

**A History of Pumpage from Water Wells in the Upper Floridan
Aquifer in South Carolina and Georgia, 1886 to 1986**

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CONTENTS

| | Page |
|-------------------------------------|------|
| Abstract | 1 |
| Introduction | 2 |
| Historical withdrawals | 4 |
| Pumpage in Glynn County, Ga. | 13 |
| Water usage by the rural population | 17 |
| Conclusions and interpretation | 20 |
| References | 28 |

FIGURES

| | Page |
|---|------|
| 1. Location of study area | 3 |
| 2. Location of towns and principal features discussed in report | 5 |
| 3. Historical water use | 21 |

TABLES

| | Page |
|--|------|
| 1. Summary of pumpage in coastal Georgia, 1943 | 6 |
| 2. Estimated pumpage in the Beaufort area, 1943 | 6 |
| 3. Metered withdrawals for the 12 Lower Coastal Plain counties of Georgia as reported by Wait and Callahan | 7 |
| 4. Pumpage in Beaufort and Jasper Counties, S.C., and in Savannah, Ga., for 1957 to 1959 | 8 |
| 5. Pumpage in the Savannah area for 1961, and estimates for Bryan, Effingham Counties, Ga., and Beaufort and Jasper Counties, S.C. | 10 |
| 6. Pumpage in Beaufort, Jasper, and Hampton Counties, S.C., and at Savannah for 1976 | 10 |
| 7. Estimated pumpage for Chatham, Glynn, Liberty, Long, and Wayne Counties, Ga., for 1977 | 11 |
| 8. Estimated 1985 pumpage for coastal Georgia | 11 |
| 9. Estimated pumpage for Glynn County, Ga., for 1937 through 1961 | 12 |

| | | |
|-----|--|----|
| 10. | Reported and estimated withdrawals for 1986 | 15 |
| 11. | Estimated and reported withdrawals for Glynn County, Ga. | 18 |
| 12. | Area, population, and estimated per capita withdrawal in South Carolina counties underlain by the Upper Floridan aquifer | 22 |
| 13. | Area, population, and estimated per capita water use in Georgia counties underlain by the Upper Floridan aquifer | 22 |

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ABSTRACT

Ground water from the Upper Floridan aquifer has served historically as the principal source of public, industrial, and farm-irrigation supply for coastal southern South Carolina and Georgia since the first Floridan well was drilled in 1884. The estimated withdrawal from the Upper Floridan in 1890 was 6 mgd (million gallons per day) at Savannah. The withdrawal rate increased modestly to 14 mgd by 1900, including 9 mgd in Savannah and 2 to 5 mgd at Brunswick. Driven primarily by industrial growth in Georgia withdrawals of Upper Floridan water grew to 140 mgd in 1943 and to 310 mgd in Georgia by 1977.

The largest water users in Georgia are the industries located in Savannah, Brunswick, Doctortown (near Jesup), and St. Marys in Georgia. The peak withdrawal rate in South Carolina was 16 mgd in 1986. The maximum withdrawal was on Hilton Head Island where pumpage peaked at 13.1 mgd.

INTRODUCTION

Ground water from the Upper Floridan aquifer (Figure 1) has served as the principal source of public, industrial, and farm-irrigation supply for coastal southern South Carolina and Georgia since about 1886. Water from the Upper Floridan supplies Fort Stewart in Liberty County, Ga., and, prior to 1965, supplied the U.S. Marine Corps Recruit Depot at Parris Island, S.C. Thus, the role played by Upper Floridan water deserves at least a footnote in the history of the defeat of Nazi Germany and Imperial Japan.

Today the Upper Floridan's role is less dramatic but still of great import. The aquifer supplies virtually all the municipal and industrial water supplies of coastal Georgia. Its role in South Carolina has been reduced by construction of the Beaufort-Jasper Water and Sewer Authority (BJWSA) and its importation of Savannah River water to most of Beaufort County. Still, the aquifer supplies most of the public, municipal, and farm-water supplies in Jasper and Hampton Counties; moreover, an easily obtained, high-quality supply is in reserve if the Water Authority's supply were to become contaminated. The purpose of this paper is to summarize the history of withdrawals, list the available references, and gather what has been reported into one reference. Included also is an estimate by the writer of historical rural water usage.

