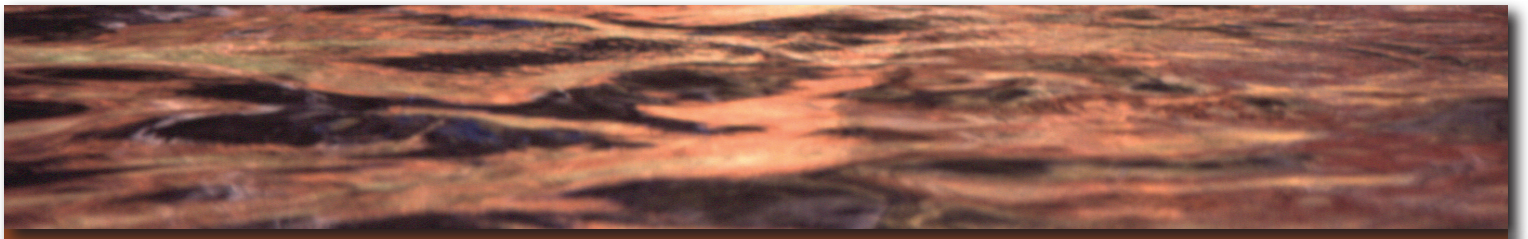


WATER USE

INTRODUCTION

Many of man's activities depend directly or indirectly on adequate supplies of freshwater. Often in regions of abundant water supply, such as South Carolina, the availability of freshwater is taken for granted and the need to carefully monitor its use is not always apparent. An increasing demand on South Carolina's water resources from an expanding economy and growing population has elevated competition for this important resource. Conflicts over the appropriate use and allocation of the State's water are becoming more prevalent and are expected to increase in the future along with demand.

Prior to the 1970's, water use in South Carolina was not routinely monitored, and water use data were supplied voluntarily to different State and Federal agencies. Because a systematic data-gathering program did not exist, early water-use data are generally widely dispersed, incomplete, and of varying quality. In 1969, the South Carolina Groundwater Use Act was passed, requiring that groundwater users in designated "Capacity Use Areas" report their quarterly water use to the South Carolina Water Resources Commission (WRC) if their withdrawals equaled or exceeded 100,000 gallons on any day of the year. Groundwater withdrawals outside capacity use areas remained unregulated and were not subject to reporting requirements. The Act gave WRC authority to "…declare and delineate… capacity use areas of the State where it finds that the use of ground water requires coordination and limited regulation for the protection of the interest and rights of residents or property owners of such area, or of the public interest." In 1994, this authority was transferred to the South Carolina Department of Health and Environmental Control (DHEC). To date, four capacity use areas have been established: the Waccamaw Capacity Use Area, designated in 1979 (Georgetown, Horry, and southern Marion Counties); the Low Country Capacity Use Area, designated in 1981 (Beaufort, Colleton, and Jasper Counties); the Trident Capacity Use Area, designated in 2002 (Berkeley, Charleston, and Dorchester Counties); and the Pee Dee Capacity Use Area, designated in 2003 (Darlington, Dillon, Florence, Marion, Marlboro, and Williamsburg Counties). The southern portion of Marion County that was originally in the Waccamaw Capacity Use Area is now included in the Pee Dee Capacity Use Area. In 2007, Hampton County was added to the Low Country Capacity Use Area.

In 1982, passage of the South Carolina Water Use Reporting and Coordination Act required that all users of ground and surface water who withdraw, divert, obtain, or discharge 100,000 gallons or more on any single day of the year report their quarterly water use to the WRC. (This authority was also reassigned to DHEC in 1994.) After enactment of this law, water-use reporting became more regular, but not all water users complied with the law. The systematic and coordinated collection of water-use data enhanced the State's water-resource planning efforts, but reporting was voluntary and the goals of the program were not fully realized.

In 2000, the Groundwater Use Act and the Water Use Reporting and Coordination Act were amended and renamed the Groundwater Use and Reporting Act and the Surface Water Withdrawal and Reporting Act, respectively. This revised legislation mandated that all ground- and surface-water users withdrawing water in excess of 3 million gallons during any single month of the year must register with or obtain a permit from DHEC and report their annual water use. The amendments vastly improved water-use reporting in the State.

PREVIOUS WORK

Every five years since 1950, the U.S. Geological Survey's National Water-Use Information Program has reported on the water use of each state in the nation: MacKichan (1951 and 1957), MacKichan and Kammerer (1961), Murray (1968), Murray and Reeves (1972 and 1977), Solley and others (1983, 1988, 1993, and 1998), and Hutson and others (2004). Additionally, the U.S. Geological Survey published national water-use and water-supply data for 1985 (Stringfield and Lambert, 1990) and 1987 (Stringfield, 1990). Viessman and DeMoncada (1980) prepared a national water-use study for Congress. In South Carolina, the WRC and its successor, the Department of Natural Resources (DNR), have published water use information in several reports: South Carolina Water Resources Commission (1971, 1983, 1992, and 1993), Duke (1977), Lonon and others (1983), Harrigan (1985), Newcome (1990, 1995, 2000, and 2005a), Castro and Hu (1997), and Castro and Foster (2000). Water-use reports published by DHEC include Bristol (2002), Bristol and Boozer (2003), Devlin and Boozer (2003), Bristol (2004), Childress and Bristol (2005), Childress and Butler (2006),

and Butler (2007). The Strom Thurmond Institute at Clemson University prepared a series of reports under the title *The Situation and Outlook for Water Resources Use in South Carolina, 1985-2000: First* (1985), *Second* (1987), and *Third* (1988) *Year Reports*; and *Water for South Carolina's Future: Policy Issues and Options in the Development of a State Water Plan* (1989). The *Second-Year Report* includes an annotated bibliography by G.E. Varenhorst. There are also a few region-wide and area-specific reports by the WRC and DNR that discuss water use, including Pelletier (1985), McCready (1989), Newcome (1989), and Rodriguez and others (1994).

WATER-USE CATEGORIES

Water-use data presented in this report are from 2006 and were collected, compiled, and disseminated by DHEC (Butler, 2007), which administers the reporting provisions of the Groundwater Use and Reporting Act and the Surface Water Withdrawal and Reporting Act. Butler (2007) compiled and analyzed the 2006 data by county; in this report, the same database is used but water use is compiled and analyzed by subbasin.

Water-use data are subdivided into water derived from ground-water sources and water derived from surface-water sources. Data collected from each source are further divided into the following water-use categories: Aquaculture; golf course irrigation; industry; irrigation; mining; other; hydroelectric power; thermoelectric power; and water supply. The following are definitions of each water-use category as defined by DHEC (Butler, 2007):

Aquaculture: Water used for raising, farming, and/or harvesting of organisms that live in water, such as fish, shrimp and other shellfish, and vegetal matter (seaweed).

Golf course irrigation: Water applied to maintain golf course turf, including tee boxes, fairways, putting greens, associated practice areas, and periphery aesthetic landscaping.

Hydroelectric power: Water used in generating electricity where turbine generators are driven by falling water.

Industry: Water used for commercial and industrial purposes, including fabrication, processing, washing, in-plant conveyance, and cooling.

Irrigation: Water used for agricultural and landscaping purposes, including turf farming and livestock management.

Mining: Water used in conjunction with surface or subsurface mining of minerals or natural materials.

Other: Any water use not specifically identified in any of the other categories.

Thermoelectric power: Water used in generating electricity from fossil fuels (coal, oil, and natural gas), geothermal sources, biomass, solid waste, or nuclear sources.

Water supply: Water that is withdrawn by public and private water suppliers and conveyed to users or groups of users. Water suppliers provide water for a variety of uses, including domestic, commercial, industrial, and public water use.

STATEWIDE WATER USE

During the reporting year of 2006, 839 registered water withdrawers operated 1,000 facilities and withdrew water from 2,506 withdrawal points (wells and surface-water intakes) in South Carolina (Table 4-1). There were 471 surface-water facilities with 689 withdrawal points and 529 ground-water facilities with 1,817 withdrawal points. Figures 4-1 and 4-2 show the statewide distribution of

Table 4-1. Number of registered water withdrawers, facilities, and sources reporting in 2006 (modified from Butler, 2007)

Water-use category	Number of registered water withdrawers	Surface water		Ground water	
		Number of facilities	Number of water sources (intakes)	Number of facilities	Number of water sources (wells)
Aquaculture	7	4	5	6	11
Golf course	242	210	267	107	249
Industry	93	45	51	65	228
Irrigation	208	105	230	150	491
Mining	11	4	4	8	10
Other	4	0	0	4	27
Hydroelectric power	35	35	37	1	1
Thermoelectric power	17	16	19	6	16
Water supply	222	52	76	182	784
Total	**839**	**471**	**689**	**529**	**1,817**

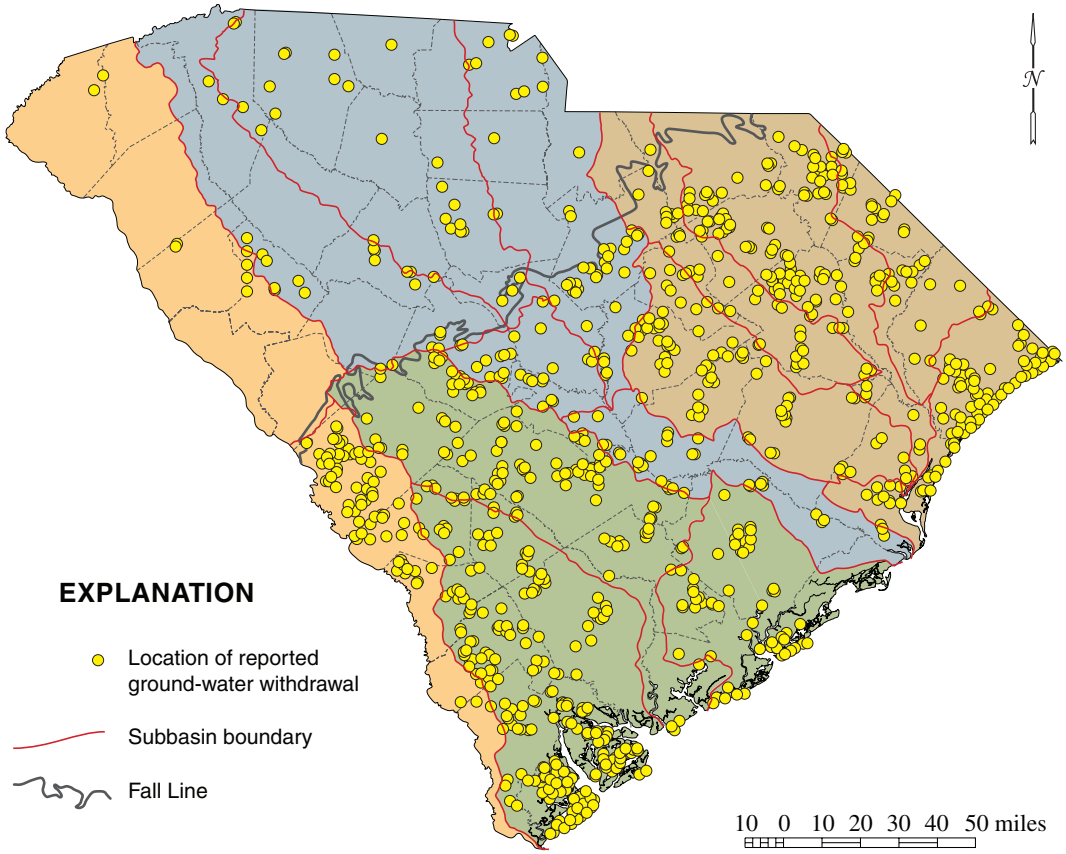


Figure 4-1. Location of reported ground-water withdrawals in the year 2006.

