Yadkin Project Relicensing (FERC No. 2197)
Operations Model IAG Meeting
September 4, 2003

Alcoa Conference Center
Badin, North Carolina

Final Meeting Summary

Meeting Agenda

See Attachment 1.

Meeting Attendees

See Attachment 2.

Introductions and Agenda

Gene Ellis, APGI Yadkin Division, opened the meeting with a welcome and introductions. Gene explained that today PB Power would provide a general overview of the OASIS model (a repeat of some information provided at the March 14, 2003 IAG meeting) and then discuss, in detail, the development of the model, including data inputs. He said that APGI hoped to build knowledge and confidence in the model with the IAG. Gene mentioned that at the March 14, 2003 meeting, the IAG discussed the two different models being used by APGI and Progress Energy to model their hydropower projects and there would be further discussion of that in this meeting. He said that since that meeting, APGI had further discussions with Progress concerning the use of the OASIS and CHEOPS models. He said that the IAG had also discussed water allocation at the March meeting. At this meeting, although APGI asserted that storage and water allocation are outside the jurisdiction of the Federal Energy Regulatory Commission (FERC), APGI agreed to meet with the North and South Carolina resource agencies and Progress Energy to discuss water allocation issues. Gene said that APGI met with the agencies and Progress Energy and committed to conducting some additional legal research and evaluating it along with other information. Gene stated further that APGI does not believe FERC has the authority to decide water allocation between two states and many of the issues that have been raised for evaluation may have a water allocation component to them. Continuing, Gene said the whole question of water allocation and FERC jurisdiction is a very difficult one which will require time and patience to work through. Finally, Gene said that APGI believes the OASIS model can be an excellent tool to examine Project operations within the FERC relicensing process and with certain additions/modifications, OASIS could also be used to evaluate other watershed/water allocation issues that are outside the FERC relicensing process.

Next, Gene introduced Jane Peeples, Meeting Director, who distributed an Initial Consultation Document (ICD) Summary and reviewed Issue Advisory Group Meeting Guidelines.

After reviewing the meeting agenda, Paul Shiers, PB Power, introduced Mary Tibbetts, PB Power, and Steve Nebiker, HydroLogics, who presented information on the development of the Yadkin Project operations model (see Attachment 3). Mary explained that APGI will use OASIS to evaluate operational alternatives and their potential impacts on reservoir water levels, stream flows, and energy generation and value. She summarized how OASIS, a simulation/optimization model, solves a set of linear equations for each identified time step to optimize benefits subject to user-defined constraints and targets. Specific to the Yadkin Project, Mary said that APGI plans to assemble data and construct the model, calibrate the model, and use the model to investigate operational alternatives.

Review of July 7, 2003 Joint Progress Energy Water Resource Workgroup and Yadkin Operations Model IAG Meeting

Paul Shiers reviewed the July 7, 2003 joint meeting with Progress Energy to discuss operations modeling. He said that at the meeting, APGI and Progress Energy exchanged technical information on OASIS and CHEOPS and discussed linking the two models. Paul acknowledged that the two models could be linked with an interface. Paul said that there have been post-meeting decisions to pursue two separate basinwide models (OASIS and CHEOPS). Paul reviewed the geographic extents of the two models – the upstream extent of the OASIS model will be W. Kerr Scott Reservoir with the downstream extent of the model to be determined (the downstream extent will extend to the Rockingham, North Carolina gage and into South Carolina) and the upstream extent of the CHEOPS model will be High Rock Dam and the downstream extent will be to at least the Pee Dee, South Carolina gage. Both models will include both the APGI and Progress Energy developments.

OASIS Modeling Effort – Review of Agency Modeling Criteria

Continuing, Mary Tibbetts reviewed the North Carolina Department of Environment and Natural Resources and South Carolina Department of Natural Resources modeling criteria. Mary said that the OASIS model meets the North Carolina modeling criteria with one exception – OASIS is not set up to display information via a GIS (Geographic Information System). Paul said that South Carolina asked that the model have the ability to interface with a salinity model at the mouth of the Pee Dee River. Paul said that APGI should be able to accommodate this request.

Danny Johnson, South Carolina Department of Natural Resources, expressed a concern that the two models, when set up to analyze the same scenario, within the same geographic area, with the same data, would generate significantly different outcomes. He asked how differences between the two models would be reconciled. Paul said that APGI and Progress Energy have a goal to input data into the two models consistently, using the same data whenever possible. He said that if there are differences, APGI and Progress Energy would have to sit down together and address them.

Yadkin OASIS Model Development

Gerrit Jobsis, South Carolina Coastal Conservation League (SCCCL) and American Rivers, commented that he is interested in an open modeling process where he and others could do their

own modeling runs. Paul Shiers said it is APGI's intent to make operations modeling an open process (discussed further later in the presentation).

Continuing, Mary said that the model would operate on a daily time step. She explained that the period of record being used in the model (1929 – 2002), although limited by the Rocky River gage, is long enough to capture hydrologic extremes. She further explained that this period of record includes the drought of 1930, the more recent drought of the past few years, several high stream flow years, and several typical or average stream flow years. Larry Jones, High Rock Lake Association, asked how the model would account for total inflow into the basin. Steve Nebiker said that he would address this question later in the presentation.

Gerrit said that there is six years of data from the early 1900's available. He said that this data is the only reference to pre-Project conditions available. He asked why APGI was excluding this information. Steve Nebiker said that he would address the question later in the presentation.

Input Data – W. Kerr Scott

Next, Steve reported that HydroLogics is working to prepare the inflow data sets that will be used as input to the model. First, Steve described reservoir operations at W. Kerr Scott. He said that HydroLogics would develop the model using operating data (inflow, change in storage, and outflow) from the US Army Corps of Engineers (USACE) website and the USACE 1991 Water Control Plan. Steve said that when the elevation of W. Kerr Scott Reservoir is less than 1,030-ft, the USACE releases 125 – 400 cfs. Don Seitz, Concerned Property Owners of High Rock Lake, asked how many consecutive days the USACE released a minimum flow of 125 cfs. Without the data in front of him, Steve was unable to answer the question.

Gene Ellis asked about the size of the W. Kerr Scott Reservoir watershed. Steve answered that the watershed is 367 square miles, approximately 9 percent of High Rock's 3,973 square mile drainage area.

Tom Fransen, North Carolina Division of Water Resources (NCDWR) asked if the USACE would be given an opportunity to review how APGI is modeling its W. Kerr Scott project. Paul said that the USACE would be given an opportunity to review the OASIS model.

Pete Petree, SaveHighRockLake.org, questioned the need to model the system above the confluence of the Yadkin and South Yadkin rivers. He said that APGI could not influence the system beyond this point. Randy Benn, Yadkin counsel, said that the USACE W. Kerr Scott and other projects are operated under the authorization of the Water Resources Development Act. He said that it would be difficult, but not impossible to change this authorization. Randy thought it necessary to study the range of opportunities. Tom Fransen commented that it is important to understand who is using the water above the Yadkin Project and how. He said that an option would be to ask the USACE to conduct a 216 study (as was done during the Dominion Power Roanoke Rapids relicensing).

Larry Jones asked if the interbasin transfers under consideration would be included in the model. Paul Shiers said that where data on such upstream interbasin transfers is made available to Yadkin by the state or others, it could be included in the model.

Input Data – Yadkin Developments

Mary Tibbetts discussed the historic inflow data available for the Yadkin Project, which includes historic operating data recorded by Yadkin, daily data for High Rock (1980 – 2003) and Tuckertown, Narrows, and Falls (1986 – 2003), and hourly data for all four developments (1997 – 2003). After describing issues related to using Yadkin calculated inflow data, Mary said that Yadkin has chosen to develop a U.S. Geological Survey (USGS) based inflow dataset for the four reservoirs.

Larry Jones suggested that rather than discounting the actual data collected at the Yadkin Project, APGI compare the Yadkin calculated data to the USGS gage data and use the relationships to better understand inflow to the Project. Larry said that he was concerned that inflow into the Project would be underestimated. Paul explained that the Yadkin data is hand written and not available electronically, but that for the time periods when electronic data is available, a comparison of Yadkin calculated data and the USGS gage data will be made. He said that he would describe how PB Power and HydroLogics are developing the inflow data set.

Donley Hill, U.S. Forest Service (USFS), said that the OASIS model development had occurred way too late in the Tapoco Project relicensing. He said that he, and others, had naively assumed that OASIS is a tool that can be used interactively during working meetings to evaluate operating alternatives. Donley asked APGI to estimate when OASIS would be fully operational and available to the IAG. He said that it would be beneficial to evaluate alternatives earlier in the process. He also questioned whether APGI would have the necessary resources (i.e. enough modelers) to complete the amount of modeling work that would need to be done. Gene Ellis said that originally APGI thought that it could use publicly available information to model Progress Energy operations. However, APGI is now discussing a data exchange with Progress Energy. Once this data is exchanged and a decision is made, in consultation with South Carolina, about what downstream nodes to include in the model, PB Power and HydroLogics can begin building this portion of the model. Gene said that even if the model were ready in early 2004, there would be plenty of time to evaluate alternatives before 2006, when Yadkin must file its application for a new license. Paul indicated that once the model is up and running it would be helpful if the IAG identified alternative operating scenarios about one week before a meeting to discuss the model results (so that any necessary model programming can be done in advance of a working meeting).

Steve Nebiker said that USGS-based inflow data is available at High Rock Dam for the periods 1919-1927 and 1941-1962. He proposed using the USGS "fill-in" program to complete the missing records for inflow to High Rock Reservoir. Steve said that the daily inflow to High Rock Reservoir would be calculated as the (daily flow at upstream gage(s)/monthly average flow at upstream gage(s)) * monthly fill-in estimated flow at High Rock. Tom Fransen warned against the artificially high data recorded at the Rocky River gage during the recent dry period. Steve

explained that the Abbots Creek gage would be used to estimate inflows post 1989. Larry asked if the formula adjusted for all the tributary inflow into High Rock. Steve replied yes.

