at all facilities. The system storage balance logic in the model allows the user to define the storage relationship between the reservoirs in the system so the Duke Energy reservoir storage (Lake Jocassee and Lake Keowee) will closely follow the USACE reservoir storage drawdown in accordance with the 1968 Agreement between Duke Energy and the USACE (Duke Power Company 1968). The reservoir storage-volume relationships modeled for the Jocassee, Keowee, Hartwell, Richard B. Russell, and J. Strom Thurmond facilities reflect the 2010 sedimentation estimates developed by HDR. The Duke Energy storage-volume relationships were revised based on bathymetric data collected in 2010, and the USACE storage-volume relationships were updated based on published sedimentation rates from the Savannah River Basin. Sedimentation rates were converted to sediment volume using methods outlined in USACE EM 1110-2-4000 (USACE 1995) and estimated compressed density of the sediment. A summary of the sedimentation calculations is provided in Appendix A.

Major features of the facilities in the basin are shown in Figure 1-1. This schematic is the basis for the conceptual model that was used to develop the SR CHEOPS Model. The SR CHEOPS and SR ResSim Models have six nodes that correspond to the major hydrologic junctures in the modeled river system. The models account for inflows, discharge, change in reservoir storage, and power generation at the various nodes.

FIGURE 1-1
SAVANNAH RIVER BASIN



2.0 PROJECT DATA

Duke Energy owns and operates the Bad Creek Pumped Storage Project and the Keowee-Toxaway Project (consisting of the Jocassee Development and the Keowee Development); the USACE owns and operates the Hartwell Project, Richard B. Russell Project, and J. Strom Thurmond Project. Each development is linked in series within the models and consists of dams and multi-unit powerhouses as shown in Table 2-1.

TABLE 2-1
SAVANNAH RIVER BASIN - MODELED SYSTEM

Facility	Upstream Reservoir	Project Type
Bad Creek	—	Pumped Storage
Jocassee	Bad Creek	Pumped Storage
Keowee	Jocassee	Conventional Hydro
Hartwell	Keowee	Conventional Hydro
Richard B. Russell	Hartwell	Conventional Hydro & Pumped Storage
J. Strom Thurmond	Richard B. Russell	Conventional Hydro

2.1 Bad Creek Project

Bad Creek and West Bad Creek were dammed to form the approximately 300-acre Bad Creek Reservoir located 8 miles north of Salem in Oconee County, South Carolina. Bad Creek Reservoir serves as the upper reservoir for the Bad Creek Project, a pumped storage facility that uses Lake Jocassee as its lower reservoir. The Bad Creek Project began producing energy on March 8, 1991. The powerhouse contains four reversible motor-pump/turbine-generator units.

The Bad Creek Project Normal Full Pond Elevation is 2,310 feet above mean sea level (ft AMSL), and normal minimum elevation is 2,150 ft AMSL (Duke Energy 2008). All vertical elevations referenced in this report are National Geodetic Vertical Datum (NGVD) 1929 unless noted. There is no license-required operating guide curve; rather, the reservoir is operated as needed for generation, typically fluctuating between 2,280 and 2,300 ft AMSL. Historically, some periods show weekly reservoir drawdown with reservoir refill on the weekends. Both the

SR CHEOPS and SR ResSim Models use the Normal Full Pond Elevation of 2,310 ft AMSL and normal minimum elevation of 2,150 ft AMSL for the Bad Creek Project.

2.2 Jocassee Development

The approximately 7,980-acre Lake Jocassee is fed by four rivers: Whitewater, Thompson, Horsepasture, and Toxaway. The Jocassee Development, the upstream development of the Keowee-Toxaway Project, was placed in service on December 19, 1973 (Units 1 and 2) and May 1, 1975 (Units 3 and 4), and is a pumped storage facility that uses Lake Keowee as its lower reservoir.

The Lake Jocassee Normal Full Pond Elevation is 1,110 ft AMSL and the normal minimum elevation is 1,080 ft AMSL (HDR 2010). For modeling purposes, Duke Energy developed an annual cycle conservation pool guide curve where the reservoir is brought to 1,109.5 ft AMSL from May 1 through October 15, then lowered gradually to 1,106 ft AMSL on January 1, then refilled gradually to 1,109.5 ft AMSL on May 1. Both the SR CHEOPS and SR ResSim Models use this conservation pool guide curve for Lake Jocassee.

2.3 Keowee Development

Lake Keowee is formed by two parallel watersheds that are connected by a 2,000-foot-long canal. The watershed draining directly into Lake Keowee is approximately 435 square miles. The reservoir surface area is approximately 17,660 acres at the Normal Full Pond Elevation of 800 ft AMSL (HDR 2012). The hydroelectric station entered commercial operation on April 17, 1971 and contains two conventional turbine-generator units.

The reservoir’s normal operation is characterized by maintaining the reservoir level between the lower and upper extremes of the normal operating range, which are 794.6 ft AMSL and 800 ft AMSL, respectively. Historically, Duke Energy has not used a target or guide curve in the operations of Lake Keowee.

For SR CHEOPS modeling purposes, a target curve of 799 ft AMSL from May 1 to October 15, which then lowers gradually to 796 ft AMSL on January 1 and refills gradually by May 1, has been simulated to calculate usable storage for coordination with the USACE. The modeled target (guide) curve from 799 to 796 ft AMSL is used in model scenarios for coordination of storage balance with the USACE. Based on a review of historical operations of Lake Keowee, special code was added to the SR CHEOPS Model for Lake Keowee to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. This was simulated in the SR ResSim Model by a flat guide curve of 799.9 ft AMSL for Lake Keowee.

Based on the additional SR CHEOPS Model control at Lake Keowee, the model will not schedule discretionary releases from Lake Keowee unless the reservoir is nearing Full Pond and available storage for capturing runoff is reduced. This additional logic for Lake Keowee was applied and evaluated through verification of the model. This additional logic is a user input whereby the SR CHEOPS Model can be adjusted to evaluate operational alternatives. The SR ResSim Model simulation of the Jocassee-Keowee pumping and generating cycles is limited to the specified flat guide curve of 799.9 for Lake Keowee.

2.4 Hartwell Project

The 55,900-acre Hartwell Lake is located 7 miles east of Hartwell, Georgia, on the border with South Carolina and 289 river miles above the mouth of the Savannah River. Hartwell Dam is located on the Savannah River 7.1 miles below the point at which the Tugaloo and Seneca Rivers join to form the Savannah River. In addition to the Hartwell Dam, the two Clemson Diversion Dams were constructed to divert flow of the Seneca River around Clemson University. Hartwell Hydro Station has been in operation since April 1962. The powerhouse contains five conventional turbine-generator units.

The Hartwell Project includes 5 feet (ft) of flood control storage from an elevation of 660 to 665 ft AMSL, which contains approximately 293,000 acre-feet (ac-ft) of storage (USACE 1996a). A flood surcharge zone exists from 665 to 679 ft AMSL. A seasonally varying guide curve exists, which provides additional flood control during the winter and early spring. The minimum pool elevation is 625 ft AMSL. Both the SR CHEOPS and SR ResSim Models use this conservation pool guide curve for Hartwell Lake.

2.5 Richard B. Russell Project

The Savannah River flows out of the Hartwell Dam and flows into and through Richard B. Russell Lake. The 26,650-acre lake is impounded by the USACE's Richard B. Russell Dam 30 miles downstream of the Hartwell Dam and approximately 259 miles above the mouth of the Savannah River. The reservoir fill period commenced in October 1983, and the powerhouse was placed in service on January 1, 1985. The powerhouse contains four conventional turbine-generator units and four motor-pump/turbine-generator units. Two small house turbine-generator units were not modeled as part of the modeling effort.

The Richard B. Russell Project includes 5 ft of flood control storage from an elevation of 475 to 480 ft AMSL (USACE 1996b). The limited conservation storage range between reservoir elevation 470 and 475 ft AMSL and fluctuation caused by pumping/generating cycles necessitates a constant guide curve with no seasonal drawdown (USACE 1996b). Both the SR CHEOPS and SR ResSim Models use this conservation pool guide curve for Richard B. Russell Lake.

2.6 J. Strom Thurmond Project

The Savannah, Broad, and Little Rivers flow into J. Strom Thurmond Lake, which is a 71,100-acre lake impounded by the J. Strom Thurmond Dam. The dam is located 37 miles downstream of the Richard B. Russell Dam and approximately 222 miles above the mouth of the Savannah River. The powerhouse contains seven conventional turbine-generator units.

The objective of flood control regulation at the J. Strom Thurmond Project is to reduce flood damages to the lower Savannah River Basin to the maximum extent possible. Normal pool varies seasonally from 330 ft AMSL April 1 through October 15; and between October 15 and

December 15, the pool is drawn down to a seasonal normal pool of 326 ft AMSL to allow for the statistically higher winter and spring inflows. Starting January 1, the pool is refilled to reach 330 ft AMSL on April 1 (USACE 1996c). Both the SR CHEOPS and SR Models use this conservation pool guide curve for J. Strom Thurmond Lake.

2.7 Hydrology

A significant input to both water mass balance models is a reconstructed inflow data set unimpaired by system operations (unimpaired inflow [UIF]), subdivided by reservoir node for each of the six reservoirs included in the models. Investigations of available options for the UIF lead to incorporating an existing Georgia Environmental Protection Division (EPD)-sponsored SR Basin UIF covering the period of 1939-2007. In June 2009, Duke Energy authorized HDR to subcontract with ARCADIS U.S. Inc. (ARCADIS) to modify the existing SR Basin UIF to include separate UIF data divisions for the three Duke Energy facilities and extend the hydrology through 2008. The hydrologic dataset, Savannah River Unimpaired Flow 1939-2008 Time Series Extension Report (ARCADIS 2010, 2013), applied in both the SR CHEOPS and SR ResSim Models was provided by ARCADIS and prepared for Duke Energy, the Savannah District of the USACE, and the Georgia EPD. The study performed by ARCADIS developed UIF time series data (UIF database dated September 16, 2010) for the five main facilities on the Savannah River from the Jocassee Development to J. Strom Thurmond Project. Due to the small size of the Bad Creek watershed, HDR developed the UIF to Bad Creek Reservoir as a portioned 1 percent of the developed Lake Jocassee UIF. As outlined in the Savannah River Unimpaired Flow 1939-2008 Time Series Extension Report released by ARCADIS on August 12, 2010, these data are suitable for the following purposes:

- Reservoir system operational modeling by Duke Energy and the USACE, with USACE serving as a cooperating agency for the FERC relicensing of the Project.
- Reservoir operational planning studies by the USACE; and
- Determination of desired flow regimes and consumptive water-use assessments for Georgia EPD.

The excerpt below from Section 1 of the Savannah River Unimpaired Flow 1939-2011 Time Series Extension Report (ARCADIS 2010, 2013) defines the methods applied in the development of the UIF time series data. All time series data were supplied in HEC-DSS databases.

> *Incremental and cumulative UIFs are developed for the Seneca River at the Jocassee and Keowee sites from historical stream flows and reservoir releases at these locations by removing (1) effects of reservoir regulation (holdouts and releases from storage), (2) differential pre- and post-reservoir net evaporation (i.e., evaporation minus precipitation excess from the reservoir surface area), and (3) consumptive water uses within the respective local drainage areas. General assumptions and methods applicable to UIF development under this study are subsequently described as follows.*
>
> - *The period of record (POR) for UIFs developed under this study uniformly extends from January 1939 through December 31, 2008. UIFs previously developed by Georgia EPD for 1939–2007 (Georgia EPD 2010) were recalculated.*
> - *Daily incremental UIFs were developed at the following nodes within the Savannah River basin: Jocassee (Seneca River); Keowee (Seneca River); Hartwell, Richard B. Russell (U.S. Geological Survey [USGS] gage 02189000, Calhoun Falls); Bell (Broad River, USGS gage 02192000); Thurmond, Augusta (USGS gage 0219700); Burtons Ferry (USGS gage 02197500); Millhaven (Brier Creek, USGS gage 02198000); and Clyo (USGS gage 02198500).*
> - *Georgia EPD has provided daily potential evapotranspiration (PET) time series data computed using the Hamon equation that extend from January 1, 1939 to December 31, 2008. These have been used in the computation of reservoir evaporation following procedures used in the development of the January 1, 1939 to December 31, 2007 UIF time series.*
> - *Federal and non-federal reservoir holdouts, net evaporation, and daily inflows and outflows have been computed and applied as appropriate to UIF derivation. For reservoirs where time series data required for these calculations are not available,*

run-of-river operation has been assumed. Operational data were provided by Duke Energy, including Bad Creek Reservoir elevation time series data and elevation and outflow time series data for the Jocassee and Keowee projects, in addition to elevation-area-storage paired data for the Keowee and Jocassee projects.

- *UIF data development has been primarily accomplished by filling and routing of missing 1939 to 2008 historical flow data and by adjustments for reservoir effects and water uses. Techniques may involve application of Riverside's TSTool software and USACE DSS utilities, interactively and by batch programming. All time series and paired data have been stored in HECDSS databases and map-referenced as approved by Georgia EPD. UIF development has largely relied upon time series previously developed by ARCADIS for Georgia EPD.*
- *Historical water use data, on a daily or monthly time step, have been provided by Georgia EPD in electronic form quality-controlled and suitable for UIF development. Water use data extends from 2005 to 2008.*
- *Routing techniques for observed flow filling and UIF derivation have been selected by ARCADIS for consistency with existing 1939 to 2007 Savannah UIF data previously developed for Georgia EPD.*

The intended use of UIFs by Duke Energy and USACE is operational modeling, as opposed to water-use assessments currently being performed by Georgia EPD.

Additional information on the development of the UIF is available in the Savannah River Unimpaired Flow 1939-2011 Time Series Extension Report revised by ARCADIS on May, 2013 (ARCADIS 2010, 2013).

During the initial stages of the model scenario development phase of the relicensing process, the OSC identified the desire to have a Savannah River Basin inflow dataset that verified well against the most severe historical drought period on record, the 2007-2008 drought. Through a review of inputs and assumptions used in the SR CHEOPS Model from May through July 2012, the OSC concluded there was too much water accounted for in the back calculated incremental inflow time series being used since September 2010. The OSC requested an investigation to determine the source of the apparent inconsistency in the inflow time series during 2007-2008 when comparing modeled results to historical data. ARCADIS assisted HDR with a review of the inflow time series development and documentation. The review compared the inflow time series to USACE calculated inflow series and recommended using a different combination of inflow data (from within the September 2010 HEC-DSS database) for all reservoirs with the most significant differences in the Richard B. Russell Lake. These datasets were pulled from the supplied September 2010 HEC-DSS files and are comprised of the time series outlined in Table 2-2. The OSC approved revising the model inflow data series in both the SR CHEOPS and the SR ResSim Models.

The 1939 through 2008 hydrologic dataset adopted by the OSC in August 2012 was used for model relicensing scenario development from September 2010 through December 2012. In the fall of 2012, Duke Energy, following a recommendation from the OSC, funded an extension of the inflow data set by three years. The inflow data set was extended by ARCADIS using the same methodology developed to construct the original data set expanding the period of record (POR) to 1939 through 2011. The final revised dataset was provided by ARCADIS in May 13, 2013, and extended the existing inflow hydrology files in both the SR CHEOPS and SR ResSim Models. A summary of the hydrology extension is provided in Appendix B, which includes a presentation from ARCADIS dated June 27, 2013, and the May 2013 Savannah River Unimpaired Flow Data Report (ARCADIS 2010, 2013).

TABLE 2-2
INFLOW TIME SERIES

Reservoir	DSS Part: B	DSS Part: C	DSS Part: F
2012 LIF			
Jocassee and Bad Creek Combined	KEOWEE_R-JOCASS_R	FLOW-LOC INC	FILLED 0ADJ
Keowee	KEOWEE_R	FLOW-LOC INC	0ADJ LOC FILL
Hartwell	HARTWL_R	FLOW-LOC INC	0ADJ LOC FILL
Richard B. Russell	RBR_R	FLOW-LOC INC	0ADJ LOC-SMOOTH
J. Strom Thurmond (sum of THRMND_R and BELL)	THRMND_R	FLOW-LOC INC	0ADJ-RES FILL ADJ
	BELL	FLOW-LOC INC	OBS

The holdout time series (net evaporation and water use) used in the review of the inflow time series were also obtained from the revised May 13, 2013 HEC-DSS files and are comprised of the time series outlined in Tables 2-3 and 2-4.

TABLE 2-3
NET EVAPORATION TIME SERIES

Reservoir	DSS Part: B	DSS Part: C	DSS Part: F
Bad Creek	JOCASS_R-BADCR_R	FLOW-EVAPNET	POST-PRE RES
Jocassee	KEOWEE_R-JOCASS_R	FLOW-EVAPNET	POST-PRE RES
Keowee	KEOWEE_R	FLOW-EVAPNET	POST-PRE RES
Hartwell	HARTWL_R	FLOW-EVAPNET	POST-PRE RES
Richard B. Russell	RBR_R	FLOW-EVAPNET	POST-PRE RES
J. Strom Thurmond	THRMND_R	FLOW-EVAPNET	POST-PRE RES

TABLE 2-4
WATER USE TIME SERIES

Reservoir	DSS Part: B	DSS Part: C	DSS Part: F
Keowee	KEOWEE_R	FLOW-DIV NET	COMP-REACH TOTAL
Hartwell	HARTWL_R	FLOW-DIV NET	COMP-REACH TOTAL
Richard B. Russell	RBR_R	FLOW-DIV NET	COMP-REACH TOTAL
J. Strom Thurmond	THRMND_R	FLOW-DIV NET	COMP-REACH TOTAL

2.8 SR CHEOPS Model Logic Enhancements

Modifications to the CHEOPS platform to support the SR CHEOPS Model include functionality enhancements enabling simulation of conditions (e.g. Duke Energy Low Inflow Protocol [LIP], and USACE Drought Plan [DP]), which were developed during the relicensing process, as well as improved logic for upstream/downstream plant interactions, specifically with pumped storage plants in the system. Overall enhancements to the model include adding wicket gate leakage for pumped storage plants when in partial pumping operations, and model administrative capabilities to use OpenOffice instead of Microsoft Excel as the application which reads the model input files.

Additionally, a series of SR CHEOPS Model modifications were required to support specific OSC member group requests developed during relicensing scenario development. The modifications include:

- The ability to specify reservoir fluctuation limits that are not a fixed elevation, but rather dependent upon the start-of-period elevation. This feature was added to support the request for fish spawning reservoir stabilization periods (South Carolina Department of Natural Resources [SCDNR]), and later was modified to be able to turn off this requirement when the LIP stage is other than "Normal."
- Enhanced support by upstream plants of downstream plant outflow requirements. The outflow enhancements take into account the sum of all required flows on the downstream plant, including required powerhouse outflows, wicket gate leakage, withdrawal requirements, and evaporation. This change prevents an upstream pumped storage or hybrid-pumped storage plant from pumping the downstream reservoir elevation too low when the downstream plant cannot meet its required flows releases.
- Pumped storage plant discharge operations may also be triggered/required without the requisite ability to pump back in order to support downstream plant outflow requirements.

3.0 SR CHEOPS MODEL – BASELINE

This section defines the development of the Baseline scenario used for the verification of the SR CHEOPS Model. Each sub-section defines specific inputs used in the SR CHEOPS Model verification to simulate historical operations.

3.1 SR CHEOPS Model Logic

Figures 3-1 and 3-2 give an overview of the model logic in sequence.

FIGURE 3-1
CHEOPS MODEL EXECUTION FLOW CHART

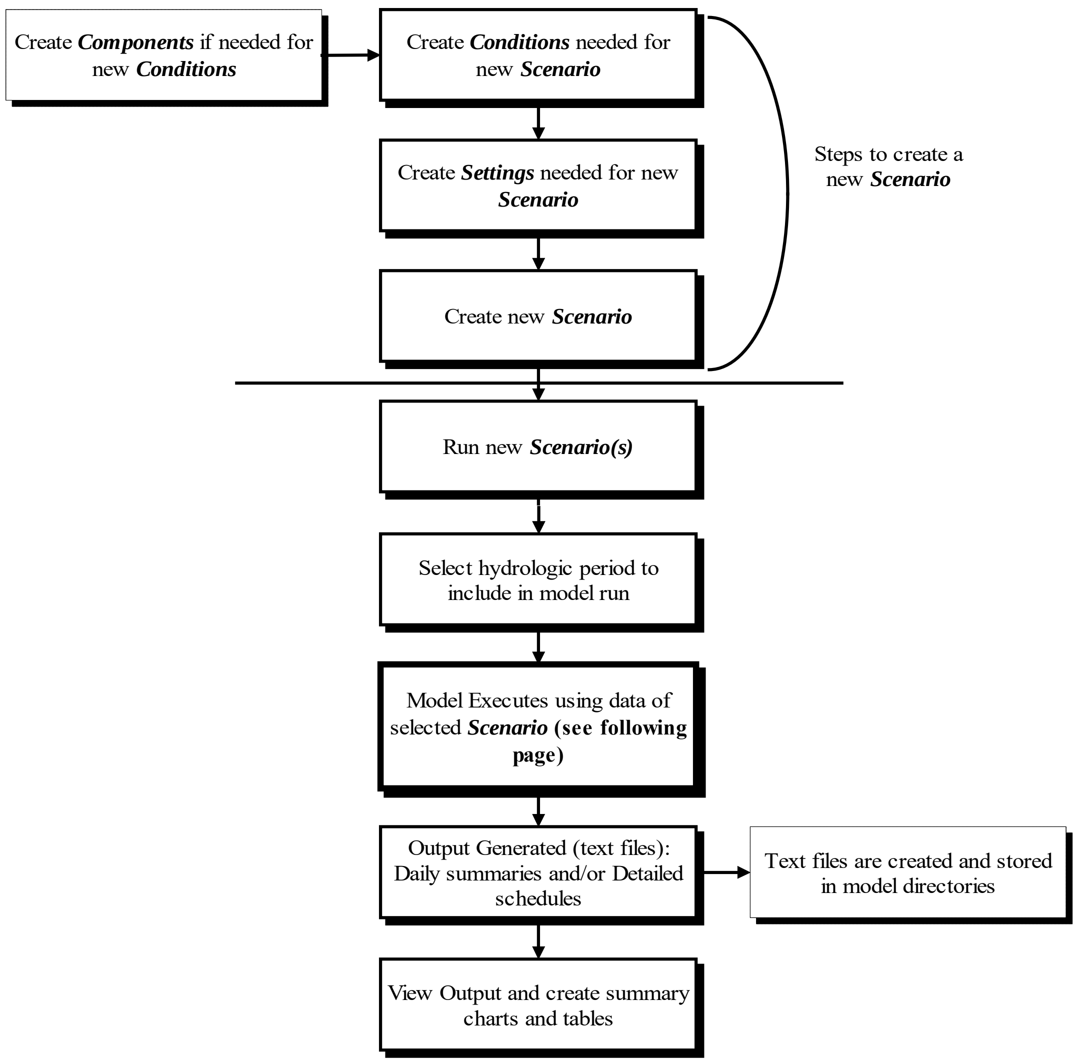
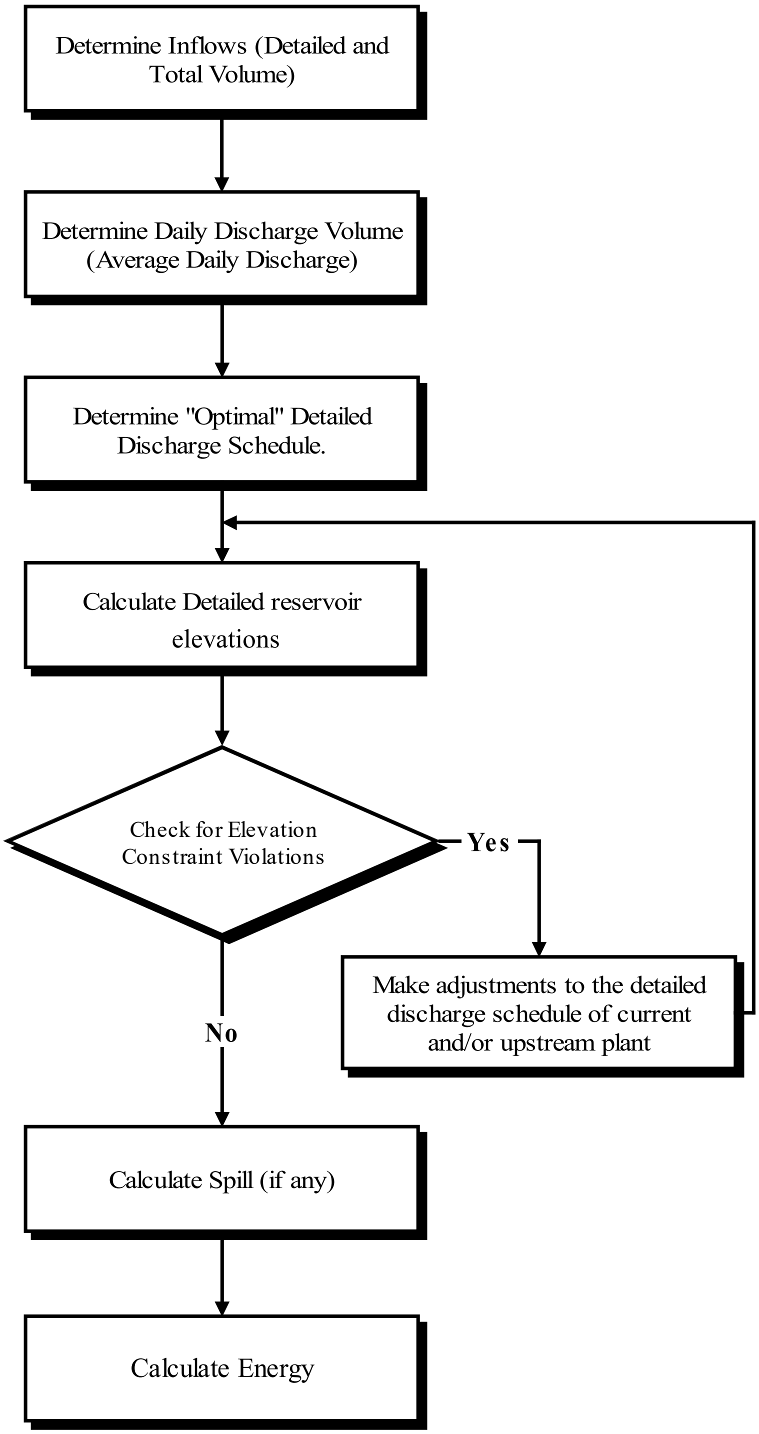


FIGURE 3-2
CHEOPS MODEL SCHEDULING FLOW CHART



3.2 SR CHEOPS Model Scenario Definition/Input Data

The project data listed in the following subsections shows the general operational constraints and physical parameters used in the SR CHEOPS Model to define the current system configuration used in both the Historical Baseline and the Baseline scenario setups. Model scenarios selected for the SR CHEOPS Model verification are the same as used for the SR ResSim Model for consistency and comparison between model architecture. Model verification uses historical data and tests the ability of the model to simulate actual operations of all six facilities. The Historical Baseline and v2007 scenarios presented in this report are based on the No Action Alternative (NAA) (Existing License) (developed for use in SR ResSim Model) scenario with adjustments as defined in the Baseline scenario below. The Baseline scenario was selected over the NAA scenario to more closely simulate historic operating conditions that have been used by Duke Energy for the selected hydrologic testing period (1998 through 2008 – Historical Baseline).

- <u>No Action Alternative (NAA)/Existing License</u>

  The NAA reflects the operating conditions of the Jocassee, Keowee, Hartwell, and J. Strom Thurmond facilities as defined in the 1968 Agreement with no changes and reflects the operations of the Project as outlined in the existing Project FERC License. The 1968 Operating Agreement is based on the concept of equalizing the percentage of combined remaining usable storage at Duke Energy's Lake Jocassee and Lake Keowee with the percentage of combined remaining usable storage at the USACE's Hartwell and J. Strom Thurmond Lakes.

- <u>Baseline (Existing Operations)</u>

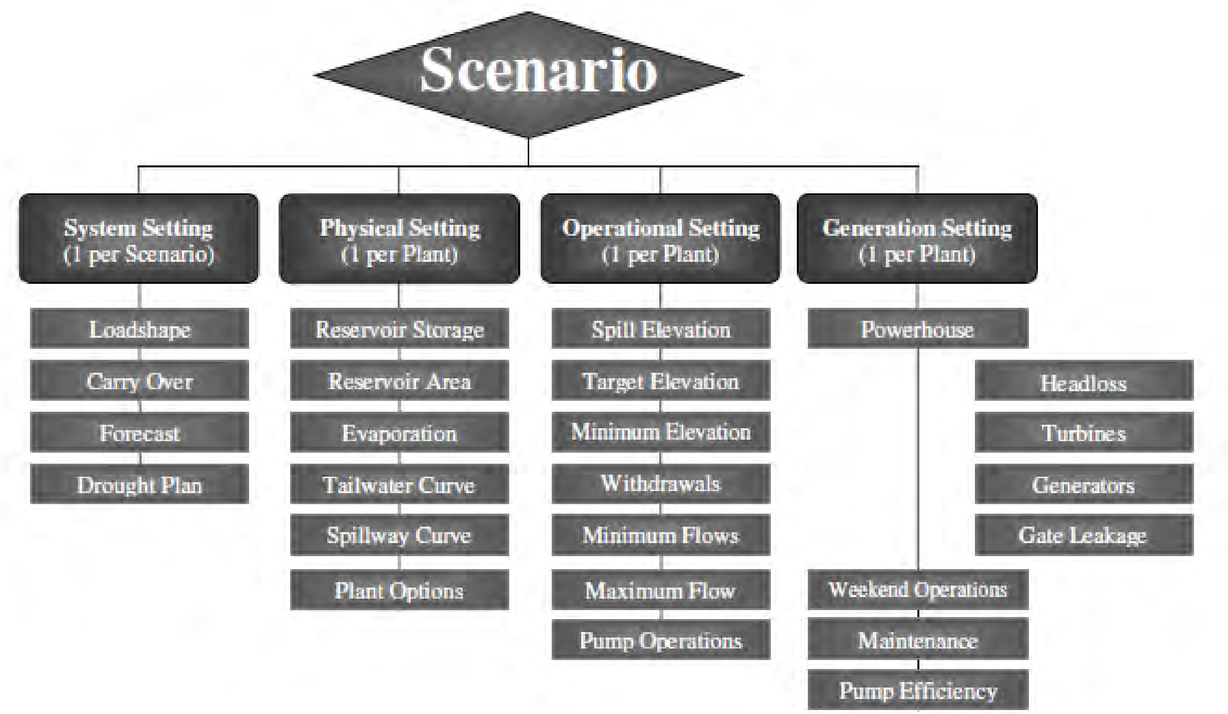
  The Baseline scenario is based on the NAA scenario, except the minimum reservoir elevation at Lake Keowee is increased from 778 to 794.6 ft AMSL. The overall methodology used to determine required weekly releases from Lake Keowee remains unchanged. This scenario best describes the current/existing operations of the Duke Energy reservoirs.

- Historical Baseline (Verification)

  The Historical Baseline is used for model verification and represents the Baseline scenario with the addition of historical water use (median 2003-2008) and USACE flow requirements to simulate actual historical operations.

The following sections are organized following the four components that define an SR CHEOPS Model scenario along with example inputs within each component, as shown in Figure 3-3.

FIGURE 3-3
SR CHEOPS MODEL SCENARIO



3.2.1 System Data

3.2.1.1 Load Shapes and Energy Values

This section contains the load shape and energy value data common to all six facilities on the Savannah River. The SR CHEOPS Model load shape defines the daily schedule of relative power pricing and the hour durations of each price in the peak, off-peak, and shoulder periods, as presented in Table 3-1. The model uses the load shape data to schedule the release of water throughout the day, prioritizing generation during peak periods. Durations for load shape periods were input as a standard 6 by 16 (16 hours of peak period generation). Dollar values for the weekday load shape periods were provided by Southeastern Power Administration (SEPA). Weekend generation values were estimated at 75 percent of the weekday values.

3.2.1.2 Carry-Over Elevations Condition

The SR CHEOPS Model Carry-Over Elevations Condition controls how to treat the beginning- and end-of-year elevations. The model begins the run on January 1 of the start year with each reservoir at its target elevation. If the scenario is run for a multiple year period, then the model can either start subsequent years with the reservoirs at the target elevations or at the end of previous year elevations.

The Carry-Over Elevations is selected (the checkbox is checked) in this model. Therefore, the model will carry-over the end-of-year elevations to the next year, and reservoirs will start the next year at the ending elevations of the previous year.

TABLE 3-1
LOAD SHAPE

Month	Weekday Durations in Hours							Weekday Power Values in "Normalized" Dollars		
	Morning Off-Peak	Morning Secondary Peak	Morning Peak	Afternoon Secondary Peak	Afternoon Peak	Evening Secondary Peak	Evening Off-Peak	Off-Peak	Secondary Peak	Peak
Jan	6	0	8	0	8	0	2	43.48	60.54	77.6
Feb	6	0	8	0	8	0	2	42.76	55.69	68.62
Mar	6	0	8	0	8	0	2	36.53	57.77	79.01
Apr	6	0	8	0	8	0	2	35.7	52.71	69.71
May	6	0	8	0	8	0	2	26.84	46.82	66.79
Jun	6	0	8	0	8	0	2	36.72	64.27	91.81
Jul	6	0	8	0	8	0	2	35.77	63.08	90.39
Aug	6	0	8	0	8	0	2	41.86	64.62	87.37
Sep	6	0	8	0	8	0	2	32.86	48.79	64.71
Oct	6	0	8	0	8	0	2	35.84	48.33	60.82
Nov	6	0	8	0	8	0	2	37.01	47.08	57.15
Dec	6	0	8	0	8	0	2	41.37	57.28	73.19

Month	Weekend Durations in Hours					Weekend Power Values in "Normalized" Dollars	
	Morning Off-Peak	Morning Peak	Afternoon Off-Peak	Afternoon Peak	Evening Off-Peak	Off-Peak	Peak
Jan	6	8	0	8	2	32.61	58.2
Feb	6	8	0	8	2	32.07	51.47
Mar	6	8	0	8	2	27.4	59.26
Apr	6	8	0	8	2	26.78	52.28
May	6	8	0	8	2	20.13	50.09
Jun	6	8	0	8	2	27.54	68.86
Jul	6	8	0	8	2	26.83	67.79
Aug	6	8	0	8	2	31.4	65.53
Sep	6	8	0	8	2	24.65	48.53
Oct	6	8	0	8	2	26.88	45.62
Nov	6	8	0	8	2	27.76	42.86
Dec	6	8	0	8	2	31.03	54.89

3.2.1.3 Forecast Set-Up Condition

The SR CHEOPS Model Forecast Set-Up Condition requires two inputs: a number of forecast days, and an accuracy of the forecast. The number of days is how many days the model looks ahead in the inflow file to calculate how much water the system is going to receive. The model is set up to look 1 day ahead with 100 percent accuracy. Since the model has "perfect" forecasting as it looks at the actual inflow file, the accuracy setting allows the user to adjust the model's ability to forecast accurately. The accuracy setting adjusts inflow by a fixed multiple. The model looks ahead the given number of days, adds up the inflows, multiplies those inflows by the entered accuracy value, then schedules releases based on this forecasted inflow volume. If the accuracy setting is not 100 percent (1), then the forecasted volume is not accurate. By running the model with 90 percent (0.9) accuracy, and then running again at 110 percent (1.1) accuracy, the user can simulate operations where the operator has an ability to forecast inflows with plus or minus 10 percent accuracy.

3.2.1.4 Drought Plan Condition (Storage Balance Operation)

This section provides details of the storage relationship between the Duke Energy and USACE facilities and how the storage relationship is modeled (USACE 1989, 2006, 2011).

On October 1, 1968, Duke Energy's predecessor company, Duke Power Company, entered into the 1968 Agreement with the USACE Savannah District and the SEPA regarding stored water sharing (releases) from the Project (Duke Power Company 1968). The 1968 Agreement defines balancing of the available storage in Duke Energy reservoirs (Lake Jocassee and Lake Keowee) with available storage in the USACE reservoirs (Hartwell Lake and J. Strom Thurmond Lake) according to storage balance rules as outlined in the 1968 Agreement. The SR CHEOPS Model incorporates the terms of the 1968 Agreement through a series of programming rules. These rules are integral in simulating the storage relationships between the facilities and significant time was spent by HDR and the USACE refining these rules in the SR ResSim Model. The SR CHEOPS Model was developed with two options for implementing the 1968 Agreement; as written and as developed and used in the SR ResSim Model. The logic applied in the SR

CHEOPS Model is the "By Agreement" logic which follows the language of the 1968 Agreement.

The SR CHEOPS Model incorporates the terms of the 1968 Agreement through a series of programming rules and follows the language of the 1968 Agreement. When a tandem or parallel reservoir system is defined within SR CHEOPS Model, the model determines the priority and the amount of release to make from each reservoir in order to operate towards a user defined storage balance. For every decision interval, an end-of-period storage is first estimated for each reservoir based on the sum of beginning-of-period storage and period average inflow volume, minus all potential outflow volumes. The estimated end-of-period storage for each reservoir is compared to a desired storage that is determined by using a system storage balance scheme. The priority for release is then given to the reservoir that is furthest above the desired storage. When a final release decision is made, the end-of-period storages are recomputed. Depending on other constraints or higher priority rules, system operation strives for a storage balance such that the reservoirs have either reached their guide curves or they are operating at the desired storage (percent of the active storage zone).

The SR CHEOPS Model follows the 1968 Agreement where balance checks are performed on a weekly basis

3.2.1.5 Low Inflow Protocol (LIP)

This section provides details of the SR CHEOPS Model functionality to simulate the Keowee-Toxaway LIP. The LIP functionality was added to enable LIP stage definitions, and specify required actions for each LIP stage. Model logic measures, on the specified day, the Duke Energy usable storage based on Full Pond Elevations and gage hydrology, then implements the LIP stage change after the appropriate delay. The LIP adds Bad Creek and Richard B. Russell reservoirs to the USACE DP usable storage calculations, which requires modifications to the USACE DP input file. The modifications to the USACE DP file to reflect the proposed LIP include specifying whether or not to include the Bad Creek and Richard B. Russell reservoirs in the usable storage calculation, and also provided cells for inputting the elevation which is considered bottom of usable storage pool for all six reservoirs.

Additionally, Keowee-Toxaway LIP/DP functionality includes the following logic:

- Functionality to allow the user to limit spring lake stabilization to LIP stage -1 (Normal).
- Functionality to allow the user to specify that the USACE and Duke Energy reservoir storage balancing logic use full pond elevation versus target elevation at Duke Energy reservoirs for calculations of usable storage.
- Functionality to fine-tune simulated Lake Keowee operations and limit discharge from Lake Keowee by allowing the user to define a percentage above the target curve (published in the 1968 Agreement) for the model to attempt to maintain a Full Pool.
- Functionality to allow the user to define two Maximum Required Weekly Release volumes from Lake Keowee for LIP stage 4. The first based on a Duke Percent Usable Storage Remaining trigger and the second is the default if less than the defined Duke Percent Usable Storage Remaining.
- Functionality to allow the user to revise the LIP logic to reference "triggered" DP level versus "In-Effect" DP level during LIP recovery. This allows the LIP to more quickly change to a lower stage number during recovery process, eliminating the 2-foot recovery delay in DP protocol.
- Ability to set lake level fluctuation base elevation to be set at the lowest instantaneous elevation from the day prior to the start of the lake stabilization period.

3.2.1.6 System Power

The USACE Projects have a power generation requirement with SEPA to achieve a minimum generation value. The weekly generation requirement can be met by any combination of the three USACE Projects, and the requirement value varies by month. The weekly targets are based on power contracts with SEPA, as listed in Table 3-2. These values are currently entered into the model in the Drought Plan input sheet.

TABLE 3-2
WEEKLY TARGET GENERATION FROM USACE PROJECTS

Month	Weekly Target Generation (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

3.2.2 Physical Data

3.2.2.1 Reservoir Storage Curves

The Reservoir Storage Curve is a tabulated link between the reservoir elevation and reservoir volume. The elevations are in units of "feet" and the volumes are in "acre-feet." The SR CHEOPS Model uses this curve to calculate elevations based on inflows and model-determined releases. Figure 3-6 shows the Bad Creek reservoir storage curve used in the model. The data is from License Exhibit I (Duke Power Company 1974). The Lake Jocassee and Lake Keowee storage-volume relationships were based on bathymetric data collected in 2010 (Figures 3-7 and 3-8) and the USACE storage-volume relationships for Hartwell, Richard B. Russell, and J. Strom Thurmond Lakes were based on published storage-volume relationships revised based on applying regional sedimentation rates from the Savannah River Basin. Sedimentation rates were converted to sediment volume using methods outlined in USACE EM 1110-2-4000 and estimated compressed density of the sediment (Figures 3-9 through 3-11). A summary of the sedimentation calculations is provided in Appendix A.

FIGURE 3-4
BAD CREEK RESERVOIR STORAGE VOLUME CURVE

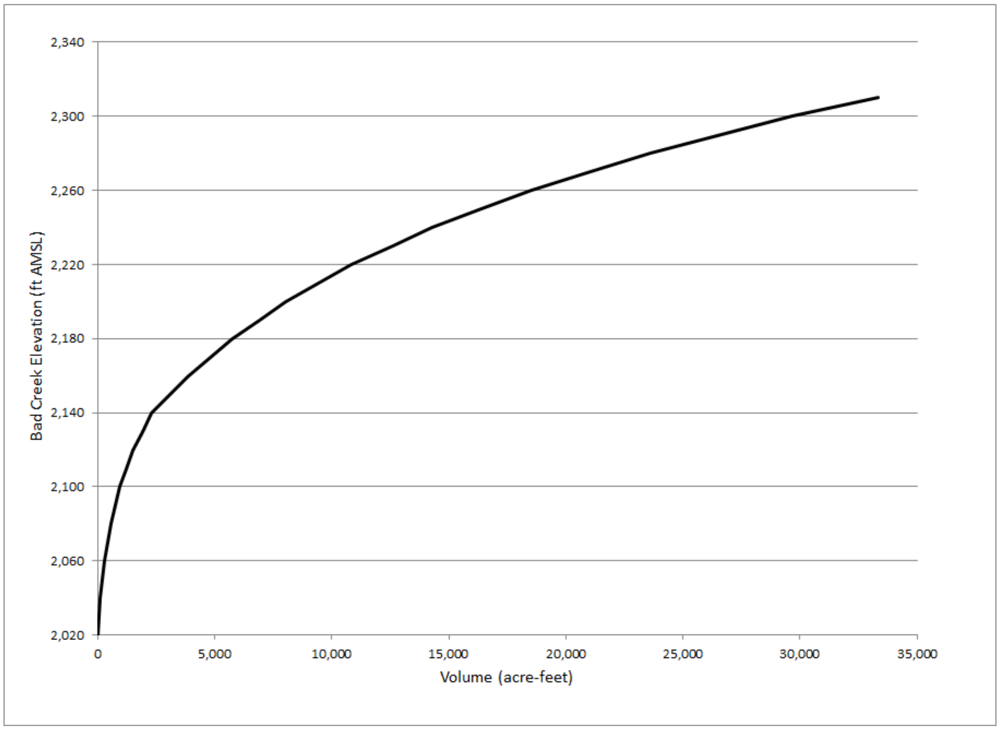


FIGURE 3-5
JOCASSEE RESERVOIR STORAGE VOLUME CURVE

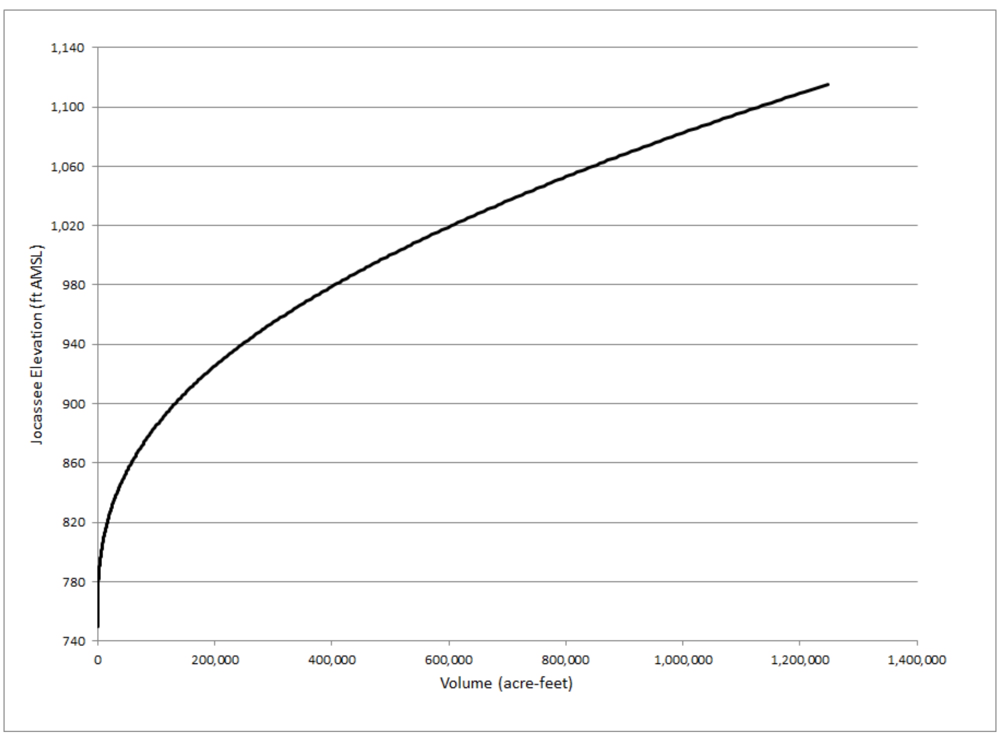


FIGURE 3-6
KEOWEE RESERVOIR STORAGE VOLUME CURVE

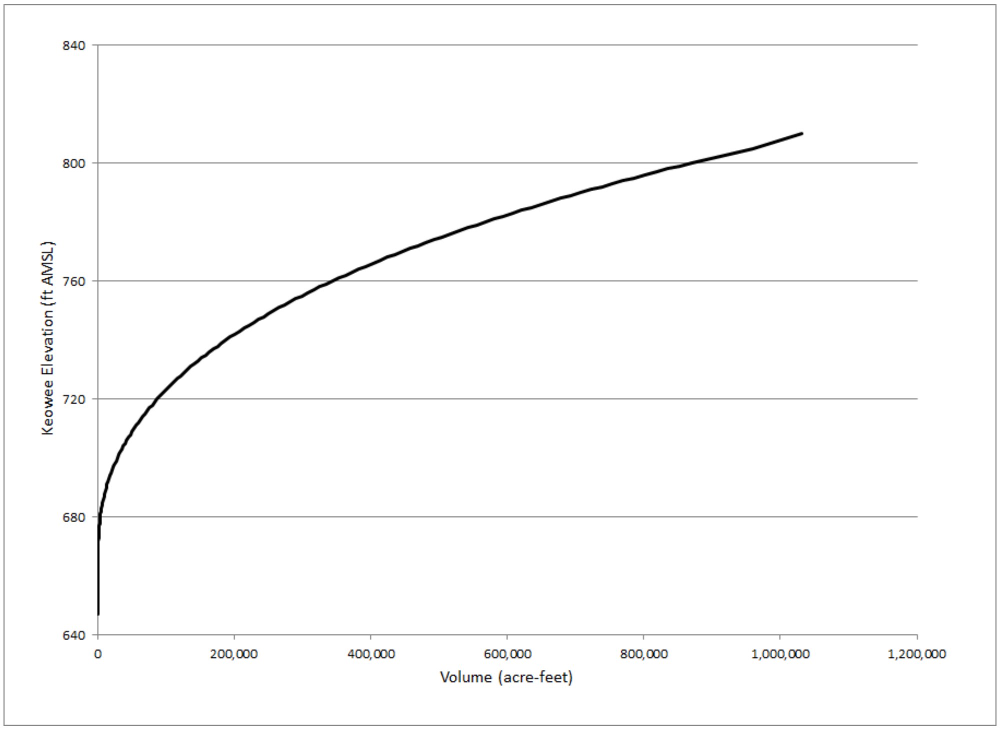


FIGURE 3-7
HARTWELL RESERVOIR STORAGE VOLUME CURVE

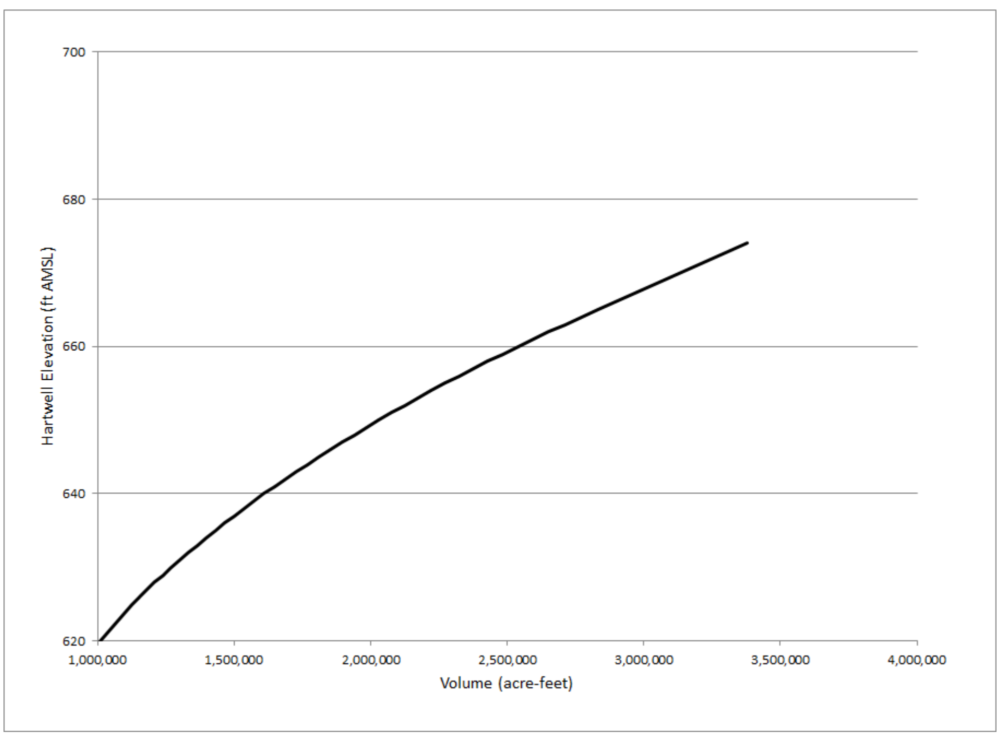


FIGURE 3-8
RICHARD B. RUSSELL RESERVOIR STORAGE VOLUME CURVE

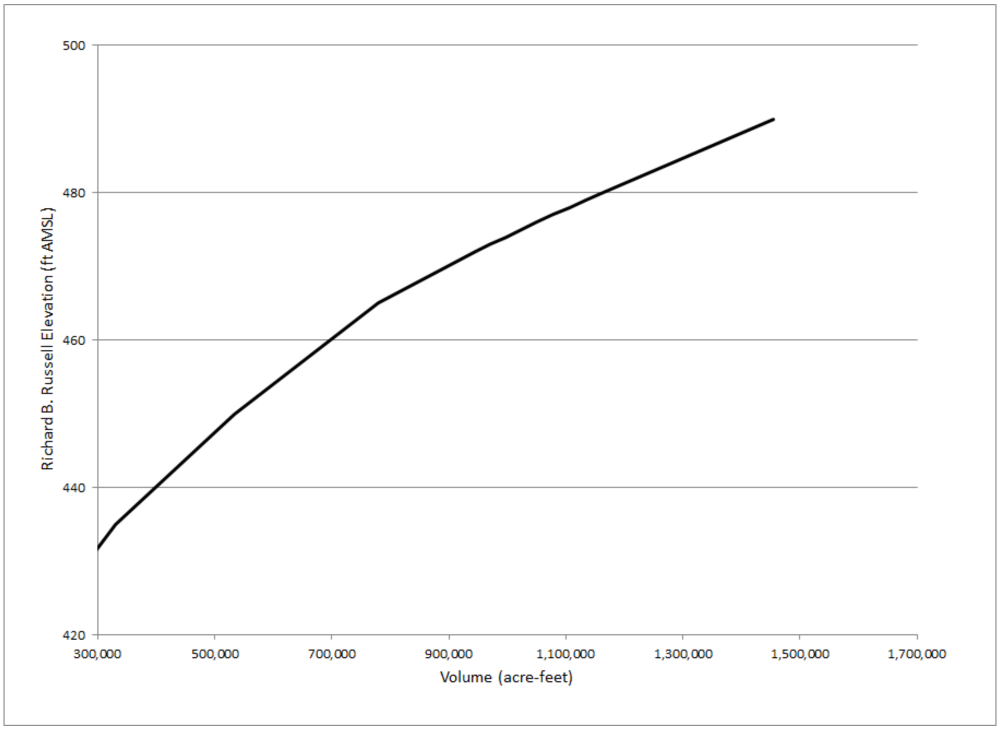
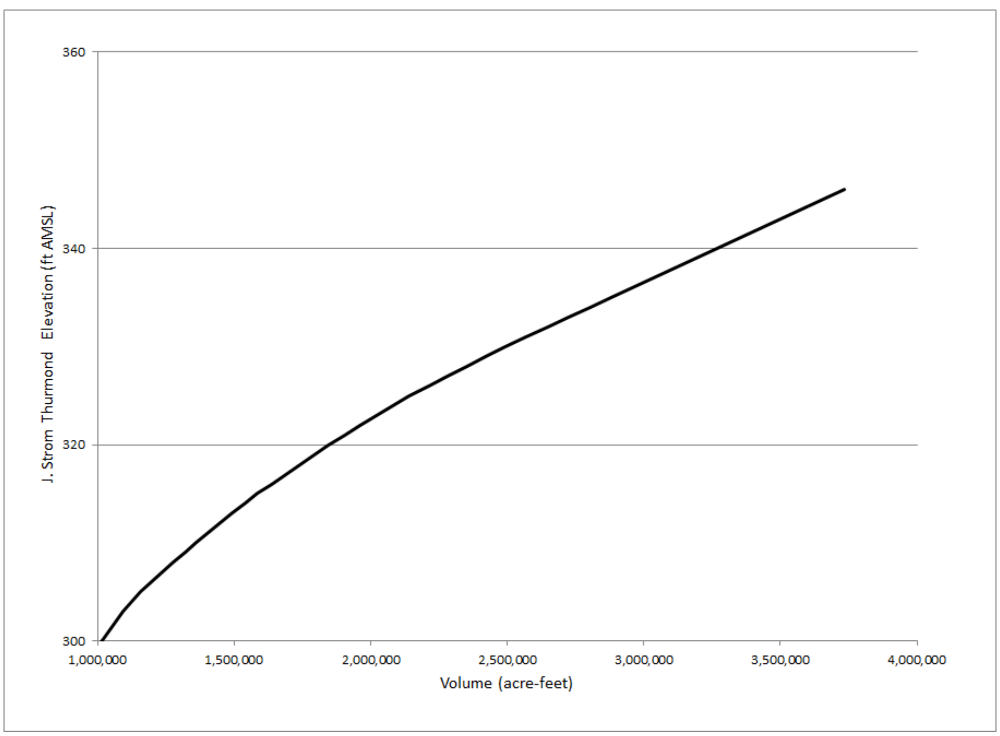


FIGURE 3-9
J. STROM THURMOND RESERVOIR STORAGE VOLUME CURVE



3.2.2.2 Reservoir Area Curves

The Reservoir Area Curve is a tabulated link between the reservoir elevation and reservoir surface area. The elevations are in units of "feet" and the areas are in "acres." The SR CHEOPS Model uses this curve to calculate the surface area and uses this data for computing evaporation losses. Figures 3-12 through 3-17 show the reservoir area curves used in the model.

FIGURE 3-10
BAD CREEK RESERVOIR AREA CURVE

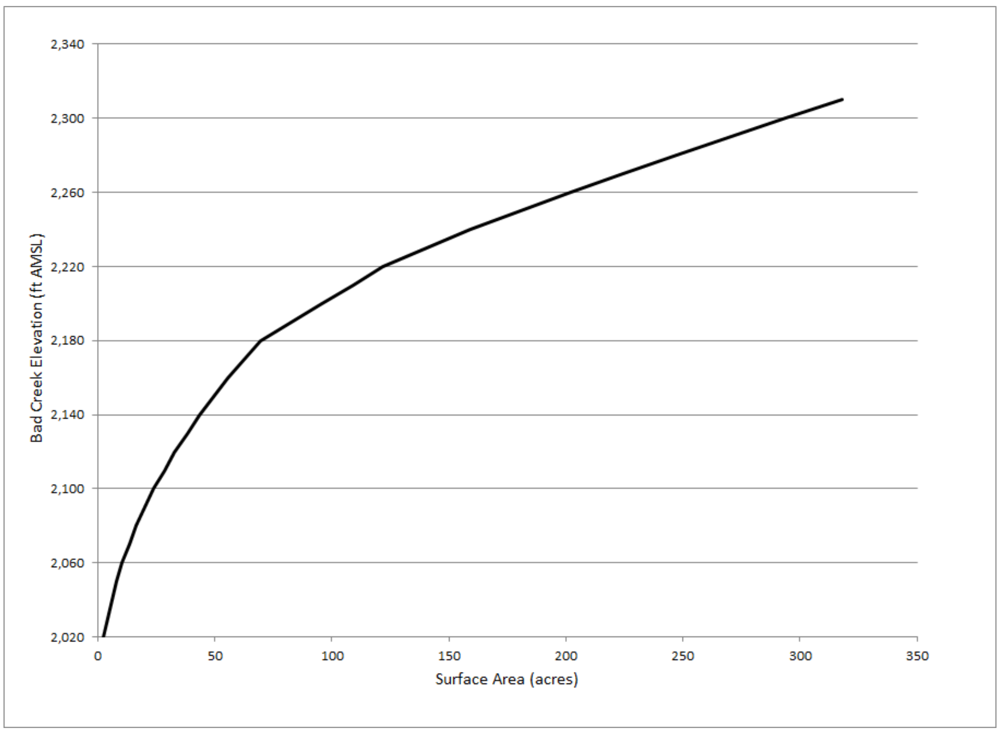


FIGURE 3-11
JOCASSEE RESERVOIR AREA CURVE

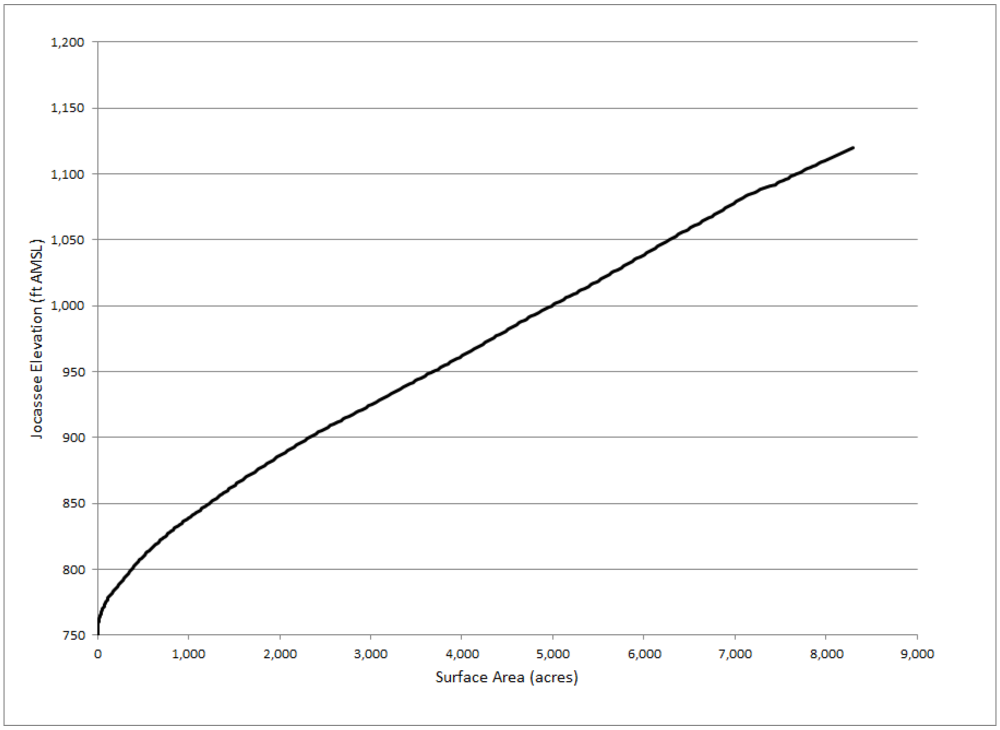


FIGURE 3-12
KEOWEE RESERVOIR AREA CURVE

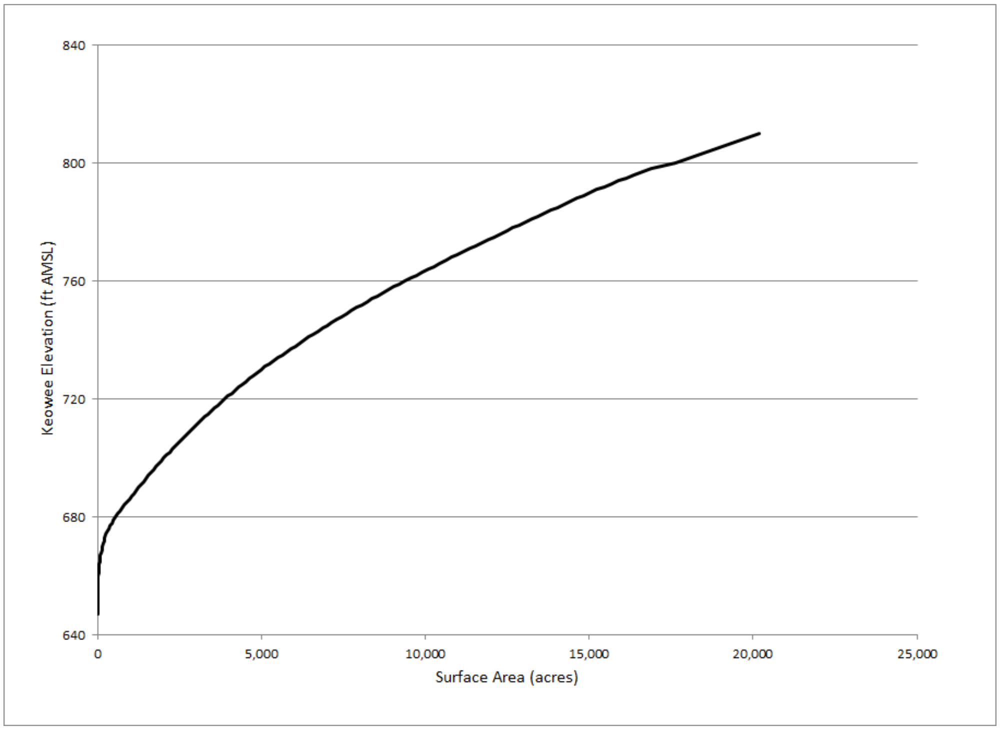


FIGURE 3-13
HARTWELL RESERVOIR AREA CURVE

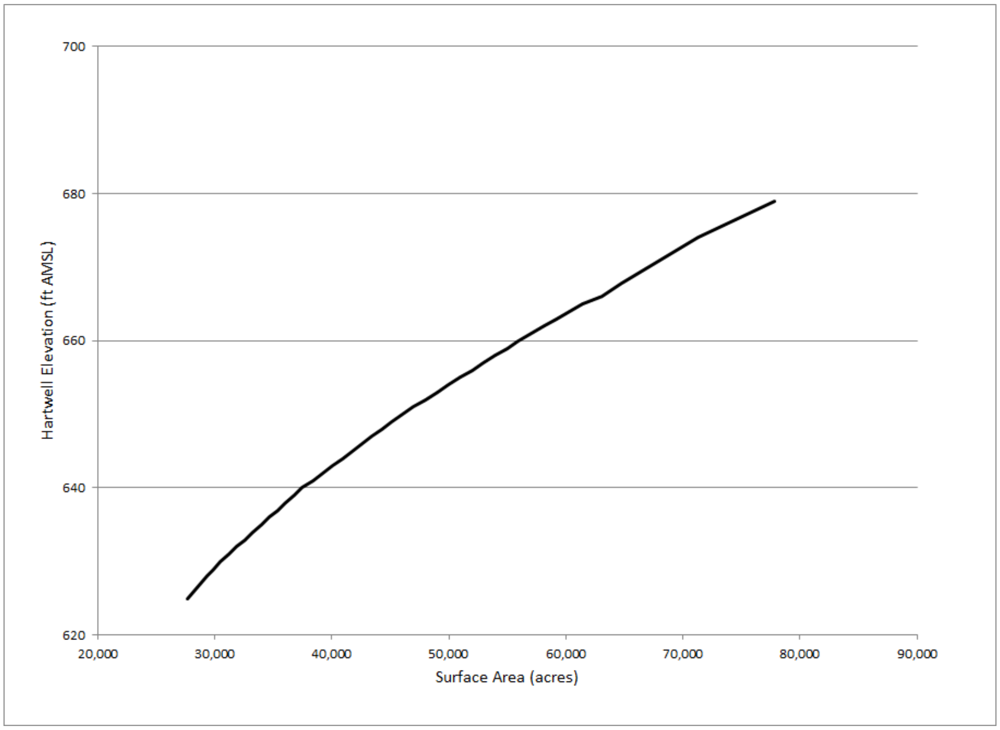


FIGURE 3-14
RICHARD B. RUSSELL RESERVOIR AREA CURVE

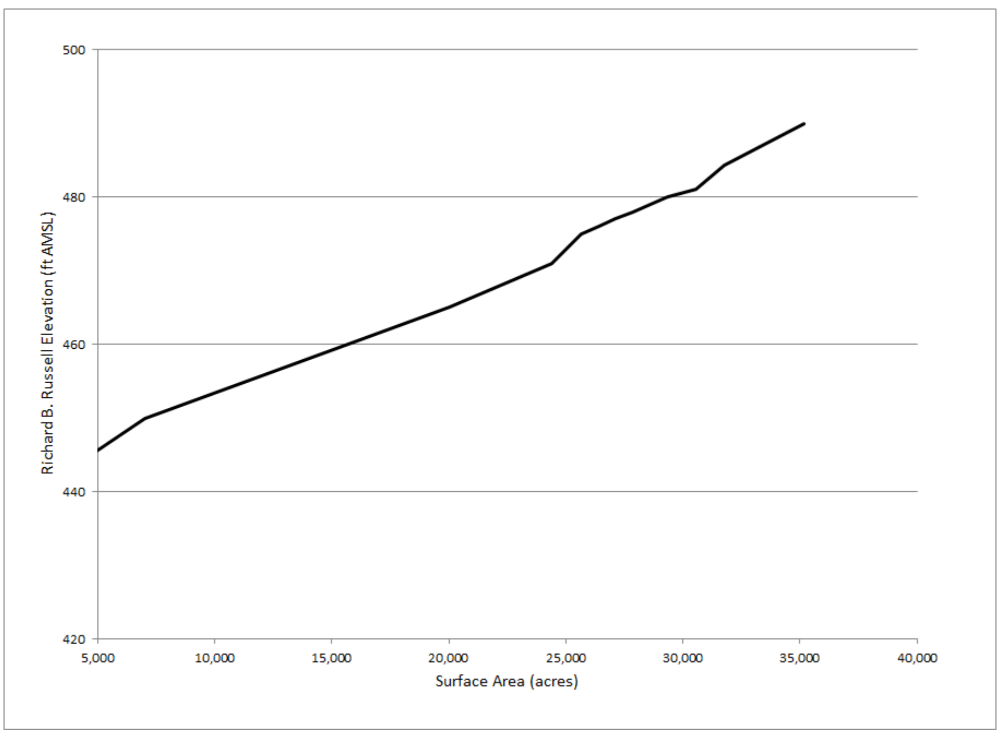
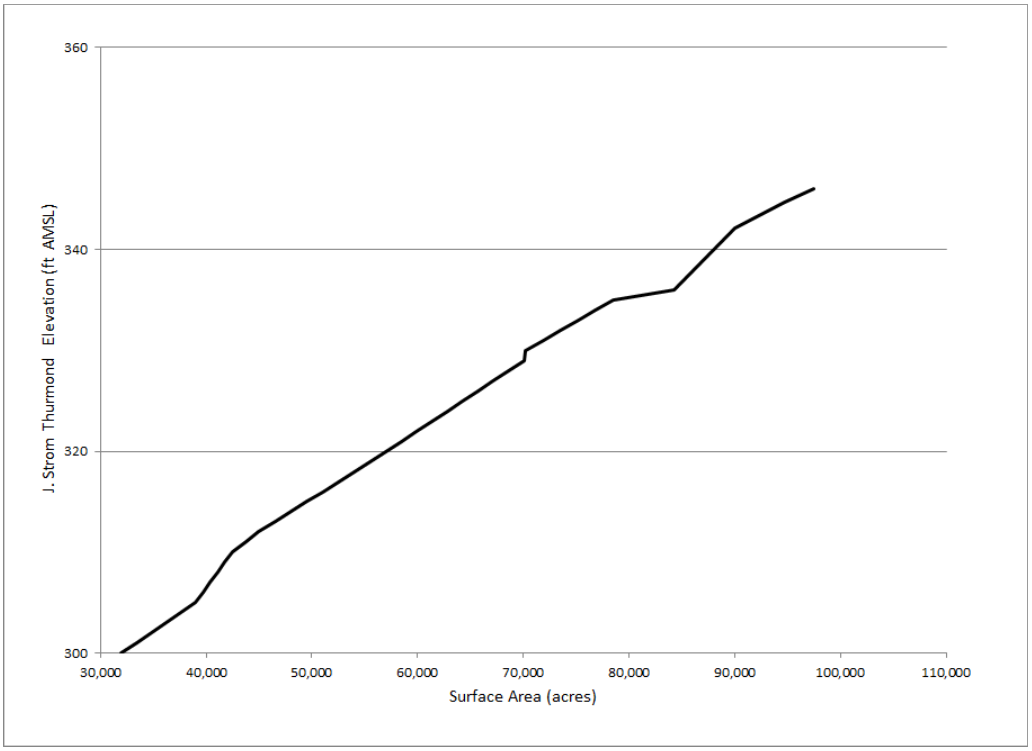


FIGURE 3-15
J. STROM THURMOND RESERVOIR AREA CURVE



3.2.2.3 Monthly Evaporation

Evaporation is based upon a monthly varying coefficient that defines the evaporative loss per reservoir. This evaporative loss is not strictly composed of losses due to evaporation, but rather a net change to inflows due to evaporation, direct precipitation to water surface, precipitation runoff, and changes to evapotranspiration losses. Negative values indicate a net inflow to the reservoir. Based on the median data, the precipitation inflow to the reservoir exceeds the evaporation from the reservoir. This coefficient (which is entered into the model in feet per day per acre) is multiplied by the surface area of the reservoir to compute total evaporative loss volume for the reservoir. Table 3-3 shows the SR CHEOPS Model evaporation loss coefficients for each reservoir by month. The evaporation loss coefficients reflect the monthly 2008 values published by ARCADIS in the Savannah River Basin May 13, 2013, time series release (ARCADIS 2010, 2013). The September 16, 2010 ARCADIS time series release contains the same 2008 evaporation values as provided in the May 2013 release. The modeled evaporation rates in the SR ResSim Model reflect the 2008 evaporation loss coefficients.

TABLE 3-3
EVAPORATIVE LOSS COEFFICIENTS

Month	Bad Creek Evaporation Loss (ft/day/acre)	Jocassee Evaporation Loss (ft/day/acre)	Keowee Evaporation Loss (ft/day/acre)	Hartwell Evaporation Loss (ft/day/acre)	Richard B. Russell Evaporation Loss (ft/day/acre)	J. Strom Thurmond Evaporation Loss (ft/day/acre)
Jan	-4.2E-03	-2.8E-03	-1.5E-03	-1.5E-03	-1.1E-03	-3.2E-03
Feb	-2.3E-03	-7.6E-04	1.0E-04	4.3E-05	-5.7E-04	-1.9E-03
Mar	-6.8E-03	-4.2E-03	6.9E-05	1.6E-05	-6.2E-05	-8.3E-05
Apr	2.5E-03	4.0E-03	4.6E-03	4.1E-03	4.1E-03	3.6E-03
May	6.1E-03	7.4E-03	6.6E-03	7.6E-03	9.6E-03	8.9E-03
Jun	1.1E-02	1.2E-02	1.3E-02	1.2E-02	1.3E-02	1.3E-02
Jul	6.3E-03	8.0E-03	9.1E-03	8.6E-03	6.5E-03	7.8E-03
Aug	-1.2E-03	1.2E-03	1.0E-03	1.9E-03	4.2E-03	3.9E-03
Sep	5.4E-03	6.4E-03	7.1E-03	7.9E-03	6.7E-03	6.4E-03
Oct	7.4E-04	1.8E-03	2.6E-03	2.1E-03	8.5E-04	7.4E-04
Nov	-1.6E-03	-6.5E-04	1.3E-04	1.3E-04	-1.1E-03	-6.4E-03
Dec	-8.8E-03	-6.6E-03	-5.8E-03	-4.9E-03	-3.0E-03	-3.4E-03

3.2.2.4 Tailwater Data

The Tailwater Curve relates the powerhouse tailwater elevation to the facility's outflow. In cases where the powerhouse releases directly into a downstream reservoir, the downstream reservoir's elevation is used to compute tailwater elevation. The elevation is in units of "feet" while the flow is in cubic feet per second, or "cfs." The tailwater elevation is subtracted from the reservoir elevation to calculate the gross head used in determining turbine and pump-turbine hydraulic performance.

Bad Creek Project releases directly into Lake Jocassee, so the elevation of Lake Jocassee is the controlling factor for the Bad Creek Project tailwater elevation. Likewise, the Jocassee powerhouse releases directly into Lake Keowee. Therefore, the elevation of Lake Keowee is the controlling factor for the Jocassee Development tailwater elevation computation.

The Keowee powerhouse discharges into Hartwell Lake. However, due to backwater effects in the upstream lake channel, there is a difference between Hartwell Lake elevation (at Hartwell Dam) and the water surface elevation below the Keowee powerhouse when the turbines are in operation. Table 3-4 shows the Keowee powerhouse tailwater curve in stage units of feet for various powerhouse outflows in cfs.

TABLE 3-4
KEOWEE POWERHOUSE TAILWATER RATING CURVE

Stage (ft AMSL)	Flow (cfs)	Stage (ft AMSL)	Flow (cfs)
657	0	680	39,867
660	5,042	684.8	59,879
665.1	11,345	689.9	85,879
670	16,545	695	113,612
674.9	26,000		

Similar to the Bad Creek Project and Lake Jocassee, the Hartwell powerhouse releases directly into Richard B. Russell Lake without backwater effects. Therefore, the Richard B. Russell Lake elevation is the control for the Hartwell Project tailwater elevation. The SR CHEOPS Model uses the greater of 470 ft AMSL or Richard B. Russell Lake water surface elevation. Reservoir elevation 470 ft AMSL is the minimum tailwater elevation provided by the USACE for modeling purposes. Richard B. Russell powerhouse releases into J. Strom Thurmond Lake. The J. Strom Thurmond Lake elevation is the control for Richard B. Russell Project tailwater elevation. The J. Strom Thurmond Project tailwater rating curve is shown in Table 3-5.

TABLE 3-5
J. STROM THURMOND POWERHOUSE TAILWATER RATING CURVE

Stage (ft AMSL)	Flow (cfs)	Stage (ft AMSL)	Flow (cfs)
187	0	220	280,000
190	15,000	230	440,000
200	65,000	240	640,000
210	155,000	250	870,000

3.2.2.5 Spillway Capacity

The Spillway Curve contains the data relating reservoir elevation (feet) and spillway discharge capacity (cfs). This data allows the model to determine the maximum amount of water that can be spilled at the current reservoir elevation and is the sum of all spillway conveyances with gates open to maximum setting. The SR CHEOPS Model allows for a simple spillway relationship of elevation and flow; therefore, all spillways, including gates, are modeled as a relationship of elevation and flow.

Spillway capacity data for the Bad Creek Project is shown in Table 3-6, derived from the Bad Creek Pumped Storage Project Supporting Technical Information (Duke Energy 2008). The Bad Creek emergency spillway is also known as the East Dike.

TABLE 3-6
BAD CREEK SPILLWAY CAPACITY VALUES

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
2,313.5	0	2,315	2,313
2,313.8	17	2,315.5	4,477
2,314.3	477	2,316	7,153
2,314.6	1,051		

Table 3-7 shows the maximum spillway capacity of the two-gated spillways as delineated in the Jocassee Development Supporting Technical Information (HDR 2010).

TABLE 3-7
JOCASSEE SPILLWAY (TOTAL GATED) CAPACITY VALUES

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
1,077	0	1102	34,531
1,082	2,762	1107	46,054
1,087	8,117	1112	58,671
1,092	15,374	1117	67,321
1,097	24,248	1122	74,138

Table 3-8 shows the spillway capacity of the four-gated spillways as delineated in the Keowee Development Supporting Technical Information (HDR 2012).

TABLE 3-8
KEOWEE SPILLWAY (TOTAL GATED) CAPACITY VALUES

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
765	0	790	63,268
770	5,505	795	82,550
775	15,851	800	102,810
780	29,399	805	123,645
785	45,393	810	144,639

The spillway capacities of the USACE projects are shown in Tables 3-9 through 3-11. These values include original data provided by the USACE, as represented in the SR ResSim Model.

TABLE 3-9
HARTWELL SPILLWAY (TOTAL GATED) CAPACITY VALUES

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
630	0	657	258,924	666	416,148
635	16,800	658	274,896	667	434,184
640	52,800	659	291,288	668	452,508
645	102,000	660	308,100	669	471,120
650	160,800	661	325,320	670	489,996
653	199,248	662	342,972	671	509,160
654	213,540	663	361,032	672	528,600
655	228,252	664	379,500	673	548,316
656	243,384	665	398,400	674	568,308

TABLE 3-10
RICHARD B. RUSSELL SPILLWAY (TOTAL GATED) CAPACITY VALUES

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
436	0	473	0	482	630,000
440	0	474	0	483	650,000
450	0	475	0	484	670,000
455	0	476	0	485	690,000
460	0	477	0	486	710,000
465	0	478	0	487	725,000
470	0	479	0	488	740,000
471	0	480	593,000	489	755,000
472	0	481	620,000	490	771,000

*Spill elevation set to 475.3 ft AMSL and spillway capacity set to zero below 480 ft AMSL to support logic to prevent pumping above 475 ft AMSL.

TABLE 3-11
J. STROM THURMOND SPILLWAY (TOTAL GATED) CAPACITY VALUES

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
300	0	325	405,000
305	27,000	330	545,000
310	95,000	335	688,000
315	182,000	340	855,000
320	282,000	345	1,025,000

3.2.2.6 Plant Operation Type

The Plant Operation Type is how the SR CHEOPS Model classifies and operates the plants. Four different components are used to describe the operation of the plants.

- Min Powerhouse Flow – All plants in this model have zero (0) value entered, as the turbine input curves accurately define the lowest operating flow of the units.
- Plant Operation Type – This condition specifies what type of scheduling logic is to be used for the plant. Options include Strictly Peaking, Non-generating, Run-of-River, and others. The plant operation types for the nodes in this model are shown below. Pumped storage

plants follow pumping and discharge schedules. Strictly peaking plants use logic to generate as much power as possible during the peak period, followed by secondary-peak and then off-peak periods. Hybrid-pumped storage plants have a pumping schedule, but schedule plant discharge using peaking plant logic.

- Bad Creek – Pumped Storage
- Jocassee – Hybrid-Pumped Storage
- Keowee – Strictly Peaking
- Hartwell – Strictly Peaking
- Richard B. Russell – Hybrid-Pumped Storage
- J. Strom Thurmond – Strictly Peaking

- Delinked Owner – This condition sets the level of water conveyance support a plant receives and provides to other plants operated by the same licensee/operator. All plants in the model have this value unchecked, meaning the plants provide supporting operation to other plants operated by the same owner.
- Delinked System – This condition sets the level of support a plant receives and provides to other plants operated by other licensees/operators in the modeled system. All plants in this model have this condition checked, meaning the default SR CHEOPS Model logic for support between plants is not in effect for plants operated by different operators. In this model, other methods and rules of setting the support between plants and owners are used.

3.2.3 Operational Data

3.2.3.1 Spill and Minimum Elevations

The spill or flood control elevation relates to a variety of physical situations (spillway crest, partial gate coverage, maximum normal pool, etc.), but it represents the elevation at which the model will begin to simulate spill to avoid increasing water elevation. Under a strictly peaking plant, when the model calculates an end of period elevation above the spill elevation, the model will calculate spill as well as the turbine/diversion discharge. The model's logic, under a strictly peaking plant, also attempts to reduce or eliminate occurrences when the reservoir elevation exceeds the spill elevation.

The minimum elevation is the minimum allowable reservoir elevation. The elevation could be set by regulations or by a physical limit (lowest available outlet invert). Bypass flows, withdrawals, wicket gate leakage, and evaporation can draw the reservoir below this level. The model will operate to eliminate occurrences when the reservoir elevation dips below this elevation.

Table 3-12 lists the spill and minimum elevations for each facility in the SR CHEOPS Model.

TABLE 3-12
RESERVOIR SPILL AND MINIMUM ELEVATIONS

Facility	Spill Elevation (ft AMSL)	Minimum Elevation (ft AMSL)
Bad Creek	2,310	2,150
Jocassee	1,110	1,080
Keowee	800	794.6
Hartwell	665	625
Richard B. Russell*	475.3	470
J. Strom Thurmond	335	312

* Richard B. Russell spill elevation set to 475.3 ft AMSL and spillway capacity set to zero below 480 ft AMSL to support logic to prevent pumping above 475 ft AMSL.

3.2.3.2 Target Elevations

The target elevation is the user-defined elevation that the model attempts to meet (targets) as the end-of-day reservoir elevation. The model straight line interpolates between user input points to identify a target elevation for each day. The model will deviate from the target to accommodate forecasted inflows, to meet the plant's own outflow requirements or constraints, and to support downstream minimum flow requirements from the J. Strom Thurmond Project.

Table 3-13 lists the guide curve elevations for the Duke Energy reservoirs (curves needed for modeling), and Table 3-14 lists the guide curves for the USACE reservoirs. Target requirements for the USACE Projects were provided by the USACE with the SR ResSim Model.

TABLE 3-13
GUIDE CURVE TARGET ELEVATIONS OF DUKE ENERGY RESERVOIRS

Day of Year	Bad Creek Target Elevation (ft AMSL)	Jocassee Target Elevation (ft AMSL)	Keowee Target Elevation (ft AMSL)
Jan 1	2,280	1,106	796
May 1	2,280	1,109.5	799
Oct 15	2,280	1,109.5	799
Dec 31	2,280	1,106	796

TABLE 3-14
GUIDE CURVE TARGET ELEVATIONS OF USACE RESERVOIRS

Day of Year	Hartwell Target Elevation (ft AMSL)	Richard B. Russell Target Elevation (ft AMSL)	J. Strom Thurmond Target Elevation (ft AMSL)
Jan 1	656	475	326
Apr 1	660	475	330
Oct 15	660	475	330
Dec 15	656	475	326

3.2.3.3 Water Withdrawals

Historical water use (withdrawals and returns in cfs) were estimated as part of the Savannah River Basin September 16, 2010 UIF time series release (ARCADIS 2010, 2013). The median 2003-2008 monthly water use in cfs was modeled in the Historical Baseline scenario to represent historical municipal and industrial water use from each reservoir. Table 3-15 shows the Historical Baseline scenario modeled withdrawals and returns in cfs. Table 3-15 also represents the equivalent modeled water use in the SR ResSim Model verification. The example calculation below describes the withdrawal calculation for a reservoir for a month:

$$WR_{\mathrm{R1,Month}} = Median(WR_{Day,Year})$$

where: $WR_{R1,Month}$ is the net withdrawal in (cfs) for the reservoir for the month

$WR_{Day,Year}$ is the withdrawal (cfs) for the reservoir for each day of the month for each of the months of interest in the 2003 through 2008 period.

TABLE 3-15
2003-2008 MEDIAN MONTHLY WATER USE – HISTORICAL BASELINE SCENARIO

	Water Withdrawal (avg cfs/day)					
Day of Year	**Bad Creek**	**Jocassee**	**Keowee**	**Hartwell**	**Richard B. Russell**	**J. Strom Thurmond**
01-Jan	0.00	0.00	76.66	29.14	0.00	2.61
01-Feb	0.00	0.00	76.67	29.53	0.00	1.70
01-Mar	0.00	0.00	76.88	30.15	0.00	0.32
01-Apr	0.00	0.00	74.67	33.75	0.00	3.14
01-May	0.00	0.00	71.82	42.23	0.00	7.00
01-Jun	0.00	0.00	84.00	50.51	0.00	7.70
01-Jul	0.00	0.00	84.70	45.39	0.00	7.25
01-Aug	0.00	0.00	83.24	45.92	0.00	8.25
01-Sep	0.00	0.00	88.23	44.03	0.00	7.01
01-Oct	0.00	0.00	79.59	42.82	0.00	6.05
01-Nov	0.00	0.00	68.19	34.16	0.00	5.07
01-Dec	0.00	0.00	74.69	29.75	0.00	3.70

	Water Return (avg cfs/day)					
Day of Year	**Bad Creek**	**Jocassee**	**Keowee**	**Hartwell**	**Richard B. Russell**	**J. Strom Thurmond**
01-Jan	0.00	0.00	0.00	0.00	4.75	0.00
01-Feb	0.00	0.00	0.00	0.00	5.50	0.00
01-Mar	0.00	0.00	0.00	0.00	6.37	0.00
01-Apr	0.00	0.00	0.00	0.00	3.92	0.00
01-May	0.00	0.00	0.00	0.00	1.80	0.00
01-Jun	0.00	0.00	0.00	0.00	1.26	0.00
01-Jul	0.00	0.00	0.00	0.00	1.65	0.00
01-Aug	0.00	0.00	0.00	0.00	1.10	0.00
01-Sep	0.00	0.00	0.00	0.00	0.96	0.00
01-Oct	0.00	0.00	0.00	0.00	1.88	0.00
01-Nov	0.00	0.00	0.00	0.00	2.92	0.00
01-Dec	0.00	0.00	0.00	0.00	4.60	0.00

3.2.3.4 Minimum Flows

The Hartwell, Richard B. Russell, and J. Strom Thurmond Projects have fish spawning rules in the SR CHEOPS Model. The rule requires outflow to equal inflow if the reservoir is at or below target elevation during the month of April. Additionally, the J. Strom Thurmond Project has a required average daily discharge of at least 3,800 cfs year-round.

3.2.3.5 Maximum Flows

The model allows a maximum flow constraint to be applied either at a powerhouse or at a downstream node. This will limit operations to restrict flow to a maximum of the defined limit. The J. Strom Thurmond Project has a maximum flow restriction at the downstream node in Augusta, Georgia depending on the reservoir elevation of the J. Strom Thurmond Lake. If the lake elevation is below 330 ft AMSL, the maximum allowable flow at Augusta is 20,000 cfs; and if the reservoir elevation is greater than or equal to 330 ft, the maximum allowable flow is 30,000 cfs. These flow restrictions are based on goals for normal operation at the development. Under extreme flooding, these flows can be exceeded.

The Richard B. Russell Project has a maximum flow constraint of 60,000 cfs, and the Hartwell Project has a maximum flow constraint of 28,500 cfs.

3.2.3.6 Pump Operations

As previously noted, the Bad Creek Project uses pumped storage logic and the Jocassee Development and Richard B. Russell Project use hybrid-pumped storage logic. These settings require pump operations schedules. The Bad Creek Project pump operations specify pumping and discharge schedules (specified in the tables by number of units available to operate), while the Jocassee Development and Richard B. Russell specify pumping only. In Tables 3-16 through 3-18, pump operations schedules are described by negative numbers. The magnitude of each negative number indicated the number of units available for pumping in a given hour. Table 3-16 also includes positive numbers, which indicate discharge in the given hour.

The model will deviate from the user-specified pumping or generating schedule when certain conditions are encountered, such as when the upper reservoir is approaching the spill elevation, the lower reservoir is approaching the minimum elevation, and when a powerhouse is undergoing maintenance. Additionally, the model will attempt to avoid operations that may empty the upper reservoir, resulting in spill at the downstream reservoir, or end the day significantly different from the target elevation. The model does this by evaluating the starting elevation, desired ending elevation, and user-specified pumping and generating unit-hours for the day. Using pumping and generating volume capacities at the start of the day, the model will adjust (reduce only), the number of unit-hours to balance the generation volume and pumping volume, taking into account the desired daily change in storage. For example, if a user inputs four unit hours of generation and four unit hours of pumping, the model will reduce the generation unit-hours to three so the total volume released from the upper reservoir can be made up with the four unit hours in the pump schedule. The exception to this general rule is when a Drawdown Volume and Drawdown Days have been entered, which is the case for the Bad Creek Reservoir in certain scenarios. This logic will allow the generation volume to be higher than the pumping volume to cause the reservoir to draw down by the volume change identified. If the user inputs 5,000 ac-ft of volume drawdown over five days, the logic will compute the desired end of day elevation to be 1,000 ac-ft less than the target elevation, and will reduce generation and/or pumping hours to allow the 1,000 ac-ft of drawdown.

For hybrid-pumped storage logic, the model will pump with the specified number of units during the hours specified unless the upper reservoir approaches spill elevation, the lower reservoir approaches minimum elevation, or units are in maintenance. The generation release scheduling of a hybrid-pumped storage plant occurs just as if the plant is a typical peaking plant, where outflow is determined by change in storage and inflow, which includes upstream plant discharge, upstream plant bypass flow return, upstream plant spill, incremental accretions, water withdrawal returns, and pumping operations. A powerhouse will not be scheduled to release for generation if an hour has been specified for pumping operations and pumping was actually scheduled.

TABLE 3-16
BAD CREEK PROJECT PUMP OPERATIONS

Month	Day Set	Draw-down Days	Drawdown Volume (acre-ft)	Hour (number of units available per hour of the day)*																							
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	Weekdays	5	5,000	-3	-3	-3	-3	-3	-3	2	3	3	2	2	0	0	0	0	0	0	2	3	3	3	2	-2	-3
Jan	Saturdays			-2	-2	-2	-2	-2	-2	0	0	2	2	0	0	0	0	0	0	0	0	2	2	2	0	0	-2
Jan	Sundays			-3	-3	-4	-4	-4	-3	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	0	-2
Feb	Weekdays	5	5,000	-3	-3	-3	-3	-3	-2	2	3	3	3	3	2	0	0	0	0	0	0	3	3	3	2	0	-3
Feb	Saturdays			-3	-3	-3	-3	-3	-2	0	3	3	3	3	2	0	0	0	0	0	0	2	2	2	2	-2	-3
Feb	Sundays			-3	-3	-3	-3	-3	-3	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	-3	-3
Mar	Weekdays	5	5,000	-3	-3	-3	-3	-3	-3	0	2	2	2	2	2	2	3	2	2	2	2	2	3	3	2	-3	-3
Mar	Saturdays			-3	-3	-3	-3	-3	-3	0	2	3	3	3	2	2	0	0	0	0	0	2	2	3	2	-3	-3
Mar	Sundays			-3	-3	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	-3	-3
Apr	Weekdays	5	5,000	-3	-3	-3	-3	-3	-3	0	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	-3	-3
Apr	Saturdays			-3	-3	-3	-3	-3	-3	0	2	3	3	3	2	2	0	0	0	0	0	2	2	3	2	-3	-3
Apr	Sundays			-3	-3	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	-3	-3
May	Weekdays	5	5,000	-3	-3	-3	-3	-3	-3	0	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	-3	-3
May	Saturdays			-3	-3	-3	-3	-3	-3	0	2	3	3	3	2	2	0	0	0	0	0	2	2	3	2	-3	-3
May	Sundays			-3	-3	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	-3	-3
Jun	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	0	0	0	0	2	3	3	4	4	4	4	4	3	2	2	2	-3	-3
Jun	Saturdays			-3	-3	-3	-3	-3	-3	0	0	0	0	0	2	3	3	3	3	3	3	3	3	2	2	-3	-3
Jun	Sundays			-3	-3	-3	-3	-3	-3	0	0	0	0	0	0	0	2	3	4	4	4	3	2	2	0	-3	-3
Jul	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	0	0	0	0	2	3	3	3	3	3	3	3	3	3	3	2	0	-4
Jul	Saturdays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	2	2	3	3	3	3	3	3	3	2	0	-4
Jul	Sundays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	1	1	2	2	2	3	2	2	1	1	-4	-4
Aug	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	0	0	0	0	2	3	3	3	3	3	3	3	3	2	2	2	0	-4
Aug	Saturdays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	3	3	3	3	3	3	3	3	2	2	2	0	-4
Aug	Sundays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	1	2	2	2	2	2	1	1	2	1	0	-4
Sep	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	0	0	0	0	2	2	3	3	3	3	3	3	3	3	3	2	-4	-4
Sep	Saturdays			-4	-4	-4	-4	-4	-4	0	0	0	0	2	2	3	3	3	3	3	3	3	2	2	0	-4	-4
Sep	Sundays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	1	1	2	2	3	3	2	1	1	0	-4	-4
Oct	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	0	0	2	2	3	3	3	3	3	3	3	3	3	3	3	2	-4	-4
Oct	Saturdays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	-4	-4
Oct	Sundays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	-4
Nov	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	1	3	3	3	3	2	2	2	0	0	0	3	3	3	3	2	-4	-4
Nov	Saturdays			-4	-4	-4	-4	-4	-4	0	0	2	2	2	0	0	0	0	0	0	0	2	3	2	0	-4	-4
Nov	Sundays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	0	-4	-4
Dec	Weekdays	5	5,000	-4	-4	-4	-4	-4	-4	0	3	3	3	2	2	0	0	0	0	0	3	3	3	3	2	0	-4
Dec	Saturdays			-4	-4	-4	-4	-4	-4	0	0	2	2	2	2	0	0	0	0	0	3	3	3	3	0	-4	-4
Dec	Sundays			-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	2	2	3	2	1	-4	-4

*Pumping unit operations are described with negative values.

TABLE 3-17
JOCASSEE STATION PUMP OPERATIONS

Month	Day Set	Draw-down Days	Drawdown Volume (acre-ft)	Hour (number of units available per hour of the day)*																							
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	Saturdays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	Sundays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	Saturdays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	Sundays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	Saturdays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	Sundays			-2	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	Saturdays			-3	-3	-3	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	Sundays			-2	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	Saturdays			-3	-3	-3	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	Sundays			-2	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	Saturdays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	Sundays			-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	Weekdays	0	0	-4	-4	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	Saturdays			-3	-3	-3	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	Sundays			-3	-3	-3	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	Weekdays	0	0	-4	-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
Aug	Saturdays			-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	Sundays			-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	Weekdays	0	0	-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2
Sep	Saturdays			-4	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	Sundays			-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
Oct	Weekdays	0	0	-4	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4	-4
Oct	Saturdays			-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	Sundays			-4	-4	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4	-4
Nov	Weekdays	0	0	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	Saturdays			-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	Sundays			-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4
Dec	Weekdays	0	0	-4	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-4
Dec	Saturdays			-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	Sundays			-4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4

*Pumping unit operations are described with negative values.

TABLE 3-18
RICHARD B. RUSSELL PROJECT PUMP OPERATIONS

Month	Day Set	Draw-down Days	Drawdown Volume (acre-ft)	Hour (number of units available per hour of the day)*																							
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Annual	Weekdays	0	0	-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Saturdays			-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sundays			-3	-3	-3	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*Pumping unit operations are described with negative values.

3.2.4 Generation Data

All unit performance information was modeled based on the information available at the time of model development.

3.2.4.1 Headloss Coefficients

The SR CHEOPS Model allows two common headloss coefficients for each plant and an individual coefficient for each unit. Headloss for each unit is calculated by multiplying the unit's common coefficient by the total flow for that common coefficient squared added to the individual coefficient multiplied by the individual unit flow squared. The formula is:

$$H_i = \left(\sum_{j=1}^{n} F_j \right)^2 h_c + F_i^2 h_i$$

Where:

H_i is the unit headloss in feet

h_c is the common coefficient for the i^{th} unit

h_i is the individual coefficient for the i^{th} unit

F_i is the flow for the i^{th} unit

j runs from 1 to n

n is the number of units that have the same common coefficient as the unit i

Table 3-19 presents the estimated headlosses for each plant as a function of flow (Q):

TABLE 3-19
HEADLOSS COEFFICIENTS

Facility	Common	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8
Bad Creek	1.25E-07								
Jocassee	1.41E-08	6.99E-08	6.99E-08	6.99E-08	6.99E-08				
Keowee	1.22E-08	2.33E-08	2.33E-08						
Hartwell		3.55E-08	3.55E-08	3.55E-08	3.55E-08	3.55E-08			
Richard B. Russell		2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08	2.40E-08
J. Strom Thurmond		1.56E-07	1.56E-07	1.56E-07	1.56E-07	1.56E-07	1.56E-07	1.56E-07	

3.2.4.2 Turbine Efficiency Curves

Turbine performance is entered into the SR CHEOPS Model by plant and as flow versus efficiency at five separate net heads. The Bad Creek powerhouse contains four reversible motor-pump/turbine-generator units with a design head of 1,115 ft AMSL. The modeled performance of the turbines in generation mode is presented in Table 3-20. The Jocassee powerhouse also contains four reversible motor-pump/turbine-generator units, shown in Table 3-21.

The Keowee powerhouse contains two similarly sized conventional turbine-generator units. The modeled performance of these turbines is presented in Table 3-22. The Hartwell powerhouse contains five conventional turbine-generator units, four of which were rehabilitated over the 11-year span of 1997 through 2007. The Richard B. Russell powerhouse contains four similarly sized conventional turbine-generator units and four reversible turbine-generator/motor-pump units. The J. Strom Thurmond powerhouse contains seven similarly sized conventional turbine-generator units. The modeled performance of the USACE turbines is presented in Tables 3-23 through 3-26.

TABLE 3-20
BAD CREEK PROJECT UNITS 1 THROUGH 4
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Units 1 through 4									
Net Head of 975 ft		Net Head of 1,050 ft		Net Head of 1,115 ft		Net Head of 1,165 ft		Net Head of 1,220 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
3,460	89.80%	3,180	91.50%	2,930	91.50%	2,825	91.20%	2,720	90.60%
3,530	89.60%	3,285	91.30%	3,140	92.00%	2,965	92.00%	2,860	91.50%
3,600	89.40%	3,390	91.00%	3,285	91.80%	3,105	92.30%	3,000	92.10%
3,670	89.20%	3,495	90.70%	3,425	91.60%	3,250	92.20%	3,070	92.40%
3,745	89.00%	3,600	90.50%	3,565	91.20%	3,390	91.90%	3,145	92.50%
3,815	88.70%	3,710	90.10%	3,700	90.90%	3,530	91.70%	3,285	92.40%
3,885	88.40%	3,815	89.80%	3,850	90.50%	3,670	91.40%	3,425	92.20%
3,955	88.00%	3,920	89.50%	3,990	90.00%	3,815	91.00%	3,565	92.00%
3,990	87.70%	4,025	89.00%	4,130	89.30%	3,955	90.70%	3,710	91.70%
4,025	87.50%	4,235	87.50%	4,415	87.40%	4,095	89.90%	3,850	91.40%

TABLE 3-21
JOCASSEE STATION UNITS 1 THROUGH 4
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Units 3 and 4									
Net Head of 278 ft		Net Head of 289 ft		Net Head of 301 ft		Net Head of 312 ft		Net Head of 323 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
7,140	91.17%	6,877	91.06%	6,612	90.93%	6,395	90.70%	6,213	90.18%
7,150	91.19%	6,900	91.13%	6,900	91.50%	6,700	91.47%	6,325	90.64%
7,400	91.50%	7,150	91.64%	7,200	92.25%	6,950	92.00%	6,450	91.15%
7,600	91.50%	7,400	92.00%	7,450	92.56%	7,250	92.65%	6,700	91.83%
7,800	91.40%	7,600	92.10%	7,700	92.45%	7,500	92.95%	6,950	92.43%
8,000	91.10%	7,850	91.80%	8,000	92.00%	7,800	92.70%	7,200	92.80%
8,250	90.56%	8,100	91.41%	8,250	91.60%	8,050	92.40%	7,450	93.16%
8,450	90.10%	8,350	91.00%	8,500	91.25%	8,350	92.00%	7,700	93.15%
8,650	89.45%	8,550	90.62%	8,800	90.80%	8,600	91.67%	7,950	92.82%
8,850	88.70%	8,800	90.00%	9,050	90.10%	8,638	91.60%	8,200	92.55%

TABLE 3-22
KEOWEE STATION UNITS 1 AND 2
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Unit 1 and 2									
Net Head of 90 ft		Net Head of 105 ft		Net Head of 117 ft		Net Head of 125 ft		Net Head of 140 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
5,400	54.00%	5,000	51.00%	4,900	48.00%	4,700	44.50%	4,300	43.00%
6,400	66.50%	5,500	62.00%	5,300	60.00%	5,100	55.50%	4,600	50.50%
6,900	72.00%	6,000	68.50%	5,700	66.50%	5,600	65.50%	4,900	56.00%
7,400	77.00%	6,500	74.00%	6,200	73.00%	6,100	73.00%	5,200	62.00%
7,900	81.00%	7,000	78.00%	6,700	77.50%	6,600	77.00%	5,600	68.50%
8,400	84.50%	7,500	81.00%	7,200	81.00%	7,100	81.00%	6,000	73.00%
8,900	88.50%	8,000	84.00%	7,700	84.00%	7,600	84.00%	6,400	76.50%
9,100	90.00%	8,500	88.00%	8,200	87.00%	8,100	87.00%	6,800	79.50%
9,300	91.50%	8,800	90.50%	8,700	90.50%	8,400	89.00%	7,200	82.00%
9,500	92.00%	9,000	92.00%	8,900	91.50%	8,600	90.50%	7,600	84.50%
9,700	91.00%	9,200	93.00%	9,000	92.00%	8,700	91.00%	7,800	86.00%
9,900	90.00%	9,400	93.50%	9,200	93.00%	8,800	91.50%	8,000	87.00%
10,100	88.00%	9,700	92.50%	9,500	93.50%	8,900	92.00%	8,200	88.00%
10,300	86.00%	10,000	91.00%	9,700	93.00%	9,100	93.00%	8,400	89.50%

TABLE 3-23
HARTWELL PROJECT UNITS 1 THROUGH 4
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Units 1 through 4									
Net Head of 170 ft		Net Head of 175 ft		Net Head of 180 ft		Net Head of 185 ft		Net Head of 190 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
2,724	81.74%	2,678	80.77%	2,635	79.81%	2,596	78.82%	2,560	77.83%
2,985	83.90%	2,931	83.00%	2,881	82.09%	2,837	81.11%	2,796	80.14%
3,245	85.71%	3,185	84.83%	3,128	83.98%	3,078	83.04%	3,032	82.08%
3,504	87.28%	3,438	86.42%	3,375	85.59%	3,319	84.68%	3,269	83.71%
3,756	88.81%	3,684	87.95%	3,619	87.05%	3,560	86.10%	3,505	85.15%
4,071	90.45%	3,987	89.71%	3,911	88.92%	3,848	87.93%	3,794	86.84%
4,335	91.34%	4,233	90.87%	4,145	90.22%	4,073	89.33%	4,012	88.30%
4,601	92.09%	4,491	91.65%	4,387	91.22%	4,299	90.57%	4,230	89.62%
4,870	92.70%	4,748	92.37%	4,637	91.95%	4,540	91.38%	4,451	90.75%
5,148	93.08%	5,015	92.82%	4,887	92.60%	4,782	92.08%	4,688	91.45%
5,463	92.77%	5,289	93.08%	5,153	92.89%	5,036	92.47%	4,924	92.09%
5,823	91.76%	5,605	92.60%	5,430	92.93%	5,291	92.80%	5,168	92.51%
6,227	90.20%	5,969	91.41%	5,739	92.43%	5,569	92.68%	5,426	92.62%
6,878	86.58%	6,482	89.25%	6,204	90.66%	5,952	91.94%	5,774	92.28%

TABLE 3-24
HARTWELL PROJECT UNIT 5
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Unit 5									
Net Head of 170 ft		Net Head of 175 ft		Net Head of 180 ft		Net Head of 185 ft		Net Head of 190 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
2,663	79.74%	2,618	78.77%	2,576	77.81%	2,538	76.82%	2,502	75.83%
2,918	81.90%	2,865	81.00%	2,816	80.09%	2,773	79.11%	2,733	78.14%
3,172	83.71%	3,113	82.83%	3,058	81.98%	3,009	81.04%	2,964	80.08%
3,425	85.28%	3,361	84.42%	3,299	83.59%	3,244	82.68%	3,195	81.71%
3,671	86.81%	3,601	85.95%	3,538	85.05%	3,480	84.10%	3,426	83.15%
3,979	88.45%	3,897	87.71%	3,823	86.92%	3,761	85.93%	3,709	84.84%
4,237	89.34%	4,138	88.87%	4,052	88.22%	3,981	87.33%	3,922	86.30%
4,497	90.09%	4,390	89.65%	4,288	89.22%	4,202	88.57%	4,135	87.62%
4,760	90.70%	4,641	90.37%	4,533	89.95%	4,438	89.38%	4,351	88.75%
5,032	91.08%	4,902	90.82%	4,777	90.60%	4,674	90.08%	4,583	89.45%
5,340	90.77%	5,170	91.08%	5,037	90.89%	4,923	90.47%	4,813	90.09%
5,692	89.76%	5,479	90.60%	5,308	90.93%	5,172	90.80%	5,052	90.51%
6,087	88.20%	5,835	89.41%	5,610	90.43%	5,444	90.68%	5,304	90.62%
6,723	84.58%	6,336	87.25%	6,064	88.66%	5,818	89.94%	5,644	90.28%

TABLE 3-25
RICHARD B. RUSSELL PROJECT UNITS 1 THROUGH 8
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Units 1 through 4									
Net Head of 139 ft		Net Head of 144 ft		Net Head of 151 ft		Net Head of 157 ft		Net Head of 162 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
5,100	79.80%	5,190	81.00%	5,300	82.75%	5,300	83.50%	5,300	83.80%
5,400	81.50%	5,400	82.30%	5,600	84.50%	5,445	84.30%	5,550	85.20%
5,625	82.80%	5,725	84.25%	5,850	85.75%	5,700	85.50%	5,800	86.60%
5,900	84.50%	6,000	85.90%	6,100	87.20%	6,000	87.00%	6,100	88.00%
6,125	85.60%	6,225	87.00%	6,350	88.50%	6,200	88.20%	6,250	88.80%
6,400	87.25%	6,450	88.25%	6,600	89.70%	6,480	89.50%	6,400	89.60%
6,590	88.25%	6,690	89.25%	6,850	90.90%	6,700	90.50%	6,590	90.45%
6,800	89.20%	6,900	90.00%	7,050	91.40%	6,990	91.50%	6,750	91.00%
7,000	90.10%	7,100	90.60%	7,250	91.40%	7,200	91.55%	6,900	91.40%
7,150	90.20%	7,250	90.70%	7,400	90.75%	7,350	91.40%	7,095	92.00%
7,325	89.60%	7,450	90.25%	7,575	90.00%	7,500	91.10%	7,255	91.95%
7,575	88.50%	7,680	88.75%	7,840	88.75%	7,690	90.45%	7,450	91.50%
7,800	87.50%	7,900	87.50%	8,040	87.60%	7,875	89.50%	7,500	91.35%

TABLE 3-26
J. STROM THURMOND PROJECT UNITS 1 THROUGH 7
TURBINE EFFICIENCIES OVER A RANGE OF NET HEADS

Units 1 through 7									
Net Head of 114 ft		Net Head of 123 ft		Net Head of 132 ft		Net Head of 141 ft		Net Head of 148.5 ft	
Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency	Flow (cfs)	Efficiency
3,110	84.32%	3,140	83.54%	3,230	84.01%	3,450	85.79%	3,570	86.53%
3,210	84.93%	3,180	84.00%	3,310	84.68%	3,570	86.43%	3,680	87.19%
3,340	86.29%	3,310	85.07%	3,430	85.64%	3,600	87.27%	3,790	87.82%
3,490	87.05%	3,440	86.05%	3,550	86.53%	3,790	88.06%	3,900	88.41%
3,640	87.74%	3,570	86.96%	3,670	87.37%	3,900	88.81%	4,010	88.97%
3,790	88.37%	3,710	87.56%	3,790	88.15%	4,020	89.29%	4,120	89.51%
3,940	88.96%	3,840	88.36%	3,910	88.88%	4,130	89.97%	4,230	90.01%
4,090	89.50%	3,980	88.87%	4,040	89.35%	4,250	90.39%	4,340	90.49%
4,230	90.22%	4,110	89.57%	4,160	90.01%	4,370	90.80%	4,450	90.95%
4,370	90.90%	4,240	90.23%	4,280	90.63%	4,490	91.18%	4,560	91.38%
4,520	91.33%	4,380	90.65%	4,410	91.02%	4,610	91.55%	4,680	91.60%
4,670	91.66%	4,520	91.03%	4,550	91.18%	4,740	91.70%	4,810	91.62%
4,850	91.24%	4,670	91.21%	4,690	91.33%	4,830	91.73%	4,940	91.63%
5,310	89.48%	4,840	90.99%	4,840	91.29%	4,930	91.58%	5,030	91.58%
5,520	87.96%	5,150	90.19%	5,230	90.49%	5,230	91.15%	5,070	91.64%

3.2.4.3 Generator Efficiency Curve

The SR CHEOPS Model generator data, like the turbine data, is entered by plant and then associated with a unit. The generator performance data is a relationship of generator output versus generator efficiency.

The generator condition includes a maximum generator output. This value is the maximum generator output the model will allow, assuming there is turbine capacity to meet this limit. The model will limit turbine output based on the generator maximum specified output. The generator efficiency curves for each of the units in the system are shown in Tables 3-27 through 3-33.

