Exhibit E-2 Operations

Final Study Plan

Hydraulic & Project Operations Model

FINAL STUDY PLAN
HYDRAULIC & PROJECT
OPERATIONS MODEL

PARR HYDROELECTRIC PROJECT

FERC NO. 1894

Prepared for:

South Carolina Electric & Gas Company
Cayce, South Carolina

Prepared by:

Kleinschmidt

Lexington, South Carolina
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FINAL STUDY PLAN
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PARR HYDROELECTRIC PROJECT

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SOUTH CAROLINA ELECTRIC & GAS COMPANY

1.0 INTRODUCTION

South Carolina Electric & Gas Company (SCE&G) is the Licensee of the Parr Hydroelectric Project (FERC No. 1894) (Project). The Project consists of the Parr Hydro Development and the Fairfield Pumped Storage Development. Both developments are located along the Broad River in Fairfield and Newberry Counties, South Carolina.

This document provides a detailed outline of the process proposed to complete a Hydrologic and Project Operations Model as part of the Parr and Fairfield relicensing project. These models will be used to assess ability to provide potential changes to project operations, and the resulting effects of potential modifications to operations of the projects. These models will primarily focus on the effects that may result from proposed changes in project operation on energy, capacity, water budget, and flood control. The intent of this effort is to develop a series of high-level fully functional modeling tools, which can be used to incorporate stakeholder requests as parameters to provide outputs and results that can be easily interpreted.

2.0 STUDY OBJECTIVES

2.1 HISTORIC INFLOW HYDROGRAPH DEVELOPMENT

Critical to the operations of hydroelectric projects is the hydrology, which generally requires using the best available gage data to determine local contributing flows. Unless there is a gage immediately upstream of the project headpond, the inflows can be derived by pro-rating available gages, to account for any ungaged drainage area between the respective gages and the site, and then summing the values. Alternatively, a downstream gage can be used to back-calculate inflow using the respective daily reservoir level and evaporation estimates. The goal of this task is to create the best available historic inflow series, which will form the input to the operations models, energy models, and habit and recreational studies.

2.2 HYDRAULIC MODELING

The operations of Parr and Fairfield may affect recreational or habitat interests on the downstream reach of the river. Rapid changes in flow result in a wave (either positive or negative) that propagates downstream, potentially affecting habitat, stream channel stability, and recreational opportunities. The hydraulics of this wave are affected by both translation and attenuation as it progresses downstream. The impacts of existing and proposed modifications to operations (if any) can best be evaluated with a 1-D hydraulic model, which will allow the evaluation of the unsteady flow wave along the downstream reach under several different operating conditions. The goal of this study is to either construct a model (or utilize an existing model) that will evaluate stage (water level), discharge, and velocity with time, along the Broad River downstream of the Parr Dam.

2.3 OPERATIONS MODEL

The Parr-Fairfield project includes several components that need to be included in an operational model. These include the Parr Dam and powerhouse hydraulic capacities, the Fairfield Pumped Storage project operational parameters (for both pumping and generating), the Monticello Reservoir, and the Parr Reservoir. The operations of this system have historically been closely coordinated for the primary purpose of supporting the electrical grid (both demand and stability). SCE&G will need to maintain this coordination during future operating conditions. Additionally, any potential changes to operations in the future will need to be evaluated for effects on dam safety, and operating rules or limitations. This is best accomplished by developing a comprehensive operation model. The goal of this task is to assess and quantify historic operations and limits, and to incorporate these rules into a comprehensive and flexible operations model that can be easily modified to simulate proposed future operations. We propose using the HEC-Res Sim model to investigate headpond fluctuations and associated hydro generation hours that SCE&G could have.

2.4 SCENARIO COMPARISON

SCE&G will develop a process for Technical Working Committees/Resource Conservation Groups (TWCs/RCGs) and stakeholders to submit scenarios to be analyzed and compared to evaluate potential future operations and their effects. The operations model will be used to run submitted scenarios. Results will be reviewed by the TWCs/RCGs during a series of meetings. Model results will be summarized and integrated into the final recommendations presented in the license application.

2.5 SUMMARY STATISTICS

With several integrated modeling efforts, each including possibly several different scenarios, it is critical to develop summary tables and/or summary metrics for each scenario. The goal of this task is to consider each of the studies, and the potential set of results, and develop a standardized means of summarizing and quantifying the results. As an example, it may include the number or percent of flood days changed from baseline conditions, the change in habitat area, the change in streamflow variance, or the increase/decrease in potential MWh. Using the summary statistics, stakeholders and TWC members can prioritize their requests and work to minimize the negative aspects of operational changes.

3.0 STUDY DOMAIN

The focus of this study includes the Parr Reservoir (defined as the elevation of the top of the crest gates, or El. 266.0'), the Fairfield Pumped Storage facility and the Monticello Reservoir, and the Broad River downstream of Parr Shoals Dam extending to and including Frost Shoals, near Boatwright Island.

Members of the Operations RCG expressed an interest in the Project's potential effects on the Congaree National Park (CNP). However, due to the complexities associated with the confluence of the Saluda and Broad Rivers upstream of the CNP, both of which are independently regulated by other hydro projects, the proposed operations model will not extend to the CNP. Rather, the Parr Project's potential to alter flows at the CNP will be statistically determined for specific flows or seasons of interest that are submitted from the TWCs or RCGs.

4.0 METHODOLOGY

4.1 Inflow Hydrograph Development

Development of the inflow hydrograph can be accomplished by two methods: the use of upstream gages prorated to the dam's drainage area, or the use of the gage immediately downstream with detailed information of the project's past operations. In the case of the Parr model, the upstream gage proration method will be used, due to the limited availability of detailed Project operation data. Historic data will be reviewed to determine the period of record and time increment to be used to represent project inflow. The proposed inflow data will be reviewed by the Operations RCG for agreement.

4.1.1 Upstream Gage Proration

Proration of streamflow gages, in order to account for ungaged drainage area, is not necessarily a linear relationship. In order to evaluate the regional relationship between runoff and drainage area, two unregulated stream gages on the same river with overlapping records is required. The only gages that meet this in the immediate Parr Dam watershed are two gages on the Enoree River. These two gages will be used to assess an appropriate proration coefficient (α) and exponent (γ), which may be used to regionally prorate all of the gages required in construction of an historic inflow series.

An equation that may be used with the fitted regional coefficients to determine inflow to Parr is below, where the values are the ratios of the total area to gaged area for each gage location. Additionally, these gages are at different distances from the Parr Reservoir, and drain through different channels, thus the arrival times should be adjusted accordingly. The angled brackets denote a routed hydrograph series.

$$Parr\ Inflow = \langle \alpha * BRC \left(\frac{3250.8}{2790}\right)^{\gamma} \rangle + \langle \alpha * TRD \left(\frac{807.9}{759}\right)^{\gamma} \rangle + \langle \alpha * ERW \left(\frac{731.3}{444}\right)^{\gamma} \rangle$$

where,

BRC – Broad River at Carlisle
TRD – Tyger River near Delta
ERW – Enoree River at Whitmire
α – Fitted Regional Coefficient
γ – Fitted Regional Exponent
⟨...⟩ - Routed Translation

Routing will be completed using a simplified Muskingum approach, and will allow for wave attenuation and travel time, which are more critical for shorter period flows. Daily flow rates would not require this routing, as the average daily flows can simply be summed.

During the development of the hydrologic dataset, the statistical modeling approach and individual gage coefficients may be adjusted to increase data correlation. This has the potential to increase the accuracy of model simulations for inflow conditions that are of greater interest to stakeholders. Details of potential adjustments will be presented to the RCG for comment via memo, with a solicitation for flows (or ranges of flow) of interest. The dataset will be finalized by maximizing correlation across the target range of flows submitted by the RCG.

TABLE 1 SUMMARY OF AVAILABLE HYDROLOGIC DATA

DATA SOURCE	PERIOD OF RECORD	DATA TYPE
Parr Reservoir (#02160990)	10-1-1984 to Current	Stage
Broad R. at Alston (#02161000)	10-1-1896 to Current	Stage & Discharge
Congaree R. at Congaree NP (#02169625)	10-1-1984 to 8-9-2013	Stage
Broad River at Blair (#02160750)	9-11-2010 to 3-7-2013	Discharge
Broad River near Carlisle (#02156500)	10-1-1938 to Current	Stage & Discharge
Broad River below Neal Shoals (#021564493)	3-27-2012 to 9-26-2013	Stage & Discharge
Broad River at Diversion Dam (#02162100)	10-1-1987 to 9-24-2012	Stage
Enoree River at Whitmire (#02160700)	10-1-1973 to Current	Stage & Discharge
Enoree River near Woodruff (#02160390)	2-9-1993 to Current	Stage & Discharge
Tyger River near Delta (#02160105)	10-1-1973 to Current	Stage & Discharge
Fairfield Pumped Storage Generation/Flow	TBD	Discharge
Monticello Reservoir	TBD	Stage

4.2 HYDRAULIC MODELING

The downstream reach of the Broad River below Parr Shoals Dam will be modeled using the Army Corps of Engineers' HEC-RAS v4.1, which is a 1-dimensional model that will allow correlation between flow releases from Parr Reservoir and resulting water level stage in the river downstream. Wave travel times, rates of rise, and stage recession times will also be available from this model. Readily available data will be used for developing the model. The model will be developed to include the hydraulic affects of flow releases down to the Frost Shoals area near Boatwright Island (approximately 20 miles downstream of the Parr Shoals Dam). The results of the model will be used to determine flow estimates for other interests in the project, such as navigation, recreation, or habitat benefits.

4.3 OPERATIONS MODEL

Development of the operations model includes two major tasks: develop the rules and patterns from historical operations, and secondly use these rules to construct a model for testing alternative scenarios. Success of this task can be measured by the ability of the model to replicate historical operations, but can also be measured by the ease and flexibility of testing future scenarios that produce easily interpreted results by stakeholders and TWC members (i.e., important information is not lost in modeling details). The operations model can become quite complicated very quickly, thus to successfully accomplish both of these goals, an appropriate model framework using the best available data is required early in the process.

4.3.1 OPERATION RULES & REGULATIONS

Not only is hydrology a stochastic process, but operating history and generation (pumping/generating) can also be stochastic as a response to weather patterns, random outages, increased grid demand, changes to grid support via addition of other generators, low flow periods, or even differences in decisions between operators using forecast data. Therefore, it is impossible to state explicit rules that define the operating regime for any of the projects, but both extreme limits (i.e., minimum/maximum pond levels, or minimum/maximum flow rates, rates of change, etc.) may be extracted from specified rules, curves, or observations of the system. Additionally, subjective operational patterns may be inferred from historic operations (i.e., typical pumping volumes in June are a certain amount, generating is typically highest during a given period of the week, etc.). Both the hard and soft rules are important for developing an understanding of conjunctive project operations. Although the rules may not exactly depict the operations at any given point in time, from either the past or the future, they should be able to depict the expected system response.

Several key components of data will be concurrently analyzed:

- pond operating levels (Parr Dam & Monticello Reservoir)
- spillway gate operating guidelines
- pumping rates (Fairfield)
- generation rates (Parr & Fairfield)
- rates of change from generation flows
- typical generation periods (time of day, weekday, months)
- seasonal influences
- influence of low river flow conditions boundary
- influence of high river flow conditions boundary
- influence of water withdrawals from Monticello Reservoir
- potential impacts of future upstream and downstream water withdrawals on project inflow and downstream effects.

In order to appropriately define typical system responses, detailed historic information is required. This includes as available:

- hourly (or finer) generation records for Parr & Fairfield
- Parr and Monticello Reservoir stage records
- meteorological data (precipitation, temperature)
- river flow gage records

These records will be reviewed, plotted, regressed, and inferred upon to develop an understanding of 'typical' system responses. Again, exact operations for a complicated system are impossible due to the stochastic nature of all influences, but typical rules may be inferred.

4.3.2 OPERATIONS MODEL FRAMEWORK

Once a comprehensive understanding and documentation of typical operating rules has been developed, they may be used within a modeling framework to replicate historic operations (validation process), and then test future or altered operating conditions.

The model will be constructed at hourly time steps to allow testing of different release rates and spilling events from the Parr Dam, and/or operating conditions at Fairfield. Longer durations may miss critical operating responses, and unnecessarily short time steps would be excessive and not add additional value. The duration of the validation period will vary based on the available data, but should cover as many sequential years as manageable.

The operations model will be developed using the Army Corps of Engineers HEC-Res Sim software package. This package is freely available, easily integrates with other models (such as HEC-RAS), and has the capacity to model multiple projects (including the Fairfield pumped-storage) with a range of complex and even contradictory operating rules. Results of the model are easily viewed either within HEC-Res Sim, or externally using the HEC-DSSVue software package.

4.4 SCENARIO COMPARISON

From the early development of the study plan, model runs should be sufficiently detailed to outline how the projects' operations will be tested. For example, what river flows are critical (low flows to high flows) and should be emphasized? What rates of generation are important, and how quickly can they be changed? A matrix defining each scenario, and how each component of the project is being operated, should be developed. This will naturally confine modeling efforts, and maintain focused efforts for comparison by the TWC members and stakeholders.

4.4.1 STATISTICS

Statistics are valuable for concisely summarizing the nature or property of a random or stochastic variable. For example, the sample mean is commonly used to describe a set of data, but additional information may be obtained from higher order moments (variance, skew, kurtosis). The critical statistic (metric) should be determined early in the study process for each study or model output. For example, the total habitat area may be critical, the average generating rate, the 1% exceedance flow rate, the variance in water levels during a critical period, the maximum headpond level, the 7Q10 flow rate, etc. are all examples of summary statistics. These should be discussed early, and concurrence with working groups or stakeholders should be achieved early in the process to determine what is considered critical.

Additional examples of potential flow statistics include:

- rise-fall rates
- mean, median, quartile flow rates
- variance, skew, kurtosis
- autocorrelation function & partial autocorrelation function lags
- flow-duration curves
- excess distribution functions and conditional excess distribution functions
- 7Q10 flow
- 5, 10, 50, 100-year peak flows
- stage-duration curves (Parr Reservoir)

5.0 REPORTING

A preliminary report documenting the development of the operations model will be provided to the RCG for review prior to the completion of the model. This preliminary report will include the methods and information as follows:

- discussion of model data acquisition
- inflow hydrograph development
- development of future inflow hydrograph(s)
- hydraulic 1D model development & calibration
- operations model development & verification
    - Parr Operations
    - Fairfield Pumping/Generating

Following a comment period, a demonstration session will be conducted to familiarize interested stakeholders with the implementation of the HEC-Res Sim and HEC RAS models for this Project. During this session, the input data and Project parameters will be reviewed, and a "hands-on" session can be conducted to allow stakeholders to learn how to run the model. After the demonstration session is conducted, the final model will be developed and used to analyze operations scenarios.

A final report will document methods and results as encountered in the modeling effort, including:

- scenario results
- hydraulic routing model
- operations model
- energy modeling
- scenario comparison matrices & statistics

6.0 SCHEDULE

Data collection and model development will begin no later than the spring of 2015, with a preliminary report documenting the development of the model completed by the end of 2015. The methodology for this modeling effort may be revised or supplemented based on consultation with TWCs and other interested stakeholders. Model results will be used as an information resource during discussion of relicensing issues and developing potential Protection, Mitigation and Enhancement measures with the SCDNR, USFWS, TWCs/RCGs and other relicensing stakeholders. The final report, which will include the scenario results, will be completed for filing with the final license application.

Exhibit E-2 Operations

Inflow Dataset Development: Statistical Methodology

INFLOW DATASET DEVELOPMENT: STATISTICAL METHODOLOGY

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INFLOW DATASET DEVELOPMENT:
STATISTICAL METHODOLOGY

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1.0 PARR RESERVOIR INFLOW DATA DEVELOPMENT

1.1 INTRODUCTION

An inflow hydrology dataset is being developed in support of developing operations models and to satisfy the Final Parr Fairfield Operations Model Study Plan (Study Plan). As discussed in the Study Plan, the operation of the pumped storage development and lack of long-term operational records prevents the back-calculation of a sufficient inflow dataset. For this reason, the inflow to Parr Reservoir was calculated using upstream flow data adjusted by statistically-derived parameters. The inflow time series datasets for Parr Reservoir were developed using statistical algorithms based on flow data records from the USGS gages upstream and downstream of the Parr Dam.

The inflow dataset developed by this process will be used for two distinctly different simulation processes. The utilization of Parr Reservoir inflows for power generation by the Fairfield Pumped Storage development and the Parr Hydro development, and corresponding upper and lower reservoir fluctuations will be simulated using the USACE modeling package HEC-ResSim; this software's primary requirement is daily inflow values. The flows released from the Parr development will be used as upstream boundary conditions in the USACE model HEC-RAS, which will simulate the downstream flow and stage regimes. The HEC-RAS model requires flow values in increments of one-hour or less.

1.2 Hydrologic Data

Data used in the statistical analyses were obtained via the USGS web portal (http://waterdata.usgs.gov/nwis). The data were processed using spreadsheets and the USACE database program HEC-DSSVue. The USGS gage sites used in the analysis are listed in Table 1. Additional flow and stage data were obtained from the USGS server for use in other phases of this study, and will be fully cited and described in the applicable summary reports.

Table 1 USGS Gage Sites

Data Source	USGS #	Drainage Area (Sq. Mi.)	Period of Record	Data Type
Enoree River at Whitmire	02160700	444	10-1-1973 to Current	Stage & Discharge
Enoree River near Woodruff	02160390	249	2-9-1993 to Current	Stage & Discharge
Tyger River near Delta	02160105	759	10-1-1973 to Current	Stage & Discharge
Broad River near Carlisle	02156500	2790	10-1-1938 to Current	Stage & Discharge
Broad River at Alston	02161000	4790	10-1-1896 to 12-1-1907, 10-1-1980 to Current	Stage & Discharge

1.3 Parr Reservoir Inflow Data Synthesis

Prior to the statistical analyses, Kleinschmidt Associates performed a review of relevant hydrologic studies published by the USGS. These included:

- Low-Flow Frequency and Flow Duration of Selected South Carolina Streams in the Broad River Basin through 2008 (USGS Open-File Report 2010-1305);
- Magnitude and Frequency of Rural Floods in the Southeastern United States, 2006: Volume 3, South Carolina (USGS Scientific Investigations Report 2009-5156); and
- Techniques for Estimating the Magnitude and Frequency of Floods in Rural Basins of South Carolina, 1999 (Water-Resources Investigations Report 02-4140)

Although these studies included hydrologic analyses of the Parr watershed, their focus was primarily on the development of statistically-based estimates of extreme events as opposed to typical hydrology. These studies were reviewed as background information regarding the physiographic nature of the watershed, which could provide insight on the hydrologic behavior of the Broad River and its tributaries upstream and downstream of Parr Reservoir.

The synthesis of streamflow data using a proration of upstream gages typically uses a statistical regression technique based on drainage area ratios. Gages were selected for summing prorated inflows with the intention of maximizing the relevant, overlapping periods of record, as well as drainage area coverage. Periods of record that are relevant represent the current development of the waterway, which would be subsequent to the commissioning of the pumped storage project (December 1978) to current day. Three gages were selected that measure contributing flows for 84% of the project's total drainage area and compared with the corresponding period of record with the Alston gage downstream of the Parr dam[1].

In order to develop the inflow data set for Parr Reservoir, various statistical methods were assessed to determine the optimal estimate. These methods included statistical regressions to determine the weighting factors for scaling the measured upstream flows (see Figure 1) to estimate the inflow to Parr Reservoir. These methods are described in the following sections.

The statistical analyses will use monthly and annual flow data rather than daily average flows. The daily data are affected by reservoir operations, which introduce a significant degree of variability due to the cyclic transfer of up to 29,000 acre-feet between the upper and lower reservoirs. Flow releases from the project may be vastly different at any given hour from the inflows to the Parr reservoir. The monthly and annual flow data statistics are much less affected by day-to-day operations.

[1] It is worth noting that the Parr dam drainage area is 4,750 square miles compared to the slightly larger Alston gage drainage area of 4,790 square miles (about 0.8% less). However, the USGS cites the Alston gage as synonymous with reservoir outflow. No adjustment was made, as the difference is statistically insignificant.

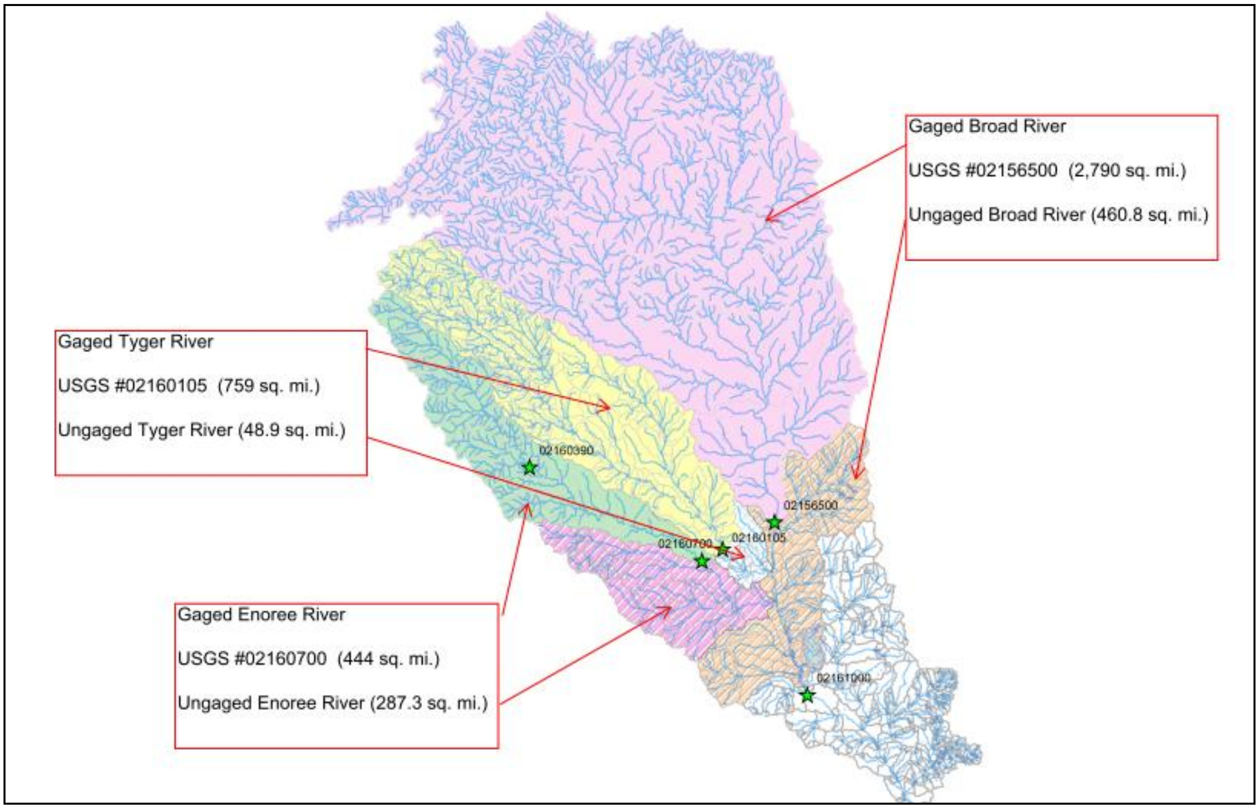


FIGURE 1 GAGED AND UNGAGED BROAD RIVER SUBWATERSHEDS

1.3.1 PRELIMINARY HYDROLOGIC REVIEW

Prior to the statistical regression analyses, a cursory review was performed to assess the hydrologic response of the subwatersheds that contribute to the Parr Reservoir inflows. The review consisted of a comparison of a sampling of monthly average flows from the upstream gages on the Broad, Tyger, and Enoree rivers to the flows at the Alston gage (see Figure 2). The purpose of the review was to determine the degree of hydrologic similarity between the three contributing subwatersheds. A high degree of hydrologic similarity indicates that the soils, topography, and land use over the entire watershed are homogeneous. The subsequent analyses, which are predicated on this assumed homogeneity, provide a basis for developing a statistical relationship between the gaged and ungaged portions of the subwatersheds.

The first comparison was the unadjusted monthly average flows from the upstream gages with the Alston gage. This comparison illustrates the relative contribution of the upstream gaged areas. For the given period, the monthly average flow at Carlisle was approximately 2/3 of the flow average at Alston.

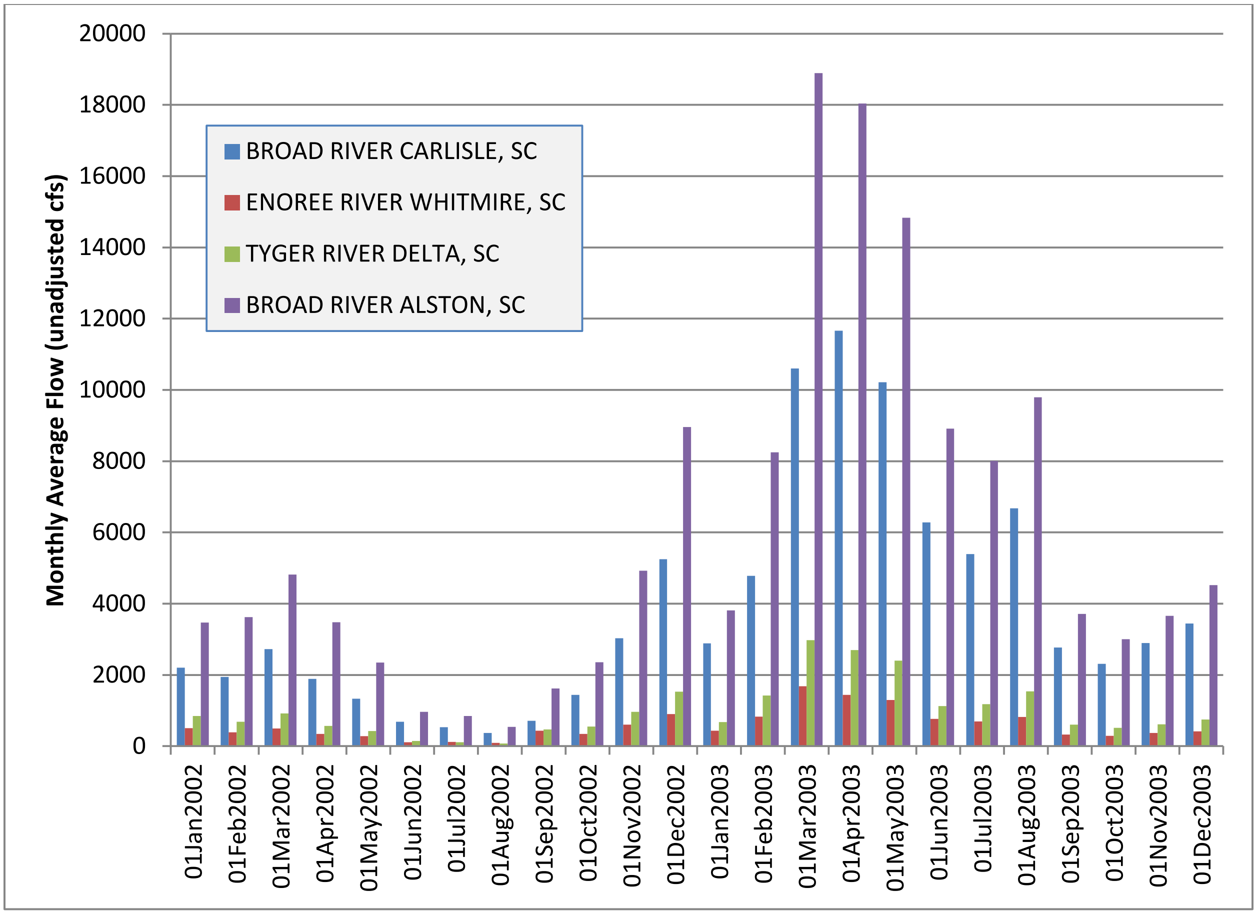


FIGURE 2 MONTHLY AVERAGE FLOWS, UNADJUSTED

The second portion of the review was a comparison of the runoff from the gaged upstream subwatersheds. The monthly average flows from the previous step were normalized by drainage area, resulting in the average flow per 100 square miles of drainage area. This comparison was performed to determine the similarity in runoff characteristics between the three gaged areas. The comparison (see Figure 3) illustrates that the range of the monthly averages (per 100 sq. mi.) was visually close to the aggregate average through a variety of flow ranges; this indicates the hydrologic similarity of the three subbasins.