Steve explained that evaporation and precipitation are not included in the "raw" inflow data set, but are included as time series to model as net evaporation. Steve showed plots of average monthly evaporation and precipitation at High Rock Reservoir. Larry asked if evaporation was adjusted according to the reservoir surface area. Steve said yes.

Gerrit Jobsis asked if it is possible to examine the evaporation data set separate from the participation data set. Steve replied yes.

Continuing, Steve reported that the accuracy of the discharge records for individual days is about 5 to 10 percent.

After a review of various plots comparing the two inflow data sets (the Yadkin measured data set and the USGS based data set) on a daily, monthly, and annual basis, Mary concluded that on an average annual basis, the USGS based inflows are on average 6 percent higher than the Yadkin calculated inflows. Gerrit asked if periods when hourly or daily flows were available matched up or correlated well. Mary responded that on a daily basis, the USGS data was somewhat higher.

After a break, Mary compared the USGS measured inflows and USGS calculated inflows at High Rock to determine a level of confidence in the USGS "fill in" program. The USGS measured flows at High Rock from 1919 to 1927 and from 1941 to 1962. "Fill-in" was used in two iterations to estimate flows during the periods when flows were recorded. The "fill-in" estimated flows were compared to the measured flows. In the first iteration, the measured flows from 1919 to 1927 and from 1952 to 1962 were used as "fill-in" input, and the "fill-in" program was used to estimate flows at High Rock from 1942 to 1951. The "fill-in" estimated flows for 1942 to 1951 were compared to the measured flows for the same time period. In the second iteration, the measured flows from 1919 to 1927 and from 1941 to 1951 were used as "fill-in" input, and the "fill-in" program was used to estimate flows at High Rock from 1952 to 1961. The "fill-in" estimated flows for 1952 to 1961 were compared to the measured flows for the same time period. Mary concluded that the calculated and measured flows compared well. On an average annual basis, the calculated inflows are less than one percent lower than the measured inflows for the 1942 to 1951 time period and four percent higher than the measured inflows for the 1952 to 1961 time period.

Next, Mary compared the USGS based inflows at High Rock and the USGS measured flows near the confluence of the South Yadkin and Yadkin rivers. She concluded that the measured flows at the Yadkin College gage were always less than USGS based inflows to High Rock and measured flows at the confluence were less than the USGS based inflows to High Rock 98 percent of the time.

In summary, there is a high level of confidence in estimates of inflows to the Yadkin developments.

In response to an earlier question about the use of unregulated flow data, Paul Shiers said that the 75-year flow data set captures two significant low flow periods of inflows and all inflows are unregulated.

Continuing, Mary reviewed the operating rules for each of the four Yadkin developments and the storage elevation relationships at each of the reservoirs. Don Seitz asked about the difference between usable and unusable storage. Mary explained that storage is unusable if it below the intakes at the dam (i.e. below the gate sill). Mary also reviewed the turbine efficiency curves for the existing and base case conditions. She said that the base case would include the planned upgrades at the High Rock and Narrows developments. She also noted that High Rock and Narrows have separate efficiency curves for with and without air injection. Tom Fransen questioned why the upgrades at High Rock and Narrows are being included in the base case. Paul stated that "base case" may be a misnomer. The base case is actually the applicant's case – Yadkin is proposing upgrades to High Rock and Narrows in the new license. For clarification, Don Rayno, NCDWR, stated that all comparisons would be based on the assumption that High Rock and Narrows are upgraded.

Gerrit Jobsis asked if APGI considered alternatives to air injection (baffles, turbine vents etc.). Paul Shiers said that APGI is proposing draft tube injection at Narrows and air injection through the runner itself at High Rock. Paul commented that there is a one to two percent loss of efficiency with air injection.

Data Input – Progress Energy Developments

Paul said that while APGI has started to assemble publicly available information on inflows, storage, reservoir area, turbine capacities, and operations at the Progress Energy developments, it is anticipated that Progress Energy will share this information with APGI. This exchange of project data will ensure that the OASIS model is more precise. John Ellis, US Fish and Wildlife Service (USFWS), asked APGI to keep the IAG briefed on the exchange of data between the two companies. Gene agreed.

Steve Nebiker discussed the development of the USGS based inflow data set to the Progress Energy developments (a USGS based inflow data set). Steve said that the trouble with using only publicly available information is the reliance on local gages to estimate inflows. When comparing the inflows to Tillery and outfalls from Falls, there is a significant monthly variation. Potential sources of this discontinuity include a large ungaged area, cumulative error from inaccuracy of USGS measurements, and different stage-storage at Blewett. In summary, he said that the flow continuity downstream of Falls needs further refinement. In response to an earlier question by Tom Fransen, Steve said that he had made adjustments for recent withdrawals at the Rocky River gage.

Marty Barfield, Pee Dee River Coalition, asked if HydroLogics had looked at the daily variation. Steve said no; the comparison was based on end of the month elevations. However, he said that the daily variation would probably be more significant than the monthly variation. Larry Jones asked if it is possible to look at the daily variation. Steve said he would need the data from Progress Energy. Larry suggested that APGI ask Progress Energy for the information.

After lunch, Paul described Progress Energy's operating protocol. For both the existing and base case, APGI will assume that Tillery is operated as run-of-river and Blewett starts when Tillery starts and operates approximately 10 hours per day. Paul showed the storage elevation relationships and reviewed turbine efficiency data for the Progress Energy developments. He understands the Progress Energy developments to operate at best efficiency, not maximum capacity.

Node Locations

Paul proposed nodes at each of the seven dams (W. Kerr Scott through Blewett). Other possible node locations include the USGS gage stations, river confluences, and/or environmental or other critical locations.

Schedule and Status of Model Development and Public Availability

Paul said that PB Power and HydroLogics would discuss the calibration and the verification of the OASIS model at a future IAG meeting. He said that APGI would be unable to verify/calibrate the Progress Energy developments if the two companies did not agree to exchange project data.

Paul said that the model might be available for use to the IAG as early as the fourth quarter 2003. He noted that in the past (specifically, with APGI's Tapoco Project), APGI had offered model training and had asked participants using the model to sign agreements covering use and confidentiality of the model and its data inputs. He said that APGI preferred to make OASIS available at meetings and work sessions. Larry Jones asked what types of information included in the model might be deemed confidential. Paul answered that this was being evaluated, but that possible examples are operational items and the price of electricity.

Before concluding, Gene Ellis said that APGI had been asked during the July 7, 2003 joint modeling meeting if it is willing to schedule additional joint meetings with Progress Energy to discuss technical modeling details. Gene said that if the IAG desires joint meetings, APGI is ready and willing to participate. In the meantime, Gene said that APGI would continue to work with Progress Energy on the exchange of project information and other issues. Tom Fransen said that it made logistical sense to combine the workgroup meetings. He said that he would like for both models to include the same nodes. He also thought it beneficial to be able to evaluate operating alternatives jointly.

Paul tentatively scheduled the next meeting of the IAG for November 6, 2003.

Marty Barfield asked how the nodes would be identified on the lower end (i.e. in South Carolina). Gene said that APGI would work with the South Carolina agencies to understand their desires for nodes downstream of the two projects. Gene said that these conversations with South Carolina could begin at anytime. He said that it would be important to not limit numerically the number of downstream nodes because, for example, the instream flow workgroup may need to add additional nodes.

Larry Jones asked if APGI was in a position to share any preliminary modeling results (independent of the Progress Energy developments). Gene said that the model would need to be developed first before any public modeling runs. Gene did say that he had already asked PB Power to start modeling the alternative High Rock Reservoir operating regime proposed by SaveHighRockLake.org on their website.

The meeting adjourned at about 2:00 p.m.

Attachment 1 – Meeting Agenda

Yadkin Project
FERC No. 2197
Communications Enhanced Three-Stage Relicensing Process

Operations Model Issue Advisory Group Meeting

Thursday, September 4, 2003
Alcoa Conference Center
Badin, North Carolina

10:00 AM – 4:00 PM

Preliminary Agenda

1. Introductions, Review Agenda

2. Review of March 14, 2003 Operations Model IAG Meeting

3. Review of July 7, 2003 Joint Progress Energy Water RWG and Yadkin Operations Model IAG Meeting

4. OASIS Modeling Effort

   I. Review of Agency Modeling Criteria

   II. Yadkin OASIS Model Development
      i. Developments
      ii. Time step
      iii. Period of record

   III. Input Data
      i. W. Kerr Scott input data
      ii. Yadkin Developments input data
      iii. Progress Energy Developments input data
      iv. Node locations

   IV. Schedule and Status of Model Development and Public Availability

5. Schedule and Agenda for Next Meeting

Attachment 2 – Meeting Attendees

Name	Organization
Coralyn Benhart	Alcoa
Danny Johnson	SC Department of Natural Resources
Don Cordell	Hazen and Sawyer PC
Don Rayno	NC Division of Water Resources
Don Seitz	Concerned Property Owners High Rock Lake
Donley Hill	US Forest Service
Donna Davis	Stanly County Utilities
Drew German	Buck Steam/Duke Energy
Dwight Wicks	City of Georgetown, SC
Gerrit Jobsis	SC Coastal Conservation League and American Rivers
Greg Ott	APGI
J. Todd Kennedy	NC Division of Water Quality
Jack Hardie	Piedmont Boat Club
Jody Cason	Long View Associates
John Ellis	US Fish and Wildlife Service
Julian Polk	PB Power
Larry Jones	High Rock Lake Association
Lawrence Dorsey	NC Wildlife Resources Commission
Lynn Farquhar	High Rock Lake Business Owners Group
Marty Barfield	Pee Dee River Coalition
Mary Tibbetts	PB Power
Paul Shiers	PB Power
Randy Benn	LLGM (Yadkin counsel)
Raymond Allen	City of Albemarle
Robert Petree	SaveHighRockLake.org
Scott Leonard	Davidson County Planning
Steven Nebiker	HydroLogics
Tom Fransen	NC Division of Water Resources
Wendy Bley	Long View Associates

Attachment 3 – Meeting Presentation

Operations Model
IAG Meeting
September 4, 2003

Agenda

- Review of March IAG meeting
- Review of July Joint IAG / RWG meeting
- Review of agencies' modeling criteria
- Review of Yadkin operations modeling effort
- Schedule and agenda for next meeting

Review of

March 14, 2003

Operations Model IAG Meeting

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Operations Model

- OASIS is the tool we will use to evaluate operational alternatives and their potential impacts on:
  - Reservoir water levels
  - Stream flows
  - Energy generation
  - Value of generation

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What is OASIS and How Does it Work?

