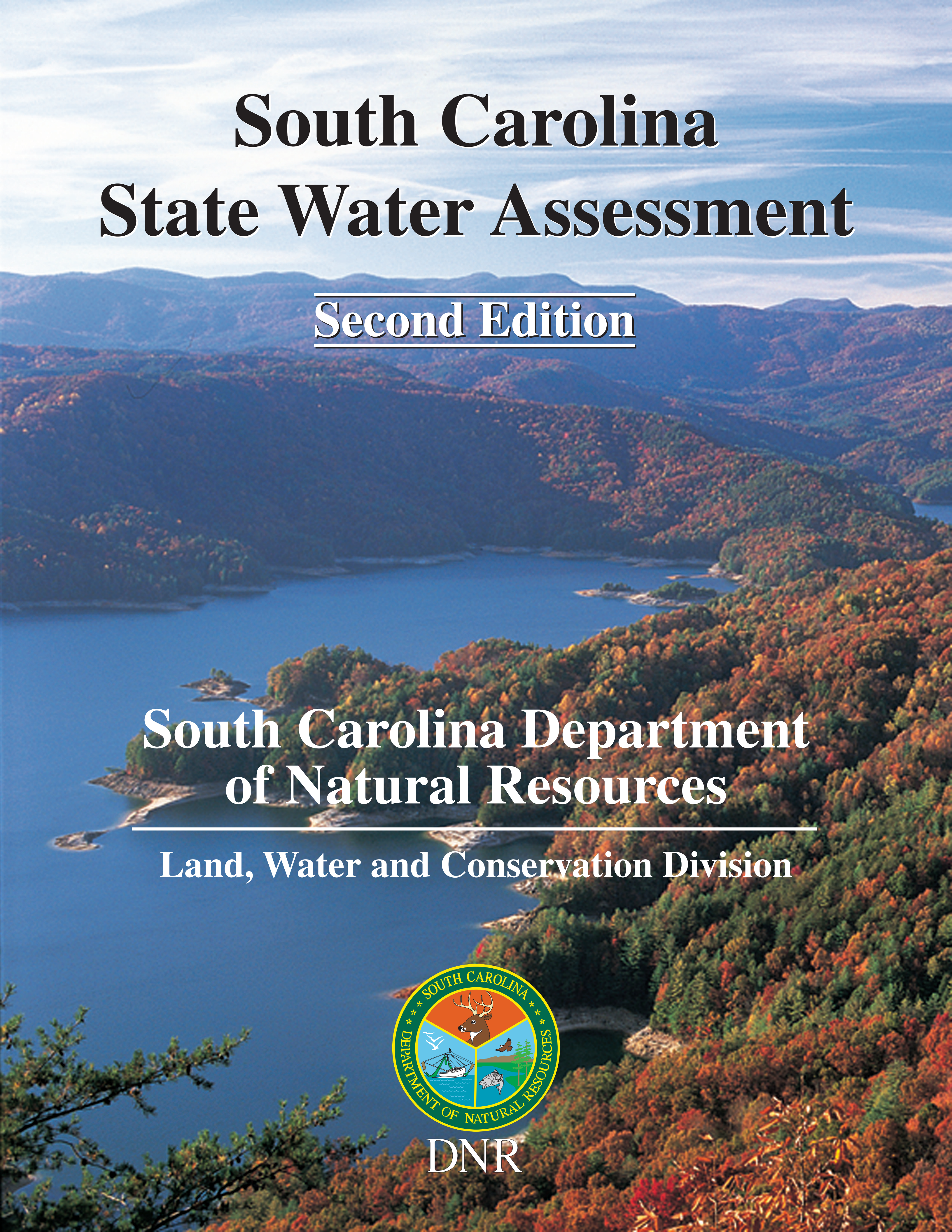

South Carolina State Water Assessment

Second Edition

South Carolina Department of Natural Resources

Land, Water and Conservation Division

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

DNR

South Carolina
STATE WATER ASSESSMENT

Second Edition

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DNR

Land, Water & Conservation Division
South Carolina Department of Natural Resources
Columbia, South Carolina

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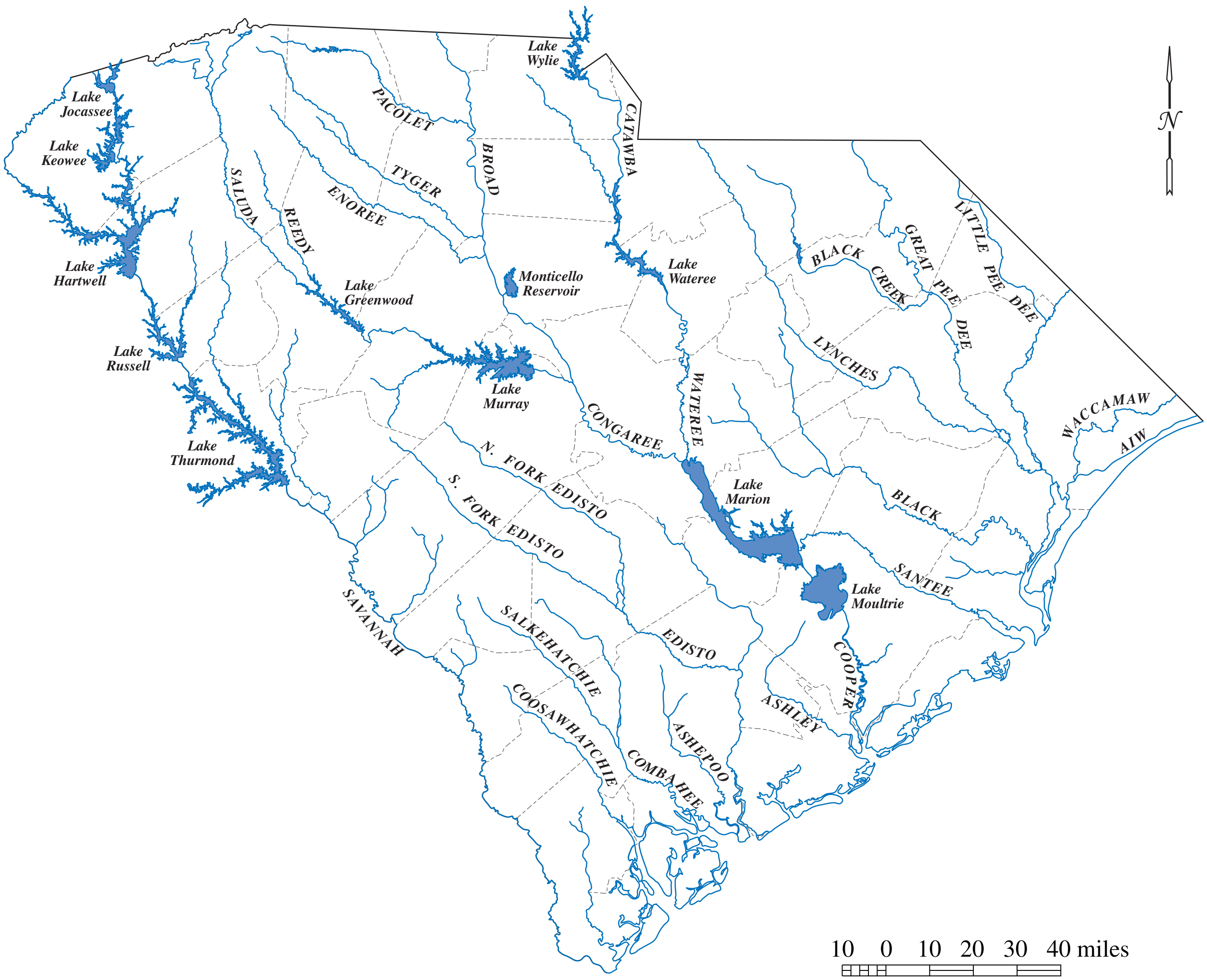
STATE OF SOUTH CAROLINA

The Honorable Mark Sanford, Governor

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

Cover: The crystal clear water of Oconee County's Lake Jocassee is an important water resource for South Carolina's Upstate residents. Cover photo by Philip Jones.



Major rivers and lakes of South Carolina.

Counties of South Carolina.

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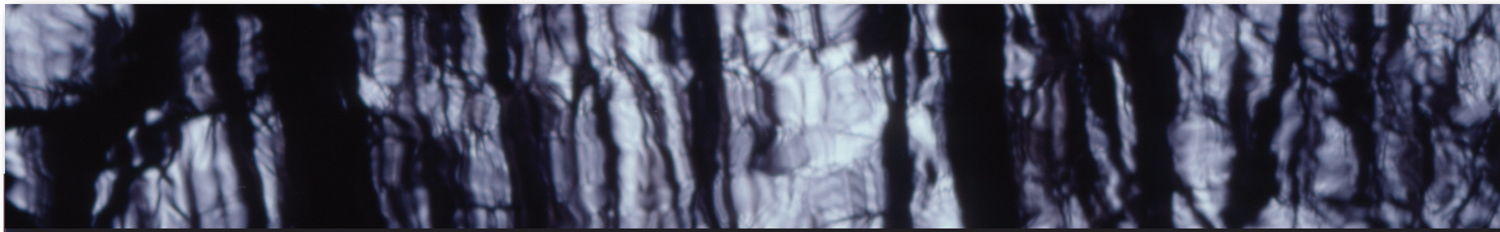

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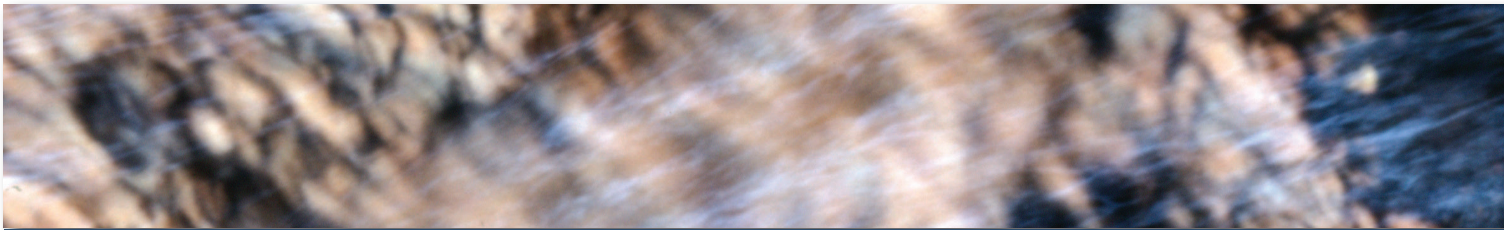
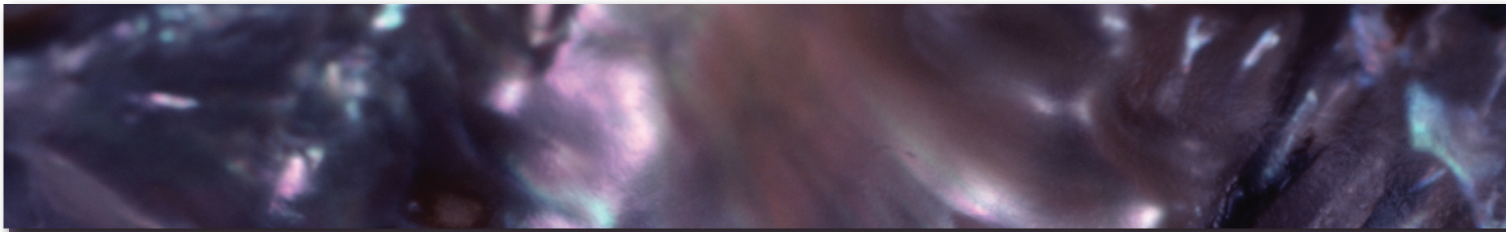


COUNTY/SUBBASIN CROSS-REFERENCE LIST



EXECUTIVE SUMMARY

South Carolina possesses nearly 30,000 miles of perennial and intermittent streams, and they discharge an average of 31 billion gallons of water each day to the Atlantic Ocean. Inflow from North Carolina accounts for 38 percent of the total flow, and most this inflow occurs through hydroelectric power facilities that are beyond South Carolina's jurisdiction.

South Carolina has approximately 50,000 lakes, 1,600 of which are 10 or more acres in area and 19 of which are 1,000 acres or more. Their total surface area exceeds 525,000 acres and they impound 15 million acre-feet (4.9 trillion gallons) of water. The largest lakes store water for hydroelectric and thermoelectric power generation. Many lakes are protected and used as sources for public water supplies and crop and golf-course irrigation. Most lakes are valued for recreation and aesthetics.

Ground water is abundant and serves as the water supply for more than three quarters of a million South Carolinians. In the Blue Ridge and Piedmont, the clayey, weathered-bedrock mantle accepts and yields water slowly but stores most of the two provinces' ground water. Shallow, bored wells commonly pump water from the contact zone between the weathered mantle and the bedrock, yielding about 5 gpm (gallons per minute), and are the most vulnerable to drought. Wells drilled into the bedrock obtain water from fractures connected to the weathered-bedrock mantle average about 300 feet in depth, and commonly yield about 20 gpm.

The availability of ground water in the Coastal Plain greatly exceeds that in the Blue Ridge and Piedmont. Six major aquifers are contained in a clay, sand, and limestone wedge that thickens from a featheredge at the Fall Line to 4,000 feet at the southern end of the State. Well yields are adequate for domestic and light-commercial uses nearly everywhere, and wells in the Coastal Plain can pump 1,000 to 3,000 gpm (1.4 to 4.3 million gallons per day) where constructed to obtain the maximum yield.

Water quality is generally good, and most of the State's water is suitable for public-supply, industrial, and irrigation use. Aquatic life is supported in most of the State's lakes, estuaries, and rivers. Recreational use is supported in nearly all of the lakes and estuaries and a majority of the rivers. Ground water typically needs no treatment, although chlorination is required of public-supply systems. Radionuclides are found in bedrock wells in some parts of the upper Piedmont and in some Coastal Plain wells near the Fall Line, but concentrations generally are less than the maximums allowed by drinking-water standards. Dilute seawater occurs in aquifers near the coast, and in some areas it is drawn inland by pumping of the freshwater in major well fields. Of most immediate concern is the lateral and vertical seawater intrusion that threatens the Floridan aquifer in southern South Carolina. This intrusion will contaminate a large part of the State's most productive aquifer during the next 50 years.

South Carolina's population surpassed 4 million in the year 2000, following a 21-percent increase during the preceding 20 years. The population increase was accompanied by greater prosperity, shifts in the way water is used, and increases in per capita water use and in total water demand. The greatest use of water in South Carolina goes toward the generation of electricity. Instream water use by hydroelectric power plants averaged 49,100 mgd (million gallons per day) in 2006, while offstream water use by thermoelectric power plants averaged 5,760 mgd. A 60-percent decrease in water use for hydroelectric power generation occurred during the 1998–2002 drought. Public-supply use increased from 380 mgd in 1980 to 620 mgd in 2006, mainly owing to the population increase and water-system expansions into areas previously supplied by private wells. Per capita household use also increased during this time, partly because of increased landscape irrigation. Industrial water use averaged 409 mgd in 2006, agricultural irrigation averaged 80 mgd, and golf-course irrigation averaged 35 mgd. Aquaculture, a relatively new business in South Carolina, used an average of 0.9 mgd in 2006.

One of the most significant changes in water use during the last two decades has been the conversion from ground-water sources to surface-water sources by many Coastal Plain communities. Public supply systems in coastal Horry County were the first of these. Faced with the prospect of dewatering their aquifers because of overpumping, both the city of Myrtle Beach and the Grand Strand Water and Sewer Authority converted from deep wells to streams in the late 1980's. Utilities maintain standby wells, but most Horry County water systems now rely on surface water.

Saltwater intrusion, caused by ground-water withdrawals in southern Beaufort County and Chatham County, Georgia, led to mandated pumping reductions from Floridan-aquifer wells in 2004. The Savannah River supplemented wells as a water source for Hilton Head Island and subsequently replaced domestic and public-supply wells in large parts of Beaufort and Jasper Counties.

Water-level declines in the Cretaceous aquifers of northern Florence County led to construction of a surface-water treatment plant in 2003. The county's public-supply demand averaged 13 mgd (million gallons per day) in 2008, and nearly a third of that demand was met by withdrawals from the Great Pee Dee River. Average ground-water levels at Florence recovered 35 feet by the middle of 2005.

Over the past 25 years, the efforts of government agencies and citizens have resulted in protection of many streams in South Carolina. Whereas only 5 miles of stream were protected under the Scenic Rivers Act in 1983, 399 miles were protected by 2008. During the 1990's, the Department of Natural Resources (DNR) River Conservation Program and local citizens created a database and advocacy organization for conservation and planning in the 2-million acre ACE (Ashley-Cooper-Edisto) basin; a similar process was applied to the Reedy River watershed in Greenville and Laurens Counties and completed in 2002.

By 2008, DNR completed ground-water reports for all of the Coastal Plain and Fall Line counties, and computer models were developed by the U.S. Geological Survey (USGS) and DNR to predict the effects of pumping from the principal Coastal Plain aquifers. Legislation passed in 1985 required well-construction reports to be filed with the Department of Health and Environmental Control (DHEC); by 1995, DHEC was receiving 10,000 new well records each year. Most of the hydrogeologic information summarized in this assessment is extracted from regional studies published by DNR, DHEC, and USGS since the mid-1980's and from many of the thousands of well reports submitted to DHEC in the past 20 years. The DHEC ground-water-quality monitoring network increased six-fold between 1987 and 2003, and USGS and DNR ground-water-level monitoring more than doubled during that same period.

During much of the past decade, severe droughts in the Southeast decreased the availability of surface water and intensified interstate competition for shared water resources. Some conflicts were resolved with beneficial, cooperative solutions, while other conflicts remain unresolved. The 1998–2002 drought reduced streamflows to the point that public-supply systems in the Great Pee Dee River basin faced water shortages, which prompted months of negotiations by State and local officials, the Federal government, and operators of hydroelectric facilities in North Carolina that led to agreements about reservoir releases and guaranteed minimum instream flows. During the severe droughts that occurred in 1998–2002 and 2007–2008, agencies from South Carolina and Georgia worked together, along with the Corps of Engineers and other stakeholders, to develop more effective drought management plans for the Savannah River basin. Although the Savannah lakes reached record low levels in 2008, the cooperative efforts of both States helped to minimize the damage caused by these severe droughts.

In recent years, the governments of South Carolina and Georgia had markedly different perspectives regarding saltwater-intrusion management and Savannah River wasteload allocations. In 2005, each state formed a Governor's Savannah River Committee to take the lead in negotiating solutions to these problems, and although agreements have yet to be reached, both states continue to work toward agreeable solutions. Another interstate water conflict developed in 2006 when South Carolina objected to North Carolina's decision to allow the transfer of 10 mgd from the Catawba River basin to the Pee Dee River basin by water suppliers near the city of Charlotte. In 2007, South Carolina filed suit against North Carolina in the U.S. Supreme Court to prevent this interbasin transfer; the issue remained unresolved by the end of 2009.

The *South Carolina State Water Assessment* provides an overview of and a general reference for the quantity, quality, availability, and use of water in South Carolina. Nine chapters address general and specific topics and water-resource conditions in the State's 15 subbasins:

1. Perspective: State demography, climate, natural resources, hydrology, and geology

2. Water Law: case law, State and Federal enabling legislation, legal shortcomings, and references

3. Water Resources: regulatory programs; water monitoring; state of knowledge; factors affecting surface-water availability and quality; and ground-water distribution, well yields, and chemistry

4. Water Use: year 2006 water-use data, by water-use category, with a comparison of water use in the 15 subbasins

5. Pee Dee River Basin: surface-water hydrology, development, and quality; ground-water availability, quality, and problems; and water use in the Great Pee Dee, Lynches, Little Pee Dee, Black, and Waccamaw River subbasins

6. Santee River Basin: surface-water hydrology, development, and quality; ground-water availability, quality, and problems; and water use in the Broad, Saluda, Catawba-Wateree, Congaree, and Santee River subbasins

7. ACE River Basin: surface-water hydrology, development, and quality; ground-water availability, quality, and problems; and water use in the Ashley-Cooper, Edisto, and Combahee-Coosawhatchie River subbasins

8. Savannah River Basin: surface-water hydrology, development, and quality; ground-water availability, quality, and problems; and water use in the upper and lower Savannah River subbasins

9. Special Topics: hydroelectric power; FERC relicensing; instream flow needs; navigation; river conservation; aquatic nuisances; water recreation; sedimentation in surface waters; unique wetland areas; coastal concerns; saltwater contamination; aquifer storage and recovery; water conservation; interbasin transfers; drought management and mitigation; and flooding.

ACKNOWLEDGMENTS

The 2009 *South Carolina State Water Assessment* contains a large amount of information and is the result of efforts by specialists and natural-resource professionals of the S.C. Department of Natural Resources (DNR) and other state, federal, and private agencies. Their contributions include statistical data and analyses, revisions to sections from the 1983 *Water Assessment*, and authorship of new chapters and subchapters.

The editors wish to thank several DNR hydrologists for their help: Brenda L. Hockensmith, P.G., provided descriptions of Coastal Plain hydrogeology, ground-water quality, and potentiometric mapping; H. Lee Mitchell, P.G., provided descriptions of Piedmont hydrogeology and ground-water quality; and Masaaki Kiuchi, Ph.D., assisted in describing surface-water hydrology. The editors are also grateful for the assistance of other DNR staff: Marc Cribb, Richard Lacy, D. Breck Carmichael, and Richard Scharf updated the overviews of land use, forestry, fish and wildlife, and soils; Hope Mizzell, Ph.D., Milton Brown, and D. Wes Tyler contributed to the description of South Carolina's climate; and Paul Nystrom, P.G., of the S.C. Geological Survey, provided descriptions of South Carolina's mineral resources and geology. The editors are especially grateful to Joseph A. Gellici for his preparation of the *Water Use* chapter and to Ann Nolte for her editorial review of the entire *Assessment*.

The editors wish to thank everyone outside the DNR who helped make this report possible. T.W. Cooney, C.L. Sanders, and T.H. Lanier of the U.S. Geological Survey, South Carolina District, helped prepare the streamflow statistics and duration hydrographs. Alex Butler, Braxton Davis, Rheta Geddings, Rick Nuzum, Jill Stewart, and Camille Ransom, III, of the S.C. Department of Health and Environmental Control provided information on water use, coastal concerns, surface-water sedimentation, and saltwater intrusion. M. McMullen Taylor, attorney with the law firm of McAngus Goudelock & Courie, LLC, Columbia, S.C., prepared the *Water Law* chapter. Dr. Nadim Aziz of Clemson University assisted in preparing the *Sedimentation in Surface Waters* section of the *Special Topics* chapter.

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SOUTH CAROLINA IN PERSPECTIVE

SOCIOECONOMIC ENVIRONMENT

Geography has played an important role in South Carolina's history and development. Archaeological evidence shows us that early Indian inhabitants found the land and climate well suited for hunting and gathering and later for agriculture. Spanish, French, and English explorers discovered that South Carolina's harbors and rivers provided ingress to the New World and its vast resources. The settlers who followed on the heels of exploration exploited the land and streams of the lower Coastal Plain, and for almost 200 years they enjoyed a predominantly agricultural economy based first on indigo and rice and later on cotton, tobacco, and timber. Abundant land, water, and labor and a mild climate attracted national and international investment and a migration to the State during the middle and late 20th century. That influx of capital and population advanced the economy from an agricultural base to a 21st-century economy that is dominated by manufacturing and is well diversified by agriculture and tourism.

Population

South Carolina's population increased from about 250,000 in 1790 to more than 4 million in 2005 (Figure 1-1). The nearly one-million person increase between 1980 and 2005 accounted for 27 percent of the state's growth during the past two centuries. Population growth is above the national average and is expected to continue at an above-average rate owing to factors such as the state's mild climate, natural attractions, favorable tax and labor laws, and relatively low cost of living.

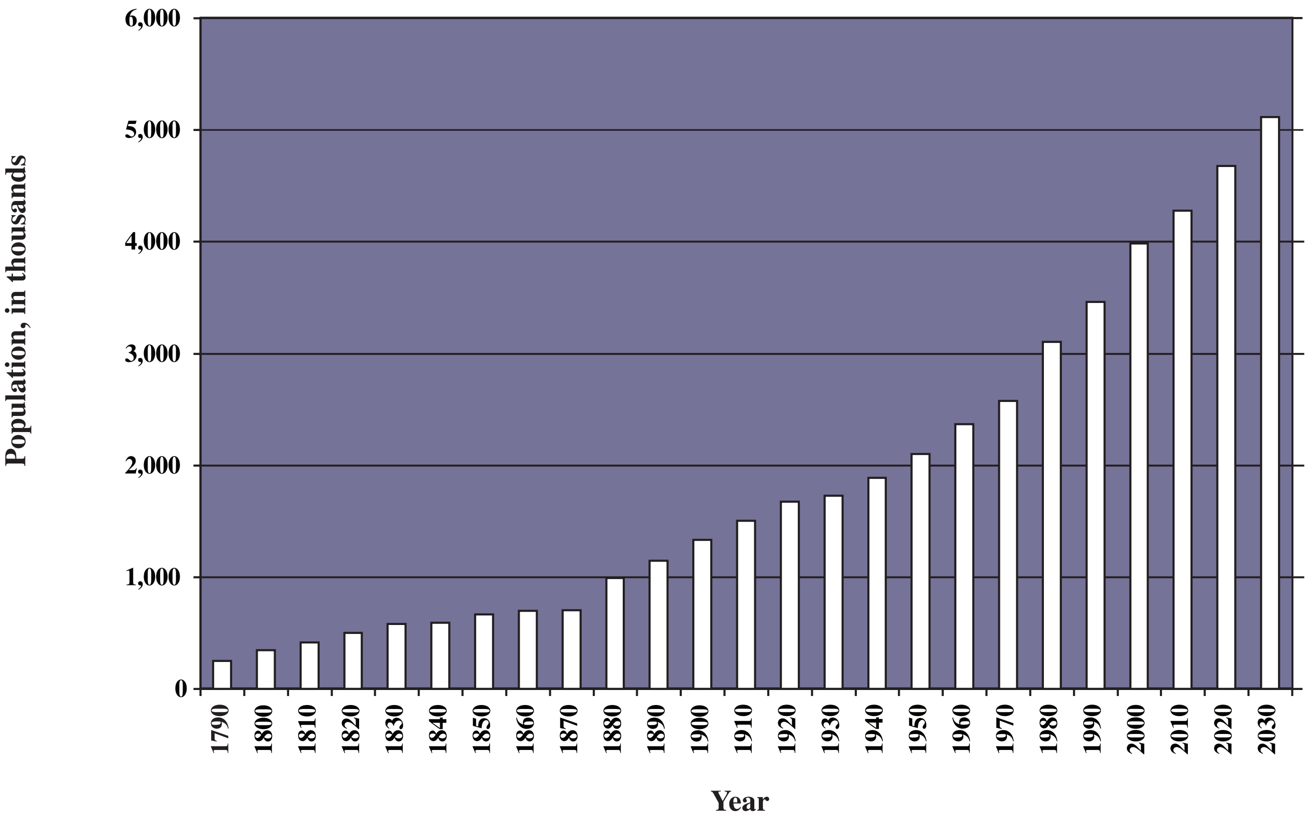

Figure 1-1. South Carolina population growth, 1790–2000 and projections to 2030 (U.S. Census Bureau, 2008).

Population in South Carolina increased at a rate greater than the national average during the past 25 years and increased by more than 17 percent between 1990 and 2005. Several counties experienced increases substantially greater than both the national and state averages. Among the most populous upstate counties, Greenville and York Counties grew by 17 and 30 percent, respectively. Lexington County saw a 34-percent increase. The coastal-zone counties, excepting Charleston County, experienced the most significant increases overall. Beaufort, Horry, and Georgetown County populations increased 43, 38, and 23 percent, respectively. Slight population declines occurred in the rural counties of Bamberg, Dillon, Marlboro, and Williamsburg. Areas that have led the way in population growth in the recent past are projected to be the major gainers through 2025.

A rural-to-urban population shift has taken place in South Carolina, mainly since the 1940's. The number of urban inhabitants increased from 54.1 percent of the State's population in 1980 to 60.5 percent in 2000. A 5.9-percent increase in urban population occurred between 1990 and 2005 and has been about the average since 1940, whereas the 0.5-percent shift in the 1980's was the smallest change in the 20th century. South Carolina's homeownership rate, well below the national average prior to 1950, has remained above average since 1970. In 2000, the State's homeownership rate was 72 percent and ranked ninth in the nation.