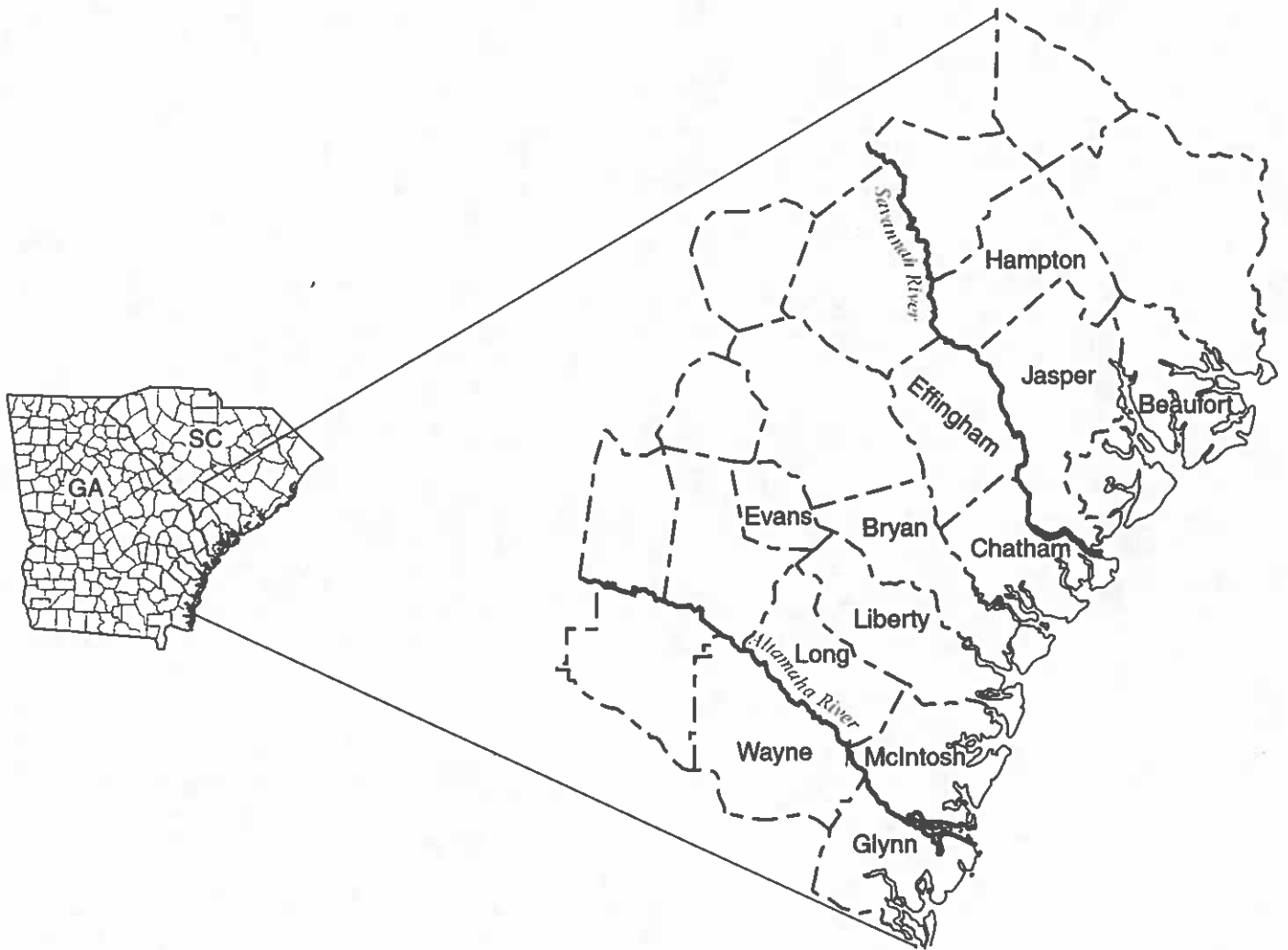


Figure 1. Location of South Carolina and Georgia counties referred to in this report.

HISTORICAL WITHDRAWALS

The principal reference for water use in Georgia during the 1930's and 40's is Moultrie Warren's 1944 publication "Artesian water in southeastern Georgia with special reference to the coastal area." Table 1 summarizes the data. In 1943, Warren estimated that 48 mgd (million gallons per day) was withdrawn from the Upper Floridan aquifer in Chatham County. In what he called the "Savannah area," 42 mgd was pumped. Warren (p.126) computed that a withdrawal rate of 26 mgd was the maximum that could be realized in Savannah while maintaining a sufficient ground-water level at Bluffton, S.C., (estimated as 2 ft msl NAVD, 1927), to prevent saltwater encroachment in the aquifer. He recommended that withdrawals in the Savannah area not exceed the 38 mgd used prior to the onset of World War II. This would have pared back pumpage by 6 to 8 mgd from its 1943 historical high. Warren (p. 11) reported that 30 mgd was wasted by uncontrolled artesian discharge, principally in Camden, McIntosh, Bryan, and Liberty Counties, Ga. (see Figure 2 for locations referenced in report.)

M. J. Mundorff (1944) estimated withdrawal in the Beaufort area in a study commissioned by the U.S. Government in an effort to secure a firm water supply for the Marine Corps Recruit Depot at Parris Island (MCRD). In his



Figure 2. Cities and location of particular importance in the history of Upper Floridan aquifer pumpage.

Table 1. Summary of pumpage in coastal Georgia 1943¹

| County | Pumpage (mgd) | Comments |
|----------------------|----------------------|---|
| Bryan | 6 | Good, free-flowing wells |
| Camden | 15 | Industrial use, some free-flowing wells |
| Chatham ² | 48 | 42 industrial/municipal wells, 1 free flowing |
| Effingham | 0.5 | Municipal/domestic |
| Glynn | 47 | Industrial/municipal |
| Liberty | 9 | 3 Ft. Stewart, 6 free flowing |
| McIntosh | 11 | Free-flowing wells |
| Total | 136 (rounded) | |

¹ Coastal counties in Georgia including Wayne, Pierce, Long, Bulloch, Brantley, Charlton, and Screven, probably used about 0.5 to 0.8 mgd each. Total pumpage probably approached 140 mgd.

² Chatham County includes in part the "Savannah area" defined by Warren (1944) as the "present city limits of Savannah, plus Hutchinsons Island the industrial area on the northwest bounded by the Savannah River and Highway 17 to the traffic circle where U.S. Highway 17 and U.S. Highway 80 intersect." The area "extends to the central junction, along U.S. Highway 80, and from Central Junction to the city limits of Savannah, along the Seaboard Air Line Railroad." Included also was "industrial area to the east between Presidents Street and the Savannah River," and the "Standard Oil Terminal."