- Generalized water resources simulation/optimization model
- LP formulation - operates with constraints and targets
- Uses the principle of mass balance to ensure that all the water in the system is accounted for
- Solves a set of linear equations for each time step to optimize benefits subject to user-defined constraints and targets

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Yadkin Project Model

- Approach
  - Assemble data and construct model
  - Calibrate model
    - Match historical stage and compare computed energy and discharges to historical
  - Utilize model to investigate operational alternatives

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Review of

July 7, 2003

Joint Water RWG

and

Operations Model IAG

Meeting

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Basin-Wide Model

- Exchange of technical information on:
  - CHEOPS model
  - OASIS model
- Discussion on linking the two models
- Post-meeting decisions to pursue two separate basin-wide models

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Proposed Geographical Extents of Models

- Yadkin OASIS model:
  - Upstream limit is W. Kerr Scott Reservoir
  - Will include Progress Energy developments
  - Downstream limit of model TBD, will extend to the Rockingham, NC gage and into South Carolina
- Progress Energy CHEOPS model:
  - Upstream limit is High Rock Dam
  - Will include Yadkin developments
  - Downstream limit of model will extend at least to Pee Dee, SC gage

Review of NCDENR Modeling Criteria

- OASIS model meets all criteria except one:
  - OASIS is not set up to display info via a GIS
  - OASIS could be run from a GIS and could produce files importable by GIS software

Review of NCDENR Modeling Criteria (cont.)

- OASIS is not in the public domain, but is licensable to anyone
- OASIS has capabilities to handle withdrawals
  - Yadkin will include those provided by appropriate agencies
  - Yadkin will not predict future demands
- OASIS has ability to run a 15-min time step
  - 75-yr period of record planned, Yadkin plans on using daily time step
  - If 15-min time step needed as input to other studies (WQ or IFIM), Yadkin would be open to making limited runs at smaller period of record

Review of South Carolina Modeling Criteria

- One basin-wide model
- Model should extend into South Carolina
- Request to be involved in step-by-step development of model
- Ability to interface operations model with downstream salinity model

Yadkin OASIS Model

- Developments:
  - W. Kerr Scott Dam and Reservoir
  - High Rock, Tuckertown, Narrows, and Falls Dams and Reservoirs
  - Tillery and Blewett Falls Dams and Reservoirs
- Time step: Daily

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Period of Record

- Period of record: 1929 to 2002
  - Limited by Rocky River gage
  - Long enough period to capture hydrologic extremes

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W. Kerr Scott Reservoir

- Inflows to W. Kerr Scott Reservoir
- Operation of W. Kerr Scott Reservoir
- Routing of discharges from W. Kerr Scott Dam to High Rock Dam

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W. Kerr Scott Reservoir, Inflow Development

- W. Kerr Scott inflows:
  - 1929 to Sept 1962: Subtract gaged Reddies River flows from gaged Wilkesboro flows and pro-rate for W. Kerr Scott drainage area
  - Oct 1962 to 2002: Use available inflow data from USACE website

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W. Kerr Scott Reservoir Operations

- Operating data and protocol obtained from USACE website and 1991 Water Control Plan
- The following data is available since project inception (1962):
  - Inflow
  - Change in storage
  - Outflow

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W. Kerr Scott Reservoir Operating Protocol

- Maintain elevation at 1030’ under normal conditions (inflow = outflow)
- Elevations between 1030’ and 1075’, release maximum of 5,400 cfs, depending on Wilkesboro stage
- Elevation < 1030’, release between 125 and 400 cfs, depending on Wilkesboro stage

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W. Kerr Scott, Review of Historic Data

- Normally operated to maintain elevation 1030'
- Discharge > 5,400 cfs only six times, maximum historic discharge = 6,721 cfs
- Low flow conditions (Elev < 1030') occurred 25% of time
  - Discharge varied some from protocol
  - Minimum discharge never less than 125 cfs
- Will use current operating protocol in evaluating base case condition
- Will be able to evaluate operational alternatives at W. Kerr Scott

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W. Kerr Scott, Routing of Flows to High Rock

- Travel time approximately 2 days
- Use average 2, lag 2 technique
- Inflows to High Rock Reservoir = Flows at High Rock (to be discussed) – Routed flows from W. Kerr Scott

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Yadkin Project

- Inflows to the Yadkin Reservoirs
- Operation of Yadkin Reservoirs
- Other pertinent Project data

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Yadkin Project, Historic Inflow Data

- Historic operating data recorded by Yadkin
  - Measure: water levels, generation, and flood gate openings
  - Calculate: change in storage, turbine discharge, flood gate discharge, and inflows
- Daily data available electronically
  - High Rock: 1980 to 2003
  - Tuckertown, Narrows & Falls: 1986 to 2003
- Hourly data available electronically, all developments from 1997 to 2003

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Issues Related to Using Yadkin Calculated Inflow Data

- Data available electronically for relatively short period of record
- Each development's data is recorded independently of other developments
- Turbine efficiency changes affect calculated turbine discharges and inflows
- Storage – elevation relationship changes affect calculated change in storage volumes and inflows

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Yadkin Project, USGS Based Inflow Data

- Yadkin has opted to develop a USGS-based inflow dataset for High Rock, Tuckertown, Narrows, and Falls Reservoirs
- Use available gage data at High Rock Dam:
  - 1919 – 1927: USGS gage at future location of High Rock Dam location (prior to dam closure)
  - 1941 – 1962: USGS gage downstream of High Rock Dam
- Use Fill-in to complete missing record for inflows to High Rock Reservoir
- Add tributary inflows downstream of High Rock based on representative USGS gages

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Fill-in Program

- Fill-in is a USGS program used to estimate monthly flows at gages with missing records based on correlations with other gages
- Limits to Fill-in accuracy:
  - Gages are only accurate to within +/- 5%, at best
  - Fill-in uses a monthly average correlation

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USGS Gages

USGS Gage	Period of Record
High Rock	1919 – 1927; 1941 – 1962
Salisbury	1895 – 1927
Wilkesboro	1903 - 1909; 1920 – present
Yadkin College	1928 – present
S.Yadkin, Cooleemee	1928 – 1965
S.Yadkin, Mocksville	1938 – present
Hunting Creek	1951 – present
Second Creek	1979 – present
Abbott's Creek	1988 – present (10/91 – 9/92 missing)
Rocky River	1929 - present

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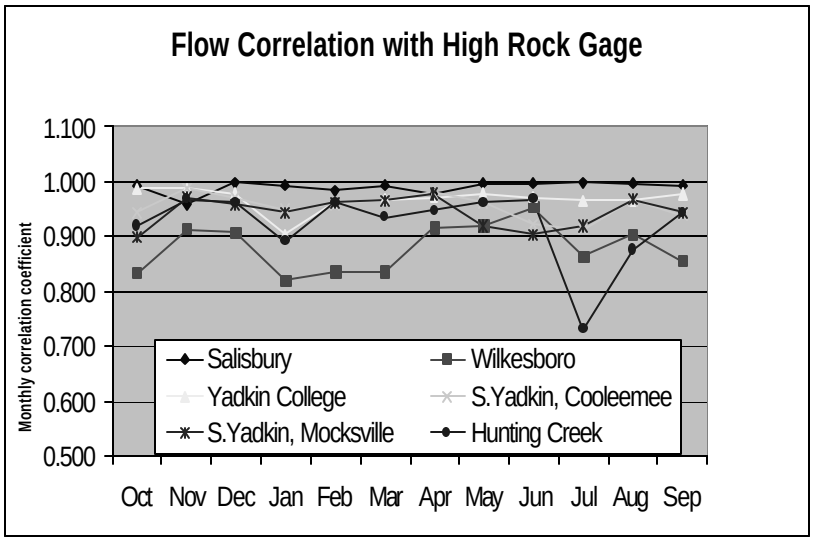
Correlations



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Daily Inflows for Yadkin Developments

- Daily inflow to High Rock Reservoir =

  (Daily flow at upstream gage(s) / monthly average flow at upstream gage(s)) * monthly Fill-in estimated flow at High Rock
- Yadkin College, South Yadkin tributary, and Abbott's Creek gages used to disaggregate to daily