TABLE 3-27
BAD CREEK PROJECT UNITS 1 THROUGH 4
GENERATOR EFFICIENCY CURVE

Units 1 through 4			
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**
97.06%	78.25	98.76%	234.75
97.80%	110	98.91%	313
98.37%	156.5	98.95%	360

TABLE 3-28
JOCASSEE STATION UNITS 1 THROUGH 4
GENERATOR EFFICIENCY CURVE

Units 1 and 2			
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**
95.20%	45	98.25%	150
96.15%	60	98.40%	180
97.50%	90	98.45%	195.5
98.00%	120	98.50%	215

TABLE 3-29
KEOWEE STATION UNITS 1 AND 2
GENERATOR EFFICIENCY CURVE

Units 1 and 2					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
89.00%	10	97.36%	42.5	98.31%	72.5
92.00%	15	97.60%	47.5	98.39%	77.5
94.00%	20	97.79%	52.5	98.44%	82.5
95.30%	25	97.95%	57.5	98.46%	87.5
96.20%	30	98.09%	62.5	98.48%	90
96.80%	35	98.20%	67.5	98.50%	100.625
97.20%	40				

TABLE 3-30
HARTWELL PROJECT UNITS 1 THROUGH 4
GENERATOR EFFICIENCY CURVE

Units 1 through 4					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
89.00%	10	97.41%	39	98.24%	64
92.00%	15	97.64%	43	98.30%	68
94.00%	19	97.83%	47	98.35%	72
95.25%	23	98.00%	52	98.40%	76
96.10%	27	98.11%	56	98.45%	80
96.75%	31	98.18%	60	98.50%	85
97.11%	35				

TABLE 3-31
HARTWELL PROJECT UNIT 5
GENERATOR EFFICIENCY CURVE

Unit 5					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
90.04%	10	96.27%	35	97.53%	60
92.76%	15	96.57%	39	97.64%	64
93.99%	19	96.82%	43	97.75%	68
94.83%	23	97.03%	47	97.84%	72
95.44%	27	97.25%	52	97.93%	76
95.90%	31	97.40%	56	98.04%	82

TABLE 3-32
RICHARD B. RUSSELL PROJECT UNITS 1 THROUGH 8
GENERATOR EFFICIENCY CURVE

Units 1 through 4					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
89.00%	10	97.36%	42.5	98.31%	72.5
92.00%	15	97.60%	47.5	98.39%	77.5
94.00%	20	97.79%	52.5	98.44%	82.5
95.30%	25	97.95%	57.5	98.46%	87.5
96.20%	30	98.09%	62.5	98.48%	90
96.80%	35	98.20%	67.5	98.50%	100.625
97.20%	40				

TABLE 3-33
J. STROM THURMOND PROJECT UNITS 1 THROUGH 7
GENERATOR EFFICIENCY CURVE

Units 1 through 7					
Efficiency	**Output (MW)**	**Efficiency**	**Output (MW)**	**Efficiency**	**Output (MW)**
94.61%	10	97.39%	30	98.33%	50
95.56%	15	97.74%	35	98.45%	55
96.32%	20	98.00%	40	98.56%	60
96.93%	25	98.19%	45		

3.2.4.4 Wicket Gate Leakage

The SR CHEOPS Model wicket gate leakage flow is active only during times of non-generation. Thus, during periods of non-generation, this leakage flow is used to make up all or a portion of the minimum flow requirement. Wicket gate leakage is only modeled at the Jocassee and Keowee Stations, where it is 11 cfs per Jocassee unit and 25 cfs per Keowee unit for a total of 44 cfs and 50 cfs when no units are operating. Wicket gate leakage is not modeled in the SR ResSim Model.

3.2.4.5 Powerhouse Weekend Operations

The Powerhouse Weekend Operations Condition permits the simulation of reduced powerhouse operations during Saturdays and/or Sundays. Minimum instantaneous and minimum daily average flow requirements will be met by bringing the powerhouse online for the required flow only. This condition removes the change-in-storage component from consideration in computing a desired daily discharge. To simulate actual usage, Saturday and Sunday powerhouse operations are minimized at the Keowee Station, Hartwell Project, and Richard B. Russell Project. During high inflow times with little usable storage, the model will bring the powerhouse online to generate with outflows, rather than permit spilling.

3.2.4.6 Maintenance

The maintenance schedule provides the functionality to take a unit out of service for all or part of each year for a scenario run. There are currently no outages modeled in the SR CHEOPS Model.

3.2.4.7 Pump Efficiency

The SR CHEOPS Model Pump Efficiency Condition provides the functionality to enter pump efficiency information for pumped storage plants. This data set is required for plants with plant operation type specified as pumped storage and hybrid-pumped storage. The pump efficiency information modeled for the Bad Creek Project, Jocassee Station, and Richard B. Russell Project is presented in Tables 3-34 through 3-36.

TABLE 3-34
BAD CREEK PROJECT PUMP EFFICIENCY

Net Head (ft)	Efficiency	Minimum Power (MW)	Maximum Power (MW)	Minimum Flow (cfs)	Maximum Flow (cfs)
1,040	92.40%	339.8	340.0	3,565	3,567
1,100	92.70%	331.6	331.8	3,300	3,302
1,160	92.60%	318.3	318.5	3,001	3,003
1,220	92.30%	304.2	304.4	2,718	2,720
1,250	92.00%	294.4	294.6	2,559	2,561

TABLE 3-35
JOCASSEE STATION PUMP EFFICIENCY

Net Head (ft)	Efficiency	Minimum Power (MW)	Maximum Power (MW)	Minimum Flow (cfs)	Maximum Flow (cfs)
286	92.45%	207.4	207.5	7,919	7,921
296	92.80%	205.2	205.3	7,599	7,601
307	93.10%	204.6	204.7	7,329	7,331
318	93.40%	201.8	201.8	6,999	7,001
328	93.50%	196.8	196.8	6,624	6,626

TABLE 3-36
RICHARD B. RUSSELL PROJECT PUMP EFFICIENCY

Net Head (ft)	Efficiency	Minimum Power (MW)	Maximum Power (MW)	Minimum Flow (cfs)	Maximum Flow (cfs)
140	91.20%	93.6	93.6	7,199	7,201
145	91.68%	93.7	93.7	6,994	6,996
150	92.10%	93.6	93.7	6,789	6,791
155	92.50%	93.4	93.4	6,579	6,581
160	92.80%	92.8	92.9	6,359	6,361

4.0 SR CHEOPS MODEL CALIBRATION/VERIFICATION PROCESS

Verification is intended to validate the SR CHEOPS Model input data and logic so the Baseline scenario may be used as the current operations comparison scenario for all subsequent scenario analyses. HDR performed model verification using comparisons of actual and model estimated generation and total discharge from the system. Verification of the model was completed using two different scenarios or model runs. The first (Historical Baseline) performs a verification of the model input data, logic and conditions for calendar years 1998 through 2008, which are the same 11 years used in the SR ResSim Model verification and with the same operations rule logic as the Baseline scenario described in Section 3.2, with modifications for historical water use (Table 3-15) and flow requirements from the J. Strom Thurmond Project (Section 3.2.3.4). This scenario is referred to as the Historical Baseline. In addition to the Historical Baseline scenario, a second verification scenario (v2007) was developed to simulate the detailed operations for calendar year 2007.

Generation data is commonly available for hydropower developments and is a metered value that has good accuracy compared to other forms of data that are not metered or based on estimated values with lower accuracy. Generation is a measure of available flow and storage volume, which relates to inflows and reservoir elevations. When performing verification of water quantity models with power generation, it is common to find discrepancies between observed data and modeled output for generation and reservoir elevation when looking at a small sample of time periods (day, week, or month). This is due to the difference between the set of rules provided in the model versus the day-to-day decisions common in large power developments that respond to power grid demands as well as storm forecasts and other non-measured impacts on the reservoir and equipment. Modeled results for each verification scenario were compared with historic generation, powerhouse flow, and reservoir levels. In addition to verifying the model under different hydrologic conditions, it was also important to select relatively recent years for model verification under conditions that are representative of current operating conditions.

As previously stated, the SR CHEOPS Model is coded to run day-to-day operations based on general operating conditions or rules. The model follows these rules strictly, 24 hours per day and 365 days per year, similar to an automated operation. Actual project operations generally follow the operating rules; however, human intervention periodically deviates from the general operating rules to accommodate day-to-day realities such as equipment failure and maintenance, changing hydrologic conditions, power demands and energy pricing, and other factors. In addition to differences between modeled operations versus actual operations that include human interventions, there are also inherent discrepancies due to input data inaccuracies (e.g., differences in hydrology data, turbine or generator efficiencies, or reservoir storage curves). It is important to understand that, due to these differences between actual operating conditions and modeled conditions, model results will never completely match historical operations.

The verification goal is to obtain less than a 5 percent difference when comparing long-term modeled results to historical generation data over the hydrologic period. In cases where the modeled results exceeded a 5 percent difference, potential causes for the differences were examined to determine whether the difference was due to deviations in model setup, historical deviations in operations, or discrepancies in the reconstructed hydrology data.

4.1 Summary of SR CHEOPS Modeled Results versus Historical Data

Verification of the SR CHEOPS Model was performed using historical operations data provided by Duke Energy and the USACE. Verification of the model was performed using two different scenarios, or model runs. The first scenario (Historical Baseline) performs a verification of the model input data, logic, and conditions for calendar years 1998 through 2008, which are the same 11 years used in the SR ResSim Model verification and with the same operations rule logic as the Baseline scenario discussed in Section 3.2, with modifications for historical water use (Table 3-15) and flow requirements from the J. Strom Thurmond Project (Section 3.2.3.4). The second verification scenario was run using the specific calendar year 2007 (v2007).

4.1.1 SR CHEOPS Model Historical Baseline

The Historical Baseline scenario results were compared to historical operations for the hydrologic period 1998 through 2008. Figures 4-1 through 4-6 show comparisons of the modeled reservoir elevations for the Historical Baseline scenario compared to the historical reported (observed) elevations for the same period. Note this scenario is not strictly based on the water balance rules defined in the 1968 Agreement, but closely represents how the developments have been operated over the simulated hydrologic period. Also, unit rehabilitation of Units 1 through 4 at the Hartwell Project was not complete until May of 2007. Unit outages associated with the rehabilitation were not taken into account in the model and it was assumed the units were operating at post-rehabilitation efficiency and capacity for the entire period.

FIGURE 4-1
SR CHEOPS MODELED AND HISTORICAL BAD CREEK RESERVOIR ELEVATION COMPARISON

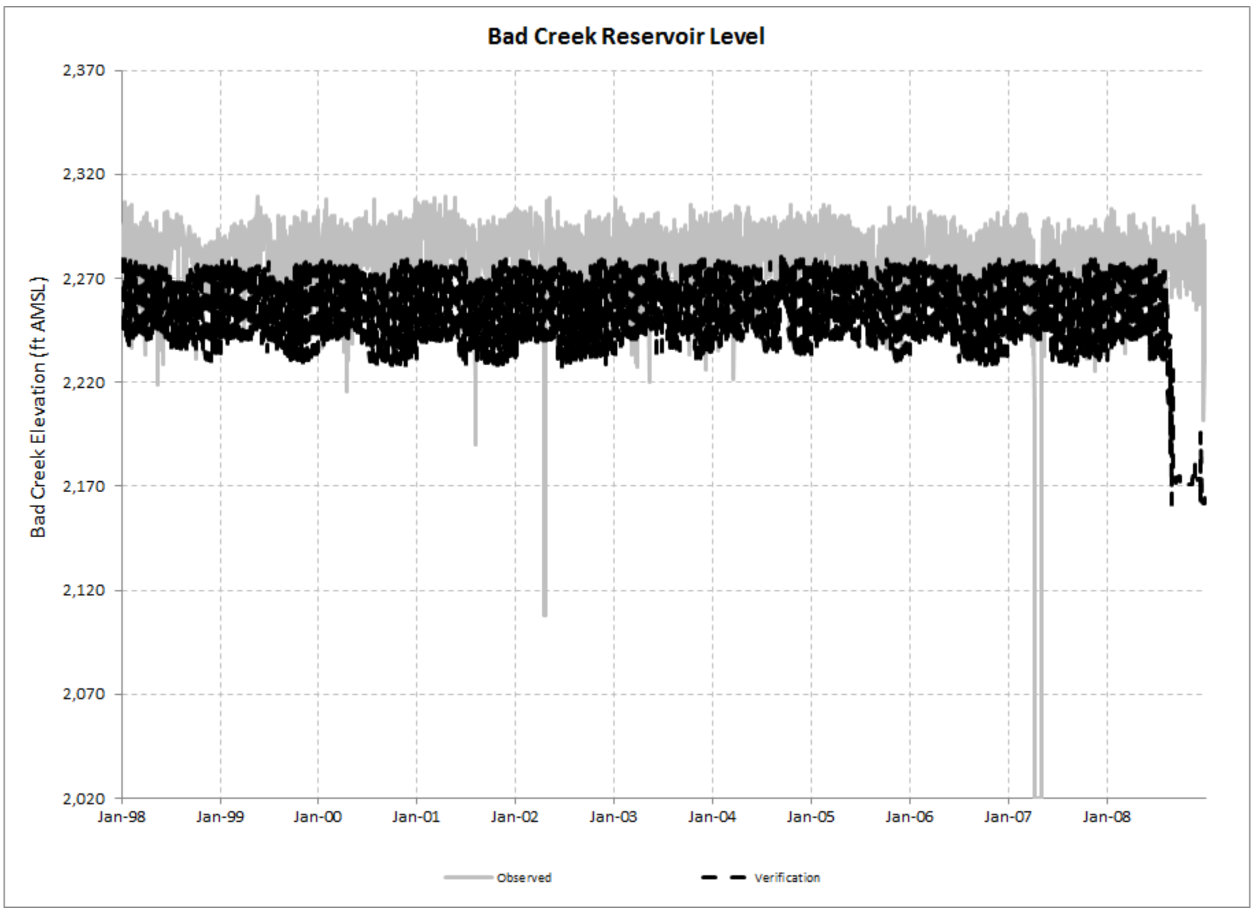


FIGURE 4-2
SR CHEOPS MODELED AND HISTORICAL JOCASSEE RESERVOIR ELEVATION COMPARISON

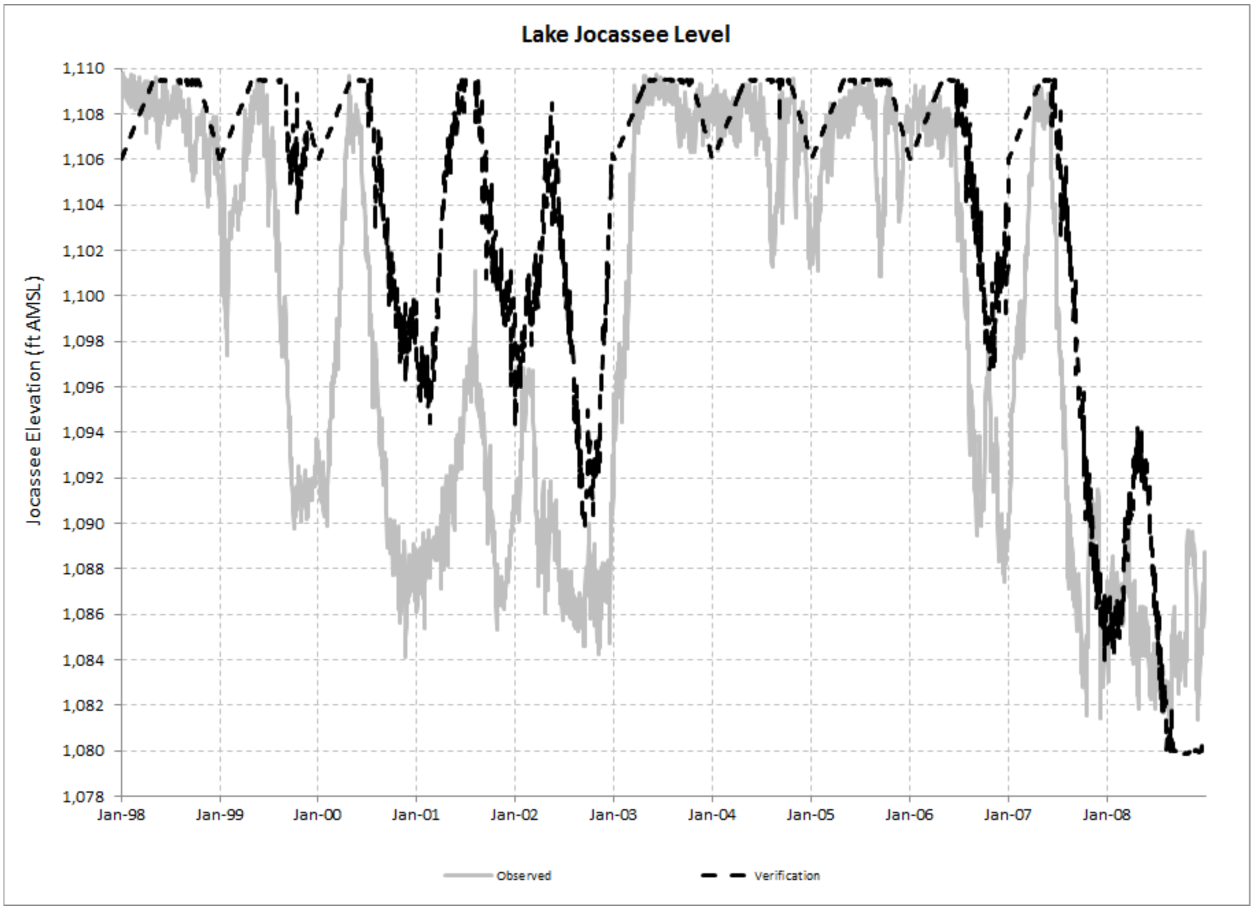


FIGURE 4-3
SR CHEOPS MODELED AND HISTORICAL KEOWEE RESERVOIR ELEVATION COMPARISON

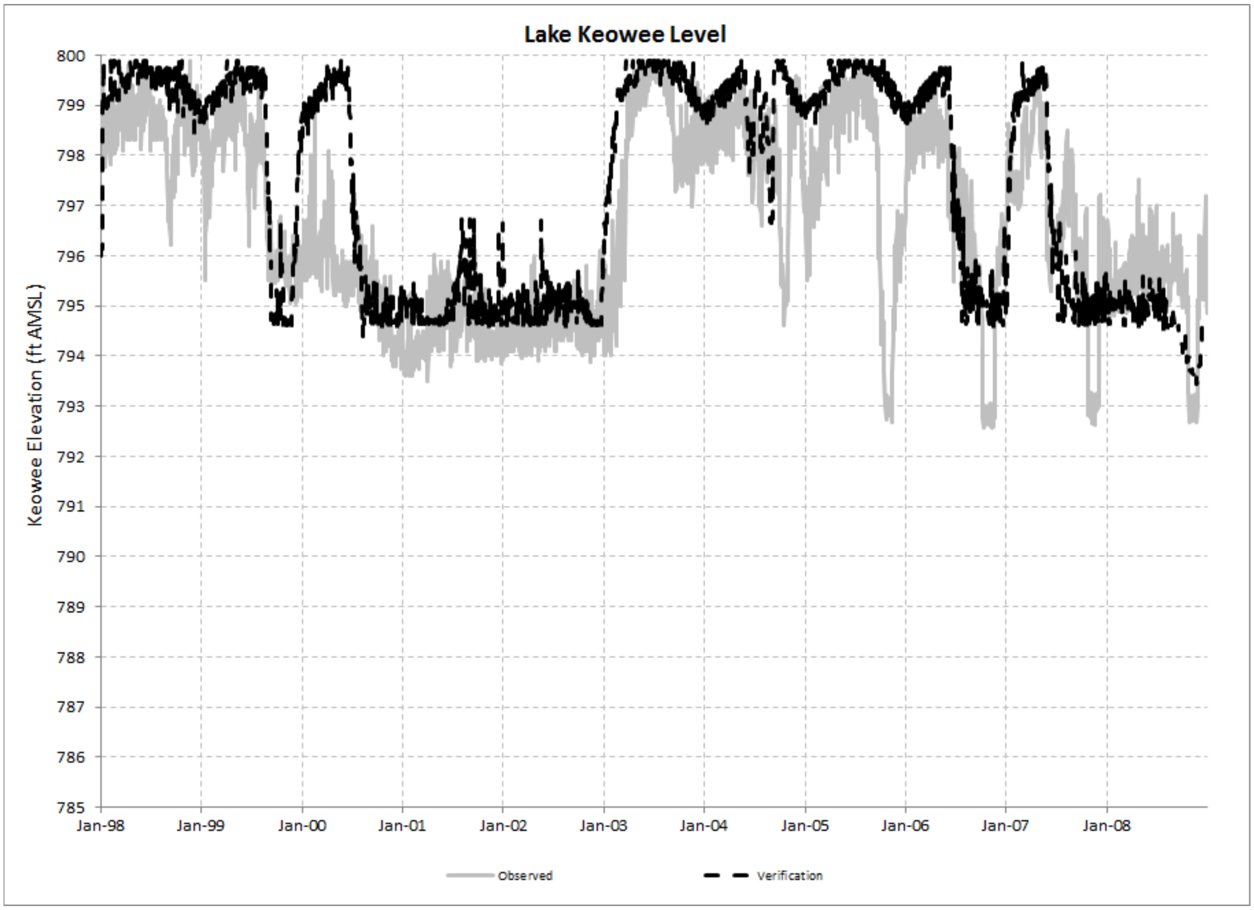


FIGURE 4-4
SR CHEOPS MODELED AND HISTORICAL HARTWELL RESERVOIR ELEVATION COMPARISON

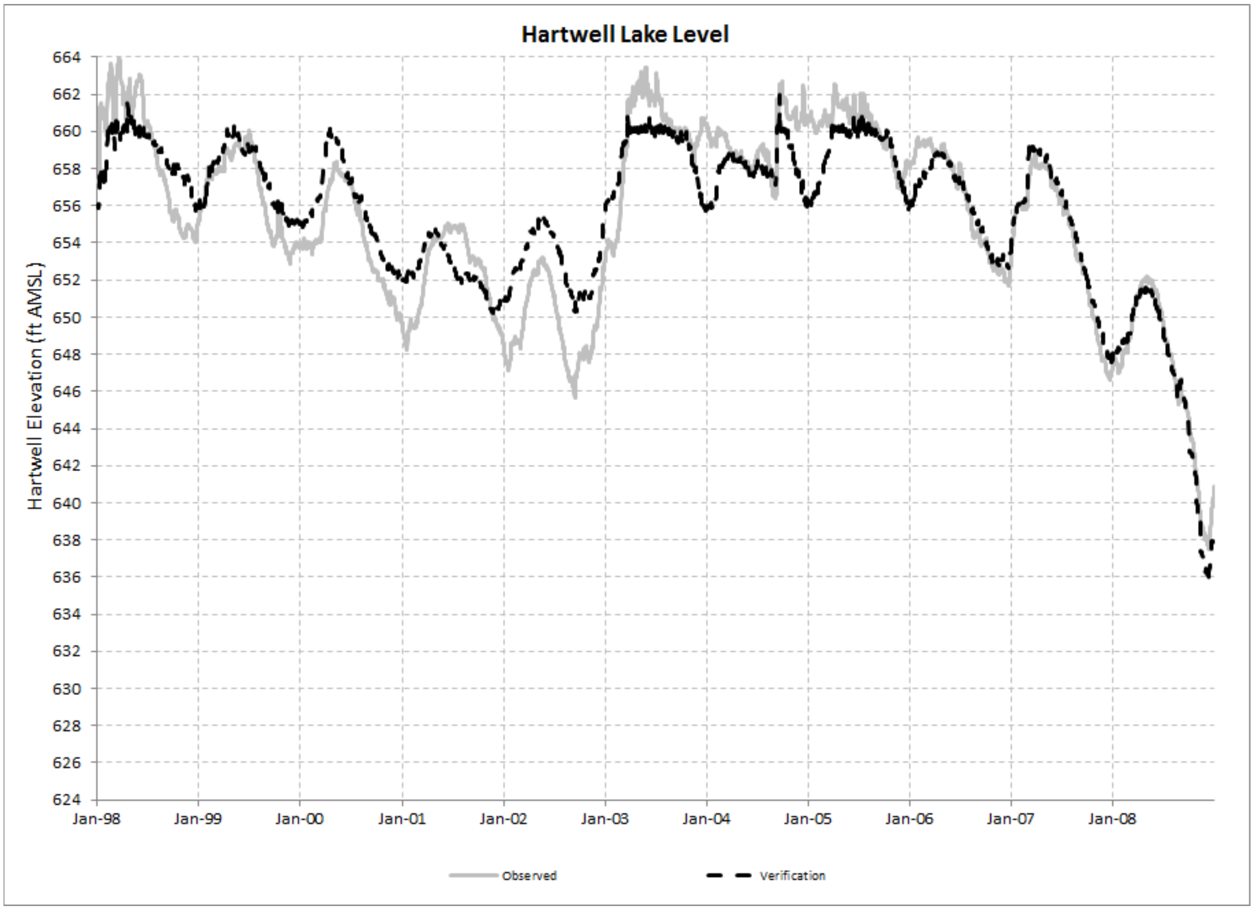


FIGURE 4-5
SR CHEOPS MODELED AND HISTORICAL RICHARD B. RUSSELL RESERVOIR ELEVATION COMPARISON

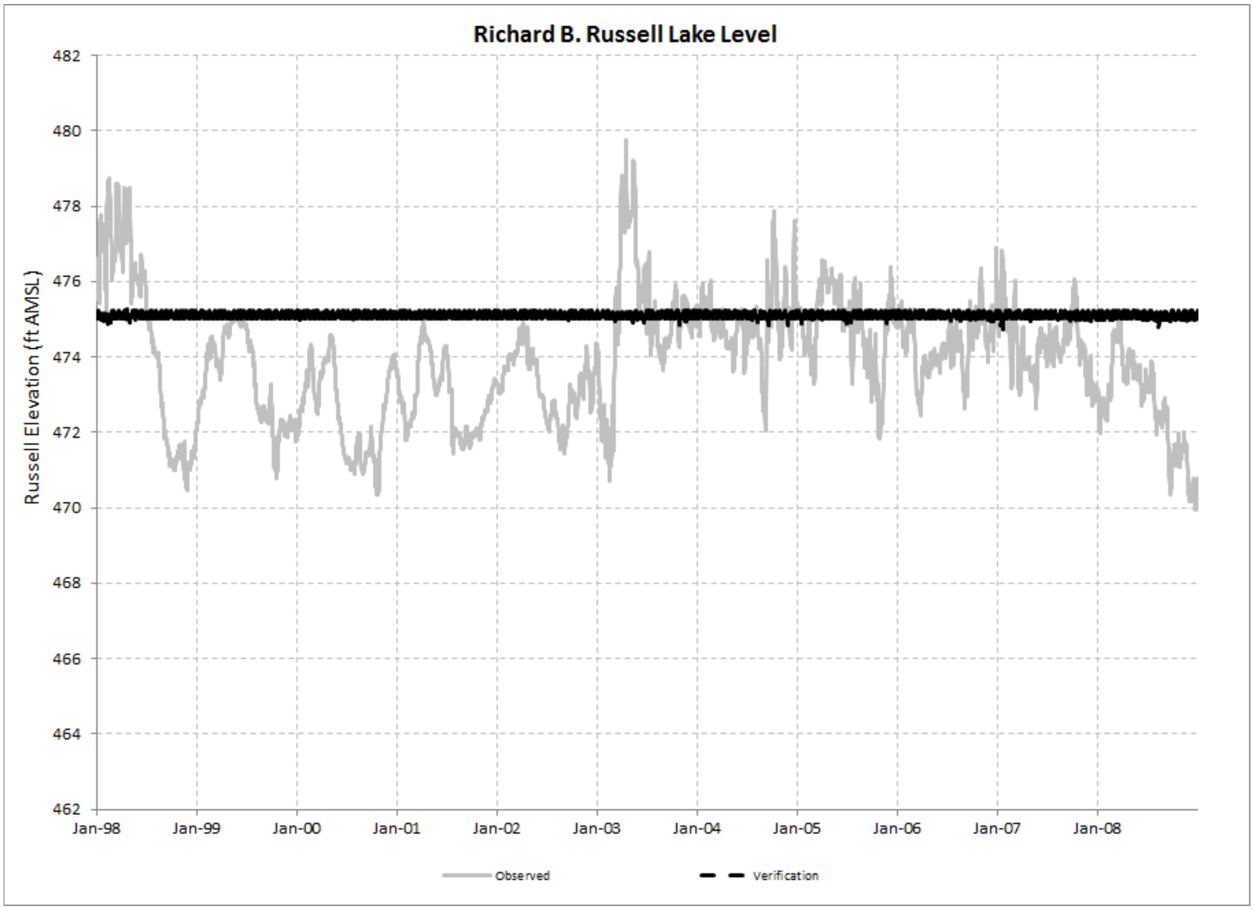
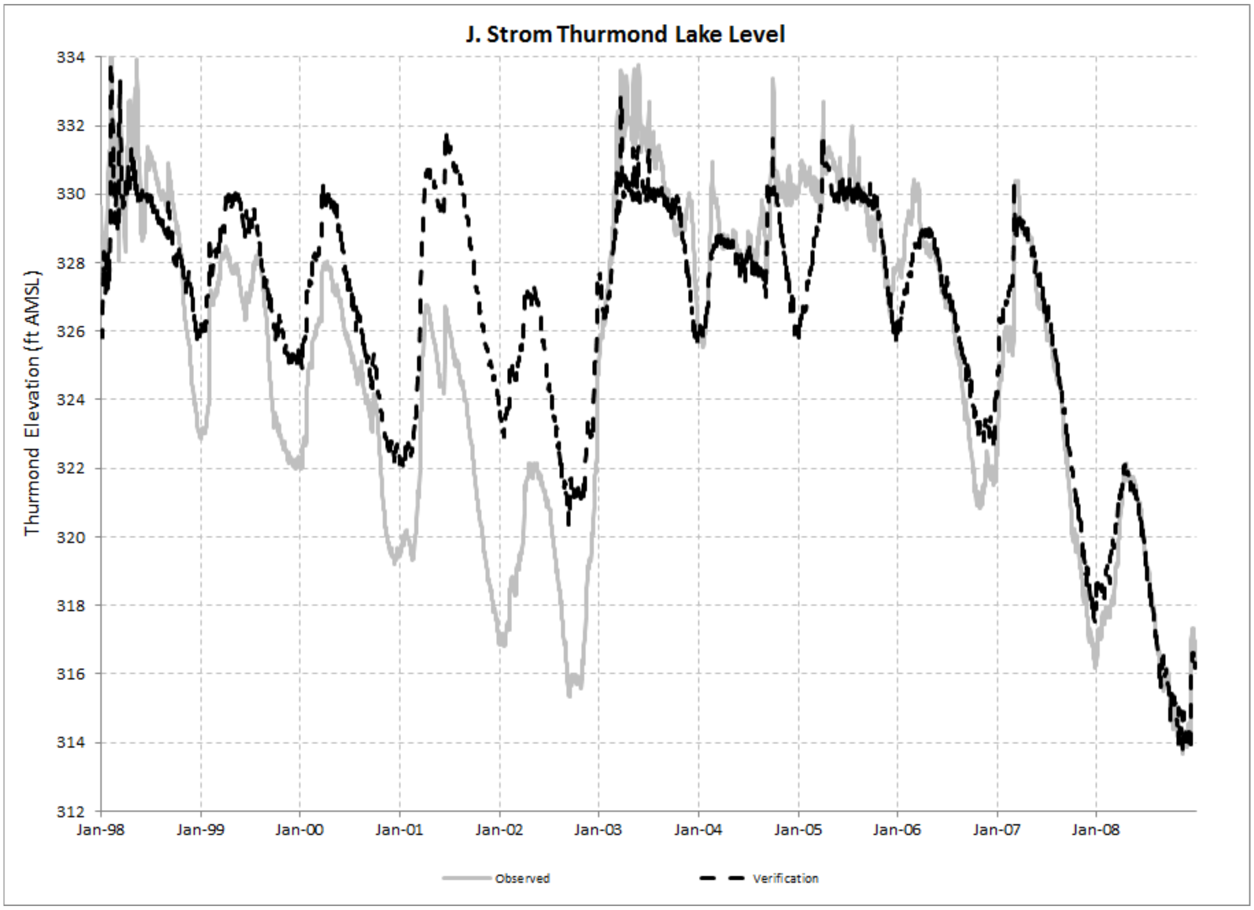


FIGURE 4-6
SR CHEOPS MODELED AND HISTORICAL J. STROM THURMOND RESERVOIR ELEVATION COMPARISON



The SR CHEOPS Model simulation of the Historical Baseline scenario estimated an average annual energy output 4 percent lower than historical generation for the same period, as shown in Table 4-1. Based on available historical generation records, modeled and historical generation were compared for the period 1998 through 2008 at all facilities except for Richard B. Russell. Generation at the Richard B. Russell Project was only compared for the time period 2006 through 2008. Prior to 2006, the Richard B. Russell pump units (four) were rarely operated. There are significant annual swings in the percent difference between historical and modeled operations for the 1998 through 2008 period, with the largest variations at the Duke Energy facilities.

The Duke Energy facilities are operated on demand with a priority on peaking operations to optimize the value of generation based on energy pricing, whereas the USACE facilities are operated on a weekly baseload schedule. The result is that the operations of the Duke Energy facilities (especially pumping operations) vary greatly depending on the value of generation. The Duke Energy system is only required to release water to the system to stay in balance with the system balance as outlined in the 1968 Agreement. The USACE system is driven by a combination of the power requirements to SEPA, the system storage balance, and the minimum discharge requirements from the J. Strom Thurmond Project.

TABLE 4-1
SR CHEOPS HISTORICAL BASELINE: GENERATION COMPARISON

Percent Difference between Modeled and Historical Generation							
([Modeled - Historic]/Historic)							
Year	**Bad Creek**	**Jocassee**	**Keowee**	**Hartwell**	**Richard B. Russell**	**J. Strom Thurmond**	**System Total**
1998	1%	19%	-10%	-2%		-6%	2%
1999	6%	47%	-25%	-1%		3%	11%
2000	-2%	32%	29%	8%		8%	6%
2001	15%	-32%	28%	10%		1%	3%
2002	5%	-45%	-7%	0%		9%	-8%
2003	-13%	-2%	12%	19%		9%	-3%
2004	5%	2%	14%	0%		1%	3%
2005	-9%	-3%	3%	1%		-9%	-6%
2006	4%	0%	-1%	-4%	-10%	-14%	-1%
2007	-10%	2%	51%	18%	-3%	6%	-4%
2008	-44%	-68%	36%	19%	7%	11%	-38%
Period Total (1998–2008)	-5%	-8%	7%	5%	-3%	0%	-4%

Figures 4-7 and 4-8 show the SR CHEOP Model daily and cumulative modeled (verification scenario) discharges from the Hartwell and J. Strom Thurmond Projects as compared to the historical (observed) discharges for the same period. For the period 1998 through 2008, the SR

CHEOPS Model estimated a cumulative discharge from Lake Hartwell and J. Strom Thurmond Lake within 1 percent of the historical cumulative discharge from each facility.

FIGURE 4-7
SR CHEOPS MODELED AND HISTORICAL HARTWELL PROJECT DISCHARGE COMPARISON

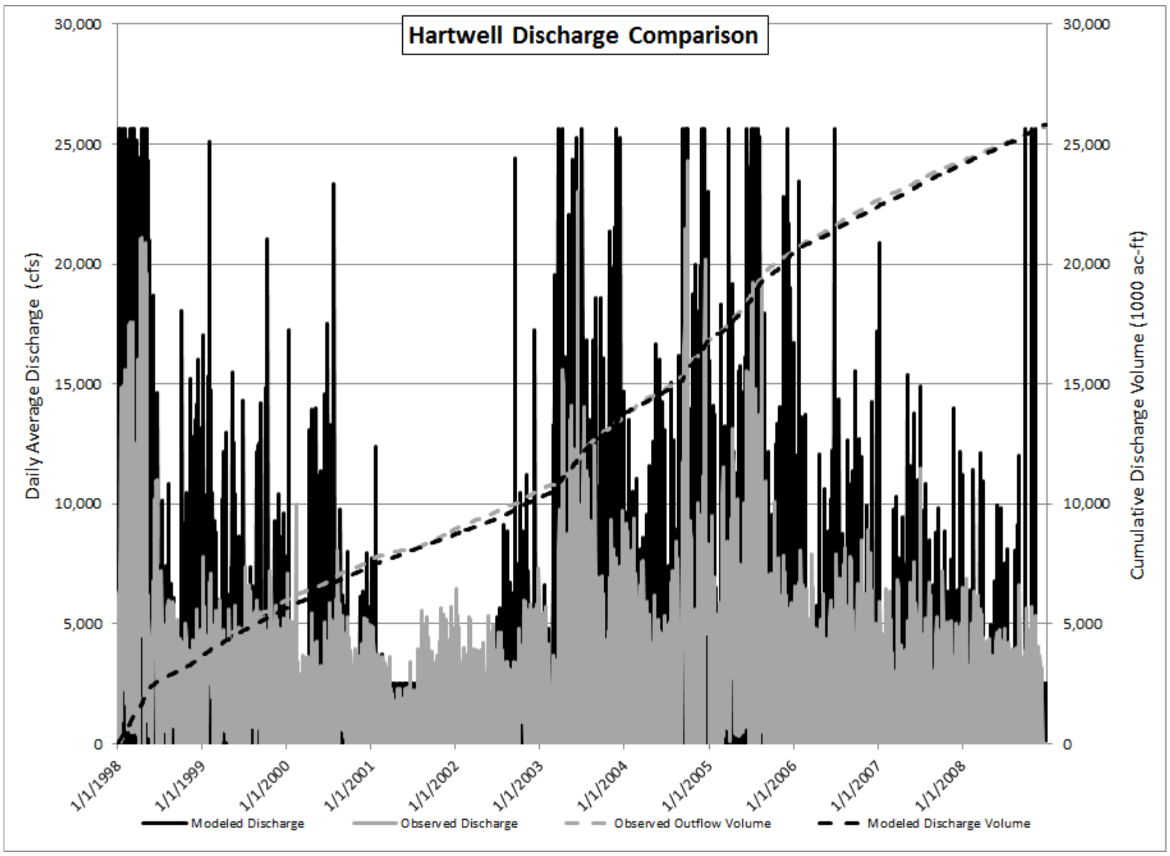
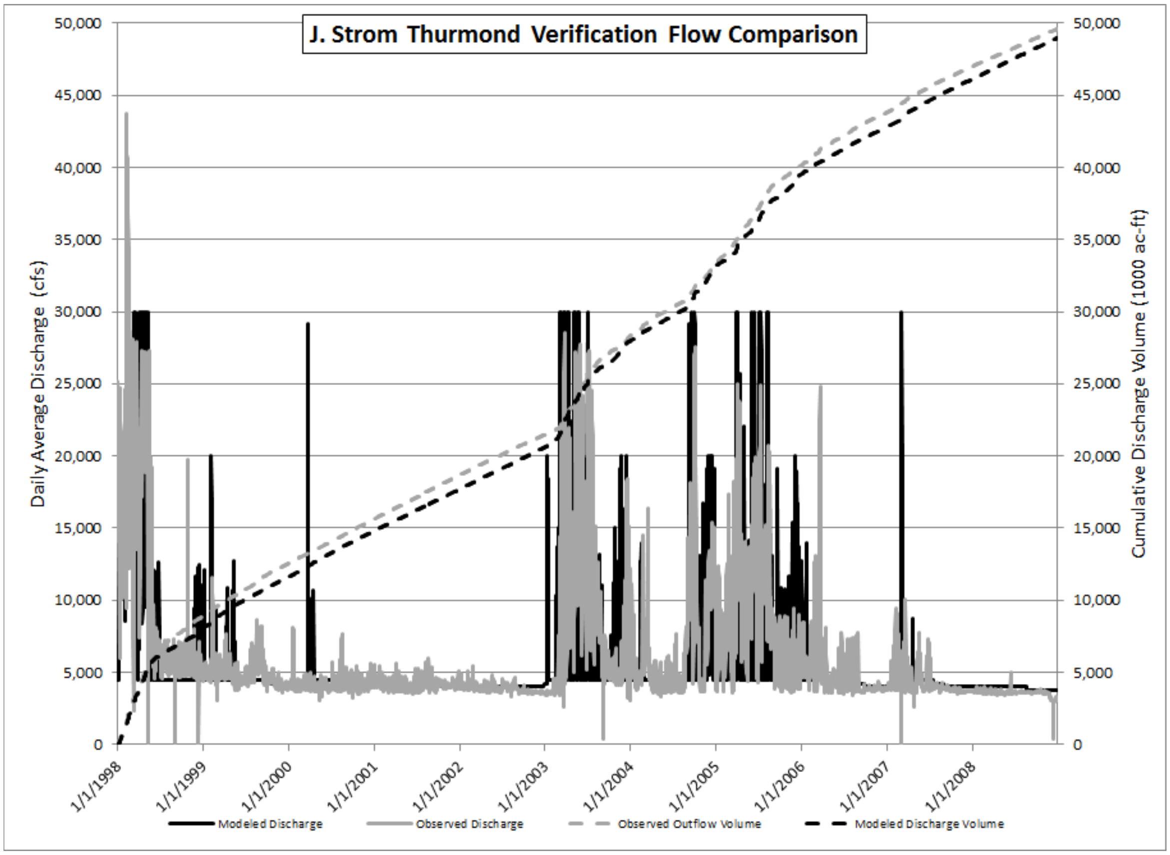


FIGURE 4-8
SR CHEOPS MODELED AND HISTORICAL J. STROM THURMOND PROJECT DISCHARGE COMPARISON



4.1.2 SR CHEOPS Scenario v2007

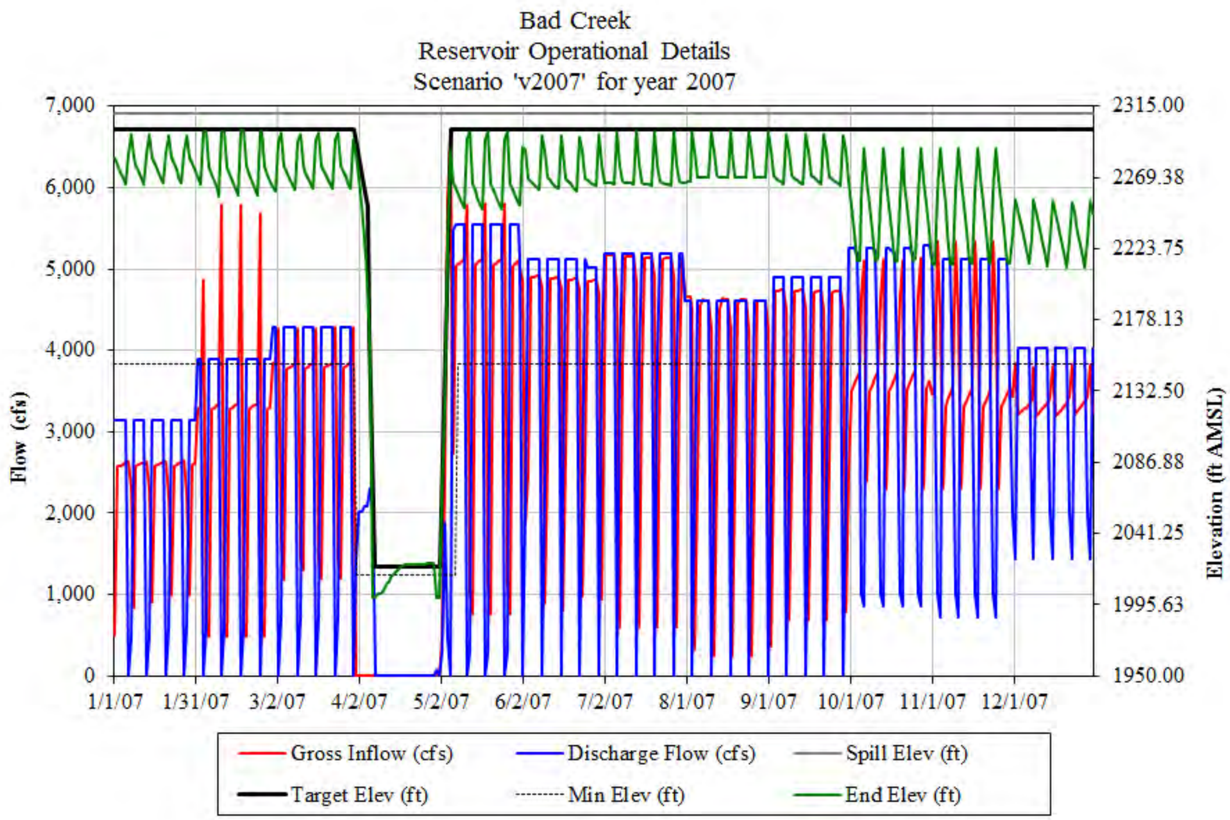
The v2007 scenario was established in the SR CHEOPS Model following the typical operating requirements of the system (same rule logic as the Historical Baseline scenario). Target elevations were applied such that the model will attempt to operate the reservoir pools as they were historically for calendar year 2007. Additionally actual reported 2007 water withdrawals and returns, pumping operations, and unit outages were applied in the v2007 scenario to simulate historical operations (where data was available) for calendar year 2007. Note this scenario is not strictly based on the water balance rules defined in the 1968 Agreement but closely represents how the facilities have been operated over the hydrologic period. Also, rehabilitation of Hartwell Project Units 1 through 4 was not complete until May of 2007. Unit outages associated with the rehabilitation were not taken into account in the model and it was assumed that the units were operating at post-rehabilitation efficiency and capacity for the entire year.

For this scenario, the Bad Creek and Jocassee Reservoirs were set to have target elevations which approximated their end of day elevations on a two-week interval. At the Bad Creek Project, non-typical operations were observed in April into early May, when the reservoir was drawn down significantly, for maintenance procedures. For the remainder of the year, typical weekly cycling of the upper reservoir was observed and mimicked in the SR CHEOPS Model. As shown in Table 4-2, simulated generation at the Bad Creek Project for the v2007 scenario is 67,894 MWh (2.8 percent) higher than historical generation for the same period. A pumping power consumption of 3,116,829 MWh was simulated, which is 1,516 MWh or 0.0 percent higher than historical. Figure 4-9 demonstrates the Bad Creek Reservoir historical elevations and modeled inflows, outflows, and elevations.

TABLE 4-2
SR CHEOPS MODEL V2007: GENERATION COMPARISON

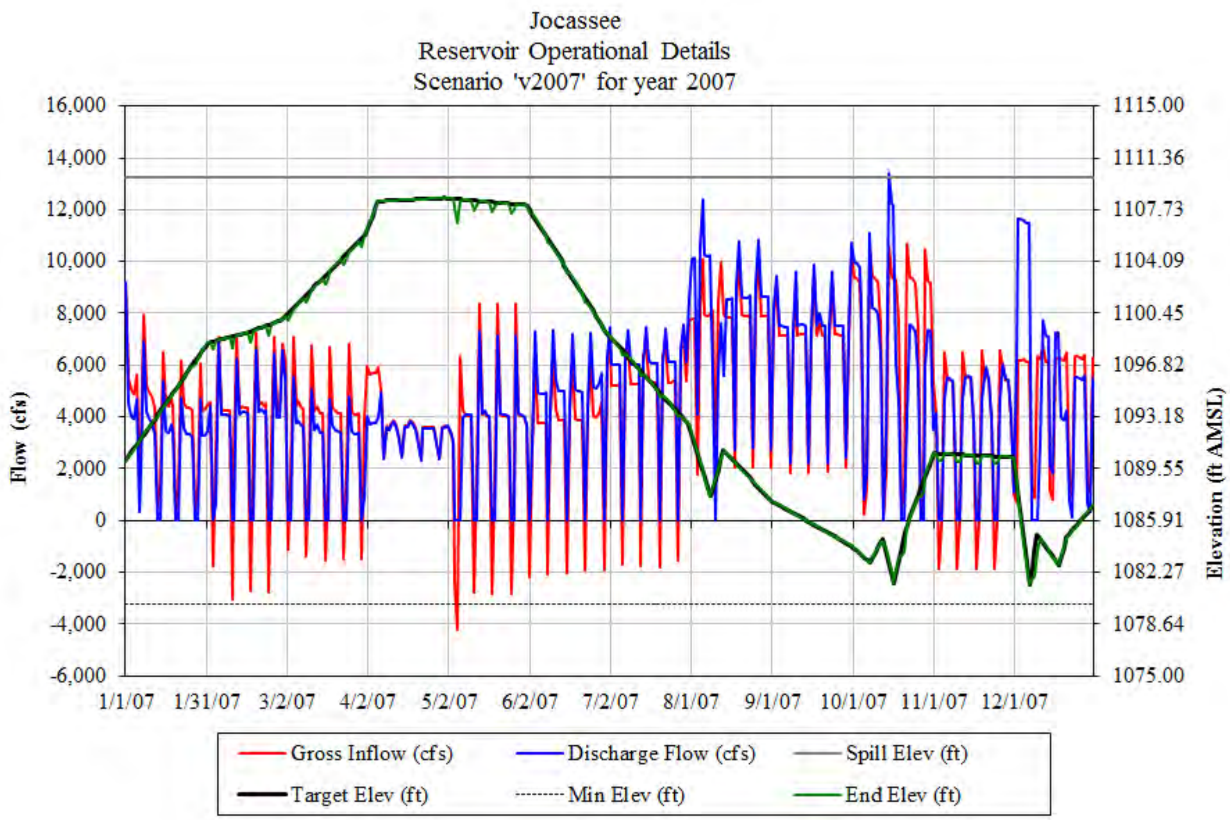
Historical (MWh)													
Facility	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Bad Creek	154,084	169,740	208,316	65,460	169,505	251,916	271,031	247,262	233,231	257,209	227,607	212,309	2,467,670
Jocassee	38,678	31,650	46,173	54,950	51,862	69,014	90,466	129,671	106,902	99,996	59,029	79,662	858,053
Keowee	1,574	2,309	922	1,216	4,944	8,523	3,755	5,552	3,275	0	-87	386	32,369
Hartwell	23,345	22,092	18,907	17,132	26,676	27,224	26,712	23,607	16,568	23,239	16,479	12,440	254,421
Richard B. Russell	64,568	40,196	31,531	20,025	34,772	50,217	48,210	48,657	40,887	54,621	39,602	23,734	497,020
J. Strom Thurmond	32,330	40,057	42,855	29,371	38,724	35,233	30,445	28,555	28,009	27,397	25,393	26,094	384,463
System Total	314,579	306,044	348,704	188,154	326,483	442,127	470,619	483,304	428,872	462,462	368,110	354,625	4,493,996
v2007 (MWh)													
Facility	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Bad Creek	161,415	170,465	207,435	28,516	228,707	247,146	286,458	251,241	239,428	261,656	237,088	216,009	2,535,564
Jocassee	53,075	50,505	48,657	56,744	54,294	72,211	92,211	131,237	108,305	101,577	58,068	79,923	906,807
Keowee	3,866	1,544	1,918	630	5,423	9,590	5,093	6,132	3,531	0	0	0	37,727
Hartwell	30,088	23,691	20,208	18,249	29,927	29,855	27,180	29,015	16,635	24,290	19,123	14,416	282,677
Richard B. Russell	30,782	43,020	45,875	45,820	50,240	48,781	45,272	48,708	31,459	35,020	43,499	41,792	510,268
J. Strom Thurmond	35,559	40,520	40,811	30,579	40,673	33,246	30,296	33,495	30,587	28,972	26,967	26,946	398,651
System Total	314,785	329,745	364,904	180,538	409,264	440,829	486,510	499,828	429,945	451,515	384,745	379,086	4,671,694
Difference (MWh) - (Modeled v2007 - Historical)													
Facility	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Bad Creek	7,331	725	-881	-36,944	59,202	-4,770	15,427	3,979	6,197	4,447	9,481	3,700	67,894
Jocassee	14,397	18,855	2,484	1,794	2,432	3,197	1,745	1,566	1,403	1,581	-961	261	48,754
Keowee	2,292	-765	996	-586	479	1,067	1,338	580	256	0	87	-386	5,358
Hartwell	6,743	1,599	1,301	1,117	3,251	2,631	468	5,408	67	1,051	2,644	1,976	28,256
Richard B. Russell	-33,786	2,824	14,344	25,795	15,468	-1,436	-2,938	51	-9,428	-19,601	3,897	18,058	13,248
J. Strom Thurmond	3,229	463	-2,044	1,208	1,949	-1,987	-149	4,940	2,578	1,575	1,574	852	14,188
System Total	206	23,701	16,200	-7,616	82,781	-1,298	15,891	16,524	1,073	-10,947	16,635	24,461	177,698
Percent Difference - ([Modeled v2007 - Historical]/Historical)													
Facility	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Bad Creek	4.8%	0.4%	-0.4%	-56.4%	34.9%	-1.9%	5.7%	1.6%	2.7%	1.7%	4.2%	1.7%	2.8%
Jocassee	37.2%	59.6%	5.4%	3.3%	4.7%	4.6%	1.9%	1.2%	1.3%	1.6%	-1.6%	0.3%	5.7%
Keowee	145.6%	-33.1%	108.0%	-48.2%	9.7%	12.5%	35.6%	10.4%	7.8%	0.0%	0.0%	-100.0%	16.6%
Hartwell	28.9%	7.2%	6.9%	6.5%	12.2%	9.7%	1.8%	22.9%	0.4%	4.5%	16.0%	15.9%	11.1%
Richard B. Russell	-52.3%	7.0%	45.5%	128.8%	44.5%	-2.9%	-6.1%	0.1%	-23.1%	-35.9%	9.8%	76.1%	2.7%
J. Strom Thurmond	10.0%	1.2%	-4.8%	4.1%	5.0%	-5.6%	-0.5%	17.3%	9.2%	5.7%	6.2%	3.3%	3.7%
System Total	0.1%	7.7%	4.6%	-4.0%	25.4%	-0.3%	3.4%	3.4%	0.3%	-2.4%	4.5%	6.9%	4.0%

FIGURE 4-9
SR CHEOPS MODEL V2007 AND HISTORICAL BAD CREEK PROJECT OPERATIONS



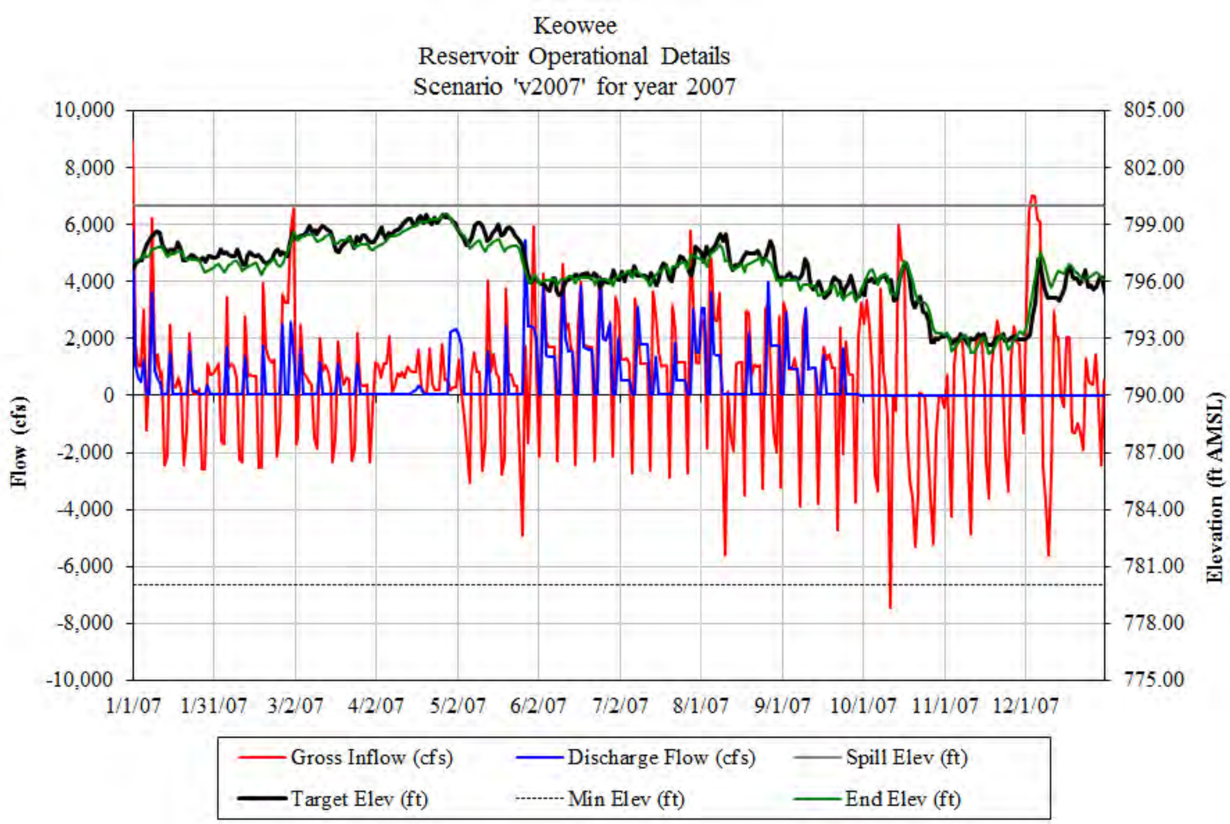
As previously noted, the historical Jocassee Reservoir operations were simulated in the v2007 scenario to mimic actual reservoir operations. Figure 4-10 shows Jocassee Reservoir historical elevation, flows, and modeled elevations and flows. As shown in Table 4-2, the simulated generation is 48,754 MWh (5.7 percent) higher than historical generation. A pumping power consumption 1,088,271 MWh was simulated, which is 1.7 percent less than historical. Negative flows are a result of upstream pumping operations.

FIGURE 4-10
SR CHEOPS MODEL V2007 AND HISTORICAL JOCASSEE DEVELOPMENT OPERATIONS



For each of the remaining four reservoirs, daily target elevations were input in the model to reflect the significantly varying end of day elevations. Figure 4-11 shows Lake Keowee historical and modeled operations for 2007. Negative flows are a result of upstream pumping operations. The model generally follows the trends of the historical elevations. During the fourth quarter of 2007, historical records show that the powerhouse did not release generation flows except for a few hours on December 31. To duplicate these operations, the Keowee powerhouse was modeled in maintenance outage, and wicket gate leakage was duplicated with a bypass flow condition during this timeframe. As shown in Table 4-2, the v2007 modeled generation at the Keowee Station is 5,358 MWh (16.6 percent) higher than historical.

FIGURE 4-11
SR CHEOPS MODEL V2007 AND HISTORICAL KEOWEE DEVELOPMENT OPERATIONS



Figures 4-12 through 4-14 show the USACE reservoir historical and modeled operations for 2007. As shown, the model follows the trends of the historical elevations very closely for each of the USACE reservoirs. Table 4-2 shows the v2007 modeled generation at Hartwell, Richard B. Russell, and J. Strom Thurmond Projects is 28,256; 13,248; and 14,188 MWh (11.1, 2.7, and 3.7 percent) higher than historical, respectively. The higher than historical modeled generation results are supported in the higher than historic discharge volume for the same period, shown in Figures 4-15 and 4-16. The simulated discharge volume from Lake Hartwell is 5.2 percent higher than the historical reported discharge for the 2007 period. Similarly, the simulated discharge volume from J. Strom Thurmond Lake is 3.8 percent higher than the historical reported discharge for the 2007 period.

FIGURE 4-12
SR CHEOPS MODEL V2007 AND HISTORICAL HARTWELL PROJECT OPERATIONS

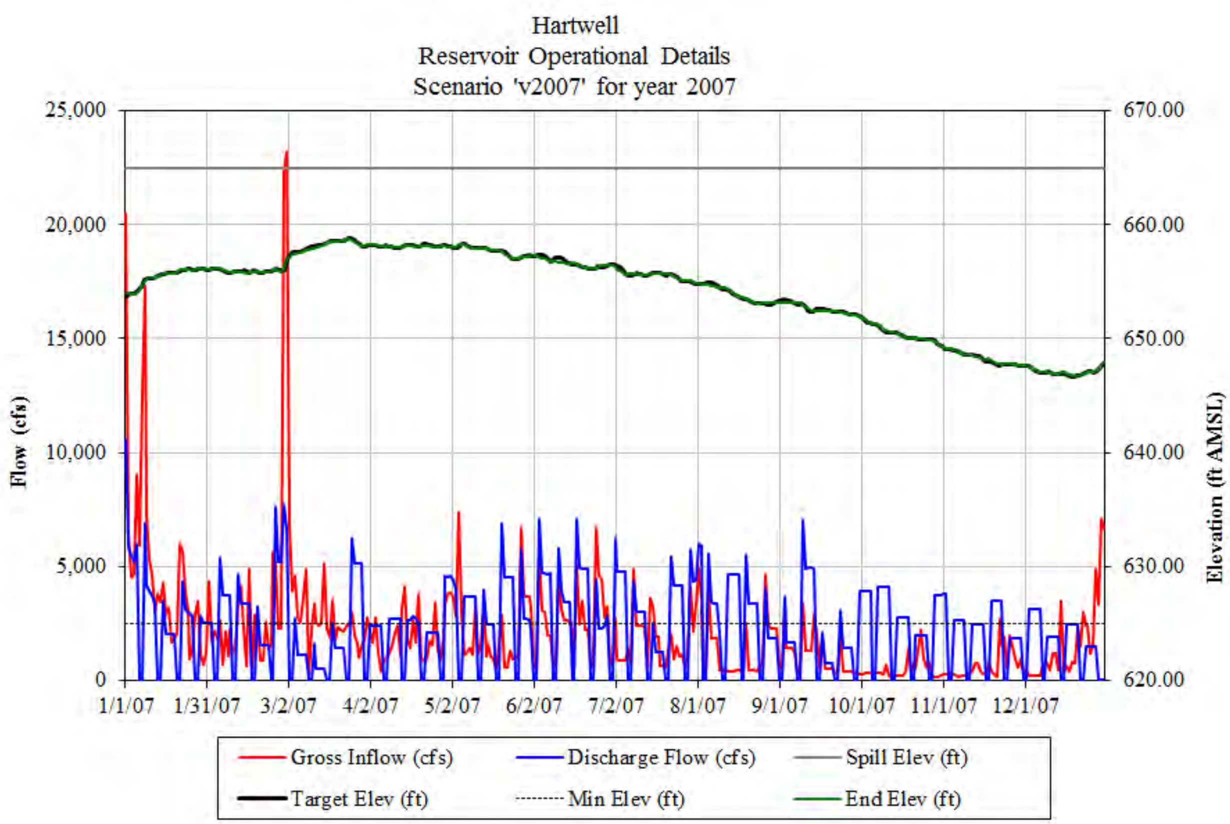


FIGURE 4-13
SR CHEOPS MODEL V2007 AND HISTORICAL RICHARD B. RUSSELL PROJECT OPERATIONS

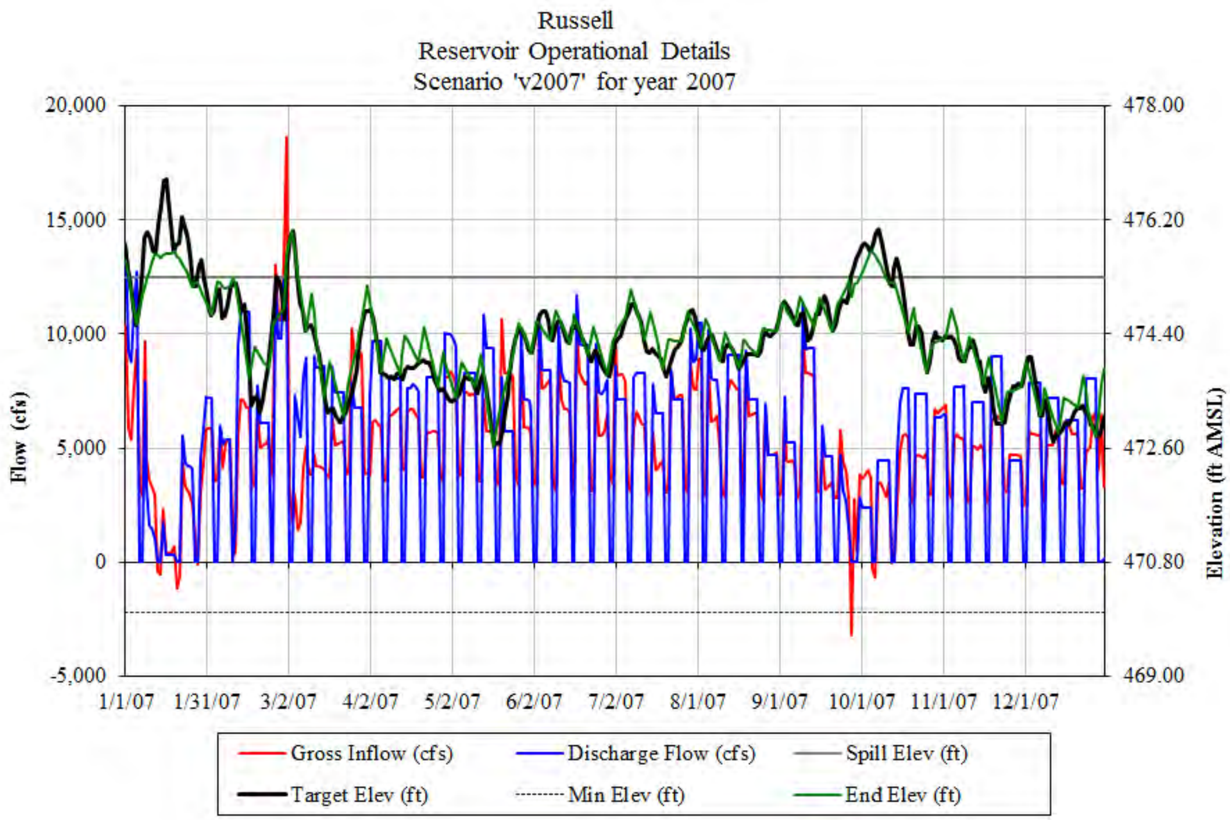


FIGURE 4-14
SR CHEOPS MODEL V2007 AND HISTORICAL J. STROM THURMOND PROJECT OPERATIONS

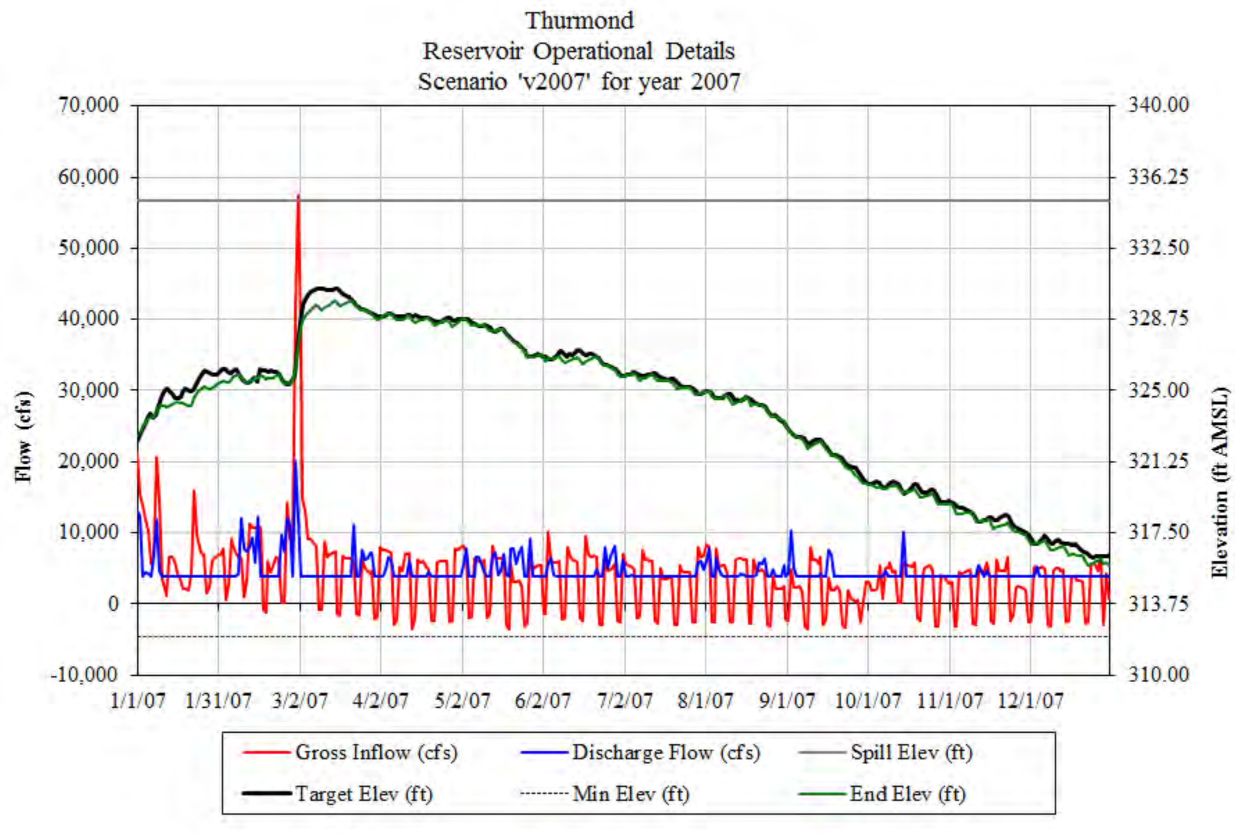


FIGURE 4-15
SR CHEOPS MODEL V2007 AND HISTORICAL HARTWELL PROJECT DISCHARGE COMPARISON

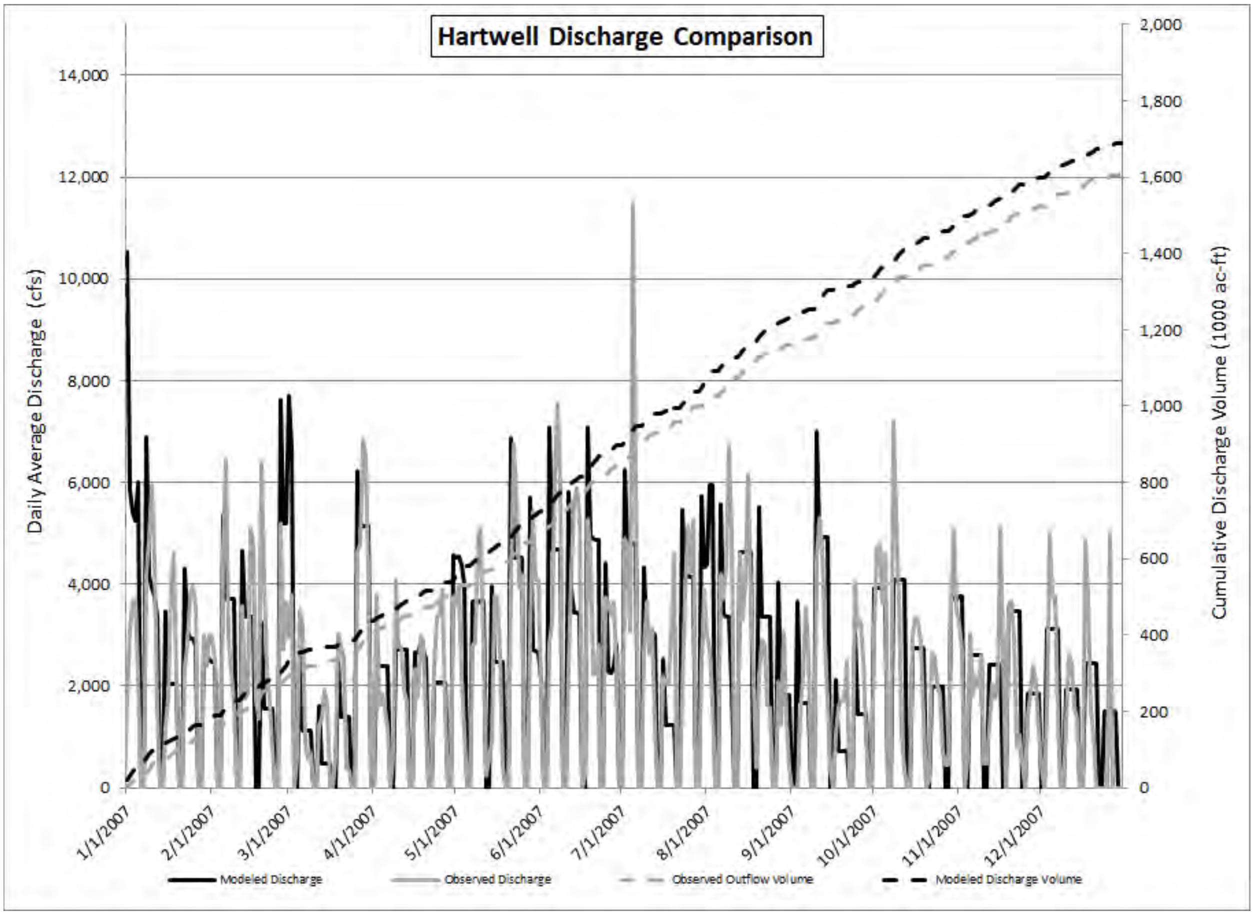
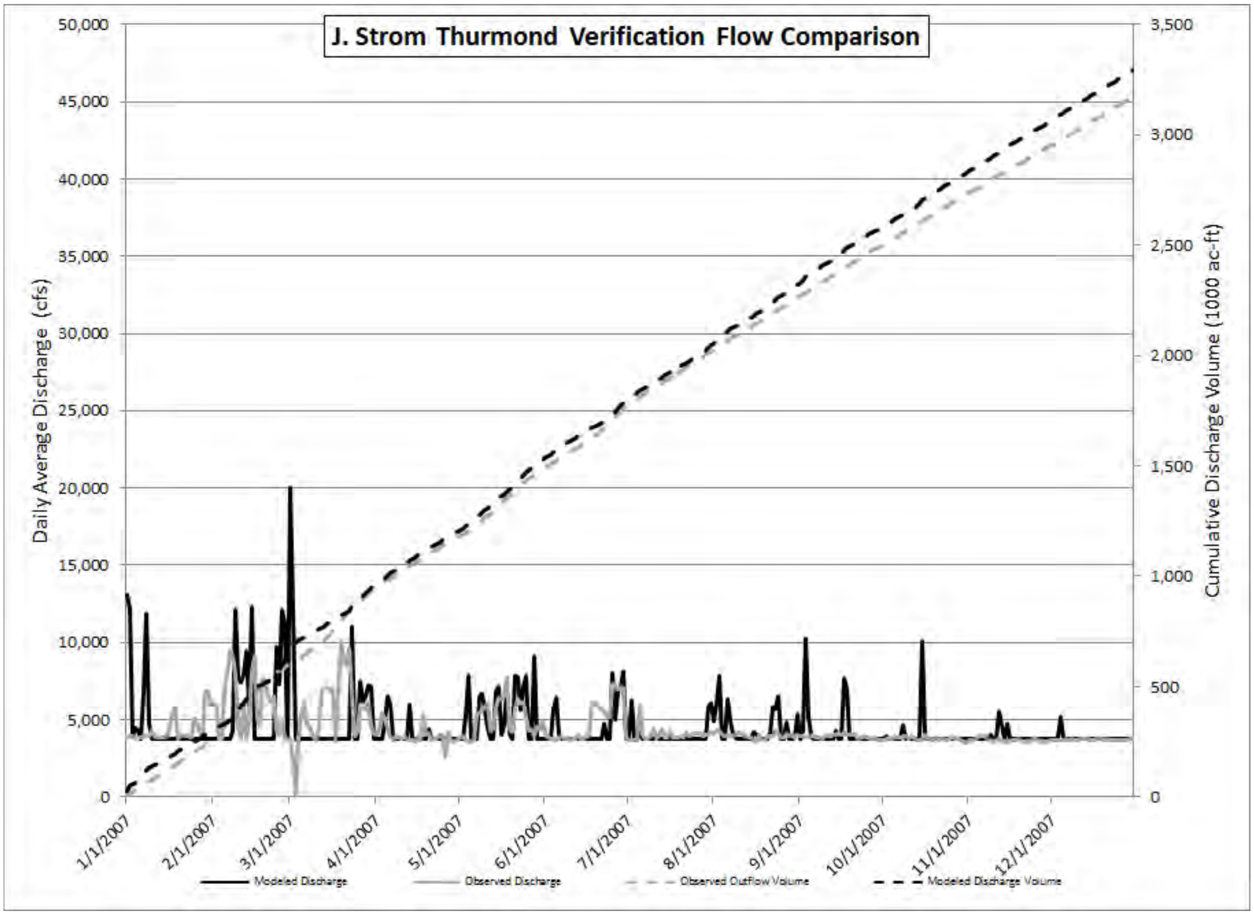


FIGURE 4-16
SR CHEOPS MODEL V2007 AND HISTORICAL J. STROM THURMOND PROJECT DISCHARGE COMPARISON



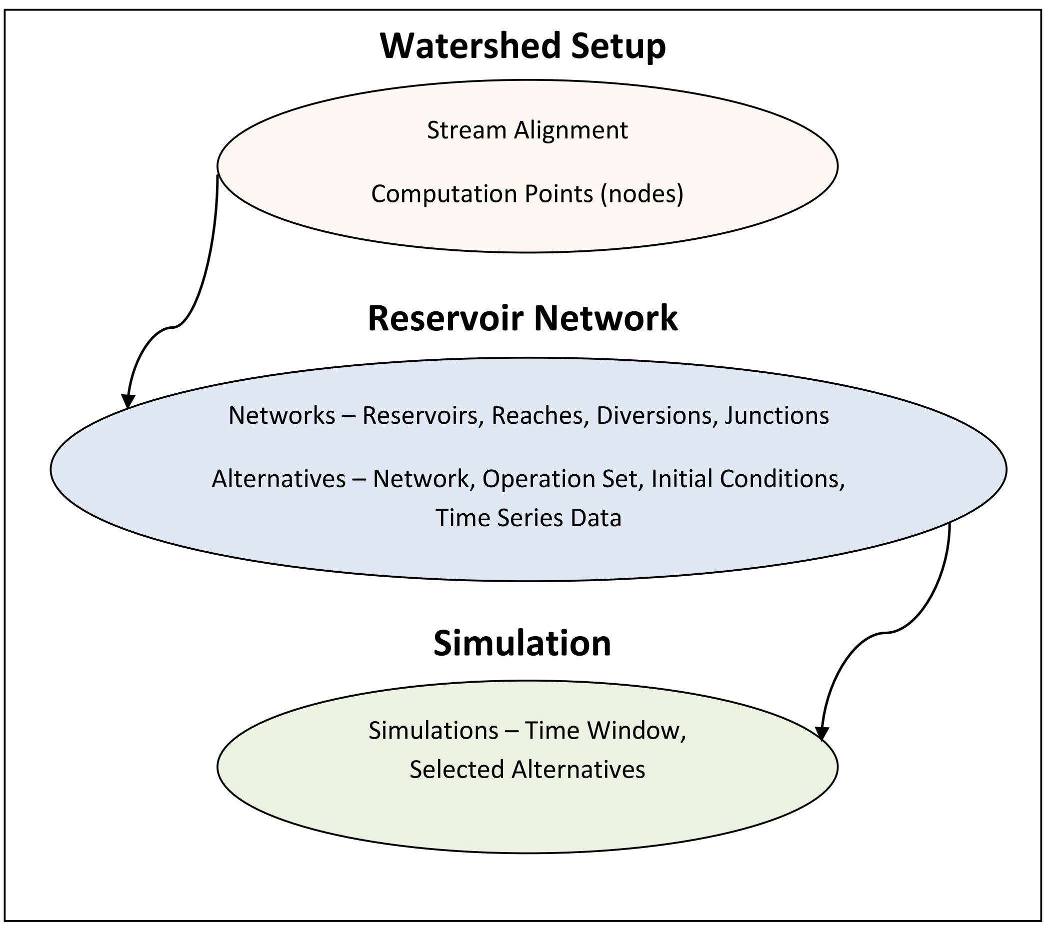
5.0 SR RESSIM MODEL – BASELINE

The following sections define the development of the Baseline scenario used for the verification of the SR ResSim Model. Each sub-section defines specific inputs used in the model verification to simulate historical operations.

5.1 SR ResSim Model Logic

ResSim is divided into three modules: Watershed Setup, Reservoir Network, and Simulation. Figure 5-1 provides an overview of the model logic and sequence (USACE 2007).

FIGURE 5-1
RESSIM MODULES



5.2 SR ResSim Model Input Data

The project data listed in the following subsections shows the general operational constraints and physical parameters used in the SR ResSim Model to define the current system configuration used in both the verification and the Baseline scenario setups. For consistency and comparison between model architecture, the model scenario selected for the SR ResSim Model verification is the same as used for the SR CHEOPS Model. Model verification uses historical data and tests the ability of the model to simulate actual operations of all six facilities. The verification scenario presented in this report is based on the NAA scenario with adjustments as defined in Baseline scenario below. The Baseline scenario was selected over the NAA scenario to more closely simulate historic operating conditions that have been used by Duke Energy for the selected hydrologic testing period (1998 through 2008 – verification).

- <u>No Action Alternative (NAA)/Existing License</u>

  The NAA reflects the operating conditions of the Jocassee, Keowee, Hartwell and J. Strom Thurmond facilities as defined in the 1968 Agreement with no changes and reflects the operations of the Project as outlined in the existing Project FERC license (FERC No. 2503). The 1968 Agreement is based on the concept of equalizing the percentage of combined remaining usable storage at Duke Energy Lake Jocassee and Lake Keowee with the percentage of combined remaining usable storage at the USACE Hartwell Lake and J. Strom Thurmond Lake.

- <u>Baseline (Existing Operations)</u>

  The Baseline scenario is based on the NAA scenario, except the minimum reservoir elevation at Lake Keowee is increased from 778 to 794.6 ft AMSL. The overall methodology used to determine required weekly releases from Lake Keowee remains unchanged. This scenario best describes the current/existing operations of the Duke Energy reservoirs.

- Verification

  The verification scenario is used for model verification and represents the Baseline scenario with the addition of historical water use (median 2003-2008) and reservoir elevations forced to simulate actual historical operations.

5.2.1 Reservoir Storage Curves

The Reservoir Storage Curve is a tabulated link between the reservoir elevation and reservoir volume. The elevations are in units of "feet" and the volumes are in "acre-feet." The model uses this curve to calculate elevations based on inflows and model-determined releases. Figure 5-2 shows the Bad Creek Reservoir storage curve used in the model. The data is from License Exhibit I Feb 4, 1974 (Duke Power Company 1974). The Lake Jocassee and Lake Keowee storage-volume relationships were revised based on bathymetric data collected in 2010 (Figures 5-3 and 5-4) and the USACE storage-volume relationships for Hartwell Lake, Richard B. Russell Lake, and J. Strom Thurmond Lake were updated based on published sedimentation rates from the Savannah River Basin. Sedimentation rates were converted to sediment volume using methods outlined in the USACE EM 1110-2-4000 and estimated compressed density of the sediment (Figures 5-5 through 5-7). A summary of the sedimentation calculations is provided in Appendix A.

FIGURE 5-2
BAD CREEK RESERVOIR STORAGE VOLUME CURVE

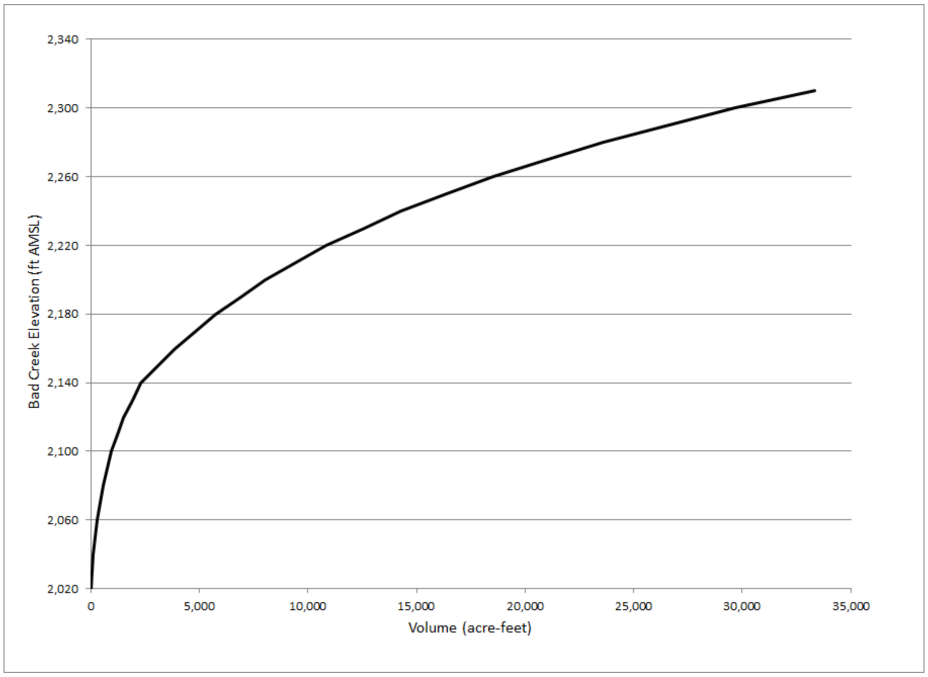


FIGURE 5-3
JOCASSEE RESERVOIR STORAGE VOLUME CURVE

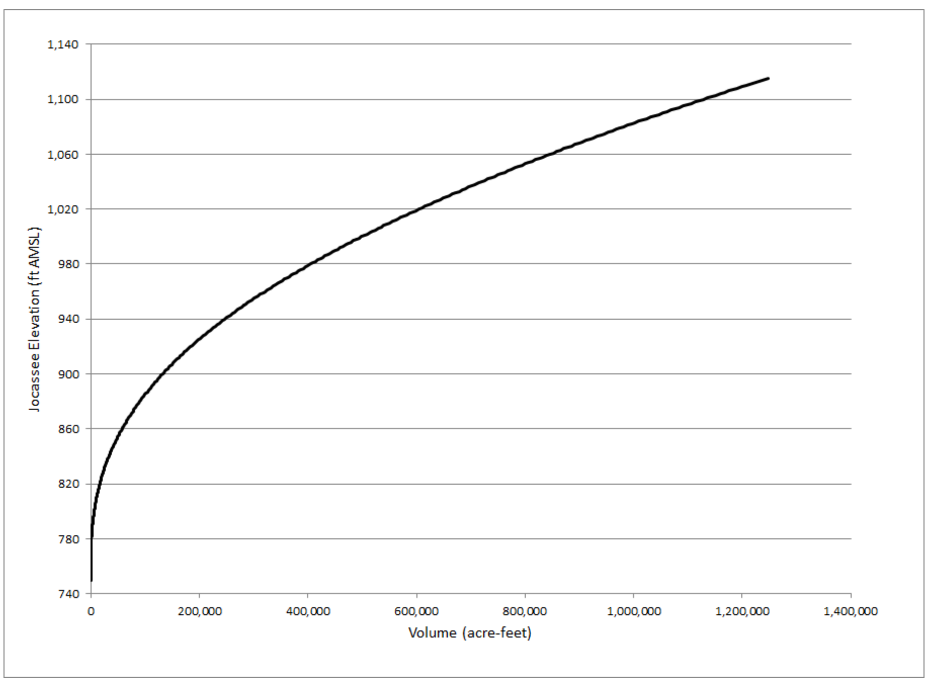


FIGURE 5-4
KEOWEE RESERVOIR STORAGE VOLUME CURVE

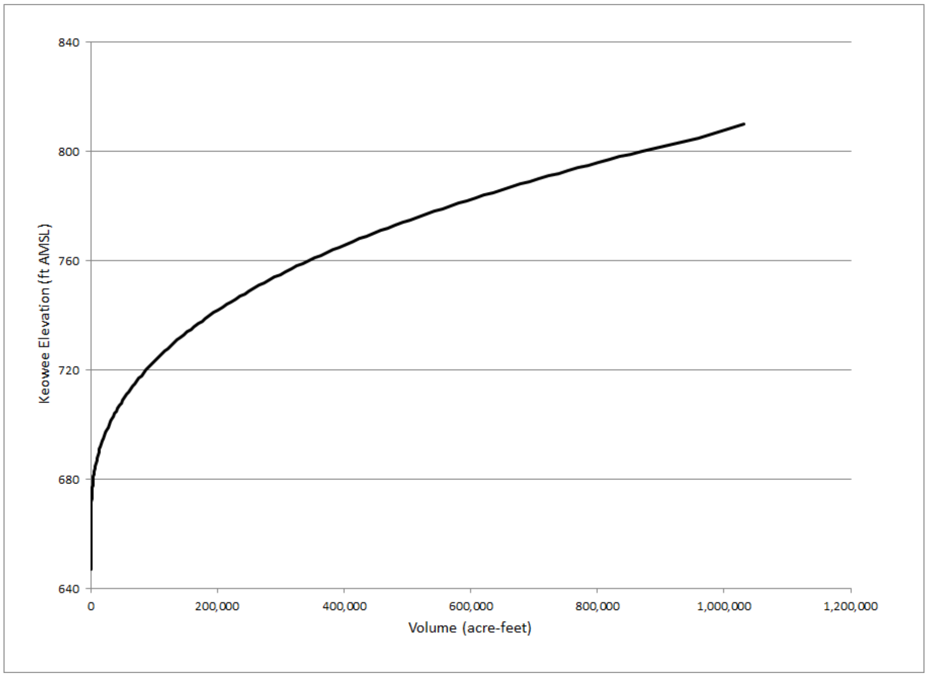


FIGURE 5-5
HARTWELL RESERVOIR STORAGE VOLUME CURVE

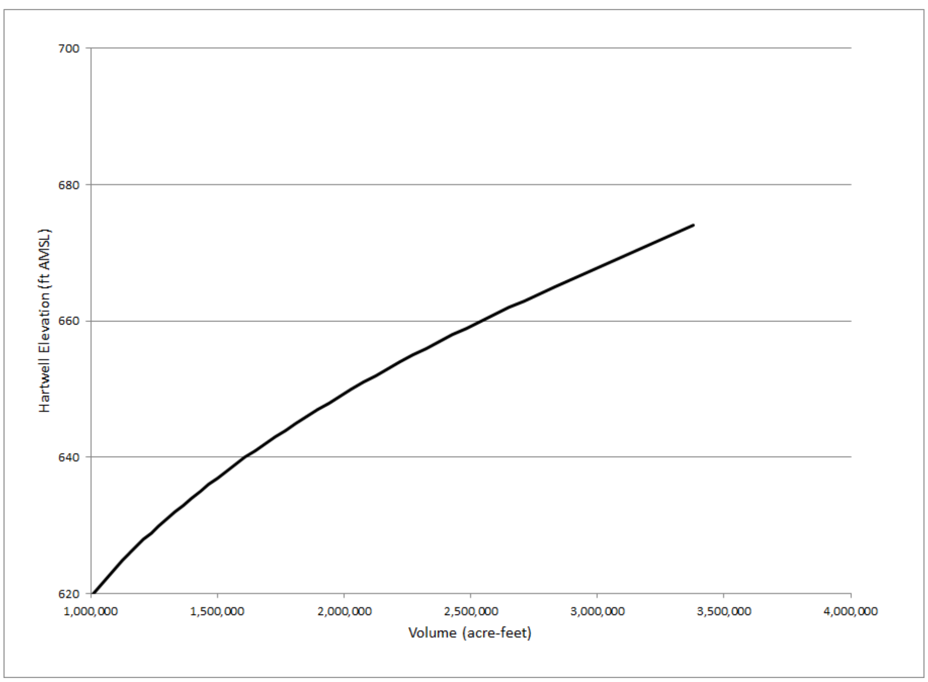


FIGURE 5-6
RICHARD B. RUSSELL RESERVOIR STORAGE VOLUME CURVE

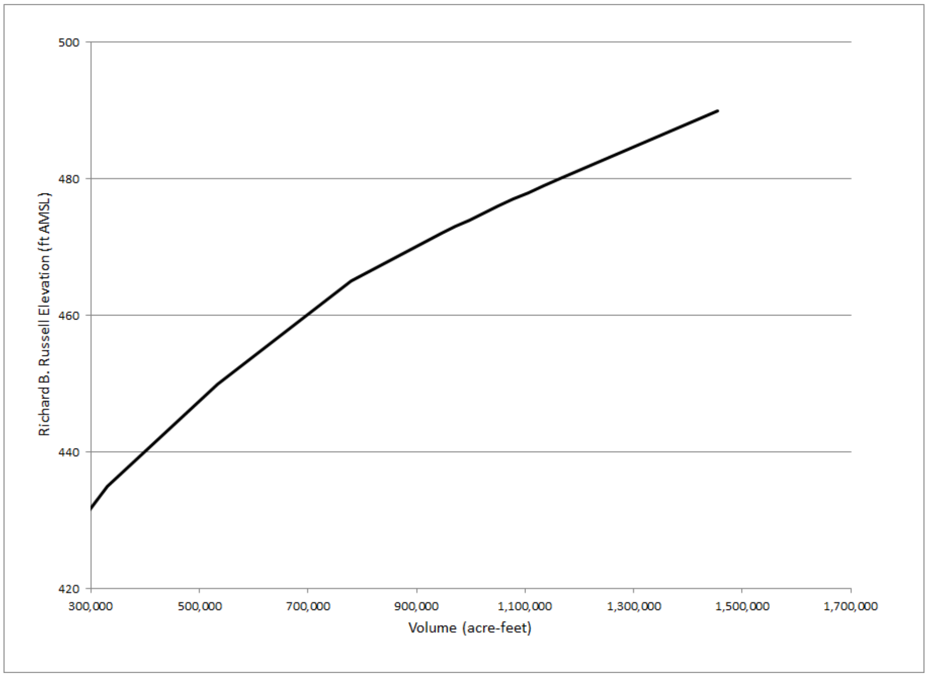
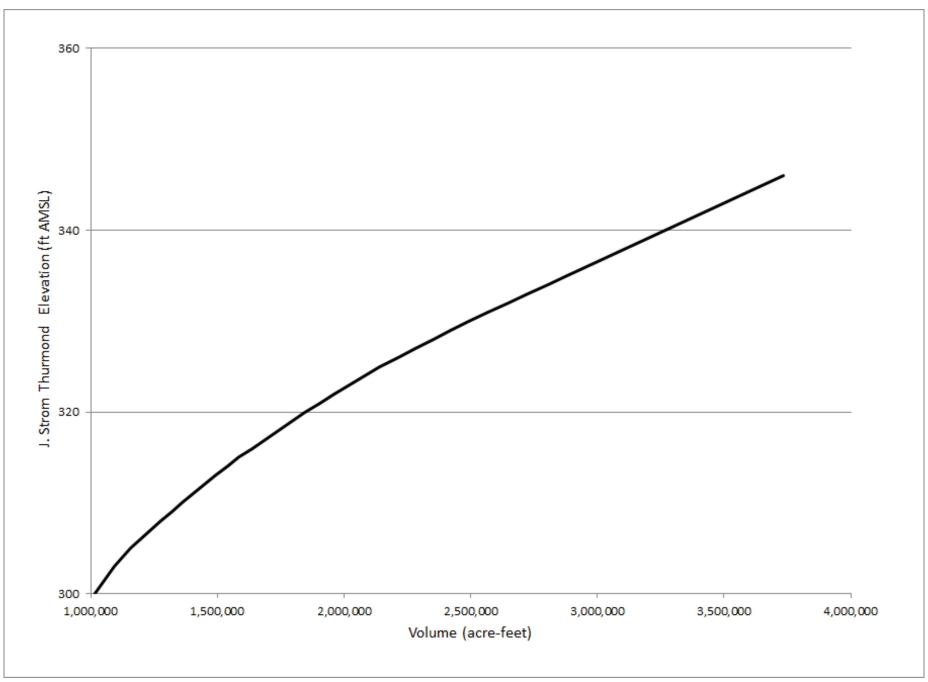


FIGURE 5-7
J. STROM THURMOND RESERVOIR STORAGE VOLUME CURVE



5.2.2 Reservoir Area Curves

The Reservoir Area Curve is a tabulated link between the reservoir elevation and reservoir surface area. The elevations are in units of "feet" and the areas are in "acres." The model uses this curve to calculate the surface area and uses this data for computing evaporation losses. Figures 5-8 through 5-13 show the reservoir area curves used in the SR ResSim Model.

FIGURE 5-8
BAD CREEK RESERVOIR AREA CURVE

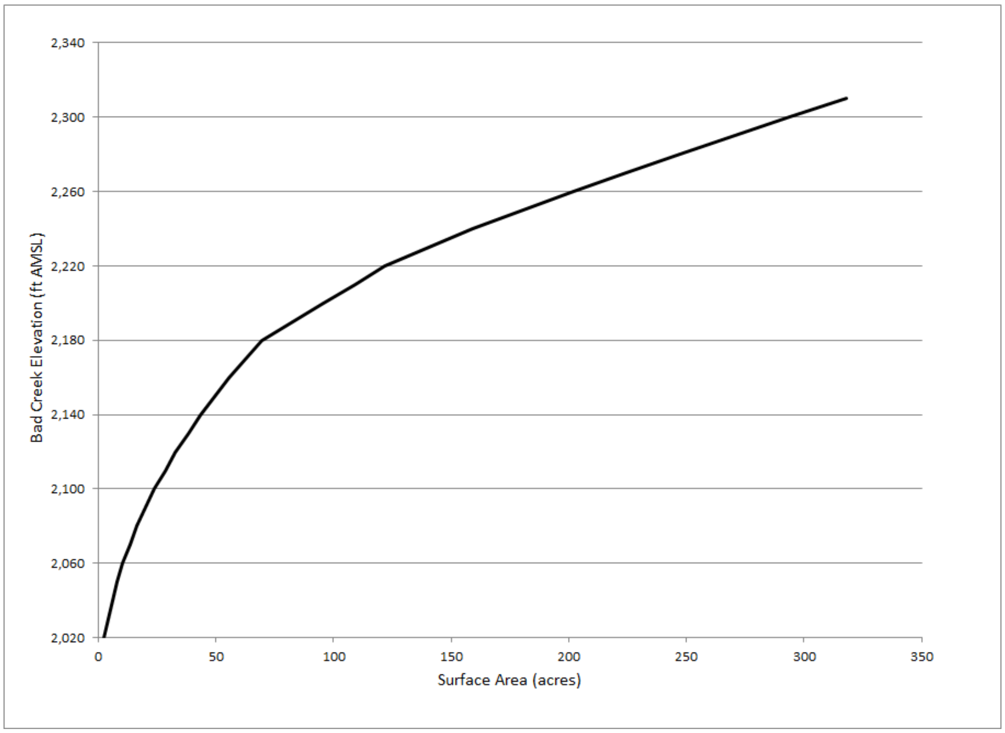


FIGURE 5-9
JOCASSEE RESERVOIR AREA CURVE

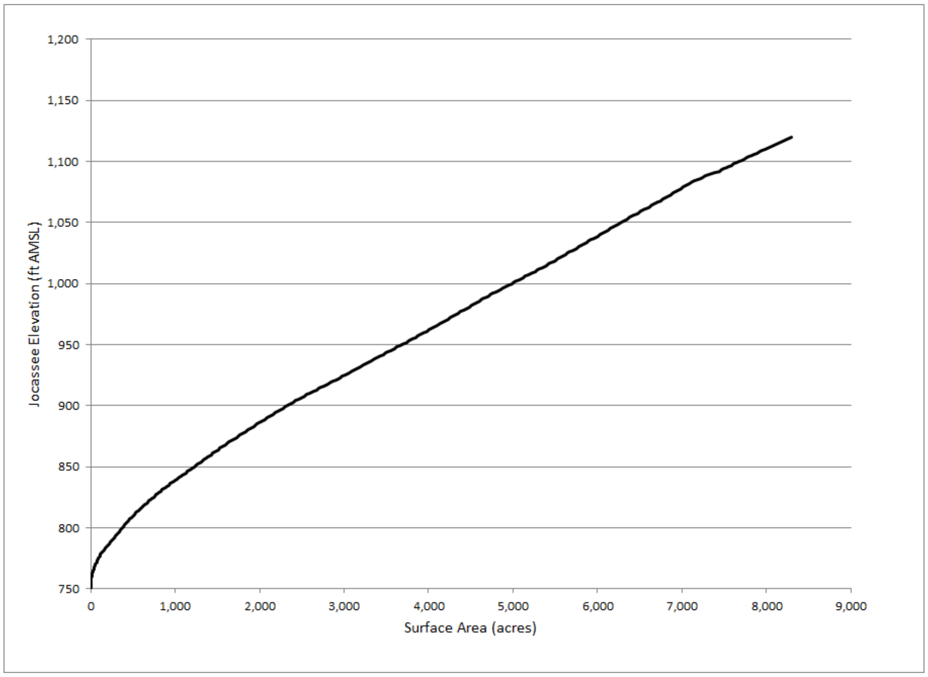


FIGURE 5-10
KEOWEE RESERVOIR AREA CURVE

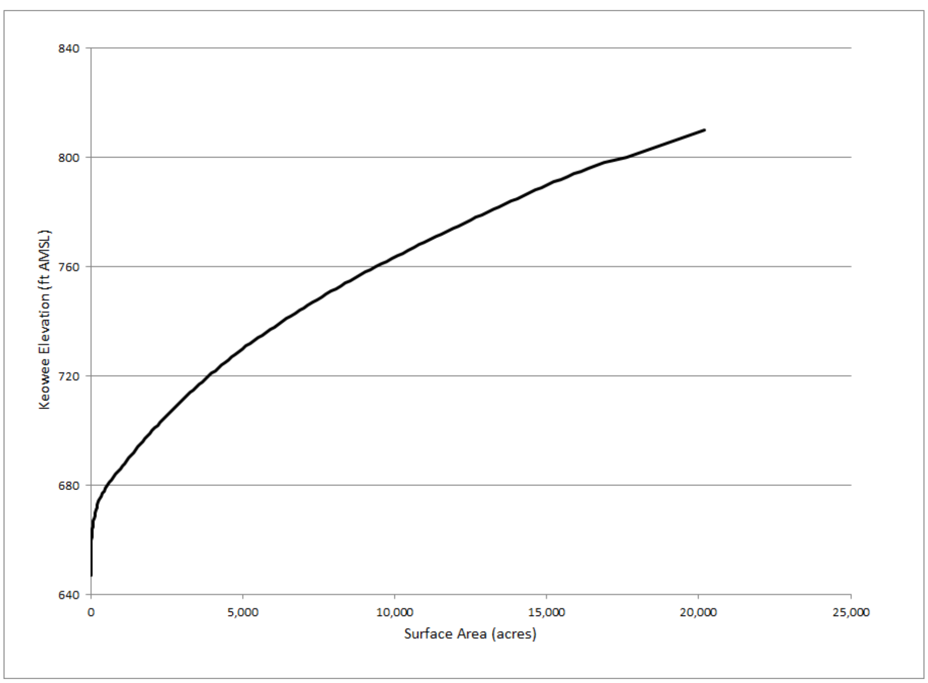


FIGURE 5-11
HARTWELL RESERVOIR AREA CURVE

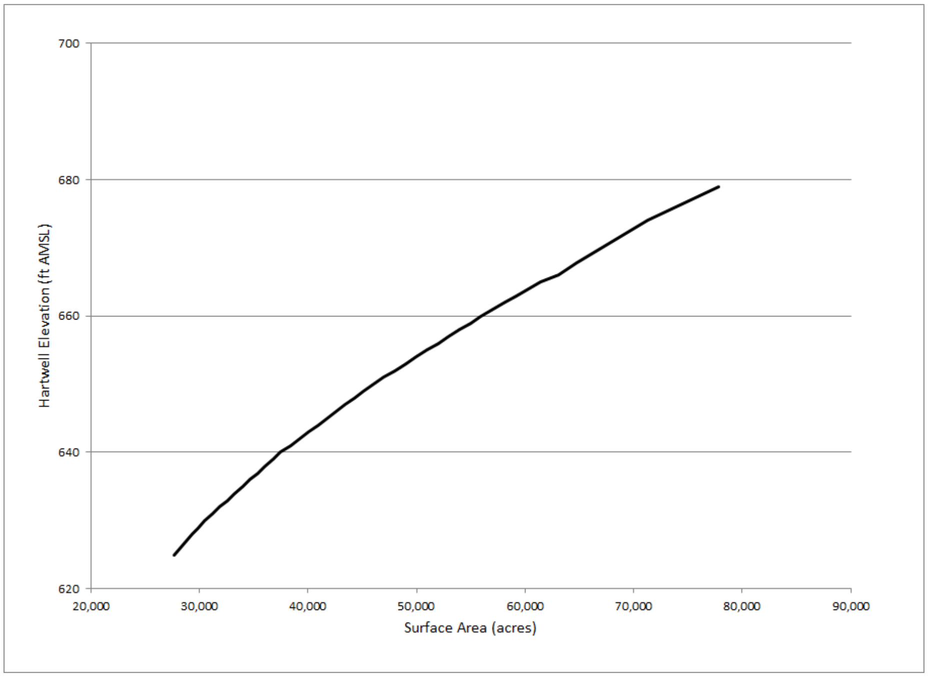


FIGURE 5-12
RICHARD B. RUSSELL RESERVOIR AREA CURVE

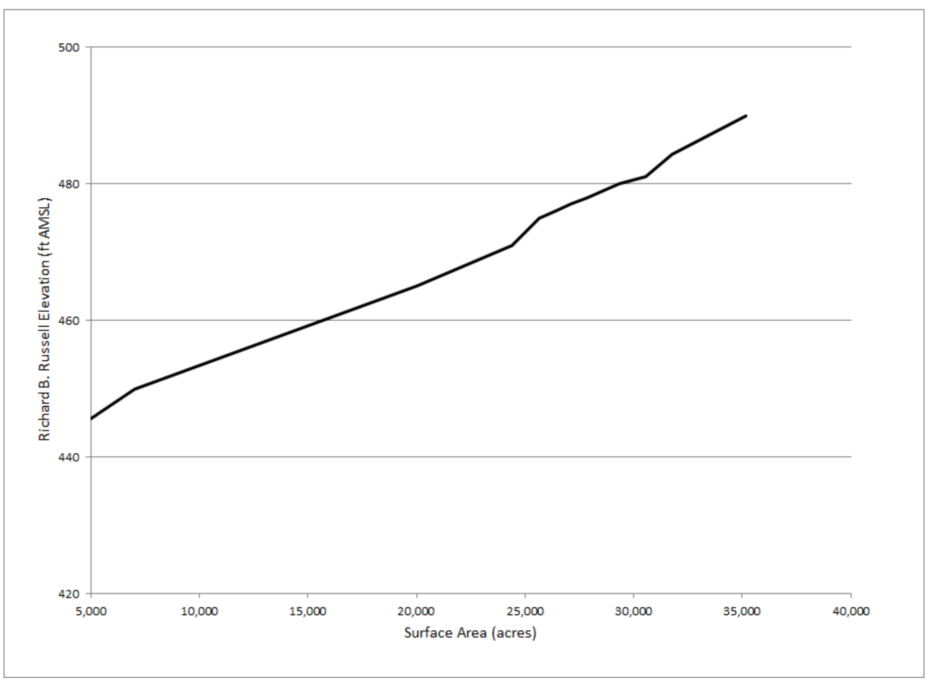
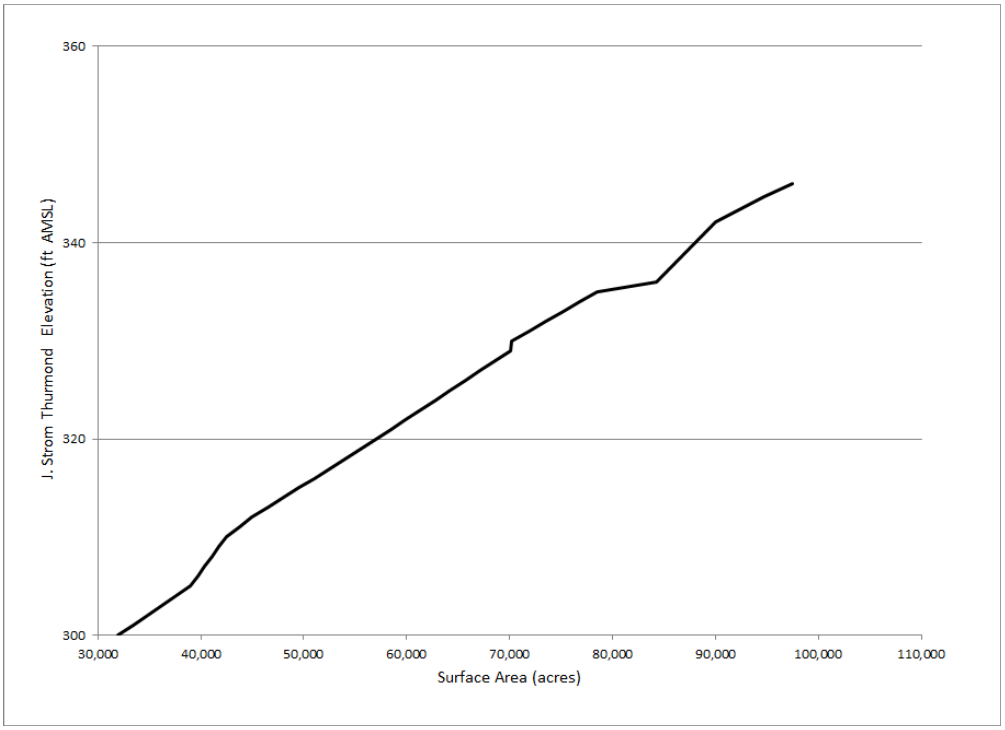


FIGURE 5-13
J. STROM THURMOND RESERVOIR AREA CURVE



5.2.3 Monthly Evaporation

The SR ResSim evaporation is based upon a monthly-varying coefficient that defines the evaporative loss in inches per month. This evaporative loss is not strictly composed of losses due to evaporation, but rather a net change to inflows as a result of evaporation, direct precipitation to water surface, precipitation runoff, and changes to evapotranspiration losses. This coefficient is multiplied by the surface area and divided by the number of days in the month to compute total evaporative loss volume for the reservoir for each day. Table 5-1 shows the evaporation losses for each reservoir by month. The evaporation loss coefficients reflect the monthly 2008 values published by ARCADIS in the Savannah River Basin May 13, 2013, time series release (ARCADIS 2010, 2013). The September 16, 2010 ARCADIS time series release contains the same 2008 evaporation values as provided in the May 2013 release.

TABLE 5-1
SR RESSIM MODEL EVAPORATIVE LOSS COEFFICIENTS

	Bad Creek Evaporation Loss (inches/month)	Jocassee Evaporation Loss (inches/month)	Keowee Evaporation Loss (inches/month)	Hartwell Evaporation Loss (inches/month)	Russell Evaporation Loss (inches/month)	Thurmond Evaporation Loss (inches/month)
Jan	-1.56	-1.04	-0.56	-0.57	-0.40	-1.18
Feb	-0.77	-0.26	0.03	0.01	-0.19	-0.65
Mar	-2.55	-1.55	0.03	0.01	-0.02	-0.03
Apr	0.90	1.45	1.65	1.47	1.47	1.30
May	2.26	2.74	2.44	2.84	3.55	3.33
Jun	4.13	4.49	4.51	4.47	4.73	4.55
Jul	2.36	2.98	3.39	3.22	2.43	2.90
Aug	-0.46	0.44	0.37	0.72	1.58	1.44
Sep	1.94	2.30	2.57	2.83	2.41	2.29
Oct	0.28	0.66	0.98	0.79	0.32	0.28
Nov	-0.58	-0.23	0.05	0.05	-0.40	-2.31
Dec	-3.29	-2.47	-2.17	-1.83	-1.11	-1.27

5.2.4 Tailwater Data

The Tailwater Curve relates the powerhouse tailwater elevation to the developments' outflow. In cases where the powerhouse discharges directly into a downstream reservoir, the downstream reservoir's elevation is used to compute tailwater elevation. The elevation is in units of "feet" while the flow is in "cfs." The tailwater elevation is subtracted from the reservoir elevation to calculate the gross head used in determining turbine and pump-turbine hydraulic performance.

The Bad Creek Project discharges directly into Lake Jocassee, so the elevation of Lake Jocassee is the controlling factor for the Bad Creek Project tailwater. Likewise, the Jocassee powerhouse discharges directly into Lake Keowee, so the elevation of Lake Keowee is the control for Jocassee Development tailwater computation.