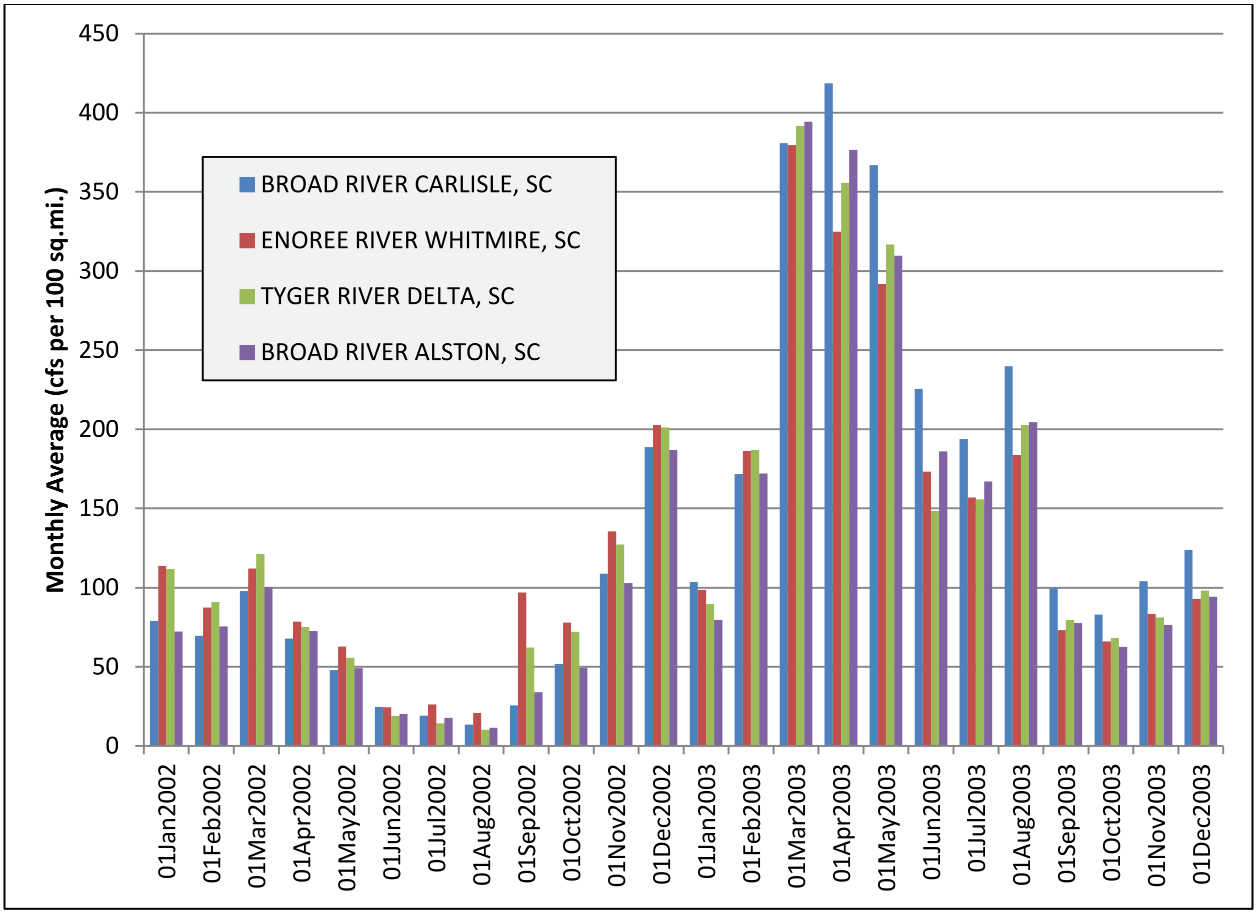


FIGURE 3 NORMALIZED MONTHLY AVERAGE FLOWS

1.3.2 MULTIVARIATE REGRESSION ANALYSIS

A multivariate regression was performed to determine the parameters of a generalized equation for estimating the inflow to Parr Reservoir. The flow estimate is based on the flows measured at three gage sites upstream of the impoundment. The two parameters include a fitted regional exponent (γ), and a fitted regional coefficient (α). The equation, shown below, is a summation of the three upstream flow values multiplied by scaling factors, which include the ratio of the total drainage area represented by each to that gage's actual drainage area.

Equation 1: $ParrInflow = \langle \alpha * BRC \left(\frac{3250.8}{2790}\right)^{\gamma} \rangle + \langle \alpha * TRD \left(\frac{807.9}{759}\right)^{\gamma} \rangle + \langle \alpha * ERW \left(\frac{731.3}{444}\right)^{\gamma} \rangle$

where,

BRC – Broad River at Carlisle
TRD – Tyger River near Delta
ERW – Enoree River at Whitmire
α – Fitted Regional Coefficient
γ – Fitted Regional Exponent

The regional exponent was developed by quantifying the relationship between monthly streamflow averages and drainage area using two unregulated stream gages on the same river with overlapping records. The only gages that meet this in the immediate Parr Dam watershed are on the Enoree River. The regional exponent was developed by performing a regression on monthly flow averages from the Woodruff gage (drainage area = 249 sq. mi.) and the Whitmire gage (drainage area = 444 sq. mi.). These two gages were selected because they have the longest overlapping (current) periods of record. The result of this regression produced the drainage area regional exponent (γ) of 0.599.

This proration exponent was used to normalize the monthly flow averages, prior to performing the second regression to develop the drainage area coefficient (α). The regression used monthly flow averages for the period 1/1/1981 through 12/31/2013, a total of 396 months. The target data used in the regression is the monthly average flow at the Alston gage, which was adjusted by adding the estimated evaporation from both the Monticello and Parr reservoirs. Evaporation estimates were based upon monthly losses in inches[2] applied to the average surface area of both reservoirs, plus estimated increased evaporation caused by the V.C. Summer Nuclear Station thermal plume in Monticello Reservoir. This adjustment ranged in value from 37.5 cfs in January to 103.5 cfs for July.

The results of this regression, using all 396 months, produced a value of $\alpha = 1.041$, an R^2 of 0.9828, and a standard error of 495.4. The scatter plot of Alston monthly flow vs. predicted flow, including a 1:1 reference line, is shown in Figure 4. The modeling residuals were also calculated and are shown graphically in Figure 5. The modeling residual values are the difference between the target value and the predicted value. In this case, a negative modeling residual indicates that the predicted value is greater than the target value. The plot of the modeling residuals indicates that the statistical model tends to overpredict flows during months for which the average flow was less than 7,700 cfs (the y-intercept shown on Figure 5) and tends to underpredict during months with flow averages greater than 7,700 cfs.

[2] Evaporative rates from "Pan Evaporation Records for the South Carolina Area," John C. Purvis, SC State Climatology Office, with FWS evaporation taken as 75% based on Discussions in "NOAA Technical Report NWS 33: Evaporation Atlas for the 48 Contiguous States," June 1982.

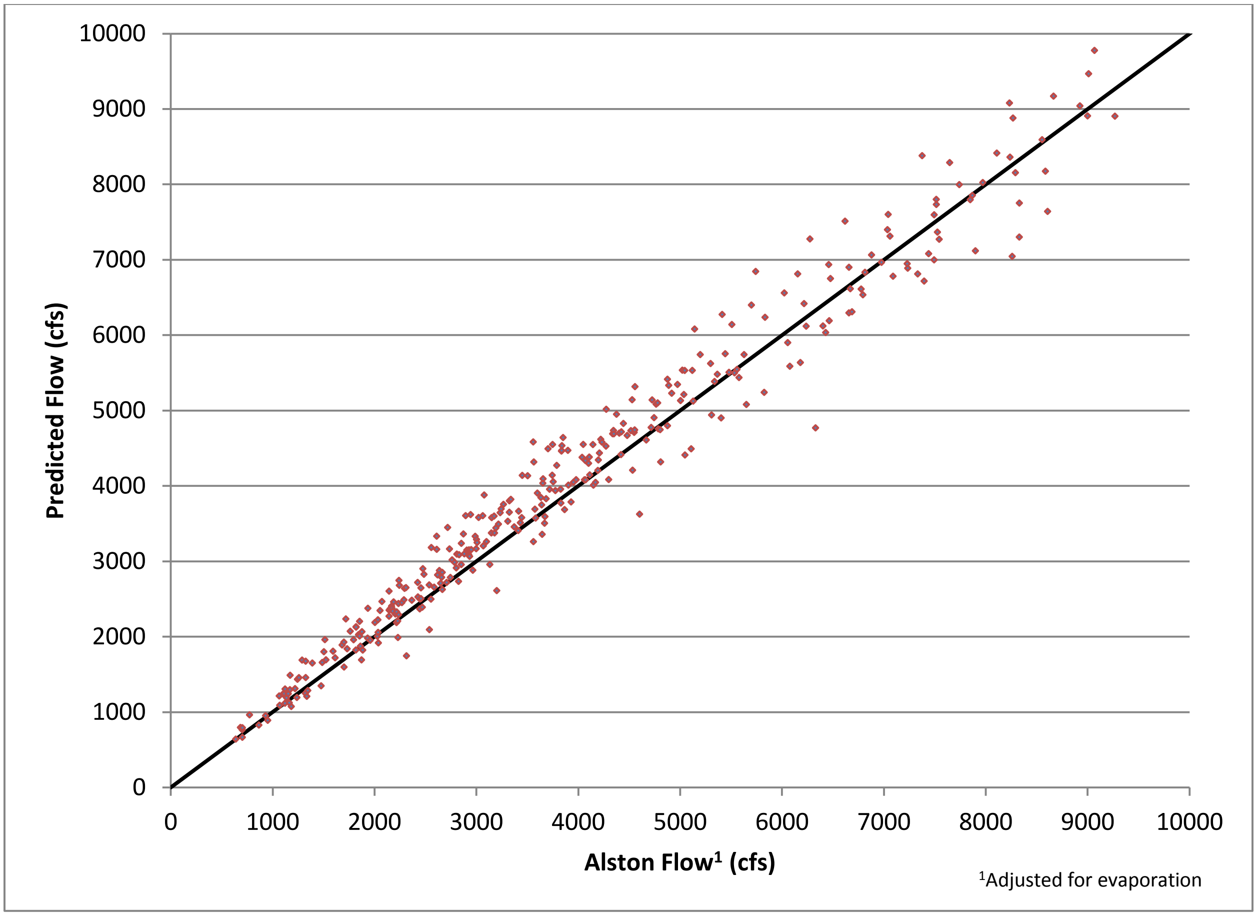


FIGURE 4 ALSTON FLOW VS. PREDICTED MONTHLY AVERAGES (33 YEARS) – REGRESSION BASED ON ALL MONTHS

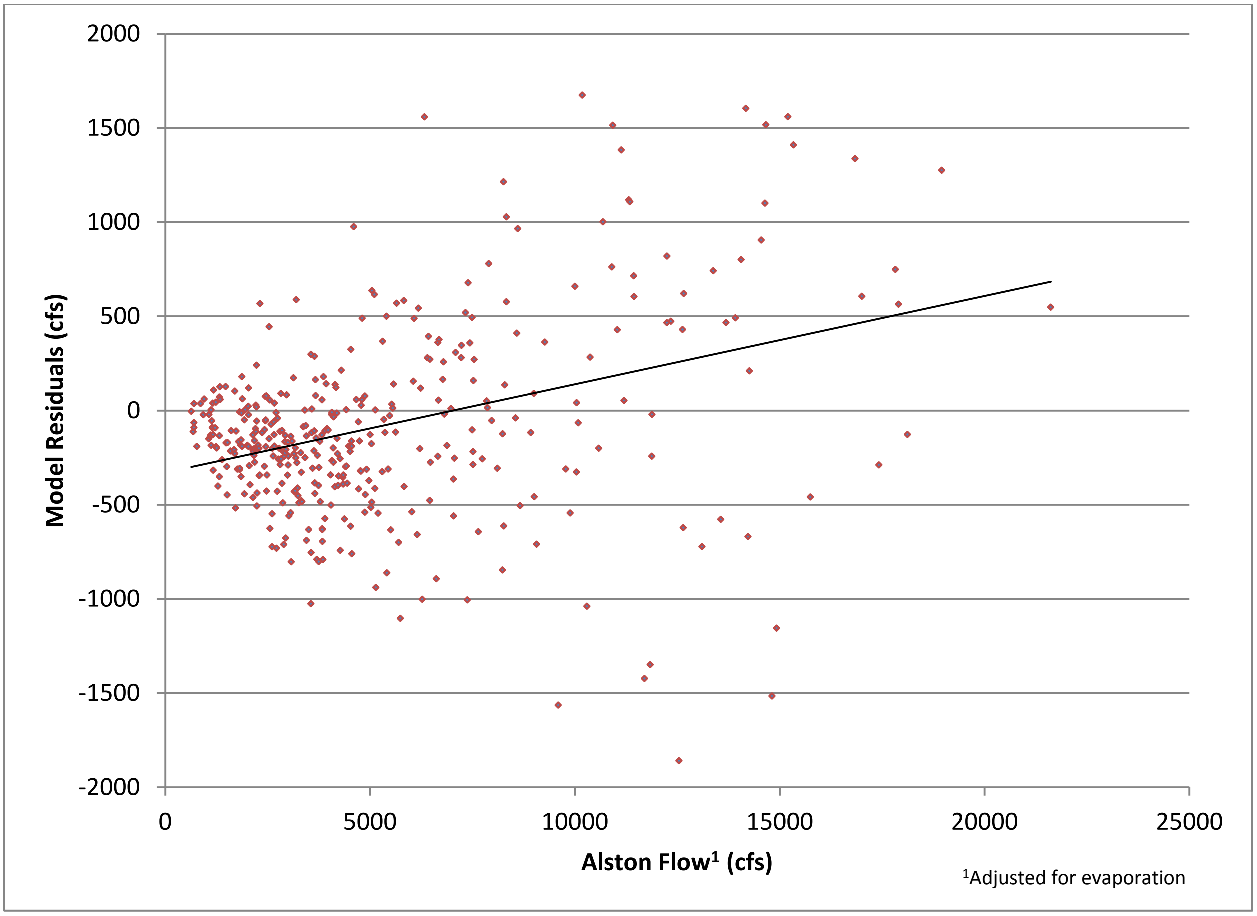


FIGURE 5 MODEL RESIDUALS – REGRESSION BASED ON CONCURRENT PERIOD OF RECORD

1.3.3 MODIFIED REGRESSION (ADJUSTED FLOW RANGE)

Due to the results of the first regression attempt, which indicated a tendency to overpredict during months with less than 7,700 cfs average flow, a second regression was developed. Because balancing the hydrologic resource is imperative during lower inflow conditions, this modified regression was performed to more accurately predict flows in the lower range. The second analysis used the lowest 75% of monthly average flows (289 out of 396 months) as a basis for the regression and then applied the resulting coefficients on the entire dataset to quantify the statistical performance.

The results of the second regression, using 289 of the 396 months, produced a value of α = 0.988, an R^2 of 0.9828, and a standard error of 469.6. Compared to the first regression, the reduced α-value did not change the R^2 value, but reduced the standard error. The most significant change was the modeling residuals. The y-intercept for the residual plot for the second regression is approximately 3,900 cfs. This indicates that the second regression has a lower statistical bias in the range of the most typical flows than the first regression. The scatter plot of Alston monthly flow vs. predicted flow is shown in Figure 6, and the modeling residuals are shown in Figure7.

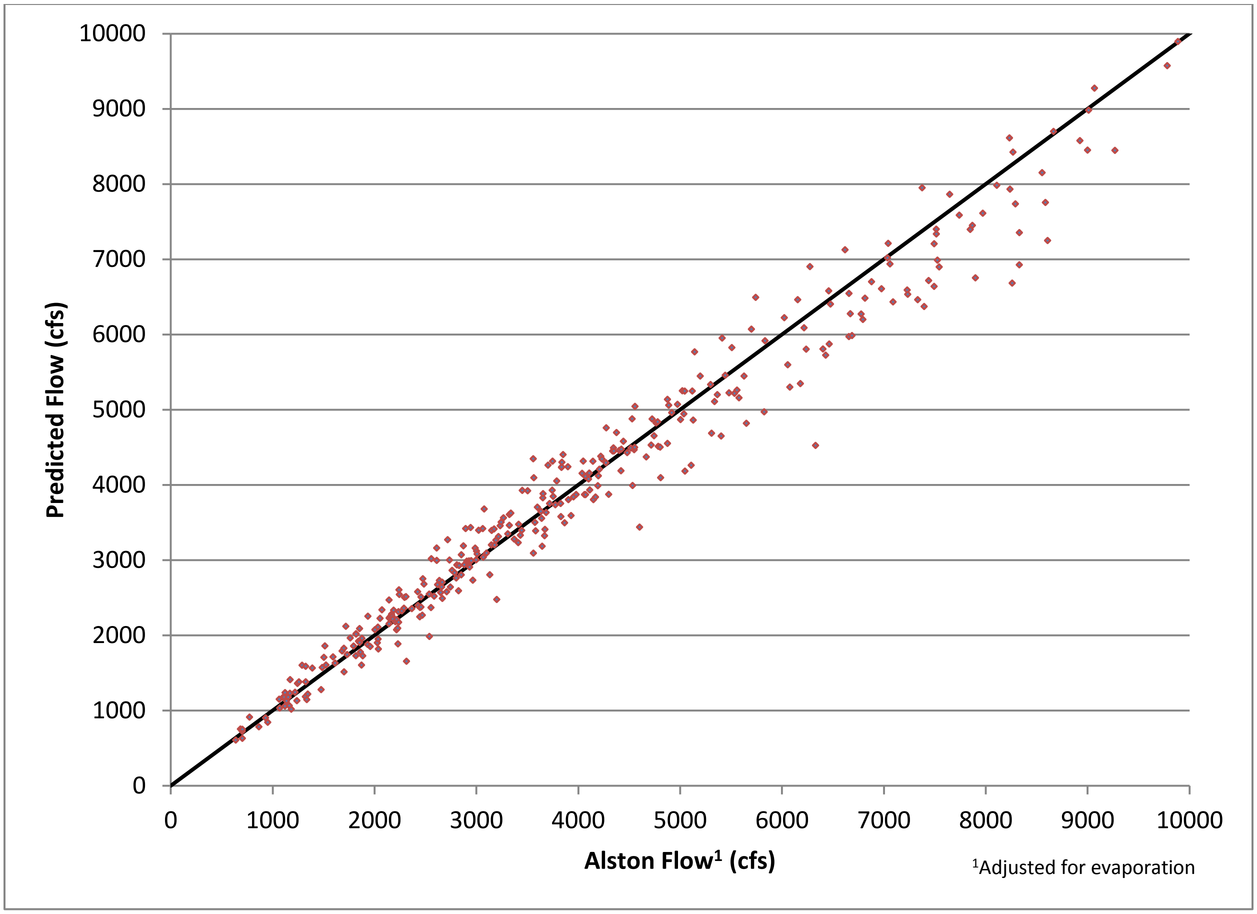


FIGURE 6 **ALSTON FLOW (ADJUSTED) VS. PREDICTED MONTHLY AVERAGES (33 YEARS) - REGRESSION BASED ON DRIEST 75% MONTHS**

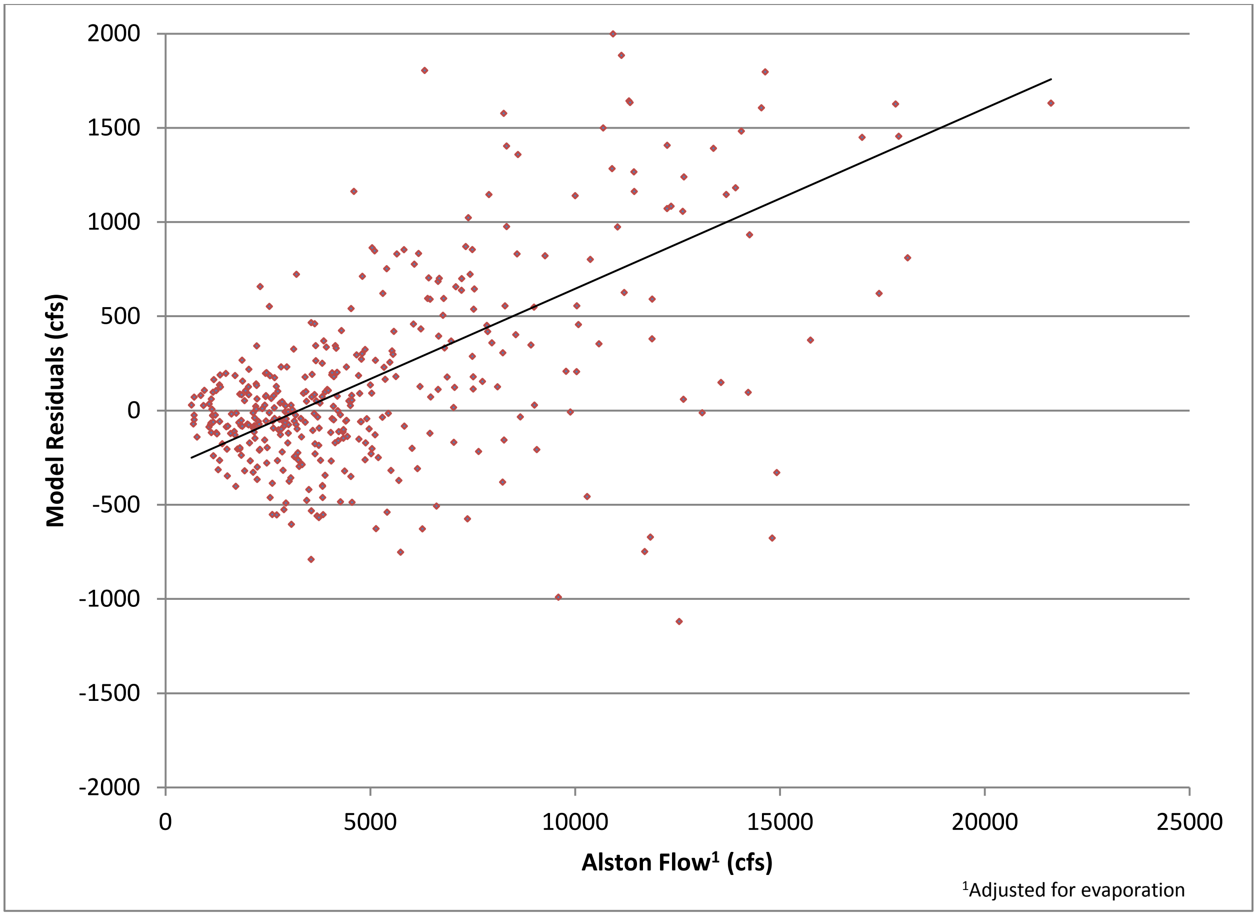


FIGURE 7 MODEL RESIDUALS - REGRESSION BASED ON 75% LOWEST FLOW AVERAGE MONTHS

1.3.4 MODEL VERIFICATION

The verification of the model results was performed by comparing the predicted flows vs. the target flows for three year periods, including statistically wet and dry periods (see Figures 8 and 9). The dry period was from January 2006 to December 2008, inclusive. The wet period was from January 1993 to December 1995, inclusive. These periods were selected on the basis of the average flow of the three years and of the 33-year period for which there was a complete flow dataset for the gages, which spanned January 1981 to December 2013.

These comparisons indicate that the estimated values have a slight overprediction bias during prolonged low-flow periods. During higher flow periods, such as 1993 - 1995, there is very little bias on the lower flows and a slight underprediction bias on the higher flows.

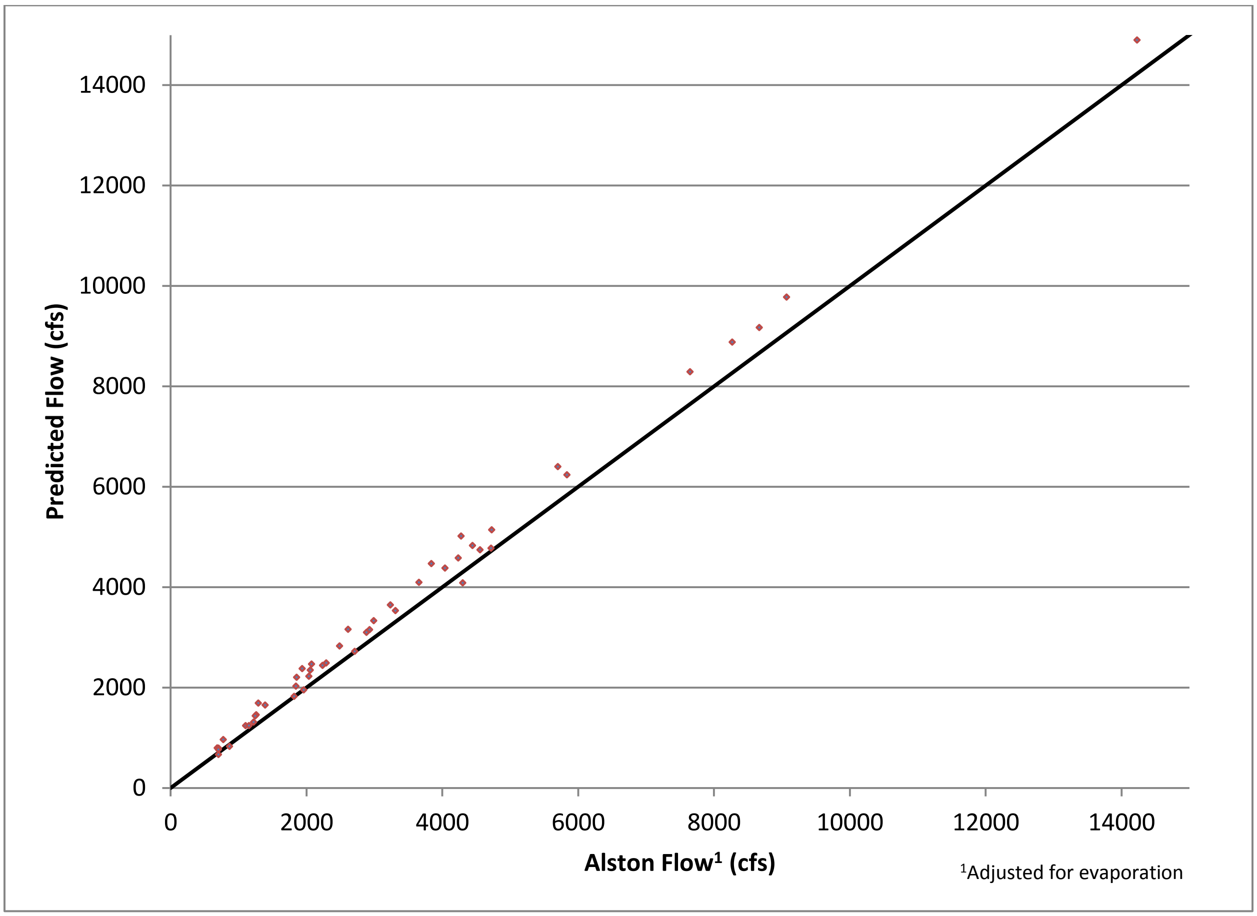


FIGURE 8 ALSTON FLOW (ADJUSTED) VS. PREDICTED MONTHLY AVERAGES (DRY 3-YEAR PERIOD) - REGRESSION BASED ON DRIEST 75% MONTHS

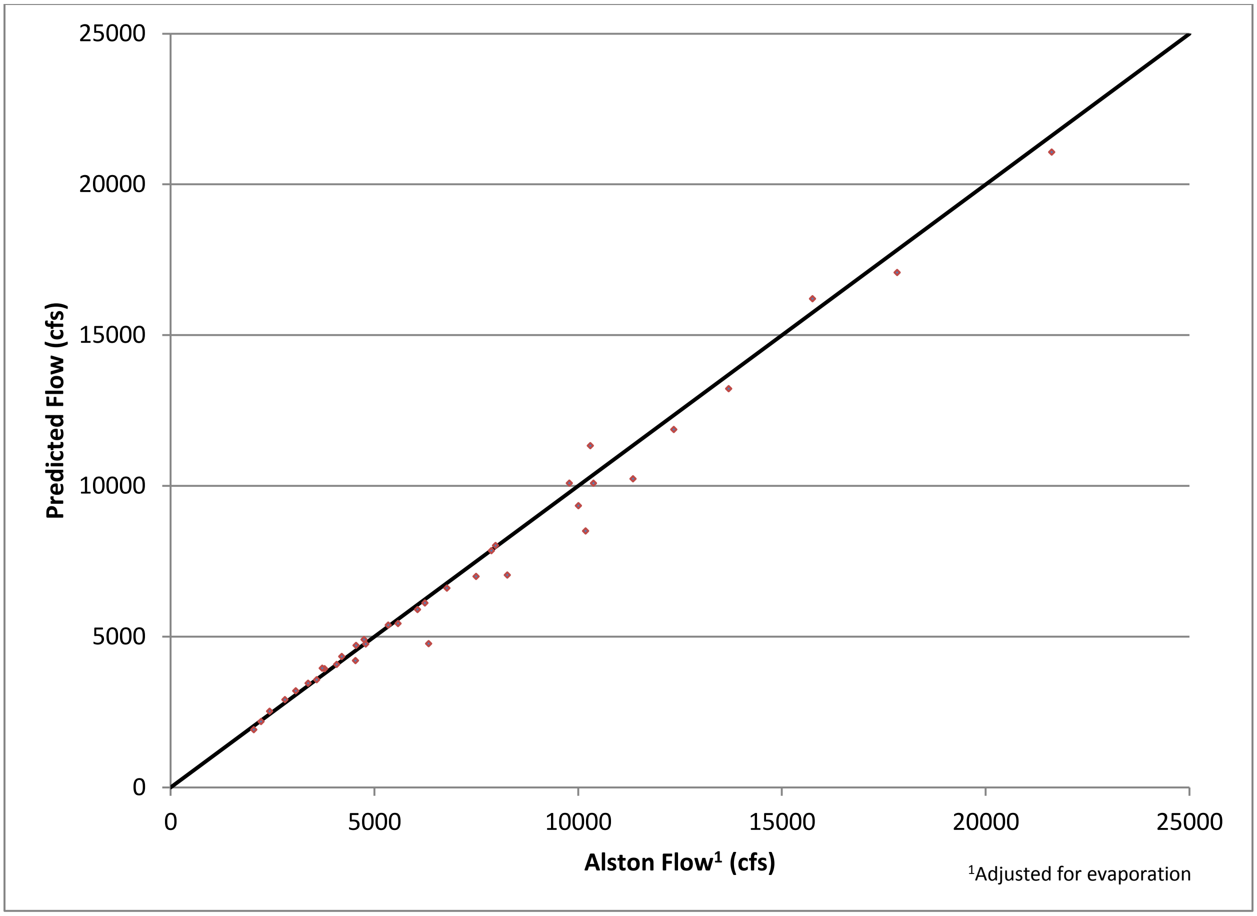


FIGURE 9 ALSTON FLOW (ADJUSTED) VS. PREDICTED MONTHLY AVERAGES (WET 3-YEAR PERIOD) - REGRESSION BASED ON DRIEST 75% MONTHS

1.4 SUMMARY

Two statistical regressions were performed to develop the coefficients used in Equation 1 (see Section 1.3.2). The first regression, using all of the monthly flow averages, resulted in a trend of negative modeling residuals (overprediction) for months with flow averages less than 7,700 cfs. A subsequent regression, using monthly flow averages less than 6,000 cfs (approximately 75% of the data values) produced a better balance between negative and positive modeling residuals. This regression performed statistically better in the range of the most frequent values of monthly average flows, with flows nearest 3,900 cfs predicted most accurately. As this lower flow range is of greater importance than the entire historic range for balancing the hydrologic resource, the coefficient and exponent determined through the second regression are preferred for the development of the inflow dataset (see Table 2).