A moderate shift in rural-to-urban demographics occurred during the past 20 years, coincident with a disproportionately greater conversion in land use. South Carolina saw 539,700 acres of land converted from farms and woodlands to urban uses between 1992 and 1997, and it ranked ninth among the 50 states with respect to total area converted. The State ranked sixth in percentage increase in developed land (30.2) and fourth in the number of acres developed per capita (0.150). The general success in attracting industry to the upstate and tourism and retirees to the coast will continue to drive urbanization and land conversion, which will continue to impact the State's water resources.

Economy

Changes in the South Carolina economy began in the 1880's as the textile industries of the Northeast took advantage of the low-cost labor and the agricultural output of the South. The textile industry quickly became established in the Piedmont, where hydroelectric-power facilities provided a ready supply of energy for textile mills. Textile and agricultural production remained cornerstones of the State's economy into the middle of the 20th century. The importance of agriculture and textiles has declined over the past several decades, and more diversified manufacturing and service industries have taken their place.

Important new contributors to the state's economic base now include transportation-related manufacturing, with automobile plants, tire production, and ancillary manufacturers spread among 33 counties. Much of the recent manufacturing growth has been funded by foreign investment, which averaged 37 percent of the total manufacturing investment between 1990 and 2000. The Port of Charleston remains one of the nation's busiest ports. The service industry also has expanded substantially, partly in response to increased tourism and the growth of retirement-related business.

South Carolina's per capita income was $24,209 in 2000, compared to the United States average of $29,760, but the influx of investment and manufacturing jobs has raised the state's rank from 47th to 41st during the last two decades.

Land Use

Various groups and agencies have developed land-use information over the years. The U.S. Department of Agriculture's Natural Resources Inventory (NRI), using sample-point units, is one of the more recent attempts to identify and address the State's major land-use categories. The results of the 2002 NRI are summarized in Table 1-1.

The predominant land-use category in South Carolina is forestland, which covers more than 60 percent of the state's land area. Forestland is defined as any land with at least 25 percent of tree-canopy cover or land stocked by forest trees of any size. Cropland includes land used primarily for growing row crops, close-grown field crops, hay land, and orchards and represents almost 12 percent of the state's land use.

Recent trends indicate a significant increase in urban sprawl, with South Carolina being ranked among the top 10 states in urban growth. Urban and built-up lands are calculated at over 6 percent. The urban and built-up land-use category includes units of land that are used for residences, industrial sites, commercial sites, utility facilities, transportation facilities, roads, and small parks and recreation facilities. The category also includes all roads and railroads outside of urban and built-up areas and tracts of less than 10 acres that are completely surrounded by urban and built-up land.

Pastureland composes almost 6 percent of the state's land use. Pastureland includes land managed primarily for the production of forage plants for livestock grazing. The land-use inventory also includes a miscellaneous category that includes farmsteads, feedlots, broiler and layer houses, greenhouses and nurseries, strip mines, quarries, gravel pits, borrow pits, coastal marshes and dunes, mines, water bodies less than 40 acres, streams less than an eighth of a mile wide, and built-up areas less than 10 acres in size. Other and miscellaneous land use represents about 10 percent of the state's total area. Water bodies greater than 40 acres compose about 4 percent of the land use.

Table 1-1. Principal land uses in South Carolina (U.S. Department of Agriculture, 2002)

Category	Acres (thousands)	Percent of total
Forest-use land	12,300	61.5
Cropland	2,330	11.6
Urban	1,200	6.0
Grassland, pasture, and range	1,180	5.9
Other or miscellaneous land[1]	1,920	9.6
Special uses[2]	1,070	5.3
Total	20,000	

[1] Miscellaneous uses not inventoried: marshes, open swamps, and other areas of low agricultural value.

[2] Areas for rural transportation, rural parks, Federal and State wildlife, defense and industry, and farmsteads and farm roads.

PHYSICAL ENVIRONMENT

Climate

South Carolina's location provides this state a mild climate and, in normal years, generous rainfall. Several factors responsible for this include the State's relatively low latitudinal location and a strong moderating influence from warm Gulf Stream water along the coast. Also of importance are the Blue Ridge Mountains to the north and west that help to block or delay the movement of cold air masses from the northwest. Abnormal weather patterns can alter or restrict precipitation, resulting in prolonged dry spells.

Precipitation

The State's average annual precipitation is slightly more than 48 inches. The greatest precipitation occurs in the mountains, where about 80 inches per year falls near Caesars Head (Figure 1-2). Moist air in this area of the State is forced up the mountains to higher and cooler elevations where condensation and precipitation are initiated. Another area of high rainfall is located between 20 and 40 miles inland from the coast where normal yearly rainfall is about 50 inches due to the upward movement of moist ocean air as it moves inland on hot, sunny days. Records indicate the driest area of the State to be Kershaw County, where an average of 44 inches of precipitation falls yearly (National Oceanic and Atmospheric Administration).

There is little difference in monthly rainfall distribution for the months of December through March, with the exception that the monthly total for March is somewhat higher than for any of the previous three months. During March, rainfall along the coast begins to increase, and by May the normal for the southern coast exceeds 5 inches. At the same time, the central part of the State receives only about 3 inches of rain and the mountains more than 5 inches. From June through September, the most important features of the summer rainfall are the heavier amounts in the mountains and near the coast. During this period, the coastal maximum rainfall migrates north along the coast. During September, the greatest rainfall occurs along the coast. This is due to the passage of tropical storms and hurricanes that may influence coastal weather at this time of year. During the fall months, September through November, precipitation is at a minimum throughout the State. Any heavy precipitation during this period is likely to be the result of a hurricane or early winter storm.

The greatest documented 24-hour rainfall was 14.80 inches observed at Myrtle Beach on September 16, 1999. The greatest total annual precipitation occurred in 1979 at Hogback Mountain in Greenville County, where more than 120 inches was recorded. In 1954, the beginning of one of South Carolina's record droughts, only 20.73 inches of precipitation fell at Rimini, in Clarendon County, to set the record annual low for the State.

Snow and sleet fall occasionally during the winter months of December through February. Snow generally occurs one to three times per winter, and seldom do accumulations remain except in the mountains. Freezing rain also falls occasionally during winter in the northern half of the State.

Several places in the State receive anomalously low annual precipitation of only 38 to 40 inches. Most of these sites are extremely localized and are usually east of the larger inland lakes. Because this appears to be a local phenomenon, these areas usually are not indicated on annual-precipitation maps.

Severe droughts occur about once every 15 years, with less severe widespread droughts about once every 7 years. During more than half of the summers, there are periods without sufficient rainfall for many crops.

Severe weather in the form of violent thunderstorms, hurricanes, and tornadoes occurs occasionally. Thunderstorms are common in the summer months, but violent storms usually accompany squall lines and cold fronts in the spring. These storms are characterized by lightning, hail, and high winds, and they sometimes spawn tornadoes. Most tornadoes occur from March through June, with April being the peak month. Historically, hurricanes are more frequent in late summer and early fall; however, these tropical cyclones have affected South Carolina as early as May and as late as November.

Temperature

The State's annual average temperature is about 61ºF. Local averages range from 55.2ºF at Caesars Head in the mountains to 66.2ºF along the southern coast at Beaufort (Figure 1-3).

Elevation, latitude, and distance from the coast are the main influences on temperature. In the mountains, temperature variation above 1,000 feet is due almost entirely to differences in elevation. The State's record low of -19ºF was recorded at Caesars Head on January 21, 1985. Along the coast, ocean water shows very small daily and annual changes in temperature when compared with the land areas. The air over coastal water is cooler than the air over land in summer and warmer than the air over land in winter, thus providing a moderating influence on temperatures at locations near the coast. Records show maximum temperatures along the coast to average 4ºF to 5ºF lower than maximum temperatures in the central part of the State. In July, the daily range in temperature is about 13ºF along the coast and about 21ºF in the central part of the State. The daily range in January is 16ºF along the coast and about 23ºF in the center of the State. The lack of any moderating influence in the interior of South Carolina has resulted in higher daily maximum temperatures. The record high temperature, 111ºF, has occurred in central South Carolina three times within the past 60 years: at Calhoun Falls on September 8, 1925; at Blackville on September 4, 1925; and at Camden on June 28, 1954. January is the coldest month, with monthly normal temperatures ranging from 39.0ºF at Caesars Head to 51.4ºF at Beaufort. July is the hottest month, with monthly normal temperatures ranging from 71.5ºF at Caesars Head to 81.5ºF at Charleston.

The growing season ranges from 201 days at Caesars Head to 294 days at Charleston. In the central region of the State, the average date of the last freezing temperature in spring ranges from March 10 in the south to April 1 in the north. Fall frost dates range from late October in the north to November 20 in the south. Minimum temperatures of less than 32ºF occur on about 70 days in the upper portion of the State and on 10 days near the coast. The central part of the State has maximum temperatures of 90ºF or more on about 80 summer days. There are 30 such days along the coast and 10 to 20 in the mountains.

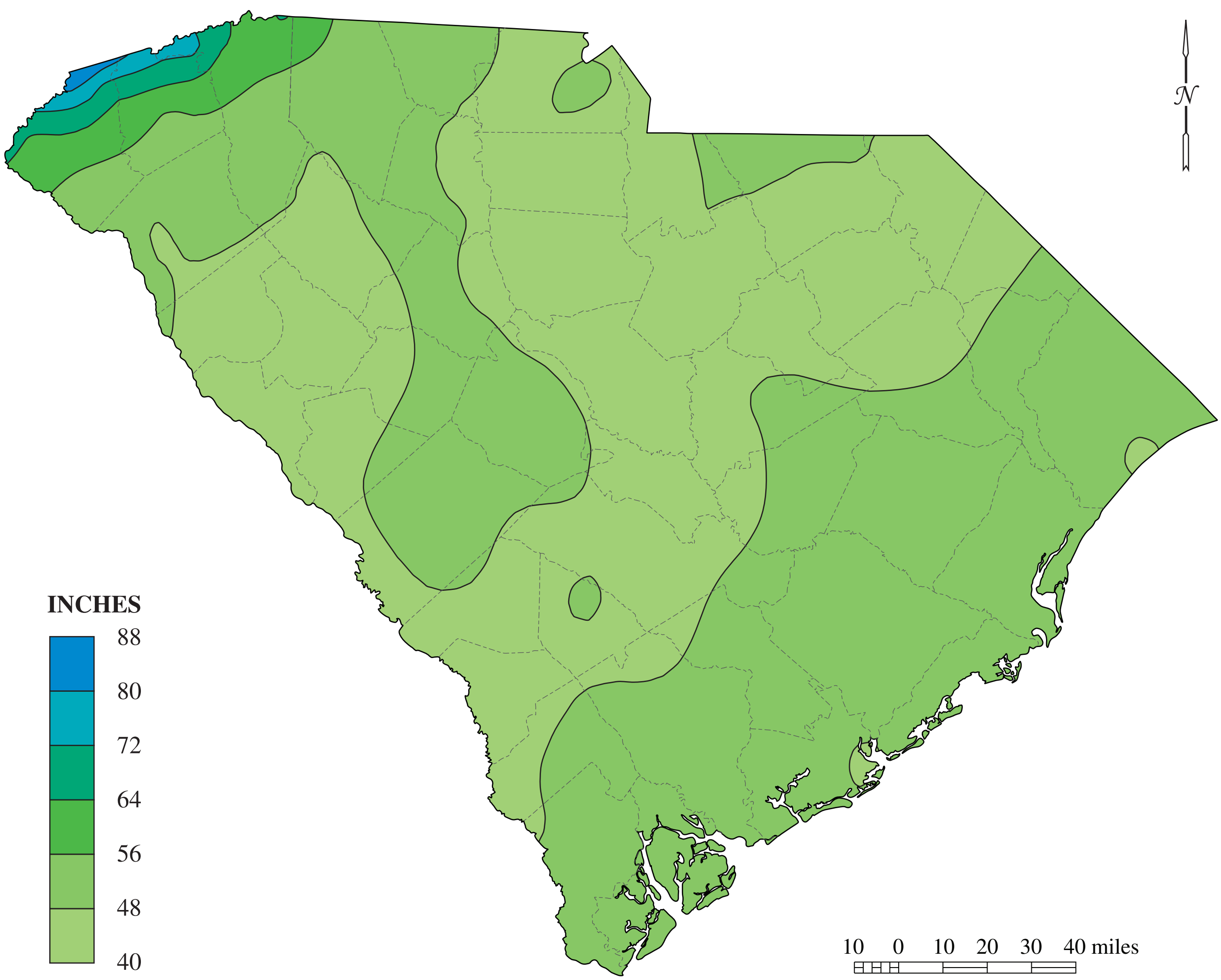

Figure 1-2. South Carolina precipitation, based on 1971–2000.

Relative Humidity

Relative humidity varies more with time of day than it does from day to day or month to month. Highest values, about 90 percent, are reached early in the morning, and the lowest values, 45 to 50 percent, occur around noon. Summertime values are about 10 percent greater than those of winter.

Winds

Winds are predominantly southwesterly and northeasterly over most land areas. Along the coast, the wind direction is distributed fairly evenly in all directions. Average wind speeds are 6 to 10 miles per hour.

NATURAL RESOURCES

South Carolina's abundant natural resources contribute much to the State's scenic beauty, economy, and recreational opportunities. Agricultural and silvicultural enterprises are sustained by fertile soils and vast forestlands. In addition, a variety of minerals on and beneath the land's surface supports a diversified minerals industry, and an abundance of fish and wildlife share and contribute to the state's natural riches.

Soils

The Soil Conservation Service has divided the State into six land-resource areas based on soil conditions, climate, and land use: Blue Ridge Mountains, Southern Piedmont, Carolina-Georgia Sandhills, Southern Coastal Plain, Atlantic Coast Flatwoods, and Tidewater Area (U.S. Department of Agriculture, 1978) (Figure 1-4). These land-resource areas generally conform to physiographic provinces, but they are defined by soil characteristics that provide a basis for identifying potential land-use types.

Blue Ridge Mountains. The Blue Ridge Mountains Land Resource Area is in the northwestern corner of the State and consists of dissected, rugged mountains with narrow valleys. Elevations range from 1,000 to more than 3,500 feet. Most soils are moderately deep to deep on sloping-to-steep ridges and side slopes. The underlying

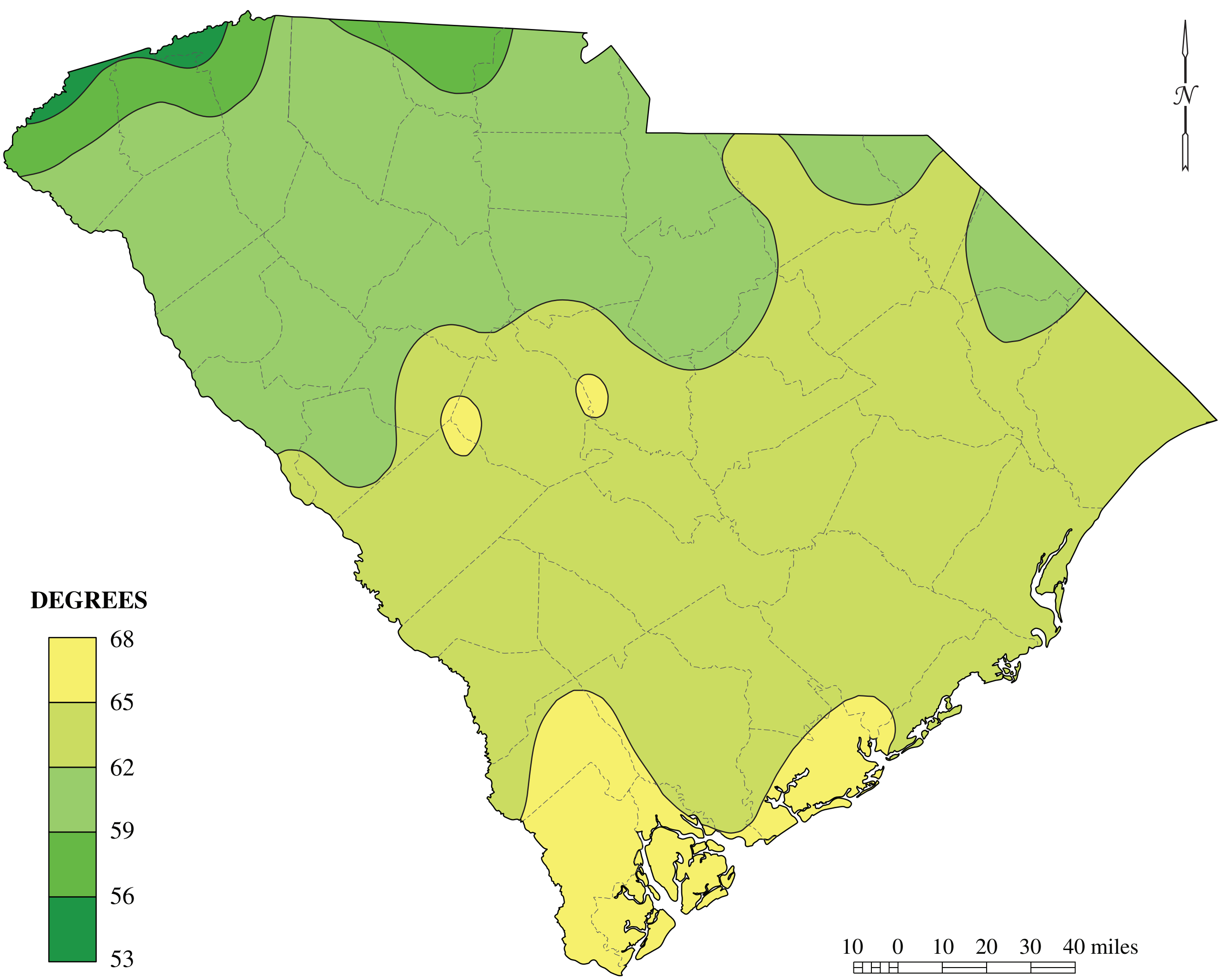

Figure 1-3. Annual mean temperature, based on 1971–2000.

material consists mainly of weathered schist, gneiss, and phyllite. Seventy percent of the area is forested with a mixture of oak, hickory, and pine. Small farms take up 10 percent of the area and primarily produce truck crops, hay, and corn.

Southern Piedmont. The Southern Piedmont Land Resource Area is an area of gentle to moderately steep slopes with broad to narrow ridge tops and narrow stream valleys. Elevations range approximately from 375 to 1,000 feet. The region is covered with strongly acid, firm clayey soils formed mainly from gneiss, schist, phyllite, and Carolina slate. Large areas of land centered near Chester and York Counties have moderately acidic to moderately alkaline soils that were formed mainly from diorite, gabbro, and hornblende schist. Similar soils occur in less widespread areas of Abbeville, McCormick, and Greenwood Counties. Approximately two-thirds of the area is forested with mixed hardwoods and various pines, and nearly 30 percent of the land is used for farming. Cotton, corn, and soybeans are the major crops.

Carolina-Georgia Sandhills. The Carolina-Georgia Sandhills Land Resource Area is characterized by moderately to strongly sloping uplands with elevations ranging from 250 to 450 feet. The sandy soils are underlain by sandy or loamy sediments. They are mostly well drained to excessively drained. About two-thirds of the Sandhills region is covered with a wide range of forest types. Cotton, corn, and soybeans are grown in this land-resource area.

Southern Coastal Plain. The Southern Coastal Plain Land Resource Area is a region of gentle slopes with increased dissection and moderate slopes to the northwest. Elevation generally ranges from about 100 to 450 feet. The loamy and clayey soils of the region are well suited for farming. These soils are underlain primarily by loamy, clayey, and sandy sediments. Many soils in the Coastal Plain are poorly drained except for sandy slopes and ridges, which are excessively drained.

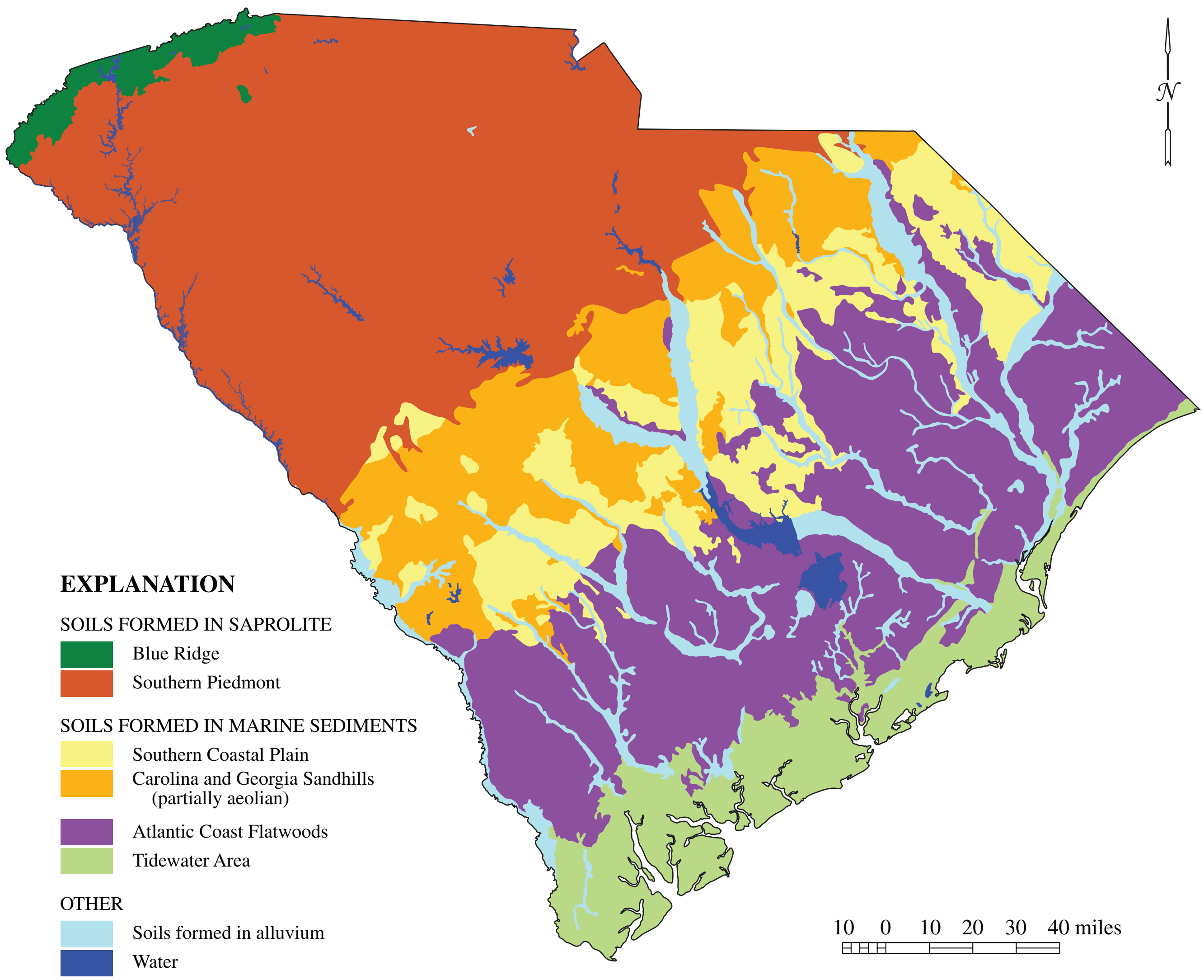

Figure 1-4. Generalized land-resource and soils map of South Carolina.

Atlantic Coast Flatwoods and Tidewater Area. The Atlantic Coast Flatwoods Land Resources Area and the Tidewater Area are products of recent geological processes. Elevations range from sea level to about 125 feet. Four general groups of soil are found in this region of nearly level coastal plain dissected by broad valleys with meandering streams. Loamy and clayey soils of the wet lowlands are predominant. These areas are underlain mostly by clayey sediments and some soft limestone. Wet, sandy soils on broad ridges can be found in strips near the coast and extensively in Hampton County. These soils are underlain by sandy and loamy sediment. Well-mixed soils underlain by clayey and loamy sediments are found in flood plains of the numerous rivers. The salt marshes and beaches of the coast consist of clayey and sandy sediments, respectively. Approximately two-thirds of the region is forested. Truck crops, corn, and soybeans are the major farm crops.

Mineral Resources

South Carolina produced $531 million in mineral commodities in 2001. This was nearly five times the value of minerals produced in 1980. Output from the Palmetto State's 503 mines placed it 27th among the 50 states in nonfuel mineral production value and accounted for approximately 1.0 percent of the U.S. total. The leading product was cement (Portland and masonry), followed by crushed stone and construction sand and gravel. These three commodities composed about 90 percent of the State's mineral production. Kaolin, industrial sand and gravel, and vermiculite were the next most important commodities by value. South Carolina ranked eleventh in the production of Portland cement, fourth in masonry cement, third in kaolin, eleventh in industrial sand and gravel, and first in vermiculite. Gold, which had been a significant commodity for more than 10 years, was not produced in 2001. Kennecott Mineral Co.'s Ridgeway Gold Mine ceased operations in the fall of 1999.

Active mines were reported in 44 of South Carolina's 46 counties. Horry County led the State with 47 active mineral mines, followed by Aiken (34) and Charleston (33). Figure 1-5 shows South Carolina counties that produce stone products, clay, sand and gravel, and various minerals.

Cement production, which ranked first in value and third in tonnage, was worth $254 million for 3,310,000 metric tons. Portland cement made up $211 million of that production for 2,920,000 metric tons. Masonry cement constituted $43 million for 390,000 metric tons. Limestone is mined in Orangeburg and Berkeley Counties for the manufacture of cement and in Berkeley and Cherokee Counties as a source of agricultural lime.

Crushed-stone production was second to cement in value at $180 million and was first in tonnage with 27,200,000 metric tons. Rock types quarried and crushed for use as aggregate in concrete, macadam, and road construction include granite, limestone, and marl. Granite accounted for 79 percent of crushed-stone production and was valued at $147 million for 22,000,000 metric tons in 2000. Granite quarried for dimension stone from mines in Kershaw County was worth $855,000 for 9,230,000 metric tons in 1999. Dimension stone is extracted in blocks, mainly for use in buildings, monuments, and curbing. Limestone was second of the crushed-stone commodities, with a value of $24 million for 4,330,000 metric tons.

Construction sand-and-gravel placed third in value at $40 million and second in tonnage with 10,100,000 metric tons. With mines in 36 counties, sand-and-gravel production is the most widespread mining activity in South Carolina. It is mainly used as aggregate in concrete and asphalt and as fill. Industrial-quality sand is mined and processed in Lexington County for glassmaking, sandblasting, foundry, and filtration applications.

Kaolin ranked fourth in value at $20 million for 422,000 metric tons, or about $50 a ton. It is mined from numerous pits near the upper edge of the Coastal Plain and used in the paper, rubber, and ceramic industries.

Other important mineral commodities mined in South Carolina are vermiculite, manganiferous schist, sericite, and peat. Vermiculite's principal use is as a soil-conditioning additive. It is also used as lightweight aggregate in concrete, plaster, and fireproofing. Manganiferous schist is mined for coloration in bricks. Sericite is processed for use as an inert filler in paint and expansion-joint cement, and peat is a soil conditioner.

Although not mined presently, gold has been an important resource since the early 1800's. The mines yielded 300,000 troy ounces in three different eras: 1829–1858, 1866–1917, and 1931–1943. From 1985 to 1999, South Carolina produced about 1.7 million troy ounces from mines in Chesterfield, Fairfield, Lancaster, and McCormick Counties. South Carolina was the only gold producer east of the Mississippi River for much of that period, and the Ridgeway mine in Fairfield County was the largest producer (Table 1-2). Silver was a by-product of the gold mining. Other metals with production histories are copper, lead, silver, and tin.

Phosphate, used as fertilizer, was mined from 1867 to 1913 between Charleston and Beaufort. In 1938, reserves were estimated at 9 million tons. Encroaching development, environmental constraints, and production costs make it unlikely that this district will be mined again.

