Surface Water Quantity Models

Progress Meeting Notes

January 4, 2016 – Teleconference

Attendees: **CDM Smith**: John Boyer, Tim Cox, Kirk Westphal, Nina Caraway, Chris Kurtz
SCDNR: Joe Gellici, Andy Wachob, Scott Harder, Alex Pellet, Bill Clendenin
DHEC: David Baize, Rob Devlin, Leigh Anne Monroe
Clemson: Katie Buckley
Technical Advisory Committee: Eddie Twilley, Ed Bruce, K.C. Price, Heather Nix, Eric Kruger, Andy Fairey, Ruth Albright, Mike Harrelson, Mullen Taylor

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1. **Saluda Basin**
    a. Response to Comments
    - Scott Harder indicated that he is still reviewing CDM Smith's response to comments on the Saluda calibration model and report, including the updated storage targets for Lake Murray. Scott suggested that it may be more appropriate to show graphical comparisons of Lake Murray simulated vs. observed levels using the Project Datum (PD) rather than NAVD88 datum. Scott also suggested, in anticipation of possible future stakeholder scrutiny, that it may be beneficial to further validate the model's ability to reproduce historical Lake Murray levels and/or releases during a drought period, as suggested by Ed Bruce during the December progress meeting. CDM Smith included a focused comparison of the 2001-2002 drought period in the calibration/validation section of the report; however, beginning in late 2002, the lake level was lowered by the operators because of the backup dam construction, therefore the lake's potential response to reduced inflow was overshadowed.
    - Ed Bruce clarified his previous suggestion, stating that if a time series of observed historical lake levels was entered into the model, then the model would calculate a release, which could be compared to actual releases over that

period. Alternatively, a time series of actual releases could be entered, and the model's ability to reproduce lake levels could be observed. This would help confirm that assumptions made regarding evaporation, bathymetry, storage targets, and withdrawals were appropriate.
- Tim Cox indicated that some hard coding would be necessary in SWAM to perform this type of analysis.
- Ed Bruce noted that it was exceptionally dry in 2001, and the existing comparison presented in the report may suffice. He also noted that during the 1980's there were periods of drought which might be worth examining.
- Joe Gellici indicated that because this is the pilot model, additional evaluation and documentation may be worth the effort, and help demonstrate the validity of the tool and approach.
- Bill Clendenin noted that during the previous meeting, an approach was floated that would table additional analyses, such as this, until later in the project, for the sake of allowing CDM Smith to focus their effort on the remaining basins.
- John Boyer indicated that CDM Smith will discuss an approach internally, and then with DNR. John noted his concern for budget and schedule, and their desire to move forward with other basin models.

b. Updated Calibration Workbooks, Report and Models
- John Boyer indicated that updated daily and monthly calibration results workbooks had been posted to the SFT site for download by DNR and DHEC staff, and that the updated model report was distributed along with the response to comments, to DNR, DHEC and the TAC.

2. Draft Edisto Calibration Model

a. Updated Calibration Results (slides)
- Tim Cox provided and update on calibration of the Edisto model. Results from the latest iteration were discussed with general reference to the slides distributed prior to the meeting. Tim noted that several iterations have been evaluated which use various reference gage combinations for the ungagged South Fork Edisto River tributaries. CDM Smith is reviewing the different iterations to determine which provide the best agreement of both low and high flows and reduces seasonal bias that was observed in the early iterations. The

latest iteration uses EDO5, a mainstem gage, as a reference for the most upstream, ungagged South Fork Edisto tributaries.
- Alex Pellet noted that EDO5 did not produce favorable results when it was evaluated for use in extending McTier Creek (via area proration), and therefor, it may not be a good, representative gage to use for the headwater tributaries.
- Tim Cox suggested that there may be hydrologic differences in McTier Creek and ungaged headwater tributaries, given that it doesn't appear to work well when used as a reference for the ungagged headwaters (based on calibration results along the mainstem).
- John Boyer indicated that CDM Smith has still to run and evaluate the daily results for the latest iteration. Once that is complete, CDM Smith will evaluate both the monthly and daily results, and determine whether additional iterations are warranted to improve results.
- Eric Krueger stated his preference for the calibration to focus on getting low flows as accurate as possible.

3. Broad UIFs

a. Response to Comments and Status
- John Boyer indicated that CDM Smith has been working on UIFs on the Enoree, Tyger and Pacolet rivers. The Enoree and Tyger are currently being checked, and CDM Smith is working with DHEC to correct and confirm withdrawal and discharge data on the Pacolet, before finishing draft UIFs there.

4. Upcoming Deliverables

a. Finalize Draft Edisto Calibration Model and Baseline Model
b. Draft Broad UIF Dataset, end of Jan target
c. Draft Pee Dee UIF Dataset, early/mid Feb target
- John also noted that CDM Smith intends to develop and submit the draft framework for the Santee Basin before the end of January.

5. Other Items

a. CDM Smith to Update Schedule for Upcoming Stakeholder Meetings
- At the beginning of the meeting, John noted that he is updating the proposed project and stakeholder meeting schedule, and would distribute it later in the week. The next meeting will be the first stakeholder meeting in the Santee Basin,

and should occur sometime in late February. The second stakeholder meetings in the Broad and Pee Dee are expected to occur in April, once the Draft SWAM models are ready.

Memorandum

To: John Boyer (CDM Smith)

From: SCDNR Hydrology Team

Date: 11/23/15 CDM Smith Responses (in red) 12/30/15

Re: Comments on updated Saluda SWAM Calibration Model (dated 10/23/15) (the original DNR comment Memorandum (and CDM Smith responses) on the Saluda Calibration Model dated 10/6/15 is provided at the end)

1. Edit Section 2, goal # 5 by adding "… and to test alternative instream flow recommendations (See also Comment #2 under "Additional Comments on the Calibration Report" below.)
   CDM Smith Response: This has been added and will appear in the final report.

2. We still request that run-of-river hydropower plants be represented in the framework. In addition, there is also no hydropower representation for Lake Greenwood and Lake Murray on Figure 4-1. (Refer to comment #3 below under "Additional Comments on the Calibration Report")
   CDM Smith Response: The hydropower plants are represented and labelled in the baseline model. Figure 4-1 of the report has been updated to show the framework with the hydropower representation.

3. In the "Model Calibration Results Saluda Daily_11-5-15" spreadsheet, the elevations do not appear to have been updated (or at least updated correctly) from the new model output storage values for Lake Greenwood (and possibly Lake Murray). We need to review these elevations to help evaluate model performance.
   CDM Smith Response: The monthly and daily storage amounts and elevations have both been updated and will be provided to DNR in the new calibration results workbooks. See response to comment 9c for further explanation with regard to Lake Murray.

4. We still question the use of a calibration period from 1983-2013 for Lake Greenwood. In an email correspondence with CDM Smith, the recommendation was made to limit the calibration period to 1993-2009, during which one guide curve was very closely followed (Refer also to comment #1 below under the overall calibration approach from our earlier Memorandum). Assuming that modeled versus observed lake elevations for Greenwood (and Murray) are considered along with the streamflow gages to determine a good calibration, there are several reasons why we think this shorter calibration period is appropriate:
   a. This period still includes a wide range of hydrologic conditions.
   b. The guide curve for this period was very closely followed so there is reasonable confidence that reservoir managers operated relatively consistently and according to defined FERC rules. In addition, FERC required releases from Lake Greenwood as

described in the new 1995 license are applied to the 1983-1993 period (1993 appears to be about when the new license requirements began to be followed, though the license may not have been official until 1995). Do you have any documentation on what the required releases were prior to 1993-1995? [**CDM Smith**: No, we did obtain any documentation of releases prior to 1993-1995] If they are different, which there is a strong possibility that they were, then this is another reason to drop this period from calibration.

c. The calibration process would lead to better defined gain/loss factors. When trying to calibrate using periods prior to 1993 and post 2009, when different guide curves were in place, the model is releasing or holding water to match a guide curve that operators were not trying to match. Assuming that the calibration procedure attempts to match downstream flows, we think this would skew the gain/loss factors because you are trying to match downstream gage data with reservoir release patterns that, at times, never occurred (see summer/fall 2012 period in Figure A for example). Instead of obtaining what should be reasonable factors associated with the 1993-2009 period, the end result is an approximation (or averaging?) over all periods. Though the uncertainty resulting from using the entire 30-year period may be small (in part due to the three guide curves being similar for some months of the year and in part because the upstream stream gages likely carry a lot of weight when determining a good calibration), we think limiting the calibration period is a better practice and gives better clarity on evaluating model performance (see d below).

d. Model evaluation is easier. When trying to evaluate model performance, there will be less doubt or confusion knowing that there is no additional uncertainty in the gain/loss factors and reservoir hydrographs are easier to interpret. One example of how model performance is obscured occurs in 2011 (see Figure A below). Observed elevations began declining in July but weren't scheduled to be reduced until the end of October under the new guide curve that began in 2010. This decline is presumably due to low inflow conditions. The modeled elevations begin to decline at end of September under the old guide curve. So a small drought period appears to be evident from the observed data, but the model obscures the drought because it tells the lake to follow the incorrect guide curve. Though we are aware that a different guide curve was in place in 2011, the average reader will not be aware and will think the model did a reasonable job, which it may very well have. But we don't really know for sure, since the declines in August 2011 are at least, in part, due to using the old guide curve. Under the new curve the lake was actually attempting to maintain 81000 through the end of October. So was the model representing this drought reasonably well or not? To determine this, you would need to use the new guide curve as an input to the model and verify whether the model was able to reproduce this low inflow period.

CDM Smith Response: Although the latest calibration results graph still presented a comparison of modeled vs measured lake storage values over the 1983 to 2013 period, the focus of the calibration, in terms of setting gain/loss factors, was on the 1993 to 2009

period, when the old guide curve was in effect. The final calibration gain/loss factors were deemed appropriate based on the excellent match in measured vs. modeled flows at downstream gage SLD18 (Saluda River near Chappells) during the 1993-2009 period. At this gage, average measured and modeled flows were 1,534 cfs and 1,539 cfs respectively, for a difference of 0.3%. Over the full calibration period (1983-2013), average measured vs. modeled flows were 1,524 cfs and 1,543 cfs respectively, for a difference of 1.2%.

We agree that including the entire period in the calibration results graphs may cause confusion to the reader. This will be removed and Section 7 of the report will be revised to reflect the fact that calibration of the model at and immediately downstream of Lake Greenwood focused on the 1993 to 2009 period, where one guide curve was closely followed. During calibration, gain/loss factors were adjusted downstream, based on the results primarily during this period.