TABLE 2 STATISTICAL MODEL RESULTS SUMMARY

MODEL NAME	REGRESSION DATASET OF ALL MONTHLY AVERAGES (396 VALUES)	REGRESSION DATASET OF LOWEST 75% MONTHLY AVERAGES (289 VALUES)
α – Coefficient	1.041	0.988
γ – Exponent	0.599	0.599
Standard Error	495.0	469.6
R^2	0.9828	0.9828

APPENDIX A

INFLOW DATASET MEMO: OPERATIONS RCG QUESTIONS AND ANSWERS

Scott Harder

Hydrologist, LWC Division, SCDNR

5/30/14

Comments regarding Kleinschmidt's "Inflow Dataset Development: Statistical Methodology" for the Parr Hydroelectric project (FERC No. 1894).

1. The methodology pertaining to how the monthly statistical analysis will used to develop daily (or hourly) Parr inflow dataset needs to be clarified in the report. Also, will time of travel be factored in when moving to a daily or hourly time step?

We propose to edit the report during the meeting so the clarifications are agreed to and understood by the RCG. Preliminary clarification follows: The statistical analyses were performed on data points that were monthly average flow values for each of the gages, for the common gaged periods of record (1981 – 2013). The regional coefficients derived from these analyses will be applied to recorded data for each of the three upstream gages. The resulting sum of these inflows will serve as the dataset input to the HEC reservoir and downstream river models. The reservoir and downstream models will use hourly (or longer) time steps for evaluating operations. The downstream river model will include travel time on an hourly basis.

Hourly inflows can use mean daily data as a substitution, or they can be calculated from hourly gage data. If done on an hourly basis, the flows will be routed from the upstream gages using one of several routing algorithms (such as Muskingum, Muskingum-Cunge and Modified Puls), the selection of which will be based on the stream hydraulics. The routing of hourly data would include travel time, whereas mean daily data would not be adjusted for travel time because the gages are only hours away from the project.

Hourly inflows are not expected to have noticeable affects on the project model runs due to the magnitude of the usable storage, except during high inflow hydrographs. The RCG should consider the benefit of developing hourly inflow data versus capturing a longer period of record with daily data. If the daily data is used, hourly model runs will assume the mean daily inflow is occurring for that 24-hour period. If the hourly data is used, the gages are limited to October 1, 1987; daily data is available back to October 1, 1980 (although monthly values used to determine the regional coefficients were truncated for complete calendar years, 1981-2013).

2. Regarding the technique to compare the hydrologic similarity between the three gages area (Tyger, Enoree and Broad in section 1.3.1:

a. Only two years were used for comparison (2002 and 2003) in Figure 3. Was there an attempt to include more years? These two years represent extremes, or close to it, for dry and wet years back to back and the comparison would be more robust if it included more normal periods as well or if a comparison was made for a longer period of time (see below also).

The comparison of normalized flows for evaluating hydrologic similarity was performed using the monthly average flows for the period 1/1/1981 to 12/31/2013, a thirty-two year period. Only two years were charted for the document for visibility, selected to illustrate consistent gaged contributions across a range of hydrologic conditions: extreme drought conditions during the summer of 2002, and high inflows the following spring. We can present additional years for comparison, and propose to include them in appendices. Our conclusions apply to the entire period of record and range of flows.

The statistical regressions were performed using several variations of inflow subsets including the entire 32-year period, as well as using an abridged dataset that included only the lowest 75% of the flow values. The abridged version used an equivalent of 24 years of monthly average flows.

b. Please rewrite or elaborate on the following statement at the end of page 6: "The comparison (see Figure 3) illustrates that the range of the monthly averages (per 100 sq. mi.) was visually close to the aggregate average through a variety of flow ranges; this indicates the hydrologic similarity of the three subbasins." Please consider summarizing the point you are trying to make here quantitatively in a table and not just visually from a plot. In Figure 3, normalized monthly average runoff is consistently higher for the Broad basin in 2003 than for the Tyger and Enoree, which maybe isn't surprising given that the Broad is a much larger basin that extends up into the North Carolina mountains. It would be instructive to see if this was observed for other years besides 2003 (my own preliminary analysis shows that it does). The higher runoff suggests that the assumption of homogeneity for the gaged portion of Broad basin (as a whole) at Carlisle as compared to the Enoree and Tyger basins may not be valid. As a result, it may be problematic to use the Broad River gage at Carlisle to develop a regional coefficient. However, I think that the assumption that the *ungaged* parts of the three basins (Tyger, Enoree, and Broad) are very nearly homogeneous is likely valid, but the question remains on how to best account for the additional flow from these ungaged areas (but see 4 below).

Visual examination of the normalized flows was done to check for consistent, significant discrepancies between gaged areas under a range of hydrologic conditions. The comparison of any single normalized gage with the aggregate average was visibly within the same order of magnitude for all months across a large range of inflow conditions, and was the basis for concluding the similarity. The Carlisle gage does appear to contribute more flow more often, but to a nominal degree compared to the aggregate. In the interest of simplicity, consistent regional coefficients were used for the analysis.

The desired end product is a dataset that consists of six time series of flow data, three of which are USGS flow records measured at the gage sites for the three rivers, and the other three time series are estimates of ungaged flows from the three rivers. Several statistical models were evaluated in an attempt to determine the most effective regression, using statistical metrics such as r-square and standard error values. The selected statistical model produced r-squared values above 95%, suggesting a strong correlation using consistent fitted regional coefficients.

Although not documented in the report, the initial screening of statistical models included many variations of regressions that were attempted in order to determine if the ungaged flows appeared to be more similar to one or two of the upstream gages as opposed to all three. A regression model was evaluated, using 1) all data, 2) three consecutive dry years, and 3) three consecutive wet years. This regression model included alpha values for each of the streamgages. The statistical regression results indicated that the ungaged flows were more similar to the Tyger River than the Broad or Enoree, but the relationship shifted between wet and dry periods. The statistical model used in this initial screening was dropped from consideration and not documented in the report.

3. In section 1.3.2, please make sure that the x and y axes scales are set to display all data points in Figures 4 and 5. For example, in figure 4, average flows at Alston extend well beyond 10,000 cfs for some months, but the maximum flow is cutoff somewhere between 9000-9500 cfs.

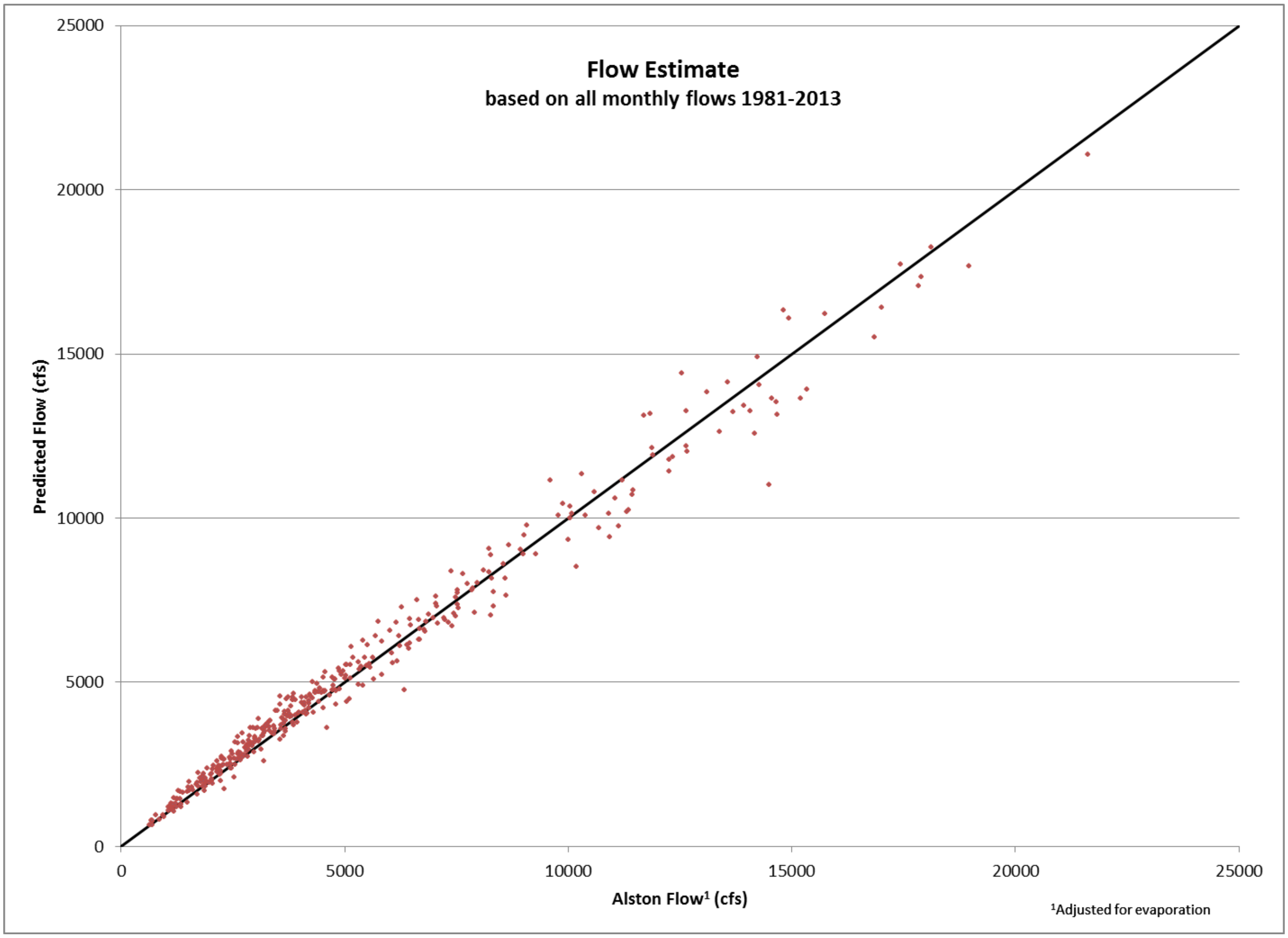


FIGURE 1 (EXPANDED) ALSTON FLOW VS. PREDICTED MONTHLY AVERAGES (33 YEARS) – REGRESSION BASED ON ALL MONTHS

4. I initially had some strong reservations with applying a regression using monthly average flows at the Alston gage as a driver for computing daily inflows to Parr. Part of the reason (maybe the whole reason) for using an alternative method for estimating daily inflow is that the straight area proration method likely overestimates daily inflow during low inflow periods. I at first was not convinced that the method presented here would provide the best estimate of low flows on daily to weekly time scales due to the reliance on statistics from monthly averages which tends to smooth out the daily variations. After comparing hydrographs for several low flow years (2002, 2007, etc.) using the method presented in this report with a hydrograph developed using the area proration method (and with a hydrograph using just the sum of the 3 gages) the resulting daily inflow dataset seems reasonable (and thus, the concern over

homogeneity above may not be an issue) for low to moderate flows. I did not look at high flows in detail since I am not too concerned at that end.

Daily data evaluation for the development of the regional coefficients is a noted concern due to the potential short-term mass balance impacts associated with the significant usable storage. Even under low flow conditions, a mass balance approach for determining the regional coefficients should have good correlation. Using the entire range of flows for developing the regional coefficients has more effect on the accuracy at the upper and lower ends, as prorating coefficients are widely acknowledged to vary with flows. Observation of the initial regression results, with coefficients derived using the entire range of flows, indicated a tendency for the model to over-predict lower flows. This inflection was noted in section 1.3.2 to be around 7,700 cfs, above which the model tended to under-predict flows. Concern for low-end accuracy led to the regression based upon flows at or below the Parr Hydro capacity, which was approximately 75% of the inflow months. This reduced the tendency of the model to over-predict lower flows, at the expense of higher flow predicted accuracy.

5. As has been suggested by others, a meeting is probably necessary to further discuss and clarify the inflow methodology.

Responses to Byron Hamstead, USFWS Fish and Wildlife Biologist

Email:

Hi Kelly,

Please see attached for the USFWS's comments/questions in track changes regarding the Parr inflow dataset statistical methodology.

Thank you,

Byron

Requested edit: "As discussed in the Study Plan, the ~~existence~~ operation of the pumped storage development and lack of long-term operational records prevents the back-calculation of a sufficient inflow dataset." [Replace existence with operation].

Answer: Agreed, edit incorporated.

Comment: *Y axis label = unadjusted Q* (regarding the Figure 2 Monthly Average Flows column chart)

Answer: Agreed, Label Added to Chart in final version.

Comment:

"The comparison (see Figure 3) illustrates that the range of the monthly averages (per 100 sq. mi.) was visually close to the aggregate average through a variety of flow ranges; this indicates the hydrologic similarity of the three subbasins."

BH: Is there a benefit of normalizing discharge by 100 sq. mi. versus normalizing by 1 sq. mi.?

Answer: The scale for normalizing was selected to match the order of magnitude of the contributing (smallest) drainage area. Examining the three gages on a cfs per unit square mile would not change the results or the relative contribution of any gage area, but only the scale. The lower flows would change from around 10 cfs/100 square miles to 0.1 cfs/square mile, while the higher 420 cfs/100 square miles would reduce to 4.2 cfs/square mile.

BH: I think it is necessary to quantify statistical differences between gages in terms of Q/square mile since subbasin hydrologic homogeneity is an important assumption included in the model. Accounting for these differences might further reduce the variance in the model, making it more accurate at lower flows.

Answer: Visual examination of the normalized flows was done to check for consistent, significant discrepancies between gaged areas under a range of hydrologic conditions. The comparison of any single normalized gage with the aggregate average was visibly within the same order of magnitude for all months across a large range of inflow conditions, and was the basis for concluding the similarity. While any given month may show one gaged area has a noticeably higher contribution, no general trend indicates a consistent bias across the range of hydrologic conditions. Significant differences in runoff characteristics would be indicated by one or more normalized areas consistently contributing more or less than the aggregate average. In the absence of significant consistent contribution by any single gage, consistent fitted regional coefficients (alpha and lambda) were selected for all three gaged areas. Variances observed for individual months, where one gaged area contributes more or less than others, is attributable to precipitation that was inconsistent for the entire drainage area, rather than differences in runoff characteristics.

BH: Was this the sole period of record [referring to Figure 3, Normalized Monthly Average Flows, which shows 2002 – 2003 calendar years] used to infer similarity of runoff characteristics among subwatersheds? According to table 1 there are overlapping discharge data for all of these gages since 1973.

There appear to be potentially significant differences in mean monthly discharge between gages even when the data is normalized by drainage area.

Answer: The period of record used to infer similarity was 1981 – 2013, the longest concurrent period for the four gages available (in complete calendar years); the Alston Gage period of record has a gap in the dataset from 1907 through 1980. We will correct the current period or record in Table 1 in the final version. Only two years were charted for the document for visibility, selected to illustrate consistent gaged contributions across a range of hydrologic conditions: extreme drought conditions during the summer of 2002, and high inflows the following spring.

Comment:

"These two gages [Woodruff and Whitmire gages on the Enoree River] were selected because they have the longest overlapping (current) periods of record."

BH: What is the period of record for discharge here?

The proposed Riverdale Project (formerly Inman Mills) was licensed in 1982, but became inoperable 12-years ago. Since this calculation assumes that the hydrologic characteristics of the Enoree River apply throughout the Broad River subwatershed, I want to make sure that the regional exponent/model is not confounded by a period of record that includes river regulation activity.

Answer: The overlapping period of record for the Whitmire and Woodruff gages is indicated in Table 1 as 2-9-1993 to present, limited by the Woodruff gage. The use of monthly flow averages to establish the pro-rating coefficient would eliminate any effects of short-term regulation upstream of the Parr dam. FERC documentation (correspondence from project licensee) indicates the Riverdale project has not operated since August 2001.

With respect to daily average flows that will be prorated to create the dataset, the project has insignificant storage and re-regulating capacity with respect to the Parr Reservoir (9 acre pond with a gross storage of 22 gross acre-feet, compared to 4,400 acres and 32,000 acre-feet).

Comment:

TABLE 1 STATISTICAL MODEL RESULTS SUMMARY

MODEL NAME	REGRESSION DATASET OF ALL MONTHLY AVERAGES (396 VALUES)	REGRESSION DATASET OF LOWEST 75% MONTHLY AVERAGES (289 VALUES)
α – Coefficient	1.041	0.988
γ – Exponent	0.599	0.599
Standard Error	495.0	469.6
R^2	0.9828	0.9828

BH: The standard error [469.6] for this model may be too high considering that annual daily flows are often below 3,000, and approach 2,000 cfs in late Summer/ early Fall.

Figure 6 shows a few stray data points that may be driving up SE. Were any statistical outliers omitted from analysis?

Answer:

The Standard Error represents the standard deviation across the entire range of flows. The Standard Error on the left and right columns are based on the associated regional coefficient and exponent, which were established according to the conditions of the headings (all flows vs. lower 75% flows, approximately 6,000 cfs limit). The Standard Error for only low-flow scenarios would have lower values. The Standard Error calculated for flows up to 6,000 cfs is 321 for the left column, and 304 for the right column. The Relative Standard Error of the entire dataset more accurately explains the error versus the total range of flows. For both regressions, the RSE is calculated at 9.3%.

No statistical outliers were omitted from the analysis, as the good correlation between the predicted and measured flows across the range of data did not suggest that data points needed eliminated.

Responses to Gerrit Jobsis, American Rivers Sr. Director:

Email:

Kelly,

Please find attached American Rivers comments on the inflow data plan. It is intended to support the Final Parr Fairfield Operations Model Study Plan. That study plan says "The goal of this task is to create the best available historic inflow series, which will form the input to the operations models, energy models, and habit and recreational studies." As my comments in the document state, I do not agree that this inflow data set will be usable to evaluate the effects of project operations on habitat and recreation. Project operations via inflow alterations and reservoir fluctuations affect habitat and recreation values *on a real time basis (hourly or less) that cannot be estimated using monthly average inflow estimates. Smoothing the data with regression equations removes the hourly and sub-hourly variation that is essential to understanding project effects.*

I received USFWS comments which also raise some important questions. It would useful to convene a call among those interested to answer some of the questions raised in our respective comments.

Gerrit

Answer:

The inflow dataset is a model input that is independent of the project operations. This effort is to determine accurate coefficients for prorating the gaged inflows for summing the total dataset. They are being determined on a monthly basis because mass balance between the upstream gages and the Alston gage can be significantly affected by project operations. Daily analysis could be performed, but would introduce a significant level of inaccuracy in determining the coefficients. The inflow dataset will be developed as mean daily flows, using the coefficients determined through the mass balance effort. Hourly inflows are proposed to be the same as daily average, as the travel time between gages under varying flows would introduce high potential for inaccuracy. The model outputs will evaluate the hourly and daily impacts on the areas within the PBL and the reach downstream of the Parr Shoals dam.

Comment:

"The statistical analyses will use monthly and annual flow data rather than daily average flows."

GJ: I don't agree with this for evaluating a project effects on stream flow (inflow versus outflow) and reservoir fluctuations. Project effects occur on an hourly or shorter time frame. Analysis of project effects should be done similarly. The issue for habitat and recreation is not how Parr/Fairfield affects monthly or annually, but within the day and hour.

Answer:

Project effects will be evaluated via modeling efforts on time steps of an hourly basis, in addition to any longer periods requested.

Comment:

"Flow releases from the project may be vastly different at any given hour from the inflows to the Parr reservoir."

GJ: This is exactly what we need to understand

Answer:

This statement is alluding to the inherent error associated with calibrating the inflows with the Alston gage on a daily basis, due to the storage of the project. The model will facilitate the understanding of these releases. The inflow dataset will not be affected by project operations, but is an independent input.

Comment:

” A multivariate regression was performed to determine the parameters of a generalized equation for estimating the inflow to Parr Reservoir.”

GJ: Again, this may be good for the operations models and energy models but I don’t understand how this will help answer the question of how the project affects streamflow and reservoir fluctuations. Smoothing things out with a regression takes away the variability of inflow that is essential to understanding project effects on habitat and recreation.

Answer:

This regression is performed only to determine the regional prorating coefficients. Project effects on streamflow and fluctuations are addressed in the Res and RAS models. The regression is not intended to smooth out the extreme high and low flows, but rather best establish the prorating coefficients to most accurately represent the inflow. Inflows will still be highly variable, based on mean daily records.

Comment on graph:

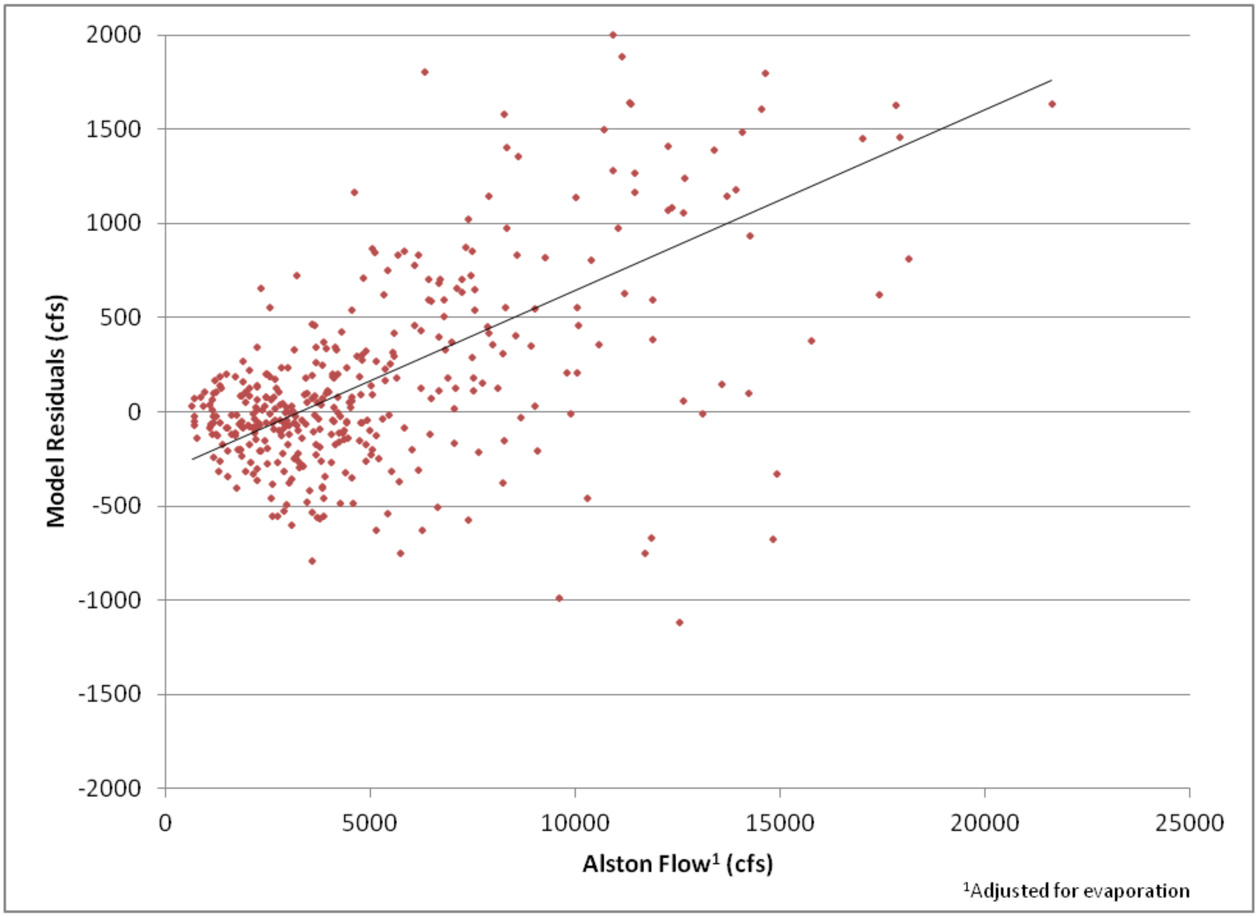
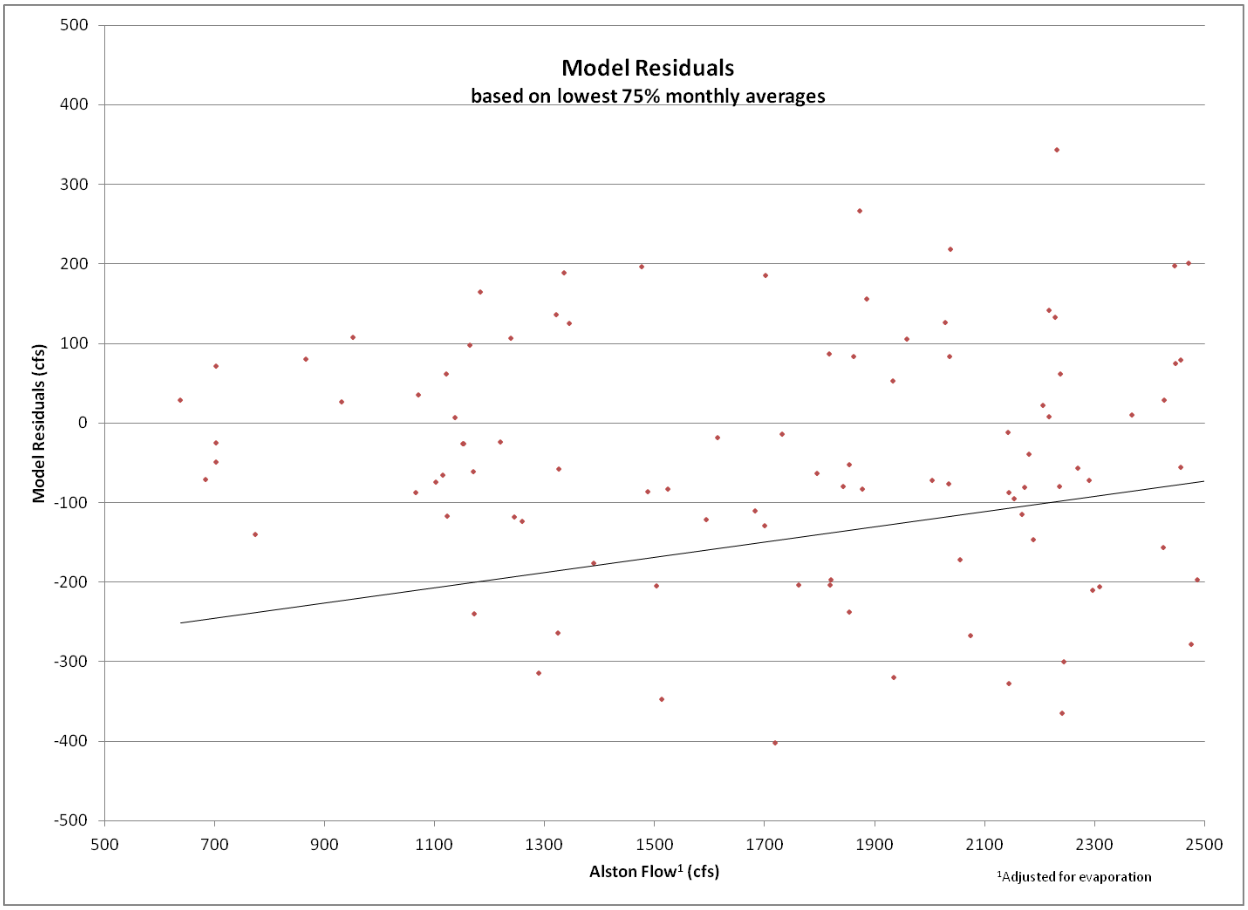


FIGURE 1 MODEL RESIDUALS - REGRESSION BASED ON 75% LOWEST FLOW AVERAGE MONTHS

GJ: Poor fit at lower end of flow range affects the reliability of the model

Answer:

The residuals diminish in magnitude as flows decrease, are appear evenly distributed about the zero value. While the inflow dataset will have calculated values both higher and lower than the Alston readings, no significant bias is evident under low flow conditions. A closer examination of the low-end flows can be made with the graph below, scaled to flows below 2500 cfs. (The trendline is a linear average across all flows for the 75% lower inflow months, and does not represent the trend of the lower flow residuals alone.)