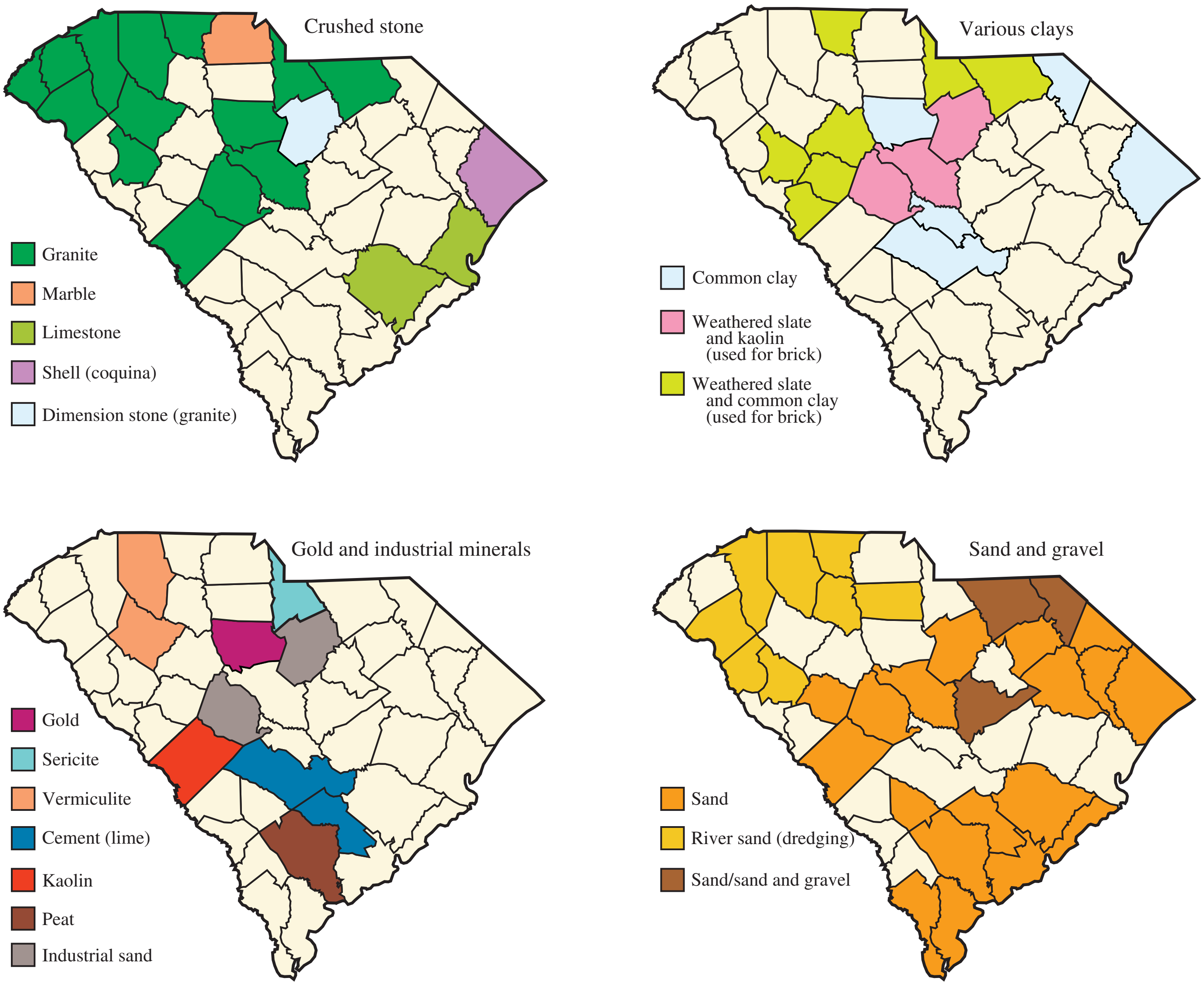

Figure 1-5. Mineral products mined in South Carolina counties (South Carolina Geological Survey, 2000).

Table 1-2. Gold-mine production in South Carolina

Company	Mine	County	Year mining started	Year gold production ended	Total gold production
Kennecott Ridgeway Mining Company	Ridgeway Mine	Fairfield	1988	1999	1.4 million ounces. Figures from company.
Brewer Gold Company	Brewer Mine	Chesterfield	1987	1994	192,000 ounces. Figures from former employee.
Haile Mining Company	Haile Mine	Lancaster	1985[1]	1992	86,000 ounces. Figures from company.
Gwalia Resources (USA), Ltd.	Barite Hill Mine	McCormick	1991	1995 - 1996	50,000–60,000 ounces. Estimated.

[1]Intermitent mining since 1829.

Sources: South Carolina Geological Survey and South Carolina Department of Health and Environmental Control

Forestry

South Carolina has a rich forestry heritage, and timber production has been an important industry since the late 1600's. The forest-products industry is the third largest manufacturing industry in the State, behind textiles and chemicals. Forests provide more than economic advantages, however. The State's extensive forests provide habitat for wildlife, areas for outdoor activities, and enhancement of environmental quality. Forests contribute scenic beauty, improved water quality, erosion control, and recreational opportunities that range from hunting to bird watching. Monetary values are difficult to place on such benefits.

Today, 12.3 million acres, representing about 60 percent of the State's land area, is forest land (Table 1-3). Timber is the largest cash crop, producing a delivered value of $876 million annually. Forest and wood products account for $5.4 billion worth of commodities and goods every year, or nearly 12 percent of the State's economic output. The more than 30,000 people employed in forestry-related industry represent 9.3 percent of the State's manufacturing employment and 2.5 percent of its total employment. Some aspect of forestry, whether it is growing, harvesting, or manufacturing, occurs in every county and benefits local, county, and regional economies. Figure 1-6 shows the distribution of the State's primary forest-product manufacturing facilities.

Table 1-3. Acreage of timberland by forest type and ownership in South Carolina – 2000

Forest type	Public acres	Private acres	Total acres
Softwood types			
White pine and hemlock	8,200	1,600	9,800
Longleaf and slash pine	182,800	364,000	546,800
Loblolly and shortleaf pine	557,400	4,855,100	5,412,500
Total softwood	748,400	5,220,700	5,969,100
Hardwood types			
Mixed hardwood	75,300	1,351,700	1,427,000
Upland hardwood	204,400	2,188,600	2,393,000
Bottomland hardwood	207,700	2,262,300	2,470,000
Total hardwood	487,400	5,802,600	6,290,000
All types	1,235,800	11,023,300	12,259,100

Pulpwood is the leading timber product in the State. It accounted for 52 percent of total product output in 1999, while sawlogs, both hardwood and softwood, accounted for 38 percent. Ten percent of total product output came from miscellaneous products including peeler logs (mainly for plywood), poles, pilings, and posts.

About 23 percent of the timber harvested is hardwood and 77 percent is softwood. The primary species of managed timber is the loblolly pine. It grows on a wide range of soils and is indigenous to all but the extreme northwestern counties. Various oak species are the primary hardwoods harvested.

Individuals own about 74 percent of private-commercial forestland; the forest industry holds 16 percent. Ten percent of commercial forests are publicly owned, and the ownership is equally divided between national forests and other public lands.

Fish and Wildlife

A diversity of habitat in South Carolina supports a wide variety of animal life. More than 400 species and subspecies of birds can be found in the State. Endangered species that receive significant management priority include the Southern bald eagle, red-cockaded woodpecker, piping plover, and wood stork. South Carolina is one of the most important wintering areas for migratory waterfowl in eastern North America, and the wood duck is a year-round resident. The wild turkey and bobwhite quail are upland gamebirds that also are subjects of conservation efforts.

Mammals, likewise, are widespread and diverse. The large-game species and furbearers are managed statewide. Amphibians and reptiles are widespread, and several threatened and endangered species are present. These include the gopher tortoise, flatwoods salamander, gopher frog, American alligator, bog turtle, spotted turtle, and loggerhead sea turtle. The wide variety and abundance of freshwater and marine fishes supports an important commercial fish industry in the State and provides anglers with exciting recreation. Fish species are diverse and include trout from the coldwater streams in the Blue Ridge region, the famous land-locked striped bass of the Santee Cooper lakes, and marine game fish such as cobia, bluefish, and swordfish.

South Carolina can be divided into six major types of habitat: forested; grassland, cropland, and brush; coastal wetland; riverine wetland; aquatic; and beach (U.S. Army Corps of Engineers, 1972).

Forested. The forests of the State, exclusive of swamplands, can be separated into three types: deciduous, evergreen, and mixed. A major factor affecting the species located in these areas is the density of vegetative growth.

The deciduous forests support a diversity of species including wild turkey, mourning dove, numerous neotropical migratory songbirds, and raptors such as the red-tailed hawk and great horned owl. Mammals common to this forest type include raccoon, opossum, gray squirrel, Southern flying squirrel, chipmunk, Eastern cottontail, whitetailed deer, and bear. The Eastern box turtle, black rat snake, Eastern hognose snake, copperhead snake, and various salamander species are representative of different amphibians and reptiles preferring the type of vegetation common to the hardwood forests.

Managed evergreen forests also support a wide array of wildlife. The longleaf pine ecosystem, although greatly reduced from historic levels, is among the most diverse of all forest systems, supporting hundreds of plant and animal species. The red-cockaded woodpecker, an endangered species, makes its home in pine forests where it prefers to live in old and diseased pine trees, particularly longleaf pine. Trees meeting these requirements are increasingly rare and are harder for the bird to find because of modern forest-management techniques.

The mixed forests have a wide variety of animal species common to both hardwood and evergreen forests. Many animal species have no difficulty adapting to different forest types as conditions and seasons change.

Grassland, Cropland, and Brush. These habitat areas consist mostly of agricultural lands but also include grasslands of improved and unimproved pasture and fields that have converted to brush. Parks and other vegetated zones of urban and suburban areas are included in this group.

Generally, only small birds and mammals are found near the fields and croplands, although larger mammals and birds of prey may feed and hunt here. Birds such as meadowlarks and sparrows are common, as is the cottontail rabbit, which is extremely widespread. Fallow fields and brushlands provide ideal management opportunities for quail and other grassland birds.

Coastal Wetlands. Both tidal and freshwater marshes make up this habitat. The freshwater marshes are the most important to waterfowl, although the salt marshes are used extensively by feeding ducks and geese. Rails, or marsh hens, are significant game birds, common in the salt marshes from Savannah to Murrells Inlet. Dabblers, diving ducks, and coot winter in the coastal area. Other occasional waterfowl include the Canada goose, blue goose, snow goose, and whistling swan. Coastal wetlands are also important as nesting areas for numerous bird species, including osprey and Southern bald eagle. Aquatic furbearers are found throughout the habitat and include muskrat, mink, and otter. The American alligator is found in the marshes and has reestablished itself owing to Federal protection.

Riverine Wetlands. This habitat consists mainly of wooded swamps along streams. Significant examples are the Santee Swamp, Four Hole Swamp, and Congaree Swamp. Flooding provides nourishment to the bottomland

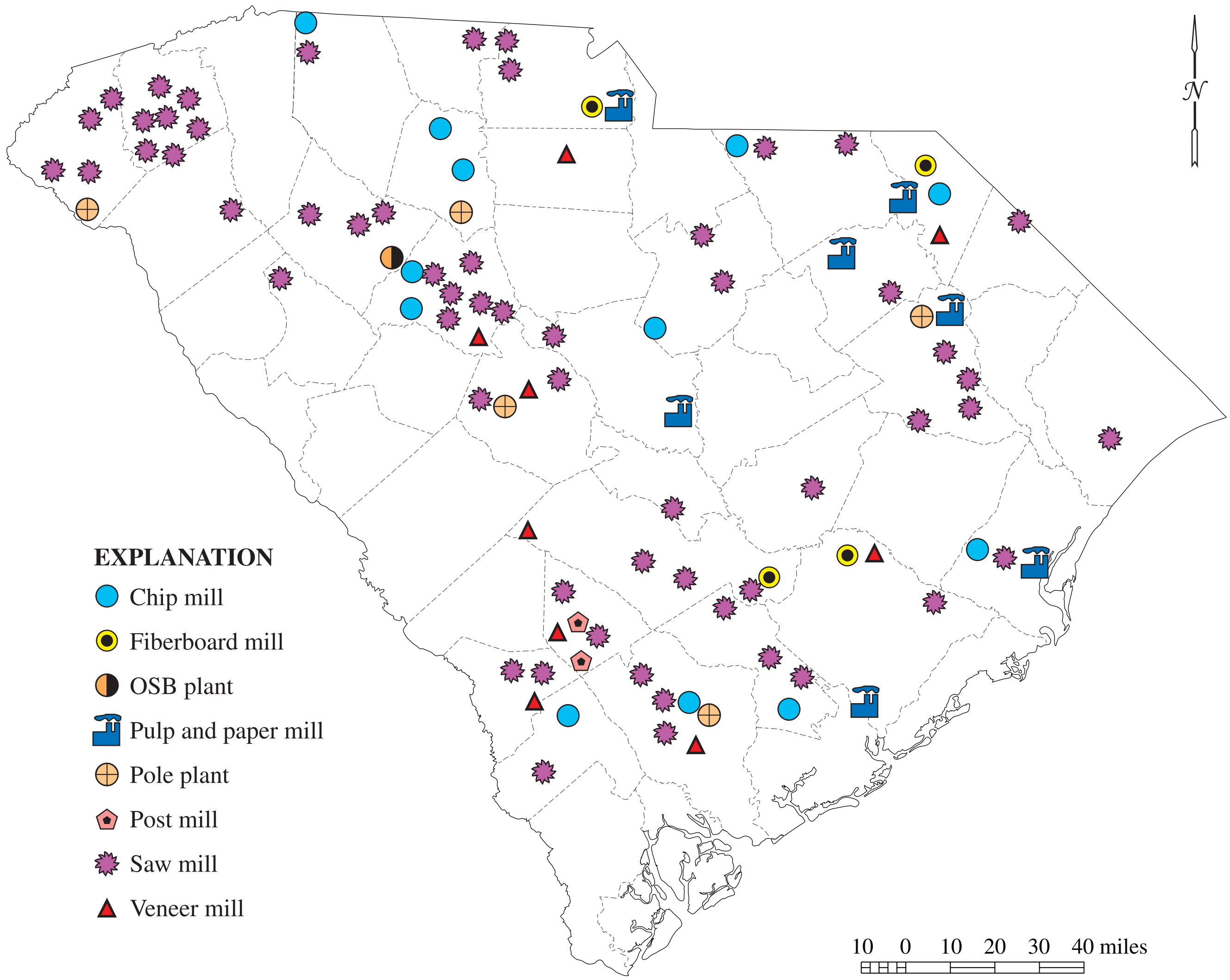

Figure 1-6. Locations of primary forest-product manufacturing facilities in South Carolina.

hardwoods and cypress trees characteristic of the habitat and contributes an abundance and diversity of fauna and flora. Many bird species are found in riverine wetlands, including owls, hawks, and wild turkeys. Bachman's warbler, a rare songbird, has been sighted in this habitat. Waterfowl, with the exception of the wood duck, do not nest in these areas. Small game and furbearing mammals are numerous and include rabbit, squirrel, opossum, raccoon, fox, muskrat, mink, and otter. Beaver colonies are found statewide, as are deer, bobcat, and black bear.

Aquatic. This habitat includes both marine and freshwater environments. The marine habitat is extensive along the entire coast and is found in the form of bays, sounds, inlets, and creeks. Approximately 160 species of saltwater fish are found in this area, of which most are inshore species. A few of the species are flounder, sheepshead, and striped bass. Offshore migratory species include tuna, mackerel, jacks, and bluefish, and examples of offshore bottom fish are black sea bass, snappers, and porgies. Oysters, shrimp, and blue crabs are the most important commercial shellfish. Numerous shorebirds live in this area and include the American oystercatcher and the osprey.

Freshwater-fish habitats include the coldwater streams of the mountains, warmwater inland lakes, and blackwater streams of the Coastal Plain. Brook, rainbow, and brown trout are stocked annually where water temperatures are sufficiently cool. These streams are generally above 1,400 feet elevation. Warmwater fish, including bass, bream, catfish, and crappie, may be found in rivers, lakes, and ponds across the state. The Santee Cooper lakes (Marion and Moultrie) are the site of South Carolina's famous striped bass (rockfish) fishery. These fish are managed intensively and are shipped to other lakes in the country. The lakes also are important waterfowl habitats.

Beach. Beach is the least extensive of all habitats in South Carolina. Beaches north of North Inlet are heavily developed and used for recreational purposes, and they consequently provide little wildlife habitat. The beaches south of North Inlet are less densely developed or are undeveloped, and they provide important habitat to the loggerhead turtle and brown pelican, two species that lay their eggs in the sand.

PHYSIOGRAPHY AND GEOLOGY

The abundance, diversity, and beauty of the State's water resources, including its mountain waterfalls, verdant swamps, Carolina bays, and valuable saltwater wetlands, are derived from a variety of physiographic domains. Those domains, broadly classified as the Blue Ridge, Piedmont, and Coastal Plain provinces, are the result of climatological and geological processes that occurred for many millions of years and that continue to alter the modern landscape.

Historical Overview

About 1.1 billion years ago North America's ancestral continent, Laurentia, was deformed and metamorphosed by a collision of continents, and the mountain range formed by that event was worn down over the next several hundred million years. The Toxaway Gneiss of northwestern South Carolina is a remnant of those ancient events and is South Carolina's oldest formation. Laurentia then began to rift (split and spread apart) 700 to 750 m.a. (million years ago), forming the Iapetus Ocean and a new eastern margin of North America. Evidence of the rift is found in the sedimentary and volcanic strata overlying the Toxaway Gneiss.

Several oceans formed off ancestral eastern North America during the Paleozoic Era in a series of continental rebounds and collisions that attached foreign terranes. Three collisional episodes occurred in the southern Appalachian Mountains, and a variety of sedimentary, volcanic, and metamorphic rock, plutons, folds, and faults in South Carolina's Inner Piedmont reflect those episodes of 470 to 270 m.a.

Mesozoic rifting, about 200 m.a., broke up the Appalachians and led to formation of the Atlantic Ocean. During that period, one of the largest volcanic events in the earth's history intruded diabase dikes and sills throughout the Piedmont and some Mesozic basins. Volcanism related to these dikes has been blamed for worldwide animal-life extinction at the end of the Triassic Period.

At the beginning of the Cretaceous Period (70 m.a.), uplift in the Blue Ridge and Piedmont produced an outpouring of deltaic and marine sediments that now compose about two thirds of the Coastal Plain stratigraphic section. During the Paleocene Period (68–58 m.a.), sea levels were lower and deposition on the Coastal Plain diminished. Miocene sea levels transgressed landward in several episodes (58–37 m.a.), and sand, silt, clay, and limestone were deposited over the middle and lower Coastal Plain. No major marine transgression occurred again for nearly 30 million years, but a unique uplift in the Blue Ridge and upper Piedmont, 10 million years ago, produced an apron of stream-transported sediment across the upper Coastal Plain. Pliocene and Pleistocene marine transgressions in the past 2½ million years, caused by retreats and advances of continental glaciers, deposited thin but widespread marine sand and lesser carbonate layers across the Middle and Lower Coastal Plain. Figure 1-7 illustrates the structure of the rocks and aquifers formed during South Carolina's geologic history.

Physiographic Provinces

Blue Ridge Province. The Blue Ridge province occupies only 2 percent of the State's land area and is located on the northwest edge of South Carolina (Figure 1-8). This mountainous region has elevations ranging from 1,000 feet in the foothills to 3,554 feet at Sassafras Mountain. Although physiographic and geologic boundaries usually coincide, northwestern South Carolina is an exception. The Blue Ridge-Piedmont physiographic boundary is the steep break in topography at the Blue Ridge front that trends N70ºE across northern Oconee, Pickens, and Greenville Counties. The Blue Ridge-Piedmont geologic boundary in this area is the N45ºE–trending Brevard fault zone. As the Blue Ridge front extends eastward from the Brevard zone across Piedmont geologic units, there is no correlation between the topography and the underlying rock formations (Figure 1-9).

The Toxaway Gneiss and the Tallulah Falls Formation represent the rocks of the Blue Ridge geologic province in South Carolina. The 1.2-billion-year-old Toxaway Gneiss has a restricted distribution just south of the North Carolina line. It typically is a medium-grained, prominently banded, quartzo-feldspathic gneiss. The Tallulah Falls Formation unconformably overlies the Toxaway Gneiss and is composed of schist and amphibolite. The gneiss, folded and metamorphosed during the Grenville orogeny, was folded and metamorphosed again with the Tallulah Falls Formation during the Taconic orogeny, and both formations were thrust northwestward during the Alleghanian orogeny.

Piedmont Province. The Piedmont province includes approximately 35 percent of the State and is between the Blue Ridge and Coastal Plain provinces. The topography is characterized by rolling hills that range in elevation from 1,000 feet near the mountains to about 400 feet at the Fall Line. A layer of chemically weathered bedrock called saprolite mantles the Piedmont in varying thickness.

Geologists recognized a pattern of northeast-trending lithologic belts in the Blue Ridge and Piedmont as early as the 1840's. Later geologists classified these belts mainly by the varying degrees of rock metamorphism, and the names of these metamorphic regions, Blue Ridge, Brevard, Inner Piedmont, Kings Mountain, Charlotte, and

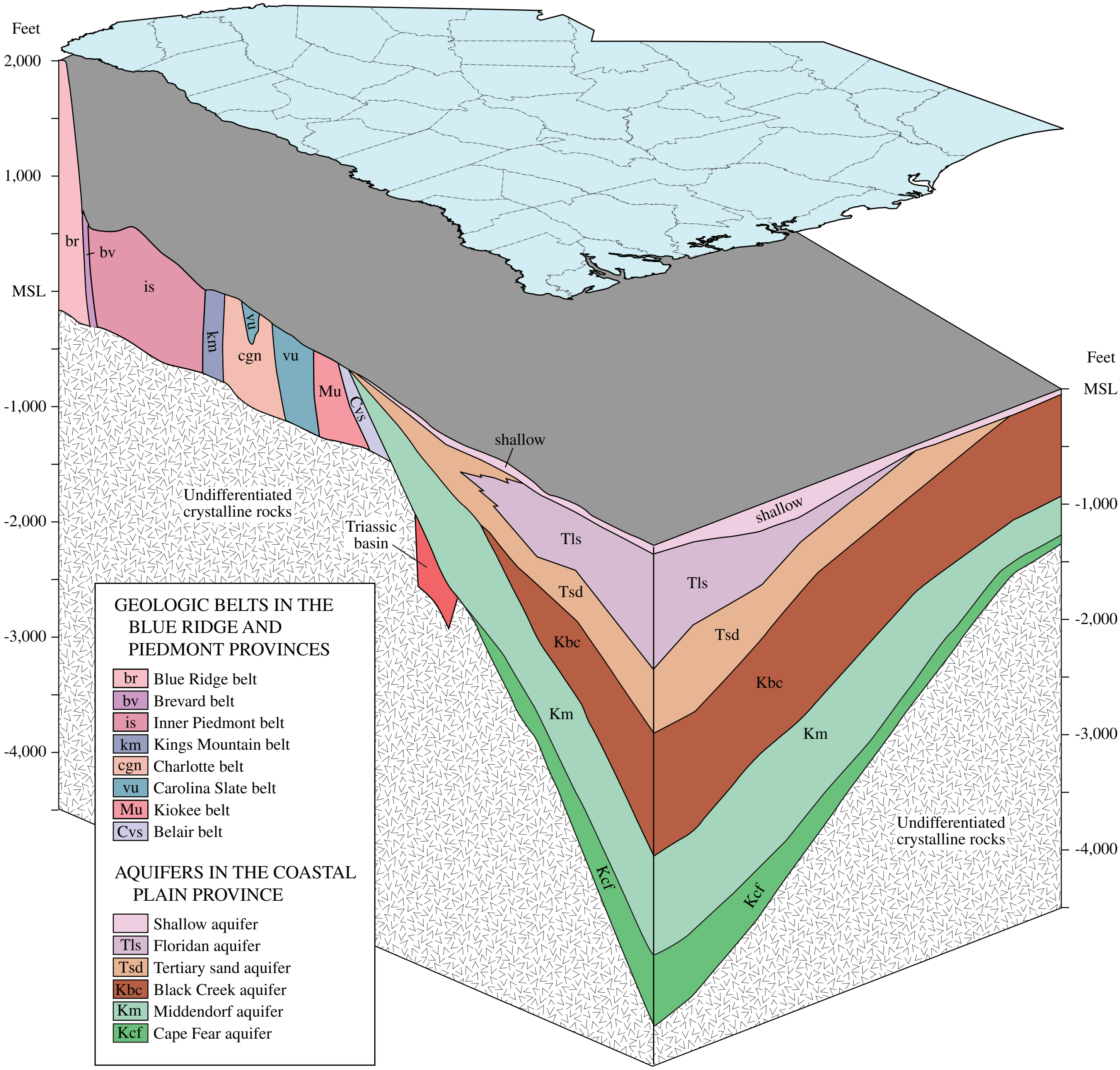

Figure 1-7. Generalized structure of geologic formations in South Carolina.

Carolina Slate belts, remain widely used.

More recent studies characterize Piedmont geology more in the context of Late Precambrian and Palezoic continental collisions and their associated accreted terranes. The terranes are defined as fault-bounded geologic entities of regional extent, an internally homogeneous geology, and a history that is different from contiguous terranes. The Inner Piedmont terrane and the Carolina terrane both are widely recognized in the Carolinas.

The Inner Piedmont terrane lies between the Brevard fault zone and three linked faults: the Lowndesville shear zone, the Central Piedmont fault, and the Kings Mountain shear zone. There are several interpretations of three geologic subareas within the terrane, and the most recent describes them as thrust sheets and thrust complexes. From west to east, they are the Chauga-Walhalla thrust complex, the Six Mile thrust sheet, and the Laurens thrust sheet.

The Carolina terrane, which extends across the Piedmont from Georgia to Virginia, is one of the largest terranes in the Appalachians. Its history begins with a thick deposition of volcanic and sedimentary strata in an island-arc setting during the late Precambrian and early Paleozoic. During the Paleozoic Era, before 415 million years ago, the strata were folded and metamorphosed to form the pattern seen today. Between about 415 and 300 m.a., numerous granitic and gabbroic plutons intruded the strata.

An assemblage of middle-Cambrian (540–523 m.a.) Atlantic Province trilobites near Batesburg, S.C., provides evidence that the Carolina terrane was formed far from North America and later accreted to it, for the trilobite assemblage is most similar to faunas in Poland and Bohemia. The alien fauna and island-arc stratigraphy contrast with the fauna and the continental-margin carbonates to the northwest.

Coastal Plain Province. The Coastal Plain province occupies the southeastern two-thirds of the State. The Piedmont-Coastal Plain contact, or Fall Line, defines the intricate boundary between the two geologic provinces. Along that boundary, Coastal Plain outliers sit isolated in the Piedmont, and here and there restricted areas of Piedmont rock occur along the headwaters of Coastal Plain streams. Elevations on the Coastal Plain land surface along the Fall Line are commonly between 400 and 500 feet but are as low as 250 feet along major rivers and as high as 725 feet near Pageland in Chesterfield County.

