

Appendix B – Water Use Hindcasting

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INTRODUCTION

The purpose of this report is to document the data and methods used in estimating historical groundwater use throughout the North Florida Southeast Georgia Groundwater Model (NFSEG) Domain, including counties in Florida, Georgia, and South Carolina. The hindcasted data is an estimate of historical groundwater use back to 1900 using an annual time step. The historical groundwater use estimates provide an estimate of the impact of historical groundwater use on baseflow groundwater contributions to water bodies within the model domain (see Appendix C in this document).

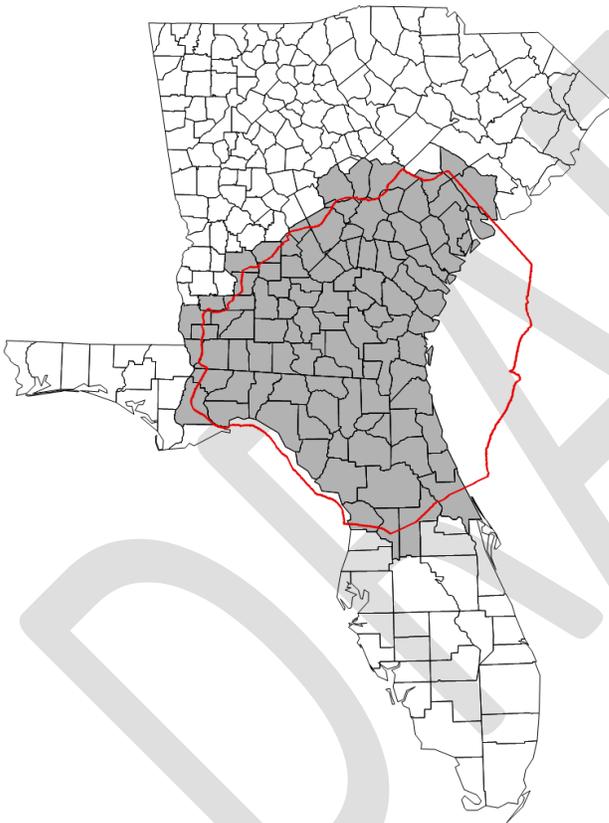


Figure 1: NFSEG Domain. Counties in gray are included in the effort to estimate historical groundwater use

OVERVIEW OF PROCESS

The data sources used to estimate historical groundwater use are summarized in the Figure 2.

Timeline of Groundwater Use Data

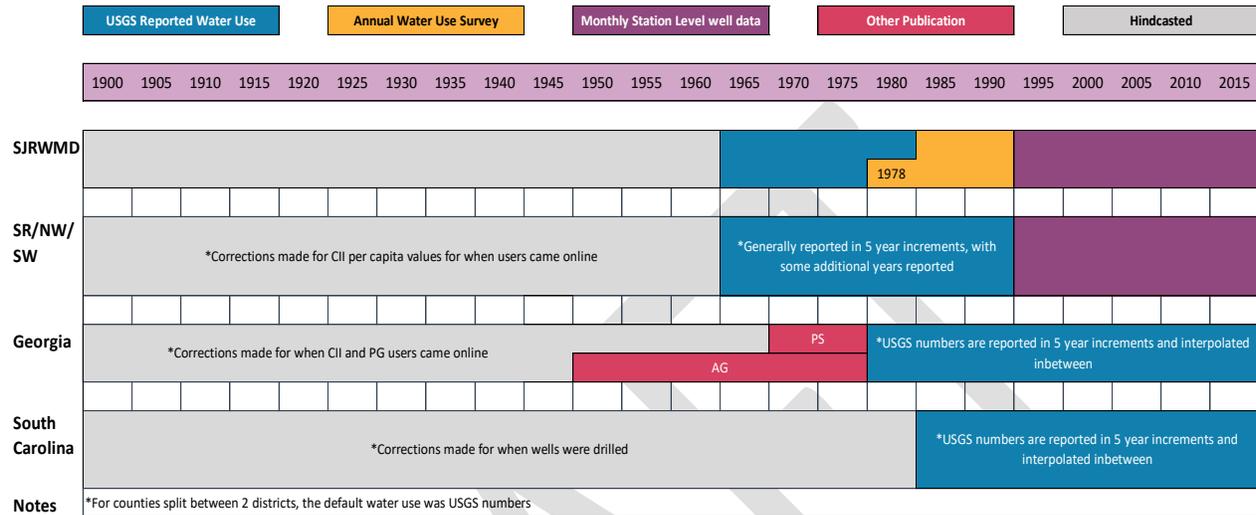


Figure 2: Timeline of Sources and Methods Used to Estimate Historic Groundwater Use

The methods used to estimate historical groundwater use differed by region based on data availability and are summarized in detail in the following sections. For each region, groundwater use was summarized into the categories in Table 1.