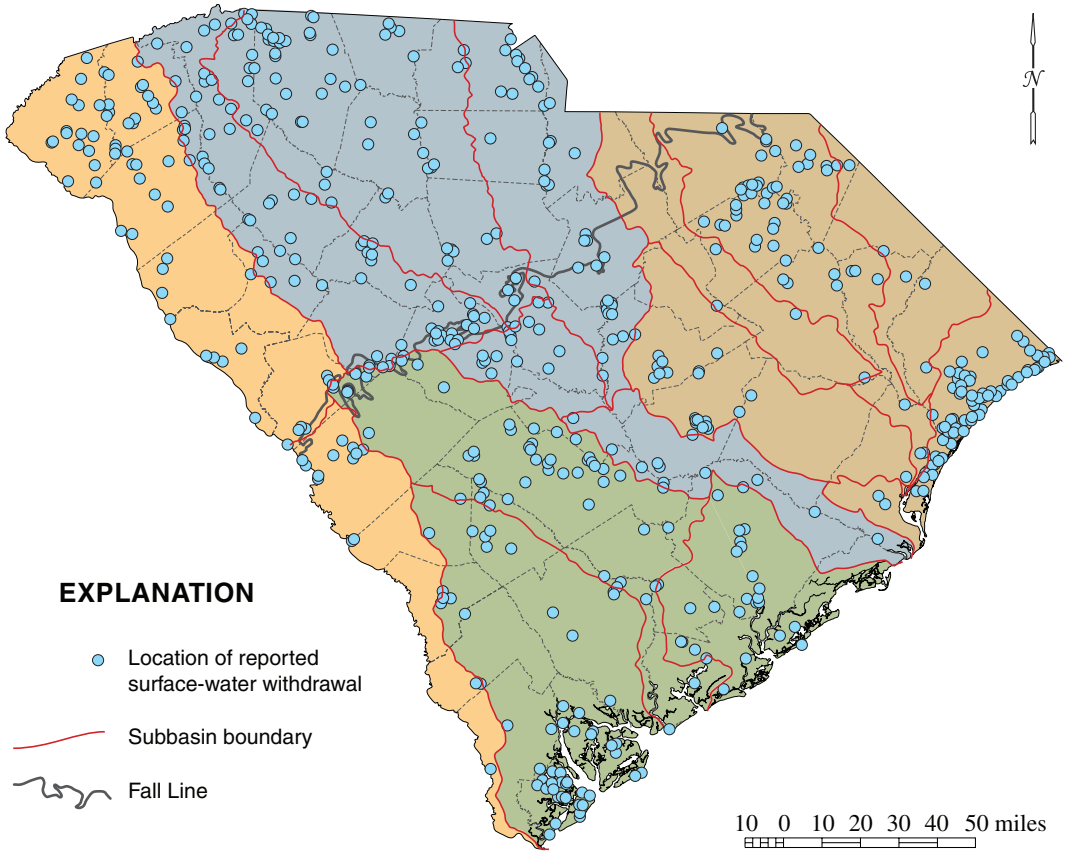


Figure 4-2. Location of reported surface-water withdrawals in the year 2006.

Table 4-2. Total water use in 2006, by water-use category (modified from Butler, 2007)

Water-use category	Surface water		Ground water		Total water	
	Million gallons	Percentage of total surface-water use	Million gallons	Percentage of total ground-water use	Million gallons	Percentage of total water use
Aquaculture	172	0.0	148	0.2	320	0.0
Golf course	9,275	0.0	3,350	4.1	12,625	0.1
Industry	138,188	0.7	11,106	13.6	149,294	0.7
Irrigation	11,177	0.1	17,981	22.1	29,157	0.1
Mining	498	0.0	3,225	4.0	3,724	0.0
Other	0	0.0	54	0.1	54	0.0
Hydroelectric power	17,940,160	88.0	1	0.0	17,940,161	87.7
Thermoelectric power	2,095,552	10.3	6,261	7.7	2,101,813	10.3
Water supply	187,119	0.9	39,275	48.2	226,394	1.1
Total	**20,382,141**		**81,401**		**20,463,542**	

Table 4-3. Offstream water use in 2006, by water-use category (modified from Butler, 2007)

Water-use category	Surface water		Ground water		Total water	
	Million gallons	Percentage of total surface-water use	Million gallons	Percentage of total ground-water use	Million gallons	Percentage of total water use
Aquaculture	172	0.0	148	0.2	320	0.0
Golf course	9,275	0.4	3,350	4.1	12,625	0.5
Industry	138,188	5.7	11,106	13.6	149,294	5.9
Irrigation	11,177	0.5	17,981	22.1	29,157	1.2
Mining	498	0.0	3,225	4.0	3,724	0.1
Other	0	0.0	54	0.1	54	0.0
Thermoelectric power	2,095,552	85.8	6,261	7.7	2,101,813	83.3
Water supply	187,119	7.7	39,275	48.2	226,394	9.0
Total	**2,441,981**		**81,400**		**2,523,381**	

ground- and surface-water withdrawal points. A registered withdrawer can have more than one facility, and each facility can have numerous withdrawal points; a registered withdrawer can also have both surface- and ground-water facilities. The city of Columbia, for example, is a registered withdrawer with two surface-water facilities, one at Lake Murray and one on the Broad River, and the city of Aiken is a registered withdrawer having a ground-water facility with eight wells and a surface-water facility with one intake.

Statewide water use for the year 2006, including hydroelectric power generation, totaled 20,463,542 million gallons, of which 20,382,141 million gallons (99.6 percent) were from surface-water sources and 81,401 million gallons (0.4 percent) were from ground-water sources (Table 4-2). Electrical power generation had the greatest demand for water in the State. Hydroelectric power generation was the greatest water use (17,940,161 million gallons, or 88 percent of the total) and thermoelectric power generation was the second largest use (2,101,813 million gallons, or 10 percent of the total). The remaining six water-use categories had a combined use of 421,568 million gallons.

Instream water use represents water that is used but not withdrawn from a surface-water or ground-water source. Instream uses include hydroelectric power generation, navigation, fish propagation, and recreation. Offstream water use represents water that is withdrawn or diverted from a surface-water or ground-water source; the volume of water in the source decreases as a result of that use. Offstream uses include aquaculture, irrigation, industry, water supply, and thermoelectric power generation.

Given that the amount of water used to generate power at hydroelectric facilities is so much greater than all other uses, and given that water used for hydroelectric power production is an instream water use, it can be helpful to exclude hydroelectric power generation and any other instream uses when comparing absolute and relative water-use data. Excluding instream uses, the total statewide offstream water use in 2006 was 2,523,381 million gallons, of which 2,441,981 million gallons (97 percent) were from surface-water sources and 81,400 million gallons (3 percent) were from ground-water sources (Table 4-3). Thermoelectric power generation accounted for 2,101,813 million gallons, or 83 percent of the total offstream use. Thermoelectric power includes nuclear power plants, which used 1,570,832 million gallons (62 percent of the total offstream use), and fossil-fuel plants (coal, gas, and oil), which used 530,981 million gallons (21 percent of the total offstream use). The second largest offstream use was water supply, which used 226,394 million gallons (9 percent), followed by industry (6 percent), crop irrigation (1 percent), golf course irrigation (0.5 percent), and all other uses (0.2 percent).

Excluding all power-generation facilities, the statewide water use in 2006 was 421,568 million gallons, of which 346,429 million gallons (82 percent) were from surface-water sources and 75,139 million gallons (18 percent)

Table 4-4. Offstream water use in 2006, by subbasin (modified from Butler, 2007)

Subbasin	Surface water		Ground water		Total water	
	Million gallons	Percentage of total surface-water use	Million gallons	Percentage of total ground-water use	Million gallons	Percentage of total water use
Ashley-Cooper	217,183	8.9	4,844	6.0	222,027	8.8
Black	520	0.0	9,580	11.8	10,100	0.4
Broad	310,486	12.7	1,293	1.6	311,778	12.4
Catawba-Wateree	272,718	11.2	2,204	2.7	274,922	10.9
Combahee-Coosawhatchie	3,564	0.1	16,684	20.5	20,249	0.8
Congaree	30,659	1.3	1,520	1.9	32,179	1.3
Edisto	30,702	1.3	16,256	20.0	46,958	1.9
Little Pee Dee	50	0.0	2,437	3.0	2,487	0.1
Lower Savannah	89,826	3.7	7,437	9.1	97,263	3.9
Lynches	69	0.0	3,115	3.8	3,184	0.1
Pee Dee	343,657	14.1	11,472	14.1	355,129	14.1
Saluda	132,226	5.4	1,144	1.4	133,370	5.3
Santee	286	0.0	1,458	1.8	1,743	0.1
Upper Savannah	944,906	38.7	47	0.1	944,953	37.4
Waccamaw	65,130	2.7	1,909	2.3	67,039	2.7
Statewide total	**2,441,981**		**81,400**		**2,523,381**	

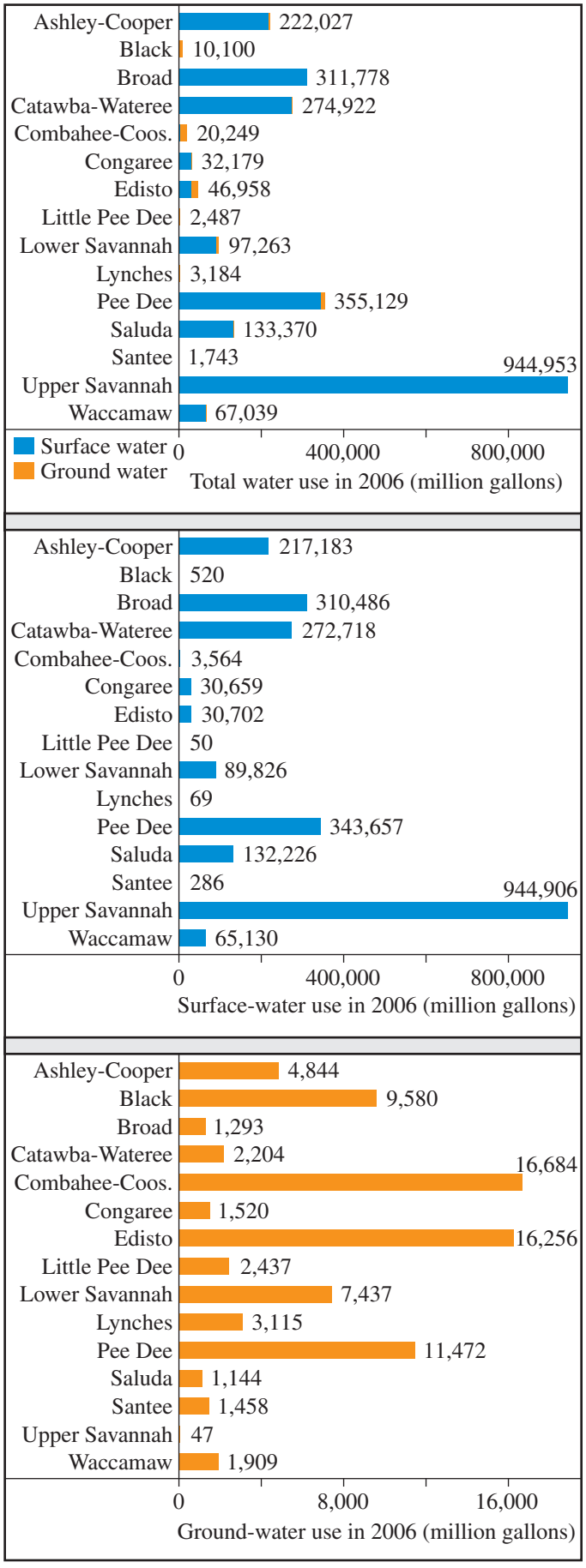


Figure 4-3. Offstream water use in 2006, by subbasin (modified from Butler, 2007).

were from ground-water sources. Water-supply use totaled 226,394 million gallons, 83 percent originating from surface-water sources and 17 percent from ground-water sources. The next largest user group was industry, totaling 149,294 million gallons, followed by crop irrigation, golf course irrigation, mining, and all other uses.