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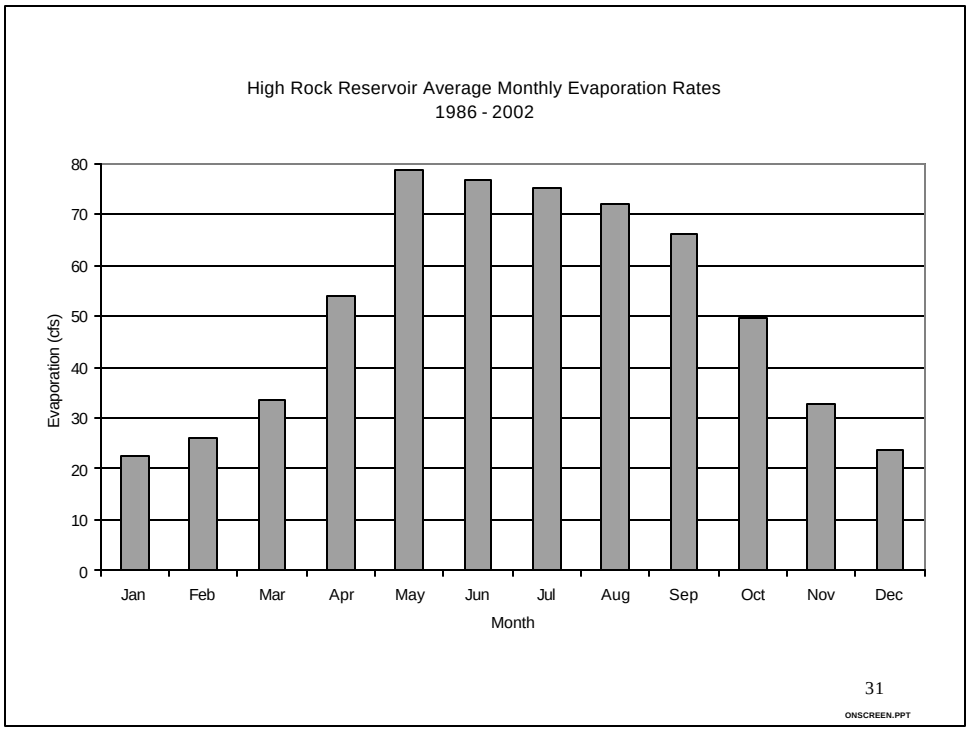
Daily Inflows for Yadkin Developments (cont.)

- Tributary inflow to downstream Yadkin Developments is ungaged
- Use Abbott's Creek gage flows, pro-rated for drainage area of each development
- When not available, use Rocky River gage flows pro-rated for drainage area
- Runoff coefficient (cfsm) for overlapping periods
  - Rocky River: 1.01, Abbott's Creek: 0.94
  - Drainage area between High Rock and Falls is 175 sq. mi.

Yadkin Project, USGS Based Inflow Data Evaporation / Precipitation

- Evaporation and precipitation are not included in "raw" inflow dataset, but are included as timeseries to model, as net evaporation
- Net evaporation (evap – precip) based on reservoir surface area at given headwater elevation
  - Lake Michie evaporation data utilized
  - Salisbury and Albemarle precipitation data utilized
- Mass balance equation for each project:
  - Change in storage = inflows – outflows – net evaporation


High Rock Reservoir Average Monthly Evaporation Rates
1986 - 2002
Evaporation (cfs)
0
10
20
30
40
50
60
70
80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
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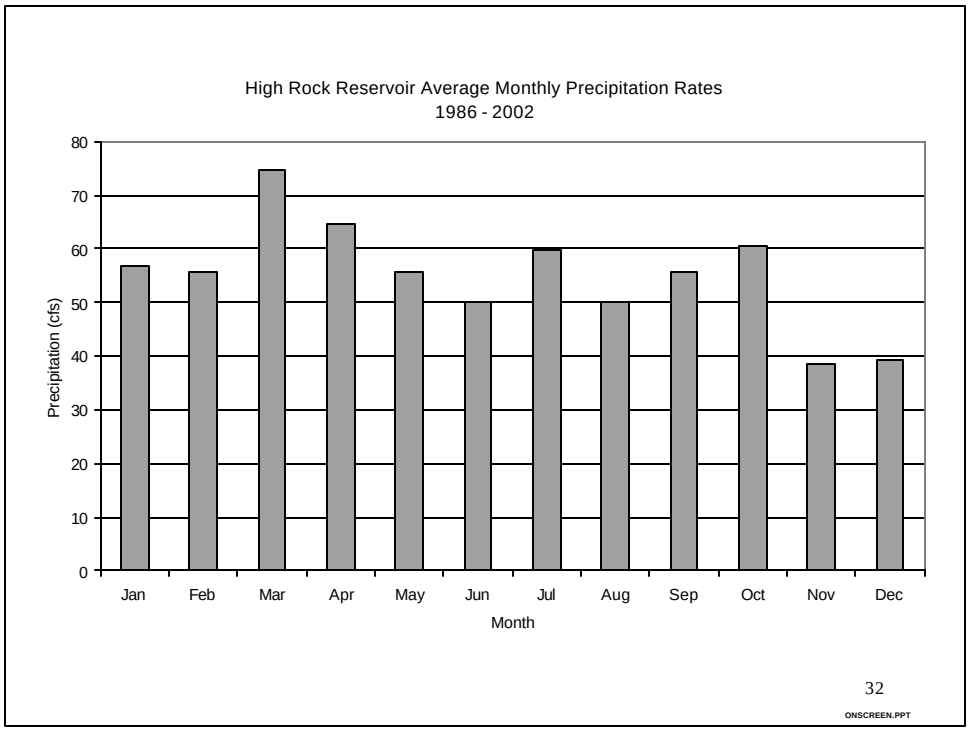
High Rock Reservoir Average Monthly Precipitation Rates
1986 - 2002
Precipitation (cfs)
0
10
20
30
40
50
60
70
80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
32
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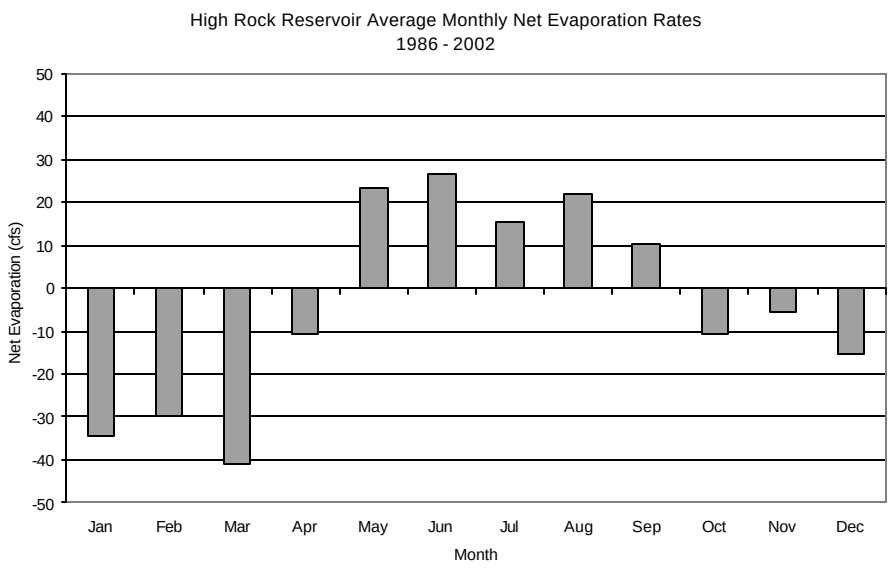

33

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Accuracy of USGS Based Flows

- Accuracy of USGS gage data:
  - "Accuracies of discharge records for individual days commonly are about 5 to 10 percent" (USGS Office of Surface Water TM No. 93.07)

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Comparison of USGS Based Inflows & Yadkin Calculated Inflows at High Rock Reservoir

- Yadkin measures High Rock headwater elevation, generation, and flood gate opening
  - Change in headwater is used to calculate change in storage in reservoir
  - Generation is used to calculate turbine discharge rate
  - Flood gate opening is used to calculate flood discharge rate
  - Yadkin Calculated Inflow = Turbine Discharge + Flood Discharge + Change in Storage
- Compared USGS based inflows and Yadkin calculated inflows at High Rock (1980 to 2002)

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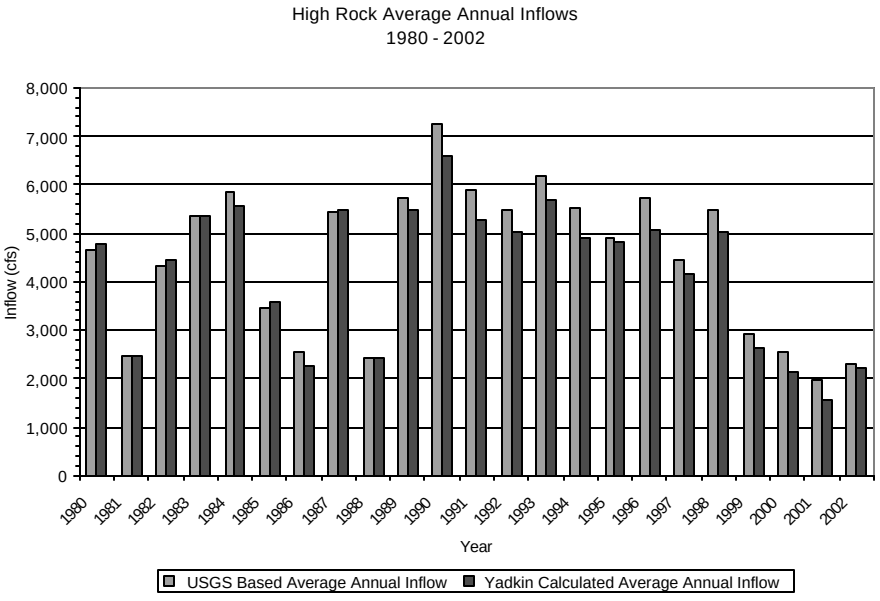