The Keowee powerhouse discharges into Hartwell Lake. However, due to backwater effects in the upstream lake channel, there is a significant difference between Hartwell Lake elevation (Hartwell Dam) and the water surface elevation below the Keowee powerhouse when the turbines are in operation. Table 5-2 shows the Keowee powerhouse tailwater curve in stage units of feet for various powerhouse outflows in cfs.

TABLE 5-2
KEOWEE STATION TAILWATER RATING CURVE

Stage (ft AMSL)	Flow (cfs)	Stage (ft AMSL)	Flow (cfs)
657.0	0	680.0	39,868
660.0	5,042	684.8	59,879
665.1	11,345	689.9	85,879
670.0	16,545	695.0	113,612
674.9	26,000		

Similar to the Bad Creek and Jocassee facilities, the Hartwell powerhouse discharges directly into the Richard B. Russell Lake without backwater effects. Therefore, Richard B. Russell Lake elevation is the control for Hartwell Project tailwater. The SR ResSim Model will use the greater of 475 ft AMSL or Richard B. Russell Lake water surface elevation. Reservoir elevation 475 ft AMSL is the minimum tailwater elevation that was provided by the USACE for modeling purposes. The Richard B. Russell powerhouse discharges into J. Strom Thurmond Lake. J. Strom Thurmond Lake elevation is the control for Richard B. Russell Project tailwater. The J. Strom Thurmond Project tailwater rating curve is shown in Table 5-3.

TABLE 5-3
J. STROM THURMOND PROJECT TAILWATER RATING CURVE

Stage (ft AMSL)	Flow (cfs)	Stage (ft AMSL)	Flow (cfs)
187	0	220	280,000
190	15,000	230	440,000
200	65,000	240	640,000
210	155,000	250	870,000

5.2.5 Spillway Capacity

The Spillway Curve contains the data relating reservoir elevation (feet) and spillway discharge capacity (cfs). This data allows the model to determine the maximum amount of water that can be spilled at the current reservoir elevation and is the sum of all spillway conveyances with gates open to maximum setting. The SR ResSim Model allows for a simple spillway relationship of elevation and flow; therefore all spillways, including gates, are modeled as a relationship of elevation and flow.

The tabulated data for Bad Creek Project is shown in Table 5-4 and is taken from the Bad Creek Pumped Storage Project Supporting Technical Information (Duke Energy 2008). The Bad Creek emergency spillway is also known as the East Dike.

TABLE 5-4
BAD CREEK SPILLWAY CAPACITY TABLE

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
2,313.5	0	2,315.0	2,313
2,313.8	17	2,315.5	4,477
2,314.3	477	2,316.0	7,153
2,314.6	1,051		

Table 5-5 shows the maximum spillway capacity of the two gated spillways as delineated in the Jocassee Pumped Storage Project Supporting Technical Information (HDR 2010).

TABLE 5-5
JOCASSEE SPILLWAY (TOTAL GATED) CAPACITY TABLE

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
1,077	0	1102	34,531
1,082	2,762	1107	46,054
1,087	8,117	1112	58,671
1,092	15,374	1117	67,321
1,097	24,248	1122	74,138

Table 5-6 shows the spillway capacity of the four gated spillways as delineated in the Keowee Supporting Technical Information (HDR 2012).

TABLE 5-6
KEOWEE SPILLWAY (TOTAL GATED) CAPACITY TABLE

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
765	0	790	63,268
770	5,505	795	82,550
775	15,851	800	102,810
780	29,399	805	123,645
785	45,393	810	144,639

The spillway capacities of the USACE projects are shown in Tables 5-7 through 5-9 and contain original data received from the USACE and as represented in their SR ResSim Model.

TABLE 5-7
HARTWELL SPILLWAY (SINGLE GATE) CAPACITY TABLE

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
630	0	657	21,577	666	34,679
635	1,400	658	22,908	667	36,182
640	4,400	659	24,274	668	37,709
645	8,500	660	25,675	669	39,260
650	13,400	661	27,110	670	40,833
653	16,604	662	28,581	671	42,430
654	17,795	663	30,086	672	44,050
655	19,021	664	31,625	673	45,693
656	20,282	665	33,200	674	47,359

*The Hartwell Project includes 12 gates.

TABLE 5-8
RICHARD B. RUSSELL SPILLWAY (SINGLE GATE) CAPACITY TABLE

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
436	0	473	45,228	482	63,000
440	1,000	474	47,137	483	65,000
450	9,000	475	49,074	484	67,000
455	14,900	476	51,042	485	69,000
460	22,300	477	53,038	486	71,000
465	30,600	478	55,063	487	72,500
470	39,532	479	57,116	488	74,000
471	41,500	480	59,300	489	75,500
472	43,349	481	62,000	490	77,100

*The Richard B. Russell Project includes 10 gates.

TABLE 5-9
J. STROM THURMOND SPILLWAY (TOTAL GATED) CAPACITY TABLE

Elevation (ft AMSL)	Capacity (cfs)	Elevation (ft AMSL)	Capacity (cfs)
300	0	325	405,000
305	27,000	330	545,000
310	95,000	335	688,000
315	182,000	340	855,000
320	282,000	345	1,025,000

5.2.6 Spill and Minimum Elevations

The spill or flood control elevation relates to a variety of physical situations (spillway crest, partial gate coverage, maximum normal pool, etc.), but it represents the elevation at which the model will begin to simulate spill to avoid increasing water elevation.

The minimum elevation, or inactive zone elevation, is the minimum allowable reservoir elevation. The elevation could be set by regulations or by a physical limit (lowest available outlet invert). The model will operate to eliminate occurrences when the reservoir elevation dips below this elevation.

Table 5-10 lists the spill and minimum elevations for each development in the model.

TABLE 5-10
SR RESSIM MODEL RESERVOIR MAXIMUM AND MINIMUM ELEVATIONS

Facility	Spill Elevation (ft AMSL)	Minimum Elevation (ft AMSL)
Bad Creek	2,310	2,150.0
Jocassee	1,110.0	1,080.0
Keowee	800.0	794.6
Hartwell	665.0	625.0
Russell	480.0	465.0
Thurmond	335.0	312.0

5.2.7 Target Elevations

The target elevation, or Conservation Pool Guide Curve, is the user defined elevation which the model attempts to meet (targets) as the end-of-day reservoir elevation. The model straight-line interpolates between user input points to identify a target elevation for each day. The model will deviate from the target to accommodate forecasted inflows, to meet system power requirements, to meet the plant's own outflow requirements or constraints, and maintain storage balance relationship.

Table 5-11 lists the guide curves used for modeling the Duke Energy reservoirs, and Table 5-12 lists the guide curves for the USACE reservoirs. Target requirements for the USACE Project were provided by the USACE with their SR ResSim Model.

TABLE 5-11
SR RESSIM MODEL GUIDE CURVE ELEVATIONS OF DUKE ENERGY RESERVOIRS

	Bad Creek Target Elev (ft AMSL)	Jocassee Target Elev (ft AMSL)	Keowee Target Elev (ft AMSL)
1-Jan	2,280	1,106	799.9
1-May	2,280	1,109.5	799.9
15-Oct	2,280	1,109.5	799.9
31-Dec	2,280	1,106	799.9

TABLE 5-12
SR RESSIM MODEL GUIDE CURVE TARGET ELEVATIONS OF USACE RESERVOIRS

	Hartwell Target Elev (ft AMSL)	Russell Target Elev (ft AMSL)	Thurmond Target Elev (ft AMSL)
1-Jan	656	475	326
1-Apr	660	475	330
15-Oct	660	475	330
15-Dec	656	475	326

5.2.8 Minimum Flows

The Hartwell, Richard B. Russell, and J. Strom Thurmond Projects each have required fish spawning rules in the SR ResSim Model. The rule requires outflow to equal inflow if the reservoir is at or below target elevation during the month of April. Additionally, the J. Strom Thurmond Project has a required daily discharge of at least 3,800 cfs year-round.

5.2.9 Maximum Flows

The model allows for a maximum flow constraint to be applied at either a powerhouse or at a downstream node – this will limit operations to restrict flow to a maximum of the defined limit. The J. Strom Thurmond Project has a maximum flow restriction at the downstream node in Augusta, Georgia, depending on the reservoir elevation of J. Strom Thurmond Lake. If J. Strom Thurmond Lake elevation is below 330 ft AMSL, the maximum allowable flow at Augusta is 20,000 cfs; and if the reservoir elevation is greater than or equal to 330 ft AMSL, the maximum allowable flow is 30,000 cfs. These flow restrictions are based on goals for normal operation at the development. Under extreme flooding, these flows can be exceeded.

The Richard B. Russell Project has a maximum flow constraint of 60,000 cfs, and the Hartwell Project has a maximum flow constraint of 28,500 cfs.

5.2.10 Water Withdrawals

Historical water use (withdrawals and returns in cfs) were estimated as part of the Savannah River Basin September 16, 2010 UIF time series release (ARCADIS 2010, 2013). The median 2003-2008 monthly water use in cfs was modeled in the Verification scenario to represent historical municipal and industrial water use from each reservoir. Additionally, the 2003 through 2008 period represents recent activity at current population levels and industrial uses. Table 5-13 below shows the withdrawals and returns in the baseline condition. Negative withdrawals represent a net flow return to the reservoir. The example calculation below describes the withdrawal calculation for a reservoir for a month:

$$WR_{\mathrm{R1,Month}} = Median(WR_{Day,Year})$$

where: $WR_{R1,Month}$ is the net withdrawal in (cfs) for the reservoir for the month

$WR_{Day,Year}$ is the withdrawal (cfs) for the reservoir for each day of the month for each of the months of interest in the 2003 through 2008 period

TABLE 5-13
WATER WITHDRAWALS

	Water Withdrawal (avg cfs/day)			Water Return (avg cfs/day)
Day of Year	**Keowee**	**Hartwell**	**J. Strom Thurmond**	**Richard B. Russell**
Jan 1	76.66	29.14	2.61	4.75
Feb 1	76.67	29.53	1.70	5.50
Mar 1	76.88	30.15	0.32	6.37
Apr 1	74.67	33.75	3.14	3.92
May 1	71.82	42.23	7.00	1.80
Jun 1	84.00	50.51	7.70	1.26
Jul 1	84.70	45.39	7.25	1.65
Aug 1	83.24	45.92	8.25	1.10
Sep 1	88.23	44.03	7.01	0.96
Oct 1	79.59	42.82	6.05	1.88
Nov 1	68.19	34.16	5.07	2.92
Dec 1	74.69	29.75	3.70	4.60

5.2.11 Storage Balance Operations and SR ResSim Model Alternatives

This section provides details of the storage relationship between the Duke Energy and USACE facilities as defined by the 1968 Agreement. Details of SR ResSim Model Alternatives (model scenarios) are also included in this section as examples of how the SR ResSim Model is set up for study purposes including testing (verification scenarios).

On October 1, 1968, Duke Energy's predecessor, Duke Power Company, entered into the 1968 Agreement with the USACE Savannah District and the SEPA regarding stored water sharing (releases) from the Project (Duke Power Company 1968). The 1968 Agreement defines the balancing of the available storage in the Duke Energy reservoirs (Lake Jocassee and Lake

Keowee) with the available storage in the USACE reservoirs (Hartwell Lake and J. Strom Thurmond Lake). The SR ResSim Model incorporates the terms of the 1968 Agreement through a series of programming rules. These rules are integral in simulating the storage relationships between the developments and significant time was spent by HDR and the USACE refining these rules in the SR ResSim Model (HDR 2014).

The storage balance operations of the system are simulated in ResSim using a combination of the Tandem and the Storage Balance Rules. The tandem operation rule establishes a link between reservoirs to achieve a storage balance. Each reservoir in the system from the Jocassee Development to the J. Strom Thurmond Project is simulated with a tandem rule. The reservoir storage at the Bad Creek Project and Richard B. Russell Project were not included in the 1968 Agreement between the USACE and Duke Energy. Therefore, Bad Creek Reservoir is not linked to the system via the tandem rule. However, for model stability purposes, the Richard B. Russell Lake is included while using a rule-link but no reservoir storage adjustments are required. Each reservoir in the system is linked to its downstream reservoir with the tandem rule (except as noted). The tandem rule is then linked to a system storage balance relationship. The storage balance definition defines the rate of drawdown at each reservoir in relation to the next downstream reservoir and is user definable. The application of the tandem rule and corresponding storage balance definition, plus weekly maximum Keowee Station release limits, simulates the system in accordance with the 1968 Agreement between the USACE and Duke Energy.

Both the Verification and Baseline scenarios include the tandem operations and supporting storage balance definitions for operating conditions currently being followed by Duke Energy. The storage balance definitions (charts) for the Verification and Baseline scenarios are presented in Figures 5-14 and 5-15. As an example of how the SR ResSim Model uses this information, if J. Strom Thurmond Lake is at 320 ft AMSL, then Hartwell Lake should be at 650 ft AMSL, Lake Jocassee should be at 1,086.2 ft AMSL, and Lake Keowee should be at 795.2 ft AMSL.

FIGURE 5-14
USACE RESERVOIR STORAGE BALANCE DRAWDOWN SCHEDULE

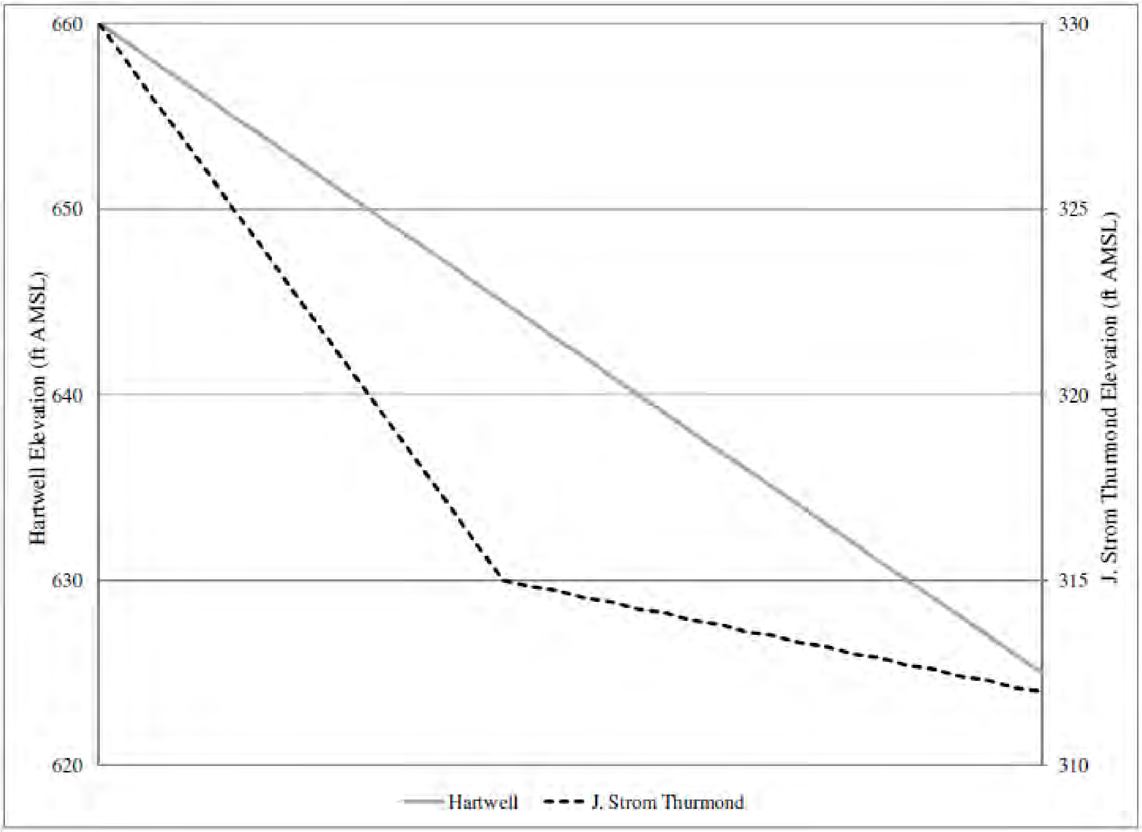
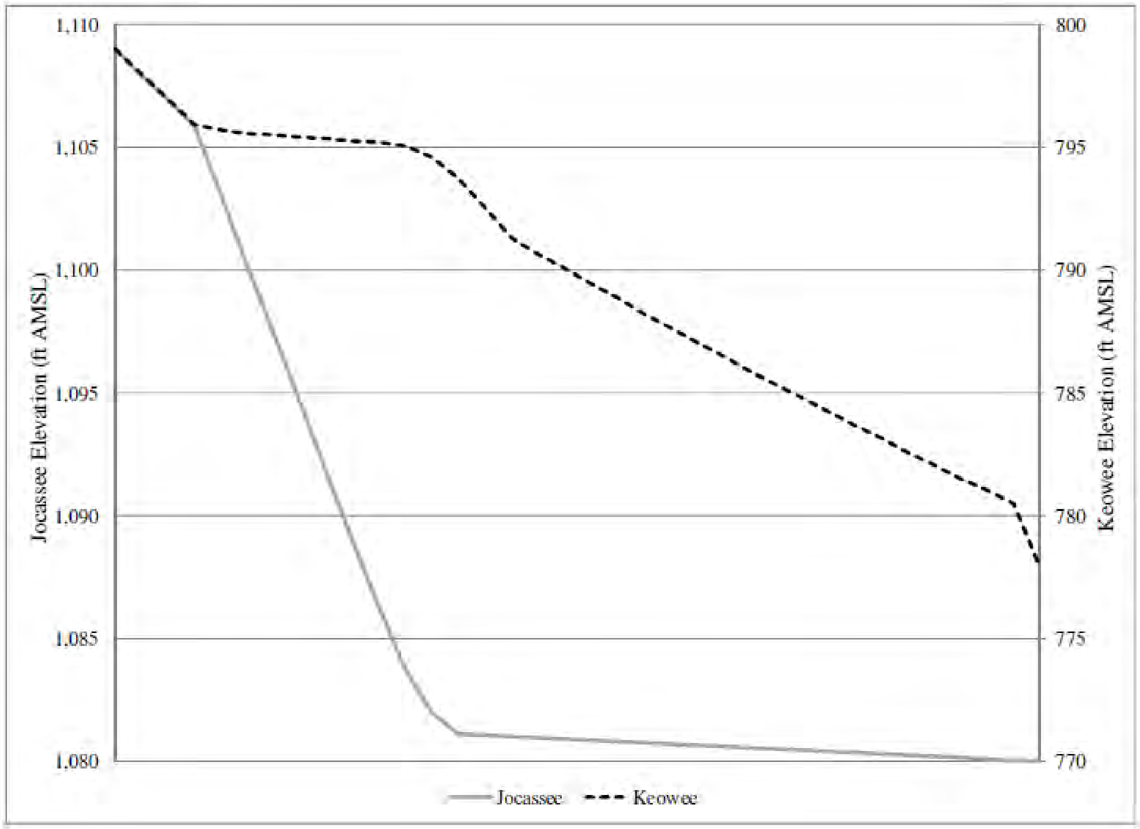


FIGURE 5-15
DUKE ENERGY RESERVOIR STORAGE BALANCE DRAWDOWN SCHEDULE



5.2.12 System Power

The USACE projects have a power generation requirement with SEPA to achieve a minimum generation value. The weekly generation requirement can be met by any combination of the three USACE plants, and the requirement value varies by month. The weekly targets are based on SEPA power contracts. Table 5-14 below lists the requirement.

TABLE 5-14
WEEKLY TARGET GENERATION OF USACE PROJECTS

Month	Weekly Total Generation (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

5.2.13 Powerhouse Settings

All unit performance information was modeled based on the information available at the time of model development.

5.2.13.1 Bad Creek Project

The SR ResSim Model powerhouse descriptor data for the Bad Creek Project is shown in Table 5-15. The powerhouse contains four reversible motor-pump/turbine-generator units with a design head of 1,115 ft. The SR ResSim Model uses total powerhouse flow and power and not individual unit dispatching calculations.

TABLE 5-15
SR RESSIM MODEL BAD CREEK POWERHOUSE SETTINGS

Descriptor	Value
Outlet Capacity	15,400 cfs
Power Capacity	1,384 MW
Efficiency	90%
Station Use (cfs)	0
Hydraulic Losses	1.1 ft at 2,930 cfs
	37.8 ft at 17,400 cfs

The SR ResSim Model pumping mode inputs include specifying a minimum tailwater elevation of 1,081.0 ft AMSL and maximum head of 1,211 ft. Pump capacity for each unit as a factor of operating head is shown in Table 5-16.

TABLE 5-16
SR RESSIM MODEL BAD CREEK UNIT PUMP RATE VERSUS HEAD

Operating Head (ft AMSL)	Pump Capacity (cfs)
1,040	3,567
1,100	3,302
1,160	3,003
1,220	2,720
1,250	2,561

5.2.13.2 Jocassee Development

The SR ResSim Model powerhouse descriptor data for Jocassee Station is shown in Table 5-17. The powerhouse contains four reversible motor-pump/turbine-generator units. Units 1 and 2 are slightly smaller in flow and power than Units 3 and 4. Units 3 and 4 were upgraded in 2007. Units 1 and 2 were upgraded in 2010. The SR ResSim Model uses total powerhouse flow and power, not individual unit dispatching calculations.

TABLE 5-17
SR RESSIM MODEL JOCASSEE POWERHOUSE SETTINGS

Descriptor	Value
Outlet Capacity	35,892 cfs
Power Capacity	737 MW
Efficiency	85%
Station Use (cfs)	0
Hydraulic Losses	2.7 ft at 5,650 cfs
	10.3 ft at 35,892 cfs

The SR ResSim Model pumping mode inputs include specifying a minimum tailwater elevation of 794.6 ft AMSL and maximum head of 315 ft. Pumping is limited to 794.6 ft AMSL to prevent pumping of Lake Keowee below 794.6 ft AMSL. This is not a physical limitation of the pumps. Pump capacity for each unit as a factor of operating head is shown in Table 5-18.

TABLE 5-18
SR RESSIM MODEL JOCASSEE UNIT PUMP RATE VERSUS HEAD

Operating Head (ft AMSL)	Pump Capacity (cfs)
286	7,921
296	7,601
307	7,331
318	7,001
328	6,626

5.2.13.3 Keowee Development

The SR ResSim Model powerhouse descriptor data for Keowee Station is shown in Table 5-19. The powerhouse contains two similarly-sized conventional turbine-generator units. The SR ResSim Model uses total powerhouse flow and power and not individual unit dispatching calculations.

TABLE 5-19
SR RESSIM MODEL KEOWEE POWERHOUSE SETTINGS

Descriptor	Value
Outlet Capacity	19,446 cfs
Power Capacity	176 MW
Efficiency	76%
Station Use (cfs)	0
Hydraulic Losses	0.7 ft at 4,300 cfs
	6.8 ft at 19,446 cfs

5.2.13.4 Hartwell Project

The SR ResSim Model powerhouse descriptor data for the Hartwell Project is shown in Table 5-20. The powerhouse contains four similarly-sized conventional turbine-generator units, and one slightly smaller turbine-generator unit. The SR ResSim Model uses total powerhouse flow and power and not individual unit dispatching calculations.

TABLE 5-20
SR RESSIM MODEL HARTWELL POWERHOUSE SETTINGS

Descriptor	Value
Outlet Capacity	13,175 cfs at 621 ft Elev.
	31,020 cfs at 678 ft Elev.
Power Capacity	338 MW
Efficiency	91%
Station Use (cfs)	0
Hydraulic Losses	1.5 ft constant headloss

5.2.13.5 Richard B. Russell Project

The SR ResSim Model powerhouse descriptor data for the Richard B. Russell Project is shown in Table 5-21. The powerhouse contains four similarly-sized conventional turbine-generator units and four reversible turbine-generator/motor-pump units. The SR ResSim Model uses total powerhouse flow and power and not individual unit dispatching calculations. Two small station service units are not included in the modeled powerhouse setup.

TABLE 5-21
SR RESSIM MODEL RICHARD B. RUSSELL POWERHOUSE SETTINGS

Descriptor	Value
Outlet Capacity	60,000 cfs
Power Capacity	660 MW
Efficiency	90.5%
Station Use (cfs)	0
Hydraulic Losses	1.5 ft constant headloss

The SR ResSim Model pumping mode inputs include specifying a minimum tailwater elevation of 320 ft AMSL and maximum head of 160 ft. Pump capacity for each unit is a constant 7,000 cfs per unit.

5.2.13.6 J. Strom Thurmond Project

The SR ResSim Model powerhouse descriptor data for the J. Strom Thurmond Project is shown in Table 5-22. The powerhouse contains seven similarly-sized conventional turbine-generator units. The SR ResSim Model uses total powerhouse flow and power and not individual unit dispatching calculations.

TABLE 5-22
SR RESSIM MODEL J. STROM THURMOND POWERHOUSE SETTINGS

Descriptor	Value
Outlet Capacity	36,680 cfs
Power Capacity	412 MW
Efficiency	87%
Station Use (cfs)	80 cfs
Hydraulic Losses	1.5 ft constant headloss

6.0 SR RESSIM MODEL CALIBRATION/VERIFICATION PROCESS

Verification is intended to validate the SR ResSim Model input data and logic so the Baseline scenario may be used as the current operations comparison scenario for all subsequent scenario analyses. HDR performed model verification using comparisons of actual and model estimated generation and total discharge from the system. The Verification simulation was completed for recent hydrologic years with available historical reservoir operations (1998-2008). Generation data is commonly available for hydropower facilities and is a metered value that has good accuracy compared to other forms of data that are not metered or based on estimated values with lower accuracy. Generation is a measure of available flow and storage volume which relates to inflows and reservoir elevations. When performing verification of water quantity models with power generation, it is common to find discrepancy between observed data and modeled output for generation and reservoir elevation when looking at a small sample of time periods (day, week, or month). This is due to the difference between the set of rules provided in the model vs. the day-to-day decisions that are common in large power developments that respond to power grid demands as well as storm forecasts and other non-measured impacts on the reservoir and equipment.

As previously stated, the SR ResSim Model is coded to run day-to-day operations based on general operating conditions or rules. The model follows these rules strictly, 24-hours per day and 365 days per year, similar to an automated operation. Actual project operations generally follow the operating rules; but human intervention periodically deviates from the general operating rules to accommodate day-to-day realities such as equipment failure and maintenance, changing hydrologic conditions, power demands and energy pricing, etc. In addition to differences between modeled operations versus actual operations that include human interventions, there are also inherent discrepancies as a result of input data inaccuracies (e.g., differences in hydrology data, turbine or generator efficiencies, reservoir storage curves, etc.). It is important to understand that, due to these differences between actual operating conditions and modeled conditions, model results will never completely match historical operations.

The verification goal is to obtain less than a five percent difference when comparing modeled results to historical generation data over the hydrologic period. In cases where the modeled results exceeded a five percent difference, potential causes for the differences were examined to determine whether the difference was due to deviations in model setup, historical deviations in operations, or discrepancies in the reconstructed hydrology data.

Modeled results of the Verification scenario runs are presented in Section 4.1. The conclusions regarding model verification are presented in Section 5.

6.1 Summary of ResSim Modeled Results versus Historical Data

The SR ResSim Model verification was performed using historical operations data provided by Duke Energy and the USACE. The Verification scenario was established following the typical operating requirements of the system (same rule logic as the Baseline scenario) with historical water use (median of 2003 – 2008) and forced elevations (rules applied such that the model will attempt to operate the reservoir pools as they were historically for the verification period, 1998-2008). Figures 6-1 through 6-6 show comparisons of the modeled reservoir elevations compared to the historical reported elevations for the same period. Note this scenario is not strictly based on the water balance rules defined in the 1968 Agreement but closely represents how the developments have been operated over the hydrologic period.

FIGURE 6-1
SR RESSIM MODELED AND HISTORICAL BAD CREEK RESERVOIR ELEVATION COMPARISON

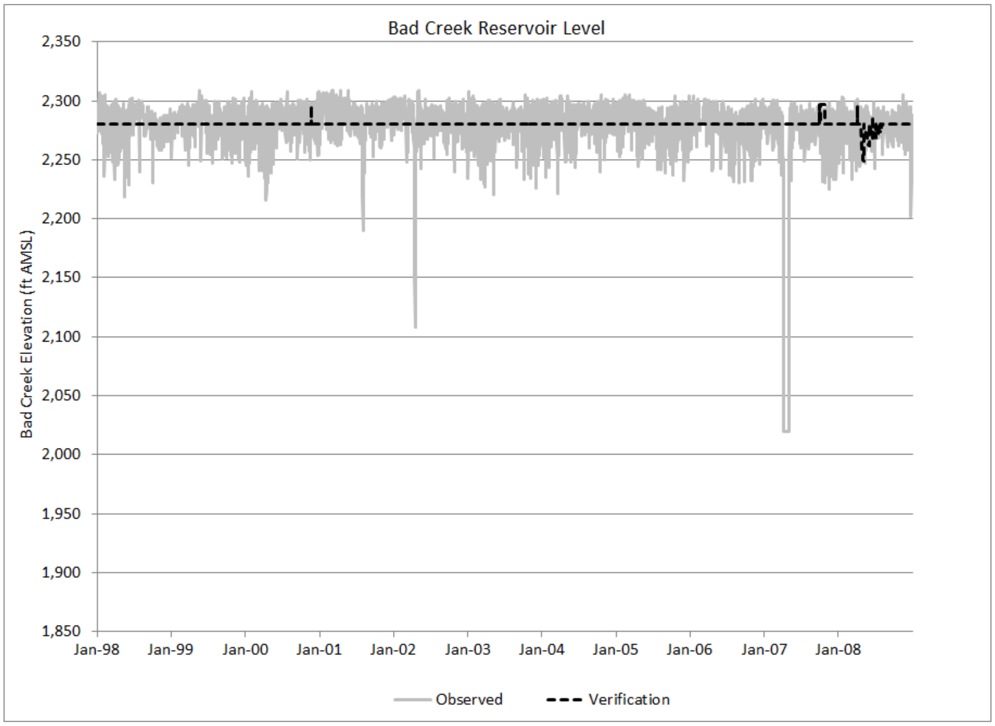


FIGURE 6-2
SR RESSIM MODELED AND HISTORICAL JOCASSEE RESERVOIR ELEVATION COMPARISON

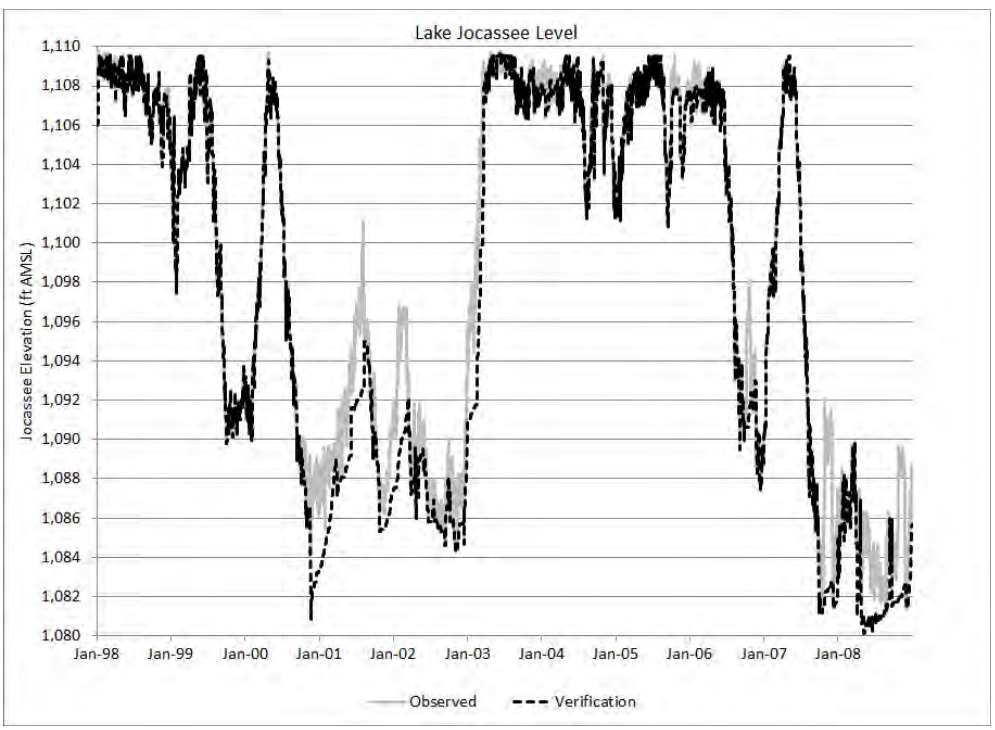


FIGURE 6-3
SR RESSIM MODELED AND HISTORICAL KEOWEE RESERVOIR ELEVATION COMPARISON

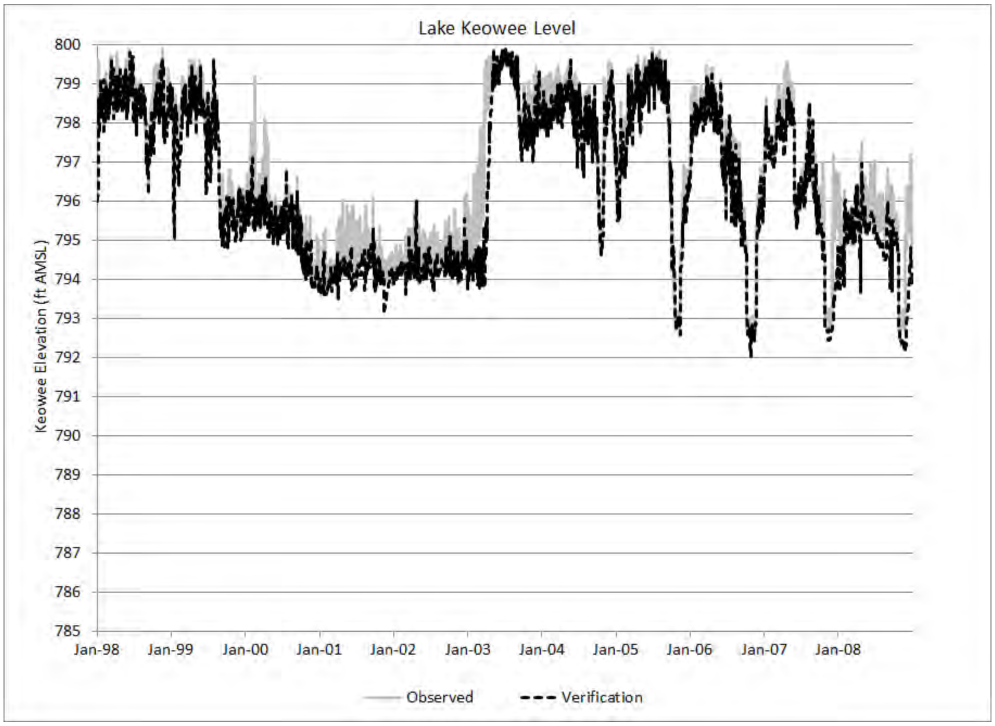


FIGURE 6-4
SR RESSIM MODELED AND HISTORICAL HARTWELL RESERVOIR ELEVATION COMPARISON

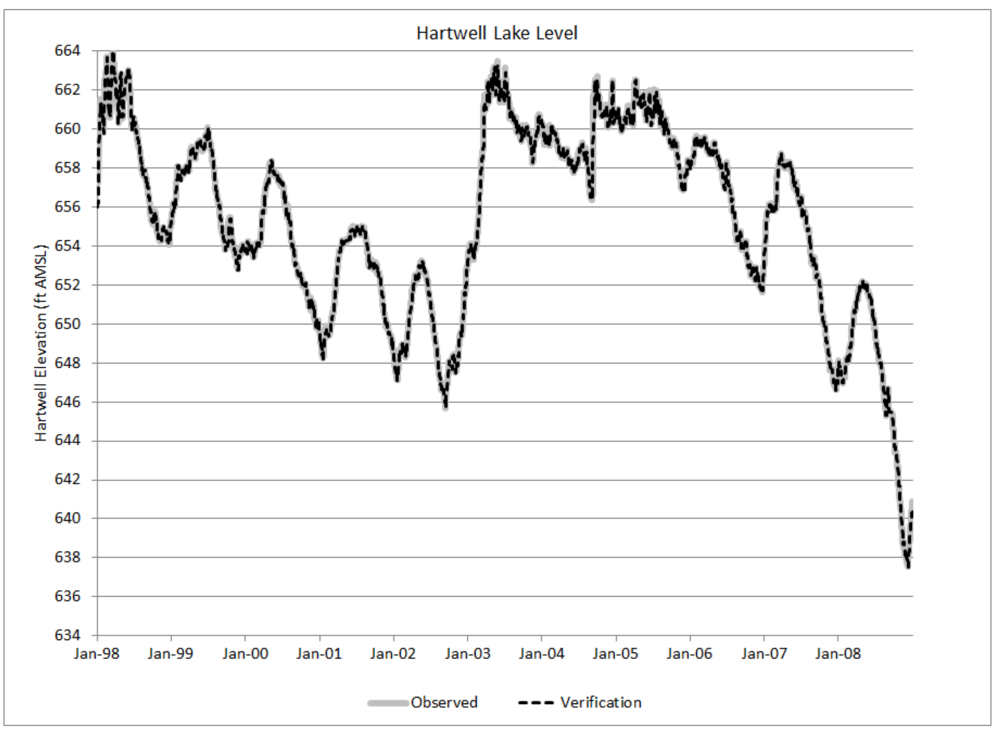


FIGURE 6-5
SR RESSIM MODELED AND HISTORICAL RICHARD B, RUSSELL RESERVOIR ELEVATION COMPARISON

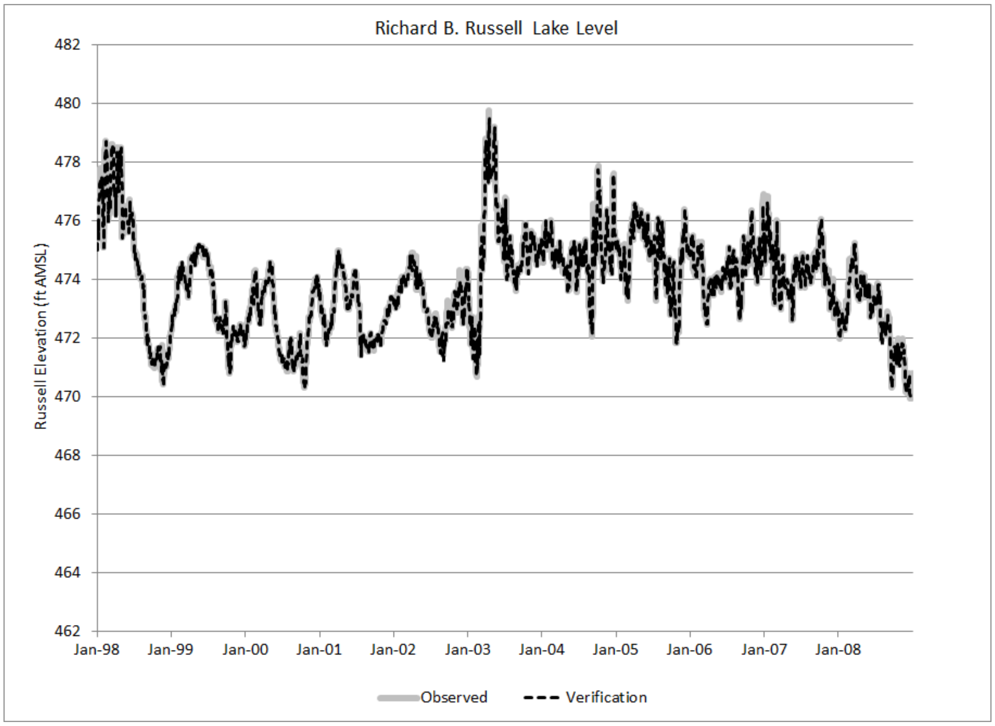
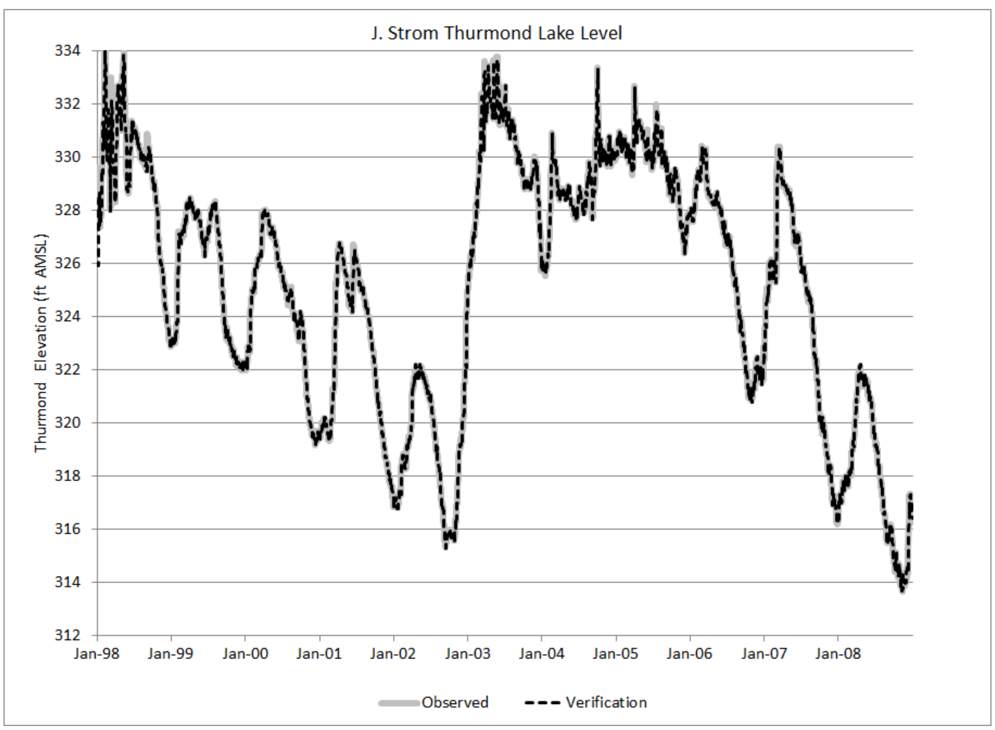


FIGURE 6-6
SR RESSIM MODELED AND HISTORICAL J. STROM THURMOND RESERVOIR ELEVATION COMPARISON



The SR ResSim Model simulation of the Verification scenario estimated an average annual energy output 2 percent lower than historical generation for the same period, as shown in Table 6-1. Based on available historical generation records, modeled and historical generation were compared for the period 1998-2008 at all facilities except for the Richard B. Russell Project. Generation at Richard B. Russell Project was only compared for the time period 2006-2008. Prior to 2006, the Richard B. Russell pump units (4) were rarely operated. There are significant annual swings in the percent difference between historical and modeled operations for the 1998-2008 period, with the largest variations at the Duke Energy facilities. The Duke Energy facilities are operated on demand with a priority on peaking operations to optimize the value of generation based on energy pricing, whereas the USACE facilities are operated on a weekly baseload schedule. The result is that the operations of the Duke Energy facilities (especially pumping operations) vary greatly depending on the value of generation. The Duke Energy system is only required to release water to the system to stay in balance with the system balance as outlined in the 1968 Agreement (Duke Power Company 1968). The USACE system is driven by a combination of the power requirements to SEPA, the system storage balance, and the minimum discharge requirements from the J. Strom Thurmond Project.

TABLE 6-1
SR RESSIM MODEL HISTORICAL BASE: GENERATION COMPARISON

Percent Difference between Modeled and Historical Generation ([modeled-historic]/historic)							
	Bad Creek	**Jocassee**	**Keowee**	**Hartwell**	**Richard B. Russell**	**J. Strom Thurmond**	**System Total**
1998	3%	34%	-3%	-2%		-7%	6%
1999	4%	174%	11%	5%		2%	34%
2000	-3%	102%	24%	8%		2%	17%
2001	11%	-93%	18%	5%		0%	-14%
2002	1%	-89%	13%	4%		-3%	-21%
2003	-11%	-24%	-4%	0%		-4%	-11%
2004	9%	24%	20%	-1%		-6%	9%
2005	-4%	23%	3%	2%		-7%	2%
2006	2%	28%	13%	5%	-6%	-5%	6%
2007	-13%	41%	33%	10%	-8%	0%	1%
2008	-37%	-67%	19%	6%	-34%	-1%	-39%
Average	-4%	6%	10%	3%	-15%	-4%	-2%

Figures 6-7 and 6-8 show the daily and cumulative SR ResSim modeled (Verification scenario) discharges from Hartwell Lake and J. Strom Thurmond Lake as compared to the historical (observed) discharges for the same period. For the period 1998-2008, the model estimated a cumulative discharge from both Hartwell Lake and J. Strom Thurmond Lake that was approximately one percent lower than historical cumulative discharge. The significant daily swings in modeled discharges from J. Strom Thurmond Lake are a result of the forced elevations driving the operations. The daily modeled discharges vary to match the forced elevation for that day, where the historical discharges from J. Strom Thurmond Lake were fairly constant for long portions of the 1998-2008 period.

FIGURE 6-7
SR RESSIM MODELED AND HISTORICAL HARTWELL DISCHARGE COMPARISON

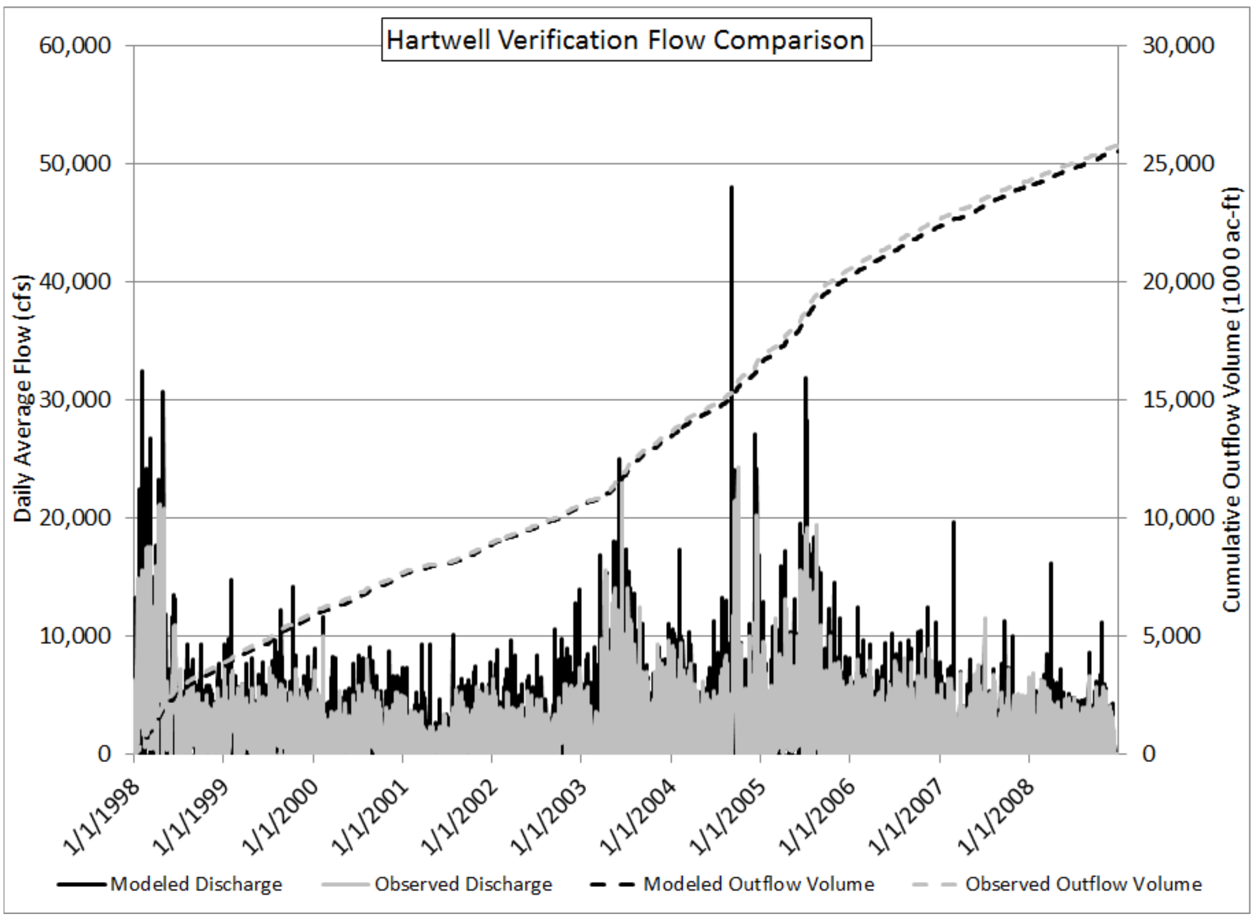
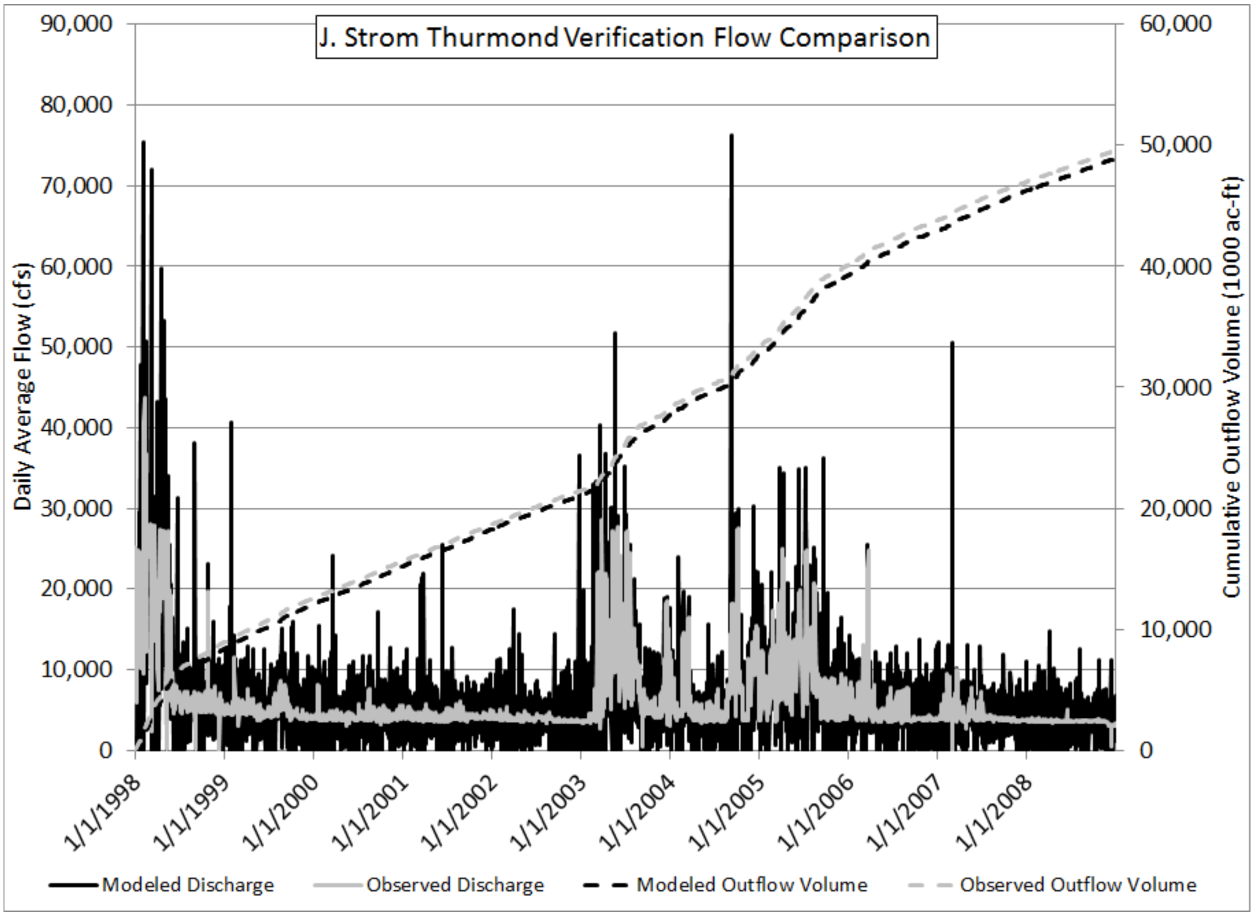


FIGURE 6-8
SR RESSIM MODELED AND HISTORICAL J. STROM THURMOND DISCHARGE COMPARISON



7.0 SR CHEOPS AND SR RESSIM MODELS SUMMARY AND CONCLUSIONS

7.1 Summary

The purpose of this report is to document inputs and assumptions used in the development of the SR CHEOPS and SR ResSim Models; to demonstrate the models reasonably characterizes operations of the system, and to demonstrate that the models are adequate for use in evaluating the effects of alternative operating scenarios. The ResSim and CHEOPS software and the SR CHEOPS Model and SR ResSim Model are tools that, as this report demonstrates, can be successfully used to evaluate the relative sensitivity and response of the Savannah River System to changing operational constraints. The models are tools and do not predict future conditions or outcomes. The model results must be analyzed and interpreted based on knowledge of hydrologic and hydraulic principles and understanding of results viewed in a relative, rather than an absolute, context.

7.2 Conclusions

As discussed in Sections 4 and 6, the model verification process includes comparisons between modeled output and historical data. The goal of this process is to obtain no more than five percent variance when comparing modeled results to historical data for generation on an annual basis. For both the SR CHEOPS and SR ResSim Models, the modeled release from the Project is compared to historical data to show whether the model provides a reasonable representation of Project operations throughout the year (e.g., the timing, magnitude, and duration of operations).

As shown in Tables 4-1, 4-2 and 6-1, there are significant swings between modeled and historical generation. However, there are many factors inherent in the model data and setups that can contribute to output discrepancies (i.e., deviations) when compared to historical data. In many cases, several of these factors may be involved simultaneously, which makes it difficult to isolate individual sources of difference. Four examples of potential sources of deviations from historical data are the standardized pumping rules, hydrology, minimum flow requirements, and historical unit outages:

- Pumping Operations – The models follow a set of defined rules for pumping; however, the historical records demonstrate that pumping operations vary greatly from year to year, month to month, and even day to day. This is probably the greatest source of deviation and swings in the generation comparison and why the goal of this summary is to compare long-term trends rather than monthly or annual values.
- Hydrology – Both the SR CHEOPS and SR ResSim Models use reconstructed UIF data as the input for daily inflow water to the system. The unimpaired hydrology was synthesized based on gage data and plant records, both of which have a certain amount of inherent error especially when multiple locations and data sources are involved. The overall hydrologic data set appears to be a good representation of daily inflows and is acceptable for use in future water management planning.
- Minimum Streamflow Requirements – The models are set up to account for minimum streamflow requirements automatically. As a result, the models are proactive in automatically addressing minimum streamflow requirements rather than reactive in providing excess flow to avoid potential violations, as the case may be in actual operations.
- Unit Outages and Performance – The model has been set up with post upgrade/rehabilitation unit performance information and does not take into account detailed unit outage information. For example, Units 1 through 4 at the Hartwell Project were rehabilitated over the 11-year period of 1997 through 2007. Unit outages associated with the rehabilitation were not taken into account in the model.

In interpreting the information provided in this model operations/verification report, it is important to reflect on the purpose of the model: to reasonably characterize development operations. Comparing model results with historical data confirms use of the model as a tool for simulating “real” operations. It is not possible with reasonable time and budget constraints to account for every outside influence or condition to match historical operations and hydrology.

Small changes in input data or model logic can often result in large swings in output. This is due to a number of reasons including (but not limited to) runoff characteristics, reliance on coordinated operations, and numerous/variable flow requirements. Each of these elements individually contributes to the sensitivity of the system. Combined, they multiply that sensitivity exponentially. The input data and logic in the historical base scenario is an attempt to consolidate the effects of these variables to achieve an approximation of "characteristic operations."

The sensitivity described above also means that those factors that are unable to be accounted for in the model (short-term operations decisions based on pricing, demand, forecasts, etc.) as well as data that is impossible to replicate exactly (synthesized hydrology data, shutdowns due to irregular maintenance, etc.) can result in relatively large discrepancies between modeled output and historical data on a per-month/per-development basis. The factors and sensitivity warrant careful model review with awareness of the potential for outliers. The ultimate acceptance of the results should not hinge on the extremes but rather on the overall impression of consistency between modeled and historical operations.

Most importantly, it must always be foremost in model discussions that the model should always be used to assess the relative impacts between scenarios. What this means is model verification is really the only time it is appropriate to compare model results with historical data. As previously stated, verification is intended to validate the model input data and model logic so the "Baseline" becomes the current operations comparison scenario for all subsequent analyses. The Verification scenario (Historical Baseline) represents the Baseline scenario with the addition of historical water use and flow requirements to simulate actual historical operations.

In the opinion of HDR, verification results show both models compare favorably to historical data, reasonably characterize study area operations, and are appropriate for use in evaluating the effects of alternative operating scenarios. However, appropriate use of the results is cautioned. As with any model, accuracy is highly dependent on input data; consequently, model results should be viewed in a relative, rather than absolute, context. The SR ResSim and SR CHEOPS Models are tools that, as this report demonstrates, can be successfully used to evaluate the relative sensitivity and response of the project to changing operational constraints.

8.0 REFERENCES

ARCADIS. 2010, 2013. Savannah River Unimpaired Flow Data Report 1939-2008, 1939-2011 time series extension. Prepared for Duke Energy, the Savannah District of the U.S. Army Corps of Engineers, and the Georgia Environmental Protection Division. August 2010, May 2013.

Duke Energy Carolinas, LLC. 2008. Bad Creek Pumped Storage Project (FERC No. 2740): Supporting Technical Information. February 2008.

———. 2011. Keowee-Toxaway Relicensing, FERC Project No. 2503. Revised Study Plan. December 2011.

Duke Power Company. 1968. Memorandum of Operating Agreement. FERC No. 2503. October 1, 1968.

———. 1974. Bad Creek Pumped Storage Project Exhibits I and L. February 4, 1974.

HDR Engineering, Inc. of the Carolinas. 2010. *Keowee-Toxaway Project: Jocassee Pumped Storage Project (FERC No. 2503): Supporting Technical Information.* October 2010.

____. 2012. *Keowee-Toxaway Project: Keowee Development (FERC No. 2503): Supporting Technical Information.* Prepared for Duke Energy. January 2012.

____. 2012, 2013. *Keowee-Toxaway Project: Savannah River Basin CHEOPS Model Operations/Verification* report. Prepared for Duke Energy Carolinas, LLC. February 2012, January 2013.

____. 2014. Comprehensive environmental, engineering, and economic analysis impact report for revising the 1968 operating agreement for the Keowee-Toxaway Project. Prepared for Duke Energy Carolinas, LLC. April 4, 2014.

U.S. Army Corps of Engineers. 1989, 2006 and 2011. Savannah River Basin drought contingency plan. Savannah District USACE. March 1989, amended 2006 and 2011

———. 1995. EM 1110-2-4000, Engineering and Design - Sedimentation investigations of rivers and reservoirs. October 1995.

———. 1996a. Hartwell Dam and Lake Georgia and South Carolina: Water control plan.

———. 1996b. J. Strom Thurmond Dam and Lake Georgia and South Carolina: Water control plan.

———. 1996c. Richard B. Russell Dam and Lake Georgia and South Carolina: Water control plan.

———. 2007. HEC-ResSim Reservoir System Simulation User's Manual Version 3.0. U.S. Army Corps of Engineers, Davis, CA. April 2007.

APPENDIX A

ESTIMATED RESERVOIR VOLUME LOSSES ON THE SAVANNAH RIVER DUE TO SEDIMENTATION

Estimated Reservoir Volume Losses on the Savannah River Due to Sedimentation

1.0 Background

The U.S. Army Corps of Engineers' (USACE) HEC-ResSim model is being used by HDR|DTA to evaluate potential changes to the 1968 Operating Agreement between the USACE, Duke Energy Carolinas, LLC (Duke Energy), and the Southeastern Power Administration (SEPA). This model simulates reservoir elevation changes and downstream flow releases based on a set of reservoir operating rules and input assumptions. Stage/volume curves for each of the five reservoirs on the mainstem of the Savannah River are used as input to the HEC-ResSim model. In 2010, Duke Energy collected bathymetry data on the two upper reservoirs in the basin (Lake Jocassee and Lake Keowee). As a result, a minor adjustment was made to the original 1967 Lake Keowee stage/volume curve based on this updated information. No changes were made to the Lake Jocassee stage/volume curve because the 2010 data was very similar to the original 1967 stage/volume curve.

In an attempt to provide consistency with HEC-ResSim model input assumptions, HDR|DTA has evaluated the need to revise the original stage/volume curves for Hartwell Lake, Richard B. Russell Lake (RBR Lake), and J. Strom Thurmond Lake (JST Lake) to year 2010 conditions. The alternative model scenarios will be run using both year 2010 and year 2060 input assumptions, including any necessary changes to reservoir stage/volume curves resulting from sedimentation.

This report outlines the methodology used to project year 2010 stage/volume curves for Hartwell Lake, RBR Lake, and JST Lake, and the year 2060 stage/volume curves for all five reservoirs. The methodology is based on using readily available sediment yield estimates from studies in the Savannah River Basin along with a USACE methodology for distributing sediment within each reservoir based on reservoir shape and size. Results of this analysis are also provided.

2.0 Sediment Yield

The weight of sediment accumulation in the five reservoirs was estimated using published sediment yields from studies conducted in the Savannah River Basin. Sediment yield results are commonly expressed in terms of tons per square mile of drainage area per year (ton/sq mi/yr). In the absence of site-specific stream sediment yield data for the Lake Jocassee and Lake Keowee sub-basins, sediment yield data collected in the Environmental Protection Agency's (EPA) Ecoregion 45 (upstate of Georgia and South Carolina) was used for Lakes Jocassee and Keowee. Sediment yields for EPA Ecoregion 45 are provided in Table 1 for stable, all streams, and unstable watershed conditions.

Table 1. Sediment Yields (tons/sq mi/yr) for EPA Ecoregion 45

Percentile	Stable	All Streams	Unstable
10	17	28	48
25	28	46	74
50	57	80	137
75	**83**	**154**	222
90	108	217	308

Source: Mukundan, Radcliffe, and Ritchie 2010

HDR|DTA's analysis used the 75 percentile values in Table 1 as an estimate of sediment yields in the Lake Jocassee and Lake Keowee sub-basins. As a result, it was assumed that the relatively undisturbed Lake Jocassee drainage basin has a sediment yield of 83 tons/sq mi/yr. The sediment yield for the Lake Keowee drainage basin was assumed to be 154 tons/sq mi/yr ('all streams').

To aid in the development of Total Maximum Daily Loads (TMDLs) for priority pollutants in streams and rivers, the EPA has also collected sediment yield data at various locations in the Hartwell Lake and JST Lake drainage basins. This information is summarized in Tables 2 and 3.

Table 2. Sediment Yields for Streams in the Hartwell Lake Drainage Area

Water Course	Drainage Area (sq mi)	Sediment Yield (tons/sq mi/yr)
Stekoa Creek	21.3	351
Scott Creek	6.1	177
Pool Creek	4.8	106
Chechero Creek	4.2	175
Saddle Gap Creek	2.7	392
Cutting Bone Creek	2.1	149
She Creek	5.5	231
Crawford Creek	7.2	432
Little Crawford Creek	2.7	309
Shoal Creek	29.6	471
Average	8.6	**279**

Source: EPA 2000, 2005a, 2005b, 2005c

Table 3. Sediment Yields for Streams in the JST Lake Drainage Area

Water Course	Drainage Area (sq mi)	Sediment Yield (tons/sq mi/yr)
Rocky Creek	32.4	190
Indian Creek	18.9	45
Upton Creek	23.5	154
South-Bigger Creek	36.4	263
Average	27.8	**163**

Source: EPA 2005b, 2005c

The average sediment yield for Hartwell Lake is 279 tons/sq mi/yr and the average sediment yield for JST Lake is 163 tons/sq mi/yr. For RBR Lake, the average for Hartwell Lake and JST Lake was used (221 tons/sq mi/yr).

To convert sediment yield (in tons) to sediment volume (in acre-feet [ac-ft]), the compressed density of the sediment was determined. The composition of the sediment samples collected in the North Fork Broad River, which drains a sub-basin stretching from the mountains to the piedmont in Georgia, is 27% sand, 54% silt, and 19% clay (Mukundan and Radcliffe 2009). Compression of the sediments on the reservoir bottom is based on years of inundation. Using the method outlined in EM 1110-2-4000 (USACE 1989), the calculated average compressed sediment densities are provided in Table 4.

Table 4. Average Sediment Density

Reservoir	Years of Inundation before 2010	Average Density (lb/ft^3)	Years of Inundation 2010–2060	Average Density (lb/ft^3)
Jocassee	37	N/A	50	70
Keowee	39	N/A	50	70
Hartwell	49	69.9	50	70
RBR	27	68.8	50	70
JST	58	70.3	50	70
Average	42	**70**	50	**70**

Based on the results provided in Table 4, an average density of 70 lb/ft^3 was used to convert the estimated sediment yields to estimated sediment deposition volumes. The resulting sediment deposition volumes for year 2010 and year 2060 are shown in Table 5.

Table 5. Reservoir Volumes Lost to Sedimentation

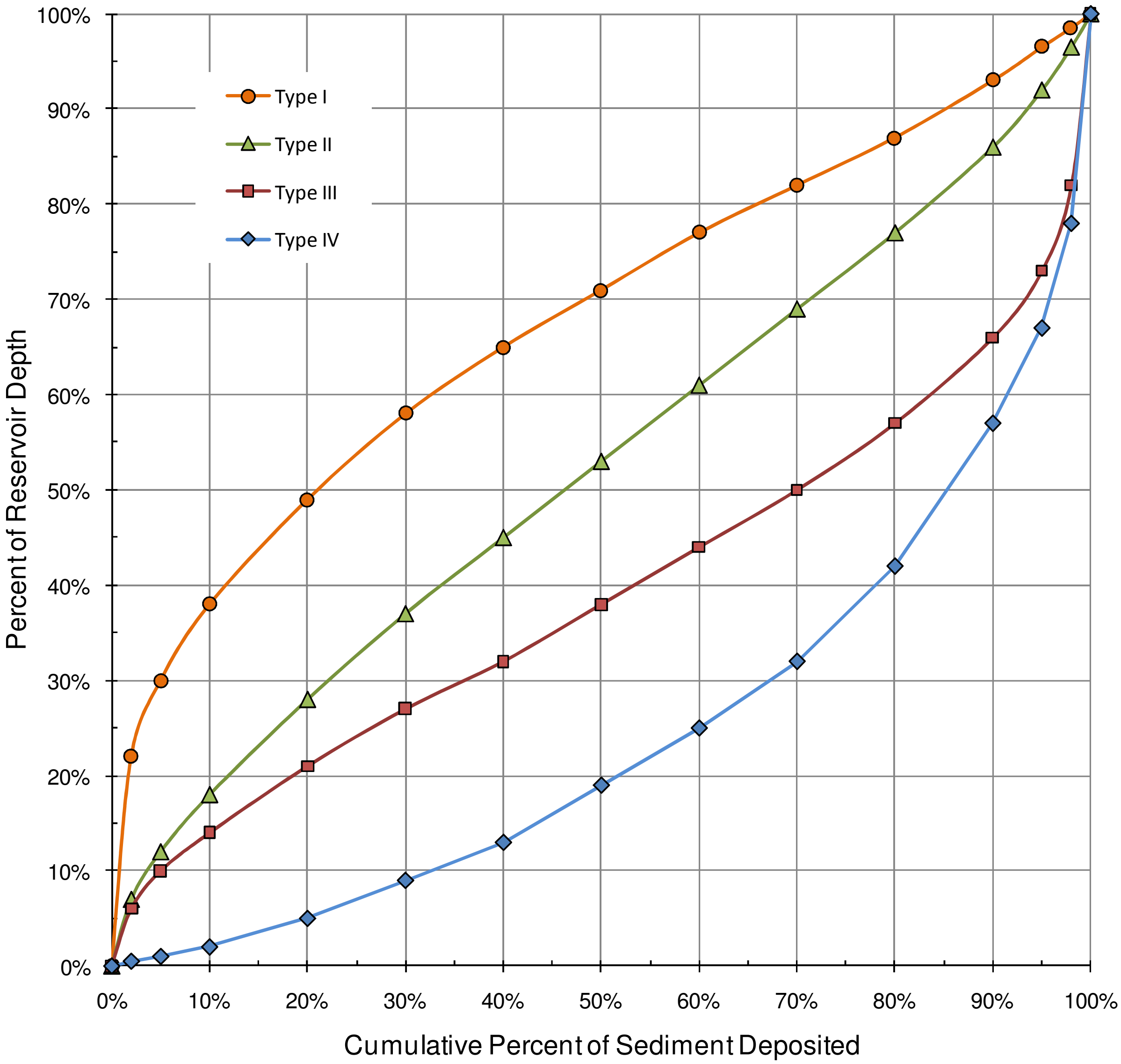
Reservoir	Sediment Yield (tons/sq mi/yr)	Drainage Area (sq mi)	Initial Fill year	Sediment Deposition to Year 2010 (ac-ft)	Sediment Deposition from 2010 to 2060 (ac-ft)
Jocassee	83	148	1973	N/A	403
Keowee	154	288	1971	N/A	1,455
Hartwell	279	1184	1961	10,617	10,834
RBR	221	742	1983	2,904	5,378
JST	163	3290	1952	20,401	17,587

Source: USACE 2010a, 2010b, 2010c

3.0 Sediment Distribution

The estimated amount of sediment deposition in each reservoir was distributed at the appropriate levels within each reservoir. The USACE has developed the "Empirical Area Reduction Method" as described in EM 1110-2-4000 (USACE 1989) to accomplish this task. To use this method, the reservoir type was first determined based on the size and shape of the impoundment. The “m” value (i.e., the change in the log of reservoir storage capacity divided by the change in the log of the reservoir depth) was calculated for each reservoir as an initial step in determining the reservoir type. The “m” values are summarized in Table 6. The reservoir type was used in conjunction with Figure H-4 in EM 1110-2-4000 (USACE 1989), reproduced as Figure 1 below, to distribute the sediment volume within each reservoir. The results are shown in Table 6 as the cumulative percent of sediment volume distributed at percent of depth (bottom to top).

Figure 1. Distribution of Sediment Deposits in Reservoirs



Source: USACE 1989

Table 6. Cumulative Percent of Sediment at Percent of Depth

Reservoir	M	Type	Percent of Depth						
			0	**10**	**20**	**50**	**80**	**90**	**100**
Jocassee	2.35	III	0	5	18	70	97	99	100
Keowee	2.67	II	0	4	12	46	83	93	100
Hartwell	2.84	II	0	4	12	46	83	93	100
RBR	2.72	II	0	4	12	46	83	93	100
JST	3.04	I	0	1	2	21	66	85	100

4.0 Estimated Reservoir Storage Curves

Volumes of sediment in Table 5 were distributed in each reservoir based on the percentages in Table 6, resulting in stage/volume curves for each reservoir for year 2010 and year 2060 (Tables 7 through 11). The volume change percentages (final column in each table) represent the entire reservoir below the corresponding reservoir elevation presented in column 1. Note that the 2010 volume estimates for Lakes Jocassee and Keowee are based on bathymetry data collected in 2010 and not the sediment yield and sediment distribution methodologies described above.

Table 7. Lake Jocassee Estimated Changes in Reservoir Volume due to Sedimentation

Reservoir Elevation (ft msl)	1967 Volume (ac-ft)	2010 Volume (ac-ft)	Volume Change 1967 – 2010 (%)	2060 Volume (ac-ft)	Volume Change 2010 – 2060 (%)
1,110	1,157,993	1,206,797	4.21	1,206,394	-0.033
1,109	1,150,442	1,198,830	4.21	1,198,429	-0.033
1,108	1,142,917	1,190,892	4.20	1,190,491	-0.034
1,107	1,135,416	1,182,987	4.19	1,182,586	-0.034
1,106	1,127,939	1,175,114	4.18	1,174,713	-0.034
1,105	1,120,488	1,167,273	4.18	1,166,872	-0.034
1,104	1,113,061	1,159,462	4.17	1,159,061	-0.035
1,103	1,105,660	1,151,682	4.16	1,151,281	-0.035
1,102	1,098,282	1,143,933	4.16	1,143,532	-0.035
1,101	1,090,930	1,136,213	4.15	1,135,812	-0.035
1,100	1,083,602	1,128,524	4.15	1,128,123	-0.036
1,099	1,076,299	1,120,864	4.14	1,120,463	-0.036
1,098	1,069,021	1,113,233	4.14	1,112,832	-0.036
1,097	1,061,768	1,105,632	4.13	1,105,231	-0.036
1,096	1,054,539	1,098,059	4.13	1,097,658	-0.037
1,095	1,047,336	1,090,516	4.12	1,090,115	-0.037
1,094	1,040,157	1,083,001	4.12	1,082,602	-0.037
1,093	1,033,003	1,075,516	4.12	1,075,117	-0.037
1,092	1,025,874	1,068,059	4.11	1,067,660	-0.037
1,091	1,018,770	1,060,642	4.11	1,060,243	-0.038
1,090	1,011,691	1,053,271	4.11	1,052,872	-0.038
1,089	1,004,637	1,045,936	4.11	1,045,537	-0.038
1,088	997,609	1,038,637	4.11	1,038,238	-0.038
1,087	990,606	1,031,372	4.12	1,030,973	-0.039
1,086	983,628	1,024,141	4.12	1,023,742	-0.039
1,085	976,676	1,016,943	4.12	1,016,544	-0.039
1,080	942,298	981,409	4.15	981,010	-0.041
1,060	811,349	845,564	4.22	845,169	-0.047
1,040	691,189	719,942	4.16	719,551	-0.054
1,020	581,761	604,370	3.89	603,987	-0.063
1,000	483,360	499,169	3.27	498,800	-0.074
980	393,873	404,853	2.79	404,505	-0.086
960	311,689	320,697	2.89	320,375	-0.100
940	238,724	247,057	3.49	246,767	-0.117
920	176,256	184,213	4.51	183,961	-0.137
900	124,721	132,347	6.11	132,133	-0.161
880	83,872	90,529	7.94	90,354	-0.194
860	52,917	57,740	9.11	57,607	-0.230
840	30,680	33,215	8.26	33,122	-0.279
820	15,742	16,544	5.10	16,488	-0.341
800	6,592	6,338	-3.85	6,312	-0.413
780	1,779	1,271	-28.55	1,265	-0.475
760	60	29	-00.00	29	-0.000
750	0	0	-00.00	0	-0.000

Table 8. Lake Keowee Estimated Changes in Reservoir Volume due to Sedimentation

Reservoir Elevation (ft msl)	1967 Volume (ac-ft)	2010 Volume (ac-ft)	Volume Change 1967 – 2010 (%)	2060 Volume (ac-ft)	Volume Change 2010 – 2060 (%)
800	953,659	869,381	-8.84	867,927	-0.17
799	935,448	851,983	-8.92	850,535	-0.17
798	917,460	834,947	-8.99	833,507	-0.17
797	899,696	818,195	-9.06	816,762	-0.18
796	882,152	801,702	-9.12	800,277	-0.18
795	864,829	785,452	-9.18	784,027	-0.18
794	847,725	769,437	-9.24	768,019	-0.18
793	830,839	753,650	-9.29	752,239	-0.19
792	814,169	738,085	-9.35	736,681	-0.19
791	797,715	722,739	-9.40	721,343	-0.19
790	781,476	707,609	-9.45	706,220	-0.20
789	765,450	692,688	-9.51	691,306	-0.20
788	749,637	677,973	-9.56	676,591	-0.20
787	734,034	663,461	-9.61	662,094	-0.21
786	718,641	649,147	-9.67	647,787	-0.21
785	703,457	635,030	-9.73	633,677	-0.21
784	688,480	621,108	-9.79	619,762	-0.22
783	673,709	607,378	-9.85	606,040	-0.22
782	659,143	593,841	-9.91	592,510	-0.22
781	644,782	580,496	-9.97	579,172	-0.23
780	630,623	567,343	-10.03	566,027	-0.23
779	616,665	554,383	-10.10	553,074	-0.24
778	602,908	541,615	-10.17	540,320	-0.24
775	562,825	504,453	-10.37	503,187	-0.25
770	499,910	446,271	-10.73	445,064	-0.27
760	388,103	343,634	-11.46	342,543	-0.32
750	293,919	258,138	-12.17	257,163	-0.38
740	216,022	187,992	-12.98	187,141	-0.45
730	153,025	131,648	-13.97	130,920	-0.55
720	103,487	87,411	-15.53	86,800	-0.70
710	65,909	53,634	-18.63	53,146	-0.91
700	38,737	29,048	-25.01	28,677	-1.28
690	20,352	12,783	-37.19	12,514	-2.11
680	9,078	3,914	-56.89	3,739	-4.46
670	3,173	799	-74.82	712	-10.93
660	828	82	-90.05	61	-26.48
650	171	1	N/A	1	-00.00

Table 9. Hartwell Lake Estimated Changes in Reservoir Volume due to Sedimentation

Reservoir Elevation (ft msl)	1961 Volume (ac-ft)	2010 Volume (ac-ft)	Volume Change 1961 – 2010 (%)	2060 Volume (ac-ft)	Volume Change 2010 – 2060 (%)
665	2,842,700	2,832,083	-0.37	2,821,250	-0.38
664	2,781,900	2,771,336	-0.38	2,760,557	-0.39
663	2,722,200	2,711,689	-0.39	2,700,964	-0.40
662	2,663,600	2,653,089	-0.39	2,642,364	-0.40
661	2,606,100	2,595,642	-0.40	2,584,971	-0.41
660	2,549,600	2,539,195	-0.41	2,528,579	-0.42
659	2,494,200	2,483,795	-0.42	2,473,179	-0.43
658	2,439,700	2,429,349	-0.42	2,418,786	-0.43
657	2,386,300	2,375,949	-0.43	2,365,386	-0.44
656	2,333,800	2,323,502	-0.44	2,312,993	-0.45
655	2,282,400	2,272,155	-0.45	2,261,700	-0.46
654	2,231,800	2,221,608	-0.46	2,211,208	-0.47
653	2,182,200	2,172,008	-0.47	2,161,608	-0.48
652	2,133,600	2,123,461	-0.48	2,113,115	-0.49
651	2,085,900	2,075,814	-0.48	2,065,522	-0.50
650	2,039,100	2,029,014	-0.49	2,018,722	-0.51
649	1,993,200	1,983,167	-0.50	1,972,929	-0.52
648	1,948,200	1,938,220	-0.51	1,928,037	-0.53
647	1,904,100	1,894,173	-0.52	1,884,044	-0.53
646	1,860,900	1,851,026	-0.53	1,840,951	-0.54
645	1,818,600	1,808,779	-0.54	1,798,758	-0.55
644	1,777,100	1,767,332	-0.55	1,757,366	-0.56
643	1,736,500	1,726,732	-0.56	1,716,766	-0.58
642	1,696,700	1,686,986	-0.57	1,677,073	-0.59
641	1,657,800	1,648,139	-0.58	1,638,280	-0.60
640	1,619,700	1,610,092	-0.59	1,600,287	-0.61
639	1,582,500	1,572,945	-0.60	1,563,195	-0.62
638	1,545,900	1,536,398	-0.61	1,526,702	-0.63
637	1,510,100	1,500,651	-0.63	1,491,009	-0.64
636	1,475,100	1,465,704	-0.64	1,456,116	-0.65
635	1,440,800	1,431,457	-0.65	1,421,924	-0.67
634	1,407,200	1,397,963	-0.66	1,388,538	-0.67
633	1,374,300	1,365,116	-0.67	1,355,745	-0.69
632	1,342,100	1,332,970	-0.68	1,323,653	-0.70
631	1,310,500	1,301,423	-0.69	1,292,160	-0.71
630	1,279,600	1,270,576	-0.71	1,261,367	-0.72
629	1,249,300	1,240,329	-0.72	1,231,174	-0.74
628	1,219,600	1,210,735	-0.73	1,201,689	-0.75
627	1,190,500	1,181,688	-0.74	1,172,696	-0.76
626	1,162,000	1,153,241	-0.75	1,144,303	-0.78
625	1,134,100	1,125,394	-0.77	1,116,511	-0.79
610	780,000	772,303	-0.99	764,448	0.00
600	680,000	673,046	-1.02	665,950	-1.05
575	300,000	294,745	-1.75	289,382	-1.82
525	45,000	43,089	-4.25	41,139	-4.53
475	0	0	-0.00	0	-0.00

Table 10. RBR Lake Estimated Changes in Reservoir Volume due to Sedimentation

Reservoir Elevation (ft msl)	1983 Volume (ac-ft)	2010 Volume (ac-ft)	Volume Change 1983 – 2010 (%)	2060 Volume (ac-ft)	Volume Change 2010 – 2060 (%)
480	1,166,166	1,163,262	-0.25	1,157,884	-0.46
479	1,137,100	1,134,210	-0.25	1,128,859	-0.47
478	1,108,581	1,105,706	-0.26	1,100,382	-0.48
477	1,080,603	1,077,743	-0.26	1,072,445	-0.49
476	1,053,159	1,050,313	-0.27	1,045,043	-0.50
475	1,026,244	1,023,413	-0.28	1,018,169	-0.51
474	999,850	997,033	-0.28	991,817	-0.52
473	973,974	971,157	-0.29	965,941	-0.54
472	948,607	945,805	-0.30	940,615	-0.55
465	783,020	780,334	-0.34	775,359	-0.64
450	535,925	533,558	-0.44	529,175	-0.82
435	331,550	329,561	-0.60	325,877	-1.12
420	190,000	188402.8	-0.84	185444.9	-1.57
400	80,000	78925.5	-1.34	76935.69	-2.52
360	5,000	4811.237	-3.78	4461.675	-7.27
340	0	0	-0.00	0	-0.00

Table 11. JST Lake Estimated Changes in Reservoir Volume due to Sedimentation

Reservoir Elevation (ft msl)	1952 Volume (ac-ft)	2010 Volume (ac-ft)	Volume Change 1952 – 2010 (%)	2060 Volume (ac-ft)	Volume Change 2010 – 2060 (%)
335	2,900,000	2,879,599	-0.70	2,862,012	-0.61
334	2,822,000	2,801,803	-0.72	2,784,391	-0.62
333	2,744,000	2,724,007	-0.73	2,706,771	-0.63
332	2,666,000	2,646,211	-0.74	2,629,151	-0.64
331	2,588,000	2,568,313	-0.76	2,551,341	-0.66
330	2,510,000	2,490,517	-0.78	2,473,721	-0.67
329	2,440,000	2,420,721	-0.79	2,404,101	-0.69
328	2,370,000	2,350,925	-0.80	2,334,481	-0.70
327	2,300,000	2,281,129	-0.82	2,264,861	-0.71
326	2,230,000	2,211,333	-0.84	2,195,241	-0.73
325	2,160,000	2,141,435	-0.86	2,125,431	-0.75
324	2,100,000	2,081,639	-0.87	2,065,810	-0.76
323	2,040,000	2,021,843	-0.89	2,006,190	-0.77
322	1,980,000	1,962,047	-0.91	1,946,570	-0.79
321	1,920,000	1,902,251	-0.92	1,886,950	-0.80
320	1,860,000	1,842,455	-0.94	1,827,330	-0.82
319	1,808,000	1,790,659	-0.96	1,775,710	-0.83
318	1,756,000	1,738,965	-0.97	1,724,280	-0.84
317	1,704,000	1,687,169	-0.99	1,672,660	-0.86
316	1,652,000	1,635,373	-1.01	1,621,039	-0.88
315	1,600,000	1,583,577	-1.03	1,569,419	-0.89
314	1,555,000	1,538,781	-1.04	1,524,799	-0.91
313	1,510,000	1,493,985	-1.06	1,480,179	-0.92
312	1,465,000	1,449,291	-1.07	1,435,749	-0.93
311	1,420,000	1,404,495	-1.09	1,391,129	-0.95
310	1,375,000	1,359,801	-1.11	1,346,699	-0.96
309	1,334,000	1,319,005	-1.12	1,306,079	-0.98
308	1,293,000	1,278,311	-1.14	1,265,648	-0.99
307	1,252,000	1,237,515	-1.16	1,225,028	-1.01
306	1,211,000	1,196,821	-1.17	1,184,598	-1.02
305	1,170,000	1,156,025	-1.19	1,143,978	-1.04
304	1,138,000	1,124,331	-1.20	1,112,548	-1.05
303	1,106,000	1,092,535	-1.22	1,080,928	-1.06
280	510,000	501,636	-1.64	494,425	-1.44
255	200,000	195,716	-2.14	192,022	-1.89
240	130,000	127,552	-1.88	125,441	-1.65
230	100,000	98,470	-1.53	97,151	-1.34
220	50,000	49,184	-1.63	48,480	-1.43
175	0	0	0.00	0	0.00

As can be seen in Tables 7 through 11, the total loss due to estimated reservoir sedimentation, when taken as a percentage of the total reservoir volume, is very small (i.e., less than 1% in most cases).

Table 12 provides the volume lost due to estimated sedimentation just within the normal operating range of each reservoir between initial fill year and year 2010.

Table 12. Volume Change Within the Normal Operating Range from Initial Fill Year to 2010

Reservoir	Top of Operating Range (ft msl)	Bottom of Operating Range (ft msl)	Number of Feet (ft)	Volume Lost in Operating Range (ac-ft)	Percent Change (%)
Jocassee	1110	1086	24	8,291	4.755
Keowee	800	778	22	-22,985	-6.553
Hartwell	660	625	35	-1,699	-0.120
RBR	475	470	5	-62	-0.049
JST	330	312	18	-3,774	-0.361

Table 13 provides the volume lost due to estimated sedimentation just within the normal operating range of each reservoir between year 2010 and year 2060.

Table 13. Volume Change Within the Normal Operating Range from 2010 to 2060

Reservoir	Top of Operating Range (ft msl)	Bottom of Operating Range (ft msl)	Number of Feet (ft)	Volume Lost in Operating Range (ac-ft)	Percent Change (%)
Jocassee	1110	1086	24	-4	-0.002
Keowee	800	778	22	-160	-0.049
Hartwell	660	625	35	-1,733	-0.123
RBR	475	470	5	-114	-0.091
JST	330	312	18	-3,254	-0.312

5.0 Conclusions and Recommendations

The volume reductions within the normal operating ranges for each of the five reservoirs on the mainstem of the Savannah River due to estimated sedimentation are relatively small compared to the overall usable volumes.

For Lake Jocassee, the 2010 stage/storage curves that were developed using recently collected bathymetry data and GIS software tools are remarkably similar to the curves that were generated in 1967. The slight increase in total storage is likely the result of very small inaccuracies due to data collection and reduction techniques that were considered best practice in the late-1960's. For Lake Keowee, the 2010 stage/storage curves based on new bathymetry data show an 8.8% reduction in total storage and a 6.6% reduction in storage down to 778 ft msl. The volume loss since 1967 is likely the result of some sedimentation, but also similar inaccuracies in data collection and reduction as described for Lake Jocassee.

For the three USACE reservoirs, the incremental volume lost due to sedimentation from initial fill to 2010 is very small from a percentage standpoint (less than 1%). These sedimentation estimates are heavily influenced by sediment yields that have been measured in the Savannah River drainage basin. For this analysis, average to slightly greater than average sediment yield estimates were used. However, even if the sediment yield estimates used in this analysis were doubled, usable reservoir volume losses would still be very small.

Similarly, the sedimentation estimates projected out to year 2060 are also very small for all five reservoirs. Less than 1% additional volume is lost from the 2010 stage/storage curves. The lost volume is even smaller within the normal operating range as some of the sediment deposits below usable storage elevations.

For HEC-ResSim modeling purposes, these stage/volume changes for 2010 and 2060, though small, will be incorporated into the "current case" and "future case" modeling scenarios as applicable.

6.0 References

Mukundan, Radcliffe, and Ritchie. 2010. Channel Stability and Sediment Source Assessment in Streams Draining a Piedmont Watershed in Georgia, USA, Wylie Online Library, February 2010.

Mukundan and Radcliffe. 2009. Rapid Geomorphic Assessment and Sediment Tracking - North Fork Broad River (PowerPoint), University of Georgia, March 2009.

U.S. Army Corps of Engineers. 1989. Directorate of Civil Works EM 1110-2-4000 Engineering and Design - Sedimentation Investigations of Rivers and Reservoirs, Original document. December 15, 1989. Change 1 - 31 October 1995; Chapter 5, Reservoir Sedimentation; Appendix C, Predicting Sediment Yields; Appendix G, Specific Weight of Deposits; Appendix H, Distribution of Sediment Deposits.

U.S. Army Corps of Engineers. 2010a. History of Hartwell Dam & Lake [Online] URL: http://www.sas.usace.army.mil/lakes/hartwell/history.htm (Accessed 12/02/10).

U.S. Army Corps of Engineers. 2010b. Introduction to Richard B. Russell Dam and Lake [Online] URL: http://www.sas.usace.army.mil/lakes/russell/intro.htm (Accessed 12/02/10).

U.S. Army Corps of Engineers. 2010c. Introduction to J. Strom Thurmond Dam and Lake [Online] URL: http://www.sas.usace.army.mil/lakes/thurmond/intro.htm (Accessed 12/02/10).

U.S. EPA Office of Research & Development. 2010. National Health and Environmental Effects Research Laboratory (NHEERL), Level IV Ecoregions of EPA Region 4 Map, Corvallis, OR, September 2010.

U.S. EPA Region 4. 2000. TMDL Development for Sediment in the Stekoa Creek Watershed, December 28, 2000.

U.S. EPA Region 4. 2005a. Final TMDL for Fecal Coliform and Sediment (Biota Impacted) in She Creek, Savannah River Basin: Franklin, Rabun County, Georgia, February 2005.

U.S. EPA Region 4. 2005b. Final TMDL for Sediment (Biota Impacted) in Rocky Creek, Savannah River Basin, Wilkes Country, Georgia, February 2005.

U.S. EPA Region 4. 2005c. Final TMDL for Sediment in Savannah River Basin, Franklin, Hart, and Madison Counties, Georgia, February 2005.

APPENDIX B

SAVANNAH RIVER

2009 – 2011 UNIMPAIRED FLOW RECORD EXTENSION

Savannah River
2009 – 2011 Unimpaired Flow Record Extension

Time-Series Data Development Informational Meeting
Duke Energy/HDR

June 27, 2013

Scope of services

Extension of 1939-2008 local and cumulative Savannah River UIFs:

–Seneca River at Jocassee Dam
–Seneca River at Keowee Dam
–Savannah River at Hartwell Dam
–Savannah River at Russell Dam
–Broad River at Bell
–Savannah River at Thurmond Dam
–Savannah River at Augusta
–Savannah River at Burtons Ferry
–Brier Creek at Millhaven
–Savannah River at Clyo
–Savannah River at Savannah

No modification of 1939 – 2008 local or cumulative UIFs

ARCADIS

RIVERSIDE
global science solutions

Unimpaired flow development tasks

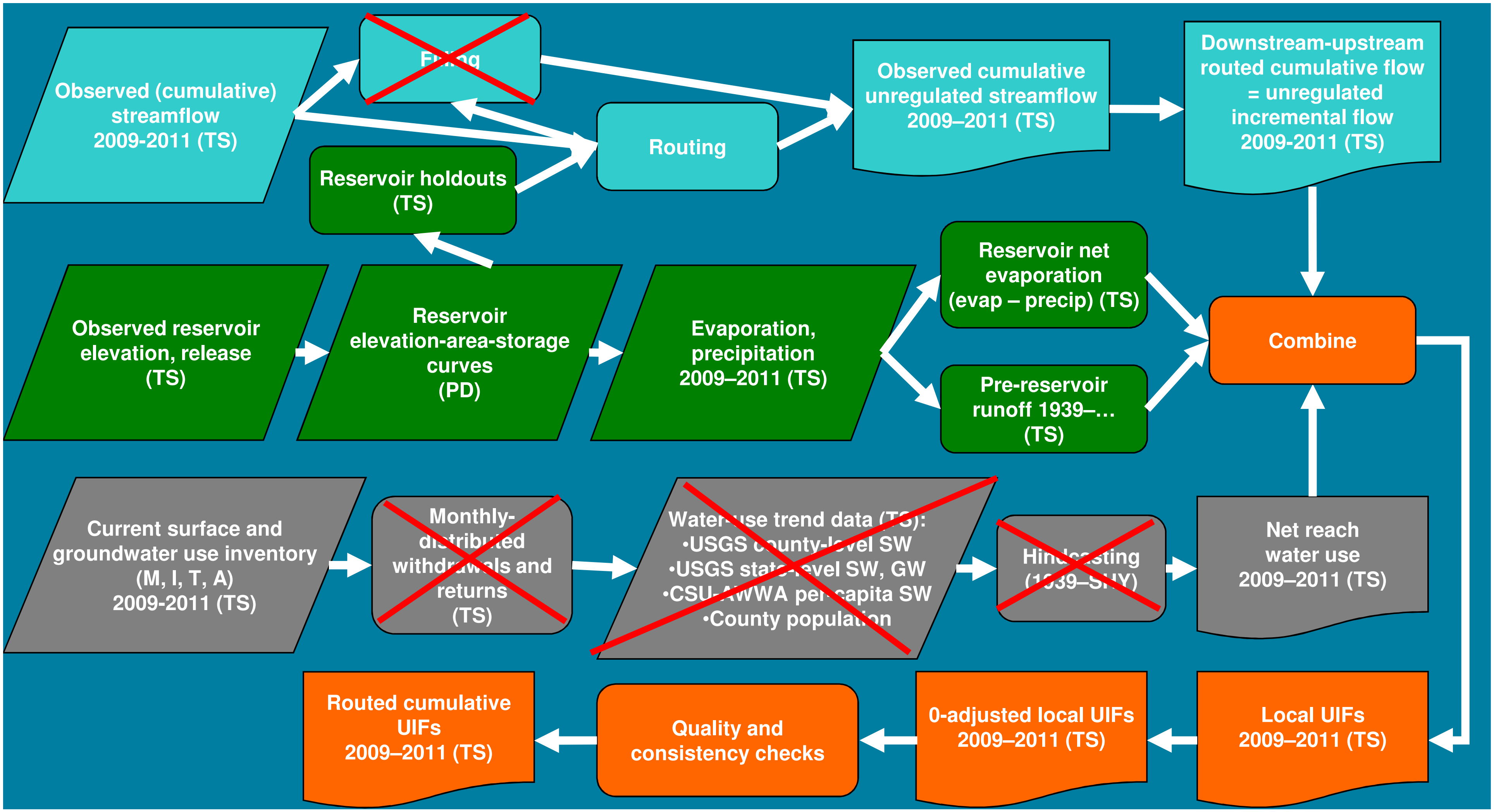
- Water-use inventory and reach aggregation
- Reservoir precipitation time series development
- Reservoir evaporation time series development
- Reservoir holdouts and net reservoir effects determination
- Routing and unregulated local inflow calculation
- Aggregation of impairments and local UIF development
- Flow adjustments
- Quality and consistency checks
- Cumulative UIF determination

ARCADIS

RIVERSIDE global science solutions

Unimpaired flow (UIF) derivation process

Filling/routing
Reservoir effects
Water use
UIF, adjustments

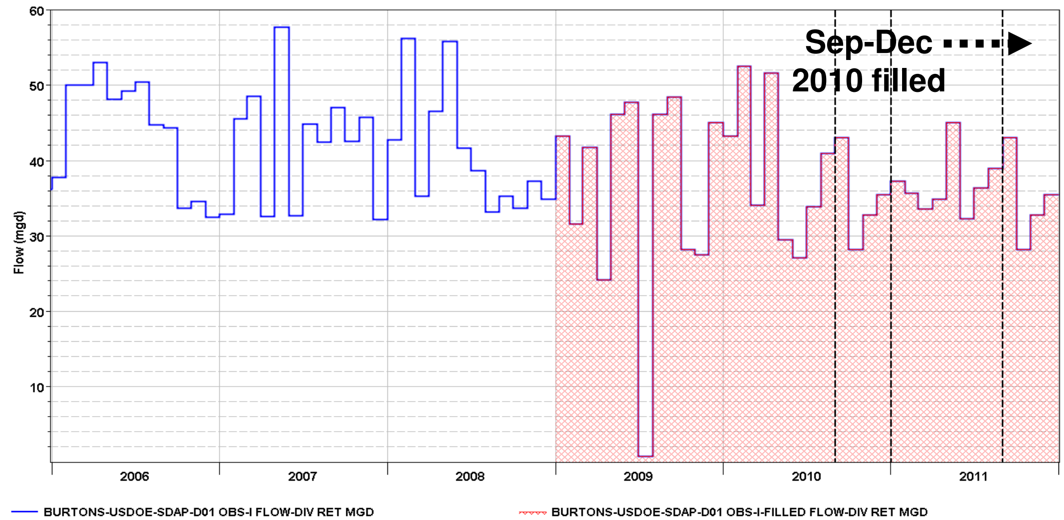


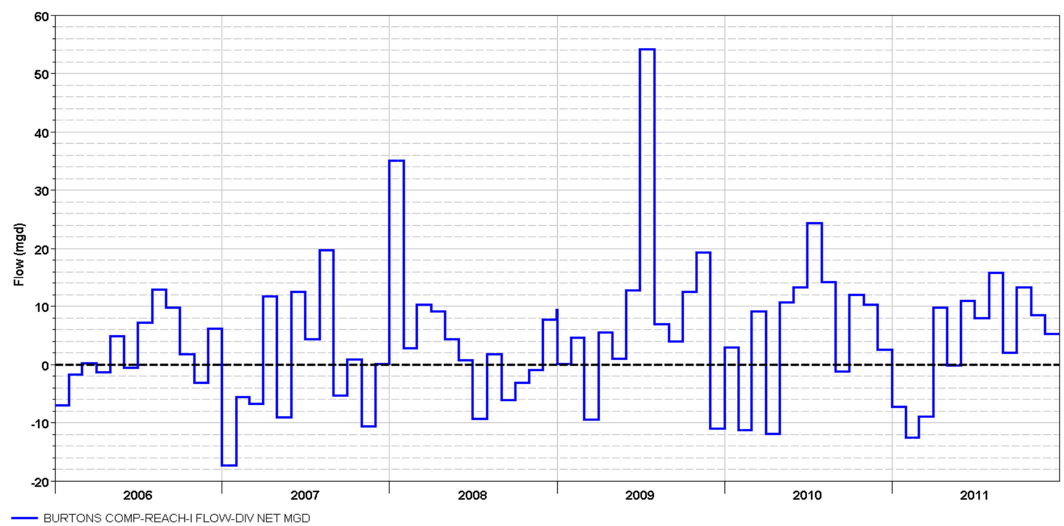
ARCADIS

RIVERSIDE
global science solutions

Water-use inventory and reach aggregation

- Filling of missing 2008 – 2011 water withdrawals and returns using 2010 data
  - By user/permittee
  - By reach
  - By month
- Aggregation of 2008 – 2011 M, I, T and A net water uses by reach
  - Net water use = monthly withdrawals – monthly returns
  - mgd to cfs unit conversion
- Conversion of monthly to daily net water use by reach





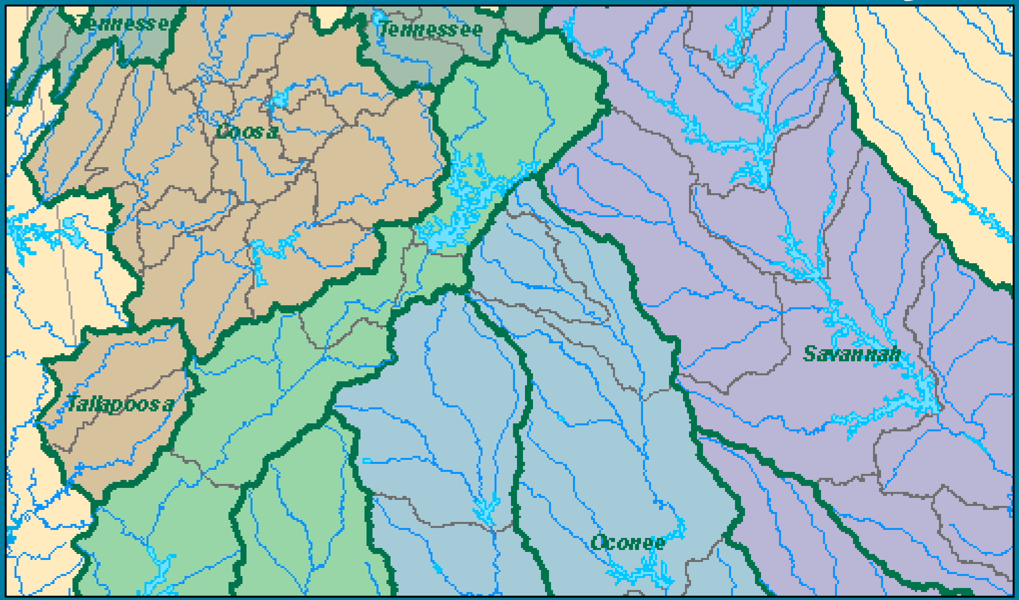
ARCADIS

RIVERSIDE
global science solutions

Net reservoir losses
Overview

- **Account for differences in runoff before and after the reservoir**
  - **Evaporation from reservoir surface**
  - **Precipitation on reservoir instead of land**

Net Loss Rate = Evap – (1 – Runoff Coefficient) * Precip
Net Loss Volume = Net Loss Rate * Daily Surface Area



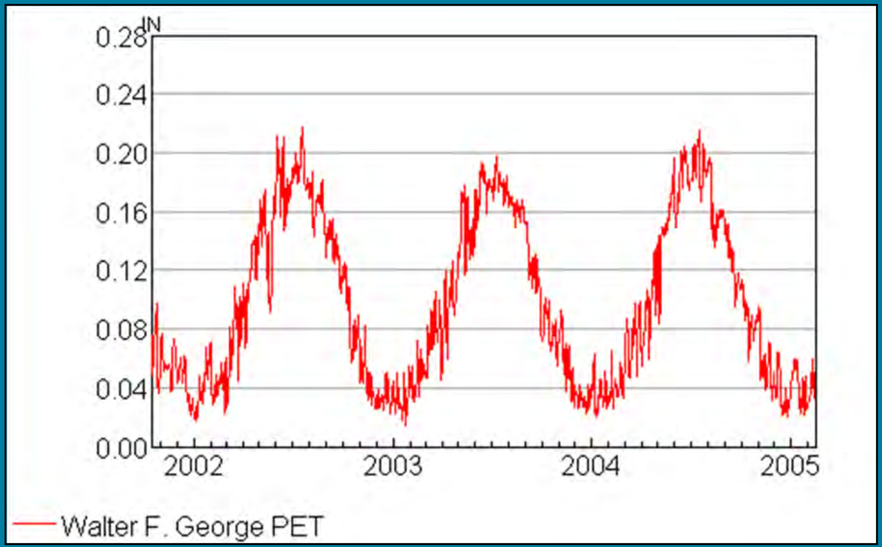
ARCADIS

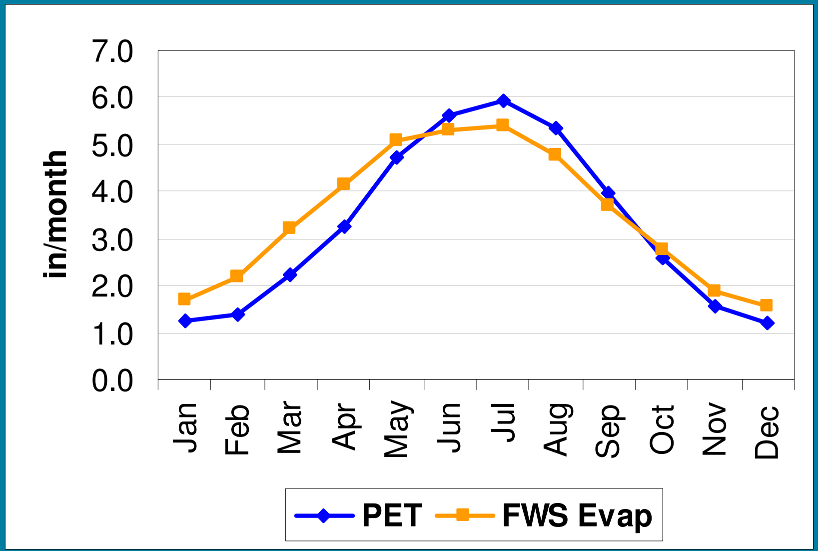
RIVERSIDE global science solutions

Net reservoir losses

Surface evaporation

- **NWS Free Water Surface Evaporation Atlas**
- **Hamon Method for daily Potential Evapotranspiration (PET)**
  - **Based on maximum and minimum temperature and latitude**
- **Adjusted daily PET to long-term evaporation**
- **Kept 2009-2011 results consistent with earlier results**





ARCADIS

RIVERSIDE
global science solutions

Net reservoir losses
Surface precipitation

- **Began with SERFC Mean Areal Precipitation (MAP) time series (1950 – 1999 and 1950 – 2004)**
- **Needed to extend time series period of record**
- **Used National Weather Service MAP program with same station inputs as original**
  - **Hourly data not available for December 2011, used only daily data that month**
- **Performed consistency checks of results**

ARCADIS

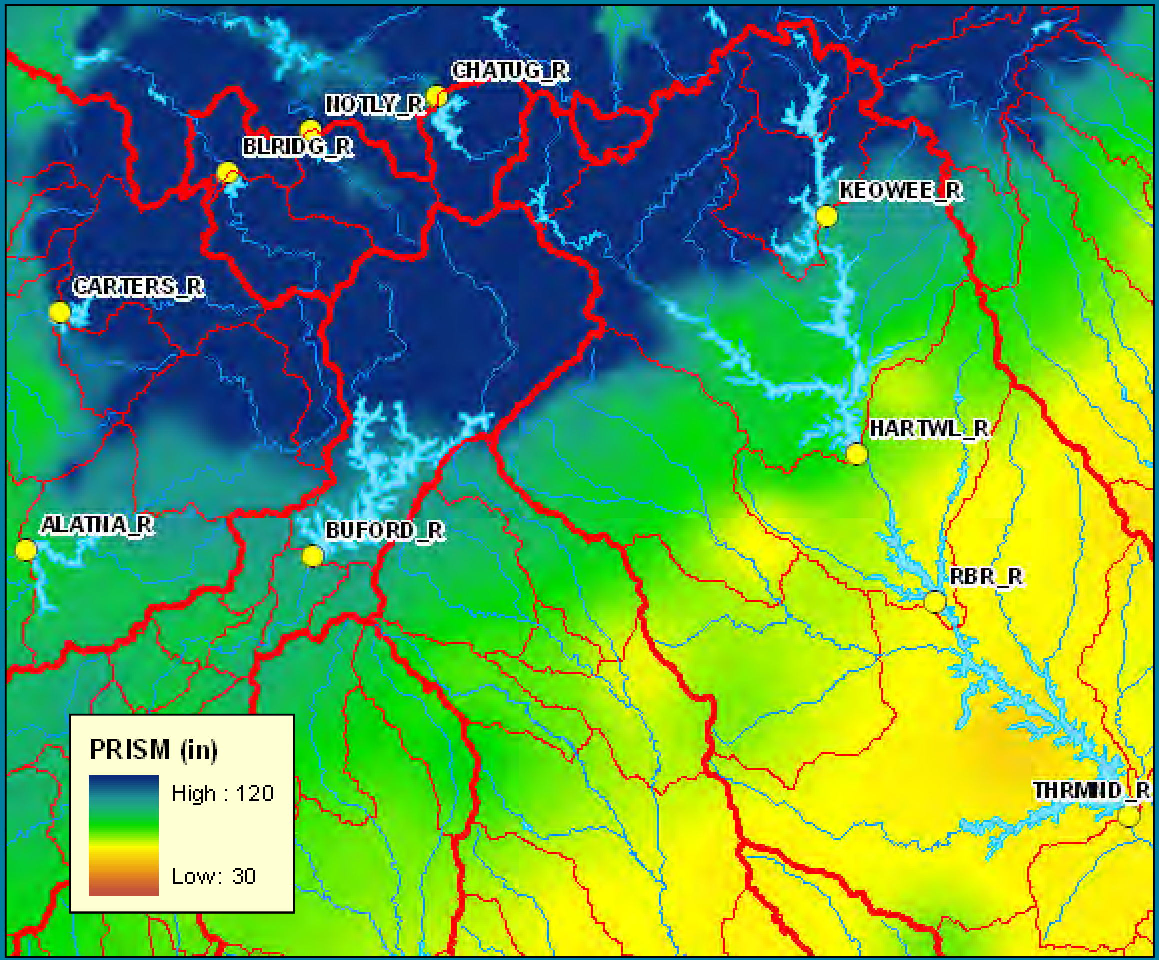
RIVERSIDE
global science solutions

Net reservoir losses

Surface precipitation

- **Adjusted MAP to represent long-term precipitation over reservoirs**

$$\text{Adjustment} = \frac{\text{PRISM}_{\text{reservoir}}}{\text{PRISM}_{\text{MAP area}}}$$