Table 1: Abbreviations and Definitions of Water Use Types

Use Type	Abbreviation	Definition
Public Supply	PS	Large municipal, public, and private systems that supply potable water to the public
Domestic Self-Supply	DSS	Domestic water uses generally associated with residential dwellings that are not served by a central public supply utility

Use Type	Abbreviation	Definition
Agricultural	AG	Irrigation of crops, water used to raise livestock, and other miscellaneous water uses associated with agricultural production
Commercial/Industrial/Institutional/Mining/ Dewatering	CII	<ul style="list-style-type: none"> -Self-Supply from wells -General businesses, office complexes, commercial cooling/heating, etc. -Manufacturing, chemical processing plants, other industrial facilities -Hospitals, assisted living facilities, churches, prisons, schools, etc. -Water associated with extraction, transport, and processing of minerals
Power Generation	PG	Water associated with power plant facilities which includes consumptive use of water for steam generation, cooling, and replenishment of cooling reservoirs from self-supply wells
Landscape/Recreation/Aesthetics	LRA	Irrigation, maintenance, and operation of golf courses, cemeteries, parks, medians, attractions, etc. from self-supply wells
Other (only for Florida)	OTH	Fire protection, environmental

Published county level groundwater use estimates were used when available. Missing data between published county level groundwater use were estimated in MS Excel using an exponential growth assumption (Excel RATE function) to create a complete annual groundwater use estimate. Using the earliest published county-level groundwater use estimate, a per capita water use estimate was calculated for each water use category. The per capita water use was multiplied by the historic county-level population. Historic population data sources are detailed for each region below. In some counties, the timing of initiation of groundwater use within categories or industries could be identified, even though county level estimates were not available. Adjustments made based on historic use data are described in detail for each region and are based on data availability.

For counties that were partially inside the model domain:

The amount of water used in the 2010 NFSEG model run was summed by county and divided by the amount of water reported from the USGS in 2010. This percentage was then used to determine the amount of water that will be attributed to Florida, Georgia, and South Carolina counties that were partially in the model domain. The water use for each category was then multiplied by that percentage amount for every year of recorded and hindcasted data.

The use categories used from the USGS water databases for Florida, Georgia, and South Carolina (see References) are as follows:

- State Code
- State Name
- County Code
- County Name
- Year
- Total Population of area, in thousands
- Public Supply population served by groundwater, in thousands
- Domestic self-supplied groundwater withdrawals, fresh, in Mgal/d
- Commercial self-supplied groundwater withdrawals, fresh, in Mgal/d
- Industrial self-supplied groundwater withdrawals, fresh, in Mgal/d
- Total Thermoelectric Power self-supplied groundwater withdrawals, fresh, in Mgal/d
- Mining self-supplied groundwater withdrawals, fresh, in Mgal/d
- Livestock self-supplied groundwater withdrawals, fresh, in Mgal/d

- Livestock (Animal Specialties) self-supplied groundwater withdrawals, fresh, in Mgal/d
 - Used in SC up until year 2000
- Aquaculture self-supplied groundwater withdrawals, fresh, in Mgal/d
- Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in Mgal/d
- Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in Mgal/d
 - Used for years 2000 and later

To coincide with the water use categories used in Florida, certain water use types were summed together. These categories are as follows:

- PS - Public Supply population served by groundwater, in thousands
- DSS - Domestic self-supplied groundwater withdrawals, fresh, in Mgal/d
- AG - Livestock self-supplied groundwater withdrawals, fresh, in Mgal/d, Livestock (Animal Specialties) self-supplied groundwater withdrawals, fresh, in Mgal/d (only in SC), Aquaculture self-supplied groundwater withdrawals, fresh, in Mgal/d, and Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in Mgal/d
- CII - Commercial self-supplied groundwater withdrawals, fresh, in Mgal/d, Industrial self-supplied groundwater withdrawals, fresh, in Mgal/d, and Mining self-supplied groundwater withdrawals, fresh, in Mgal/d
- PG - Total Thermoelectric Power self-supplied groundwater withdrawals, fresh, in Mgal/d
- LRA - Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in Mgal/d

Things to note:

- Prior to 2000, water used for golf course irrigation in Georgia was incorporated in the Agricultural irrigation category.