Considering only offstream uses (that is, excluding water used by hydroelectric power facilities), more water was used in the Upper Savannah River subbasin than in any other subbasin, 944,953 million gallons (Table 4-4 and Figure 4-3). The Santee River subbasin had the lowest water use, 1,743 million gallons. The Upper Savannah River subbasin also had the greatest surface-water use, 944,906 million gallons, and the Combahee-Coosawhatchie subbasin had the greatest ground-water use, 16,684 million gallons.

Hydroelectric Power

Hydroelectric power is generated by flowing or falling water that drives a water turbine and generator. Water at the larger hydroelectric plants in the State is stored in instream reservoirs behind large dams. An example of such a reservoir is Lake Murray, which contains 763 billion gallons of water when full and has a surface area of about 50,000 acres. Saluda Dam, which impounds Lake Murray on the Saluda River, was once the largest earthen dam in the world, containing over 11 million cubic yards of material and reaching a maximum height of 211 feet. The SCE&G Saluda Dam Hydroelectric Plant operates five turbines and has a total rating capacity of 202.6 megawatts.

Smaller reservoirs also provide water for hydroelectric power and not all are located on the main stem of a river. At the SCE&G Fairfield Pumped Storage facility, an instream impoundment on the Broad River forms Parr Shoals Reservoir, which has a surface area of 4,400 acres. Water from Parr Shoals Reservoir is diverted and pumped into a nearby offstream reservoir—Lake Monticello—which has a surface area of 6,800 acres. Once in Monticello, the water is used to generate electricity from hydroelectric and nuclear power plants. Most of the smaller hydroelectric plants in the State are located on diversion canals off the main stem of a river or are run-of-the-river, low-head plants that have little or no reservoir-storage capacity and generate electricity from the natural flow and elevation of the river.

At conventional hydroelectric plants, water is passed through turbines and flows downstream where it can be used for other purposes. At pumped-storage hydroelectric plants, however, water is passed through turbines and into a downstream reservoir, where it is held in storage. When electrical demands are low and inexpensive power is available, the turbines are used as pumps to bring water back from the lower reservoir into the upper reservoir, where it can later be reused to generate electricity during periods of high electrical demand. Total water use at

these facilities is high, but the same water is often used over and over again. An example of such a plant is Duke Energy's Bad Creek Hydroelectric Station located in Oconee County. This facility consists of two reservoirs formed by damming Bad Creek and West Bad Creek. The plant operates four turbines and has a rating capacity of 1,065 megawatts. Three other hydroelectric facilities in South Carolina—Lake Russell, Fairfield Pumped Storage Facility, and Lake Jocassee—operate as pumped-storage facilities.

In reporting year 2006, 31 conventional and 4 pumped-storage hydroelectric plants reported a total annual water use of 17,940,161 million gallons. This value includes water used at four U.S. Army Corps of Engineers hydroelectric facilities: Lake Hartwell, Lake Russell, and Lake Thurmond, all of which use water from the Savannah River, and the St. Stephen Rediversion Canal, which takes water from Lake Moultrie. These facilities are not required to report their annual water use to DHEC. They are included in this report owing to their relatively high water use, and because the water of the Savannah River is shared between South Carolina and Georgia. In all, the 35 plants operate 147 turbines and have a total rating capacity of about 4,500 megawatts. In 2006, hydroelectric plants generated 1,806,948 megawatt-hours of energy, which was 1.8 percent of the total energy generated in the State (U.S. Energy Information Administration, 2009). In comparison, hydroelectric facilities produced 7 percent of the country's electrical power in 2006 (U.S. Energy Information Administration, 2008). Most hydroelectric plants in the State are used for peaking power generation and normally only operate during times when the demand for electricity is greatest, typically on hot summer days and cold winter mornings.

Water was used for hydroelectric-power generation in seven of the State's fifteen subbasins in 2006 (Figure 4-4). The greatest reported use was in the Upper Savannah River subbasin, which has nine hydroelectric facilities that used 7,885,878 million gallons of water (44 percent of the total hydroelectric-power use). The next greatest use was in the Catawba-Wateree River subbasin, which has seven facilities that used 4,085,584 million gallons (23 percent). Eight facilities in the Broad River subbasin used 3,098,700 million gallons (17 percent); two facilities in the Santee River subbasin used 1,027,173 million gallons (6 percent); one facility in the Ashley-Cooper River subbasin used 983,111 million gallons (6 percent); seven facilities in the Saluda River subbasin used 508,945 million gallons (3 percent); and one facility in the Congaree River subbasin used 350,800 million gallons (2 percent). A small amount (0.88 million gallons) of ground water was used by Santee Cooper's Jefferies Plant in Berkeley County. The hydroelectric facilities that used the most water in 2006 are shown in Figure 4-5.

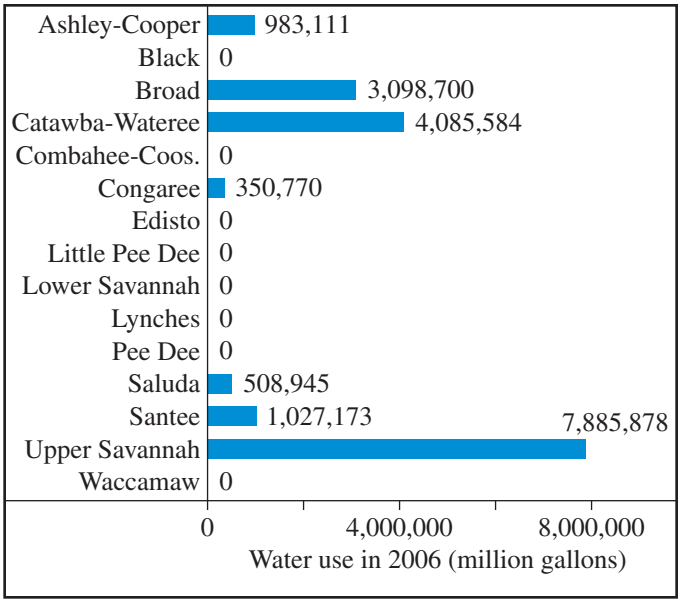
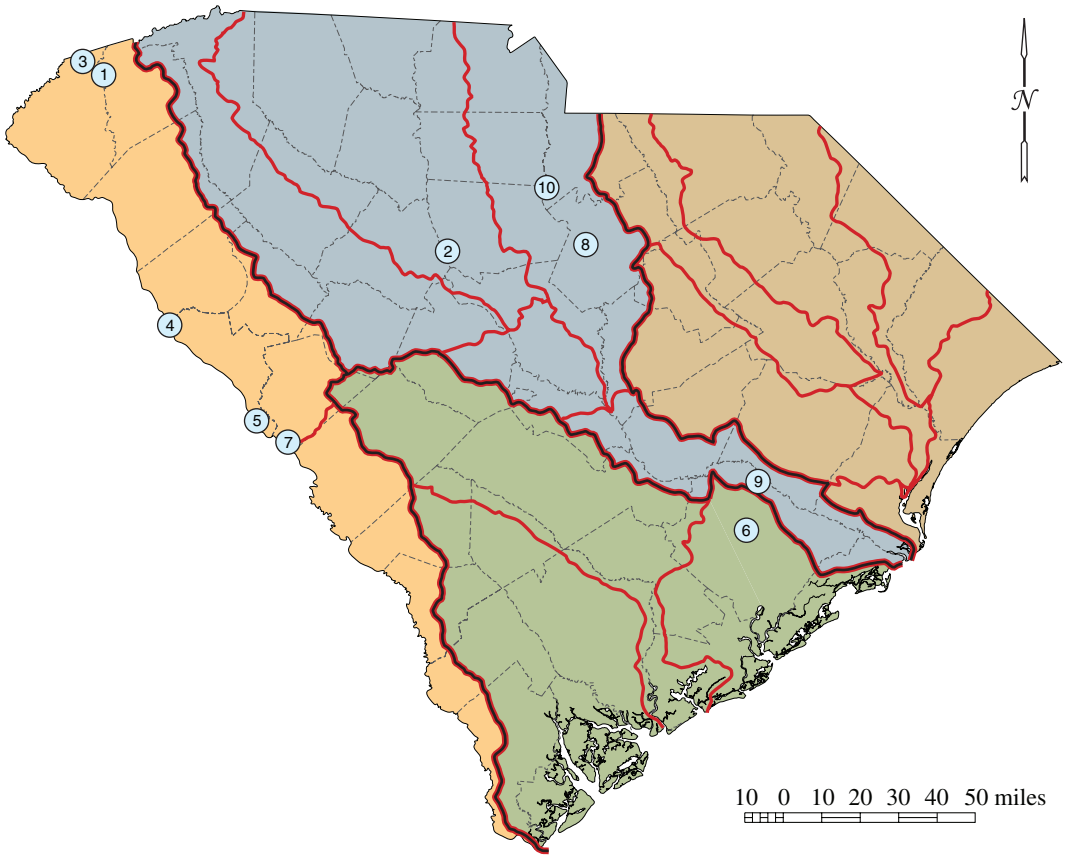


Figure 4-4. Hydroelectric water use in 2006, by subbasin.

Generation of hydroelectric power is the largest use of water in the State. Most of the water, however, remains instream and consumptive use is small. Evaporation from storage reservoirs can, however, result in a substantial loss of water, especially during the summer months. Evaporation rates of about 320 million gallons per day occur during June and July on Lake Thurmond (71,100 acres of surface area) and 120 million gallons per day on Lake Russell (26,650 acres of surface area) (U.S. Army Corps of Engineers, 2008). Such rates are equivalent to a flow of about 500 and 190 cfs (cubic feet per second), respectively. During December and January, daily evaporation rates drop to 65 (100 cfs) and 25 million gallons (40 cfs), respectively. Considering that the average annual streamflow of the Savannah River near Augusta is about 10,000 cfs, the equivalent of 5 percent of the flow is evaporated from Lake Thurmond during the summer.

The amount of water used for hydroelectric power generation can vary significantly from year to year, primarily because of variations in streamflow and water availability due to climatic conditions. At Lake Thurmond, for example, releases were curtailed during the severe droughts of 1999–2002 and 2006–2007 to help maintain lake levels for public-supply systems and recreation (Figure 4-6). During years of normal and above-normal precipitation (1997–1998 and 2003–2005) water use increased markedly, in some cases doubling from previous years.