Table 2 . Estimated pumpage in the Beaufort area, 1943

| Location | Pumpage (mgd) | Comments |
|---------------------|---------------|----------------------------|
| City of Beaufort | 0.25 | Municipal |
| MCRD, Parris Island | 1.85 | Military training facility |
| Total | 2.10 | |

report, he discussed the farms of rural St. Helena Island, Port Royal Island, and the area north of the Whale Branch River, but he offered no estimates of pumpage. Wait and Callahan (1955, p. 116) reported that "pumpage of ground water for municipal and industrial purposes amounted to 280 mgd." They further

Table 3. Metered withdrawal for the 12 Lower Coastal Plain counties of Georgia as reported by Wait and Callahan¹

| Year | Savannah | Brunswick | St. Marys | Doctortown ² | Totals(mgd) |
|------|----------|-----------|-----------|-------------------------|-------------|
| 1950 | 28.3 | 43.4 | 9.58 | 0.00 | 81.3 |
| 1951 | 27.0 | 49.4 | 13.6 | 0.00 | 90.0 |
| 1952 | 29.3 | 46.5 | 12.5 | 0.00 | 88.3 |
| 1953 | 32.0 | 54.8 | 12.5 | 24.0 | 123 |
| 1954 | 34.2 | 59.5 | 12.7 | 24.0 | 130 |
| 1955 | 57.0 | 53.7 | 24.0 | 24.0 | 159 |

¹ Wait and Callahan reported withdrawal in units of acre-feet. One acre-foot is the volume of water necessary to cover 1 acre to a depth of 1 foot. It is equal to 43,560 cubic-feet, or 325,804 gallons.

² Wait and Callahan reported 73.68 acre-feet (74 mgd) of pumpage for 1955 at Doctortown. Krause (1972) reported 45 mgd for 1954 and 1955. The difference in the two values cannot be reconciled with available data.

reported that the "12 coastal counties amounted to 135 mgd." Table 3 is from Wait and Callahan¹ (1955). Doctortown, where pumpage of 24 mgd was reported, is located in Wayne County, Ga. Wait and Callahan did not include Wayne County as one of the 12 coastal counties. In addition, they did not report estimates for unmetered and rural pumpage.

G.E. Siple (1960), in a study commissioned by the Department of the Navy, reported pumpage in the Beaufort area for 1959, including nearby Chatham County Georgia (Table 4). He reported the increase in pumping in Savannah and evidently reopened a festering controversy between South Carolina and Georgia regarding the concern about saltwater intrusion of the Upper Floridan aquifer in

Table 4 . Pumpage in Beaufort and Jasper Counties, S. C. and in Savannah, Ga. for 1957 to 1959

| Location | Pumpage (mgd) | Comments |
|-----------------------------------|--|-------------------------|
| City of Beaufort | 0.48 (peak 0.75) | Municipal |
| Town of Port Royal | 0.06 | Municipal |
| MCRD, Parris Island ¹ | 1.65 mgd 1956 1.63 mgd 1958 (peak daily 2.75 mgd) 1.72 1/59 through 7/59 | |
| Naval Hospital | 0.11 | Military hospital |
| MCAAS (now MCAS) | 0.42 (peak 0.75 in 1958) | Military base |
| Capehart Housing | 0.55 (1960) | Military housing |
| Port Royal and St. Helena Islands | 1.58 | Domestic and irrigation |
| Beaufort County | 5.2 (total, 1.4 outside of the above) | |
| Jasper County | 1.0 | Estimated |
| City of Savannah | 18.1 mgd (1956) 20.2 mgd (1957) 16.9 mgd (1958) | Municipal metered |
| Savannah industrial | 42 | Estimated |

¹ The MCRD, PI from 1944 to 1955 used water from well fields at Jericho, Burton, and the NAS (later the MCAAS, now the MCAS). From 1955 to 1965 the Jericho well field was, in a practical sense, only backup usage. In 1965 the Beaufort-Jasper Water Authority water line reached the base.

the vicinity of Hilton Head Island.

In response to concerns about saltwater intrusion in South Carolina and the long-term productivity of their coastal aquifers, the State of Georgia commissioned the U.S. Geological Survey (USGS) to undertake a second study of the hydrology and geology of the Floridan aquifer at Savannah. As a result of this study, Counts and Donsky (1963) reported Upper Floridan pumpage (Table 5) in the Savannah area. They included estimates for Beaufort and

Jasper County withdrawals (possibly understated); they included no estimate for Hampton County withdrawals.

R. E. Krause and D.O. Gregg (1972), in a report commissioned by the Georgia Department of Natural Resources, reported 1971 average daily Upper Floridan withdrawal rates for the four principal pumping locales in Georgia (Table 6). They did not include an estimate of artesian discharge, but in writing of aquifer development they stated that "the area where artesian flow could be obtained decreased." Their withdrawal data principally were metered industrial and municipal pumpage. They included an excellent graph of historical withdrawals for Glynn County.

Hayes (1979) reported upper Floridan withdrawals for 1976 in a study commissioned by the South Carolina Water Resources Commission (Table 7). By 1976, the BJWSA was supplying 4.9 mgd of Savannah River water to the areas north of the Broad River, including the city of Beaufort, the town of Port Royal, MCRD, the Naval Hospital, and the MCAS. Hayes went on to report (p. 53) that in the Savannah area about 75 mgd was pumped. Hayes referenced Counts and Krause (1976). It is not clear how Counts and Krause were defining "Savannah area," and whether or not they were including Beaufort County in their estimates of Savannah area withdrawals.