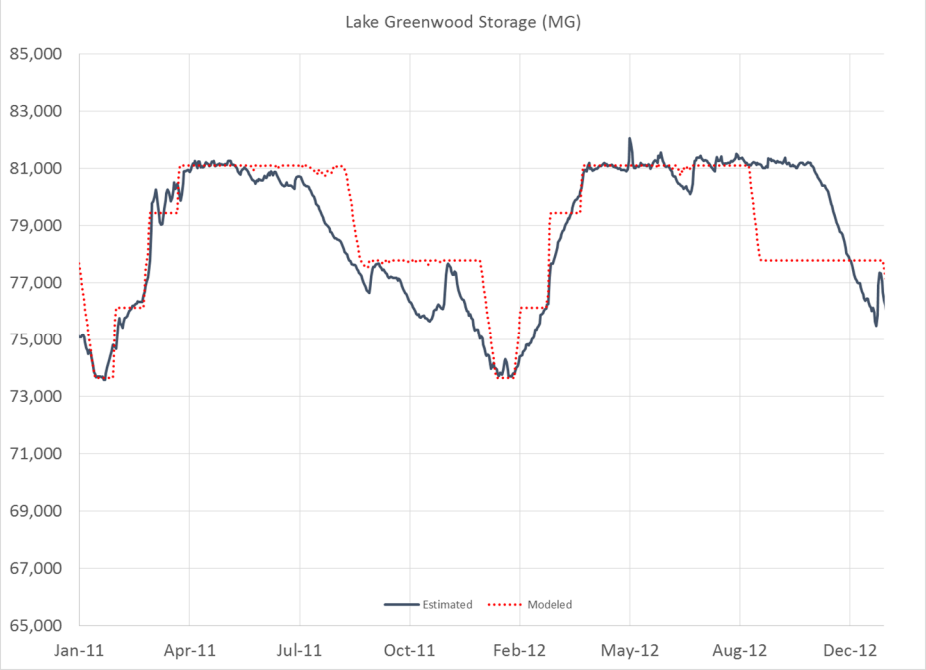


Figure A.

5. Refer to comment #2 below under the calibration approach. The original comment was a little unclear, though we thought this was clarified on a conference call in October. We were referring to a detailed review of a drought year(s) for Lake Greenwood and Lake Murray to test whether the model was reproducing any resulting declines in lake elevations. We still strongly recommend that the calibration/verification method incorporate such a test. This has been a fairly common practice for water allocation modeling in the Carolinas over the past decade for FERC relicensing and COE drought planning. We understand that we should not expect a *very high* degree of accuracy when trying to compare modeled elevations to observed elevations

owing to the (understandable) uncertainty in UIFs and inability to model every human operational decision regarding the reservoirs. In addition, historic drawdowns due solely to drought and not management in Lake Greenwood and Lake Murray are not real severe, approximately only 1-2 feet typically. Expecting the model to accurately match *all these small drawdowns* may be unreasonable, but the evaluation of model performance for the Saluda basin on droughts must include a thorough review for two reasons:

a. We have to have confidence that the model is representing the drought of record and perhaps other severe droughts reasonably well since these are times where water shortages are most likely to occur and are most critical for water management.
b. Other basins have more severe drawdowns. Though this may be more challenging for the Saluda Basin, we need to develop a method to evaluate model performance during droughts to set a precedent for other basins where drawdowns are more severe.

CDM Smith Response: A focused examination of modeled vs. measured lake levels during drought periods has been added to Section 7 of the report. An example of the calibration/validation check for Lake Greenwood was presented during the December Progress Meeting. A similar analysis was completed for Lake Murray during the drought period of 2001-2002 and added to Section 7. SCE&G began lowering the lake levels in mid-2002, due to safety concerns associated with the backup dam construction, therefore drought impacts associated with potentially reduced inflow are hard to discern. In the 2007-2008 drought, the new guide curve was being followed.

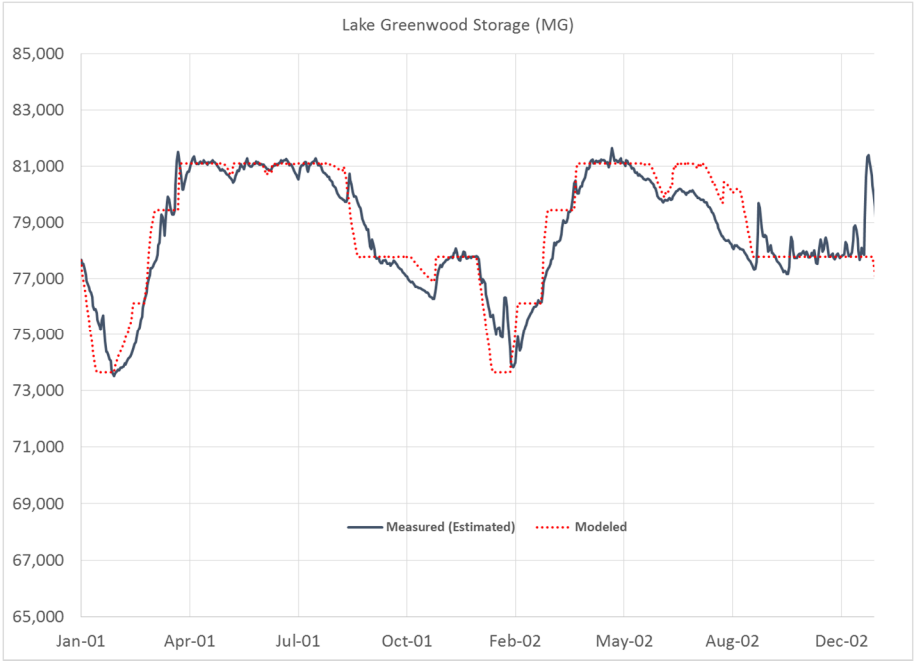


Figure 1. Lake Greenwood 2001 to 2003 Calibration (Drought Period) Check

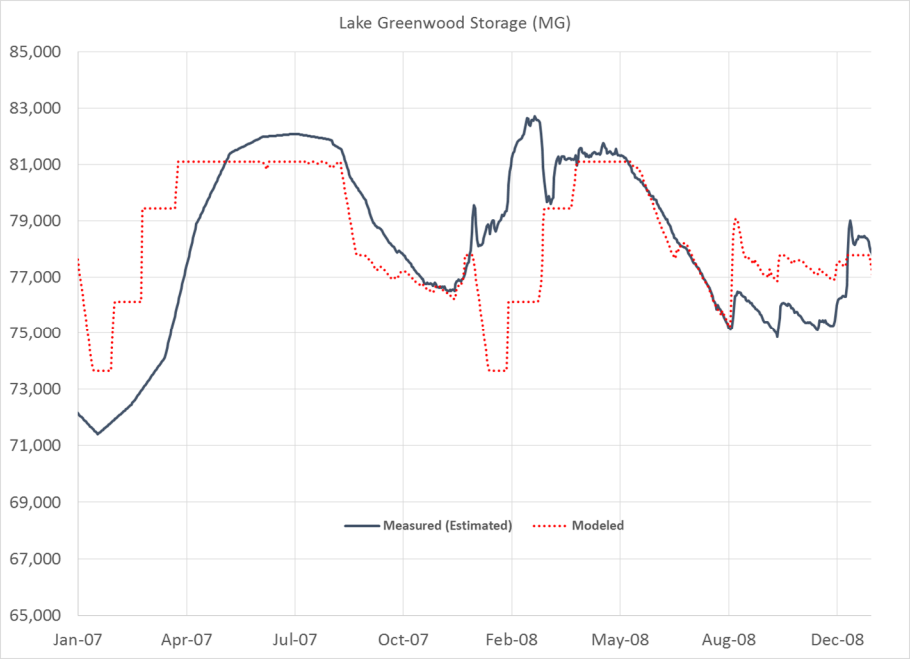


Figure 2. Lake Greenwood 2007 to 2009 Calibration (Drought Period) Check

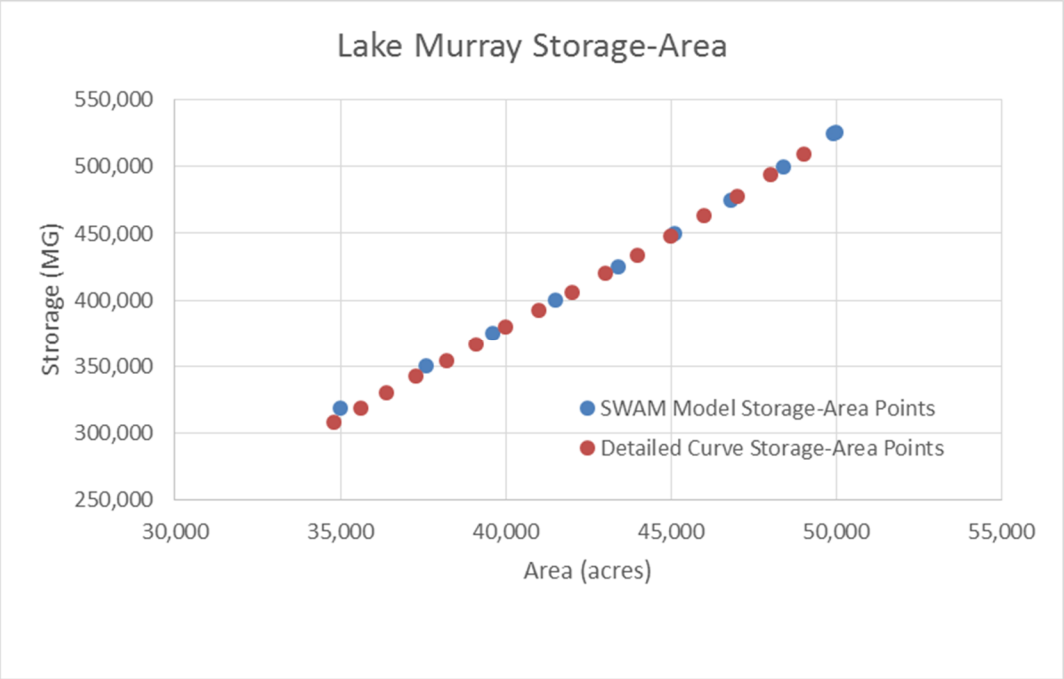
6. When storage targets change from month to month, the model appears to make the transition over the first 3-10 days of the month, so that the rest of the month (20-27 days) has the end of month storage target value. We were not aware that this was how these transitions were done and does not seem to reflect actual guide curve dynamics (though this may no longer be an issue with the planned model enhancements).
   CDM Smith Response: As it pertains to the daily model, the planned model enhancements can improve this representation by offering more flexibility with regard to defining storage targets and time periods. This does not apply to the monthly model.

7. We have had some discussion on this, but not sure if we have decided as a general rule to use pending FERC requirements in the baseline models?
   CDM Smith Response: As it stands now, the pending rules can be toggled on or off. Once the enhancements are in place, it is up to DNR as to which rules are included by default – current or pending. Annotation describing both current and pending rules can be included in the model and/or report so that the model user can incorporate one or the other.

8. Refer to comment 4c under the calibration approach below. We are still not sure the right minimum flow release is being used. Was there an attempt to look into this? The CDM Smith below response does not address this part of the original comment. We have some documentation that suggests there is a 180 cfs minimum release requirement at all times in addition to the requirement that at least 285 cfs be maintained at USGS gage 2169000.

CDM Smith Response: As a simplifying assumption, a release sufficient to maintain 285 cfs minimum day average flow at USGS gage 2169000 was included during the calibration. Including the minimum flow release of 180 CFS as measured at USGS Gauge 02168504 was determined to have no effect on the calibration, since that gage was only slightly upstream of the other one.