Ten largest hydroelectric-power water users					
Rank	**Facility**	**Operator**	**Source of water**	**Subbasin**	**2006 water use (million gallons)**
①	Jocassee Pumped Storage	Duke Energy	Lake Jocassee	Upper Savannah	2,168,735
②	Fairfield Pumped Storage	SCE&G	Lake Monticello	Broad	1,920,104
③	Bad Creek Pumped Storage	Duke Energy	Bad Creek Reservoir	Upper Savannah	1,412,404
④	Richard B. Russell	U.S. Army Corps of Engineers	Lake Russell	Upper Savannah	1,297,653
⑤	J. Strom Thurmond	U.S. Army Corps of Engineers	Lake Thurmond	Upper Savannah	1,199,816
⑥	Jefferies Station	Santee Cooper	Lake Moultrie	Ashley-Cooper	983,110
⑦	Stevens Creek	SCE&G	Savannah River	Upper Savannah	939,326
⑧	Wateree Hydro Station	Duke Energy	Lake Wateree	Catawba-Wateree	923,086
⑨	St. Stephen	U.S. Army Corps of Engineers	Lake Moultrie Rediversion Canal	Santee	878,848
⑩	Cedar Creek Hydro Station	Duke Energy	Catawba River	Catawba-Wateree	859,455

Figure 4-5. The ten largest hydroelectric water-use facilities in 2006.

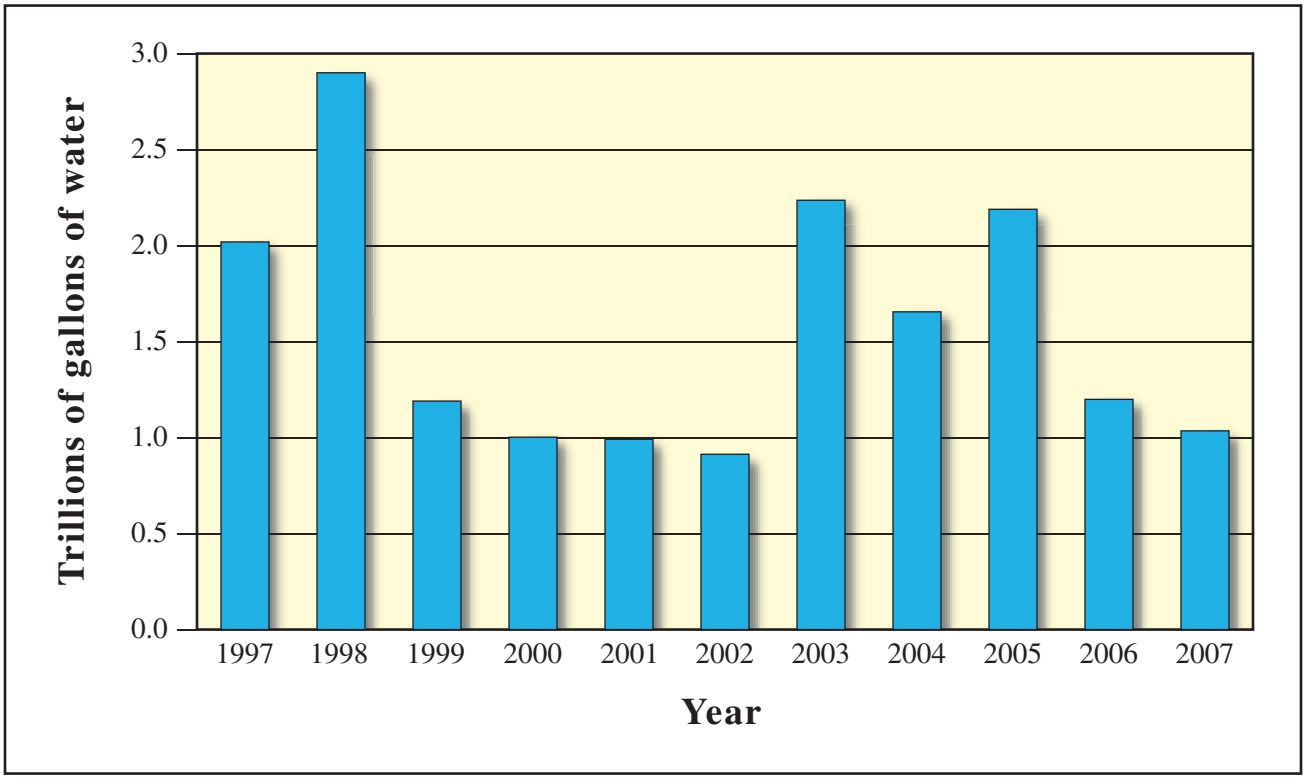


Figure 4-6. Total annual volume of water released from Lake Thurmond, 1997–2007.

Thermoelectric Power

Thermoelectric power is produced by superheating water in boilers until steam is produced. Pressurized steam is then forced through the blades of turbines that are attached to generators, which produce electricity. Steam leaving the turbines is circulated through heat exchangers and condensed back to water, which is then either discharged or piped back to the boilers to be reused. Fossil fuels—coal, natural gas, and petroleum—or nuclear fuels (uranium) are typically used as the energy source to heat the water.

Most of the water used at steam-driven turbine plants is for cooling purposes. The amount of water used is dictated by the type of cooling system that is used at the plant. Many of the older plants use a once-through (or open-loop) system, in which cooling water is used once and discharged at a higher temperature back to a surface-water body. Water use at these facilities is high, but most is returned to its original source where it can be used for other purposes. Many newer plants employ a closed-loop system, in which cooling water is sent to a cooling tower or cooling pond where it is cooled and then reused by the plant. Some water is lost to evaporation, blowdown, drift, and leakage, which must be replaced; therefore, closed-loop systems have a higher consumptive use, relative to the amount of water withdrawn, although total withdrawals are less than once-through cooling systems. Consumptive use is usually more than 60 percent in closed-looped systems and generally less than 3 percent in once-through systems (Solley and others, 1998). Plants that have access to large volumes of water can utilize once-through cooling; plants with limited access must recycle their cooling water.

Internal combustion turbines are also used in the State. At these plants, turbine blades are spun, not by steam, but by the combustion of natural gas and compressed air. Natural gas is the primary fuel, but units can also operate on diesel fuel. In a simple-cycle plant, the combustion of gas is the only source of electric generation and exhaust heat is emitted through a stack. In a combined-cycle plant, exhaust heat from the combustion of gas is used to turn water into steam, which turns the blades of another turbine to produce additional electricity. Steam is cooled using water from a nearby river or lake and the condensed water is returned to the plant to be converted into steam again.

In 2006, thermoelectric plants generated 96,654,911 megawatt-hours of electricity, which was 97 percent of the total power generated in the State (U.S. Energy Information Administration, 2009). Nuclear plants accounted for 50,797,372 megawatt-hours (51 percent of the State total) and fossil-fuel plants accounted for 45,858,539 megawatt-hours (46 percent). In comparison, fossil fuels (excluding oil) accounted for 69 percent of the

nation's electrical power in 2006 and nuclear accounted for 19 percent (U.S. Energy Information Administration, 2008).

In 2006, a total of 2,101,813 million gallons of water were used by the 17 thermoelectric plants that reported water use. Of this amount, 2,095,552 million gallons were withdrawn from surface-water sources and 6,261 million gallons were from ground-water sources. Four of the plants used nuclear fuels and the remaining thirteen used fossil fuels. The four nuclear plants used a total of 1,570,831 million gallons of water, and the thirteen fossil-fuel plants used a total of 530,981 million gallons. Owing to the large volumes of water required, most thermoelectric plants in the State are located on large rivers or impoundments that can provide ample cooling water.

Water was used for thermoelectric-power generation in nine of the State's fifteen subbasins in 2006 (Figure 4-7). The greatest reported use was in the Upper Savannah River subbasin, which has two thermoelectric plants that used 920,066 million gallons of water (44 percent of the State's total thermoelectric-power use). It was followed by the Pee Dee River subbasin, which has one facility that used 296,425 million gallons (14 percent); the Broad River subbasin, which has two facilities that used 271,236 million gallons (13 percent); and the Catawba-Wateree River subbasin, which has two facilities that used 229,788 million gallons (11 percent). All other subbasins used less than ten percent of the total water withdrawn for thermoelectric power. Only in the Edisto River subbasin was ground water a significant source of water for thermoelectric use. The thermoelectric facilities that used the most water in 2006 are shown in Figure 4-8.

Water Supply

Water-supply use refers to water that is withdrawn by public and private water suppliers and sold to the public mainly for domestic, commercial, and industrial use. Approximately 252 surface-water systems and 2,506 ground-water systems operated in South Carolina in 2006 (DHEC, 2007a). Many of these systems are small and do not use 3 million gallons in any single month and, therefore, are not required to report their use by the Groundwater Use and Reporting Act and/or the Surface Water Withdrawal and Reporting Act. In 2006, 52 surface-water facilities and 182 ground-water facilities reported water-supply use to DHEC.

Water-supply use is the largest nonpower-generating use of water in South Carolina. Of the 226,394 million gallons reported for water-supply use in 2006, 187,119 million gallons were from surface-water sources (83 percent) and 39,275 million gallons were from ground-water sources (17 percent).

The Saluda River subbasin reported the greatest overall water-supply use in 2006, withdrawing a total of 40,055 million gallons (18 percent) (Figure 4-9). It