Groundwater Use Estimates by State:

Florida:

The NFSEG model domain incorporates counties from four different Water Management Districts throughout the state of Florida. Since the St. Johns River Water Management District (SJRWMD) started estimating water use earlier than the other three, the methodology slightly varies in order to include the most accurate estimates of water use. Historical water use in the Suwannee River Water Management District (SRWMD), Northwest Florida Water Management District (NFWFMD), and Southwest Florida Water Management District (SWFWMD) are grouped together because of similar data locations and methods. A monthly timestep of water use was generated for all Florida counties located in the NFSEG model domain. Monthly values were later averaged across the year to obtain an annual timestep.

St. Johns River Water Management District (SJRWMD):

The United States Geological Service (USGS) publishes county-level water use, for the following types of water use, every 5 years starting in 1965: Public Supply, Domestic Self-Supply, Commercial-Industrial-Mining, Agricultural, Landscape and Recreational Irrigation, and Power Generation. Some interim years are also available in the USGS data between the five-year intervals from 1965-1995 (“Historical Water-Use in Florida - Counties - 1965-2010”). The SJRWMD publishes county-level water use by category annually in their Annual Water Use Survey (AWUS), starting in 1978 (*Survey of Annual Water Use for St. Johns River Water Management District*). Using these two sources, groundwater use data was aggregated to the county and use type category for every five-year period from 1965 to 1994, and some years in between 1965-1994. Any missing years for each county and use category were estimated using an exponential growth assumption to create a complete aggregate table. If USGS and AWUS are not equal, published AWUS data was used.

The SJRWMD maintains a historical water use database with monthly use and station-level detail for each well point for the years 1995-2015. For each station, it was determined if there was missing data to gap fill. For each year that has more than 5 months of reported data, missing months were estimated. To do this, the station’s average proportion of water use for each month was determined, using all data from 1995-2015. The missing month’s corresponding average proportion was applied to the annual water use for the year with missing data to develop an estimate of water use for that month. This was done for all stations.

Suwannee River Water Management District (SRWMD)/Northwest Florida Water Management District (NFWFMD)/Southwest Florida Water Management District (SWFWMD):

The USGS groundwater use data from 1965-1994 was used to estimate groundwater use in counties not located in the SJRWMD. Groundwater use data was aggregated to the county and use type category for every five-year period from 1965 to 1994, and some years in between 1965-1994. Any missing years for each county and use category were estimated using an

exponential growth assumption. The historical water use database with monthly use and station level detail for each well point from 1995-2015 was used to fill in the remaining years of data.

Population data for all counties in Florida from 1860-2000 in 10-year increments was obtained from the U.S. Census (Forstall, R. L. 1996). Population data for all Florida counties from 2001-2010, and 2011-2015 was obtained from the Bureau of Economic and Business Research (BEBR) ("Florida Estimates of Population"). The same interpolation approach used for groundwater use was employed between 10-year and 5-year population increments to estimate population for in-between years. Hindcasting was completed by multiplying the water use specific GPCD (gallons per capita daily) value by the population for that year. For example, in Alachua county the 1965 Public Supply water use was 8.60 MGD at a population of 88,092, therefore the per capita value was 98 GPCD. This GPCD was applied to the population of all previous years to calculate the MGD of that given year. In 1950, the population of Alachua county was 57,026 people, the 98 GPCD was then multiplied by the population and divided by 1,000,000 to get the Public Supply MGD water use value which resulted in 5.57 MGD. The annual hindcasting was completed in Excel.

Historical statewide water use estimates were published by the USGS in 1945, 1950, 1955, 1960, 1965, 1970, 1975, and 1980 for all states in the United States. The statewide water use estimates were used to provide a check on groundwater estimates using this methodology.

Two counties in the SRWMD and one county in SJRWMD had large industrial users. The water use attributed to these industrial users was removed from the per capita water use estimate for the CII use category prior to the year the industry came online.

Florida Corrections

- Taylor – Buckeye/Foley Cellulose, now known as the Georgia-Pacific Foley Plant, came online in 1954, therefore Taylor county's CII water use category has two different GPCD values that were used for hindcasting. The first one uses the 1965 per capita value as is with all CII use, including Buckeye water use. The second GPCD value uses the 1965 water use value minus the 1965 Buckeye water use, which creates a smaller GPCD value. The 1965 Buckeye water use value came from USGS paper documents on CII water use. The Buckeye operation came online in 1954 therefore, the first large GPCD was used to estimate 1954-1964 water use for the CII category and the second smaller GPCD was used to estimate 1900-1953 water use.
- Hamilton – The PCS Phosphate mine, now known as Nutrien, came online in 1965. Hamilton county's 1965 water use value for the CII category was 10.3 MGD. Prior to 1965, any water use from PCS should not be used in the GPCD value that estimates 1900 - 1964 water use because the reported 10.3 MGD of CII water use was only from the PCS operation, according to USGS paper records on 1965 CII water use ("Suwannee River Mine"). Therefore, the GPCD value for CII prior to 1965 was zero.
- Nassau – Pumping in Fernandina Beach was very low prior to 1938, therefore CII water use was set to zero in 1937 and all years prior. Information on this area came from "Impact of

Development on Availability and Quality of Ground Water in Easter Nassau County, Florida, and Southeastern Camden, County, Georgia” (Brown, D. P. (1984)).