9. Refer to Section 6.2.3:
    a. Adding more resolution (more points) to the area-capacity relationships may be warranted and seems this would be an easy addition/enhancement to the model.
    CDM Smith Response: In future basins, where data is available, this can be done, if warranted. In the Saluda, we obtained a detailed table of area-capacity relationships for Lake Murray; however, over the operating range of lake levels observed at least since 1980 (minimum elevation of 346.2 ft PD), the area-capacity relationship is basically defined by a straight line (see graph below). Therefore, for simplicity, we only used enough points to define this straight line using the "simple" table option. No additional resolution would result if more points were included, and the "detailed" table option was used, especially since it is only being used here to calculate evaporation. For all other reservoirs in the basin, only enough data was available to define the area-capacity relationships using the "simple" table option.



    b. Saluda Lake has a 1 cfs flood control outflow? How critical is this to include? Please provide more detail on why this was needed.
    CDM Smith Response: The 1 cfs was a residual number from an earlier model version. It has no impact on the model, since the lake is always at full capacity (spilling/bypassing much more than 1 cfs). We have removed it to avoid confusion.

c. Refer to comment 4a below under the calibration approach. There still appears to be confusion over Lake Murray guide curve elevations and storage targets for the calibration model. Again, the wrong datum, we believe, is being used. See Table 1 below for appropriate storage targets which is based on SCE&G's Plant Datum. According to SCE&G, the USGS gage data for Lake Murray is also Plant Datum. We understand that this guide curve was not followed closely at all times, especially during winter drawdowns, but the summer target storages were typically followed if inflow allowed. We understand altering storage targets during the calibration process during the winter drawdowns, but are not sure about adjusting the late spring/early summer targets. Regardless the *input storage targets and output storage results* for Lake Murray in the Calibration model suggest that the Lake was maintained at 359 or above (Plant Datum) for the late spring/early summer periods, but the 358 was the actual target elevation (though storage for some years ranged from 358-358.5).

   In addition, the baseline model's storage targets do not reflect the current guide curve that is pending under the new FERC license (nor does it match any known curve that has been used at the lake, see also comment 7 above). See Table 1 for appropriate baseline storage targets Also, Lake Murray storage targets were used as a calibration parameter, but as the last paragraph of page 7-3 states, there were only slight changes. Please quantify 'slightly'.

Calibration Targets				Baseline Targets		
Date	Elevation (PD)	Storage (MG)		Date	Elevation	Storage (M
1-Jan	350	379633		1-Jan	354	433839
1-Feb	351	392697		1-Feb	356	462928
1-Mar	353	419796		1-Mar	358	493542
1-Apr	356	462928		1-Apr	358	493542
1-May	358	493542		1-May	358	493542
1-Jun	358	493542		1-Jun	358	493542
1-Jul	357	478041		1-Jul	358	493542
1-Aug	356	462928		1-Aug	358	493542
1-Sep	354	433839		1-Sep	358	493542
1-Oct	352	406082		1-Oct	357.3	482692
1-Nov	351	392697		1-Nov	356.7	473502
1-Dec	350	379633		1-Dec	356	462928

Table 1.

Until the storage targets are updated correctly, the performance of the model cannot be properly assessed.

CDM Smith Response: The storage targets have been revisited and revised. The datum conversion that was used to generate the storage target curve for the calibration model was incorrect, as noted. This has been corrected. Additionally, we have switched the storage targets to reference Lake Murray gross storage instead of usable storage. Prior to the most recent FERC application, SCE&G had reported only usable storage. As part of the recent FERC application, the relationship between lake elevation and gross storage is now available. Finally, in both models, the (revised) calibration and baseline storage targets have each been increased by 1%. The increase came out of the calibration process to better match observed levels and to offset the model's tendency to track slightly lower than the prescribed curve. This is further explained in Section 7.

d. For the baseline model, there is an additional pending FERC license requirement that incorporates a low inflow protocol that is not described in the report.
CDM Smith Response: The low inflow protocol (LIP) in the pending FERC license has been summarized in the report (see Appendix D) and will be included in the baseline model. CDM Smith is waiting on approval of the reservoir enhancements change order before updating the baseline model to include these. If DNR determines that the added flexibility offered by the proposed reservoir enhancements is not needed, the rules associated with the LIP can still be included, but the user will only have the option of turning them on or off, as opposed to adjusting individual components of the rules.

   In addition, how are the Broad River flows being incorporated into the baseline model when the Striped Bass Rule is turned on? Is this based on gage data? Or will it be based on modeled Broad River flows?
CDM Smith Response: This will depend on the scenario that is being modeled. If the model user wants to account for future changes in the Broad River, then they will have to use output from the Broad model as input to the Saluda model. If the given scenario does not call for changes to Broad River baseline then no changes to those flows will be required. In this case, gage data can be used – which ideally, will be very similar to Broad river baseline flows. However, eventually the baseline Broad River flows in the Saluda model will be output from the baseline Broad River model – not gage data.

10. Table 6-13 has percent consumptive use for SCE&G's McMeekin Station listed as 2.5%, but the text under section 6.3.4 states a percent consumptive use of 26%. In addition, the McMeekin Station is scheduled to close and may be replaced by a Natural Gas facility soon. Should this be reflected in the baseline model (We think this question had come up before, but do not remember how or if this was ever resolved).
CDM Smith Response: Table 6-13 has been corrected to show 26% consumptive use. Initially, due to poor NPDES discharge records, we were going to assume 2.5% consumptive use, which is a general, literature-based amount for thermoelectric facilities. After further discussions with SCE&G, we decided to use 26%, which is the estimate provided by SCE&G when their withdrawal

permit was issued. The calibration and baseline models both reflect a 26% consumptive use amount.

When McMeekin Station closes, the baseline model can be updated by removing the SCE&G Water User object, or alternatively, the withdrawal can be set to zero until the expected withdrawal amounts of the future natural gas facility are known.

11. We still would like to know "How large were changes in reach gains and losses and how large were the subsequent changes in flow volumes for your UIFs?" (Refer also to comment 3 below under the calibration approach). Please consider adding to Table 6-3 a column showing the initial estimate of gain/loss based on area ratio, for comparison with the final, calibrated gain/loss factor.
    CDM Smith Response: A column in Table 6-3 listing the initial area ratio-based estimates of the gain/loss factors has been added to facilitate comparison with the final gain/loss factor.

12. Will there be a "follow-up" calibration for SLD27 (Congaree River at Columbia) after the Broad basin is complete. We understand how the Broad River was used to check the calibration for the Saluda Basin, but ultimately, won't another calibration need to be done that tests both the Saluda and Broad basin models concurrently in their ability to reproduce flow at SLD27?
    CDM Smith Response: Yes**,** we will revisit the calibration after we complete the Broad model. The initial, area-weighted adjustment to the Broad at Alston gage data is an estimate of the flow at the confluence of the Broad and Saluda rivers. The calibrated Broad model may give us a better estimate of that flow and, therefore, it may be worth validating the gain/loss coefficient in this lower reach. We have added additional text to Section 7 of the report discussing this.

13. We do not understand why Gill's Creek and Cedar Creek were used as calibration targets since they are smaller tribs below the confluence of the Broad and Saluda and have had little impairment. Why were additional gages upstream of Greenwood and Murray not used, Rabun Creek for example, that are more important on the mainstem Saluda (above the confluence with the Broad) and reservoirs?
    CDM Smith Response: As described in the report, we selected a reasonable number of mainstem gages to achieve adequate spatial coverage for the calibration. We also included tributary gages with data available in our calibration period and with locations downstream of our headwater locations (e.g., Gill's Creek and Cedar Creek). The Rabon Creek gage is our headwater location, so it was not suitable for model calibration.

    Along the mainstem, we have added an additional gage (SLD07, near Williamston). This enhances the spatial coverage along mainstem, even though the gage doesn't have full period of record. Along the Reedy River, we have added an additional gage (SLD11, above Fork Shoals). This enhances the spatial coverage along the Reedy River, even though the gage doesn't have full period of record. We have also included SLD16 (Saluda River, Lake Greenwood Tailrace) for the purpose of more directly verifying the model's ability to represent releases from Lake

Greenwood, especially during drought years. Otherwise, SLD18, which is not far downstream, is used because it has a more complete period of record.

The reasons for excluding other gages are noted below:

a. SLD01 (South Saluda River near Cleveland) – too limited a period of record, and too close to the headwater to be useful.
b. SLD03 – (North Saluda River above Slater) – too limited period of record, and too close to the headwater to be useful.
c. SLD10 (Reedy River near Greenville) – too close to the headwater to be useful.
d. SLD26 (Saluda River near Columbia) – SLD25 and SLD27 are just upstream and downstream of SLD26, and are used instead.
e. SLD30 (Congaree River at Congaree NP near Gadsden) – too limited period of record to be useful.
f. SLD33 (Middle Branch near Easley) – too limited period of record to be useful.

Original DNR comments on Saluda Calibration Model:

Memorandum

To: John Boyer (CDM Smith)

From: SCDNR Hydrology Team

Date: 10/9/15 - CDM Smith Responses (in red) 10/14/15, SCDNR responses in blue (11/19/15)

Re: Comments on Saluda SWAM Calibration Model

We have some questions regarding the overall calibration approach:

1. The calibration period spanned a 30 year period (1983-2013); however, there are known and noticeable differences in operations at Lake Greenwood and Lake Murray over this period. Attempting to calibrate a model for such a long period with only one set of rules for each lake is problematic. We recommend using a smaller calibration period where there is confidence that an existing set of rules was reasonably followed (obviously every human operating decision cannot be modeled). Periods with a different set of operating rules can then possibly be used for verification purposes. We also recommend that CDM look into adding some calibration steps that consider elevations as well as gaged flows in the lower part of the basin. We recognize that this approach may be challenging in the Saluda given that there were some management drawdowns in the period of record that likely can't be modeled (we assume that these periods were left out of the calibration when adjusting gains and losses).
   CDM Smith Response: As described in Section 7.2, in selecting the calibration period we attempted to balance a desire to include as wide a range of hydrologic and climate conditions as possible with concerns about data reliability and operational consistency as we go back further in time. In any model calibration/verification exercise, we attempt to "test" the model against as large a range of conditions as possible. If the historical sampling band is too narrow, we have less confidence in the model's ability to predict future conditions that may reside outside of that band. That being said, in this case we restricted our simulation period to 30 years due to concerns about data reliability prior to 1983. Further restricting the simulation period is not recommended unless there is clear reason for doing so. We are not aware of a formal change in operating rules for either Lake Murray or Lake Greenwood during our calibration period and none are overtly apparent in looking at the lake level data; however, if DNR is aware of any, we can consider evaluating whether these should be included.

   DNR has noted formal changes in operating rules for both Lake Murray and Lake Greenwood. The proposed calibration period for Lake Greenwood (1993-2009) would still include a broad range of conditions and we would not consider it to be too narrow.

   Additionally, it is usually more important in a calibration exercise such as this to determine if generalized or current operating rules for reservoirs (to be used in future condition assessment,

for example) result in any bias or climate insensitivity over a broad range of conditions, than it is to reproduce variability in historic rules and performance with high precision (which effectively just reconstructs the impaired flows).

The operating rules for Lake Murray and Lake Greenwood in the current calibration model are not representative of current real operating rules nor would they be representative for an assessment of future conditions. We want to ensure that the models are representing historic drawdowns caused by drought. The current calibration procedures obscure the effects of drought with confounding effects of disparate, anachronistic operating rules. See new comments from Memorandum above.

Please clarify your second comment regarding the use of elevations in the lower basin. Reservoir elevations (storage) were considered in the calibration process, as described in the report.

We understand how elevations were used in the calibration process after further review, but our comments on calibration periods and storage targets above still apply. We also advocate for focusing on drawdowns caused by drought in the calibration model review.