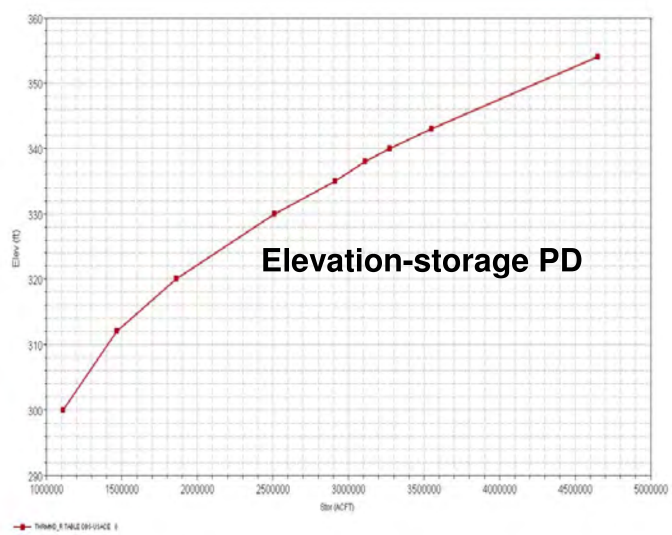


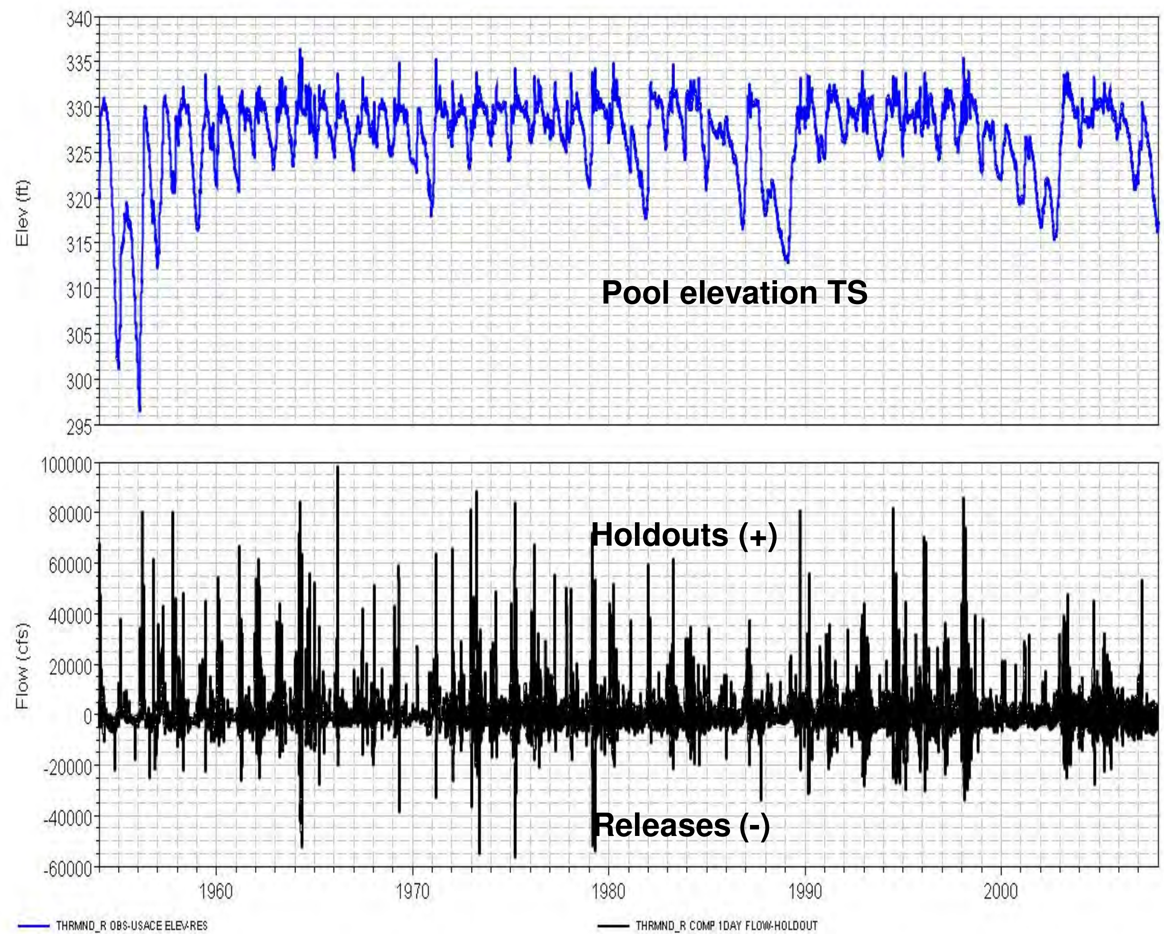
ARCADIS

RIVERSIDE global science solutions

Holdouts and net reservoir effects

- **Holdouts: = +ΔS when**
  O < I (rising pool)
- **Holdouts: = –ΔS when**
  O > I (falling pool)
- **Net RE =**
  E – P + $RO_{natural}$ + holdouts



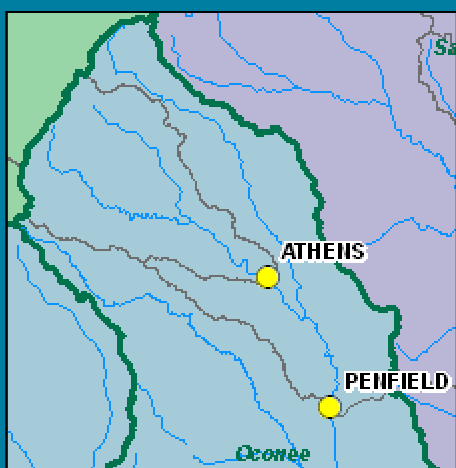


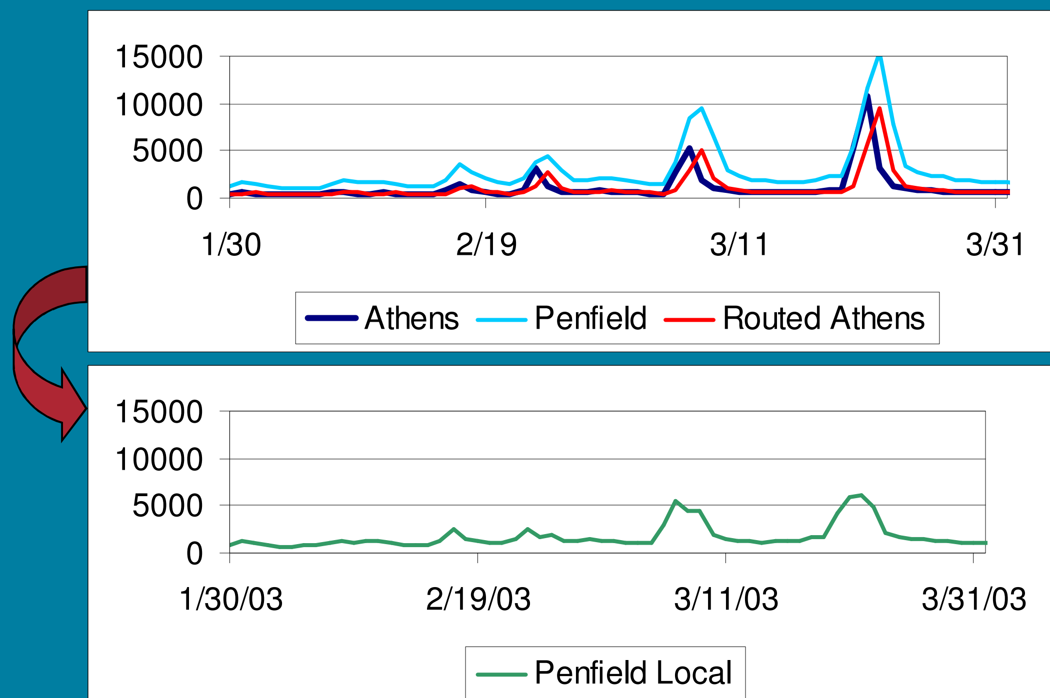
ARCADIS

RIVERSIDE
global science solutions

Local incremental flow (LIF) calculation
(RTi)

- **Route upstream cumulative streamflow (+ holdouts) to next downstream node**
- **Subtract upstream routed flow from downstream cumulative flow**





ARCADIS

RIVERSIDE
global science solutions

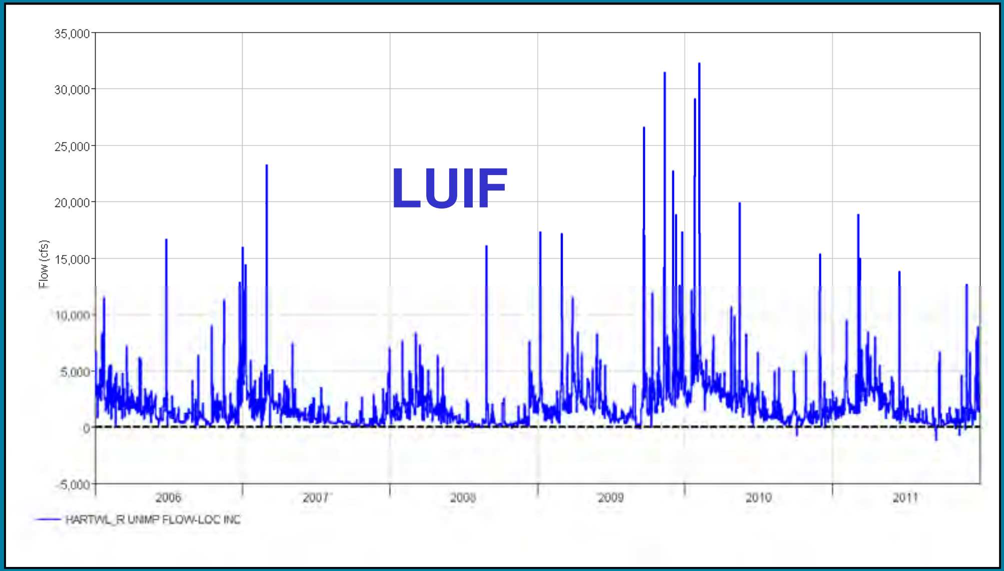
Aggregation of impairments (local UIF development)

Local UIF =

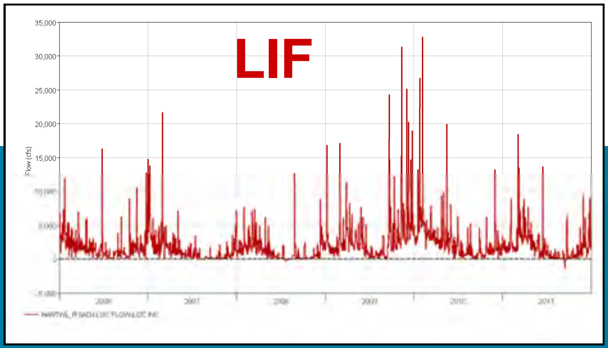
Local incremental flow +

Net water use +

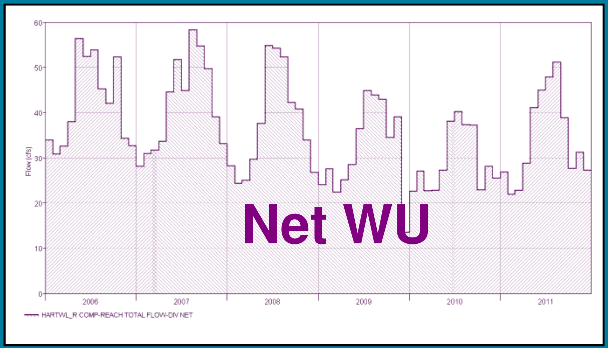
Net reservoir effects



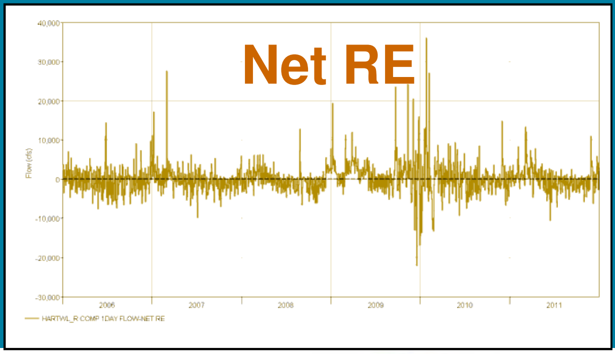
=



+



+



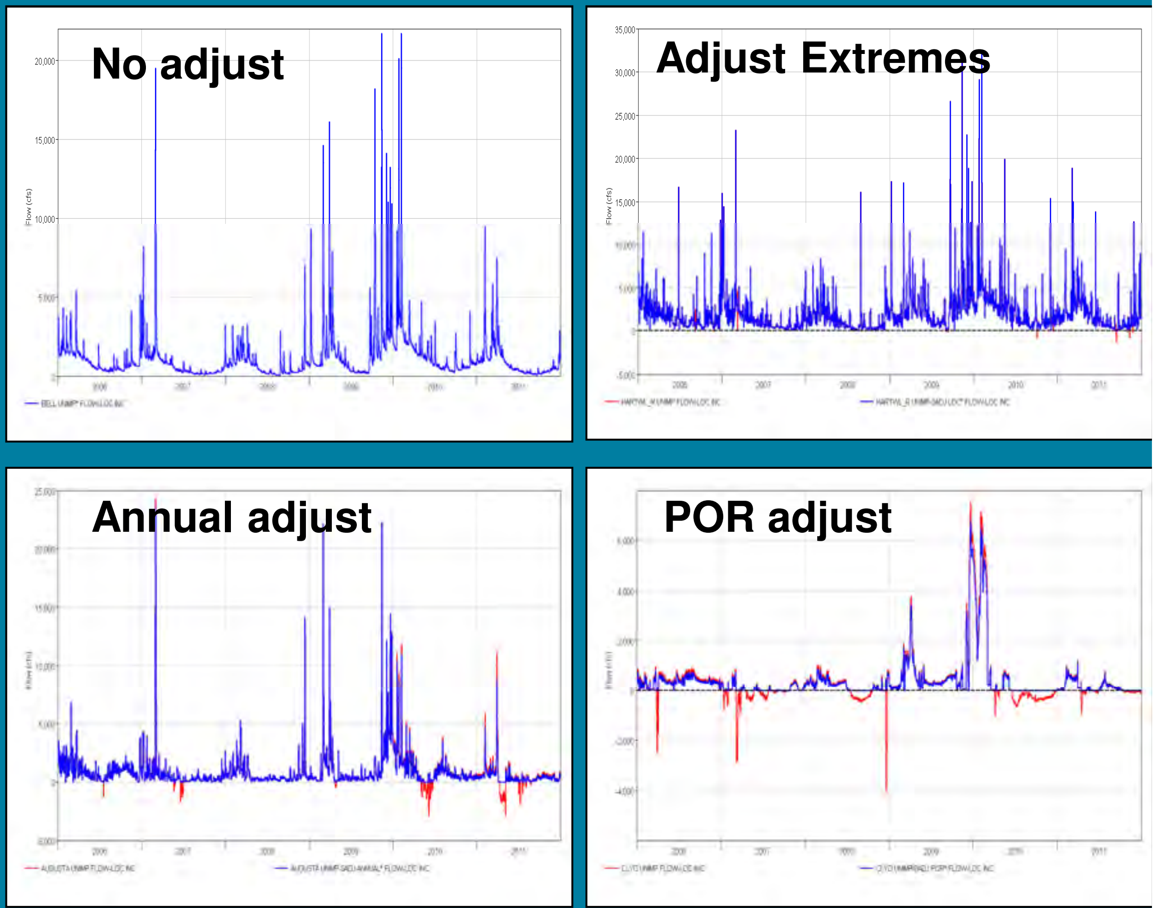
ARCADIS

RIVERSIDE
global science solutions

Flow adjustments

- Objective:
  - Removal of negative LUIFs
  - Flow volume maintenance over minimum time interval

- Procedures:
  - TSTool Adjust Extremes (variable centered-moving average value ≥ 0)
  - Annual adjust (DSSMATH procedure, raise –s to 0, reduce +s to maintain annual flow volume)
  - POR adjust (DSSMATH procedure, raise –s to 0, reduce +s to maintain POR flow volume)



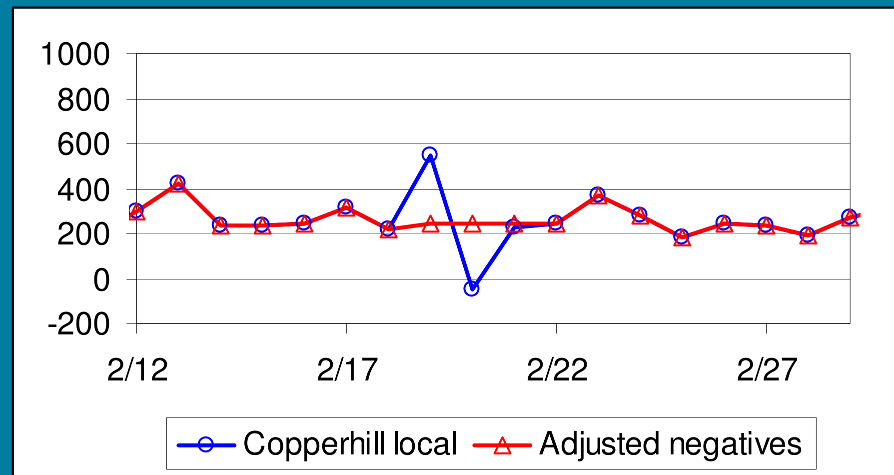
ARCADIS

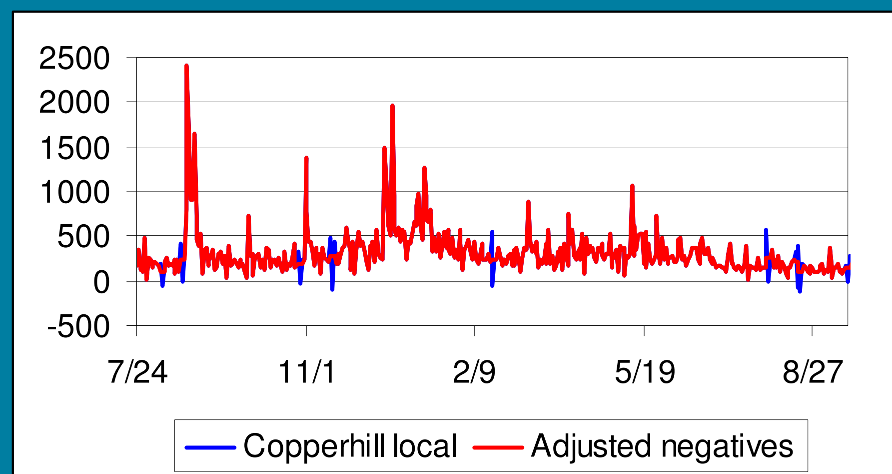
RIVERSIDE
global science solutions

Flow adjustments

TSTool AdjustExtremes

- **Adjustment of localized errors**
  - **Reservoir inflows**
  - **Routing**
- **Inputs**
  - **Specify threshold for adjustments**
  - **Define maximum time window for adjustments**
- **Calculations**
  - **Flags values below threshold**
  - **Computes average of flagged value and surrounding points**
  - **Consecutively increases number of points until average exceeds threshold**



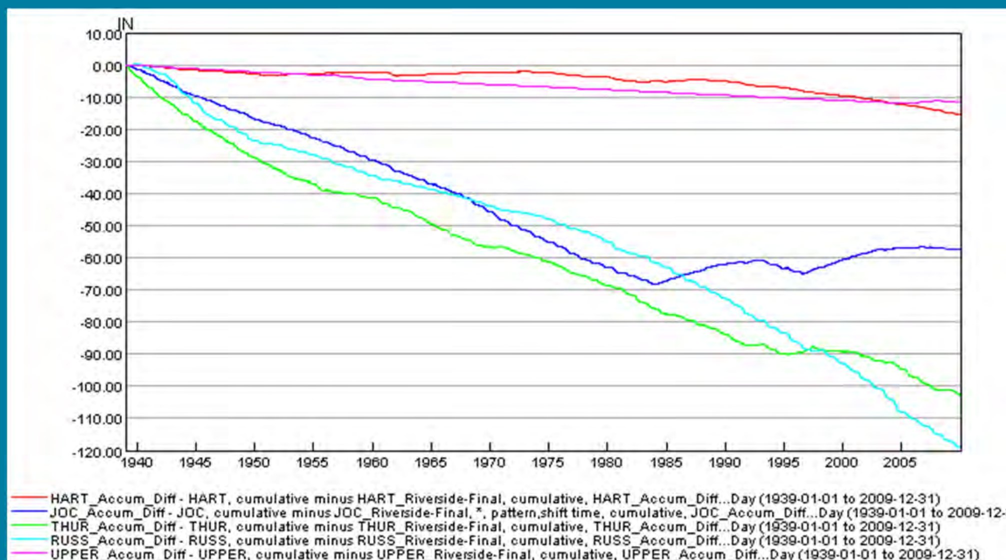


ARCADIS

RIVERSIDE
global science solutions

Quality and consistency checks
(RTi)

- MAP Consistency Checks
  - Used DMA to check extended MAPs
  - 2009-2011 data and older data were consistent
- Evap Consistency Checks
  - Used the same temperature station lists to keep results consistent
  - For Jocassee evap, scaled resulting evap to match previous results

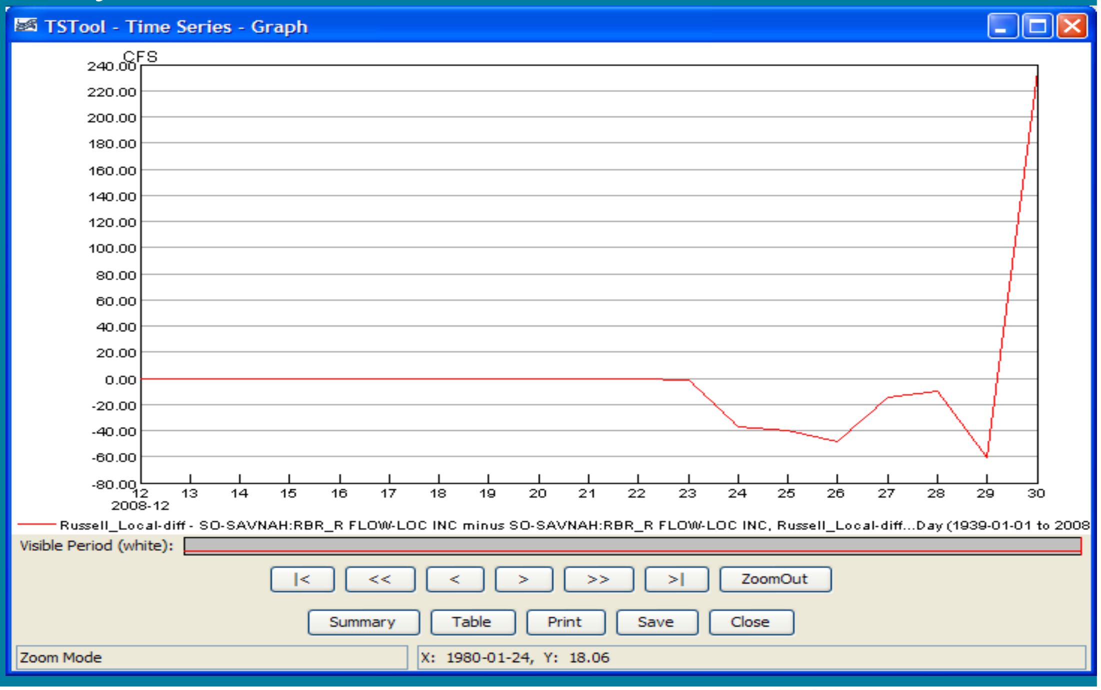


ARCADIS

RIVERSIDE
global science solutions

Quality and consistency checks
Local Incremental Flows

- Checked new calculations against original data
  - Some differences near the end of 2008 – more data available now for AdjustExtremes procedure
  - USGS revised flow records at Eden for Nov and Dec 2008 – affects Kings Ferry and Savannah nodes only
- No changes were made to original 2008 data, new data was appended

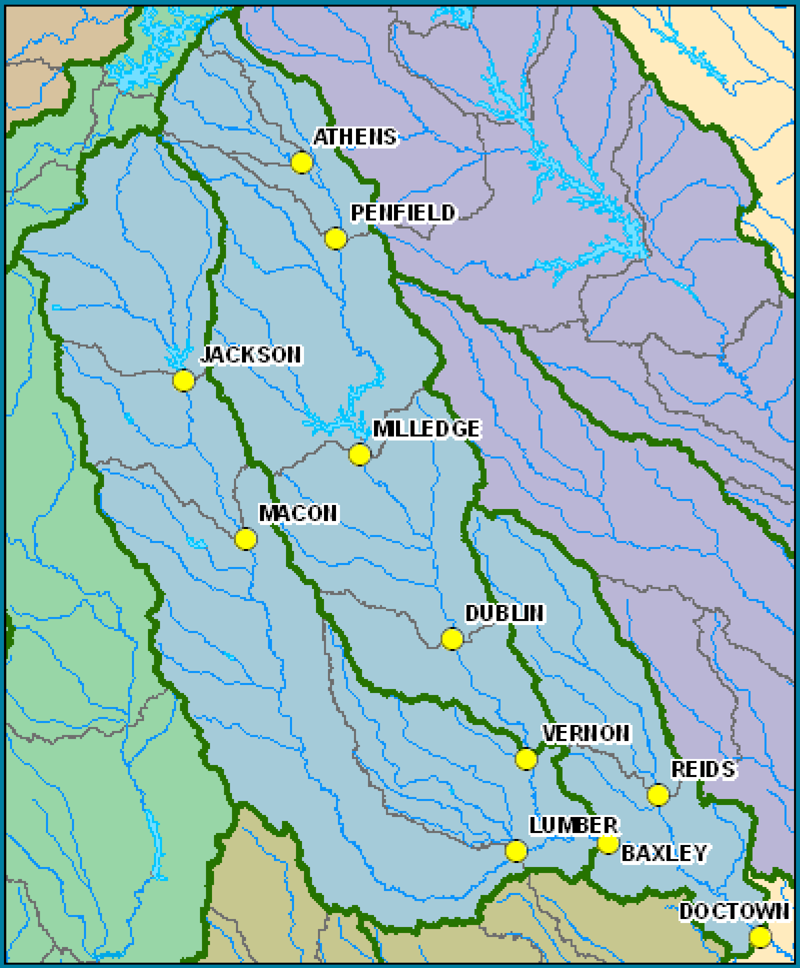


ARCADIS

RIVERSIDE
global science solutions

Routing and combining (cumulative UIF development)

- Began with local UIF time series
- Routed headwaters to the next node
- Summed with local UIF
- Routed the sum downstream

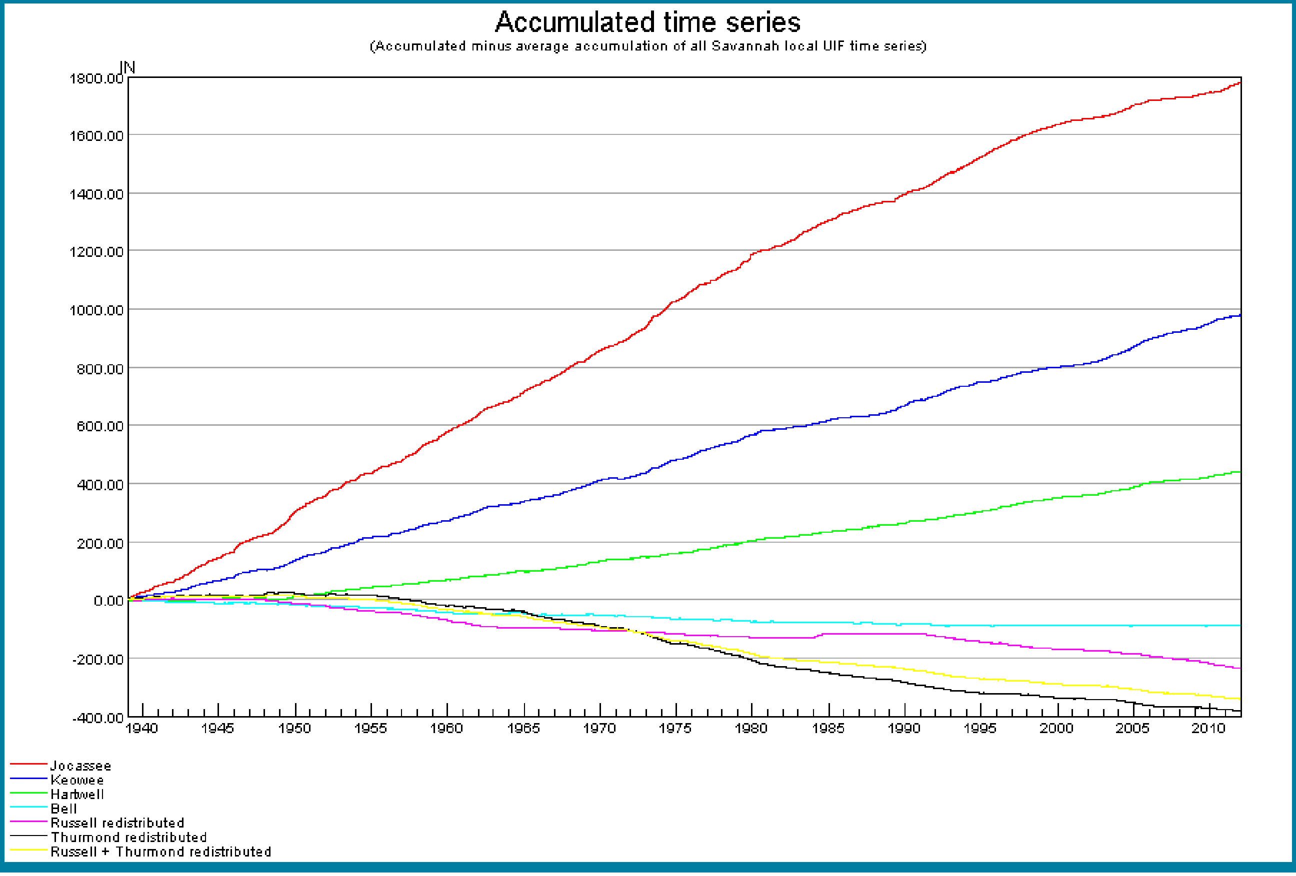


ARCADIS

RIVERSIDE
global science solutions

Quality and consistency checks
Unimpaired Flows

- Final local and total unimpaired flows checked for consistency
- No issues



Final steps

- Substitution of actual reported for filled 2011 water-use data

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

FERC NO. 2503

OPERATIONS MODEL

SCENARIO DOCUMENTATION REPORT

Prepared for:
DUKE ENERGY CAROLINAS, LLC
Charlotte, North Carolina

Prepared by:
HDR ENGINEERING, INC. OF THE CAROLINAS
Charlotte, North Carolina

MAY 1, 2014

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503
OPERATIONS MODEL
SCENARIO DOCUMENTATION REPORT

TABLE OF CONTENTS

Section	Title	Page No.

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503
OPERATIONS MODEL
SCENARIO DOCUMENTATION REPORT

TABLE OF CONTENTS
Continued

KEOWEE-TOXAWAY HYDROELECTRIC PROJECT
FERC NO. 2503
OPERATIONS MODEL
SCENARIO DOCUMENTATION REPORT

LIST OF FIGURES

Figure	Title	Page No.

LIST OF TABLES

Table **Title** **Page No.**

1.0 INTRODUCTION

The goal of the Operations Model Study was to simulate various Keowee-Toxaway Hydroelectric Project (Federal Energy Regulatory Commission [FERC] No. 2503) (Project) operations proposed during the relicensing process to aid in making decisions regarding the effects of various operating scenarios on water quantity, reservoir levels, hydropower generation, and flow releases from the Project. This study incorporates two computer-based hydraulic water quantity simulation models of the Project and downstream U.S. Army Corps of Engineers (USACE) reservoirs that are capable of using both a daily unimpaired inflow (UIF) data series and hydraulic characteristics of the reservoirs and flow release structures. The development of the two models and inputs is documented in the Savannah River Basin Operations Model Study Model Logic and Verification Report (HDR 2014a). This report presents the process and results of the relicensing operations modeling study plan by documenting the Existing License, Baseline (Existing Operations), and Relicensing Agreement (RA) (Blend 2Db v2) scenarios developed and run using the Savannah River Basin CHEOPS Model (SR CHEOPS Model) using water use projections from the *Final Keowee-Toxaway Water Supply Study Report* (HDR 2014b). This report supersedes and replaces the previously submitted March 2013 Model Scenario Documentation Report and November 2013 Model Scenario Documentation Report Addendum (HDR 2013a, b).

Duke Energy Carolinas, LLC (Duke Energy), contracted with HDR Engineering, Inc. of the Carolinas (HDR) to develop the operations models of "the system" which includes the Bad Creek Pumped Storage Project (FERC No. 2740) (Bad Creek Project), the Keowee-Toxaway Hydroelectric Project (FERC No. 2503) (Project), and three USACE-owned facilities (Hartwell, Richard B. Russell, and J. Strom Thurmond) along the Upper Savannah River. The system has been modeled utilizing HDR's proprietary SR CHEOPS Model and the ResSim Savannah River Model (SR ResSim Model) first developed by the USACE and refined by HDR.

Major features of the hydro developments in the Savannah River Basin are shown in Figure 1-1. This schematic is the basis for the conceptual model that was used to develop both the SR CHEOPS Model and the SR ResSim Model. The models have six nodes that correspond to the major hydrologic junctures in the modeled river system. The models account for inflows, discharge, change in reservoir storage, and power generation at the various nodes. A scenario describes how each node in the model responds to user-defined specific operating rules or conditions.

The Operations Model Study Plan outlines the scenario modeling process as guided by the Operations Model Study Team. In addition to the Operations Model Study Team, an Operating Scenarios Committee (OSC) was formed to develop and review modeling scenarios for consideration by the Stakeholder Team. The scenario modeling process began in February 2012 with formal training on the use of the two models. In May 2012, scenario development was initiated through a series of meetings and presentations using the SR CHEOPS Model. Both the SR ResSim and SR CHEOPS Models were made available to the OSC members for their use in evaluating and identifying various operating scenario alternatives outside of formal meetings. As outlined in this report, licensing scenario alternatives identified by the OSC have been simulated utilizing the SR CHEOPS Model.

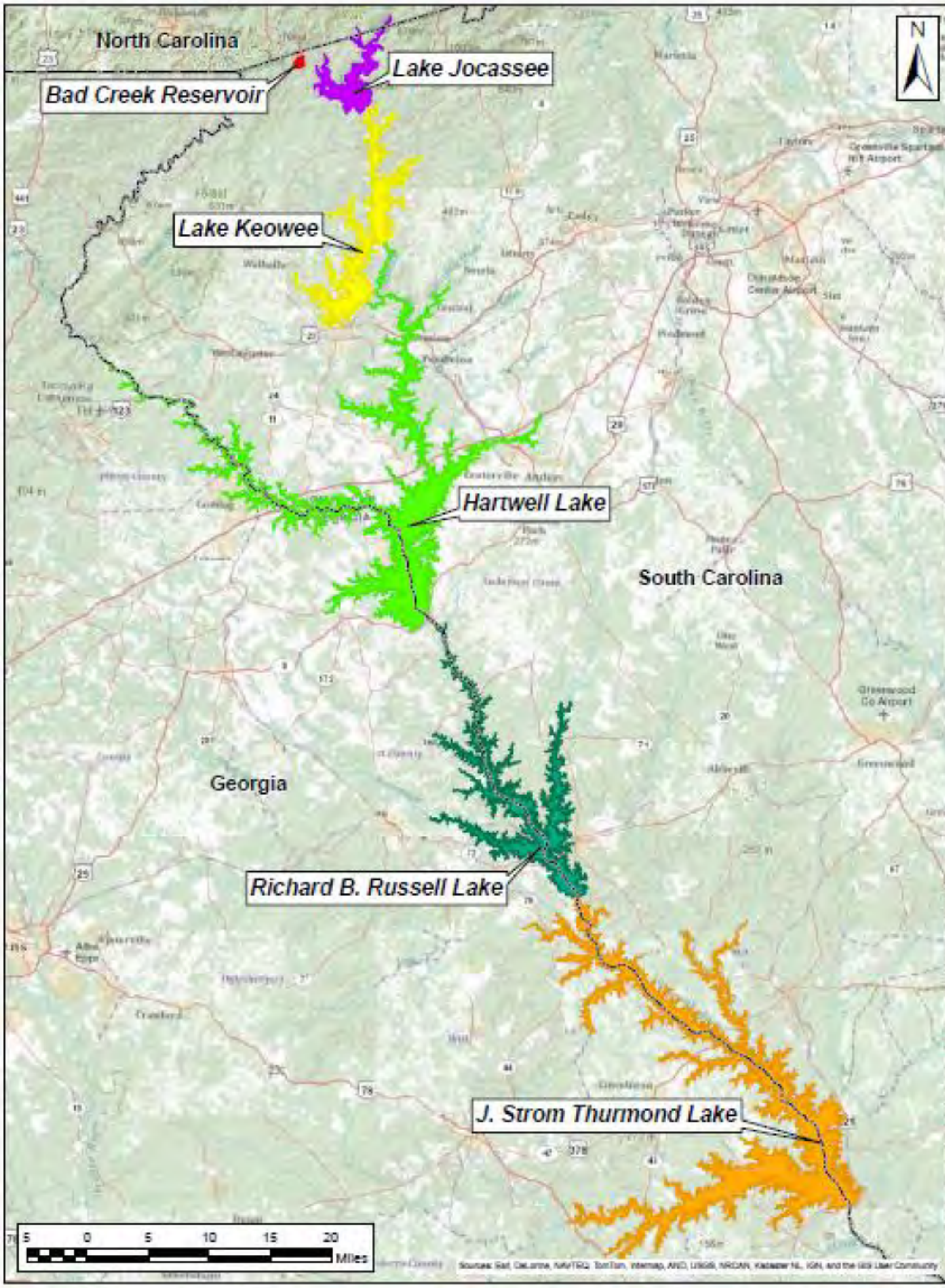
The OSC developed the RA (Blend 2Db v2) scenario through a multi-stage modeling process beginning with the introduction of a Trial Balloon scenario in September 2012 and evolving into the RA (Blend 2Db v2) scenario in May 2013. Potential Project operations were proposed to address a broad range of stakeholder interests including lake levels, hydropower generation, and flow releases from the Project. Several iterations of the Trial Balloon scenario were simulated with the SR CHEOPS Model and evaluated by the OSC. The basis of the RA (Blend 2Db v2) scenario is an operating lake-level range between Full Pond and a Normal Minimum Elevation and the addition of a Low Inflow Protocol (LIP) that allows Lake Keowee and Lake Jocassee to be drawn down further during drought periods.

Extensive meetings and consultation were performed through the OSC in support of the development of the scenarios evaluated. The full record of consultation (including meeting summaries) associated with the OSC is included in the consultation record of the License Application filed with the FERC. Additionally, the Draft Operations Model Scenario Documentation Report was made available for review and comment on February 15, 2013.

Comments on the draft report were received from three reviewers. A table listing the comments received and Duke Energy responses is provided in Appendix I of this report.

This report documents the final scenarios evaluated, which include the Existing License scenario, Baseline (Existing Operations) scenario, and RA (Blend 2Db v2) scenario using water use projections from the *Final Keowee-Toxaway Water Supply Study Report* (HDR 2014b).

FIGURE 1-1
UPPER SAVANNAH RIVER BASIN



2.0 PROJECT LICENSED AND EXISTING SYSTEM OPERATIONS

This section summarizes the six nodes and the operating settings in the SR CHEOPS Model that are user-defined in scenario development.

Duke Energy owns and operates the Bad Creek Pumped Storage Project, Jocassee Pumped Storage Station, and Keowee Hydro Station; the USACE owns and operates the Hartwell Dam and Lake Project, Richard B. Russell Pumped Storage Project, and J. Strom Thurmond Lake. For ease of discussion, each reservoir and its associated powerhouse is referred to as a development in this report. Each development is linked in series within the SR CHEOPS Model and consists of dams and multi-unit powerhouses as shown in Table 2-1.

TABLE 2-1
SAVANNAH RIVER BASIN - MODELED SYSTEM

Development	Upstream Reservoir	Project Type
Bad Creek	—	Pumped Storage
Jocassee	Bad Creek	Pumped Storage
Keowee	Jocassee	Conventional Hydro
Hartwell	Keowee	Conventional Hydro
Richard B. Russell	Hartwell	Conventional Hydro & Pumped Storage
J. Strom Thurmond	Richard B. Russell	Conventional Hydro

2.1 Description of Duke Energy Hydroelectric Developments

2.1.1 Bad Creek Development

Bad Creek and West Bad Creek were dammed to form the approximately 300-acre Bad Creek Reservoir located approximately 8 miles north of Salem in Oconee County, South Carolina. Bad Creek Reservoir serves as the upper reservoir for the Bad Creek Project, a pumped storage facility that uses Lake Jocassee as its lower reservoir. Bad Creek began producing energy on March 8, 1991. The powerhouse contains four reversible motor-pump/turbine-generator units.

The Bad Creek Normal Full Pond Elevation is 2,310 feet above mean sea level (ft AMSL), and the normal minimum elevation is 2,150 ft AMSL. All vertical elevations referenced in this report are National Geodetic Vertical Datum 1929 unless noted. There is no license-required operating guide curve; rather, the reservoir is operated as needed for generation, typically fluctuating between 2,280 and 2,300 ft AMSL. Historically, some periods show weekly reservoir drawdown with reservoir refill on the weekends.

2.1.2 Jocassee Development

The approximately 7,980-acre Lake Jocassee is fed by four rivers: Whitewater, Thompson, Horsepasture, and Toxaway. The Jocassee Development, the upstream development of the Keowee-Toxaway Project, was placed in service on December 19, 1973 (Units 1 and 2) and May 1, 1975 (Units 3 and 4) and is a pumped storage facility that uses Lake Keowee as its lower reservoir.

The Lake Jocassee Normal Full Pond Elevation is 1,110 ft AMSL and the normal minimum elevation is 1,080 ft AMSL (HDR 2010). For modeling purposes, Duke Energy developed an annual cycle conservation pool guide curve where the reservoir is brought to 1,109.5 ft AMSL from May 1 through October 15, then lowered gradually to 1,106 ft AMSL on January 1, and then refilled gradually to 1,109.5 ft AMSL on May 1. The SR CHEOPS Model uses this conservation pool guide curve for Jocassee.

2.1.3 Keowee Development

Lake Keowee is formed by two parallel watersheds that are connected by a 2,000-foot-long canal. The watershed draining directly into Lake Keowee is approximately 435 square miles. The reservoir surface area is approximately 17,660 acres at the Normal Full Pond Elevation of 800 ft AMSL and a licensed minimum of 775 ft AMSL (HDR 2012). The hydroelectric station began commercial operation on April 17, 1971, and contains two conventional turbine-generator units.

The reservoir's normal operation is characterized by maintaining the reservoir level between the lower and upper extremes of the normal operating range, which are 794.6 ft AMSL and 800 ft

AMSL, respectively. Historically, Duke Energy has not used a target or guide curve in the operations of the Keowee reservoir.

For modeling purposes in the SR CHEOPS Model, a target curve of 799 ft AMSL from May 1 to October 15, which then lowers gradually to 796 ft AMSL on January 1 and refills gradually by May 1, has been simulated to calculate usable storage for coordination with the USACE. The modeled target (guide) curve from 799 to 796 ft AMSL is used in the SR CHEOPS Model Existing License and Existing Operations scenarios for coordination of storage balance with the USACE.

2.2 Description of USACE Projects

2.2.1 Hartwell Development

The 55,900-acre Hartwell Lake is located approximately 7 miles east of Hartwell, Georgia, on the border with South Carolina and 289 river miles above the mouth of the Savannah River. Hartwell Dam is located on the Savannah River 7.1 miles below the point at which the Tugaloo and Seneca Rivers join to form the Savannah River. In addition to the Hartwell Dam, the two Clemson Diversion Dams were constructed to divert flow of the Seneca River around Clemson University. Hartwell Hydro Station has been in operation since April 1962. The powerhouse contains five conventional turbine-generator units.

The Hartwell development includes 5 feet (ft) of flood control storage from an elevation of 660 to 665 ft AMSL, which contains approximately 293,000 acre-feet (ac-ft) of storage (USACE 1996a). A flood surcharge zone exists from 665 to 679 ft AMSL. A seasonally varying guide curve exists, which provides additional flood control during the winter and early spring. The guide curve ranges from 660 ft AMSL from April 1 to October 15, which then lowers gradually to 656 ft AMSL on December 31, and refills gradually by April 1. The minimum pool elevation is 625 ft AMSL.

2.2.2 Richard B. Russell Development

The Savannah River flows out of the Hartwell Dam and flows into and through Richard B. Russell Lake. The 26,650-acre lake is impounded by the USACE's Richard B. Russell Dam 30 miles downstream of the Hartwell Dam and approximately 259 miles above the mouth of the Savannah River. The reservoir fill period commenced in October 1983, and the powerhouse was placed in service on January 1, 1985. The powerhouse contains four conventional turbine-generator units and four motor-pump/turbine-generator units. Two small house turbine-generator units were not modeled as part of the SR CHEOPS Model effort.

The Richard B. Russell development includes 5 ft of flood control storage from an elevation of 475 to 480 ft AMSL (USACE 1996b). The limited conservation storage range between reservoir elevation 470 and 475 ft AMSL and fluctuation caused by pumping/generating cycles necessitates a constant guide curve with no seasonal drawdown (USACE 1996b).

2.2.3 J. Strom Thurmond Development

The Savannah, Broad, and Little Rivers flow into J. Strom Thurmond Lake, which is a 71,100-acre lake impounded by the J. Strom Thurmond Dam. The dam is located approximately 37 miles downstream of the Richard B. Russell Dam and approximately 222 miles above the mouth of the Savannah River. The powerhouse contains seven conventional turbine-generator units.

The objective of flood control regulation at the J. Strom Thurmond development is to reduce flood damages to the lower Savannah River Basin to the maximum extent possible. Normal pool varies seasonally from 330 ft AMSL from April 1 through October 15, and between October 15 and December 15, the pool is drawn down to a seasonal normal pool of 326 ft AMSL to allow for the statistically higher winter and spring inflows. Starting January 1, the pool is refilled to reach 330 ft AMSL on April 1 (USACE 1996c).

2.3 Description of USACE Drought Plan

The USACE has developed and periodically updated the Savannah River Basin Drought Plan (DP) to help sustain the basin's water supply needs for domestic and industrial water users, navigation, and environmental protection. To decelerate the decline in reservoir elevations during the early stages of drought, the USACE reduces weekly average flow releases from the Hartwell and J. Strom Thurmond developments. Once the DP has been activated, flows are reduced in a step-wise fashion, starting with a reduction of downstream releases from J. Strom Thurmond Lake. Reservoir elevations at Hartwell and J. Strom Thurmond are kept in balance during both normal and drought conditions. The conservation pool is the amount of usable storage in the reservoir (USACE 1989).

When developed in 1989, the DP included three trigger levels. In 2006, the DP was revised to include a fourth trigger level. The 2006 DP allowed the USACE to maintain higher pools at the reservoirs without causing further impacts to water intakes upstream or downstream of the dams. Table 2.3-1 provides the flood control, conservation, and minimum conservation pool elevations for Hartwell, Richard B. Russell, and J. Strom Thurmond Lakes.

TABLE 2.3-1
FLOOD CONTROL, CONSERVATION, AND MINIMUM CONSERVATION POOL ELEVATIONS

Pool Elevation	Hartwell Lake (ft AMSL)	Richard B. Russell Lake (ft AMSL)	J. Strom Thurmond Lake (ft AMSL)
Top Flood Control	665	480	335
Top of Conservation Pool (Summer/Winter)	660/656	475	330/326
Minimum Conservation Pool	625	470	312

Source: USACE 2010.

In 2012, the DP flows required out of J. Strom Thurmond were revised, along with the addition of an inflow trigger, as presented in Table 2.3-2 (USACE 2012). The trigger levels in the DP are based on the reservoir elevations at Hartwell and J. Strom Thurmond Lakes as well as flows in the Broad River, a tributary of J. Strom Thurmond Lake. Table 2.3-2 provides the seasonal trigger levels and management action (i.e., minimum required release from J. Strom Thurmond Lake).

TABLE 2.3-2
HARTWELL AND J. STROM THURMOND LAKE SEASONAL TRIGGER LEVELS

Level	1 Apr–15 Oct (ft AMSL)		15 Dec–1 Jan (ft AMSL)		Action
	Hartwell Lake	J. Strom Thurmond Lake	Hartwell Lake	J. Strom Thurmond Lake	
1	656	326	654	324	If Broad River inflows > 10th percentile of historical flow rate, set J. Strom Thurmond outflow to 4,200 cfs. If Broad River inflows <= 10th percentile of historical flow rate, set J. Strom Thurmond outflow to 4,000 cfs.
2	654	324	652	322	If Broad River inflows > 10th percentile of historical flow rate, set J. Strom Thurmond outflow to 4,000 cfs. If Broad River inflows <= 10th percentile of historical flow rate, set J. Strom Thurmond outflow to 3,800 cfs. Set J. Strom Thurmond outflow to 3,600 cfs November through January.
3	646	316	646	316	Set J. Strom Thurmond outflow to 3,800 cfs. Set J. Strom Thurmond outflow to 3,100 cfs November through January.
4	625	312	625	312	Set J. Strom Thurmond outflow to 3,600 cfs. Set J. Strom Thurmond outflow to 3,100 cfs November through January. Continue release as long as possible, then outflow = inflow.

Note: Broad River inflow is measured as the Broad River nears the Bell Piedmont reference stream gage for reservoir inflow. > means greater than; < means less than; = means equals; cfs means cubic feet per second. Source: USACE 2012.

The requirements of the 2012 USACE DP are incorporated into the simulated alternatives. It is important to note the USACE DP is a significant water quantity operating parameter with basin-wide impacts during drought periods; however, it is not a FERC-licensed Project operating rule that can be directly modified by the FERC relicensing process as it directly relates to USACE operations and authorized hydro project purposes.

2.4 Duke Energy Oconee Nuclear Station

Duke Energy operates the 2,538-megawatt (MW) Oconee Nuclear Station (ONS) on the shores of Lake Keowee. The facility has three 846 MW pressurized light water reactors. Construction of the facility began in 1967. Unit 1 began commercial operation in 1973 followed by Units 2 and 3 in 1974. On May 23, 2000, the Nuclear Regulatory Commission (NRC) renewed the licenses for all three reactors for an additional 20 years. The licenses for Units 1 and 2 expire on February 6, 2033, and the license for Unit 3 expires on July 19, 2034 (HDR 2014c).

ONS uses a once-through condenser circulating water (CCW) system to operate its three reactor units and relies on the Keowee Hydro Station as a backup power supply in the event of a loss of off-site power. This system relies on water stored in Lake Keowee to support normal station operations and emergency operating situations. Due to various NRC requirements associated with the operation of ONS, Duke Energy maintains Lake Keowee at a reservoir elevation of 794.6 ft AMSL or higher (Normal Full Pond Elevation is 800 ft AMSL) for ONS to continue unrestricted operations (HDR 2014c).

2.5 Description of 1968 Operating Agreement

On October 1, 1968, Duke Energy's predecessor company, Duke Power Company, entered into an Operating Agreement (1968 Agreement) with the USACE and the Southeastern Power Administration (SEPA) regarding water releases from the Project. The purpose of the 1968 Agreement was to assure that Duke Energy's Project would be operated such that the ability of the USACE and SEPA to meet power-generating requirements would not be impaired. The 1968 Agreement further recognizes the requirement for minimum flow releases from the USACE's most downstream project (J. Strom Thurmond) and other responsibilities, including flood control, in connection with the USACE's Hartwell Lake and J. Strom Thurmond Lake. The 1968 Agreement is based in part on a minimum reservoir elevation at Lake Keowee of 778 ft AMSL, with provisions for use of additional water volume down to elevation 775 ft AMSL for pumping operations.

The requirements of the 1968 Agreement are incorporated into the SR CHEOPS Modeled Existing License scenario. A modification of the 1968 Agreement to accommodate operations for ONS is used in the Baseline (Existing Operations) scenario and the operating conditions of a new operating agreement to replace the 1968 Agreement are included in the RA scenario.

2.6 System Water Supply Summary

As part of the FERC relicensing of the Project, Duke Energy contracted with HDR to complete a Water Supply Study of the Savannah River Basin. This study is detailed in the *Final Keowee-Toxaway Water Supply Study Report* (HDR 2014b). The Water Supply Study provided the following data for the SR CHEOPS Model:

- Water withdrawals and returns within the Savannah River Basin greater than or equal to 100,000 gallons per day (HDR 2014b). The modeled withdrawals and returns are tabulated in Appendix A.
- Future projections for water withdrawals and returns within the Savannah River Basin to the year 2066 (50 years from Existing License expiration). These projections are provided in Appendix A.
- Geographic Information System (GIS) database of withdrawals and returns including ownership information, physical descriptions, historical water use, and future projections.

The physical locations of intakes in the six Duke Energy and USACE reservoirs are important to successful calculation of municipal and industrial water demand used in the model. During the execution of the Water Supply Study, the intake locations were identified by reservoir and critical operating elevations specified using the best available data. A summary table of intakes is included in Appendix B. For several of the water withdrawal points, the intake level indicated may not be the actual physical elevation, but instead it may be the critical operating level under baseline conditions. Table 2.6-1 identifies the critical intake elevations for each of the six reservoirs. Each of the proposed future licensing operations scenarios were reviewed for impacts relative to existing critical water intakes.

TABLE 2.6-1
CRITICAL INTAKE ELEVATION SUMMARY

Reservoir	Critical Intake Elevation (ft AMSL)	Comments
Bad Creek	2,150.00	Hydropower operations limitation
Jocassee	1,080.00	Hydropower operations limitation
Keowee	794.60	Oconee Nuclear Station limitation
Hartwell	638.00[1]	Clemson University Central Energy Facility intake (Note: Although Clemson University's Musser Fruit Farm irrigation intake is higher at 645.00 ft AMSL, in the event this intake is exposed, the facility can purchase water from the City of Seneca. Therefore, the Musser Fruit Farm intake is not considered the Critical Intake.)
Richard B. Russell	470	Hydropower operations limitation
J. Strom Thurmond	312.00	Columbia County Water Utility (GA) and McDuffie County – City of Thomson (GA) raw water intake elevation (second highest of three intakes; if highest intake is exposed, the remaining two intakes are capable of meeting water demands, thus making the second highest intake the critical intake elevation); hydropower operations limitation

[1]This critical intake elevation is considered a "soft" constraint as USACE does not limit Hartwell drawdown to this level (and historically has not).

3.0 SR CHEOPS MODEL SCENARIO DEFINITIONS

Model inputs are outlined below (Sections 3.1 through 3.3) and detailed in the scenario input sheets included in Appendix C. All scenarios were modeled with withdrawals projected into the future. Each hydrologic year modeled corresponds to a projected withdrawal year in the future. The projected withdrawals and corresponding hydrologic year are presented in Appendix A. Scenario names (used in this report) and corresponding simulation names (scenario naming conventions used in the CHEOPS model database) are summarized in Table 3-1.

TABLE 3-1
SIMULATED AND REPORTED SCENARIO NAME MATRIX

Simulation Name	Climate Change Low (ccLow) Sensitivity Simulation Name	Climate Change High (ccHigh) Sensitivity Simulation Name
Existing License Scenario		
Existing_License_73yr	Existing_License_73yr_ccLow	Existing_License_73yr_ccHigh
Baseline (Existing Operations) Scenario		
BaseProjected_2012-08-23_73yr	BaseProjected_2012-08-23_73yr_ccLow	BaseProjected_2012-08-23_73yr_ccHigh
Relicensing Agreement (RA) (Blend 2Db v2) Scenario		
Blend2Db_v2_73yr	Blend2Db_v2_73yr_ccLow	Blend2Db_v2_73yr_ccHigh

3.1 Existing License

The Existing License scenario simulates the system as outlined in Section 2 of this report. The scenario includes the requirements of the 1968 Agreement as written, FERC license limitations, and the USACE DP as defined by the USACE in August 2012. The Existing License scenario designates, per the 1968 Agreement, the minimum elevation for Lake Keowee as 778.0 ft AMSL and Lake Jocassee as 1,086.0 ft AMSL, with a pumping volume allowance that allows Lake Keowee to be at 775.0 ft AMSL or Jocassee to be at 1,080.0 ft AMSL. The 1968 Agreement as written (and as modeled in this scenario) includes storage from Jocassee, Keowee, Hartwell, and Thurmond Lakes in the calculation of usable storage.

The purpose of the Existing License scenario is to simulate the existing FERC License, 1968 Agreement, and current USACE DP operations for comparison to the Baseline (Existing

Operations) scenario and the RA scenario. The Existing License scenario is not an operationally feasible alternative due to NRC requirements for ONS relative to required minimum Lake Keowee elevations.

3.2 Baseline (Existing Operations)

The Baseline (Existing Operations) scenario is based on the Existing License scenario except the minimum elevation for Lake Keowee has been revised from 778.0 to 794.6 ft AMSL. The minimum elevation used for calculation of usable storage remains as written in the 1968 Agreement (778.0 ft AMSL at Lake Keowee) and includes storage from Jocassee, Keowee, Hartwell, and J. Strom Thurmond Lakes in the calculation of usable storage. The Baseline (Existing Operations) scenario simulates current reservoir operations used by Duke Energy based on Lake Keowee drawdown limits to maintain operation of ONS. The Baseline (Existing Operations) scenario represents how the Project has been operated since the mid-1990s, particularly during extreme drought conditions. For the Baseline (Existing Operations) scenario, the overall methodology used to determine required weekly water releases from Lake Keowee is the same as the Existing License scenario. However, no water release would be made from Lake Keowee if that release would result in a Lake Keowee elevation below 794.6 ft AMSL. Therefore, the Duke Energy reservoirs may go out of "storage balance" with the USACE usable storage if the USACE usable storage drops below the level that would require Lake Keowee to drop below 794.6 ft AMSL.

The purpose of this scenario is to simulate the current operations of the system. Alternative model scenarios were compared to the Baseline (Existing Operations) scenario for identification of how the system responds to changes in Project operating rules.

3.3 Relicensing Agreement (Blend 2Db v2)

The RA (Blend 2Db v2) scenario was developed by the OSC through a multi-stage modeling process outlined in the Operations Model Study Plan prepared by Duke Energy (2011). The starting point for this scenario was a Trial Balloon scenario proposed by Duke Energy in September 2012. Potential Project operations were proposed to address a broad range of stakeholder interests including lake levels, hydropower generation, and flow releases from the Project. Several iterations of the Trial Balloon scenario were simulated with the SR CHEOPS Model and evaluated by the OSC evolving over a period of approximately seven months to become the RA (Blend 2Db v2) scenario. The basis of the RA (Blend 2Db v2) scenario is an operating lake-level range between Full Pond and a Normal Minimum Elevation (i.e., 796.0 ft AMSL for Lake Keowee and 1,096.0 ft AMSL for Lake Jocassee) and the addition of a LIP that allows Lake Keowee and Lake Jocassee to be drawn down further during drought periods (Appendix D). Additional RA parameters associated with the RA (Blend 2Db v2) scenario include:

- The minimum elevation for Lake Keowee is 790.0 ft AMSL. However, the elevation will remain above 791.5 ft AMSL until the Duke Energy system remaining usable storage is at or below 12 percent (see Table 3.3-1).
- The percentage of Duke Energy remaining usable storage at which the outflow from Lake Keowee is limited to evaporation, water use, and leakage is 12 percent.
- The LIP minimum reservoir elevations for each LIP stage as listed in Table 3.3-1.
- The Lake Keowee water release calculation uses 790.0 ft AMSL as the minimum Lake Keowee reservoir elevation for the calculation of Duke Energy remaining usable storage.
- The Jocassee minimum reservoir elevation for the calculation of Duke Energy remaining usable storage is 1,080.0 ft AMSL.
- Full Pond at the Duke Energy reservoirs is defined as the maximum elevation in the remaining usable storage calculation.
- The volume of storage in the Bad Creek reservoir from elevation 2,310.0 ft AMSL to 2,150.0 ft AMSL is included in the calculation of Duke Energy storage balancing contribution with the USACE system.
- The volume of storage in the Richard B. Russell reservoir between elevations 475.0 ft AMSL and 470.0 ft AMSL is included in the USACE remaining usable storage balancing calculations.

The LIP specifies how Duke Energy will operate the Project during droughts. The LIP includes five stages based on specific triggers (i.e., remaining usable storage and DP levels, streamflows, and the U.S. Drought Monitor). The LIP also specifies maximum reservoir drawdowns and maximum downstream flow releases from Keowee Hydro Station based upon the specific LIP stage. It should also be noted the remaining usable storage for determination of LIP stage (only applicable at Duke Energy reservoirs) is based on Normal Full Pond Elevations.

The RA (Blend 2Db v2) scenario references U.S. Geological Survey (USGS) gage averaging using 4-month rolling average and LIP logic to reference "triggered" DP level versus "in-effect" DP level during LIP recovery. The referenced DP level allows the LIP to change more quickly to a lower stage number during the recovery process, eliminating the 2-foot recovery delay in the USACE's DP. The specific model inputs associated with the LIP are summarized in the RA (Blend 2Db v2) scenario input form in Appendix C; the LIP at the date of scenario set up is included in Appendix D.

TABLE 3.3-1
LAKES JOCASSEE AND KEOWEE LOW INFLOW PROTOCOL STAGE MINIMUM ELEVATION

LIP Stage	RA (Blend 2Db v2) Scenario Minimum Jocassee Elevation (ft AMSL)	RA (Blend 2Db v2) Scenario Minimum Keowee Elevation (ft AMSL)
0	1,096.0	796.0
1	1,092.0	795.0
2	1,087.0	793.0
3	1,083.0	792.0
4	1,080.0	791.5*

*Note: In Stage 4 of this scenario, the Keowee reservoir elevation will be maintained at or above 791.5 ft AMSL until Duke Energy storage balance reaches 12 percent. The minimum elevation used to calculate the usable storage for storage balancing with the USACE is 790.0 ft AMSL for the RA (Blend 2D v2) scenario.

3.4 Climate Change Sensitivity

Two water quantity sensitivity assessments were completed for each scenario outlined in Sections 3.1 through 3.3. These sensitivity assessments were simulated to evaluate possible impacts of future temperature increases and basin inflow reduction and were developed from climate change sensitivity scenarios identified and outlined in the September 19, 2012, *Keowee-Toxaway Climate Change Scenario Development Summary* report, Appendix E. From the

Keowee-Toxaway Climate Change Scenario Development Summary report, the OSC adopted the recommended cc-01 and cc-02 climate change sensitivities to represent future possible climate change conditions. These two sensitivities are a simplification of possible future decreases in available water in the basin, but were agreed upon by the OSC as a method to provide stakeholders with additional information to evaluate potential Project operation scenarios. The Period of Record (POR) plus the two climate change sensitivities represent the three hydrologic conditions discussed in this report.

3.4.1 Low Impact of Climate Change Sensitivity (ccLow)

The scenarios outlined in Sections 3.1 through 3.3 were simulated with a 3°F temperature increase, which is modeled as a 10 percent increase in natural surface evaporation, and was developed based on the recommended cc-01 climate change scenario. The net impact was to simulate a reduction in available water in the basin due to increased surface evaporation applied uniformly over the entire 12 months of each year simulated. The application of the surface evaporation increase to the modeled net monthly evaporation coefficient included consideration of a positive or negative coefficient due to some months historically having more precipitation than evaporation. In the case of a negative monthly net evaporation coefficient, the adjustment was applied so that it would always result in less water being available in that reservoir.

3.4.2 High Impact of Climate Change Sensitivity (ccHigh)

The scenarios outlined in Sections 3.1 through 3.3 were simulated with the addition of a 6°F temperature rise simulated as a 10 percent decrease in incremental inflows to each reservoir and a 20 percent increase in natural surface evaporation (see explanation of application of increased evaporation in Section 3.4.1). The high impact climate change sensitivity was developed based on the recommended cc-02 climate change scenario (Appendix E).

4.0 SR CHEOPS MODEL RESULTS

4.1 Scenario Results

The modeled minimum end-of-day reservoir elevations, based on 15-minute detailed model output over 73 years of modeled operation, for each reservoir and scenario, are summarized in Tables 4.1-1 through 4.1-3. Modeled elevation duration curves showing reservoir elevations (15-minute model output) plots and pie charts for Lake Jocassee and Lake Keowee are shown in Figures 4.1-1 through 4.1-4. Included in Figures 4.1-1 through 4.1-4 are plots covering the full extended POR 1939–2011 and 2-year sample summaries from the POR simulations showing the drought periods of 2007 and 2008.

The pie charts shown in Figures 4.1-3 and 4.1-4 use local datum reference for reservoir elevations based on 100 ft representing Normal Full Pond Elevation. Lake Keowee's Normal Full Pond Elevation is 800 ft AMSL, which equates to 100 ft local datum, and Lake Jocassee's Normal Full Pond Elevation is 1,110 ft AMSL, which equates to 100 ft local datum. Elevation duration curve plots showing the detailed elevations (15-minute model output) for each scenario, all six reservoirs, and each of the three hydrologic conditions (POR, ccLow, and ccHigh) are provided in Appendix F. Discharge duration curve plots from Lake Keowee (discharge from Project) and J. Strom Thurmond Lake (discharge to lower Savannah River Basin) are provided for each scenario and hydrologic condition in Appendix G.

Comparison of scenario outcomes for key parameters can also be made using a Performance Measure (PM) Worksheet. The PM Worksheet is a tool developed to provide a "side-by-side" comparison of key parameters to the Baseline (Existing Operations) scenario. The scenario outcome comparisons for each measure are color coded based on a minimum increment of significant change (MISC) outcome. PM Worksheets for the scenarios under each of the hydrologic conditions are provided in Appendix H. The PMs summarized in these sheets were identified as specific areas of interest to the OSC through the study meetings.

TABLE 4.1-1
MINIMUM SIMULATED END-OF-DAY RESERVOIR ELEVATIONS COMPARED TO THE BASELINE (EXISTING OPERATIONS) SCENARIO
(FT AMSL)

Scenario	Bad Creek	Jocassee	Keowee	Hartwell	Richard B. Russell	J. Strom Thurmond
Baseline (Existing Operations)	**2,154.9**	**1,079.7**	**791.8**	**635.5**	**474.3**	**313.7**
Existing License	2,228.9	1,092.9	778.0	631.8	474.3	313.3
Difference from Baseline	*74.0*	*13.2*	*-13.8*	*-3.6*	*0.0*	*-0.4*
RA (Blend 2Db v2)	2,201.7	1,083.5	791.5	630.8	474.0	313.2
Difference from Baseline	*46.8*	*3.8*	*-0.3*	*-4.6*	*-0.3*	*-0.5*

TABLE 4.1-2
MINIMUM SIMULATED END-OF-DAY RESERVOIR ELEVATION
(FT AMSL)
(CCLOW SENSITIVITY)

Scenario	Bad Creek	Jocassee	Keowee	Hartwell	Richard B. Russell	J. Strom Thurmond
Baseline (Existing Operations)	**2,157.2**	**1,079.8**	**791.8**	**627.3**	**473.8**	**313.2**
Existing License	2,228.6	1,097.2	778.0	635.8	474.3	313.6
Difference from Baseline	*71.4*	*17.5*	*-13.7*	*8.4*	*0.6*	*0.4*
RA (Blend 2D b v2)	2,183.2	1,082.1	791.5	629.1	473.8	313.2
Difference from Baseline	*26.0*	*2.3*	*-0.3*	*1.8*	*0.0*	*0.0*

TABLE 4.1-3
MINIMUM SIMULATED END-OF-DAY RESERVOIR ELEVATION
(FT AMSL)
(CCHIGH SENSITIVITY)

Scenario	Bad Creek	Jocassee	Keowee	Hartwell	Richard B. Russell	J. Strom Thurmond
Baseline (Existing Operations)	**2,155.2**	**1,079.1**	**789.1**	**625.0**	**469.4**	**312.0**
Existing License	2,228.5	1,083.4	778.0	625.0	469.6	312.0
Difference from Baseline	*73.2*	*4.3*	*-11.0*	*0.0*	*0.2*	*0.0*
RA (Blend 2Db v2)	2,161.3	1,079.9	790.6	625.0	469.6	312.0
Difference from Baseline	*6.1*	*0.8*	*1.6*	*0.0*	*0.2*	*0.0*

FIGURE 4.1-1
JOCASSEE SIMULATED RESERVOIR ELEVATION DURATION CURVES
FOR FULL 1939 – 2011 POR AND 2007 – 2008 ZOOMED (15-MINUTE CHEOPS OUTPUT DATA)

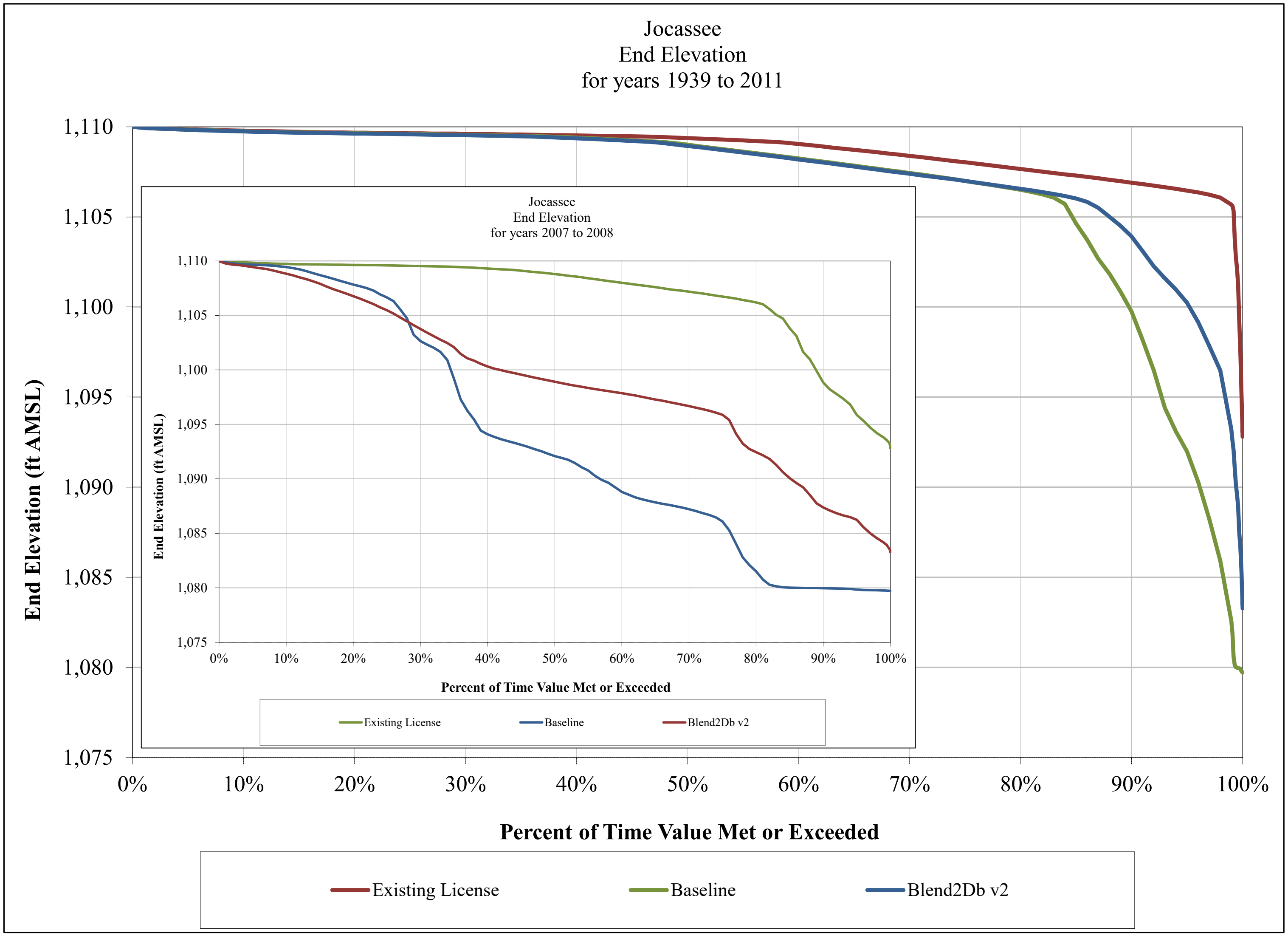


FIGURE 4.1-2
KEOWEE SIMULATED RESERVOIR ELEVATION DURATION CURVES
FOR FULL 1939 – 2011 POR AND 2007 – 2008 ZOOMED (15-MINUTE CHEOPS OUTPUT DATA)

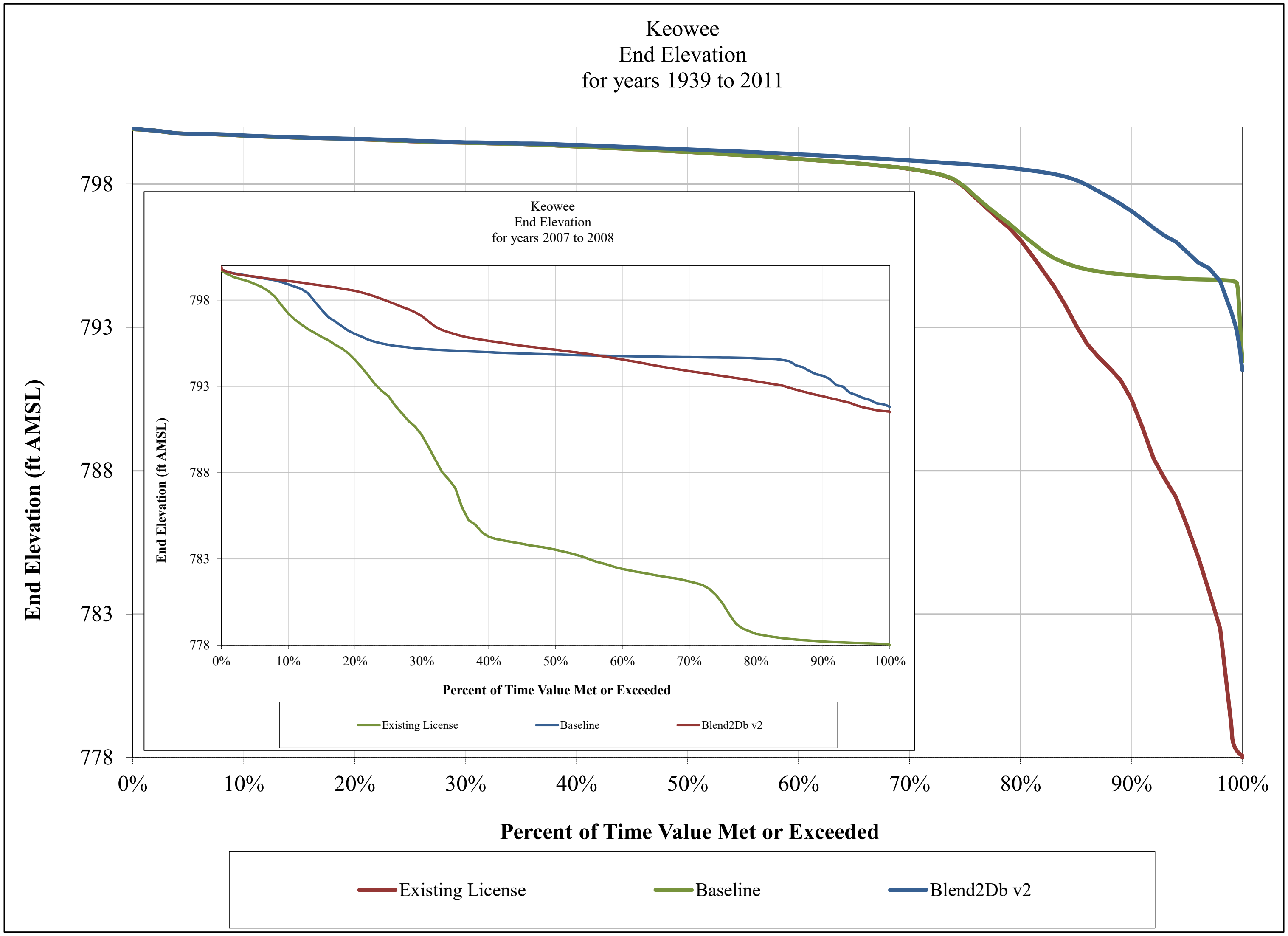
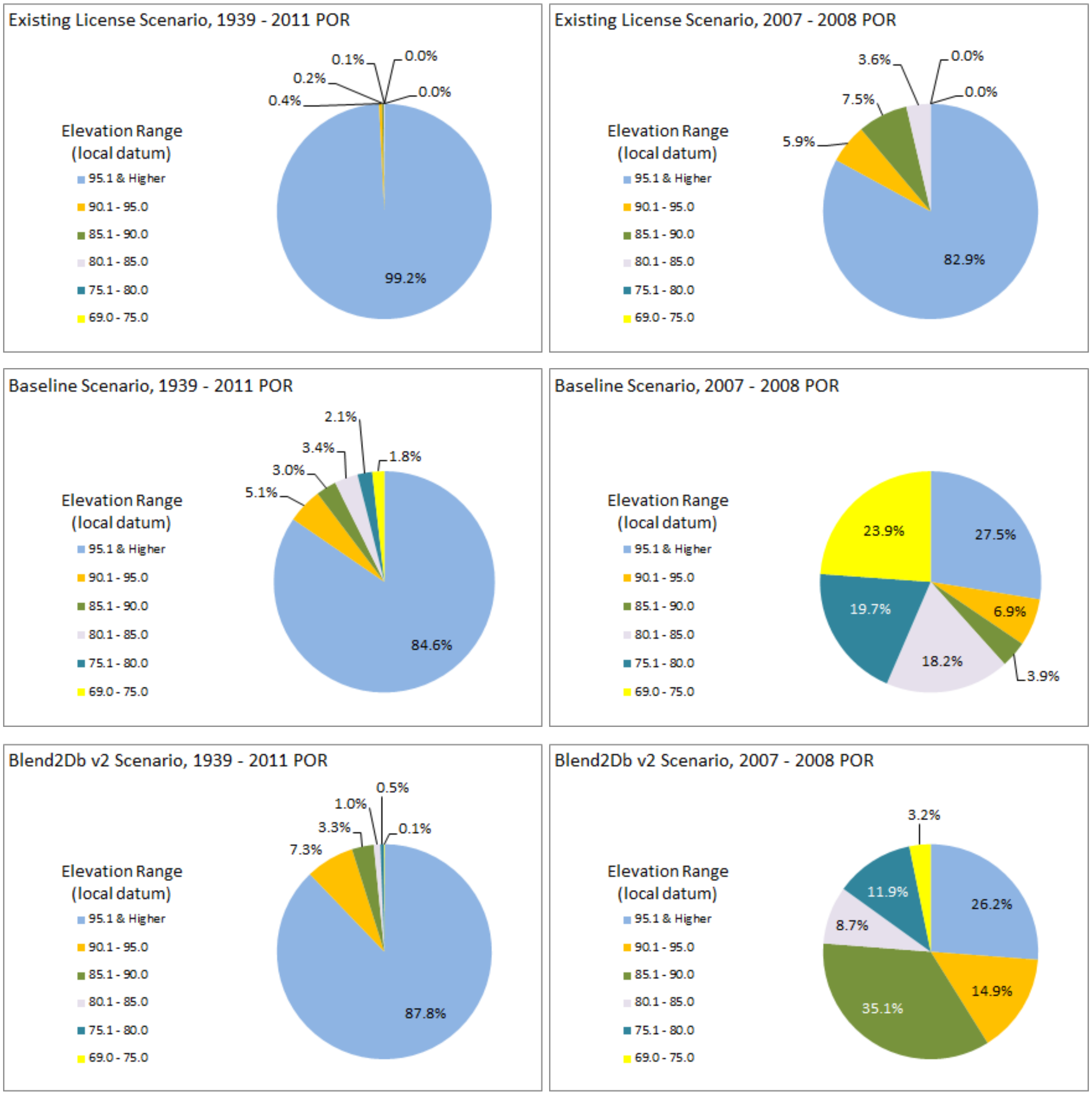
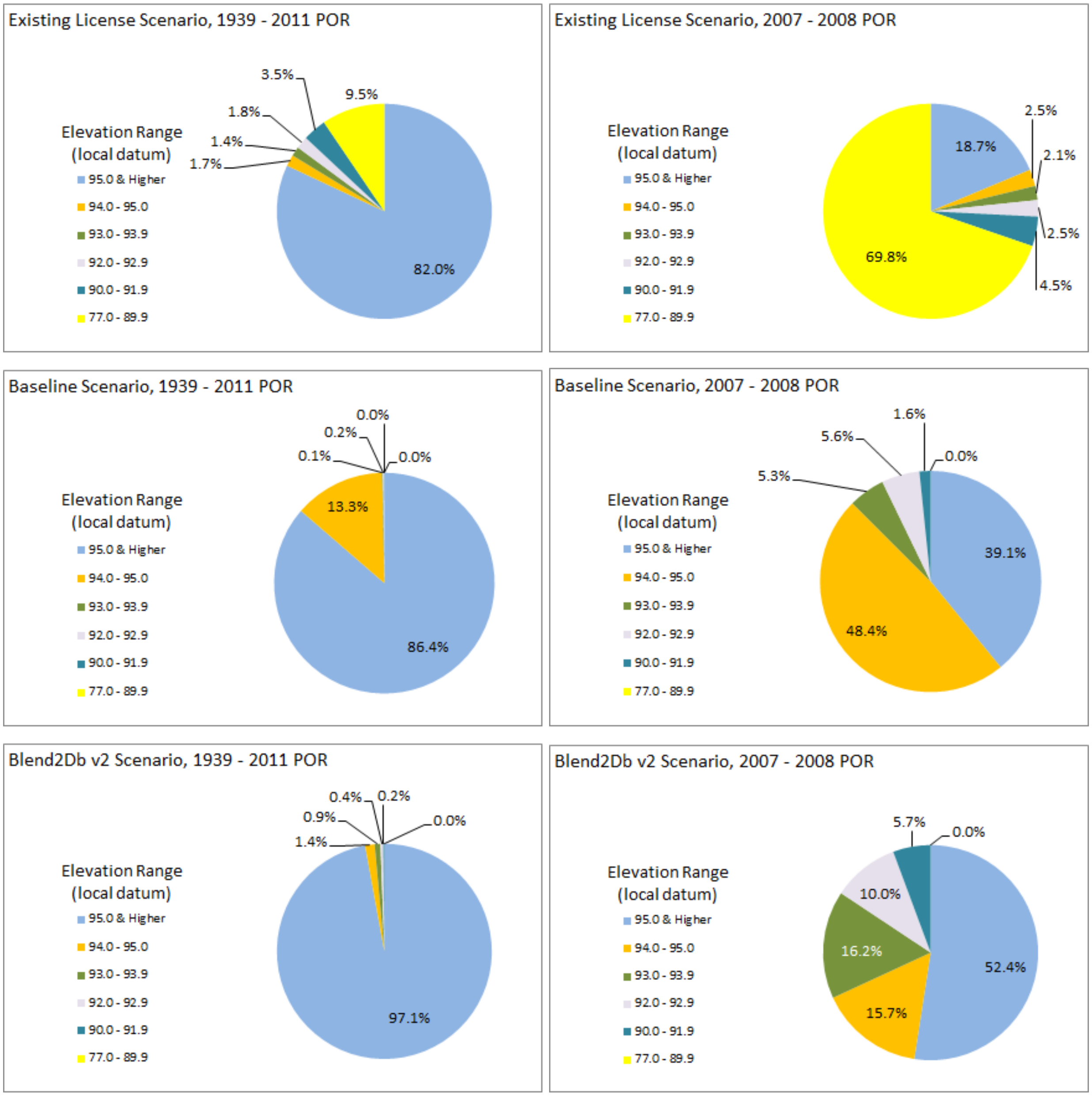


FIGURE 4.1-3
JOCASSEE SIMULATED RESERVOIR ELEVATION PIE CHARTS FOR FULL POR HYDROLOGY FROM 1939 – 2011 AND ZOOMED 2007 – 2008 HYDROLOGY (15-MINUTE CHEOPS OUTPUT DATA)



NOTE: Pie charts use local datum reference for reservoir elevations based on 100 ft representing Normal Full Pond Elevation. Jocassee Normal Full Pond Elevation is 1,110 ft AMSL (100).

FIGURE 4.1-4
KEOWEE SIMULATED RESERVOIR ELEVATION PIE CHARTS
FOR FULL POR HYDROLOGY FROM 1939 – 2011 POR AND ZOOMED 2007 – 2008
HYDROLOGY (15-MINUTE CHEOPS OUTPUT DATA)



NOTE: Pie charts use local datum reference for reservoir elevations based on 100 ft representing Normal Full Pond Elevation. Keowee Normal Full Pond Elevation is 800 ft AMSL (100).

4.1.1 Baseline (Existing Operations)

The Baseline (Existing Operations) scenario results in approximately 237,500 ac-ft of usable storage (compared to total calculated usable storage in the 1968 Agreement) remaining in the Duke Energy system that is not available to be released downstream, or to make up for water withdrawals and natural and forced evaporation.

For the 73-year POR, the Baseline (Existing Operations) scenario simulates approximately 3,163,233 megawatt hours (MWh) per year from the three Duke Energy developments and 1,807,697 MWh/year from the three USACE developments.

4.1.2 Existing License

The Existing License scenario results in lower reservoir elevations than the Baseline (Existing Operations) scenario at Keowee, Hartwell, and J. Strom Thurmond, which are drawn down 13.8, 3.6, and 0.4 ft lower than in the Baseline (Existing Operations) scenario, respectively. Modeled minimum reservoir elevations are summarized in Table 4.1-1. The modeled daily average releases from J. Strom Thurmond ranged from a minimum of 3,100 cubic feet per second (cfs) to a median of 4,500 cfs, which is consistent with the Baseline (Existing Operations) scenario.

The Existing License scenario simulates approximately 3,242,742 MWh/year from the three Duke Energy developments and 1,810,482 MWh/year from the three USACE developments or approximately a 2.5 percent and 0.2 percent increase from the Baseline (Existing Operations) scenario, respectively. It should be noted the Existing License scenario would result in ONS shutting down for an extended amount of time, resulting in potential significantly increased costs to the Licensee due to power purchases and transmission system upgrades.

4.1.3 Relicensing Agreement (Blend 2Db v2)

The RA (Blend 2Db v2) scenario results in lower reservoir elevations than the Baseline (Existing Operations) scenario for Keowee, Hartwell, and J. Strom Thurmond, which are drawn down 0.3, 4.6, and 0.5 ft lower than in the Baseline (Existing Operations) scenario, respectively. The lower reservoir elevation at Keowee is due to lowering the minimum operating elevation during periods of prolonged drought. Modeled minimum reservoir elevations are summarized in Table 4.1-1. The modeled daily average releases from J. Strom Thurmond ranged from a minimum of 3,100 cfs to a median of 4,500 cfs, which is consistent with the Baseline (Existing Operations) scenario.

The RA (Blend 2Db v2) scenario simulates approximately 3,357,972 MWh/year from the three Duke Energy developments and 1,805,484 MWh/year from the three USACE developments, or approximately a 6.2 percent increase and 0.1 percent decrease from the Baseline (Existing Operations) scenario, respectively.

4.1.4 Climate Change Sensitivity

Two sensitivity analyses were completed for each scenario outlined in Sections 3.1 through 3.3 to evaluate possible impacts of future climate change. Results of the two sensitivity analysis runs are included in Appendices F and G with PM Worksheets included in Appendix H.

4.2 General Conclusions

Reviewing the results of all the scenarios documented in this report leads to the following observations:

1. The RA (Blend 2Db v2) scenario does not significantly affect long-term reservoir elevations and energy production at the USACE's developments, or USACE operations and authorized purposes, due to the relative size of the Duke Energy Project reservoirs compared to the USACE Project reservoirs.

2. Raising the minimum reservoir elevation at Keowee from 775 to 790 ft AMSL in the RA (Blend 2Db v2) scenario minimizes the reservoir drawdown at Lake Keowee when compared to the drawdown elevation reached under the Existing License scenario, while producing very minor impacts on USACE operations and authorized Project purposes. This can be seen in reservoir elevation and Project flow release duration curves included in Appendices E and F and PM Worksheets in Appendix H.
3. As compared to the Baseline (Existing Operations) scenario, the RA (Blend 2Db v2) scenario does not have a significant impact on critical water intakes located on the USACE Project reservoirs.
4. The RA (Blend 2Db v2) scenario has no impact on municipal water intakes on Lake Keowee, but would affect operation of ONS unless it is modified to operate at lower Lake Keowee levels.
5. The RA (Blend 2Db v2) scenario does not significantly impact critical water intakes located on the USACE Project reservoirs.

5.0 REFERENCES

Duke Energy Carolinas, LLC. 2011. *Keowee-Toxaway Relicensing, FERC Project No. 2503, Revised Study Plan.* December 2011.

Duke Power Company. 1968. *Memorandum of Operating Agreement. FERC No. 2503.* October 1, 1968.

HDR Engineering, Inc. of the Carolinas. 2010. *Keowee-Toxaway Project: Jocassee Pumped Storage Project (FERC No. 2503): Supporting Technical Information.* October 2010.

——. 2012. *Keowee-Toxaway Project: Keowee Development (FERC No. 2503): Supporting Technical Information.* Prepared for Duke Energy. January 2012.

——. 2013a. *Modeling Scenario Documentation Report.* Prepared for Duke Energy Carolinas, LLC. March 2013.

——. 2013b. *Modeling Scenario Documentation Report Addendum.* Prepared for Duke Energy Carolinas, LLC. November 2013.

——. 2014a. Savannah River Basin Operations Model Study Model logic and verification report. Prepared for Duke Energy Carolinas, LLC. May 2014.

——. 2014b. Final Keowee-Toxaway Hydroelectric Project Water Supply Study. Prepared for Duke Energy Carolinas, LLC. May 2014.

——. 2014c. *Comprehensive Environmental, Engineering, and Economic Analysis Impact Report for Revising the 1968 Operating Agreement for the Keowee-Toxaway Project.* Prepared for Duke Energy Carolinas, LLC. April 4, 2014.

U.S. Army Corps of Engineers. 1989. Savannah River Basin drought contingency plan. Savannah District USACE. March 1989, amended 2006 and 2011.

——. 1996a. *Hartwell Dam and Lake Georgia and South Carolina: Water Control Plan.*

——. 1996b. *Richard B. Russell Dam and Lake Georgia and South Carolina: Water Control Plan.*

——. 1996c. *J. Strom Thurmond Dam and Lake Georgia and South Carolina: Water Control Plan.*

——. 2010. *Water Management Page for the Savannah River Projects.* [Online] URL: http://water.sas.usace.army.mil/home/indexDU.htm (Accessed August 11, 2010).

——. 2012. *News Release No. 12-40: Corps Completes Environmental Assessment to Update Savannah River Basin Drought Plan.* August 10, 2012.

APPENDICES

APPENDIX A

WITHDRAWALS AND RETURNS

Bad Creek Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1940	2011	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1941	2012	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1942	2013	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
1943	2014	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1944	2015	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1945	2016	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
1946	2017	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1947	2018	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1948	2019	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
1949	2020	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
1950	2021	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
1951	2022	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
1952	2023	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
1953	2024	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
1954	2025	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
1955	2026	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
1956	2027	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
1957	2028	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
1958	2029	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
1959	2030	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
1960	2031	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
1961	2032	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
1962	2033	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
1963	2034	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
1964	2035	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
1965	2036	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
1966	2037	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1967	2038	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1968	2039	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
1969	2040	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
1970	2041	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
1971	2042	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
1972	2043	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
1973	2044	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
1974	2045	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
1975	2046	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
1976	2047	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
1977	2048	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
1978	2049	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
1979	2050	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
1980	2051	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
1981	2052	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
1982	2053	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
1983	2054	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
1984	2055	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
1985	2056	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
1986	2057	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
1987	2058	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
1988	2059	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
1989	2060	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
1990	2061	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
1991	2062	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
1992	2063	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
1993	2064	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
1994	2065	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
1995	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1996	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1997	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1998	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1999	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2000	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2001	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2002	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2003	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2004	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2005	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2006	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2007	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2008	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2009	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2010	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
2011	2066	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Bad Creek Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1940	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1941	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1942	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1943	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1944	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1945	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1946	2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1947	2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1949	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	2024	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	2026	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	2028	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	2029	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	2031	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	2032	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	2033	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	2034	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	2035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	2036	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	2037	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	2038	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	2039	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	2040	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	2041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	2042	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	2043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	2044	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	2045	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	2046	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	2047	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	2048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	2049	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	2050	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	2051	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	2052	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	2053	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	2054	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	2055	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	2056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	2057	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	2058	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	2059	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	2060	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2061	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	2062	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	2063	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	2064	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	2065	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Withdrawal and Return Estimates from Keowee - Toxaway Hydroelectric Project Water Supply Study
Data Transmitted on September 24, 2012
Original Source File: KT_WSS_CHEOPS_Data_9242012.xls

Jocassee Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22	7.22
1940	2011	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28	7.28
1941	2012	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34
1942	2013	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40	7.40
1943	2014	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46	7.46
1944	2015	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52	7.52
1945	2016	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
1946	2017	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
1947	2018	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59
1948	2019	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59	7.59
1949	2020	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
1950	2021	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
1951	2022	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60	7.60
1952	2023	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
1953	2024	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
1954	2025	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
1955	2026	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
1956	2027	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
1957	2028	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64	7.64
1958	2029	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65
1959	2030	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65	7.65
1960	2031	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66	7.66
1961	2032	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
1962	2033	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68	7.68
1963	2034	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69
1964	2035	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69
1965	2036	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70	7.70
1966	2037	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71
1967	2038	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
1968	2039	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
1969	2040	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
1970	2041	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74
1971	2042	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75
1972	2043	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75	7.75
1973	2044	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76
1974	2045	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77	7.77
1975	2046	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
1976	2047	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79
1977	2048	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79	7.79
1978	2049	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80
1979	2050	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81	7.81
1980	2051	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82
1981	2052	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82
1982	2053	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83
1983	2054	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84	7.84
1984	2055	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85
1985	2056	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86
1986	2057	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87	7.87
1987	2058	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88
1988	2059	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89	7.89
1989	2060	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90
1990	2061	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91
1991	2062	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
1992	2063	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93	7.93
1993	2064	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94
1994	2065	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95	7.95
1995	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1996	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1997	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1998	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
1999	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2000	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2001	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2002	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2003	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2004	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2005	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2006	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2007	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2008	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2009	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2010	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96
2011	2066	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96	7.96

Withdrawal and Return Estimates from Keowee - Toxaway Hydroelectric Project Water Supply Study
Data Transmitted on September 24, 2012
Original Source File: KT_WSS_CHEOPS_Data_9242012.xls

Jocassee Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1940	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1941	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1942	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1943	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1944	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1945	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1946	2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1947	2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1949	2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1951	2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1952	2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1953	2024	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1954	2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1955	2026	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1956	2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1957	2028	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1958	2029	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1959	2030	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1960	2031	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1961	2032	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1962	2033	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1963	2034	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1964	2035	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1965	2036	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1966	2037	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1967	2038	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	2039	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	2040	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1970	2041	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1971	2042	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1972	2043	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1973	2044	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	2045	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	2046	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1976	2047	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	2048	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	2049	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	2050	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	2051	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	2052	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	2053	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	2054	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	2055	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	2056	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	2057	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	2058	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	2059	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	2060	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	2061	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	2062	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	2063	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	2064	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	2065	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	2066	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Keowee Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	94.67	93.15	91.34	98.09	101.61	117.99	116.09	113.32	109.48	98.73	89.68	94.04
1940	2011	97.13	95.57	93.73	100.72	104.41	121.23	119.24	116.39	112.45	101.41	92.13	96.55
1941	2012	99.60	97.99	96.12	103.35	107.21	124.47	122.39	119.45	115.41	104.10	94.59	99.07
1942	2013	102.06	100.41	98.50	105.99	110.01	127.72	125.53	122.52	118.37	106.79	97.05	101.58
1943	2014	104.53	102.83	100.89	108.62	112.81	130.96	128.68	125.59	121.34	109.48	99.51	104.09
1944	2015	106.99	105.25	103.28	111.26	115.61	134.20	131.83	128.66	124.30	112.17	101.96	106.61
1945	2016	109.46	107.67	105.66	113.89	118.42	137.44	134.98	131.72	127.26	114.86	104.42	109.12
1946	2017	111.32	109.48	107.46	116.02	120.85	140.21	137.63	134.30	129.73	117.13	106.53	111.13
1947	2018	113.17	111.28	109.26	118.15	123.28	142.97	140.28	136.87	132.19	119.40	108.63	113.13
1948	2019	115.03	113.08	111.06	120.28	125.71	145.74	142.93	139.44	134.66	121.67	110.74	115.14
1949	2020	116.89	114.89	112.85	122.42	128.14	148.50	145.58	142.02	137.13	123.94	112.85	117.14
1950	2021	118.74	116.69	114.65	124.55	130.57	151.27	148.23	144.59	139.59	126.21	114.95	119.15
1951	2022	120.60	118.50	116.45	126.68	133.00	154.03	150.88	147.16	142.06	128.48	117.06	121.15
1952	2023	122.46	120.30	118.25	128.81	135.43	156.80	153.53	149.74	144.52	130.75	119.17	123.16
1953	2024	124.32	122.11	120.05	130.94	137.86	159.56	156.18	152.31	146.99	133.02	121.27	125.17
1954	2025	126.17	123.91	121.85	133.07	140.29	162.33	158.82	154.88	149.46	135.29	123.38	127.17
1955	2026	128.03	125.72	123.64	135.20	142.72	165.09	161.47	157.46	151.92	137.56	125.49	129.18
1956	2027	131.45	129.08	126.95	138.77	146.44	169.42	165.72	161.60	155.92	141.16	128.76	132.59
1957	2028	134.88	132.45	130.25	142.34	150.16	173.75	169.97	165.75	159.92	144.77	132.04	136.01
1958	2029	138.30	135.82	133.55	145.91	153.89	178.07	174.22	169.89	163.93	148.38	135.31	139.43
1959	2030	141.73	139.19	136.86	149.48	157.61	182.40	178.47	174.04	167.93	151.98	138.59	142.85
1960	2031	145.16	142.55	140.16	153.05	161.33	186.73	182.72	178.19	171.93	155.59	141.86	146.26
1961	2032	148.58	145.92	143.46	156.63	165.05	191.06	186.97	182.33	175.93	159.20	145.14	149.68
1962	2033	152.01	149.29	146.77	160.20	168.78	195.38	191.22	186.48	179.93	162.80	148.41	153.10
1963	2034	155.43	152.66	150.07	163.77	172.50	199.71	195.47	190.62	183.93	166.41	151.68	156.52
1964	2035	158.86	156.02	153.37	167.34	176.22	204.04	199.72	194.77	187.94	170.02	154.96	159.93
1965	2036	162.28	159.39	156.68	170.91	179.94	208.36	203.97	198.92	191.94	173.62	158.23	163.35
1966	2037	164.12	161.18	158.47	173.05	182.40	211.17	206.63	201.49	194.41	175.90	160.35	165.37
1967	2038	165.96	162.97	160.26	175.19	184.85	213.97	209.28	204.07	196.89	178.19	162.47	167.38
1968	2039	167.81	164.76	162.05	177.33	187.30	216.77	211.94	206.64	199.36	180.47	164.58	169.39
1969	2040	169.65	166.55	163.84	179.47	189.75	219.57	214.59	209.22	201.84	182.75	166.70	171.41
1970	2041	171.49	168.34	165.63	181.61	192.20	222.37	217.25	211.79	204.31	185.03	168.82	173.42
1971	2042	173.33	170.13	167.42	183.76	194.65	225.17	219.90	214.37	206.79	187.31	170.94	175.43
1972	2043	175.17	171.92	169.21	185.90	197.10	227.97	222.56	216.94	209.26	189.59	173.05	177.45
1973	2044	177.01	173.71	171.00	188.04	199.55	230.77	225.21	219.52	211.74	191.87	175.17	179.46
1974	2045	178.85	175.50	172.79	190.18	202.00	233.57	227.87	222.10	214.21	194.15	177.29	181.47
1975	2046	180.69	177.29	174.58	192.32	204.45	236.37	230.52	224.67	216.69	196.43	179.40	183.49
1976	2047	182.49	179.03	176.33	194.41	206.85	239.11	233.11	227.19	219.10	198.66	181.47	185.45
1977	2048	184.29	180.78	178.08	196.50	209.24	241.84	235.70	229.70	221.52	200.88	183.54	187.42
1978	2049	186.09	182.53	179.83	198.59	211.63	244.57	238.30	232.21	223.93	203.11	185.60	189.38
1979	2050	187.88	184.28	181.58	200.68	214.02	247.30	240.89	234.73	226.35	205.34	187.67	191.35
1980	2051	189.68	186.02	183.32	202.77	216.41	250.03	243.48	237.24	228.77	207.56	189.73	193.31
1981	2052	191.48	187.77	185.07	204.86	218.80	252.77	246.07	239.76	231.18	209.79	191.80	195.28
1982	2053	193.28	189.52	186.82	206.95	221.20	255.50	248.66	242.27	233.60	212.01	193.87	197.24
1983	2054	195.08	191.27	188.57	209.04	223.59	258.23	251.25	244.78	236.01	214.24	195.93	199.21
1984	2055	196.88	193.02	190.32	211.13	225.98	260.96	253.84	247.30	238.43	216.47	198.00	201.17
1985	2056	198.67	194.76	192.07	213.22	228.37	263.70	256.43	249.81	240.84	218.69	200.06	203.14
1986	2057	200.72	196.75	194.05	215.59	231.09	266.80	259.38	252.67	243.59	221.22	202.41	205.37
1987	2058	202.76	198.74	196.04	217.97	233.81	269.91	262.33	255.53	246.34	223.76	204.77	207.61
1988	2059	204.81	200.73	198.03	220.35	236.53	273.02	265.28	258.39	249.09	226.29	207.12	209.84
1989	2060	206.86	202.72	200.02	222.73	239.25	276.13	268.22	261.25	251.84	228.82	209.47	212.08
1990	2061	208.90	204.70	202.01	225.11	241.97	279.24	271.17	264.11	254.58	231.35	211.82	214.31
1991	2062	210.95	206.69	204.00	227.48	244.70	282.35	274.12	266.97	257.33	233.89	214.17	216.55
1992	2063	212.99	208.68	205.99	229.86	247.42	285.46	277.07	269.83	260.08	236.42	216.52	218.79
1993	2064	215.04	210.67	207.98	232.24	250.14	288.56	280.01	272.69	262.83	238.95	218.87	221.02
1994	2065	217.08	212.66	209.97	234.62	252.86	291.67	282.96	275.55	265.58	241.49	221.22	223.26
1995	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1996	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1997	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1998	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
1999	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2000	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2001	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2002	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2003	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2004	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2005	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2006	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2007	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2008	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2009	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2010	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49
2011	2066	219.13	214.65	211.96	236.99	255.58	294.78	285.91	278.41	268.32	244.02	223.57	225.49

Withdrawal and Return Estimates from Keowee - Toxaway Hydroelectric Project Water Supply Study
Data Transmitted on September 24, 2012
Original Source File: KT_WSS_CHEOPS_Data_9242012.xls

Keowee Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	2.71	2.21	1.82	2.28	2.24	2.70	2.44	2.51	2.61	2.22	2.03	2.43
1940	2011	2.82	2.30	1.89	2.37	2.33	2.81	2.54	2.61	2.71	2.31	2.11	2.52
1941	2012	2.93	2.38	1.96	2.46	2.42	2.91	2.63	2.71	2.81	2.40	2.19	2.62
1942	2013	3.03	2.47	2.03	2.54	2.50	3.02	2.73	2.81	2.91	2.48	2.26	2.71
1943	2014	3.14	2.55	2.09	2.63	2.59	3.12	2.82	2.91	3.02	2.57	2.34	2.81
1944	2015	3.24	2.64	2.16	2.72	2.67	3.23	2.92	3.01	3.12	2.66	2.42	2.90
1945	2016	3.35	2.73	2.23	2.80	2.76	3.33	3.01	3.11	3.22	2.74	2.50	3.00
1946	2017	3.45	2.81	2.29	2.89	2.84	3.43	3.10	3.20	3.32	2.82	2.57	3.09
1947	2018	3.55	2.89	2.36	2.97	2.92	3.53	3.19	3.30	3.42	2.91	2.64	3.18
1948	2019	3.65	2.97	2.42	3.05	3.00	3.63	3.28	3.39	3.52	2.99	2.72	3.27
1949	2020	3.75	3.05	2.49	3.14	3.09	3.73	3.37	3.49	3.62	3.07	2.79	3.36
1950	2021	3.85	3.13	2.55	3.22	3.17	3.83	3.46	3.58	3.71	3.15	2.87	3.45
1951	2022	3.95	3.21	2.62	3.30	3.25	3.93	3.55	3.67	3.81	3.24	2.94	3.54
1952	2023	4.05	3.30	2.68	3.38	3.33	4.03	3.64	3.77	3.91	3.32	3.01	3.63
1953	2024	4.16	3.38	2.75	3.47	3.41	4.13	3.73	3.86	4.01	3.40	3.09	3.72
1954	2025	4.26	3.46	2.81	3.55	3.49	4.23	3.82	3.96	4.11	3.48	3.16	3.82
1955	2026	4.36	3.54	2.87	3.63	3.58	4.33	3.91	4.05	4.20	3.57	3.23	3.91
1956	2027	4.46	3.62	2.94	3.72	3.66	4.43	4.00	4.15	4.30	3.65	3.31	4.00
1957	2028	4.56	3.70	3.00	3.80	3.74	4.53	4.09	4.24	4.40	3.73	3.38	4.09
1958	2029	4.66	3.78	3.07	3.88	3.82	4.63	4.18	4.34	4.50	3.81	3.46	4.18
1959	2030	4.76	3.86	3.13	3.96	3.90	4.73	4.27	4.43	4.60	3.90	3.53	4.27
1960	2031	4.86	3.95	3.20	4.05	3.99	4.83	4.36	4.53	4.70	3.98	3.60	4.36
1961	2032	4.96	4.03	3.26	4.13	4.07	4.93	4.45	4.62	4.79	4.06	3.68	4.45
1962	2033	5.06	4.11	3.33	4.21	4.15	5.03	4.54	4.71	4.89	4.14	3.75	4.54
1963	2034	5.16	4.19	3.39	4.30	4.23	5.13	4.63	4.81	4.99	4.23	3.83	4.63
1964	2035	5.26	4.27	3.46	4.38	4.31	5.23	4.72	4.90	5.09	4.31	3.90	4.72
1965	2036	5.36	4.35	3.52	4.46	4.39	5.33	4.81	5.00	5.19	4.39	3.97	4.81
1966	2037	5.46	4.43	3.58	4.55	4.48	5.43	4.90	5.09	5.28	4.47	4.05	4.90
1967	2038	5.56	4.52	3.65	4.63	4.56	5.53	4.99	5.19	5.38	4.56	4.12	4.99
1968	2039	5.67	4.60	3.71	4.71	4.64	5.63	5.08	5.28	5.48	4.64	4.20	5.09
1969	2040	5.77	4.68	3.78	4.79	4.72	5.73	5.17	5.38	5.58	4.72	4.27	5.18
1970	2041	5.87	4.76	3.84	4.88	4.80	5.83	5.26	5.47	5.68	4.80	4.34	5.27
1971	2042	5.97	4.84	3.91	4.96	4.88	5.93	5.35	5.56	5.78	4.88	4.42	5.36
1972	2043	6.07	4.92	3.97	5.04	4.97	6.03	5.44	5.66	5.88	4.97	4.49	5.45
1973	2044	6.17	5.01	4.03	5.13	5.05	6.13	5.53	5.75	5.97	5.05	4.56	5.54
1974	2045	6.27	5.09	4.10	5.21	5.13	6.23	5.62	5.85	6.07	5.13	4.64	5.63
1975	2046	6.38	5.17	4.16	5.29	5.21	6.33	5.71	5.94	6.17	5.21	4.71	5.72
1976	2047	6.48	5.25	4.23	5.37	5.29	6.43	5.80	6.04	6.27	5.30	4.78	5.81
1977	2048	6.58	5.33	4.29	5.46	5.37	6.53	5.89	6.13	6.36	5.38	4.86	5.90
1978	2049	6.68	5.41	4.35	5.54	5.45	6.63	5.98	6.22	6.46	5.46	4.93	5.99
1979	2050	6.77	5.49	4.42	5.62	5.53	6.72	6.07	6.31	6.56	5.54	5.00	6.08
1980	2051	6.87	5.57	4.48	5.70	5.61	6.82	6.15	6.41	6.65	5.62	5.07	6.17
1981	2052	6.97	5.65	4.54	5.78	5.69	6.92	6.24	6.50	6.75	5.70	5.15	6.26
1982	2053	7.07	5.73	4.61	5.86	5.77	7.02	6.33	6.59	6.85	5.78	5.22	6.35
1983	2054	7.17	5.81	4.67	5.94	5.85	7.12	6.42	6.69	6.94	5.86	5.29	6.44
1984	2055	7.27	5.89	4.73	6.03	5.93	7.22	6.51	6.78	7.04	5.94	5.36	6.53
1985	2056	7.37	5.97	4.79	6.11	6.01	7.32	6.60	6.87	7.14	6.02	5.44	6.62
1986	2057	7.49	6.06	4.87	6.20	6.10	7.43	6.70	6.98	7.25	6.12	5.52	6.72
1987	2058	7.60	6.15	4.94	6.29	6.19	7.54	6.80	7.08	7.36	6.21	5.60	6.82
1988	2059	7.71	6.24	5.01	6.38	6.28	7.65	6.90	7.19	7.47	6.30	5.68	6.92
1989	2060	7.82	6.33	5.08	6.48	6.38	7.76	7.00	7.29	7.57	6.39	5.76	7.03
1990	2061	7.94	6.43	5.15	6.57	6.47	7.87	7.10	7.40	7.68	6.48	5.85	7.13
1991	2062	8.05	6.52	5.22	6.66	6.56	7.98	7.20	7.50	7.79	6.57	5.93	7.23
1992	2063	8.16	6.61	5.29	6.75	6.65	8.09	7.29	7.61	7.90	6.66	6.01	7.33
1993	2064	8.27	6.70	5.37	6.85	6.74	8.20	7.39	7.71	8.01	6.76	6.09	7.43
1994	2065	8.39	6.79	5.44	6.94	6.83	8.32	7.49	7.81	8.12	6.85	6.17	7.53
1995	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1996	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1997	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1998	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
1999	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2000	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2001	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2002	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2003	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2004	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2005	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2006	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2007	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2008	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2009	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2010	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63
2011	2066	8.50	6.88	5.51	7.03	6.92	8.43	7.59	7.92	8.23	6.94	6.26	7.63

Withdrawal and Return Estimates from Keowee - Toxaway Hydroelectric Project Water Supply Study
Data Transmitted on September 24, 2012
Original Source File: KT_WSS_CHEOPS_Data_9242012.xls