Comment:

TABLE 2 STATISTICAL MODEL RESULTS SUMMARY

MODEL NAME	REGRESSION DATASET OF ALL MONTHLY AVERAGES (396 VALUES)	REGRESSION DATASET OF LOWEST 75% MONTHLY AVERAGES (289 VALUES)
α – Coefficient	1.041	0.988
γ – Exponent	0.599	0.599
Standard Error	495.0	469.6
R^2	0.9828	0.9828

GJ: This [referring to the 469.6 standard error value] seems significantly high when evaluating low flow periods and could represent 20% to 25% of the average flow

Answer:

The Standard Error represents the standard deviation across the entire range of monthly average flows (up to 20,000 cfs). The Standard Error on the left and right columns are based on the associated regional coefficient and exponent, which were established according to the conditions of the headings (all flows vs. lower 75% flows, approximately 6,000 cfs limit). The Standard Error calculated for low-flow conditions has lower values. For example, the calculated Standard Error for the two columns limited to flows up to 6,000 cfs are 320 and 304 (left and right respectively). For flows up to 2,000 cfs, they are 155 and 147. If considered from a percentage perspective, as the Relative Standard Error, it would more accurately explain the error versus the total range of flows. For both regressions, the RSE is calculated at 9.3%.

Response to Pace Wilber, NOAA National Marine Fisheries Service Atlantic Branch Supervisor

Hi Kelly. I agree with the comments from FWS and American Rivers that short-term variation important for assessing project effects on fishes and riverine habitat may be masked by using monthly average flows as model inputs. I also agree there are much better ways to judge the similarity of flows between subwatersheds than "eyeballing" the histograms in figures 2 and 3. A correlation matrix may be a more rigorous way to make the comparisons. Pace

Answer: Short-term variation will still be performed using daily mean inflows. Monthly average flows are only being used to determine regional pro-rating coefficients for daily inflow calculations, due to the mass balance errors associated with daily operations.

Visual examination of the normalized flows was done to check for consistent, significant discrepancies between gaged areas under a range of hydrologic conditions. The comparison of any single normalized gage with the aggregate average was visibly within the same order of magnitude for all months across a large range of inflow conditions, and was the basis for concluding the similarity. Due to the good overall correlation, it is unlikely that altering one set of regional coefficients to more accurately represent the contributing ungaged area will offer significant improvement to the model. Lower homogeneity in runoff characteristics may be inferred from metrics when the contributing factor is actual weather event(s) specific to a single subbasin within a given month.

Exhibit E-2 Operations

Parr-Fairfield Operations Modeling System

PARR-FAIRFIELD OPERATIONS MODELING SYSTEM

PARR HYDROELECTRIC PROJECT

FERC NO. 1894

Prepared for:

South Carolina Electric & Gas Company
Columbia, South Carolina

Prepared by:

Kleinschmidt

Lexington, South Carolina
www.KleinschmidtGroup.com

December 2014

PARR-FAIRFIELD OPERATIONS MODELING SYSTEM

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FERC NO. 1894

SOUTH CAROLINA ELECTRIC & GAS COMPANY

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1.0 INTRODUCTION

South Carolina Electric & Gas Company (SCE&G) is the Licensee of the Parr Hydroelectric Project (FERC No. 1894) (Project). The Project consists of the Parr Shoals Development and the Fairfield Pumped Storage Development. Both developments are located along the Broad River in Fairfield and Newberry Counties, South Carolina.

This document provides a description of the development of the Hydrologic and Project Operations Modeling system as part of the Parr and Fairfield relicensing project. This modeling system will be used to assess the ability to change project operations, and the resulting effects of potential modifications to project operations. The effects that could result from proposed changes in project operation include energy, capacity and generator availability, flood control, and water budget. The intent of this effort is to develop a modeling tool that can be used to incorporate stakeholder requests as parameters to provide outputs and results that can be easily interpreted.

This report includes sections covering the development of the modeling tools, and the data required to run the models, including:

- Description of the models and software;
- river routing model development (HEC-RAS);
- reservoir routing model development (HEC-ResSim);
- hydrologic data used in the models; and
- modeling system data management.

It is important to note that the vertical datum for the reservoir model is NGVD29, while the HEC-RAS model is NAVD88. This discrepancy does not affect the performance of the models, since the only data interchange between the models is outflow from Parr Reservoir. The reason for the difference lies in the fact that all elevation references for the two reservoirs has consistently been stated as NGVD29 values, and the terrain data for the HEC-RAS model (Source: USGS) is in NAVD88. Unless stated otherwise, all elevation data cited in this report will follow this convention.

2.0 MODELS AND SOFTWARE

The modeling system is comprised of two USACE models and the accompanying DSS data storage system. Full descriptions of the software may be found on the USACE-HEC website. The URLs for each of the software components are included in the following brief descriptions.

2.1 RIVER ROUTING MODEL (HEC-RAS)

The reservoir routing model is the U.S. Army Corps of Engineers HEC-RAS http://www.hec.usace.army.mil/software/hec-ras/). HEC-RAS (v4.1) is a 1-dimensional model designed to perform hydraulic calculations for a full network of natural and constructed channels. The HEC-RAS model will simulate the flow releases from Parr Reservoir and the resulting water level stage in the river downstream. Wave travel times, rates of rise, and stage recession times will also be available from this model.

2.2 RESERVOIR ROUTING MODEL (HEC-RESSIM)

The reservoir routing model is the U.S. Army Corps of Engineers HEC-ResSim (http://www.hec.usace.army.mil/software/hec-ressim/). This software package was developed by the U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, and is used to model reservoir operations for single or multiple reservoir systems. The software accepts a variety of operational constraints and goals, and can be used to simulate ranges of inflows and response of the reservoir operations. The entire period of record can be simulated or specific events such as flood inflows or drought conditions can be routed to evaluate the response based on the constraints and goals. The results of these simulations facilitate decisions on adjusting one or more constraint or goal to better meet the interests of stakeholders.

2.3 MODEL DATABASE MANAGEMENT (HEC-DSSVUE)

The time series data used in the analyses are stored in direct access database files, in the USACE DSS database format. The DSS data storage system was developed by the Corps, and has been integrated into all HEC modeling systems, including HEC-ResSim and HEC-RAS. The DSS software, similar to the models, is public domain software and available for download at http://www.hec.usace.army.mil/software/hec-dssvue/. The use of the DSS system allows for the storage of time series data in a manner that allows the HEC models to read and write data to facilitate the exchange of data from one model to another. For the Parr-Fairfield Operations Model, the DSS data files are used to store streamflow and reservoir stage data, subsequently used as input to the HEC-ResSim model, followed by the storage of HEC-ResSim output data to be used as input for the HEC-RAS model.

3.0 RIVER ROUTING (HEC-RAS) MODEL DEVELOPMENT

The model of the downstream reach of the Broad River below Parr Shoals Dam was developed using readily available data to simulate the hydraulic effects of flow releases. The modeled reach below the Parr Shoals Dam extends down to the Columbia Diversion Dam, a distance of approximately 24 miles. The results of the model simulations can be used to determine flow and stage estimates for other interests in the project, such as navigation, recreation, or habitat benefits.

The geometric data and mapping were developed using an ArcGIS Geographic Information System (GIS). These data were utilized in conjunction with the HEC-GeoRAS v4.1 GIS extension for development of the model geometry, which was then exported to the HEC-RAS model.

3.1 DATA SOURCES

Data used in the development of the model were acquired from a number of sources and assembled in a GIS. The following is a list of items used in the development of the model:

- Aerial Imagery – Environmental Systems Research Institute (ESRI) Aerial Color Imagery Server, and Google Earth imagery.
- Topographic Data – South Carolina Digital Elevation Model (DEM) derived from LiDAR data.
- Flow vs. stage rating tables – The flow vs. stage data were obtained from the USGS web portal for two gage sites within the model domain.[1]
- Flow and stage time series data were obtained from the USGS web portal
- River stage time series data were monitored for approximately at 12 locations by SCE&G using Solinst Levellogger® dataloggers. These data series were converted to elevation data, by adding the stage readings to the surveyed elevation datum values for each datalogger. Barometric compensation was also performed using data collected with a Solinst Barologger® datalogger.

[1] A third discontinued USGS gage exists within the model domain, but has less than two years of overlapping flow data, and only has stage data available for peak annual events. For these reasons, the gage was not used to develop the model. See Section 3-5 and Figure 3-6.

3.2 GEOMETRY DATA

The simulation covers the reach of river from the tailwater of the Parr Shoals Dam to the Columbia Dam, a total length of approximately 24 miles. The cross-section geometry was derived from digital terrain data from the South Carolina GIS web portal. The terrain dataset was derived from LiDAR data, developed by the South Carolina LiDAR Consortium[2]. The processed DEM has an effective horizontal resolution of approximately 10 feet and supports 2-foot contours.

Cross-section locations were sampled using the ArcMap HEC-GeoRAS v.4.1 GIS extension. Figure 3-1 through Figure 3-3 show the cross-section locations from the HEC-RAS model.

The digital terrain data required by the HEC-RAS model consist of a series of river cross-sections, represented by a series of X-Y points for cross-sectional width and vertical range of interest in the channel. Although the GIS terrain data is adequate for the near-bank and overbank portions of the cross-section, the portion of the channel that is typically underwater must be augmented by other means. The thalweg elevation of the channel is typically estimated from previous models, such as detailed FEMA Flood Insurance Studies (FIS), but the coverage of FIS data on the Broad River is currently limited to the downstream-most 8 miles of the model.

[2] http://www.dnr.sc.gov/GIS/lidar.html

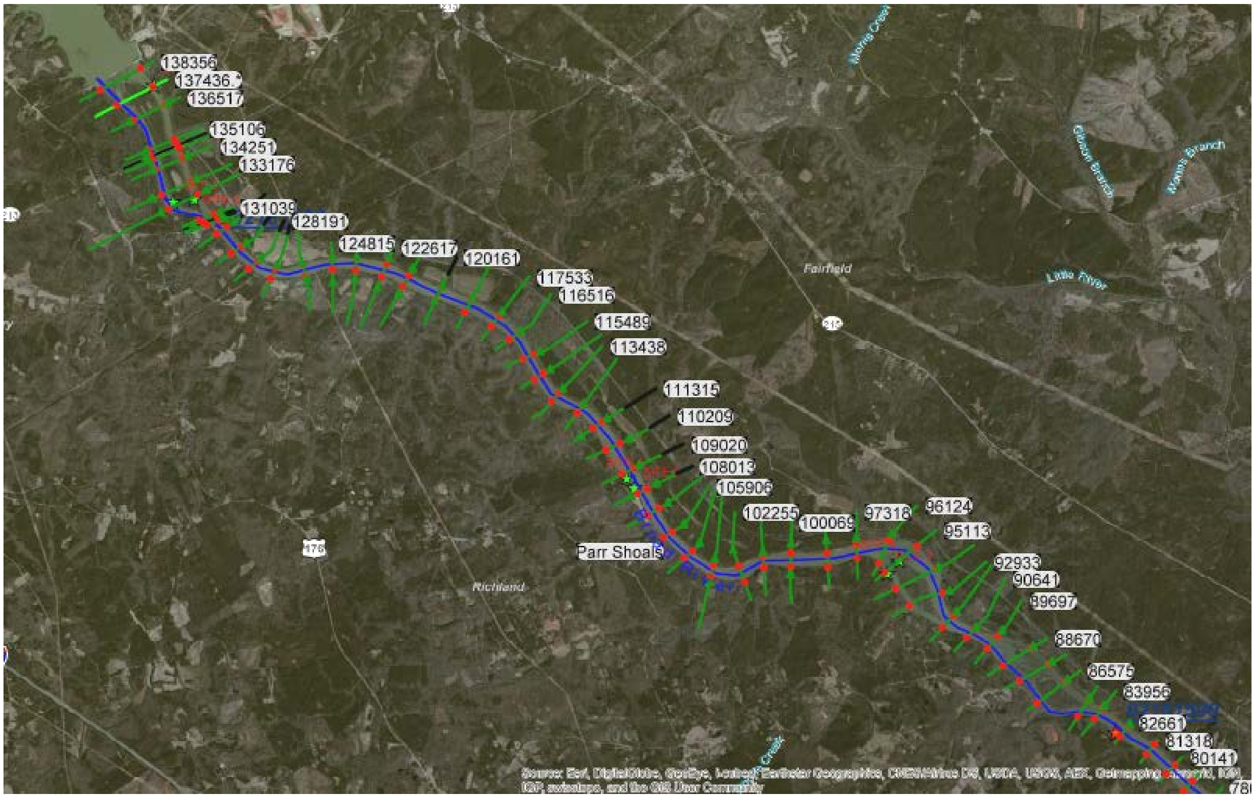

FIGURE 3-1 HEC-RAS SECTIONS (1 OF 3)

FIGURE 3-2 HEC-RAS SECTIONS (2 OF 3)

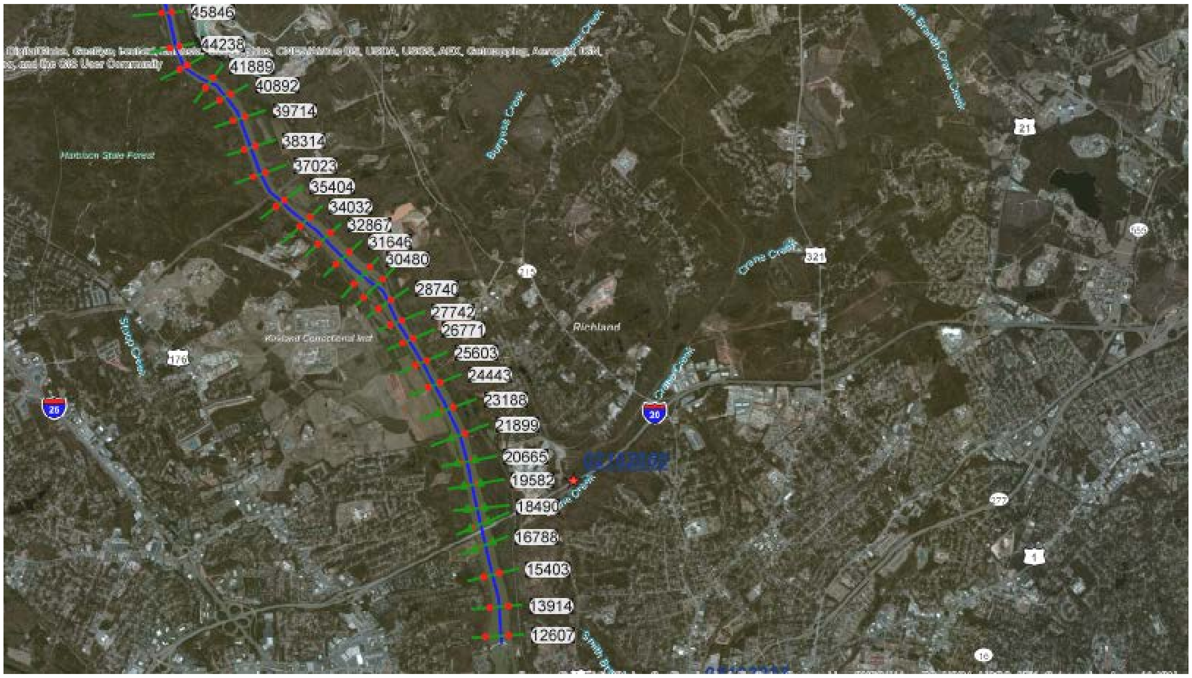

FIGURE 3-3 HEC-RAS SECTIONS (3 OF 3)

The instream cross-section data for this model were estimated by two methods. Datum elevations from the two USGS gages within the model domain were used as reference elevations, and the remaining portion of the channel reach was interpreted from the GIS terrain data. Investigation of the digital terrain data indicated that the LiDAR data were developed during a period when the streamflow rate was approximately 3,000 cfs. Based on this approximation, the configuration of the instream channel cross-section were developed as trapezoidal sections with a depth that would produce the approximate river surface elevation as indicated by the digital terrain data. The vertical adjustment of the instream cross-section data was refined based on the datalogger stage readings as part of the calibration process. The datalogger readings included periods of low flows, which provided an indication of the channel invert at each of the datalogger cross-sections.

3.3 ROUGHNESS COEFFICIENTS

The water surface elevation computation in the HEC-RAS model is a function of the channel and overbank conveyance; the conveyance is a function of the cross-sectional area and the roughness of the composite channel. The roughness values used in the model were developed as a function of the following factors:

- Land cover, as shown in aerial photography;
- the channel sinuosity; and
- the hydraulic connectivity between the channel and overbank areas.

The preliminary roughness values were also readjusted during the calibration process.

3.4 Boundary Conditions

The downstream boundary condition for the model is a rating curve at the Columbia Dam. The flow rating curve was developed using a combination of observed stage vs. flow readings from the USGS gage (Broad River near Columbia, No 02162035), and augmented with computed values. This USGS gage has been in operation since July 2011, and has experienced flows as high as 62,000 cfs. The rating curve is shown graphically in Figure 3-4.

The upstream boundary condition for the HEC-RAS model is an inflow time series. The inflow data series will be the outflow from HEC-ResSim model, which has an hourly time increment. For the purposes of calibrating the RAS model, the inflow data were assumed to be equal to the flows from the USGS gage site at Alston.

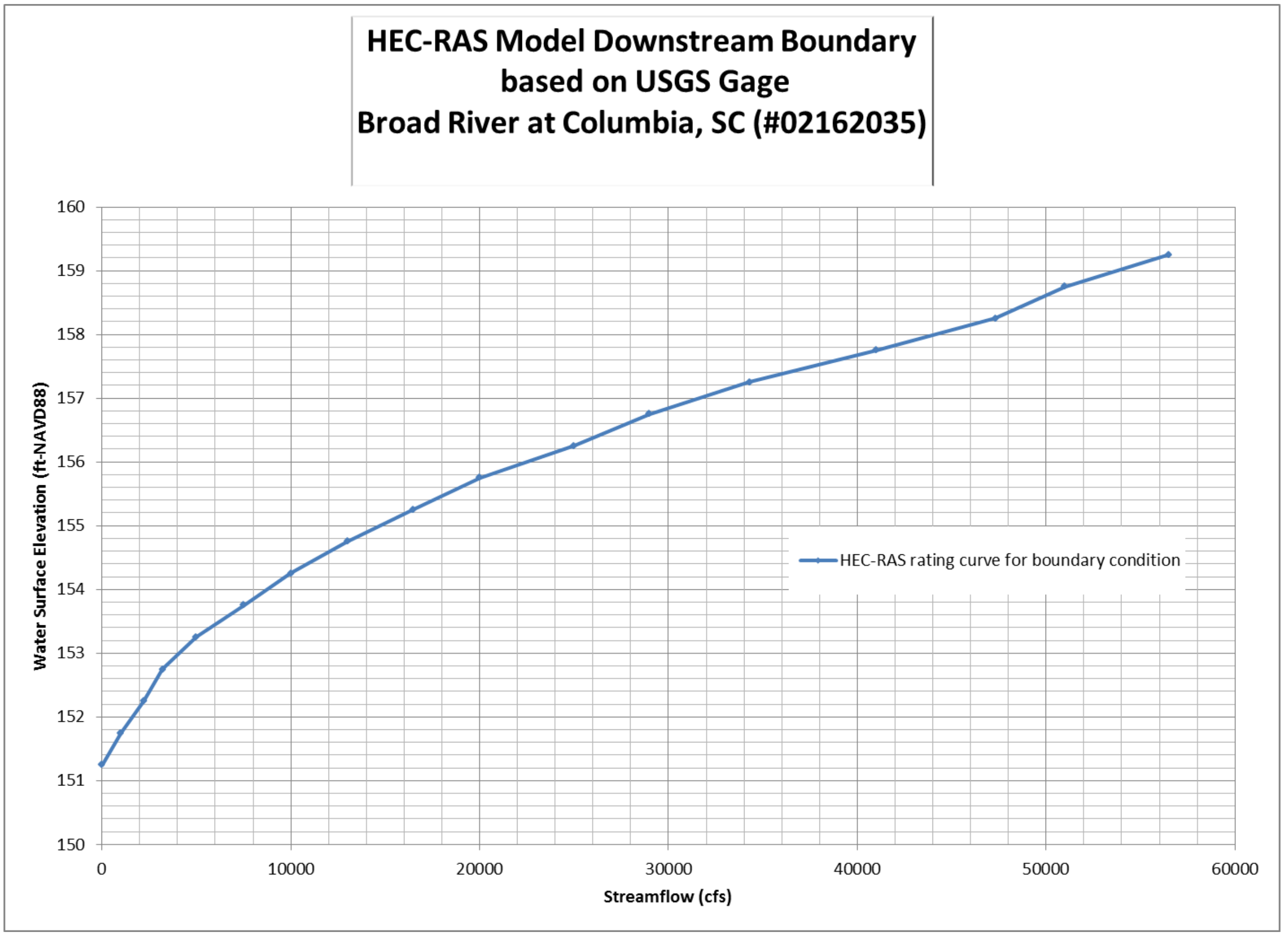

FIGURE 3-4 HEC-RAS DOWNSTREAM BOUNDARY

3.5 CALIBRATION – USGS GAGES

The calibration of the HEC-RAS model was performed using two methods. The first method was the use of the stage vs. flow rating tables from the two USGS gage sites within the model domain. The second method was the use of stage data measured and recorded by dataloggers at several locations.

The model was calibrated to the rating table from the USGS gage at Alston, South Carolina, by adjusting the channel and overbank roughness values. The USGS rating table data included a range of flows from near zero to 120,000 cfs, which encapsulated the range of flows for this model. The calibration process resulted in the model producing results (see Figure 3-5) within one foot of the USGS rating for the entire range of flows.

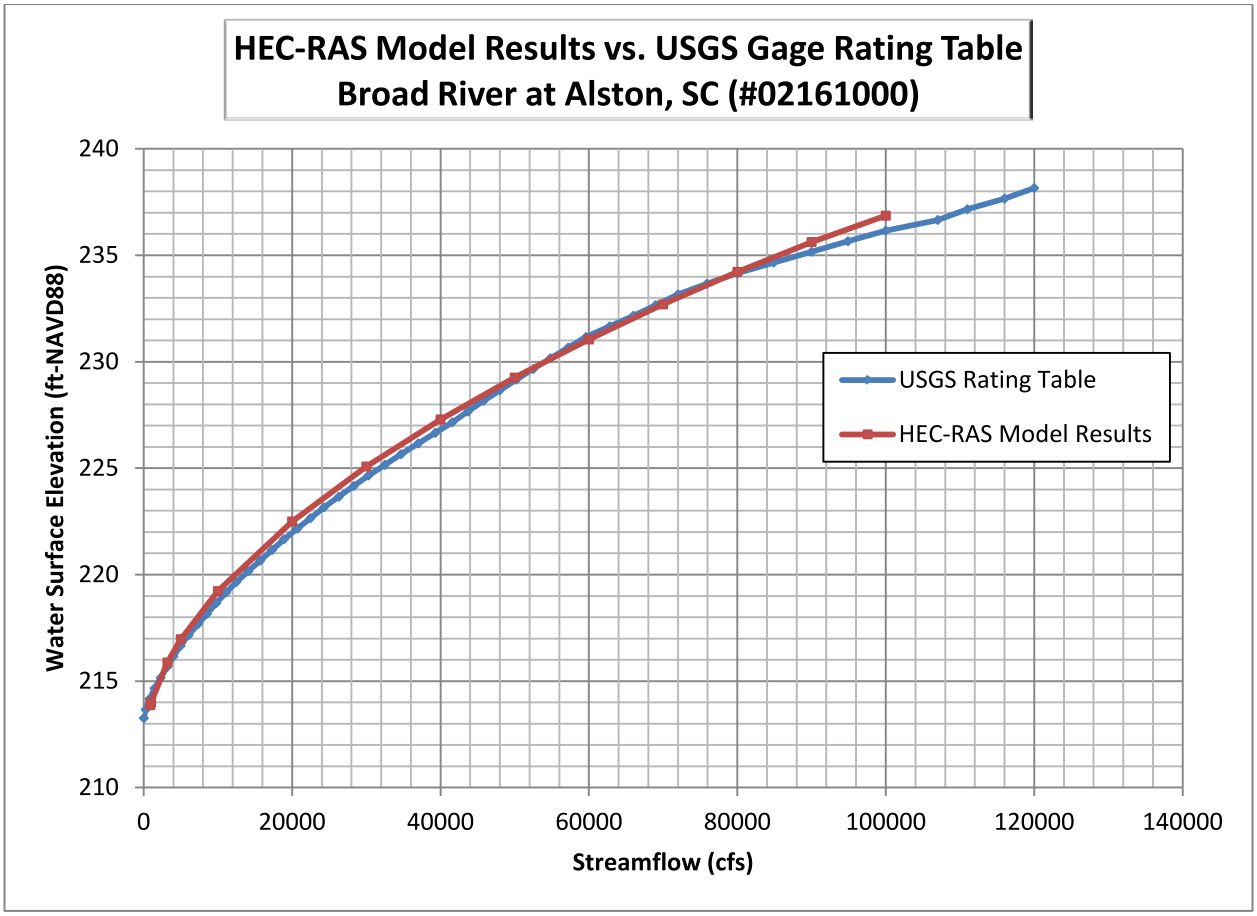

FIGURE 3-5 CALIBRATION RESULTS – ALSTON SITE

The model calibration (see Figure 3-6) was also compared to data from the discontinued USGS gage at Richtex, South Carolina. The data from this site was limited to annual peak flows measured at the site during the period 1925 to 1983, which was not useful for calibrating to typical daily flows. The USGS data included a range of flow/stage data points from 23,000 cfs (stage = 191.9 NAVD88) to 228,000 cfs (stage = 214.8 NAVD88).

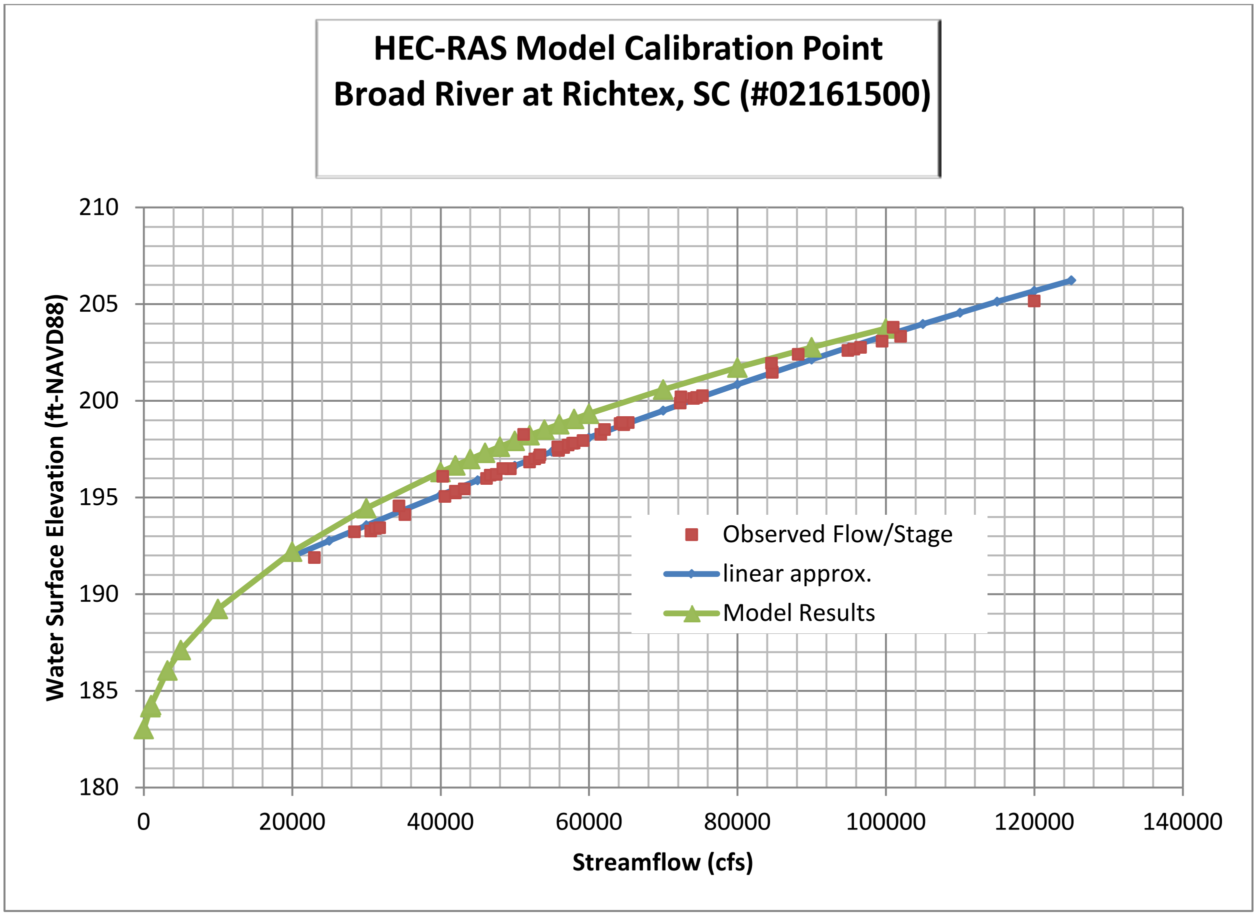

FIGURE 3-6 HEC-RAS CALIBRATION AT RICHTEX GAGE SITE

3.6 CALIBRATION – MONITORING DATA AND SURVEYS

During the initial model development, field data were gathered to refine the model with the intent of improving the resolution of the estimates of the water surface elevations at various locations. The field data gathered on October 23, 2013, consisted of bathymetric elevations measured at four transects (see Figure 3-7) downstream of the dam. The measured elevations were used to improve or confirm the configuration of the wetted portion of the cross-sections coded into the initial model.