2. We strongly believe that a calibration (and perhaps validation) approach should include a detailed review of the model's performance during drought periods (the drought of record if possible). Review of the calibration results suggest that the model may not be handling drought periods well and some additional testing may be necessary (also, see #5 below).
CDM Smith Response: We agree that calibration should include a detailed review of drought performance. To this point, we looked very closely at modeled flows during low flow periods as part of the calibration process. The timeseries plots (annual, monthly, and daily) and percentile plots (which include extreme low and high flows) were developed and carefully reviewed over the entire calibration period, which included several droughts/periods of low flows. In our assessment, the model does an excellent job in capturing low flows throughout the basin. Furthermore, as noted in Section 7.3, the model reproduces 7Q10 flows along the mainstem within 25%, which is very reasonable given the small associated flow volumes. Please let us know where, specifically, you have concerns and we can take a closer look.

We should have been a little more specific on this issue. We were referring to a detailed review of Lake Greenwood and Lake Murray during the drought of record and perhaps other major droughts to assess how well the model predicted historical drawdowns.

3. We generally understand the calibration approach using the reach gains and losses, but are a little vague on the specifics. When is a calibration considered good enough? Were all USGS gage sites targets for calibration? If so, was there an optimization routine that determined the best parameters? How large were changes in reach gains and losses and how large were the subsequent changes in flow volumes for your UIFs?

CDM Smith Response: Please refer to Section 7.2 for a detailed description of both the specific steps in our approach, our approach to assessing performance, and the rationale underlying the approach.

We summarize reach gain/loss factors in Table 6-3 of the report. However, we can certainly add more detail and/or discussion on these factors.

We assume there is an initial best guess for gain/loss factors based on the area ratio method and we are simply curious as to the magnitude of changes to the factors that were necessary to get a "calibrated" model. Please consider adding to Table 6-3 a column showing the initial estimate of gain/loss based on area ratio, for comparison with the final, calibrated gain/loss factor.

4. Lake Greenwood and Lake Murray Elevations:
    a. Storage targets in the model for Lake Murray (and maybe Lake Greenwood) don't appear to match any known historic guide curve that we are aware of. We believe that the elevations used to determine the storage targets in the model were incorrectly based on the NAVD88 datum instead of SCE&G's plant datum. Or perhaps the guide curve received by CDM (ranging from 354-358 under the current guide curve or 350-358 under the previous license) was assumed to be in NAVD88 and not SCE&G's plant datum. The maximum storage target in the model is 515000 MG which corresponds to 359.4 for plant datum and 357.9 for NAVD88; the correct maximum storage, we think, should be based on SCE&Gs 358 ft. plant datum (356.5 for NAVD88) which corresponds to approximately 493000 MG. See Figure 1 below which shows old and new guide curves (there is a 1.5 ft offset between the two datums). We also need clarification on the datum used for the USGS elevation data for Lake Murray to ensure that modeled elevations can be compared to gaged elevations appropriately. We have reached out to SCE&G and the USGS for clarification on this issue and are waiting for responses.

CDM Smith Response: We will continue to look into this. We previously attempted to resolve confusion about datums and the reported reservoir levels through communication with both SCG&E and the USGS. However, it is worth another look and we will clarify in the report text.

We believe there are still issues with the datum and the storage targets.

Note also that, for Lake Murray, we did adjust the actual input targets slightly in the model (Apr – Jun only) to better meet the true monthly targets. The model does its best to meet specified targets exactly based on start-of-timestep conditions. However, inflows and outflows in the current timestep are unknown so this is an approximation. In the case of Lake Murray, we were consistently undershooting the intended targets during these peak months. To rectify this, we bumped up the prescribed targets in the model inputs to better achieve the actual targets. Note that these changes won't carry through to the baseline

model, which will have its own set of new operating rules. We can add more text to the report to explain this piece of the calibration.

b. The storage/elevation targets and/or range for Lake Murray and Lake Greenwood appear to change when moving from the daily timestep to the monthly timestep when looking at the hydrographs. This may partly be caused by the monthly timestep using an average target or end of month target (please verify), but we don't think this explains all the differences. (See Figure 2a and 2b). Also, observe discrepancies between the modeled daily and monthly outputs in 2008 and 2011 for Lake Greenwood. These difference, we believe, are unrealistic. We don't think that such large differences should exist by simply going from a daily to monthly timestep.
CDM Smith Response: Differences between daily and monthly models are expected. For reservoir levels, these differences are attributable to: daily vs. monthly fluctuations in river inflow data; daily vs. monthly fluctuations in evaporation rates (and corresponding reservoir surface areas); and daily vs. monthly operational decision making. Regarding the latter, the model makes decisions about releases required to achieve storage targets at the start of each timestep in the model. For the monthly model, these decisions are therefore made on a monthly basis; while for the daily model they are made on a daily basis. We expect the daily decision making to result in better accuracy in achieving prescribed storage targets, compared to the monthly (and we believe this holds up in the modeling results). That being said, the differences are only a few percent, at worst.

   For a normal to above normal hydrologic year, we would expect that the max and min for a given year would be the same whether or not you were on a daily or monthly timestep since the same guide curve is used for both. Let us ask the question a different way. How come under the monthly timestep during the original 30-year calibration period, Lake Murray's modeled elevation ***never*** reached its max storage target during May and June?

c. We have documentation that suggests the Lake Murray historic release rule (prior to current license requirements) had a minimum flow rule of 180 cfs. Minimum flow releases (and guide curve) changed noticeably after the FERC relicensing agreement around 2009-2010 (FERC license hasn't officially been issued, but SCEG has attempted to operate according to the new rules over the past 4-6 years – how closely may need further review). Using a calibration period that covers multiple guide curve and flow release rules could be problematic (see #1 above).

CDM Smith Response: This may explain the calibration discrepancies during the final few years of the calibration period. We could hard code these operational changes into the calibration model if they can be well defined. This will ensure that releases during this period better match actual values. However, it is highly unlikely that these changes will

impact the calibration anywhere else in the basin and this is a very short period of change relative to the overall 30 year period.

d. For Lake Greenwood what elevation does the storage capacity refer to (440 ft?). And does 81105 MG correspond to 439 ft? This guide curve changed in 2010 and so using a calibration period that covers multiple guide curve rules could be problematic (see #1 above).

CDM Smith Response: Yes, storage capacity equates to an elevation of 440 feet and the 81105 MG in the storage curve equates to an elevation of 439 ft.

Any changes to rule curves after 2010 would have very little impact on the overall 30 year calibration. In our opinion, there would be no value in changing the calibration period (or hard coding the change) based on only 2 – 3 years of operational changes.

We disagree that there is no value. Note – the guide curve prior to 1993 was also different from the guide curve used from 1993-2009. See new comments from Memorandum above dated 11/19/15.

5. Based on some of the above concerns with the calibration approach and potential errors in storage targets, it is very difficult to assess the performance of the model in the lower part of the basin.
CDM Smith Response: The impacts of storage target changes, if any, would be minor in the overall 30 year calibration assessment. We have full confidence in the model performance in the lower part of the basin, as supported by the downstream gage comparisons (e.g. SLD 25 and SLD 27).

We stated that it is difficult to ***assess the performance*** of the model. We have not made a statement on whether it is a good model or bad model. See comments from new Memorandum above.

Additional Comments on the Calibration Report:

1. Are the "predefined rules" editable in the baseline version of the model? Will the baseline model have to rely on "hard coded" rules?
CDM Smith Response: Predefined rules are only editable via the code itself. Baseline models will use hard coded rules as required. Any changes in the future to these hard coded rules will have to be made by the CDM Smith team.

We have discussed this and hopefully have resolved this issue with additional model enhancements.

2. Edit Section 2, goal # 5 by adding "… and to test alternative instream flow recommendations.
CDM Smith Response: We will make this addition.

Addition not made.

3. We believe that run of river hydropower facilities should be represented or displayed in the model. Though they will have little impact on daily flows, they will still likely factor into some management decisions in the future.
   CDM Smith Response: Are you simply suggesting some sort of representation in the visual schematic? If so, easy to do.

   Yes.

4. Using a ten-year average for baseline water use may be appropriate; however, further review of water use data is necessary before committing to this approach.
   CDM Smith Response: We can provide the time history of withdrawals by water user over the last ten years for DNR to review and determine if, for certain users, a shorter time period is preferred.

   Information was provided to us regarding the use of a 10-year average, and after review deemed this approach appropriate.

5. We prefer to review UIFs and the calibration results for the Congaree portion of the Saluda basin after Broad River UIFs are completed and reviewed.
   CDM Smith Response: Note that we do not use any Broad River UIFs in the Saluda model. Rather, we use gage data (Alston gage) to represent Broad river inflows to the Saluda. There is no reason to wait for Broad River UIFs.

   See comment 12 above in the new memorandum. We still believe an additional calibration check will need to be made that uses both Saluda and Broad model output results to evaluate modeled flow versus gaged flow on the Congaree mainstem.

6. When units of MG are used in the model, some of the input windows/tables will sometimes display “AF” instead of “MG”.
   CDM Smith Response: The units options are a new feature in SWAM and it is certainly possible that some labels were missed. We will review the model and make corrections where needed.
   Ok.

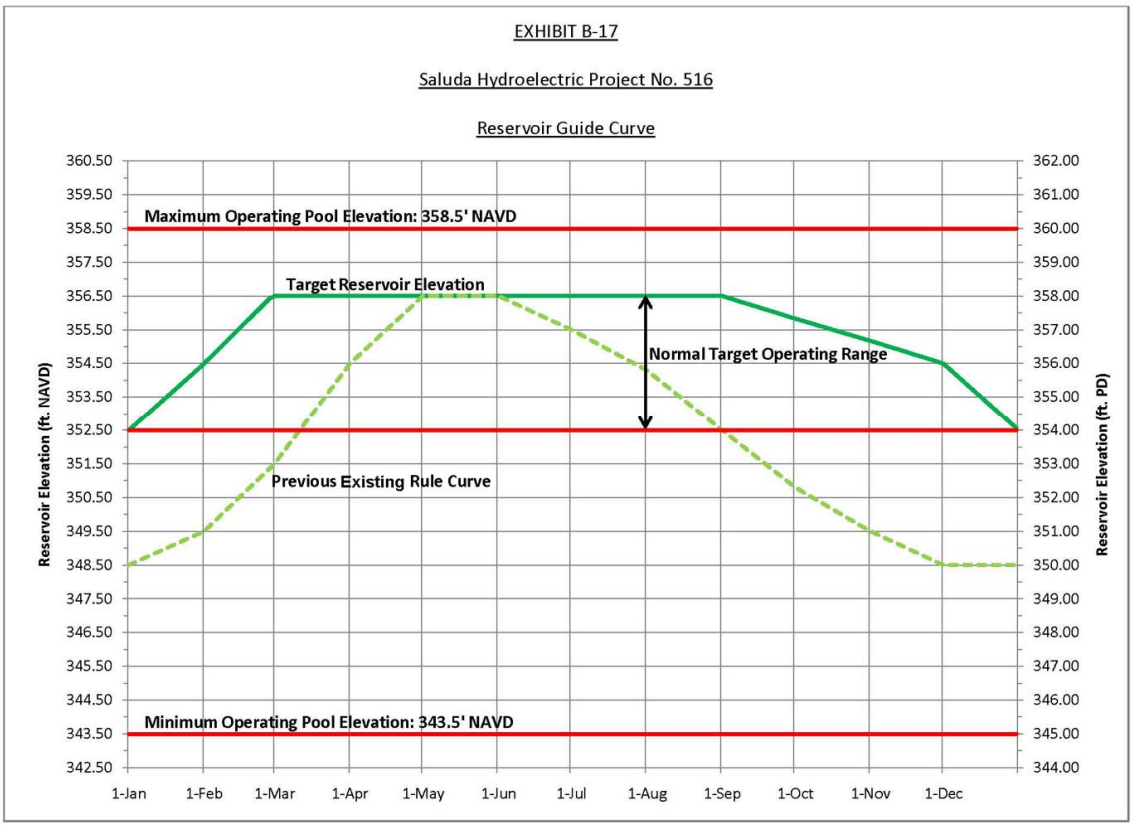


Figure 1. Green line is new guide curve and green dashed is the old guide curve. PD is plant datum and NAVD is NAVD88.