36

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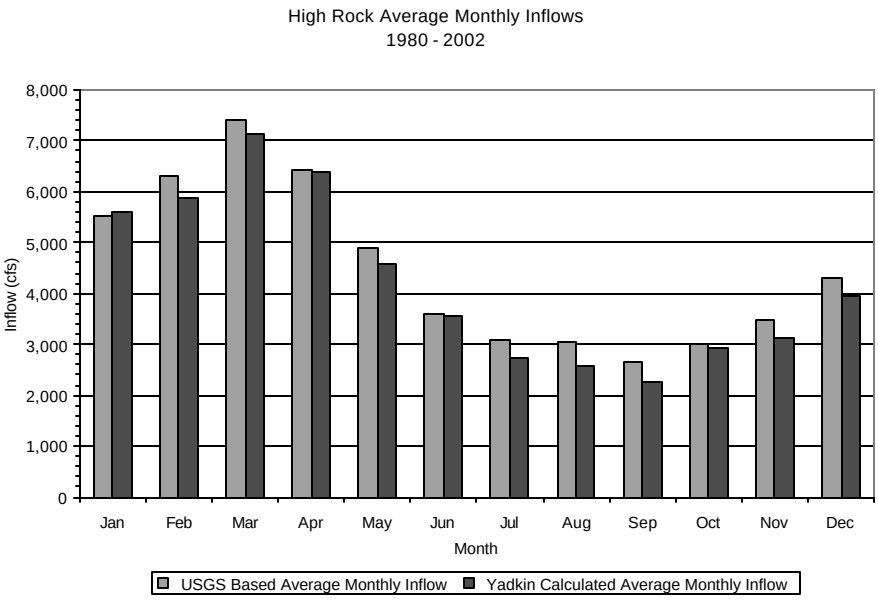

37

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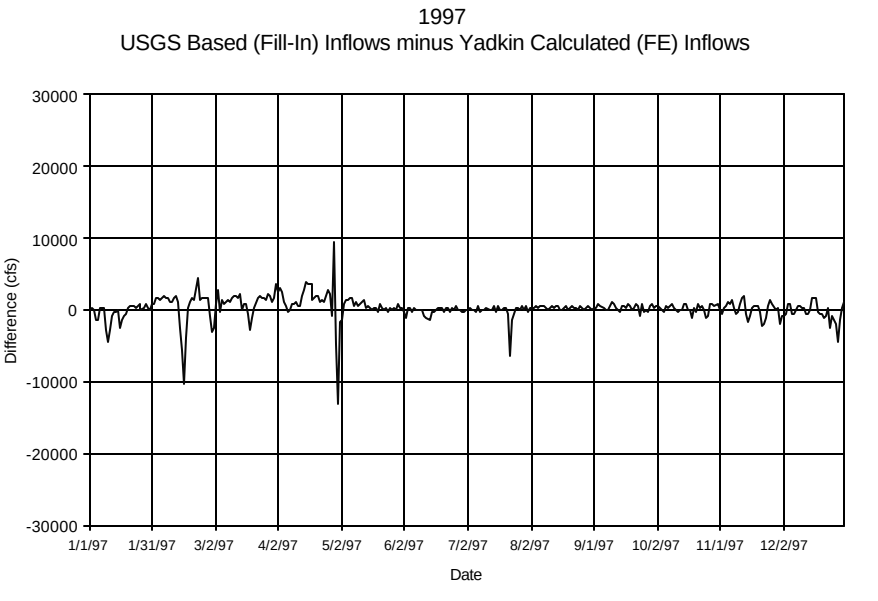

38

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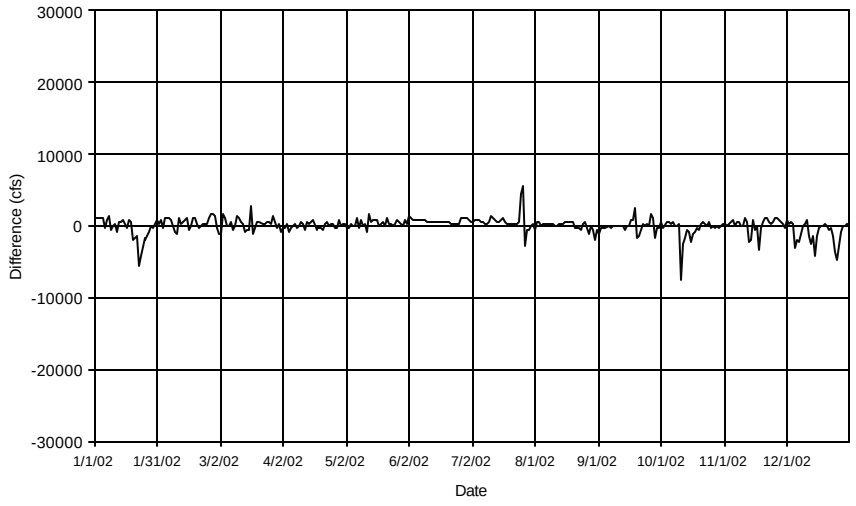
2002
USGS Based (Fill-In) Inflows minus Yadkin Calculated (FE) Inflows



39

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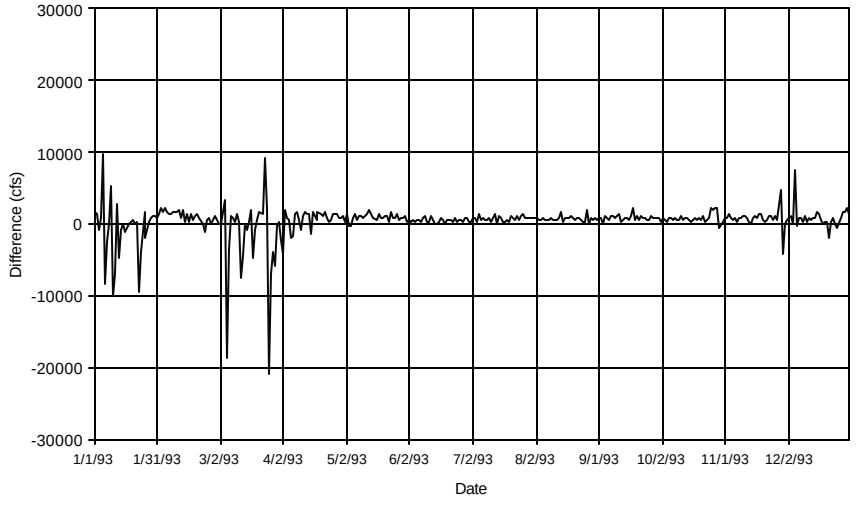
1993
USGS Based (Fill-In) Inflows minus Yadkin Calculated (FE) Inflows



40

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Comparison Conclusions

- On an average annual basis, the USGS based inflows are on average 6% higher than the Yadkin calculated inflows (1980 to 2002)
- Possible reasons include:
  - Accuracy of USGS gage data
  - Accuracy of Yadkin data
    - Turbine degradation
    - Changes in storage-elevation relationship
    - Net evaporation
    - Gate discharge calculations
- Neither data set is “correct”

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Comparison of USGS “Measured” Inflows & USGS Based Inflows at High Rock

- Known flows at High Rock from 1919 to 1927 and 1941 to 1962
  - Known flows at High Rock from 1919 to 1927 and 1941 to 1951 time period were used for Fill-in input. Used Fill-in to estimate flows for 1952 to 1962 time period and compared with known flows.
  - Known flows at High Rock from 1919 to 1927 and 1952 to 1962 time period were used for Fill-in input. Used Fill-in to estimate flows for 1941 to 1951 time period and compared with known flows.