FIGURE 3-7 TRANSECT LOCATIONS

The elevation data points from the field measurements confirmed that the original cross-section configurations were reasonable, and provided additional information on the slope of the channel thalweg. The field data, in conjunction with the digital terrain data, indicates that the channel has mild slopes in the 10,000 foot reach downstream of the railroad bridge (sections 120,000 to 130,000 in the HEC-RAS model).

Leveloggers® were deployed in twelve locations (see Figure 3-8) along the Broad River in June, 2014. The Levelogger® data consists of river stage readings on 30-minute intervals. The data recorded during the months of June and July, 2014 included periods in which the flow cycled between low flows (less than 1,000 cfs) and greater than 10,000 cfs. The Leveloggers'® elevations were surveyed to allow conversion of the data to the same elevation datum as the HEC-RAS model (NAVD88). These data were used to adjust the vertical offset of the HEC-RAS cross-sections, in addition to the roughness coefficients. The resulting calibrated stage hydrographs from the Levelogger® collection sites are included in Appendix A.

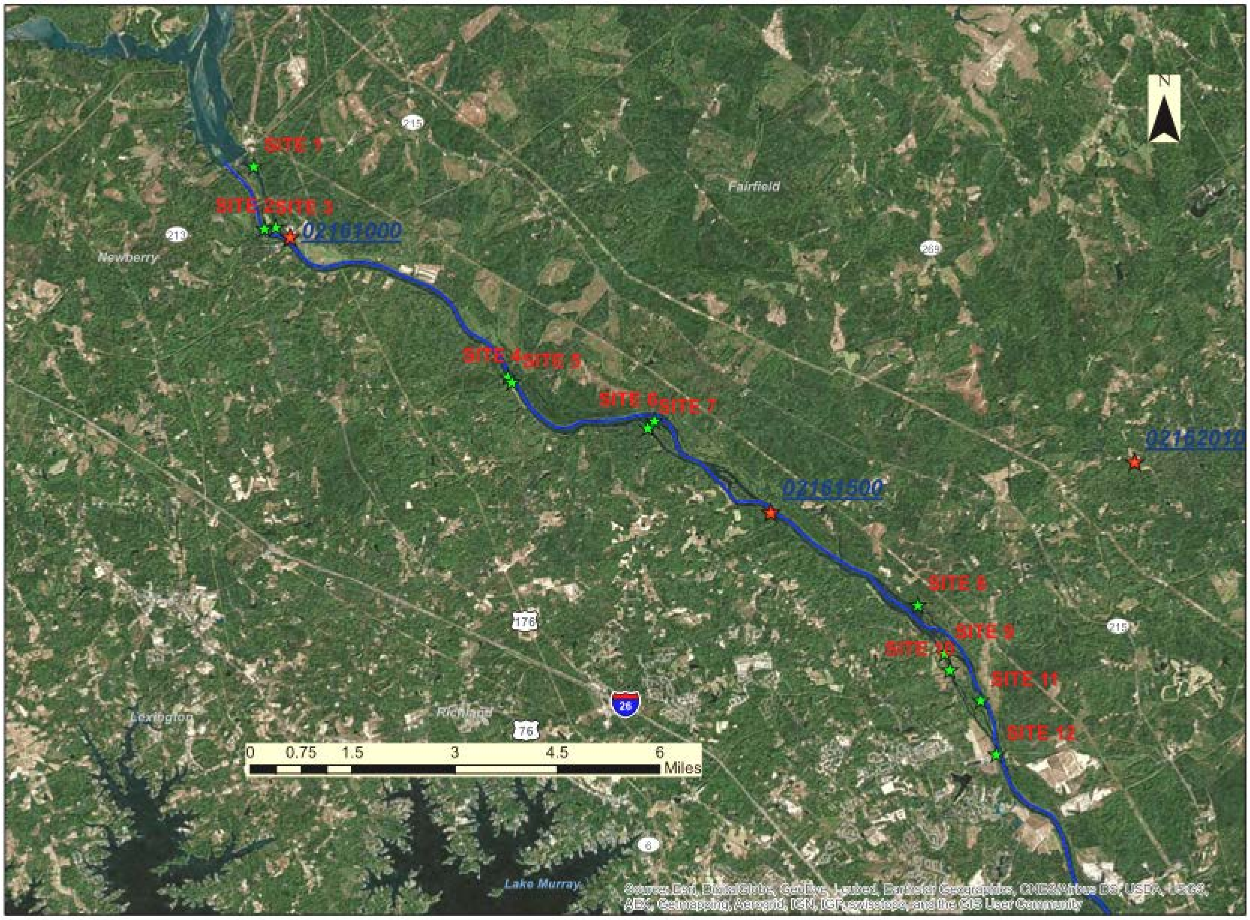

FIGURE 3-8 LEVELOGGER® SITES

4.0 RESERVOIR ROUTING (HEC-RESSIM) MODEL DEVELOPMENT

4.1 OBJECTIVES AND MODEL SETUP

The reservoir routing model (HEC-ResSim) has numerous simulation capabilities that were designed to allow the user to perform optimizations of river flows and hydroelectric generation. The model requires two general types of input, static and temporal, as well as operational rule sets. The static input consists of the fixed, physical setup of the river and reservoir system. Examples of this include the surface area and volume of the reservoir, and the capacity of the spillway and hydropower equipment. The temporal input data include the time series of reservoir inflows and evaporation. The operational constraints of the reservoir system are coded into the model input in one of two ways – as fixed values to be used in all scenarios, and operational constraints that vary among the different scenarios. Examples of this include the conservation or minimum pool level, which may be deemed a fixed value for a given project. The variable constraints may include seasonal minimum flows, which could be varied among the different scenarios.

The ResSim model for this project is configured with emphasis on the management of river flows and system losses, including evaporation. The model configuration includes the inflow to the Parr Reservoir, the pumping and generation cycles between Parr and Monticello Reservoirs, and the downstream releases from the Parr Reservoir via the spillway and powerhouse.

4.2 STATIC MODEL INPUT AND DATA SOURCES

The static model input includes the parameterization of the capacity components of the model, such as the reservoir size, the spillway capacity, and the power generation capacity. Some of the values are a single number, such as the power generation capacity of a turbine/generator unit, while others are input as rating tables, such as stage-storage curves. Static single number inputs to the model are summarized in Table 4-1. It should be noted that the hydropower computations in HEC-ResSim require efficiency parameters, but these values do not affect the simulated outflow amounts as coded in this model.

The HEC-ResSim model generates numerous time-series datasets during the simulation process. In addition to the simulated outflow and power generation values, the model generates output datasets that are primarily used to debug the model logic. A large number of output time series datasets are produced, many of which may not be useful for review (such as a reservoir threshold, representing a single value for the entire dataset series). As the Parr model produces over 280 time series datasets, an abridged tabulation of the datasets is included in Appendix B. This list contains the datasets that will be the primary focus during the evaluation of simulated operational schemes. The pathname shown in the table refers to the datasets within the model output HEC-DSS file, which is typically named "simulation.dss" and is located in the same folder as the simulation input files.

TABLE 4-1 STATIC MODEL INPUT VALUES

PARAMETER	VALUE
Generating Capacity – Parr	6 Units, total capacity 14.88 MW
Hydraulic Capacity – Parr	6,000 cfs (1,000 cfs per unit)
Generating Capacity – Fairfield	8 units, total capacity 511 MW
Hydraulic Capacity – Fairfield (Generating)	50,400 cfs (6,300 cfs per unit)
Pumping Capacity – Parr to Monticello	8 Pumps, 5,225 cfs at median head per unit
Assumed Hydropower Efficiency – Parr	70%
Assumed Hydropower Efficiency – Fairfield	85%

The following figures include the reservoir stage-area-storage curves for Parr and Monticello, the Parr tailwater curve, and the Parr spillway capacity.

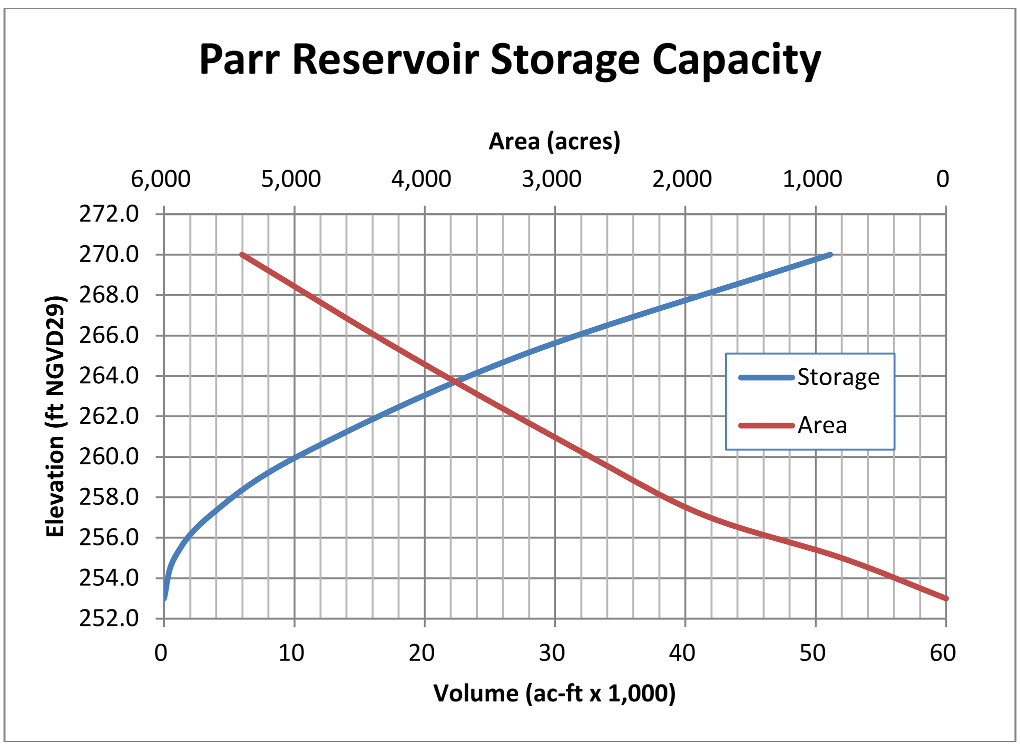

FIGURE 4-1 PARR RESERVOIR STORAGE CAPACITY

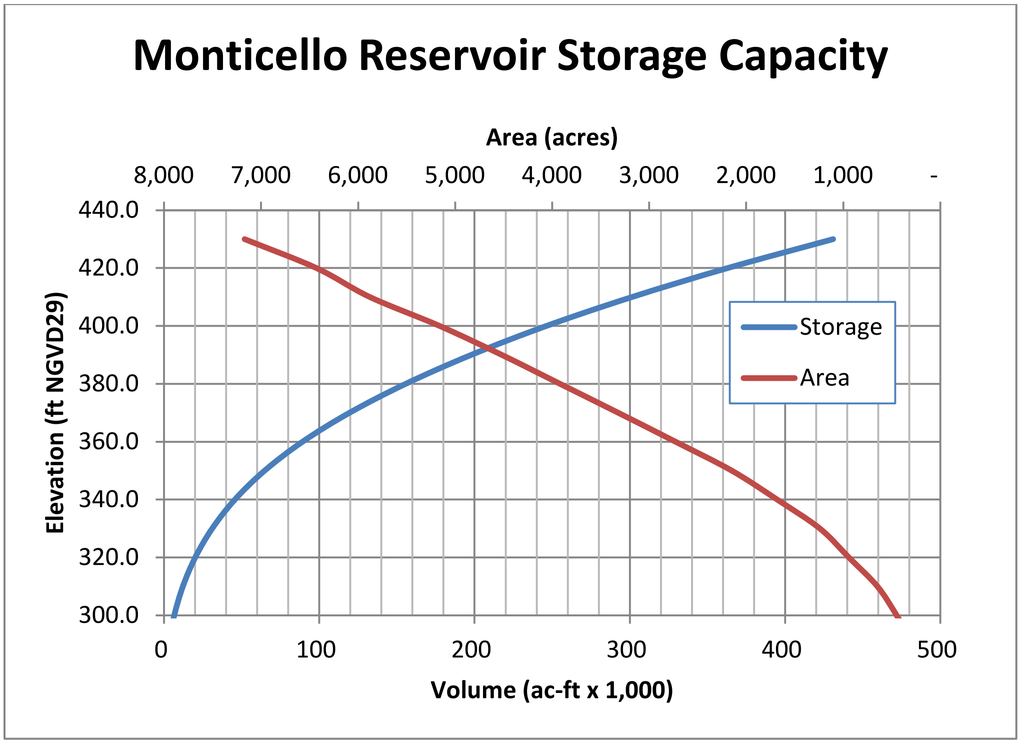

FIGURE 4-2 MONTICELLO RESERVOIR STORAGE CAPACITY

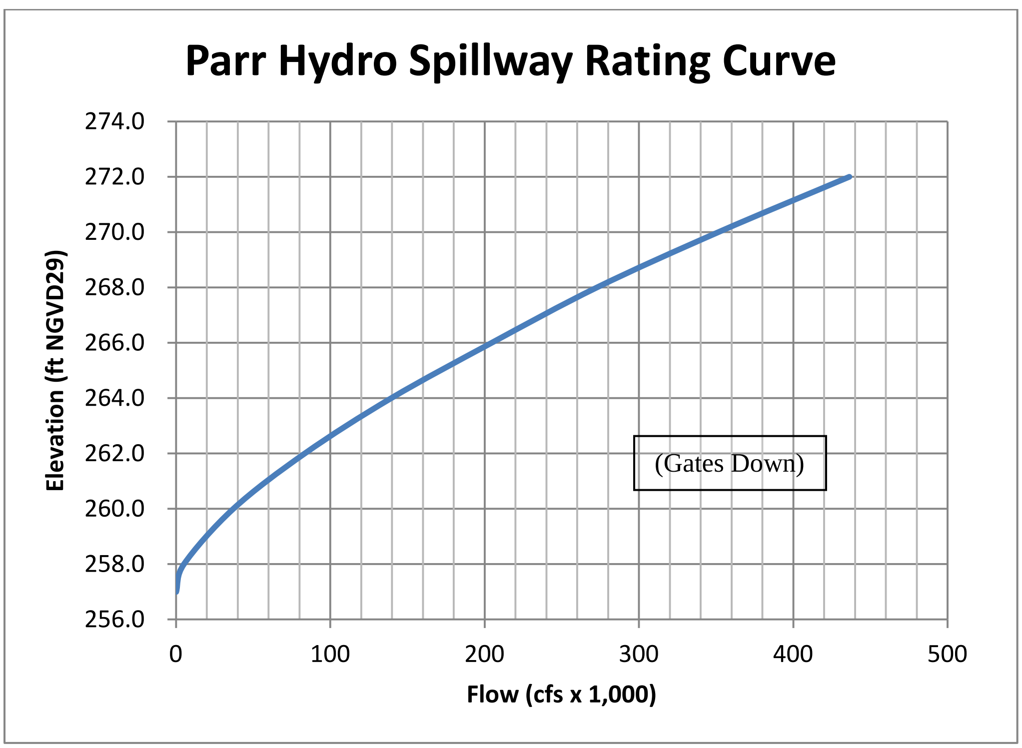

FIGURE 4-3 PARR HYDRO SPILLWAY RATING CURVE

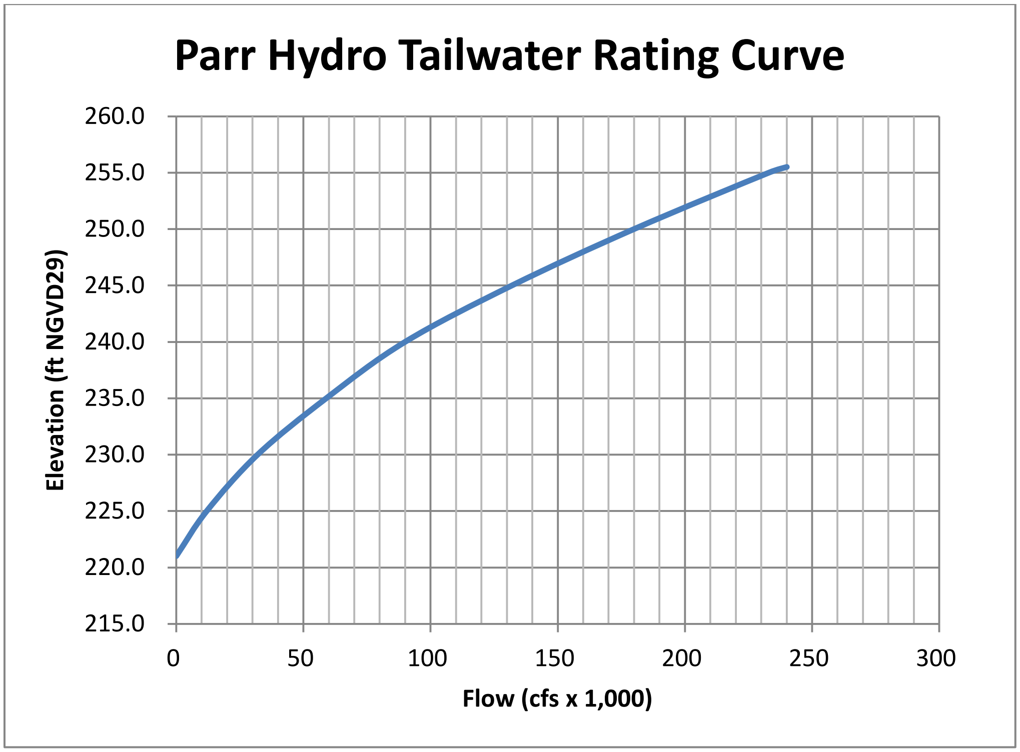

FIGURE 4-4 PARR HYDRO TAILWATER RATING CURVE

4.3 TEMPORAL MODEL INPUT - STREAMFLOW

Statistical analyses were performed to develop weighting factors to apply to the streamflow records for the nearest upstream gages on the Broad, Enoree, and Tyger Rivers. For discussion purposes, a brief synopsis of the statistical analysis follows; the complete documentation of the data development is provided in Kleinschmidt's "Inflow Dataset Development: Statistical Methodology; Parr Hydroelectric Project," August, 2014, available at: http://parrfairfieldrelicense.com/studyreport.html.

The statistical analyses used monthly and annual flow data rather than daily average flows. The daily data are affected by Project operations, which introduce a significant degree of variability due to the cyclic transfer flows between the upper and lower reservoirs. Flow releases from the project may be vastly different at any given hour from the inflows to the Parr reservoir. The monthly and annual flow data statistics are much less affected by day-to-day operations.

A multivariate regression was performed to determine the fitted regional exponent (γ), and a fitted regional coefficient (α) for estimating the inflow to Parr Reservoir based on the flows measured at three upstream USGS gages. The equation is a summation of the three upstream flow values multiplied by scaling factors, which include the ratio of the total drainage area represented by each to that gage's actual drainage area.

Equation 1: $ParrInflow = \langle \alpha * BRC \left(\frac{3250.8}{2790}\right)^{\gamma} \rangle + \langle \alpha * TRD \left(\frac{807.9}{759}\right)^{\gamma} \rangle + \langle \alpha * ERW \left(\frac{731.3}{444}\right)^{\gamma} \rangle$

where,

BRC – Broad River at Carlisle

TRD – Tyger River near Delta

ERW – Enoree River at Whitmire

α – Fitted Regional Coefficient

γ – Fitted Regional Exponent

The regional exponent was developed by quantifying the relationship between monthly streamflow averages and drainage area (see Figure 4-5) using two unregulated stream gages on the Enoree River with the longest overlapping periods of record. The result of this regression produced the drainage area regional exponent (γ) of 0.599.

Monthly flow averages from 1981 through 2013, inclusive, were normalized to perform the second regression for the drainage area coefficient (α). The target data used in the regression was the monthly average flow at the Alston gage, which was adjusted by adding the estimated evaporation from both the Monticello and Parr reservoirs (including the thermal plume effects cause by V.C. Summer Nuclear Station). The regression analysis yielded an α – coefficient of 1.041. These fitted regional values were used to produce daily inflow estimates for the 1981-2013 time periods.

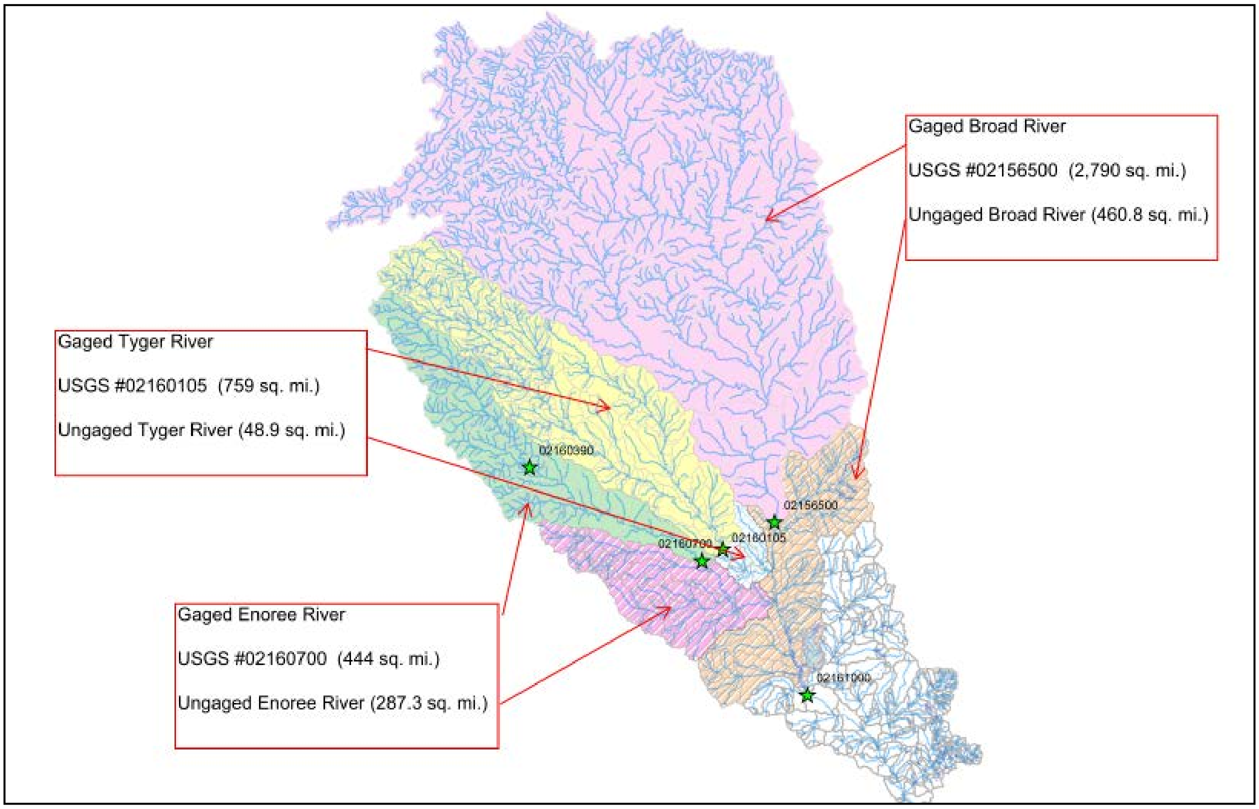

FIGURE 4-5 GAGED AND UNGAGED BROAD RIVER SUBWATERSHEDS

4.4 TEMPORAL MODEL INPUT – EVAPORATIVE LOSSES

The evaporation lost from the reservoir system is computed as a function of the daily pan evaporation and the water surface area. The pan evaporation estimate used in the HEC-ResSim model was based on values obtained from the South Carolina State Climatology Office web portal (http://www.dnr.sc.gov/climate/sco/Publications/pan_evap_tables.php#12). The Elgin pan values were used in the model, and were adjusted by a pan coefficient of 0.73, which was obtained from NOAA Technical Report NWS 33, *Evaporation Atlas for the 48 Contiguous States* (June, 1982). The monthly evaporation rates used in the model are listed in Table 4-2. Evaporation rates from the Parr and Monticello reservoirs are computed during each time step of the model simulation, based on the simulated surface area for that step.

Additional evaporation caused by the V.C. Summer Nuclear Station thermal plume effects in Monticello Reservoir is included in this analysis, and is simulated in the model as a flow diversion with a fixed monthly pattern. These monthly evaporative rates were obtained from SCE&G, and ranged in value from 20 cfs in January to 26 cfs for July.

TABLE 4-2 EVAPORATION RATES

	AVG. ELGIN PAN RATE, 1963-92 (INCH/MONTH)	ADJUSTED RATE, 0.73X (INCH/MONTH)	ADJUSTED RATE (CFS/1000 AC.)	VCS PLUME EVAP. RATE (CFS)
January	1.80	1.31	1.78	20
February	2.72	1.99	2.98	21
March	4.76	3.47	4.71	21
April	7.34	5.36	7.50	23
May	7.81	5.70	7.73	24
June	8.23	6.01	8.41	25
July	8.49	6.20	8.40	26
August	7.12	5.20	7.04	25
September	5.88	4.29	6.01	24
October	4.79	3.50	4.74	23
November	3.19	2.33	3.26	21
December	1.98	1.45	1.96	20

5.0 BASELINE SIMULATION

The general usage of the HEC-ResSim model is to simulate a range of operational schemes for a reservoir system to compare the effects of operational changes on a wide range of metrics, such as:

- Flow magnitudes and frequency;
- reservoir levels and frequency; and
- hydropower generation.

As such, the first step in the investigation process is to develop a baseline model to serve as a basis for comparison. The Parr/Fairfield baseline model (see schematic Figure 5-1) was developed with the following constraints.

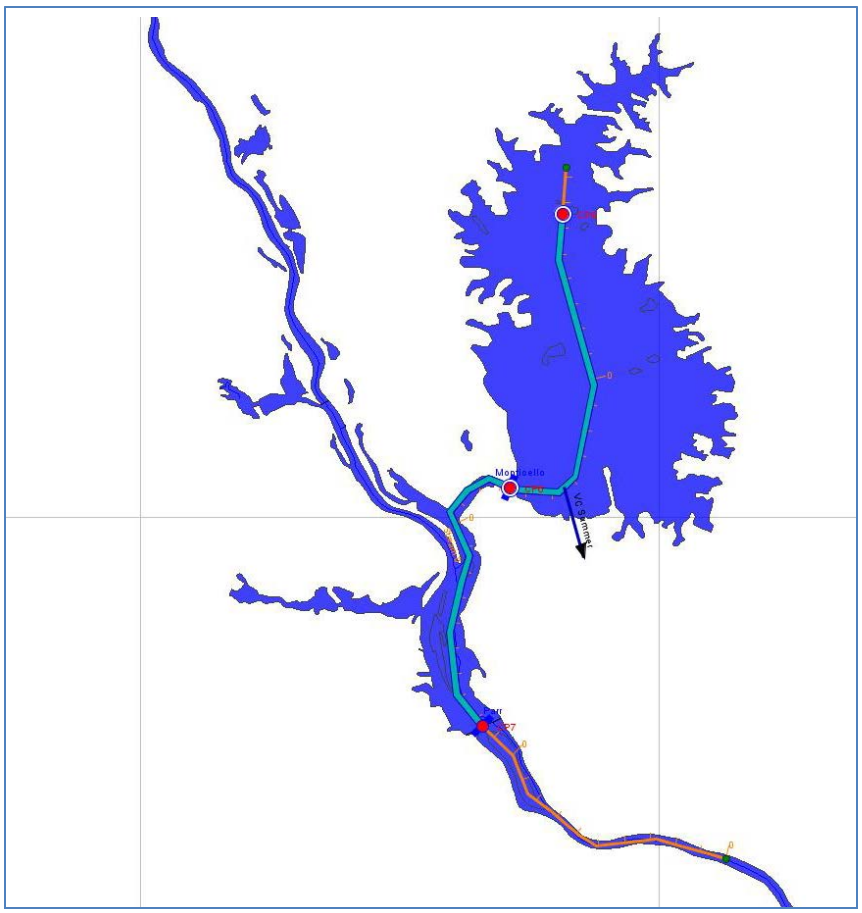

FIGURE 5-1 HEC-RESSIM SCHEMATIC

5.1 Reservoir Minimum and Maximum Stage

The model requires inputs to constrain the minimum and maximum levels. The elevation constraints are coded as conditional, which directs the model to alter operations as a function of reservoir level. The baseline model has been coded to allow fluctuations of Parr Reservoir between elevations 256.0 and 266.0 feet, and Monticello between elevations 420.5 and 425.0 feet, according to the existing license conditions.

5.2 Parr Reservoir Minimum Outflow

The baseline minimum outflow constraint for Parr Reservoir has been coded as a combination of two factors, both according to existing license conditions. The minimum outflow is set at 800 cfs for the months of June through February, and 1,000 cfs for the months of March through May. This daily minimum flow changes during periods in which the net inflow to Parr Reservoir drops below the seasonal flow. The baseline model is coded to evaluate the net inflow to Parr on a daily basis, and the model uses the greater of 150 cfs or the net inflow as the minimum flow.