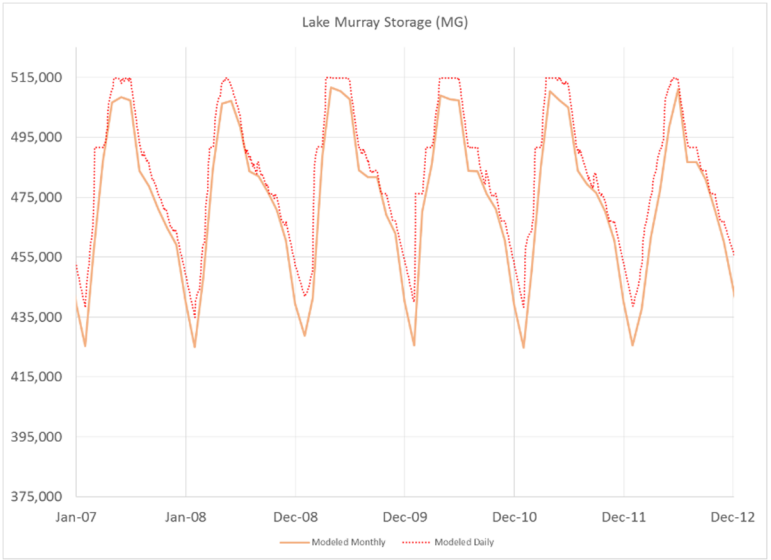


Figure 2a. Shift in storage range between daily and monthly timestep for Lake Murray.

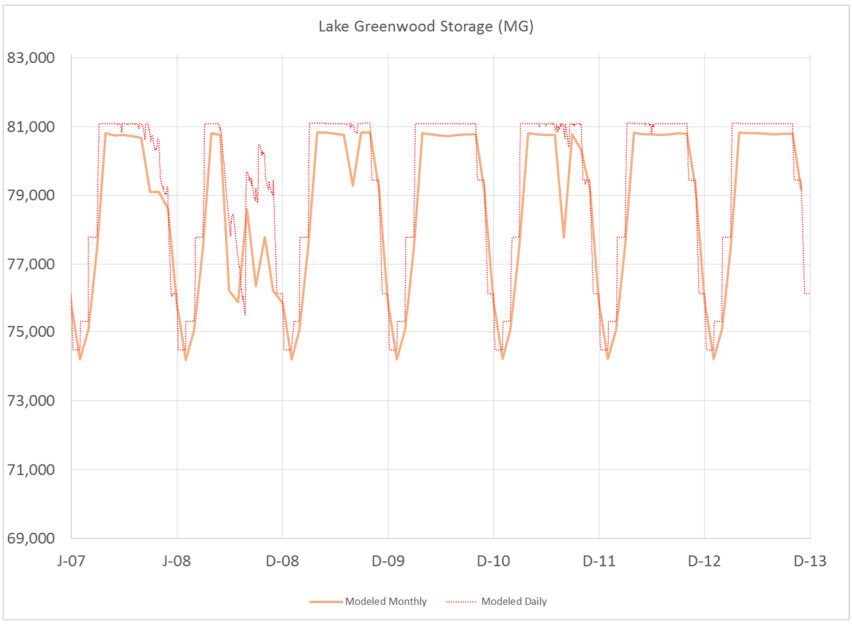


Figure 2b. Small Shift in Storage range between daily and monthly timestep for Lake Greenwood. Note also the discrepancies between the daily and monthly outputs in 2008 and 2011.

January 4th Progress Meeting Materials

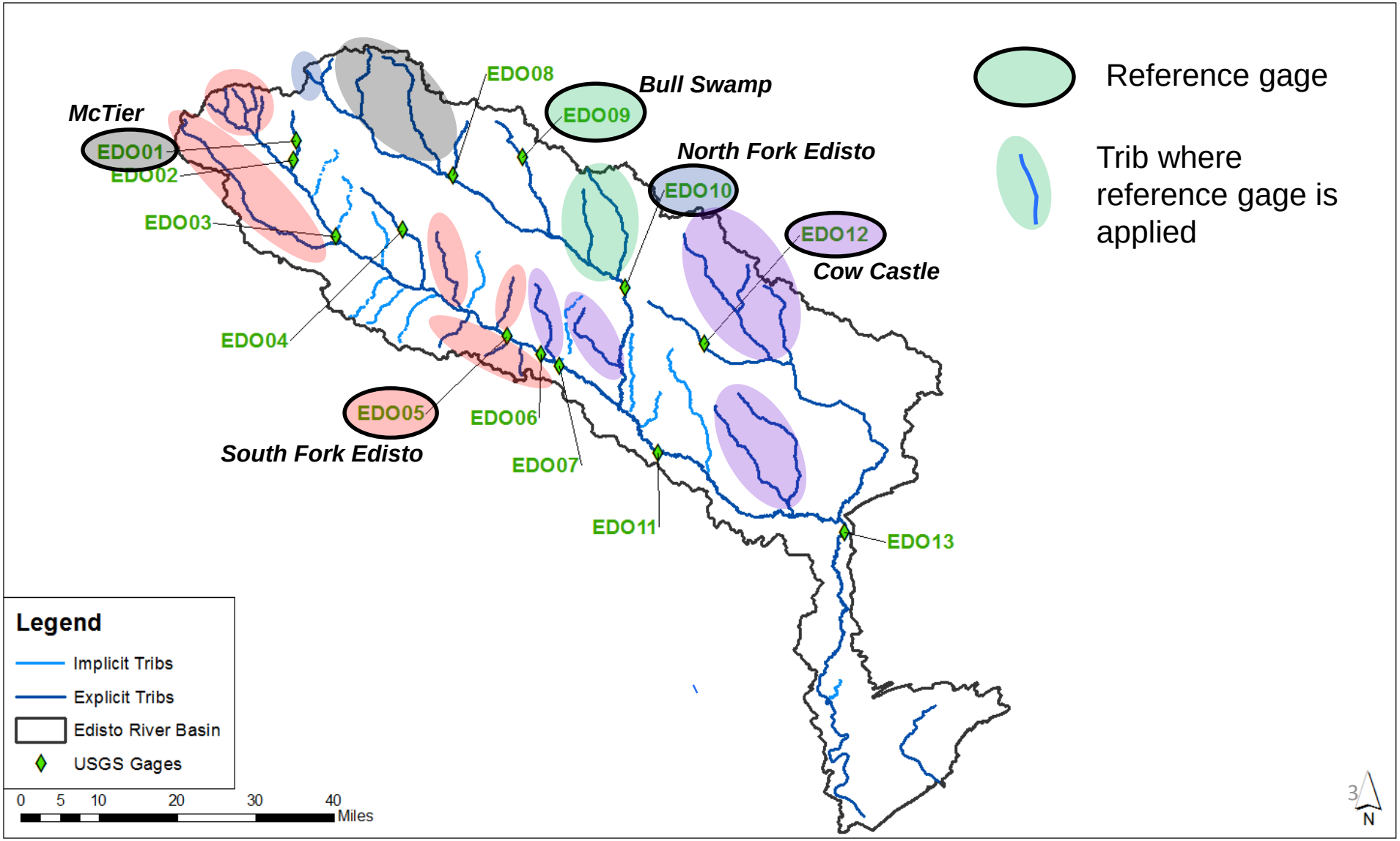
South Carolina Surface Water Quantity Modeling Project

- Edisto Basin
  - Updated Calibration Results

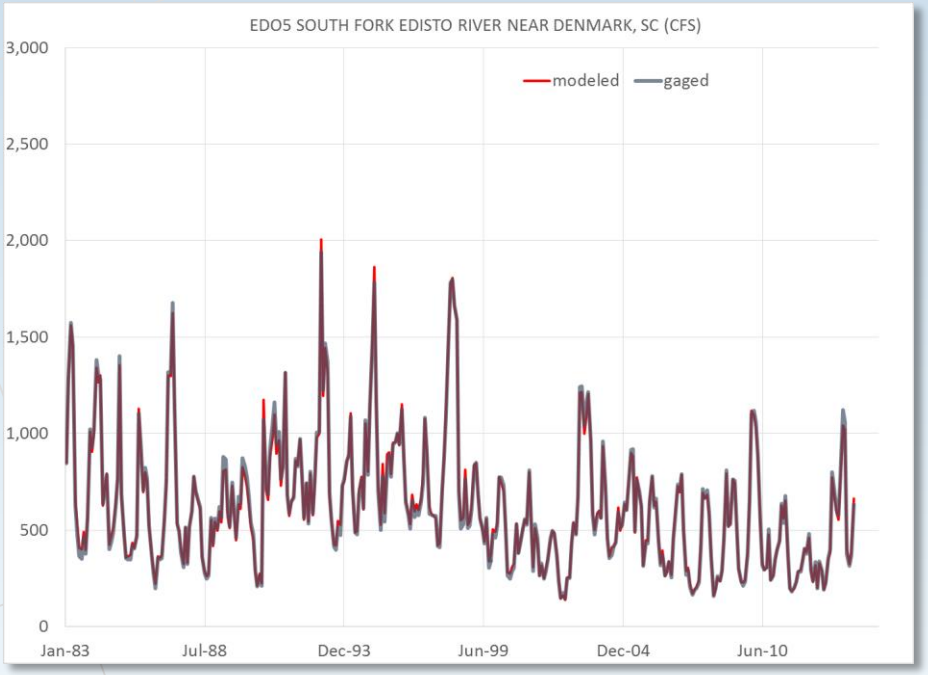
Overview of Edisto Calibration Adjustments