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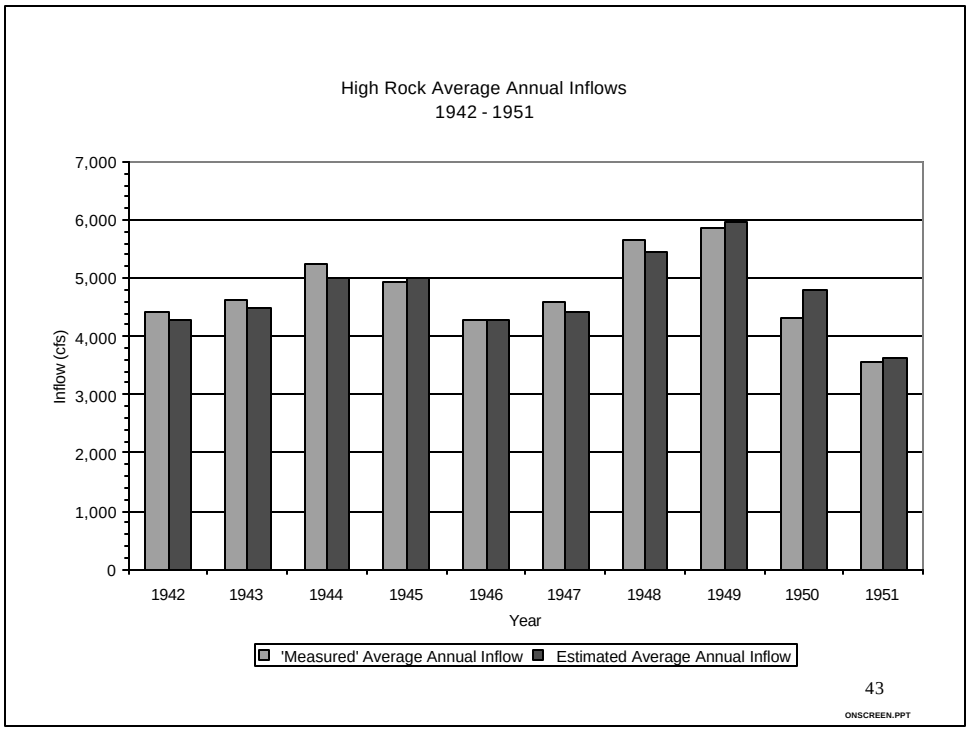
High Rock Average Annual Inflows
1942 - 1951
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Inflow (cfs)
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
Year
'Measured' Average Annual Inflow
Estimated Average Annual Inflow
43
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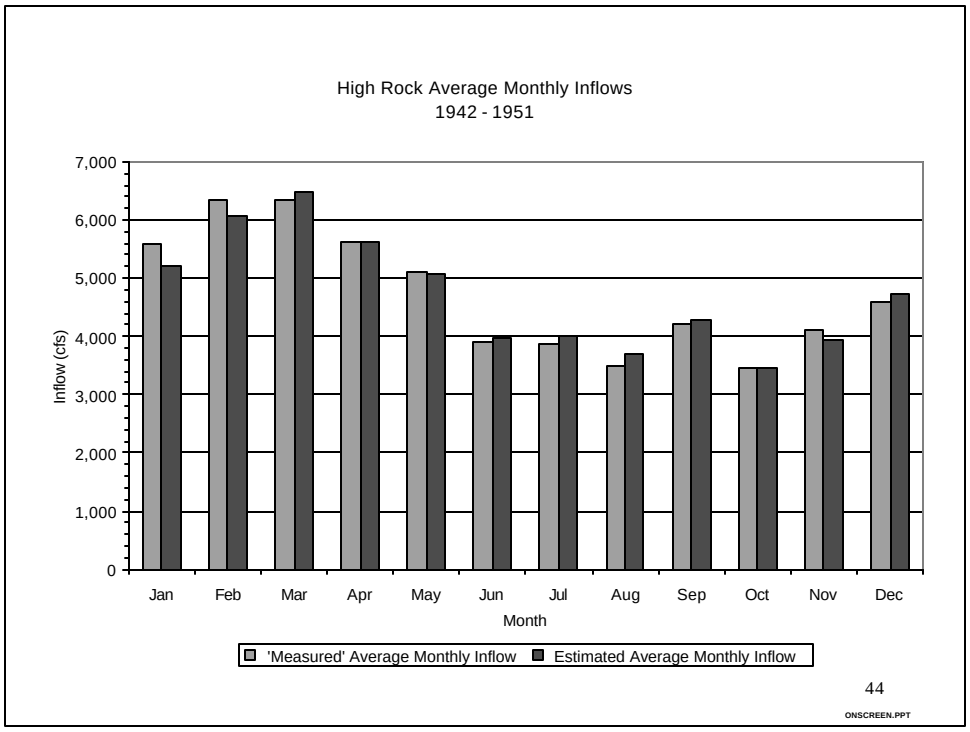
High Rock Average Monthly Inflows
1942 - 1951
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Inflow (cfs)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
'Measured' Average Monthly Inflow
Estimated Average Monthly Inflow
44
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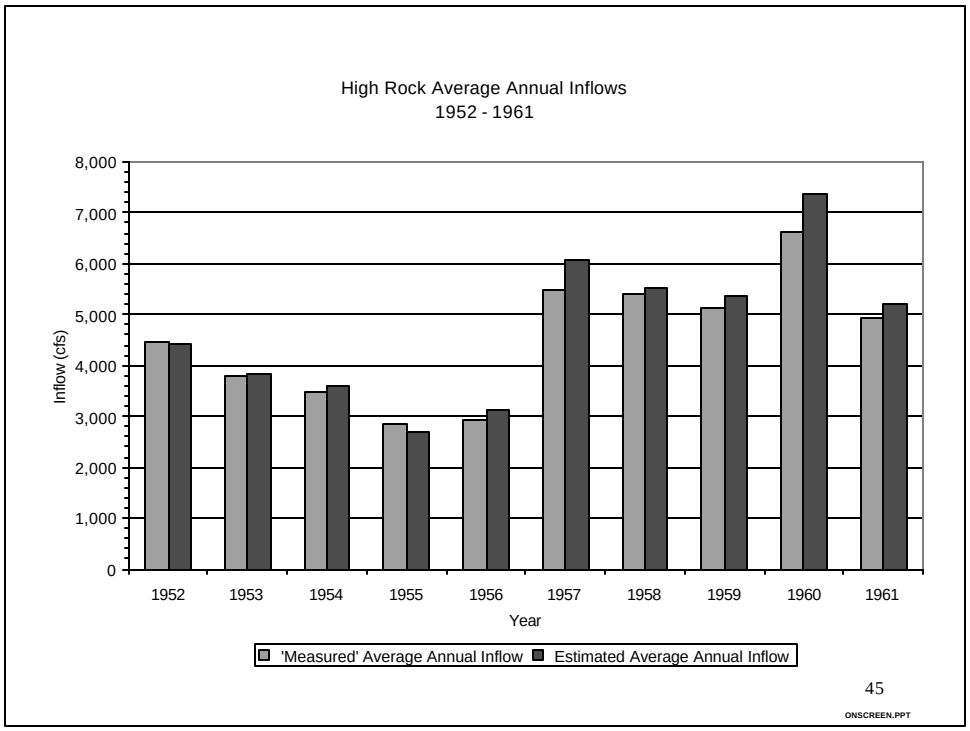
High Rock Average Annual Inflows
1952 - 1961
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Inflow (cfs)
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
Year
'Measured' Average Annual Inflow
Estimated Average Annual Inflow
45
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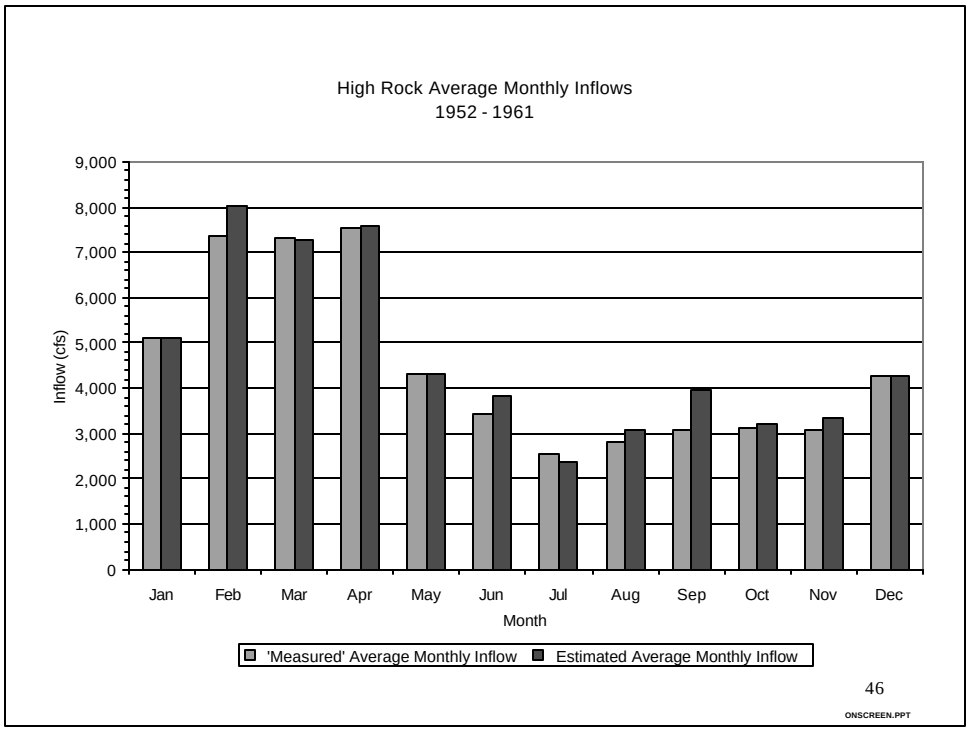
High Rock Average Monthly Inflows
1952 - 1961
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Inflow (cfs)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
'Measured' Average Monthly Inflow
Estimated Average Monthly Inflow
46
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Comparison Conclusions

- Calculated and measured flows compared well
  - On an average annual basis, the calculated inflows are less than 1% lower than the measured inflows (1942 to 1951)
  - On an average annual basis, the calculated inflows are 4% higher than the measured inflows (1952 to 1961)

Comparison of USGS Based Inflows at High Rock & USGS "Measured" Flows Near the Confluence of the S. Yadkin and Yadkin Rivers

- Compared USGS based inflows at High Rock to USGS measured flows at Yadkin College
- Compared USGS based inflows at High Rock to USGS measured flows at the confluence of the of the S. Yadkin and Yadkin Rivers
- Flows at the confluence were estimated by summing:

  Flows recorded on Yadkin River at Yadkin College + Flows recorded on South Yadkin River at Mocksville * 2.15 (DA proration)
- DA at HR =~4,000 sq. mi.
- DA at confluence =~3,000 sq. mi.