Hartwell Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	52.40	55.65	55.48	58.80	63.36	67.38	67.47	67.72	65.47	61.21	60.35	55.05
1940	2011	55.18	58.90	58.74	62.35	67.24	71.59	71.71	71.96	69.51	64.87	64.15	58.24
1941	2012	57.96	62.15	62.01	65.90	71.13	75.81	75.95	76.19	73.56	68.53	67.94	61.42
1942	2013	60.74	65.40	65.27	69.45	75.01	80.03	80.18	80.42	77.61	72.19	71.73	64.60
1943	2014	63.51	68.65	68.54	73.00	78.89	84.24	84.42	84.66	81.66	75.84	75.52	67.79
1944	2015	66.29	71.90	71.80	76.55	82.77	88.46	88.66	88.89	85.71	79.50	79.31	70.97
1945	2016	69.07	75.15	75.07	80.10	86.66	92.68	92.90	93.12	89.76	83.16	83.10	74.15
1946	2017	70.05	76.28	76.20	81.33	88.00	94.13	94.36	94.58	91.15	84.43	84.41	75.27
1947	2018	71.03	77.41	77.33	82.57	89.34	95.59	95.81	96.03	92.54	85.70	85.71	76.39
1948	2019	72.01	78.54	78.46	83.80	90.68	97.05	97.27	97.49	93.93	86.96	87.02	77.51
1949	2020	72.98	79.68	79.59	85.03	92.03	98.51	98.73	98.94	95.32	88.23	88.33	78.62
1950	2021	73.96	80.81	80.72	86.26	93.37	99.97	100.19	100.40	96.71	89.50	89.63	79.74
1951	2022	74.94	81.94	81.85	87.49	94.71	101.43	101.65	101.85	98.10	90.77	90.94	80.86
1952	2023	75.92	83.07	82.99	88.72	96.05	102.88	103.11	103.31	99.50	92.04	92.25	81.98
1953	2024	76.90	84.20	84.12	89.96	97.40	104.34	104.57	104.76	100.89	93.31	93.55	83.10
1954	2025	77.88	85.34	85.25	91.19	98.74	105.80	106.03	106.22	102.28	94.58	94.86	84.21
1955	2026	78.86	86.47	86.38	92.42	100.08	107.26	107.49	107.67	103.67	95.84	96.17	85.33
1956	2027	80.98	88.67	88.58	94.68	102.41	109.65	109.89	110.08	106.03	98.13	98.45	87.52
1957	2028	83.10	90.87	90.79	96.93	104.73	112.05	112.29	112.48	108.40	100.42	100.74	89.70
1958	2029	85.22	93.08	92.99	99.19	107.06	114.44	114.69	114.89	110.76	102.71	103.03	91.88
1959	2030	87.35	95.28	95.19	101.45	109.39	116.84	117.09	117.29	113.12	105.00	105.32	94.07
1960	2031	89.47	97.48	97.40	103.71	111.72	119.24	119.49	119.69	115.49	107.28	107.61	96.25
1961	2032	91.59	99.68	99.60	105.96	114.04	121.63	121.89	122.10	117.85	109.57	109.90	98.44
1962	2033	93.71	101.88	101.80	108.22	116.37	124.03	124.29	124.50	120.22	111.86	112.18	100.62
1963	2034	95.84	104.09	104.01	110.48	118.70	126.42	126.69	126.91	122.58	114.15	114.47	102.80
1964	2035	97.96	106.29	106.21	112.73	121.02	128.82	129.10	129.31	124.94	116.43	116.76	104.99
1965	2036	100.08	108.49	108.41	114.99	123.35	131.21	131.50	131.71	127.31	118.72	119.05	107.17
1966	2037	100.86	109.35	109.28	115.92	124.36	132.30	132.60	132.81	128.36	119.68	120.01	108.02
1967	2038	101.64	110.22	110.14	116.85	125.38	133.40	133.69	133.91	129.41	120.65	120.97	108.86
1968	2039	102.42	111.08	111.00	117.78	126.39	134.49	134.79	135.01	130.46	121.61	121.94	109.71
1969	2040	103.20	111.95	111.86	118.71	127.40	135.58	135.89	136.11	131.52	122.57	122.90	110.56
1970	2041	103.98	112.81	112.73	119.64	128.42	136.68	136.99	137.21	132.57	123.54	123.86	111.40
1971	2042	104.76	113.68	113.59	120.57	129.43	137.77	138.09	138.31	133.62	124.50	124.83	112.25
1972	2043	105.54	114.54	114.45	121.50	130.44	138.86	139.19	139.41	134.68	125.46	125.79	113.10
1973	2044	106.32	115.41	115.31	122.43	131.46	139.96	140.29	140.51	135.73	126.43	126.75	113.94
1974	2045	107.10	116.27	116.18	123.36	132.47	141.05	141.39	141.61	136.78	127.39	127.71	114.79
1975	2046	107.88	117.14	117.04	124.28	133.48	142.15	142.48	142.71	137.83	128.36	128.68	115.64
1976	2047	108.69	118.02	117.92	125.23	134.51	143.26	143.60	143.83	138.90	129.34	129.65	116.50
1977	2048	109.50	118.90	118.80	126.18	135.55	144.37	144.72	144.95	139.98	130.32	130.62	117.37
1978	2049	110.30	119.79	119.69	127.13	136.58	145.48	145.84	146.07	141.05	131.30	131.60	118.24
1979	2050	111.11	120.67	120.57	128.07	137.61	146.59	146.95	147.19	142.12	132.29	132.57	119.10
1980	2051	111.92	121.56	121.45	129.02	138.64	147.70	148.07	148.31	143.19	133.27	133.54	119.97
1981	2052	112.73	122.44	122.33	129.97	139.67	148.82	149.19	149.42	144.26	134.25	134.51	120.83
1982	2053	113.53	123.33	123.21	130.92	140.71	149.93	150.30	150.54	145.33	135.23	135.49	121.70
1983	2054	114.34	124.21	124.09	131.86	141.74	151.04	151.42	151.66	146.40	136.22	136.46	122.57
1984	2055	115.15	125.09	124.98	132.81	142.77	152.15	152.54	152.78	147.47	137.20	137.43	123.43
1985	2056	115.95	125.98	125.86	133.76	143.80	153.26	153.65	153.90	148.54	138.18	138.41	124.30
1986	2057	116.84	126.95	126.83	134.80	144.94	154.49	154.88	155.13	149.72	139.26	139.47	125.25
1987	2058	117.73	127.93	127.80	135.84	146.07	155.71	156.11	156.36	150.90	140.34	140.54	126.20
1988	2059	118.62	128.90	128.77	136.88	147.20	156.93	157.33	157.59	152.07	141.42	141.61	127.16
1989	2060	119.51	129.87	129.74	137.92	148.34	158.15	158.56	158.82	153.25	142.50	142.68	128.11
1990	2061	120.40	130.84	130.71	138.96	149.47	159.37	159.79	160.05	154.43	143.59	143.75	129.06
1991	2062	121.29	131.82	131.68	140.01	150.61	160.59	161.02	161.28	155.60	144.67	144.81	130.01
1992	2063	122.18	132.79	132.65	141.05	151.74	161.81	162.24	162.50	156.78	145.75	145.88	130.97
1993	2064	123.07	133.76	133.62	142.09	152.87	163.04	163.47	163.73	157.96	146.83	146.95	131.92
1994	2065	123.96	134.74	134.59	143.13	154.01	164.26	164.70	164.96	159.13	147.91	148.02	132.87
1995	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1996	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1997	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1998	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
1999	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2000	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2001	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2002	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2003	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2004	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2005	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2006	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2007	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2008	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2009	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2010	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82
2011	2066	124.85	135.71	135.56	144.17	155.14	165.48	165.92	166.19	160.31	148.99	149.08	133.82

Withdrawal and Return Estimates from Keowee - Toxaway Hydroelectric Project Water Supply Study
Data Transmitted on September 24, 2012
Original Source File: KT_WSS_CHEOPS_Data_9242012.xls

Hartwell Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	23.61	23.87	23.07	22.94	23.81	22.56	21.85	22.66	23.65	23.28	24.21	25.57
1940	2011	23.84	24.11	23.31	23.16	24.01	22.75	22.04	22.85	23.87	23.48	24.41	25.79
1941	2012	24.07	24.35	23.54	23.38	24.20	22.94	22.23	23.05	24.09	23.68	24.61	26.01
1942	2013	24.30	24.59	23.78	23.60	24.39	23.12	22.42	23.24	24.30	23.88	24.82	26.23
1943	2014	24.53	24.83	24.02	23.82	24.59	23.31	22.61	23.44	24.52	24.08	25.02	26.45
1944	2015	24.76	25.07	24.26	24.04	24.78	23.50	22.80	23.64	24.73	24.28	25.22	26.66
1945	2016	25.00	25.31	24.49	24.26	24.98	23.69	22.98	23.83	24.95	24.49	25.42	26.88
1946	2017	25.18	25.50	24.68	24.43	25.14	23.84	23.15	24.00	25.13	24.65	25.59	27.06
1947	2018	25.36	25.69	24.87	24.61	25.30	24.00	23.31	24.17	25.31	24.82	25.76	27.25
1948	2019	25.55	25.88	25.06	24.78	25.46	24.16	23.47	24.33	25.49	24.99	25.93	27.43
1949	2020	25.73	26.07	25.25	24.96	25.63	24.32	23.64	24.50	25.67	25.16	26.10	27.61
1950	2021	25.91	26.26	25.44	25.14	25.79	24.48	23.80	24.67	25.85	25.33	26.27	27.79
1951	2022	26.10	26.44	25.63	25.31	25.95	24.63	23.96	24.83	26.04	25.50	26.44	27.97
1952	2023	26.28	26.63	25.82	25.49	26.11	24.79	24.13	25.00	26.22	25.67	26.61	28.15
1953	2024	26.46	26.82	26.01	25.66	26.28	24.95	24.29	25.17	26.40	25.84	26.78	28.33
1954	2025	26.65	27.01	26.20	25.84	26.44	25.11	24.45	25.34	26.58	26.01	26.95	28.52
1955	2026	26.83	27.20	26.39	26.02	26.60	25.26	24.62	25.50	26.76	26.17	27.12	28.70
1956	2027	27.01	27.38	26.57	26.19	26.76	25.43	24.78	25.67	26.94	26.34	27.29	28.87
1957	2028	27.19	27.57	26.76	26.37	26.93	25.59	24.94	25.84	27.13	26.51	27.46	29.05
1958	2029	27.37	27.76	26.95	26.55	27.09	25.75	25.10	26.01	27.31	26.68	27.63	29.22
1959	2030	27.55	27.95	27.14	26.73	27.26	25.92	25.27	26.17	27.49	26.85	27.80	29.40
1960	2031	27.73	28.13	27.32	26.91	27.42	26.08	25.43	26.34	27.67	27.02	27.97	29.58
1961	2032	27.91	28.32	27.51	27.08	27.58	26.24	25.59	26.51	27.85	27.19	28.14	29.75
1962	2033	28.09	28.51	27.70	27.26	27.75	26.41	25.75	26.68	28.03	27.36	28.31	29.93
1963	2034	28.27	28.70	27.89	27.44	27.91	26.57	25.91	26.84	28.22	27.53	28.48	30.10
1964	2035	28.44	28.88	28.08	27.62	28.07	26.73	26.08	27.01	28.40	27.70	28.65	30.28
1965	2036	28.62	29.07	28.26	27.79	28.24	26.89	26.24	27.18	28.58	27.87	28.82	30.46
1966	2037	28.76	29.21	28.40	27.93	28.36	27.04	26.36	27.31	28.72	28.00	28.95	30.58
1967	2038	28.89	29.36	28.55	28.07	28.49	27.18	26.48	27.44	28.85	28.13	29.08	30.70
1968	2039	29.02	29.50	28.69	28.22	28.62	27.32	26.61	27.57	28.99	28.26	29.21	30.83
1969	2040	29.15	29.64	28.83	28.36	28.75	27.46	26.73	27.70	29.13	28.39	29.34	30.95
1970	2041	29.28	29.79	28.97	28.50	28.88	27.61	26.85	27.83	29.27	28.52	29.47	31.07
1971	2042	29.41	29.93	29.11	28.64	29.01	27.75	26.97	27.96	29.41	28.65	29.60	31.20
1972	2043	29.54	30.07	29.26	28.78	29.14	27.89	27.09	28.09	29.54	28.78	29.73	31.32
1973	2044	29.67	30.21	29.40	28.92	29.26	28.03	27.22	28.21	29.68	28.92	29.86	31.45
1974	2045	29.80	30.36	29.54	29.06	29.39	28.18	27.34	28.34	29.82	29.05	29.99	31.57
1975	2046	29.93	30.50	29.68	29.20	29.52	28.32	27.46	28.47	29.96	29.18	30.12	31.69
1976	2047	30.19	30.77	29.95	29.45	29.76	28.56	27.69	28.72	30.22	29.42	30.36	31.94
1977	2048	30.45	31.04	30.22	29.71	30.00	28.79	27.93	28.96	30.48	29.66	30.61	32.19
1978	2049	30.71	31.31	30.49	29.97	30.23	29.03	28.16	29.20	30.74	29.91	30.85	32.44
1979	2050	30.96	31.58	30.76	30.23	30.47	29.27	28.39	29.44	31.00	30.15	31.10	32.69
1980	2051	31.22	31.85	31.03	30.48	30.71	29.50	28.63	29.68	31.26	30.40	31.34	32.94
1981	2052	31.48	32.12	31.29	30.74	30.94	29.74	28.86	29.92	31.52	30.64	31.59	33.20
1982	2053	31.74	32.38	31.56	31.00	31.18	29.98	29.09	30.17	31.78	30.88	31.83	33.45
1983	2054	32.00	32.65	31.83	31.25	31.42	30.21	29.33	30.41	32.04	31.13	32.08	33.70
1984	2055	32.25	32.92	32.10	31.51	31.65	30.45	29.56	30.65	32.30	31.37	32.32	33.95
1985	2056	32.51	33.19	32.37	31.77	31.89	30.69	29.79	30.89	32.56	31.62	32.57	34.20
1986	2057	32.82	33.52	32.69	32.07	32.17	30.97	30.07	31.18	32.87	31.90	32.86	34.50
1987	2058	33.13	33.84	33.01	32.38	32.46	31.26	30.35	31.47	33.18	32.19	33.15	34.79
1988	2059	33.44	34.16	33.34	32.69	32.74	31.55	30.63	31.76	33.49	32.48	33.45	35.09
1989	2060	33.75	34.48	33.66	33.00	33.03	31.83	30.91	32.05	33.80	32.77	33.74	35.39
1990	2061	34.06	34.81	33.98	33.30	33.31	32.12	31.19	32.34	34.11	33.06	34.03	35.69
1991	2062	34.36	35.13	34.30	33.61	33.60	32.40	31.47	32.63	34.41	33.35	34.33	35.99
1992	2063	34.67	35.45	34.62	33.92	33.88	32.69	31.75	32.92	34.72	33.64	34.62	36.29
1993	2064	34.98	35.77	34.94	34.23	34.17	32.97	32.03	33.20	35.03	33.93	34.91	36.59
1994	2065	35.29	36.09	35.27	34.54	34.45	33.26	32.31	33.49	35.34	34.22	35.20	36.89
1995	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1996	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1997	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1998	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
1999	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2000	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2001	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2002	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2003	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2004	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2005	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2006	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2007	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2008	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2009	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2010	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18
2011	2066	35.60	36.42	35.59	34.84	34.74	33.55	32.59	33.78	35.65	34.51	35.50	37.18

Richard B. Russell Withdrawals (cfs)													
Hydrology Year	**Projection Year**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
1939	2010	8.59	8.43	9.03	9.72	10.38	11.73	11.57	12.23	11.56	10.32	9.48	8.81
1940	2011	8.67	8.51	9.11	9.80	10.46	11.82	11.65	12.31	11.64	10.40	9.56	8.89
1941	2012	8.75	8.59	9.19	9.88	10.54	11.90	11.74	12.39	11.72	10.48	9.63	8.97
1942	2013	8.83	8.67	9.27	9.96	10.62	11.98	11.82	12.48	11.80	10.56	9.71	9.05
1943	2014	8.91	8.75	9.35	10.04	10.70	12.06	11.90	12.56	11.88	10.64	9.79	9.12
1944	2015	8.99	8.82	9.43	10.12	10.78	12.14	11.98	12.64	11.96	10.72	9.87	9.20
1945	2016	9.07	8.90	9.51	10.20	10.86	12.23	12.06	12.72	12.04	10.80	9.95	9.28
1946	2017	10.62	10.46	11.06	11.75	12.42	13.79	13.62	14.29	13.60	12.36	11.50	10.83
1947	2018	12.17	12.01	12.61	13.31	13.98	15.35	15.18	15.85	15.17	13.92	13.06	12.38
1948	2019	13.73	13.56	14.17	14.87	15.54	16.92	16.75	17.42	16.73	15.47	14.61	13.93
1949	2020	15.28	15.12	15.72	16.42	17.10	18.48	18.31	18.98	18.29	17.03	16.17	15.49
1950	2021	16.84	16.67	17.28	17.98	18.66	20.04	19.87	20.55	19.85	18.59	17.72	17.04
1951	2022	18.39	18.22	18.83	19.54	20.22	21.61	21.43	22.11	21.41	20.15	19.27	18.59
1952	2023	19.94	19.78	20.39	21.09	21.78	23.17	22.99	23.68	22.97	21.71	20.83	20.14
1953	2024	21.50	21.33	21.94	22.65	23.34	24.73	24.55	25.24	24.54	23.27	22.38	21.69
1954	2025	23.05	22.89	23.50	24.21	24.90	26.30	26.12	26.81	26.10	24.83	23.94	23.24
1955	2026	24.61	24.44	25.05	25.76	26.45	27.86	27.68	28.37	27.66	26.38	25.49	24.79
1956	2027	24.65	24.48	25.10	25.81	26.50	27.91	27.72	28.42	27.71	26.43	25.53	24.83
1957	2028	24.69	24.52	25.14	25.85	26.55	27.96	27.77	28.47	27.75	26.47	25.58	24.87
1958	2029	24.73	24.57	25.18	25.89	26.59	28.01	27.82	28.52	27.80	26.52	25.62	24.91
1959	2030	24.78	24.61	25.23	25.94	26.64	28.06	27.87	28.57	27.85	26.56	25.66	24.95
1960	2031	24.82	24.65	25.27	25.98	26.68	28.11	27.91	28.62	27.90	26.61	25.70	24.99
1961	2032	24.86	24.69	25.31	26.03	26.73	28.15	27.96	28.67	27.94	26.65	25.74	25.03
1962	2033	24.90	24.73	25.36	26.07	26.78	28.20	28.01	28.72	27.99	26.70	25.78	25.07
1963	2034	24.94	24.78	25.40	26.11	26.82	28.25	28.06	28.77	28.04	26.74	25.83	25.11
1964	2035	24.99	24.82	25.44	26.16	26.87	28.30	28.10	28.82	28.08	26.79	25.87	25.15
1965	2036	25.03	24.86	25.49	26.20	26.91	28.35	28.15	28.87	28.13	26.83	25.91	25.19
1966	2037	25.07	24.90	25.53	26.25	26.96	28.40	28.20	28.92	28.18	26.88	25.95	25.24
1967	2038	25.12	24.95	25.57	26.29	27.01	28.45	28.25	28.97	28.23	26.93	26.00	25.28
1968	2039	25.16	24.99	25.62	26.34	27.06	28.50	28.30	29.02	28.28	26.97	26.04	25.32
1969	2040	25.20	25.03	25.66	26.38	27.10	28.55	28.35	29.07	28.33	27.02	26.08	25.36
1970	2041	25.25	25.08	25.71	26.43	27.15	28.60	28.39	29.12	28.38	27.07	26.13	25.40
1971	2042	25.29	25.12	25.75	26.47	27.20	28.65	28.44	29.18	28.42	27.11	26.17	25.44
1972	2043	25.33	25.17	25.80	26.52	27.25	28.70	28.49	29.23	28.47	27.16	26.21	25.48
1973	2044	25.38	25.21	25.84	26.56	27.29	28.75	28.54	29.28	28.52	27.21	26.26	25.53
1974	2045	25.42	25.25	25.89	26.61	27.34	28.80	28.59	29.33	28.57	27.25	26.30	25.57
1975	2046	25.47	25.30	25.93	26.65	27.39	28.85	28.64	29.38	28.62	27.30	26.34	25.61
1976	2047	27.01	26.84	27.48	28.20	28.94	30.41	30.19	30.94	30.17	28.85	27.89	27.15
1977	2048	28.56	28.39	29.03	29.75	30.49	31.97	31.75	32.50	31.73	30.40	29.44	28.70
1978	2049	30.11	29.94	30.58	31.30	32.05	33.52	33.30	34.05	33.28	31.96	30.99	30.25
1979	2050	31.66	31.49	32.13	32.86	33.60	35.08	34.86	35.61	34.84	33.51	32.54	31.79
1980	2051	33.21	33.04	33.68	34.41	35.15	36.64	36.41	37.17	36.39	35.06	34.09	33.34
1981	2052	34.76	34.59	35.23	35.96	36.71	38.19	37.97	38.72	37.95	36.61	35.63	34.89
1982	2053	36.31	36.14	36.78	37.51	38.26	39.75	39.52	40.28	39.50	38.16	37.18	36.43
1983	2054	37.86	37.69	38.33	39.06	39.81	41.31	41.08	41.84	41.06	39.72	38.73	37.98
1984	2055	39.41	39.24	39.88	40.61	41.37	42.86	42.63	43.40	42.61	41.27	40.28	39.52
1985	2056	40.96	40.78	41.43	42.16	42.92	44.42	44.19	44.95	44.17	42.82	41.83	41.07
1986	2057	41.01	40.84	41.48	42.21	42.97	44.48	44.24	45.01	44.22	42.87	41.88	41.12
1987	2058	41.06	40.89	41.53	42.27	43.03	44.54	44.30	45.07	44.28	42.93	41.93	41.17
1988	2059	41.11	40.94	41.59	42.32	43.09	44.60	44.36	45.13	44.34	42.98	41.98	41.21
1989	2060	41.16	40.99	41.64	42.37	43.14	44.66	44.41	45.19	44.39	43.04	42.03	41.26
1990	2061	41.21	41.04	41.69	42.42	43.20	44.71	44.47	45.25	44.45	43.09	42.08	41.31
1991	2062	41.26	41.09	41.74	42.48	43.25	44.77	44.53	45.31	44.51	43.14	42.13	41.36
1992	2063	41.31	41.14	41.80	42.53	43.31	44.83	44.59	45.37	44.56	43.20	42.18	41.41
1993	2064	41.37	41.19	41.85	42.58	43.36	44.89	44.64	45.43	44.62	43.25	42.23	41.46
1994	2065	41.42	41.25	41.90	42.64	43.42	44.95	44.70	45.49	44.68	43.31	42.28	41.50
1995	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1996	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1997	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1998	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
1999	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2000	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2001	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2002	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2003	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2004	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2005	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2006	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2007	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2008	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2009	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2010	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55
2011	2066	41.47	41.30	41.95	42.69	43.47	45.01	44.76	45.55	44.73	43.36	42.33	41.55

Richard B. Russell Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	16.23	16.17	18.81	16.91	15.13	14.69	14.95	15.09	14.99	14.40	14.07	16.24
1940	2011	16.45	16.40	19.08	17.14	15.34	14.89	15.15	15.28	15.19	14.59	14.26	16.47
1941	2012	16.67	16.62	19.35	17.37	15.54	15.10	15.36	15.48	15.39	14.78	14.46	16.69
1942	2013	16.89	16.84	19.62	17.60	15.74	15.31	15.57	15.67	15.59	14.97	14.65	16.92
1943	2014	17.12	17.06	19.89	17.83	15.95	15.52	15.78	15.87	15.79	15.16	14.84	17.15
1944	2015	17.34	17.29	20.16	18.06	16.15	15.72	15.98	16.06	16.00	15.34	15.04	17.38
1945	2016	17.56	17.51	20.43	18.29	16.36	15.93	16.19	16.25	16.20	15.53	15.23	17.61
1946	2017	17.82	17.76	20.74	18.55	16.59	16.17	16.43	16.47	16.43	15.75	15.45	17.87
1947	2018	18.07	18.02	21.06	18.82	16.82	16.41	16.67	16.70	16.65	15.97	15.68	18.13
1948	2019	18.33	18.28	21.37	19.09	17.05	16.64	16.91	16.92	16.88	16.19	15.90	18.40
1949	2020	18.59	18.54	21.68	19.35	17.29	16.88	17.14	17.14	17.11	16.41	16.12	18.66
1950	2021	18.85	18.79	21.99	19.62	17.52	17.12	17.38	17.37	17.34	16.63	16.35	18.93
1951	2022	19.11	19.05	22.30	19.88	17.75	17.36	17.62	17.59	17.57	16.85	16.57	19.19
1952	2023	19.36	19.31	22.61	20.15	17.98	17.60	17.86	17.81	17.80	17.07	16.79	19.45
1953	2024	19.62	19.57	22.92	20.41	18.22	17.83	18.10	18.03	18.03	17.28	17.02	19.72
1954	2025	19.88	19.82	23.23	20.68	18.45	18.07	18.33	18.26	18.26	17.50	17.24	19.98
1955	2026	20.14	20.08	23.54	20.95	18.68	18.31	18.57	18.48	18.49	17.72	17.46	20.25
1956	2027	20.38	20.32	23.83	21.19	18.90	18.53	18.79	18.69	18.70	17.93	17.67	20.49
1957	2028	20.62	20.56	24.12	21.44	19.12	18.75	19.01	18.90	18.92	18.13	17.88	20.74
1958	2029	20.87	20.80	24.41	21.69	19.33	18.98	19.24	19.11	19.13	18.34	18.09	20.99
1959	2030	21.11	21.05	24.70	21.93	19.55	19.20	19.46	19.32	19.35	18.54	18.30	21.24
1960	2031	21.35	21.29	24.98	22.18	19.76	19.42	19.68	19.52	19.56	18.74	18.51	21.48
1961	2032	21.59	21.53	25.27	22.43	19.98	19.64	19.90	19.73	19.78	18.95	18.72	21.73
1962	2033	21.84	21.77	25.56	22.68	20.20	19.86	20.12	19.94	19.99	19.15	18.93	21.98
1963	2034	22.08	22.01	25.85	22.92	20.41	20.09	20.34	20.15	20.21	19.36	19.14	22.23
1964	2035	22.32	22.25	26.14	23.17	20.63	20.31	20.56	20.36	20.42	19.56	19.35	22.47
1965	2036	22.56	22.50	26.43	23.42	20.85	20.53	20.79	20.57	20.64	19.77	19.56	22.72
1966	2037	22.84	22.77	26.76	23.70	21.09	20.78	21.04	20.81	20.88	20.00	19.80	23.01
1967	2038	23.13	23.05	27.09	23.98	21.34	21.04	21.29	21.05	21.13	20.24	20.04	23.29
1968	2039	23.41	23.33	27.42	24.26	21.59	21.29	21.55	21.29	21.38	20.47	20.29	23.57
1969	2040	23.69	23.61	27.75	24.55	21.83	21.55	21.80	21.53	21.62	20.71	20.53	23.86
1970	2041	23.97	23.89	28.08	24.83	22.08	21.80	22.05	21.77	21.87	20.94	20.77	24.14
1971	2042	24.25	24.17	28.41	25.11	22.33	22.06	22.30	22.01	22.11	21.18	21.01	24.43
1972	2043	24.53	24.44	28.74	25.39	22.58	22.31	22.56	22.25	22.36	21.41	21.25	24.71
1973	2044	24.81	24.72	29.07	25.68	22.82	22.56	22.81	22.49	22.61	21.65	21.49	25.00
1974	2045	25.09	25.00	29.40	25.96	23.07	22.82	23.06	22.73	22.85	21.88	21.74	25.28
1975	2046	25.37	25.28	29.72	26.24	23.32	23.07	23.32	22.97	23.10	22.12	21.98	25.56
1976	2047	25.63	25.54	30.02	26.49	23.54	23.30	23.54	23.19	23.33	22.33	22.20	25.83
1977	2048	25.89	25.79	30.32	26.75	23.76	23.53	23.77	23.41	23.55	22.55	22.42	26.09
1978	2049	26.15	26.05	30.62	27.00	23.99	23.76	24.00	23.63	23.78	22.76	22.65	26.35
1979	2050	26.41	26.31	30.91	27.26	24.21	24.00	24.23	23.85	24.00	22.98	22.87	26.61
1980	2051	26.67	26.56	31.21	27.51	24.43	24.23	24.46	24.07	24.23	23.19	23.09	26.87
1981	2052	26.93	26.82	31.51	27.77	24.65	24.46	24.68	24.29	24.45	23.40	23.31	27.13
1982	2053	27.19	27.08	31.80	28.02	24.87	24.69	24.91	24.51	24.68	23.62	23.54	27.39
1983	2054	27.45	27.33	32.10	28.28	25.10	24.92	25.14	24.73	24.90	23.83	23.76	27.65
1984	2055	27.71	27.59	32.40	28.53	25.32	25.15	25.37	24.95	25.13	24.05	23.98	27.91
1985	2056	27.97	27.84	32.69	28.79	25.54	25.38	25.60	25.17	25.35	24.26	24.20	28.17
1986	2057	28.27	28.14	33.03	29.08	25.80	25.65	25.86	25.43	25.61	24.51	24.46	28.48
1987	2058	28.58	28.44	33.38	29.37	26.05	25.92	26.12	25.69	25.87	24.76	24.73	28.78
1988	2059	28.88	28.74	33.72	29.67	26.31	26.19	26.38	25.95	26.14	25.01	24.99	29.09
1989	2060	29.19	29.04	34.06	29.96	26.57	26.45	26.65	26.20	26.40	25.26	25.25	29.39
1990	2061	29.49	29.34	34.40	30.26	26.82	26.72	26.91	26.46	26.66	25.51	25.51	29.69
1991	2062	29.80	29.64	34.74	30.55	27.08	26.99	27.17	26.72	26.92	25.76	25.77	30.00
1992	2063	30.11	29.94	35.09	30.84	27.34	27.26	27.44	26.97	27.18	26.00	26.03	30.30
1993	2064	30.41	30.24	35.43	31.14	27.59	27.53	27.70	27.23	27.45	26.25	26.29	30.61
1994	2065	30.72	30.54	35.77	31.43	27.85	27.79	27.96	27.49	27.71	26.50	26.55	30.91
1995	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1996	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1997	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1998	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
1999	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2000	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2001	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2002	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2003	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2004	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2005	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2006	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2007	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2008	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2009	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2010	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22
2011	2066	31.02	30.84	36.11	31.72	28.10	28.06	28.22	27.75	27.97	26.75	26.81	31.22

J. Strom Thurmond Withdrawals (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	31.25	31.40	31.88	33.11	35.66	37.83	38.64	37.99	36.19	34.07	32.94	31.97
1940	2011	31.52	31.68	32.19	33.44	36.05	38.26	39.09	38.43	36.58	34.41	33.26	32.27
1941	2012	31.80	31.96	32.49	33.77	36.43	38.69	39.55	38.86	36.98	34.76	33.57	32.56
1942	2013	32.07	32.25	32.80	34.09	36.82	39.13	40.00	39.30	37.37	35.11	33.89	32.86
1943	2014	32.35	32.53	33.10	34.42	37.21	39.56	40.45	39.74	37.77	35.45	34.21	33.15
1944	2015	32.62	32.82	33.40	34.75	37.60	39.99	40.91	40.18	38.17	35.80	34.53	33.44
1945	2016	32.90	33.10	33.71	35.08	37.99	40.42	41.36	40.61	38.56	36.14	34.84	33.74
1946	2017	34.64	34.86	35.49	36.89	39.87	42.35	43.32	42.55	40.45	37.97	36.64	35.51
1947	2018	36.39	36.61	37.27	38.70	41.75	44.28	45.28	44.49	42.34	39.80	38.44	37.28
1948	2019	38.14	38.37	39.05	40.51	43.63	46.21	47.23	46.43	44.23	41.63	40.24	39.05
1949	2020	39.88	40.13	40.83	42.31	45.51	48.14	49.19	48.37	46.12	43.47	42.04	40.82
1950	2021	41.63	41.89	42.61	44.12	47.39	50.07	51.15	50.31	48.01	45.30	43.83	42.59
1951	2022	43.38	43.65	44.39	45.93	49.27	52.00	53.11	52.25	49.90	47.13	45.63	44.36
1952	2023	45.12	45.40	46.18	47.74	51.15	53.93	55.07	54.19	51.78	48.96	47.43	46.13
1953	2024	46.87	47.16	47.96	49.55	53.03	55.87	57.02	56.13	53.67	50.79	49.23	47.91
1954	2025	48.62	48.92	49.74	51.36	54.91	57.80	58.98	58.07	55.56	52.62	51.03	49.68
1955	2026	50.36	50.68	51.52	53.17	56.79	59.73	60.94	60.01	57.45	54.45	52.82	51.45
1956	2027	50.66	50.99	51.86	53.55	57.25	60.25	61.50	60.54	57.93	54.85	53.19	51.77
1957	2028	50.96	51.30	52.21	53.92	57.72	60.78	62.06	61.08	58.40	55.25	53.55	52.10
1958	2029	51.25	51.61	52.55	54.30	58.18	61.30	62.61	61.61	58.87	55.65	53.91	52.43
1959	2030	51.55	51.93	52.89	54.67	58.64	61.83	63.17	62.15	59.35	56.06	54.27	52.76
1960	2031	51.85	52.24	53.23	55.05	59.11	62.35	63.73	62.69	59.82	56.46	54.63	53.08
1961	2032	52.15	52.55	53.57	55.43	59.57	62.87	64.29	63.22	60.29	56.86	54.99	53.41
1962	2033	52.44	52.86	53.92	55.80	60.04	63.40	64.85	63.76	60.77	57.26	55.35	53.74
1963	2034	52.74	53.17	54.26	56.18	60.50	63.92	65.41	64.29	61.24	57.66	55.71	54.07
1964	2035	53.04	53.49	54.60	56.55	60.96	64.45	65.96	64.83	61.72	58.06	56.07	54.39
1965	2036	53.34	53.80	54.94	56.93	61.43	64.97	66.52	65.36	62.19	58.47	56.43	54.72
1966	2037	53.70	54.17	55.36	57.39	61.99	65.61	67.21	66.02	62.77	58.95	56.87	55.12
1967	2038	54.05	54.55	55.77	57.84	62.56	66.25	67.89	66.67	63.34	59.44	57.31	55.51
1968	2039	54.41	54.93	56.19	58.30	63.12	66.90	68.57	67.33	63.92	59.93	57.75	55.91
1969	2040	54.77	55.31	56.60	58.75	63.69	67.54	69.26	67.98	64.50	60.42	58.18	56.30
1970	2041	55.13	55.68	57.02	59.21	64.25	68.18	69.94	68.64	65.08	60.90	58.62	56.70
1971	2042	55.49	56.06	57.43	59.67	64.81	68.82	70.62	69.29	65.65	61.39	59.06	57.10
1972	2043	55.85	56.44	57.85	60.12	65.38	69.46	71.31	69.95	66.23	61.88	59.50	57.49
1973	2044	56.21	56.81	58.26	60.58	65.94	70.10	71.99	70.60	66.81	62.37	59.93	57.89
1974	2045	56.56	57.19	58.68	61.04	66.51	70.74	72.67	71.26	67.39	62.85	60.37	58.29
1975	2046	56.92	57.57	59.10	61.49	67.07	71.38	73.36	71.91	67.96	63.34	60.81	58.68
1976	2047	58.85	59.52	61.10	63.54	69.26	73.66	75.69	74.21	70.16	65.43	62.84	60.66
1977	2048	60.79	61.48	63.10	65.60	71.45	75.94	78.02	76.51	72.37	67.52	64.87	62.64
1978	2049	62.72	63.43	65.10	67.65	73.63	78.22	80.35	78.80	74.57	69.61	66.90	64.62
1979	2050	64.65	65.39	67.11	69.70	75.82	80.50	82.68	81.10	76.77	71.71	68.93	66.59
1980	2051	66.58	67.34	69.11	71.75	78.01	82.78	85.02	83.40	78.97	73.80	70.96	68.57
1981	2052	68.51	69.30	71.11	73.81	80.19	85.06	87.35	85.70	81.17	75.89	72.99	70.55
1982	2053	70.44	71.25	73.12	75.86	82.38	87.34	89.68	87.99	83.37	77.98	75.02	72.53
1983	2054	72.38	73.21	75.12	77.91	84.57	89.62	92.01	90.29	85.58	80.07	77.05	74.51
1984	2055	74.31	75.16	77.12	79.96	86.75	91.90	94.35	92.59	87.78	82.16	79.07	76.49
1985	2056	76.24	77.12	79.13	82.02	88.94	94.18	96.68	94.88	89.98	84.25	81.10	78.46
1986	2057	76.76	77.67	79.74	82.69	89.78	95.13	97.70	95.86	90.84	84.97	81.75	79.04
1987	2058	77.28	78.22	80.35	83.36	90.62	96.08	98.71	96.83	91.69	85.69	82.39	79.62
1988	2059	77.81	78.77	80.96	84.04	91.46	97.04	99.73	97.81	92.55	86.41	83.03	80.20
1989	2060	78.33	79.33	81.58	84.71	92.29	97.99	100.75	98.78	93.41	87.13	83.68	80.78
1990	2061	78.85	79.88	82.19	85.38	93.13	98.94	101.77	99.76	94.26	87.85	84.32	81.36
1991	2062	79.37	80.43	82.80	86.06	93.97	99.89	102.78	100.73	95.12	88.57	84.96	81.94
1992	2063	79.90	80.98	83.41	86.73	94.81	100.85	103.80	101.71	95.98	89.29	85.61	82.52
1993	2064	80.42	81.53	84.03	87.40	95.65	101.80	104.82	102.68	96.83	90.01	86.25	83.10
1994	2065	80.94	82.09	84.64	88.07	96.49	102.75	105.84	103.65	97.69	90.73	86.89	83.68
1995	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1996	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1997	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1998	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
1999	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2000	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2001	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2002	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2003	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2004	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2005	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2006	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2007	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2008	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2009	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2010	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26
2011	2066	81.46	82.64	85.25	88.75	97.33	103.70	106.86	104.63	98.55	91.45	87.54	84.26

Withdrawal and Return Estimates from Keowee - Toxaway Hydroelectric Project Water Supply Study
Data Transmitted on September 24, 2012
Original Source File: KT_WSS_CHEOPS_Data_9242012.xls

J. Strom Thurmond Returns (cfs)													
Hydrology Year	Projection Year	January	February	March	April	May	June	July	August	September	October	November	December
1939	2010	7.37	7.46	9.68	7.98	6.29	7.99	7.28	6.67	6.66	6.94	6.09	6.74
1940	2011	7.40	7.50	9.72	8.02	6.32	8.02	7.32	6.71	6.70	6.98	6.13	6.77
1941	2012	7.44	7.54	9.76	8.06	6.36	8.06	7.36	6.75	6.74	7.02	6.17	6.81
1942	2013	7.47	7.59	9.80	8.10	6.39	8.10	7.40	6.79	6.78	7.06	6.21	6.85
1943	2014	7.51	7.63	9.84	8.14	6.42	8.14	7.44	6.82	6.82	7.10	6.25	6.88
1944	2015	7.54	7.67	9.89	8.18	6.46	8.17	7.48	6.86	6.86	7.13	6.29	6.92
1945	2016	7.58	7.71	9.93	8.22	6.49	8.21	7.52	6.90	6.90	7.17	6.33	6.96
1946	2017	7.63	7.77	9.99	8.27	6.54	8.26	7.57	6.95	6.96	7.23	6.39	7.01
1947	2018	7.68	7.83	10.04	8.32	6.59	8.31	7.62	7.00	7.01	7.28	6.44	7.06
1948	2019	7.73	7.88	10.10	8.38	6.63	8.36	7.67	7.06	7.06	7.33	6.50	7.11
1949	2020	7.78	7.94	10.16	8.43	6.68	8.41	7.72	7.11	7.11	7.38	6.55	7.16
1950	2021	7.83	8.00	10.22	8.48	6.72	8.46	7.78	7.16	7.16	7.44	6.60	7.21
1951	2022	7.88	8.05	10.27	8.53	6.77	8.52	7.83	7.21	7.21	7.49	6.66	7.26
1952	2023	7.93	8.11	10.33	8.59	6.82	8.57	7.88	7.26	7.26	7.54	6.71	7.31
1953	2024	7.98	8.17	10.39	8.64	6.86	8.62	7.93	7.31	7.31	7.59	6.77	7.36
1954	2025	8.03	8.22	10.45	8.69	6.91	8.67	7.98	7.37	7.36	7.64	6.82	7.41
1955	2026	8.08	8.28	10.50	8.74	6.96	8.72	8.03	7.42	7.41	7.70	6.88	7.46
1956	2027	8.15	8.36	10.58	8.82	7.02	8.79	8.11	7.49	7.48	7.77	6.95	7.53
1957	2028	8.22	8.43	10.66	8.89	7.09	8.86	8.18	7.56	7.55	7.84	7.02	7.60
1958	2029	8.29	8.51	10.74	8.96	7.15	8.93	8.25	7.63	7.62	7.91	7.10	7.67
1959	2030	8.36	8.59	10.82	9.04	7.22	9.00	8.32	7.70	7.70	7.98	7.17	7.74
1960	2031	8.43	8.67	10.91	9.11	7.29	9.07	8.39	7.77	7.77	8.05	7.25	7.81
1961	2032	8.50	8.75	10.99	9.18	7.35	9.14	8.46	7.84	7.84	8.13	7.32	7.88
1962	2033	8.57	8.83	11.07	9.26	7.42	9.21	8.53	7.91	7.91	8.20	7.40	7.95
1963	2034	8.64	8.90	11.15	9.33	7.48	9.28	8.60	7.98	7.98	8.27	7.47	8.02
1964	2035	8.71	8.98	11.23	9.40	7.55	9.35	8.67	8.05	8.05	8.34	7.54	8.09
1965	2036	8.78	9.06	11.31	9.48	7.61	9.42	8.75	8.13	8.12	8.41	7.62	8.17
1966	2037	8.84	9.13	11.37	9.54	7.67	9.48	8.81	8.19	8.18	8.48	7.68	8.23
1967	2038	8.89	9.19	11.44	9.60	7.73	9.54	8.87	8.25	8.24	8.54	7.75	8.28
1968	2039	8.95	9.26	11.51	9.66	7.78	9.61	8.93	8.31	8.30	8.60	7.82	8.34
1969	2040	9.01	9.32	11.58	9.73	7.84	9.67	8.99	8.37	8.36	8.67	7.88	8.40
1970	2041	9.07	9.39	11.65	9.79	7.89	9.73	9.05	8.44	8.43	8.73	7.95	8.46
1971	2042	9.12	9.46	11.71	9.85	7.95	9.79	9.11	8.50	8.49	8.79	8.01	8.52
1972	2043	9.18	9.52	11.78	9.91	8.00	9.85	9.17	8.56	8.55	8.85	8.08	8.58
1973	2044	9.24	9.59	11.85	9.98	8.06	9.91	9.24	8.62	8.61	8.92	8.15	8.64
1974	2045	9.30	9.65	11.92	10.04	8.11	9.97	9.30	8.69	8.67	8.98	8.21	8.70
1975	2046	9.35	9.72	11.98	10.10	8.17	10.03	9.36	8.75	8.74	9.04	8.28	8.76
1976	2047	9.43	9.80	12.07	10.18	8.24	10.10	9.43	8.82	8.81	9.12	8.36	8.83
1977	2048	9.50	9.88	12.15	10.25	8.31	10.18	9.51	8.90	8.89	9.20	8.44	8.91
1978	2049	9.57	9.96	12.23	10.33	8.37	10.25	9.58	8.97	8.96	9.27	8.52	8.98
1979	2050	9.64	10.04	12.31	10.40	8.44	10.32	9.66	9.05	9.04	9.35	8.60	9.05
1980	2051	9.71	10.12	12.40	10.48	8.51	10.40	9.73	9.13	9.11	9.43	8.68	9.13
1981	2052	9.78	10.20	12.48	10.56	8.58	10.47	9.81	9.20	9.19	9.50	8.76	9.20
1982	2053	9.85	10.29	12.56	10.63	8.65	10.54	9.88	9.28	9.26	9.58	8.83	9.27
1983	2054	9.92	10.37	12.65	10.71	8.71	10.62	9.96	9.35	9.34	9.66	8.91	9.34
1984	2055	9.99	10.45	12.73	10.78	8.78	10.69	10.03	9.43	9.41	9.73	8.99	9.42
1985	2056	10.06	10.53	12.81	10.86	8.85	10.77	10.11	9.50	9.49	9.81	9.07	9.49
1986	2057	10.16	10.63	12.92	10.96	8.94	10.86	10.20	9.60	9.59	9.91	9.18	9.59
1987	2058	10.25	10.74	13.03	11.06	9.03	10.96	10.30	9.70	9.68	10.01	9.28	9.68
1988	2059	10.34	10.85	13.14	11.16	9.12	11.06	10.40	9.80	9.78	10.11	9.38	9.78
1989	2060	10.44	10.95	13.25	11.26	9.21	11.15	10.50	9.89	9.88	10.21	9.49	9.87
1990	2061	10.53	11.06	13.36	11.36	9.29	11.25	10.59	9.99	9.97	10.31	9.59	9.97
1991	2062	10.63	11.16	13.47	11.46	9.38	11.35	10.69	10.09	10.07	10.41	9.70	10.07
1992	2063	10.72	11.27	13.58	11.56	9.47	11.44	10.79	10.19	10.17	10.51	9.80	10.16
1993	2064	10.81	11.37	13.68	11.66	9.56	11.54	10.89	10.29	10.27	10.60	9.90	10.26
1994	2065	10.91	11.48	13.79	11.76	9.65	11.64	10.99	10.38	10.36	10.70	10.01	10.36
1995	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1996	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1997	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1998	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
1999	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2000	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2001	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2002	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2003	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2004	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2005	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2006	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2007	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2008	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2009	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2010	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45
2011	2066	11.00	11.59	13.90	11.86	9.74	11.73	11.08	10.48	10.46	10.80	10.11	10.45

APPENDIX B

RAW WATER INTAKE SUMMARY

Safe Yield - Reservoir Intake Level Evaluation

Lake System	Entity/Source Description	Facility	Lake/River	Description	Elevation (FT MSL)	Study Verified	Comments
JOCASSEE DAM							
	Full Pond Elevation			**Full Pond**	**1110.00**	**Y**	
	Critical Boat Access Levels			**Public Access**	**1080.00**	**Y**	Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access (provided by Duke Energy).
	Critical Swimming Access Levels			**Public Access**	**N/A**	**Y**	
	Hydro Operations			**Hydro**	**1080.00**	**Y**	
KEOWEE DAM							
	Full Pond Elevation			**Full Pond**	**800.00**	**Y**	
	Critical Boat Access Levels			**Public Access**	**790.00**	**Y**	Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).
	Critical Swimming Access Levels			**Public Access**	**N/A**	**Y**	
	Greenville Water System	Witty Atkins WTP	Lake	Intake	770.00	Y	
	City of Seneca	Seneca City WTP	Lake	Intake	775.00	Y	
	Duke Energy Corporation	Oconee Nuclear Station	Lake	Intake	794.60	Y	
	Hydro Operations			**Hydro**	**775.00**	**Y**	
HARTWELL DAM[5]							
	Full Pond Elevation			**Full Pond**	**660.00**	**Y**	
	Critical Boat Access Levels[6]			**Public Access**	**652.00**	**Y**	
	Critical Swimming Access Levels			**Public Access**	**654.00**	**Y**	Level at which all USACE operated designated swimming areas are dry.
	Anderson Regional Joint Water System	Hartwell Lake Filter Plant	Lake	Intake	615.00	Y	
	City of Hartwell	Hartwell WTP	Lake	Intake	612.00	Y	
	City of Lavonia	N/A	Lake	Intake	636.00	Y	
	Milliken & Company	Pendleton Finishing Plant	Lake	Intake	611.00	Y	
	J.P. Stevens	Westpoint Stevens Plant	Lake	Intake	610.00	Y	Facility demolished in 2008, intake no longer operational
	Clemson University	Central Energy Facility	Lake	Intake	638.00	Y	
	Clemson University Agriculture[3]	Musser Fruit Farm	Lake	Intake	645.00	Y	Can obtain water from City of Seneca if intake exposed, therefore not a critical intake
	Clemson Golf Course[3]	Walker Golf Course	Lake	Intake	633.00	Y	
	Hydro Operations			**Hydro**	**625.00**	**Y**	
RUSSELL DAM[5]							
	Full Pond Elevation			**Full Pond**	**475.00**	**Y**	
	Critical Boat Access Levels[6]			**Public Access**	**466.00**	**Y**	
	Critical Swimming Access Levels			**Public Access**	**N/A**	**Y**	There are no USACE operated designated swimming areas on this reservoir.
	City of Abbeville	Abbeville City WTP	Lake	Intake	457.50	Y	
	City of Elberton	Elberton WTP	Lake	Intake	465.00	Y	
	Town of Calhoun Falls[4]	Calhoun Falls WTP	Lake	Intake	457.00	Y	
	Mohawk Industries, Inc.	Rocky River Plant	Lake	Intake	464.75	Y	Highest intake elevation of 3
	Santee Cooper	John Rainy Generating Station	Lake	Intake	460.50	Y	
	RBR State Park[3]	RBR Golf Course	Lake	Intake	468.80	Y	
	Hydro Operations			**Hydro**	**470.00**	**Y**	

Safe Yield - Reservoir Intake Level Evaluation

Lake System	Entity/Source Description	Facility	Lake/River	Description	Elevation (FT MSL)	Study Verified	Comments
THURMOND DAM[5]							
	Full Pond Elevation			**Full Pond**	**330.00**	**Y**	
	Critical Boat Access Levels[6]			**Public Access**	**320.00**	**Y**	
	Critical Swimming Access Levels			**Public Access**	**324.00**	**Y**	Level at which all USACE operated designated swimming areas are dry.
	McCormick Commission of Public Works	McCormick WTP	Lake	Intake	304.00	Y	
	Columbia County Water Utility	Clarks Hill WTP	Lake	Intake	312.00	Y	2nd highest of 3 intakes[2]
	City of Lincolnton	James Allen Reed WTP	Lake	Intake	311.00	Y	Physical limit of pumping operation for intake structure[7]
	McDuffie County-City of Thomson	Big Creek	Lake	Intake	312.00	Y	2nd highest of 3 intakes[2]
	City of Washinton[4]	Washington WTP	Lake	Intake	307.00	Y	
	Savannah Lakes POA[3]	Monticello Golf Course	Lake	Intake	324.00	Y	
	Savannah Lakes POA[3]	Tara Golf Course	Lake	Intake	324.00	Y	
	Hickory Knob State Park[3]	Hickory Knob Golf Course	Lake	Intake	324.00	Y	
	Hydro Operations			**Hydro**	**312.00**	**Y**	

Notes:
1. Critical Levels are defined in the shaded boxes
2. Entity has 3 intakes; if highest intake is exposed, the remaining two intakes are capable of meeting water demands, thus making the second highest intake the critical intake for the entity.
3. Not included in Water Supply Study water use projections as included in overall A/I category projections
4. Not included in Water Supply Study water use projections as use < 0.1 mgd
5. All reservoir elevations for Hartwell, Russell and Thurmond were provided by USACE, unless noted otherwise. Reference SRB Drought Revision Draft EA 4/13/2012.
6. USACE critical boat ramp and swimming access levels at Hartwell, Russell and Thurmond assume 70% of access points remain useable for each reservoir (30% become unuseable) due to shear number of access points.
7. Critical elevation for 2nd highest of 3 intake levels is 314.00' as listed in USACE Draft EA 4/13/3012. Per 8/2/2012 phone call with Stanly Pardon, the intake can operate below EL 314.00' to a critical elevation of 311.00'.

Latest Update: August 8, 2012

HDR | ONE COMPANY *Many Solutions*℠

Telephone Record

Project:	Keowee-Toxaway Water Supply Study	Project No:	018-143812
Date:	7/31/2012	Subject:	Raw Water Intake Elevations
Call to:	Tony Putnam, Clemson Central Energy Fac.	Phone No:	864-656-7300
Call from:	Jonathan Williams, HDR	Phone No:	704-338-6744

Discussion, Agreement and/or Action:

- Mr. Williams called Mr. Putnam who is the Utilities Services Director for Clemson University to discuss Clemson's Central Energy Facility raw water intake elevations for the purpose of verifying the critical intake elevation on Lake Hartwell, as currently being used for the water yield analysis of the K-T Water Supply Study.

- Mr. Putnam confirmed that the Central Energy Facility is Clemson University's physical plant and that the raw water intake is used for cooling water for the campus's chiller units. The water is used to provide once-through cooling for the chiller plant.

- Mr. Putnam confirmed that the intake structure has three intake openings, with the following elevations:
  - EL 650.0' AMSL (top intake elevation; currently closed and abandoned)
  - EL 638.0' AMSL (middle intake elevation; currently used by HDR as the critical intake elevation for Lake Hartwell, based on published value by the USACE)
  - EL 625.0' AMSL (bottom intake elevation)

- Mr. Putnam confirmed that the entire intake structure (all openings) was not exposed during the 2008 drought when the lake was down approximately 23 feet. He did, however, confirm that there was a period of time the lake was below the middle opening (EL 638.0') level.

- The lowest Hartwell lake elevations during 2008 drought occurred in the late fall, when the campus' cooling requirements were low. Mr. Putnam stated that had lake levels dropped below the 638.0' earlier in the year, during the summer months (peak required cooling months for the campus), they would have had major problems providing adequate cooling water for their physical plant.
- Mr. Putnam noted that when the lake elevation did drop below the 638.0' level, their facility experienced poor raw water intake flows and high water temperatures above their optimum cooling water temperatures. This put the university in a situation where they were "limping" along to provide cooling to the campus.

- In response to the 2008 drought, Clemson has begun to install more cooling towers for their chillers to replace the once-through cooling process. However, this has yet to be fully implemented, as they still use their raw water intake for once-through cooling for some chillers. Additionally, the transition to cooling tower technology is being implemented primarily as a response to the high lake temperatures in Hartwell, which appear to be a continual issue even during non-drought years. However, cooling towers technology does not address the flow issues of the existing intake if lake levels drop below EL 638.0'

HDR Engineering, Inc. of the Carolinas | 440 South Church Street
Suite 1000
Charlotte, NC 28202-2075 | Phone (704) 338-6700
Fax (704) 338-6760
www.hdrinc.com

HDR ONE COMPANY *Many Solutions*℠

Telephone Record

Project:	Keowee-Toxaway Water Supply Study	Project No:	018-143812
Date:	8/6/2012	Subject:	Raw Water Intake Elevations
Call to:	Tony Putnam, Clemson Central Energy Fac.	Phone No:	864-656-7300
Call from:	Jonathan Williams, HDR	Phone No:	704-338-6744

Discussion, Agreement and/or Action:

- Mr. Williams called Mr. Putnam who is the Utilities Services Director for Clemson University to follow up on previous 7-31-2012 discussions regarding Clemson's Central Energy Facility raw water intake elevations for the purpose of verifying the critical intake elevation on Lake Hartwell, as currently being used for the water yield analysis of the K-T Water Supply Study.

- Mr. Putnam confirmed that had the lake levels dropped below EL 638.0' AMSL during the 2008 drought during the peak summer months instead of in the fall as experienced, Clemson's Central Energy Facility would have been required to bring in additional portable cooling towers for their chillers. The facility currently has 2-18 ton chillers units that utilize water from their stationary raw water intake on Lake Hartwell that is used for once-through cooling. If lake elevations drop below EL 638 in peak summer months, they cannot provide adequate flow to supply cooling water to their chillers and would require portable units that would be a cost to the university in excess of $1 million USD for the units alone. Additionally, the evaporative water loss from the cooling process would be an additional cost, as they would purchase water from Anderson Regional Joint Water Supply.

- Mr. Putnam acknowledged that the impact of the above scenario would be a major financial and operation burden.

- Mr. Putnam acknowledged that eventually, the once-through cooling process and intake on Hartwell will be abandoned and replaced with cooling tower technology for chiller units. However, this plan is in the distant future and the facility will likely rely on the existing intake structure for at least 2 more decades.

HDR | ONE COMPANY *Many Solutions*℠

Telephone Record

Project:	Keowee-Toxaway Water Supply Study	Project No:	018-143812
Date:	8/2/2012	Subject:	Raw Water Intake Elevations
Call to:	David Hudson, City of Elberton, GA	Phone No:	706-213-3278
Call from:	Jonathan Williams, HDR	Phone No:	704-338-6744

Discussion, Agreement and/or Action:

- Mr. Williams called Mr. Hudson with the City of Elberton, Georgia to discuss their raw water intake elevations for the purpose of verifying the intake elevation on Lake Richard B. Russell, as currently being used for the water yield analysis of the K-T Water Supply Study.
- The critical elevation used for Russell in the water yield analysis is a hydropower operation limit of USACE. However, the next highest intake elevation is the City of Elberton.
- Mr. Hudson confirmed that EL 465.0' AMSL is the top of the intake opening and that use of this value as their critical elevation is correct.
- Mr. Hudson stated that this intake is a stationary intake structure.
- Mr. Hudson stated that the city does have an emergency intake on Beaverdam Creek that can supply the city's water needs for a period of time in the event their primary intake structure is unusable.
- Mr. Hudson stated that their intake has never been exposed, as the USACE operational guidelines require that Lake Russell be maintained between EL 470 and 475.

HDR | ONE COMPANY *Many Solutions*℠

Telephone Record

Project:	Keowee-Toxaway Water Supply Study	Project No:	018-143812
Date:	8/2/2012	Subject:	Raw Water Intake Elevations
Call to:	Stanly Pardon, City of Lincolnton, GA	Phone No:	706-401-1430 (mobile)
Call from:	Jonathan Williams, HDR	Phone No:	704-338-6744

Discussion, Agreement and/or Action:

- Mr. Williams called Mr. Pardon who is the Water Treatment Plant operator for the City of Lincolnton, Georgia to discuss their raw water intake elevations for the purpose of verifying the critical intake elevation on Lake J. Strom Thurmond, as currently being used for the water yield analysis of the K-T Water Supply Study.

- Mr. Pardon confirmed that the Lincolnton constructed a new water intake structure between 2005 and 2006 and that the critical intake elevation of 314, as published by USACE, is not accurate. The new structure has three openings with the following elevations:

    - EL 321.0’ AMSL (Top opening)
    - EL 314.0’ AMSL (Middle opening)
    - EL 307.0’ AMSL (Bottom opening)

- Mr. Pardon confirmed that during the 2007-2008 drought, their new intake structure was never completely exposed.

- Mr. Pardon confirmed that the old water intake structure operational limit was EL 314.0’ which corresponds to the published USACE value, and that the pump was located on the shoreline. This intake is no longer used, however.

- Mr. Pardon confirmed that the new raw water intake experiences pumping problems at EL 311.0’ AMSL and this elevation is their physical limit (i.e. critical elevation).

- Mr. Williams asked Mr. Pardon what Lincolnton would do if the lake level were to drop below EL 311.0’. Mr. Pardon stated that the city does not have an emergency interconnect, and that their contingency plan is to use their two shoreline pumps where they could install another intake screen to meet the city’s water need by floating the intake out in the lake.

HDR Engineering, Inc. of the Carolinas
440 South Church Street
Suite 1000
Charlotte, NC 28202-2075
Phone (704) 338-6700
Fax (704) 338-6760
www.hdrinc.com

APPENDIX C

SCENARIO INPUT FORMS

This appendix includes input forms for each of the following CHEOPS scenarios and scenario sensitivity runs. The scenario input forms are included in the appendix in the order noted below.

APPENDIX C
SCENARIO INPUT FORMS
TABLE OF CONTENTS

BASELINE

FOR HDR USE ONLY	
Run #	BaseProjected_2012-08-23_73yr

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 08/23/2012 extended hydrology 04/01/2013

Stakeholder Group: Duke Energy   Needed By: ASAP

Period of Run:
- ☐ Typical Normal Conditions
- ☐ Typical Dry Conditions
- ☐ Typical Wet Conditions
- ☒ Full Record
- ☐ 14yr Record (1995 – 2008)
- ☐ Other: ______________________________

Lake Level Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ____

Downstream Release Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ____

Hydropower Output Format:
- ☐ Tables
- ☐ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ____

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
- ☐ Present
- ☐ Future (2066)
- ☒ Projecting
- ☐ Other: ____

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	Same
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	Same
	Minimum Flow Release(cfs)		
	MinDF (cfs)		
	MaxDF (cfs)		
	Maximum Weekly Release (ac-ft)	25,000	Same

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee****	
Month	*Current Operations Baseline*	*Scenario*	*Current Operations Baseline*	*Scenario*
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

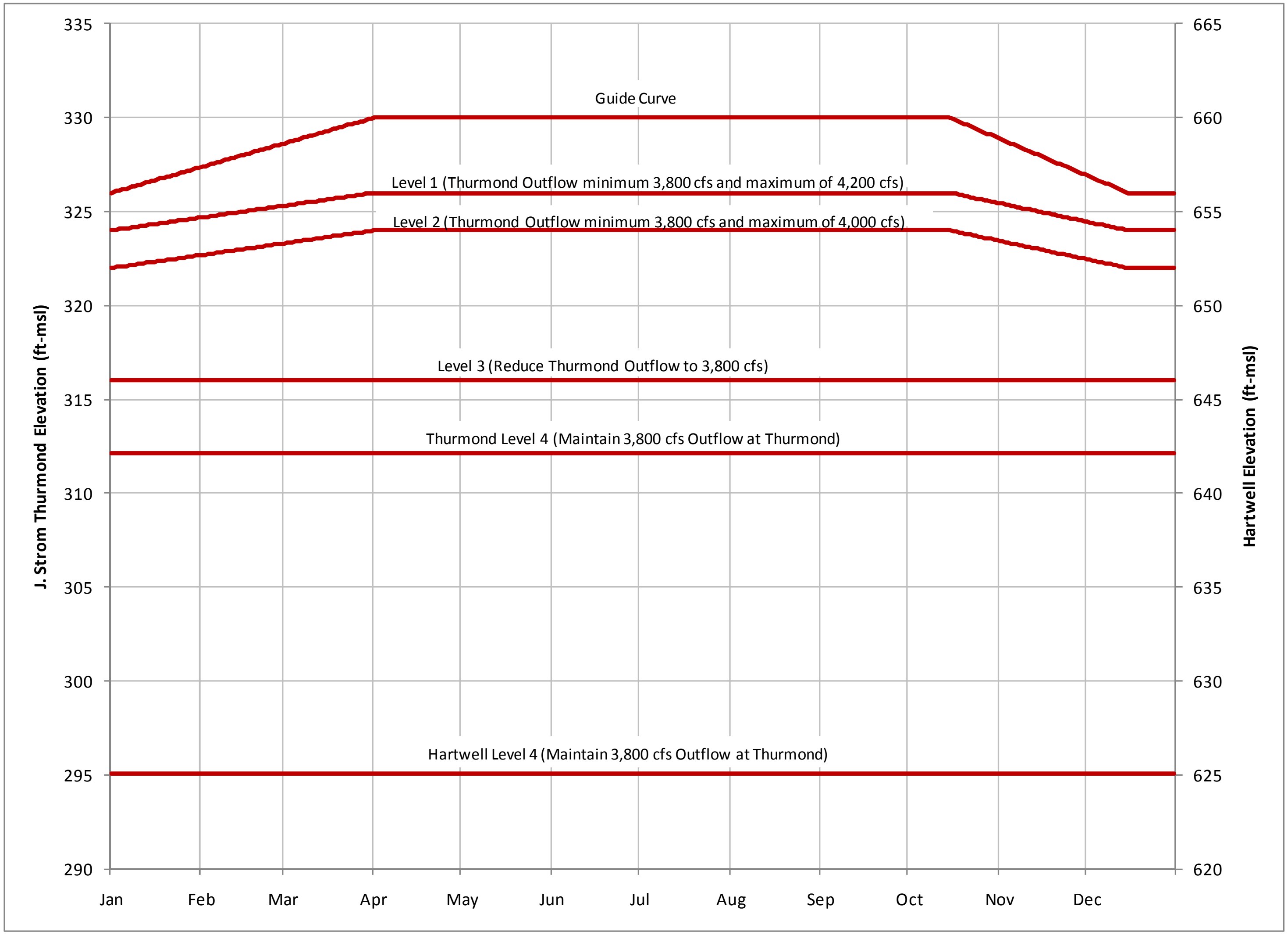
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	Same	794.6	Same
February	1,080		794.6	
March	1,080		794.6	
April	1,080		794.6	
May	1,080		794.6	
June	1,080		794.6	
July	1,080		794.6	
August	1,080		794.6	
September	1,080		794.6	
October	1,080		794.6	
November	1,080		794.6	
December	1,080		794.6	

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

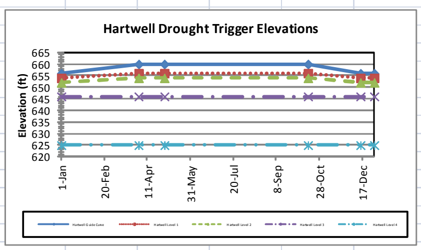
Data updated:	11/1/2012
Intended Scenario:	Base Condition, with DCP2
Modified By:	Angie Scangas

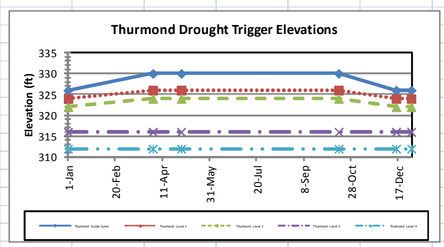
Day of Week to evaluate storage condition:	6									
Delay time in days before implementing flow change:	0									
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2									
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.								
Hours of Keowee Peak operations during 4 month refill:	120									
Maximum required Keowee weekly discharge volume	25000	0.00%	Pct of Joc support for Outflows (BPK 2012-07-24)							
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000									
Volume Reserved for Pumped Storage Cycling (acre-ft)	41000	Keo	Hart	Rus	Thur	Bad Crk				
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1086	778	625	470	312	2150	if blank, sets to UI's MinElev setting			

Plant 4	Hartwell	Same as Base	From HartwellDa	Same as Base	Same as Base	
Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**
1-Jan	1	656	654	652	646	625
1-Apr	91	660	656	654	646	625
1-May	121	660	656	654	646	625
15-Oct	288	660	656	654	646	625
15-Dec	349	656	654	652	646	625
31-Dec	365	656	654	652	646	625
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600

Plant 6	Thurmond	From Thurmondl	From Thurmondl	From Thurmondl	Same as Base	Same as Base
Date	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE

Use Fish Spawning Rule	TRUE
Use Bad Creek in Storage Calcs	FALSE
Use Russell in Storage Calcs	FALSE





SEPAPower Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

EXISTING LICENSE

FOR HDR USE ONLY	
Run #	Existing_License_73yr

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 01/11/2013 extended hydrology 04/01/2013

Stakeholder Group: Duke Energy   Needed By: ASAP

Period of Run:
- ☐ Typical Normal Conditions
- ☐ Typical Dry Conditions
- ☐ Typical Wet Conditions
- ☒ Full Record
- ☐ 14yr Record (1995 – 2008)
- ☐ Other: ______________________________

Lake Level Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Downstream Release Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Hydropower Output Format:
- ☐ Tables
- ☐ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
- ☐ Present
- ☐ Future (2066)
- ☒ Projecting
- ☐ Other: ______________________________

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	Same
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	Same
	Minimum Flow Release(cfs)		
	MinDF (cfs)		
	MaxDF (cfs)		
	Maximum Weekly Release (ac-ft)	25,000	Same

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee****	
Month	*Current Operations Baseline*	*Scenario*	*Current Operations Baseline*	*Scenario*
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

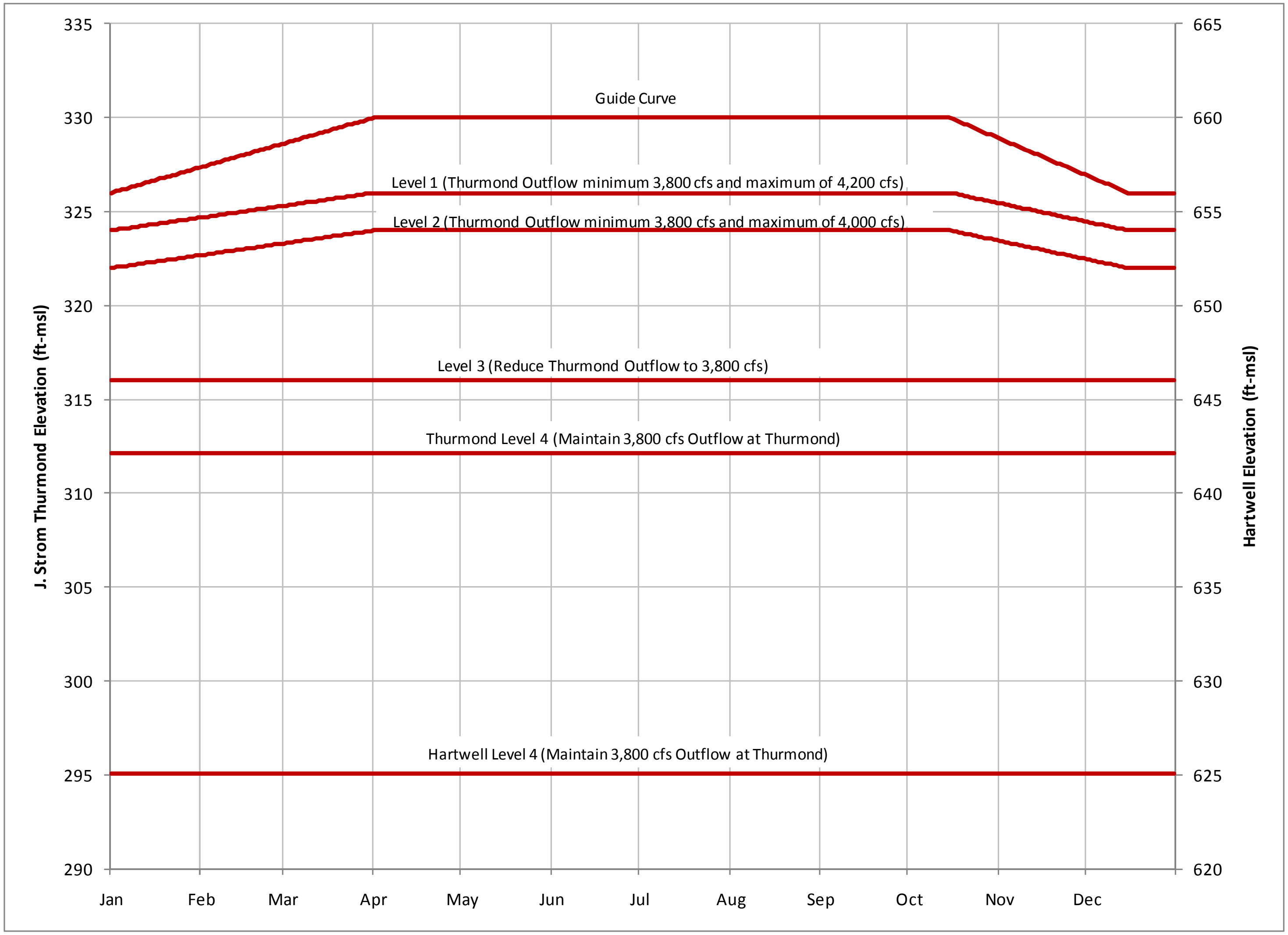
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	Same	794.6	778
February	1,080		794.6	778
March	1,080		794.6	778
April	1,080		794.6	778
May	1,080		794.6	778
June	1,080		794.6	778
July	1,080		794.6	778
August	1,080		794.6	778
September	1,080		794.6	778
October	1,080		794.6	778
November	1,080		794.6	778
December	1,080		794.6	778

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

This scenario simulates existing FERC license requirements, the requirements of the 1968 MOA as written, and the USACE DCP as defined by the USACE August 2012.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

Data updated:	11/1/2012
Intended Scenario:	Base Condition, with DCP2
Modified By:	Angie Scangas

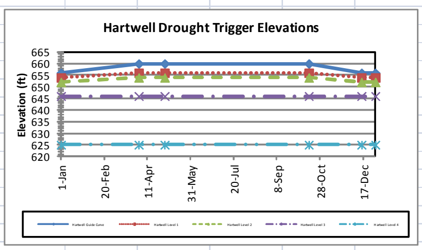
Day of Week to evaluate storage condition:	6										
Delay time in days before implementing flow change:	0										
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2										
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.									
Hours of Keowee Peak operations during 4 month refill:	120										
Maximum required Keowee weekly discharge volume	25000	0.00%	Pct of Joc support for Outflows (BPK 2012-07-24)								
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%	
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1	
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000										
Volume Reserved for Pumped Storage Cycling (acre-ft)	41000	Keo	Hart	Rus	Thur	Bad Crk					
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1086	778	625	470	312	2150	if blank, sets to UI's MinElev setting				

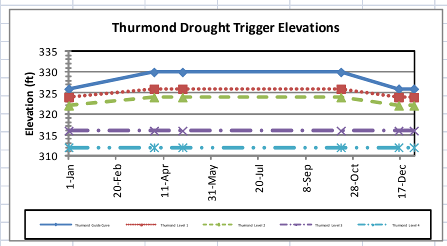
	Plant 4	Hartwell	Same as Base	From HartwellDa	Same as Base	Same as Base
	Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**

Date	Julian	Hartwell Guide Curve	Hartwell Level 1	Hartwell Level 2	Hartwell Level 3	Hartwell Level 4
Plant 4	Hartwell	Same as Base	From HartwellDa	Same as Base	Same as Base	
1-Jan	1	656	654	652	646	625
1-Apr	91	660	656	654	646	625
1-May	121	660	656	654	646	625
15-Oct	288	660	656	654	646	625
15-Dec	349	656	654	652	646	625
31-Dec	365	656	654	652	646	625
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600

Use Fish Spawning Rule	TRUE
Use Bad Creek in Storage Calcs	FALSE
Use Russell in Storage Calcs	FALSE

Date	Julian	Thurmond Guide Curve	Thurmond Level 1	Thurmond Level 2	Thurmond Level 3	Thurmond Level 4
Plant 6	Thurmond	From ThurmondI	From ThurmondI	From ThurmondI	Same as Base	Same as Base
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

BLEND 2Db V2

FOR HDR USE ONLY	
Run #	Blend2Db_v2_73yr

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 05/06/2013

Stakeholder Group: OSC   Needed By: ASAP

Period of Run:
☐ Typical Normal Conditions   ☐ Typical Dry Conditions
☐ Typical Wet Conditions   ☒ Full Record
☐ 14yr Record (1995 – 2008)   ☐ Other: ______________________________

Lake Level Output Format:

☒ Tables   ☒ Figures   ☐ Report

☒ Performance Measures Sheet

☐ Other: ______________________________

Downstream Release Output Format:

☐ Tables   ☒ Figures   ☐ Report

☒ Performance Measures Sheet

☐ Other: ______________________________

Hydropower Output Format:

☐ Tables   ☐ Figures   ☐ Report

☒ Performance Measures Sheet

☐ Other: ______________________________

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:

☐ Present   ☐ Future (2066)

☒ Projecting

☐ Other: ______________________________

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	See Attached DCP3 and LIP2 Blend2D-b forms
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	See Attached DCP3 and LIP2 Blend2D-b forms
	Minimum Flow Release(cfs)		
	MinDF (cfs)		See Attached DCP3 and LIP2 Blend2D-b forms
	MaxDF (cfs)		See Attached DCP3 and LIP2 Blend2D-b forms
	Maximum Weekly Release (ac-ft)	25,000	See Attached DCP3 and LIP2 Blend2D-b forms

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee****	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

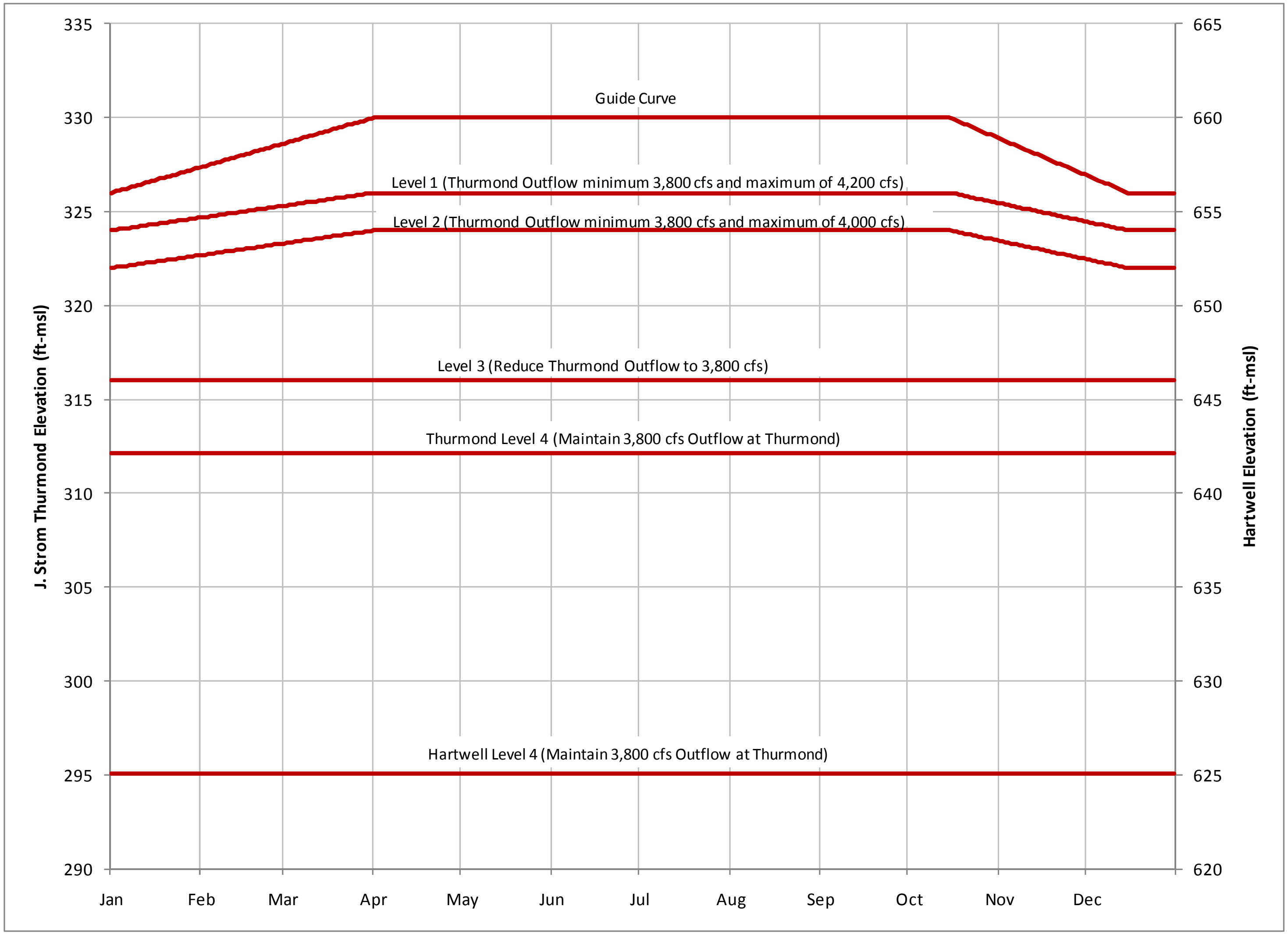
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	1096 – See Attached DCP3 and LIP2 Blend2D-b forms	794.6	796- See Attached DCP3 and LIP2 Blend2D-b forms
February	1,080	"	794.6	"
March	1,080	"	794.6	"
April	1,080	"	794.6	"
May	1,080	"	794.6	"
June	1,080	"	794.6	"
July	1,080	"	794.6	"
August	1,080	"	794.6	"
September	1,080	"	794.6	"
October	1,080	"	794.6	"
November	1,080	"	794.6	"
December	1,080	"	794.6	"

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

Keowee-Toxaway LIP implementation with Jocassee support of Keowee weekly required outflows per equal ratio of usable storage, and also restricts Jocassee refill rate. The Jocassee and Keowee drawdown is paired based on usable storage…this is achieved through discharge and pumping. LIP code will not permit Jocassee to refill via pumping if it is going to cause the two reservoir storages to be out of balance based on defined usable storage. Usable storage in Keowee-Toxaway LIP and DCP is based on full pond elevation. Note the DCP criterion was formerly the guide curve. See attached DCP3 (modifications from DCP2 highlighted in yellow cells with red text) and LIP2 Blend2D-b input forms. Blend 2D-b reflects the language from the 04/23/2013 AIP, including LIP logic revised to reference "triggered" DCP level versus "In-Effect" DCP level, and LIP gage averaging modified from 6 months to 4 months per AIP documentation.

No fish spawning lake stabilization requirements in effect.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

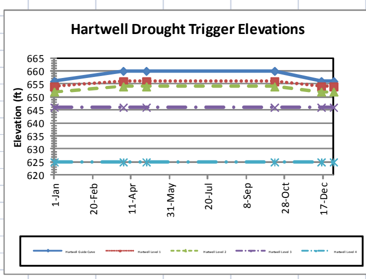
Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

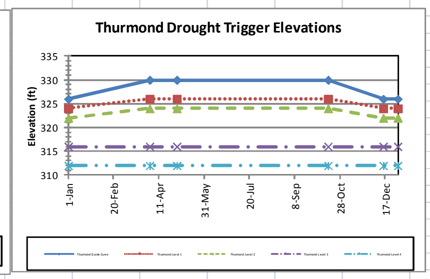
Data updated:	11/1/2012	1/31/2013	2/1/2013							
Intended Scenario:	Trial Balloon Revised Kefied for Keowee back to 75%									
Modified By:	Angie Scang:	Bkrolak	Kadamec							
Day of Week to evaluate storage condition:	6									
Delay time in days before implementing flow change:	0									
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2									
Jocassee and Keowee support reservoir storage balancing	ByAgreement		"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.							
Hours of Keowee Peak operations during 4 month refill:	120									
Maximum required Keowee weekly discharge volume	25000	**paired**	Pct of Joc support for Outflows (BPK 2012-07-24)							
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000									
Volume Reserved for Pumped Storage Cycling (acre-ft)	0	Keo	Hart	Rus	Thur	Bad Crk				
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1080	790	625	470	312	2150	if blank, sets to UI's MinElev setting			

Plant 4	Hartwell	Same as Base	From HartwellDa	Same as Base	Same as Base	
Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**
1-Jan	1	656	654	652	646	625
1-Apr	91	660	656	654	646	625
1-May	121	660	656	654	646	625
15-Oct	288	660	656	654	646	625
15-Dec	349	656	654	652	646	625
31-Dec	365	656	654	652	646	625
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600

Plant 6	Thurmond	From Thurmondl	From Thurmondl	From Thurmondl	Same as Base	Same as Base
Date	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE

Use USACE Fish Spawning Rule	TRUE
Use Bad Creek in Storage Calcs	TRUE
Use Russell in Storage Calcs	TRUE
Use Duke 100ft Elevs for Calcs	TRUE
Keowee Outflow Logic Key	75%





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

Input sheet for LIP criterion to be modeled in the Keowee Toxaway CHEOPS Model

Data updated:	8/29/2012	8/29/2012	3/22/2013	3/22/2013	4/28/2013	4/30/2013	5/6/2013	5/7/2013
Intended Scenario:	Keo-Tox LIP	Checked	Blend2D	Checked	Blend2Da	Checked	Blend2Db. Shee	Checked
Modified By:	Bkrolak	Ascangas	Bkrolak	Kadamec	Bkrolak	Ascangas	Bkrolak	Ascangas

Reservoir Critial Elevations (should be at or below the Minimum Elevation entered in the scenario being run.)

Reservoir Name	1	2	3	4	5	6
Critical Reservoir Elevation (ft, amsl)	2150.0	1080.0	791.5	625.0	470.00	312.0

	Condition Set 1		Plus Any 1 of Condition Set 2		
	Remaining Usable Reservoir Storage Less Than	USACE Drought Protocol Level	% of 6-month Long Term Avg Streamflow (Less than)	Area-Weighted US Drought Monitor (Greater than or equal to)	% of 6-month Long Term Avg Rainfall (Less than)
Normal	10000%		10000%	0	10000%
Stage 0 - Watch	90%		85%	0	85%
Stage 1		1	75%	1	75%
Stage 2		2	65%	2	65%
Stage 3		3	55%	3	55%
Stage 4	25%		40%	4	40%

Actions to be performed - Reservoir Minimum Elevation Change

Licensee Actions	Licensee Delay in implementing Actions (days)	Plant 1 Normal Minimum Pond Elevation (ft amsl)	Plant 2 Normal Minimum Pond Elevation (ft amsl)	Plant 3 Normal Minimum Pond Elevation (ft amsl)	Plant 4 Normal Minimum Pond Elevation (ft amsl)	Plant 5 Normal Minimum Pond Elevation (ft amsl)	Plant 6 Normal Minimum Pond Elevation (ft amsl)
Stage 0	1	2160	1096	796			
Stage 1	1	2160	1092	795			
Stage 2	1	2160	1087	793			
Stage 3	1	2160	1083	792			
Stage 4	1	Critical	Critical	Critical			

Actions to be performed - Maximum Keowee Weekly Releases (acre-ft)

Licensee Action (Title Only)	LIP Stage	Or Percent of Duke Usable Storage (Greater Than)	Maximum Required Weekly Keowee Release (acre-ft)
Limit 0	0	85%	25,000
Limit 0 Low	0	80%	20,000
Limit 1	1		18,750
Limit 2	2		15,000
Limit 3	3		10,000
Limit 4	4	12%	7,500
Limit 4 Low	4		1

LIP 0
max weekly vol discharge adjustment at >85% 25kaf
max weekly vol discharge adjustment at <=85% 20kaf

LIP 1 max weekly vol discharge adjustment 18,750kaf

LIP 2 max weekly vol discharge adjustment 15,000kaf

LIP 3 max weekly vol discharge adjustment 10,000kaf

LIP 4 max weekly vol discharge adjustment 7,500kaf
LIP 4 Low when usable storage <=12% weekly required volume is leakage. A non-zero number must be entered. Any value below leakage will result in leakage being released.

Actions to be performed - Owners of Large Water Withdrawal Sites

Owners of public and large water supply intakes	Owner Delay in implementing Actions (days)	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
Stage 0	14						
Stage 1	14	3.0%	3.0%	3.0%	0.0%	0.0%	0.0%
Stage 2	14	5.0%	5.0%	5.0%	0.0%	0.0%	0.0%
Stage 3	14	10.0%	10.0%	10.0%	0.0%	0.0%	0.0%
Stage 4	14	20.0%	20.0%	20.0%	0.0%	0.0%	0.0%

Disable Duke Spawn in LIP 0 and Higher	TRUE
Disable USACE DCP Recovery Delay	TRUE

FALSE (default) assumes LIP recovery of stages uses the DCP stage in effect.
TRUE indicates the 2 foot USACE DCP recovery delay into higher DCP elevation band is DISABLED for triggered DCP to be used in LIP logic. Added BPK 2013-04-28

Date	122-Day Running Average of 3 Gage Average Flow (cfs)			Date	Avg of Composite Gage Flow by Day and Mon (cfs)
1/1/1939	124			1/1/2000	322.6
1/2/1939	120			1/2/2000	323.1
1/3/1939	118.7			1/3/2000	323.9
1/4/1939	118			1/4/2000	324.6
1/5/1939	193.4			1/5/2000	326.1
1/6/1939	210			1/6/2000	327
1/7/1939	211			1/7/2000	328.1
1/8/1939	208.3			1/8/2000	329.4
1/9/1939	204			1/9/2000	330.2

CC LOW SENSITIVITY
BASELINE – CC LOW SENSITIVITY

FOR HDR USE ONLY	
Run #	BaseProjected_2012-08-23_73yr_ccLow

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy Date Requested: 08/23/2012 extended hydrology 04/01/2013

Stakeholder Group: Duke Energy Needed By: ASAP

Period of Run:
- ☐ Typical Normal Conditions
- ☐ Typical Dry Conditions
- ☐ Typical Wet Conditions
- ☒ Full Record
- ☐ 14yr Record (1995 – 2008)
- ☐ Other: ______________________________

Lake Level Output Format:
- ☐ Tables ☒ Figures ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ____

Downstream Release Output Format:
- ☐ Tables ☒ Figures ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ____

Hydropower Output Format:
- ☐ Tables ☐ Figures ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ____

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
- ☐ Present ☐ Future (2066)
- ☒ Projecting
- ☐ Other: ____

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	Same
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	Same
	Minimum Flow Release(cfs)		
	MinDF (cfs)		
	MaxDF (cfs)		
	Maximum Weekly Release (ac-ft)	25,000	Same

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee**	
Month	*Current Operations Baseline*	*Scenario*	*Current Operations Baseline*	*Scenario*
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

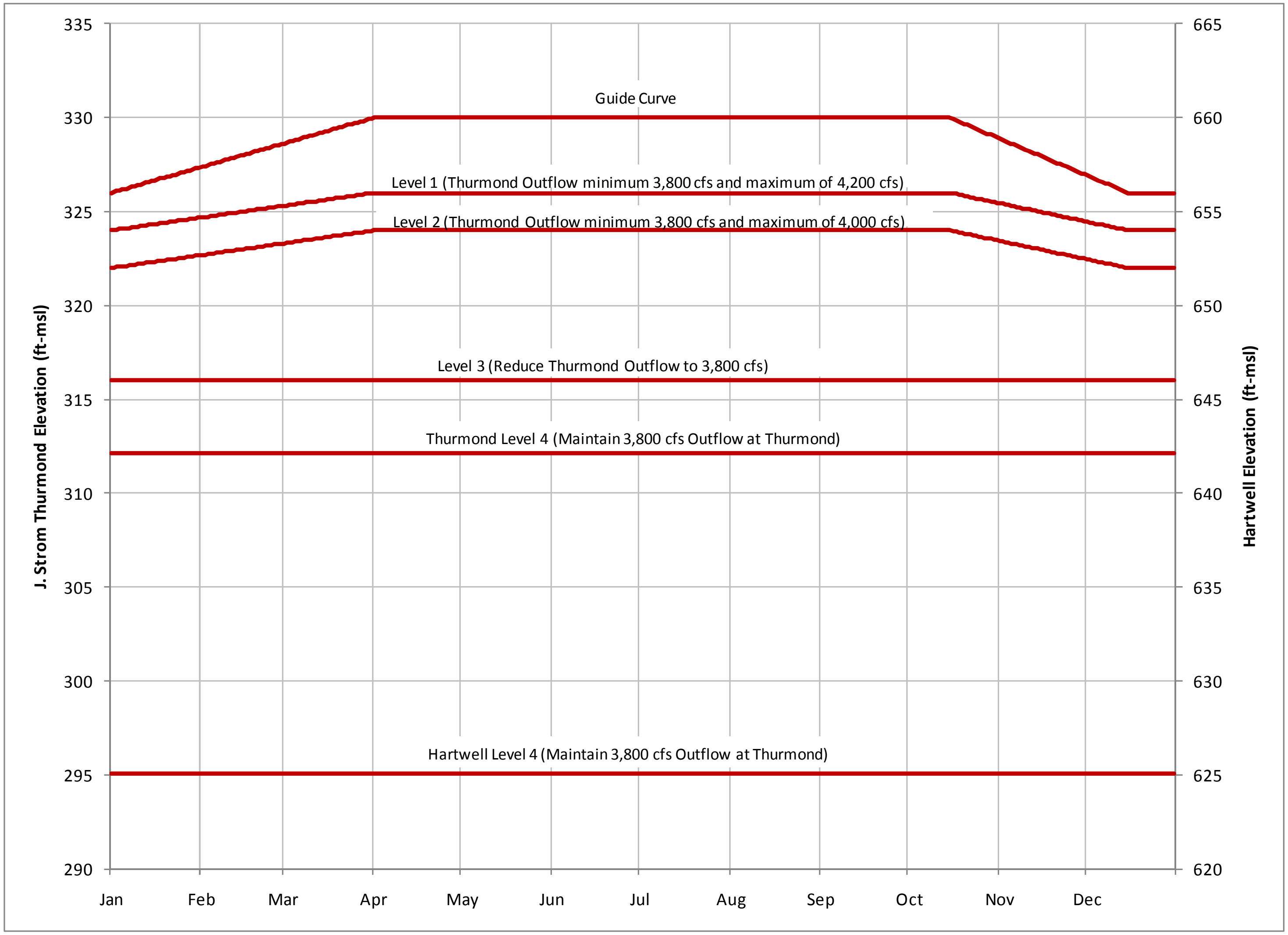
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	Same	794.6	Same
February	1,080		794.6	
March	1,080		794.6	
April	1,080		794.6	
May	1,080		794.6	
June	1,080		794.6	
July	1,080		794.6	
August	1,080		794.6	
September	1,080		794.6	
October	1,080		794.6	
November	1,080		794.6	
December	1,080		794.6	

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

Evaporation modified to simulate potential low impacts of climate change. Evaporation coefficients increased by 10 percent to account for 3 degree temperature increase.

Specific Questions this Model Run Should Answer

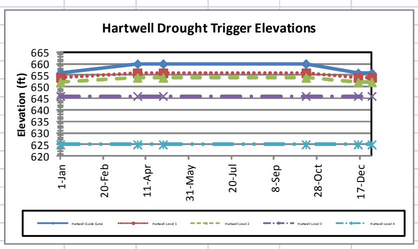
Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

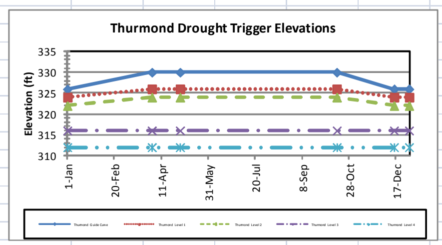
Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

Data updated:	11/1/2012
Intended Scenario:	Base Condition, with DCP2
Modified By:	Angie Scangas

Day of Week to evaluate storage condition:	6										
Delay time in days before implementing flow change:	0										
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2										
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.									
Hours of Keowee Peak operations during 4 month refill:	120										
Maximum required Keowee weekly discharge volume	25000	0.00%	Pct of Joc support for Outflows (BPK 2012-07-24)								
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%	
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1	
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000										
Volume Reserved for Pumped Storage Cycling (acre-ft)	41000	Keo	Hart	Rus	Thur	Bad Crk					
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1086	778	625	470	312	2150	if blank, sets to UI's MinElev setting				

	Plant 4	Hartwell	Same as Base	From Hartwell Da	Same as Base	Same as Base			Plant 6	Thurmond	From Thurmond	From Thurmond	From Thurmond	Same as Base	Same as Base
	Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**		**Date**	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
	1-Jan	1	656	654	652	646	625		1-Jan	1	326	324	322	316	312
	1-Apr	91	660	656	654	646	625		1-Apr	91	330	326	324	316	312
	1-May	121	660	656	654	646	625		1-May	121	330	326	324	316	312
	15-Oct	288	660	656	654	646	625		15-Oct	288	330	326	324	316	312
	15-Dec	349	656	654	652	646	625		15-Dec	349	326	324	322	316	312
	31-Dec	365	656	654	652	646	625		31-Dec	365	326	324	322	316	312
	Action - min		4500	4200	4000	3800	3600		Action - min		4500	4200	4000	3800	3600
	Action - max		-	4200	4000	3800	3600		Action - max		-	4200	4000	3800	3600
Use Fish Spawning Rule	TRUE								<=10Pct			4000	3800		
Use Bad Creek in Storage Calcs	FALSE								Nov-Jan				3600	3100	3100
Use Russell in Storage Calcs	FALSE								Extend Winter flows to Feb?						FALSE





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

EXISTING LICENSE – CC LOW SENSITIVITY

FOR HDR USE ONLY	
Run #	Existing_License_73yr_ ccLow

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 01/11/2013 extended hydrology 04/01/2013

Stakeholder Group: Duke Energy   Needed By: ASAP

Period of Run:
- ☐ Typical Normal Conditions
- ☐ Typical Dry Conditions
- ☐ Typical Wet Conditions
- ☒ Full Record
- ☐ 14yr Record (1995 – 2008)
- ☐ Other: ______________________________

Lake Level Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Downstream Release Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Hydropower Output Format:
- ☐ Tables
- ☐ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
- ☐ Present
- ☐ Future (2066)
- ☒ Projecting
- ☐ Other: ______________________________

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	Same
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	Same
	Minimum Flow Release(cfs)		
	MinDF (cfs)		
	MaxDF (cfs)		
	Maximum Weekly Release (ac-ft)	25,000	Same

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee**	
Month	*Current Operations Baseline*	*Scenario*	*Current Operations Baseline*	*Scenario*
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

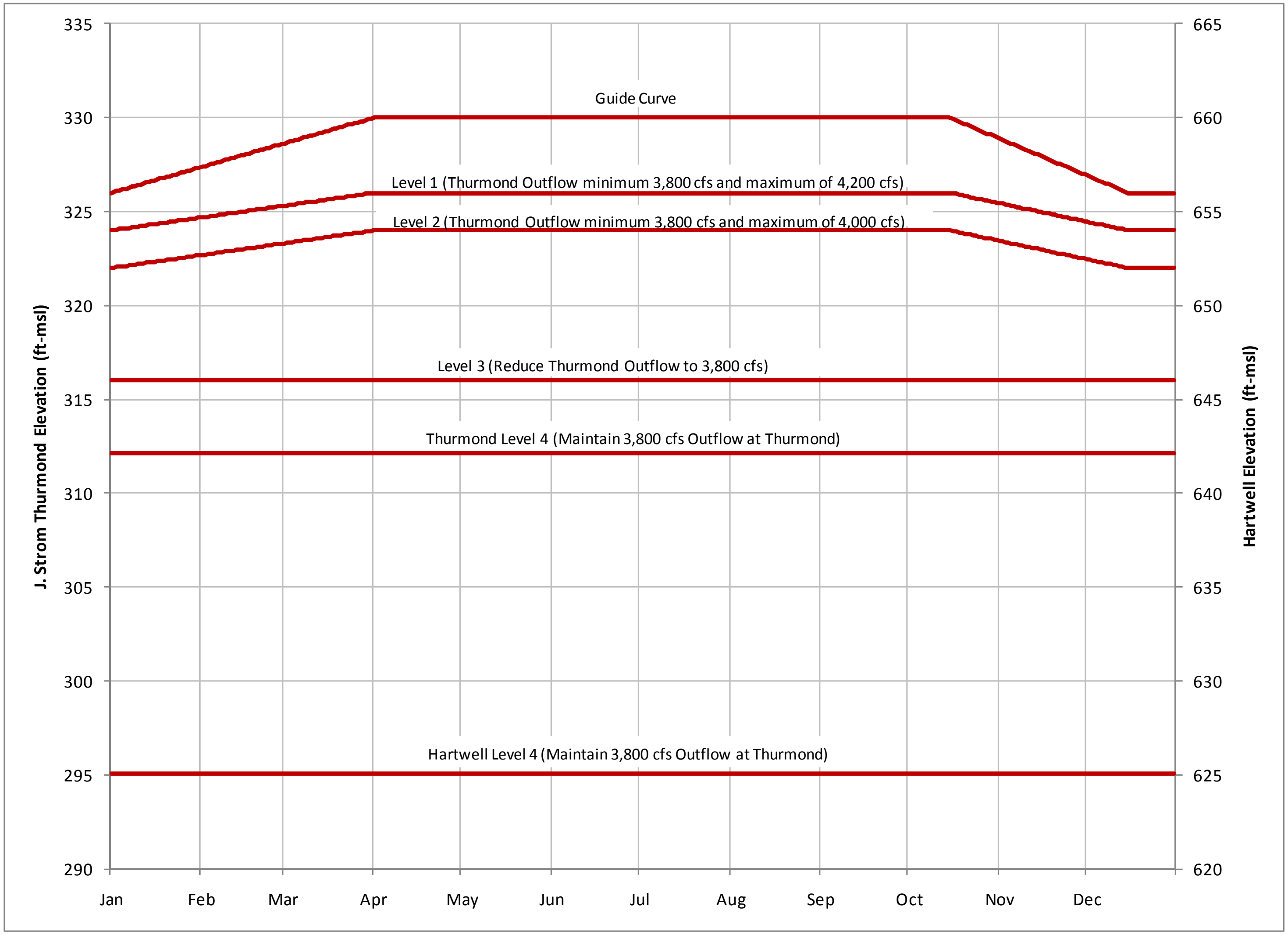
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	Same	794.6	778
February	1,080		794.6	778
March	1,080		794.6	778
April	1,080		794.6	778
May	1,080		794.6	778
June	1,080		794.6	778
July	1,080		794.6	778
August	1,080		794.6	778
September	1,080		794.6	778
October	1,080		794.6	778
November	1,080		794.6	778
December	1,080		794.6	778

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

This scenario simulates existing FERC license requirements, the requirements of the 1968 MOA as written, and the USACE DCP as defined by the USACE August 2012. Evaporation modified to simulate potential low impacts of climate change. Evaporation coefficients increased by 10 percent to account for 3 degree temperature increase.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

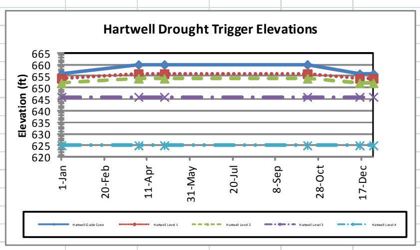
Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

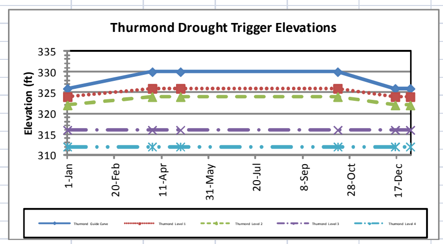
Data updated:	11/1/2012
Intended Scenario:	Base Condition, with DCP2
Modified By:	Angie Scangas

Day of Week to evaluate storage condition:	6									
Delay time in days before implementing flow change:	0									
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2									
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.								
Hours of Keowee Peak operations during 4 month refill:	120									
Maximum required Keowee weekly discharge volume	25000	0.00%	Pct of Joc support for Outflows (BPK 2012-07-24)							
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000									
Volume Reserved for Pumped Storage Cycling (acre-ft)	41000	Keo	Hart	Rus	Thur	Bad Crk				
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1086	778	625	470	312	2150	if blank, sets to UI's MinElev setting			

	Plant 4	Hartwell	Same as Base	From Hartwell Da	Same as Base	Same as Base	
	Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**
	1-Jan	1	656	654	652	646	625
	1-Apr	91	660	656	654	646	625
	1-May	121	660	656	654	646	625
	15-Oct	288	660	656	654	646	625
	15-Dec	349	656	654	652	646	625
	31-Dec	365	656	654	652	646	625
	Action - min		4500	4200	4000	3800	3600
	Action - max		-	4200	4000	3800	3600
Use Fish Spawning Rule	TRUE						
Use Bad Creek in Storage Calcs	FALSE						
Use Russell in Storage Calcs	FALSE						

Plant 6	Thurmond	From Thurmond I	From Thurmond I	From Thurmond I	Same as Base	Same as Base
Date	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

BLEND 2Db V2 – CC LOW SENSITIVITY

FOR HDR USE ONLY	
Run #	Blend2Db_v2_CCLow

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 05/06/2013

Stakeholder Group: OSC   Needed By: ASAP

Period of Run:
- ☐ Typical Normal Conditions
- ☐ Typical Dry Conditions
- ☐ Typical Wet Conditions
- ☒ Full Record
- ☐ 14yr Record (1995 – 2008)
- ☐ Other: ______________________________

Lake Level Output Format:
- ☒ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Downstream Release Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Hydropower Output Format:
- ☐ Tables
- ☐ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________________

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
- ☐ Present
- ☐ Future (2066)
- ☒ Projecting
- ☐ Other: ______________________________

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	See Attached DCP3 and LIP2 Blend2D-b forms
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	See Attached DCP3 and LIP2 Blend2D-b forms
	Minimum Flow Release(cfs)		
	MinDF (cfs)		See Attached DCP3 and LIP2 Blend2D-b forms
	MaxDF (cfs)		See Attached DCP3 and LIP2 Blend2D-b forms
	Maximum Weekly Release (ac-ft)	25,000	See Attached DCP3 and LIP2 Blend2D-b forms

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee****	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

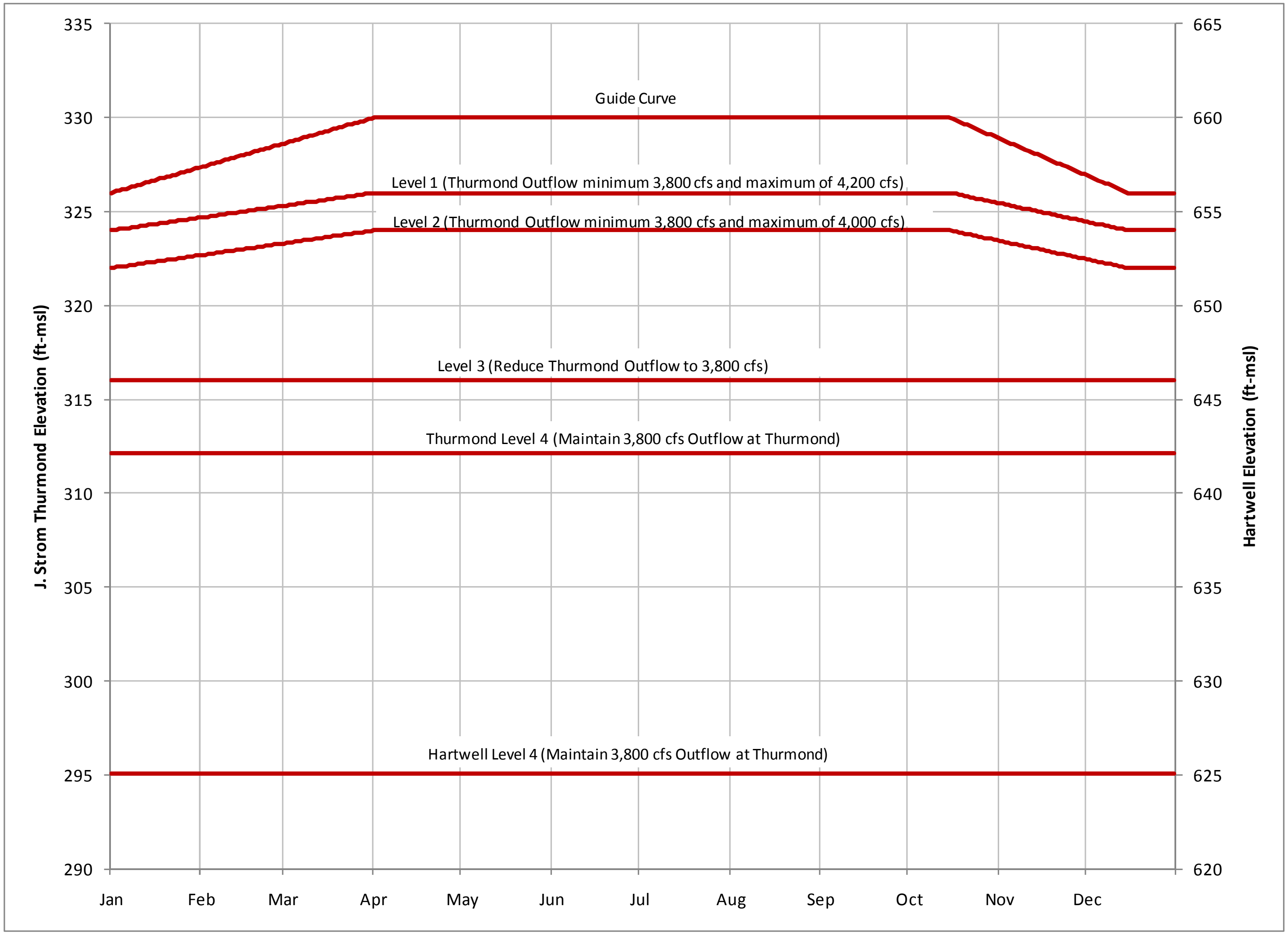
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	1096 – See Attached DCP3 and LIP2 Blend2D-b forms	794.6	796- See Attached DCP3 and LIP2 Blend2D-b forms
February	1,080	"	794.6	"
March	1,080	"	794.6	"
April	1,080	"	794.6	"
May	1,080	"	794.6	"
June	1,080	"	794.6	"
July	1,080	"	794.6	"
August	1,080	"	794.6	"
September	1,080	"	794.6	"
October	1,080	"	794.6	"
November	1,080	"	794.6	"
December	1,080	"	794.6	"

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

Keowee-Toxaway LIP implementation with Jocassee support of Keowee weekly required outflows per equal ratio of usable storage, and also restricts Jocassee refill rate. The Jocassee and Keowee drawdown is paired based on usable storage…this is achieved through discharge and pumping. LIP code will not permit Jocassee to refill via pumping if it is going to cause the two reservoir storages to be out of balance based on defined usable storage. Usable storage in Keowee-Toxaway LIP and DCP is based on full pond elevation. Note the DCP criterion was formerly the guide curve. See attached DCP3 (modifications from DCP2 highlighted in yellow cells with red text) and LIP2 Blend2D-b input forms. Blend 2D-b reflects the language from the 04/23/2013 AIP, including LIP logic revised to reference "triggered" DCP level versus "In-Effect" DCP level, and LIP gage averaging modified from 6 months to 4 months per AIP documentation. Evaporation modified to simulate potential low impacts of climate change. Evaporation coefficients increased by 10 percent to account for 3 degree temperature increase.

No fish spawning lake stabilization requirements in effect.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

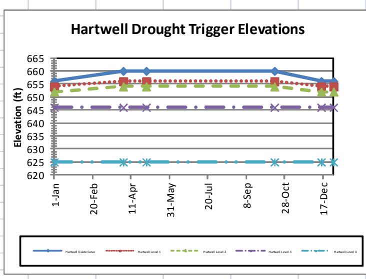
Data updated:	11/1/2012	1/31/2013	2/1/2013
Intended Scenario:	Trial Balloon Revised Kefied for Keowee back to 75%		
Modified By:	Angie Scanga	Bkrolak	Kadamec

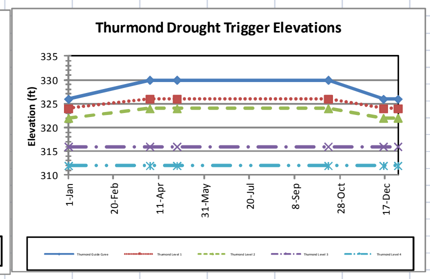
Day of Week to evaluate storage condition:	6									
Delay time in days before implementing flow change:	0									
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2									
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.								
Hours of Keowee Peak operations during 4 month refill:	120									
Maximum required Keowee weekly discharge volume	25000	paired	Pct of Joc support for Outflows (BPK 2012-07-24)							
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000									
Volume Reserved for Pumped Storage Cycling (acre-ft)	0	Keo	Hart	Rus	Thur	Bad Crk				
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1080	790	625	470	312	2150	if blank, sets to UI's MinElev setting			

Plant 4	Hartwell	Same as Base	From HartwellDa	Same as Base	Same as Base	
Date	Julian	Hartwell Guide Curve	Hartwell Level 1	Hartwell Level 2	Hartwell Level 3	Hartwell Level 4
1-Jan	1	656	654	652	646	625
1-Apr	91	660	656	654	646	625
1-May	121	660	656	654	646	625
15-Oct	288	660	656	654	646	625
15-Dec	349	656	654	652	646	625
31-Dec	365	656	654	652	646	625
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600

Plant 6	Thurmond	From ThurmondI	From ThurmondI	From ThurmondI	Same as Base	Same as Base
Date	Julian	Thurmond Guide Curve	Thurmond Level 1	Thurmond Level 2	Thurmond Level 3	Thurmond Level 4
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE

Use USACE Fish Spawning Rule	TRUE
Use Bad Creek in Storage Calcs	TRUE
Use Russell in Storage Calcs	TRUE
Use Duke 100ft Elevs for Calcs	TRUE
Keowee Outflow Logic Key	75%





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

Input sheet for LIP criterion to be modeled in the Keowee Toxaway CHEOPS Model

Data updated:	8/29/2012	8/29/2012	3/22/2013	3/22/2013	4/28/2013	4/30/2013	5/6/2013	5/7/2013
Intended Scenario:	Keo-Tox LIP	Checked	Blend2D	Checked	Blend2Da	Checked	Blend2Db. Shee	Checked
Modified By:	Bkrolak	Ascangas	Bkrolak	Kadamec	Bkrolak	Ascangas	Bkrolak	Ascangas

Reservoir Critial Elevations (should be at or below the Minimum Elevation entered in the scenario being run.)