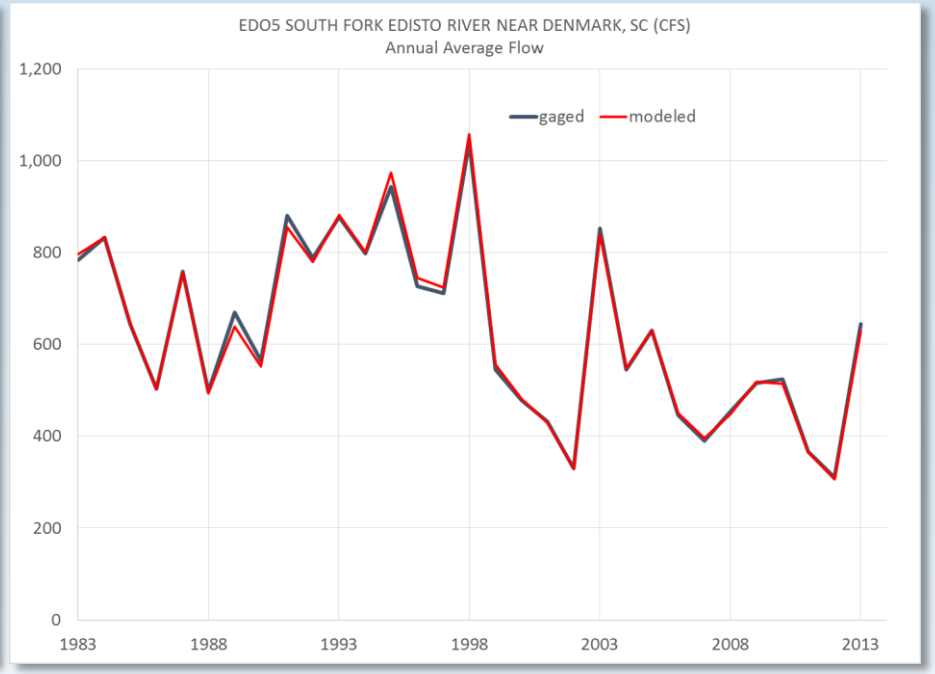
- Original approach used headwater gages as reference for ungagged headwater tribs
- Modified approach explored use of N and S Fork gages (EDO5 and 10) for headwater tribs
- Several hybrid approaches have been evaluated aimed at:
  - Improving agreement with both low and high flows (percentile plots)
  - Reducing or eliminating seasonal bias observed at select gages (monthly mean flow plots)
  - Maintaining match of peak flows

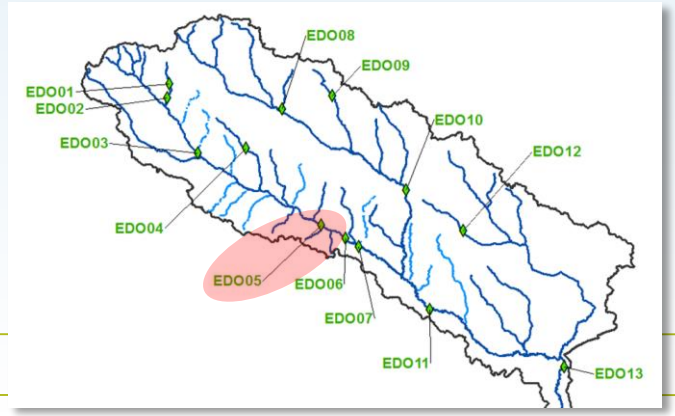
Edisto Basin
Reference Gages Used for UIFs – Latest Iteration



EDO 05 – South Fork near Denmark (USGS 2173000) - MONTHLY







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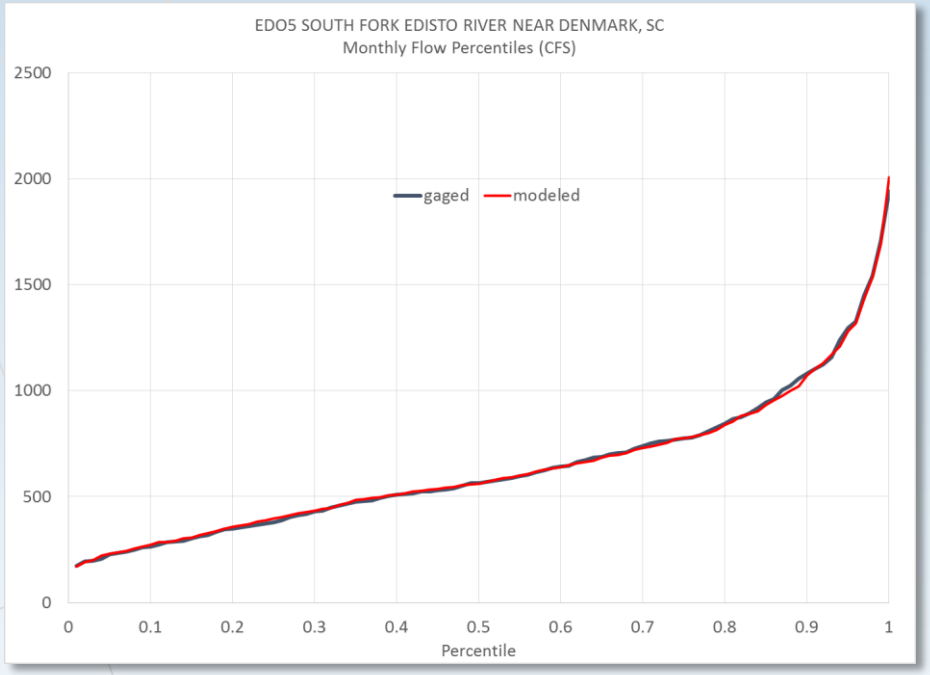
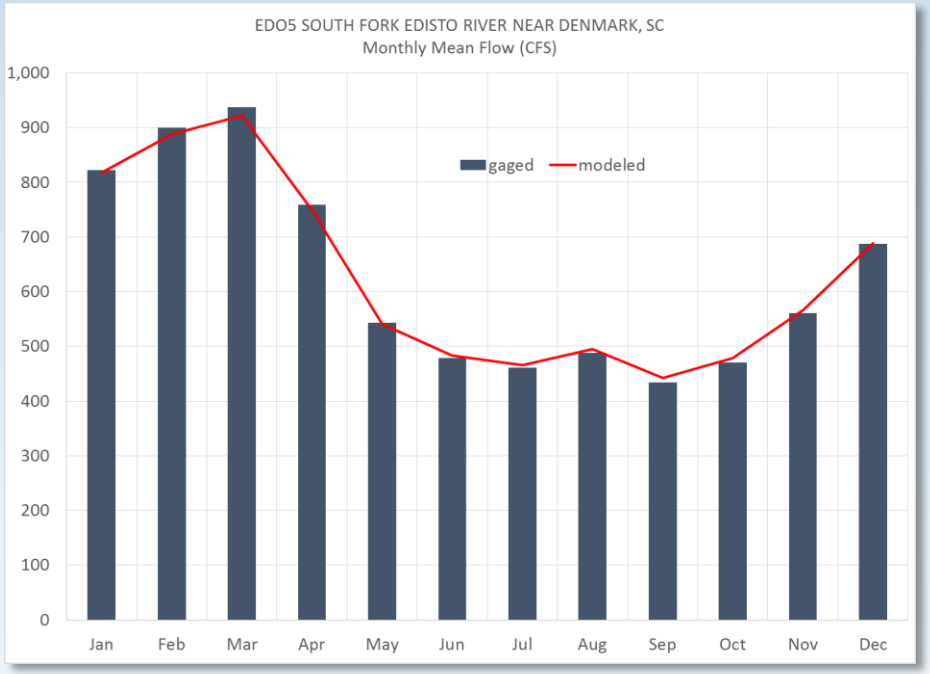
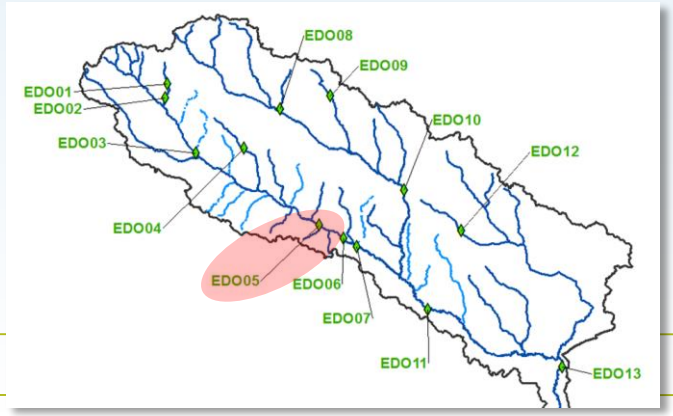
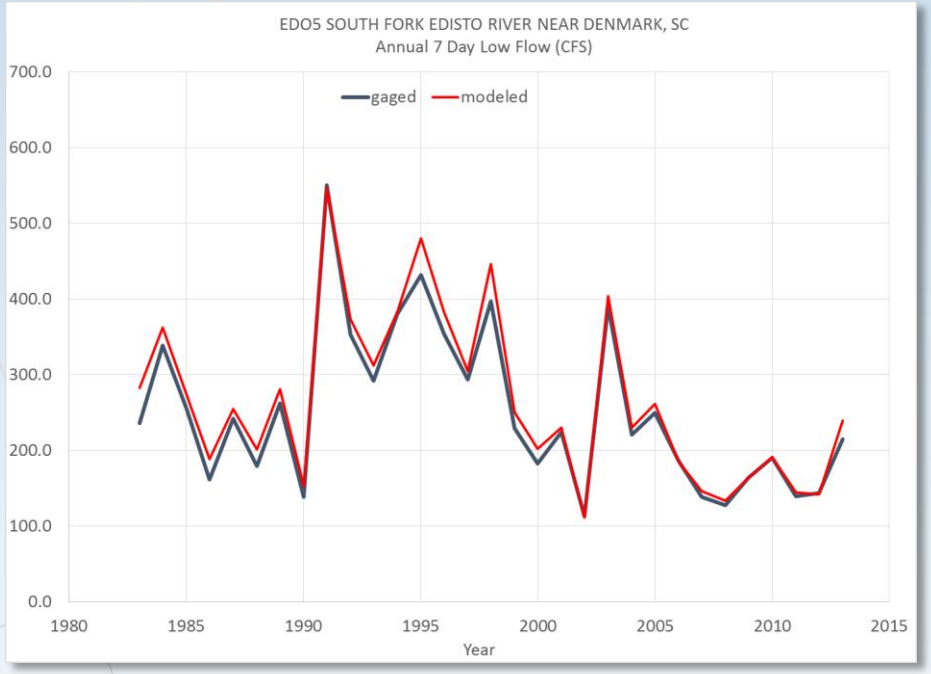
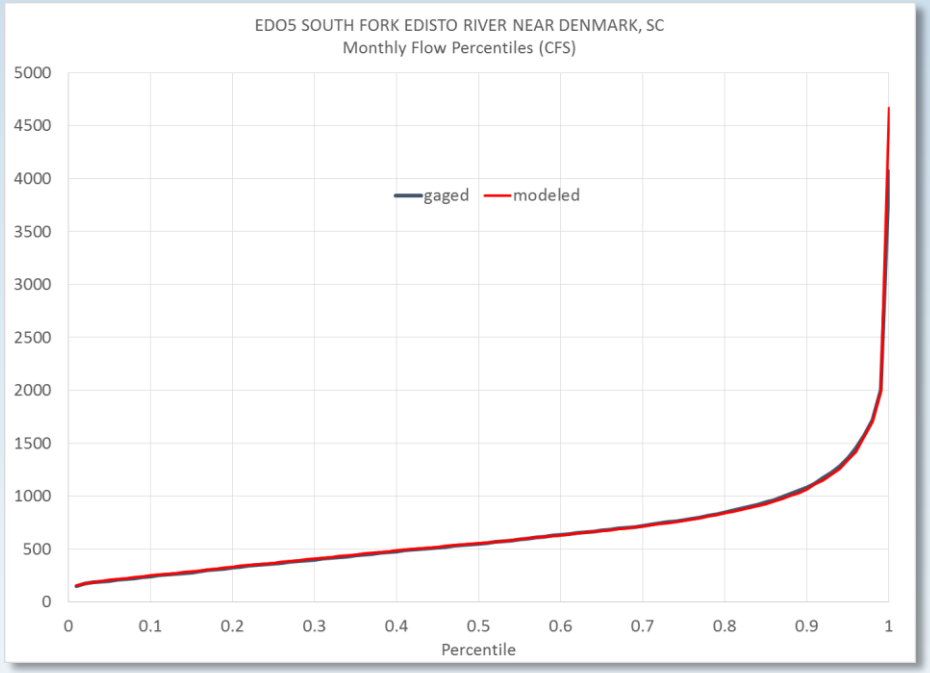