The Coastal Plain is divided into three subregions (Figure 1-8): upper, middle, and lower Coastal Plain. The land surfaces of each subregion are successively lower, less dissected, and younger toward the coast. The upper Coastal Plain is bounded by the Fall Line on the northwest

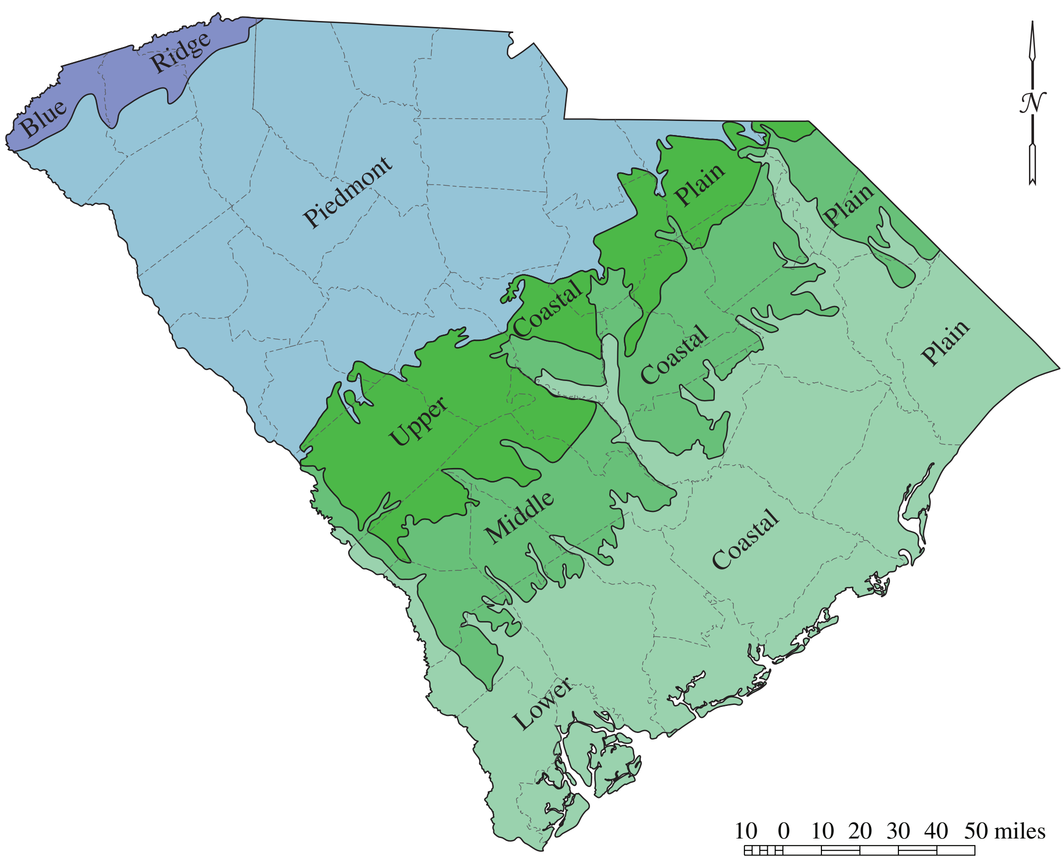

Figure 1-8. Physiographic provinces of South Carolina.

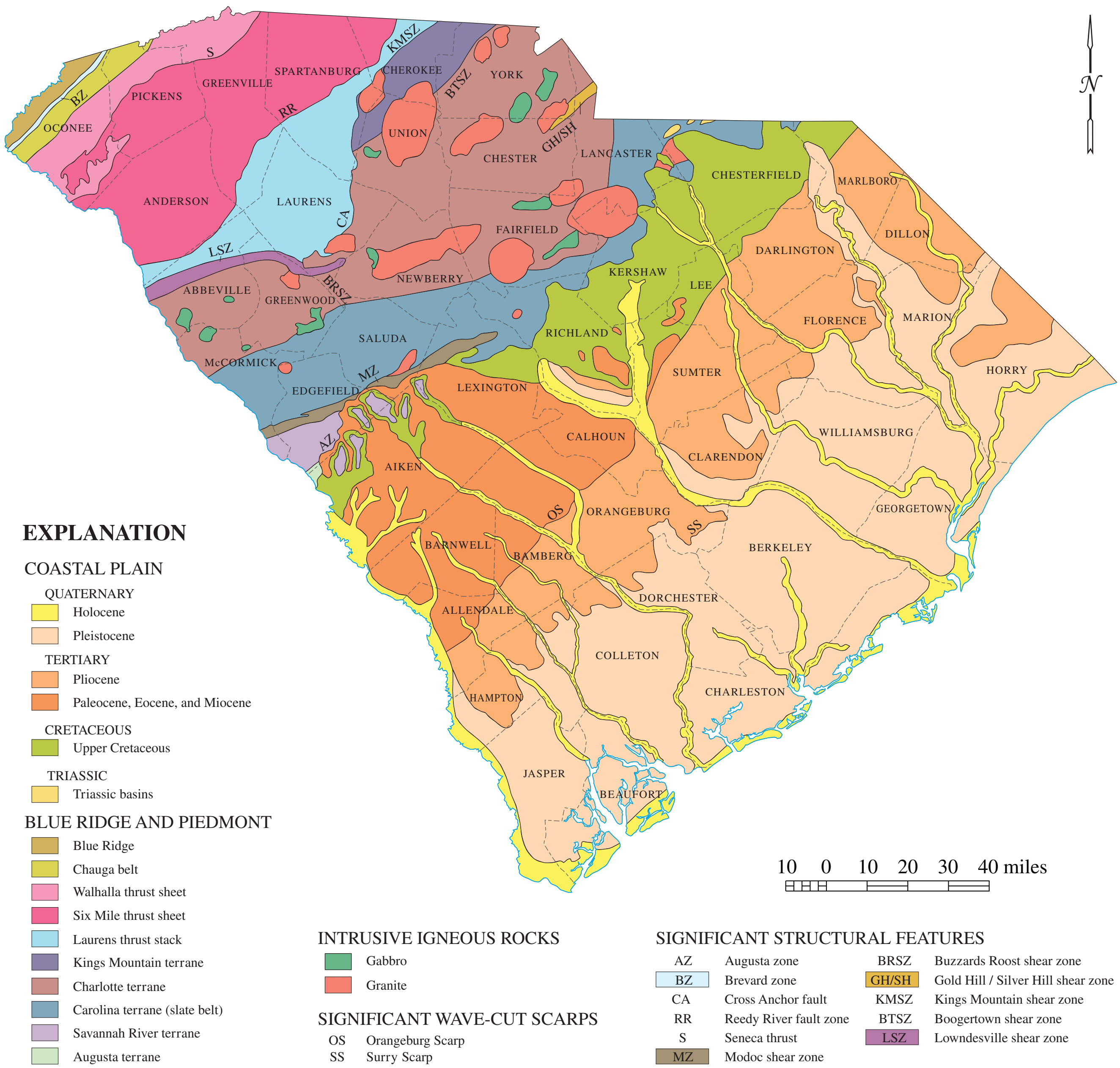

Figure 1-9. Generalized geologic map of South Carolina.

and the Orangeburg Scarp on the southeast. The terrain is characterized by an erosional topography of relatively high relief and high drainage density similar to the lower Piedmont, and it contrasts with the constructional topography to the east. The gently undulating upland surfaces and the underlying soils of the upper Coastal Plain are old: the thick, mineralogically mature soils may be 10 million years old, or an order of magnitude older than the thinner and less mature soils of the Piedmont. Quartz sand derived from the fluvial erosion of the upper Cretaceous and lower Tertiary units during the late Miocene to early Pliocene was transported northeastward by wind to form the largest dune field in the southeastern U.S. Many dunes preserve a distinctive dunal topography and are up to a mile across and 100 feet thick. The contrast in topography between the upper Coastal Plain and the more subdued land surfaces of the middle and lower Coastal Plains suggests that most upper Coastal Plain uplift and erosion occurred prior to deposition of the Pliocene and Pleistocene marine units of the middle and lower Coastal Plain.

The middle and lower areas of the Coastal Plain are distinguished by a stair-stepped topography of terraces separated by scarps. Each successive terrace is younger and lower toward the coast. The advances and retreats of massive continental glaciers caused a series of sea-level highstands during the Pliocene and Pleistocene that deposited the terraced formations. The middle Coastal Plain lies between the Orangeburg Scarp and the Surry Scarp. It is underlain by two upper Pliocene formations separated by the Mechanicsville-Parler Scarp. The region is a gently rolling to flat terrain dissected by transverse streams and locally covered by Quaternary eolian, lacustrian, and alluvial deposits. Elevations range from 215 to 100 feet. The lower Coastal Plain is between the Surry Scarp and the present shoreline. Pleistocene and Holocene deposits underlie the surface.

Metamorphic and igneous rocks similar in type and age to the Carolina terrane underlie the Coastal Plain province. The contact between those rocks and the Coastal Plain strata is an irregular surface that dips southeastward to about 4,000 feet below mean sea level (Figure 1-10). The basement surface beneath the South Atlantic seaboard is characterized by broad upwarps and downwarps. The Cape Fear Arch, the Charleston Embayment, and the Yamacraw Arch are three such structures; geologic sections over the arches provide a less complete stratigraphic record than the thicker sections in the embayments.

Two northeast-trending Triassic basins exist in the crystalline bedrock beneath the Coastal Plain: the

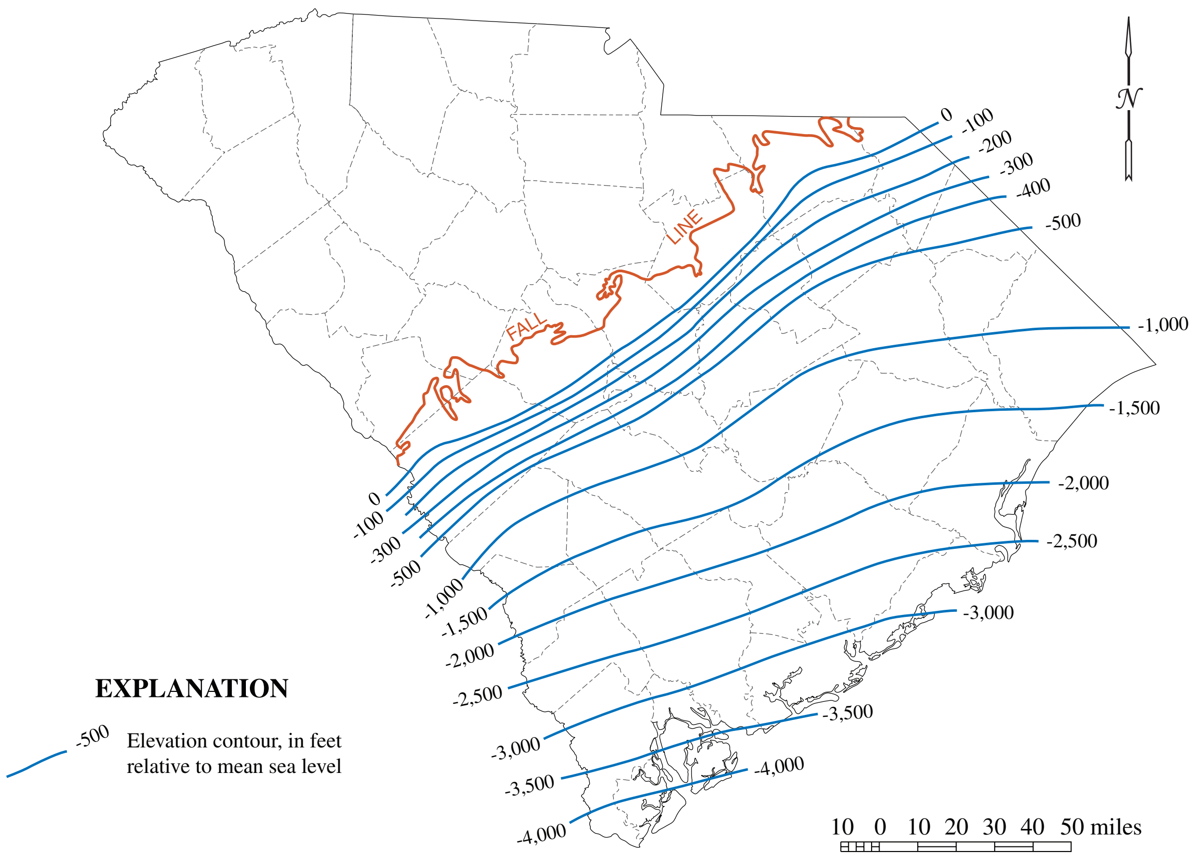

Figure 1-10. Structure contours on top of the crystalline-basement rock of the South Carolina Coastal Plain.

Dunbarton Basin that underlies the Savannah River Site in Barnwell County and the Florence Basin below the Florence area. The large, east-west trending South Georgia Basin extends from South Carolina to Mississippi. It underlies the South Carolina Coastal Plain south of a line between Allendale and Georgetown, and basin sediment consists of red siltstone, sandstone, and some limestone pebbles.

Geologic Formations

Upper Cretaceous Formations. The Middendorf Formation is composed of light-colored, crossbedded, kaolinitic sand with lenses of white, tan, red, and purple kaolinitic clay exposed at the surface southeast of the Fall Line. The thickness ranges from a few feet at the Fall Line to 1,060 feet in Beaufort County. The top of the unit dips from a depth of about 50 feet below the land surface in the northern part of the Coastal Plain to about 2,800 feet in Beaufort County.

The Black Creek Formation is composed of dark-gray to black laminated clay with white or gray phosphatic, lignitic, and glauconitic sand, and light-gray sand interbedded with dark-gray marine clay. The formation is exposed along Black Creek a few miles above Darlington. The Black Creek Formation near Sumter is 285 feet thick and occurs from 50 feet above sea level to 235 feet below sea level. At Charleston the top of the unit is 815 feet below sea level, and the base is at about 1,800 feet. At Beaufort, the Black Creek is 2,100 to 2,800 feet below sea level.

The Peedee Formation crops out between Florence and Georgetown Counties. It consists of dark-gray clay interbedded with fine to medium micaceous and glauconitic sand and streaks of hard shelly limestone and siltstone. Dark marine-clay interlayers up to 6 feet in thickness occur but are subordinate. Burrows are common, and the bioturbation may account for the massive character of Peedee sand beds. The top of the formation ranges from 70 feet below mean sea level in the Orangeburg area to more than 1,700 feet in Beaufort County. Thickness of the formation varies from a few feet near the updip limit to 360 feet in the Beaufort area.

Paleocene Formations. Today the Black Mingo is recognized as a group that includes the lower Paleocene Rhems Formation and upper Paleocene Williamsburg Formation in the lower Coastal Plain and the upper Paleocene Lang Syne Formation in the upper Coastal Plain. The Rhems Formation is a light-gray to black shale interlaminated with thin seams of fine-grained sand and mica. The Williamsburg Formation consists of fine-grained silicified mudstone; fossiliferous, laminated, sandy shale; glauconitic, clayey, fossiferous sand; and indurated, molluscan-rich limestone. The Lang Syne Formation is composed of glauconitic, pebbly, poorly sorted sand; thin-bedded, micaceous, medium-grained quartz sand interlayered with clay laminae; and thick dove-gray to black beds of fullers earth. The Lang Syne Formation overlies upper Cretaceous strata in exposures in Lexington, Richland, Calhoun, Sumter, and Lee Counties.

Lower and middle Eocene Formations. The updip Fourmile Branch Formation and downdip Fishburne Formation are subsurface units apparently of the same lower Eocene depositional sequence. The Fourmile Branch Formation consists of as much as 30 feet of mainly orange, green, yellow, or tan, moderately to well-sorted, fine- to coarse-grained quartz sand. Green and gray clay beds, several feet thick, occur in the middle and upper parts of the unit. The Fishburne Formation, named for Fishburne Creek in southern Dorchester County, is a greenish-gray, glauconitic, impure, clayey, fine-grained, poorly stratified limestone. Thin (24 to 74 feet thick) but laterally persistent, the unit occurs near the coast and southwest of the Charleston-Summerville area.

The Huber and Congaree Formations, exposed in the upper Coastal Plain, are updip-downdip facies variants of a Lower Eocene to lower middle Eocene sequence. The Huber Formation is characterized by distinctive, cross-bedded, poorly sorted, generally coarse sand with kaolin balls, and commercial kaolin deposits are found in the upper part of the unit. Its lower part consists of thinly layered, well-sorted, fine-grained sand with minimal interstitial clay and thin, laterally continuous clay interlayers. The Huber Formation grades downdip into medium-grained, cross-bedded quartz sand of the upper part of the Congaree Formation and green, thinly layered, indurated claystone in the lower part of the unit. The Huber and Congaree Formations are about 60 feet thick throughout their outcrop area. In the Tertiary outcrop area above the Orangeburg Scarp, the Huber-Congaree depositional sequence is, by far, the most widespread stratigraphic unit. From Aiken County along the Fall Line to Lexington County, a distance of 39 miles, the Huber Formation overlaps upper Cretaceous strata and lies directly on Piedmont crystalline rocks. The Congaree Formation caps the hilltops throughout the High Hills of Santee in western Sumter and Lee Counties.

The Warley Hill Formation is a distinctive lower Middle Eocene unit composed of dark-green, glauconitic, quartz sand. It has an outcrop area confined to southern Calhoun and northern Orangeburg Counties and is generally 5 to 20 feet thick. The unit grades downdip into glauconitic, calcareous beds in the lower Coastal Plain. In Orangeburg County, the strata include the oyster *Cubitostrea lisbonensis*, a guide fossil to the lower middle Eocene.

Like the Huber-Congaree, the McBean Formation and Santee Limestone are updip-downdip facies of the same middle Eocene depositional sequence. The McBean Formation overlies the Warley Hill Formation and in South Carolina is composed of pale-green, fine-grained, cohesive clayey sand. In Georgia, the unit is a cream-white marl at its type locality. The McBean Formation is restricted in the upper Coastal Plain to the region between the Savannah and Congaree Rivers, and it is characterized by two middle Eocene guide fossils, the oyster *Cubitostrea sellaeformis* and the clam *Pteropsella lapidosa*.

The Santee Limestone is a creamy yellow to white, fossiliferous, indurated sediment that crops out in a belt, about 25 miles wide, from Allendale County on the Savannah River eastward to the Santee River. In the northern part of its outcrop area, the formation contains numerous caverns and sinkholes related to karst topography.

The Orangeburg District bed and Castle Hayne Limestone are updip-downdip facies of the uppermost middle Eocene depositional sequence. The Orangeburg District bed overlies the McBean Formation and is composed of well-sorted, fine- to medium-grained to poorly sorted, medium- to very-coarse-grained sand with minor interstitial clay. The formation is commonly pale yellow with black manganese oxide splotches and with very thin interstratified green clay laminae. Pale green beds of quartz sand with some glauconite occur in the lower part of the unit. Like the McBean Formation, the Orangeburg District bed is restricted in the upper Coastal Plain to south of the Congaree River. A fossil assemblage in the unit at Orangeburg contains 91 molluscs, including the clam *Glyptoactis (Claibornicardia) alticostata*, a guide fossil to the uppermost middle Eocene Gosport Sand of the Gulf Coast region. The Castle Hayne Limestone of the middle and lower Coastal Plain is composed of buff to gray, crumbly fossiliferous limestone. The *Crassatella alta*-bearing limestone beds of the middle and lower Coastal Plains are the downdip carbonate equivalent of the Orangeburg District bed and have been called the Cross Formation.

Upper Eocene and Oligocene Formations. The Dry Branch Formation and the Tobacco Road Sand of the upper Coastal Plain are the lower and upper stratigraphic units of the upper Eocene. The two formations are distinctive and readily mappable. They represent the transgressive and regressive facies of a single depositional sequence. Exposures in Aiken County show wispy clay laminae extending from the uppermost Dry Branch Formation into the very-coarse-grained sand-and-pebble bed at the base of the Tobacco Road Sand, demonstrating continual sedimentation at the contact. The units occur between the Congaree and Savannah Rivers. The Dry Branch Formation typically is composed of poorly-sorted, cross-bedded, golden-yellow sand with beds of green montmorillonite clay in the lower part of the unit and interstratified thin clay layers in the upper part. It is commonly 30 to 40 feet thick. The formation lies on the Orangeburg District bed and overlaps that unit to lie directly on the Congaree Formation. The Tobacco Road Sand is composed of red, purple, or lavender poorly-sorted sand beds, commonly with abundant white, clay-lined burrows. The base of the unit is marked by a 1- to 3-foot clayey, discoidal quartz-pebble bed. The stratum is a distinctive marker bed throughout Aiken and Barnwell Counties and ranges from 30 to 60 feet in thickness. The two formations extend updip to the edge of the Coastal Plain except in parts of Edgefield and Lexington Counties. The Dry Branch Formation and Tobacco Road Sand grade downdip into the Ocala Limestone, the Harleyville Formation, and the Parkers Ferry Formation.

Three formations are generally within the grayish-green marl of the Cooper Group (formerly Cooper Marl or Formation): the late Eocene Harleyville and Parkers Ferry Formations and the Oligocene Ashley Formation. The Harleyville is a compact, phosphatic, calcareous clay, and the Parkers Ferry is composed of glauconitic, clayey, fine-grained limestone with abundant microfossils and locally abundant mollusc and bryozoan fragments. The Ashley Formation is made up of phosphatic, muddy, calcareous, fine-grained sand. The upper Oligocene Chandler Bridge Formation and the uppermost Eocene to lowermost Oligocene Drayton limestone beds now are included, respectively, at the top and middle of the group by recent researchers. The Chandler Bridge Formation is a fossiliferous, noncalcareous phosphatic sand with diverse whale fauna.

Miocene Formations. Near Charleston, three lower Miocene units and one upper Miocene unit have been recognized. The three lower Miocene units include the Tiger Leap Formation, the Parachucla Shale, and the Marks Head Formation. The Tiger Leap Formation is a phosphatic, shelly calcarenite with a patchy distribution. The Parachucla Shale is an olive-gray, dense, silty clay that occurs in the western part of the Charleston area. The Marks Head Formation is an olive-brown, clayey, quartz phosphate sand that is the most widespread of the Miocene units. The upper Miocene Ebenezer Formation is composed of shelly shelf sand and occurs in two small patches between Moncks Corner and Harleyville.

Northwest of the Orangeburg Scarp, a fluvial upland unit of late middle Miocene to early late Miocene age occurs on the high parts of the interfluves. The formation is composed of poorly-sorted, very-coarse-grained, clayey sand or clayey grit that locally includes abundant, well-rounded quartz cobbles 3 to 4 inches in diameter. Remnants of the formation extend from western Lee County southwestward into Georgia. From Lee County, where the upland unit overlies the lower to lower-middle Eocene Congaree Formation, the unit overlies younger marine formations toward the southwest. The widespread distribution of the fluvial sediments in the upland unit reflects uplift of the southeastern Blue Ridge approximately 10 million years ago.

Pliocene Formations. The middle and lower parts of the Coastal Plain are distinguished by a stair-stepped topography of marine terraces bounded by scarps. Each successive terrace is younger and lower as the present shoreline is approached. The middle Coastal Plain, a gently rolling to flat terrain with transverse streams, is underlain by Pliocene marine sediment locally covered by Quaternary eolian, lacustrian, and alluvial deposits. Elevations range from about 215 to 100 feet. The middle Coastal Plain surface is underlain by the upper Pliocene Duplin Formation, exposed in a belt just southeast of the Orangeburg Scarp, and the uppermost Pliocene Bear Bluff Formation, separated from the Duplin by the Mechanicsville-Parler Scarp. The fossiliferous marine-shelf sand beds of the Duplin Formation record the maximum Plio-Pleistocene marine high stand, an inundation that reached Orangeburg and that formed the prominent Orangeburg Scarp.

In the Charleston area, the Pliocene is covered by Pleistocene units and encompasses the lower Pliocene Goose Creek Limestone and the upper Pliocene Raysor and Duplin Formations. The Goose Creek Limestone is a quartzose calcarenite widespread near the Cooper River but patchy elsewhere. The Raysor Formation crops out on the Edisto River and consists of shells in a blue-mud matrix; it is absent at Charleston and may have been stripped by erosion. The Duplin Formation occurrence is patchy.

Pleistocene Formations. Pleistocene stratigraphic units underlie the lower Coastal Plain, separated from the middle Coastal Plain by the Surry Scarp. The units are thin, marine formations that are dominantly composed of quartz sand. Seven Pleistocene formations have been recognized, each one underlying a separate terrace. From oldest to youngest they are the Lower Pleistocene Waccamaw and Penholoway Formations, the middle Pleistocene Canepatch Formation and Ten Mile beds, and the upper Pleistocene Socastee Formation, Wando Formation, and Silver Bluff beds.

SOUTH CAROLINA WATER LAW

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In reviewing water law, several considerations must be identified at the outset to adequately appreciate the application of law. First, water law is not neatly contained in any one combined set of statutes that one can quickly and easily review. Rather, the law must be gleaned from a broad range of sources, including the constitutions of the United States and South Carolina, federal and state statutes, federal and state regulations, and the common law of this State. Second, both the federal government and the state of South Carolina exercise jurisdiction over water bodies that flow through and around South Carolina. In many instances the jurisdiction overlaps and is concurrent, but in other situations the jurisdiction is reposed in only one level of government. Third, the matter of ownership of water must be considered. In most situations, water is not subject to ownership; instead, water is common property, inuring to the benefit of the citizenry in general. Water, however, is subject to ownership under various circumstances and in most instances is available for reasonable use without actual ownership. Fourth, water is generally limited in value to anyone unless it is of adequate quantity and quality; therefore, the effects of laws relating to pollution control must be borne in mind. Finally, the very nature of water must be considered. Traditionally, water has been broken down into classifications, such as natural watercourses, ground water, and diffused surface water (runoff); however, water must be viewed, in reality, as part of the hydrologic cycle (see Chapter 3). Thus, consideration of a problem that superficially appears to be one of surface water may directly affect ground water. As water use and consumption continue to increase, this relationship will become increasingly important in water law.

This chapter will first summarize South Carolina's common law on water. Common law is "the body of law derived from judicial decisions rather than from statutes."[1] Different common-law schemes vary, depending on the characteristic of the water involved. Therefore, this chapter is organized by the different water types recognized by the courts – natural water courses, diffused surface water, ground water, navigable water, and tidelands. Thereafter, this chapter will summarize the state and federal statutory law that may or may not supercede the common law. Finally, outstanding water-law issues and needs will be briefly discussed.

NATURAL WATERCOURSES[2]

The basic law governing natural watercourses in South Carolina is the common-law riparian doctrine. The word "riparian" is derived from the Latin word "ripa" which means riverbank.[3] The basic principle of the riparian doctrine is that a person who owns land bounded or crossed by a natural watercourse has a property right to the access and use of the streamflow running through his/her property. A natural water course has been defined by the court as:

> A stream usually flowing in a particular direction, though it need not flow continually. It may sometimes be dry. It must flow in a definite channel, having a bed, sides or banks, and it naturally discharges itself into some other stream or body of water. It must be something more than mere surface drainage over the entire face of a tract of land occasioned by unusual freshets or other extraordinary causes.[4]

Overflow from the banks of a watercourse caused by flood or freshet is considered part of the watercourse if the water returns to the watercourse upon recession of the flood or freshet.[5]

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1 *Black's Law Dictionary* 113 (Bryan A. Garner ed., pocket ed., West 1996).

2 The parts of this chapter discussing the law of natural watercourses, ground water, diffused surface water, and tidelands were largely drawn from the State Water Law Chapter of the *S.C. Water Assessment*, SCWRC Report No. 140 (S.C. Dept. of Natural Resources, 1983), and Stephen A. Spitz, *South Carolina*, in 6 Waters and Water Rights, (Robert E. Beck ed. 2001).

3 Joseph W. Dellapenna, *The Law of Water Allocation in the Southeastern States at the Opening of the Twenty-First Century*, 25 U. Ark. Little Rock L. Rev. 9, 11 (2002).

4 *Lawton v. South Bound R.R.*, 61 S.C. 548, 552-53, 39 S.E. 752, 753-754 (1901).

5 *Jones v. Seaboard Air Line R.R.*, 67 S.C. 181, 45 S.E. 188 (1903).

Nature and Extent of Riparian Rights

A riparian owner does not own the water itself but, rather, owns a property right to access and use the water flowing by the owner's property.[6] The riparian right to use water is automatically conveyed in the transfer of title to riparian land.[7] Whether water is used or not does not alter a riparian right, nor extinguish it.[8] Another means of obtaining riparian rights in South Carolina is for a downstream riparian owner to grant or release its riparian rights to an upstream user.[9]

The acquisition of rights to use water by prescription has been addressed in one early case, establishing that an adverse use of water for 20 years against successive owners of the servient soil is sufficient to establish a prescriptive right.[10] To successfully claim a prescriptive right, the water user must show continuous wrongful use, hostile to the rightful riparian owner, for 20 years. The only South Carolina case on the subject established a riparian right by prescription to an upstream riparian owner who diverted an entire water channel flowing from a creek for irrigation.[11] Although conceivable that a nonriparian landowner could acquire riparian rights by prescription, no case in South Carolina has addressed this scenario.