Reservoir Name	1	2	3	4	5	6
Critical Reservoir Elevation (ft, amsl)	2150.0	1080.0	791.5	625.0	470.00	312.0

	Condition Set 1		Plus Any 1 of Condition Set 2		
	Remaining Usable Reservoir Storage Less Than	USACE Drought Protocol Level	% of 6-month Long Term Avg Streamflow (Less than)	Area-Weighted US Drought Monitor (Greater than or equal to)	% of 6-month Long Term Avg Rainfall (Less than)
Normal	10000%		10000%	0	10000%
Stage 0 - Watch	90%		85%	0	85%
Stage 1		1	75%	1	75%
Stage 2		2	65%	2	65%
Stage 3		3	55%	3	55%
Stage 4	25%		40%	4	40%

Actions to be performed - Reservoir Minimum Elevation Change

Licensee Actions	Licensee Delay in implementing Actions (days)	Plant 1 Normal Minimum Pond Elevation (ft amsl)	Plant 2 Normal Minimum Pond Elevation (ft amsl)	Plant 3 Normal Minimum Pond Elevation (ft amsl)	Plant 4 Normal Minimum Pond Elevation (ft amsl)	Plant 5 Normal Minimum Pond Elevation (ft amsl)	Plant 6 Normal Minimum Pond Elevation (ft amsl)
Stage 0	1	2160	1096	796			
Stage 1	1	2160	1092	795			
Stage 2	1	2160	1087	793			
Stage 3	1	2160	1083	792			
Stage 4	1	Critical	Critical	Critical			

Actions to be performed - Maximum Keowee Weekly Releases (acre-ft)

Licensee Action (Title Only)	LIP Stage	Or Percent of Duke Usable Storage (Greater Than)	Maximum Required Weekly Keowee Release (acre-ft)
Limit 0	0	85%	25,000
Limit 0 Low	0	80%	20,000
Limit 1	1		18,750
Limit 2	2		15,000
Limit 3	3		10,000
Limit 4	4	12%	7,500
Limit 4 Low	4		1

LIP 0
max weekly vol discharge adjustment at >85% 25kaf
max weekly vol discharge adjustment at <=85% 20kaf

LIP 1 max weekly vol discharge adjustment 18,750kaf

LIP 2 max weekly vol discharge adjustment 15,000kaf

LIP 3 max weekly vol discharge adjustment 10,000kaf

LIP 4 max weekly vol discharge adjustment 7,500kaf
LIP 4 Low when usable storage <=12% weekly required volume is leakage. A non-zero number must be entered. Any value below leakage will result in leakage being released.

Actions to be performed - Owners of Large Water Withdrawal Sites

Owners of public and large water supply intakes	Owner Delay in implementing Actions (days)	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
Stage 0	14						
Stage 1	14	3.0%	3.0%	3.0%	0.0%	0.0%	0.0%
Stage 2	14	5.0%	5.0%	5.0%	0.0%	0.0%	0.0%
Stage 3	14	10.0%	10.0%	10.0%	0.0%	0.0%	0.0%
Stage 4	14	20.0%	20.0%	20.0%	0.0%	0.0%	0.0%

Disable Duke Spawn in LIP 0 and Higher	TRUE
Disable USACE DCP Recovery Delay	TRUE

FALSE (default) assumes LIP recovery of stages uses the DCP stage in effect.
TRUE indicates the 2 foot USACE DCP recovery delay into higher DCP elevation band is DISABLED for triggered DCP to be used in LIP logic. Added BPK 2013-04-28

Date	122-Day Running Average of 3 Gage Average Flow (cfs)		Date	Avg of Composite Gage Flow by Day and Mon (cfs)
1/1/1939	124		1/1/2000	322.6
1/2/1939	120		1/2/2000	323.1
1/3/1939	118.7		1/3/2000	323.9
1/4/1939	118		1/4/2000	324.6
1/5/1939	193.4		1/5/2000	326.1
1/6/1939	210		1/6/2000	327
1/7/1939	211		1/7/2000	328.1
1/8/1939	208.3		1/8/2000	329.4
1/9/1939	204		1/9/2000	330.2

CC HIGH SENSITIVITY
BASELINE – CC HIGH SENSITIVITY

FOR HDR USE ONLY	
Run #	BaseProjected_2012-08-23_73yr_ccHigh

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 08/23/2012 extended hydrology 04/01/2013

Stakeholder Group: Duke Energy   Needed By: ASAP

Period of Run:
☐ Typical Normal Conditions ☐ Typical Dry Conditions
☐ Typical Wet Conditions ☒ Full Record
☐ 14yr Record (1995 – 2008) ☐ Other: ______________________

Lake Level Output Format:
☐ Tables ☒ Figures ☐ Report
☒ Performance Measures Sheet
☐ Other: ______________________

Downstream Release Output Format:
☐ Tables ☒ Figures ☐ Report
☒ Performance Measures Sheet
☐ Other: ______________________

Hydropower Output Format:
☐ Tables ☐ Figures ☐ Report
☒ Performance Measures Sheet
☐ Other: ______________________

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.
Water Withdrawal Format:

☐ Present ☐ Future (2066)
☒ Projecting
☐ Other: ______________________

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	Same
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	Same
	Minimum Flow Release(cfs)		
	MinDF (cfs)		
	MaxDF (cfs)		
	Maximum Weekly Release (ac-ft)	25,000	Same

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee****	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

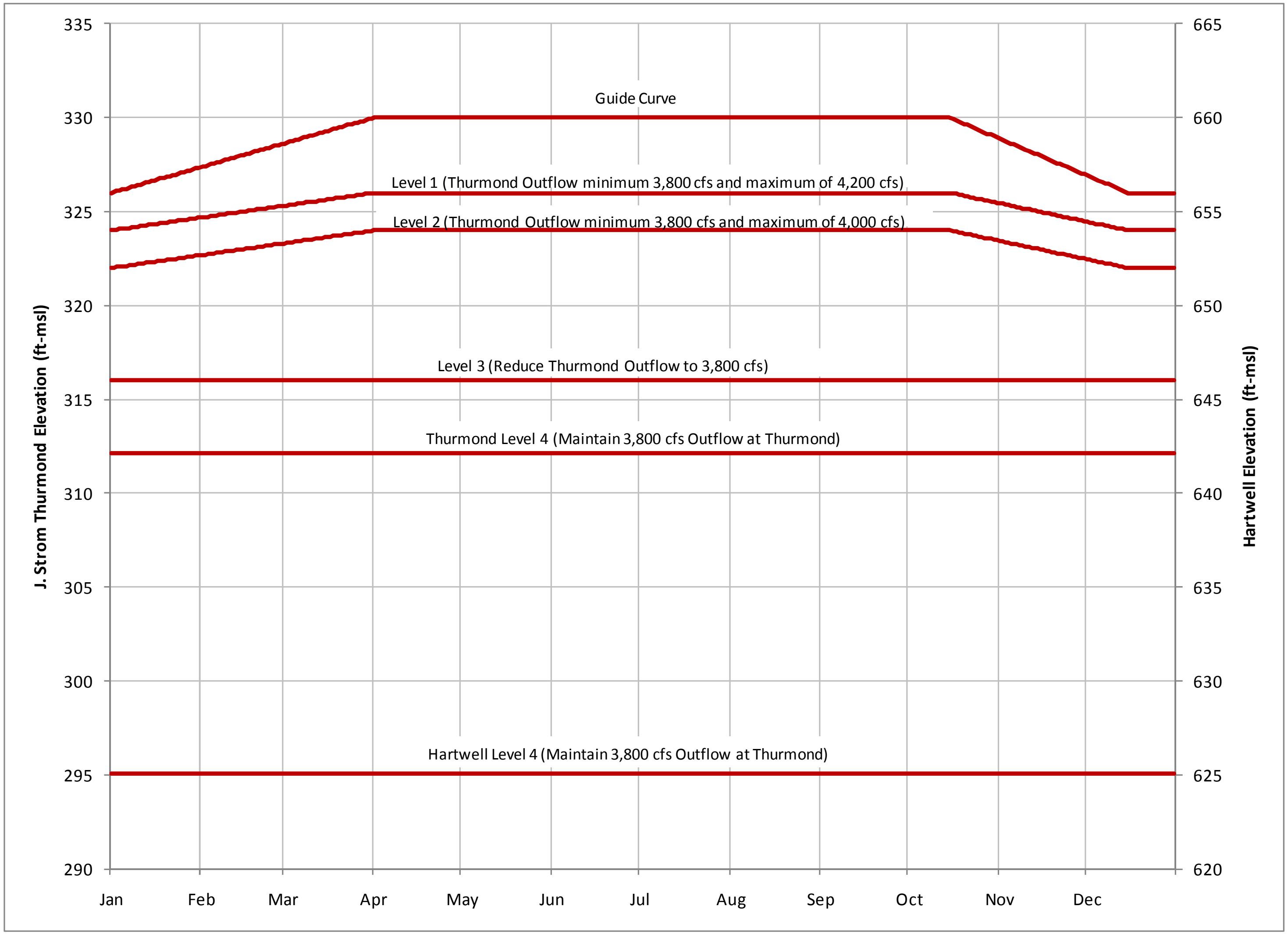
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee*	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	Same	794.6	Same
February	1,080		794.6	
March	1,080		794.6	
April	1,080		794.6	
May	1,080		794.6	
June	1,080		794.6	
July	1,080		794.6	
August	1,080		794.6	
September	1,080		794.6	
October	1,080		794.6	
November	1,080		794.6	
December	1,080		794.6	

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

Inflows and evaporation modified to simulate potential high impacts of climate change. Evaporation coefficients increased by 20 percent to account for 6 degree temperature increase and inflows reduced by 10 percent.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

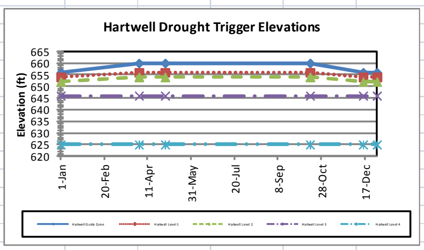
Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

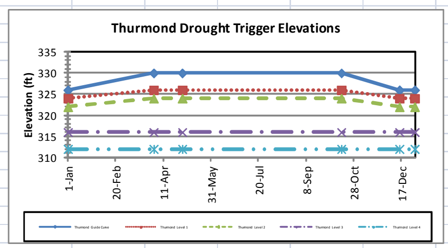
Data updated:	11/1/2012
Intended Scenario:	Base Condition, with DCP2
Modified By:	Angie Scangas

Day of Week to evaluate storage condition:	6										
Delay time in days before implementing flow change:	0										
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2										
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.									
Hours of Keowee Peak operations during 4 month refill:	120										
Maximum required Keowee weekly discharge volume	25000	0.00%	Pct of Joc support for Outflows (BPK 2012-07-24)								
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%	
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1	
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000										
Volume Reserved for Pumped Storage Cycling (acre-ft)	41000	Keo	Hart	Rus	Thur	Bad Crk					
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1086	778	625	470	312	2150	if blank, sets to UI's MinElev setting				

	Plant 4	Hartwell	Same as Base	From Hartwell Da	Same as Base	Same as Base	
	Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**
	1-Jan	1	656	654	652	646	625
	1-Apr	91	660	656	654	646	625
	1-May	121	660	656	654	646	625
	15-Oct	288	660	656	654	646	625
	15-Dec	349	656	654	652	646	625
	31-Dec	365	656	654	652	646	625
	Action - min		4500	4200	4000	3800	3600
	Action - max		-	4200	4000	3800	3600
Use Fish Spawning Rule	TRUE						
Use Bad Creek in Storage Calcs	FALSE						
Use Russell in Storage Calcs	FALSE						

Plant 6	Thurmond	From Thurmond	From Thurmond	From Thurmond	Same as Base	Same as Base
Date	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

EXISTING LICENSE – CC HIGH SENSITIVITY

FOR HDR USE ONLY	
Run #	Existing_License_73yr_ccHigh

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy   Date Requested: 01/11/2013 extended hydrology 04/01/2013

Stakeholder Group: Duke Energy   Needed By: ASAP

Period of Run:
☐ Typical Normal Conditions   ☐ Typical Dry Conditions
☐ Typical Wet Conditions   ☒ Full Record
☐ 14yr Record (1995 – 2008)   ☐ Other: ______________________________

Lake Level Output Format:
☐ Tables   ☒ Figures   ☐ Report
☒ Performance Measures Sheet
☐ Other: ____

Downstream Release Output Format:
☐ Tables   ☒ Figures   ☐ Report
☒ Performance Measures Sheet
☐ Other: ____

Hydropower Output Format:
☐ Tables   ☐ Figures   ☐ Report
☒ Performance Measures Sheet
☐ Other: ____

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
☐ Present   ☐ Future (2066)
☒ Projecting
☐ Other: ____

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	Same
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	Same
	Minimum Flow Release(cfs)		
	MinDF (cfs)		
	MaxDF (cfs)		
	Maximum Weekly Release (ac-ft)	25,000	Same

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		*Lake Keowee**	
Month	*Current Operations Baseline*	*Scenario*	*Current Operations Baseline*	*Scenario*
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

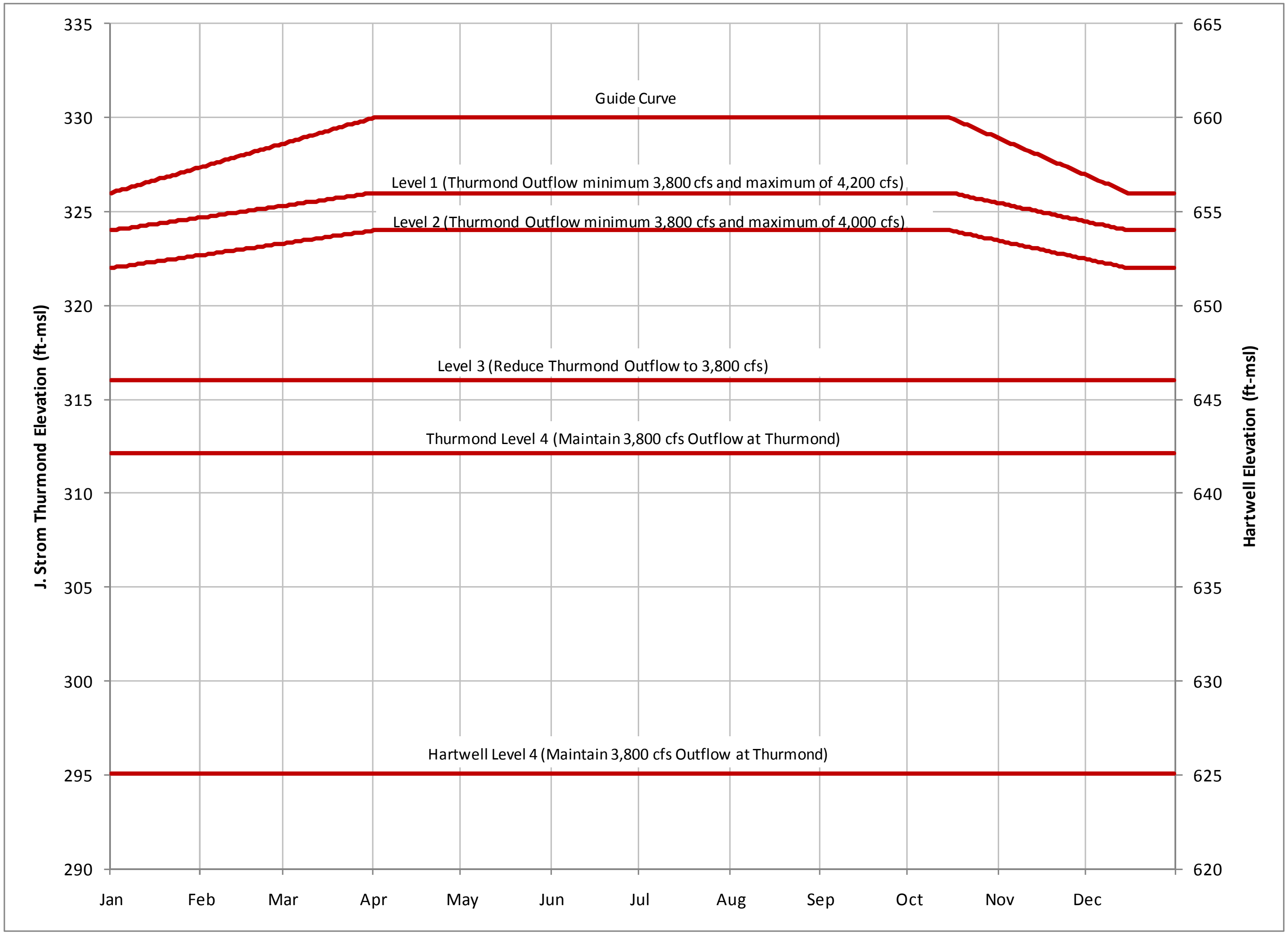
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	Same	794.6	778
February	1,080		794.6	778
March	1,080		794.6	778
April	1,080		794.6	778
May	1,080		794.6	778
June	1,080		794.6	778
July	1,080		794.6	778
August	1,080		794.6	778
September	1,080		794.6	778
October	1,080		794.6	778
November	1,080		794.6	778
December	1,080		794.6	778

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

This scenario simulates existing FERC license requirements, the requirements of the 1968 MOA as written, and the USACE DCP as defined by the USACE August 2012. Inflows and evaporation modified to simulate potential high impacts of climate change. Evaporation coefficients increased by 20 percent to account for 6 degree temperature increase and inflows reduced by 10 percent.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

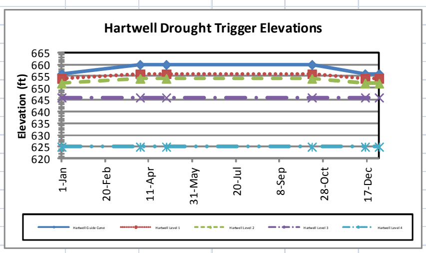
Data updated:	11/1/2012
Intended Scenario:	Base Condition, with DCP2
Modified By:	Angie Scangas

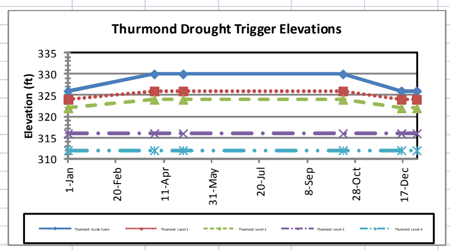
Day of Week to evaluate storage condition:	6										
Delay time in days before implementing flow change:	0										
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2										
Jocassee and Keowee support reservoir storage balancing	ByAgreement		"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.								
Hours of Keowee Peak operations during 4 month refill:	120										
Maximum required Keowee weekly discharge volume	25000	0.00%	Pct of Joc support for Outflows (BPK 2012-07-24)								
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%	
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1	
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000										
Volume Reserved for Pumped Storage Cycling (acre-ft)	41000	Keo	Hart	Rus	Thur	Bad Crk					
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1086	778	625	470	312	2150	if blank, sets to UI's MinElev setting				

Plant 4	Hartwell	Same as Base	From HartwellDa	Same as Base	Same as Base
Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**
1-Jan	1	656	654	652	646	625
1-Apr	91	660	656	654	646	625
1-May	121	660	656	654	646	625
15-Oct	288	660	656	654	646	625
15-Dec	349	656	654	652	646	625
31-Dec	365	656	654	652	646	625
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600

Use Fish Spawning Rule	TRUE
Use Bad Creek in Storage Calcs	FALSE
Use Russell in Storage Calcs	FALSE

Plant 6	Thurmond	From ThurmondL	From ThurmondL	From ThurmondL	Same as Base	Same as Base
Date	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE





SEPA Power Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

BLEND 2Db V2 – CC HIGH SENSITIVITY

FOR HDR USE ONLY	
Run #	Blend2Db_v2_ccHigh

SAVANNAH RIVER CHEOPS SCENARIO INPUT SHEET
Request For Operations Model Run

Originator: Duke Energy　　Date Requested: 05/06/2013

Stakeholder Group: OSC　　Needed By: ASAP

Period of Run:
- ☐ Typical Normal Conditions
- ☐ Typical Dry Conditions
- ☐ Typical Wet Conditions
- ☒ Full Record
- ☐ 14yr Record (1995 – 2008)
- ☐ Other: ______________________

Lake Level Output Format:
- ☒ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________

Downstream Release Output Format:
- ☐ Tables
- ☒ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________

Hydropower Output Format:
- ☐ Tables
- ☐ Figures
- ☐ Report
- ☒ Performance Measures Sheet
- ☐ Other: ______________________

Directions: Complete the entire form, including the specific areas of interest that are targeted by the specific reservoir or flow parameters included in this scenario. The Current Operations Baseline parameters are fixed. Use the "Scenario" column to add new model parameters. Elevations are in feet based on 1929 Vertical datum. Flow parameters are in cubic feet per second (cfs). Please contact Chris Ey at (704) 342-7385 or Chris.Ey@HDRInc.com with questions or to submit form.

Water Withdrawal Format:
- ☐ Present
- ☐ Future (2066)
- ☒ Projecting
- ☐ Other: ______________________

Facility	*Constraint*	*Current Operations Baseline*	*Scenario*
JOCASSEE DEVELOPMENT			
Lake Jocassee	Normal Operating Ranges for Lake Levels	See Attached	See Attached DCP3 and LIP2 Blend2D-b forms
KEOWEE DEVELOPMENT			
Lake Keowee & PH	Normal Operating Ranges for Lake Levels	See Attached	See Attached DCP3 and LIP2 Blend2D-b forms
	Minimum Flow Release(cfs)		
	MinDF (cfs)		See Attached DCP3 and LIP2 Blend2D-b forms
	MaxDF (cfs)		See Attached DCP3 and LIP2 Blend2D-b forms
	Maximum Weekly Release (ac-ft)	25,000	See Attached DCP3 and LIP2 Blend2D-b forms

MinDF = Minimum Average Daily Flow Release
MaxDF = Maximum Average Daily Flow Release
PH = Powerhouse

Target Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee****	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,106	Same	796	Same
February	1,106.9		796.8	
March	1,107.7		797.5	
April	1,108.6		798.3	
May	1,109.5		799	
June	1,109.5		799	
July	1,109.5		799	
August	1,109.5		799	
September	1,109.5		799	
October	Oct 15 - 1,109.5		Oct 15 - 799	
November	1,108.7		798.3	
December	1,107.4		797.2	

*Since Keowee reservoir is not required in normal conditions to release more than the wicket gate leakage of 50 cfs, the CHEOPS model is structured to reduce or eliminate outflows from the reservoir. This duplicates Duke's operational history to retain water in the Jocassee-Keowee pumped storage system for pumping and generating cycles. Because of this unique requirement, the model's target curve is not followed as strictly specified under normal hydroelectric reservoir operating conditions. The model will not schedule discretionary releases from Keowee unless the reservoir is nearing full pond and available storage for capturing runoff is reduced.

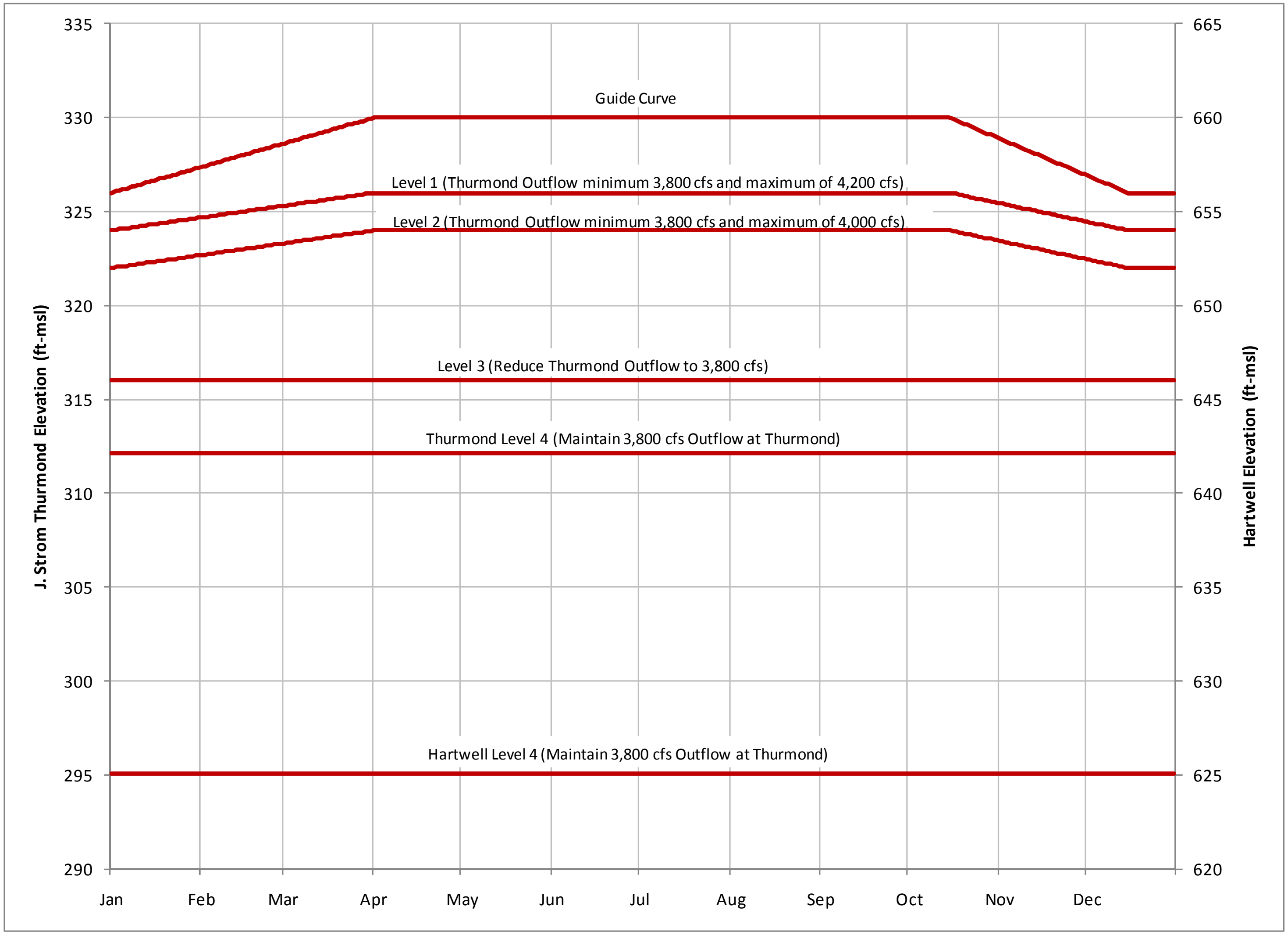
Maximum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,110	Same	800	Same
February	1,110		800	
March	1,110		800	
April	1,110		800	
May	1,110		800	
June	1,110		800	
July	1,110		800	
August	1,110		800	
September	1,110		800	
October	1,110		800	
November	1,110		800	
December	1,110		800	

Minimum Elevations as of Day 1 of Each Month (ft-AMSL)

	Lake Jocassee		***Lake Keowee***	
Month	***Current Operations Baseline***	***Scenario***	***Current Operations Baseline***	***Scenario***
January	1,080	1096 – See Attached DCP3 and LIP2 Blend2D-b forms	794.6	796- See Attached DCP3 and LIP2 Blend2D-b forms
February	1,080	“	794.6	“
March	1,080	“	794.6	“
April	1,080	“	794.6	“
May	1,080	“	794.6	“
June	1,080	“	794.6	“
July	1,080	“	794.6	“
August	1,080	“	794.6	“
September	1,080	“	794.6	“
October	1,080	“	794.6	“
November	1,080	“	794.6	“
December	1,080	“	794.6	“

Hartwell and J. Strom Thurmond
Operating Action Levels Plot



Additional Information

Keowee-Toxaway LIP implementation with Jocassee support of Keowee weekly required outflows per equal ratio of usable storage, and also restricts Jocassee refill rate. The Jocassee and Keowee drawdown is paired based on usable storage…this is achieved through discharge and pumping. LIP code will not permit Jocassee to refill via pumping if it is going to cause the two reservoir storages to be out of balance based on defined usable storage. Usable storage in Keowee-Toxaway LIP and DCP is based on full pond elevation. Note the DCP criterion was formerly the guide curve. See attached DCP3 (modifications from DCP2 highlighted in yellow cells with red text) and LIP2 Blend2D input forms. Blend 2D-b reflects the language from the 04/23/2013 AIP, including LIP logic revised to reference "triggered" DCP level versus "In-Effect" DCP level, and LIP gage averaging modified from 6 months to 4 months per AIP documentation. Inflows and evaporation modified to simulate potential high impacts of climate change. Evaporation coefficients increased by 20 percent to account for 6 degree temperature increase and inflows reduced by 10 percent.

No fish spawning lake stabilization requirements in effect.

Specific Questions this Model Run Should Answer

Input sheet for Drought Plan criterion to be modeled in the Keowee-Toxaway CHEOPS Model

Input data into yellow shaded cells. Do not insert rows, columns, or move data tables.

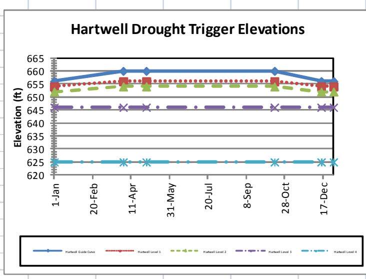
Data updated:	11/1/2012	1/31/2013	2/1/2013
Intended Scenario:	Trial Balloon Revised Kefied for Keowee back to 75%		
Modified By:	Angie Scang:	Bkrolak	Kadamec

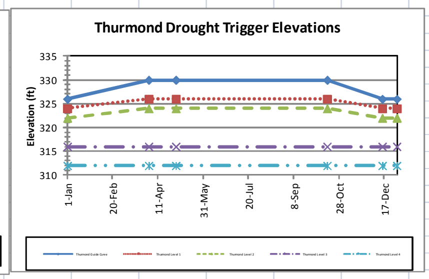
Day of Week to evaluate storage condition:	6										
Delay time in days before implementing flow change:	0										
Recovery elevation delay - depth into recovering level before triggering increasing flows:	2										
Jocassee and Keowee support reservoir storage balancing	ByAgreement	"False": no support, "ByStoreMatch": use usable storage relationships on Storage (plants 2 to 6 only), "ByAgreement": use Volume relationships as specified in rows 13 through 16.									
Hours of Keowee Peak operations during 4 month refill:	120										
Maximum required Keowee weekly discharge volume	25000	**paired**	Pct of Joc support for Outflows (BPK 2012-07-24)								
ACOE Percent Available Storage Level Greater than or equal to:	90.0%	80.0%	70.0%	60.0%	50.0%	40.0%	30.0%	20.0%	10.0%	0.0%	
Next Friday's Duke Storage Percent Shortage Multiplier:	0	2	1	1	1	1	1	1	1	1	
Next Week's Duke Presumed Inflow Volume (acre-ft):	5000										
Volume Reserved for Pumped Storage Cycling (acre-ft)	0	Keo	Hart	Rus	Thur	Bad Crk					
Plant 2/3/4/5/6/1 MinEl (feet) for Storage Calcs	1080	790	625	470	312	2150	if blank, sets to UI's MinElev setting				

Plant 4	Hartwell	Same as Base	From HartwellD:	Same as Base	Same as Base
Date	**Julian**	**Hartwell Guide Curve**	**Hartwell Level 1**	**Hartwell Level 2**	**Hartwell Level 3**	**Hartwell Level 4**
1-Jan	1	656	654	652	646	625
1-Apr	91	660	656	654	646	625
1-May	121	660	656	654	646	625
15-Oct	288	660	656	654	646	625
15-Dec	349	656	654	652	646	625
31-Dec	365	656	654	652	646	625
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600

Plant 6	Thurmond	From Thurmondl	From Thurmondl	From Thurmondl	Same as Base	Same as Base
Date	**Julian**	**Thurmond Guide Curve**	**Thurmond Level 1**	**Thurmond Level 2**	**Thurmond Level 3**	**Thurmond Level 4**
1-Jan	1	326	324	322	316	312
1-Apr	91	330	326	324	316	312
1-May	121	330	326	324	316	312
15-Oct	288	330	326	324	316	312
15-Dec	349	326	324	322	316	312
31-Dec	365	326	324	322	316	312
Action - min		4500	4200	4000	3800	3600
Action - max		-	4200	4000	3800	3600
<=10Pct			4000	3800		
Nov-Jan				3600	3100	3100
Extend Winter flows to Feb?						FALSE

Use USACE Fish Spawning Rule	TRUE
Use Bad Creek in Storage Calcs	TRUE
Use Russell in Storage Calcs	TRUE
Use Duke 100ft Elevs for Calcs	TRUE
Keowee Outflow Logic Key	75%





SEPAPower Requirement

Month	Weekly Requirement (MWh)
Jan	27,233
Feb	26,714
Mar	20,669
Apr	18,504
May	21,948
Jun	25,935
Jul	31,195
Aug	32,035
Sep	30,685
Oct	27,304
Nov	26,284
Dec	27,104

Input sheet for LIP criterion to be modeled in the Keowee Toxaway CHEOPS Model

Data updated:	8/29/2012	8/29/2012	3/22/2013	3/22/2013	4/28/2013	4/30/2013	5/6/2013	5/7/2013
Intended Scenario:	Keo-Tox LIP	Checked	Blend2D	Checked	Blend2Da	Checked	Blend2Db. Shee	Checked
Modified By:	Bkrolak	Ascangas	Bkrolak	Kadamec	Bkrolak	Ascangas	Bkrolak	Ascangas

Reservoir Critial Elevations (should be at or below the Minimum Elevation entered in the scenario being run.)

Reservoir Name	1	2	3	4	5	6
Critical Reservoir Elevation (ft, amsl)	2150.0	1080.0	791.5	625.0	470.00	312.0

	Condition Set 1		Plus Any 1 of Condition Set 2		
	Remaining Usable Reservoir Storage Less Than	USACE Drought Protocol Level	% of 6-month Long Term Avg Streamflow (Less than)	Area-Weighted US Drought Monitor (Greater than or equal to)	% of 6-month Long Term Avg Rainfall (Less than)
Normal	10000%		10000%	0	10000%
Stage 0 - Watch	90%		85%	0	85%
Stage 1		1	75%	1	75%
Stage 2		2	65%	2	65%
Stage 3		3	55%	3	55%
Stage 4	25%		40%	4	40%

Actions to be performed - Reservoir Minimum Elevation Change

Licensee Actions	Licensee Delay in implementing Actions (days)	Plant 1 Normal Minimum Pond Elevation (ft amsl)	Plant 2 Normal Minimum Pond Elevation (ft amsl)	Plant 3 Normal Minimum Pond Elevation (ft amsl)	Plant 4 Normal Minimum Pond Elevation (ft amsl)	Plant 5 Normal Minimum Pond Elevation (ft amsl)	Plant 6 Normal Minimum Pond Elevation (ft amsl)
Stage 0	1	2160	1096	796			
Stage 1	1	2160	1092	795			
Stage 2	1	2160	1087	793			
Stage 3	1	2160	1083	792			
Stage 4	1	Critical	Critical	Critical			

Actions to be performed - Maximum Keowee Weekly Releases (acre-ft)

Licensee Action (Title Only)	LIP Stage	Or Percent of Duke Usable Storage (Greater Than)	Maximum Required Weekly Keowee Release (acre-ft)
Limit 0	0	85%	25,000
Limit 0 Low	0	80%	20,000
Limit 1	1		18,750
Limit 2	2		15,000
Limit 3	3		10,000
Limit 4	4	12%	7,500
Limit 4 Low	4		1

LIP 0
max weekly vol discharge adjustment at >85% 25kaf
max weekly vol discharge adjustment at <=85% 20kaf

LIP 1 max weekly vol discharge adjustment 18,750kaf

LIP 2 max weekly vol discharge adjustment 15,000kaf

LIP 3 max weekly vol discharge adjustment 10,000kaf

LIP 4 max weekly vol discharge adjustment 7,500kaf
LIP 4 Low when usable storage <=12% weekly required volume is leakage. A non-zero number must be entered. Any value below leakage will result in leakage being released.

Actions to be performed - Owners of Large Water Withdrawal Sites

Owners of public and large water supply intakes	Owner Delay in implementing Actions (days)	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
Stage 0	14						
Stage 1	14	3.0%	3.0%	3.0%	0.0%	0.0%	0.0%
Stage 2	14	5.0%	5.0%	5.0%	0.0%	0.0%	0.0%
Stage 3	14	10.0%	10.0%	10.0%	0.0%	0.0%	0.0%
Stage 4	14	20.0%	20.0%	20.0%	0.0%	0.0%	0.0%

Disable Duke Spawn in LIP 0 and Higher	TRUE
Disable USACE DCP Recovery Delay	TRUE

FALSE (default) assumes LIP recovery of stages uses the DCP stage in effect.
TRUE indicates the 2 foot USACE DCP recovery delay into higher DCP elevation band is DISABLED for triggered DCP to be used in LIP logic. Added BPK 2013-04-28

Date	122-Day Running Average of 3 Gage Average Flow (cfs)	Date	Avg of Composite Gage Flow by Day and Mon (cfs)
1/1/1939	124	1/1/2000	322.6
1/2/1939	120	1/2/2000	323.1
1/3/1939	118.7	1/3/2000	323.9
1/4/1939	118	1/4/2000	324.6
1/5/1939	193.4	1/5/2000	326.1
1/6/1939	210	1/6/2000	327
1/7/1939	211	1/7/2000	328.1
1/8/1939	208.3	1/8/2000	329.4
1/9/1939	204	1/9/2000	330.2

APPENDIX D
LOW INFLOW PROTOCOL
FOR THE KEOWEE-TOXAWAY PROJECT

APPENDIX D

LOW INFLOW PROTOCOL (LIP) FOR THE KEOWEE-TOXAWAY HYDROELECTRIC PROJECT

Purpose

To establish a joint management plan that Duke Energy Carolinas, LLC (Licensee); Seneca Light & Water (Seneca), Greenville Water (GW), any public water suppliers that add Large Water Intakes withdrawing water from Project Reservoirs (Jocassee and Keowee); and any public water suppliers with Large Water Intakes on the U.S. Army Corps of Engineers' (USACE) Reservoirs (Hartwell, Russell and Thurmond) that choose to participate, will follow in response to drought conditions.

Key Facts and Assumptions

1. Importance of Human Health and Safety and the Integrity of the Public Water Supply and Electric Systems – Nothing in this LIP will limit the Licensee's ability to take any and all lawful actions necessary at the Keowee-Toxaway Hydroelectric Project ("Project") to protect human health and safety, to protect its equipment from damage, to ensure the stability of the regional electric grid, to protect the equipment of the Large Water Intake owners from damage, and to ensure the stability of public water supply systems; provided that nothing in the Relicensing Agreement (RA) or LIP obligates the Licensee to take any actions to protect the equipment of Large Water Intake owners from damage or to ensure the stability of public water supply systems. It is recognized that the Licensee may provide this protection without prior consultation or notification.
2. This LIP is intended to support management of the Licensee's Reservoirs (Bad Creek, Jocassee and Keowee) in the Upper Savannah River Basin for the Licensee's operations, while meeting the water resource needs of the public.
3. As of the date of this LIP, only five entities have Large Water Intakes withdrawing water from the Project. GW and Seneca are public water suppliers. The Licensee's Large Water Intake at Oconee Nuclear Station (ONS) is used for thermal power plant cooling. The Reserve at Lake Keowee and The Cliffs Club at Keowee Vineyards, LLC each use Large Water Intakes for irrigation. The Reserve at Lake Keowee and The Cliffs Club at Keowee Vineyards, LLC have easements with clauses permitting the Licensee to require water conservation measures during droughts.
4. Any public water supplier owning a Large Water Intake that intends to locate a new intake, expand an existing intake, or rebuild an existing intake on Lake Keowee will be required to abide by the applicable portions of this LIP, except as provided for in existing agreements (e.g., easements, leases, lake use permits or other written agreements) between the Large Water Intake owner and the Licensee.
5. Nothing in this LIP amends or replaces any other contract or agreement to which the Licensee and/or any other Large Water Intake owner is a party.
6. Revising the LIP – During the term of the New License, the Keowee-Toxaway Drought Management Advisory Group (KT-DMAG) will periodically review and recommend updates to the LIP to ensure continuous improvement of the LIP and its implementation. These evaluations and modifications will be considered at least

once every ten (10) years during the New License term. Any modifications must be approved by the Licensee and all of the applicable public water suppliers with Large Water Intakes on Project Reservoirs. If such unanimous approval cannot be reached, then the dispute resolution procedures set forth in the RA will apply. Approved modifications will be incorporated through revision of the LIP, and the Licensee will file the revised LIP with the Federal Energy Regulatory Commission (FERC). If any modifications of the LIP require amendment of the New License, the Licensee will: (i) provide notice to all Parties to the RA, pursuant to Section 23.0 of the RA, advising them of the New License amendment and the Licensee's intent to file it with the FERC; (ii) submit a modification request to the South Carolina Department of Health and Environmental Control (SCDHEC) for formal review and approval if required; and (iii) file a license amendment request for FERC approval if required. The filing of a revised LIP by the Licensee will not constitute or require modification of the RA, and any Party to the RA may be involved in the FERC's or SCDHEC's public processes for assessing the revised LIP, but may not oppose any part of a revised LIP that is consistent with the LIP included in the RA.

7. Transitioning to a Lower Critical Reservoir Elevation on Lake Keowee – The Licensee will operate in accordance with the provisions of the LIP, except Lake Keowee's Critical Reservoir Elevation will remain at or above 94.6 ft local datum / 794.6 ft above Mean Sea Level (AMSL) until December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. The Licensee may also, in its sole discretion, decide to maintain Lake Keowee's Critical Reservoir Elevation at or above 94.6 ft local datum / 794.6 ft AMSL until both of the following are complete:

   a. A New License that is consistent with the RA has been issued, the end of all appeals, and all rehearing and administrative challenge periods have closed; and

   b. The Licensee, the USACE, and the Southeastern Power Administration (SEPA) have signed a New Operating Agreement (NOA) that is not inconsistent with the RA.

8. The following table provides storage volumes at various lake elevations in the Licensee's Reservoirs. Data for the Bad Creek Reservoir are from original licensing data. Data for Lakes Jocassee and Keowee are from a 2010 bathymetric study performed by the Licensee. These data are for planning purposes and not of physical survey quality.

Reservoir	Elevations (ft local datum / ft AMSL)		Storage Increment (ac-ft)	Storage Increment (%)
	Elevation From	Elevation To		
Bad Creek	100.0 / 2310	-60.0 / 2150	30,229	
		Total Bad Creek	30,229	7
Jocassee	100.0 / 1110	86.0 / 1096	108,738	
	86.0 / 1096	82.0 / 1092	30,000	
	82.0 / 1092	77.0 / 1087	36,687	
	77.0 / 1087	73.0 / 1083	28,730	
	73.0 / 1083	70.0 / 1080	21,233	
		Total Jocassee	225,387	54
Keowee	100.0 / 800.0	96.0 / 796.0	67,636	
	96.0 / 796.0	95.0 / 795.0	16,249	
	95.0 / 795.0	94.6 / 794.6	6,434	
	94.6 / 794.6	93.0 /793.0	25,368	
	93.0 / 793.0	92.0 / 792.0	15,565	
	92.0 / 792.0	91.5 / 791.5	7,700	
	91.5 / 791.5	90.0 / 790.0	22,775	
		Total Keowee	161,727	39
Total for Licensee's Reservoirs			417,343	100

Definitions

1. Critical Reservoir Elevation – Unless otherwise defined herein, the Critical Reservoir Elevation is the level of water in a reservoir (measured by reference to local datum or in ft AMSL) below which any Large Water Intake used for public water supply, industrial water supply, or any regional power plant water supply located on the reservoir will not operate at its Licensee-approved capacity. The Critical Reservoir Elevations are:

Reservoir	Critical Reservoir Elevation (ft local datum / ft AMSL)	Type of Limit
Lake Keowee	90.0[1] / 790.0[1]	Power Production
Lake Jocassee	70.0 / 1080.0	Power Production
Bad Creek	-60.0 / 2150.0	Power Production

Note 1 – This new Critical Reservoir Elevation will become effective December 1, 2019, to allow time for ONS to be modified to support its operation at lower Lake Keowee levels. See Item 7 under Key Facts and Assumptions for guidance prior to converting to this new Critical Reservoir Elevation.

2. Total Usable Storage – For the Licensee's Reservoirs (Keowee, Jocassee, and Bad Creek), Total Usable Storage is the sum of the volume of water contained between

each reservoir's Critical Reservoir Elevation and its Full Pond Elevation, expressed in acre-feet (ac-ft). For the USACE Reservoirs in the Upper Savannah River Basin (Hartwell, Richard B. Russell, and J. Strom Thurmond), Total Usable Storage is the sum of the volume of water contained between each reservoir's bottom-of-power-pool elevation (top of inactive pool) and the guide curve elevation denoting the top of conservation storage for any particular time of year, expressed in ac-ft.

3. Remaining Usable Storage – The sum of the volume of water contained between each reservoir's Critical Reservoir Elevation and the actual reservoir elevation at any given point in time, expressed in ac-ft, for the Licensee's Reservoirs. The Remaining Usable Storage calculation for the Licensee's Reservoirs is based on a maximum drawdown elevation of 90 ft local datum / 790 ft AMSL for Lake Keowee, a maximum drawdown elevation of 70 ft local datum / 1080 ft AMSL for Lake Jocassee, and a maximum drawdown elevation of -60 ft local datum / 2150 ft AMSL for the Bad Creek Reservoir. For the USACE Reservoirs in the Upper Savannah River Basin (Hartwell, Richard B. Russell, and J. Strom Thurmond), Remaining Usable Storage is the sum of the volume of water contained between each reservoir's bottom-of-power-pool elevation (top of inactive pool) and the actual elevation, expressed in ac-ft.

4. Storage Index – The ratio, expressed in percent, of Remaining Usable Storage to Total Usable Storage at any given point in time.

5. Large Water Intake – Any water intake (e.g., public water supply, industrial, agricultural, power plant, irrigation, etc.) having a maximum instantaneous capacity greater than or equal to one million gallons per day (MGD).

6. Keowee-Toxaway Drought Management Advisory Group (KT-DMAG) – The KT-DMAG is a voluntary advisory group to be formed and tasked with working with the Licensee when the LIP is initiated. This KT-DMAG will also meet as necessary to foster a basin-wide response to a Low Inflow Condition (see Specific Actions at Each LIP Stage). The KT-DMAG will consist of a representative from each of the following organizations that decides to form or join the KT-DMAG. By agreeing to form or join the KT-DMAG, each Member agrees to comply with all applicable requirements of this LIP. Each KT-DMAG Member may have a primary representative and an alternate representative, who may act in the absence of the primary representative.

   a. SC Department of Natural Resources (SCDNR);
   b. SCDHEC;
   c. US Geological Survey (USGS);
   d. USACE;
   e. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on the Project Reservoirs;
   f. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on any tributary stream within the Keowee-Toxaway River Basin that ultimately drains to Lake Keowee and that agrees to coordinate its drought planning and management under the KT-DMAG;
   g. Each owner of a Large Water Intake used for municipal, industrial, or power plant water supply located on the USACE Reservoirs that agrees to coordinate its drought planning and management under the KT-DMAG; and
   h. Licensee (KT-DMAG Coordinator).

Members of the KT-DMAG will adopt a Charter to guide the operation of the KT-DMAG, as set forth in part below, and said Charter will require KT-DMAG Members to comply with the applicable requirements of this LIP. The KT-DMAG will meet at least annually (typically during the month of June), beginning in 2014 and continuing throughout the term of the New License, regardless of the Low Inflow Condition status, to review prior year activities, discuss data input from public water suppliers that are Large Water Intake owners, and discuss other issues relevant to the LIP. The Licensee will lead the formation of the KT-DMAG, will call meetings and set agendas, and will maintain an active roster of the KT-DMAG and update the roster as needed. The Licensee will prepare meeting summaries of all KT-DMAG meetings, make these meeting summaries available to the public by posting on its website, and notify Parties to the RA without specific responsibilities under the LIP of the availability of information on the current LIP status and possible actions.

Basic Responsibilities

Licensee's Responsibilities

The Licensee accepts the following basic responsibilities in furtherance of this LIP.

1. Monitor the following drought triggers and relevant data at least monthly or as specified for each LIP Stage.
    - Remaining Usable Storage in the Licensee's Reservoirs
    - Composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC (USGS Gage # 02186000); Chattooga River near Clayton, GA (USGS Gage # 02177000); French Broad River near Rosman, NC (USGS Gage # 03439000))
    - U.S. Drought Monitor for the Upper Savannah River Basin (i.e., from Thurmond Dam upstream)
    - Composite average of the Licensee's rainfall gauge readings at the Jocassee Pumped Storage Station, Keowee Hydro Station, and the Bad Creek Project
    - Oconee County USGS groundwater gage (USGS Gage # 345051083041800 OC-233) (Note: Data from other groundwater gages can be added in the future if beneficial.)
    - Remaining Usable Storage in the USACE Reservoirs downstream
    - USACE Savannah River Basin drought status
2. Coordinate KT-DMAG meetings including those noted for the particular drought stage. Provide to the KT-DMAG trigger updates, composite rainfall gauge readings, and operational and meteorological projections. Meetings can be in person, telephonic or by use of other appropriate communications. In consultation with KT-DMAG members, select and publicly communicate the LIP Stage based on the triggers established in this LIP.
3. Provide to the KT-DMAG the estimated water consumption rate by ONS (average for the current month and projections for the next month) and the estimated natural evaporation rate by reservoir from the Licensee's Reservoirs for the current month and projections for the next month.

4. Quantify total weekly flow releases (hydro generation, flood gate releases, hydro unit leakage, and dam seepage) made from the Keowee Development for the previous four weeks and provide to the KT-DMAG.

5. Coordinate with the USACE to make flow releases from Lake Keowee in accordance with the NOA between the Licensee, USACE, and SEPA regarding flow releases from the Keowee Development into the USACE's Hartwell Project and this LIP.

6. Depending on the LIP Stage, request voluntary or require mandatory water use restrictions for withdrawing water from the Licensee's Reservoirs to irrigate lakeside properties.

7. When operating in the LIP near Stage Minimum Elevations, except for flow releases required for ONS operations or situations covered by the Maintenance and Emergency Protocol (MEP), the Licensee will not make an intentional flow release from Keowee Dam if that flow release would reduce the level of Lake Jocassee or Lake Keowee below its Stage Minimum Elevation as specified for the applicable LIP stage.

8. When operating in the LIP, the Licensee will limit weekly flow releases from the Keowee Dam to no more than the maximum weekly flow release for the applicable LIP Stage except for flow releases required for ONS operations or situations covered in the MEP. The weekly flow release amount includes the sum of all water released downstream from the Keowee Dam (i.e., hydro unit generation plus hydro unit leakage plus dam seepage plus any flood gate releases).

9. Stage Minimum Elevations are defined for each Stage of the LIP. When a subsequent Stage of the LIP is reached, the Licensee agrees both Project Reservoirs must be within 0.25 ft of the Stage Minimum Elevation of the previous Stage of the LIP before each reservoir can be lowered to the next Stage Minimum Elevation.

Responsibilities of Large Water Intake Owners that are Public Water Suppliers

Large Water Intake owners that are public water suppliers withdrawing water from the Licensee's Reservoirs agree to the following basic responsibilities in furtherance of this LIP.

1. Provide to the Licensee current month and projections for next month's water use from the Licensee's Reservoirs and from any alternative water supply sources.

2. Provide to the Licensee an overview of system conditions related to water use from the Licensee's Reservoirs (i.e., leaks, status of alternative water sources, new or potential large water users, etc.).

3. Request or require water use restrictions from water customers and/or make greater use of alternative water sources for the purpose of reducing water withdrawals from the Licensee's Reservoirs below what those withdrawals would have been otherwise, consistent with best practices and operating principles for those Large Water Intake owners' systems in accordance with the specific actions listed in this document at each LIP stage.

LIP Stage Triggers

For the purposes of this LIP, the following triggers will define the LIP Stage.

Stage 0 (Low Inflow Watch) Drought Trigger Levels

1. Storage Index in USACE Reservoirs and Storage Index in the Licensee's Reservoirs are both less than 90% (using the Critical Reservoir Elevations defined above); and
2. One of the following triggers:
    a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 0; or
    b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 85% of long-term average for the previous four months.

Stage 1 Drought Trigger Levels

1. USACE implements Level 1 of its existing Drought Contingency Plan (DCP); and
2. One of the following triggers:
    a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 1; or
    b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 75% of long-term average for the previous four months.

Stage 2 Drought Trigger Levels

1. USACE implements Level 2 of its existing DCP; and
2. One of the following triggers:
    a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 2; or
    b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 65% of long-term average for the previous four months.

Stage 3 Drought Trigger Levels

1. USACE implements Level 3 of its existing DCP; and
2. One of the following triggers:
    a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is greater than or equal to 3; or

b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 55% of long-term average for the previous four months.

<u>Stage 4 Drought Trigger Levels</u>

1. Storage Index in the Licensee's Reservoirs is less than 25%; and
2. One of the following triggers:
   a. Twelve-week average of the area-weighted U.S. Drought Monitor for Upper Savannah River Basin (Thurmond Dam and upstream) is equal to 4; or
   b. Streamflow based on composite average of selected USGS streamflow gages (Twelvemile Creek near Liberty, SC; Chattooga River near Clayton, GA; and French Broad River near Rosman, NC) is less than 40% of long-term average for the previous four months.

<u>Specific Actions at Each LIP Stage</u>

<u>Stage 0</u>

The Licensee will:

1. Notify the KT-DMAG members and the South Carolina Department of Parks, Recreation and Tourism (SCDPRT) that LIP Stage 0 has been reached;
2. Initiate drought meetings (typically monthly) among the KT-DMAG members and any other interested water system managers;
3. Provide detailed updates to the KT-DMAG on drought triggers and other relevant data, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous four weeks;
5. Provide flow releases from Keowee Dam in accordance with the following limitations:
   a. When the Storage Index for the Licensee's Reservoirs is below 90% but greater than or equal to 85%, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 25,000 ac-ft (1800 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Normal Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP;
   b. When the Storage Index for the Licensee's Reservoirs is below 85% but greater than or equal to 80%, limit the total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 20,000 ac-ft (1440 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Normal Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
6. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will provide detailed updates to the Licensee on relevant data as noted in the Basic Responsibilities section.

Stage 1

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 1 has been reached;
2. Coordinate drought meetings (typically monthly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous four weeks;
5. Request those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties voluntarily limit their withdrawals to no more than two days per week, with the days to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 95.0 ft local datum / 795.0 ft AMSL (Stage 1 Minimum Elevation);
7. Reduce the Minimum Elevation for Lake Jocassee to 82.0 ft local datum / 1092.0 ft AMSL (Stage 1 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 18,750 ac-ft (1350 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 1 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are pubic water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 3-5% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Stage 2

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 2 has been reached;
2. Coordinate drought meetings (typically bi-weekly) among the KT-DMAG members and any other interested water system managers;

3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to limit their withdrawals to no more than two days per week, with the days to be specified by the Licensee;
6. Reduce the Minimum Elevation for Lake Keowee to 93 ft local datum / 793.0 ft AMSL (Stage 2 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 77.0 ft local datum / 1087.0 ft AMSL (Stage 2 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 15,000 ac-ft (1080 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 2 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 5-10% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

<u>Stage 3</u>

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 3 has been reached;
2. Coordinate drought meetings (typically bi-weekly) among the KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to limit their withdrawals to no more than one day per week, with the day to be specified by the Licensee;

6. Reduce the Minimum Elevation for Lake Keowee to 92.0 ft local datum / 792.0 ft AMSL (Stage 3 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 73.0 ft local datum / 1083.0 ft AMSL (Stage 3 Minimum Elevation);
8. Limit flow releases from Keowee Dam to a total maximum weekly flow release (i.e., hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) of 10,000 ac-ft (720 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee or Lake Keowee below its Stage 3 Minimum Elevation except flow releases required for ONS operations or situations covered by the MEP; and
9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with increased emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee, as a goal, by 10-20% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Stage 4

The Licensee will:

1. Notify the FERC, KT-DMAG members and the SCDPRT that LIP Stage 4 has been reached;
2. Coordinate bi-weekly (or more frequently if needed) drought meetings among KT-DMAG members and any other interested water system managers;
3. Continue to provide detailed updates on drought triggers and other relevant data to the KT-DMAG, as noted in the Basic Responsibilities section;
4. Provide data to the KT-DMAG on the amount of water released from Lake Keowee for the previous two weeks;
5. Require those lake neighbors withdrawing water from the Licensee's Reservoirs for irrigating lakeside residential properties to cease all such withdrawals;
6. Reduce the Minimum Elevation for Lake Keowee to 90.0 ft local datum / 790.0 ft AMSL (Stage 4 Minimum Elevation), but no lower than the appropriate Critical Reservoir Elevation;
7. Reduce the Minimum Elevation for Lake Jocassee to 70.0 ft local datum / 1080.0 ft AMSL (Stage 4 Minimum Elevation);
8. Limit flow releases from Keowee Dam to the following:
    a. When the Storage Index for the Licensee's Reservoirs is below 25% but greater than 12%, except for flow releases required by the FERC, for ONS operations, or situations covered by the MEP, limit the total maximum weekly flow release (i.e.,

hydro unit flow releases, flood gate flow releases, hydro unit leakage, and dam seepage) to 7,500 ac-ft (540 cfs on a weekly average basis) or a lesser amount if required to avoid driving the level of Lake Jocassee below its Stage 4 Minimum Elevation and to maintain the level of Lake Keowee at or above 91.5 ft local datum / 791.5 ft AMSL or its Critical Reservoir Elevation, whichever is higher;

b. When the Storage Index for the Licensee's Reservoirs is at or below 12%, cease making hydro unit and floodgate flow releases, except for flow releases required by the FERC, for ONS operations, or situations covered by the MEP.

9. Provide the drought stage and other relevant information on the Licensee's lake information website and toll-free telephone system.

Large Water Intake owners that are public water suppliers will:

1. Notify their water customers of the Low Inflow Condition through public outreach and communication with increased emphasis on the need to conserve water;
2. Reduce water withdrawals from Lake Keowee by 20-30% (or more) from the withdrawal amounts otherwise expected; and
3. Provide detailed updates on relevant data to the Licensee as noted in the Basic Responsibilities section.

Recovery from LIP Stages

Recovery under this LIP as conditions improve will be accomplished by reversing the staged approach outlined above, except the only trigger to recover from a stage is for either the storage index for the Licensee's Reservoirs or the USACE drought trigger to be exceeded for the current stage as described below. The following table provides the storage levels required for recovery from a higher numbered "Stage Y" to a lower numbered "Stage X":

Recovery from Stage Y to Stage X	**Required Storage**
From Stage 4 to Stage 3	Storage Index for the Licensee's Reservoirs is greater than or equal to 25%
From Stage 3 to Stage 2	Storage for the USACE Reservoirs recovers to amount for initial implementation[1] of Level 2 of its DCP
From Stage 2 to Stage 1	Storage for the USACE Reservoirs recovers to amount for initial implementation[1] of Level 1 of its DCP
From Stage 1 to Stage 0	Storage for the USACE Reservoirs returns to amount required for Normal operations[1]
From Stage 0 to Normal	Storage Index for the Licensee's Reservoirs is greater than or equal to 90%

Note 1 – These are USACE storage amounts that indicate when the USACE <u>increases</u> its drought level (Normal to 1, 1 to 2 or 2 to 3) which is not the same storage amount that indicates when USACE <u>decreases</u> its drought level (3 to 2, 2 to 1 or 1 to Normal). The USACE requires greater storage amounts when recovering from drought (decreasing drought levels).

APPENDIX E

KEOWEE-TOXAWAY CLIMATE CHANGE SCENARIO DEVELOPMENT SUMMARY MEMO

KEOWEE-TOXAWAY CLIMATE CHANGE SCENARIO DEVELOPMENT SUMMARY

1.0 PURPOSE

Various technologies have been developed to consider the impacts of climate change due to increases in carbon dioxide levels. These technologies are beginning to be applied in water supply modeling efforts for river systems utilized by energy utilities. While a robust Computer Hydro-Electric Operations and Planning Software (CHEOPS™) model has been developed to calculate future water supply and operational parameters of the Keowee-Toxaway Hydroelectric Project within the Savannah River Basin, climate change impacts have not previously been considered. As such, it was determined that an updated modeling effort should include potential climate change scenarios. The analysis, as discussed herein, relies heavily on climate change scenarios previously developed for the nearby Catawba-Wateree River Basin. This document presents a brief summary of research and investigation into climate change, and lays the foundation for defining climate change scenarios for incorporation into the CHEOPS™ model for the Savannah River Basin.

2.0 BACKGROUND

2.1 South Carolina Department of Natural Resources

The following text is a summary of *The Impact of Climate Change on South Carolina*, as presented by the South Carolina Department of Natural Resources (SCDNR) State Climatology Office (SC-SCO, 2012a).

To determine how the climate will respond to future increases in carbon dioxide levels, climatologists use general circulation models (GCMs). GCMs express mathematically the large-scale dynamic and thermodynamic processes of the atmosphere and their associated feedbacks. While such models cannot replicate reality, they can reveal what could reasonably be expected to happen if certain components of the earth's climate system change. For instance, when researchers double the carbon dioxide levels, the models indicate global temperature will increase from 2 to 4 degrees F.

The Goddard Institute of Space Sciences (GISS), the Geophysical and Fluid Dynamics Lab (GFDL) of Princeton, and Oregon State University (OSU) have designed some of the more prominent general circulation models. While these GCMs are currently the tools used for estimating climate change, they are not problem-free. For example, certain important variables (like clouds) are too small to be included individually in the models and must be represented collectively (i.e., parameterized). The differences in how models parameterize these variables has an effect on the estimates of climate change produced. As a case in point, when the designers of one model recalculated its parameterization of clouds, the estimated temperature increase was more than halved, dropping from 9.9 to 3.4 degrees F.

Other uncertainties arise because modelers do not fully understand the feedback mechanisms at work in the climate. The long-term response of vegetation and the deep oceans, which are treated crudely if at all in GCMs, may diminish or amplify anticipated changes. Alternately, these feedbacks may affect the rate of change, acting to accelerate or retard it. GCMs also present problems when they are used to study climate impacts. Because GCMs attempt to describe global processes of the atmosphere, they do not translate easily into regional change scenarios. It is the regional patterns of changes, however, that determine how the impacts are felt.

Even with these caveats and uncertainties, GCMs, when combined with the historical climate record, are the best tools that modelers have for predicting future climatic change. The current models suggest that if the amount of carbon dioxide in the atmosphere were doubled, temperatures would increase from 2 to 4 degrees F. But increased temperatures would not be the only change to be expected. Although climate change is often discussed in terms of temperature, temperature is only one factor of this change, and it drives other climate features. Wind systems, precipitation patterns, and ocean circulation arise from the atmospheric energy balance. Temperature increases will change these patterns, too. Scientists also believe that this change might bring about an increase in the number of extreme weather events, especially in the mid-latitudes. Hurricanes, droughts, and the number of 100-degree days might all become more frequent in a warmer world, but there is no evidence to confirm this theory.

The U.S. Environmental Protection Agency has used three models (GISS, GFDL, and OSU) to produce a range of climate change scenarios for the southeastern region of the United States. Although they differ in particulars, the three GCMs produce similar forecasts of annual warming trends in this region. The GFDL model estimates a higher winter increase than the other two, but all three suggest that both summer and winter temperatures will increase.

Differences among the models become more apparent when the expected change in precipitation is examined. Averaged over the year, the GISS and OSU models see a slight increase in precipitation, while the GFDL model sees a decrease. Most important is the difference in summer rainfall patterns. The GISS model predicts large increases, the OSU model a slight increase, and the GFDL model a dramatic decrease. These discrepancies are important to consider, as it is possible that the availability and reliability of water supply will be more important than temperature changes in determining the impact of climatic change of societies.

2.2 North Carolina State Climatologist Office

The following text is a summary of *Climate Change in North Carolina*, as presented by the State Climate Office of North Carolina (SCO-NC, 2012).

With the advancement of numerical modeling there exists an abundance of climate model resources, in addition to historical sensor data, to analyze past climate patterns and provide guidance for future forecasting. The global climate models that are used by the Intergovernmental Panel on Climate Change (IPCC) assessments are generally satisfactory in simulating global average temperatures over the past 50-100 years, and so there is confidence in their ability to predict future global average temperatures with some accuracy. Indeed, the models are another source of evidence for the impact of greenhouse gases to global warming. When model simulations are run that include greenhouse gas emissions and physics, the models fairly accurately simulate global temperatures. However, when models simulations are performed with greenhouse gas emissions and physics removed, the models simulate a global temperature pattern much cooler than that observed.

Unfortunately, widely accepted global climate models still do not accurately simulate the temperature and precipitation patterns over the southeastern United States. An ongoing evaluation of the models used in the latest IPCC assessments shows that all of the models predict warming over the past 50 years that has not been observed. Similarly, the models generally do not accurately simulate the location and amount of precipitation over the southeastern United States. One explanation of this is likely due to limitations in computing power; the models solve the physics of the atmosphere at regular geographic intervals, but the intervals are too large to properly handle local weather and climate patterns. As computer power increases, future simulations will be able to better simulate local weather and climate dynamics.

While global climate model predictions for future climate change in the Carolinas and Georgia are not necessarily incorrect, there is a low level of confidence in the precision of their future predictions as a result of their inability to directly correlate with historical observed climate in this region. With errors in simulating historic climate over the Southeast, and low confidence in their future outlook for North Carolina, these models simply do not currently produce exact guidance for what global warming impacts might occur in North Carolina, South Carolina, or Georgia.

Our society is more aware of global warming, and increasingly more concerned about future climate impacts. But while there is substantial climate awareness, there is little climate education. Moreover, state climatologist offices often see climate model simulations improperly used without calibration or even an evaluation of their accuracy. Research to calibrate the global climate models to the Carolinas and Georgia and downscale their forecasts is essential to provide more confident guidance on the possible impacts to these states. In addition, resources for climate education and climate applications are required to meet the needs of statewide and local agencies and businesses.

3.0 GLOBAL-SCOPE CLIMATE CHANGE MODELS

3.1 Introduction

While the need for regional-scope climate change models exists in the southeastern United States, as previously described, the reality is that regional-scope climate change projections are typically based upon a set of accepted global-scope climate change models and then downscaled through a statistical probability evaluation process (as discussed later in this paper). As such, these global-scope models form the basis for any subsequent regional evaluation of climate change, and are therefore applicable for consideration in climate change scenarios for the Savannah River Basin, in the absence of regional-scope climate change models. Two known and widely accepted climate change research programs include the U.S. Global Change Research Program (USGCRP) and the IPCC, which rely on a series of global-scope climate change models to form the basis of their climate change projections.

3.2 U.S. Global Change Research Program

Results from the *Global Climate Change Impacts in the United States* report (Karl, Melillo and Peterson, 2009) are proposed for use in the development of climate change scenarios for the CHEOPS™ modeling effort on the Keowee-Toxaway Project and Savannah River Basin. The report summarizes the science of climate change and the impacts of this phenomenon on the United States, now and in the future. It is largely based on results of the USGCRP.

The report draws from a large body of scientific information. The foundation of this report is a set of 21 Synthesis and Assessment Products (SAPs), which were designed to address key policy-relevant issues in climate science. In addition, other peer-reviewed scientific assessments were used, including those of the IPCC, the U.S. National Assessment of the Consequences of Climate Variability and Change, the Arctic Climate Impact Assessment, the National Research Council's Transportation Research Board report on the Potential Impacts of Climate Change on U.S. Transportation, and a variety of regional climate impact assessments. These assessments were augmented with government statistics as necessary (such as population census and energy usage) as well as publicly available observations and peer-reviewed research published through the end of 2008. This new work was carefully selected with advice from expert reviewers to update key aspects of climate change science relevant to the Savannah River Basin, particularly as related to future temperature and precipitation predictions.

In general, projections of future temperature were developed by 16 of the Coupled Model Intercomparison Project Three (CMIP3) climate models using two emissions scenarios from the IPCC Special Report on Emission Scenarios (SRES). The lower emission scenario is called B1, and the higher emission scenario is called A2.

The characteristics of the lower emission scenario (B1) include:

- Rapid economic growth, but with rapid changes towards a service and information economy;
- Global population rising to nine billion in 2050 and then gradually declining;
- Reductions in material intensity and the introduction of clean and resource efficient technologies; and
- An emphasis on global solutions to economic, social, and environmental stability.

The characteristics of the higher emission scenario (A2) include:

- A world of independently operating, self-reliant nations;
- Continuously increasing population;
- Regionally oriented economic development;
- Slower, more fragmented technological changes; and
- Improvements to per capita income.

3.3 Future Changes in Evaporation

The *Global Climate Change Impacts on the United States* report does not include specific evaporation data or figures. However, the report does note that "a warmer climate increases evaporation of water from land and sea, and allows more moisture to be held in the atmosphere. For every 1°F rise in temperature, the water holding capacity of the atmosphere increases by about 4 percent" (Karl, Melillo and Peterson, 2009). HDR Engineering, Inc. (HDR) concluded a similar result when analyzing reservoir evaporation that would result from potential increases in temperature in northeast Texas during the water supply modeling for Tarrant Regional Water District and Dallas Water Utilities' Raw Water Transmission System Integration (Choffel et al., 2010). HDR found that for every 1 degree F rise in temperature, gross reservoir evaporation increases between 3.3 and 3.4 percent. HDR developed two regression equations: one for spring and one for all other months based on monthly evaporation values and average daily high temperature for each month. The increased temperature values for each month were then applied to the exponential regression equations to produce a new value of gross reservoir evaporation for each month corresponding to the temperature increase.

For climate change scenarios developed for the Catawba-Wateree River Basin in North and South Carolina, temperature and gross pan evaporation for Charlotte, North Carolina were applied to the two northeast Texas regression equations and showed that the data correlates to the summer/fall/winter trendline. Therefore, similar to northeast Texas, for every 1 degree F rise in temperature, it is estimated that gross reservoir evaporation will increase by about 3.3 to 3.4 percent in the areas of North and South Carolina surrounding the Catawba-Wateree River Basin, which includes the nearby upper Savannah River Basin (Mosteller, 2012).

3.4 IPCC – Intergovernmental Panel on Climate Change

The following three IPCC reports are proposed for use in the development of climate change scenarios for the Keowee-Toxaway Project and Savannah River Basin modeling effort:

- *Climate Change and Water* (Bates et al., 2008)
- *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Parry et al., 2007)
- *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Christensen et al., 2007)

The IPCC reports summarize the science, technical aspect, and socio-economic impact of climate change on the world. The climate change projections presented by IPCC are based on average projections of future conditions from 21 different global models, called the Multi-Model Datasets (MMDs), running various emission scenarios. The product of these 21 models run with three different modeling scenarios was averaged into one result. The three emissions scenarios, further described below, included the B1 and A2 scenarios used with the USGCRP models discussed in the previous section, and an average emission scenario called A1B.

The characteristics of the average emission scenario (A1B) include:

- Very rapid economic growth;
- Global population that peaks in mid-century and declines thereafter; and
- The rapid introduction of new, more efficient technologies balanced across all energy sectors.

Future changes in temperature and precipitation are specifically addressed by these IPCC reports.

3.5 Summary

Predictions of global-scope climate change models from the *United States Global Change Research Program* (U.S. Program) and the IPCC were researched to estimate future changes in climate to the Savannah River Basin located in portions of North and South Carolina and Georgia. The U.S. Program uses 16 models and the IPCC uses 21 models to predict future changes in climate. The U.S. Program model is focused on the United States and the IPCC model includes global results.

Table 3.1 summarizes each model group's predictions for temperature and precipitation in relation to the modeling scenario and climate attribute. Additionally, this table includes estimates of future increases in gross reservoir evaporation based on estimated changes in temperature. The U.S. Program model predicts temperature will increase by 3 to 4 degrees F by 2050 and by 5 to 8 degrees F by 2090 for the low and high emission scenarios, respectively. The IPCC model predicts that by 2090, temperature will increase by 5.4 degrees F for the average emission scenario and between 6.3 and 13.5 degrees F for the high emissions scenario.

Average annual precipitation in the nearby Catawba-Wateree River Basin over the last 50 years is estimated to have decreased by about 10 percent (Mosteller, 2012). Additionally, the South Carolina State Climatologist Office shows that between 1901 and 2012, areas of the upper Savannah River Basin have experienced a decrease in average annual precipitation, while the lower Savannah River Basin has experienced an increase. (SC-SCO, 2012b). As shown in Table 3.1, additional decreases or increases of up to 5 percent by 2090 in the Southeast are predicted using the U.S. Program model. Additional increases of between 0 to 5 percent by 2090 are predicted in the Southeast using the IPCC model.

Gross annual reservoir evaporation in Charlotte, North Carolina averages about 40.6 inches. Based on estimated increases in temperature by the U.S. Program model, gross reservoir evaporation is expected to increase between 10 to 13.4 percent (to between 44.7 and 46.0 inches) by 2050 for the low and high emission scenarios, respectively, and between 16.8 to 26.8 percent (to between 47.4 and 51.5 inches) in 2090. Using estimates from the IPCC models, gross reservoir evaporation is expected to increase about 18.1 percent (to about 47.9 inches) by 2090 for the average emissions scenario and between 21.1 to 45 percent (to between 47.9 and 58.9 inches) in 2090 for the high emissions scenario.

Table 3.1 Summary of climate change data by report and scenario for the Savannah River Basin

Model	Scenario	2000	2020	2050	2090
Projected temperature increase (change from baseline)					
U.S. Program	Average of low and high emission scenario	2°F (1.1°C)	3°F (1.7°C)		
	Low emission scenario (B1)			3-4°F (1.7-2.2°C)	5°F (2.8°C)
	High emission scenario (A1)			4°F (2.2°C)	8°F (4.4°C)
IPCC	Average emission scenario (A1B)				5.4°F (3°C)
	Low emission scenario (B1)[1]				3.6-8.1°F (2-4.5°C)
	High emission scenario (A1)[1]				6.3-13.5°F (3.5-7.5°C)
Projected percent change in precipitation (change from baseline)					
U.S. Program	High emission scenario (A1)				±5%
IPCC	Average emission scenario (A1B)				0-5% Increase
Projected percent change in gross reservoir evaporation (change from baseline)					
U.S. Program	Average of low and high emission scenario	6.7%	10%		
	Low emission scenario (B1)			10-13.4%	16.8%
	High emission scenario (A1)			13.4%	26.8%
IPCC	Average emission scenario (A1B)				18.1%
	Low emission scenario (B1)[1]				12-27%
	High emission scenario (A1)[1]				21.1-45%

[1] For eastern United States

4.0 REGIONAL-SCOPE CLIMATE CHANGE MODELS

4.1 Climate Change Scenario Development

As previously discussed, the precision of localized climate change projections for the Carolinas and Georgia based upon global models is questionable, due to an inability of the global models to correlate to past climate in this region. However, as there are few regionalized climate change projections available for the Southeast, and as these regionalized climate change models are typically based upon larger global models, the use of global climate change models must be considered in developing climate change scenarios for studies related to the Savannah River Basin and relicensing the Keowee-Toxaway Project.

Although these global models cannot be relied upon to provide a precise projection of the actual climate change that will occur in the Southeast United States, they can be used with confidence to provide a set of bookend scenarios that represent the low and high end of potential climate change within this region. As determined through the work of the IPCC and other reputable climate change research initiatives, climate change is a reality. However, the future impacts of climate change will depend largely upon societies' responses in reducing emissions, among other factors. Therefore, the actual effect of climate change in the Southeast over the next century may fall in the lower or higher range of the projections made by global models.

For the purposes of relicensing the Keowee-Toxaway Project, three climate change scenarios are proposed. Climate change modeling scenarios CC-01 and CC-02 are based on global climate change model projections and are proposed for use as bookend scenarios representing the low end and high end of potential climate change in the Savannah River Basin, respectively. Alternately, proposed climate change modeling scenario CC-03 is based on a regionally downscaled climate change model for the southeastern United States, as described in the next section. This scenario seeks to provide a more localized and likely climate change scenario for the Savannah River Basin, which falls between the bookend projections of CC-01 and CC-02.

4.2 Regional Climate-Change Projection (Multi-Model Ensembles)

Climate change scenario CC-03 was developed with reference to the Regional Climate-Change Projection from the Multi-Model Ensembles (RCPM) website. RCPM is a statistical analysis of the projections made by different climate models (http://rcpm.ucar.edu). The following summary was adapted from the RCPM website. A Bayesian statistical model (Giorgi and Mearns, 2002) is used to synthesize the information in an ensemble of global climate models into a probability density function (PDF) of change in temperature or precipitation for a given geographic region.

A PDF describes the likelihood that an unknown variable will take on a value found within a particular range. Bayesian analysis uses known data to infer probabilistic values for unknown data that are consistent with the known values. This allows inferences as to the reliability of the models' forecasts for the future (which is unknown) based on their ability to reproduce observed data and their agreement with one another (both of which are known). In generating the PDF, the analysis assigns an implicit weight to each model's contribution based on two factors: bias and convergence. A model's bias is assessed by comparing its reproduction of the current climate to observed historical data, averaged over a region and season of interest. Convergence among models is rewarded by giving relatively more weight to projections that agree with the other members of the ensemble than to outliers. Because agreement between models may be due to model dependence, the analysis downweights the convergence criterion relative to the bias criterion.

The analysis is performed at a regional scale, area-averaging data from several grid-points into regional means of temperature and precipitation. For any given season and emissions scenario, the Bayesian model is used to determine a PDF of temperature and precipitation change. A season is any set of one or more consecutive months up to a year. The available emissions scenarios are SRES A2 (high), A1B (average), and B1 (low) (IPCC, 2000); and change is the difference between two 20-year averages, for example 1980-1999 (the typical "current climate" period) versus 2080-2099 (Tebaldi et al., 2005). The regional nature of the analysis means that these two criteria are evaluated for each model only with respect to the region of interest, not at a global scale. This method is only one of many for creating a probabilistic climate projection from an ensemble of different models.

There are several caveats to this regional downscaling that should be considered:

- The uncertainty range as represented by PDFs does not encompass all the uncertainties that characterize climate change projections, especially at regional scales. In particular:
  - The PDFs are conditional on the specified emissions scenario. Probabilities are not assigned to the different scenarios.
  - Generally speaking, the projections are conditional on the global climate models used. Global climate models were acquired from the PCMDI archive organized by IPCC Fourth Assessment Report (AR4) participants. These global client models are state-of-the-art coupled climate models, but each of them carries considerable uncertainty in its parameterizations and in its representation of processes and dynamics, especially at regional scales. These uncertainties have not been explicitly incorporated into the analysis.
  - For regions of complex topography and small extent, the preceding caveat is even more significant than it is for large areas over smooth terrain. Consequently, an area encompassing four gridpoints (a gridpoint is approximately 2.8 degrees on each side) is the minimum extent addressed using this framework.
- PDFs are normalized so the area under the curve integrates to 1. It is only meaningful to discuss probabilities in terms of a range of possible values (e.g., 60 percent probability of warming between 2 and 4 degrees F), not for a single value.
- Changes in temperature and precipitation are derived separately. The quantiles of one distribution should not be associated with the corresponding quantiles of the other.
- Change in precipitation is presented in both absolute and relative amounts. Percent change values for areas with low precipitation can be very large even though the absolute change is small.
- Each model grid has been interpolated to the median resolution of the available models, the T42 gaussian grid. This grid covers the globe with 64 gridpoints in latitude and 128 gridpoints in longitude.

It is important to note that the projections should be used as probable guidelines, not certain forecasts for the future. These results can help determine what the range of likely outcomes is given a particular assumption about emissions, and help to incorporate that uncertainty (as well as uncertainty about emissions) into the modeler's perspectives about future climate. The modeler should think in terms of bounding the set of likely scenarios, rather than picking a single characteristic outcome.

Table 4.1 summarizes predictions derived from the RCPM PDF of change in temperature and precipitation for the southeastern United States geographic region. The following acknowledgement for use of this data is provided by NCAR on the RCPM website: RCPM data and analysis provided by the Institute for Mathematics Applied to Geosciences (IMAGe) at the National Center for Atmospheric Research (NCAR), based on model data from the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 (WCRP CMIP3) multi-model dataset. More information about the RCPM analysis can be found at http://rcpm.ucar.edu.

Table 4.1 Summary of climate change data for the southeastern United States

Scenario	2050	2090
Projected percent change in temperature (change from baseline)		
Low emission scenario (B1)	2.3°F (1.3°C)	3.0°F (1.7°C)
Average emission scenario (A1B)	3.2°F (1.8°C)	5.2°F (2.9°C)
High emission scenario (A2)	3.4°F (1.9°C)	6.8°F (3.8°C)
Projected percent decrease in precipitation (change from baseline)		
Low emission scenario (B1)	0%	0-1%
Average emission scenario (A1B1)	0-1%	3-4%
High emission scenario (A2)	1-2%	6-8%

4.3 Southeast Regional Assessment Project

The following text is a summary of the *Southeast Regional Assessment Project*, as presented by the National Climate Change and Wildlife Science Center (NCCWSC), which is a division of the United States Geological Survey (USGS) (Dalton and Jones, 2010).

The USGS is working with the Southeast Region of the U.S. Fish and Wildlife Service (FWS) to develop science collaboration between the Southeast Regional Climate Science Center (RCSC) and future Landscape Conversation Cooperatives (LCCs). The National Climate Change and Wildlife Science Center's Southeast Regional Assessment Project (SERAP) will begin to develop regional downscaled climate models, land cover change models, regional ecological models, regional watershed models, and other science tools. Models and data produced by SERAP will be used in a collaborative process between the USGS, the FWS, state and federal partners, nongovernmental organizations, and academia to produce science at appropriate scales to answer resource management questions. The SERAP will produce an assessment of climate change and impacts on land cover, ecosystems, and priority species in the region. The predictive tools developed by the SERAP project team will allow end users to better understand potential impacts of climate change and sea level rise on terrestrial and aquatic populations in the southeastern United States.

The SERAP proposes to develop the climatic datasets necessary to project regional ecosystem impacts resulting from 21st century climate change by using an approach that assesses model uncertainty, down-scales climate projections to the scale of important ecosystem processes, and focuses on the most impact-relevant climatic variables. In doing so the SERAP will address three questions: (1) what is the magnitude and direction of climate change expected in the Southeast U.S. over the next 100 years, (2) how do the projected changes in climate relate to those parameters that most affect ecosystem processes specific to the Southeast, and (3) what is the level of uncertainty associated these projections?

The proposed approach improves upon many existing impact assessments by incorporating global climate models from the IPCC AR4, providing new information for decision makers through an improved quantifiable uncertainty analysis and providing seamless downscaled ecosystem-relevant climate products for the entire Southeast.

5.0 CONCLUSION

While the results of the down-scaled, regionally based SERAP model for climate change in the southeastern United States will be a beneficial tool for projecting climate change on a more localized level once developed, this effort is not scheduled for completion until September of 2014. As previously discussed, both the state climatologist's offices for North and South Carolina agree that there are few reliable resources currently available to project climate change on a micro-based regional level in the southeastern United States. The SERAP seeks to fill this void, but will not be completed prior to completion of the CHEOPS™ modeling for relicensing of the Keowee-Toxaway Project.

Therefore, it is recommended that three climate change scenarios founded on globally based climate change models be used for the CHEOPS™ modeling runs. The CC-01 and CC-02 scenarios, as previously described, rely on global models and climate change projections published by USGCRP and IPCC and are considered bookend scenarios for climate change (low and high impact, respectively) in the Savannah River Basin. The CC-03 scenario, which relies on Multi-Model Ensembles as previously described, may be considered an intermediate impact scenario between the low and high impact scenarios of CC-01 and CC-02, which is based on regionally downscaled global model projections specific to the southeastern United States. It is believed that that the implementation of these three scenarios will provide the most useful and accurate range of potential climate change effects to water supply in the Savannah River Basin, in the absence of more detailed and definitive regionally based projections.

6.0 RECCOMENDED MODELING SCENARIOS

Based on the results of this evaluation of climate change modeling resources available, the recommended climate change scenarios for use on the Keowee-Toxaway Relicensing effort are presented in Table 6.1. Recommended values presented for these scenarios are approximations based on comparison of exponential and linear forecasts of the decadal model projections for the year 2066.

Table 6.1 Recommended water modeling scenarios to evaluate climate change

Scenario	Description
CC-01	***Low impact of climate change on water supply (Global Models – Low Emission Scenario B1)*** • Assume temperature increase of 3°F to 2066 (~10% gross reservoir evaporation increase). • Assume no change in precipitation (Note: The upper Savannah River Basin has experienced a reduction in rainfall while the lower Savannah River Basin has experienced an increase in rainfall between 1901 and 2012 [SC-SCO, 2012b]. Future predictions are mixed in climate change models.) • Assume no change to inflow dataset. • Assume no change in net water demands. • Gross reservoir evaporation increase is applied as a constant value throughout the Period of Record. While global climate change models generally project a gradual warming, the use of a constant value for evaporation increase allows for the full Period of Record, including all drought years, to be evaluated based on common criteria and represents a conservative projection of the low end effects of climate change.
CC-02	***High impact of climate change on water supply (Global Models – High Emission Scenario A1)*** • Assume temperature increase of 6°F to 2066 (~20% gross reservoir evaporation increase). • Assume no change in precipitation. • Assume inflow dataset decrease of 10% to 2066 (from increases in evapo-transpiration due to higher temperatures). Inflow applied equally throughout the period of record. • Assume no change in net water demands. • Gross reservoir evaporation increase and inflow dataset decrease are applied as a constant value throughout the Period of Record. While global climate change models generally project a gradual warming, the use of a constant value for evaporation increase and inflow decrease allows for the full Period of Record, including all drought years, to be evaluated based on common criteria and represents a conservative projection of the high end effects of climate change.

Scenario	Description
CC-03	***Climate change scenario derived from NCAR RCPM (Regionally Downscaled Global Models)*** • Enhance CC-01 and CC-02 by creating a climate change scenario from an ensemble of global climate change models synthesized into a probability density function of temperature and precipitation change for the southeastern U.S. geographic region, using the average emission scenario A1B1. • Assume gradual temperature increase of 4°F to 2066 (~13% gross reservoir evaporation increase). • Assume gradual 2% reduction in precipitation that will result in a 5% reduction in inflow. • Reduction in inflow adapted from the regression relationship between normal runoff and rainfall in the Piedmont Province (Rose, 2007). • Assume no change in net water demands. • The gross reservoir evaporation increase and inflow dataset decrease are applied as a gradually increasing or decreasing value, respectively, throughout the Period of Record. Since the NCAR RCPM projects a gradual warming of temperatures and decreasing precipitation, the use of a gradually increasing or decreasing value throughout the Period of Record provides a probable and realistic regional projection of the likely climate change in the Southeast United States.

REFERENCES

Bates, B. C., Z. W. Kundzewicz, S. Wu, and J. P. Palutikof, eds. 2008. *Climate Change and Water.* Geneva: Intergovernmental Panel on Climate Change.

Choffel, K., C. Shockley, and Z. Stein. 2010. *Tarrant Regional Water District and Dallas Water Utilities Raw Water Transmission System Integration Technical Memorandum No. 5 – Reservoir Evaporation and Climate Adjustment Factors*. HDR Engineering, Inc.

Christensen, J. H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton, [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H .L. Miller, eds.] 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

Dalton, M. S. and S. A. Jones, comps. 2010. *Southeast Regional Assessment Project for the National Climate Change and Wildlife Science Center.* U.S. Geological Survey: U.S. Geological Survey Open-File Report 2010–1213.

Giorgi F. and L. O. Mearns. 2002. Calculation of Average, Uncertainty Range, and Reliability of Regional Climate Changes from AOGCM Simulations via the "Reliability Ensemble Averaging" (REA) method. *Jour. Climate*, 15(10):1141-1158.

IPCC (Intergovernmental Panel on Climate Change). 2000. *Summary for Policymakers Emissions Scenarios* [Online]. Available: <http://www.ipcc.ch/pdf/specialreports/spm/sres-en.pdf>. [referenced September 2012]

Karl, T. R., J. M. Melillo, and T. C. Peterson, eds. 2009. *Global Climate Change Impacts in the United States*. New York, NY: Cambridge University Press.

Mosteller, L. K. 2012. *Defining and Enhancing the Safe Yield of a Multi-Use, Multi-Reservoir Water Supply.* Water Research Foundation. 19-34.

NCAR (National Center for Atmospheric Research). 2007. Regional Climate-Change Projection from Multi-Model Ensembles (RCPM). [Online]. Available: <http://rcpm.ucar.edu>. [referenced September 2012]

Parry, M. L, O .F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, eds. 2007. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Rose, S. 2007. Decadal Rainfall and Runoff Trends in the Southeastern United States. In *Proceedings of the 2007 Georgia Water Resources Conference, April 27-29, 2007, Atlanta, Georgia.*

SCO-NC (State Climate Office of North Carolina). 2012. Climate change in North Carolina [Online]. Available: <http://www.nc-climate.ncsu.edu/climate/climate_change>. [referenced September 2012]

SC-SCO (South Carolina State Climatology Office). 2012a. The impact of climate change on South Carolina [Online]. Available:<http://www.dnr.sc.gov/climate/sco/Publications/climate_ change_ impacts.php>.[referenced September 2012]

———. 2012b. Average annual precipitation trends: 1901-2010. The impact of climate change on South Carolina [Online]. Available:<http://www. dnr.sc.gov/climate/sco/Publications/2010TP_Trends/2010P_annual.php>.[referenced September 2012]

Tebaldi, C., R. L. Smith, D. Nychka, and L. O. Mearns. 2005. Quantifying uncertainty in Projections of Regional Climate Change: a Bayesian Approach to the Analysis of Multimodel Ensembles. *Jour. Climate,* 18(10); 1524-1540.

APPENDIX F

SIMULATED ELEVATION DURATION PLOTS

APPENDIX F

This appendix includes simulated reservoir elevation duration plots for each reservoir (based on 15-Minute CHEOPS modeled output). The duration plots are included in the appendix in the order noted below.

1. Bad Creek Elevation Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

2. Jocassee Elevation Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

3. Keowee Elevation Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

4. Hartwell Elevation Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

5. Richard B. Russell Elevation Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

6. J. Strom Thurmond Elevation Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

7. Bad Creek Elevation Duration B, ccLow Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

8. Jocassee Elevation Duration B, ccLow Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

9. Keowee Elevation Duration B, ccLow Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

10. Hartwell Elevation Duration B, ccLow Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

11. Richard B. Russell Elevation Duration B, ccLow Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

12. J. Strom Thurmond Elevation Duration B, ccLow Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

13. Bad Creek Elevation Duration C, ccHigh Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

14. Jocassee Elevation Duration C, ccHigh Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

15. Keowee Elevation Duration C, ccHigh Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

16. Hartwell Elevation Duration C, ccHigh Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

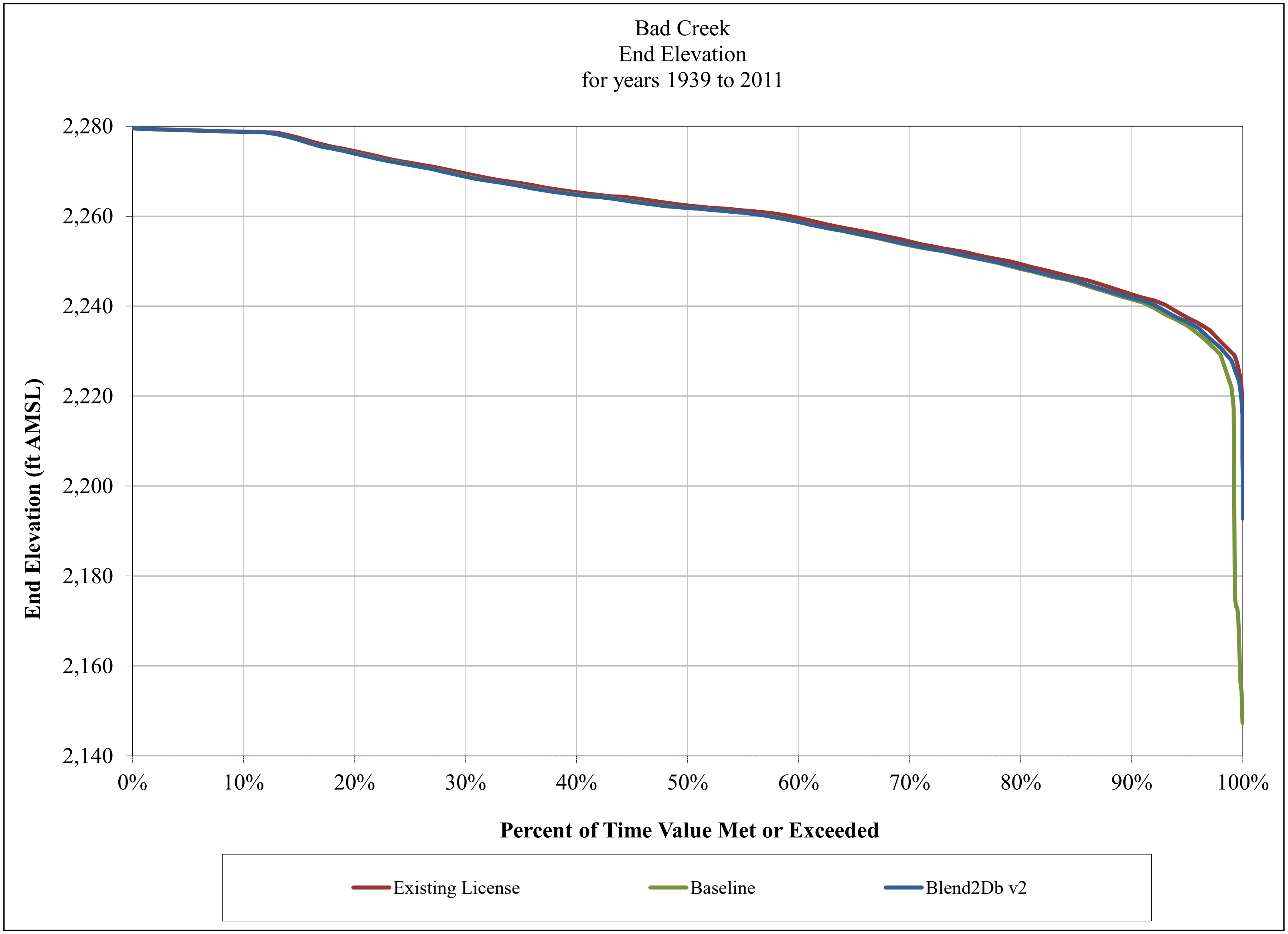
17. Richard B. Russell Elevation Duration C, ccHigh Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

18. J. Strom Thurmond Elevation Duration C, ccHigh Sensitivity – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

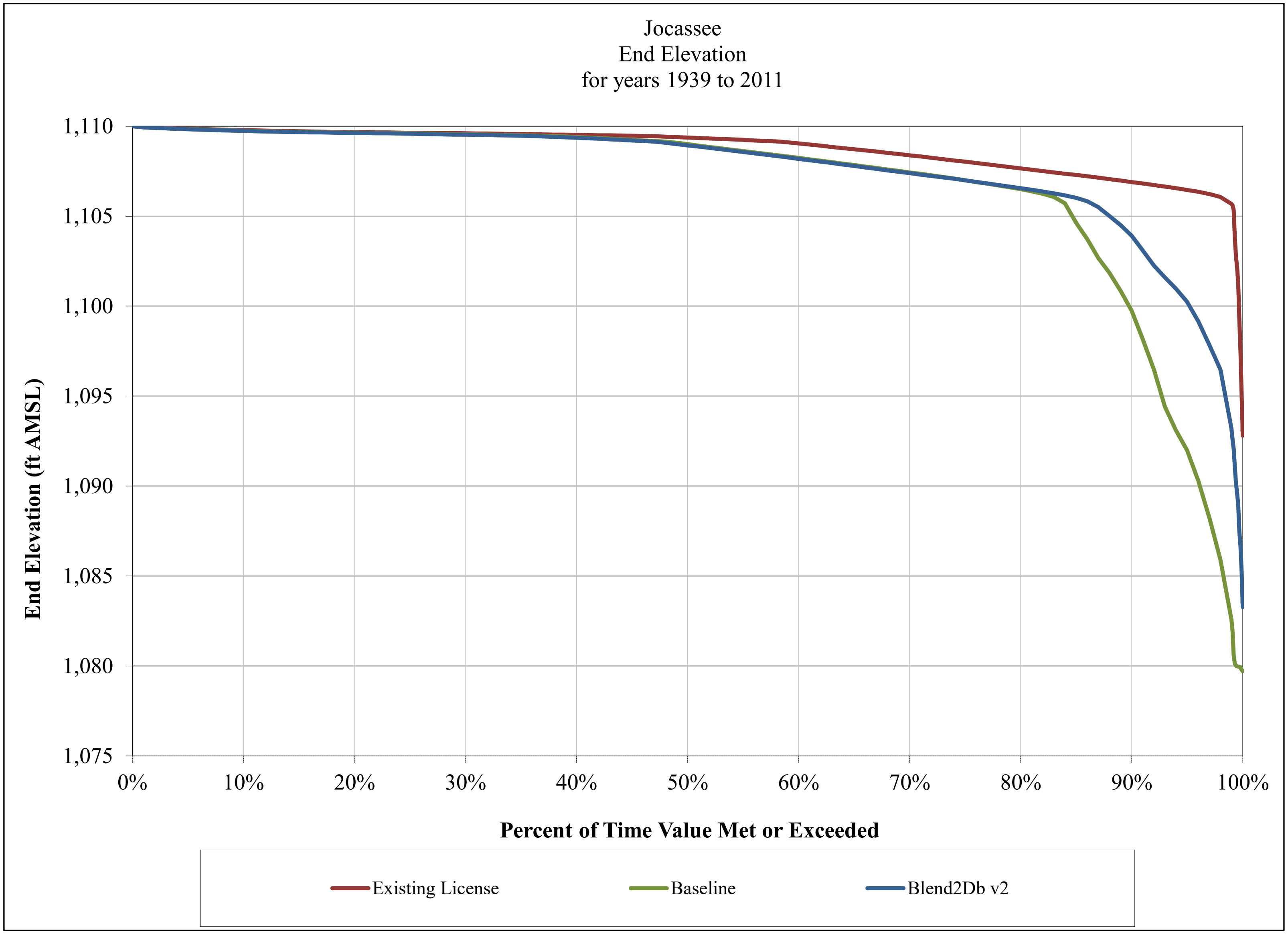
Modeled Reservoir Elevation Duration

(based on 15-Minute modeled output)

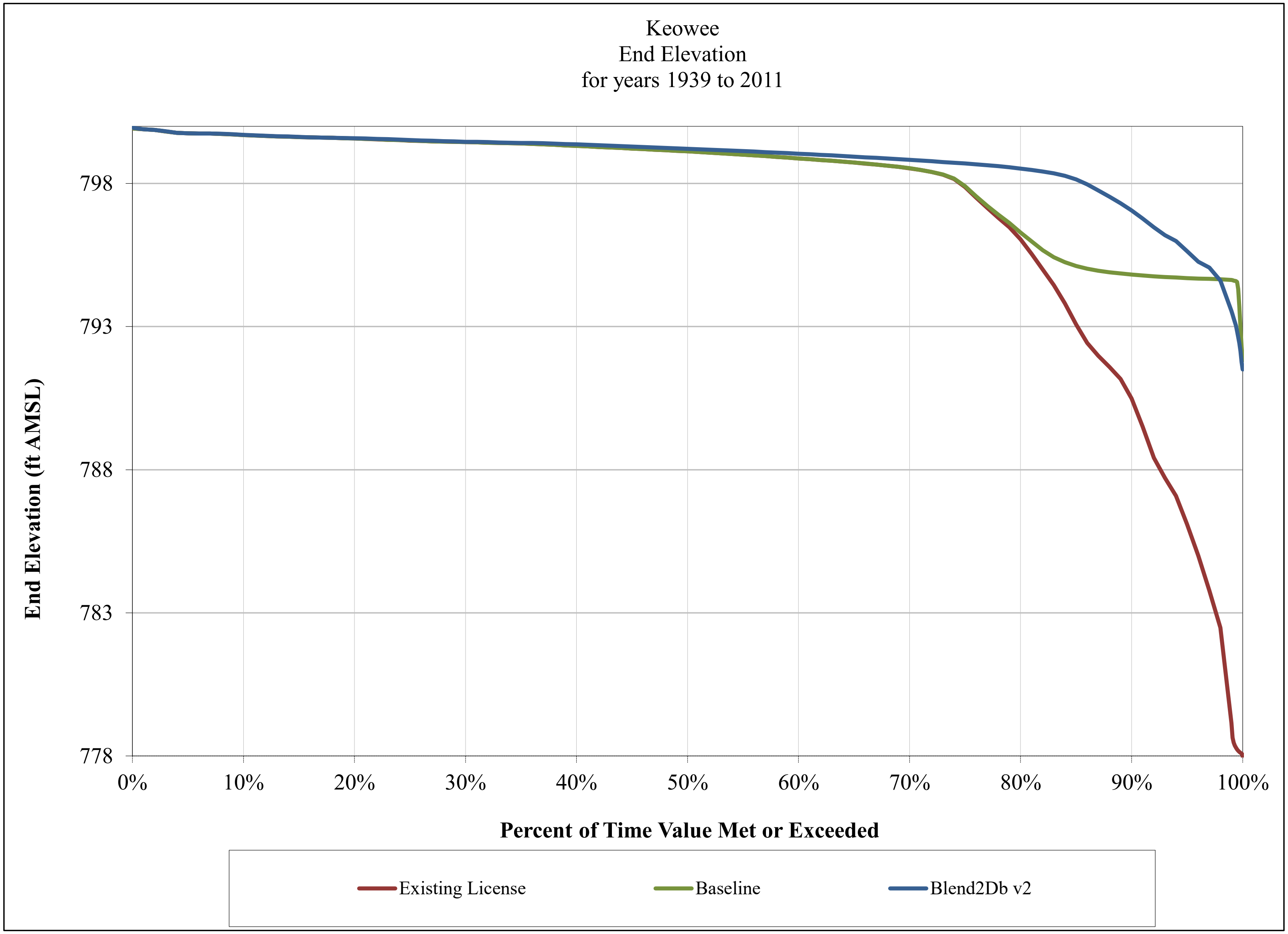
Bad Creek Elevation Curve A



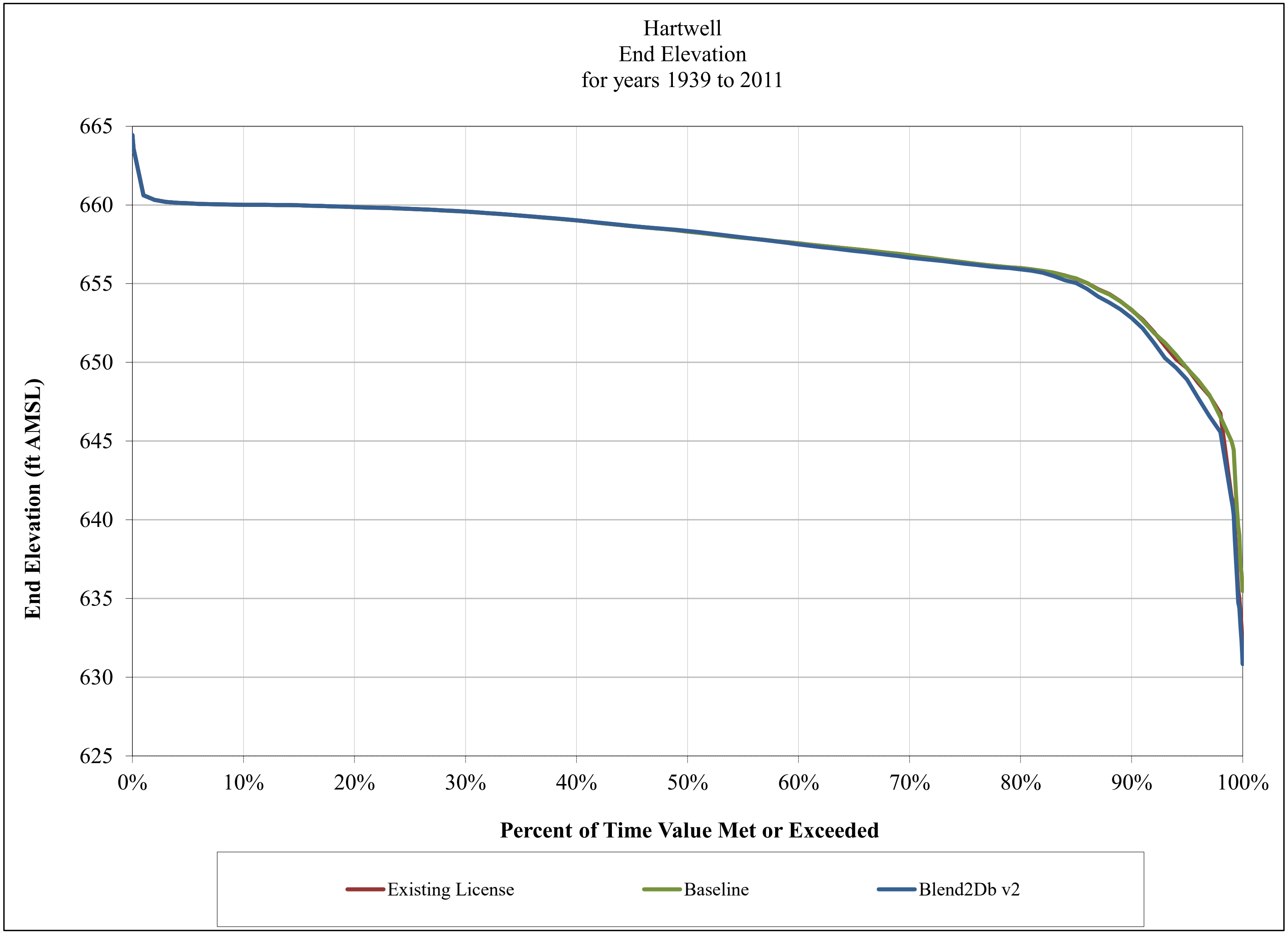
Jocassee Elevation Curve A



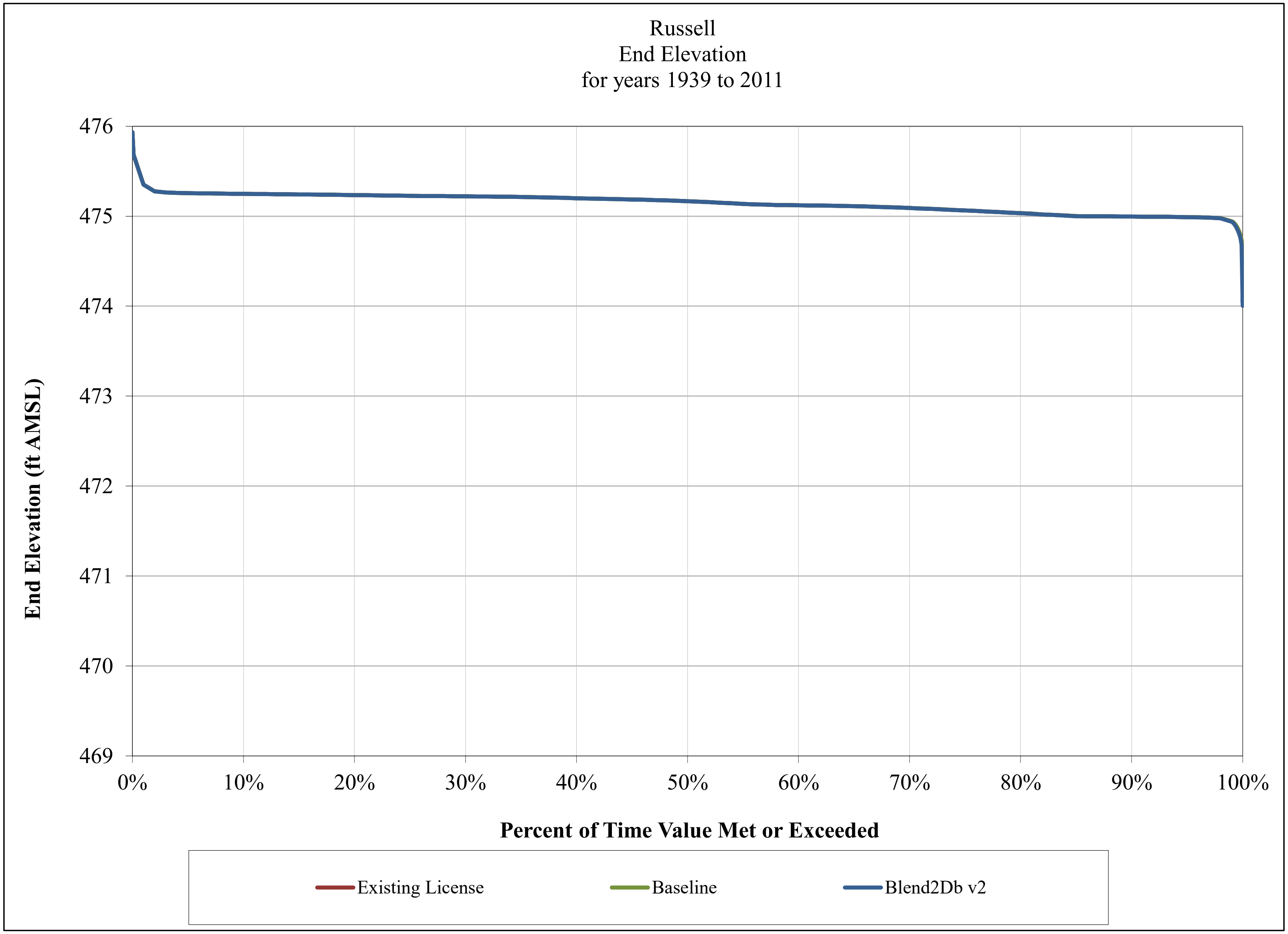
Keowee Elevation Curve A



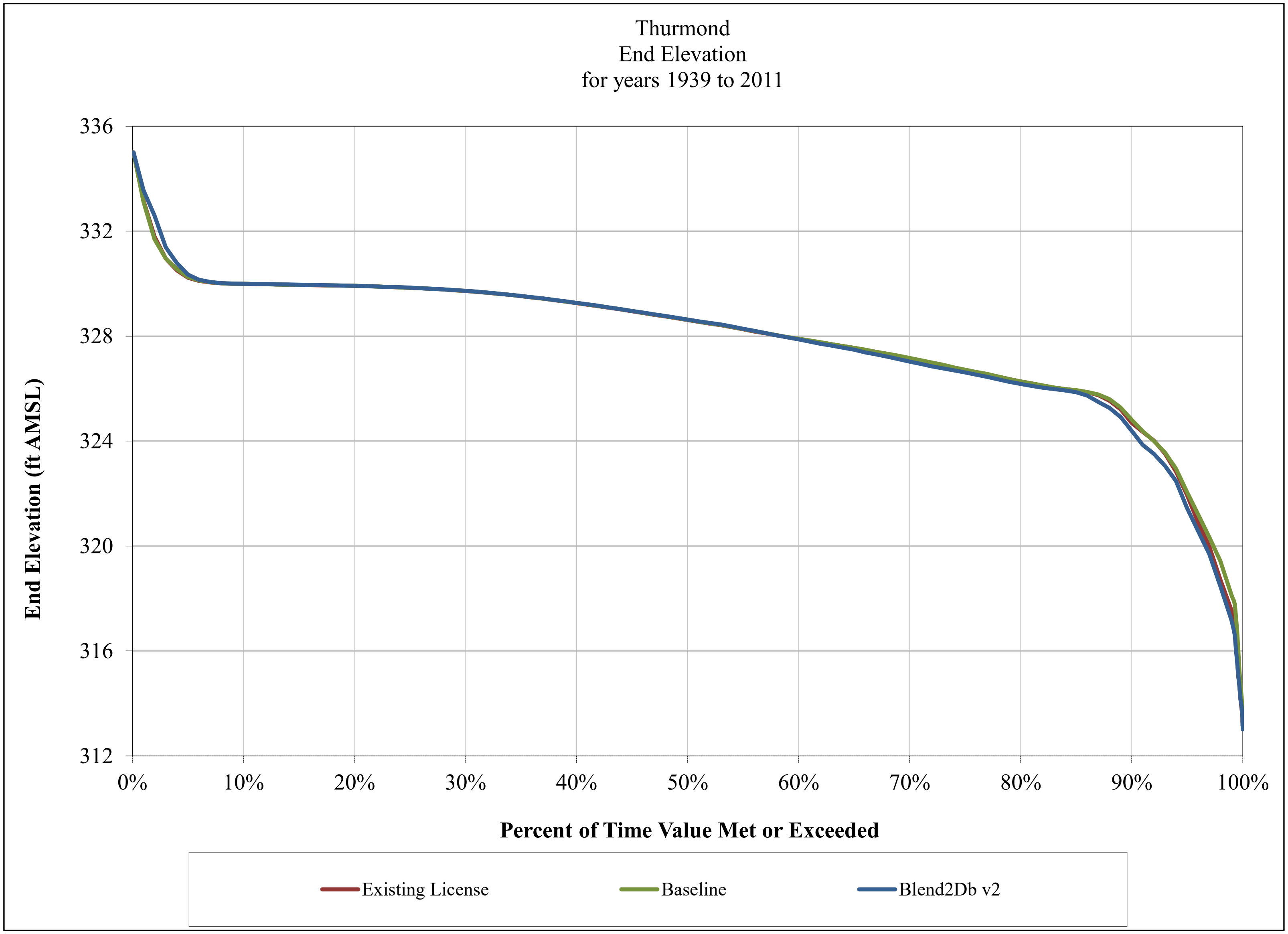
Hartwell Elevation Curve A



Richard B. Russell Elevation Curve A



J. Strom Thurmond Elevation Curve A

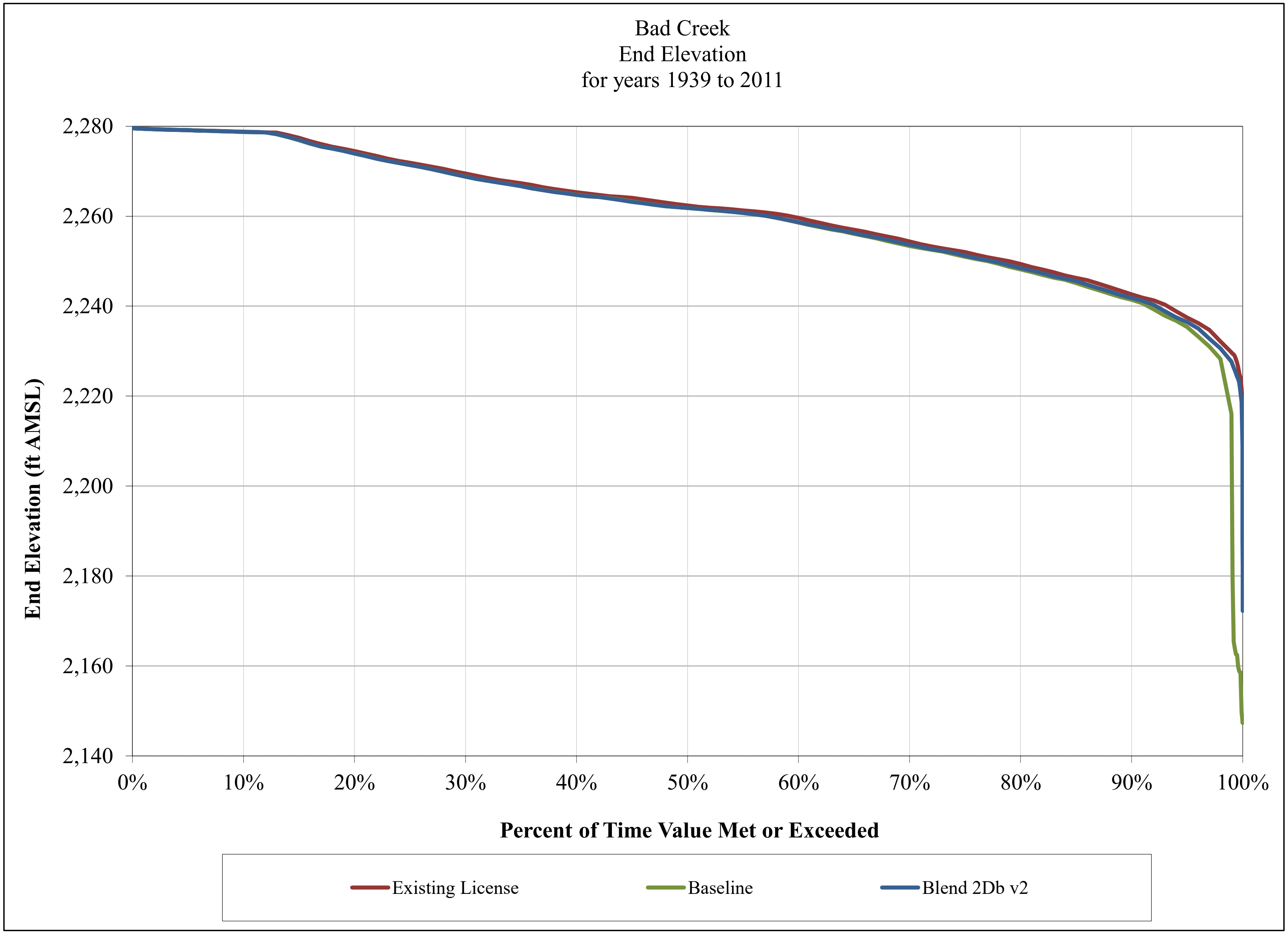


Modeled Reservoir Elevation Duration

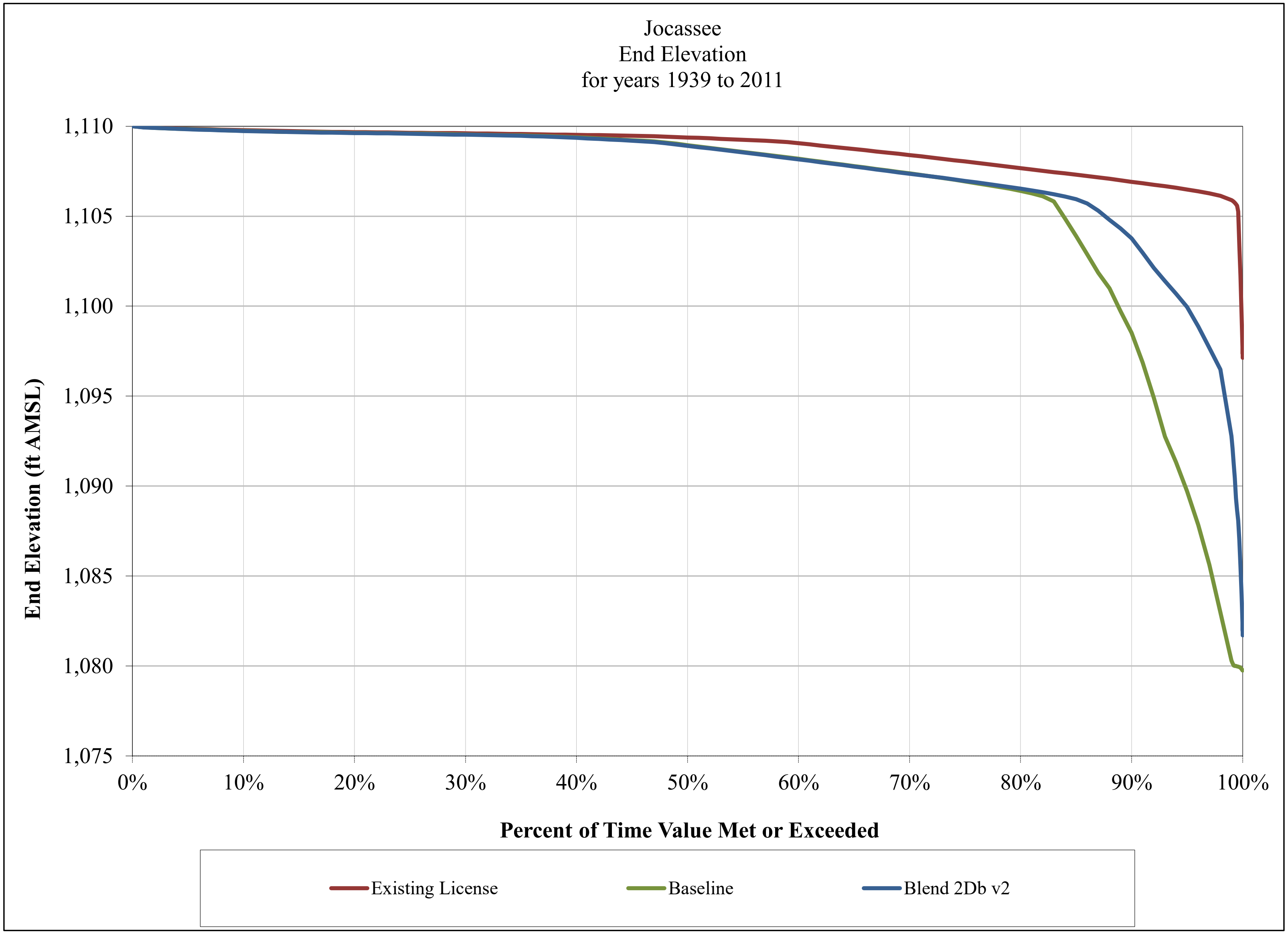
Low Climate Change (ccLow) Sensitivity

(based on 15-Minute modeled output)