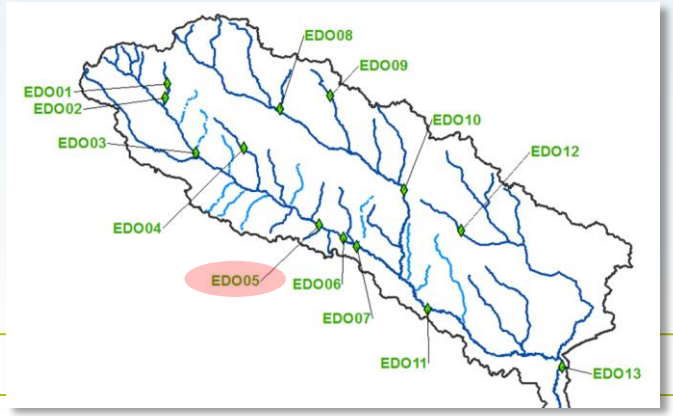




EDO 05 – South Fork near Denmark (USGS 2173000) - DAILY

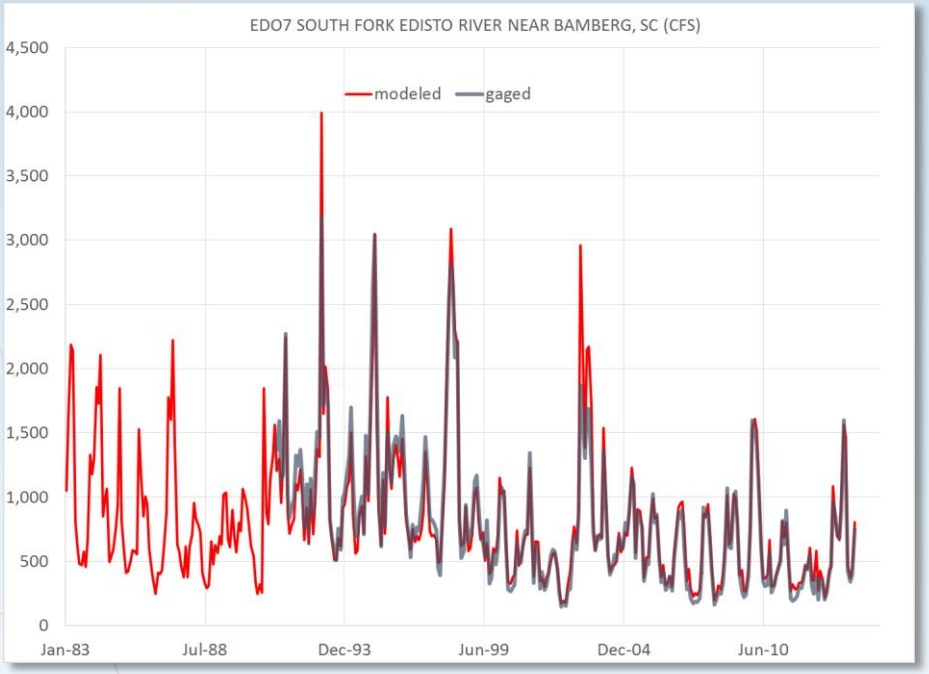


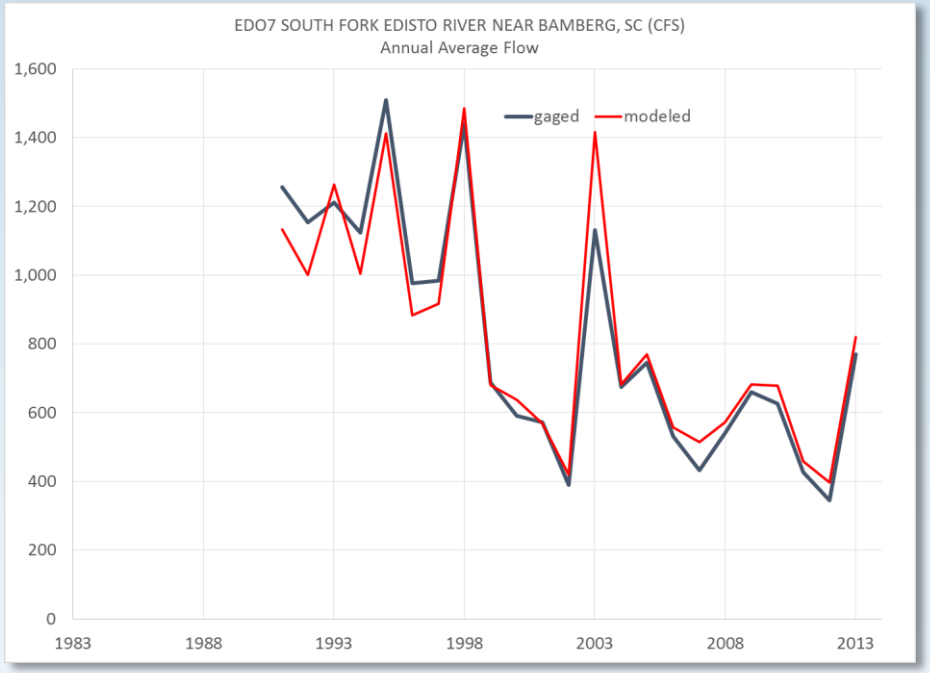


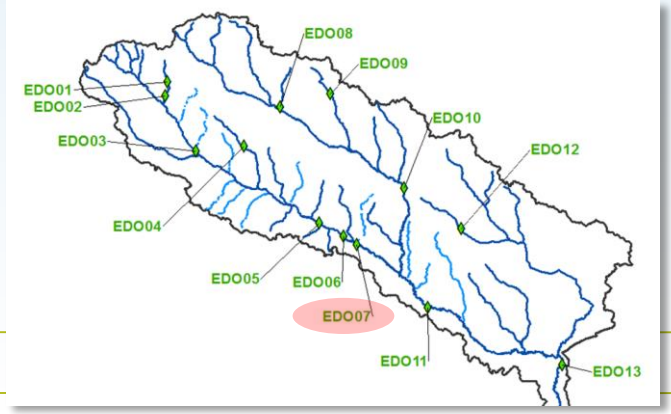


EDO 07 – South Fork

MONTHLY

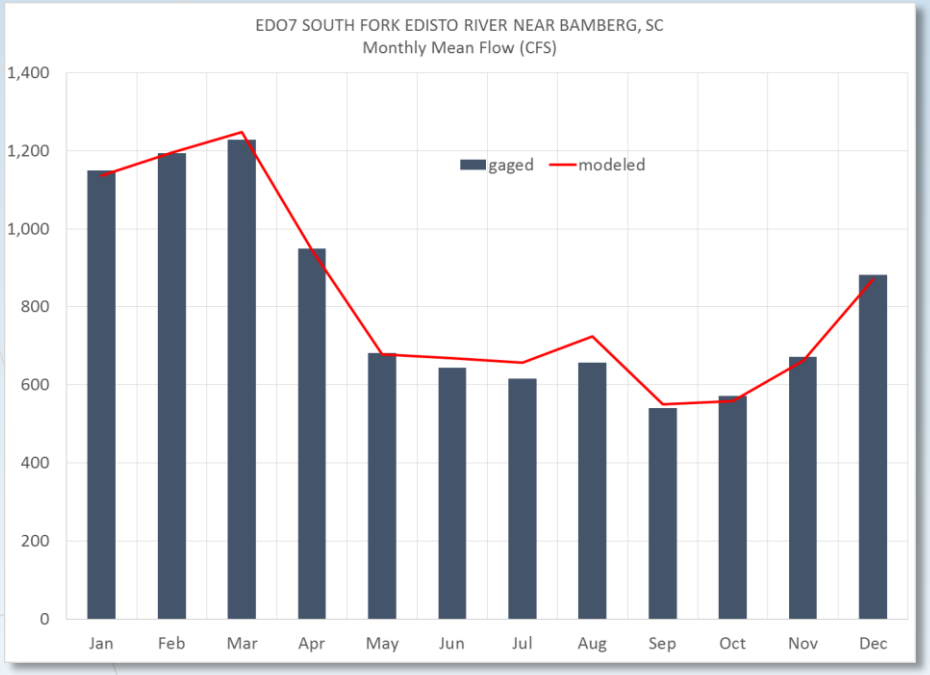


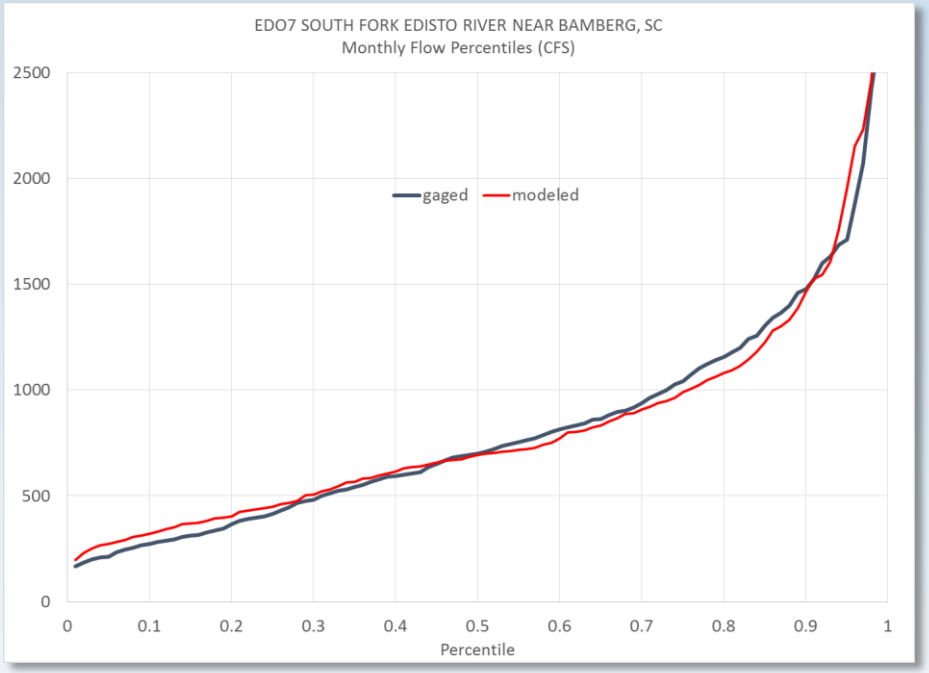


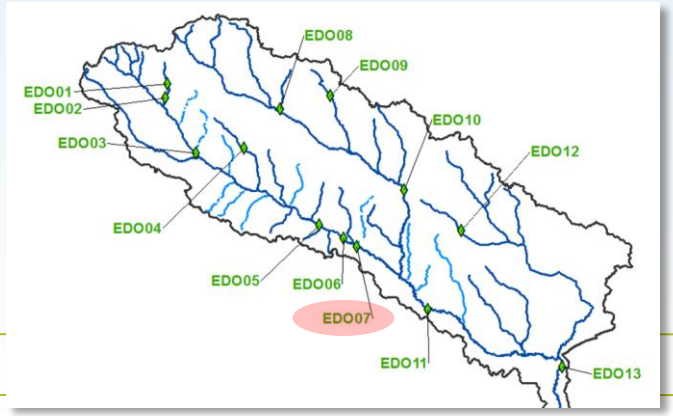


EDO 07 – South Fork

