Memorandum

To: *South Carolina Department of Natural Resources (DNR)*
South Carolina Department of Health and Environmental Control (DHEC)

From: *CDM Smith*

Date: *June 10, 2015*

Subject: *Catawba River Basin Unimpaired Flow Development – Overview of Approach*

This memorandum explains the status of currently developed Unimpaired Flows (UIFs) for the Catawba basin and their relevancy to the South Carolina Surface Water Quantity Modeling efforts. CDM Smith has developed a recommended approach that utilizes the existing UIF dataset to the greatest extent possible, and clearly defines the steps needed to adapt and expand the dataset to be consistent with other UIFs developed for the SC Surface Water Quantity Modeling. Specifically, the following issues are discussed:

1. Purpose and utilization of the existing Catawba UIFs
2. Summary of the methods used for the existing Catawba UIFs
3. Applicability to the SC Surface Water Quantity Modeling
4. Requirements for adaptation of existing UIF dataset

1.0 Purpose and Utilization of Existing Catawba UIFs

UIFs for the Catawba-Wateree Hydro Project were developed for use by Duke Energy in support of FERC relicensing. The UIFs were developed as an average daily value, covering the period January 1, 1929 through December 31, 2010. The UIFs were employed in the CHEOPS Model (Computer Hydro Electric Operations and Planning Software) of the reservoir and hydropower system. To this end, the objective of the UIFs was to naturalize the flow primarily with respect to the impacts of dams and reservoirs, but not necessarily all of the other instream uses of water throughout the basin. In this way, hydropower operations could be evaluated on the partially impaired flows that can be expected as inflow to and outflow from the reservoirs.

In other words, the objective of hydropower UIFs is slightly different than that of UIFs for statewide water planning. Planning entities typically develop unimpaired flow data sets to the extent to which they have influence on the flows of interest. Since hydropower operators do not typically

have regulatory purview over upstream tributary withdrawals and discharges, such activities are often not removed when estimating unimpaired flow. It is unclear if historic withdrawals and discharges along the mainstem were included in the UIFs for the Catawba-Wateree system, or if only the withdrawals and discharges directly out of or into the impoundments were included.

Hence, the UIFs for the Catawba CHEOPS model represent flows that could be expected in the rivers without the influence of dams and reservoirs, but do not account for the influence of all riverine withdrawals and discharges elsewhere in the basin. In the Catawba Basin, these other influences are considered to be minimal relative to the impacts of dams and reservoirs, and therefore the existing UIFs should be readily adaptable to the SC Surface Water Quantity Modeling process. As seen in **Figure 1**, there are only three former water withdrawal intakes upstream of Lake Wateree, which are not on the mainstem, and only one current agricultural withdrawal intake on the upstream tributaries (no current municipal or industrial withdrawals on these tributaries).