Georgia:

Population for Georgia was obtained from the Georgia Governor’s Office of Planning and Budget (“Historical Census Data”). Data include county level estimates from 1900 through 2000 in 10-year increments. The estimates for in-between years were interpolated using an exponential RATE function in Excel. Annual estimates for Georgia from 2000-2015 were obtained from the US Census (US Census Bureau).

County data for each water use category was obtained from the USGS with groundwater use estimates dating back to 1985 (*USGS Water Use Data for Georgia*). Additional county groundwater data for Georgia in 1980 was published in “Water Use in Georgia By County For 1980” (Pierce, R. R., Barber, N. L., & Stiles, H. R. (1982)). County level Public Supply water use estimates were obtained from “Use of water in Georgia, 1970, with projections to 1990” (Carter, R. F., & Johnson, A. M. F. (1974)). The GPCD values were calculated for each water use type in each county for the earliest year in which water use data was reported (1970 for Georgia PS, 1980 for all other categories except agriculture, which is described below). The GPCD value was calculated by dividing the groundwater use (in MGD) for each category by the population for that county and multiplying by 1,000,000. For example, in Appling County, Georgia, the 1980 Domestic Self-Supply groundwater use was 1.12 MGD with a population of 15,565, therefore the per capita value was 71.956 GPCD. The calculated GPCD values were held constant dating back to 1900, or back to the earliest year in which population data was recorded.

Historical statewide water use estimates published by the USGS in 1945, 1950, 1955, 1960, 1965, 1970, 1975, and 1980 for all states in the United States were used to refine agricultural groundwater use estimates in Georgia. Agricultural irrigation and other agricultural groundwater use was assumed to be zero prior to 1950 in Georgia based on agricultural irrigation trends in Georgia and total statewide water use reported in USGS publications (“Agricultural Irrigation Trends in Georgia”, “Watering Georgia: The State of Water and Agriculture in Georgia”). Agriculture groundwater use for Georgia was estimated between 1950 and 1980 using statewide groundwater estimates. Statewide estimates of groundwater use by category were published in 5-year increments starting in 1945. The agricultural groundwater use reported for Georgia in 1945 was zero, and “negligible” in 1950. The total AG groundwater use in Georgia in 1980 was estimated to be 397 MGD. Since agricultural groundwater use in 1950 was said to be “negligible,” a value of 0.1 MGD was used (0.1 MGD was used because it is the lowest value that can be input into the Excel equation). This value was then multiplied by the AG groundwater use in each county for the corresponding year and divided by 397 MGD.

Statewide Georgia AG values from USGS publications:

- 1945 – 0 MGD
- 1950 – “negligible” – assigned as 0.1 MGD
- 1955 – 12 MGD
- 1960 – 21.8 MGD

- 1965 – 19.1 MGD
- 1970 – 37.6 MGD
- 1975 – 33.6 MGD (center point irrigation system introduced)
- 1980 – 397 MGD

For example, Appling County had a reported 2.89 MGD of water used for AG in 1980. This was multiplied by 0.1 MGD and divided by 397 MGD, to get a total water use of 0.00073 MGD for 1950. Water use was then interpolated between 1950-1955 using the exponential RATE function in Excel. This methodology was applied for every 5-year increment from 1950-1980. In 1955, the 1980 value was multiplied by 12 MGD (what was reported from USGS statewide estimate), and then divided by 397 MGD. Water use was then interpolated between 1955-1960. The main assumption is that the percent of water use in each individual county compared to the total state-wide water use was the same in 1950 as it was in 1980.

Corrections were made for counties in Georgia where the initiation date of CII and PG water use could be estimated. The corrections made were based on the best estimate of the timing for initiation of groundwater use based on records of when large users came online. The estimated use for the affected use category was set to zero prior to initiation of the identified entity. These corrections are documented below. Corrections for Power Generation facilities were also made and based on the in-service year documented in “Power Generation and Related Water Use in Georgia” (Fanning, J. L., Doonan, G. A., Trent, V. P., & McFarlane, R. D. (1991)).