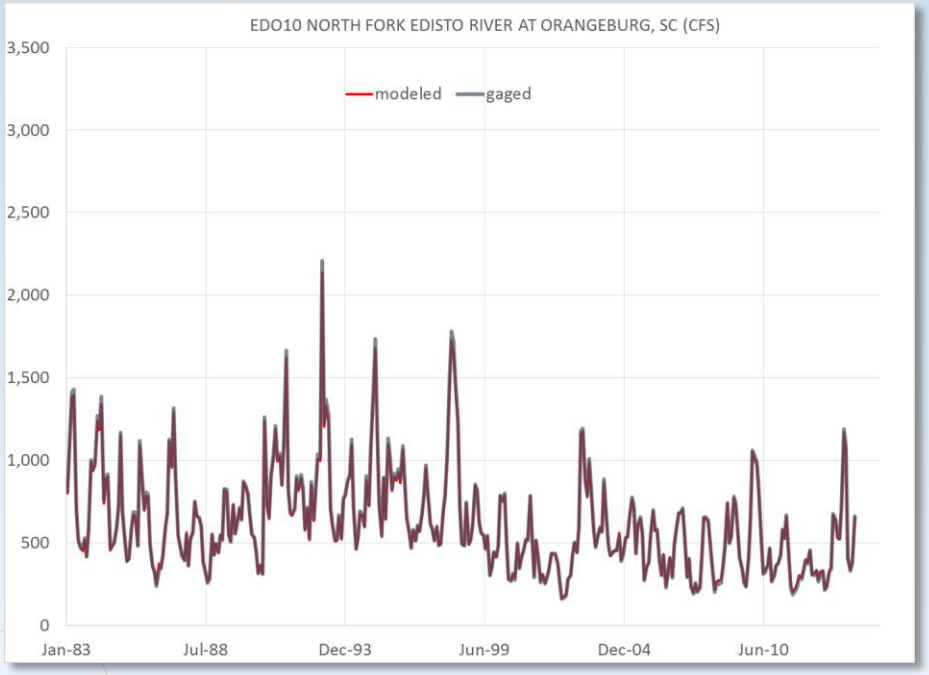
MONTHLY

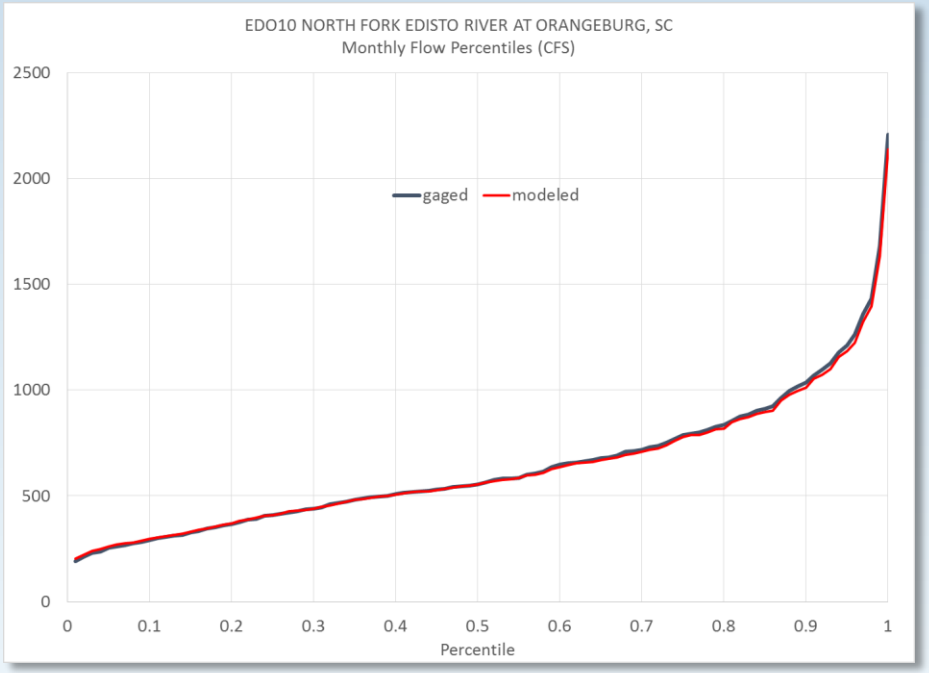


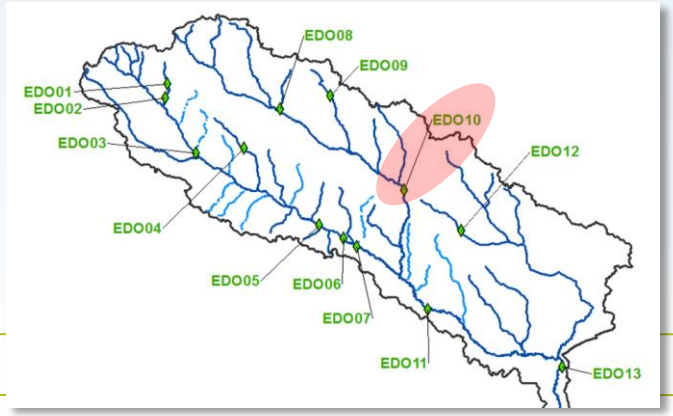




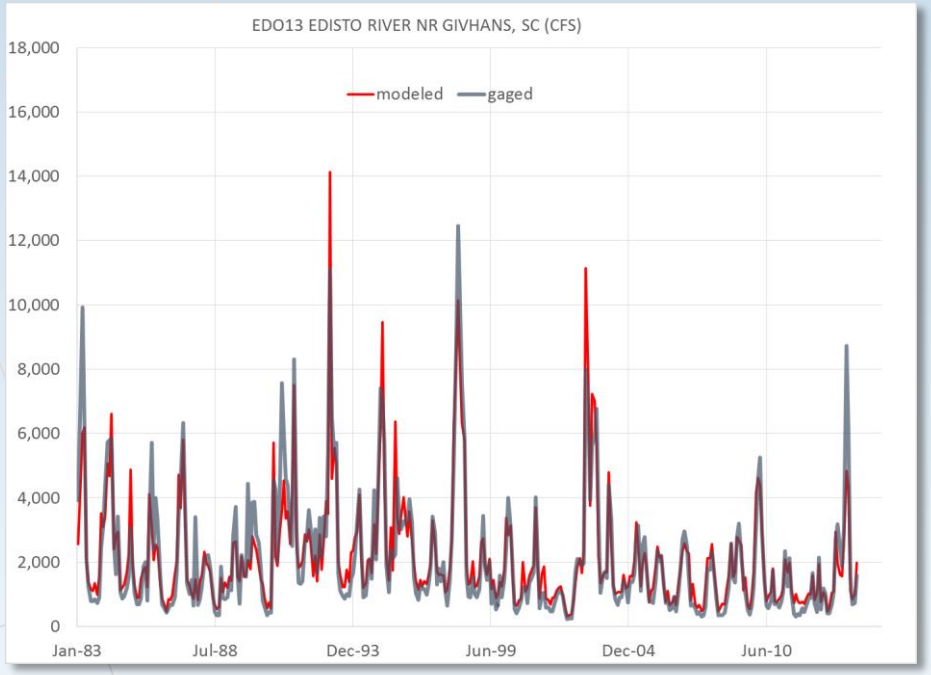
EDO10 NORTH FORK AT ORANGEBURG (USGS 2173500) - MONTHLY

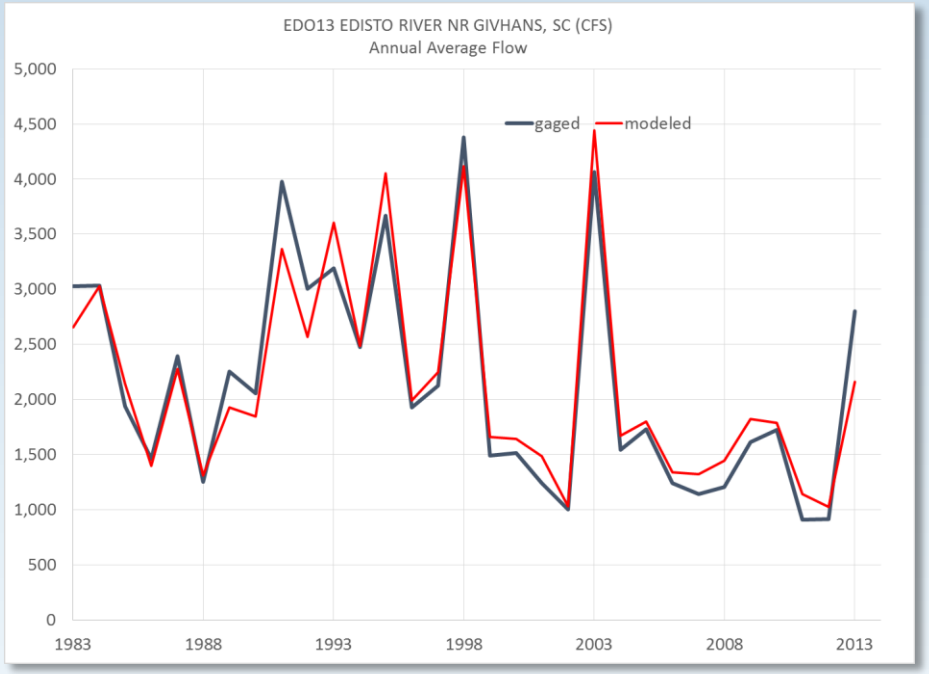


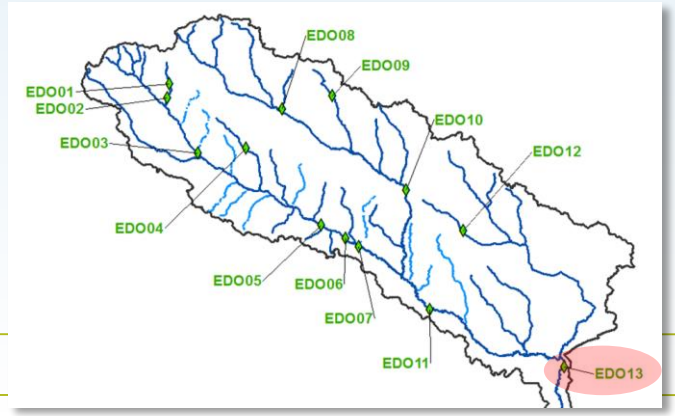




EDO13 EDISTO RIVER Near GIVHANS (USGS 2175000) - MONTHLY







EDO13 EDISTO RIVER Near GIVHANS (USGS 2175000) - MONTHLY