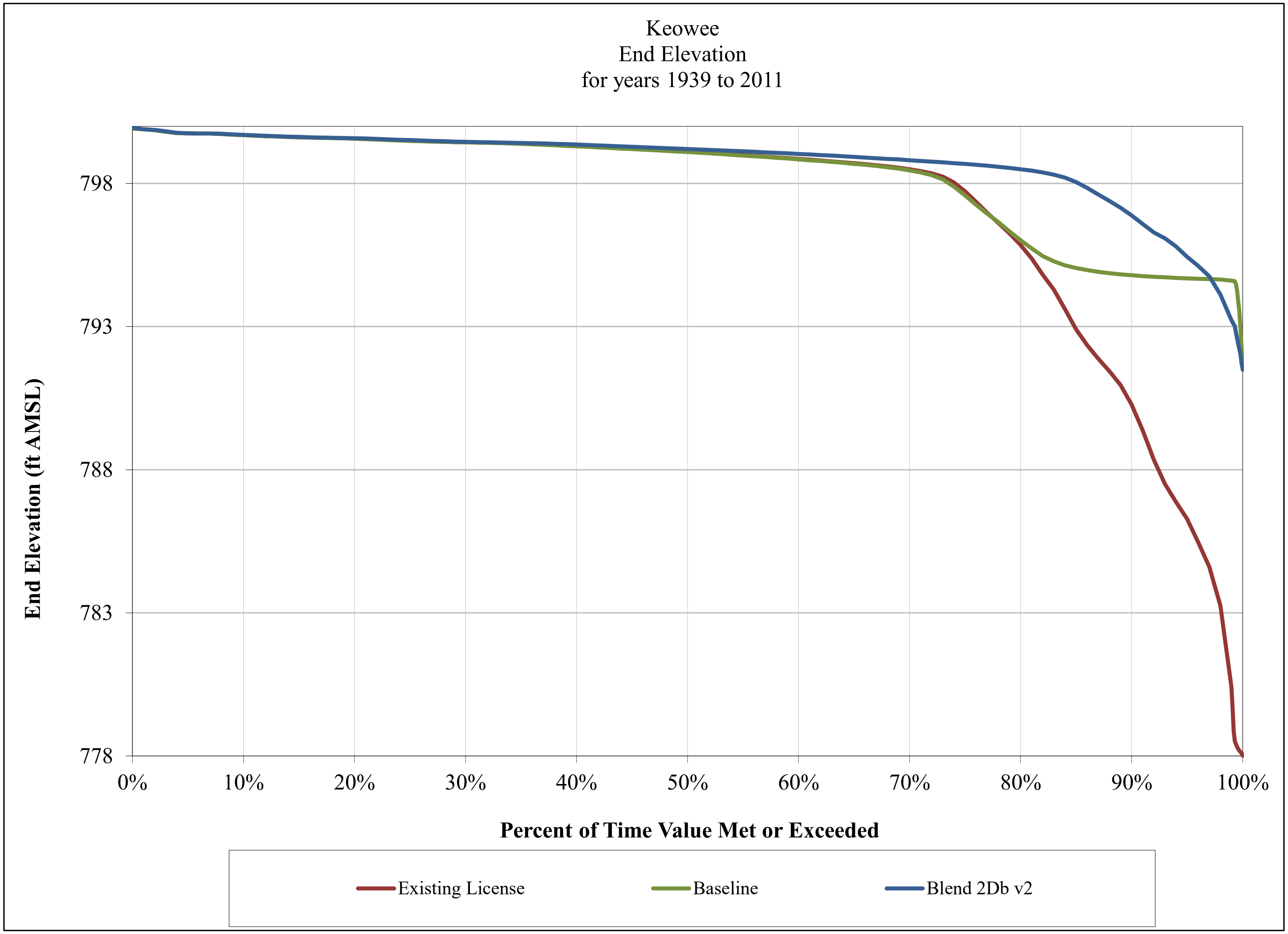
Bad Creek Elevation Curve B, ccLow Sensitivity



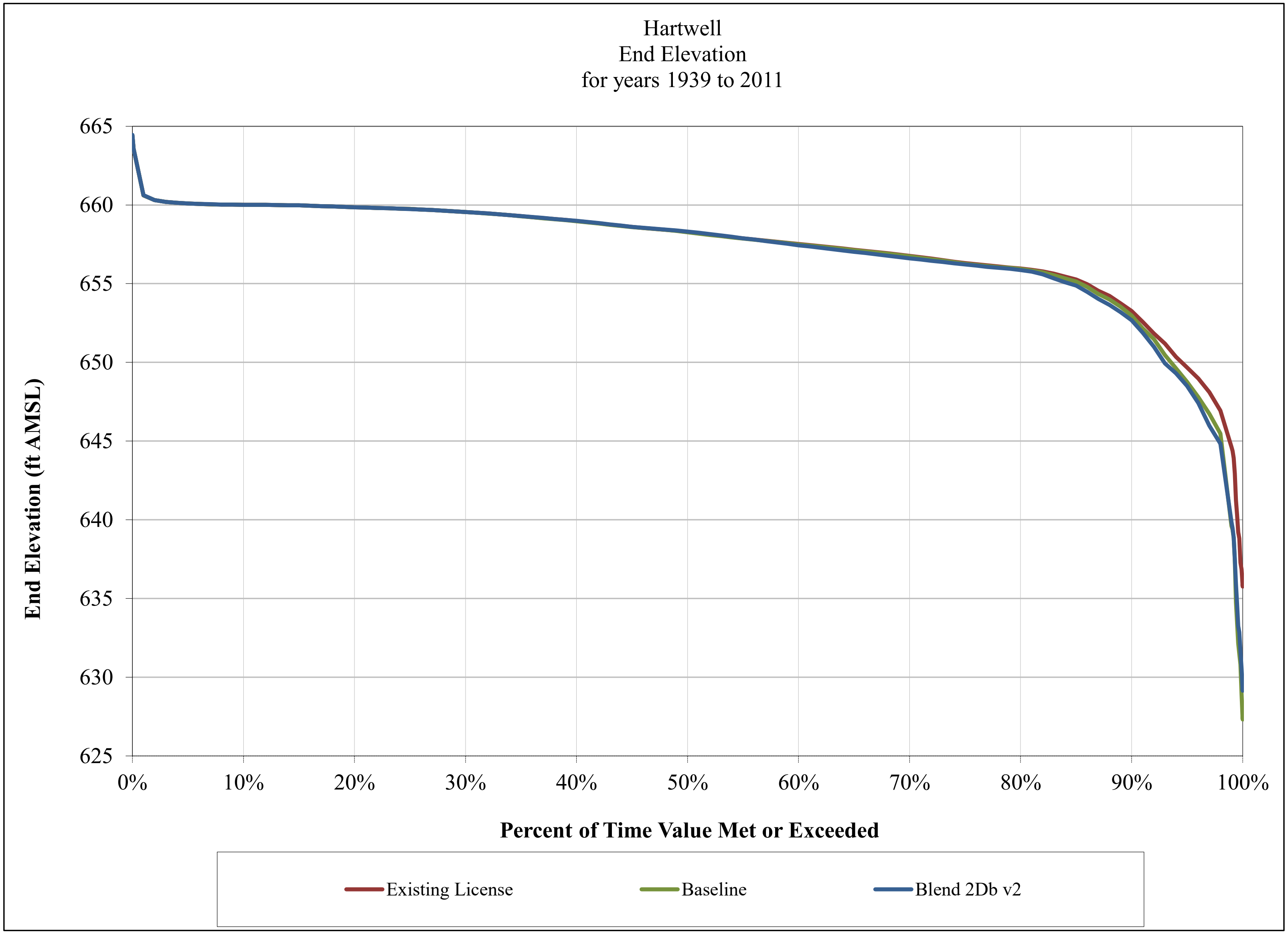
Jocassee Elevation Curve B, ccLow Sensitivity



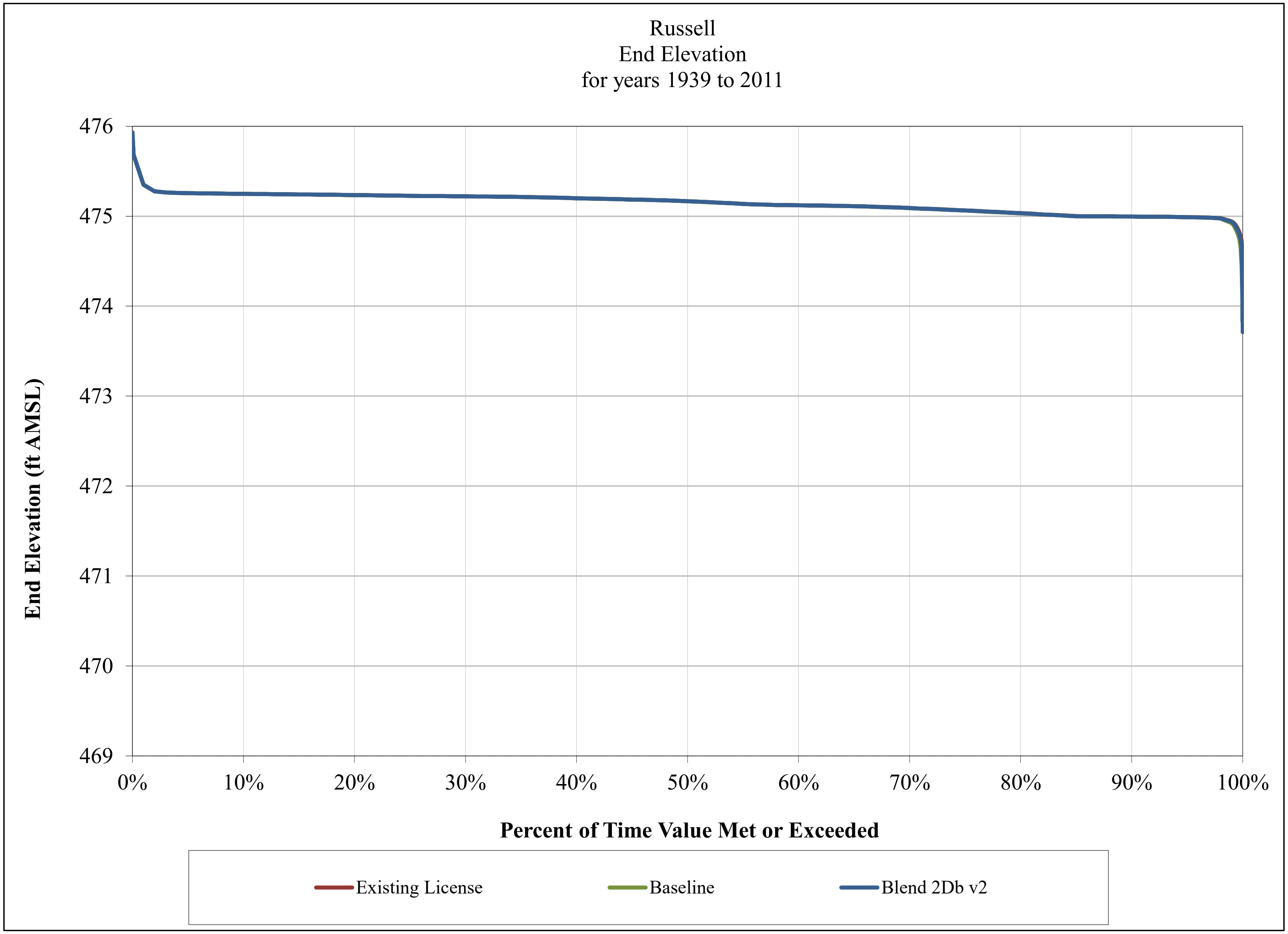
Keowee Elevation Curve B, ccLow Sensitivity



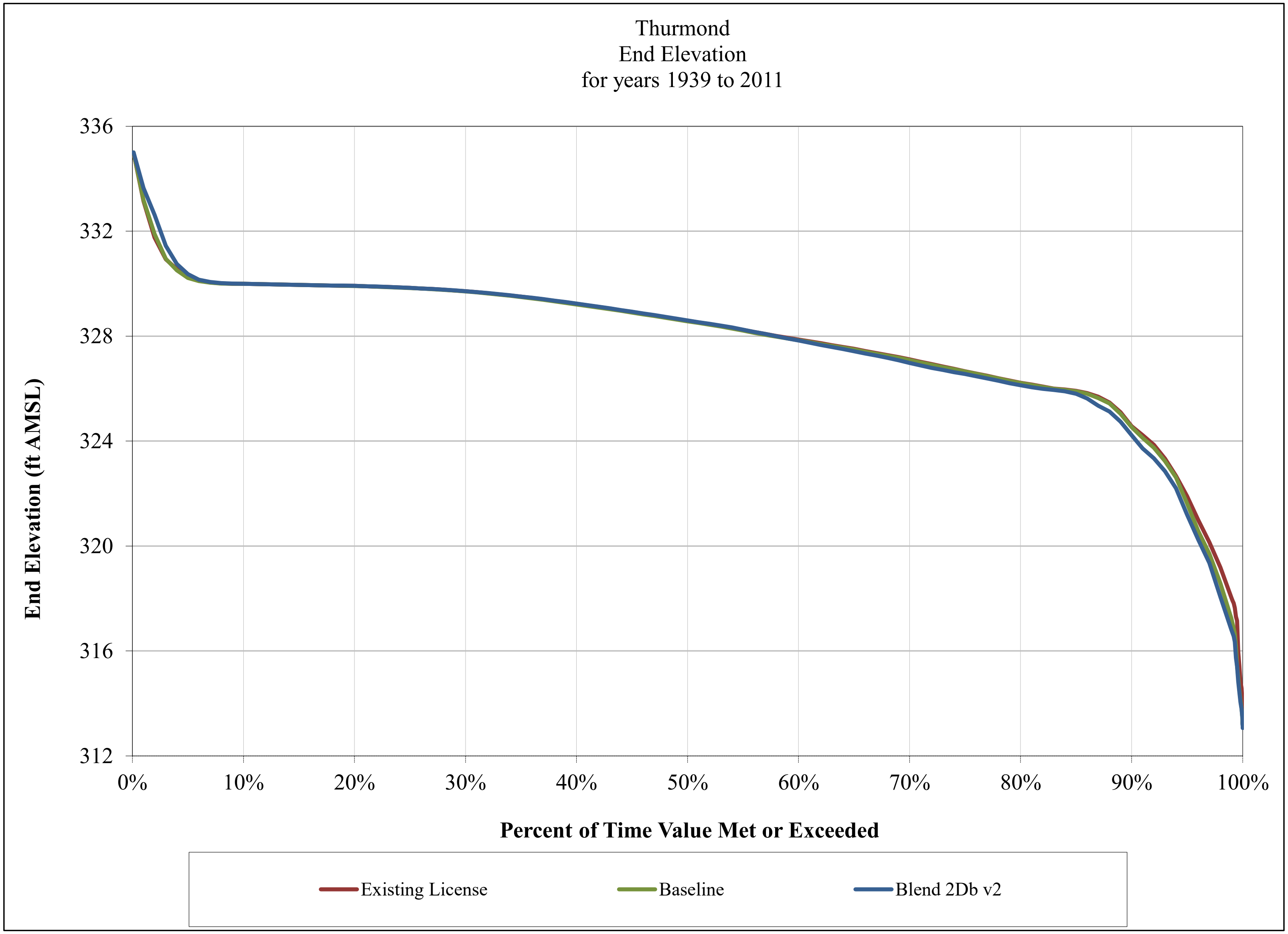
Hartwell Elevation Curve B, ccLow Sensitivity



Richard B. Russell Elevation Curve B, ccLow Sensitivity



J. Strom Thurmond Elevation Curve B, ccLow Sensitivity

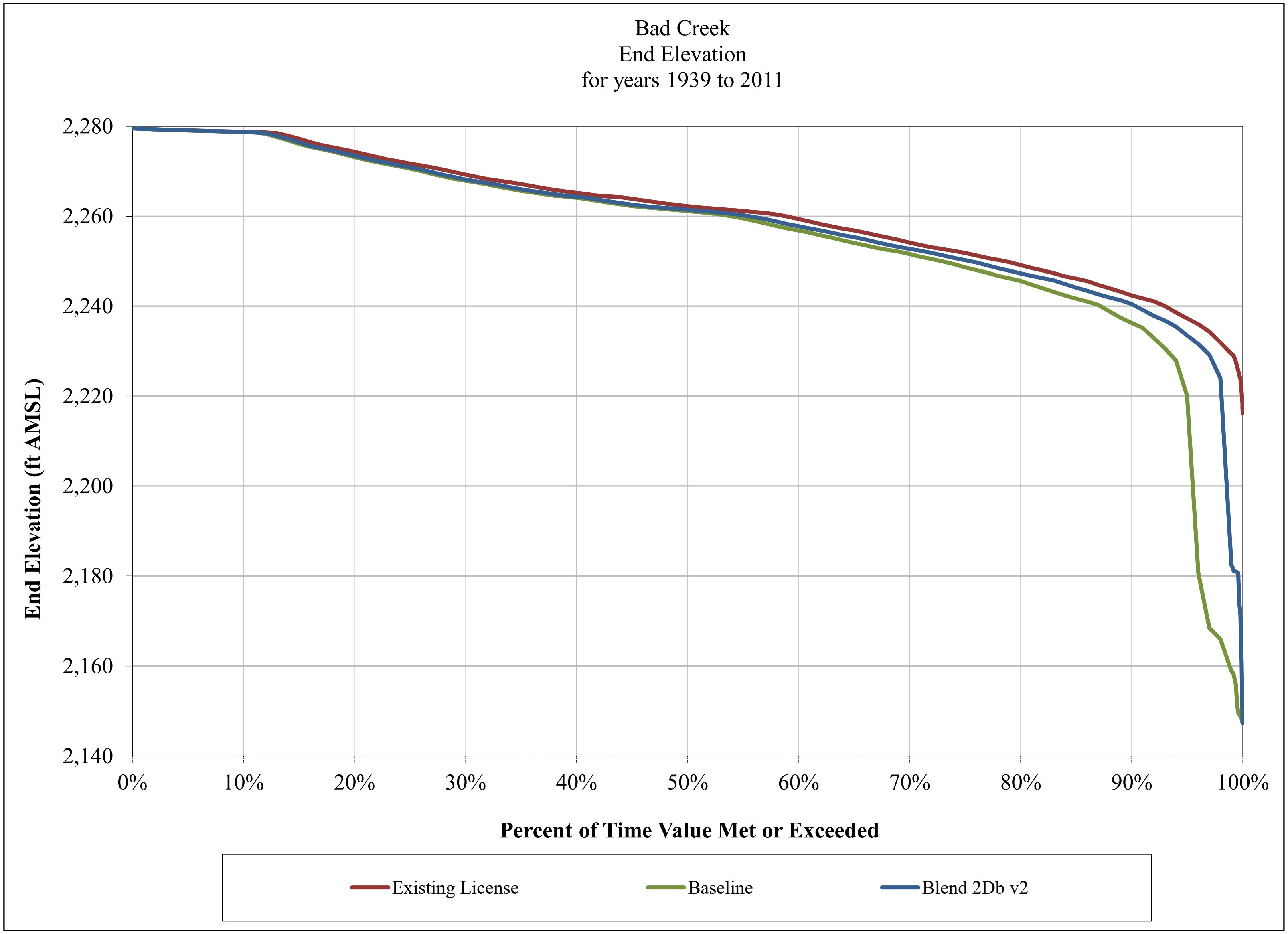


Modeled Reservoir Elevation Duration

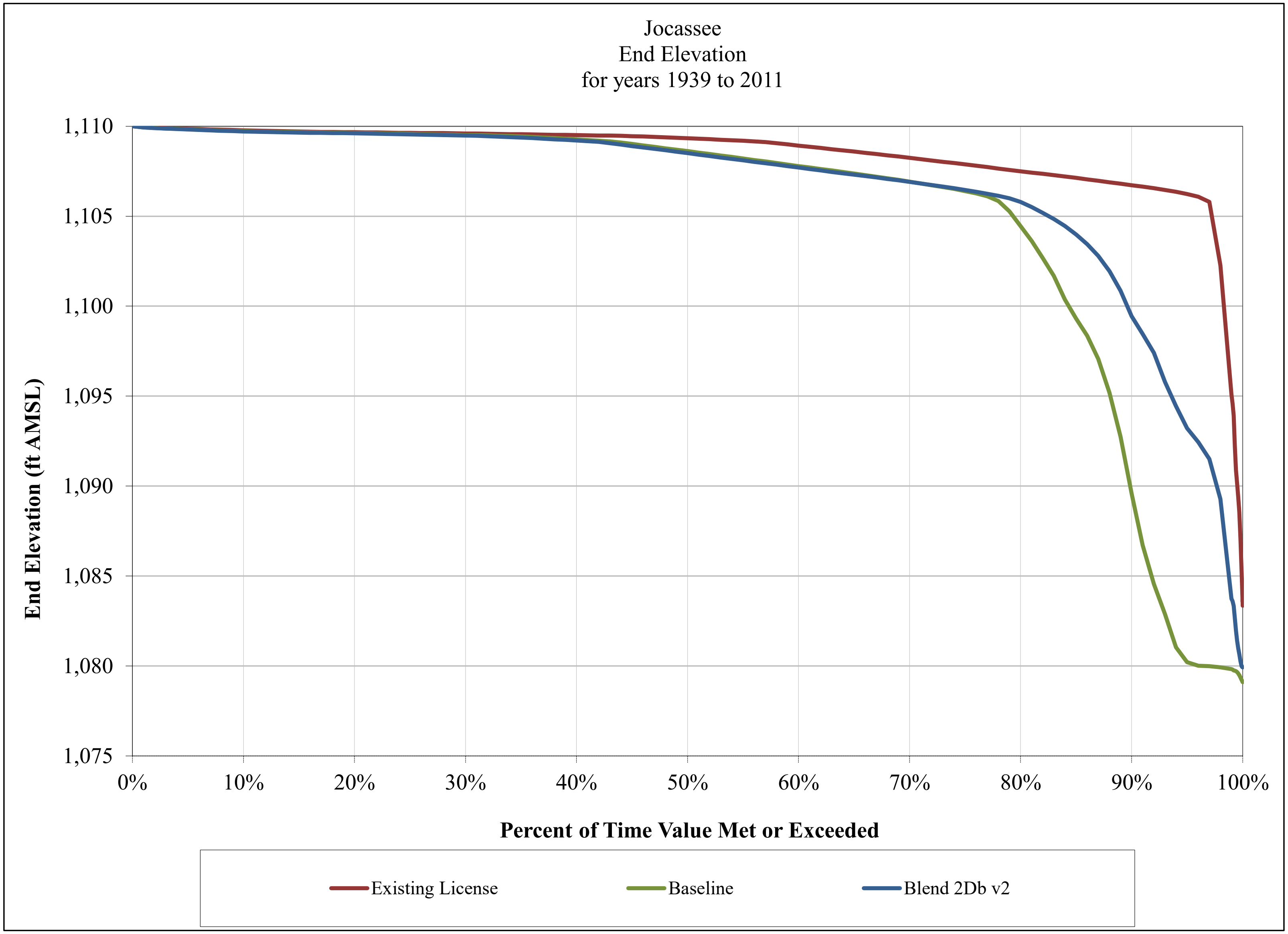
High Climate Change (ccHigh) Sensitivity

(based on 15-Minute modeled output)

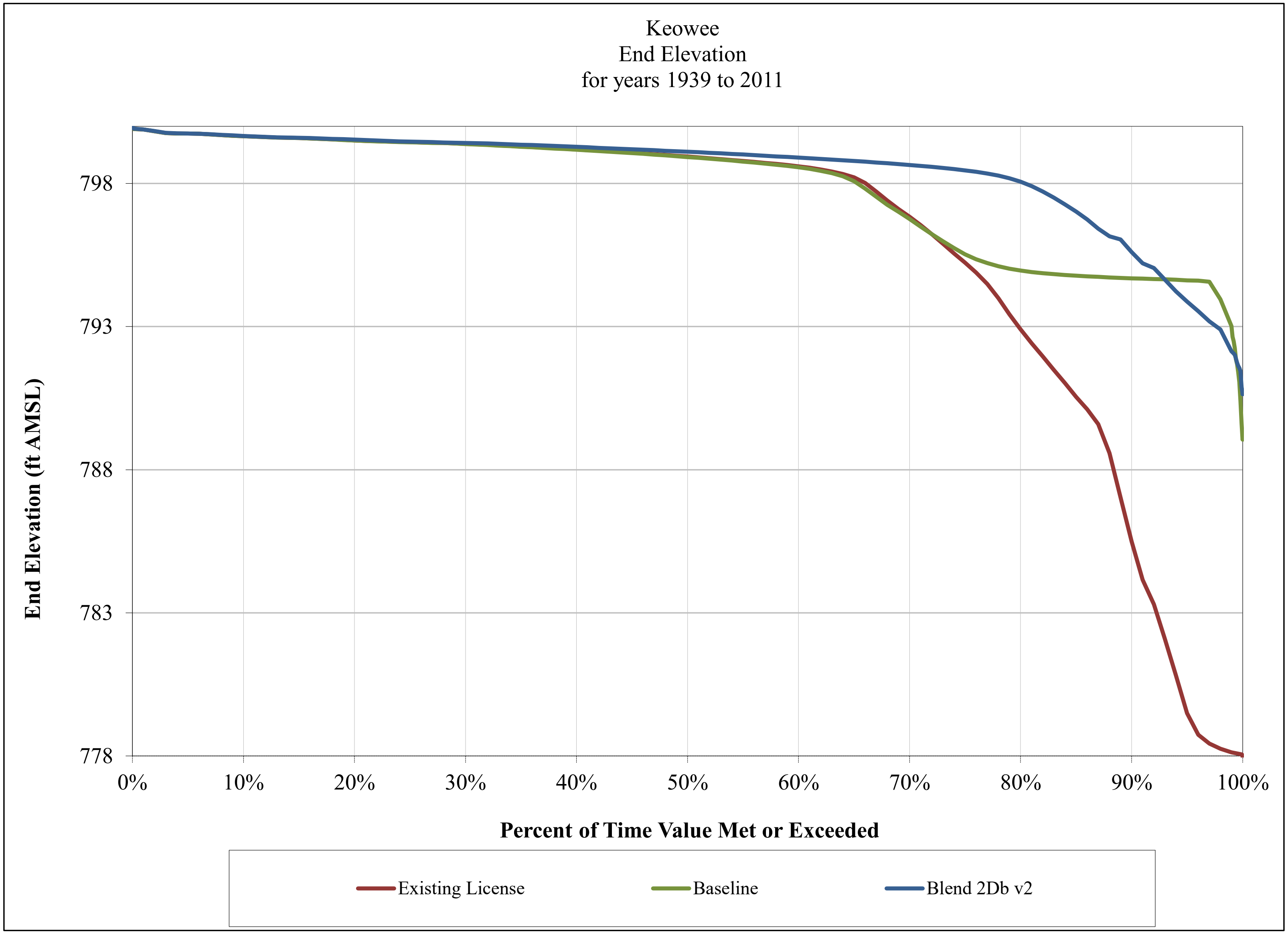
Bad Creek Elevation Curve C, ccHigh Sensitivity



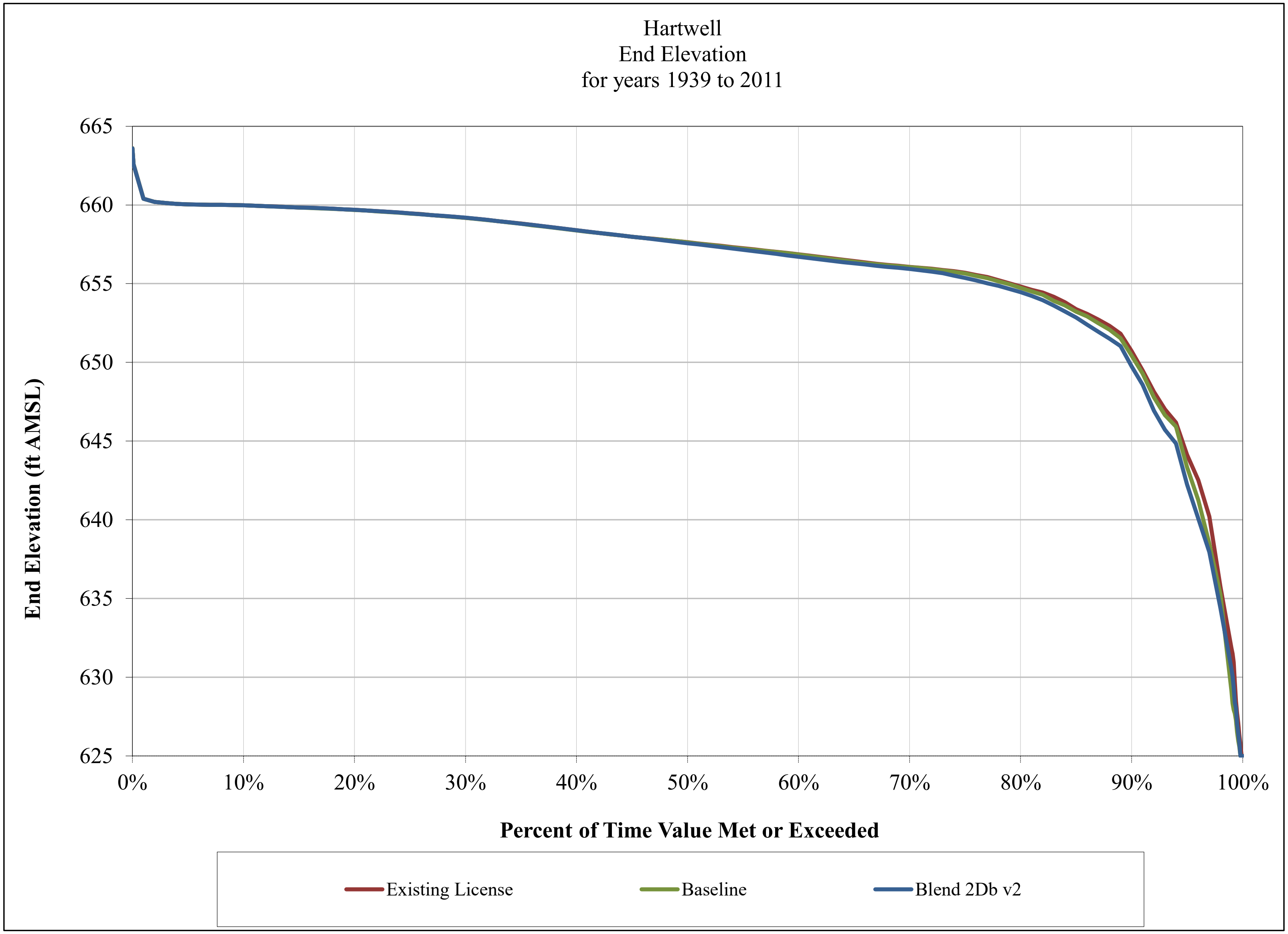
Jocassee Elevation Curve C, ccHigh Sensitivity



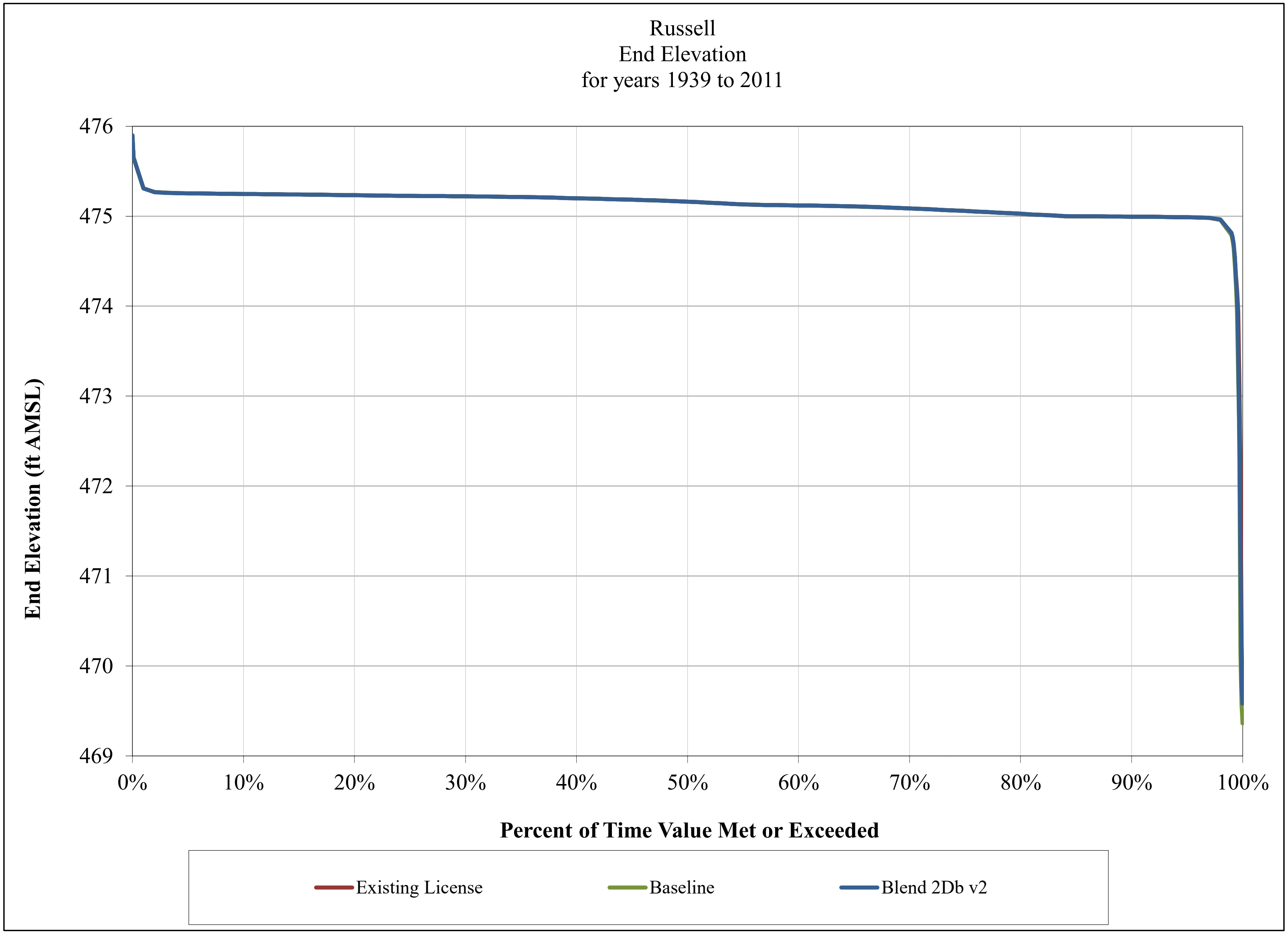
Keowee Elevation Curve C, ccHigh Sensitivity



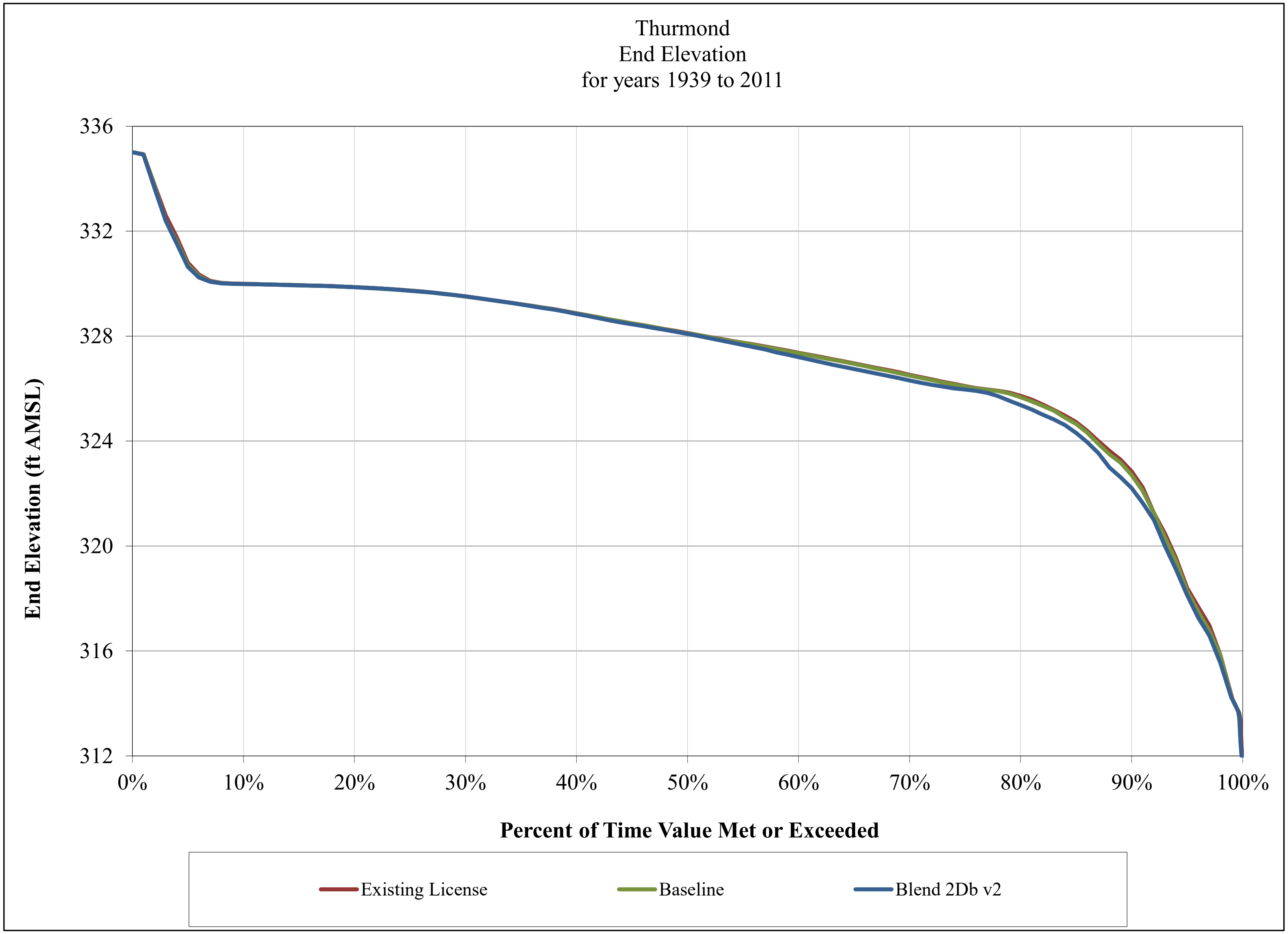
Hartwell Elevation Curve C, ccHigh Sensitivity



Richard B. Russell Elevation Curve C, ccHigh Sensitivity



J. Strom Thurmond Elevation Curve C, ccHigh Sensitivity



APPENDIX G

SIMULATED OUTFLOW DURATION PLOTS

APPENDIX G

This appendix includes simulated reservoir discharge duration plots for each reservoir (based on daily average CHEOPS modeled output). The duration plots are included in the appendix in the order noted below.

1. Keowee Discharge Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

2. J. Strom Thurmond Discharge Duration A – Includes results of the following scenarios (Baseline, Existing License, and Blend 2Db v2)

3. Keowee Discharge Duration B, ccLow Sensitivity – Includes results of the ccLow Sensitivity for the following scenarios (Baseline, Existing License, and Blend 2Db v2)

4. J. Strom Thurmond Discharge Duration B, ccLow Sensitivity – Includes results of the ccLow Sensitivity for the following scenarios (Baseline, Existing License, and Blend 2Db v2)

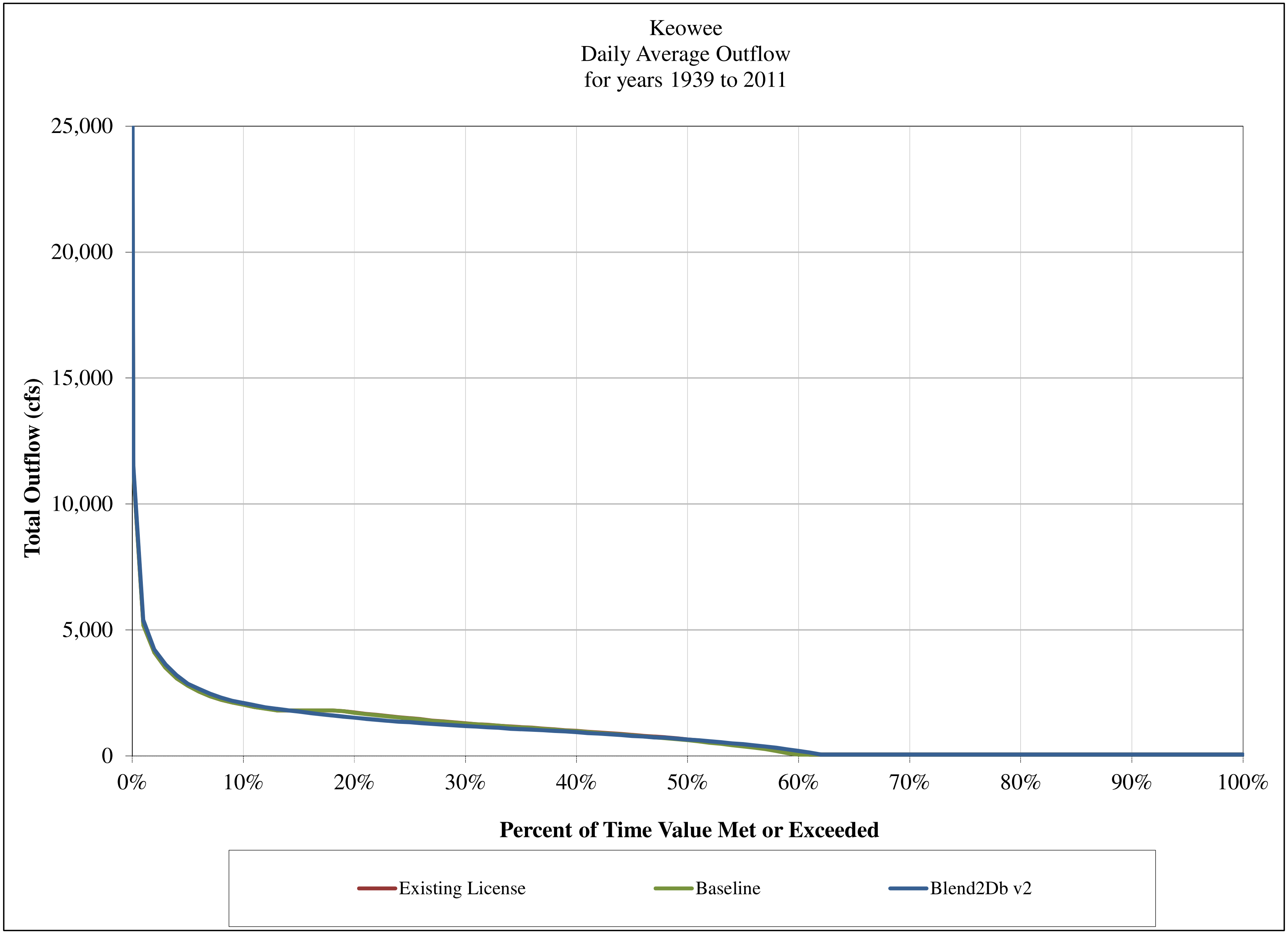
5. Keowee Discharge Duration C, ccHigh Sensitivity – Includes results of the ccHigh Sensitivity for the following scenarios (Baseline, Existing License, and Blend 2Db v2)

6. J. Strom Thurmond Discharge Duration C, ccHigh Sensitivity – Includes results of the ccHigh Sensitivity for the following scenarios (Baseline, Existing License, and Blend 2Db v2)

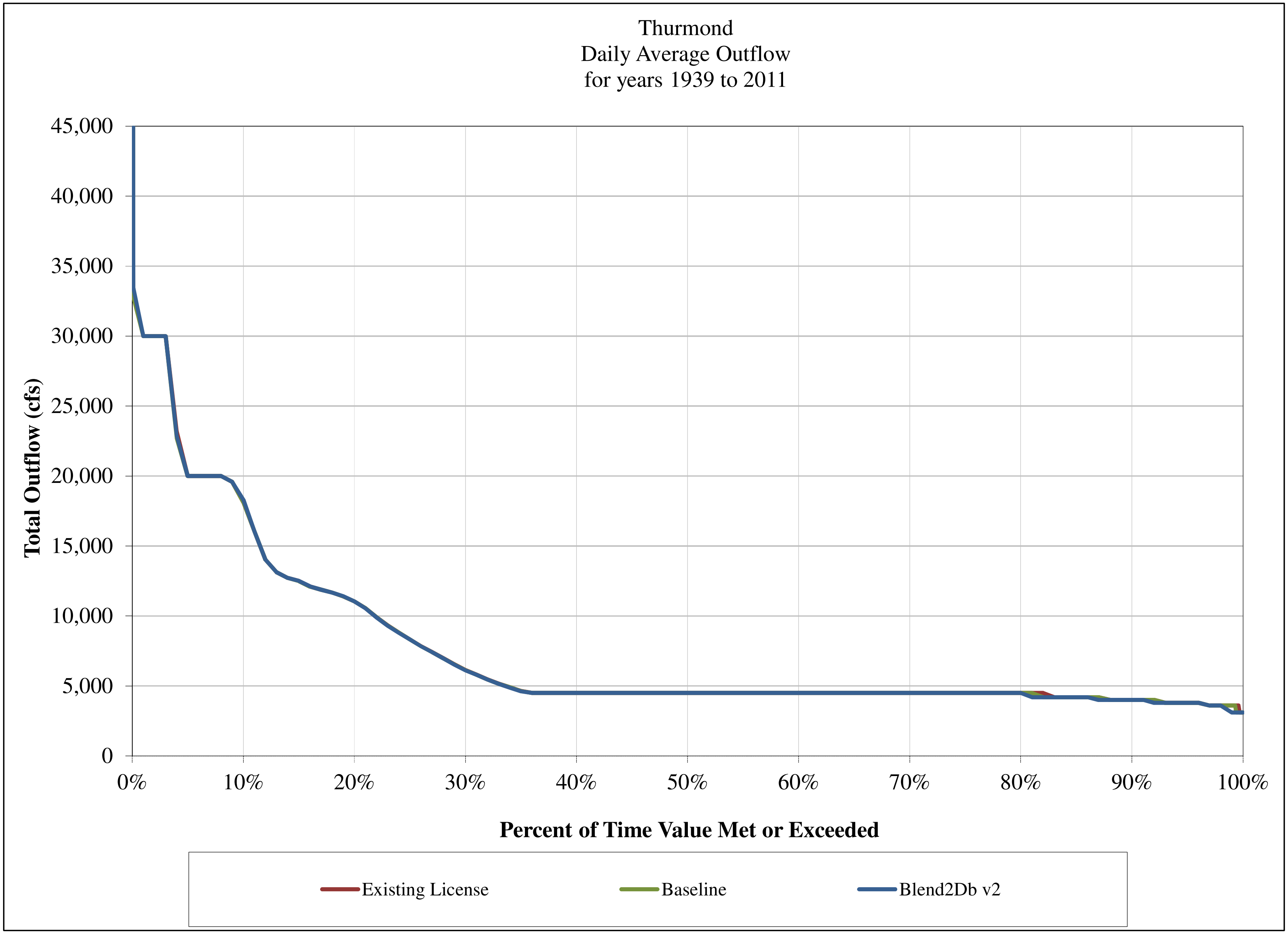
Modeled Reservoir Discharge Duration

(based on daily average modeled output)

Keowee Discharge Duration A



J. Strom Thurmond Discharge Duration A

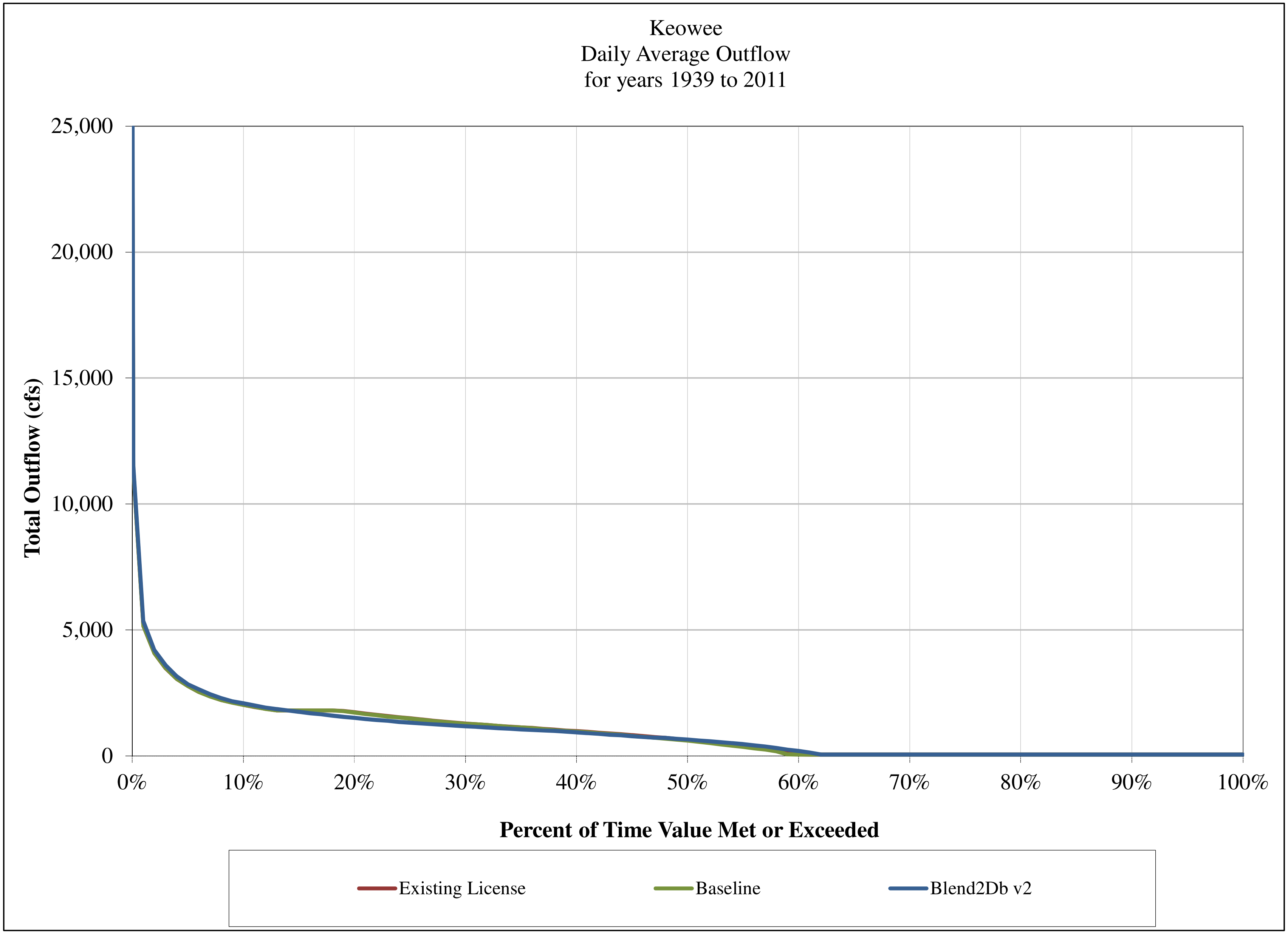


Modeled Reservoir Discharge Duration

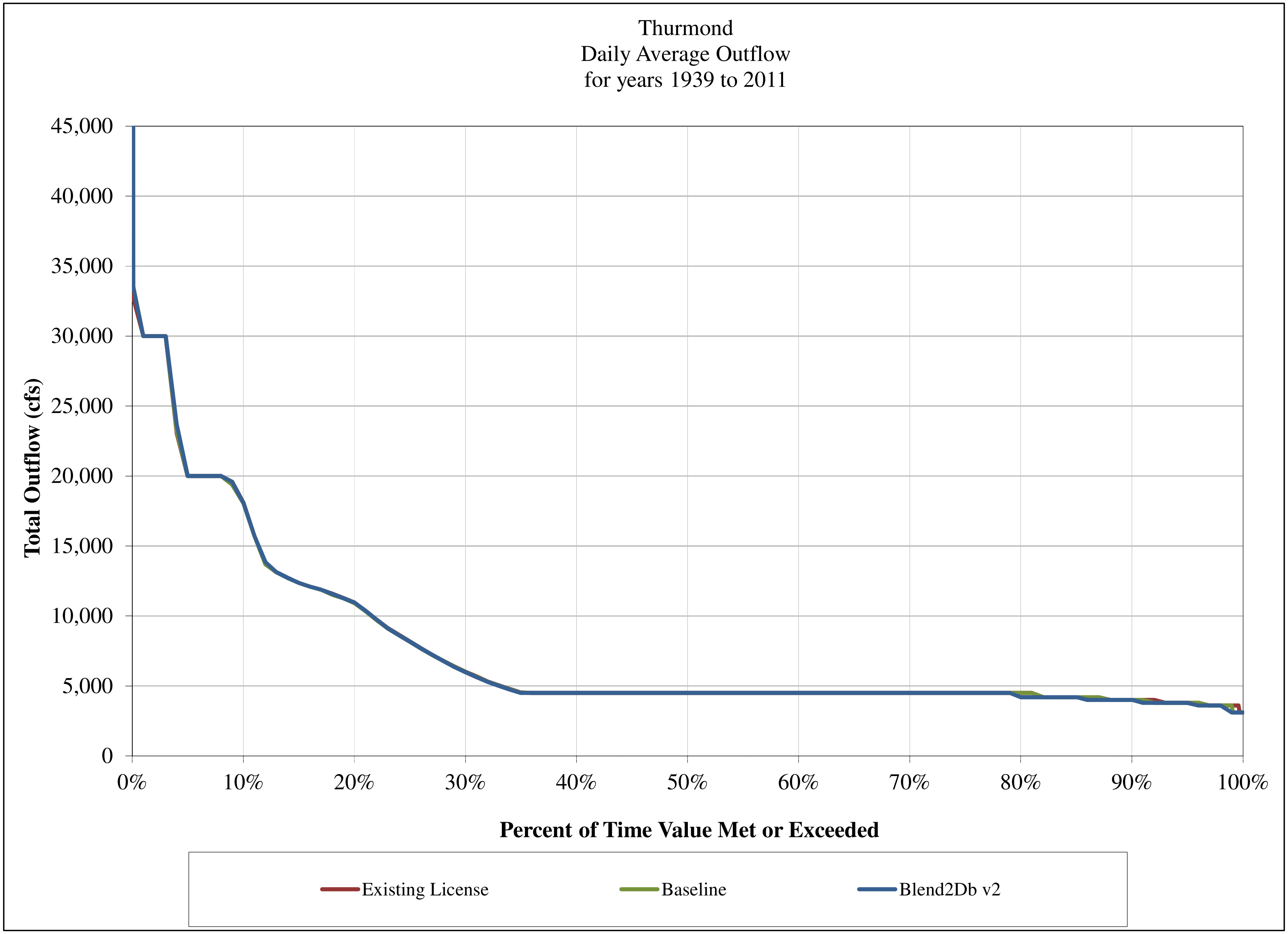
Low Climate Change (ccLow) Sensitivity

(based on daily average modeled output)

Keowee Discharge Duration B, ccLow Sensitivity



J. Strom Thurmond Discharge Duration B, ccLow Sensitivity

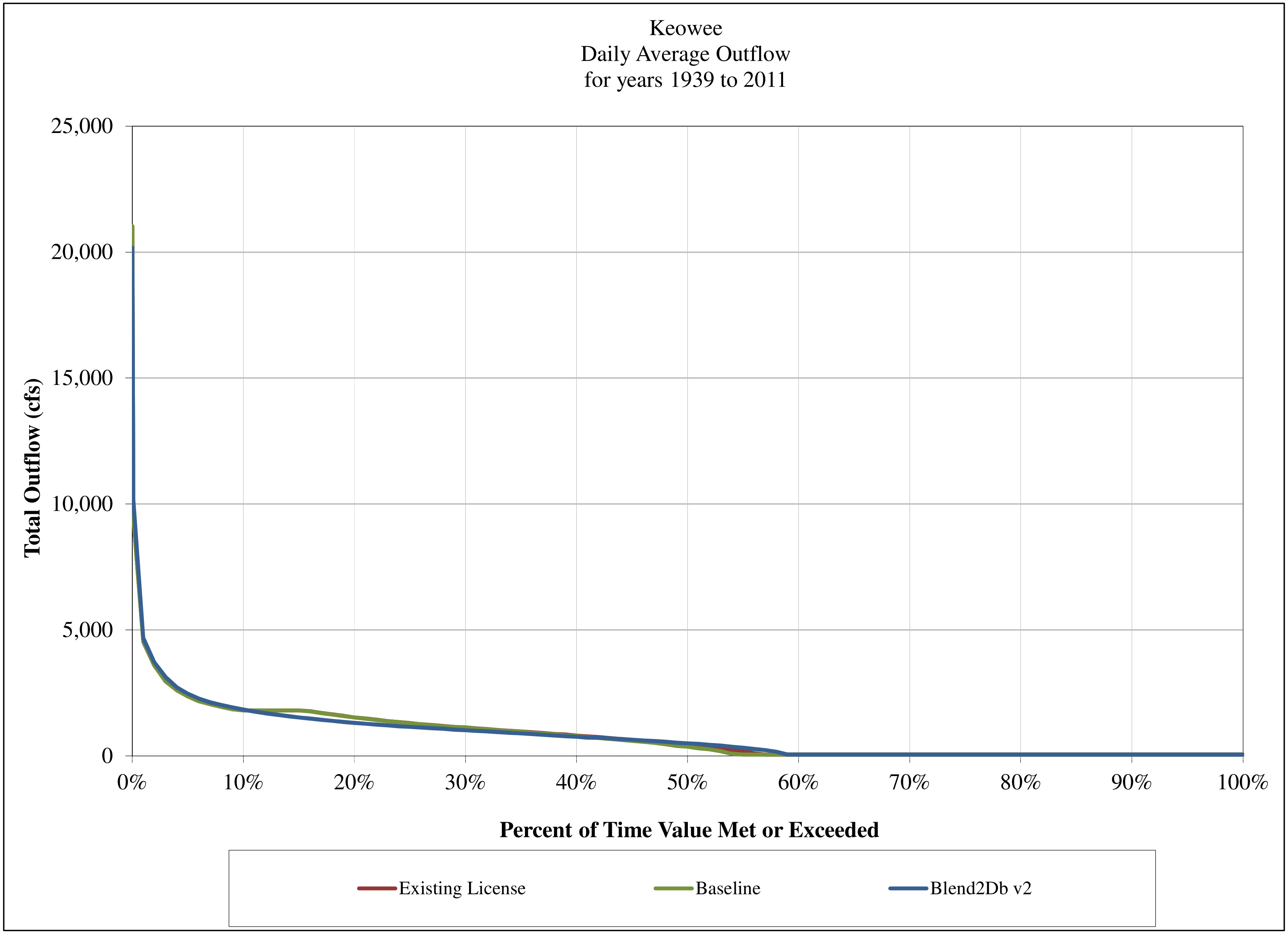


Modeled Reservoir Discharge Duration

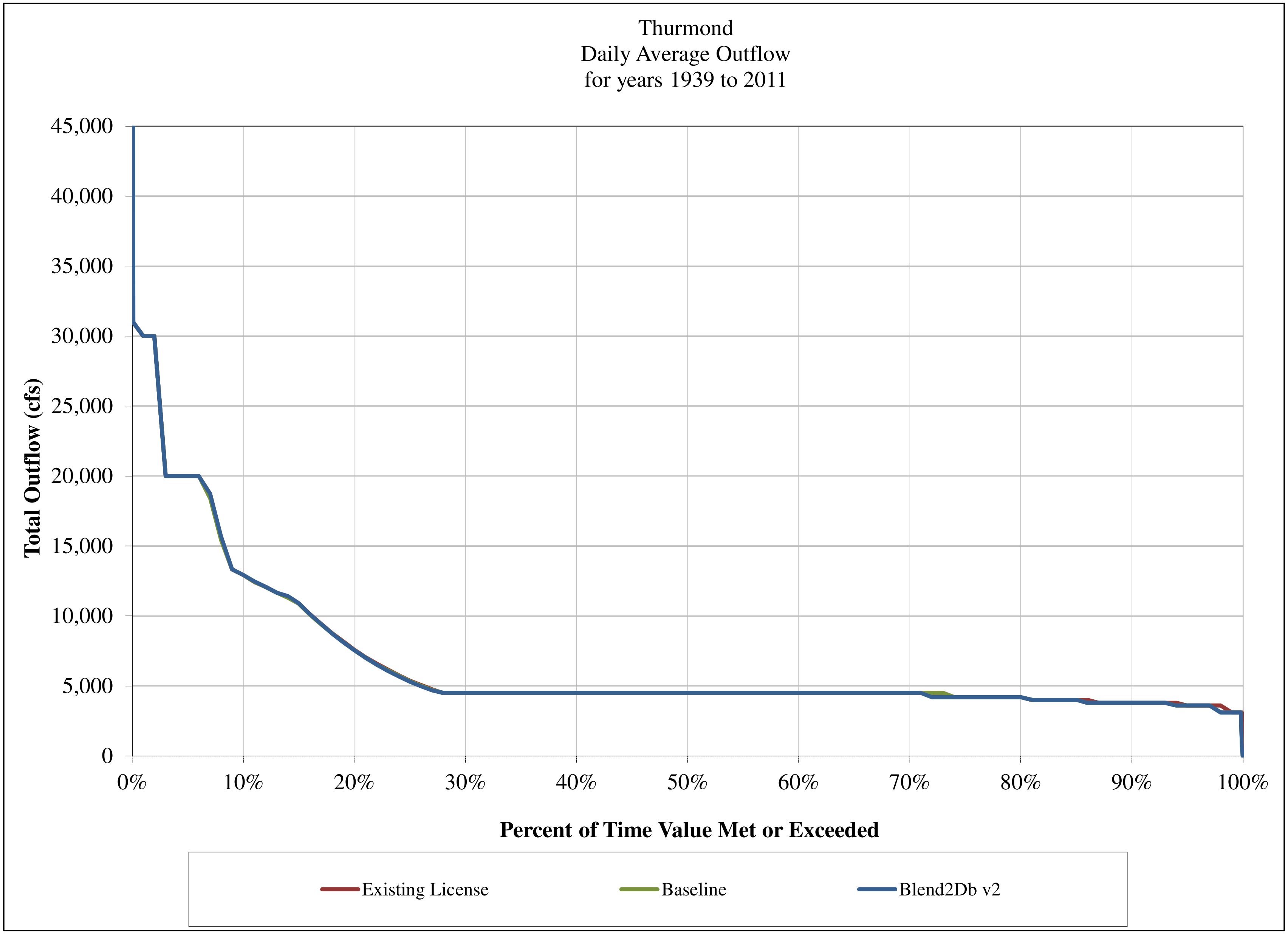
High Climate Change (ccHigh) Sensitivity

(based on daily average modeled output)

Keowee Discharge Duration C, ccHigh Sensitivity



J. Strom Thurmond Discharge Duration C, ccHigh Sensitivity



APPENDIX H

PERFORMANCE MEASURES SHEETS

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Existing License	Blend 2Db v2
	Bad Creek					(1939-2011)	(1939-2011)	(1939-2011)
	Elevation - Electric Operations							
1	Maximize adherence to high-head operating band	Percent of time reservoir level more than 60 ft below 2,310 ft AMSL (Full Pool)	1-Jan	31-Dec	2%	23%	21%	22%
	Pumped Storage							
2	Minimize impacts on pumped storage operations	Avg. Pumped Volume (ac-ft)/yr	1-Jan	31-Dec	210,000	2,024,675	2,030,325	2,046,446
	Lake Jocassee							
	Elevation - Storage Availability							
3	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 1,108 ft AMSL on May 1	1-May	1-May	5	66	73	66
	Elevation - Recreation							
4	Minimize restricted recreation	Number of years where cove access (reservoir level below 1,090 ft AMSL) is restricted for more than 25 days (Note 3)	1-Jan	31-Dec	2	9	0	2
5		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) during higher use months in any calendar year (Note 3)	1-Mar	31-Oct	5	150	0	55
6		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) in any calendar year (Note 3)	1-Jan	31-Dec	5	271	0	116
7	Minimize restricted boat launching	Number of years where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months for more than 25 days (Note 4)	1-Mar	31-Oct	2	1	0	0
8		Greatest number of days where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months in any calendar year (Note 4)	1-Mar	31-Oct	5	63	0	0
	Elevation - Natural Resources							
9	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	1-Apr	15-May	10%	97%	100%	100%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	1-Apr	15-May	10%	93%	100%	97%
12	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
13		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
15	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	95%	100%	97%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	89%	100%	93%
18	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	96%	100%	100%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	92%	100%	96%

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Existing License	Blend 2Db v2
21	Minimize entrainment due to Bad Creek operations	Percent of days average reservoir level at or below 1,096 ft AMSL (Note 5)	1-Jan	31-Dec	10%	8%	0%	2%
22		Percent of days average reservoir level below 1,096 ft AMSL (Note 5)	1-Dec	31-Mar	10%	9%	0%	2%
23	Maximize littoral habitat during growing season	Percent of days average reservoir level above 1,107 ft AMSL (Note 6)	1-Apr	30-Sep	10%	87%	100%	87%
24		Percent of days average reservoir level above 1,105 ft AMSL (Note 6)	1-Apr	30-Sep	10%	88%	100%	89%
25	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 1,107 ft AMSL (Note 6)	1-Apr	31-May	10%	90%	100%	90%
26		Percent of days average reservoir level above 1,105 ft AMSL (Note 6)	1-Apr	31-May	10%	91%	100%	93%
	Pumped Storage							
27	Minimize impacts on pumped storage operations	Avg Pumped Volume (ac-ft)/yr	1-Jan	31-Dec	300,000	3,060,942	3,290,394	3,693,381
28	Minimize days below lake levels that impact Bad Creek operations	Number of days reservoir level below 1,099 ft AMSL (Note 7)	1-Jan	31-Dec	227	2,563	79	1,107
29	Minimize days below lake levels that impact Jocassee operations	Number of days reservoir level below 1,090 ft AMSL (Note 7)	1-Jan	31-Dec	14	1,062	0	176
30	Minimize days below lake levels that impact Bad Creek efficiency	Number of days reservoir level below 1,081 ft AMSL (Note 8)	1-Jan	31-Dec	12	226	0	0

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Existing License	Blend 2Db v2
	Lake Keowee							
	Elevation - Storage Availability							
31	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 798 ft AMSL on May 1	1-May	1-May	5	65	65	67
	Elevation - Aesthetics							
32	Maximize lake levels	Percent of time reservoir level at or above 797 ft AMSL	1-Jan	31-Dec	20%	78%	77%	90%
33		Percent of time reservoir level at or above 795 ft AMSL	1-Jan	31-Dec	10%	86%	82%	97%
34	Minimize significant drawdown of lake level	Number of days reservoir level below 796 ft AMSL	1-Jan	31-Dec	5	5,280	5,411	1,818
	Elevation - Recreation							
35	Minimize restricted recreation	Number of years where cove access (reservoir level below 792 ft AMSL) is restricted for more than 25 days (Note 9)	1-Jan	31-Dec	2	0	20	1
36		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) during higher use months in any calendar year (Note 9)	1-Mar	31-Oct	5	0	245	12
37		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) in any calendar year (Note 9)	1-Jan	31-Dec	5	12	366	58
38	Minimize restricted lake boat launching	Number of years where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months for more than 25 days (Note 10)	1-Mar	31-Oct	2	0	12	0
39		Greatest number of days where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months in any calendar year (Note 10)	1-Mar	31-Oct	5	0	245	0
40	Maximize boat dock usage	Percent of time reservoir level is at or above level where 85% of docks are usable (796.25 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 27)	1-Mar	31-Oct	5%	82%	81%	93%
41		Percent of time reservoir level is at or above level where 70% of docks are usable (793.5 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 27)	1-Mar	31-Oct	5%	100%	86%	99%
	Elevation - Natural Resources							
42	Minimize number of days water level is below toe of riprap	Number of days reservoir level below 794 ft AMSL (Note 11)	1-Jan	31-Dec	250	93	4,417	435
43	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
44		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
45		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
46	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
47		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
48		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
49	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
50		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	96%	100%
51		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	99%	95%	100%

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Existing License	Blend 2Db v2
52	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
53		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	97%	100%
54		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	99%	95%	100%
55	Maximize littoral habitat during growing season	Percent of days average reservoir level above 798 ft AMSL (Note 12)	1-Apr	30-Sep	10%	79%	78%	87%
56		Percent of days average reservoir level above 797 ft AMSL (Note 12)	1-Apr	30-Sep	10%	81%	81%	92%
57	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 798 ft AMSL (Note 12)	1-Apr	31-May	10%	88%	87%	91%
58		Percent of days average reservoir level above 797 ft AMSL (Note 12)	1-Apr	31-May	10%	88%	88%	95%
	Elevation - Water Supply							
59	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (775 ft AMSL) for shallowest public water supply intake operation (Note 13)	1-Jan	31-Dec	1	0	0	0
60		Number of days reservoir level below critical level (794.6 ft AMSL) for shallowest thermal power station operation (Note 14)	1-Jan	31-Dec	1	206	4,718	643
61		Number of days reservoir level below critical level (787.9 ft AMSL) for Keowee dam to supply backup power to ONS (Note 15)	1-Jan	31-Dec	1	0	2,040	0
	Duke Energy Hydropower & Water Quantity Management							
62	USACE DCP Drought Level (Note 16)	Percent of time in Normal Conditions	1-Jan	31-Dec	2%	81%	82%	80%
63		Number of years attaining Drought Level 1	1-Jan	31-Dec	5	22	20	24
64		Number of years with more than 60 days in Drought Level 1	1-Jan	31-Dec	5	14	13	16
65		Number of years attaining Drought Level 2	1-Jan	31-Dec	4	16	16	18
66		Number of years with more than 60 days in Drought Level 2	1-Jan	31-Dec	4	13	12	12
67		Number of years attaining Drought Level 3	1-Jan	31-Dec	2	4	3	7
68		Number of years with more than 60 days in Drought Level 3	1-Jan	31-Dec	2	3	2	4
69		Number of years attaining Drought Level 4	1-Jan	31-Dec	1	0	0	0
70		Number of years with more than 60 days in Drought Level 4	1-Jan	31-Dec	1	0	0	0
71	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 28)	1-Jan	31-Dec	-	N/A	N/A	17,912
72		Number of days in LIP Stage 0 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	4,550
73		Number of days in LIP Stage 1 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	1,862
74		Number of days in LIP Stage 2 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	1,765
75		Number of days in LIP Stage 3 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	504
76		Number of days in LIP Stage 4 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	70
77	Maximize Duke Energy hydropower generation	Avg. MWh/yr of hydropower produced	1-Jan	31-Dec	300,000	3,163,233	3,242,742	3,357,972
78		Average equivalent # of homes per year that could be powered by the hydro project (Note 17)	1-Jan	31-Dec	1,000	239,639	245,662	254,392
79	Maximize Duke Energy hydropower value	Avg. hydro generation value Dollars/yr (generation value provided by SEPA)	1-Jan	31-Dec	$1,000,000	$228,171,212	$233,581,057	$241,981,867

	Background (green)	Performance Measure has improved vs. the Baseline Scenario
	Background (red)	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Existing License	Blend 2Db v2
	Hartwell Lake (Note 18)					(1939-2011)	(1939-2011)	(1939-2011)
	Elevation - Aesthetics							
80	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	60%	60%	60%
81		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	72%	73%	72%
82		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	82%	82%	80%
	Elevation - Recreation							
83	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (652 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	2	8	9	10
84		Greatest number of days where reservoir level is below the boat ramp use level (652 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	5	245	245	245
85	Minimize restricted swimming at beaches	Number of years where reservoir level is below suitable level (654 ft AMSL) for public swimming beaches during higher use months for more than 25 days	1-Apr	31-Oct	2	12	12	12
86		Number of years where reservoir level is below suitable level (654 ft AMSL) for public swimming beaches during higher use months in any calendar year	1-Apr	31-Oct	5	12	12	16
	Elevation - Water Withdrawal							
87	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (638 ft AMSL) for shallowest agricultural intake operation (Note 21)	1-Jan	31-Dec	1	65	159	171
88		Number of days reservoir level below critical level (636 ft AMSL) for shallowest public water supply intake operation	1-Jan	31-Dec	1	9	122	127
	Richard B. Russell Lake (Note 18)							
	Elevation - Aesthetics							
89	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	100%	100%	100%
90		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	100%	100%	100%
91		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	100%	100%	100%
	Elevation - Recreation					0	0	0
92	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (466 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	5	0	0	0
93		Greatest number of days where reservoir level is below the boat ramp use level (466 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	2	0	0	0
	Elevation - Water Withdrawal					0	0	0
94	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (470 ft AMSL) for shallowest agricultural intake operation (Note 22)	1-Jan	31-Dec	1	0	0	0
95		Number of days reservoir level below critical level (465 ft AMSL) for shallowest public water supply intake operation (Note 23)	1-Jan	31-Dec	1	0	0	0

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline	Existing License	Blend 2Db v2
	J. Strom Thurmond Lake (Note 18)							
	Elevation - Aesthetics							
96	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	64%	64%	63%
97		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	76%	76%	74%
98		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	85%	84%	82%
	Elevation - Recreation							
99	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (320 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	2	4	3	4
100		Greatest number of days where reservoir level is below the boat ramp use level (320 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	5	132	207	202
101	Minimize restricted swimming at beaches	Number of years where reservoir level is below suitable level (324 ft AMSL) for public swimming beaches during higher use months for more than 25 days	1-Apr	31-Oct	2	9	9	10
102		Number of years where reservoir level is below suitable level (324 ft AMSL) for public swimming beaches during higher use months in any calendar year	1-Apr	31-Oct	5	11	11	15
	Elevation - Water Withdrawal							
103	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (324 ft AMSL) for shallowest agricultural intake operation (Note 24)	1-Jan	31-Dec	1	2,166	2,155	2,510
104		Number of days reservoir level below critical level (312 ft AMSL) for shallowest public water supply intake operation (Note 25)	1-Jan	31-Dec	1	0	0	0
	Flow							
105	Flow Release From JST	Number of days at or below 4,200 cfs daily average flow	1-Jan	31-Dec	500	4,950	4,685	5,291
106		Number of days at or above 4,000 cfs and below 4,200 cfs daily average flow	1-Jan	31-Dec	100	1,368	1,269	1,292
107		Number of days at or above 3,800 cfs and below 4,000 cfs daily average flow	1-Jan	31-Dec	10	1,181	1,196	1,313
108		Number of days below 3,800 cfs daily average flow	1-Jan	31-Dec	5	889	892	967
109		Number of days below 3,600 cfs daily average flow	1-Jan	31-Dec	5	161	98	301
110		Number of days below 3,100 cfs daily average flow	1-Jan	31-Dec	5	0	0	0
111		Lowest daily average flow (cfs)	1-Jan	31-Dec	250	3,100	3,100	3,100
	USACE Hydropower & Water Quantity Management							
112	USACE DCP Drought Level (Note 16)	Percent of time in Normal Conditions	1-Jan	31-Dec	2%	81%	82%	80%
113		Number of years attaining Drought Level 1	1-Jan	31-Dec	5	22	20	24
114		Number of years with more than 60 days in Drought Level 1	1-Jan	31-Dec	5	14	13	16
115		Number of years attaining Drought Level 2	1-Jan	31-Dec	4	16	16	18
116		Number of years with more than 60 days in Drought Level 2	1-Jan	31-Dec	4	13	12	12
117		Number of years attaining Drought Level 3	1-Jan	31-Dec	2	4	3	7
118		Number of years with more than 60 days in Drought Level 3	1-Jan	31-Dec	2	3	2	4
119		Number of years attaining Drought Level 4	1-Jan	31-Dec	1	0	0	0
120		Number of years with more than 60 days in Drought Level 4	1-Jan	31-Dec	1	0	0	0
121	Maximize USACE hydropower generation	Avg. MWh/yr of hydropower produced	1-Jan	31-Dec	300,000	1,807,697	1,810,482	1,805,484
122		Average equivalent # of homes per year that could be powered by the hydro project (Note 17)	1-Jan	31-Dec	1,000	136,947	137,158	136,779
123	Maximize USACE hydropower value	Avg. hydro generation value Dollars/yr (generation value provided by SEPA)	1-Jan	31-Dec	$1,000,000	$126,236,822	$126,428,943	$126,060,476

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Notes

1 For criterion that measure on an hourly or daily basis, unless stated otherwise:
a. If an hourly criteria occurs during the average of four contiguous 15-minute periods, then it counts as 1 hour.
b. If a daily criterion occurs for 5 contiguous 1-hour periods, then it counts as 1 day.
Also, daytime flows are assumed to be flows provided between 7:00 am and 7:00 pm. To the extent possible, each criterion is defined in terms of percents and averages/yr so that the same criterion is useful regardless of the length of the hydrology period (i.e., 1-yr, 3-yr, full period of record, etc.)

2 MISC = Minimum Increment of Significant Change. The MISC has the same units (i.e., days, days/yr, percent, etc.) as does the criterion on that same row of the spreadsheet. If the output of two scenarios for a particular criterion differs by less than or equal to the MISC, then there is no significant difference between those two scenarios as far as the criterion in question is concerned. The following guidelines were used to establish the MISC numbers:

a. As a general rule, MISC numbers are set at 10% of the possible total for that criterion considering the Start/Stop dates.
b. MISC numbers for criteria that have the most adverse outcomes if reached are typically set at less than 10% of the possible total for that criterion. criterion.
c. Adjustments to the MISC numbers (up or down) have also been made depending on the desires of the stakeholders that primarily have the interests that are being measured by a particular criterion.

3 Jocassee restricted recreation elevation 1,090 ft AMSL provided by Chris Starker (Upstate Forever) and confirmed by Devils Fork State Park Staff.

4 Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access. Boat ramp elevations provided by Duke Energy.

5 Jocassee entrainment elevation (1,096 ft AMSL) provided by Bill Marshall of SCDNR.

6 Jocassee fish habitat elevations provided by Bill Marshall of SCDNR.

7 Jocassee elevation 1,099 ft AMSL is the elevation at which an MOU between Duke Energy and SCDNR requires Duke Energy to implement operational changes at Bad Creek. Jocassee elevation 1,090 ft AMSL is the elevation at which Jocassee powerhouse efficiency is degraded.

8 Jocassee elevation 1,081 ft AMSL provided by Duke Energy based on impact to pumping equipment.

9 Keowee restricted recreation elevation of 792 ft AMSL provided by James McRacken (HDR) and Scott Fletcher (Duke Energy).

10 Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).

11 Toe of Keowee reservoir riprap elevation 794 ft AMSL provided by Duke Energy.

12 Keowee fish habitat elevations provided by Bill Marshall of SCDNR.

13 Keowee elevation 775 ft AMSL is the minimum level permitted in the Existing FERC License, and all current Keowee water supply intakes were confirmed to operate at this reservoir level.

14 For this measure a -0.5 ft buffer was added to filter out model excursions below the Keowee reservoir elevation limit of 794.6 ft AMSL. No counts will be displayed for reservoir levels between 794.1 ft AMSL and 794.6 ft AMSL for this measure.

15 Keowee elevation 787.9 ft AMSL is the critical elevation for Keowee to provide backup power to ONS elevation provided by Duke Energy.

16 USACE DCP - United States Army Corps of Engineers' Drought Contingency Plan

17 Calculated by [(Total Scenario MWh / 13.2 MWh per home) / the # of years in the scenario]
The MISC of 1000 homes per year is roughly 2% of the average equivalent homes/yr under the Baseline conditions.
Power produced by the hydro project is actually supplied to Duke Energy's electric system grid and is used by Duke Energy's electric customers (including residential, industrial and commercial customers), as is power produced at other Duke Energy generating stations. This criterion of average equivalent homes per year is intended to simply make the total energy production potential of the hydro project more understandable to stakeholders and to put a perspective around potential differences in hydropower production between various operational scenarios. This measure does not imply that any number of homes will go without power if a particular scenario is chosen.

18 All reservoir elevations for Hartwell, Richard B. Russell and Thurmond performance measures were provided by USACE unless otherwise specified.

19 1939 thru 2011, inclusive (73 years)
26,663 days (Integer of 73 years * 365.25 days/year)
2,559,648 15-minute time steps (26,663 days * 24 hours/day * 4 time steps/hour)

20 This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.

21 Source for PM 78 elevation: 7/31/12 Telephone call between HDR Jonathan Williams and Clemson Univ. Tony Putnam.

22 Source for PM 85 elevation: 8/2/12 Telephone call between HDR Chris Ey and USACE Joe Hoke.

23 Source for PM 86 elevation: 8/2/12 Telephone call between HDR Jonathan Williams and City of Elberton, GA David Hudson.

24 Source for PM 94 elevation: HDR Jonathan Williams/Hickory Knob State Park (golf course), Savannah Lake Development (Monticello, Tara golf courses).

25 Source for PM 95 elevation: 8/2/12 Telephone call between HDR Jonathan Williams and City of Lincolnton, GA Stanly Pardon.

26 For Climate Change (CC Low/CC High) scenarios, the Trial Balloon scenario is evaluated and color coded according to the Baseline scenario for the same CC level.

27 Percent of time is measured as the percent of 15-minute time steps at or above threshold elevation during period starting 07:00 am and period ending 7:00 pm.

28 No MISC comparisons are made for this Performance Measure since the Baseline scenario does not contain this condition.

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

CHEOPS Operations Model Scenario Log

Scenario	Description	Purpose
Baseline	Duke Energy/USACE Reservoir Storage Balance Agreement and modified operation at Keowee and Jocassee to limit the minimum reservoir elevation at Lake Keowee to 794.6 ft AMSL. Duke Energy reservoir water release calculations use 778 ft AMSL as the minimum Keowee reservoir elevation for usable storage calculation. USACE DCP plan of 2012 is in effect. Model run date March 2014. Withdrawals in CFS.	Base Line Scenario simulates current reservoir operations used by Duke Energy based on Keowee reservoir drawdown limits to maintain operations of the Oconee Nuclear Station located on Lake Keowee. Keowee reservoir drawdown elevation is 794.6 ft AMSL.
Existing License	Conditions as would be applicable given current license requirements and current USACE DCP (2012 Alt 0) with original 1968 Agreement criteria. Model run date March 2014. Withdrawals in CFS.	Evaluate impact of operations given license requirements and agreements currently in effect.
Blend 2Db v2	April 10, 2013 proposed Blend scenario with LIP Stages at Keowee of 796 ft AMSL (0), 795 ft AMSL (1), 793 ft AMSL (2), 792 ft AMSL (3), 790 ft AMSL (4). In Stage 4, the Keowee reservoir elevation will be maintained at or above 791.5 ft. AMSL until Duke Energy storage balance reaches 12 percent. The minimum elevation used to calculate the usable storage for storage balancing with the USACE is 790.0 ft. AMSL. No fish spawning. LIP logic revised to reference "triggered" DCP level versus "In-Effect" DCP level during LIP recovery. Allows LIP to more quickly change to a lower stage number during recovery process, eliminating the 2-foot recovery delay in DCP protocol. LIP gage averaging modified from 6 months to 4 months per AIP documentation (Rev. 4/23/13). Model run date March 2014. Withdrawals in CFS.	Evaluate proposed changes to operating rules (LIP, changes to coordination agreement).

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC Low	Existing License CC Low	Blend 2Db v2 CC Low
	Bad Creek					(1939-2011)	(1939-2011)	(1939-2011)
	Elevation - Electric Operations							
1	Maximize adherence to high-head operating band	Percent of time reservoir level more than 60 ft below 2,310 ft AMSL (Full Pool)	1-Jan	31-Dec	2%	23%	21%	23%
	Pumped Storage							
2	Minimize impacts on pumped storage operations	Avg. Pumped Volume (ac-ft)/yr	1-Jan	31-Dec	210,000	2,021,159	2,030,612	2,046,510
	Lake Jocassee							
	Elevation - Storage Availability							
3	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 1,108 ft AMSL on May 1	1-May	1-May	5	66	73	66
	Elevation - Recreation							
4	Minimize restricted recreation	Number of years where cove access (reservoir level below 1,090 ft AMSL) is restricted for more than 25 days (Note 3)	1-Jan	31-Dec	2	11	0	2
5		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) during higher use months in any calendar year (Note 3)	1-Mar	31-Oct	5	245	0	63
6		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) in any calendar year (Note 3)	1-Jan	31-Dec	5	366	0	124
7	Minimize restricted boat launching	Number of years where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months for more than 25 days (Note 4)	1-Mar	31-Oct	2	1	0	0
8		Greatest number of days where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months in any calendar year (Note 4)	1-Mar	31-Oct	5	91	0	0
	Elevation - Natural Resources							
9	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	1-Apr	15-May	10%	95%	100%	100%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	1-Apr	15-May	10%	93%	100%	93%
12	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
13		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
15	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	95%	100%	97%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	86%	100%	92%
18	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	97%	100%	99%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	92%	100%	97%

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC Low	Existing License CC Low	Blend 2Db v2 CC Low
21	Minimize entrainment due to Bad Creek operations	Percent of days average reservoir level at or below 1,096 ft AMSL (Note 5)	1-Jan	31-Dec	10%	8%	0%	2%
22		Percent of days average reservoir level below 1,096 ft AMSL (Note 5)	1-Dec	31-Mar	10%	9%	0%	2%
23	Maximize littoral habitat during growing season	Percent of days average reservoir level above 1,107 ft AMSL (Note 6)	1-Apr	30-Sep	10%	86%	100%	87%
24		Percent of days average reservoir level above 1,105 ft AMSL (Note 6)	1-Apr	30-Sep	10%	87%	100%	89%
25	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 1,107 ft AMSL (Note 6)	1-Apr	31-May	10%	90%	100%	91%
26		Percent of days average reservoir level above 1,105 ft AMSL (Note 6)	1-Apr	31-May	10%	91%	100%	92%
	Pumped Storage							
27	Minimize impacts on pumped storage operations	Avg Pumped Volume (ac-ft)/yr	1-Jan	31-Dec	300,000	3,047,366	3,293,371	3,705,069
28	Minimize days below lake levels that impact Bad Creek operations	Number of days reservoir level below 1,099 ft AMSL (Note 7)	1-Jan	31-Dec	227	2,839	26	1,152
29	Minimize days below lake levels that impact Jocassee operations	Number of days reservoir level below 1,090 ft AMSL (Note 7)	1-Jan	31-Dec	14	1,409	0	187
30	Minimize days below lake levels that impact Bad Creek efficiency	Number of days reservoir level below 1,081 ft AMSL (Note 8)	1-Jan	31-Dec	12	357	0	0

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC Low	Existing License CC Low	Blend 2Db v2 CC Low
	Lake Keowee							
	Elevation - Storage Availability							
31	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 798 ft AMSL on May 1	1-May	1-May	5	64	65	67
	Elevation - Aesthetics							
32	Maximize lake levels	Percent of time reservoir level at or above 797 ft AMSL	1-Jan	31-Dec	20%	77%	77%	90%
33		Percent of time reservoir level at or above 795 ft AMSL	1-Jan	31-Dec	10%	86%	82%	96%
34	Minimize significant drawdown of lake level	Number of days reservoir level below 796 ft AMSL	1-Jan	31-Dec	5	5,505	5,532	1,982
	Elevation - Recreation							
35	Minimize restricted recreation	Number of years where cove access (reservoir level below 792 ft AMSL) is restricted for more than 25 days (Note 9)	1-Jan	31-Dec	2	0	20	1
36		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) during higher use months in any calendar year (Note 9)	1-Mar	31-Oct	5	0	245	16
37		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) in any calendar year (Note 9)	1-Jan	31-Dec	5	19	366	67
38	Minimize restricted lake boat launching	Number of years where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months for more than 25 days (Note 10)	1-Mar	31-Oct	2	0	12	0
39		Greatest number of days where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months in any calendar year (Note 10)	1-Mar	31-Oct	5	0	245	0
40	Maximize boat dock usage	Percent of time reservoir level is at or above level where 85% of docks are usable (796.25 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 27)	1-Mar	31-Oct	5%	81%	80%	93%
41		Percent of time reservoir level is at or above level where 70% of docks are usable (793.5 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 27)	1-Mar	31-Oct	5%	100%	85%	99%
	Elevation - Natural Resources							
42	Minimize number of days water level is below toe of riprap	Number of days reservoir level below 794 ft AMSL (Note 11)	1-Jan	31-Dec	250	116	4,485	583
43	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
44		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
45		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
46	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
47		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
48		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
49	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
50		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	99%	97%	100%
51		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	99%	95%	100%

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC Low	Existing License CC Low	Blend 2Db v2 CC Low
52	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
53		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	99%	100%
54		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	99%	95%	100%
55	Maximize littoral habitat during growing season	Percent of days average reservoir level above 798 ft AMSL (Note 12)	1-Apr	30-Sep	10%	77%	78%	87%
56		Percent of days average reservoir level above 797 ft AMSL (Note 12)	1-Apr	30-Sep	10%	80%	80%	91%
57	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 798 ft AMSL (Note 12)	1-Apr	31-May	10%	86%	87%	90%
58		Percent of days average reservoir level above 797 ft AMSL (Note 12)	1-Apr	31-May	10%	87%	88%	94%
	Elevation - Water Supply							
59	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (775 ft AMSL) for shallowest public water supply intake operation (Note 13)	1-Jan	31-Dec	1	0	0	0
60		Number of days reservoir level below critical level (794.6 ft AMSL) for shallowest thermal power station operation (Note 14)	1-Jan	31-Dec	1	261	4,796	868
61		Number of days reservoir level below critical level (787.9 ft AMSL) for Keowee dam to supply backup power to ONS (Note 15)	1-Jan	31-Dec	1	0	2,085	0
	Duke Energy Hydropower & Water Quantity Management							
62	USACE DCP Drought Level (Note 16)	Percent of time in Normal Conditions	1-Jan	31-Dec	2%	81%	81%	80%
63		Number of years attaining Drought Level 1	1-Jan	31-Dec	5	23	22	28
64		Number of years with more than 60 days in Drought Level 1	1-Jan	31-Dec	5	14	14	16
65		Number of years attaining Drought Level 2	1-Jan	31-Dec	4	16	16	19
66		Number of years with more than 60 days in Drought Level 2	1-Jan	31-Dec	4	12	12	12
67		Number of years attaining Drought Level 3	1-Jan	31-Dec	2	5	3	7
68		Number of years with more than 60 days in Drought Level 3	1-Jan	31-Dec	2	3	3	4
69		Number of years attaining Drought Level 4	1-Jan	31-Dec	1	0	0	0
70		Number of years with more than 60 days in Drought Level 4	1-Jan	31-Dec	1	0	0	0
71	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 28)	1-Jan	31-Dec	-	N/A	N/A	17,849
72		Number of days in LIP Stage 0 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	4,550
73		Number of days in LIP Stage 1 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	1,456
74		Number of days in LIP Stage 2 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	1,982
75		Number of days in LIP Stage 3 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	728
76		Number of days in LIP Stage 4 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	98
77	Maximize Duke Energy hydropower generation	Avg. MWh/yr of hydropower produced	1-Jan	31-Dec	300,000	3,154,592	3,243,157	3,360,455
78		Average equivalent # of homes per year that could be powered by the hydro project (Note 17)	1-Jan	31-Dec	1,000	238,984	245,694	254,580
79	Maximize Duke Energy hydropower value	Avg. hydro generation value Dollars/yr (generation value provided by SEPA)	1-Jan	31-Dec	$1,000,000	$227,519,037	$233,618,757	$242,172,733

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC Low	Existing License CC Low	Blend 2Db v2 CC Low
	Hartwell Lake (Note 18)					(1939-2011)	(1939-2011)	(1939-2011)
	Elevation - Aesthetics							
80	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	59%	60%	60%
81		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	72%	72%	71%
82		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	81%	81%	79%
	Elevation - Recreation							
83	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (652 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	2	9	9	11
84		Greatest number of days where reservoir level is below the boat ramp use level (652 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	5	245	245	245
85	Minimize restricted swimming at beaches	Number of years where reservoir level is below suitable level (654 ft AMSL) for public swimming beaches during higher use months for more than 25 days	1-Apr	31-Oct	2	12	12	12
86		Number of years where reservoir level is below suitable level (654 ft AMSL) for public swimming beaches during higher use months in any calendar year	1-Apr	31-Oct	5	12	12	17
	Elevation - Water Withdrawal							
87	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (638 ft AMSL) for shallowest agricultural intake operation (Note 21)	1-Jan	31-Dec	1	200	58	195
88		Number of days reservoir level below critical level (636 ft AMSL) for shallowest public water supply intake operation	1-Jan	31-Dec	1	168	5	161
	Richard B. Russell Lake (Note 18)							
	Elevation - Aesthetics							
89	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	100%	100%	100%
90		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	100%	100%	100%
91		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	100%	100%	100%
	Elevation - Recreation							
92	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (466 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	5	0	0	0
93		Greatest number of days where reservoir level is below the boat ramp use level (466 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	2	0	0	0
	Elevation - Water Withdrawal							
94	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (470 ft AMSL) for shallowest agricultural intake operation (Note 22)	1-Jan	31-Dec	1	0	0	0
95		Number of days reservoir level below critical level (465 ft AMSL) for shallowest public water supply intake operation (Note 23)	1-Jan	31-Dec	1	0	0	0

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC Low	Existing License CC Low	Blend 2Db v2 CC Low
	J. Strom Thurmond Lake (Note 18)							
	Elevation - Aesthetics							
96	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	63%	63%	62%
97		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	75%	76%	74%
98		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	84%	84%	81%
	Elevation - Recreation							
99	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (320 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	2	4	4	5
100		Greatest number of days where reservoir level is below the boat ramp use level (320 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	5	215	133	219
101	Minimize restricted swimming at beaches	Number of years where reservoir level is below suitable level (324 ft AMSL) for public swimming beaches during higher use months for more than 25 days	1-Apr	31-Oct	2	10	9	10
102		Number of years where reservoir level is below suitable level (324 ft AMSL) for public swimming beaches during higher use months in any calendar year	1-Apr	31-Oct	5	12	11	16
	Elevation - Water Withdrawal							
103	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (324 ft AMSL) for shallowest agricultural intake operation (Note 24)	1-Jan	31-Dec	1	2,343	2,274	2,557
104		Number of days reservoir level below critical level (312 ft AMSL) for shallowest public water supply intake operation (Note 25)	1-Jan	31-Dec	1	0	0	0
	Flow							
105	Flow Release From JST	Number of days at or below 4,200 cfs daily average flow	1-Jan	31-Dec	500	4,917	4,978	5,397
106		Number of days at or above 4,000 cfs and below 4,200 cfs daily average flow	1-Jan	31-Dec	100	1,214	1,388	1,332
107		Number of days at or above 3,800 cfs and below 4,000 cfs daily average flow	1-Jan	31-Dec	10	1,293	1,161	1,341
108		Number of days below 3,800 cfs daily average flow	1-Jan	31-Dec	5	906	889	1,081
109		Number of days below 3,600 cfs daily average flow	1-Jan	31-Dec	5	252	105	350
110		Number of days below 3,100 cfs daily average flow	1-Jan	31-Dec	5	0	0	0
111		Lowest daily average flow (cfs)	1-Jan	31-Dec	250	3,100	3,100	3,100
	USACE Hydropower & Water Quantity Management							
112	USACE DCP Drought Level (Note 16)	Percent of time in Normal Conditions	1-Jan	31-Dec	2%	81%	81%	80%
113		Number of years attaining Drought Level 1	1-Jan	31-Dec	5	23	22	28
114		Number of years with more than 60 days in Drought Level 1	1-Jan	31-Dec	5	14	14	16
115		Number of years attaining Drought Level 2	1-Jan	31-Dec	4	16	16	19
116		Number of years with more than 60 days in Drought Level 2	1-Jan	31-Dec	4	12	12	12
117		Number of years attaining Drought Level 3	1-Jan	31-Dec	2	5	3	7
118		Number of years with more than 60 days in Drought Level 3	1-Jan	31-Dec	2	3	3	4
119		Number of years attaining Drought Level 4	1-Jan	31-Dec	1	0	0	0
120		Number of years with more than 60 days in Drought Level 4	1-Jan	31-Dec	1	0	0	0
121	Maximize USACE hydropower generation	Avg. MWh/yr of hydropower produced	1-Jan	31-Dec	300,000	1,799,496	1,802,700	1,797,927
122		Average equivalent # of homes per year that could be powered by the hydro project (Note 17)	1-Jan	31-Dec	1,000	136,325	136,568	136,207
123	Maximize USACE hydropower value	Avg. hydro generation value Dollars/yr (generation value provided by SEPA)	1-Jan	31-Dec	$1,000,000	$125,675,462	$125,891,304	$125,535,276

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Notes

1 For criterion that measure on an hourly or daily basis, unless stated otherwise:

a. If an hourly criteria occurs during the average of four contiguous 15-minute periods, then it counts as 1 hour.

b. If a daily criterion occurs for 5 contiguous 1-hour periods, then it counts as 1 day.

Also, daytime flows are assumed to be flows provided between 7:00 am and 7:00 pm. To the extent possible, each criterion is defined in terms of percents and averages/yr so that the same criterion is useful regardless of the length of the hydrology period (i.e., 1-yr, 3-yr, full period of record, etc.)

2 MISC = Minimum Increment of Significant Change. The MISC has the same units (i.e., days, days/yr, percent, etc.) as does the criterion on that same row of the spreadsheet. If the output of two scenarios for a particular criterion differs by less than or equal to the MISC, then there is no significant difference between those two scenarios as far as the criterion in question is concerned. The following guidelines were used to establish the MISC numbers:

a. As a general rule, MISC numbers are set at 10% of the possible total for that criterion considering the Start/Stop dates.

b. MISC numbers for criteria that have the most adverse outcomes if reached are typically set at less than 10% of the possible total for that criterion. criterion.

c. Adjustments to the MISC numbers (up or down) have also been made depending on the desires of the stakeholders that primarily have the interests that are being measured by a particular criterion.

3 Jocassee restricted recreation elevation 1,090 ft AMSL provided by Chris Starker (Upstate Forever) and confirmed by Devils Fork State Park Staff.

4 Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access. Boat ramp elevations provided by Duke Energy.

5 Jocassee entrainment elevation (1,096 ft AMSL) provided by Bill Marshall of SCDNR.

6 Jocassee fish habitat elevations provided by Bill Marshall of SCDNR.

7 Jocassee elevation 1,099 ft AMSL is the elevation at which an MOU between Duke Energy and SCDNR requires Duke Energy to implement operational changes at Bad Creek. Jocassee elevation 1,090 ft AMSL is the elevation at which Jocassee powerhouse efficiency is degraded.

8 Jocassee elevation 1,081 ft AMSL provided by Duke Energy based on impact to pumping equipment.

9 Keowee restricted recreation elevation of 792 ft AMSL provided by James McRacken (HDR) and Scott Fletcher (Duke Energy).

10 Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).

11 Toe of Keowee reservoir riprap elevation 794 ft AMSL provided by Duke Energy.

12 Keowee fish habitat elevations provided by Bill Marshall of SCDNR.

13 Keowee elevation 775 ft AMSL is the minimum level permitted in the Existing FERC License, and all current Keowee water supply intakes were confirmed to operate at this reservoir level.

14 For this measure a -0.5 ft buffer was added to filter out model excursions below the Keowee reservoir elevation limit of 794.6 ft AMSL. No counts will be displayed for reservoir levels between 794.1 ft AMSL and 794.6 ft AMSL for this measure.

15 Keowee elevation 787.9 ft AMSL is the critical elevation for Keowee to provide backup power to ONS elevation provided by Duke Energy.

16 USACE DCP - United States Army Corps of Engineers' Drought Contingency Plan

17 Calculated by [(Total Scenario MWh / 13.2 MWh per home) / the # of years in the scenario]
The MISC of 1000 homes per year is roughly 2% of the average equivalent homes/yr under the Baseline conditions.
Power produced by the hydro project is actually supplied to Duke Energy's electric system grid and is used by Duke Energy's electric customers (including residential, industrial and commercial customers), as is power produced at other Duke Energy generating stations. This criterion of average equivalent homes per year is intended to simply make the total energy production potential of the hydro project more understandable to stakeholders and to put a perspective around potential differences in hydropower production between various operational scenarios. This measure does not imply that any number of homes will go without power if a particular scenario is chosen.

18 All reservoir elevations for Hartwell, Richard B. Russell and Thurmond performance measures were provided by USACE unless otherwise specified.

19 1939 thru 2011, inclusive (73 years)
26,663 days (Integer of 73 years * 365.25 days/year)
2,559,648 15-minute time steps (26,663 days * 24 hours/day * 4 time steps/hour)

20 This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.

21 Source for PM 78 elevation: 7/31/12 Telephone call between HDR Jonathan Williams and Clemson Univ. Tony Putnam.

22 Source for PM 85 elevation: 8/2/12 Telephone call between HDR Chris Ey and USACE Joe Hoke.

23 Source for PM 86 elevation: 8/2/12 Telephone call between HDR Jonathan Williams and City of Elberton, GA David Hudson.

24 Source for PM 94 elevation: HDR Jonathan Williams/Hickory Knob State Park (golf course), Savannah Lake Development (Monticello, Tara golf courses).

25 Source for PM 95 elevation: 8/2/12 Telephone call between HDR Jonathan Williams and City of Lincolnton, GA Stanly Pardon.

26 For Climate Change (CC Low/CC High) scenarios, the Trial Balloon scenario is evaluated and color coded according to the Baseline scenario for the same CC level.

27 Percent of time is measured as the percent of 15-minute time steps at or above threshold elevation during period starting 07:00 am and period ending 7:00 pm.

28 No MISC comparisons are made for this Performance Measure since the Baseline scenario does not contain this condition.