For example, in Charlton County, GA, the Humphreys Mining Company started mining minerals in Folkston, GA in 1965. The CII water use for Charlton County was then assumed to be zero prior to when they came online in 1965.

Georgia Corrections to CII and PG users:

- Appling – Edwin I. Hatch plant with Georgia Power Company in 1975
- Bacon – American Protein came online in 1949
- Berrien – Propex Operating Company came online in 1968
- Camden – Gilman Paper Company came online in 1940s
- Charlton – Humphreys Mining Company started mining in 1965
- Chatham – Savannah Sugar came online in 1917 and International Paper in 1920s and 1930s, Riverside Plant with Savannah Electric and Power Company in 1949
- Clinch – BWAY came online in 1957
- Colquitt – National Beef came online in 1914
- Decatur – BASF came online in 1921
- Dougherty – FL Rock Industries came online in 1965, Mitchell Plant with Georgia Power Company in 1948
- Early – Great Southern Paper Company came online in 1963
- Effingham – McIntosh Plant with Savannah Electric and Power Company came online in 1979
- Evans – Claxton Poultry came online in 1949

- Glynn – Pinova Inc. came online in 1911, King and Prince Shrimp in 1924, Mead Corporation/Scott Paper in 1937, and SeaPak Shrimp in 1948, McManus Plant with Georgia Power company in 1952
- Grady – Grace Fertilizer came online in 1954 and Oil-Dri in the early 1960s
- Jeff Davis – Propex Operating Company came online in 1953
- Laurens – J.P. Stevens came online in 1947
- Liberty – Interstate Paper (now DS Smith) came online in 1968
- Lowndes – Georgia-Pacific came online in 1927
- Sumter – McClesky Cotton Company came online 1929
- Thomas – Flowers Foods came online in 1919 and Oil-Dri in the early 1960s
- Ware – CSX Railroad came online in 1944 and Flanders Provision in 1958
- Washington - Thiele Kaolin Company came online in 1947
- Wayne - Rayonier's Cellulose Specialties came online in 1954
- Worth – Olam Edible Nuts (Universal Blanchers LLC) came online in 1978

South Carolina:

Population data for South Carolina was obtained from the US Census (Forstall, Richard L., 1995). Data include county level estimates from 1900 through 2000 in 10-year increments. The estimates for in-between years were interpolated using an exponential RATE function in Excel. Annual estimates for South Carolina from 2000-2015 were obtained from the US Census (US Census Bureau).

County data for each water use category was obtained from the USGS (*USGS Water Use Data for South Carolina*). Water use estimates dating back to 1985 were used for counties in South Carolina that are in the model domain. The GPCD values were calculated for each water use type in each county for the earliest year in which water use data was reported. The GPCD value was calculated by dividing the estimated groundwater use (in MGD) for each category by the population for that county and multiplying by 1,000,000. The calculated GPCD values were held constant dating back to 1900, or back to the earliest year in which population data was recorded.

Corrections were made for counties in South Carolina using well records from the South Carolina Department of Natural Resources (SCDNR) Hydrology Section (South Carolina Department of Natural Resources). This provided information on when the earliest well was drilled for each water use category. These dates were then used to adjust the water use for each use type in each county.

South Carolina Corrections:

- Allendale
 - Earliest DSS well - 1905
 - Earliest AG well – 1950
 - Earliest PS well – 1952
 - Earliest CII well – 1960

- Bamberg
 - Earliest DSS well - 1952
 - Earliest AG well – 1950
 - Earliest PS well – 1938
- Beaufort
 - Earliest DSS well - 1900
 - Earliest AG well – 1955
 - Earliest PS well – 1941
 - Earliest CII well – 1966
- Colleton
 - Earliest DSS well - 1917
 - Earliest AG well – 1955
 - Earliest PS well – 1942
- Hampton
 - Earliest DSS well - 1880
 - Earliest AG well – 1927
 - Earliest PS well – 1898
 - Earliest CII well – 1942
- Jasper
 - Earliest DSS well - 1900
 - Earliest AG well – 1928
 - Earliest PS well – 1941
 - Earliest CII well – 1953

Moving Average Calculation

For each county and use type combination a moving 5-year average was calculated. The average was computed based on the current year and the four years preceding that year. For example, the 5-year moving average in 1930 included the years 1930, 1929, 1928, 1927, and 1926. This moving average was then calculated for all years starting with 1904. Results for each state, county, and use-type combination in the model domain were then merged into one dataset.

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