South Carolina common law has not addressed the extent to which riparian rights are attached to land. Riparian water rights can only be exercised upon riparian land.[12] A transfer of title to riparian land conveys the riparian water rights as well as the land. If a riparian owner subdivides a riparian parcel so that a portion is no longer contiguous to the watercourse, whether riparian rights attach to the severed portion depends on what test South Carolina chooses to adopt.[13] In a state recognizing the "source of title" doctrine, the severed land is never again entitled to riparian rights.[14] None of the southeastern states appear to have adopted this approach.[15] In a state recognizing the "unity of title" doctrine, land that was formerly part of a larger parcel abutting a watercourse retains its riparian right.[16]

A riparian landowner's ownership of the bed of a natural watercourse, as opposed to access and use of the water, was not raised as an issue until 1985. In *State v. Sloan Construction Company*,[17] Sloan Construction Company was the riparian owner of land alongside the Broad River in Union County. The Company was physically occupying the riverbed to mine sand in the riverbed. The State initiated a declaratory action seeking a ruling that the State held title to the river bed. The South Carolina Court of Appeals held that ownership of a freshwater river bed depends upon whether the riparian land was granted to a private property owner by the former English sovereign during Colonial rule.[18] If riparian land was granted by England, the English Rule that the grantee receives title to the center of the river applies, and those subsequent owners under that chain of title retain ownership of half the river bed.[19] If the riparian land was never granted by England, then the State has the presumption of title to the river bed.[20] This ruling does not affect a riparian landowner's use of water, and as a practical matter it has little effect on an average riparian owner unless he/she plans to make use of the riverbed.

Limitations upon Riparian Rights

The riparian doctrine not only defines who is entitled to use of water, but also the degree of use. In *Omelvany v. Jaggers*,[21] the South Carolina Supreme Court set forth a natural-flow theory of riparian rights:

> Every proprietor of lands on the banks of a river has naturally an equal right to the use of

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6 3 Kent, Comm. 353, 354 cited in *White v. Whitney Manufacturing Co.,* 60 S.C. 254, 266, 38 S.E. 456, 460 (1901).

7 William C. Moser, *Accommodating Interwatershed Transfer under the Riparian Doctrine* in *Legal and Administrative Systems for Water Allocation and Management: Options for Change*, 63, 69 (William R. Walker, Phyllis G. Bridgeman, William E. Cox & Margaret S. Hrezo eds., Virginia Water Resources Research Center, Virginia Polytechnic Institute & State University 1984).

8 *Id*.

9 *Id*.

10 *Jordan v. Lang*, 22 S.C. 159, 37 S.E. 69 (1885).

11 *Id*.

12 Moser, *supra* n. 7 at 72.

13 *Id*.

14 *Id*.

15 *Id*.

16 *Id*.

17 *Id*. at 495-496.

18 *Id*.

19 *Id*. at 499.

20 20 S.C.L. (2 Hill) 634 (1835).

21 *Id.* at 640.

> the water which flows in the stream adjacent to his lands, as it was wont to flow . . . without diminution or alteration. No proprietor has a right to use the water to the prejudice of other proprietors above or below him, unless he has a prior right to divert it, or a title to some exclusive enjoyment. He has no property in the water itself, but a simple use of it while it passes along . . . Without the consent of the adjoining proprietors, he cannot divert or diminish the quantity of water which would otherwise descend to the proprietors below, nor throw back the water upon the proprietors above, without a grant, or an uninterrupted possession of twenty years, which is evidence of it.[22]

The natural-flow theory emphasizes the right of a riparian to water flow in its natural condition, without pollution or reduction in quantity.[23] This theory was criticized amid increased industrial demands on water. In 1901, the court qualified the natural-flow theory with the reasonable-use theory. In *White v. Whitney Manufacturing Company*, the South Carolina Supreme Court quoted approvingly from an out-of-state case that "[e]ach proprietor is entitled to such use of the stream, so far as it is reasonable … and not inconsistent with a likewise reasonable use by the other proprietors of land on the same stream above and below."[24] The Court suggested that reasonable use may turn on any number of factors, including the width, depth and capacity of a stream, the volume of water, the state of improvement in manufacturing, as well as other relevant facts.[25] The question of whether a use is reasonable is a question of fact for the jury.

For a use to be unreasonable, it has long been the South Carolina rule that the use must cause "appreciable damage."[26] Thus, a lower riparian cannot obstruct the flow of water so as to back up the water onto the lands of an upper landowner, thereby damaging those lands.[27] When a downstream riparian does flood an upstream owner's property, injunctive relief has been granted.[28]

The extent of the right to use water, based upon the reasonable-use doctrine, has not been explored sufficiently in South Carolina decisions to provide a reliable basis for judging the merits of contemporary water use controversies.[29] Serious riparian litigation has been dormant in state courts since 1920;[30] however, several very general observations can be made concerning the extent of reasonable-use doctrine from the limited number of reported cases.

The majority of riparian actions in South Carolina involve private versus commercial users; half involve pollution. Domestic, agricultural, or irrigation uses have been accorded no special preference over other uses, there being no decisions in these areas.[31]

Apparently, the discharge of waste, mine tailings, or pollution is not considered unreasonable per se under the South Carolina decisions. In *United States v. 531.13 Acres of Land,*[32] the Fourth Circuit Court of Appeals quoted approvingly from an earlier state case on the subject:

> Owners of land on the banks of a stream are entitled to the reasonable use of a stream; that they can use the stream for their own purposes to a reasonable extent; that while it is true that a stream must not be polluted, still this does not mean that nothing can be put in the stream; but that nothing can be put therein that will deprive the landowners below to the reasonable use of the stream.[33]

Nonetheless, such uses have consistently been held unreasonable and subject to injunction.[34] Several cases, however, demonstrate the tendency of the court and bar to avoid reasonable-use determinations, relying instead on the more customary nuisance doctrines.[35] Taken as a whole, the South Carolina decisions involving pollution by upstream riparians indicate rather uniformly that juries find such use unreasonable.

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22 *Id*. at 640.

23 Larry O. Putt, *Allocation of Supplies Among Competing Off Stream Uses Within the Basin*, in *Legal and Administrative Systems for Water Allocation and Management: Options for Change*, 17, 27, (William R. Walker et al eds. Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, 1984).

24 *White v. Whitney Mfg. Co*., 60 S.C. 254, 38 S.E. 456, 457 (1901).

25 *Id*. at 457.

26 *Chalk v. McAlily*, 45 S.C.L. (11 Rich.) 153, 162 (1857).

27 *Johnson v. Williams*, 238 S.C. 623, 121 S.E.2d 223 (1961).

28 *Mack v. Edens*, 306 S.C. 433, 412 S.E.2d 431 (Ct.App. 1992) (holding that permanent flooding of the upstream riparian's land was a continuous trespass and warranted injunctive relief).

29 *See*, to same effect, Dewsnup et al., *A Summary-Digest of State Water Laws*, 667 (National Water Commission, 1973).

30 However, one recent federal decision explored the reasonable use doctrine of South Carolina, *United States v. 531.13 acres of Land*, 366 F.2d 915 (1966).

31 The case of *Jordan v. Lang*, 22 S.C. 159, 37 S.E. 69 (1885), did involve the use of waters for irrigating rice, the downstream riparian complaining of the quantity being used. The case was decided, however, on prescription rather than reasonable use.

32 *United States v. 531.13 Acres of Land*, 366 F.2d 915 (1966).

33 *Id*. at 919, citing *Duncan v. Union-Buffalo Mills Co.,* 110 S.C. 302, 96 S.E. 522, 524 (1917).

34 *E.g. Griffin v. National Light & Thorium Co.,* 79 S.C. 351, 60 S.E. 702 (1908); *Williams v. Haile Gold Mining Co*., 85 S.C. 1, 66 S.E. 117 (1910); *Mason v. Apalache Mills*, 81 S.C. 554, 62 S.E. 399 (1907); *Threat v. Brewer Mining Co*., 49 S.C. 95, 26 S.E. 970 (1897).

35 *Williams v. Haile Gold Mining Co*., 85 S.C. 1, 66 S.E. 117 (1910); *Threat v. Brewer Mining Co*., 49 S.C. 95, 26 S.E. 970 (1897).

Many of the cases in which quantity issues were in conflict, as in the right to detain and release water or to flood lands above or below, also found uses to be unreasonable. In *White v. Whitney Manufacturing Company,*[36] the detention of water by an upstream riparian for power generation was held unreasonable. The court, in *McMahon v. Walhalla Light and Power Company,*[37] held as a construction of law that downstream riparians are under no obligation to pond water in such a way as to put them to beneficial use as a condition of the rights afforded them under the reasonable use rule. In this case, the defendant constructed a dam above plaintiff's mill for the purpose of power generation. Water was detained and released but not diverted. The court rejected the argument that lower proprietors must use due care in the construction and operation of their mill before he/she can complain of a similar upstream use.[38] In a 1915 decision, the court held that a lower riparian who owned both banks of a nonnavigable stream was entitled to use a ford without interference from the detention and release of water from an upstream power dam.[39] The foregoing series of cases have been cited for the proposition that the doctrine of natural flow is still influential in issues of water quantity.[40]

Whether a watercourse is navigable or nonnavigable appears to have little, if any, bearing on the existence of riparian rights in South Carolina.[41] No cases seem to draw such a distinction; however, if the natural watercourse is deemed navigable it is subject to the State's navigational servitude to the mean or ordinary high-water lines. A navigational servitude means that the State holds the watercourse up to the mean high-water mark in public trust as a recreational resource and mode of travel for members of the public. The riparian owner adjacent to a navigable watercourse is not deprived of access or other riparian rights.[42]

No case clearly confirms the common-law limit of interbasin, or interwatershed, transfer. Absent such decision, interbasin transfers presumably would result in actionable violation of downstream riparian rights.[43]

Statutory Effect upon Riparian Common Law

Despite this uncertainty over interbasin transfer, the General Assembly of South Carolina has enacted several local acts, dealing with particular municipal water-supply problems, which purport to authorize the diversion of water from one watershed to be used and discharged into another watershed.[44] Generally the diversions are by nonriparians for use on nonriparian lands. Some of the acts specifically recognize the right of riparians to the water being diverted and inferentially allow suit to be brought against the diverting municipality or industry.[45] Others are silent as to the rights of riparians.[46]

In general, municipalities have planned or implemented interbasin transfers with little regard to the possible consequences. It is quite common and often most practical for a waterworks system to withdraw water from one watershed, process it, and distribute it to another watershed for use, treatment, and discharge.[47] No reported case has considered either the enactment and results of the above acts, nor any municipal interbasin transfer for water supply purposes. Whether interbasin transfer for public purposes constitutes a reasonable use, when such water is used on nonriparian lands, has not been determined.[48]

With the exception of certain statutes affecting ground water, as will be discussed later, few legislative enactments alter or tend to alter riparian doctrines in South Carolina. The South Carolina Surface Water Withdrawal and Reporting Act merely requires large water withdrawers to report the quantity withdrawn. The Act does not curtail or regulate actual water consumption.[49]

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36 *White v. Whitney Mfg. Co*., 60 S.C. 254, 38 S.E. 456 (1901).

37 *McMahon v. Walhalla Light & Power Co.*, 102 S.C. 57, 86 S.E. 194 (1915).

38 *Id*. at 59.

39 *Fewell v. Catawba Power Co*., 102 S.C. 452, 86 S.E. 947 (1915).

40 Busby, *The Beneficial Use of Water in South Carolina*, (South Carolina Soil Conservation Committee 1953). Busby views the *Fewell* decision as subjecting the use of an entire drainage system to one lower proprietor's right to ford a stream.

41 Dewsnup, *supra* n. 15, at 668. *But see* E. Guerard, *The Riparian Rights Doctrine in South Carolina*, 21 S.C. L. Rev. 757, 760-762 (1969).

42 *Jones v. Seaboard Air Line Ry. Co*, 67 S.C. 181, 45 S.E. 188, 194 (1903) (the defendant railroad caused, in the construction of a bridge, the flooding of plaintiff's land. The court found that the plaintiff was entitled to access to the watercourse, saying that "the right which the plaintiff says the defendant invaded was not the right of navigation, or any other right which he held in common with the public, but the right to the unimpaired use of his land on the banks of the river. The fact that the stream was navigable does not affect the question.")

43 *See* C.E. Hill, *Limitation on Diversion from the Watershed: Riparian Roadblock to Beneficial Use*, 23 S.C. L. Rev. 63 (1971), for a full discussion of interbasin transfer in South Carolina.

44 A comprehensive list of these statutes is found in Hill, *Id*. at 59-60. Most of these acts have been removed from the *Code of Laws of South Carolina, 1976*, as local legislation.

45 *Id*. at 59. *See* S.C. Code Ann. § 70-471 (1962).

46 *See* S.C. Code Ann. § 70-491 (1962).

47 *See* Hill, *supra* n. 31. Hill, while deploring the effect of the common law limitation on interbasin transfer, attributes the rather indiscriminate transfer of water to the state's abundant supply and a "carefree cavorting" caused by plentiful water. *Id*. at 59.

48 *See* Hill, *supra* note 31, at 57-58.

49 DHEC is seeking amendments to the Surface Water Withdrawal and Reporting Act to incorporate the Interbasin Transfer Act so that all withdrawals of surface water over 3 million gallons per month would be permitted.

The Interbasin Transfer Act does authorize permitting for the transferring of water from one basin to another that exceeds one million gallons per day; however, this Act preserves the right of a riparian owner to recover damages for any material injury caused by transfers.

The State's pollution laws,[50] however, could exert substantial influence on a riparian's choice of remedies in a water-use controversy involving pollution caused by upstream proprietors. In addition to the regulatory activities of the State in setting the quantity and quality of discharges,[51] the pollution statute provides its remedies in addition to remedies afforded a riparian under the reasonable-use doctrine.[52] A riparian would have a cause of action based upon the "reasonableness" of a discharge, despite such discharge being permitted or otherwise not in violation of State water quality standards.

Additionally, several statutes limit or regulate the erection of dams or the backing up or overflowing of water dams.[53] Other provisions prohibit obstruction of navigable water bodies and require landowners to clean obstructions from streams.[54] The latter statutes have been wholly unenforced in recent times.

Beyond federal permitting requirements, the State regulates construction activities, although not water withdrawals, in the navigable water bodies and wetlands of South Carolina.[55] Occasionally, low flow discharge conditions are imposed upon permits for impoundments in navigable water bodies. No other State enactments appear to have regulated instream flows.

LAKES, PONDS, AND OCEANS

Interests attached to land contiguous to a lake, pond, or ocean are called littoral rights.[56] Although owners of land adjacent to ponds, lakes and oceans are often called riparian owners, the accurate term is "littoral." The extent of littoral rights in South Carolina has not been addressed, except for the right to construct a wharf upon submerged tidelands.[57] The general common law of littoral rights provides access to and use of water in a natural water body, but a landowner adjacent to an artificial lake or pond does not have littoral rights.[58] Water rights can be obtained to an artificial water body through prescription.[59]

DIFFUSED SURFACE WATER

Diffused surface water is treated entirely differently from natural watercourses. Diffused surface water is defined as "waters of a casual and vagrant character, which ooze through the soil or diffuse or squander themselves over the surface, following no definite course. They are waters which, though customarily and naturally flowing in a known direction and course, have nevertheless no banks or channels in the soil, and include waters which are diffused from rains and melting snows…."[60] that would be sustained by the public generally.

The Common-Enemy Rule

Since 1893,[61] South Carolina has adhered to the common-enemy rule in dealing with diffused surface water. The application of the common-enemy rule to diffused surface water was reaffirmed by the court 6 years later in the case of *Baltzeger v. Carolina Midland Railroad Company*,[62] the leading case on the subject. The rule applies only to controversies involving diffused water, not to natural watercourses. Under the common-enemy rule, "surface water is regarded as a common enemy, and every landed proprietor has the right to take any measure necessary to the protection of his own property from its ravages, even if in doing so he throws it back upon a coterminous proprietor to his damage…."[63] The rule's application means that courts will not recognize any wrong in action taken to get rid of diffused water; thus, a property owner whose land is damaged by another property owner who diverts, detains or repulses diffused water cannot recover such damages.[64]

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50 Pollution Control Act, S.C. Code Ann. § 48-1-10, et seq. (1976).

51 NPDES Permits, 23 S.C. Code Ann. Regs. 61-9 (Supp. 2002); *See infra* n. 204.

52 S.C. Code Ann. § 48-1-240 (1987).

53 *See* S.C. Code Ann. §§ 49-11-10 and 49-11-20 (1987).

54 S.C. Code Ann. §§ 49-1-10, 20, 30, 40 (1987).

55 Permits for Construction in Navigable Waters, 23 S. C. Code Ann. Regs. 19-450, et seq. (Supp. 2002), requires permits for construction activities in the navigable waters of South Carolina below the mean or ordinary high-water lines of such waters. S.C. Code Ann. § 48-39-10, et seq. (Supp. 2002), as amended, requires permits for any construction or alteration in the saline waters and tidelands of the State. This permit replaces the above permit in the coastal area and is broader in its jurisdiction over wetlands, beaches and sand dunes. The Act also requires that a coastal management plan be drafted and submitted to the Governor and General Assembly.

56 *Lowcountry Open Land Trust v. State*, 347 S.C. 96, 108, 552 S.E.2d 778, 785 (Ct. App. 2001).

57 *Id*.

58 Jan G. Laitos and Joseph P. Tomain, *Energy and Natural Resources Law in a Nutshell*, 356-357 (West, 1992).

59 *Id*.

60 *Lawton v. South Bound R.R. Co*, 61 S.C. 548, 552, 39 S.E. 752, 753 (1901).

61 *Edwards v. Charlotte*, *Columbia & Augusta R.R.*, 39 S.C. 472, 18 S.E. 58 (1893).

62 *Baltzeger v. Carolina Midland Ry.*, 54 S.C. 242, 32 S.E. 358 (1899).

63 *Id*. at 475.

64 *Rivenbark v. Atlantic Coast Line Ry. Co.*, 124 S.C. 136, 117 S.E. 206, 208 (1923).

Exceptions to the Rule

The application of a strict common-enemy rule to diffused-water controversies is extreme and often has been criticized.[65] The rule in South Carolina, however, has been modified to some extent by the recognition of two exceptions. One exception is that a landowner must not deal with his diffused surface water in a manner so as to constitute a nuisance. The court in *Baltzeger*[66] found that the right of a landowner to deal with diffused water "….is subject to the general law in regard to nuisances, if its accumulation has become a nuisance per se, as for example, whenever it has become dangerous at all times and under all circumstances to life, health or property."[67] The court further indicated that even if a nuisance per se was not established, recovery could be based upon private as opposed to public nuisance. This required a showing of special damage, different in kind and degree from damage.

In early cases against railroads where construction of railroad embankments caused flooding, plaintiffs invoking the nuisance exception were largely unsuccessful.[68] In recent cases involving flooding of water caused by poorly constructed storm drainage, courts seem more likely to allow the nuisance exception to be heard by a jury.[69]

Another exception to the common-enemy rule is that a landowner cannot collect diffused water into an artificial channel and cast it upon another's land in concentrated form.[70] The courts have modified the "concentrated form" exception so as to allow an upper landowner to cast water in concentrated form upon a lower landowner if the upper landowner possessed a contractual[71] or prescriptive right.[72]

In *Irwin v. Michelin Tire Corporation,*[73] the court seemingly modified the exception to reflect the reality of increasing development in the State. In *Irwin*, the lower riparian owner sought the court's adoption of the "New Jersey Rule," which imposes liability upon an upper proprietor if the upper proprietor installs an artificial drain that decreases natural absorption, seepage, and percolation of water on his property and increases the volume and rate of water flow onto the property of a lower proprietor, causing damage.[74] The rationale for adoption of the "New Jersey Rule" was that lower riparian owners needed greater protection in the face of rapid development in South Carolina.[75] The South Carolina Supreme Court rejected the "New Jersey Rule," stating such a rule would have a "traumatic effect upon the orderly development of our state."[76] Instead, the Court approved the use of the "Virginia Rule" as an adequate modernization of South Carolina common law, noting that it is more consistent with the State's common enemy rule.[77] The adopted "Virginia Rule" states that "where no greater surface-water drainage occurs than would normally result from the reasonable development of an upper landowner's property, liability will not be imposed merely due to the presence of an artificial drainage system."[78] Therefore, the court affirmed the lower court charge that "where no greater surface-water drainage occurs than would naturally result

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65 W.T. Toal, *Surface Water in South Carolina*, 23 S.C. L. Rev. 82, 83 (1971). See also *Williams v. Skipper*, 284 S.C. 261, 263 325 S.E.2d 577, 579 (Ct. App. 1985), where appellant urged court to overrule the common-enemy rule and replace with a "reasonable use rule" because: 1) the rule was adopted by mistake in South Carolina, 2) trend is toward a standard of reasonable use, and 3) exceptions to rule make application of the rule uncertain. The court declined to overrule the common-enemy rule.

66 *Baltzeger v. Carolina Midland Ry.*, 54 S.C. 242, 32 S.E. 358 (1899).

67 *Id*. at 247.

68 *See Rivenbark v. Atlantic Coast Line Ry. Co.*, 124 S.C. 136, 117 S.E. 206, 208 (1923) (railroad's drainage ditch within embankment became obstructed, causing flooding and destruction of plaintiff's vegetable garden, found not to constitute nuisance); *Banks v. Southern Ry*., 126 S.C. 241, 118 S.E. 923 (1923) (in claim that obstruction of surface water by railroad embankment created a public nuisance, plaintiff failed to show that flooding caused damage to plaintiff.). *But see Deason v. Southern Ry*., 142 S.C. 328, 140 S.E. 575 (1927) (the allegations that both a constructed railroad embankment and a filled ditch caused periodic overflowing of pond at every rain, and created mosquito infestation as pond dried, were sufficient to take to the jury the question of whether the railroad created a nuisance *per se* or a continuing private nuisance).

69 *See Suddeth v. Knight*, 280 S.C. 540, 314 S.E.2d 11 (Ct. App. 1984) (trial judge committed error in not submitting nuisance exception to jury, where evidence infers that developers' construction of inadequate drainage system caused water to back up on plaintiff's land, filling an old ditch with stagnant water for 6-10 months of the year and creating mosquito problem); *Silvester v. Spring Valley Country Club*, 344 S.C. 280, 543 S.E.2d 563 (Ct. App. 2001) (plaintiff's claim that inadequate drainage system caused erosion, trash accumulation and potential health problem due to standing water caused continuing nuisance sufficient to withstand summary judgment).

70 *Branderberg v. Zeigler*, 62 S.C. 18, 39 S.E. 790 (1901); *Rivenbark v. Atlantic Coast Line Ry. Co.*, 124 S.C. 136, 117 S.E. 206, 208 (1923)*; Garmony v. Southern Ry*., 152 S.C. 205, 149 S.E. 765 (1929).

71 *Kirkland Distribg. Co. v. Seaboard Airline Ry*., 109 S.C. 331, 96 S.E. 122 (1918).

72 *Hays v. Hoffman*, 162 S.C. 284, 160 S.E. 852 (1931).

73 288 S.C. 221, 225 n. 2, 341 S.E. 2d 783, 785 n. 2 (1986).

74 *Id*. at 784.

75 *Id*.

76 *Id*.

77 *Id*.

78 *Id*. at n. 2, 785.

from the reasonable development of an upper landowner's property, liability will not be imposed merely due to the presence of an artificial drainage system."[79]

In the subsequent case of *Johnson v. Phillips*,[80] the South Carolina Supreme Court seemed to apply the "Virginia Rule" in reversing the lower court's decision finding that the facts did not fall into the concentrated-form exception. In *Johnson*, a dispute arose between adjacent landowners over the diversion of diffused surface water. The upper landowners brought an action against the lower landowners, claiming both a contract and prescriptive right to discharge water on the lower landowners' property. The lower landowners counterclaimed for unlawful discharge of surface water upon their land. In ruling on the lower landowner's counterclaim, the circuit court found in favor of the upper landowner, stating that the upper landowner had a right to discharge water onto the lower landowner's property. The South Carolina Court of Appeals reversed the circuit court, holding that it was proper under the facts and circumstances of that particular case to have a jury consider whether the upper landowner's increase of surface water drainage of 15 percent constituted the collection and discharge in a concentrated form onto the lower landowners' property. Although the court cited *Irwin* as an example of a recent case illustrating South Carolina's adherence to the classical formulation of the common-enemy rule, the court's decision appeared to follow the "Virginia Rule" pertaining to the "concentrated-form" exception. The court suggested that under the "concentrated-form" exception,[81] although an upper landowner is not liable for using an artificial-drainage system to divert diffused water in an amount no greater than reasonable development would cause, an upper proprietor is liable to a lower landowner for damage caused by a development that unreasonably increases the volume of water draining upon a lower property.

While the court in *Branderberg v. Zeigler*[82] drew a distinction between casting water upon another's land and preventing the flow of diffused water upon one's own land, at least one other case suggests the application of the exception to a lower landowner who would dam the flow of diffused water and thus throw it back upon his upper neighbor.[83]

Statutory Effect upon Common Law of Diffused Surface Water

Municipalities, owing to their sovereign status, are governed by different principles. Whereas municipalities and other governmental agencies are immune from suit in many situations, the General Assembly has chosen to remove sovereign immunity with regard to drainage of diffused surface water. A general statute[84] authorizes the institution of a civil action against a municipality for actual damages sustained by causing surface water to be drained from public streets across private property. The statute requires the landowner to demand that the municipality provide proper drainage before such landowner may bring suit; moreover, the statute authorizes municipalities to condemn private property if the necessary drains cannot be maintained along or under the public street. In order for a municipality to be held liable, the municipality's actions must not be negligent, but rather an overt, intentional act that proximately caused the damages.[85]

GROUND WATER

Research has revealed no reported South Carolina cases setting forth any common-law rules concerning the ownership of ground water in South Carolina. In other states, early case law established the Absolute Ownership Rule, where a landowner was entitled to absolute ownership of percolating water from the ground.[86] As knowledge concerning the behavior of ground water increased, many states have replaced the Absolute Ownership Rule with a regulated form of riparianism, adopting for a reasonable-use rule for ground water.[87]

Instead of adopting any common-law riparian rule specifically relating to use of ground water, the South Carolina courts have approached ground water issues through common-law tort actions and the State Constitution. A South Carolina case has found diversion of ground water to be an unconstitutional taking.[88] In *South Carolina Department of Highways and Public Transportation v. Balcome*, the State highway department, during the construction of a freeway, diverted ground water

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79 *Id*.

80 315 S.C. 407, 433 S.E. 2d 895 (Ct. App. 1993), *rev'd in part on other grounds, sub. nom. Smith v. Phillips*, 318 S.C. 452, 458 S.E. 2d 427 (1995).

81 *Id*. at 898-899.

82 *Branderberg v. Zeigler*, 62 S.C. 18, 39 S.E. 790 (1901).

83 *See Slater v. Price*, 96 S.C. 245, 80 S.E. 372 (1913).

84 S.C. Code Ann. § 5-31-450 (1976).

85 *Hall v. City of Greenville*, 88 S.E. 2d 246 (1955); *Taleff v. City of Greer*, 284 S.C. 510, 327 S.E. 2d 363 (Ct. App. 1985).

86 Joseph W. Dellapenna, *The Law of Water Allocation in the Southeastern States at the Opening of the Twenty-First Century*, 25 U. Ark. Little Rock L. Rev. 9, 41 (2002).

87 *Id*. at 44.

88 *S.C. Dept. of Hwys. & Pub. Transp. v. Balcome*, 289 S.C. 243, 345 S.E.2d 762 (Ct.App. 1986).

that fed the plaintiff's pond.[89] As a result, the plaintiff's pond level permanently dropped 4 feet.[90] The highway department attempted to defend itself by introducing common-law principles governing the use of ground water.[91] The Court held that common-law theories were irrelevant in light of the State's constitutional prohibition against a public taking of private property without just compensation.[92]

In Federal District Court, a chemical plant's contamination of ground water under an adjacent property was held to be actionable under several theories.[93] The Court found that the chemical company engaged in an ultrahazardous activity, which warranted strict liability for damages to the plaintiff; negligently disposed of hazardous chemicals and failed to warn the plaintiff of contamination; trespassed upon plaintiff's property; and caused a nuisance.[94] The South Carolina Supreme Court has also heard and upheld a claim of trespass for ground-water contamination against a chemical company.[95] The court held that the plaintiff was entitled to recover all damages that were the natural, proximate cause of the trespass.