Table 5 . Pumpage in the Savannah area¹ for 1961, and estimates for Bryan, Effingham, and Beaufort and Jasper Counties, S.C.

| County | Pumpage (mgd) | Comment |
|--------------|---------------|---------------------------------------|
| Bryan | 1.5 | Municipal/domestic/ some free-flowing |
| Chatham | 62 | Municipal/industrial/domestic (3 mgd) |
| Effingham | 1.5 | Municipal/domestic |
| Beaufort | 2.5 | Municipal/domestic/military bases |
| Jasper | 0.5 | Towns, rural, some farm |
| Total | 68 | |

¹ Counts and Donsky defined "Savannah area" as the city of Savannah coupled with Garden City, Bloomingdale, and the remainder of Chatham, Effingham, and Bryan Counties.

Table 6. Pumpage for the four principal pumping centers for coastal Georgia for 1971

| Location | Pumpage | Comments |
|--------------|------------|---|
| Savannah | 70 | Savannah includes municipal and industrial pumpage for all of Chatham Co. |
| Brunswick | 105 | Brunswick pumpage is for all of Glynn County |
| Riceboro | 10 | Primarily industrial pumpage |
| Jesup | 45 | Primarily industrial pumpage at Doctortown |
| St. Marys | 40 | Industrial pumpage: additional 70 mgd at Fernandina Beach, Fla. |
| Total | 270 | |

The USGS (1977) reported withdrawals for the three principal Georgia pumping centers (Brunswick, Doctortown, and Savannah, see Figure 2) in the Georgia Coastal Plain. Table 8 summarizes the data.

Turlington and others (1987), in a study commissioned by the State of

Table 7. Pumpage in Beaufort and Jasper Counties, S. C., and in Savannah for 1976

| Locality | Pumpage (mgd) | Comments (pumpage in mgd) |
|-----------------------|---------------|---|
| Beaufort County, S.C. | 10.5 | 10.1, Hilton Head Island 0.4, St. Helena Island 0.1, Port Royal Island 4.9 Savannah River, domestic, Irrigation |
| Jasper County, S.C. | 1.8 | Municipal and domestic, 1.43 Irrigation, 0.35 Industrial, 0.0 |
| Hampton County, S.C. | 1.4 | Municipal and domestic, 0.74 Irrigation, 0.28 Industrial, 0.35 |
| Savannah area | 75 | Ref. : Counts and Krause, 1976 |

Table 8. Estimated pumpage for Chatham, Glynn, Liberty, Long, and Wayne Counties, Ga. for 1977

| County | Pumpage (mgd) | Comments |
|------------|---------------|---|
| Chatham | 80 | City of Savannah + industries (pg. 75) |
| Glynn | 100 | City of Brunswick + industries (pg. 24) |
| Liberty | 10 | Riceboro, starting 1968 (pg 38) |
| Wayne/Long | 75 | Doctortown, GA, pumpage expanded from 45 in (pg. 32) 1972 |
| Total | 265 | It 45 mgd used at St. Marys, GA, then daily yield approaches 305 mgd. |

Georgia, reported withdrawals for the Georgia Coastal Plain for year 1985 (Table 9). This was the first comprehensive report for the Georgia Coastal Plain since Warren's of 1944. They reported withdrawals of 185 mgd for the 12 Georgia coastal counties. In large part, increases in pumpage at Doctortown and

Table 9 . Estimated 1985 pumpage for coastal Georgia

| County | Pumpage (mgd) | Comments |
|----------------------|---------------|--|
| Bryan | 1.2 | Municipal (0.67), Domestic (0.49), Industrial (0.1) |
| Bulloch | 3.61 | Municipal (1.32), Domestic (1.49), Industrial (0.80) |
| Chatham ¹ | 73.4 | Municipal (32.49), Domestic (2.71), Industrial (38.22) |
| Effingham | 1.57 | Municipal (0.73), Domestic (0.84), Industrial (0.0) |
| Evans | 1.39 | Municipal (0.45), Domestic (0.22), Industrial (0.72) |
| Glynn | 76.5 | Municipal (10.91), Domestic (2.41), Industrial (63.17) |
| Liberty ² | 16.1 | Municipal (4.52), Domestic (2.85), Industrial (8.74) |
| Long | 0.51 | Municipal (0.21), Domestic (0.30), Industrial (0.0) |
| McIntosh | 1.44 | Municipal (0.40), Domestic (0.53), Industrial (0.51) |
| Screven | 3.49 | Municipal (1.32), Domestic (0.81), Industrial (1.36) |
| Tattnall | 2.60 | Municipal (1.06), Domestic (1.54), Industrial (0.0) |
| Wayne | 69.1 | Municipal (1.62), Domestic (0.84), Industrial (66.59) |
| Total | 185 | |

¹ Does not separate upper Floridan and lower Floridan pumpage.

² Does not include estimate of pumping in Hinesville/ Ft. Stewart area.

³ Includes mining and pit dewatering

⁴ Does not include Camden County

Brunswick are supported by declines in artesian discharge in McIntosh, Bryan, and Liberty Counties. For example, in 1943 there was 11 mgd freely discharged by wells in McIntosh County. By 1985 that had declined to 1 mgd withdrawn by

pumping.

McCready (1989) compiled water-use data for Beaufort County south of Port Royal Sound and for Jasper County (see Table 10). In his report he listed separately the Upper Floridan aquifer withdrawals. He reported 15 mgd withdrawn, including 13.1 mgd on Hilton Head and Daufuskie Islands.

About 1.7 mgd (total withdrawal of million gallons divided by 365 days) was used for golf-course irrigation on Hilton Head Island (McCready, 1989, p. 8), and 0.09 was used on Daufuskie Island (p. 11).