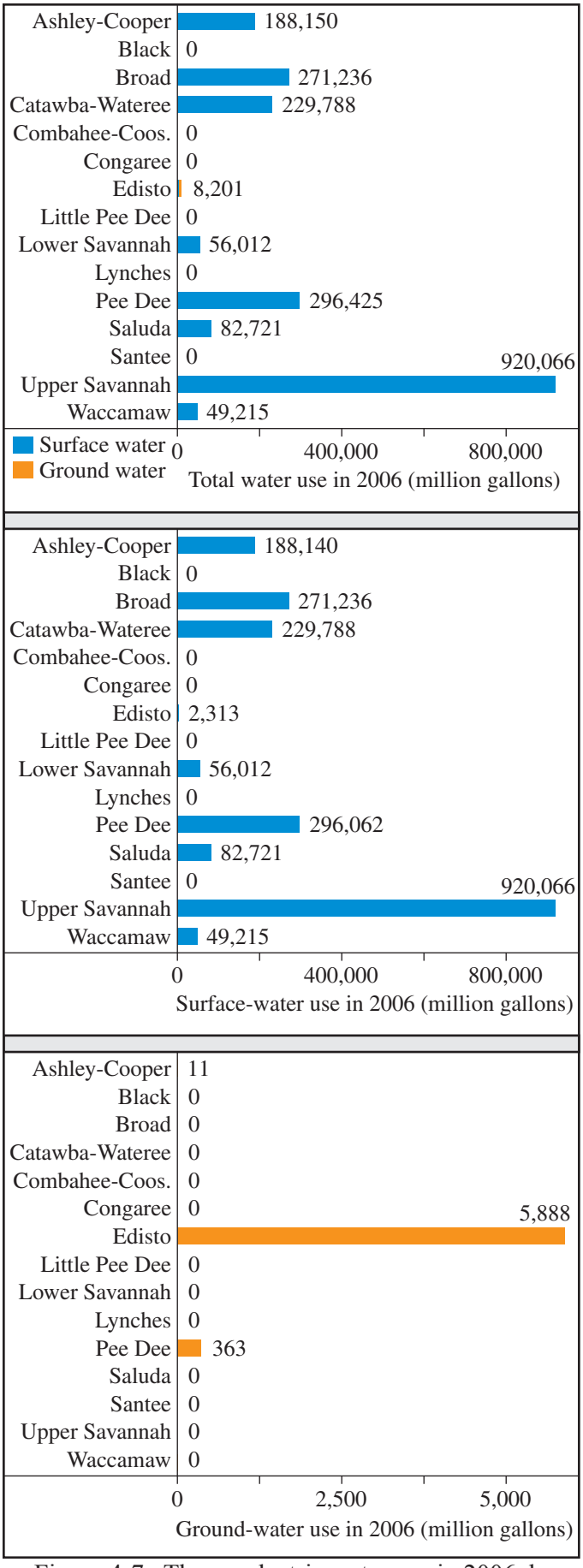
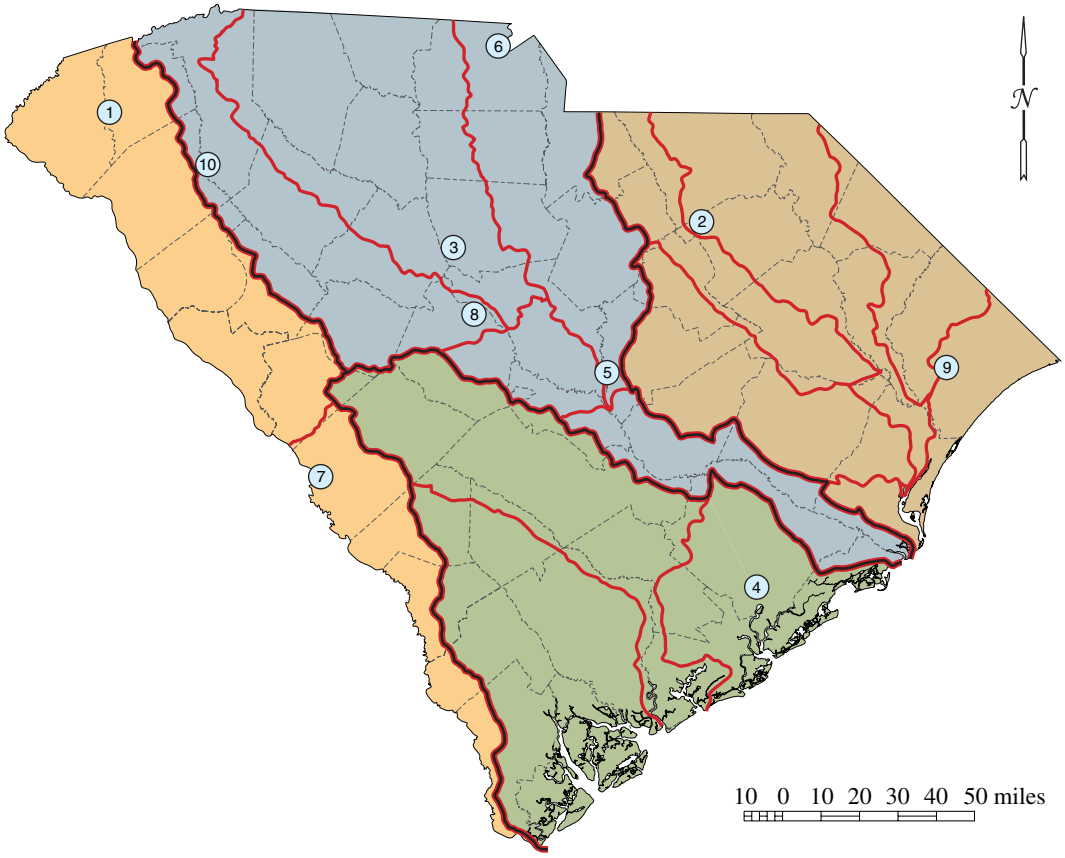


Figure 4-7. Thermoelectric water use in 2006, by subbasin (modified from Butler, 2007).



Ten largest thermoelectric-power water users					
Rank	**Facility**	**Operator**	**Source of water**	**Subbasin**	**2006 water use (million gallons)**
①	Oconee Nuclear Station	Duke Energy	Lake Keowee	Upper Savannah	919,732
②	H.B. Robinson Plant	Progress Energy	Lake Robinson	Pee Dee	296,425
③	V.C. Summer Nuclear Station	SCE&G	Lake Monticello	Broad	271,236
④	Williams Station	SCE&G	Cooper River	Ashley-Cooper	172,369
⑤	Wateree Station	SCE&G	Wateree River	Catawba-Wateree	146,349
⑥	Catawba Nuclear Station	Duke Energy	Lake Wylie	Catawba-Wateree	83,439
⑦	Urquhart Station	SCE&G	Savannah River	Lower Savannah	56,012
⑧	McMeekin Station	SCE&G	Lake Murray	Saluda	50,964
⑨	Grainger Station	Santee Cooper	Waccamaw River	Waccamaw	44,499
⑩	Lee Station	Duke Energy	Saluda River	Saluda	31,757

Figure 4-8. The ten largest thermoelectric water-use facilities in 2006.

was followed closely by the Broad River subbasin, with a total use of 37,367 million gallons (17 percent). Other subbasins with significant use include the Ashley-Cooper, with withdrawals of 26,762 million gallons (12 percent); the Pee Dee, with withdrawals of 21,433 million gallons (10 percent); and the Upper Savannah, with withdrawals of 20,977 million gallons (9 percent). Water-supply use was lowest in the Congaree River subbasin, with only 435 million gallons (0.2 percent), and the Santee River subbasin, with 694 million gallons (0.3 percent).

Water-supply use represents the greatest ground-water use of any water-use category in the State, accounting for 48 percent of the total ground water withdrawn in 2006. It is also the second largest surface-water use, after electrical power generation. The Saluda, Broad, and Ashley-Cooper subbasins had the largest use of surface water for water-supply use and the Pee Dee, Black, and Combahee-Coosawhatchie subbasins had the largest ground-water use (Figure 4-9). Six subbasins reported no surface water used for water supply. In general, when surface water is reliably available in adequate quantities, it is the preferred source for water supplies because of its easier accessibility. Water suppliers in subbasins containing large rivers and reservoirs, such as the Saluda, Broad, and Upper Savannah, rely almost exclusively on surface water, whereas suppliers in subbasins with less reliable surface-water sources, such as the Black, Lynches, and Little Pee Dee, rely primarily on ground water.

Most of the ground-water supply systems are located in the Coastal Plain region. The Coastal Plain is underlain by thick layers of permeable sediments, which constitute the major aquifers of the State. These aquifers can yield large quantities of fresh water to a single well. In contrast, the Piedmont region is underlain by low-permeability igneous and metamorphic rocks that generally cannot sustain large withdrawals. Of the 182 ground-water supply facilities in the State, only about ten are located in the Piedmont.

The water-supply facilities that used the most surface water and ground water in 2006 are shown in Figure 4-10.

The largest cities in the State use surface water for their supplies. In 2006, the city of Charleston withdrew 30,247 million gallons from Bushy Park Reservoir and the Edisto River; the city of Columbia withdrew 22,910 million gallons from the Broad River (Columbia Canal) and Lake Murray; and the city of Greenville withdrew 22,312 million gallons from the North Saluda Reservoir, Table Rock Reservoir, and Lake Keowee.

The largest facility supplied solely by ground water is the city of Sumter, which used 4,525 million gallons in 2006. Other ground-water systems of note include the city of Florence, which used 3,445 million gallons, and the city of Aiken, which used 2,585 million gallons. All of these cities are located in the Coastal Plain.

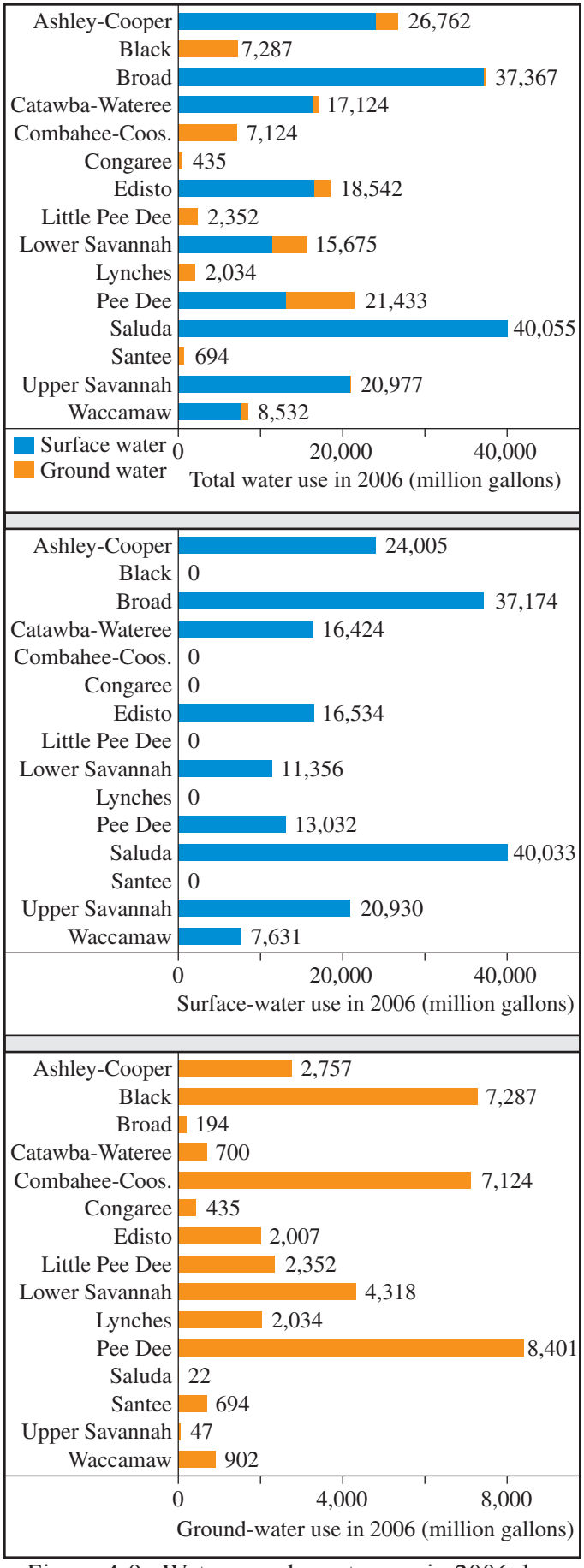


Figure 4-9. Water-supply water use in 2006, by subbasin (modified from Butler, 2007).

A significant amount of water use may go unreported owing to the numerous water-supply systems that are small and are not required to report. Almost 2,500 small systems did not report their water use in 2006. Assuming that each serves a minimum of 25 residents and assuming a per capita water use of 75 gallons per day, about 1,700 million gallons went unreported.

Industry

Industrial water use refers to water used for commercial and industrial purposes, including fabrication, processing, washing, in-plant conveyance, cooling, and sanitation needs of the facility. Process water, which is incorporated into products or comes in direct contact with the final product during the manufacturing process, must often be of high quality. Industries that use large volumes of water in South Carolina produce such commodities as food, paper, chemicals, and primary metals.

Industrial use represents the third largest overall offstream use of water, the second largest use of surface water, and the third largest use of ground water in South Carolina. Of the 149,294 million gallons used in 2006, 138,188 million gallons were supplied by surface-water sources (93 percent) and 11,106 million gallons by ground-water sources (7 percent).

The Pee Dee River subbasin reported the greatest overall industrial water use in 2006, with withdrawals totaling 36,038 million gallons (24 percent) (Figure 4-11). It was followed by the Congaree River subbasin, which used 30,520 million gallons (20 percent), and the Catawba-Wateree River subbasin, which used 26,734 million gallons (18 percent). The subbasins reporting the lowest industrial water use in 2006 were the Little Pee Dee (69 million gallons, less than 0.1 percent of the State total), the Santee (134 million gallons, or 0.1 percent), and the Combahee-Coosawhatchie (530 million gallons, or 0.3 percent).