South Carolina has, by statute, imposed reasonable-use restrictions on ground-water use. Prompted by fears of water-level declines and saltwater intrusion in the coastal areas of the state, the South Carolina General Assembly enacted the Ground Water Use Act of 1969,[96] which was based upon a similar North Carolina statute.[97] In 2000, the Act was substantially overhauled.[98] This statute is more fully discussed later in this chapter.

NAVIGABLE WATER BODIES

The issue of whether a watercourse or water body is navigable affects private riparian and littoral rights by placing a concurrent public right of access to water, as well as determining ownership of submerged land. Although the South Carolina Constitution has established a public right in navigable water bodies, and state legislation has given some contours to what is considered navigable, the courts have been left to add more detail to the definition of navigability.

Public Servitude

The South Carolina Constitution declares that "all navigable waters within the limits of the State shall be common highways and forever free, as well to the inhabitants of this State as to the citizens of the United States, without any tax or impost therefor, unless the same be expressly provided for by the General Assembly."[99] Further, a State statute defines navigability as "all streams which have been rendered or can be rendered capable of being navigated by rafts of lumber or timber by the removal of accidental obstructions and all navigable watercourses and cuts."[100] Thus, a common right or servitude in the public to freely use the navigable water bodies of South Carolina is well established. Such a servitude exists regardless of the ownership of the banks or bed of a navigable stream, whether public or private.[101] The public right of navigation, as well as the right of fishing in navigable water bodies,[102] is superior to any rights that might be possessed by the riparian owners.[103] What constitutes navigable water bodies is less clear, however.

At the turn of the 20th century, the court established that the extent of the servitude embraces not only that which is actually used but that which is susceptible to use for navigation in its ordinary state.[104] Navigable, though artificial, canals connected to, or improving navigation on, otherwise navigable water bodies may be impressed with the public servitude over those water bodies.[105]

The court has extensively reviewed the powers of the State to take, use, or modify the navigable water bodies of

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89 *Id*. at 763.

90 *Id*. at 764.

91 *Id*.

92 *Id*.

93 *Shockley v. Hoechst Celanese Corp.*, 793 F. Supp. 670 (D.S.C. 1992).

94 *Id*.

95 *Kelly v. Para-Chem Southern Inc*., 311 S.C. 223, 428 S.E.2d 703 (1993).

96 S.C. Code Ann. § 49-5-10 et seq. (Supp. 2002).

97 N.C. Gen. Stat. § 143-215.11.

98 *See* S.C. Act 366 (June 14, 2000) (available at http://www.scstatehouse.net/sess113_1999-2000/bills/3434.doc).

99 S.C. Const. Art. XIV, § 1.

100 S.C. Code Ann. § 49-1-10 (1976).

101 *Rice Hope Plantation v. S.C. Pub. Serv. Auth.*, 126 S.C. 500, 528 59 S.E. 2d 132 (1950).

102 *Id*. at 524.

103 *See State ex rel. Lyon v. Columbia Water Power Co*., 82 S.C. 181, 63 S.E. 884 (1909).

104 *Id*. at 187.

105 *Id*. at 186-187.

South Carolina for public purposes:

> The waters of the ocean and its bays, and of public watercourses and lakes, so far as they lie within the jurisdiction of a state, are part of the public domain, and the state may authorize the diversion of such waters for any purpose it deems advantageous to the public, without providing compensation to riparian proprietors injuriously affected. Such diversion is not a taking of private property by eminent domain, but a disposition by the public of the public property.[106]

Obstruction of navigable waterways may be abated as a public or private nuisance.[107] The construction of a dam across a navigable waterway is not a nuisance *per se* if authorized by the legislature.[108] The legislature, while having the power to authorize the construction of an impoundment across a navigable stream by a private person, has no power to release that person from liability for damages created by a nuisance.[109] Whoever constructs a dam or bridge in or over a stream must exercise reasonable and prudent care and must consider the natural flow of the stream and its usual freshets and occasional "great floods."[110] The owner of a dam is required to exercise ordinary care in the operation and maintenance of the dam to avoid injury to those upstream and downstream.[111]

The powers of the State in the exercise of the navigation servitude coincide with those of the federal government, and although the rights and powers of the federal government with respect to waterways subject to interstate commerce are paramount, the powers of the State remain in full force and effect unless and until Congress acts upon the subject.[112] These powers exist regardless of ownership.

Definition of a Navigable Waterway

What constitutes a navigable waterway so as to raise a servitude or easement in the public in South Carolina has been an ongoing source of dispute.

State law provides that all streams that are capable or can be made capable of being navigated by "rafts of lumber or timber" by removal of accidental obstructions are navigable, as well as all navigable watercourses or cuts.[113] Although in a 1903 Federal decision the circuit court held this statute to be declarative of existing law,[114] it seems by no means clear what law the court considered it declarative of. Nonetheless, the statute, as the only legislative pronouncement on the subject, has been used by the State in determining the extent of public navigation for permit purposes.[115]

In the 1894 case of *Heyward v. Farmer's Mining Company,*[116] the court extensively reviewed the various doctrines determining which waterways may be considered navigable in fact, finding that a stream should have sufficient depth and width of water to float useful commerce;[117] that neither the character of the craft nor the relative ease or difficulty of navigation are tests of navigability;[118] that the test is navigable capacity and surroundings have no bearing on the question;[119] that if water is navigable for pleasure boating it is navigable;[120] and that the purpose of navigation is not a subject of inquiry, but the fact of the capacity of the water for use in navigation establishes navigability.[121] While both the "log raft" test under the statute and the navigation in-fact tests as pronounced by the court are somewhat subjective and are questions to be determined by the trier of fact, in practical application it would be difficult to distinguish between the tests.

Another line of cases, however, offers an additional test of which waterways are considered navigable based upon the individual declarations of navigability made by the legislature. Apparently, those streams that have been declared navigable by act of the General Assembly and made or kept navigable by expenditure of public moneys

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106 *Rice Hope Plantation v. S.C. Pub. Serv. Auth.*, 216 S.C. 500, 59 S.E. 2d 132 (1950).

107 S.C. Code Ann. § 49-1-10 (1976).

108 *Free v. Parr Shoals Power Co*., 111 S.C. 192, 196, 97 S.E. 243, 244 (1918).

109 *McDaniel v. Greenville-Carolina Power Co*., 95 S.C. 268, 273, 78 S.E. 980, 981 (1913).

110 *Jones v. Seaboard Air Line R.R*., 67 S.C. 181, 45 S.E. 188, 195 (1903).

111 *Key Sales Co. v. S.C. E & G Co*., 290 F. Supp. 8 (D.C.S.C. 1968).

112 *Id*. at 527-528.

113 S.C. Code Ann. § 49-1-10 (1976).

114 *Manigault v. Ward*, 123 F. 707, 714 (1903), *aff'd*, 199 U.S. 473 (1905).

115 *See* 23 S.C. Code Ann. Regs. 19-450 et. seq. (Supp. 2002).

116 *Heyward v. Farmer's Mining Co*., 42 S.C. 138, 152, 19 S.E. 963 (1894).

117 *Id*. at 150.

118 *Id*. at 151.

119 *Id*.

120 *Id*. at 155.

121 *Id*.

are recognized as navigable by the courts,[122] at least to the extent that they are viewed as public highways.[123] Whether such legislative declarations would find favor in contemporary litigation is not known.

In 1986, the South Carolina Supreme Court undertook to clarify the murky issue of the definition of navigable water bodies. In *State v. South Carolina Coastal Council*,[124] the Court determined that the Coastal Council could not issue a permit that would have allowed a landowner of old rice fields to close off access to the fields' canals. The Court determined that these canals could be navigated by pleasure boats. The Court went on to say that the true test for determining navigability is the capacity for valuable floatage, but valuable floatage is not necessarily limited to commercial floatage.[125] The Court found that the use of these waterways by the general public for boating, hunting and fishing is a legitimate and beneficial use and thus had the capacity for valuable floatage.[126] This case moves the doctrine of navigable servitude away from the mere commercial use of a waterway to one of capacity for general public use for boating, hunting and fishing.

In 1990, the Court of Appeals decided the case of *Hughes v. Nelson*, which held that an artificial canal that was connected to a navigable river and used for sport fishing by the general public was navigable water.[127] The Court noted that a navigable waterway need not be large[128] nor be a natural watercourse. When a canal is constructed to connect with a navigable river, the canal may be regarded as part of that river.[129]

In 1997, the Court of Appeals determined that an artificial interruption in an otherwise navigable stream did not convert what was once a navigable stream into a nonnavigable stream. In *State v. Head*, the court held that the presence of a dam between a lake and a stream did not render the water body nonnavigable. Thus, where a navigable body of water is lawfully or unlawfully impounded and the public has access upstream, a person may float the stream into a lake and use the lake for fishing and boating.

TIDELANDS

Ownership of Tidelands

The issue of tidelands ownership presents a most significant and difficult water-oriented area of litigation in South Carolina. The claim of the State to those lands lying between the mean high and mean low water lines on the coast, an area of perhaps a half million acres, has been hotly contested by coastal landowners. While public ownership of tidelands and submerged lands appears to have been a well-settled common-law doctrine, vast areas of the coast throughout the eighteenth century were cultivated for growing rice. Although rice cultivation ceased many years ago, the tidal areas are still considered valuable. Most tideland litigation surrounds the issue of whether the claimant has fee simple title to the tidelands in question.

The leading case in South Carolina is *Cape Romain Land Improvement Company v. Georgia-Carolina Canning Company*, a trespass action to determine whether the plaintiff or defendant had the right to harvest oysters on a large tract of land between the high and low water lines of tidal and navigable water bodies.[130] The court considered the question of public ownership of tidelands in the context of this proprietary claim to the oysters. The court stated that "the title to land below the high water mark on tidal navigable streams, under the well settled rule, is in the State not for purpose of sale, but to be held in trust for public purposes."[131] Any doubt as to the applicability of the rule has been eliminated by its subsequent reaffirmation.[132] In *Coburg v. Lesser*, the South Carolina Supreme Court extended the presumption of state ownership to include islands located within marshland.[133]

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122 *State v. Thompson*, 2 Strob. 12 (S.C. 1847).

123 *Carey v. Brooks*, 1 Hill 365 (S.C. 1833). See *State v. Cullum*, 2 Spears 581 (S.C. 1844); *State v. Hickson,* 5 Rich. 447 (S.C. 1852); *McDaniel v. Greenville-Carolina Power Co.,* 95 S.C. 268, 78 S.E. 980 (1913). From the mid-eighteenth to the mid-nineteenth century, dozens, if not hundreds, of declarations of navigability were made by the legislature.

124 289 S.C. 445, 346 S.E.2d 716 (1986).

125 *Id*. at 449, 719.

126 *Id*.

127 303 S.C. 102, 399 S.E.2d 24 (Ct.App. 1990).

128 The Court stated that a "waterway need not accommodate the Carnival Cruise Lines or be able to float the Love Boat." *Id*. at 25.

129 *Id*.

130 *Cape Romain Land Imp. Co. v. Georgia-Carolina Canning Co*., 148 S.C. 428, 146 S.E. 434 (1928).

131 *Id*. at 438.

132 *Rice Hope Plantation v. S.C. Public Service Authority*, 126 S.C. 500, 59 S.E.2d 132 (1950); *Lane v. McEachern,* 251 S.C. 272, 162 S.E. 2d 174 (1968); *State v. Hardee*, 259 S.C. 535, 193 S.E. 2d 297 (1972); *State v. Yelsen*, 265 S.C. 43, 216 S.E.2d 765 (1975); *Coburg v. Lesser*, 309 S.C. 252, 422 S.E.2d 96 (1992).

133 309 S.C. 252, 253 422 S.E. 2d 96, 97 (1992).

The *Cape Romain* decision does not stand for the proposition, however, that tidelands are not capable of private ownership. If a grant to such lands from the State, or the State's predecessors in title (the King of England or Lords Proprietors) can be produced and traced in a direct and unbroken chain to the claimant, private ownership can be made out.[134] A State grant can convey not only a private title to tidelands, but also its public trust title, releasing the State's right to the channel beds and other land beneath the tidewater.[135] Because virtually all of the coastal area of South Carolina was settled, and thus granted, prior to independence, most tidelands claimants can produce a royal or proprietory grant of some nature. The more recent tidelands cases involve the construction of such grants.

Because of the nature and public importance of tidelands, submerged lands, and lands beneath navigable water bodies, they are held by the State in trust, in a fiduciary rather than proprietary capacity.[136] Included in the category of tidelands, wetlands created by encroachment of navigable tidal water also are held by the State.[137] Grants purporting to convey such lands held in public trust are construed strictly in favor of the State and against the grantee.[138]

The State comes to court with a presumption of title, that it did not grant away public domain lands.[139] Therefore, the party arguing a transfer of title by grant bears the burden of proving his/her own good title.[140] The claimant must show that their predecessors in title acquired title from either the British crown or from the State since independence, and the grant's language was sufficient to convey the land below the high-water mark.[141] General words will convey lands only to the mean high-water line:

> Under well-settled rules of construction naming such boundaries ("inlet," "sound or creek") will convey land only to the high-water mark in the absence of specific language, either in the grant or upon a plat showing that it was intended to convey land below the high water mark.[142]

The location of the mean high-water line is a question of fact for jury determination.[143] As such, the method of determining and presenting evidence of this line to the trier of fact is often critical in tidelands litigation.

The law of tidelands takes into account erosion of land caused by tides and currents. Accretions by natural alluvial action to tidelands become the property of the tideland owner whose lands are added to.[144] For lands gradually submerged by water, the owner loses his/her right to the submerged land.[145] Even if at the time of grant to the property owner, the land was not submerged, yet rising tidewater subsequently submerged the highland, the owner cannot defeat the State's ownership of the tidelands.[146]

Access

The public's ownership of tidelands assures public use of those areas between the mean high-water and mean low-water lines, but it does not necessarily follow that the public has an unlimited right to cross highlands to gain access to these properties. The public has the right to access through areas that have been dedicated to the public or are owned by the State. Moreover, it is possible for the public to gain such access by prescription or dedication. Mere public use, however, even if longstanding, does not necessarily create a prescriptive right or an implied dedication.[147]

Only one case in South Carolina has addressed the right of access of an owner of land adjacent to tidelands to construct a wharf or pier over tidelands.[148] A littoral owner has the right of access from his/her land to the

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[134] *Lane v. McEachern,* 251 S.C. 272, 162 S.E. 2d 174 (1968).

[135] *Lowcountry Open Land Trust v. State*, 347 S.C. 96, 105 fn. 6, 552 S.E. 2d 778, 783 n. 6 (Ct. App. 2001)

[136] See *Cape Romain Land Imp. Co. v. Georgia-Carolina Canning Co*., 148 S.C. 428, 146 S.E. 434 (1928); *Heyward v. Farmer's Mining Co.,* 42 S.C. 138, 19 S.E. 963 (1894); *State v. Pickney*, 22 S.C. 484 (1884); *State v. Pacific Guano Co*., 22 S.C. 50 (1884).

[137] *Coburg Dairy Inc. v. Lesser*, 318 S.C. 510, 458 S.E. 2d 547 (1995).

[138] *LowCountry Open Land Trust v. State,* 347 S.C. 96, 103, 552 S.E. 2d 778, 782 (Ct. App. 2001); *State v. Fain,* 273 S.C. 748, 259 S.E. 2d 606 (1979); *State v. Pacific Guano Co*., 22 S.C. 50, 86 (1884).

[139] *State v. Pacific Guano Co.,* 22 S.C. 50, 86 (1884).

[140] *Id*. at 74.

[141] *Lowcountry Open Land Trust v. State,* 347 S.C. 96, 103, 552 S.E. 2d 778, 782 (Ct. App. 2001).

[142] *State v. Yelsen*, 265 S.C. 43, 216 S.E. 2d 765 (1975).

[143] *State v. Yelsen*, 257 S.C. 401, 185 S.E. 2d 897 (1972).

[144] *Horry County v. Tilghman*, 283 S.C. 475, 478, 322 S.E. 2d 831, 833 (Ct. App. 1984), quoting *Horry County v. Woodward*, 318 S.E. 2d 584 (Ct. App. 1984).

[145] *Id. See also McQueen v. S.C. Coastal Council*, 354 S.C. 142, 580 S.E. 2d 116 (2003).

[146] *State v. Fain*, 273 S.C. 748, 259 S.E. 2d 606 (1979).

[147] *See State v. Beach Co*., 271 S.C. 425, 248 S.E. 2d 115 (1978).

[148] *Lowcountry Open Land Trust v. State,* 347 S.C. 96, 552 S.E. 2d 778 (Ct. App. 2001).

water, but this access does not include title in the soil below the high water mark.[149] To build a wharf or pier over tidelands owned by the state, the littoral owner must obtain a license from the State that allows such a structure to rest upon the ocean or channel bed.[150] Furthermore, if the tidelands are privately owned, the littoral owner must obtain the express consent of the fee-simple owner before the State will issue a permit.[151]

STATE STATUTORY AND ADMINISTRATIVE MECHANISMS AFFECTING WATER

South Carolina Water Resources Planning and Coordination Act

The South Carolina Water Resources Planning and Coordination Act charges the Department of Natural Resources (DNR) with the overall responsibility of recommending to the Governor and General Assembly a comprehensive water resources policy.[152] The act also requires DNR to advise and assist the Governor and General Assembly in developing policies and proposals to resolve special problems of water use facing the State.[153] DNR is given the power to review the actions and policies of other state agencies that possess water-resource responsibilities to ensure consistency with a comprehensive water policy of the State,[154] and recommend to the General Assembly any amendments to State law required to implement a State water policy.[155]

In assisting the implementation of a state water policy, DNR has the authority to conduct studies and enjoy full access to relevant records of other state departments and political subdivisions of the state.[156] DNR is also required to "encourage, assist and advise" regional and local governments in water planning and coordination of water-resource programs.[157]

South Carolina Surface Water Withdrawal and Reporting Act

The South Carolina Surface Water Withdrawal and Reporting Act was originally enacted in 1982, and revised in 2000.[158] The 2000 amendments relaxed the act's reporting requirements.[159] Surface water is defined as "all water, which is open to the atmosphere and subject to surface runoff which includes lakes, streams, ponds, and reservoirs."[160] A surface-water withdrawer is defined as "a public water system withdrawing surface water in excess of three million gallons during any one month and any other person withdrawing surface water in excess of three million gallons during any one month from a single intake or multiple intakes under common ownership within a one-mile radius from any one existing or proposed intake."[161]

Surface-water withdrawers are required to register their surface-water use with the South Carolina Department of Health and Environmental Control (DHEC) and file annual reports providing the quantity of water withdrawn.[162] A registered withdrawer must notify DHEC in writing within 30 days of constructing a new water intake, changing the method of measuring withdrawals, ceasing to withdraw water, abandoning an intake, or of a change in ownership.[163] Dewatering operations, emergency withdrawals, withdrawals for environmental remediation, withdrawals from a private pond supplied only by diffuse surface water, an Interbasin Transfer Act permittee, and withdrawals for wildlife habitat management are exempt from the Act.[164]

Willful violation of the Act is a misdemeanor, with a maximum fine of $1,000 per day for each violation.[165] Violation of the Act may also expose the violator to civil liability up to the same maximum penalty as a criminal misdemeanor.[166] DHEC may also seek an injunction to

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149 *Id*. at 785. In contrast, a riparian owner adjacent to a nontidal navigable stream holds title from their shoreline to the center of the stream subject to a public easement for use of the waterway for navigational purposes. Thus, a riparian owner can construct a dock or pier so long as the dock does not impede or obstruct navigation. Citing *McDaniel v. Greenville-Carolina Power Co*., 95 S.C. 268, 272-273, 78 S.E. 980, 981 (1913).

150 *Id*.

151 *Id*.

152 S.C. Code Ann. § 49-3-10 et seq. (Supp. 2002).

153 S.C. Code Ann. § 49-3-40(a)(2) (Supp. 2002).

154 S.C. Code Ann. § 49-3-40(a)(3) (Supp. 2002).

155 S.C. Code Ann. § 49-3-40(a)(6) (Supp. 2002).

156 S.C. Code Ann. § 49-3-40(b) (Supp. 2002).

157 S.C. Code Ann. § 49-3-40(d) (Supp. 2002).

158 S.C. Code Ann. § 49-3-40(d) (Supp. 2002).

159 *See* S.C. Act 366 (June 14, 2000) (available at http://www.scstatehouse.net/sess113_1999-2000/bills/3434.doc).

160 S.C. Code Ann. § 49-4-20(10) (Supp. 2002).

161 S.C. Code Ann. § 49-4-20(11) (Supp. 2002).

162 S.C. Code Ann. § 49-4-40 and 49-4-50 (Supp. 2002).

163 S.C. Code Ann. § 49-4-70 (Supp. 2002).

164 S.C. Code Ann. § 49-4-30 (Supp. 2002).

165 S.C. Code Ann. § 49-4-80 (Supp. 2002).

166 S.C. Code Ann. § 49-4-80(B) (Supp. 2002).

prevent violation of the act.[167]

Groundwater Use and Reporting Act

As stated previously, South Carolina has imposed reasonable-use restrictions on ground-water use through the Groundwater Use and Reporting Act.[168] The Act defines ground water as "water in the void spaces of geologic materials within the zone of saturation."[169] In comparison with other Southeastern states, the act defines ground water in a fairly narrow manner.[170]

The Act requires the DHEC to establish a ground-water management program.[171] In order to carry out this mandate, the Act requires all ground-water withdrawers to register their ground-water sources and report their ground-water use to DHEC.[172] DHEC must also establish, after required studies, a "capacity use area."[173]

A capacity use area is defined as any area where DHEC finds that the excessive withdrawal of ground water presents potential adverse effects to the natural resources or poses a threat to public health, safety or economic welfare or where conditions pose a significant threat to the long-term integrity of a ground-water source, including saltwater intrusion.[174] Either DHEC, local government authorities, other government agencies, or a ground-water withdrawer can initiate the capacity use designation process.[175]

After notice and public hearing of initiation of the capacity use area designation, DHEC must coordinate with affected governmental bodies and ground-water withdrawers to develop a ground-water management plan.[176] The plan is then approved by DHEC. Thereafter, ground-water withdrawers in the capacity use area must apply to DHEC for a permit, and DHEC must issue permits in accordance with the plan.[177] Currently, there are four capacity use areas established. The Waccamaw Capacity Use Area comprises Horry and Georgetown Counties.[178] The Low Country Capacity Use Area comprises Beaufort, Colleton, Hampton, and Jasper Counties.[179] The Trident Capacity Use Area comprises Charleston, Berkeley, and Dorchester Counties, and the Pee Dee Capacity Use Area comprises Darlington, Dillon, Florence, Marboro, Marion, and Williamsburg Counties.

Emergency withdrawals of ground water, withdrawal for nonconsumptive uses, withdrawal for wildlife habitat management, and withdrawal for a single-family residence or household for noncommercial use are exempted from the Act.[180] Aquifer storage and recovery wells are also exempt from the Act if the withdrawer already possesses a permit in accordance with the Underground Injection Control Regulations or the amount of water withdrawn does not exceed the amount of water injected.[181] Dewatering operations, replacement of an existing well, and wells constructed with an open hole in a crystalline bedrock aquifer in the Coastal Plain Ground-Water Management area are exempt from permitting and notification requirements.[182]

Dams and Reservoirs Safety Act

The Dams and Reservoirs Safety Act[183] is designed to reduce the risk of failure of dams, to prevent personal injury and property damage, and to authorize DHEC to certify and inspect dams.[184] While a dam or reservoir owner remains solely responsible for maintaining his/her dam or reservoir in safe condition, DHEC may, after appropriate investigation, order the owner to undertake

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167 S.C. Code Ann. § 49-4-80(D) (Supp. 2002).

168 S.C. Code Ann. § 49-5-10 et. seq. (Supp. 2002).

169 S.C. Code Ann. § 49-5-30(10) (Supp. 2002).

170 Joseph W. Dellapenna, *The Law of Water Allocation in the Southeastern States at the Opening of the Twenty-First Century*, 25 U. Ark. Little Rock L. Rev. 9, 41, 84 (2002). For example, Georgia's Ground-water Act defines ground water as "water of underground streams, channels, artesian basins, reservoirs, lakes, and other water under the surface of the earth, whether public or private, natural or artificial, which is contained within, flows through, or borders upon this state or any portion thereof, including those portions of the Atlantic Ocean over which this state has jurisdiction." Ga. Code Ann. 12-5-92(6).

171 S.C. Code Ann. § 49-5-40 (Supp. 2002).

172 *Id.*

173 S.C. Code Ann. § 49-5-60 (Supp. 2002).

174 S.C. Code Ann. § 49-5-60(A) (Supp. 2002).

175 *Id.*

176 S.C. Code Ann. § 49-5-60(B) (Supp. 2002).

177 S.C. Code Ann. § 49-5-60(B) and (C) (Supp. 2002).

178 27 S.C. Code Ann. Regs. 121-1 (1976).

179 27 S.C. Code Ann. Regs. 121-2 (1976).

180 S.C. Code Ann. § 49-5-70(A) (Supp. 2002).

181 S.C. Code Ann. § 49-5-70(C) (Supp. 2002).

182 S.C. Code Ann. § 49-5-70(B) (Supp. 2002).

183 S.C. Code Ann. § 49-11-10 et seq. (Supp. 2002).

184 S.C. Code Ann. § 49-11-130 (Supp. 2002).

maintenance, alteration, repair or removal as necessary if dangerous to life or property.[185] Dams that are less than 25 feet in elevation or impound less than 55 acre-feet of water ordinarily are not regulated except where the dam has a hazard potential that may cause loss of life in the event of dam failure or improper reservoir operation.[186]

Navigable Waters Permit

Construction, dredging, filling, or alterations in State navigable waterways require a permit from DHEC.[187] The Department's permitting program is based upon statutes declaring a State navigational servitude and control of vacant State lands.[188] DHEC is designated as the coordinating agency for the program, assigned the duty of obtaining and reviewing comments from the public and interested State agencies, and issuing permits. Navigable waterways are defined as "those waters which are now navigable, or have been navigable at any time, or are capable of being rendered navigable by the removal of accidental obstructions, by rafts of lumber or timber or by small pleasure or sport fishing boats."[189] DHEC is responsible for determining navigability.[190] Lands and water bodies subject to a public navigational servitude are defined as "those lands below the mean high water line in tidally influenced areas, or below the ordinary high water mark of any nontidal navigable waterway of the state."[191]

A permit issued is considered revocable by the State.[192] For continuous operations such as marinas, permits are issued for a term of 10 years or longer and are renewable, provided that there has been no material adverse change in circumstances.[193] Issuance of a permit does not convey any property right in the land or water in which the permitted activity is located.[194] No permitted activity shall obstruct navigation or the flow of water unless specifically authorized, and the permittee shall not prevent the "full and free use by the public" of all navigable water bodies at or adjacent to the permitted area.[195]

DHEC must provide public notice of the receipt of a permit application,[196] allow other State agencies to review and comment on the application,[197] and, if any agency objects to issuance of the permit, follow a reconciliation process.[198] If DHEC determines that the proposed activity would be likely to create an adverse impact on navigable water bodies or other associated natural resources that is not so great as to require denial of a permit, and the applicant has taken all reasonable measures to prevent the adverse impact, the applicant may be requested to submit a plan creating or providing natural-resource benefits to compensate for the adverse impact.[199]

Any person with legal standing to contest DHEC's decision to grant or deny a permit may appeal the decision to the DHEC Board.[200] A final decision by the Board may be appealed to an Administrative Law Judge.[201]

Drainage

The Drainage or Levee Districts Act of 1911 provides a comprehensive scheme for the creation of drainage or levee districts to accomplish the legislative public-interest declarations that "the drainage of swamps, drainage of surface water from agricultural lands and the reclamation of tidal marshes shall be considered a public benefit and conducive to the public health, convenience, utility and welfare."[202]

The 1911 Act requires an extensive series of actions to establish a drainage district, including petitions to the Clerk of Court, boards of reviewers, public hearings, appeals, surveys, assessments of damage, appointment

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185 S.C. Code Ann. § 49-11-170 (Supp. 2002).

186 S.C. Code Ann. § 49-11-120(4)(a) (Supp. 2002).

187 23 S.C. Code Ann. Regs. 19-450(A) (Supp. 2002).