Harrigan estimated water use in Hampton County for 1983. He reported 1.12 mgd of ground water for industrial usage and 1.1 mgd for irrigation. He reported no usage for public supply. The industrial usage probably was not upper Floridan water. The mills and factories in the town of Hampton use water from deeper wells completed in the older Cretaceous aquifers. The 1.1 mgd used for irrigation was probably Upper Floridan water. Most rural water from private wells is Upper Floridan water. The writer has estimated the latter as 0.4 mgd in 1983.

WITHDRAWALS IN GLYNN COUNTY, GA.

Wait (1965, p. E29) wrote of the knowledge of water use in Glynn County, "Warren (1944, p24) estimated that the total discharge of artesian water in

Table 10 . Reported and estimated withdrawals for 1986

| County | Pumpage (mgs) | Comments (pumpage in mgd) |
|-----------------------|---------------|--|
| Beaufort ¹ | 17.0 | 13.1, Hilton Head and Daufuskie Islands 1.9, Beaufort County, S. of Port Royal Sound, including Public supply 2.0, N. of Port Royal Sound, Domestic, public supply, industrial |
| Jasper ¹ | 0.61 | 0.61, Domestic and public supply |
| Hampton ² | 1.5 | 1.1, Agriculture 0.4, Domestic |
| Totals | 19.1 | |

¹ From McCready (1989), coupled with unpublished water use data from files of SCDNR.

² From Harrigan (1983), coupled with writer's estimate for domestic usage.

Glynn County in 1942 was 47 mgd. He estimated that 37 mgd was discharged within a 3-mile radius of the Glynn County Courthouse and that 80 percent of that was used by industry. Reliable estimates for previous years are not available." In the following section the writer offers an estimate of withdrawal rates.

The first well reported for Glynn County was drilled in 1884 (McCallie, in Wait, p. E24), and by 1898 a total 16 wells flowing at rates of 100 to 250 gpm (gallons per minute). had been drilled. These wells were reportedly drilled to depths of 400 to 500 (feet). Wait (p. E24) stated that these wells were artesian and completed in the Hawthorn Formation. What Wait termed the Hawthorn Formation is a three-time repetitive sequence of three lithologies:

carbonate, clay, and sand. Within this sequence there exist two water-bearing sands sufficiently extensive in Glynn County to be termed the upper and lower Brunswick aquifers. The Brunswick aquifers are a part of the larger Floridan aquifer system. The Brunswick aquifers are not, however, synonymous with Upper Floridan aquifer in the usual sense. By 1898, wells in the Brunswick aquifers discharged 2 to 5 mgd. By 1908, water levels in these wells had declined and the resultant flowing discharge was insufficient for Brunswick's needs; pumps had to be installed.

Water levels were known to be higher and artesian discharge greater with aquifer depth in the Brunswick area, and deeper wells were eventually drilled. McCallie (in Wait) reported a well drilled to depth 525 ft. In 1908 the water level in that well stood at an elevation of 57 ft above mean sea level Stevenson and Veatch (Wait, p. E25) reported a well northwest of Brunswick drilled to a depth of 1,000 ft that yielded 3,500 gpm (5 mgd). Thus, it is likely that by this time 5 mgd was discharged from the Upper Floridan aquifer.

Warren (1945) reported that the city of Brunswick's first Upper Floridan water well was drilled in 1918. It flowed at a rate of 350 gpm (0.5 mgd) and was pumped at 2 mgd. It seems reasonable to assume that this well replaced the Brunswick aquifer wells that Wait reported as needing pumps.

Warren (1945) reported that the Hercules Powder Co. had three wells drilled prior to 1935. Two are of sufficient depth to be Upper Floridan wells. It is not known if these wells were drilled for Hercules Powder, nor if they were pumped to support production at Hercules Powder prior to 1935. In addition, Warren stated that two wells drilled in 1935 were reported to flow at 3,000 and 3,650 gpm (total of 9.6 mgd). Moreover, an additional well was pumped at 1,600 gpm (2.3 mgd). The pumped well was 450 ft deep and it may be a Brunswick aquifer well. The other two wells were 880 and 969 ft deep, respectively, and are Upper Floridan aquifer wells. The fact that a well could flow does not mean that it was free to do so; thus, at a minimum the Hercules Powder Co. likely pumped 2.3 mgd in 1935, and they may have pumped as much as 11.9 mgd. This last figure is line with their reported pumpage for 1943. The large possible flow rates for the wells drilled in 1935 is interpreted by the writer to mean that Upper Floridan discharge was, at a minimum, 9.6 mgd. Warren (1945) reported also that Brunswick Pulp and Paper drilled their first wells in 1937. These wells were all about 900 ft deep. They reportedly pumped 7,000 gpm (10.1 mgd.)

If it is accepted that the Brunswick aquifer is part of the Upper Floridan aquifer, then it can be concluded that by 1898 2 to 5 mgd was being withdrawn from the Floridan aquifer system. If a more restrictive sense of the term

Upper Floridan is assumed, then withdrawal from the Upper Floridan began in 1918, and by the end of that year 2 mgd was being withdrawn in Brunswick and 7 mgd total was being withdrawn in Glynn County. The writer is including Brunswick aquifer discharge as a part of the Floridan discharge in the accounting of withdrawals.

It is not known by the writer when the Hercules Powder Co. began operations, but by 1935 it is likely that upwards of 23 mgd was withdrawn in the county. After 1935, major water usage in Glynn County was metered. Free-artesian discharge and water use by the rural population, however, was not metered and thus was not reported. For the estimate of free discharge, the writer has assumed Warren's reported free-discharge. Table 11 summarizes estimated and reported withdrawals for Glynn County. These suppositions and interpretations are included in the pumpage graph shown later in the report as Figure 3.

