Technical Memorandum

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

From: *CDM Smith*

Date: *February 2015;* ***Updated July 2015***

Subject: *Methodology for Developing Historical Surface Water Withdrawals for Agriculture Irrigation (Prepared as part of the South Carolina Surface Water Quantity Modeling Program)*

This document describes the methodology and data used to develop estimated time histories of surface water withdrawals for agricultural irrigation in South Carolina. The objective of these efforts was to develop a time series for water withdrawals from 1930 through 2013 to be used as inputs into the development of Unimpaired Flows (UIFs) throughout the state, and as input to surface water quantity models, based on the best, readily available data.

Please note, as explained in Section 1.1, irrigation of agriculture lands was not documented in South Carolina in the 1930's or 1940's. Based on historical accounts, very little irrigation withdrawals are presumed during this time period. Thus, the amount of irrigated acres across the state prior to 1950 was expected to be very low, and thus insignificant with regard to developing Unimpaired Flow records. Also, for the surface water model, the agriculture model estimates are used up to 2001 and DHEC reported values are used from 2002-2014.

1.0 Data Sources

Agriculture irrigation data are somewhat limited in South Carolina, as the state does not have a large amount of agriculture irrigation in relation to other states in the U.S. An extensive data search was undertaken to assess all agriculture data available that could be utilized for estimating surface water irrigation withdrawals. This section describes the data used for the analysis as well as additional data sources that were reviewed in support of developing the methodology.

1.1 NASS COA

The U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) conducts the Census of Agriculture (COA) every five years. The COA captures a detailed picture of farms and ranches across the U.S. by state and county. NASS maintains a list of farmers and ranchers from which the census mail list is compiled. The goal is to build as complete a list as possible of agricultural places that meet NASS farm definition, which is an operation that produces

and sells $1,000 or more of agricultural products per year. Data are collected through a mail-out and mail-back methodology that begins in December of the census year. Electronic data reporting via the internet is also allowed. Non-responses are followed-up with telephone calls and personal enumeration. The report form includes data items that all respondents answer and data items with regional significance.

Among the data collected for the South Carolina COA are irrigated acres by county. Data on the type of crop irrigated by county is not released. Historical COA data for irrigated acres were obtained back to 1950 for all years available up to 2012. Prior to 1950, no irrigation was reported in the South Carolina COA results. This is consistent with historical accounts that state the collapse of cotton and tobacco prices in the 1920's followed by a series of droughts and infestations greatly impacted South Carolina agriculture through the 1930's[1].

1.2 DHEC Water Use

South Carolina's Department of Health and Environmental Control (DHEC) collects data from agriculture surface water users who fall under SC Code 49-4-10. Beginning in January 1, 2011, any agriculture user withdrawing more than 3 million gallons (MG) or more in any one month from surface waters of South Carolina must register their use with the DHEC. Voluntary withdrawal data was collected prior to 2011. DHEC provided agriculture irrigation reported use for surface water from 1983-2013 and groundwater from 2002-2013. The water use data includes monthly withdrawals in million gallons (MG) by Source ID and year. The Source ID is a unique identification for each withdrawal location. Related geographic information system (GIS) data were provided for each Source ID. GIS analysis was conducted to determine the basin and county for each Source ID.

1.3 Other Sources Reviewed

Several data sources were reviewed but not used in the estimation algorithm. Mandated by Congress, the USDA Natural Resources Conservation Service (NRCS) collects data for the National Resource Inventory (NRI) database. NRI data is based on statistical sampling of land use throughout the US from high-resolution imagery. Data for irrigated acres by water source is one of the possible outputs of the NRI database. NRI data is generally available online in summary format only. County-level data for South Carolina was requested from NRCS and provided via email. Upon review of the data, large sampling errors were noted for most of the counties and thus the NRI data was determined to be unusable for estimating agriculture irrigation surface water use.

U.S. Geological Survey (USGS) water use reports were collected for all years available (1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990, 2000, 2005, and 2010). The reports from 1955-1980 provided only a state-level summary. The reports from 1985-1995 were blank for South Carolina. County-level reports were available from 2000-2010. Review of the county-level reports uncovered wide variations in irrigation practices and inconsistent data among the three years. As with the NRI data, USGS reports were determined to be unusable for estimating agriculture irrigation surface water use.

[1] Edgar, Walter B. *South Carolina: A History*. Columbia: University of South Carolina Press, 1998.

The NRCS publishes a national irrigation guide directed at helping farmers efficiently and effectively irrigate their crops. In addition to the national guide, NRCS publishes state-specific supplements for select states. While no supplemental report was available for South Carolina, the North Carolina NRCS Irrigation Guide Supplement was reviewed for insight into the amount of irrigation water suggested for crops of various types in the region. The guide recommends an irrigation supply of 1.3 acre-feet per irrigated acre (AF/A) for most row crops and 1.6 AF/A for orchards[2].

Data available from the USDA NASS County Agricultural Production (CAP) survey were reviewed. This data is collected annually by county and made available through a quick stats portal on the NASS website. Available data varies state to state, depending on the dominant irrigation practices within the state. For South Carolina, no data regarding crop irrigation was available.

2.0 Methodology

This section describes how the irrigation withdrawals are estimated using a basic irrigation withdrawal equation, which is then adjusted to account for the actual monthly variations in precipitation over time. The resulting values are then calibrated to align with the average water use per basin from 2002-2012, as reported to DHEC.