188 S.C. Code Ann. § 49-1-10 (1976); S.C. Code Ann. § 1-11-70 (1986).

189 23 S.C. Code Ann. Regs. 19-450.2(C) (Supp. 2002).

190 *Id.*

191 23 S.C. Code Ann. Regs. 19-450.2(D) (Supp. 2002).

192 23 S.C. Code Ann. Regs. 19-450.4(A)(1) (Supp. 2002).

193 *Id.*

194 23 S.C. Code Ann. Regs. 19-450.4(A)(5) (Supp. 2002).

195 23 S.C. Code Ann. Regs. 19-450(4)(A)(7) (Supp. 2002).

196 23 S.C. Code Ann. Regs. 19-450.5 (Supp. 2002).

197 23 S.C. Code Ann. Regs. 19-450.6 (Supp. 2002).

198 23 S.C. Code Ann. Regs. 19-450.7 (Supp. 2002).

199 23 S.C. Code Ann. Regs. 19-450.9(B) (Supp. 2002).

200 23 S.C. Code Ann. Regs. 19-450.10 (Supp. 2002).

201 *Id.*

202 S.C. Code Ann. § 49-17-10 (1987).

of drainage commissioners, and construction of improvements. Basically, the Act taxes landowners who will benefit from the improvements in order to recover the cost of those improvements.

The Drainage Districts Act of 1920 seeks to accomplish goals similar to those in the 1911 Act; however, the 1920 Act pursues the goals in a slightly less cumbersome but more detailed fashion. Apparently, the legislature intended the two acts not to conflict with one another but, instead, to be complementary.

South Carolina Pollution Control Act

The South Carolina Pollution Control Act[203] is South Carolina's basic law with regard to control of air and water resources. It declares the public policy of the State to maintain reasonable standards of air and water purity, balancing the needs of public health and welfare with employment and industrial development.[204] The Act directs DHEC to adopt standards indicating polluted conditions in water and air.[205] Broad powers have been granted to DHEC in order to carry out the fundamental purposes of the Act, including: 1) holding of public hearings; 2) assessment of penalties; 3) making, revoking, or modifying orders to discontinue the discharge of various wastes into State water bodies; 4) institution of court proceedings to require compliance with the Act; 5) issuance, denial, ratification, and suspension of permits to discharge various wastes; and 6) implementation of the Federal Water Pollution Control Act in South Carolina.[206]

DHEC is authorized to prescribe standards for water quality considering the extent of floating and suspended solids, bacteriological organisms, oxygen levels, and other physical, chemical, or biological properties that are present and permitted in water.[207] The Act provides factors for DHEC to consider in developing classifications and standards for water.[208]

The Act imposes a permitting system for construction or alteration of sewage disposal facilities and creates classifications for all public wastewater treatment plants.[209] Any public wastewater treatment facility operating without a valid certificate or operating in a manner inconsistent with conditions of its permit is in violation of the Act.[210] If an undesirable level of pollution exists, DHEC must allow the permittee reasonable time to brings its operations into compliance.[211] If not corrected, DHEC must issue an order to cease and desist.[212] The operator is once again given the opportunity to abate the pollution prior to a final order to discontinue discharge of pollution,[213] and a public hearing may be held.[214] Any person may appeal an order to the Court of Common Pleas.[214] The Court renders judgment in equity, which also may be appealed.[216] The criminal penalty for violation is a fine of up to $25,000 per day, or imprisonment of up to two years, or both.[217] Civil penalties must not exceed $10,000 per day.[218]

DHEC is also authorized to issue emergency orders effective immediately, without the benefit of notice or a hearing, if the situation requires immediate action to protect public health or property.[219] A permittee receiving such order must comply but may apply for a hearing within 48 hours of the issuance of the order.[220]

Upon request of DHEC, the South Carolina Attorney General must seek an injunction or other court action in furtherance of the purpose of the Act.[221] The Act expressly preserves State common-law remedies to abate nuisances or pollution.[222] A determination by DHEC that a violation of the Act has occurred creates no presumption of law or

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203 S.C. Code Ann. § 48-1-10 et seq. (1987).

204 S.C. Code Ann. § 48-1-20 (1987).

205 S.C. Code Ann. § 48-1-40 (1987).

206 S.C. Code Ann. § 48-1-50 (1987).

207 S.C. Code Ann. § 48-1-70 (1987).

208 S.C. Code Ann. § 48-1-80 (1987).

209 S.C. Code Ann. § 48-1-110(a) and (b) (Supp. 2002).

210 *Id*. at (c).

211 S.C. Code Ann. § 48-1-120 (1987).

212 *Id*.

213 S.C. Code Ann. § 48-1-130 (1987).

214 S.C. Code Ann. § 48-1-50 (1987).

215 S.C. Code Ann. § 48-1-200 (1987).

216 *Id*.

217 S.C. Code Ann. § 48-1-320 (1987).

218 S.C. Code Ann. § 48-1-330 (1987).

219 S.C. Code Ann. § 48-1-290 (1987).

220 *Id*.

221 S.C. Code Ann. § 48-1-210 (1987).

222 S.C. Code Ann. § 48-1-240 (1987).

fact inuring to or for the benefit of anyone other than the State.[223]

State Safe Drinking Water Act

The State Safe Drinking Water Act[224] seeks to protect the quality of the State's drinking water supplies. The Act confers authority to DHEC to set standards for the design and construction of public water systems and the proper functioning of those systems.[225] Construction, expansion, or modification of public water facilities must be accomplished pursuant to a permit granted by DHEC.[226] Additionally, DHEC is authorized to investigate the system, collect water samples, and monitor operations. DHEC can enter the premises of a water system to carry out the provisions of the Act.[228]

If DHEC believes an imminent hazard exists that poses a serious, immediate threat to public health in a public water system, it can issue an emergency order without notice or hearing.[229]

The Act makes it unlawful for a person to violate the Act, the conditions of a permit, or any order of DHEC. Violators are subject to criminal penalties and injunction.[230]

Stormwater Management and Sediment Reduction Act

In 1991, the Legislature passed the Stormwater Management and Sediment Reduction Act.[231] The purpose of this Act was to replace the old county sediment control programs with a stronger, more uniform system.[232] The Act's provisions are administered by DHEC, which, in turn, may delegate their implementation to a local government. DHEC is responsible for developing regulations, minimum standards, guidelines, and criteria for carrying out provisions of the Act.[233] Under the Act, a stormwater-management and sediment-control plan must first be submitted, and a permit obtained, prior to conducting any soil-disturbing activity.[234] All land-disturbing activity must be done according to the submitted plan.[235]

The implementing agency has a statutory right to enter land on which land-disturbing activity is taking place to ensure compliance.[236] If the land disturbance is being done without the requisite stormwater-management and sediment-control plan, the implementing agency is authorized to issue a stop-work order.[237] Violators of the Act are subject to civil penalties in an amount determined by the implementing agency.[238] Additionally, the implementing agency may seek injunctive relief if it has reasonable cause to believe that any person is violating or is threatening to violate the requirements of the Act.[239]

South Carolina Drought Response Act

In 2000, the Legislature substantially revised the South Carolina Drought Response Act.[240] The purpose of the Act is to provide the State with a mechanism to effectively react to drought conditions. The Act applies to all of the water resources above and below ground with some exceptions.[241] It does not authorize any restriction

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223 S.C. Code Ann. § 48-1-250 (1987).

224 S.C. Code Ann. § 44-55-10 et seq. (2002).

225 S.C. Code Ann. § 44-55-30 (2002).

226 S.C. Code Ann. § 44-55-40 (2002).

227 *Id.*

228 *Id.*

229 S.C. Code Ann. § 44-55-60 (2002).

230 S.C. Code Ann. § 44-55-90 (2002).

231 S.C. Code Ann. § 48-14-10 et seq. (Supp. 2002).

232 County Sediment Control Programs, S.C. Code Ann. § 48-13-10 to § 48-13-60, (Supp. 2002) repealed by 1991 Act No. 51 § 3.

233 S.C. Code Ann. § 48-14-50(C) (Supp. 2002).

234 S.C. Code Ann. § 48-14-30(A) (Supp. 2002).

235 *Id.*

236 S.C. Code Ann. § 48-14-95 (Supp. 2002).

237 *Id.* at (B).

238 S.C. Code Ann. § 48-14-140(B) (Supp. 2002).

239 S.C. Code Ann. § 48-14-150 (Supp. 2002).

240 S.C. Code Ann. § 49-23-10 (Supp. 2002).

241 S.C. Code Ann. § 49-23-40 (Supp. 2002).

in the use of water that is injected into aquifer storage and recovery facilities or water stored in managed watershed impoundments or water from a private pond that is fed only by surface water.[242]

Under the Act, the DNR is responsible for formulating and executing a Drought Mitigation Plan, monitoring drought conditions, making investigations to determine whether action is necessary, determining levels of drought after consultation with the Drought Response Committee, and establishing drought management areas.[243]

The DNR is responsible for coordinating the appropriate response to drought upon consultation with the Drought Response Committee.[244] The Committee is a two-tiered organization made up of a statewide committee composed of State agencies, and local committees within each Drought Management Area.[245] The Governor is responsible for appointing the Chairperson of the Drought Response Committee.[246]

On the basis of data collected by the DNR, the Committee determines whether or not an area of the state has reached any of four designated levels of drought: 1) incipient drought; 2) moderate drought; 3) severe drought; and 4) extreme drought.[247]

DNR is empowered to promulgate regulations to specify categories of nonessential water use.[248] Water used strictly for firefighting, health and medical purposes, minimum stream flow, minimum water levels in drinking-water supplies, and any water used to satisfy federal, state, or local public health and safety requirements is considered essential water use.[249] The Department may also promulgate regulations to provide for mandatory curtailment of nonessential water uses during periods of severe and extreme drought in affected drought-management areas.[250] Mandatory curtailment of nonessential water use becomes effective only after the Drought Response Committee determines the action to be reasonably necessary to ensure supplies of water in drought management areas.[251] On the local level, each water supplier is to enact an ordinance or plan to implement a drought response.[252]

Once a determination for curtailment has been issued, "any person adversely affected by mitigation or mandatory curtailment may within ten days submit information to the Department and obtain relief as appropriate." Further, a party affected by a declaration of the Drought Response Committee has the right to appeal that action to the Administrative Law Judge Division.[253] The appeal must be filed within five days of the declaration and operates as an immediate stay of the declaration of the Drought Response Committee.[254] The appeals process in essence eviscerates the authority of the Committee to trigger mandatory water mitigation or curtailment. There are provisions for the Governor to issue an emergency declaration to curtail water withdrawal or equitably allocate water if the Committee determines that the severity of conditions threatens public health and safety.[255] The Governor's emergency declaration is not affected by any appeal.

The Drought Response Committee met several times in 2002 during the fourth year of a severe drought; however, the Committee never issued a mandatory water curtailment declaration. Thus, there was no opportunity to know how well or how poorly the Act would stand up under urgent circumstances.

Interbasin Transfer of Water Act

The Interbasin Transfer of Water Act[256] requires any person to obtain a permit who withdraws, diverts, pumps, or directly causes the transfer of either 5 percent of the 7-day, 10-year low flow, or 1 million gallons or more a day, whichever is less, from one river basin for use and

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[242] *Id.*

[243] S.C. Code Ann. § 49-23-50 (Supp. 2002).

[244] S.C. Code Ann. § 49-23-60 (Supp. 2002).

[245] *Id.*

[246] *Id.*

[247] S.C. Code Ann. § 49-23-70 (Supp. 2002).

[248] *Id.*

[249] *Id.*

[250] *Id.*

[251] *Id.*

[252] S.C. Code Ann. § 49-23-90(A) (Supp. 2002).

[253] S.C. Code Ann. § 49-23-70(D) (Supp. 2002).

[254] *Id.*

[255] S.C. Code Ann. § 49-23-80 (Supp. 2002).

[256] S.C. Code Ann. § 49-21-10 et seq. (Supp. 2002).

discharge into another river basin.[257] As the responsible agency, DHEC is empowered to grant, deny, or condition a permit for interbasin water transfer.[258] Upon application for a permit, DHEC's consideration must include current and projected stream uses of both the losing river basin and the receiving river basin, the water quality of the losing river basin, reasonably foreseeable water needs of the applicant, the beneficial impact of the transfer, whether the nature of the proposed water use is reasonable, the transfer's effect on water conservation, any alternative water supplies, the impact on interstate water use, and the availability of water for the losing stream to respond to drought.[259] DHEC is forbidden to issue a permit if the transfer will violate the water classification system or stream classification regulations or will adversely affect the public health and welfare.[260] The duration of the permit cannot exceed 20 years.[261]

DHEC may suspend, modify, or revoke a permit for good cause, provided that the permittee is given notice and an opportunity to be heard before the DHEC Board.[262] Following a decision by DHEC, the permittee may appeal that decision to the Administrative Law Judge Division.[263] An appeal of an Administrative Law Judge decision must be taken to the DHEC Board.[264]

Violators of the Act are subject to criminal penalties as well as an injunction.[265]

Any riparian owner or person with a legal right to use water who suffers material injury in the loss of water rights as a result of an interbasin transfer has a cause of action against the transferor. The injured person can recover all provable damages for loss of riparian rights, except against those transfers grandfathered in due to transfers existing in December 1984 or under license by the Federal Energy Regulatory Commission prior to December 1984.[266]

Soil and Water Conservation Districts Act

The purpose of the Soil and Water Conservation Districts Act is to conserve the soil and water resources, prevent soil erosion and flooding, prevent impairment of dams and reservoirs, maintain the navigability of rivers and harbors, provide water storage, and generally promote the health and safety of the public.[267] The goals of the Districts are carried out through the operation of the DNR Land, Water and Conservation Division, which includes the former Land Resources Conservation Commission, and through the local soil and water conservation districts.[268] The Act provides the authority to assist and coordinate local districts; coordinate the development of comprehensive conservation plans for State-owned lands; coordinate a statewide landscape inventory, flood-plain inventory, and soil-survey system; formulate guidelines to implement local landscape and beautification programs; and assist local government in flood-plain conservation, in erosion-control programs, and with conservation guidelines for land-use plans.[269]

The Act also provides a detailed procedure for creation of local soil and water conservation districts, including provisions for petitioning for the creation of such districts,[270] hearings on such petitions,[271] determination of need for the districts,[272] referendum on establishment,[273] and final establishment of the district.[274] The districts' powers include surveying and investigating soil erosion, flood damage, and preventative controls needed; demonstration projects; implementing preventative and control measures for flood prevention and water disposal; constructing and operating structures needed to carry out its duties; and developing comprehensive plans for soil and water conservation.[275] Local districts also are authorized to formulate local land-use regulations, which may be given the force and effect of law after proper

257 S.C. Code Ann. § 49-21-20 (Supp. 2002).

258 S.C. Code Ann. § 49-21-30 (Supp. 2002).

259 S.C. Code Ann. § 49-21-30(C) (Supp. 2002). The above criteria are not exhaustive of the listed criteria set forth in the statute.

260 *Id*. at (D).

261 S.C. Code Ann. § 49-21-40(A) (Supp. 2002).

262 S.C. Code Ann. § 49-21-40(B) (Supp. 2002).

263 *Id*.

264 *Id*.

265 S.C. Code Ann. § 49-21-70 (Supp. 2002).

266 S.C. Code Ann. § 49-21-30(g) and § 49-21-50(A)(2) (Supp. 2002).

267 S.C. Code Ann. § 48-9-20 (1987).

268 S.C. Code Ann. § 48-9-220 (1987).

269 S.C. Code Ann. § 48-9-290 (Supp. 2002).

270 S.C. Code Ann. § 48-9-510 (Supp. 2002).

271 S.C. Code Ann. § 48-9-540 (Supp. 2002).

272 S.C. Code Ann. § 48-9-560 (Supp. 2002).

273 S.C. Code Ann. § 48-9-580 (Supp. 2002).

274 S.C. Code Ann. § 48-9-600 (Supp. 2002).

275 S.C. Code Ann. § 48-9-1270 (1987).

promulgation, including a local referendum on proposed regulations.[276]

Watershed Conservation Districts Act

The Watershed Conservation Districts Act[277] sets out a process for the creation of watershed conservation districts that are political subdivisions of the State. These districts may be created within one or more of the soil and water conservation districts to develop plans relating to erosion control, flooding, soil and water conservation, stormwater management, and/or water disposal.[278] The area of a district must be contiguous, lie within an established watershed, and be located within one or more soil and water conservation districts.[279] Districts are formed by filing a petition with the Board of Commissioners of the soil and water conservation district in which the proposed watershed district is located.[280] The commissioners must then hold a public hearing, and, upon a favorable recommendation, a referendum is held.[281] If approved by a majority of qualified electors residing in the proposed district, the district is established with an elected five-member board of directors.[282] The district residents are levied a tax for any improvements within the district made to further its mission.

South Carolina Coastal Conservation

Pursuant to State law regulating coastal tidelands and wetlands,[283] the Office of Ocean and Coastal Resource Management of DHEC possesses the authority to develop a comprehensive coastal management program and undertake the responsibility of enforcing that program.[284] The Division must inventory and designate areas of critical concern such as port areas, significant natural environmental areas, and recreational areas.[285] Persons who wish to use a critical area, or fill, remove, dredge, drain, or erect a structure in a critical area must first receive a permit from DHEC.[286] Emergency orders to protect public health and safety, hunting, trapping and fishing, discharge of treated effluent as permitted by law, and dredging harbor channels by the Corps of Engineers are exempt from the permitting requirement.[287]

Further, it must develop and implement a comprehensive beach erosion control policy and issue permits for erosion control structures.[288]

Violators of the Act are subject to criminal and civil penalties and injunction.[289]

The Act expressly states that it does not affect the status of the State's title to land below the mean high-water mark.[290] Furthermore, the Act provides a means for a person to claim an interest in tidelands, defined as all lands except beaches in the coastal zone between the mean high-water mark and mean low-water mark of navigable water bodies without regard to salinity.[291]

FEDERAL STATUTES

Neither the United States Constitution nor the laws enacted by Congress directly attempt to dictate water rights in South Carolina, but the effect of court interpretations and actual application of both the Constitution and various statutes play a significant role in water resources considerations in South Carolina. It is not the primary purpose of this chapter to review and propose modification in federal law; however, the multitude of federal provisions ranging from grants for sewer construction to impoundment of significant rivers for hydroelectric-power generation cannot be ignored. Federal activities may often carry implications beyond the intended purpose or scope of a particular action. For instance, the total dominion over the upper Savannah River by federal authorities seriously impacts the ability of individuals, industries, agriculture, and municipalities

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276 S.C. Code Ann. § 48-9-1510 and 1520 (Supp. 2002).

277 S.C. Code Ann. § 48-11-10 et seq. (Supp. 2002).

278 S.C. Code Ann. § 48-11-20 (Supp. 2002).

279 S.C. Code Ann. § 48-11-30 (Supp. 2002).

280 S.C. Code Ann. § 48-11-40 (Supp. 2002).

281 S.C. Code Ann. § 48-11-50 and § 48-11-60 (Supp. 2002).

282 S.C. Code Ann. § 48-11-70 and § 48-11-100 (Supp. 2002).

283 S.C. Code Ann. § 48-39-10 et seq. (Supp. 2002).

284 S.C. Code Ann. § 48-39-80 (Supp. 2002).

285 *Id.*

286 S.C. Code Ann. § 48-39-130 (Supp. 2002).

287 *Id.*

288 S.C. Code Ann. § 48-39-120 (Supp. 2002).

289 S.C. Code Ann. § 48-39-170 (Supp. 2002).

290 S.C. Code Ann. § 48-39-190 (Supp. 2002).

291 S.C. Code Ann. § 48-39-190 (Supp. 2002).

to draw upon the vast water supply in the Upper Savannah Region for future development and growth.

The federal government exercises numerous opportunities to involve itself in decision making regarding natural watercourses, primarily those water bodies affected by the Commerce Clause in the United States Constitution. To date, none of the three branches of federal government have sought to exercise control over ground water in any degree approaching involvement in watercourses. Recent decisions of the United States Supreme Court and a Federal District Court clearly state, however, that under appropriate circumstances, ground water may be covered by the Commerce Clause, providing the federal government a sufficient basis to regulate ground-water use.[292]

With the above in mind, no attempt will be made to identify each federal program or activity that affects water law and administration in South Carolina; rather, several federal programs will be briefly discussed that may have the greatest present impact on water-use decisions.

Federal Power Act

Enacted in 1920, the Federal Power Act provides a comprehensive federal scheme for the development of hydroelectric power.[293] Finding its power under the Commerce Clause of the U.S. Constitution, the Act preempts any state law or regulation that conflicts with its provisions.[294] The Act is administered by a five-member quasi-judicial body, the Federal Energy Regulatory Commission (FERC), whose members are appointed by the President with advice and consent from the Senate.[295] FERC is authorized to issue licenses for the operation of hydropower dams that 1) are located on a navigable waterway of the United States; 2) occupy Federal lands; 3) use surplus water or water power from a Federally-operated dam; or 4) are located on a water body over which Congress properly exercises Commerce Clause jurisdiction and the project affects interstate or foreign commerce.[296] Holding a FERC license is not a property right in the river on which the dam is located, because rivers are held in public trust.[297] Rather, the issuance of a license is considered a privilege. A FERC license can extend for a maximum term of fifty years.[298] Throughout the life of the license, the licensee must comply with its license terms, FERC regulations governing operations, and any applicable FERC orders.

In deciding whether to issue a hydropower license, FERC is mandated by the Federal Power Act to "equal consideration" of both economic and environmental values, including the necessity for hydropower generation, fish and wildlife habitat, visual resources, cultural resources, recreational opportunities, irrigation, water supply and flood control.[299] FERC must also make sure that the project under consideration: 1) is amenable to state comprehensive water plans;[300] 2) includes the means to protect or mitigate damage to fish and wildlife;[301] and 3) includes fishways as may be prescribed by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.[302] Additionally, FERC requires an applicant to receive a water-quality certification under section 401 of the Clean Water Act. Any minimum streamflow conditions a state may place upon its 401 certification must be included in the FERC license.[303]

If an existing license has expired during its relicensing process, FERC is authorized to grant an annual license on the same terms as the original license.[304] An annual license is automatically renewable each year unless FERC takes action to do otherwise.[305]

The Federal Power Act explicitly states that "nothing contained in this chapter shall be construed as affecting or intending to affect or in any way to interfere with the laws of the respective States relating to the control, appropriation, use or distribution of water used in irrigation or for municipal or other uses, or any vested right acquired therein."[306] The term "municipal" includes a state and its political subdivisions.[307] The term "other uses" is construed narrowly to mean rights of the same nature as those relating to irrigation and municipal

[292] *Sporhase v. Nebraska*, 458 U.S. 941 (1982).

[293] 16 U.S.C. § 791 et seq. (2000).

[294] *See* 3 Pub. Nat. Resources L. § 21C:8 (2002).

[295] 16 U.S.C. § 792 (2000).

[296] 16 U.S.C. § 794(e) (2000).

[297] *United States v. Grand River Dam Authority*, 363 U.S. 229 (1960).

[298] 16 U.S.C. § 799 (2000).

[299] 16 U.S.C. § 808 (2000).

[300] 16 U.S.C. § 803(a)(2)(a) (2000).

[301] 16 U.S.C. § 803(j) (2000).

[302] 16 U.S.C. § 811 (2000).

[303] *PUD No. 1 of Jefferson County v. Washington Dept. of Ecology*, 511 U.S. 700 (1994).

[304] 18 C.F.R. § 16.18(b) (2002).

[305] *Id.*

[306] 16 U.S.C. § 821 (2000).

[307] *Id.*

purposes.[308] State regulation of all other uses not specified above is preempted by the Federal Power Act. State common law or statutory law pertaining to private proprietary rights to use, divert or distribute water are left intact.[309] FERC licensees are liable to riparian water users for any interference with their water rights under state law.[310]

FERC issued a new rule that revises its regulations concerning the licensing process. The revisions create a new licensing procedure, called the Integrated Licensing Process, that collapses two formerly sequential steps, the applicant's prefiling consultation and FERC's environmental review, into a combined step. The new process was optional for applicants until July 2005, after which it became the required process unless specific approval by FERC is granted to use a former procedure. The rulemaking took effect on October 23, 2002.

Federal Water Pollution Control Act

Congress enacted the Federal Water Pollution Control Act in 1972,[311] subject, in part, to the following goals and policies:

> The objective of this act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. In order to achieve this objective it is hereby declared that, consistent with the provisions of this act
>
> 1. it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985;
> 2. it is the national goal that wherever attainable, an interim goal of water quality that provides for the protection and propagation of fish, shellfish, and wildlife and provides recreation in and on the water be achieved by July 1, 1983;
> 3. it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited;
>
> It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of states to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources, and to consult with the administrator in the exercise of his authority under this act.
>
> * * *
>
> It is the policy of Congress that the authority of each state to allocate quantities of water within its jurisdiction shall not be superseded, abrogated, or otherwise impaired by this act. It is the further policy of Congress that nothing in this Act shall be construed to supersede or abrogate rights to quantities of water that have been established by any state. Federal agencies shall cooperate with state and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water resources.

The Water Pollution Control Act, extensively amended by the Clean Water Act in 1977,[312] provides a comprehensive scheme to upgrade and protect the Nation's water. While a thorough understanding of all parts of the Act are necessary to realize the full impact of this law on activities in South Carolina, this assessment will restrict itself to briefly reviewing three important programs created by the act.

Section 401.[313] Section 401 is contained in Title IV of the Act. The section requires an applicant to obtain certification from the State-designated permitting agency before Federal licensing or permitting of an activity that, during construction or operation, may result in a discharge to navigable waters.[314] Federal permits or licenses for which certification is required as determined by the Federal agency include but are not necessarily limited to:

a. individual or general Federal permits issued pursuant to Section 404 of the Clean Water Act, 33 U.S.C. Section 1344.

b. Federal permits issued pursuant to Sections 9 and 10 of the Federal River and Harbor Act, 33 U.S.C. Sections 401 and 403.

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308 *First Iowa Hydro-Electric Co-Op v. FERC*, 328 U.S. 152 (1946).

309 *U.S. v. Twin City Power Co*., 215 F.2d 592 (4th Cir. 1954).

310 South Carolina common law recognizes a cause of action against a dam owner for damages to upstream or downstream property caused by construction of the dam. *See McDaniel v. Greenville-Carolina Power Co*., 95 S.C. 268, 78 S.E. 890 (1913); *McMahon v. Walhalla Light & Power Co*., 102 S.C. 57, 86 S.E. 194 (1915). Claims against dam operators subsequent to the enactment of the FPA involve takings challenges. *See infra* n.

311 33 U.S.C. § 1251 et seq. (2000).

312 P.L. 95-217.

313 33 U.S.C. § 1431 (2000).

314 33 U.S.C. § 1341(a)(1) (2000).

c. permits or licenses issued by the Federal Energy Regulatory Commission, 16 U.S.C. Section 1791, et seq. dealing with permits and licenses.[315]

"Navigable waters" is defined as "waters of the United States."[316] Sections 1311 through 1313 and sections 1316 and 1317 state applicable standards and provide for enforcement under the act, including effluent limitations. The 401 certification can be seen as an important attempt on the part of Congress to comply with its own declaration of policy in placing primary responsibility with the states to prevent, reduce, and eliminate pollution.

Further, because the Section 401 certification is a state program conducted pursuant to state as well as Federal authority, the State of South Carolina has included a requirement for 401 certification in State permits, issued by DHEC, for various activities in State navigable water bodies.[317]

Section 402.[318] Section 402 creates the "National Pollutant Discharge Elimination System" (NPDES) which requires a permit for the point-source discharge of pollutants into the waters of the United States. "Pollutant" is defined broadly and includes all discharges of municipal, industrial, and agricultural waste. Point sources are discrete conveyances such as pipes or man-made ditches, and typically involve publicly owned wastewater treatment facilities, industrial dischargers, and urban runoff.[319] Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface water.[320]

The NPDES program is one of the primary tools for maintaining water quality. In South Carolina, the program is implemented by DHEC, pursuant to the broad authority granted to the Department under the Act.[321] Even though the NPDES program is administered by the State, the U.S. Environmental Protection Agency retains various oversight and approval authorities for procedures and standards in the program.