WATER USAGE BY THE RURAL POPULATION

Tables 12 and 13 summarize population data for the year 1940. At that time the population withdrawing water from wells in the Upper Floridan aquifer was largely rural, the population of Savannah, Ga, and Beaufort, S.C., being the

Table 11. Estimated and reported withdrawals for Glynn County, Ga.

| Year | Pumpage (mgd) | Comments |
|------|---------------|--|
| 1898 | 2 to 5 | Brunswick aquifers? |
| 1918 | 7 | 100 % Upper Floridan |
| 1934 | 11 | Brunswick plus artesian discharge |
| 1935 | 23 | Hercules Powder plus Brunswick and artesian discharge |
| 1937 | 45 | Hercules Powder plus Brunswick Pulp and Paper, city of Brunswick, and artesian discharge |
| 1943 | 47 | Warren (1944) |
| 1945 | 33.9 | Wait (1955) |
| 1946 | 39.4 | Wait (1955) |
| 1947 | 44.2 | Wait (1955) |
| 1948 | 38.2 | Wait (1955) |
| 1949 | 42.3 | Wait (1955) |
| 1950 | 47.7 | Wait (1955) |
| 1951 | 51.4 | Wait (1955) |
| 1952 | 48.7 | Wait (1955) |
| 1953 | 57.4 | Wait (1955) |
| 1954 | 60.6 | Wait (1955) |
| 1955 | 56.5 | Wait (1955) |
| 1956 | 80.6 | Wait (1965) |
| 1957 | 84.8 | Wait (1965) |
| 1958 | 84.7 | Wait (1965) |
| 1959 | 89.0 | Wait (1965) |
| 1960 | 91.0 | Wait (1965) |
| 1961 | 90.2 | Wait (1965) |
| 1971 | 105 | Krause and Gregg (1972) |

exceptions. In 1943, the city of Savannah pumped 12.1 mgd (Warren, p. 112). The computed per capita usage was 135 gpd (gallons per day). In 1943 the city of Beaufort pumped about 0.45 mgd. Census data (State Planning Board) show that 3,185 persons resided in Beaufort. If it is assumed that the city's water system served only that population, then a per capita usage of 155 gpd is computed. It is known that Beaufort supplied water to local businesses, including ice-making and seafood processing plants. It is also certain that the city of Savannah supplied water to businesses, hotels, and seafood processors. The computed per capita estimates are closely similar, and because they are the per capita usage is considered a reasonable estimator of water withdrawal and usage for coastal towns; for example, Port Royal, S.C., and Darien, Ga. If 135 gpd is applied as an estimator of usage for the rural population, then a computed usage of 29.1 mgd is derived for the rural population of Georgia in 1940. In similar fashion, 7.5 mgd is derived for the rural population in South Carolina. The writer believes these estimates to be grossly high.

Modern water-using appliances and indoor plumbing were not common in rural South Carolina and Georgia in 1940. A more reasonable estimator of rural per capita use is believed to be about 35 gpd. Assuming the 35 gpd estimator to

be reasonable, then the rural withdrawal was 1.8 mgd in South Carolina and 4.4 mgd in Georgia. Thus, of the 45 mgd Warren measured as a flowing discharge, perhaps 40 mgd was wasted. He reported 30 mgd wasted. The difference in estimates probably results from the definition of "wasted." In 1940, flowing wells in Georgia were used to fill farm ponds, and even to generate electricity. It is doubtful that Warren considered those uses to be waste. By 1968 most of the free-flowing discharge by wells in McIntosh and Bryan Counties had stopped, owing to the regional drawdown (Krause, 1972, p. 3). While the cause of the regional drawdown was primarily industrial pumping in 1968, the per capita rural water usage in South Carolina and Georgia probably doubled from the usage of 1938 (see Table 11) and this usage has affected aquifer water levels.

CONCLUSIONS AND INTERPRETATION

Figure 3 illustrates pumpage according to the data included in Tables 1 through 13. The curve is probably overly smooth owing to the fact there are very few control points.

Warren reported the city of Savannah's public- supply withdrawals as 20 mgd in 1936. Siple (1960) reported values ranging from 16 to 19 mgd, and Counts and Donsky reported 20 mgd in 1960. It increased to 27 mgd by 1985. The writer has assumed the City's withdrawal rate remained steady from 1943