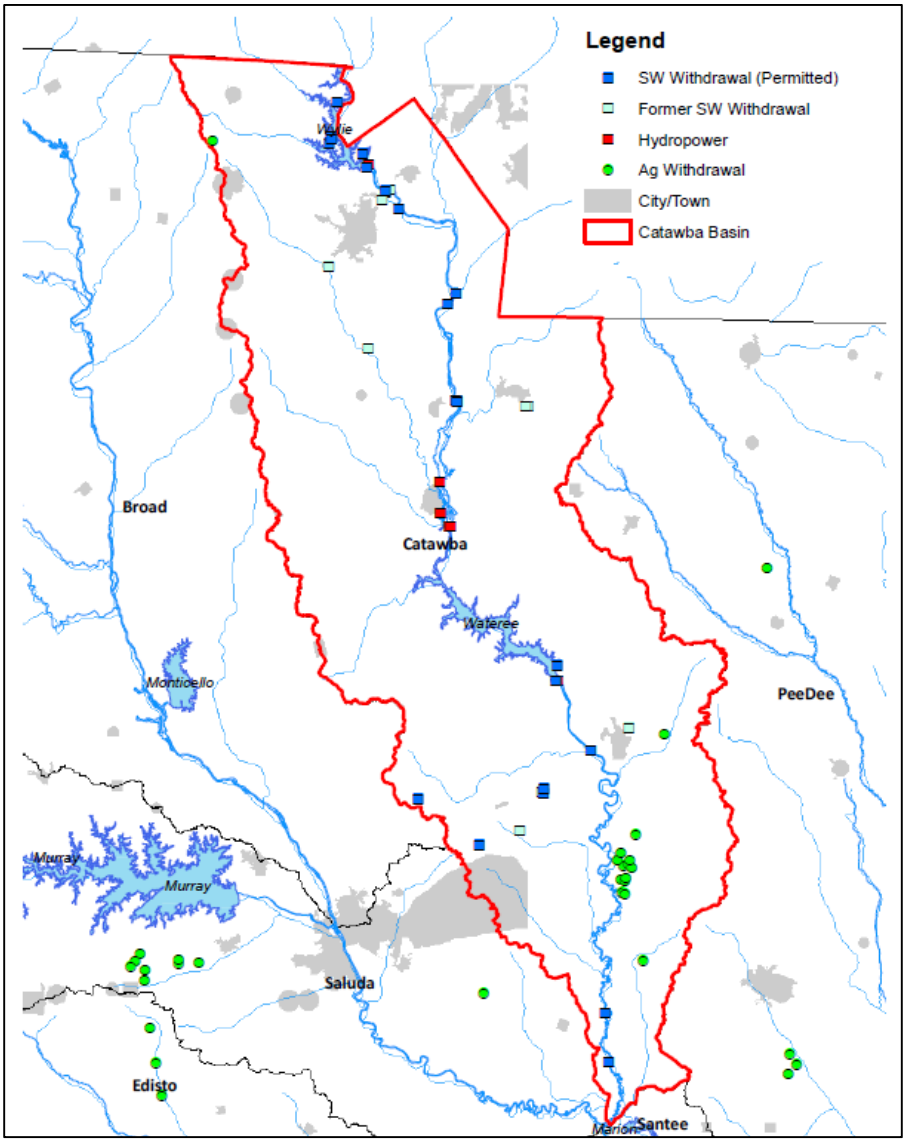

Figure 1. Catawba River Basin in South Carolina

2.0 Summary of the Methods Used for the Existing Catawba UIFs

UIFs for the Catawba-Wateree System were developed at each dam location. In South Carolina, UIFs were developed at Lake Wylie, Fishing Creek Reservoir, Great Falls Reservoir, Rock Creek Reservoir, and Lake Wateree – for a total of five UIF points (see **Figure 2**). The fundamental approach was to employ mass balance calculations using historic flow data and operating logs (withdrawals, discharges, releases, storage levels). It appears that natural tributary flows (an unmeasurable component in the water budget) were back-calculated by removing measured terms from the mass balance equation at each reservoir. According to Section 3.1 of the *Operations/Verification Report for the Catawba-Wateree CHEOPS Model* (HDR, May 2006), the following equation was used:

$$\Delta V = \left[I_{UpGen} + I_{Disc} + I_{Trib} + I_{UpLeak}\right] - \left[O_{Gen} + O_{Evap} + O_{ForcedEvap} + O_{WD} + O_{leak}\right]$$

where:

ΔV =	*Change in reservoir volume*
I_{UpGen} =	*Flow released from upstream hydroelectric dam*
I_{Disc} =	*Municipal and Industrial discharges*
I_{Trib} =	*Natural inflow (from the incremental area between dams)*
I_{UpLeak} =	*Leakage from the upstream hydroelectric dam*
O_{Gen} =	*Downstream hydropower release at the site of unimpairment*
O_{Evap} =	*Evaporation from the reservoir*
$O_{ForcedEvap}$ =	*Forced evaporation at industrial plants*
O_{WD} =	*Municipal and Industrial withdrawals*
O_{Leak} =	*Leakage downstream through the dam*

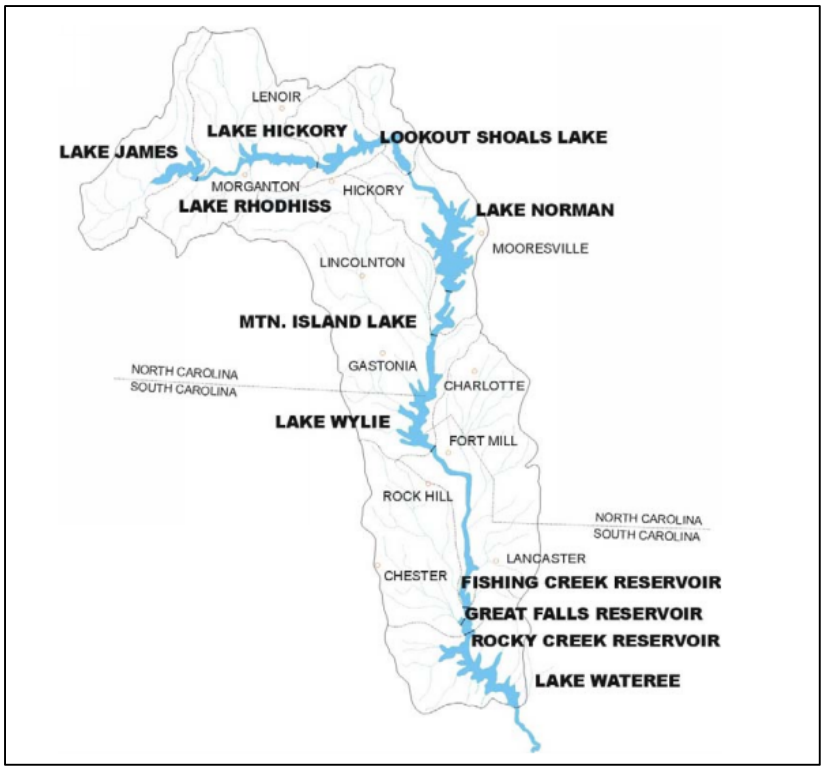

Figure 2. Catawba-Wateree Hydro Project
(from the *Operations/Verification Report for the Catawba-Wateree CHEOPS Model*, May 2006.)