CHEOPS Operations Model Scenario Log

Scenario	Description	Purpose
Baseline CC Low	Duke Energy/USACE Reservoir Storage Balance Agreement and modified operation at Keowee and Jocassee to limit the minimum reservoir elevation at Lake Keowee to 794.6 ft AMSL. Duke Energy reservoir water release calculations use 778 ft AMSL as the minimum Keowee reservoir elevation for usable storage calculation. USACE DCP plan of 2012 is in effect. Includes evaporation coefficient increase of 10 percent to represent a 3 degree temperature increase. Model run date March 2014. Withdrawals in CFS.	Base Line Scenario simulates current reservoir operations used by Duke Energy based on Keowee reservoir drawdown limits to maintain operations of the Oconee Nuclear Station located on Lake Keowee. Keowee reservoir drawdown elevation is 794.6 ft AMSL.
Existing License CC Low	Conditions as would be applicable given current license requirements and current USACE DCP (2012 Alt 0) with original 1968 Agreemement criteria. Includes evaporation coefficient increase of 10 percent to represent a 3 degree temperature increase. Model run date March 2014. Withdrawals in CFS.	Evaluate impact of operations given license requirements and agreements currently in effect.
Blend 2Db v2 CC Low	Same as Blend 2D v2 with LIP logic revised to reference "triggered" DCP level versus "In-Effect" DCP level during LIP recovery. Allows LIP to more quickly change to a lower stage number during recovery process, eliminating the 2-foot recovery delay in DCP protocol. LIP gage averaging modified from 6 months to 4 months per AIP documentation (Rev. 4/23/13). Includes evaporation coefficient increase of 10 percent to represent a 3 degree temperature increase. Model run date March 2014. Withdrawals in CFS.	Evaluate proposed changes to operating rules (LIP, changes to coordination agreement).

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC High	Existing License CC High	Blend 2Db v2 CC High
	Bad Creek					(1939-2011)	(1939-2011)	(1939-2011)
	Elevation - Electric Operations							
1	Maximize adherence to high-head operating band	Percent of time reservoir level more than 60 ft below 2,310 ft AMSL (Full Pool)	1-Jan	31-Dec	2%	27%	21%	25%
	Pumped Storage							
2	Minimize impacts on pumped storage operations	Avg. Pumped Volume (ac-ft)/yr	1-Jan	31-Dec	210,000	1,953,854	2,037,563	2,027,789
	Lake Jocassee							
	Elevation - Storage Availability							
3	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 1,108 ft AMSL on May 1	1-May	1-May	5	63	72	63
	Elevation - Recreation							
4	Minimize restricted recreation	Number of years where cove access (reservoir level below 1,090 ft AMSL) is restricted for more than 25 days (Note 3)	1-Jan	31-Dec	2	14	2	3
5		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) during higher use months in any calendar year (Note 3)	1-Mar	31-Oct	5	245	30	138
6		Greatest number of days with restricted cove access (reservoir level below 1,090 ft AMSL) in any calendar year (Note 3)	1-Jan	31-Dec	5	366	91	199
7	Minimize restricted boat launching	Number of years where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months for more than 25 days (Note 4)	1-Mar	31-Oct	2	3	0	0
8		Greatest number of days where reservoir level is below boat ramp critical level (1,080 ft AMSL) during higher use months in any calendar year (Note 4)	1-Mar	31-Oct	5	212	0	8
	Elevation - Natural Resources							
9	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	1-Apr	15-May	10%	99%	100%	100%
10		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	1-Apr	15-May	10%	97%	100%	100%
11		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	1-Apr	15-May	10%	92%	99%	96%
12	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
13		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	1-Apr	15-May	10%	100%	100%	100%
14		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	1-Apr	15-May	10%	97%	100%	99%
15	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
16		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	92%	100%	93%
17		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	86%	99%	89%
18	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	100%	100%
19		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	95%	100%	96%
20		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	88%	99%	93%

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC High	Existing License CC High	Blend 2Db v2 CC High
21	Minimize entrainment due to Bad Creek operations	Percent of days average reservoir level at or below 1,096 ft AMSL (Note 5)	1-Jan	31-Dec	10%	12%	1%	7%
22		Percent of days average reservoir level below 1,096 ft AMSL (Note 5)	1-Dec	31-Mar	10%	13%	1%	8%
23	Maximize littoral habitat during growing season	Percent of days average reservoir level above 1,107 ft AMSL (Note 6)	1-Apr	30-Sep	10%	80%	97%	80%
24		Percent of days average reservoir level above 1,105 ft AMSL (Note 6)	1-Apr	30-Sep	10%	82%	98%	85%
25	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 1,107 ft AMSL (Note 6)	1-Apr	31-May	10%	85%	99%	86%
26		Percent of days average reservoir level above 1,105 ft AMSL (Note 6)	1-Apr	31-May	10%	87%	99%	90%
	Pumped Storage							
27	Minimize impacts on pumped storage operations	Avg Pumped Volume (ac-ft)/yr	1-Jan	31-Dec	300,000	2,879,611	3,251,915	3,714,248
28	Minimize days below lake levels that impact Bad Creek operations	Number of days reservoir level below 1,099 ft AMSL (Note 7)	1-Jan	31-Dec	227	3,978	418	2,666
29	Minimize days below lake levels that impact Jocassee operations	Number of days reservoir level below 1,090 ft AMSL (Note 7)	1-Jan	31-Dec	14	2,722	132	598
30	Minimize days below lake levels that impact Bad Creek efficiency	Number of days reservoir level below 1,081 ft AMSL (Note 8)	1-Jan	31-Dec	12	1,655	0	129

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC High	Existing License CC High	Blend 2Db v2 CC High
	Lake Keowee							
	Elevation - Storage Availability							
31	Maximize adherence to reliably meet all Project-related water demands	Number of years reservoir level at or above 798 ft AMSL on May 1	1-May	1-May	5	58	58	67
	Elevation - Aesthetics							
32	Maximize lake levels	Percent of time reservoir level at or above 797 ft AMSL	1-Jan	31-Dec	20%	69%	69%	85%
33		Percent of time reservoir level at or above 795 ft AMSL	1-Jan	31-Dec	10%	79%	76%	92%
34	Minimize significant drawdown of lake level	Number of days reservoir level below 796 ft AMSL	1-Jan	31-Dec	5	7,486	7,431	3,014
	Elevation - Recreation							
35	Minimize restricted recreation	Number of years where cove access (reservoir level below 792 ft AMSL) is restricted for more than 25 days (Note 9)	1-Jan	31-Dec	2	2	25	2
36		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) during higher use months in any calendar year (Note 9)	1-Mar	31-Oct	5	60	245	87
37		Greatest number of days with restricted cove access (reservoir level below 792 ft AMSL) in any calendar year (Note 9)	1-Jan	31-Dec	5	121	366	148
38	Minimize restricted lake boat launching	Number of years where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months for more than 25 days (Note 10)	1-Mar	31-Oct	2	0	16	0
39		Greatest number of days where reservoir level is below boat ramp critical level (790 ft AMSL) during higher use months in any calendar year (Note 10)	1-Mar	31-Oct	5	2	245	0
40	Maximize boat dock usage	Percent of time reservoir level is at or above level where 85% of docks are usable (796.25 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 27)	1-Mar	31-Oct	5%	73%	73%	88%
41		Percent of time reservoir level is at or above level where 70% of docks are usable (793.5 ft AMSL) during higher use months from 7:00 am to 7:00 pm (Note 27)	1-Mar	31-Oct	5%	99%	80%	97%
	Elevation - Natural Resources							
42	Minimize number of days water level is below toe of riprap	Number of days reservoir level below 794 ft AMSL (Note 11)	1-Jan	31-Dec	250	557	5,969	1,663
43	Maximize spawning success for black bass and blueback herring (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
44		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
45		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-Mar	15-May	10%	99%	99%	100%
46	Maximize spawning success for black bass and blueback herring (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
47		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-Mar	15-May	10%	100%	100%	100%
48		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-Mar	15-May	10%	99%	99%	100%
49	Maximize spawning success for sunfish and threadfin shad (2.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	99%	100%
50		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	97%	100%
51		Percent of years (hourly) reservoir level remains within (-0.5 to 2.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	93%	99%

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC High	Existing License CC High	Blend 2Db v2 CC High
52	Maximize spawning success for sunfish and threadfin shad (3.5-ft fluctuation band)	Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 10 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	99%	100%
53		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 15 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	97%	100%
54		Percent of years (hourly) reservoir level remains within (-0.5 to 3.0)-ft band for 20 consecutive days at least once (Note 20)	15-May	15-Jul	10%	100%	93%	99%
55	Maximize littoral habitat during growing season	Percent of days average reservoir level above 798 ft AMSL (Note 12)	1-Apr	30-Sep	10%	69%	70%	82%
56		Percent of days average reservoir level above 797 ft AMSL (Note 12)	1-Apr	30-Sep	10%	73%	73%	87%
57	Maximize littoral habitat during spawning season	Percent of days average reservoir level above 798 ft AMSL (Note 12)	1-Apr	31-May	10%	77%	78%	89%
58		Percent of days average reservoir level above 797 ft AMSL (Note 12)	1-Apr	31-May	10%	80%	80%	90%
	Elevation - Water Supply							
59	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (775 ft AMSL) for shallowest public water supply intake operation (Note 13)	1-Jan	31-Dec	1	0	0	0
60		Number of days reservoir level below critical level (794.6 ft AMSL) for shallowest thermal power station operation (Note 14)	1-Jan	31-Dec	1	996	6,335	2,008
61		Number of days reservoir level below critical level (787.9 ft AMSL) for Keowee dam to supply backup power to ONS (Note 15)	1-Jan	31-Dec	1	0	3,088	0
	Duke Energy Hydropower & Water Quantity Management							
62	USACE DCP Drought Level (Note 16)	Percent of time in Normal Conditions	1-Jan	31-Dec	2%	73%	73%	71%
63		Number of years attaining Drought Level 1	1-Jan	31-Dec	5	29	28	34
64		Number of years with more than 60 days in Drought Level 1	1-Jan	31-Dec	5	17	19	19
65		Number of years attaining Drought Level 2	1-Jan	31-Dec	4	22	22	21
66		Number of years with more than 60 days in Drought Level 2	1-Jan	31-Dec	4	17	17	19
67		Number of years attaining Drought Level 3	1-Jan	31-Dec	2	9	9	11
68		Number of years with more than 60 days in Drought Level 3	1-Jan	31-Dec	2	7	7	9
69		Number of years attaining Drought Level 4	1-Jan	31-Dec	1	2	2	2
70		Number of years with more than 60 days in Drought Level 4	1-Jan	31-Dec	1	0	0	0
71	Keowee-Toxaway Low Inflow Protocol (LIP) Stage	Number of days in LIP Stage Normal (Note 28)	1-Jan	31-Dec	-	N/A	N/A	16,610
72		Number of days in LIP Stage 0 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	4,284
73		Number of days in LIP Stage 1 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	2,380
74		Number of days in LIP Stage 2 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	2,192
75		Number of days in LIP Stage 3 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	945
76		Number of days in LIP Stage 4 (Note 28)	1-Jan	31-Dec	-	N/A	N/A	252
77	Maximize Duke Energy hydropower generation	Avg. MWh/yr of hydropower produced	1-Jan	31-Dec	300,000	3,014,622	3,221,973	3,321,056
78		Average equivalent # of homes per year that could be powered by the hydro project (Note 17)	1-Jan	31-Dec	1,000	228,380	244,089	251,595
79	Maximize Duke Energy hydropower value	Avg. hydro generation value Dollars/yr (generation value provided by SEPA)	1-Jan	31-Dec	$1,000,000	$217,671,079	$232,192,823	$239,705,857

	Background (green)	Performance Measure has improved vs. the Baseline Scenario
	Background (red)	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC High	Existing License CC High	Blend 2Db v2 CC High
	Hartwell Lake (Note 18)					(1939-2011)	(1939-2011)	(1939-2011)
	Elevation - Aesthetics							
80	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	50%	51%	51%
81		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	63%	64%	63%
82		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	73%	74%	70%
	Elevation - Recreation							
83	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (652 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	2	13	13	13
84		Greatest number of days where reservoir level is below the boat ramp use level (652 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	5	245	245	245
85	Minimize restricted swimming at beaches	Number of years where reservoir level is below suitable level (654 ft AMSL) for public swimming beaches during higher use months for more than 25 days	1-Apr	31-Oct	2	17	17	19
86		Number of years where reservoir level is below suitable level (654 ft AMSL) for public swimming beaches during higher use months in any calendar year	1-Apr	31-Oct	5	22	22	23
	Elevation - Water Withdrawal							
87	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (638 ft AMSL) for shallowest agricultural intake operation (Note 21)	1-Jan	31-Dec	1	721	624	818
88		Number of days reservoir level below critical level (636 ft AMSL) for shallowest public water supply intake operation	1-Jan	31-Dec	1	573	538	609
	Richard B. Russell Lake (Note 18)							
	Elevation - Aesthetics							
89	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	99%	100%	100%
90		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	100%	100%	100%
91		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	100%	100%	100%
	Elevation - Recreation							
92	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (466 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	5	0	0	0
93		Greatest number of days where reservoir level is below the boat ramp use level (466 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	2	0	0	0
	Elevation - Water Withdrawal							
94	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (470 ft AMSL) for shallowest agricultural intake operation (Note 22)	1-Jan	31-Dec	1	50	25	44
95		Number of days reservoir level below critical level (465 ft AMSL) for shallowest public water supply intake operation (Note 23)	1-Jan	31-Dec	1	0	0	0

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

Line Number	Performance Measures	Criterion (Note 1)	Start Date	End Date	MISC (Note 2)	Baseline CC High	Existing License CC High	Blend 2Db v2 CC High
	J. Strom Thurmond Lake (Note 18)							
	Elevation - Aesthetics							
96	Maximize adherence to reservoir guide curve	Percent of time reservoir level within +/- 1 ft of reservoir guide curve	1-Jan	31-Dec	10%	54%	54%	53%
97		Percent of time reservoir level within +/- 2 ft of reservoir guide curve	1-Jan	31-Dec	5%	66%	66%	65%
98		Percent of time reservoir level within +/- 3 ft of reservoir guide curve	1-Jan	31-Dec	2%	76%	76%	73%
	Elevation - Recreation							
99	Minimize restricted lake boat launching	Number of years where reservoir level is below the boat ramp use level (320 ft AMSL) during higher use months for more than 25 days	1-Mar	31-Oct	2	8	8	10
100		Greatest number of days where reservoir level is below the boat ramp use level (320 ft AMSL) during higher use months in any calendar year	1-Mar	31-Oct	5	245	245	245
101	Minimize restricted swimming at beaches	Number of years where reservoir level is below suitable level (324 ft AMSL) for public swimming beaches during higher use months for more than 25 days	1-Apr	31-Oct	2	15	14	16
102		Number of years where reservoir level is below suitable level (324 ft AMSL) for public swimming beaches during higher use months in any calendar year	1-Apr	31-Oct	5	19	19	20
	Elevation - Water Withdrawal							
103	Minimize days of restricted operation at lake-located intakes	Number of days reservoir level below critical level (324 ft AMSL) for shallowest agricultural intake operation (Note 24)	1-Jan	31-Dec	1	3,563	3,504	3,800
104		Number of days reservoir level below critical level (312 ft AMSL) for shallowest public water supply intake operation (Note 25)	1-Jan	31-Dec	1	6	4	5
	Flow							
105	Flow Release From JST	Number of days at or below 4,200 cfs daily average flow	1-Jan	31-Dec	500	7,045	6,975	7,487
106		Number of days at or above 4,000 cfs and below 4,200 cfs daily average flow	1-Jan	31-Dec	100	1,314	1,450	1,385
107		Number of days at or above 3,800 cfs and below 4,000 cfs daily average flow	1-Jan	31-Dec	10	2,227	2,082	2,303
108		Number of days below 3,800 cfs daily average flow	1-Jan	31-Dec	5	1,603	1,582	1,608
109		Number of days below 3,600 cfs daily average flow	1-Jan	31-Dec	5	576	511	653
110		Number of days below 3,100 cfs daily average flow	1-Jan	31-Dec	5	37	10	35
111		Lowest daily average flow (cfs)	1-Jan	31-Dec	250	0	0	0
USACE Hydropower & Water Quantity Management								
112	USACE DCP Drought Level (Note 16)	Percent of time in Normal Conditions	1-Jan	31-Dec	2%	73%	73%	71%
113		Number of years attaining Drought Level 1	1-Jan	31-Dec	5	29	28	34
114		Number of years with more than 60 days in Drought Level 1	1-Jan	31-Dec	5	17	19	19
115		Number of years attaining Drought Level 2	1-Jan	31-Dec	4	22	22	21
116		Number of years with more than 60 days in Drought Level 2	1-Jan	31-Dec	4	17	17	19
117		Number of years attaining Drought Level 3	1-Jan	31-Dec	2	9	9	11
118		Number of years with more than 60 days in Drought Level 3	1-Jan	31-Dec	2	7	7	9
119		Number of years attaining Drought Level 4	1-Jan	31-Dec	1	2	2	2
120		Number of years with more than 60 days in Drought Level 4	1-Jan	31-Dec	1	0	0	0
121	Maximize USACE hydropower generation	Avg. MWh/yr of hydropower produced	1-Jan	31-Dec	300,000	1,617,508	1,621,700	1,615,749
122		Average equivalent # of homes per year that could be powered by the hydro project (Note 17)	1-Jan	31-Dec	1,000	122,538	122,856	122,405
123	Maximize USACE hydropower value	Avg. hydro generation value Dollars/yr (generation value provided by SEPA)	1-Jan	31-Dec	$1,000,000	$113,660,093	$113,930,802	$113,548,426

	Background	Performance Measure has improved vs. the Baseline Scenario
	Background	Performance Measure has declined vs. the Baseline Scenario
	White Background	There is no significant difference between the scenario and the Baseline Scenario by definition of MISC

Notes

1 For criterion that measure on an hourly or daily basis, unless stated otherwise:
a. If an hourly criteria occurs during the average of four contiguous 15-minute periods, then it counts as 1 hour.
b. If a daily criterion occurs for 5 contiguous 1-hour periods, then it counts as 1 day.
Also, daytime flows are assumed to be flows provided between 7:00 am and 7:00 pm. To the extent possible, each criterion is defined in terms of percents and averages/yr so that the same criterion is useful regardless of the length of the hydrology period (i.e., 1-yr, 3-yr, full period of record, etc.)

2 MISC = Minimum Increment of Significant Change. The MISC has the same units (i.e., days, days/yr, percent, etc.) as does the criterion on that same row of the spreadsheet. If the output of two scenarios for a particular criterion differs by less than or equal to the MISC, then there is no significant difference between those two scenarios as far as the criterion in question is concerned. The following guidelines were used to establish the MISC numbers:

a. As a general rule, MISC numbers are set at 10% of the possible total for that criterion considering the Start/Stop dates.
b. MISC numbers for criteria that have the most adverse outcomes if reached are typically set at less than 10% of the possible total for that criterion. criterion.
c. Adjustments to the MISC numbers (up or down) have also been made depending on the desires of the stakeholders that primarily have the interests that are being measured by a particular criterion.

3 Jocassee restricted recreation elevation 1,090 ft AMSL provided by Chris Starker (Upstate Forever) and confirmed by Devils Fork State Park Staff.

4 Jocassee elevation 1,077 ft AMSL is the lowest boat ramp elevation with an additional 3 ft added for boat access. Boat ramp elevations provided by Duke Energy.

5 Jocassee entrainment elevation (1,096 ft AMSL) provided by Bill Marshall of SCDNR.

6 Jocassee fish habitat elevations provided by Bill Marshall of SCDNR.

7 Jocassee elevation 1,099 ft AMSL is the elevation at which an MOU between Duke Energy and SCDNR requires Duke Energy to implement operational changes at Bad Creek. Jocassee elevation 1,090 ft AMSL is the elevation at which Jocassee powerhouse efficiency is degraded.

8 Jocassee elevation 1,081 ft AMSL provided by Duke Energy based on impact to pumping equipment.

9 Keowee restricted recreation elevation of 792 ft AMSL provided by James McRacken (HDR) and Scott Fletcher (Duke Energy).

10 Keowee elevation 790 ft AMSL is based on the lowest boat ramp elevation of 787 ft AMSL plus 3 ft for boat access (provided by Duke Energy).

11 Toe of Keowee reservoir riprap elevation 794 ft AMSL provided by Duke Energy.

12 Keowee fish habitat elevations provided by Bill Marshall of SCDNR.

13 Keowee elevation 775 ft AMSL is the minimum level permitted in the Existing FERC License, and all current Keowee water supply intakes were confirmed to operate at this reservoir level.

14 For this measure a -0.5 ft buffer was added to filter out model excursions below the Keowee reservoir elevation limit of 794.6 ft AMSL. No counts will be displayed for reservoir levels between 794.1 ft AMSL and 794.6 ft AMSL for this measure.

15 Keowee elevation 787.9 ft AMSL is the critical elevation for Keowee to provide backup power to ONS elevation provided by Duke Energy.

16 USACE DCP - United States Army Corps of Engineers' Drought Contingency Plan

17 Calculated by [(Total Scenario MWh / 13.2 MWh per home) / the # of years in the scenario]
The MISC of 1000 homes per year is roughly 2% of the average equivalent homes/yr under the Baseline conditions.
Power produced by the hydro project is actually supplied to Duke Energy's electric system grid and is used by Duke Energy's electric customers (including residential, industrial and commercial customers), as is power produced at other Duke Energy generating stations. This criterion of average equivalent homes per year is intended to simply make the total energy production potential of the hydro project more understandable to stakeholders and to put a perspective around potential differences in hydropower production between various operational scenarios. This measure does not imply that any number of homes will go without power if a particular scenario is chosen.

18 All reservoir elevations for Hartwell, Richard B. Russell and Thurmond performance measures were provided by USACE unless otherwise specified.

19 1939 thru 2011, inclusive (73 years)
26,663 days (Integer of 73 years * 365.25 days/year)
2,559,648 15-minute time steps (26,663 days * 24 hours/day * 4 time steps/hour)

20 This criterion evaluates a day as 24 contiguous hours, not as specified in Note 1.

21 Source for PM 78 elevation: 7/31/12 Telephone call between HDR Jonathan Williams and Clemson Univ. Tony Putnam.

22 Source for PM 85 elevation: 8/2/12 Telephone call between HDR Chris Ey and USACE Joe Hoke.

23 Source for PM 86 elevation: 8/2/12 Telephone call between HDR Jonathan Williams and City of Elberton, GA David Hudson.

24 Source for PM 94 elevation: HDR Jonathan Williams/Hickory Knob State Park (golf course), Savannah Lake Development (Monticello, Tara golf courses).

25 Source for PM 95 elevation: 8/2/12 Telephone call between HDR Jonathan Williams and City of Lincolnton, GA Stanly Pardon.

26 For Climate Change (CC Low/CC High) scenarios, the Trial Balloon scenario is evaluated and color coded according to the Baseline scenario for the same CC level.

27 Percent of time is measured as the percent of 15-minute time steps at or above threshold elevation during period starting 07:00 am and period ending 7:00 pm.

28 No MISC comparisons are made for this Performance Measure since the Baseline scenario does not contain this condition.

Keowee-Toxaway/Savannah River CHEOPS Model Performance Measures Sheet

CHEOPS Operations Model Scenario Log

Scenario	Description	Purpose
Baseline CC High	Duke Energy/USACE Reservoir Storage Balance Agreement and modified operation at Keowee and Jocassee to limit the minimum reservoir elevation at Lake Keowee to 794.6 ft AMSL. Duke Energy reservoir water release calculations use 778 ft AMSL as the minimum Keowee reservoir elevation for usable storage calculation. USACE DCP plan of 2012 is in effect. With increased evaporation coefficient of 20 percent and reduced inflows of 10 percent to represent a 6 degree temperature increase. Model run date March 2014. Withdrawals in CFS.	Base Line Scenario simulates current reservoir operations used by Duke Energy based on Keowee reservoir drawdown limits to maintain operations of the Oconee Nuclear Station located on Lake Keowee. Keowee reservoir drawdown elevation is 794.6 ft AMSL.
Existing License CC High	Conditions as would be applicable given current license requirements and current USACE DCP (2012 Alt 0) with original 1968 Agreemement criteria. With increased evaporation coefficient of 20 percent and reduced inflows of 10 percent to represent a 6 degree temperature increase. Model run date March 2014. Withdrawals in CFS.	Evaluate impact of operations given license requirements and agreements currently in effect.
Blend 2Db v2 CC High	Same as Blend 2D v2 with LIP logic revised to reference “triggered” DCP level versus “In-Effect” DCP level during LIP recovery. Allows LIP to more quickly change to a lower stage number during recovery process, eliminating the 2-foot recovery delay in DCP protocol. LIP gage averaging modified from 6 months to 4 months per AIP documentation (Rev. 4/23/13). With increased evaporation coefficient of 20 percent and reduced inflows of 10 percent to represent a 6 degree temperature increase. Model run date March 2014. Withdrawals in CFS.	Evaluate proposed changes to operating rules (LIP, changes to coordination agreement).

APPENDIX I
CONSULTATION RECORD

The CHEOPS Modeling Scenario Documentation draft report was posted for comment on February 15, 2013. Comments on the draft report were received from three reviewers. Copies of the comments are included in this appendix. A table listing the comments and responses is provided below.

CHEOPS Modeling Scenario Documentation Draft Report Comments			
Item	**Comment by / Date**	**Summary of Comment**	**Duke Energy Response**
1	FOLKS 3/11/2013	See tracked suggested edits in the report body text	Suggestions for grammar were reviewed and accepted as appropriate. Responses to suggested text changes are documented in the attached reprint of the Draft report using comment balloons (included at the end of this Appendix).
2	FOLKS 3/11/2013	Provide pie charts of level-duration outputs for each scenario, along with the duration plots for the 70 year simulations, to magnify/illustrate differences better. The Performance Sheets in the Appendices will help the reader evaluate the scenario output differences in more detail.	The requested level-duration plots were added to the report in Section 4.
3	FOLKS 3/11/2013	Add a new section to the report that describes/presents level-duration results (e.g., via pie charts) obtained focusing in on the 2007/2009 drought (say 1999-2012) scenario(s) relative to keeping Lake Keowee levels as high as possible for the greatest length of time during drought periods. Consider including climate change sensitivity results for these runs.	Pie charts showing the POR and focused time segments of 2007-2008 were added to Section 4 for all scenarios discussed in Section 3 including climate change sensitivities.
4	Greenville Water 3/18/2013	Sections 3.1 and 3.2 Draft Report p. 13: Add more detail to the description of the existing and baseline scenarios including differences in operating and storage-balancing rules and identification of which projects are considered in usable storage calculations.	Sections 3.1 and 3.2 were revised to include reference to Jocassee, Keowee, Hartwell and JS Thurmond for calculating usable storage. Descriptions of operations rules are included in Section 2 for each development with specific differences noted in Sections 3.1 and 3.2 along with scenario input forms included in Appendix C.

CHEOPS Modeling Scenario Documentation Draft Report Comments			
Item	**Comment by / Date**	**Summary of Comment**	**Duke Energy Response**
5	Greenville Water 3/18/2013	Section 3.13, Draft Report p. 19: The approach used to quantify climate change effects on reservoir operations does not capture the effects of associated climate variability, which due to seasonal variability are likely to be more severe than indicated by increased net evaporation and reduced streamflow on an annual average basis. Characterize the sensitivity analyses as uniformly reduced-inflow scenarios.	Section 3.13 describes the development of the climate change sensitivities through OSC meetings over the course of several months in the summer of 2012. Text was added to this section to note that the two sensitivities approved by the OSC are simplifications of possible impacts of future temperature increases (increased reservoir evaporation) and decreases in natural inflows.

Attachment 2

Raw Climate Data for Oconee County (50 Years)

This page intentionally left blank.

Oconee County 50-Year Climate Data (1973-2023) Source: NOAA 2024 URL: https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/time-series.

Average Temperatures			Maximum Temperatures			Minimum Termperatures			Precipitation			Drought Index (Palmers)		
Units: Degrees Fahrenheit			Units: Degrees Fahrenheit			Units: Degrees Fahrenheit			Units: Inches			Missing: -99		
Date	Value	Anomaly	Date	Value	Anomaly	Date	Value	Anomaly	Date	Value	Anomaly	Date	Value	Anomaly
197301	41.3	0.1	197301	51.8	0.2	197301	30.7	-0.2	197301	5.54	0.04	197301	1.16	1.43
197302	41.5	-1	197302	53.5	-1.5	197302	29.8	-2.7	197302	5.02	-0.42	197302	0.98	1.19
197303	46	0.8	197303	65.1	2.7	197303	45	6.2	197303	9.93	3.73	197303	1.59	1.83
197304	48.6	-0.1	197304	67.3	-4.5	197304	45.4	-1	197304	6.7	1.99	197304	2	2.26
197305	51.7	-0.7	197305	76.7	-2.9	197305	51.5	-3.5	197305	9.96	5.41	197305	3.37	3.52
197306	55.4	-0.7	197306	83.8	-2.1	197306	63.8	0.9	197306	5.28	0.32	197306	3.21	3.39
197307	58.5	-0.6	197307	86.8	-1.3	197307	67.4	0.8	197307	4.3	-1.52	197307	2.6	2.83
197308	60.6	-0.7	197308	85.2	-1.6	197308	65.5	-0.2	197308	3.86	-1.78	197308	2.03	2.24
197309	62	-0.3	197309	83.8	1.9	197309	63.1	2.9	197309	5.25	0.86	197309	1.94	2.08
197310	62	-0.1	197310	73.8	1.7	197310	50.6	2.4	197310	2.22	-1.79	197310	1.27	1.45
197311	61.3	0.3	197311	65.7	3.9	197311	41.1	2.9	197311	3.9	-0.15	197311	0.92	1.38
197312	59.7	0.2	197312	52.5	-0.2	197312	31.9	0	197312	8.58	3	197312	1.55	1.88
197401	51.5	10.3	197401	61	9.4	197401	41.9	11	197401	9.5	4	197401	2.18	2.45
197402	48.1	5.6	197402	57.5	2.5	197402	31.9	-0.6	197402	6.46	1.02	197402	2.2	2.41
197403	50.6	5.4	197403	68.5	6.1	197403	42.6	3.8	197403	4.02	-2.18	197403	1.3	1.54
197404	52.7	4	197404	71.6	-0.2	197404	46.3	-0.1	197404	5.32	0.61	197404	1.31	1.57
197405	55.8	3.4	197405	79.9	0.3	197405	56.6	1.6	197405	6.8	2.25	197405	1.74	1.89
197406	58.2	2.1	197406	81.7	-4.2	197406	59	-3.9	197406	3.5	-1.46	197406	1.42	1.6
197407	60.8	1.7	197407	86.2	-1.9	197407	66	-0.6	197407	6.85	1.03	197407	1.58	1.81
197408	62.5	1.2	197408	83.7	-3.1	197408	65.4	-0.3	197408	7.76	2.12	197408	2.1	2.31
197409	63.2	0.9	197409	78.6	-3.3	197409	58.5	-1.7	197409	2.88	-1.51	197409	-0.09	0.05
197410	62.7	0.6	197410	73.5	1.4	197410	42.7	-5.5	197410	1.44	-2.57	197410	-0.61	-0.43
197411	61.5	0.5	197411	62.4	0.6	197411	37	-1.2	197411	3.61	-0.44	197411	-0.71	-0.25
197412	59.9	0.4	197412	51.8	-0.9	197412	32.3	0.4	197412	4.65	-0.93	197412	-0.8	-0.47
197501	44.9	3.7	197501	55.7	4.1	197501	34.1	3.2	197501	5.76	0.26	197501	-0.72	-0.45
197502	45.7	3.2	197502	57	2	197502	35.7	3.2	197502	8.45	3.01	197502	0.71	0.92
197503	46.5	1.3	197503	59.3	-3.1	197503	37.2	-1.6	197503	11.09	4.89	197503	1.78	2.02
197504	49.5	0.8	197504	71.7	-0.1	197504	44.9	-1.5	197504	1.4	-3.31	197504	-0.82	-0.56
197505	53.6	1.2	197505	80.7	1.1	197505	59.4	4.4	197505	7.71	3.16	197505	0.59	0.74
197506	56.9	0.8	197506	84.4	-1.5	197506	62.2	-0.7	197506	5.27	0.31	197506	0.74	0.92
197507	59.6	0.5	197507	85.8	-2.3	197507	66.4	-0.2	197507	5.42	-0.4	197507	0.67	0.9
197508	61.8	0.5	197508	87.4	0.6	197508	66.7	1	197508	2.89	-2.75	197508	0.04	0.25
197509	62.7	0.4	197509	78.9	-3	197509	60.2	0	197509	10.65	6.26	197509	1.64	1.78
197510	62.6	0.5	197510	73.7	1.6	197510	50.6	2.4	197510	5.53	1.52	197510	1.82	2
197511	61.7	0.7	197511	63.9	2.1	197511	40.3	2.1	197511	6.05	2	197511	2.12	2.58
197512	60.1	0.6	197512	53.1	0.4	197512	31.6	-0.3	197512	4.78	-0.8	197512	-0.14	0.19
197601	36.8	-4.4	197601	48.6	-3	197601	25.1	-5.8	197601	6.2	0.7	197601	0.22	0.49
197602	43.2	0.7	197602	63.9	8.9	197602	35.4	2.9	197602	2.8	-2.64	197602	-0.75	-0.54
197603	46.8	1.6	197603	66.1	3.7	197603	42.1	3.3	197603	9.55	3.35	197603	-0.03	0.21
197604	50.1	1.4	197604	75.6	3.8	197604	43.7	-2.7	197604	1.23	-3.48	197604	-0.93	-0.67

197605	52.7	0.3	197605	75.1	-4.5	197605	51.9	-3.1	197605	13.55	9	197605	2.36	2.51
197606	55.9	-0.2	197606	81.9	-4	197606	61.8	-1.1	197606	5.82	0.86	197606	2.52	2.7
197607	58.7	-0.4	197607	86.6	-1.5	197607	64.4	-2.2	197607	4.53	-1.29	197607	2.1	2.33
197608	60.7	-0.6	197608	85.2	-1.6	197608	64.2	-1.5	197608	3.95	-1.69	197608	1.64	1.85
197609	61.6	-0.7	197609	79.3	-2.6	197609	57.4	-2.8	197609	4.9	0.51	197609	1.72	1.86
197610	60.9	-1.2	197610	66.2	-5.9	197610	44	-4.2	197610	7.29	3.28	197610	2.46	2.64
197611	59.4	-1.6	197611	56.9	-4.9	197611	32.4	-5.8	197611	3.61	-0.44	197611	2.21	2.67
197612	57.8	-1.7	197612	50.6	-2.1	197612	27.9	-4	197612	6.77	1.19	197612	2.33	2.66
197701	30	-11.2	197701	39.8	-11.8	197701	20.1	-10.8	197701	4.17	-1.33	197701	-0.25	0.02
197702	35.7	-6.8	197702	55.8	0.8	197702	26.8	-5.7	197702	2.24	-3.2	197702	-0.96	-0.75
197703	41.7	-3.5	197703	65.5	3.1	197703	41.8	3	197703	11.54	5.34	197703	1.12	1.36
197704	46.9	-1.8	197704	75.4	3.6	197704	49.3	2.9	197704	4.12	-0.59	197704	-0.27	-0.01
197705	51.3	-1.1	197705	80.9	1.3	197705	57.3	2.3	197705	2.68	-1.87	197705	-0.81	-0.66
197706	55.3	-0.8	197706	87.5	1.6	197706	62.5	-0.4	197706	3.61	-1.35	197706	-1.11	-0.93
197707	58.7	-0.4	197707	91.6	3.5	197707	67.8	1.2	197707	2.66	-3.16	197707	-1.92	-1.69
197708	61	-0.3	197708	87	0.2	197708	66.8	1.1	197708	4.61	-1.03	197708	-2.06	-1.85
197709	62.3	0	197709	81.8	-0.1	197709	62.8	2.6	197709	9.58	5.19	197709	1	1.14
197710	61.8	-0.3	197710	69.2	-2.9	197710	45.7	-2.5	197710	7.65	3.64	197710	1.86	2.04
197711	60.9	-0.1	197711	61.2	-0.6	197711	43.4	5.2	197711	6.93	2.88	197711	2.38	2.84
197712	59.2	-0.3	197712	50.4	-2.3	197712	30.2	-1.7	197712	4.67	-0.91	197712	2	2.33
197801	32.4	-8.8	197801	41.8	-9.8	197801	23	-7.9	197801	9.54	4.04	197801	2.87	3.14
197802	34.6	-7.9	197802	47.8	-7.2	197802	25.6	-6.9	197802	0.56	-4.88	197802	-1.1	-0.89
197803	39.3	-5.9	197803	61.7	-0.7	197803	36	-2.8	197803	5.12	-1.08	197803	-1.23	-0.99
197804	44.6	-4.1	197804	74	2.2	197804	46.5	0.1	197804	3.01	-1.7	197804	-1.59	-1.33
197805	48.8	-3.6	197805	76.8	-2.8	197805	54.7	-0.3	197805	6.32	1.77	197805	0.54	0.69
197806	53.1	-3	197806	86.2	0.3	197806	63	0.1	197806	3.47	-1.49	197806	-0.31	-0.13
197807	56.6	-2.5	197807	88.9	0.8	197807	66.5	-0.1	197807	4.81	-1.01	197807	-0.54	-0.31
197808	59.1	-2.2	197808	86	-0.8	197808	66.3	0.6	197808	8.98	3.34	197808	0.84	1.05
197809	60.5	-1.8	197809	82.7	0.8	197809	61.4	1.2	197809	2.7	-1.69	197809	-0.24	-0.1
197810	60.3	-1.8	197810	72.6	0.5	197810	45	-3.2	197810	0.54	-3.47	197810	-0.99	-0.81
197811	59.8	-1.2	197811	65.6	3.8	197811	43.6	5.4	197811	3.51	-0.54	197811	-1.26	-0.8
197812	58.4	-1.1	197812	53.8	1.1	197812	31.8	-0.1	197812	5.55	-0.03	197812	0.02	0.35
197901	37	-4.2	197901	47.2	-4.4	197901	26.7	-4.2	197901	8.66	3.16	197901	0.84	1.11
197902	38.2	-4.3	197902	49.5	-5.5	197902	29.1	-3.4	197902	7.11	1.67	197902	1.24	1.45
197903	42.9	-2.3	197903	64.3	1.9	197903	40.4	1.6	197903	6.46	0.26	197903	1.08	1.32
197904	47	-1.7	197904	70.5	-1.3	197904	47.6	1.2	197904	10.56	5.85	197904	2.43	2.69
197905	50.9	-1.5	197905	77	-2.6	197905	56.7	1.7	197905	7.61	3.06	197905	3.02	3.17
197906	54.5	-1.6	197906	82.2	-3.7	197906	62.2	-0.7	197906	4.89	-0.07	197906	2.86	3.04
197907	57.4	-1.7	197907	83.4	-4.7	197907	65.9	-0.7	197907	7.22	1.4	197907	3.03	3.26
197908	59.7	-1.6	197908	87.4	0.6	197908	64.8	-0.9	197908	6.18	0.54	197908	2.98	3.19
197909	60.8	-1.5	197909	78.1	-3.8	197909	62	1.8	197909	7.31	2.92	197909	3.65	3.79
197910	60.6	-1.5	197910	70.9	-1.2	197910	45.9	-2.3	197910	3.37	-0.64	197910	3.22	3.4
197911	59.8	-1.2	197911	62.9	1.1	197911	41.2	3	197911	8.94	4.89	197911	4.14	4.6
197912	58.5	-1	197912	55.1	2.4	197912	32	0.1	197912	1.61	-3.97	197912	2.84	3.17

198001	42	0.8	198001	50.2	-1.4	198001	33.8	2.9	198001	6.77	1.27	198001	2.84	3.11
198002	40.6	-1.9	198002	51	-4	198002	27.3	-5.2	198002	1.87	-3.57	198002	1.75	1.96
198003	43	-2.2	198003	58.4	-4	198003	37	-1.8	198003	14.43	8.23	198003	3.51	3.75
198004	46.8	-1.9	198004	70.6	-1.2	198004	45.9	-0.5	198004	5.02	0.31	198004	3.24	3.5
198005	50.8	-1.6	198005	78.8	-0.8	198005	55.2	0.2	198005	7.43	2.88	198005	3.69	3.84
198006	54.7	-1.4	198006	84.9	-1	198006	62.7	-0.2	198006	4.17	-0.79	198006	-0.1	0.08
198007	58.4	-0.7	198007	92.6	4.5	198007	68.7	2.1	198007	2.11	-3.71	198007	-1.07	-0.84
198008	60.9	-0.4	198008	91.6	4.8	198008	65.9	0.2	198008	1.95	-3.69	198008	-2.02	-1.81
198009	62.3	0	198009	84.1	2.2	198009	63.2	3	198009	7.98	3.59	198009	-1.33	-1.19
198010	61.8	-0.3	198010	68.5	-3.6	198010	45.6	-2.6	198010	4.53	0.52	198010	-1	-0.82
198011	60.6	-0.4	198011	60.6	-1.2	198011	36.8	-1.4	198011	3.4	-0.65	198011	-1.03	-0.57
198012	59.1	-0.4	198012	55.1	2.4	198012	29.4	-2.5	198012	0.69	-4.89	198012	-1.99	-1.66
198101	37.1	-4.1	198101	49.6	-2	198101	24.7	-6.2	198101	0.68	-4.82	198101	-2.93	-2.66
198102	39.7	-2.8	198102	53.5	-1.5	198102	30.8	-1.7	198102	6.57	1.13	198102	-2.32	-2.11
198103	42.4	-2.8	198103	61.1	-1.3	198103	34.9	-3.9	198103	3.53	-2.67	198103	-2.68	-2.44
198104	47.7	-1	198104	76.1	4.3	198104	50.6	4.2	198104	2.12	-2.59	198104	-3.22	-2.96
198105	51	-1.4	198105	77.3	-2.3	198105	51.4	-3.6	198105	4.27	-0.28	198105	-2.97	-2.82
198106	55.4	-0.7	198106	88	2.1	198106	66.1	3.2	198106	3.19	-1.77	198106	-3.15	-2.97
198107	58.6	-0.5	198107	88.5	0.4	198107	68.2	1.6	198107	4.05	-1.77	198107	-3.34	-3.11
198108	60.6	-0.7	198108	83.8	-3	198108	65.4	-0.3	198108	1.1	-4.54	198108	-4.03	-3.82
198109	61.5	-0.8	198109	81.3	-0.6	198109	55.7	-4.5	198109	3.26	-1.13	198109	-4.1	-3.96
198110	61.1	-1	198110	69.8	-2.3	198110	45.8	-2.4	198110	3.73	-0.28	198110	-3.8	-3.62
198111	60.1	-0.9	198111	62.8	1	198111	36.6	-1.6	198111	1.94	-2.11	198111	-4.13	-3.67
198112	58.2	-1.3	198112	46.7	-6	198112	28.4	-3.5	198112	6.84	1.26	198112	0.3	0.63
198201	36.5	-4.7	198201	47.2	-4.4	198201	25.7	-5.2	198201	8.68	3.18	198201	1.1	1.37
198202	41.3	-1.2	198202	56.5	1.5	198202	35.5	3	198202	8.62	3.18	198202	1.74	1.95
198203	45.2	0	198203	65	2.6	198203	40.9	2.1	198203	2.69	-3.51	198203	-0.92	-0.68
198204	48	-0.7	198204	67.9	-3.9	198204	44.8	-1.6	198204	5.98	1.27	198204	-0.43	-0.17
198205	52.2	-0.2	198205	82.2	2.6	198205	56.2	1.2	198205	2.73	-1.82	198205	-0.94	-0.79
198206	55.7	-0.4	198206	84.3	-1.6	198206	62.5	-0.4	198206	4.21	-0.75	198206	-1.01	-0.83
198207	58.8	-0.3	198207	87	-1.1	198207	67.5	0.9	198207	6.57	0.75	198207	-0.79	-0.56
198208	60.8	-0.5	198208	84.4	-2.4	198208	65	-0.7	198208	5.12	-0.52	198208	-0.71	-0.5
198209	61.6	-0.7	198209	78.6	-3.3	198209	57.8	-2.4	198209	2.62	-1.77	198209	-0.92	-0.78
198210	61.4	-0.7	198210	70.1	-2	198210	48.5	0.3	198210	4.36	0.35	198210	0.08	0.26
198211	60.4	-0.6	198211	61.3	-0.5	198211	40.6	2.4	198211	6	1.95	198211	0.56	1.02
198212	59.3	-0.2	198212	55.4	2.7	198212	38.1	6.2	198212	7.25	1.67	198212	0.86	1.19
198301	38.8	-2.4	198301	48.5	-3.1	198301	29	-1.9	198301	3.88	-1.62	198301	0.4	0.67
198302	40.5	-2	198302	52.6	-2.4	198302	31.9	-0.6	198302	5.95	0.51	198302	0.52	0.73
198303	43.8	-1.4	198303	62	-0.4	198303	38.6	-0.2	198303	7.21	1.01	198303	0.66	0.9
198304	46.4	-2.3	198304	65.9	-5.9	198304	42.5	-3.9	198304	6.55	1.84	198304	1.2	1.46
198305	50.2	-2.2	198305	77.7	-1.9	198305	53.7	-1.3	198305	6.04	1.49	198305	1.54	1.69
198306	53.9	-2.2	198306	83.6	-2.3	198306	60.7	-2.2	198306	2.18	-2.78	198306	-0.55	-0.37
198307	57.5	-1.6	198307	91.1	3	198307	67	0.4	198307	1.9	-3.92	198307	-1.51	-1.28
198308	60.2	-1.1	198308	91.3	4.5	198308	66.8	1.1	198308	2.54	-3.1	198308	-2.29	-2.08

198309	61.1	-1.2	198309	79.2	-2.7	198309	58.8	-1.4	198309	5.63	1.24	198309	0.07	0.21
198310	61	-1.1	198310	71.1	-1	198310	48.9	0.7	198310	4.01	0	198310	0.01	0.19
198311	60	-1	198311	61.6	-0.2	198311	38.2	0	198311	6.82	2.77	198311	0.66	1.12
198312	58.3	-1.2	198312	49	-3.7	198312	28.5	-3.4	198312	10.93	5.35	198312	1.89	2.22
198401	38.5	-2.7	198401	49.9	-1.7	198401	27.2	-3.7	198401	4.31	-1.19	198401	1.43	1.7
198402	41.5	-1	198402	56.7	1.7	198402	32.2	-0.3	198402	6.7	1.26	198402	1.59	1.8
198403	44.1	-1.1	198403	62	-0.4	198403	37.1	-1.7	198403	5.17	-1.03	198403	1.17	1.41
198404	47.1	-1.6	198404	66.7	-5.1	198404	44.9	-1.5	198404	6.78	2.07	198404	1.66	1.92
198405	50.6	-1.8	198405	77.7	-1.9	198405	51.9	-3.1	198405	6.92	2.37	198405	2.23	2.38
198406	54.7	-1.4	198406	87.4	1.5	198406	62.4	-0.5	198406	4.57	-0.39	198406	1.96	2.14
198407	57.5	-1.6	198407	83.5	-4.6	198407	65.6	-1	198407	12.5	6.68	198407	3.39	3.62
198408	59.7	-1.6	198408	84.7	-2.1	198408	66.4	0.7	198408	5.11	-0.53	198408	0.02	0.23
198409	60.8	-1.5	198409	81.1	-0.8	198409	56.6	-3.6	198409	0.14	-4.25	198409	-0.81	-0.67
198410	61.3	-0.8	198410	76.8	4.7	198410	55.3	7.1	198410	3.44	-0.57	198410	-1.08	-0.9
198411	60	-1	198411	60.2	-1.6	198411	34.7	-3.5	198411	3.13	-0.92	198411	-1.29	-0.83
198412	59.2	-0.3	198412	61.5	8.8	198412	38.8	6.9	198412	3.09	-2.49	198412	-1.83	-1.5
198501	35.2	-6	198501	45.6	-6	198501	24.8	-6.1	198501	4.24	-1.26	198501	-1.89	-1.62
198502	38.9	-3.6	198502	53	-2	198502	32	-0.5	198502	7.33	1.89	198502	-1.2	-0.99
198503	43.7	-1.5	198503	65.9	3.5	198503	40.7	1.9	198503	1.31	-4.89	198503	-2.32	-2.08
198504	48	-0.7	198504	74.9	3.1	198504	47	0.6	198504	2.47	-2.24	198504	-2.7	-2.44
198505	51.8	-0.6	198505	78.6	-1	198505	55.2	0.2	198505	4.79	0.24	198505	-2.4	-2.25
198506	55.5	-0.6	198506	86	0.1	198506	62.3	-0.6	198506	3.63	-1.33	198506	-2.4	-2.22
198507	58.4	-0.7	198507	85	-3.1	198507	66.4	-0.2	198507	9.37	3.55	198507	0.84	1.07
198508	60.5	-0.8	198508	83.8	-3	198508	65.9	0.2	198508	9	3.36	198508	1.74	1.95
198509	61.4	-0.9	198509	80.6	-1.3	198509	57.4	-2.8	198509	0.62	-3.77	198509	0.88	1.02
198510	61.7	-0.4	198510	73.3	1.2	198510	55.7	7.5	198510	5.01	1	198510	0.87	1.05
198511	61.5	0.5	198511	67.3	5.5	198511	50.6	12.4	198511	8.34	4.29	198511	1.67	2.13
198512	59.6	0.1	198512	49.9	-2.8	198512	27.7	-4.2	198512	1.41	-4.17	198512	-0.86	-0.53
198601	39.4	-1.8	198601	52.3	0.7	198601	26.5	-4.4	198601	2.06	-3.44	198601	-1.6	-1.33
198602	43.4	0.9	198602	58.7	3.7	198602	35.8	3.3	198602	1.72	-3.72	198602	-2.4	-2.19
198603	45.7	0.5	198603	63.7	1.3	198603	37.2	-1.6	198603	3.37	-2.83	198603	-2.85	-2.61
198604	49.4	0.7	198604	75.5	3.7	198604	45.4	-1	198604	1.02	-3.69	198604	-3.54	-3.28
198605	53.1	0.7	198605	79.7	0.1	198605	55.4	0.4	198605	4.21	-0.34	198605	-3.52	-3.37
198606	57	0.9	198606	88.4	2.5	198606	64.6	1.7	198606	1.23	-3.73	198606	-4.21	-4.03
198607	60.4	1.3	198607	93.9	5.8	198607	68	1.4	198607	2.51	-3.31	198607	-4.94	-4.71
198608	62.3	1	198608	84.7	-2.1	198608	66.3	0.6	198608	5.19	-0.45	198608	-4.6	-4.39
198609	63.3	1	198609	80.6	-1.3	198609	62.5	2.3	198609	3.92	-0.47	198609	-4.6	-4.46
198610	63.1	1	198610	71.5	-0.6	198610	50.3	2.1	198610	8.25	4.24	198610	-3.29	-3.11
198611	62.2	1.2	198611	60.5	-1.3	198611	46.7	8.5	198611	7.81	3.76	198611	-2.04	-1.58
198612	60.6	1.1	198612	51.6	-1.1	198612	33	1.1	198612	6.68	1.1	198612	-1.53	-1.2
198701	39.2	-2	198701	48.5	-3.1	198701	29.9	-1	198701	5.7	0.2	198701	-1.3	-1.03
198702	41	-1.5	198702	52.3	-2.7	198702	33.1	0.6	198702	5.86	0.42	198702	-1.04	-0.83
198703	44	-1.2	198703	61.8	-0.6	198703	38.5	-0.3	198703	6.6	0.4	198703	-0.87	-0.63
198704	47.2	-1.5	198704	69.8	-2	198704	43.4	-3	198704	2.72	-1.99	198704	-1.21	-0.95

198705	51.7	-0.7	198705	81.5	1.9	198705	58.6	3.6	198705	3.51	-1.04	198705	-1.47	-1.32
198706	55.6	-0.5	198706	85.8	-0.1	198706	63.9	1	198706	5.86	0.9	198706	-1.07	-0.89
198707	58.8	-0.3	198707	89.8	1.7	198707	66.6	0	198707	4.08	-1.74	198707	-1.34	-1.11
198708	61.3	0	198708	89.3	2.5	198708	67.8	2.1	198708	3.73	-1.91	198708	-1.7	-1.49
198709	62.3	0	198709	81.1	-0.8	198709	59.9	-0.3	198709	4.33	-0.06	198709	-1.65	-1.51
198710	61.5	-0.6	198710	69.3	-2.8	198710	38.8	-9.4	198710	0.41	-3.6	198710	-2.23	-2.05
198711	60.6	-0.4	198711	64.5	2.7	198711	39.7	1.5	198711	4.13	0.08	198711	-2.22	-1.76
198712	59.3	-0.2	198712	53.6	0.9	198712	34.6	2.7	198712	5.44	-0.14	198712	-2.04	-1.71
198801	35.6	-5.6	198801	45.6	-6	198801	25.6	-5.3	198801	5.35	-0.15	198801	-1.81	-1.54
198802	38.6	-3.9	198802	53.7	-1.3	198802	29.3	-3.2	198802	2.49	-2.95	198802	-2.3	-2.09
198803	42.5	-2.7	198803	62.9	0.5	198803	37.7	-1.1	198803	2.74	-3.46	198803	-2.91	-2.67
198804	46.7	-2	198804	72.8	1	198804	45.7	-0.7	198804	4.95	0.24	198804	-2.56	-2.3
198805	50.3	-2.1	198805	79.4	-0.2	198805	50.7	-4.3	198805	1.37	-3.18	198805	-3.05	-2.9
198806	54.3	-1.8	198806	89	3.1	198806	59.1	-3.8	198806	2.1	-2.86	198806	-3.52	-3.34
198807	57.5	-1.6	198807	87	-1.1	198807	66.1	-0.5	198807	5.16	-0.66	198807	-3.46	-3.23
198808	60	-1.3	198808	88.7	1.9	198808	67.4	1.7	198808	3.59	-2.05	198808	-3.71	-3.5
198809	61.1	-1.2	198809	78.8	-3.1	198809	60.8	0.6	198809	5.17	0.78	198809	-3.34	-3.2
198810	60.4	-1.7	198810	66.2	-5.9	198810	42.3	-5.9	198810	3.52	-0.49	198810	-3.01	-2.83
198811	59.5	-1.5	198811	61.9	0.1	198811	39.3	1.1	198811	4.48	0.43	198811	-2.67	-2.21
198812	58.1	-1.4	198812	53.7	1	198812	29.7	-2.2	198812	1.85	-3.73	198812	-3.19	-2.86
198901	45.1	3.9	198901	56.5	4.9	198901	33.7	2.8	198901	3.53	-1.97	198901	-3.42	-3.15
198902	45.6	3.1	198902	56.5	1.5	198902	35.6	3.1	198902	5.67	0.23	198902	-3.04	-2.83
198903	48.3	3.1	198903	64.7	2.3	198903	42.6	3.8	198903	5.29	-0.91	198903	-3.06	-2.82
198904	50.7	2	198904	70.5	-1.3	198904	45.2	-1.2	198904	3.47	-1.24	198904	-3.03	-2.77
198905	53.3	0.9	198905	76.1	-3.5	198905	51.1	-3.9	198905	5.42	0.87	198905	0.38	0.53
198906	56.6	0.5	198906	82.8	-3.1	198906	63.4	0.5	198906	11.8	6.84	198906	2.24	2.42
198907	59.4	0.3	198907	85	-3.1	198907	68	1.4	198907	10.09	4.27	198907	3.05	3.28
198908	61.5	0.2	198908	86	-0.8	198908	65.2	-0.5	198908	4.76	-0.88	198908	2.67	2.88
198909	62.4	0.1	198909	78.5	-3.4	198909	61.2	1	198909	7.6	3.21	198909	3.42	3.56
198910	62.2	0.1	198910	73.2	1.1	198910	47.5	-0.7	198910	5.58	1.57	198910	3.47	3.65
198911	61.1	0.1	198911	61.8	0	198911	38.5	0.3	198911	4.29	0.24	198911	3.19	3.65
198912	59	-0.5	198912	45.3	-7.4	198912	27	-4.9	198912	5.12	-0.46	198912	2.87	3.2
199001	46.2	5	199001	57.2	5.6	199001	35.1	4.2	199001	7.66	2.16	199001	3.02	3.29
199002	48	5.5	199002	61.2	6.2	199002	38.3	5.8	199002	7.54	2.1	199002	3.12	3.33
199003	50.2	5	199003	65.9	3.5	199003	43.5	4.7	199003	9.67	3.47	199003	3.46	3.7
199004	52.3	3.6	199004	71.9	0.1	199004	45.3	-1.1	199004	2.44	-2.27	199004	-0.57	-0.31
199005	55.2	2.8	199005	78.6	-1	199005	55	0	199005	4.2	-0.35	199005	-0.58	-0.43
199006	58.5	2.4	199006	86.9	1	199006	62.5	-0.4	199006	1.26	-3.7	199006	-1.4	-1.22
199007	61.2	2.1	199007	88.7	0.6	199007	66.3	-0.3	199007	4.96	-0.86	199007	-1.61	-1.38
199008	63.2	1.9	199008	87.6	0.8	199008	66.6	0.9	199008	4.63	-1.01	199008	-1.74	-1.53
199009	64.1	1.8	199009	82.2	0.3	199009	59.9	-0.3	199009	6.22	1.83	199009	0.26	0.4
199010	63.8	1.7	199010	72.4	0.3	199010	49.8	1.6	199010	7.14	3.13	199010	0.93	1.11
199011	62.8	1.8	199011	67.8	6	199011	38.7	0.5	199011	2.13	-1.92	199011	-0.58	-0.12
199012	61.5	2	199012	56	3.3	199012	37.2	5.3	199012	6.13	0.55	199012	-0.41	-0.08

199101	41.9	0.7	199101	50.5	-1.1	199101	33.4	2.5	199101	5.76	0.26	199101	-0.32	-0.05
199102	44.1	1.6	199102	58.1	3.1	199102	34.5	2	199102	3.65	-1.79	199102	-0.76	-0.55
199103	47.1	1.9	199103	64.5	2.1	199103	41.4	2.6	199103	7.11	0.91	199103	0.11	0.35
199104	50.8	2.1	199104	72.6	0.8	199104	51	4.6	199104	6.74	2.03	199104	0.5	0.76
199105	54.6	2.2	199105	79.2	-0.4	199105	61.3	6.3	199105	8.29	3.74	199105	1.33	1.48
199106	57.8	1.7	199106	83.1	-2.8	199106	64.3	1.4	199106	6.76	1.8	199106	1.77	1.95
199107	60.8	1.7	199107	88.1	0	199107	69	2.4	199107	6.23	0.41	199107	1.69	1.92
199108	62.6	1.3	199108	84.4	-2.4	199108	65.9	0.2	199108	8.78	3.14	199108	2.43	2.64
199109	63.5	1.2	199109	81.5	-0.4	199109	59.5	-0.7	199109	2.7	-1.69	199109	-0.2	-0.06
199110	63.1	1	199110	73.2	1.1	199110	47.3	-0.9	199110	0.32	-3.69	199110	-1.02	-0.84
199111	61.8	0.8	199111	59.7	-2.1	199111	36.9	-1.3	199111	2.84	-1.21	199111	-1.33	-0.87
199112	60.5	1	199112	57.6	4.9	199112	36	4.1	199112	4.97	-0.61	199112	-1.38	-1.05
199201	42.7	1.5	199201	53.6	2	199201	31.8	0.9	199201	3.85	-1.65	199201	-1.68	-1.41
199202	45.2	2.7	199202	59.2	4.2	199202	36.1	3.6	199202	7.24	1.8	199202	0.38	0.59
199203	46.9	1.7	199203	62.5	0.1	199203	37.9	-0.9	199203	6.71	0.51	199203	0.42	0.66
199204	49.7	1	199204	71.4	-0.4	199204	44.7	-1.7	199204	2.55	-2.16	199204	-0.52	-0.26
199205	52.5	0.1	199205	75.1	-4.5	199205	52.4	-2.6	199205	4.54	-0.01	199205	0.14	0.29
199206	55.6	-0.5	199206	80.2	-5.7	199206	62.2	-0.7	199206	7.88	2.92	199206	1.09	1.27
199207	58.8	-0.3	199207	88.2	0.1	199207	67.4	0.8	199207	3.09	-2.73	199207	-0.57	-0.34
199208	60.6	-0.7	199208	81.9	-4.9	199208	64.2	-1.5	199208	11.42	5.78	199208	1.54	1.75
199209	61.7	-0.6	199209	79.3	-2.6	199209	61.6	1.4	199209	5.99	1.6	199209	2.02	2.16
199210	61.2	-0.9	199210	69.2	-2.9	199210	45.7	-2.5	199210	4.33	0.32	199210	2	2.18
199211	60.2	-0.8	199211	59.7	-2.1	199211	40.3	2.1	199211	10.66	6.61	199211	3.56	4.02
199212	58.7	-0.8	199212	51.1	-1.6	199212	33.2	1.3	199212	7.75	2.17	199212	3.73	4.06
199301	45.1	3.9	199301	54	2.4	199301	36.2	5.3	199301	8.99	3.49	199301	4.14	4.41
199302	43.6	1.1	199302	52	-3	199302	32	-0.5	199302	4.7	-0.74	199302	3.57	3.78
199303	44.8	-0.4	199303	57.6	-4.8	199303	37.2	-1.6	199303	8.41	2.21	199303	3.75	3.99
199304	47.5	-1.2	199304	68.5	-3.3	199304	42.3	-4.1	199304	4.69	-0.02	199304	3.46	3.72
199305	51.3	-1.1	199305	78	-1.6	199305	55.2	0.2	199305	4.62	0.07	199305	3.16	3.31
199306	55.2	-0.9	199306	86.4	0.5	199306	63.4	0.5	199306	2.23	-2.73	199306	-0.64	-0.46
199307	59	-0.1	199307	94.6	6.5	199307	68.1	1.5	199307	2.09	-3.73	199307	-1.72	-1.49
199308	61.3	0	199308	88.3	1.5	199308	67.2	1.5	199308	2.17	-3.47	199308	-2.53	-2.32
199309	62.5	0.2	199309	83.2	1.3	199309	60.6	0.4	199309	4.17	-0.22	199309	-2.69	-2.55
199310	62.2	0.1	199310	71.1	-1	199310	47.8	-0.4	199310	2.46	-1.55	199310	-2.9	-2.72
199311	61	0	199311	60.8	-1	199311	38.1	-0.1	199311	4.86	0.81	199311	-2.64	-2.18
199312	59.4	-0.1	199312	50.8	-1.9	199312	30.9	-1	199312	4.19	-1.39	199312	-2.67	-2.34
199401	36.2	-5	199401	45.7	-5.9	199401	26.7	-4.2	199401	6.22	0.72	199401	0.23	0.5
199402	40.6	-1.9	199402	56	1	199402	33.8	1.3	199402	5.7	0.26	199402	0.26	0.47
199403	44.5	-0.7	199403	64.9	2.5	199403	39.8	1	199403	8.2	2	199403	0.62	0.86
199404	48.7	0	199404	75.1	3.3	199404	47.4	1	199404	4.33	-0.38	199404	0.37	0.63
199405	51.8	-0.6	199405	77.2	-2.4	199405	51.6	-3.4	199405	2.88	-1.67	199405	0.01	0.16
199406	55.7	-0.4	199406	85.4	-0.5	199406	64.7	1.8	199406	8.71	3.75	199406	1.01	1.19
199407	58.5	-0.6	199407	84.4	-3.7	199407	66.6	0	199407	6.95	1.13	199407	1.28	1.51
199408	60.5	-0.8	199408	83.7	-3.1	199408	65	-0.7	199408	11.5	5.86	199408	2.74	2.95

199409	61.4	-0.9	199409	79.2	-2.7	199409	58.1	-2.1	199409	3.44	-0.95	199409	2.5	2.64
199410	61.2	-0.9	199410	68.8	-3.3	199410	49.4	1.2	199410	6.78	2.77	199410	2.96	3.14
199411	60.5	-0.5	199411	66.7	4.9	199411	41.8	3.6	199411	3.23	-0.82	199411	-0.31	0.15
199412	59.4	-0.1	199412	56.6	3.9	199412	37.6	5.7	199412	4.01	-1.57	199412	-0.67	-0.34
199501	42.1	0.9	199501	52.1	0.5	199501	32	1.1	199501	6.83	1.33	199501	-0.29	-0.02
199502	42	-0.5	199502	51.9	-3.1	199502	31.6	-0.9	199502	6.23	0.79	199502	-0.02	0.19
199503	46	0.8	199503	66.4	4	199503	41.8	3	199503	3.82	-2.38	199503	-0.71	-0.47
199504	49.6	0.9	199504	74.3	2.5	199504	46.8	0.4	199504	2.3	-2.41	199504	-1.3	-1.04
199505	53.3	0.9	199505	79.7	0.1	199505	56	1	199505	4.96	0.41	199505	0.05	0.2
199506	56.5	0.4	199506	82.9	-3	199506	61.9	-1	199506	7.35	2.39	199506	0.82	1
199507	59.6	0.5	199507	89.8	1.7	199507	67.3	0.7	199507	2.88	-2.94	199507	0.09	0.32
199508	61.9	0.6	199508	86.9	0.1	199508	68.9	3.2	199508	11.6	5.96	199508	1.46	1.67
199509	62.7	0.4	199509	78.6	-3.3	199509	59.8	-0.4	199509	2.02	-2.37	199509	0.98	1.12
199510	62.4	0.3	199510	71.3	-0.8	199510	48.3	0.1	199510	9.39	5.38	199510	2.15	2.33
199511	60.9	-0.1	199511	57.5	-4.3	199511	34.5	-3.7	199511	6.85	2.8	199511	2.76	3.22
199512	59.3	-0.2	199512	51.4	-1.3	199512	30	-1.9	199512	2.97	-2.61	199512	1.95	2.28
199601	38.9	-2.3	199601	48.8	-2.8	199601	28.9	-2	199601	8.34	2.84	199601	2.48	2.75
199602	42	-0.5	199602	56.2	1.2	199602	33.8	1.3	199602	4.36	-1.08	199602	-0.28	-0.07
199603	43.5	-1.7	199603	57.6	-4.8	199603	35.4	-3.4	199603	7.55	1.35	199603	0.36	0.6
199604	47.1	-1.6	199604	71.6	-0.2	199604	44	-2.4	199604	4.54	-0.17	199604	-0.01	0.25
199605	51.5	-0.9	199605	81.4	1.8	199605	57	2	199605	4.17	-0.38	199605	-0.19	-0.04
199606	55.2	-0.9	199606	84.9	-1	199606	62.1	-0.8	199606	3.85	-1.11	199606	-0.34	-0.16
199607	58.3	-0.8	199607	88	-0.1	199607	66.8	0.2	199607	3.56	-2.26	199607	-0.81	-0.58
199608	60.5	-0.8	199608	85	-1.8	199608	66.2	0.5	199608	7.02	1.38	199608	0.36	0.57
199609	61.4	-0.9	199609	79.3	-2.6	199609	59	-1.2	199609	7.19	2.8	199609	1.17	1.31
199610	61.3	-0.8	199610	71.4	-0.7	199610	48	-0.2	199610	1.4	-2.61	199610	-0.55	-0.37
199611	59.9	-1.1	199611	57	-4.8	199611	36.1	-2.1	199611	3.98	-0.07	199611	0.02	0.48
199612	58.6	-0.9	199612	54.7	2	199612	33.2	1.3	199612	6.23	0.65	199612	0.19	0.52
199701	43	1.8	199701	52.3	0.7	199701	33.7	2.8	199701	6.66	1.16	199701	0.42	0.69
199702	45	2.5	199702	57.2	2.2	199702	36.9	4.4	199702	6.13	0.69	199702	0.5	0.71
199703	48.9	3.7	199703	69.7	7.3	199703	43.9	5.1	199703	6.01	-0.19	199703	0.2	0.44
199704	50.6	1.9	199704	69.1	-2.7	199704	41.9	-4.5	199704	6.58	1.87	199704	0.75	1.01
199705	53	0.6	199705	75.7	-3.9	199705	49.7	-5.3	199705	4.04	-0.51	199705	0.73	0.88
199706	55.9	-0.2	199706	79.4	-6.5	199706	61.7	-1.2	199706	4.89	-0.07	199706	0.86	1.04
199707	59	-0.1	199707	88.9	0.8	199707	66.3	-0.3	199707	5.44	-0.38	199707	-0.04	0.19
199708	61	-0.3	199708	86.1	-0.7	199708	63	-2.7	199708	1.16	-4.48	199708	-0.93	-0.72
199709	62	-0.3	199709	81.7	-0.2	199709	59.5	-0.7	199709	5.77	1.38	199709	0.21	0.35
199710	61.8	-0.3	199710	71.3	-0.8	199710	49.1	0.9	199710	7.35	3.34	199710	0.95	1.13
199711	60.4	-0.6	199711	57.2	-4.6	199711	34.7	-3.5	199711	3.28	-0.77	199711	0.74	1.2
199712	58.9	-0.6	199712	52.5	-0.2	199712	32.4	0.5	199712	5.24	-0.34	199712	0.63	0.96
199801	44.8	3.6	199801	54.4	2.8	199801	35.2	4.3	199801	10.43	4.93	199801	1.72	1.99
199802	45.6	3.1	199802	55.9	0.9	199802	36.9	4.4	199802	9.88	4.44	199802	2.6	2.81
199803	46.6	1.4	199803	59.5	-2.9	199803	37.9	-0.9	199803	4.86	-1.34	199803	2.02	2.26
199804	49.4	0.7	199804	69.3	-2.5	199804	46.4	0	199804	9.44	4.73	199804	3.03	3.29

199805	53.6	1.2	199805	82	2.4	199805	58.4	3.4	199805	3.42	-1.13	199805	-0.42	-0.27
199806	57.4	1.3	199806	88.4	2.5	199806	64.4	1.5	199806	4.22	-0.74	199806	-0.62	-0.44
199807	60.5	1.4	199807	90	1.9	199807	68.2	1.6	199807	3.01	-2.81	199807	-1.32	-1.09
199808	62.6	1.3	199808	88.8	2	199808	65.9	0.2	199808	3.21	-2.43	199808	-1.85	-1.64
199809	63.9	1.6	199809	87	5.1	199809	61.4	1.2	199809	3.63	-0.76	199809	-2.24	-2.1
199810	63.8	1.7	199810	76	3.9	199810	50.1	1.9	199810	4.22	0.21	199810	-2.16	-1.98
199811	62.9	1.9	199811	64.4	2.6	199811	43	4.8	199811	3.54	-0.51	199811	-2.34	-1.88
199812	61.6	2.1	199812	57.4	4.7	199812	38.4	6.5	199812	4.77	-0.81	199812	-2.37	-2.04
199901	44.8	3.6	199901	55.8	4.2	199901	33.7	2.8	199901	5.69	0.19	199901	-2.15	-1.88
199902	45.4	2.9	199902	57.5	2.5	199902	34.4	1.9	199902	5.73	0.29	199902	-1.88	-1.67
199903	46.5	1.3	199903	61.4	-1	199903	35.8	-3	199903	3.03	-3.17	199903	-2.42	-2.18
199904	50.5	1.8	199904	75.3	3.5	199904	49.5	3.1	199904	4.58	-0.13	199904	-2.33	-2.07
199905	53.6	1.2	199905	79	-0.6	199905	52.9	-2.1	199905	2.7	-1.85	199905	-2.52	-2.37
199906	56.9	0.8	199906	83.7	-2.2	199906	63.4	0.5	199906	6.35	1.39	199906	-1.84	-1.66
199907	59.9	0.8	199907	88.6	0.5	199907	67.2	0.6	199907	2.96	-2.86	199907	-2.25	-2.02
199908	62.3	1	199908	91.8	5	199908	66.4	0.7	199908	2.45	-3.19	199908	-2.87	-2.66
199909	63.2	0.9	199909	84.1	2.2	199909	56.2	-4	199909	3.47	-0.92	199909	-3	-2.86
199910	62.9	0.8	199910	71.2	-0.9	199910	49	0.8	199910	6.41	2.4	199910	-2.24	-2.06
199911	62.1	1.1	199911	68.2	6.4	199911	41.8	3.6	199911	5.18	1.13	199911	-1.85	-1.39
199912	60.7	1.2	199912	56.5	3.8	199912	32.8	0.9	199912	3.06	-2.52	199912	-2.22	-1.89
200001	40.9	-0.3	200001	51.2	-0.4	200001	30.5	-0.4	200001	5.12	-0.38	200001	-2.09	-1.82
200002	44	1.5	200002	60.6	5.6	200002	33.6	1.1	200002	2.71	-2.73	200002	-2.6	-2.39
200003	47.7	2.5	200003	68	5.6	200003	42.1	3.3	200003	5.24	-0.96	200003	-2.71	-2.47
200004	50.2	1.5	200004	70.4	-1.4	200004	44.7	-1.7	200004	5.47	0.76	200004	-2.2	-1.94
200005	54.1	1.7	200005	83.1	3.5	200005	57.2	2.2	200005	1.08	-3.47	200005	-3.01	-2.86
200006	57.7	1.6	200006	87.6	1.7	200006	62.8	-0.1	200006	3.6	-1.36	200006	-3.24	-3.06
200007	60.5	1.4	200007	89.1	1	200007	66.3	-0.3	200007	3.99	-1.83	200007	-3.51	-3.28
200008	62.5	1.2	200008	86.9	0.1	200008	65.5	-0.2	200008	3.43	-2.21	200008	-3.73	-3.52
200009	63.2	0.9	200009	78.9	-3	200009	59	-1.2	200009	4.8	0.41	200009	-3.44	-3.3
200010	63.1	1	200010	75.9	3.8	200010	47.5	-0.7	200010	0.14	-3.87	200010	-4.1	-3.92
200011	61.7	0.7	200011	59.7	-2.1	200011	37.4	-0.8	200011	5.2	1.15	200011	-3.59	-3.13
200012	59.5	0	200012	45.1	-7.6	200012	24.7	-7.2	200012	2.99	-2.59	200012	-3.72	-3.39
200101	39.8	-1.4	200101	51.6	0	200101	28	-2.9	200101	4.23	-1.27	200101	-3.64	-3.37
200102	43.9	1.4	200102	59.3	4.3	200102	36.6	4.1	200102	3.21	-2.23	200102	-3.87	-3.66
200103	45.4	0.2	200103	60.1	-2.3	200103	36.8	-2	200103	6.61	0.41	200103	-3.37	-3.13
200104	49.4	0.7	200104	74	2.2	200104	48.5	2.1	200104	1.11	-3.6	200104	-4.01	-3.75
200105	52.8	0.4	200105	79.5	-0.1	200105	54	-1	200105	3.41	-1.14	200105	-4.13	-3.98
200106	56.2	0.1	200106	83.8	-2.1	200106	62.5	-0.4	200106	4.24	-0.72	200106	-3.88	-3.7
200107	59.1	0	200107	85.4	-2.7	200107	66.7	0.1	200107	6.74	0.92	200107	-3.29	-3.06
200108	61.3	0	200108	86.6	-0.2	200108	67.8	2.1	200108	3.67	-1.97	200108	-3.39	-3.18
200109	62.1	-0.2	200109	78.7	-3.2	200109	57.7	-2.5	200109	5.07	0.68	200109	-2.83	-2.69
200110	61.6	-0.5	200110	71	-1.1	200110	44	-4.2	200110	2.06	-1.95	200110	-2.92	-2.74
200111	61.1	0.1	200111	70.5	8.7	200111	41.4	3.2	200111	2.24	-1.81	200111	-3.31	-2.85
200112	60	0.5	200112	59.5	6.8	200112	36.7	4.8	200112	3.25	-2.33	200112	-3.56	-3.23

200201	43.2	2	200201	55.6	4	200201	30.9	0	200201	5.97	0.47	200201	-3.12	-2.85
200202	43.7	1.2	200202	57.3	2.3	200202	30.8	-1.7	200202	2.06	-3.38	200202	-3.62	-3.41
200203	46.2	1	200203	64.2	1.8	200203	38.3	-0.5	200203	6.99	0.79	200203	-3.12	-2.88
200204	50.6	1.9	200204	76.2	4.4	200204	51.3	4.9	200204	2.22	-2.49	200204	-3.6	-3.34
200205	53.5	1.1	200205	77.2	-2.4	200205	53.2	-1.8	200205	4.6	0.05	200205	-3.26	-3.11
200206	57.1	1	200206	86.7	0.8	200206	64	1.1	200206	2.88	-2.08	200206	-3.41	-3.23
200207	60.3	1.2	200207	90	1.9	200207	68.4	1.8	200207	2.29	-3.53	200207	-4	-3.77
200208	62.5	1.2	200208	89.7	2.9	200208	66.3	0.6	200208	4.73	-0.91	200208	-3.94	-3.73
200209	63.6	1.3	200209	80.7	-1.2	200209	64.2	4	200209	11.08	6.69	200209	1.37	1.51
200210	63.6	1.5	200210	71.2	-0.9	200210	55	6.8	200210	5.45	1.44	200210	1.54	1.72
200211	62.1	1.1	200211	59.2	-2.6	200211	36.5	-1.7	200211	5.94	1.89	200211	1.93	2.39
200212	60.5	1	200212	52.4	-0.3	200212	32.2	0.3	200212	8.22	2.64	200212	2.38	2.71
200301	38.7	-2.5	200301	49.8	-1.8	200301	27.6	-3.3	200301	2.44	-3.06	200301	1.41	1.68
200302	41.1	-1.4	200302	53.8	-1.2	200302	33	0.5	200302	6.71	1.27	200302	1.59	1.8
200303	45.4	0.2	200303	64.6	2.2	200303	43.3	4.5	200303	6.47	0.27	200303	1.36	1.6
200304	48.7	0	200304	69.8	-2	200304	47.3	0.9	200304	5.9	1.19	200304	1.52	1.78
200305	52.2	-0.2	200305	76.2	-3.4	200305	56.7	1.7	200305	7.45	2.9	200305	2.18	2.33
200306	55.6	-0.5	200306	83.2	-2.7	200306	61.8	-1.1	200306	6.4	1.44	200306	2.49	2.67
200307	58.5	-0.6	200307	85.4	-2.7	200307	66.2	-0.4	200307	11.32	5.5	200307	3.57	3.8
200308	60.8	-0.5	200308	86.5	-0.3	200308	67.8	2.1	200308	7.25	1.61	200308	3.68	3.89
200309	61.8	-0.5	200309	80.9	-1	200309	58.4	-1.8	200309	4.66	0.27	200309	3.63	3.77
200310	61.6	-0.5	200310	71.2	-0.9	200310	47.8	-0.4	200310	3.05	-0.96	200310	-0.16	0.02
200311	61	0	200311	68.6	6.8	200311	42.5	4.3	200311	5.36	1.31	200311	0.22	0.68
200312	59.3	-0.2	200312	52.7	0	200312	28.6	-3.3	200312	4.38	-1.2	200312	-0.2	0.13
200401	40.7	-0.5	200401	52.3	0.7	200401	29.1	-1.8	200401	2.39	-3.11	200401	-0.95	-0.68
200402	41.1	-1.4	200402	51.3	-3.7	200402	31.7	-0.8	200402	4.75	-0.69	200402	-0.98	-0.77
200403	45.5	0.3	200403	66.8	4.4	200403	41.6	2.8	200403	2.06	-4.14	200403	-1.98	-1.74
200404	48.9	0.2	200404	72.8	1	200404	45.5	-0.9	200404	2.05	-2.66	200404	-2.46	-2.2
200405	53.3	0.9	200405	82.3	2.7	200405	59.3	4.3	200405	4.23	-0.32	200405	-2.48	-2.33
200406	56.8	0.7	200406	83.9	-2	200406	65.2	2.3	200406	8.38	3.42	200406	0.92	1.1
200407	59.7	0.6	200407	87	-1.1	200407	66.6	0	200407	7.13	1.31	200407	1.2	1.43
200408	61.5	0.2	200408	84.1	-2.7	200408	64.5	-1.2	200408	3.89	-1.75	200408	0.85	1.06
200409	62.4	0.1	200409	78.9	-3	200409	60.8	0.6	200409	16.92	12.53	200409	4.09	4.23
200410	62.5	0.4	200410	72.5	0.4	200410	54.3	6.1	200410	1.39	-2.62	200410	3.02	3.2
200411	61.7	0.7	200411	64.4	2.6	200411	42.9	4.7	200411	6.14	2.09	200411	3.12	3.58
200412	60.1	0.6	200412	54.6	1.9	200412	30.1	-1.8	200412	6.49	0.91	200412	3.05	3.38
200501	45	3.8	200501	56.4	4.8	200501	33.7	2.8	200501	2.58	-2.92	200501	1.95	2.22
200502	45.4	2.9	200502	56	1	200502	35.3	2.8	200502	5.23	-0.21	200502	1.67	1.88
200503	46.6	1.4	200503	61	-1.4	200503	37.4	-1.4	200503	6.23	0.03	200503	1.5	1.74
200504	49.4	0.7	200504	70.1	-1.7	200504	45.5	-0.9	200504	4.93	0.22	200504	1.43	1.69
200505	52.5	0.1	200505	77.2	-2.4	200505	52.2	-2.8	200505	3.23	-1.32	200505	1.04	1.19
200506	55.9	-0.2	200506	82.6	-3.3	200506	63.6	0.7	200506	11.73	6.77	200506	2.8	2.98
200507	59	-0.1	200507	86.8	-1.3	200507	68.6	2	200507	12.42	6.6	200507	4.03	4.26
200508	61.4	0.1	200508	87.2	0.4	200508	68.3	2.6	200508	7.14	1.5	200508	4.04	4.25

200509	62.7	0.4	200509	85.7	3.8	200509	61.6	1.4	200509	1.01	-3.38	200509	-0.72	-0.58
200510	62.8	0.7	200510	73.9	1.8	200510	51.8	3.6	200510	3.1	-0.91	200510	-0.98	-0.8
200511	61.8	0.8	200511	64.5	2.7	200511	40	1.8	200511	4.31	0.26	200511	-0.98	-0.52
200512	60	0.5	200512	51	-1.7	200512	29.8	-2.1	200512	5.54	-0.04	200512	-0.82	-0.49
200601	46.9	5.7	200601	57.9	6.3	200601	35.9	5	200601	5.25	-0.25	200601	-0.9	-0.63
200602	45.1	2.6	200602	54	-1	200602	32.7	0.2	200602	2.34	-3.1	200602	-1.55	-1.34
200603	47.3	2.1	200603	64.2	1.8	200603	39.4	0.6	200603	1.85	-4.35	200603	-2.47	-2.23
200604	51.4	2.7	200604	77.6	5.8	200604	49.5	3.1	200604	3.08	-1.63	200604	-2.79	-2.53
200605	54.3	1.9	200605	78.6	-1	200605	52.7	-2.3	200605	2.01	-2.54	200605	-3.11	-2.96
200606	57.7	1.6	200606	87.7	1.8	200606	61.6	-1.3	200606	5.71	0.75	200606	-2.63	-2.45
200607	60.6	1.5	200607	89.1	1	200607	66.9	0.3	200607	2.84	-2.98	200607	-3.05	-2.82
200608	62.9	1.6	200608	89.2	2.4	200608	68.6	2.9	200608	4.56	-1.08	200608	-3.12	-2.91
200609	63.5	1.2	200609	78.3	-3.6	200609	59	-1.2	200609	5.6	1.21	200609	-2.6	-2.46
200610	63	0.9	200610	70	-2.1	200610	46.1	-2.1	200610	5.31	1.3	200610	-1.99	-1.81
200611	61.9	0.9	200611	63.7	1.9	200611	38.8	0.6	200611	4.18	0.13	200611	-1.77	-1.31
200612	60.7	1.2	200612	59.7	7	200612	35	3.1	200612	5.25	-0.33	200612	-1.7	-1.37
200701	44.2	3	200701	54.5	2.9	200701	33.8	2.9	200701	5.62	0.12	200701	-1.55	-1.28
200702	43.1	0.6	200702	53.8	-1.2	200702	30	-2.5	200702	2.99	-2.45	200702	-1.95	-1.74
200703	47.7	2.5	200703	70.3	7.9	200703	43.9	5.1	200703	4.54	-1.66	200703	-2.35	-2.11
200704	50.2	1.5	200704	70.9	-0.9	200704	44.2	-2.2	200704	2.13	-2.58	200704	-2.72	-2.46
200705	53.5	1.1	200705	80.9	1.3	200705	53	-2	200705	1.61	-2.94	200705	-3.21	-3.06
200706	57.2	1.1	200706	87.8	1.9	200706	62.8	-0.1	200706	4.04	-0.92	200706	-3.22	-3.04
200707	59.7	0.6	200707	85.4	-2.7	200707	64.9	-1.7	200707	3.76	-2.06	200707	-3.38	-3.15
200708	62.4	1.1	200708	93.5	6.7	200708	69.2	3.5	200708	1.94	-3.7	200708	-4.18	-3.97
200709	63.6	1.3	200709	85	3.1	200709	61.4	1.2	200709	2.2	-2.19	200709	-4.7	-4.56
200710	63.6	1.5	200710	74.6	2.5	200710	52.6	4.4	200710	2.56	-1.45	200710	-4.79	-4.61
200711	62.4	1.4	200711	63.3	1.5	200711	36.2	-2	200711	2.16	-1.89	200711	-5.07	-4.61
200712	61.1	1.6	200712	57.8	5.1	200712	37.4	5.5	200712	6.16	0.58	200712	-4.62	-4.29
200801	39.4	-1.8	200801	50.7	-0.9	200801	28.1	-2.8	200801	2.84	-2.66	200801	-4.78	-4.51
200802	42.7	0.2	200802	58.1	3.1	200802	33.7	1.2	200802	5.21	-0.23	200802	-4.38	-4.17
200803	45.2	0	200803	63.2	0.8	200803	37.5	-1.3	200803	5.66	-0.54	200803	-4.09	-3.85
200804	48.7	0	200804	71.1	-0.7	200804	46.8	0.4	200804	3.75	-0.96	200804	-3.92	-3.66
200805	52	-0.4	200805	78.3	-1.3	200805	52.8	-2.2	200805	3.53	-1.02	200805	-3.71	-3.56
200806	56.1	0	200806	89.5	3.6	200806	63.8	0.9	200806	1.73	-3.23	200806	-4.17	-3.99
200807	59.2	0.1	200807	89.4	1.3	200807	65.3	-1.3	200807	3.38	-2.44	200807	-4.44	-4.21
200808	61.4	0.1	200808	87.9	1.1	200808	66.5	0.8	200808	8.6	2.96	200808	-3.37	-3.16
200809	62.5	0.2	200809	80.9	-1	200809	61.2	1	200809	1.44	-2.95	200809	-3.71	-3.57
200810	62.1	0	200810	70.2	-1.9	200810	46.8	-1.4	200810	2.91	-1.1	200810	-3.61	-3.43
200811	60.7	-0.3	200811	59.5	-2.3	200811	34.7	-3.5	200811	2.54	-1.51	200811	-3.7	-3.24
200812	59.5	0	200812	54.4	1.7	200812	37.1	5.2	200812	7.24	1.66	200812	-2.98	-2.65
200901	40.3	-0.9	200901	50.9	-0.7	200901	29.7	-1.2	200901	4.72	-0.78	200901	-2.86	-2.59
200902	42.1	-0.4	200902	56.4	1.4	200902	31.3	-1.2	200902	2.77	-2.67	200902	-3.22	-3.01
200903	45.1	-0.1	200903	62.3	-0.1	200903	40.1	1.3	200903	7.91	1.71	200903	0.34	0.58
200904	48.4	-0.3	200904	71.1	-0.7	200904	45	-1.4	200904	4.69	-0.02	200904	0.32	0.58

200905	52.3	-0.1	200905	77.3	-2.3	200905	58.2	3.2	200905	7.9	3.35	200905	1.17	1.32
200906	56.3	0.2	200906	88.1	2.2	200906	65	2.1	200906	3.5	-1.46	200906	-0.38	-0.2
200907	59.1	0	200907	86.8	-1.3	200907	64.4	-2.2	200907	2.49	-3.33	200907	-1.07	-0.84
200908	61.3	0	200908	87.4	0.6	200908	66.4	0.7	200908	4.26	-1.38	200908	-1.34	-1.13
200909	62.3	0	200909	79	-2.9	200909	62	1.8	200909	12.04	7.65	200909	1.74	1.88
200910	61.9	-0.2	200910	67.6	-4.5	200910	48.8	0.6	200910	7.91	3.9	200910	2.56	2.74
200911	61.1	0.1	200911	64.7	2.9	200911	41.8	3.6	200911	7.17	3.12	200911	3.06	3.52
200912	59.4	-0.1	200912	49.9	-2.8	200912	30.6	-1.3	200912	10.32	4.74	200912	3.89	4.22
201001	37.6	-3.6	201001	48.3	-3.3	201001	26.9	-4	201001	7.52	2.02	201001	4.03	4.3
201002	37.8	-4.7	201002	48	-7	201002	27.9	-4.6	201002	4.64	-0.8	201002	-0.11	0.1
201003	41.5	-3.7	201003	60.5	-1.9	201003	37.6	-1.2	201003	3.77	-2.43	201003	-0.67	-0.43
201004	46.8	-1.9	201004	77	5.2	201004	47.7	1.3	201004	3.93	-0.78	201004	-0.92	-0.66
201005	51.4	-1	201005	80.6	1	201005	59.1	4.1	201005	5.71	1.16	201005	-0.62	-0.47
201006	55.9	-0.2	201006	89.6	3.7	201006	67	4.1	201006	5.43	0.47	201006	-0.51	-0.33
201007	59.3	0.2	201007	90.9	2.8	201007	69.5	2.9	201007	3.27	-2.55	201007	-1.13	-0.9
201008	61.9	0.6	201008	88.4	1.6	201008	70.4	4.7	201008	5.58	-0.06	201008	-1.17	-0.96
201009	63.1	0.8	201009	85.8	3.9	201009	61	0.8	201009	4.59	0.2	201009	-1.22	-1.08
201010	62.9	0.8	201010	74.9	2.8	201010	47	-1.2	201010	3.06	-0.95	201010	-1.41	-1.23
201011	61.8	0.8	201011	63	1.2	201011	38.5	0.3	201011	3.59	-0.46	201011	-1.54	-1.08
201012	59.6	0.1	201012	45.4	-7.3	201012	25.3	-6.6	201012	3.61	-1.97	201012	-1.72	-1.39
201101	37.9	-3.3	201101	48.3	-3.3	201101	27.4	-3.5	201101	2.87	-2.63	201101	-2.16	-1.89
201102	42.3	-0.2	201102	58.5	3.5	201102	34.9	2.4	201102	3.44	-2	201102	-2.47	-2.26
201103	45.9	0.7	201103	63.3	0.9	201103	42.6	3.8	201103	11.32	5.12	201103	-1.12	-0.88
201104	49.9	1.2	201104	75.2	3.4	201104	48.9	2.5	201104	4.27	-0.44	201104	-1.23	-0.97
201105	53.5	1.1	201105	81.1	1.5	201105	54.9	-0.1	201105	2.09	-2.46	201105	-1.78	-1.63
201106	57.5	1.4	201106	90.3	4.4	201106	64.9	2	201106	5.15	0.19	201106	-1.73	-1.55
201107	60.8	1.7	201107	91	2.9	201107	70	3.4	201107	3.17	-2.65	201107	-2.38	-2.15
201108	63.2	1.9	201108	92	5.2	201108	66.9	1.2	201108	1.82	-3.82	201108	-3.24	-3.03
201109	64	1.7	201109	81.4	-0.5	201109	60.6	0.4	201109	4.74	0.35	201109	-3.14	-3
201110	63.5	1.4	201110	70.8	-1.3	201110	46.1	-2.1	201110	2.5	-1.51	201110	-3.22	-3.04
201111	62.4	1.4	201111	63.4	1.6	201111	40.2	2	201111	6.29	2.24	201111	-2.55	-2.09
201112	61.1	1.6	201112	57.2	4.5	201112	35.9	4	201112	5.32	-0.26	201112	-2.36	-2.03
201201	44.4	3.2	201201	54.9	3.3	201201	34	3.1	201201	5.6	0.1	201201	-2.15	-1.88
201202	45.6	3.1	201202	58.6	3.6	201202	35	2.5	201202	2.05	-3.39	201202	-2.81	-2.6
201203	50.7	5.5	201203	72.5	10.1	201203	49.1	10.3	201203	4.54	-1.66	201203	-3.23	-2.99
201204	53.5	4.8	201204	75.1	3.3	201204	48.8	2.4	201204	3.01	-1.7	201204	-3.44	-3.18
201205	56.9	4.5	201205	81.5	1.9	201205	59.3	4.3	201205	4.67	0.12	201205	-3.17	-3.02
201206	59.6	3.5	201206	84.4	-1.5	201206	61.8	-1.1	201206	4.28	-0.68	201206	-0.05	0.13
201207	62.6	3.5	201207	91.1	3	201207	69.6	3	201207	6.71	0.89	201207	0.07	0.3
201208	64.2	2.9	201208	85.1	-1.7	201208	65.8	0.1	201208	7.09	1.45	201208	0.55	0.76
201209	64.9	2.6	201209	81.2	-0.7	201209	60.2	0	201209	3.93	-0.46	201209	0.61	0.75
201210	64.4	2.3	201210	70.6	-1.5	201210	48.8	0.6	201210	3.95	-0.06	201210	0.59	0.77
201211	63	2	201211	62.3	0.5	201211	35.8	-2.4	201211	0.77	-3.28	201211	-0.84	-0.38
201212	61.7	2.2	201212	57.2	4.5	201212	38.3	6.4	201212	6.96	1.38	201212	0.27	0.6

201301	46.4	5.2	201301	55.8	4.2	201301	37	6.1	201301	10.46	4.96	201301	1.37	1.64
201302	44.6	2.1	201302	53.2	-1.8	201302	32.4	-0.1	201302	5.5	0.06	201302	1.27	1.48
201303	44.8	-0.4	201303	56.8	-5.6	201303	33.5	-5.3	201303	5.06	-1.14	201303	0.95	1.19
201304	48.4	-0.3	201304	70.8	-1	201304	47.1	0.7	201304	7.53	2.82	201304	1.55	1.81
201305	51.7	-0.7	201305	76	-3.6	201305	53.8	-1.2	201305	5.59	1.04	201305	1.77	1.92
201306	55.5	-0.6	201306	84.7	-1.2	201306	64.5	1.6	201306	9.14	4.18	201306	2.74	2.92
201307	58.4	-0.7	201307	84.6	-3.5	201307	67.4	0.8	201307	16.64	10.82	201307	4.99	5.22
201308	60.5	-0.8	201308	82.7	-4.1	201308	66.7	1	201308	10.75	5.11	201308	5.87	6.08
201309	61.6	-0.7	201309	80.4	-1.5	201309	60.8	0.6	201309	3.45	-0.94	201309	5.26	5.4
201310	61.5	-0.6	201310	71.6	-0.5	201310	49.8	1.6	201310	2.19	-1.82	201310	4.31	4.49
201311	60.2	-0.8	201311	58.9	-2.9	201311	35.9	-2.3	201311	5.24	1.19	201311	4.22	4.68
201312	59	-0.5	201312	55.6	2.9	201312	35.4	3.5	201312	9.22	3.64	201312	4.61	4.94
201401	34.5	-6.7	201401	46.4	-5.2	201401	22.6	-8.3	201401	3.78	-1.72	201401	-0.36	-0.09
201402	39.8	-2.7	201402	57	2	201402	33.1	0.6	201402	3.22	-2.22	201402	-0.88	-0.67
201403	42.6	-2.6	201403	60.9	-1.5	201403	35.5	-3.3	201403	3.99	-2.21	201403	-1.29	-1.05
201404	46.9	-1.8	201404	73.2	1.4	201404	46.6	0.2	201404	5.79	1.08	201404	-0.92	-0.66
201405	51.1	-1.3	201405	80.7	1.1	201405	54.9	-0.1	201405	4.84	0.29	201405	-0.77	-0.62
201406	55.2	-0.9	201406	86.4	0.5	201406	64.4	1.5	201406	4.27	-0.69	201406	-0.82	-0.64
201407	58	-1.1	201407	85.5	-2.6	201407	65.1	-1.5	201407	5.55	-0.27	201407	-0.71	-0.48
201408	60.2	-1.1	201408	85.2	-1.6	201408	64.8	-0.9	201408	4.95	-0.69	201408	-0.66	-0.45
201409	61.5	-0.8	201409	80.9	-1	201409	63.6	3.4	201409	3.56	-0.83	201409	-0.74	-0.6
201410	61.4	-0.7	201410	73.5	1.4	201410	48.4	0.2	201410	5.6	1.59	201410	-0.32	-0.14
201411	60	-1	201411	58.6	-3.2	201411	33.2	-5	201411	4.49	0.44	201411	-0.07	0.39
201412	59	-0.5	201412	57.4	4.7	201412	37	5.1	201412	4.27	-1.31	201412	-0.39	-0.06
201501	40.4	-0.8	201501	51	-0.6	201501	29.7	-1.2	201501	4.72	-0.78	201501	-0.54	-0.27
201502	38.7	-3.8	201502	47.9	-7.1	201502	26	-6.5	201502	4.48	-0.96	201502	-0.62	-0.41
201503	43.8	-1.4	201503	65.5	3.1	201503	42.5	3.7	201503	3.21	-2.99	201503	-1.38	-1.14
201504	48.2	-0.5	201504	72.3	0.5	201504	50.4	4	201504	6.85	2.14	201504	-0.79	-0.53
201505	52.5	0.1	201505	82.5	2.9	201505	56.6	1.6	201505	2.02	-2.53	201505	-1.47	-1.32
201506	56.6	0.5	201506	88.7	2.8	201506	65.6	2.7	201506	4.88	-0.08	201506	-1.52	-1.34
201507	59.8	0.7	201507	89.3	1.2	201507	68.4	1.8	201507	4.07	-1.75	201507	-1.92	-1.69
201508	61.9	0.6	201508	87.3	0.5	201508	66.4	0.7	201508	5.84	0.2	201508	0	0.21
201509	62.9	0.6	201509	80.4	-1.5	201509	61	0.8	201509	4.63	0.24	201509	-0.06	0.08
201510	62.6	0.5	201510	71.2	-0.9	201510	49.8	1.6	201510	9.26	5.25	201510	1.18	1.36
201511	61.9	0.9	201511	63.9	2.1	201511	44.5	6.3	201511	10.15	6.1	201511	2.58	3.04
201512	61.2	1.7	201512	62.9	10.2	201512	44.4	12.5	201512	11.83	6.25	201512	3.58	3.91
201601	39.7	-1.5	201601	50.2	-1.4	201601	29.2	-1.7	201601	4.54	-0.96	201601	-0.22	0.05
201602	41.8	-0.7	201602	54.4	-0.6	201602	33.3	0.8	201602	4.54	-0.9	201602	-0.42	-0.21
201603	46.8	1.6	201603	69.4	7	201603	44	5.2	201603	1.55	-4.65	201603	-1.66	-1.42
201604	50.2	1.5	201604	73.4	1.6	201604	47.7	1.3	201604	2.29	-2.42	201604	-2.12	-1.86
201605	53.6	1.2	201605	79	-0.6	201605	55	0	201605	3.23	-1.32	201605	-2.34	-2.19
201606	57.7	1.6	201606	90.5	4.6	201606	65.4	2.5	201606	1.3	-3.66	201606	-3.19	-3.01
201607	61	1.9	201607	93.4	5.3	201607	69.2	2.6	201607	3.49	-2.33	201607	-3.83	-3.6
201608	63.4	2.1	201608	89.1	2.3	201608	70.1	4.4	201608	6.7	1.06	201608	-3.42	-3.21

201609	64.7	2.4	201609	87.3	5.4	201609	63.6	3.4	201609	1.38	-3.01	201609	-4.26	-4.12
201610	64.7	2.6	201610	77.3	5.2	201610	51.3	3.1	201610	0.72	-3.29	201610	-4.85	-4.67
201611	63.7	2.7	201611	68	6.2	201611	40.6	2.4	201611	2.12	-1.93	201611	-5.25	-4.79
201612	62.2	2.7	201612	55	2.3	201612	35.1	3.2	201612	3.43	-2.15	201612	-5.38	-5.05
201701	47.4	6.2	201701	56.8	5.2	201701	38	7.1	201701	5.36	-0.14	201701	-5.05	-4.78
201702	49.6	7.1	201702	64.9	9.9	201702	38.6	6.1	201702	1.7	-3.74	201702	-5.59	-5.38
201703	50.7	5.5	201703	65	2.6	201703	40.5	1.7	201703	4.26	-1.94	201703	-5.57	-5.33
201704	53.9	5.2	201704	75	3.2	201704	52	5.6	201704	7.77	3.06	201704	0.61	0.87
201705	56.6	4.2	201705	79.4	-0.2	201705	55.5	0.5	201705	7.13	2.58	201705	1.23	1.38
201706	59.5	3.4	201706	84.2	-1.7	201706	64	1.1	201706	4.75	-0.21	201706	1.14	1.32
201707	62.2	3.1	201707	88.9	0.8	201707	67.6	1	201707	5.65	-0.17	201707	0.99	1.22
201708	63.9	2.6	201708	85.4	-1.4	201708	66.6	0.9	201708	5.27	-0.37	201708	0.92	1.13
201709	64.6	2.3	201709	80.4	-1.5	201709	59.1	-1.1	201709	4.64	0.25	201709	1.05	1.19
201710	64.3	2.2	201710	72.7	0.6	201710	50.7	2.5	201710	8.61	4.6	201710	2.02	2.2
201711	63.2	2.2	201711	63	1.2	201711	40.8	2.6	201711	0.94	-3.11	201711	-0.86	-0.4
201712	61.6	2.1	201712	53.5	0.8	201712	34.2	2.3	201712	2.96	-2.62	201712	-1.35	-1.02
201801	37.6	-3.6	201801	48.7	-2.9	201801	26.6	-4.3	201801	4.55	-0.95	201801	-1.41	-1.14
201802	45.4	2.9	201802	62.2	7.2	201802	44.1	11.6	201802	6.01	0.57	201802	-1.29	-1.08
201803	46.5	1.3	201803	59.4	-3	201803	38.4	-0.4	201803	5.4	-0.8	201803	-1.35	-1.11
201804	48.9	0.2	201804	68.8	-3	201804	43.2	-3.2	201804	6.26	1.55	201804	0.48	0.74
201805	53.2	0.8	201805	81	1.4	201805	60	5	201805	11.57	7.02	201805	2.17	2.32
201806	57.1	1	201806	87.5	1.6	201806	65.9	3	201806	4.11	-0.85	201806	1.72	1.9
201807	60	0.9	201807	86.2	-1.9	201807	67.9	1.3	201807	5.36	-0.46	201807	1.43	1.66
201808	62	0.7	201808	85.5	-1.3	201808	66	0.3	201808	7.04	1.4	201808	1.7	1.91
201809	63.6	1.3	201809	85.3	3.4	201809	67.4	7.2	201809	2.9	-1.49	201809	1.17	1.31
201810	63.5	1.4	201810	73.4	1.3	201810	52.8	4.6	201810	5.08	1.07	201810	1.2	1.38
201811	62	1	201811	57.1	-4.7	201811	37.2	-1	201811	9	4.95	201811	2.46	2.92
201812	60.6	1.1	201812	52.9	0.2	201812	36.2	4.3	201812	12.6	7.02	201812	3.82	4.15
201901	42	0.8	201901	51.4	-0.2	201901	32.5	1.6	201901	6.38	0.88	201901	3.62	3.89
201902	45.5	3	201902	58.8	3.8	201902	39.3	6.8	201902	9.13	3.69	201902	4.07	4.28
201903	46.9	1.7	201903	60.9	-1.5	201903	38.5	-0.3	201903	3.98	-2.22	201903	-0.54	-0.3
201904	50.3	1.6	201904	72.7	0.9	201904	48.5	2.1	201904	6.69	1.98	201904	-0.05	0.21
201905	54.5	2.1	201905	83	3.4	201905	59.7	4.7	201905	2.37	-2.18	201905	-0.79	-0.64
201906	57.7	1.6	201906	83	-2.9	201906	63.4	0.5	201906	6.39	1.43	201906	-0.36	-0.18
201907	60.6	1.5	201907	88.3	0.2	201907	67.8	1.2	201907	4.64	-1.18	201907	-0.61	-0.38
201908	62.6	1.3	201908	87.6	0.8	201908	66.7	1	201908	3.48	-2.16	201908	-1.04	-0.83
201909	64.1	1.8	201909	88.3	6.4	201909	63.8	3.6	201909	0.93	-3.46	201909	-2.09	-1.95
201910	64.1	2	201910	74.3	2.2	201910	54.1	5.9	201910	6.8	2.79	201910	0.42	0.6
201911	62.7	1.7	201911	60.2	-1.6	201911	36.4	-1.8	201911	3.02	-1.03	201911	0.09	0.55
201912	61.4	1.9	201912	57	4.3	201912	37.1	5.2	201912	7.08	1.5	201912	0.39	0.72
202001	45.4	4.2	202001	54.9	3.3	202001	35.8	4.9	202001	8.13	2.63	202001	0.93	1.2
202002	45.7	3.2	202002	55.1	0.1	202002	36.7	4.2	202002	12.16	6.72	202002	2.45	2.66
202003	49.2	4	202003	65.7	3.3	202003	46.7	7.9	202003	5.34	-0.86	202003	1.81	2.05
202004	51.5	2.8	202004	71.7	-0.1	202004	45.2	-1.2	202004	7.17	2.46	202004	2.25	2.51

202005	54	1.6	202005	75.3	-4.3	202005	53.1	-1.9	202005	6.66	2.11	202005	2.71	2.86
202006	57.3	1.2	202006	83.8	-2.1	202006	63.7	0.8	202006	4.51	-0.45	202006	2.42	2.6
202007	60.5	1.4	202007	89.9	1.8	202007	68.8	2.2	202007	4.23	-1.59	202007	1.77	2
202008	62.5	1.2	202008	85.9	-0.9	202008	67.8	2.1	202008	10.81	5.17	202008	2.84	3.05
202009	63.3	1	202009	77.8	-4.1	202009	61.1	0.9	202009	7	2.61	202009	3.47	3.61
202010	63.2	1.1	202010	72.9	0.8	202010	52.2	4	202010	7.47	3.46	202010	3.91	4.09
202011	62.5	1.5	202011	66.6	4.8	202011	43.1	4.9	202011	4.19	0.14	202011	-0.08	0.38
202012	60.8	1.3	202012	53.2	0.5	202012	30.7	-1.2	202012	4.23	-1.35	202012	-0.32	0.01
202101	42.4	1.2	202101	52.1	0.5	202101	32.6	1.7	202101	4.56	-0.94	202101	-0.55	-0.28
202102	43.1	0.6	202102	53.2	-1.8	202102	34.3	1.8	202102	4.79	-0.65	202102	-0.64	-0.43
202103	46.8	1.6	202103	65.8	3.4	202103	43.1	4.3	202103	7.75	1.55	202103	-0.35	-0.11
202104	49.7	1	202104	71.8	0	202104	44.6	-1.8	202104	3.88	-0.83	202104	-0.51	-0.25
202105	52.8	0.4	202105	76.9	-2.7	202105	53.7	-1.3	202105	3.48	-1.07	202105	-0.65	-0.5
202106	56.3	0.2	202106	84	-1.9	202106	63.8	0.9	202106	5	0.04	202106	0.11	0.29
202107	59.3	0.2	202107	86.2	-1.9	202107	67.6	1	202107	5.8	-0.02	202107	0.15	0.38
202108	61.5	0.2	202108	86.5	-0.3	202108	67.3	1.6	202108	6.05	0.41	202108	0.33	0.54
202109	62.4	0.1	202109	79.3	-2.6	202109	60	-0.2	202109	5.3	0.91	202109	0.78	0.92
202110	62.4	0.3	202110	72.4	0.3	202110	53.3	5.1	202110	6.65	2.64	202110	1.3	1.48
202111	61.1	0.1	202111	61.3	-0.5	202111	35.6	-2.6	202111	1.34	-2.71	202111	-0.68	-0.22
202112	60.3	0.8	202112	61.7	9	202112	40.2	8.3	202112	3.29	-2.29	202112	-1.23	-0.9
202201	39.9	-1.3	202201	50.2	-1.4	202201	29.6	-1.3	202201	4.01	-1.49	202201	-1.46	-1.19
202202	43.6	1.1	202202	58.9	3.9	202202	35.5	3	202202	5.52	0.08	202202	-1.34	-1.13
202203	46.9	1.7	202203	65.6	3.2	202203	41.3	2.5	202203	6.88	0.68	202203	-1.16	-0.92
202204	49.6	0.9	202204	71.6	-0.2	202204	44.1	-2.3	202204	3.46	-1.25	202204	-1.32	-1.06
202205	53.5	1.1	202205	81.1	1.5	202205	57	2	202205	5.45	0.9	202205	-1.01	-0.86
202206	57.3	1.2	202206	87.5	1.6	202206	64.6	1.7	202206	3.28	-1.68	202206	-1.32	-1.14
202207	60.3	1.2	202207	88.4	0.3	202207	69.4	2.8	202207	4.31	-1.51	202207	-1.65	-1.42
202208	62.3	1	202208	84.8	-2	202208	67.2	1.5	202208	6.15	0.51	202208	0.13	0.34
202209	63	0.7	202209	79.6	-2.3	202209	58.3	-1.9	202209	5.79	1.4	202209	0.51	0.65
202210	62.4	0.3	202210	70.1	-2	202210	43.6	-4.6	202210	1.26	-2.75	202210	-0.53	-0.35
202211	61.5	0.5	202211	63	1.2	202211	41.4	3.2	202211	6.62	2.57	202211	0.58	1.04
202212	59.9	0.4	202212	51	-1.7	202212	33	1.1	202212	5.19	-0.39	202212	0.48	0.81
202301	45.6	4.4	202301	55.7	4.1	202301	35.5	4.6	202301	7.81	2.31	202301	0.92	1.19
202302	48.9	6.4	202302	62.8	7.8	202302	41.6	9.1	202302	3.98	-1.46	202302	-0.51	-0.3
202303	50.2	5	202303	65.7	3.3	202303	40.1	1.3	202303	4.22	-1.98	202303	-1.02	-0.78
202304	52.4	3.7	202304	71.4	-0.4	202304	46.2	-0.2	202304	7.28	2.57	202304	0.64	0.9
202305	54.8	2.4	202305	75.2	-4.4	202305	54.3	-0.7	202305	2.78	-1.77	202305	0.22	0.37
202306	57.4	1.3	202306	80.6	-5.3	202306	60	-2.9	202306	6.13	1.17	202306	0.7	0.88
202307	60.3	1.2	202307	88	-0.1	202307	66.8	0.2	202307	3.12	-2.7	202307	-0.55	-0.32
202308	62.3	1	202308	86.6	-0.2	202308	66.6	0.9	202308	6.74	1.1	202308	-0.2	0.01
202309	63.2	0.9	202309	80.9	-1	202309	60.2	0	202309	2.25	-2.14	202309	-0.62	-0.48
202310	63	0.9	202310	72.8	0.7	202310	48.6	0.4	202310	1.13	-2.88	202310	-1.28	-1.1
202311	61.9	0.9	202311	62.3	0.5	202311	38.9	0.7	202311	1.45	-2.6	202311	-2.02	-1.56
202312	60.5	1	202312	56.7	4	202312	33.8	1.9	202312	5.95	0.37	202312	-0.02	0.31