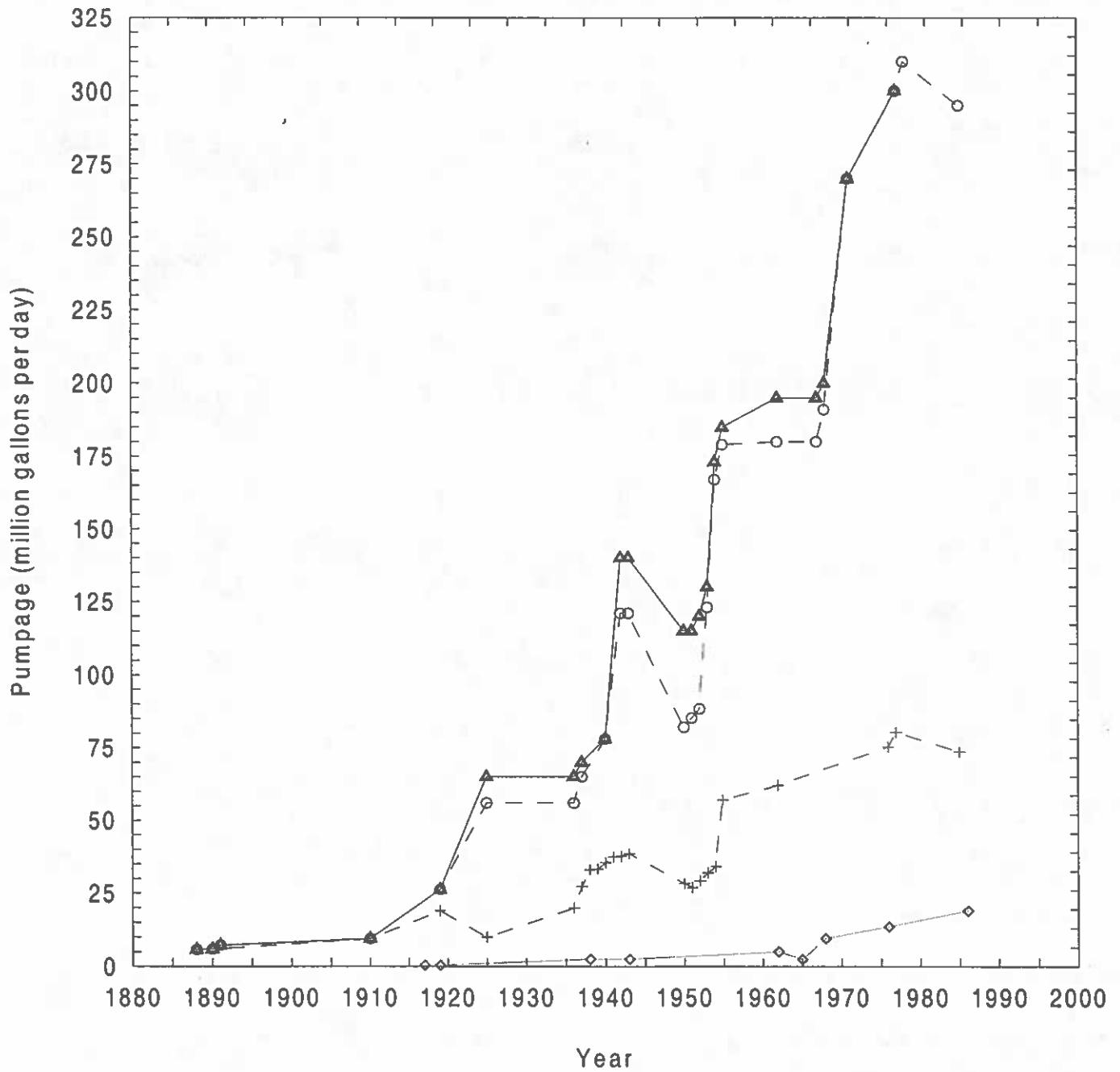
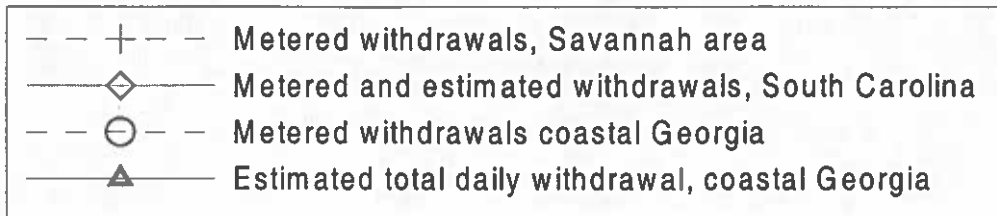


Figure 3. Withdrawals from the Upper Floridan aquifer for the period 1886 to 1986.

Table 12 . Area, population and estimated per capita water use in South Carolina counties underlain by the Upper Floridan aquifer

| County | Area (square miles) | Population 1940 | Population (per square mile) | Rural water usage |
|--------------|---------------------|-----------------|------------------------------|-------------------|
| Beaufort | 702 ¹ | 27,128 | 38.5 | 0.81 |
| Jasper | 596 | 11,011 | 18.5 | 0.39 |
| Hampton | 513 | 17,465 | 34.0 | 0.61 |
| Total | 1,811 | 55,604 | | 1.8 |

¹ In 1940 Beaufort County encompassed 702 square miles. In 1954, a 64 square-mile area of Beaufort seceded and joined Jasper County.

Table 13. Area, population and estimated per capita water use in Georgia counties underlain by the Upper Floridan aquifer

| County | Area (square miles) | Population 1940 | Population (per square mile) | Rural water usage |
|----------------------|---------------------|-----------------|------------------------------|-------------------|
| Brantley | 434 | 6,871 | 15.8 | 0.24 |
| Bryan | 431 | 6,288 | 14.6 | 0.22 |
| Camden | 711 | 5,910 | 8.3 | 0.21 |
| Charlton | 792 | 5,256 | 6.6 | 0.18 |
| Chatham ¹ | 370 | 117,970 | 318.8 | 0.95 |
| Effingham | 448 | 9,646 | 21.5 | 0.34 |
| Glynn | 439 | 21,920 | 49.9 | 0.77 |
| Liberty | 543 | 8,595 | 15.8 | 0.30 |
| Long | 393 | 4,086 | 10.4 | 0.14 |
| McIntosh | 470 | 5,292 | 11.3 | 0.19 |
| Pierce | 345 | 11,800 | 34.2 | 0.41 |
| Wayne | 615 | 13,122 | 21.3 | 0.46 |
| Total | 5,991 | 216,756 | | 4.4 |

¹Savannah's population in 1940 was approximately 90,000, therefore approximately 27,000 people lived in rural Chatham County.

to 1962, in part owing to the effect of the Savannah River treatment plant that met a portion of the demand.