The Pee Dee and Congaree subbasins had the greatest surface-water use with withdrawals totaling 34,151 and 29,956 million gallons, respectively. Industrial ground-water use was greatest in the Lower Savannah and Pee Dee subbasins, totaling 1,961 and 1,887 million gallons, respectively. The industrial facilities that used the most surface water and ground water in 2006 are shown in Figure 4-12.

Irrigation

Irrigation water use includes water used for agricultural and landscaping purposes, including turf farming and livestock management, but excludes water used for golf course maintenance, which is reported separately owing to the large number of golf courses in the State. Irrigation water can be applied with sprinkler, microirrigation, or surface (flooding) irrigation systems. Center-pivot systems, in which crops are irrigated in a circular pattern using a series of overhead sprinkler heads that pivot around a center point, are one of the most common forms of sprinkler systems used in the State. Efficiency can be increased by suspending the sprinkler heads several feet above the crop to limit losses to evaporation and wind drift. Microirrigation, also referred to as drip or trickle irrigation, slowly provides water directly to the plant root, thus reducing the amount of water lost to wind drift and evaporation. This type of irrigation is typically very efficient and normally used for high-value specialty crops such as vegetables, fruits, and greenhouse plants. Surface irrigation refers to a variety of techniques that apply and distribute water over land using gravity.

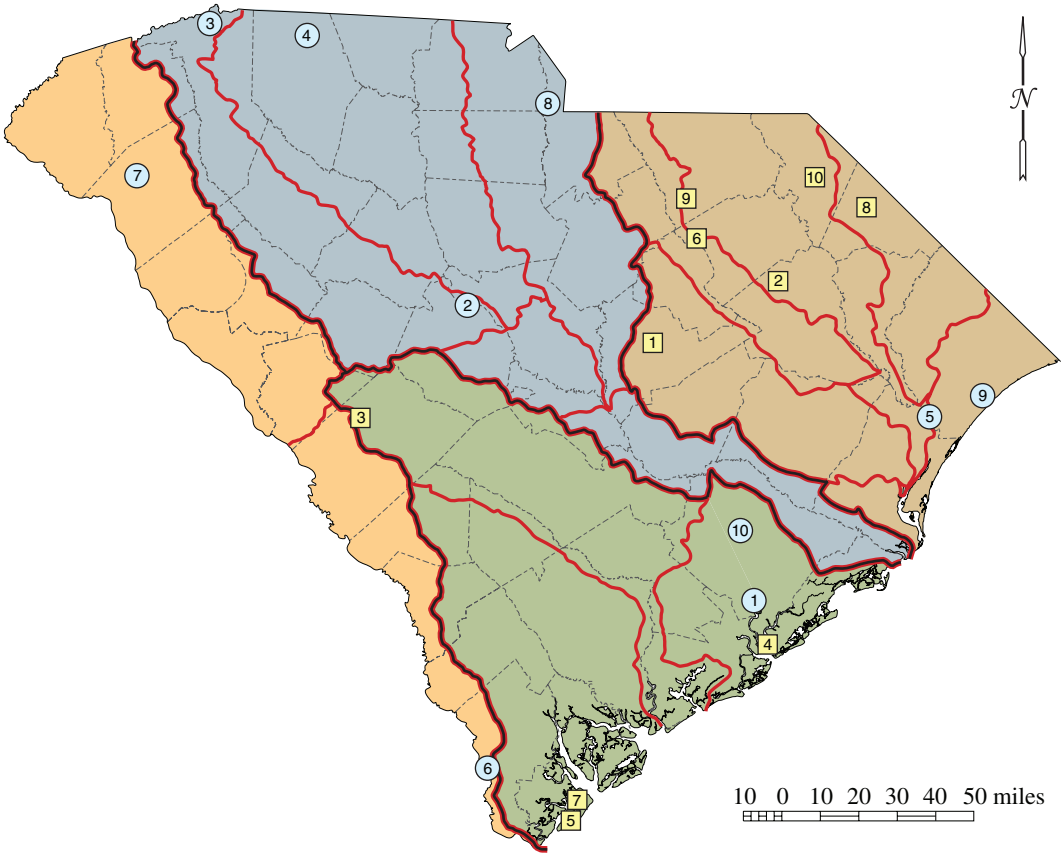
Crop irrigation occurs throughout the State, from peach and apple orchards in the upper Piedmont to tobacco, corn, and soybean fields in the lower Coastal Plain. In 2007, 25,897 farms were in operation in South Carolina, a total of 4,889,339 acres of land were in farms and a total of 1,551,670 acres were harvested cropland. From 2002 to 2007, the number of farms using irrigation increased 6 percent from 1,918 to 2,030, and the area of irrigated farmland increased 38 percent from 95,642 acres to 132,439 acres (U.S. Department of Agriculture, 2009). This notable increase in irrigation may be a result of the severe drought that occurred from 1998–2002. Still, in 2007, only about 9 percent of the harvested cropland was under irrigation.

Agricultural irrigation does not occur year round, but only during critical periods of the growing season when soil moisture is low. In South Carolina, irrigation generally occurs from April to September, with peak application during June and July. Because irrigation water use is seasonal, it may vary from year to year depending on the distribution of annual precipitation.

Although irrigation is limited to a few months of the year, it represents a major use during the growing season, particularly because of its consumptive nature. Because irrigation water is usually either taken in by plants, evaporated, or soaked into the soil, little if any of the water is returned to its source. Unlike most other water-use categories, irrigation withdrawals are considered almost totally consumed.

Irrigation is the fourth largest use of water in South Carolina. In 2006, 230 surface-water intakes for irrigation systems and 491 irrigation water wells reported a total use of 29,157 million gallons. Of that total, 17,981 million gallons (62 percent) originated from ground-water sources and 11,177 million gallons (38 percent) originated from surface-water sources. The number of farms reported to be under irrigation in the 2007 agricultural census would indicate that water use for this category is under-reported (U.S. Department of Agriculture, 2009).

The Combahee-Coosawhatchie and Edisto subbasins together accounted for more than half the reported



Ten largest water-supply surface-water users					Ten largest water-supply ground-water users			
Rank	**Facility**	**Source of water**	**Subbasin**	**2006 water use (million gallons)**	**Rank**	**Facility**	**Subbasin**	**2006 water use (million gallons)**
①	Charleston CPW	Edisto River, Cooper River	Edsito, Ash.-Coop.	30,247	1	City of Sumter	Black	4,525
②	City of Columbia	Broad River, Lake Murray	Broad, Saluda	22,910	2	City of Florence	Pee Dee	3,445
③	Greenville Water System	Saluda River, Lake Keowee	Saluda, Upper Sav.	22,312	3	City of Aiken	Edisto	2,585
④	Spartanburg Water System	South Pacolet River	Broad	12,092	4	Mount Pleasant CPW	Ashley-Cooper	1,783
⑤	Grand Strand WSA	Bull Creek	Pee Dee	9,904	5	South Island PSD	Comb.-Coosaw.	1,697
⑥	Beaufort-Jasper WSA	Savannah River	Lower Savannah	8,072	6	Darlington County WSA	Lynches	1,587
⑦	Anderson Regional Water System	Lake Hartwell	Upper Savannah	7,098	7	Hilton Head PSD #1	Comb.-Coosaw.	1,113
⑧	Catawba River WTP	Catawba River	Catawba-Wateree	6,354	8	Trico Water	Little Pee Dee	1,004
⑨	City of Myrtle Beach	AIW	Waccamaw	5,964	9	Alligator Rural Water	Pee Dee	937
⑩	Santee Cooper Regional Water	Lake Moultrie	Ashley-Cooper	5,658	10	City of Bennettsville	Pee Dee	636

Figure 4-10. The ten largest surface- and ground-water water-supply facilities in 2006.

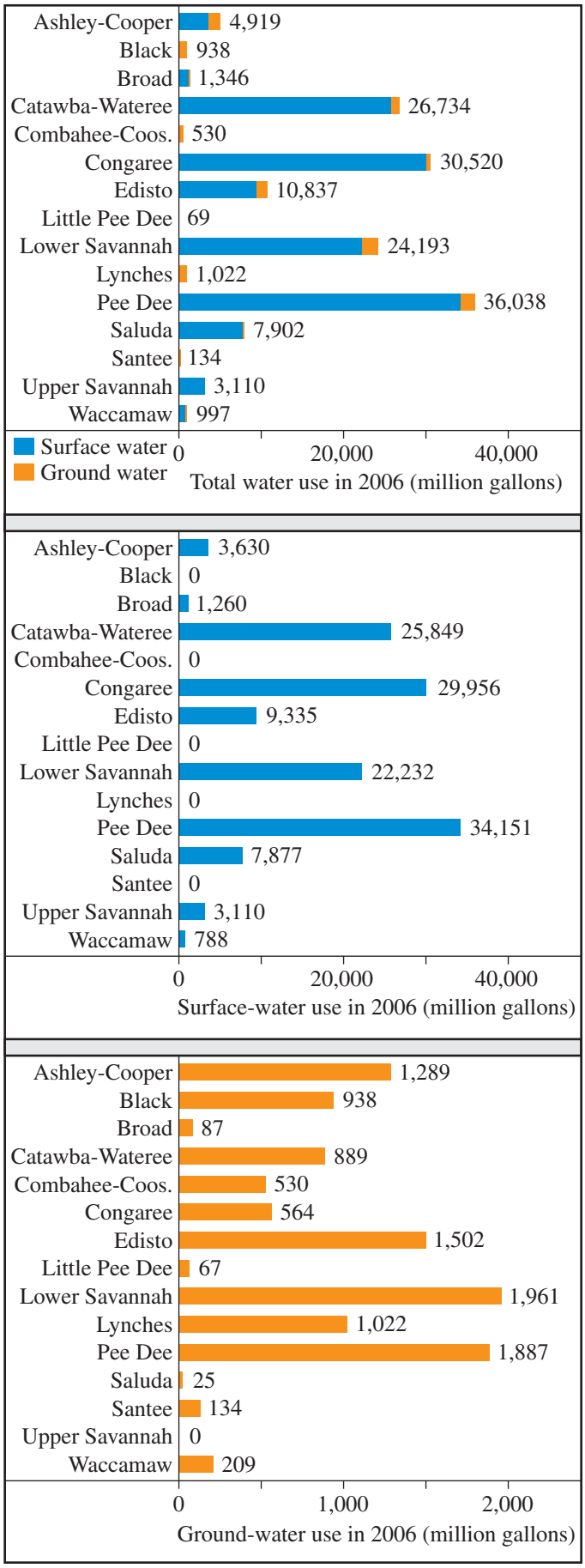


Figure 4-11. Industrial water use in 2006, by subbasin (modified from Butler, 2007).