5.3 Power Generation – Parr Shoals

The baseline model is coded to generate power from Parr Reservoir during periods for which the outflow is sufficient. The general constraint is to produce power for outflows in the range of 1,000 to 6,000 cfs. The simulated power generation is computed using the net head differential on a time-step basis, using the computed Parr Reservoir level and a tailwater rating curve. For the baseline condition, there are no time-dependent generation requirements coded into the model.

5.4 High Flow Releases – Parr Shoals

Gates atop the Parr Shoals dam spillway are lowered as flows increase beyond the hydraulic capacity of the powerhouse. As flows increase, gates are lowered more to pass the flows without raising the headpond above license conditions, or incur flooding of an upstream railroad (see Section 5.5). Higher inflows result in decreased gate elevations to pass inflows. The baseline model is coded to pass inflows above 6,000 cfs from the Parr Reservoir as spilled flows, within the bounds of the total outflow rating curve.

5.5 Maximum Reservoir Level Limitation for Parr – High Inflows

The baseline model has a constraint for the maximum level for Parr Reservoir, which is a function of the reservoir inflow. The intent of this constraint is to reduce the upstream railroad inundation risk that occurs during above-average flows. This constraint limits Parr Reservoir to an elevation of 266.30 feet for an inflow of 3,000 cfs, and varies linearly to an elevation of 263.28 feet for an inflow of 40,000 cfs. This control is of lower priority than the previously noted maximum reservoir constraint of elevation 266.0, therefore that elevation is not exceeded under the low flow conditions.

5.6 Power Generation – Fairfield

The baseline model is coded to generate power from Fairfield on a daily basis. The simulated power generation is computed using the net head differential on a time-step basis, using the computed Parr Reservoir level as the tailwater elevation. For the baseline condition, the model is coded to limit power generation to between the hours of 8 AM and 6 PM; however, there are no daily generation requirements coded into the model. The power generation continues within these hours until the power pool is depleted, which is set at elevation 420.5 feet.

5.7 High-Flow Power Generation Cutoff – Fairfield

There is a conditional rule for the power generation for Fairfield that constrains the power generation during high inflows. The model checks the total inflow to Parr Reservoir on a time-step basis to limit Fairfield generation as total inflow to Parr Reservoir approaches 40,000 cfs.

5.8 Pumping from Parr to Monticello

The baseline model is coded to pump from Parr to Monticello every evening, between the hours of 9 PM and 6 AM. The model simulates the beginning of pumping at the specified time, and simulated pumping continues until the target (full) upper pond level is achieved.

5.9 EVAPORATIVE LOSSES

The baseline model is coded to account for evaporative losses at Parr and Monticello Reservoirs, and V. C. Summer Nuclear Plant (VCS) Unit 1. The evaporative losses from VCS are represented in the model as a direct diversion from the Monticello Reservoir.

6.0 MODELING SYSTEM VALIDATION

The use of numerical models as part of a decision support system requires a series of validation checks to verify that the models are producing results within the expected bounds of accuracy. The Parr-Fairfield Operations Modeling System is comprised of three major components:

1. A statistically-derived streamflow dataset, representative of the daily inflows to Parr Reservoir for the period 1981 through 2013;
2. a reservoir routing model (HEC-ResSim) to simulate the operations of the Parr Reservoir and the Fairfield pumped storage project, and the resulting downstream releases to the Broad River; and
3. a river routing model (HEC-RAS) to simulate the flows released from Parr Reservoir.

The validation of the modeling data inputs and the model performance has been and will continue within each phase of the system development and deployment. The sequence of validation checks and the status of each are summarized below.

6.1 TEMPORAL MODEL INPUTS

The temporal model inputs include the streamflow and evaporation time series data. The derivation of these data sets was described in detail in a previous report, and a summary is provided herein under Section 4.3. The validation of the data was quantified by various goodness-of-fit statistics, also described in the previous report.

6.2 RESERVOIR ROUTING MODEL

The primary HEC ResSim model has been developed, and the performance of the model has been evaluated from two distinct aspects. The primary model was developed to be used as a base-case framework, from which modifications/restrictions can be applied. The operational constraints within the primary model, as described in Section 5, were developed with the intent of testing the base model's ability to simulate the full range of operations as allowed by the current license and equipment capacities. The performance evaluations of the model included the following checks:

- A check of the model for a mass balance of inflows and outflows
- A check of the model to determine if the simulated operations adhered to the intended operational constraints under varying hydrologic conditions
- A comparison of the flow duration curve from the Alston gage to the simulated outflows from Parr Reservoir

The mass balance check was performed by computing the average values of the reservoir inflow, evaporative losses, and simulated Parr Reservoir outflows over the 33-year period of record. The values, as shown in Table 6-1, show that the net balance is essentially zero. There are minor discrepancies, attributable to round-off error and differences in reservoir storage at the beginning and end of the simulation period, and historic operations that deviated from the base-case framework, which could slightly alter evaporation rates due to differences in free water surface areas on the stage-area curve. The Alston gage has an average flow of 5,195 cfs for the same period of record, approximately 205 cfs higher. This is due to an intended bias of regression to more accurately fit low flows, which are of greater interest to the stakeholders. This bias is discussed in the previous report on the inflow dataset development *(Inflow Dataset Development: Statistical Methodology, Kleinschmidt, August 2014*).

The performance of the model was also spot-checked with respect to modeling constraints. An example of this would be the minimum flow during drought conditions. The spot check was performed for a 24-hour period, starting at noon on Sep.2, 2011. The average inflow to Parr for this period was 398 cfs, which is less than the seasonal minimum flow of 800 cfs. The model is coded to release flows from Parr Reservoir in the amount of the average inflow minus the evaporative losses. The evaporative losses for the 24-hour period were approximately 84 cfs, which produces a net value of 314 cfs. The model simulated a release of 315 cfs for this period.

There were numerous other spot-checks performed in a similar manner, with respect to maximum and minimum pond levels and maximum releases. Figure 6-1 illustrates the cycling of the Monticello reservoir level between 420.5 and 425. Parr reservoir has similar pool elevation constraints (see Figure 6-2), with an additional constraint to decrease the maximum pool level during periods of increased upstream inflows. There are constraints on operation at Fairfield, which are intended to eliminate Fairfield generation when Parr outflows are in excess of 40,000 cfs.

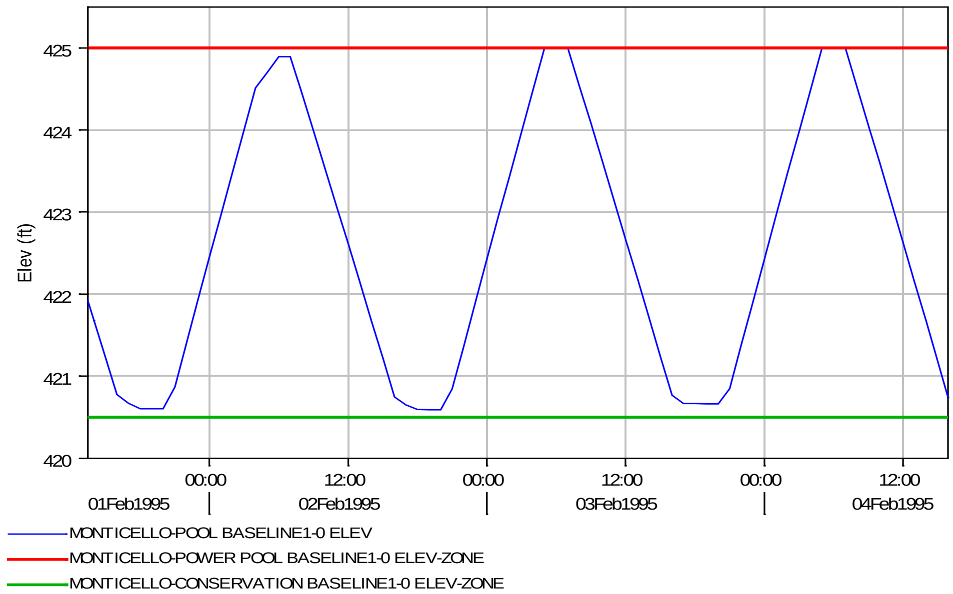

FIGURE 6-1 MONTICELLO - MAX/MIN POOL

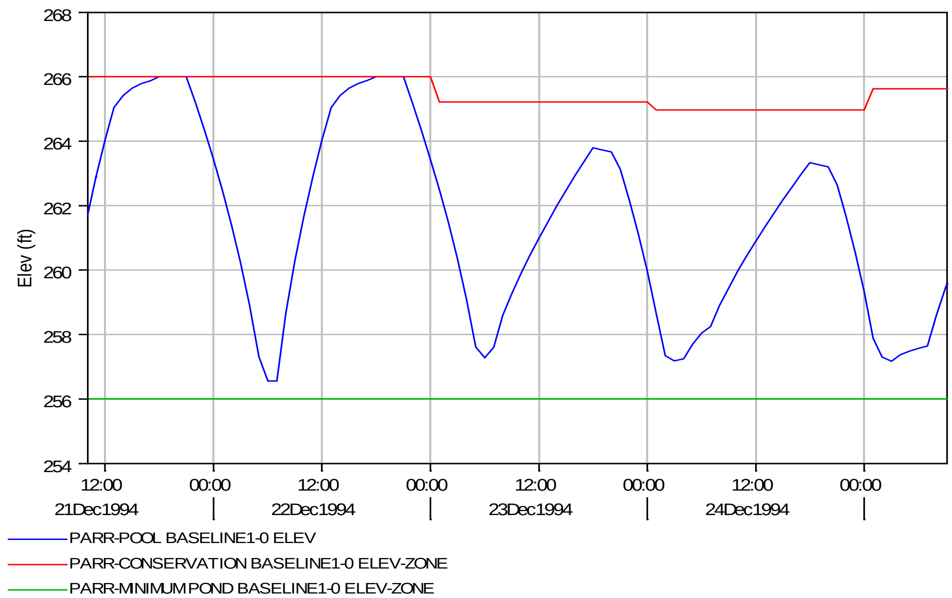

FIGURE 6-2 PARR MAX/MIN POOL

7/7 – normal Fairfield generation	7/8 – increased Parr inflow, decreased Fairfield generation	7/9 – high Parr inflow, no Fairfield generation	7/10 – increased Parr inflow, decreased Fairfield generation

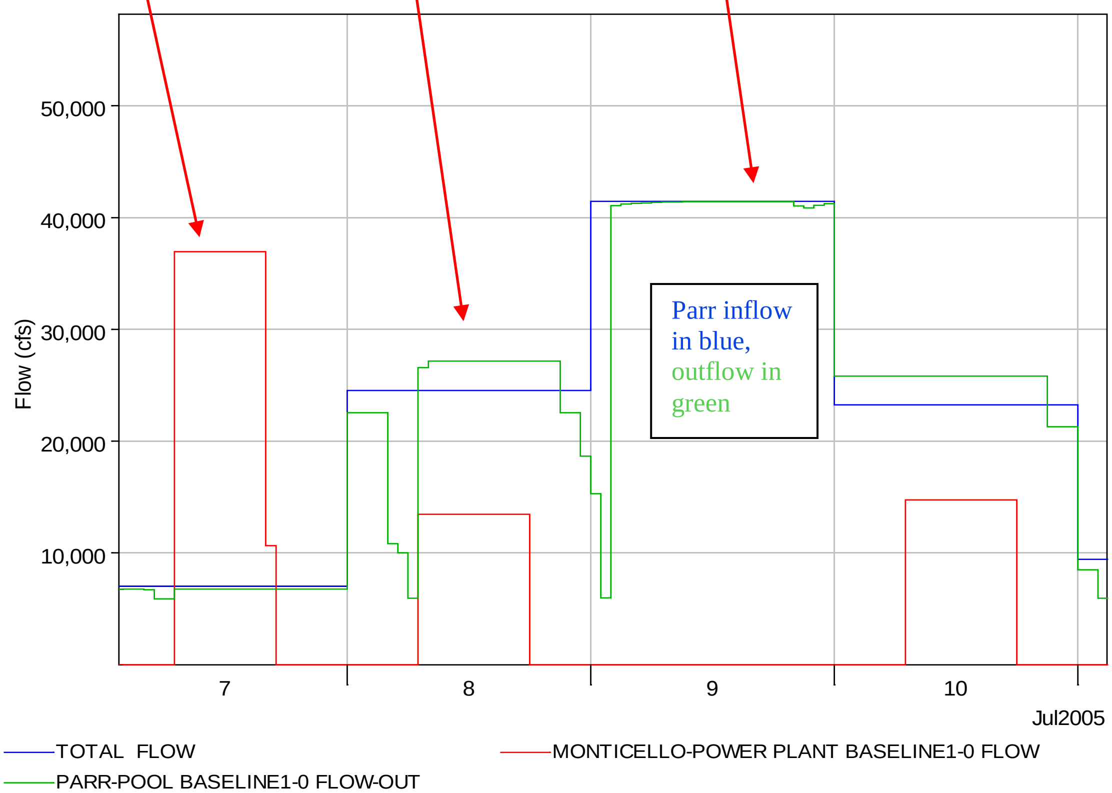

FIGURE 6-3 FAIRFIELD GENERATION CURTAILMENT

Figure 6-3 illustrates a simulated time period that includes a cycle of increasing and decreasing Parr inflows, and the constrained Fairfield generation during the time periods such that the added Fairfield outflows do not artificially induce downstream flooding.

TABLE 6-1 HYDROLOGIC MASS BALANCE

Hydrologic Component	Average Value, 1981 – 2013 (cfs)
Estimated Inflow to Parr Reservoir (/Parr Reservoir/Total/Flow/*/1Hour/-Baseline1-0/)*	5066.7
Simulated evaporation from Parr Reservoir (/ /Parr-Pool/Flow-Evap/Flow/*/1Hour/-Baseline1-0/)*	17.7
Simulated evaporation from Monticello Reservoir (//Monticello-Pool/Flow-Evap/Flow/*/1Hour/-Baseline1-0/)*	35.7
Assumed evaporative losses at VC Summer Nuclear Plant Unit 1 (//Monticello-VC Summer Tailwater/Flow/*/1Hour/Baseline1-0)*	22.8
Estimated Inflow minus Evaporative Losses)	4990.5
Simulated outflow from Parr Reservoir (/ /Parr-Pool/Flow-Out/Flow/*/1Hour/-Baseline1-0/)*	4990.3

*Data set from DSS output file

As a final check of the base model, the flow duration curve of the simulated outflow from Parr Reservoir was computed for the 33-year period of record. This flow duration curve was compared to that of the Alston gage, for the same time period. The resulting comparison, shown graphically in Figure 6-4 and Figure 6-4, show that the flow duration curves match very closely for flows below 1,000 cfs, and are within 3% of expected frequency for the flows greater than 1,000 cfs. This comparison is indicative of the combination of the statistical derivation of the estimated inflows and the results of simulating the estimated inflows with HEC-ResSim. Therefore, discrepancies between the flow duration curves may be attributable to either component.

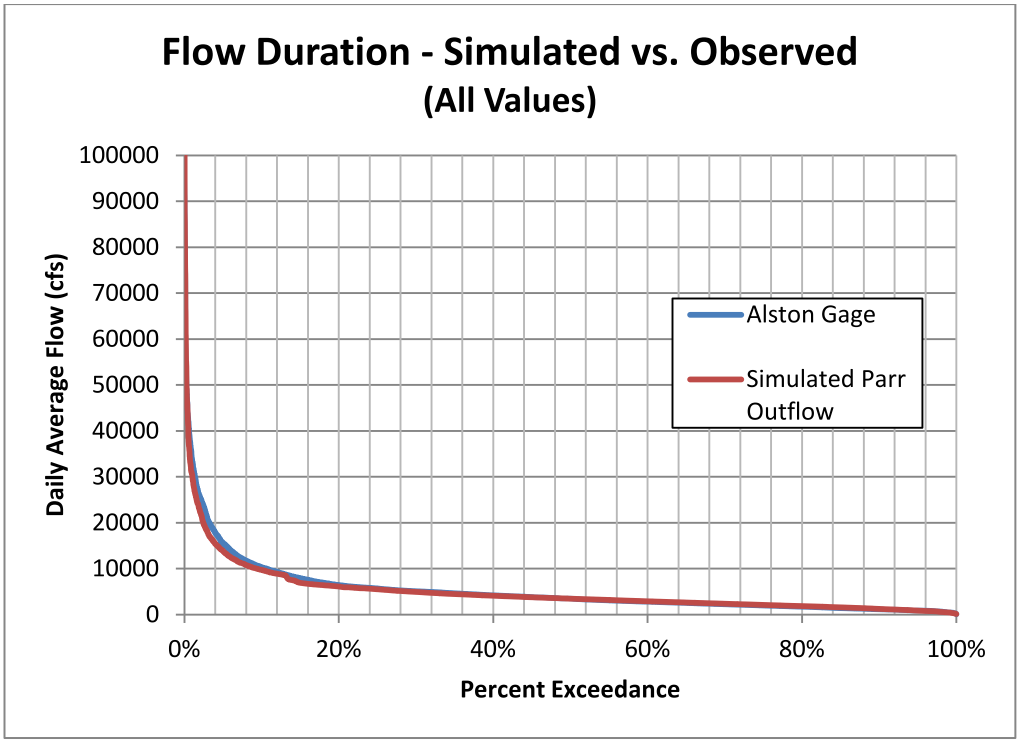

FIGURE 6-4 FLOW DURATION – RESSIM VS ALSTON, ALL VALUES

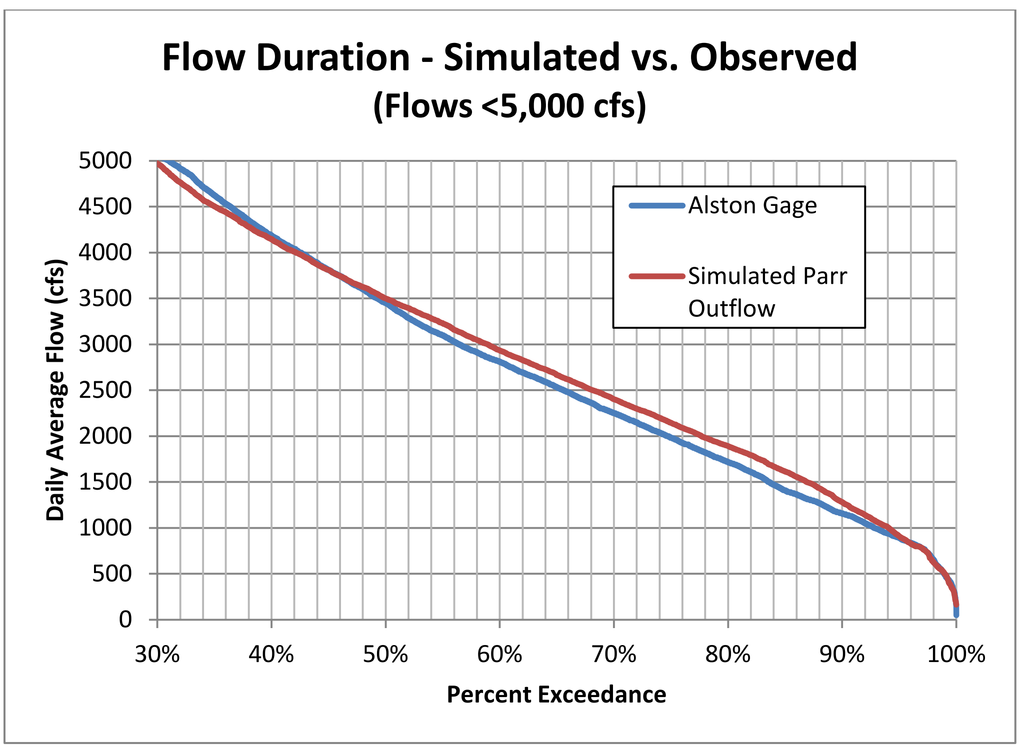

FIGURE 6-5 FLOW DURATION - RESSIM VS ALSTON, FLOWS < 5,000 CFS

6.3 RIVER ROUTING MODEL

The river routing model (HEC-RAS) is generally referred to as a closed system, which performs mass balance checks as part of the simulation. The primary performance checks for the HEC-RAS model are essentially identical to the evaluations performed as part of the calibration of the model, which include a comparison of simulated flow and stage values at various locations along the river. The calibration comparisons are fully described in Sections 3-5 and 3-6.