Comparison Conclusions

- Measured flows at Yadkin College always less than USGS based inflows to High Rock
- "Measured" flows at confluence less than USGS based inflows to High Rock 98% of the time
  - During April 1980, June 1981, April 1987, and April 2002 "measured" flows at the confluence were higher than flows at High Rock

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Yadkin Developments Inflow Summary

- High level of confidence in estimates of inflows to Yadkin Developments

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Operating Rules

- Existing and base case conditions:
  - High Rock: follow guide curve, operate to maximize the value of generation
  - Tuckertown and Falls: run of river
  - Narrows: modified run of river, follow licensed drawdown schedule

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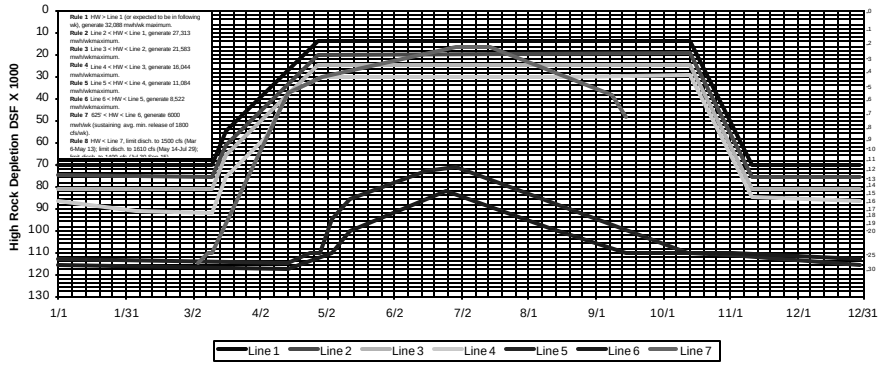
High Rock Reservoir Guide Curve

Figure 2.7-1
High Rock Development Operating Guide



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High Rock – Narrows Drawdown Schedule

High Rock Reservoir Elevation (ft, YD)	High Rock Reservoir Drawdown (ft)	Narrows Reservoir Elevation (ft, YD)	Narrows Reservoir Drawdown (ft)
655.0	0.0	541.1 - 539.0	0.0 - 2.1
654.0	1.0	539.5 - 534.5	1.6 - 6.6
631.0	24.0	539.5 - 534.5	1.6 - 6.6
631.0	24.0	534.0	7.1
629.0	26.0	525.0	16.1
625.0	30.0	510.0	31.1

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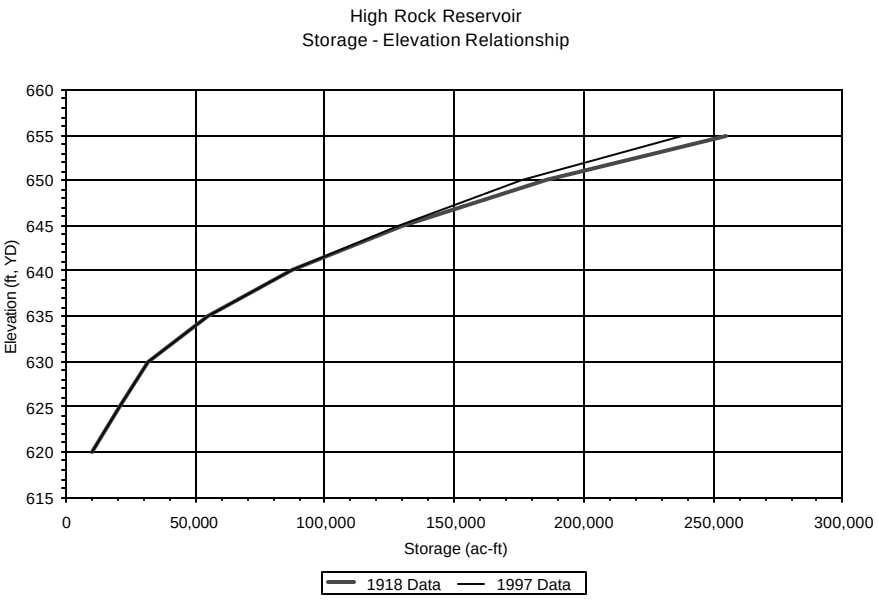

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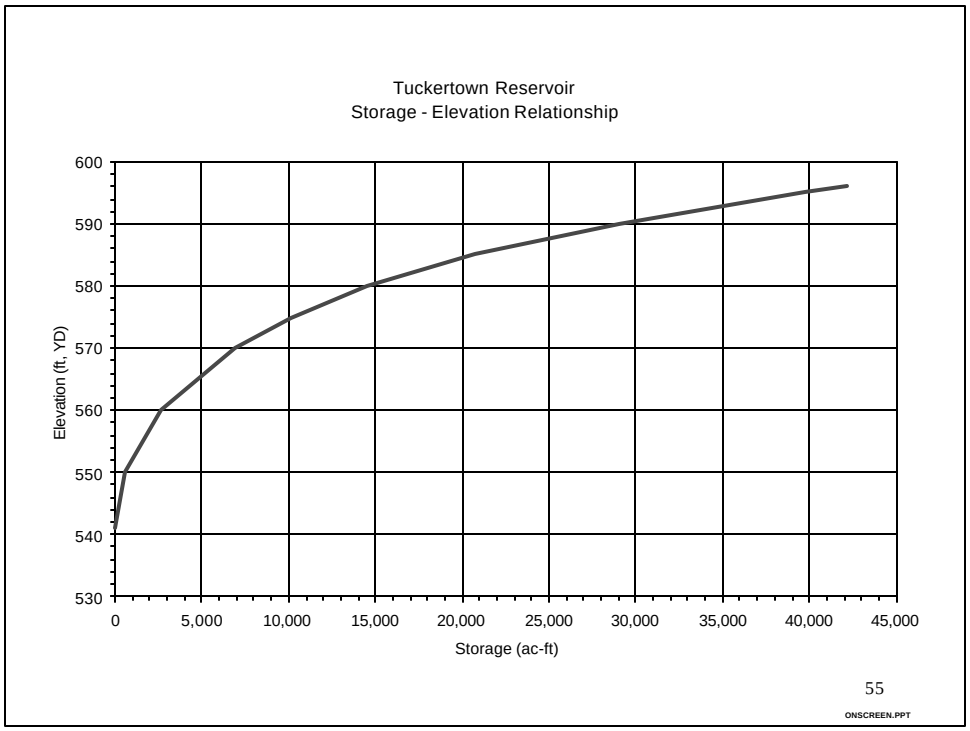
Tuckertown Reservoir
Storage - Elevation Relationship
600
590
580
570
560
550
540
530
Elevation (ft, YD)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Storage (ac-ft)
55
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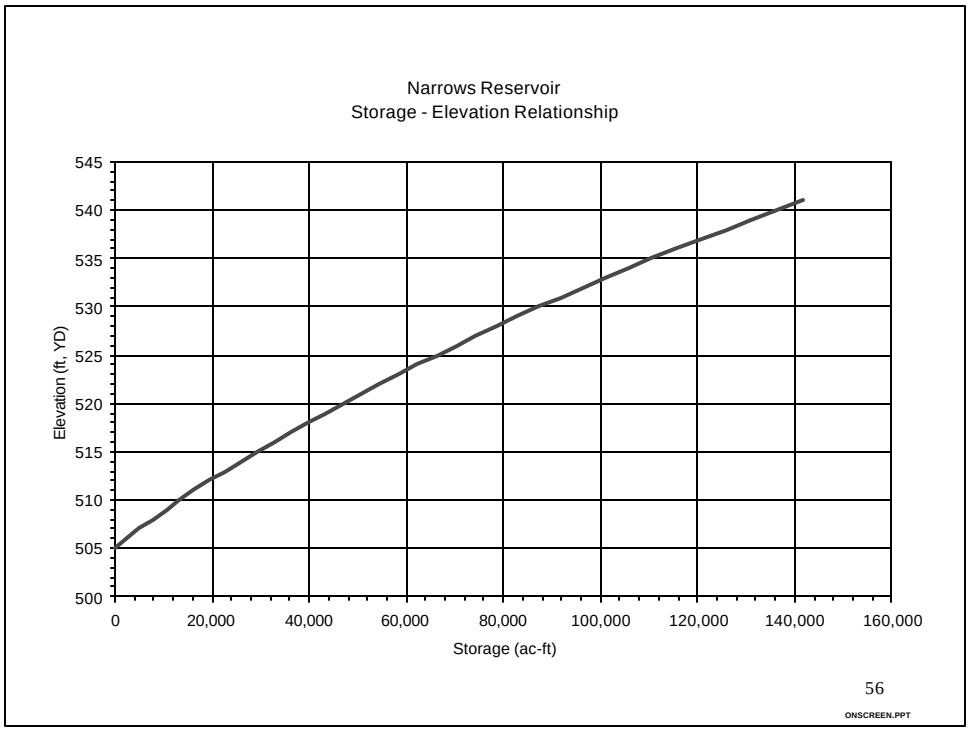
Narrows Reservoir
Storage - Elevation Relationship
545
540
535
530
525
520
515
510
505
500
Elevation (ft, YD)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Storage (ac-ft)
56
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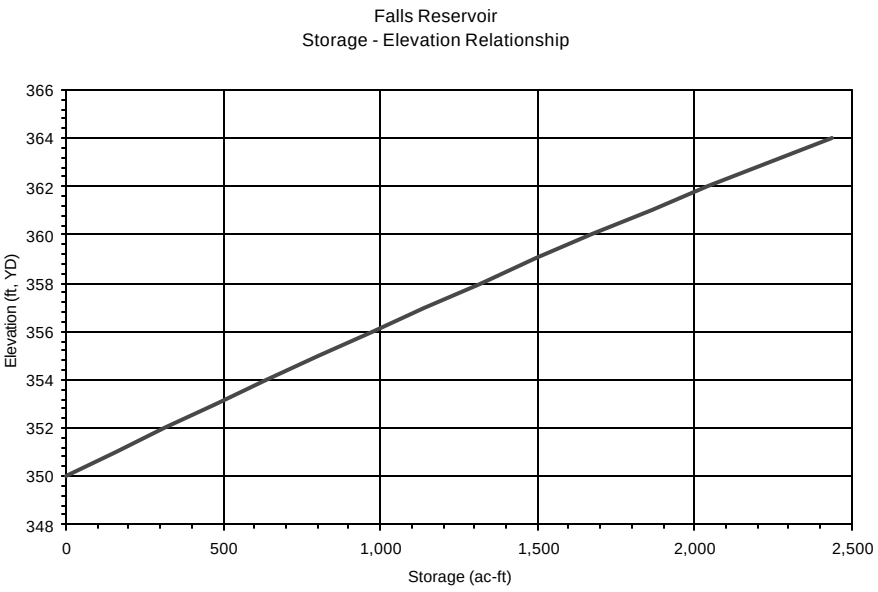

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Turbine Efficiency Curves

- Existing condition (calibration & verification):
  - Turbine degradation taken into account
  - High Rock and Narrows have multiple curves for varying heads
  - Narrows has separate curve for with and without air injection
- Base case condition (alternative evaluation):
  - High Rock and Narrows units upgraded
  - High Rock and Narrows have multiple curves for varying heads
  - High Rock and Narrows have separate curves for with and without air injection

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Progress Energy Developments

- Inflows to the Progress Energy Reservoirs
- Operation of Progress Energy Reservoirs
- Other pertinent data

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Progress Energy Developments

- Plan to exchange information with Progress Energy
- Have started effort of assembling publicly available data
  - USGS based inflows
  - Storage – Elevation relationships in ICD
  - Estimated Area – Elevation relationships
  - Limited operating data in ICD
  - Maximum turbine capacities in ICD

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Progress Energy Developments USGS Based Inflow Data

- Fill-in not used since Yadkin River down to Blewett Falls is ungaged
- Falls to Tillery (420 sq. mi.)
  - 1938 – 1971: Use Eldorado gage on the Uwharrie (360 sq. mi.)
  - For remainder of record, use Rocky River gage
  - Pro-rate gage flows by drainage areas
  - Cfsm for overlapping period
    - Eldorado: 0.95
    - Rocky River: 0.92

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Progress Energy Developments USGS Based Inflow Data (cont.)