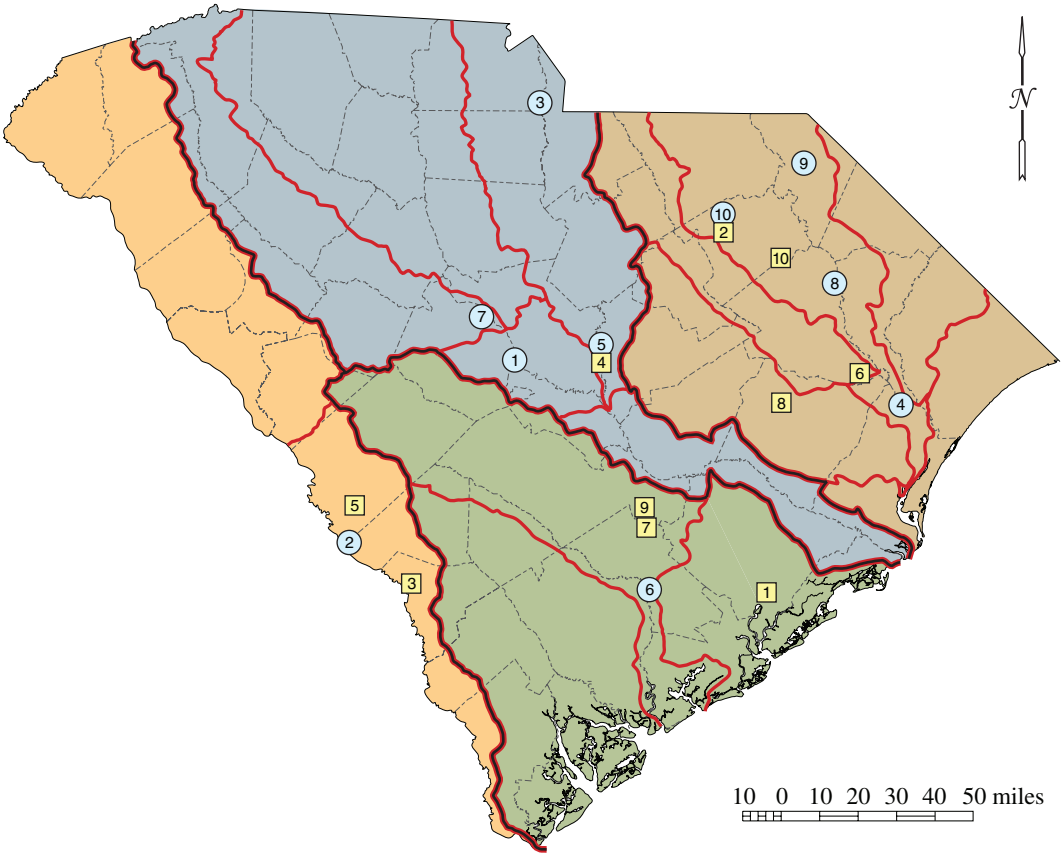
irrigation use in 2006 (Figure 4-13). Withdrawals from the Combahee-Coosawhatchie totaled 9,024 million gallons (31 percent of the statewide total) and those from the Edisto totaled 7,348 million gallons (25 percent). Irrigation use was lowest in the Lynches River subbasin (27 million gallons) and the Little Pee Dee River subbasin (29 million gallons). The largest surface-water use was in the Waccamaw and Edisto subbasins, with withdrawals totaling 3,583 and 2,410 million gallons, respectively. The largest ground-water use was in the Combahee-Coosawhatchie and Edisto subbasins, with withdrawals totaling 7,563 and 4,939 million gallons, respectively.

Golf Course Irrigation

Golf course irrigation use refers to water that is used to maintain golf course turf, including tee boxes, fairways, putting greens, associated practice areas, and periphery aesthetic landscaping. DHEC distinguishes this use from agricultural irrigation because of the large number of golf courses in the State. In 2006, 242 golf courses reported water withdrawals totaling 12,625 million gallons, of which 9,275 million (74 percent) were from surface-water sources and 3,350 million (26 percent) were from ground-water sources. Because the majority of golf courses in South Carolina are located near the coast, this type of water use is greatest in coastal areas.

The Waccamaw River subbasin, in which the many Grand Strand golf resorts are located, accounts for more than one-third of the statewide golf course water use, with withdrawals totaling 4,379 million gallons (Figure 4-14). The Combahee-Coosawhatchie subbasin, which contains numerous golf courses in the Hilton Head Island and Bluffton areas, accounts for more than one-quarter of the statewide use, with withdrawals totaling 3,394 million gallons. Golf course irrigation was lowest in the Little Pee Dee and Lynches subbasins, where withdrawals totaled only 37 million gallons and 84 million gallons, respectively.

At least some surface water was used for golf-course irrigation in each subbasin, and only in the Upper Savannah and Little Pee Dee subbasins was no ground water used for golf course irrigation. Together, the Waccamaw and Combahee-Coosawhatchie subbasins accounted for more than 60 percent of the surface water used for golf course irrigation in 2006, withdrawing 3,810 and 2,056 million gallons, respectively. The Combahee-Coosawhatchie and Ashley-Cooper subbasins collectively accounted for more than 60 percent of the ground water used for golf course irrigation, withdrawing 1,338 and 774 million gallons, respectively.



Ten largest industrial surface-water users					Ten largest industrial ground-water users			
Rank	Facility	Source of water	Subbasin	2006 water use (million gallons)	Rank	Facility	Subbasin	2006 water use (million gallons)
①	Eastman Chemical	Congaree River	Congaree	28,262	1	Nucor Steel	Ashley-Cooper	1,067
②	Primesouth	Savannah River	Lower Savannah	18,184	2	Sonoco Products	Pee Dee	865
③	Bowater	Catawba River	Catawba-Wateree	12,303	3	Clariant Corp.	Lower Savannah	850
④	International Paper	Pee Dee River	Pee Dee	11,418	4	International Paper	Catawba-Wateree	701
⑤	International Paper	Wateree River	Catawba-Wateree	10,516	5	Westinghouse SRS	Lower Savannah	686
⑥	MeadWestvaco	Edsito River	Edsito	9,168	6	Wellman Inc.	Lynches	635
⑦	Shaw Industries	Saluda River	Saluda	7,788	7	Holcim Inc.	Edisto	623
⑧	Smurfit-Stone Container Enterprises	Pee Dee River	Pee Dee	6,343	8	Martek Biosciences	Black	607
⑨	Domtar Co.	Crooked Creek	Pee Dee	6,222	9	Roseburg Forest Products	Edisto	508
⑩	Sonoco Products	Black Creek	Pee Dee	6,047	10	Wellman Inc.	Pee Dee	438

Figure 4-12. The ten largest surface- and ground-water industrial water-use facilities in 2006.

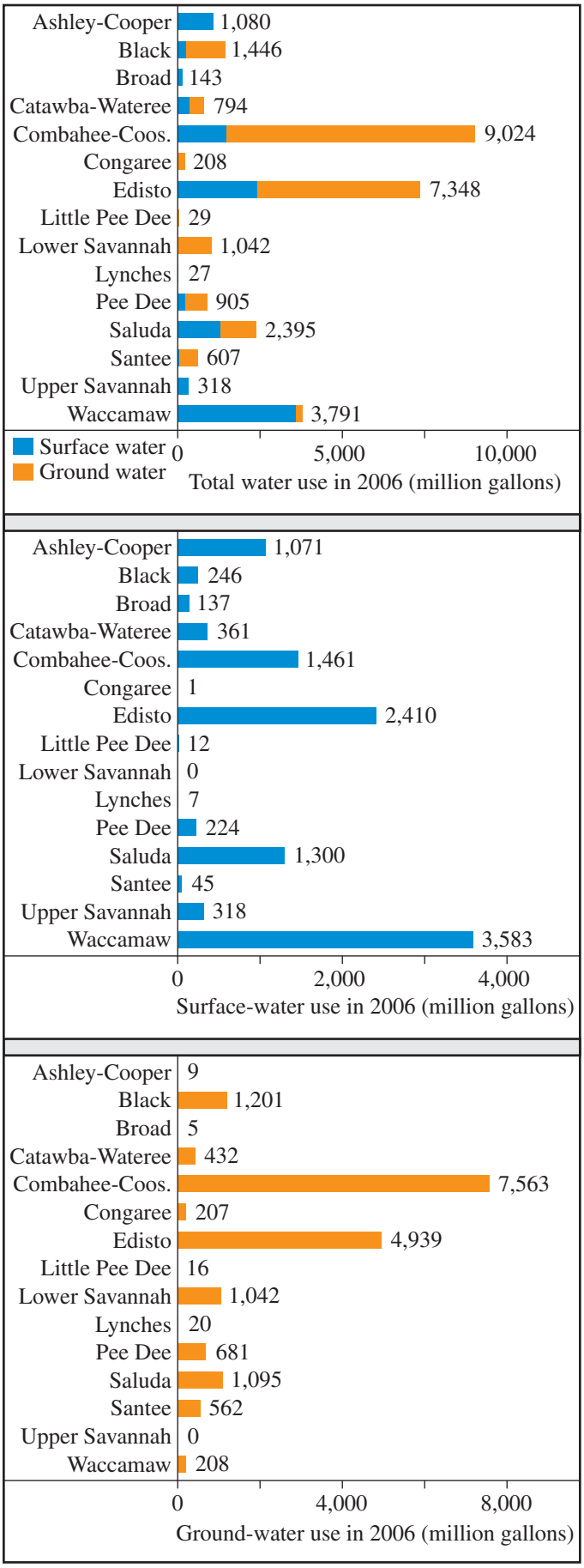


Figure 4-13. Irrigation water use in 2006, by subbasin (modified from Butler, 2007).

Mining

Water used in conjunction with surface or subsurface mining of minerals or natural materials was reported in only seven subbasins in 2006, and amounted to a total of 3,724 million gallons. Of that total, 3,225 million gallons (87 percent) were supplied by ground-water sources and 498 million gallons (13 percent) by surface-water sources.

In 2006, two mines in the Edisto River subbasin collectively used 1,891 million gallons, representing more than half (51 percent) of the statewide total mining water use for that year, and one mine in the Broad River subbasin used 982 million gallons (26 percent).

Only three subbasins—the Congaree, Waccamaw, and Edisto—reported any surface-water use associated with mining, and six subbasins reported some ground-water use related to mining. Most ground-water use was associated with pumping ground water in order to dewater quarries. The Edisto, Broad, and Congaree subbasins collectively accounted for 99 percent of the reported ground-water mining use in 2006.

Aquaculture

Aquaculture water use refers to water used for raising, farming, and/or harvesting of organisms that live in water, such as fish, shrimp and other shellfish, and vegetal matter (seaweed). A total use of 320 million gallons was reported in 2006, of which 172 million gallons (54 percent) was surface water and 148 million gallons (46 percent) was ground water.

Aquaculture water use was reported in five subbasins: Combahee-Coosawhatchie, Ashley-Cooper, Congaree, Broad, and Pee Dee. The Combahee-Coosawhatchie and Ashley-Cooper subbasins accounted for two-thirds of the statewide aquaculture total, using 143 and 72 million gallons, respectively, and two-thirds of the aquaculture surface-water total, with withdrawals of 47 million gallons (27 percent) and 68 million gallons (40 percent), respectively. The Broad and Congaree subbasins also reported some surface-water usage. Ground-water use was concentrated in the Combahee-Coosawhatchie subbasin, in which 95 million gallons were used, accounting for nearly two-thirds of the total aquaculture ground-water use. Ground-water use was also reported in the Pee Dee, Congaree, and Ashley-Cooper subbasins.

Other

Reported water use not specifically identified as belonging to any other water-use group is assigned to this category, which, in 2006, totaled 54 million gallons, all of it ground water. Withdrawals were largely in the Combahee-Coosawhatchie River subbasin, which accounted for about 33 million gallons (60 percent), and the Waccamaw River subbasin, which accounted for 21 million gallons (40 percent). A very small amount was also reported from the Edisto River subbasin.

Self-Supplied Domestic

Self-supplied domestic use is water supplied by individual homeowners from private wells. This use is not reported to DHEC, or included in its water-use reports, because of the relatively small amount of water withdrawn by each individual well. Using year-2000 census data, J.E. Castro (written communication, 2003) applied a per-capita water-use rate of 75 gallons per day to the population not served by public-supply systems in order to calculate self-supplied domestic use (Table 4-5) and estimated that 23,218 million gallons were self-supplied by residents with private water wells, which represents about 12 percent of the reported water-supply use for that year. It is estimated that more than 680,000 people—about 17 percent of the State's population—use private water sources (J.E. Castro, written communication, 2003). Withdrawals ranged from 365 million gallons in the Lower Savannah and Waccamaw subbasins to 3,650 million gallons in the Broad subbasin. All withdrawals were assumed to come solely from ground-water sources.