APPENDIX A
CALIBRATION PLOTS

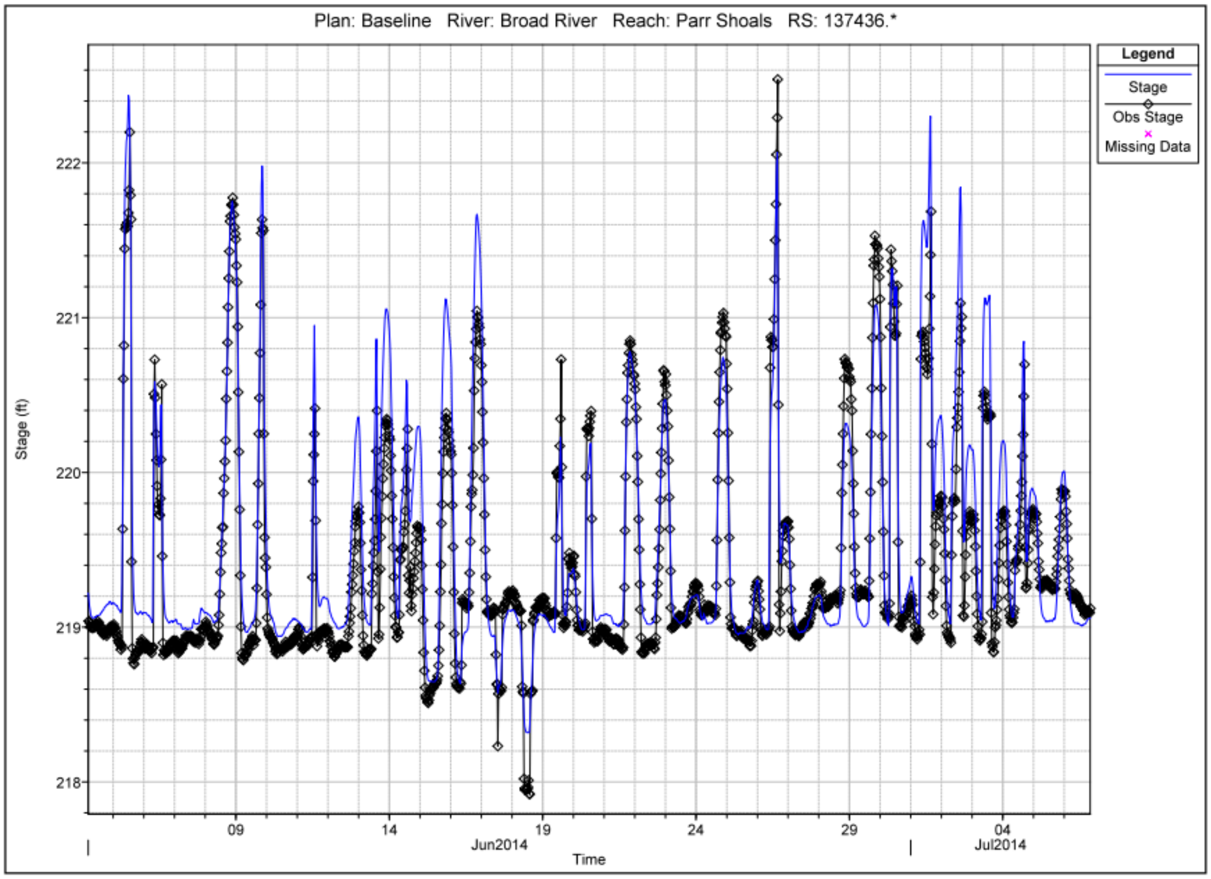

FIGURE A-6-6 CALIBRATION PLOT – SITE 1

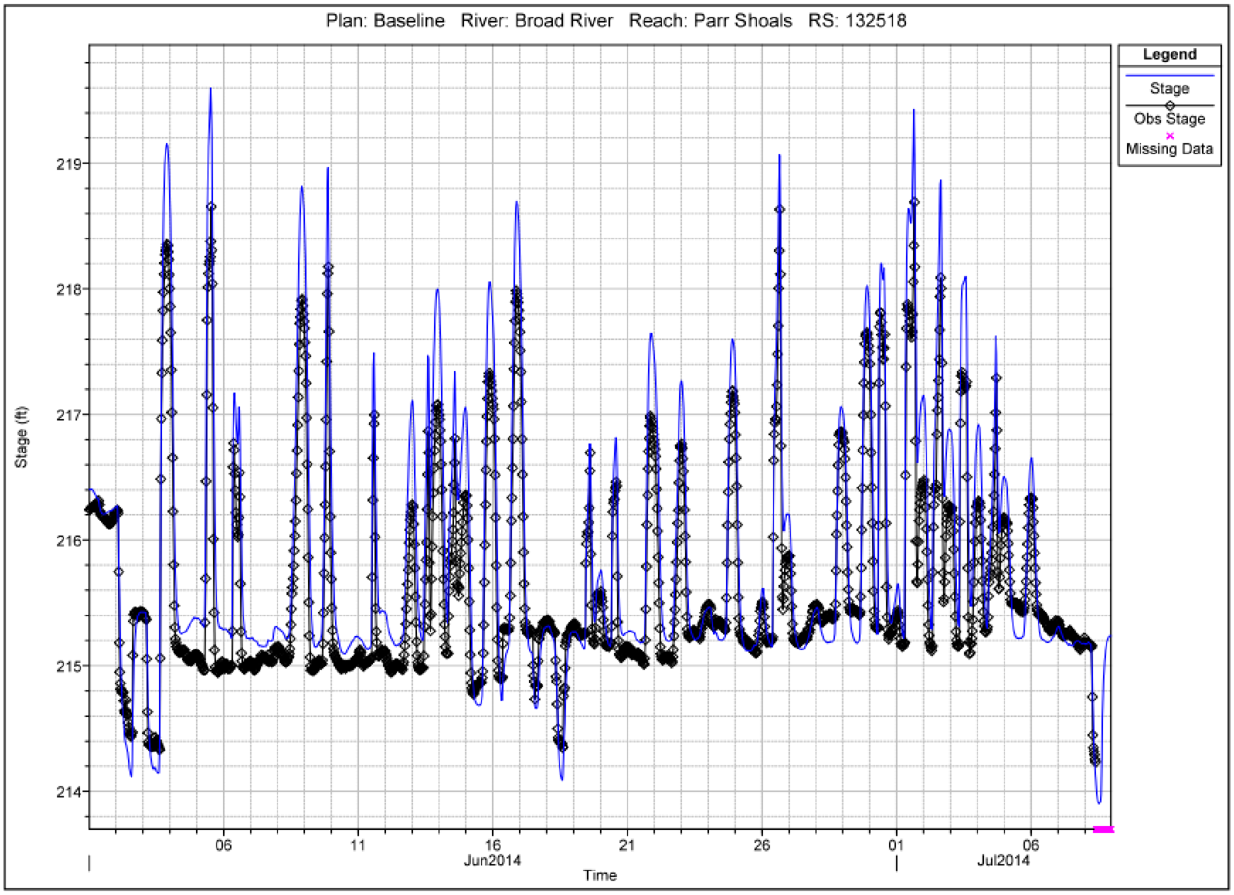

FIGURE A-6-7 CALIBRATION PLOT – SITE 2 / 3

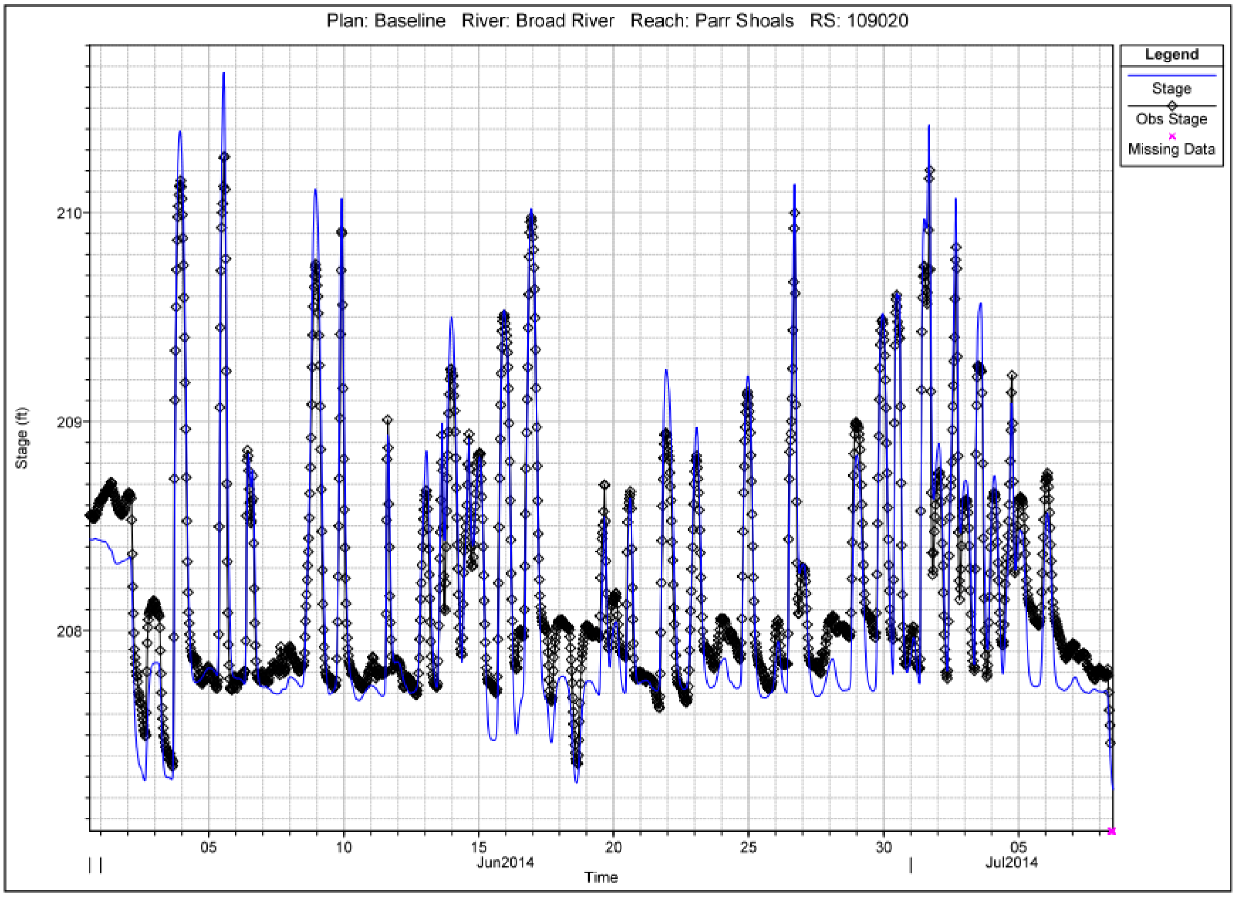

FIGURE A-6-8 CALIBRATION PLOT – SITE 4

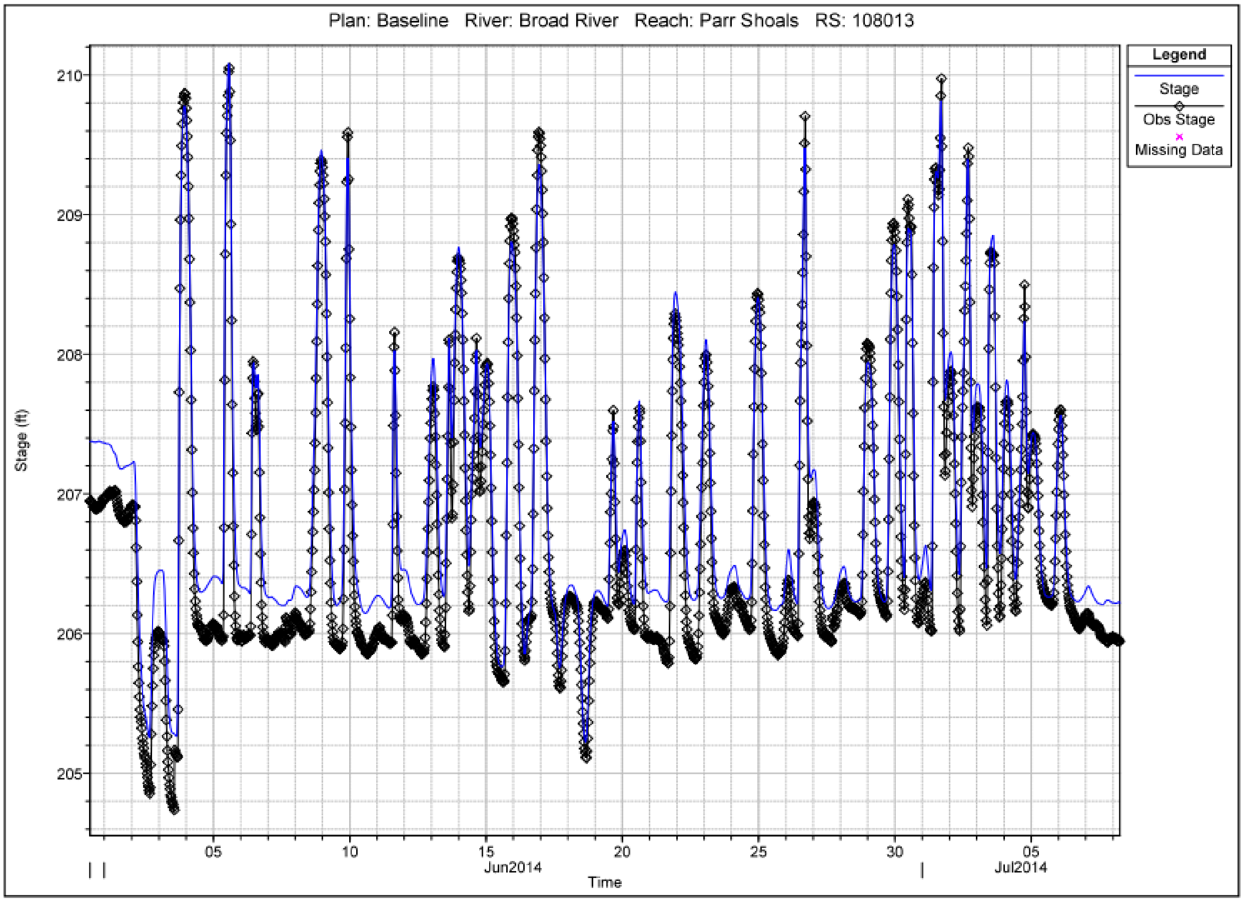

FIGURE A-6-9 CALIBRATION PLOT – SITE 5

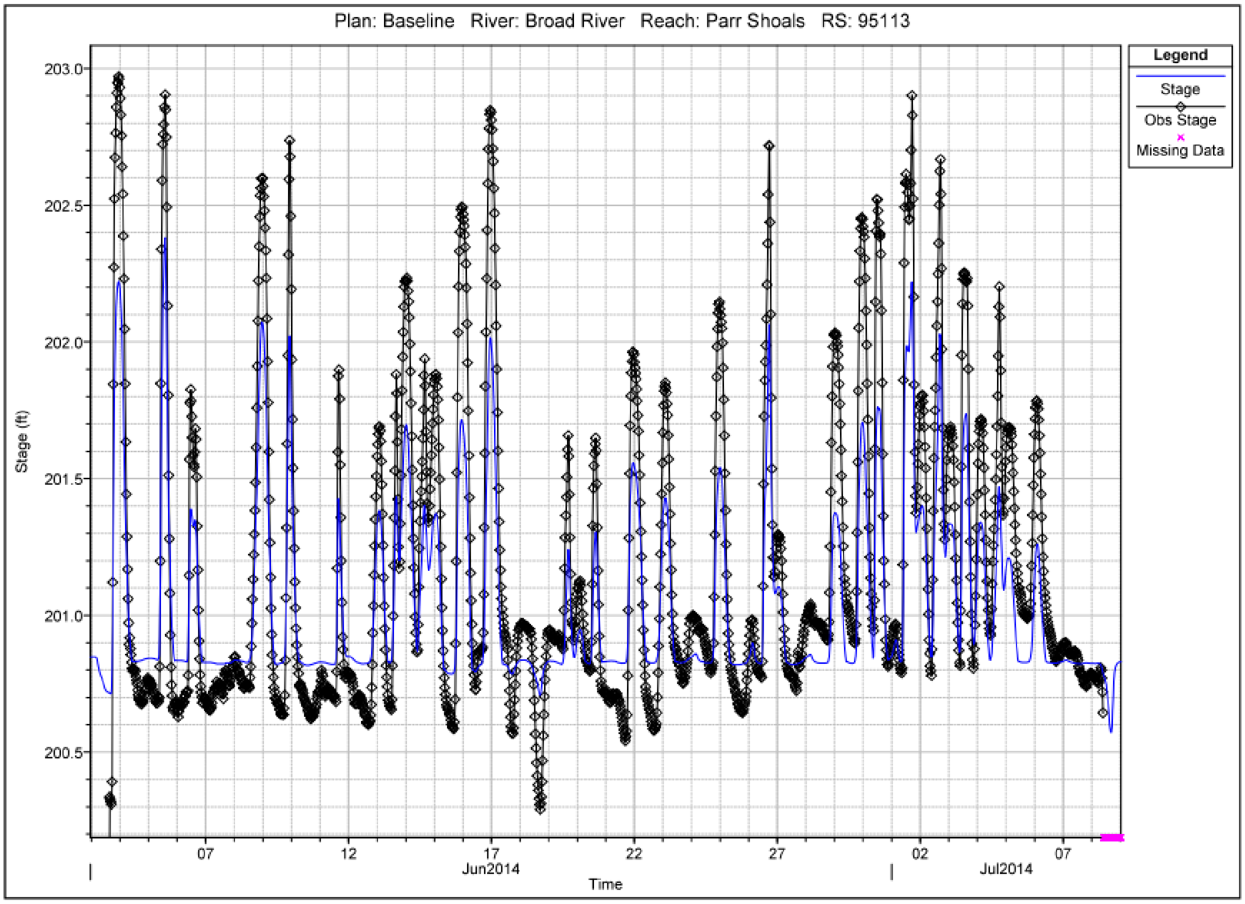

FIGURE A-6-10 CALIBRATION PLOT – SITES 6 / 7

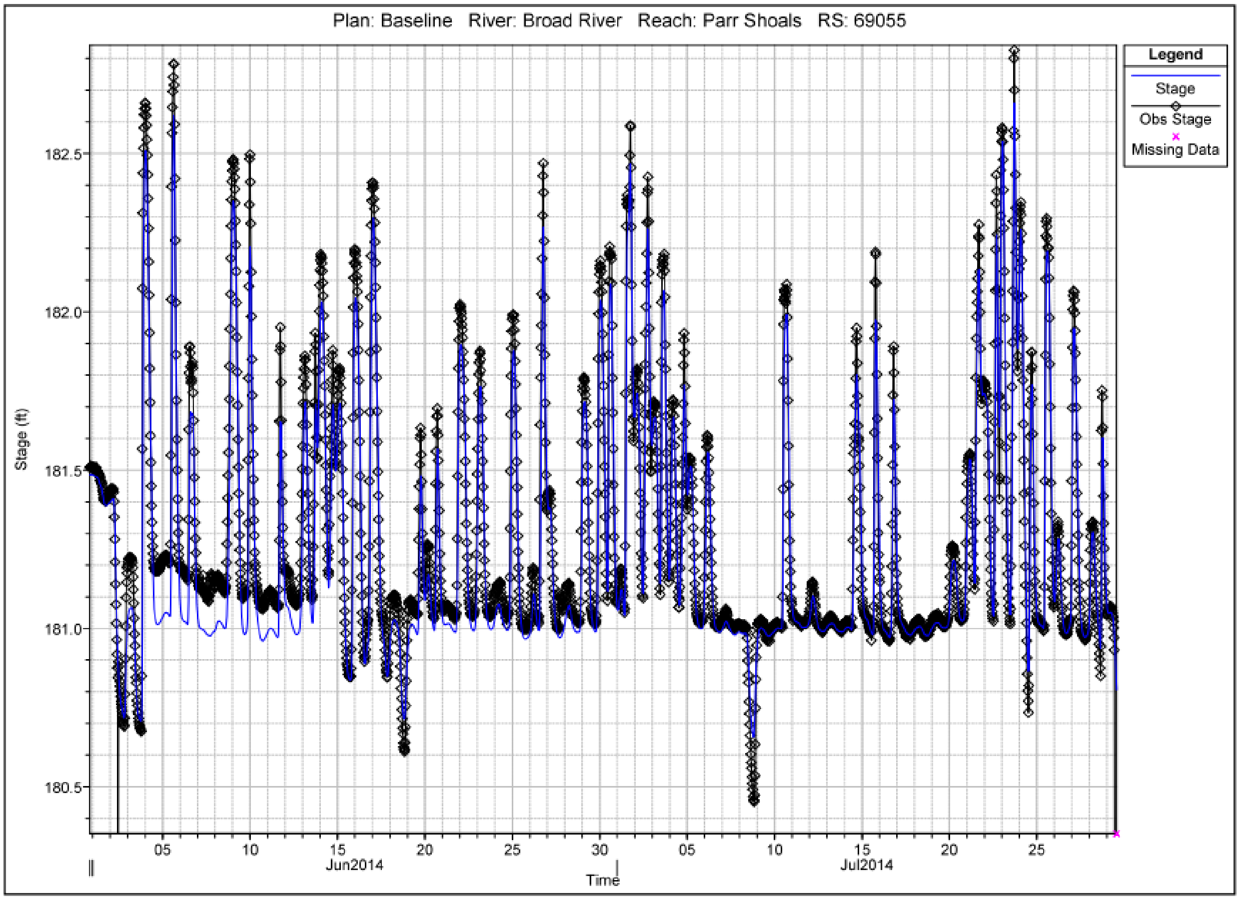

FIGURE A-6-11 CALIBRATION PLOT – SITES 8

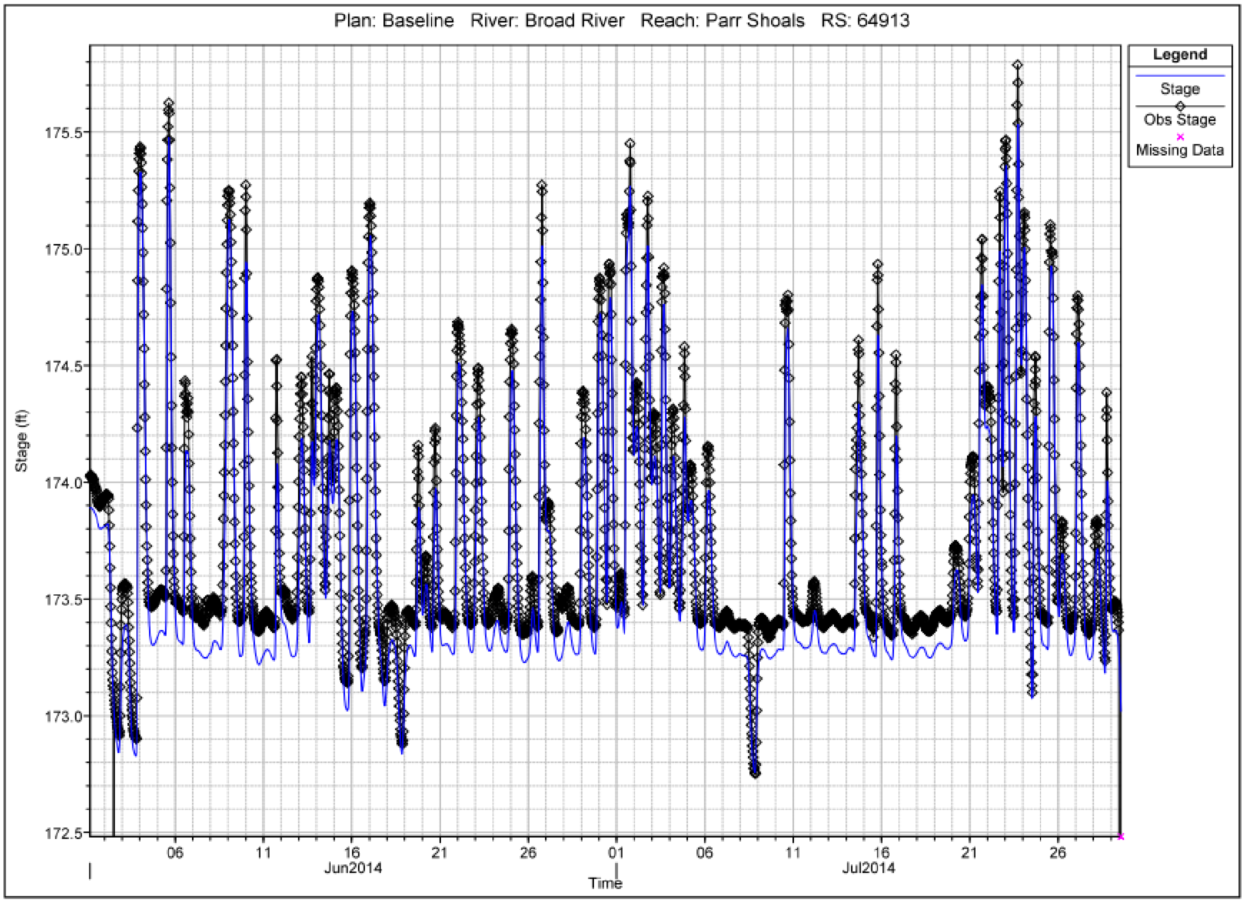

FIGURE A-6-12 CALIBRATION PLOT – SITES 9

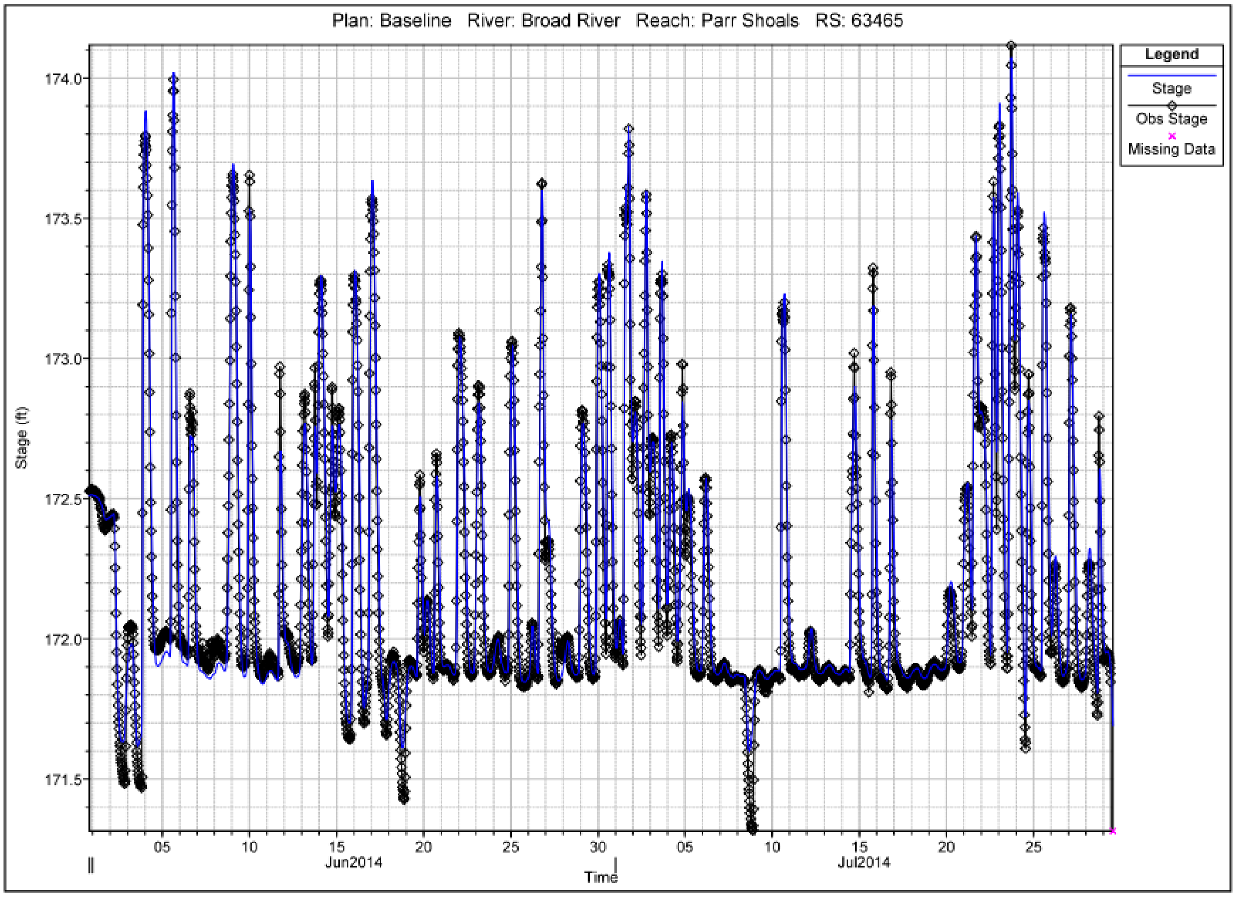

FIGURE A-6-13 CALIBRATION PLOT – SITE 10

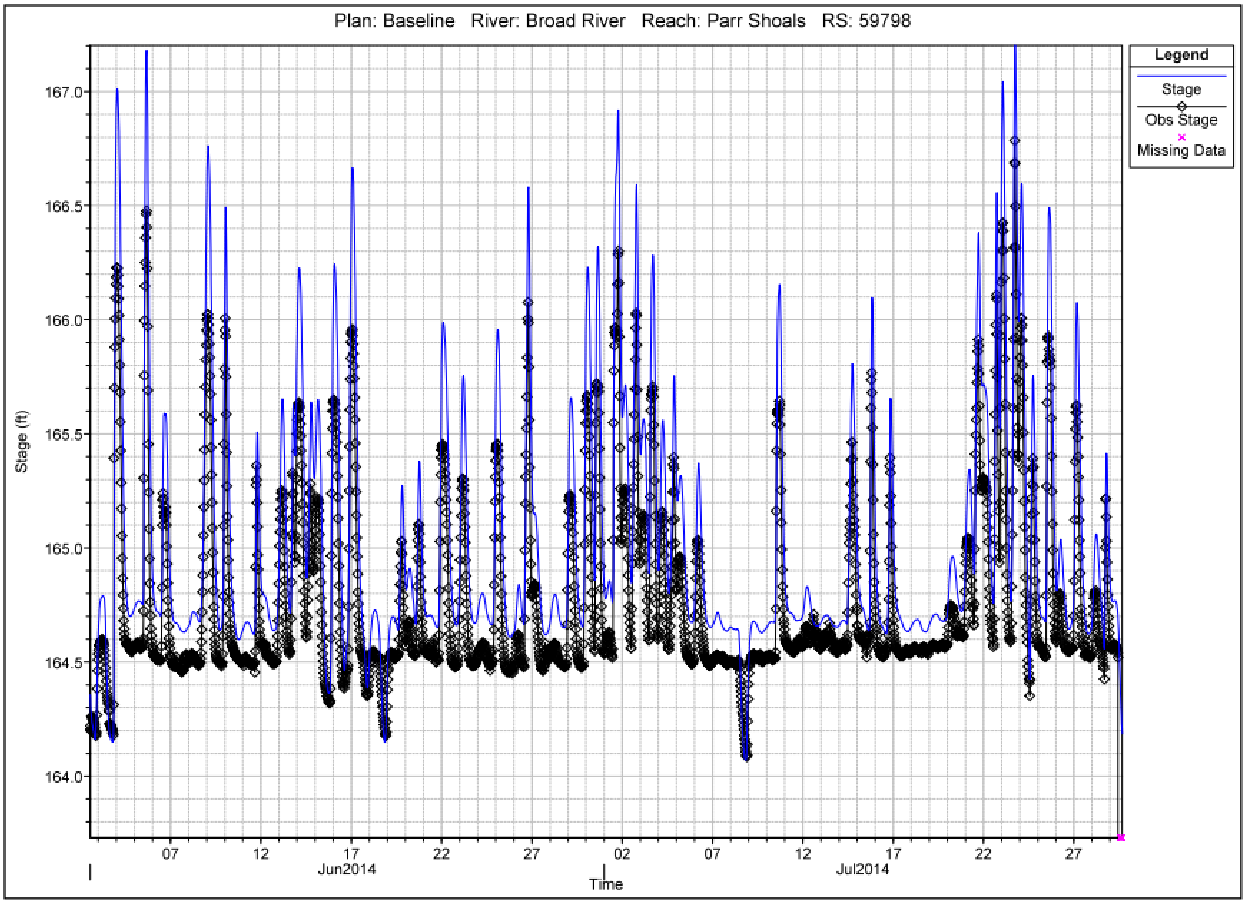

FIGURE A-6-14 CALIBRATION PLOT – SITE 11

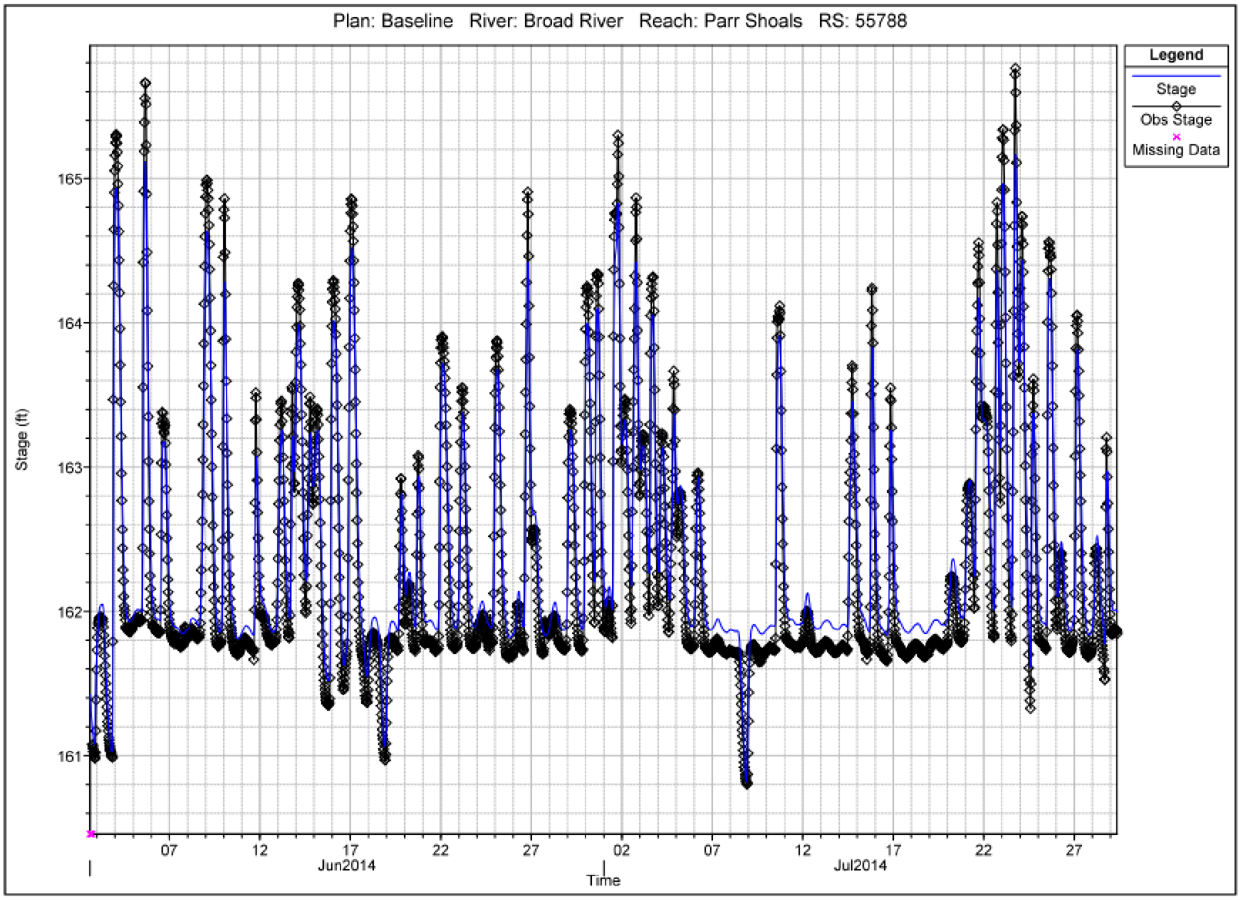

FIGURE A-6-15 CALIBRATION PLOT – SITE 12

APPENDIX B
HEC-RESSIM DATA INDEX

DATA SET	UNITS	HEC-DSS PATHNAME
Parr - upstream inflow	cfs	/PARR RESERVOIR/TOTAL/FLOW//1DAY//
Parr – evaporation loss	cfs	//PARR-POOL/FLOW-EVAP//1HOUR/BASELINE1-0/
Parr - spill	cfs	//PARR-CONTROLLED OUTLET/FLOW//1HOUR/BASELINE1-0/
Parr - powerhouse outflow	cfs	//PARR-POWER PLANT/FLOW//1HOUR/BASELINE1-0/
Parr - total outflow	cfs	//PARR-POOL/FLOW-OUT//1HOUR/BASELINE1-0/
Parr - power	MW	//PARR-POWER PLANT/POWER//1HOUR/BASELINE1-0/
Parr - generation	MWh	//PARR-POWER PLANT/ENERGY//1HOUR/BASELINE1-0/
Parr - stage	feet	//PARR-POOL/ELEV//1HOUR/BASELINE1-0/
Parr - volume	ac-ft	//PARR-POOL/STOR//1HOUR/BASELINE1-0/
Parr - target max stage	feet	//PARR-CONSERVATION/ELEV-ZONE//1HOUR/BASELINE1-0/
Parr - target min stage	feet	//PARR-MINIMUM POND/ELEV-ZONE//1HOUR/BASELINE1-0/
Fairfield – power	MW	//MONTICELLO-POWER PLANT/POWER//1HOUR/BASELINE1-0/
Fairfield – generation	MWh	//MONTICELLO-POWER PLANT/ENERGY//1HOUR/BASELINE1-0/
Fairfield - powerhouse outflow	cfs	//MONTICELLO-POWER PLANT/FLOW//1HOUR/BASELINE1-0/
Fairfield – pumping	cfs	//MONTICELLO-PUMP-PUMP0/FLOW-PUMP-AVG//1HOUR/BASELINE1-0/
Monticello – stage	feet	//MONTICELLO-POOL/ELEV//1HOUR/BASELINE1-0/
Monticello – volume	ac-ft	//MONTICELLO-POOL/STOR//1HOUR/BASELINE1-0/
Monticello - target max stage	feet	//MONTICELLO-POWER POOL/ELEV-ZONE//1HOUR/BASELINE1-0/
Monticello - target min stage	feet	//MONTICELLO-CONSERVATION/ELEV-ZONE//1HOUR/BASELINE1-0/
Monticello - evaporation loss	cfs	//MONTICELLO-POOL/FLOW-EVAP//1HOUR/BASELINE1-0/
VC Summer - eq. evaporation loss	cfs	//MONTICELLO-VC SUMMER TAILWATER/FLOW//1HOUR/BASELINE1-0/

Exhibit E-2 Operations

Parr-Fairfield Operations Modeling System Addendum 2

PARR-FAIRFIELD
OPERATIONS MODELING SYSTEM
Addendum 2

PARR HYDROELECTRIC PROJECT

FERC NO. 1894

Prepared for:

South Carolina Electric & Gas Company
Columbia, South Carolina

Prepared by:

Kleinschmidt

Lexington, South Carolina
www.KleinschmidtGroup.com

May 2016

PARR-FAIRFIELD OPERATIONS MODELING SYSTEM
Addendum 2

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ADDENDUM 2

PARR HYDROELECTRIC PROJECT
FERC NO. 1894

SOUTH CAROLINA ELECTRIC & GAS COMPANY

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PARR-FAIRFIELD OPERATIONS MODELING SYSTEM
ADDENDUM 2

PARR HYDROELECTRIC PROJECT
FERC NO. 1894

SOUTH CAROLINA ELECTRIC & GAS COMPANY

1.0 INTRODUCTION

In support of the ongoing studies and relicensing efforts for the Parr Hydroelectric Project, a model of the project's hydrology and hydraulics was created to assess the ability to change operations, and determine the potential effects of changes in project operations. The details of the methods used to create the model are summarized in "Parr-Fairfield Operations Modeling System," Kleinschmidt, December 2014, and in Addendum 1, April 2015. In support of modeling the historic and future load conditions under existing license conditions, load datasets were added to the model. This Addendum 2 describes those additions, as well as modifications to the model made since the initial report and Addendum 1.