- Tillery to Blewett Falls (2230 sq. mi.)
  - Three tributary gages
    - 1929 – present: Rocky River (1372 sq. mi.)
    - 1954 – present: Little River (106 sq. mi.)
    - 1938 – 1971: Brown Creek (110 sq. mi.)
  - Total ungaged drainage area = 642 sq. mi.
  - Inflows to Blewett =

    Sum of tributary flows + weighted average cfsm * ungaged drainage area

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Comparison of USGS Based Inflows to Tillery and USGS Based Outflows from Falls

- Use Rockingham gage flows and work upstream, accounting for change in storage and net evaporation at Blewett and Tillery and estimated tributary inflows
  - USGS publishes monthly elevations and change in storage for all projects in the Yadkin basin
- Compare Tillery inflows and Falls outflow based on the sum of Fill-in estimated High Rock inflows + tributary inflows to Tuckertown, Narrows, and Falls + change in storage and net evaporation at each project

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Comparison of Inflows to Tillery and Outflows from Falls (cont.)

- Monthly variation significant, but average difference for two year period only 5%
- Potential sources of discontinuity:
  - Large ungaged area
  - Cumulative error from inaccuracy of USGS measurements
  - Different stage-storage at Blewett (USGS vs. Progress Energy)

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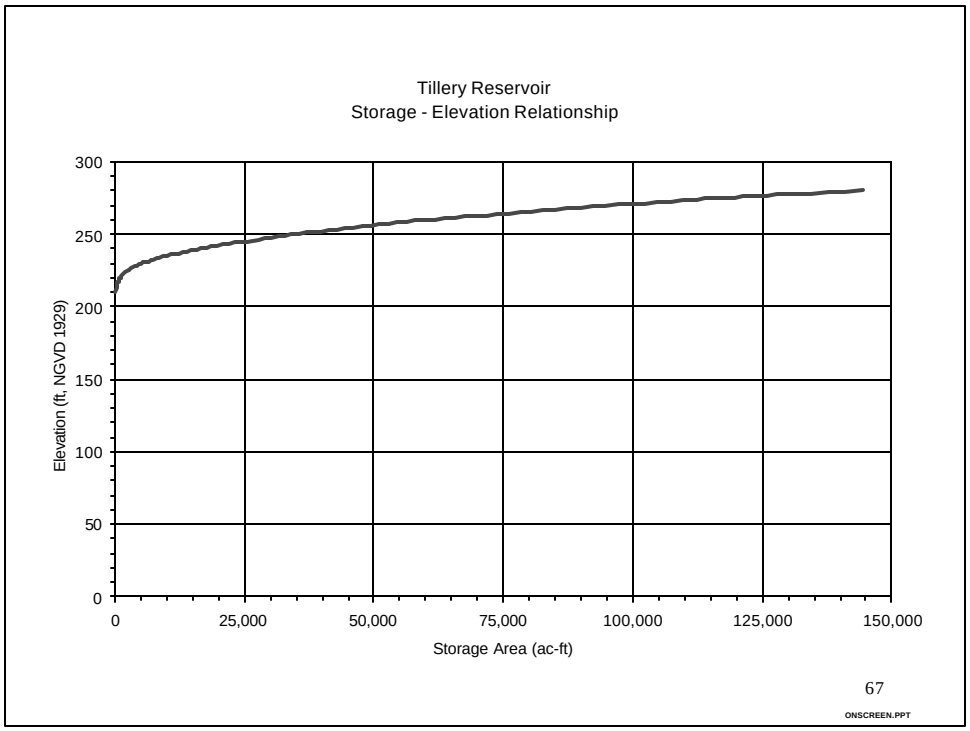
Summary of Progress Energy Developments Inflow Development

- Flow continuity downstream of Falls needs further refinement
  - Improve tributary inflow estimation
  - Sharing of inflow data with Progress Energy

Operating Protocol

- Existing and base case conditions:
  - Tillery: assume run of river (1.5 ft daily drawdown in reality)
  - Blewett Falls: starts operating when Tillery starts, operates approximately 10 hours/day, daily drawdown of 2 to 3 ft
  - Continuous releases
    - Tillery: 40 cfs
    - Blewett Falls: 140 cfs
    - Tillery average leakage flow: 78 cfs


Tillery Reservoir
Storage - Elevation Relationship
Elevation (ft, NGVD 1929)
300
250
200
150
100
50
0
0
25,000
50,000
75,000
100,000
125,000
150,000
Storage Area (ac-ft)
67
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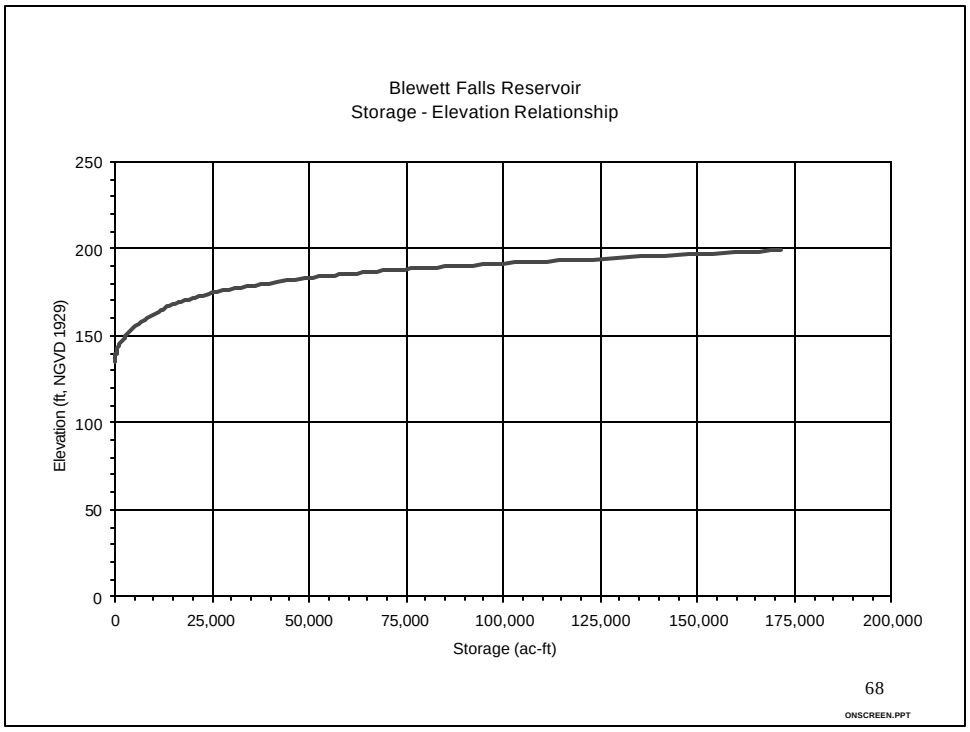
Blewett Falls Reservoir
Storage - Elevation Relationship
Elevation (ft, NGVD 1929)
250
200
150
100
50
0
0
25,000
50,000
75,000
100,000
125,000
150,000
175,000
200,000
Storage (ac-ft)
68
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Turbine Efficiency Data

- Progress Energy ICD:
  - Maximum capacity of Tillery:
    - 17,700 cfs
  - Maximum capacity of Blewett Falls:
    - 9,200 cfs
- Understand developments typically operated at best efficiency, not maximum capacity
  - No way to estimate operation of Tillery from publicly available data
  - Can estimate operation of Blewett from Rockingham gage

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Node Locations

- Nodes are most meaningful when used at locations where inflows are known
- Yadkin proposed having nodes at each of the 7 dams (W. Kerr Scott through Blewett Falls)
- Other possible node locations include:
  - USGS gage stations
  - River confluences
  - Environmental or other critical locations

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Schedule and Status of Model Development

- Yadkin Developments
  - USGS based inflow dataset complete
  - Calibration / verification
    - Using Yadkin calculated inflows – complete
  - Operations model
    - Using USGS based inflows – in progress
- Progress Energy Developments
  - USGS based inflow dataset development in progress
  - Gathering of publicly available data in progress
  - Unless data is exchanged – calibration / verification not possible

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Schedule and Status of Model Development (cont.)

- Model available to public 4th quarter
- Previous experience on making model available to public
  - Confidentiality agreements
  - Training classes
  - In the end, model runs made by PB Power and data shared with participants
- Yadkin's preference would be to provide model at IAG meetings / work sessions, similar to Tapoco
- Confidentiality agreement will be needed

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Schedule and Agenda for Next Meeting

- Desire for joint operations workgroup meetings discussed at last Progress Energy Water RWG meeting

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