Table 4-5. Estimated self-supplied domestic water use in 2000, by subbasin

Subbasin	Million gallons
Ashley-Cooper	1,752
Black	1,716
Broad	3,650
Catawba-Wateree	2,519
Combahee-Coosawhatchie	1,022
Congaree	1,205
Edisto	2,847
Little Pee Dee	475
Lower Savannah	365
Lynches	1,059
Pee Dee	1,205
Saluda	2,811
Santee	876
Upper Savannah	1,351
Waccamaw	365
Statewide total	**23,218**

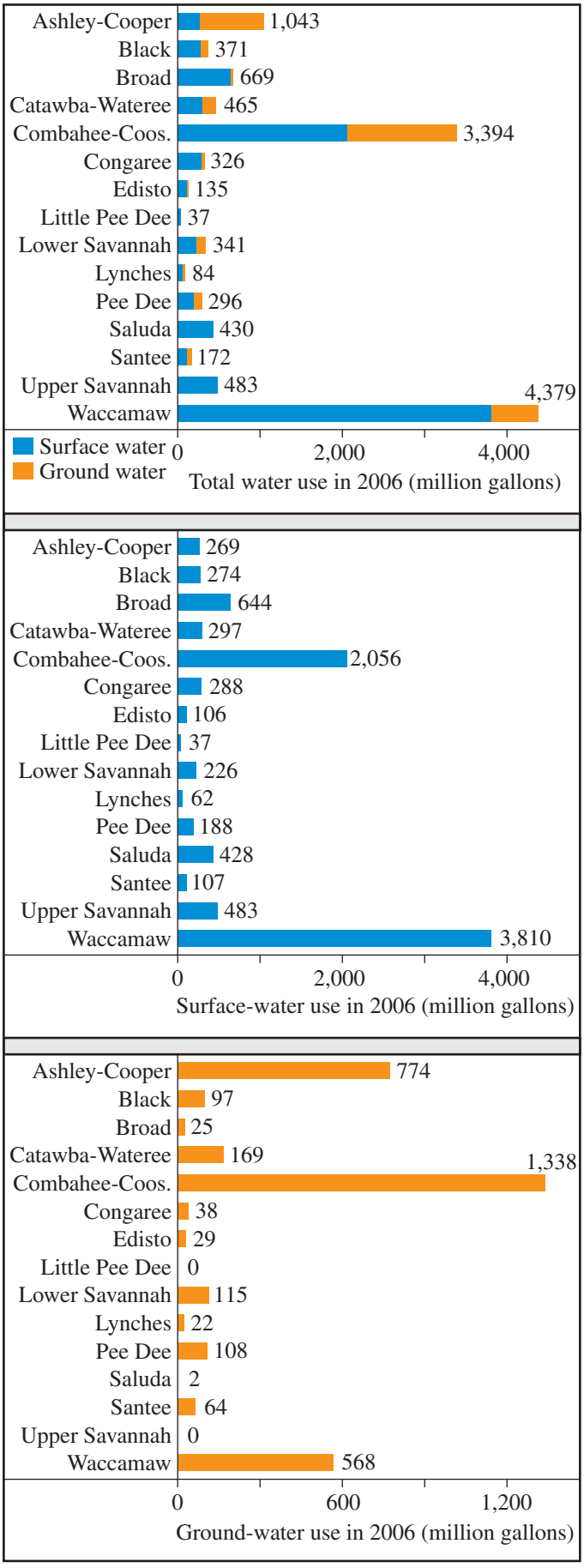


Figure 4-14. Golf course water use in 2006, by subbasin (modified from Butler, 2007).

Consumptive Water Use

Consumptive water use is the amount of water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from an immediate water environment (Shaffer, 2008). It is strongly dependent upon the specific use of the water and less so on the climate of the region where the water is used. Non-consumptive water use is the amount of water that is returned to an immediate water environment after being used in a specific water-use application.

Consumptive use is determined by calculating the difference between the amount of water withdrawn and the amount of water returned to its source. Because this information is often not available, consumptive use is typically estimated for each water-use category by applying consumptive-use coefficients. A consumptive-use coefficient is the percentage of water not returned to an immediate water environment after particular use. The product of the consumptive-use coefficient (expressed as a fraction) and the water withdrawn provides an estimate of the amount of water that is consumed.

When estimating consumptive use, each water-use category is assigned a different coefficient because the amount of water consumed is largely a function of its use. Coefficients represent an average percentage of the water consumed within that category. In actuality, within each water-use category, the percentage of water consumed can vary greatly. In the category of irrigation use, for example, the type of irrigation system used influences the efficiency of water use: Cosgrove and Rijsberman (2000) estimated consumptive-use coefficients of 30 to 40 percent for flood-irrigation systems and 90 percent for drip-irrigation systems. Similarly, industrial consumptive use rates vary with the type of industry: the production of chemicals and allied products consume an average of 6 percent of the water used, whereas the production of stone, clay, and glass products consumes 12 percent (Shaffer and Runkle, 2007). Compared to thermoelectric power plants that use a once-through cooling system, power plants that use closed-loop cooling systems consume a much greater fraction of their total water use. Even within the aquaculture-use category, the amount of water consumed varies depending upon the type of fish being farmed (Solley and others, 1998).

As the demand for water increases, wisely managing and utilizing South Carolina's water resources will require not only detailed information about the amount of water withdrawn but also about the amount of water consumed. Consumptive-use coefficients for the southeastern United States are not well-established, and additional research is needed to determine more accurate coefficients for South Carolina that better reflect the State's climate and the types of irrigation systems, industries, and energy plants found in the State. Consumptive-use coefficients used in this report were calculated from consumptive-use data collected in the Great Lakes Basin, where detailed studies have been made (Shaffer and Runkle, 2007).

Consumptive-use coefficients used in this report are as follows: aquaculture, 5 percent (Solley and others, 1998); irrigation and golf course, 90 percent (Shaffer and Runkle, 2007); industry, 10 percent (Shaffer and Runkle, 2007); mining, 14 percent (Shaffer and Runkle, 2007); other, 50 percent; thermoelectric, 2 percent for plants that have once-through cooling systems (Shaffer and Runkle, 2007) and 60 percent for plants that have closed-looped cooling systems (Solley and others, 1998); and water-supply, 12 percent (Shaffer and Runkle, 2007).

Statewide consumptive use for the year 2006 was estimated to be 131,366 million gallons, of which 102,315 million gallons (78 percent) were from surface-water sources and 29,051 million gallons (22 percent) were from ground-water sources (Table 4-6). Thermoelectric power generation had the greatest consumptive use, 51,101 million gallons (39 percent of the total consumptive use), followed by water supply (21 percent), irrigation (20 percent), and industry (11 percent).

The greatest consumptive use occurred in the Upper Savannah River subbasin, where it was 22,144 million gallons (Figure 4-15), which represents only 2.3 percent of the total amount of water withdrawn in the subbasin in 2006. Most of the water withdrawn in this subbasin was used for thermoelectric power generation, which consumes little water. The Little Pee Dee River subbasin had the lowest consumptive use, 349 million gallons. Consumptive surface-water use was highest in the Upper Savannah subbasin (22,138 million gallons) and consumptive ground-water use was highest in the Combahee-Coosawhatchie subbasin (8,940 million gallons).

Table 4-6. Estimated consumptive water use in 2006, by water-use category

Water-use category	Consumptive use coefficient	Surface water		Ground water		Total water	
		Million gallons	Percentage of total surface-water use	Million gallons	Percentage of total ground-water use	Million gallons	Percentage of total water use
Aquaculture	0.05	9	0.0	7	0.0	16	0.0
Golf course	0.90	8,348	8.2	3,015	10.4	11,362	8.6
Industry	0.10	13,819	13.5	1,111	3.8	14,929	11.4
Irrigation	0.90	10,059	9.8	16,182	55.7	26,241	20.0
Mining	0.14	70	0.1	452	1.6	521	0.4
Other	0.50	0	0.0	27	0.1	27	0.0
Thermoelectric power	0.02 or 0.60*	47,557	46.5	3,544	12.2	51,101	38.9
Water supply	0.12	22,454	21.9	4,713	16.2	27,167	20.7
Total		102,315		29,051		131,366	

** Consumptive use coefficient for thermoelectric power is 0.02 for plants having once-through cooling systems and 0.60 for plants having closed-loop cooling systems*

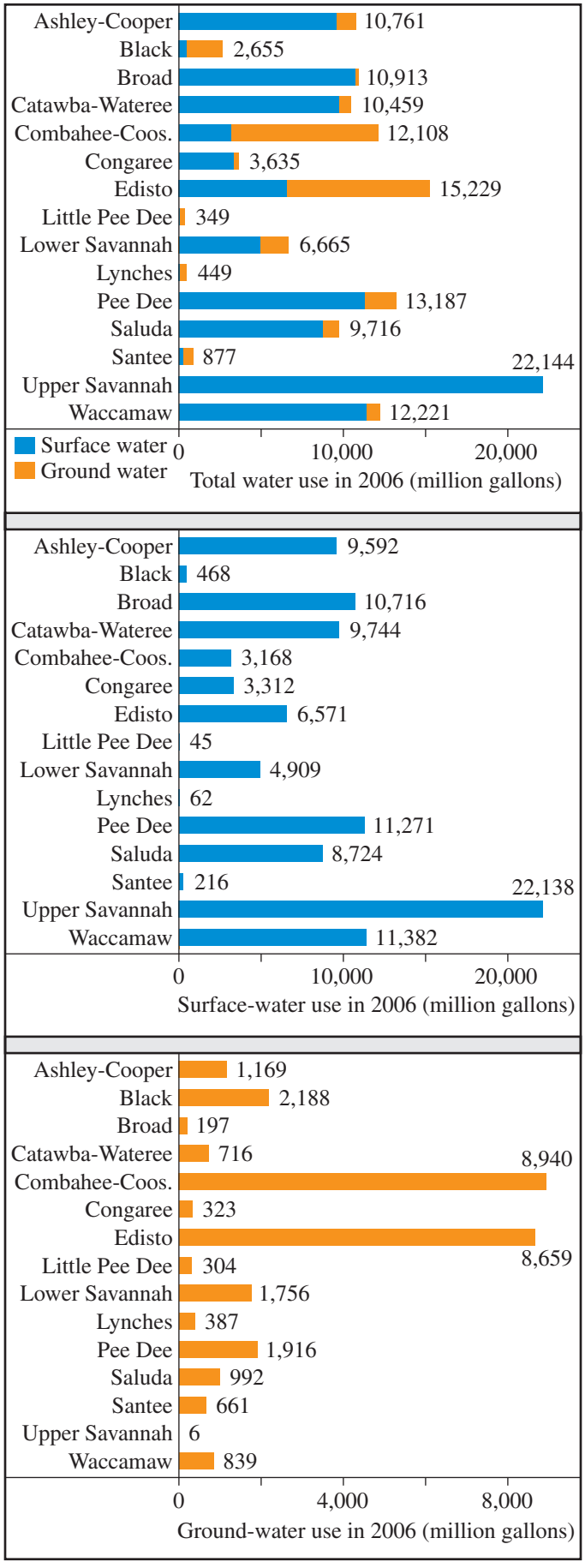


Figure 4-15. Consumptive water use in 2006, by subbasin.