2.0 INFLOW DATASET UPDATE

The original model inflow data set spanned the years 1981 through 2013. The estimated inflows to Parr Reservoir were based on the results of a regression analysis of the three nearest upstream gages as compared to the flows at the Alston gage, as described in “Inflow Dataset Development: Statistical Methodology,” Kleinschmidt, August 2014. Because of the ongoing USGS data collection, the inflow dataset has been extended to incorporate the hydrologic period through the end of 2015 (calendar year).

3.0 BASE MODEL STRUCTURE

The model structure was developed with the ability to 1) simulate the full range of operations as allowed by the current license and project's physical constraints, and 2) accurately simulate the power generation for Parr and Fairfield. In order to accurately simulate the power quantities, the model requires an accurate assessment of the gross head differential at each plant, as well as the net head losses and overall generation efficiency.

As described in Addendum 1, the model includes input features to control the minimum flow release from Parr and a consumptive use by the VC Summer Nuclear plant. There were also constraints that went into effect during high inflows to Parr reservoir, which limited the maximum reservoir level and the flow component from Fairfield generation.

4.0 SCENARIO MODELS

The most significant change to the overall reservoir modeling system is the addition of power generation target data. The base model structure was programmed to generate power with the only limitation being the amount of volume in the reservoirs. The base model utilized the full volume of Fairfield, to the extent possible. The primary limitation in the scenario model was during dry periods, which was caused by the slow depletion of system storage due to evaporation and minimum flow requirements.

Accompanying the development of the scenario model was the processing of the generation and load data for the Fairfield pumped storage development. There are currently two load data input sets, one representing the historic scenario and the other the future scenario. The historic scenario incorporates actual hourly generation data from the period January 1, 2000 through the end of 2015. This data set was used to develop a data set for the full 1983-2015 period by duplication. The 2000-2015 data set was copied into the period 1984 to 1999, and the years 1981 to 1983 were copies of 2013-2015.

The future scenario incorporates simulated generation and load data for the year 2030, subsequent to the addition of two nuclear generator units. This data set was copied 35 times to fill in the 35 year period associated with the inflow dataset. The leap year days were filled in with a copy of the February 28 data. The simulated dataset was vetted to ensure the capacity of the facility to accommodate individual cycles of generation and pumping.

5.0 SUMMARY

The historic and future scenarios have been tested, and can simulate the 35-year period of record. During the evaluation of proposed license alternatives, simulations can incorporate proposed changes to operational constraints. Comparison of those simulated results may then be compared with the baseline historic and future scenarios.

A graphic representation of the historic and future load demands and upper reservoir fluctuations for two selected periods of the year are provided below.

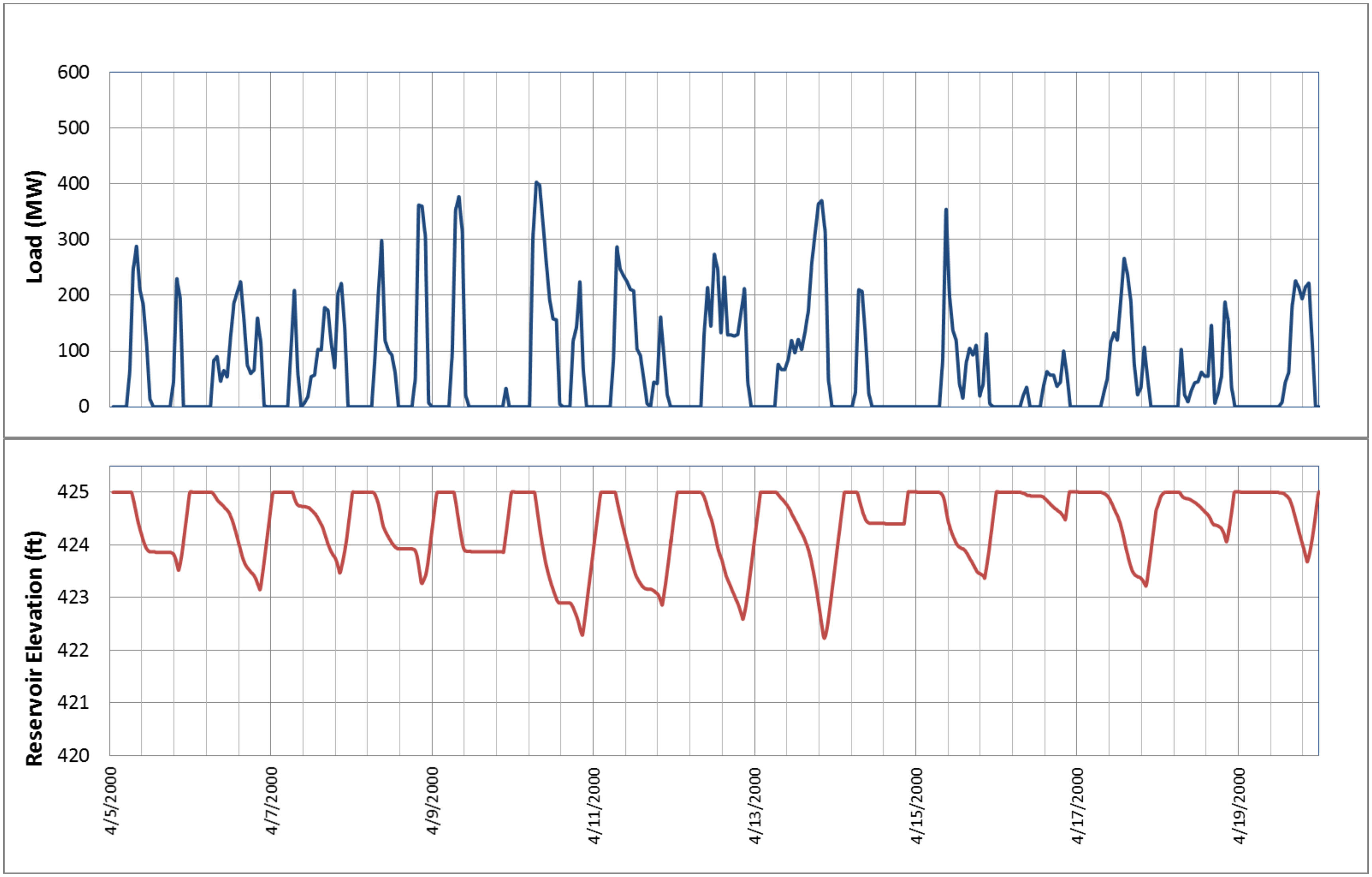

FIGURE 5-1 FAIRFIELD HISTORIC SPRING LOADS AND LAKE MONTICELLO STAGE

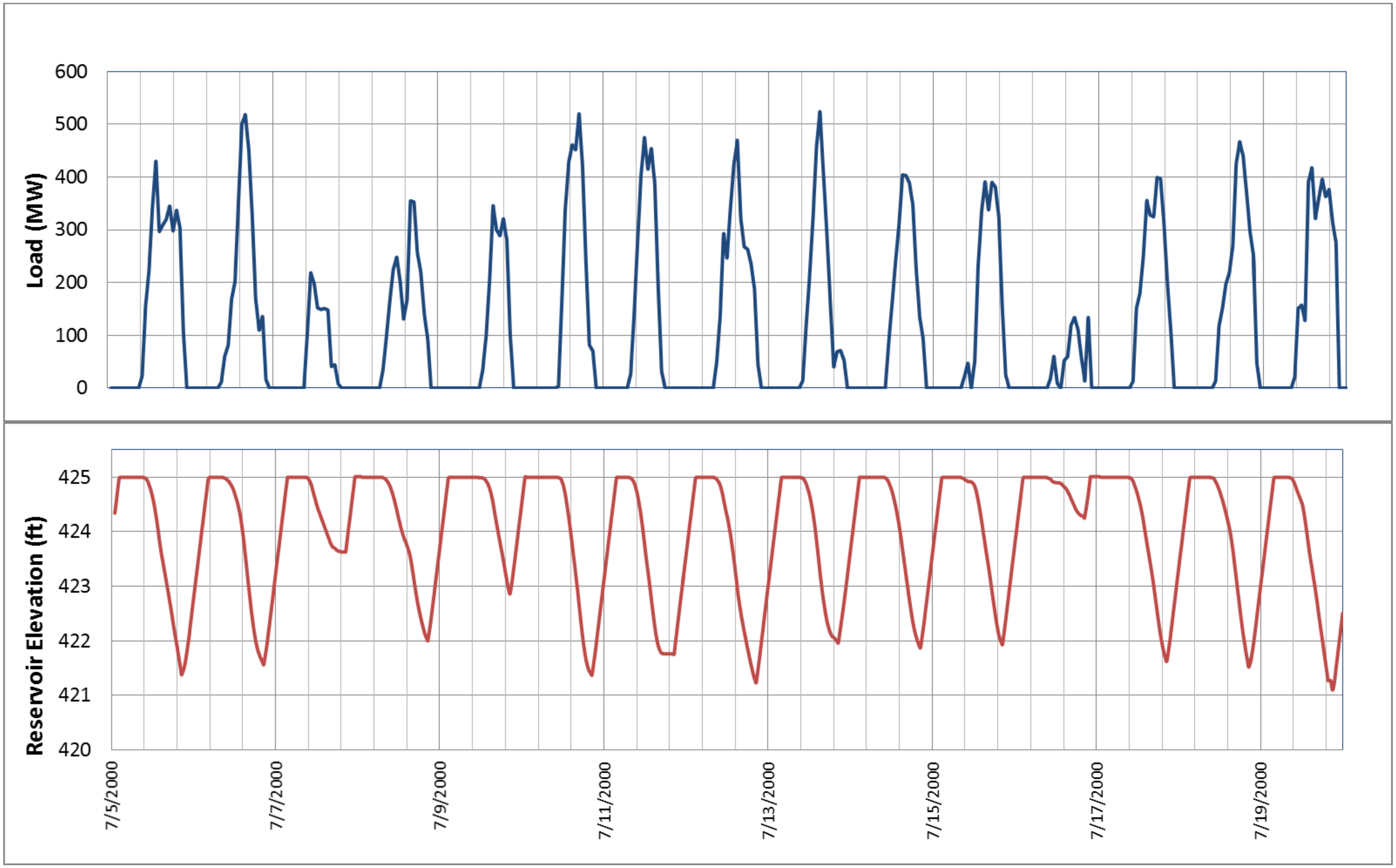

FIGURE 5-2 FAIRFIELD HISTORIC SUMMER LOADS AND LAKE MONTICELLO STAGE

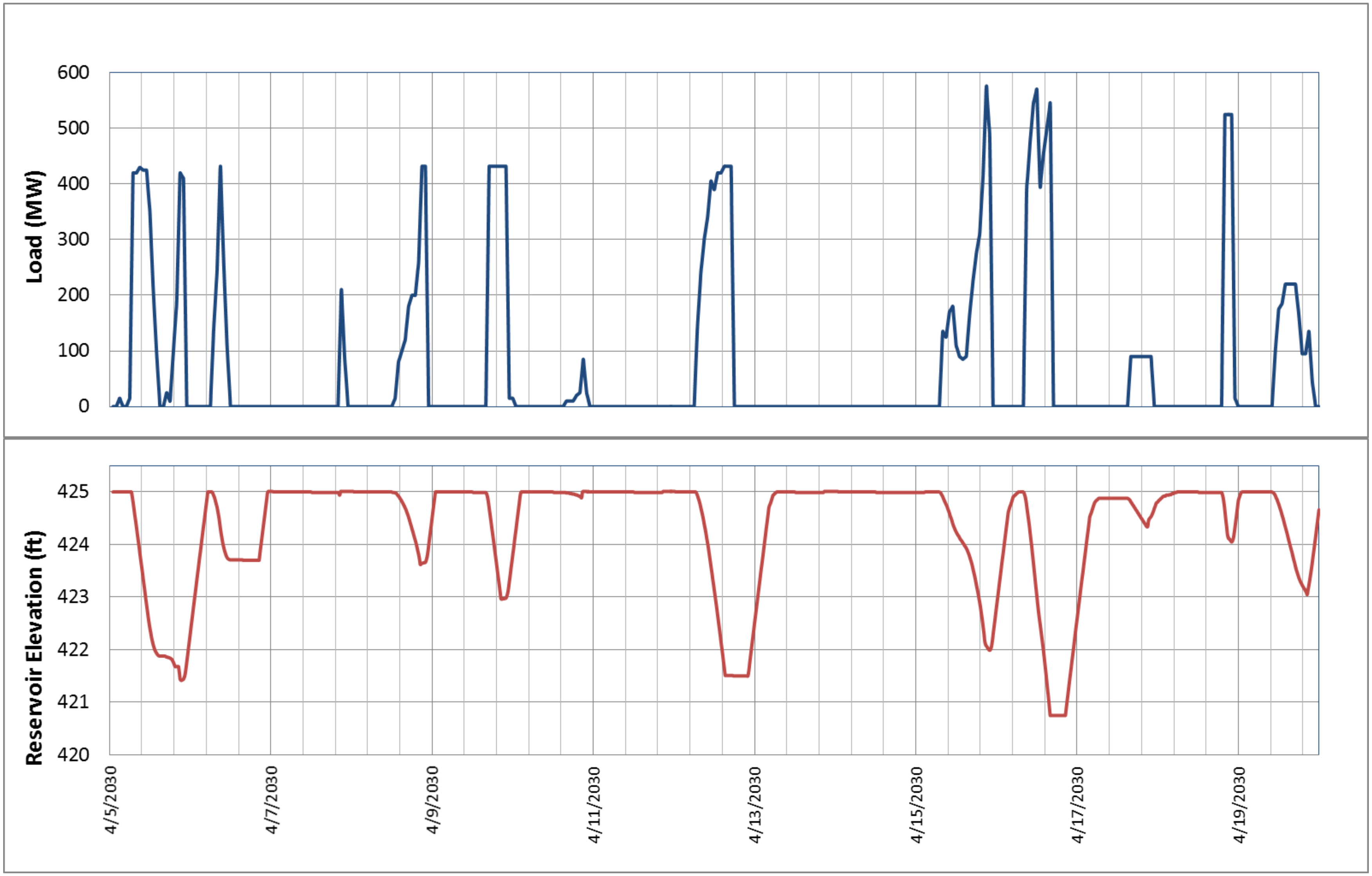

FIGURE 5-3 FAIRFIELD SIMULATED FUTURE SPRING LOADS AND MODELED LAKE MONTICELLO STAGE

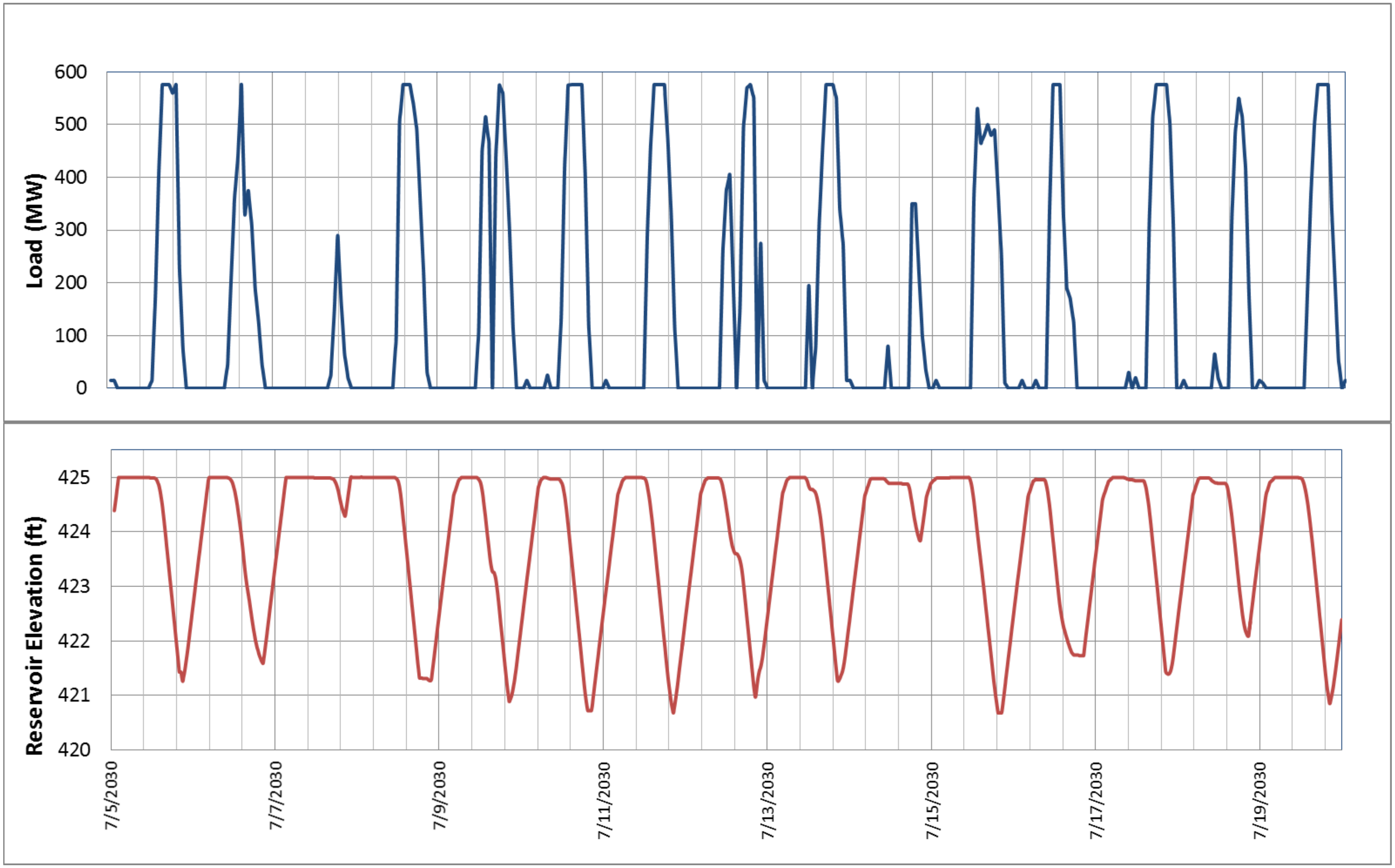

FIGURE 5-4 FAIRFIELD SIMULATED FUTURE SUMMER LOADS AND MODELED LAKE MONTICELLO STAGE

Exhibit E-2 Operations

Upgrade/Replacement of Generators at

Parr Shoals Development

Implementation Plan

IMPLEMENTATION PLAN

UPGRADE/REPLACEMENT OF GENERATORS
PARR SHOALS DEVELOPMENT

SOUTH CAROLINA ELECTRIC & GAS COMPANY

FERC No. 1894

Prepared by:

South Carolina Electric & Gas Company

October 2017

IMPLEMENTATION PLAN
FOR
UPGRADE/REPLACEMENT OF GENERATORS AT PARR SHOALS DEVELOPMENT

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DEFINITIONS OF TERMS, ACRONYMS, AND ABBREVIATIONS

AMP	Adaptive Management Plan
AR	American Rivers
CFR	Code of Federal Regulations
cfs	cubic feet per second
Commission	Federal Energy Regulatory Commission
CRK	Congaree Riverkeeper
CRSA	Comprehensive Relicensing Settlement Agreement
DLA	Draft License Application
FERC	Federal Energy Regulatory Commission
FLA	Final License Application
ft	foot
Generator capacity	the maximum amount of electricity that can be produced within the safety limitation of a generator
Head	the difference in the elevation of the upstream reservoir in relation to the tailrace elevation
Hydraulic capacity	the maximum amount of water that can be passed through the Project turbines
IFIM	Instream Flow Incremental Methodology
installed capacity	the nameplate megawatt rating of a generator or group of generators
interested parties	individuals and entities that have an interest in a proceeding
kW	Kilowatt
kWh	kilowatt-hour
Licensee	South Carolina Electric & Gas Company
Licensing/Relicensing	the process of acquiring an original FERC license for a new proposed hydropower project; or, the process of acquiring a new FERC license for an existing hydropower project after the previous license has expired.
Minimum Flow	A continuous flow, measured in CFS that is required to be released from the Project dam during specified periods of time.
Msl	mean sea level
MW	megawatt
MWh	megawatt-hour
Net inflow	The previous day's daily average inflow as calculated using the sum of the three upstream USGS gages (USGS 02156500, Broad River near Carlisle, SC; USGS 02160105, Tyger River near Delta, SC; and USGS 02160700, Enoree River at Whitmire, SC) minus evaporation from the reservoirs.
NGO	non-governmental organization
NMFS	National Marine Fisheries Services, also known as NOAA Fisheries
NOAA	National Oceanic and Atmospheric Administration, including NMFS
normal operating capacity	The maximum MW output of a generator or group of generators under normal maximum head and flow conditions

PM&E	protection, mitigation and enhancement measures
Project	Parr Hydroelectric Project (FERC No. 1894)
Project Area	Zone of potential, reasonably direct project effects within the FERC Project Boundary.
Project Boundary	The boundary line defined in the license issued by FERC that surrounds areas needed for Project purposes.
Review Committee	A group, including SCE&G and stakeholders, formed to direct the implementation of a particular AMP or monitoring plan. Members of a Review Committee must be signatories to the Comprehensive Relicensing Settlement Agreement.
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCE&G	South Carolina Electric & Gas Company
SHPO	State Historic Preservation Officer
Tailrace	Channel through which water is discharged from the turbines
TLP	Traditional Licensing Process
Turbine capacity	maximum shaft horsepower for an individual turbine at full gate
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WQFW RCG	Water Quality, Fish and Wildlife Resource Conservation Group
WUA	Weighted Usable Area

IMPLEMENTATION PLAN
FOR
UPGRADE/REPLACEMENT OF GENERATORS AT PARR SHOALS DEVELOPMENT

1.0 INTRODUCTION

South Carolina Electric & Gas Company (SCE&G) must file an application for a new license for its Parr Hydroelectric Project (Project) (FERC No. 1894) on the Broad River with the Federal Energy Regulatory Commission (FERC) by June 2018. During relicensing, the issue of downstream flow fluctuations associated with Project operations was identified by the Water Quality, Fish and Wildlife Resource Conservation Group (WQFW RCG) as an issue that needed to be addressed. The WQFW RCG includes representatives from SCE&G, South Carolina Department of Natural Resources (SCDNR), U.S. Fish and Wildlife Service (USFWS), South Carolina Department of Health and Environmental Control (SCDHEC), National Oceanic and Atmospheric Administration (NOAA), American Rivers and Congaree Riverkeeper. The WQFW RCG discussed and determined beneficial changes to Project operations to stabilize downstream flows, and a framework for a Downstream Flow Fluctuation Adaptive Management Plan (AMP) was developed to address downstream flow stabilization during the new license term.

One component of that AMP was to upgrade (by rewinding the existing stator) or completely replace the existing generators at the Parr Development, which will allow operation of the turbines at greater gate openings under maximum normal gross head. The gross head was increased following the installation of the spillway crest gates during redevelopment of the project in the 1970s. This proposed modification will allow more water to pass through the turbines, reducing the need for spillage at the Project and reducing the frequency of the resulting downstream flow fluctuations.

This Implementation Plan (IP) outlines SCE&G's proposed scope and schedule for generator upgrades or replacements that will be performed during the term of the new Project license.

1.1 PROJECT DESCRIPTION

The Parr Hydroelectric Project includes the 14.88-megawatt (MW) Parr Shoals Development (Parr Development) and the 511.2-MW Fairfield Pumped Storage Development (Fairfield Development) located in Fairfield and Newberry counties, South Carolina. Parr Reservoir is a 4,400-acre impoundment formed by the Broad River and the Parr Shoals Dam and serves as the lower reservoir for the Fairfield Development's pumped storage operations. Monticello Reservoir is a 6,800-acre impoundment formed by a series of four earthen dams and serves as the upper reservoir for the Fairfield Development's pumped storage operations. The existing Project license was issued by FERC on August 28, 1974 for a period of 46 years, terminating on June 30, 2020. SCE&G intends to file for a new license with FERC on or before May 31, 2018.

2.0 CURRENT OPERATIONS

The original hydraulic capacity (the maximum amount of water that can be passed through the six turbines) of the Parr Development powerhouse was approximately 6,000 cfs. The increase in operating head due to installation of crest gates on the spillway section of Parr Dam during the construction of the Fairfield Development resulted in a turbine capacity (maximum shaft horsepower for an individual turbine at full gate) that exceeded the generator capacity (the maximum amount of electricity that can be produced within the safety limitation of a generator). The generator limitations have reduced the hydraulic capacity of the Parr Development from its original 6,000 cfs to approximately 4,800 cfs, due to the need to operate the turbines at a reduced gate opening. When inflow exceeds the plant's hydraulic capacity, water must be spilled by lowering one or more sets of crest gates. Parr Reservoir level rises and falls during pumped storage cycles at the Fairfield Development, which varies the head on the crest gates when in the lowered position and results in fluctuations in project discharge. Restoring the hydraulic capacity of the six main units to 6,000 cfs or more would reduce the frequency of spilling and of the resulting flow fluctuations.

3.0 UPGRADE OR REPLACEMENT OF UNIT GENERATORS

During the period of the new license issued by the Commission, SCE&G plans to upgrade the existing generators, or if feasible to install new generators of increased capacity. When completed, the new or upgraded generators will permit operation of the units at increased gate settings using the available hydraulic head, with a corresponding increase in plant hydraulic capacity as described in Section 2.0. Complete replacement of the generators, if feasible, will potentially increase the hydraulic capacity of each unit from approximately 800 cfs at present to between 1,000 and 1,200 cfs. If all six generators are replaced, the plant hydraulic capacity will potentially increase from approximately 4,800 cfs presently to between 6,000 and 7,200 cfs. Replacement of all six generators would also increase the installed capacity of the Parr Development from its present 14.88 MW to an estimated maximum of 22.72 MW. Upgrading the existing generators by rewinding them will result in a smaller increase in both hydraulic capacity and installed generating capacity (estimated to be 10 to 15 percent, possibly greater). Preliminary investigation has indicated that the major turbine components can mechanically withstand the increased shaft horsepower required by the new or upgraded generators, however certain auxiliary electrical equipment (i.e. exciters, switchgear, and bus work) may need to be upgraded or replaced to safely handle the increased electrical power.

4.0 IMPLEMENTATION SCHEDULE

The proposed schedule for changes to the generators is to have all six units upgraded or replaced within ten years after license issuance. The upgrade or replacement of the first unit will be completed within three years from issuance of the license. Subsequent units will be upgraded or replaced one each year, after testing and acceptance of the initial unit. Should reliability, economic advantage, or other issues require it, the schedule may be accelerated at SCE&G's discretion.

Year 1:	Scoping and design including auxiliary equipment and structural/foundation design;
Year 2:	Final design and manufacture of first unit;
Year 3:	Installation and acceptance testing of first unit;
Year 4:	Implement design changes if required based on acceptance tests of first unit;
Year 5:	Manufacture of second unit;
Year 6	Installation of second unit and manufacture of third unit;
Year 7:	Installation of third unit and manufacture of fourth unit;
Year 8:	Installation of fourth unit and manufacture of fifth unit;
Year 9:	Installation of fifth unit and manufacture of sixth unit;
Year 10:	Installation of sixth unit.

5.0 REFERENCES

Federal Power Commission (FPC). 1974. Order Issuing New License (Major). Authorizing Project Redevelopment, Permitting use of Project Waters for Condenser Cooling Purposes, Vacating Hearing Order, and Permitting Withdrawal of Intervention. (Project No. 1894). Issued August 28, 1974.