2.1 Basic Equation

The surface water irrigation withdrawals are estimated by withdrawal points identified in the DHEC database. Total basin withdrawals can be determining by adding the demand for all the withdrawal points located in the basin. **Equation 1** provides the basic algorithm used to estimate water use for a given month and year by withdrawal point.

$$SW_{y,m}^{P} = IA_{y}^{c} \times CIR \times SWP_{y}^{c} \times SeasonP_{m}^{b} \times PT_{c}^{P} \qquad \textbf{Equation 1}$$

Where:

$SW_{y,m}^{P}$ = Surface water withdrawal for the withdrawal point (P) for the year (y) and month (m), in acre-feet (AF)

IA_{y}^{c} = Irrigated acres in the county (c) for with the withdrawal point is located for year (y)

CIR = Annual crop irrigation requirement (CIR) in AF/A

SWP_{y}^{c} = Percent of the irrigated acres that are irrigated by surface water in county (c) where the withdrawal point is located for year (y)

$SeasonP_{m}^{b}$= The average monthly seasonal percentage of irrigation water applied in month (m) for the basin (b) in which the withdrawal point is located

[2] USDA NCRS, 2010, *North Carolina Irrigation Guide.* Available for download at: http://www.bae.ncsu.edu/topic/irrigation_society/info/NC_Irrigation_Guide_Apr_2010.pdf

PT_c^P = Average percent of the total county withdrawals (c) for the withdrawal point (P)

Irrigated acres by county are assumed from the COA from 1950-2012. Specifically, COA data years are: 1950, 1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987, 1992, 1997, 2002, 2007, and 2012. For the years in between COA release years, linear interpolation was used to estimate the number of acres irrigated. The 2013 value was assumed constant from 2012.

For counties in South Carolina, a CIR of 0.9 AF/A was assumed for all irrigated acres. This value was derived as a conservative estimate based on the recommended irrigation supply from the USDA NCRS North Carolina Irrigation Guide Supplement and the value derived from comparing DHEC reported water use and USDA reported irrigated acres for recent years. The value is a starting point only and is adjusted for weather and calibrated to DHEC reported use by basin (see Section 2.2 and 2.3).

The percentage of total irrigated acres irrigated by surface water was derived from the DHEC database. The DHEC database represents irrigation water applied, and not acres. To estimate acres from water use, both surface water and groundwater withdrawal data were summed by county and year. The number of acres irrigated was estimated by dividing reported water use by a factor of 1.2 for groundwater withdrawals and 1.5 for surface water withdrawals. These values represent average application rates per acre (i.e. the CIR per acre). Irrigators using ground water are assumed to utilize water saving pivot technology, thus requiring less water per acre. Using the estimated acres irrigated by county and source, annual percentages were calculated for groundwater and surface water in relation to total estimate acres. The annual values varied greatly for some counties, possibly due to improvements in reporting, fallow cropping practices, drought, etc. In order to smooth the data, average values were calculated for 2002-2004, 2005-2007, 2008-2010, and 2011-2013. The average value was assumed for the "middle" year (e.g., 2003, 2006, 2009, and 2012). Linear interpolation was then applied to estimate in between years. The percentage derived for 2003 was applied for all years prior to 2003.

Seasonality was derived by basin using reported surface water withdrawals from the DHEC data. An average monthly withdrawal percentage was calculated from all reported monthly use within a basin for all years from 2001-2013. The average for each month was then taken to achieve the average seasonality for surface water withdrawals.

2.2 Weather Adjustment

The monthly estimates derived using Equation 1 represent an average water use factor. Irrigation withdrawals, however, vary depending on the amount of rainfall experienced in a given month. Withdrawals go up during dry months and down during wet months. Thus, the withdrawals were adjusted to account for monthly variations in rainfall using a weather factor. The weather factors were applied during the growing season only, which runs from May through September.

To calculate the weather factors, monthly precipitation was collected from 1950 to 2013 from three U.S. Historical Climatology Network (USHCN) gages. For each month, the average between the three gage values was derived so that a statewide-average rainfall amount could be obtained. From

these monthly values, average monthly precipitation for the period of record (POR) was calculated. For each month from 1950-2013, a ratio was calculated of the 3-gage monthly precipitation average to the POR average. The minimum ratio was capped at 0.7 to avoid overestimating withdrawals. The resulting decimal value was applied to the surface water withdrawal estimate according to Equation 2.

$$WA\_SW_{y,m}^{P} = SW_{y,m}^{P} \div WF_{y,m} \qquad \textbf{Equation 2}$$

Where:

$WA\_SW_{y,m}^{P}$ = Weather adjusted surface water withdrawal for the withdrawal point (P) for the year (y) and month (m), in AF

$SW_{y,m}^{P}$ = Surface water withdrawal for the withdrawal point (P) for the year (y) and month (m), in acre-feet AF

$WF_{y,m}$ = Weather factor for year (y) and (month)

2.3 Calibration

To more closely align the water use estimates derived from the agriculture irrigation model with the water use reported to DHEC by agriculture producers, the values resulting from Equation 2 were adjusted according to the comparison of reported withdrawals to modeled withdrawals, thus calibrating the model. The numbered items below outline the calibration process. Essentially, the process adjusts the AF/A estimate for each county, thus lowering or raising demands.

1. Calibration was applied by county for all basins.
2. The draft model was derived assuming an average AF/A of 0.9.
3. A ratio was calculated by basin of weather adjusted demand to DHEC reported withdrawals.
4. Apparent outliers in the ratios were identified in the data and were not carried forth in the analysis.
5. The average ratio was calculated from 2002-2012 by basin.
6. The average ratio was then applied to the 0.9 AF/A assumption, essentially lowering or raising the AF/A assumption for each basin.
7. The calibrated AF/A by basin was then noted for each county falling within the basin. Some counties fall in multiple basins, so the average was assumed.
8. The AF/A assumption by county was then updated to reflect the calibrated value.