In this equation, I_{Trib} represents total natural inflow into the reservoir from the incremental basin area between two dams (it is not disaggregated into individual tributaries). As such, it includes natural streamflow, precipitation onto the surface of the reservoir, losses or gains to/from groundwater, and correction factors based on nearby USGS flow measurements of relatively unimpaired tributary reaches. The summation of these factors is then considered to be the incremental unimpaired inflow for a particular reservoir.

3.0 Applicability to the SC Surface Water Quantity Modeling

The above approach is similar to the approach being used by CDM Smith for the SC Surface Water Quantity UIFs, although it is focused primarily on reservoirs. It appears that there has been minimal need for hindcasting of data because the required data are well established and available.

Also, the UIFs for the Catawba-Wateree CHEOPS model are relevant to the SC Surface Water Quantity Models (i.e., the SWAM models) only as starting points and verification data sets, because they represent in-stream flow conditions, and not individual headwater boundary conditions for specific tributaries. They will be useful, however, for the disaggregation of UIFs at the dams into contributing UIFs from individual tributaries, and for subsequent verification that upstream UIFs combine into the computed UIFs at the dams Alternatively, if we determine on a case-by-case basis that incremental mainstem UIFs are preferred over individual tributary UIFs (which may be more likely in the Catawba than in other basins due to the low levels of water use beyond the reservoirs), the existing data sets can be used to define aggregated UIFs in between mainstem dams, exactly as they are in the CHEOPS model.

Two elements in the SC Surface Water Quantity UIFs that do not appear to be included in the CHEOPS UIFs are the flow contributions from previously unsubmerged areas (the land now inundated by the reservoirs), and the historic withdrawals and discharges on tributaries. We assume that withdrawals and discharges on the mainstem are included, but will need to confirm this, as the previously referenced report (HDR, 2006) illustrates the UIF calculations in the impoundments only. It is also not clear if the withdrawals and discharges on the mainstem, below Lake Wylie and above Fishing Creek Reservoir are included. These impacts are not likely to have a significant effect on the overall availability of water, but for consistency with other basins in South Carolina, these factors should be included in the adaptation of the CHEOPS UIFs.

4.0 Suggested Adaptation of CHEOPS UIFs for SC DNR and DHEC

To be useful for the SWAM modeling of the Catawba River Basin, the UIFs at the dam nodes in the CHEOPS model must be slightly modified and disaggregated into individual tributaries so that water management can be simulated and evaluated throughout the basin. There are several ways to do this. One way would be to disaggregate the UIFs at each dam into contributing tributaries based on area ratios. However, a more precise method, and one that is consistent with the rest of the South Carolina basins, would be to use the CHEOPS UIFs as validation points for individual tributary UIFs. In this capacity, they would take the place of mainstem UIFs computed from USGS gages (which are likewise used primarily for validation in the other South Carolina basins). This would avoid the need to re-compute the mainstem UIFs in the Catawba Basin, and would take

advantage of the work done to date while adapting it to fit DNR's and DHEC's objectives. The following steps are recommended:

1. Adjust the UIFs at each dam to include the would-be contribution of runoff from the previously unsubmerged area (land now inundated by the reservoirs).

2. Compute UIFs for tributary USGS gages (it is not necessary to compute these for mainstem gages, since mainstem UIFs at the dams are plentiful, and used only for SWAM model calibration). This is NOT expected to be a data-intensive exercise, since:

    a. Many of these tributary gages already represent reasonably unimpaired flow conditions, and their records may only require statistical extension.

    b. Because discharges and withdrawals in the Catawba Basin are not as significant or numerous as in other basins, those USGS gages that require unimpairment calculations should not require extensive data collection or calculations.

3. Extend the tributary UIFs through the period of record for the Catawba (currently the UIFs begin in 1929) using the statistical techniques outlined currently for the Saluda Basin.

4. Transfer UIFs to ungaged tributaries that are significant enough to be included in the SWAM model explicitly.

5. Calibrate or adjust the UIFs so that their combinations equate to the corresponding UIFs used for the CHEOPS model (cumulative values of I_{Trib} above each dam, adjusted per Step 1 above). This will be an excellent source of quality control, because effectively, the UIFs at the dams will have been developed using two independent methods.

The UIFs for the Catawba Basin currently extend geographically to Lake Wateree. CDM Smith will add UIF locations below Lake Wateree to the terminus of the basin at the confluence with the Congaree River, and calculate UIFs using the same methodology that is being used for the other SC basins.

The UIFs for the Catawba Basin currently extend temporally through December 31, 2010. Given that they begin in 1929, and that they are based on a large quantity of measured data, we recommend that in this case, it is not necessary to extend the dataset through to the start of 2014. The purpose of doing so in other basins is that the most recent years typically have the most reliable and comprehensive data. In the Catawba, however, this is not necessarily the case. Data sets from earlier years in the Catawba are likely to be just as comprehensive, and adding three years of data to a data set that already spans more than 80 years would add little value. It is recommended that DNR and DHEC engage in a discussion with the Catawba-Wateree Management Group regarding any potential plans that they may have to extend the existing UIF dataset in future years.