Warren (1945) reported on artesian water in southeastern Georgia, with special reference to the coastal area and presented many well records. What impresses most about his well records are the number of farms, motels, and small businesses relying on Upper Floridan water that was free-flowing. As time passed and industrial pumpage increased, the rate of artesian discharge declined. This decline is not well quantified and it may be poorly depicted in Figure 3. It is worth noting that many of these wells still exist. A reduction of industrial withdrawals will bring with it a consequent rise in water levels. This water will again be wasted if old, abandoned water wells are not located and properly sealed.

The city of Beaufort withdrawal rates reported by Siple (1960) are known to be accurate, because Siple regularly recorded the meter readings; the unpublished data are in files of the SCDNR (South Carolina Department of Natural Resources). He reported estimates for the remainder of the county. The BJWSA began delivery of water to Beaufort and areas north of Port Royal Sound in 1965 in response to concerns about saltwater intrusion of the Upper Floridan aquifer at Beaufort. This is also about the same time as intensive

building started on Hilton Head Island, located on the south side of Port Royal Sound. Port Royal Sound had always been a natural barrier faced by Beaufort Countians, and in some respects the county has developed differently because of it. The same would be true for the intrusion of saltwater caused by groundwater withdrawals. Hilton Head Island is located in the drawdown cone created by Georgia pumping -- Beaufort is not so located. The cone of depression resulting from Hilton Head Island pumping reported by Hayes (see Table 7) was superimposed on the regional cone of depression for the pumping reported for Georgia. The cone of depression for pumping reported by Mundorff (Table 2) and by Siple (Table 3) was located outside of the regional cone. In effect, South Carolina did not begin pumping the section of the Upper Floridan in hydraulic contact with the salty water of Port Royal Sound until 1965. This partly explains why the saltwater intrusion problem forecast by Warren was so slow to manifest itself.

Hayes (1979, p. 52) accounted total Beaufort area pumping from the Upper Floridan for public supply as 3.9 mgd in 1976; he had 3.2 mgd of this on Hilton Head Island, 0.1 mgd on Port Royal Island, and 0.4 mgd on St. Helena Island. Hayes' 3.2 mgd usage for public supply was approximately known from metering and/or by accounting the mass of chlorine added to the water during treatment.

Hayes accounted irrigation withdrawal as 6.24 mgd on Hilton Head Island. For a 150-day irrigation season, the 6.24 mgd daily average normalizes to 12 mgd. There were approximately 1,800 acres of golf course on Hilton Head Island in 1976. For reported rates of irrigation withdrawal, it is calculated that 3 ft of water, in addition to rainfall, was applied to every course. This seems to the writer to be much too high. Golf course irrigators did not generally meter their pumpage. Hayes evidently estimated pumpage by multiplying time-duration of pumping by rate, where rate was derived from a pump capacity curve. This method of estimating pumping volume tends to overestimate because of head losses and well inefficiency. The order of overestimate probably is 15 to 20 percent. Perhaps 5 mgd (as an annual average) was pumped for irrigation.

Hayes reported 2.5 mgd for domestic usage for the remaining areas of Beaufort, Jasper, and Hampton Counties. This is unmetered flow and is based on an estimate of the population not served by a water system multiplied by an assumed usage. The estimate is consistent with the estimates of Counts and Donsky for unmetered water use in Chatham County by residents not served by public supply. Both Counts and Donsky (1963) and Hayes (1976) probably used a similar estimation technique, for all were contemporaries at the USGS.

Krause (1972) stated that industrial pumping at Riceboro (Liberty County,

Ga.) began in March 1968. The average withdrawal for 1968 was 8.6 mgd. At that time the withdrawal at Doctortown was approximately 45 mgd. Pumping there was started in 1954 and continued at this rate until late 1972 when it increased to 72 mgd.

The withdrawal rates reported for 1977 (Table 8) are the highest found in the literature. The writer is of the opinion that they are probably too high. The USGS report is useful, however, for it is an excellent history of the time evolution of pumpage, particularly at Doctortown, Ga. The report, in particular, documents the pumping shutdown at Doctortown in the fall of 1977 when the withdrawal went from 75 to 7 mgd, and in December 1972 when pumpage decreased to " 2 - 3 million gallons per day" (p. 34). It is interesting to note that the USGS (1978) reported pumpage of 75 mgd at Doctortown, whereas Turlington and others reported 67 mgd. The reported pumpage at Doctortown was 45 mgd for 1990 (unpublished data from Georgia DEP). For 1991 it was 74 mgd. A possible explanation for the difference in reported water withdrawal is that industrial pumping at Doctortown was suspended for about 16 weeks in 1990. Differences in reported pumping could result from a myriad of causes, including differing lengths of industrial shutdown, implementation of effective conservation measures, or fluctuation in water demand owing to variation in the

production schedule.

Turlington and others (1987) reported that 251 mgd was pumped from the Upper Floridan aquifer in 1985. Their total for unmetered domestic usage is 15.03 mgd. Their total for McIntosh County is 1 mgd, and possibly that is too low. Water levels are presently near land surface in much of McIntosh County. Warren estimated 11 mgd wasted from free-flowing wells in 1943. If free-flowing discharge has declined exponentially with decline in water level, then it can be reasonably assumed that discharge is about 10 percent of the 11 mgd of Warren, or about 1 mgd.

Turlington and others included mining in their estimated industrial pumpage. Mine dewatering typically results from pumping shallow- aquifer water. If it is assumed that most of the rural area industrial usage reported by Turlington and others is for mining, then the total shallow water included in the report is about 3.4 mgd. This amount must be subtracted from the estimated Upper Floridan pumpage. Thus, Upper Floridan withdrawal can be reduced slightly, from 251 to 248 mgd.

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