Section 404.[322] Section 404 prohibits the discharge of dredged or fill material into the navigable waterways of the United States without first obtaining a permit. This Federal program is the joint responsibility of the Secretary of the Army, administered through the Army Corps of Engineers, and the Administrator of the U.S. Environmental Protection Agency.[323] The Corps issues permits, and the EPA develops guidelines for issuing the permits.[324] Applicants for a Section 404 permit must also receive a Section 401 water quality certification from the State.[325] States may obtain approval from the EPA to administer the Section 404 permitting program.[326]

The Corps of Engineers has defined "navigable waters" to include intrastate water bodies, "the use, degradation or destruction of which could affect interstate or foreign commerce."[327] In 1986, the Corps attempted to clarify its jurisdiction over isolated intrastate water bodies by stating, in what is referred to as the "Migratory Bird Rule," that Section 404(a) jurisdiction extends to intrastate water bodies that, among other things, provide habitat to migratory birds.[328] This Rule has served to protect wetlands, particularly isolated wetlands, from destruction.

In *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*,[329] the U.S. Supreme Court held that the Corps' exercise of jurisdiction over isolated wetlands exceeded the statutory grant of authority to the Corps under section 404.[330] The Corps denied the Solid Waste Agency of Northern Cook County (SWANCC) a 404 permit to fill an abandoned quarry that, over time, had evolved into a series of permanent and seasonal ponds. The ponds attracted a large migratory bird population. The Corps asserted its jurisdiction over the quarry pursuant to its Migratory Bird Rule and denied SWANCC a 404 permit. The Court struck down the Migratory Bird Rule.

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315 25A S.C. Code Ann. Regs. 61-101(a)(2) (Supp. 2002).

316 33 U.S.C. § 1362(7) (2000).

317 23 S.C. Code Ann. Regs. 19-450(16) (Supp. 2002).

318 33 U.S.C. § 1342 (2000).

319 EPA, Office of Wastewater Management, *Water Permitting 101*, p. 5. <http://www.epa.gov/npdes/pubs/101pape.pdf> (accessed Sept. 11, 2003).

320 *Id.*

321 33 U.S.C. § 1342(b) (2000).

322 33 U.S.C. § 1344 (2002).

323 33 U.S.C. § 1344(d) (2002).

324 40 C.F.R. § § 230.1 – 230.80 (2002).

325 33 U.S.C. § 1341 (2002).

326 33 U.S.C. § 1344(g) (2002).

327 33 C.F.R. § 328.3(a)(3) (2002).

328 15 Fed. Reg. 41206, 41217 (Nov. 13, 1986).

329 531 U.S. 159 (2001).

330 *Id.* at 173-174.

The Court's ruling has left the protection of nonnavigable, intrastate, isolated wetlands solely to state governments.[331] Jurisdiction over this type of water can only be asserted if its degradation could adversely affect navigable water bodies of the United States.[332] The Corps' jurisdiction over navigable water bodies, interstate water bodies, and tributaries of navigable or interstate water bodies remains unaffected for Section 404 purposes.

PROBLEMS AND NEEDS RELATED TO WATER LAW

Uncertainty in Riparian Law

The single greatest problem in riparian water law in South Carolina is uncertainty as to the law itself, primarily common law, which leads to uncertainty and questionable security of rights to use water. Three issues seem to present the most consistent source of concern: (1) insecurity of a riparian right; (2) limitations on where water may be used; and (3) inadequate protection of the resource and public interest in the resource.

Insecurity of Riparian Rights. A riparian owner has a right to a reasonable use of water as it flows by his land. There is no guarantee of a specific amount, however, even if the use is reasonable; moreover, there is no protection based upon the date reasonable use commenced. Water use over a long period of time can later be found unreasonable if a newer use is seen as more reasonable.[333] If any competing uses change, then the "calculus of reasonableness" can change.[334] In essence, the reality is "that courts cannot deliver a decision, even as between the litigants themselves, which will be good for more than the day on which it was given."[335] Such insecurity is an obstacle to private investment in water development.[336]

A civil action is the sole mechanism for enforcing and maintaining a riparian right. Given that South Carolina courts have not heard any significant riparian litigation since 1920, how it would be applied to a contemporary water use conflict is, at best, speculative. The difference in theories under the riparian doctrine, natural flow and reasonable use, is so substantial as to permit total consumption of a stream in one case and spread the use of water so thinly between so many riparians that no beneficial use can be made in another.

The riparian right is a right held commonly—the right of each riparian is coequal. New water users compete on equal footing with older users. In practice, all reasonable uses of water are permitted, regardless of the amount of water consumed and the date the use started, with reasonableness being measured either by the lack of damage to others, or by the significance of the damage versus the significance of the use. The various potential reasonable uses defy any quantitative determination as to where, when, under what circumstances, and how much water each riparian is entitled to use or how much will remain available for use. Theoretically, all reasonable uses of water are threatened with physical uncertainty equally, both as to time and amount, and users would suffer a shortage proportionally. While such an equality of right has an appealing and democratic sound, an equal share of an insufficient supply does not damage all users equally and, of course, does not allocate or devote remaining supplies to the highest and best uses.

As for certainty of tenure of water rights, the riparian right is acquired by land ownership and not lost by nonuse. The acquisition and continued maintenance of a right is, therefore, certain, but a particular use of the right is always subject to future determinations of its reasonableness in view of later needs for the water, and even if the use is reasonable the right gives no guarantee of a certain quality of water as others with equal rights later demand a share. What is considered reasonable also varies with supply conditions, such that what is reasonable in good water years may become unreasonable in times of drought.

Water rights acquired by subscription are no more secure than water rights acquired by ownership of riparian land. Further, prescriptive rights are extremely difficult to establish under the riparian reasonable-use theory, as they only come into existence when unreasonable harm is done to other riparian rights. Not only must an injury be sustained but it must be of a continuous nature, not merely during unusually dry years. The chances are small that a riparian would suffer harm in silence for a 20-year period.

Water use is increasing, as is the cost to obtain water. Providing a more secure and stable form of water right would benefit all water-using sectors of the economy and, of course, is a keystone in any state water policy.

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331 C. Victor Pyle, III, Student Author, *Isolated Wetlands Jurisprudence Post SWANCC and Resulting Federal and State Attempts to Fill the Void*, 11 S.E. ENV. L. J. 91, 92 (2002).

332 *Id.* at 95.

333 Joseph W. Dellapenna, *The Law of Water Allocation in the Southeastern States at the Opening of the Twenty-First Century*, 25 U. ARK. LITTLE ROCK L. REV. 9, 16 (2002).

334 *Id.*

335 *Id.*

336 *Id.*

Limitations on Water Use. Perhaps the most prominent criticism of riparian law is the limitation, or outright illegality, of water use on nonriparian lands by nonriparians. A corresponding limitation is the requirement that the use must be within the watershed or the stream from which the water was taken. These territorial limitations are founded on several concepts, such as reserving water for the sole use of the owner on the basis of an alleged real-property right or as a protection against diminishing the quantity of water for downstream users.

Use by nonriparians or by riparians beyond the watershed of origin or by interbasin transfer exists and is common in South Carolina despite riparian law. Above the Fall Line, many municipal water-supply systems transfer water from one watershed to serve customers in another watershed. Along the coast, much of the population now is served through interbasin transfers by public water systems: 1) Beaufort County and parts of Jasper County from the Savannah River; 2) the city of Charleston from the Edisto River; and 3) the city of Georgetown and parts of Horry County from the Great Pee Dee River. Interbasin transfer of water for industrial and agricultural use is not widespread at present.

The frequency of interbasin transfer by municipal suppliers is based on simple expediency, for few cities lie wholly within one watershed. Further, limiting distribution of publicly supplied water to a single watershed would not be practical in most cases. The limited number of cases against municipal suppliers by injured riparians in the past has produced little knowledge or concern about the watershed limitation.

Because court cases in this State have not clarified the problem, it must be assumed that the territorial limitations inherent in the riparian law remain in effect. The requirement that water be used only in the watershed of origin, from a water-development standpoint, is an excessively burdensome limitation and one that would lead to absurd results if it became a mandatory provision of State water policy. Interbasin transfer should not be viewed as inherently good or bad but should be judged on the merits of each proposed transfer.

Protection of the Resource for Public Interests. The ultimate public interest in any system of water law is to discourage waste and foster the best possible use of the resource. Beyond the interest in providing security to beneficial private uses, a public interest exists in the protection of the resource in general. Such public interests include the maintenance of minimum streamflow for protection of water quality, fishery resources, navigation, recreation, and aesthetics. The riparian system does not provide protection to these public interests, because riparian rights are a common-property system. Under a common-property scheme, it is up to all the co-owners to decide if, how, and when to use their water right.[337] The problem with a common-property scheme is that when the use reaches capacity, a "tragedy of the commons" results.[338] Water users, exercising their own private interests, appropriate their share of water to the point of exhaustion.[339]

Because riparian rights apply to private use, lawsuits are brought in the nature of individual property actions. The adversary process rivets the court's attention to the particular parcel of land in dispute and is based on particular individual damages. This method of enforcement is not designed to reach conclusions regarding social policy and the public interest. The practical policy implication of riparian law is that water must be used without damage to others as opposed to a public policy that water be used wisely and beneficially.

No riparian-law mechanism is available to protect minimum streamflow, that is, to establish a base flow for planning and regulatory purposes beyond which water consumption will be discouraged in the public interest. Unlike some western states where all water in streams is allocated to an active use, South Carolina is in an advantageous position to protect minimum streamflows and still provide for continued development.

To address these problems, about half of the eastern states have moved towards a permit system to replace common-law riparian rights.[340] This new system, sometimes called "regulated riparianism," attempts a transition from a common property system to that of a public-property system.[341] Under a regulated riparian system, a water user must obtain a permit from the state in order to withdraw water. The water rights of users are determined by the permit instead of the riparian doctrine.[342] Even so, the criterion of reasonable use is applied by the state in deciding whether to approve a permit.[343] The major difference, however, in applying the reasonable-use standard under a permitting system is that the reasonable use of water is decided prior

[337] Joseph W. Dellapenna, *The Law of Water Allocation in the Southeastern States at the Opening of the Twenty-First Century*, 25 U. Ark. Little Rock L. Rev. 9, 16 (2002).

[338] *Id.*

[339] *Id.*

[340] *Id.* at 31. Those states that have adopted comprehensive permit systems are Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Hawaii, Iowa, Kentucky, Maryland, Massachusetts, Minnesota, Mississippi, New Jersey, North Carolina, New York, Virginia, and Wisconsin. States that have adopted a regulated riparian system to ground water, but not surface water, are Arizona, Illinois, Indiana, and South Carolina.

[341] *Id.*

[342] *Id.* at 35.

[343] *Id.*

to actual water consumption; whereas under a traditional riparian approach the determination of reasonable use occurs after the use has begun and litigation over such use is underway.[344] Additionally, states judge reasonable use in a broader context, including public-policy considerations.[345]

Potential for Increased Takings Litigation

In the past, South Carolina courts have adjudicated few takings challenges from riparian owners.[346] All of these early cases involved damage incurred by a riparian owner from a hydroelectric-power plant. And in every case, the plaintiffs opted for a takings claim simply to avoid the sovereign immunity from tort claims that existed prior to 1985.[347] As South Carolina adopted statutes regulating water use, the legislature pointedly left riparian rights intact, which explains why the State has not seen a rash of regulatory takings claims. As private development increases, however, the State's water resources will be under pressure. The need for greater conservation and regulation of water in South Carolina may lead to legislation that limits the scope of riparian rights. Consequently, South Carolina may encounter takings challenges to any increased regulation of water use.[348]

Nationally, water law is seen as a likely battlefield for takings cases.[349] Recent riparian takings cases in other states arose from legislation or government action that limited or eliminated riparian rights.[350] Only two states, California and Oklahoma, have struck down legislation limiting riparian rights; and of these two, only Oklahoma based its decision on a takings theory.[351] Both of these states operate under the prior appropriation doctrine, which confers a vested water right upon users. South Carolina's riparian law does not give any user a vested right. Additionally, the State's navigational servitude is superior to an individual riparian right. Thus, the area where increased takings challenges may be a possibility is ground-water regulation.

Applying takings jurisprudence to water resources raises difficult ambiguities because takings cases have traditionally dealt with real property instead of water use.[352] Questions over whether a regulation constitutes a physical taking of all legal rights to water use, and whether restricting water use deprives an owner of all economically beneficial use of water, will prove to be novel issues facing courts.[353] If South Carolina chooses to alter riparian rights, care should be employed to avoid takings challenges.

FERC Relicensing of Hydroelectric-Power Dams in South Carolina

In South Carolina, 25 hydroelectric-power projects are licensed by FERC. These plants are located on the Santee, Saluda, Broad, Wateree, Little, Savannah, Pacolet, Enoree, and Rocky Rivers, as well as Bad Creek, Lawsons Fork Creek, and Conecross Creek.[354] As noted earlier, FERC hydropower licenses are granted for a term no longer than fifty years.[355] For those licenses granted prior to the enactment of Federal environmental laws such as the National Environmental Policy Act (NEPA),[356] the Clean Water Act (CWA),[357] and the Endangered Species Act (ESA),[358] the relicensing experience will take on new complexity. Furthermore, the Federal Power Act was amended in 1986 to require FERC to

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344 *Id.*

345 *Id.*

346 *McDaniel v. Greenville-Carolina Power Co.,* 95 S.C. 268, 78 S.E. 980 (1913); *Werts v. Greenwood County*, 205 S.C. 258, 31 S.E. 2d 451 (1944); *Webb v. Greenwood County*, 229 S.C. 267, 92 S.E. 2d 688 (1956); *Rice Hope Plantation v. S.C. Public Service Authority*, 216 S.C. 500, 59 S.E. 2d 132 (1950).

347 The S.C. Supreme Court abolished the doctrine of sovereign immunity, subject to limitations, in *McCall v. Batson*, 285 S.C. 243, 329 S.E. 2d 741 (1985).

348 Recently, the S.C. Supreme Court has wrestled with a takings challenge of tidelands regulation in *McQueen v. S.C. Coastal Council*, 354 S.C. 142, 580 S.E. 2d 116 (2003) (no taking where land reverted to navigable tidelands because State holds water below high water mark held in public trust).

349 Barton H. Thompson, Jr., *Takings and Water Rights* in *Water Law: Trends, Policies and Practice*, 43, 43 (Kathleen Marion Carr & James D. Crammond, eds. American Bar Association, 1995).

350 *Id.* at 45. *See R.W. Docks & Slips v. State*, 244 Wis. 2d 497, 628 N.W. 2d 781 (Wis. 2001) (DNR denied dredging permit to construct boat slips); *Stupak-Thrall v. U.S.,* 89 F. 3d 1269 (6th Cir. 1996) (U.S. Forest Service regulations governing national forest restricted motor boats on lake); *Peterman v. State Dept. of Natural Resources*, 446 Mich. 177, 521 N.W. 2d 499 (Mich. 1994) (DNR constructed boat launch and jetties which caused erosion of property owner's beachfront); *Franco-American Charolaise*, *Ltd. v. Oklahoma Water Resources Bd.,* 1990 OK 44, 855 P.2d 568 (Okl. 1990) (statute limiting riparian owner to domestic use and declaring all other water in stream to be public subject to appropriation without compensation); *Belvedere Dev. Corp. v. Div. Of Admin., State Dept. of Transp.,* 476 So.2d 649 (Fla. 1985) (condemnation that attempted to reserve riparian rights to condemnee to avoid compensation).

351 *In re Waters of Long Valley Creek Stream System*, 25 Cal. 3d 339, 599 P. 2d 656 (1979*); Franco-American Charolaise, Ltd. V. Oklahoma Water Resources Bd*., 855 P. 2d 568 (Okla. 1990).

352 Thompson, *supra* n. 346 at 48.

353 *Id.*

354 Federal Energy Regulatory Commission, *Complete List of Issued Licenses* (available at http://www.ferc.gov/industries/hydropower.asp).

355 16 U.S.C. § 799 (2000).

356 Enacted in 1969.

357 Enacted in 1972, and amended in 1977.

358 Enacted in 1973.

consider environmental impacts on equal footing with economic needs.[359] In South Carolina, three of the top hydropower licenses have expired or will expire by the year 2010, triggering an extensive relicensing process. Santee Cooper's license to operate its dam on the Santee River expired in 2006.[360] South Carolina Electric & Gas Company's license to operate its dam on the Saluda River will expire in 2010.[361] Duke Energy Corporation's license to operate its dam on the Catawba-Wateree expired in 2008.[362] In North Carolina, the Alcoa license[363] and Progress Energy license[364] to operate dams on the Yadkin-Pee Dee River expired in 2008. Revisions to this license will impact the Pee Dee in South Carolina.

The Duke, Alcoa, and Progress Energy dams were originally licensed prior to the enactment of NEPA, ESA, and CWA. Thus, in order to receive a new license, these plants must comply with Federal environmental law. Additionally, all five relicensings are subject to environmental conditions recommended by State and Federal natural resource agencies as approved by FERC, any fishway prescribed by the U.S. Department of Interior and/or the U.S. Department of Commerce, and water-quality certification by the South Carolina Department of Health and Environmental Control.[365] Relicensing proceedings for these projects will "create a significant window of opportunity for the State of South Carolina … to seek new license conditions that will reduce adverse environmental impacts of dams on these four major river systems."[366]

Interstate Water Allocation

The Yadkin-Pee Dee River, flowing from North Carolina into South Carolina, and the Savannah River, whose centerline serves as the boundary between Georgia and South Carolina, are at risk for larger consumptive use by North Carolina and Georgia. South Carolina's neighboring states are developing at a more rapid pace than South Carolina. In Georgia, the city of Atlanta's demand for water is increasing each year at an estimated rate of 16 million gallons a day.[367] To meet its future needs, the city is exploring additional sources for public drinking and wastewater.[368] As for North Carolina, FERC hydropower licenses granted to Alcoa and Progress Energy control the streamflow of the Pee Dee River, which provides almost a third of South Carolina's freshwater needs.[369] South Carolina's economic base of tourism and manufacturing rely on an adequate water supply. Preservation and conservation of South Carolina's water resources is critical not only to existing business but also to future growth. Water allocation between South Carolina and its neighbor states is critical to protection of the State's water resources. There are three ways to allocate the waters of interstate rivers – interstate compacts, litigation in the U.S. Supreme Court, and congressional apportionment.

Congress is authorized to allocate water through its power to regulate interstate commerce. The first recognition of this authority came in *Arizona v. California*, where the U.S. Supreme Court held that Congress had imposed a "statutory apportionment" of the Colorado River among Arizona, California, and Nevada.[370] Since 1963, when *Arizona v. California* was decided, Congress has allocated interstate water on only one other occasion. In 1990, it apportioned the waters of the Truckee and Carson Rivers and Lake Tahoe among California and Nevada.[371] Congressional apportionment is not likely to occur often owing to Congress' reluctance to force a resolution upon states.[372] And states are not comfortable with leaving their destinies in the hands of Congress.

Interstate compacts are the most favored and most adaptable means of water allocation.[373] Compacts are negotiated agreements between states that are adopted

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359 Electric Consumer Protection Act of 1986, Pub. L. No. 99-495, § 3, 100 Stat. 1243 (codified in 16 U.S.C. §§ 792-828(c) (2000).

360 Santee Cooper license was issued on Apr. 2, 1926, and amended in 1927 and 1933 (1 F.P.C. 78). A new license was granted in 1979 (7 F.E.R.C. P 61, 148).

361 Lexington Water Power Company was issued a license on Aug. 5, 1927 (Lexington Water Power Co., Eighth Annual Report of the Federal Power Act, 1928, pp. 64, 70 (1928). The license was transferred to SCE&G in 1943 (3 F.P.C. 1007), and amended in 1967 (38 F.P.C. 1235). A new license was issued in 1984 (27 F.E.R.C. P 61,332), and amended in 1988 (44 F.E.R.C. P 62,289).

362 Duke license issued on Sept. 17, 1958 (20 F.P.C. 360).

363 Carolina Aluminum Company license issued on May 19, 1958 (19 F.P.C. 704) and amended in 1968 (39 F.P.C. 397).

364 Carolina Power & Light (now Progress Energy) license issued on May 19, 1958 (19 F.P.C. 704).

365 Mullen Taylor, Student Author, Hydropower Relicensing in South Carolina, 11 S.E. ENVR. L. J. 41, 43 (2002).

366 *Id*.

367 Charles Seabrook, *Atlanta Comes Up Dry in Bid for More Water* <http://www.accessatlanta.com/ajc/metro/0502/26water.html> (May 25, 2002).

368 *See* Chuck Crumbo, *Courts Could Divide Water*, *The Sun News*, July 28, 2002, <http://www.myrtlebeachonline.com/mld/sunnews/2002/07/28/news/ htm > (July 28, 2002); Seabrook, *supra* n. 364.

369 Crumbo, *supra* n. 365.

370 373 U.S. 546 (1963).

371 Jerome C. Muys, *Approaches and Considerations for Allocation of Interstate Waters*, in *Water Law: Trends, Policies and Practice*, 311, 312 (Kathleen Marion Carr & James D. Crammond, eds. American Bar Association, 1995).

372 Robert Haskell Abrams, *Interstate Water Allocation: A Contemporary Primer for Eastern States*, 25 U. Ark. Little Rock L. Rev. 155, 158 (2002).

373 Muys, *supra* n. 368 at 313.

legislatively by each state and by Congress.[374] Thus, the enabling legislation of an interstate compact becomes Federal law. There are currently 18 water compacts in existence, primarily in the western region of the United States. Modern interstate water compacts establish a permanent agency to implement the compact's functions and objectives. Although states can delegate power to these interstate agencies, states have historically been unwilling to delegate any significant authority in the compact's enabling statute for fear of losing control of the agency.[375] Ironically, by not delegating enough state power, states are more exposed to the prospect that their water problems will be subject to Federal programs that may preempt state authority to resolve water issues.[376] Disputes arising from enforcement of interstate compacts are heard by the U.S. Supreme Court; however, the Court will not exercise discretion to relieve a state from an obligation imposed by a compact.[377] Instead, the Court limits itself to determining whether a breach of the compact occurred and what the appropriate remedy for the breach will be.[378]

The U.S. Supreme Court has original jurisdiction over interstate disputes. Consequently, states battling over water allocation may invoke the Court's jurisdiction to adjudicate the dispute. The U.S. Supreme Court exercises its original jurisdiction cautiously, requiring that a state seeking such jurisdiction show that the water dispute is "of serious magnitude" and its assertion is supported by "clear and convincing evidence."[379] If the Court does decide to hear the case, the principle it applies is the equitable-apportionment doctrine. The basic principle of equitable apportionment is not governed by how state law determines private water rights.[380] Interstate disputes are resolved on the basis of equality of right of states as equal sovereigns;[381] however, equality of right does not require that each state receive an equal division of water from an interstate watercourse. The analysis is very fact specific and flexible, focusing on balancing benefits and harms.

Under equitable apportionment, the Court may consider a state's common law on water rights, but other factors may prove to be more despositive. These factors include the "priority of appropriation, physical and climatic conditions, the consumptive use of water, character and rate of return flows, extent of established uses, availability of storage water, the practical effect of wasteful uses on downstream areas, and the damage to upstream areas as compared to the benefits to downstream areas."[382] Another factor recognized is water conservation in each state.[383] Because of the extreme complexity of the legal, factual, and policy considerations involved in equitable apportionment, the Court encourages resolution through a negotiated interstate compact between the states rather than adjudication.[384]

In the Court's most recent equitable-apportionment cases,[385] *Colorado v. New Mexico I* and *Colorado v. New Mexico II*, the Court seemingly raised the evidentiary standard of "clear and convincing" evidence.[386] The Court emphasized that a state seeking diversion of water must show that actual inefficiencies exist in present use or that future benefits of a proposed use are highly probable.[387] Proposed uses where the benefits are speculative will not meet the Court's burden.[388] The Court also signaled movement toward imposing greater conservation and planning responsibilities on states, which it saw as a way to reduce uncertainties that have plagued equitable apportionment.[389] In a subsequent case, *Nebraska v. Wyoming*, the Court added that a state may show environmental damage to fish and wildlife to support its showing of injury.[390]

The Court's new stringency in evidence requirements of harm will probably result in a reduction in equitable

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374 Abrams, *supra* n. 369 at 157.

375 Muys, *supra* n. 368 at 314.

376 *Id.*

377 Abrams, *supra* n. 369 at 157.

378 *Id.*

379 *Id.*, citing *Colorado v. New Mexico*, 459 U.S. 176, 188 n. 13 (1982).

380 *Connecticut v. Massachusetts*, 282 U.S. 660, 670-671 (1931).

381 *Id.*

382 *Nebraska v. Wyoming*, 325 U.S. 589, 618 (1945).

383 *Colorado v. New Mexico*, 459 U.S. 176, 188 n. 13 (1982).

384 *Nebraska v. Wyoming*, 325 U.S. 589, 616 (1945).

385 *Colorado v. New Mexico*, 467 U.S. 310 (1984); *Colorado v. New Mexico*, 459 U.S. 176 (1981).

386 George William Sherk, *Equitable Apportionment After Vermejo: The Demise of a Doctrine*, 29 Nat. Resources J. 565, 578 (1989).

387 A. Dan Tarlock, *Law of Water Rights & Resources*, 10:19 (2003).

388 *Id.*

389 *Id.*

390 *Nebraska v. Wyoming*, 515 U.S. 1, 12-13 (1995). This case dealt with enforcement of a previous decree, not an original equitable apportionment claim.

apportionment cases, simply because states cannot afford to wait until such actual or highly probable injury has occurred before taking action.[391] Because the U.S. Supreme Court now requires such a high standard, states may seek recourse in other ways. Interstate compacts have taken on a more attractive light.[392] Interest in development of water markets is attracting more attention.[393] Alternative litigation strategies used by other states include challenging water diversions based on violation of the National Environmental Policy Act and other Federal environmental statutes.[394]

A more discouraging message in *Colorado v. New Mexico* appears to be that a state slower to develop or is conservation minded may be the loser in equitable apportionment; a state may be forced to engage in a race to use as much water as possible, as quickly as possible, in order to lay claim to water before other states do.[395] Strategies for these slower developing states, such as South Carolina, include using water-quality standards as a means of challenging other states' diversions,[396] and in the context of FERC hydropower licensing and other Federal licenses, using the 401 water-quality certification to protect instream flows. A state may also be able to protect its water by setting instream-flow requirements for all its rivers, which could create a foundation to block exportation of water to another state.

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[391] Sherk, *supra* n. 383 at 578.

[392] *Id*. at 581.

[393] *Id*.

[394] *Id*.

[395] Abrams, *supra* n. 369 at 168.

[396] *Arkansas v. Oklahoma*, 503 U.S. 91 (1992).

SOUTH CAROLINA'S WATER RESOURCES

THE WATER CYCLE

The earth's water is in constant motion above, on, and under its surface. Energy from the sun causes water to evaporate from the surface and drives soil and plants to transpire water into the atmosphere. This atmospheric water concentrates into cloud formations, and, under proper meteorological conditions, precipitates to earth. Once on the earth's surface, water flows into streams, lakes, and oceans; infiltrates into the subsurface and enters ground-water storage; or evaporates and transpires into the atmosphere. This continuous change in the geographical position and physical state of water is known as the hydrologic cycle, or water cycle. The cycle is a worldwide process modified by local geographical and meteorological factors. Regional variation in the water cycle affects vegetation, topography, and climate and results in landscapes ranging from deserts to rain forests. Precipitation, evapotranspiration, ground-water infiltration, and surface runoff compose the four basic processes of the hydrologic cycle (Figure 3-1).

Precipitation

The air contains varying amounts of water vapor. Warm air can hold greater concentrations of water molecules than cool air. Winds, temperature variations, and physical and meteorological obstructions (hills, mountains, colder or slower-moving air masses) cause air and water vapor to rise higher into the atmosphere. As the air rises, atmospheric pressure decreases and the air expands, cools, and loses its moisture-holding ability. When this cooling air reaches its saturation point, the gaseous water molecules condense to the liquid state. Clouds are the visible manifestation of moisture-laden air reaching saturation. Water droplets are extremely small and are kept aloft by air currents initially. Where these droplets coalesce around ice and dust particles, larger drops may form and fall to earth. Depending on the surrounding air temperatures and atmospheric conditions, these drops may fall as liquid or solid precipitation or may even evaporate before reaching the earth.

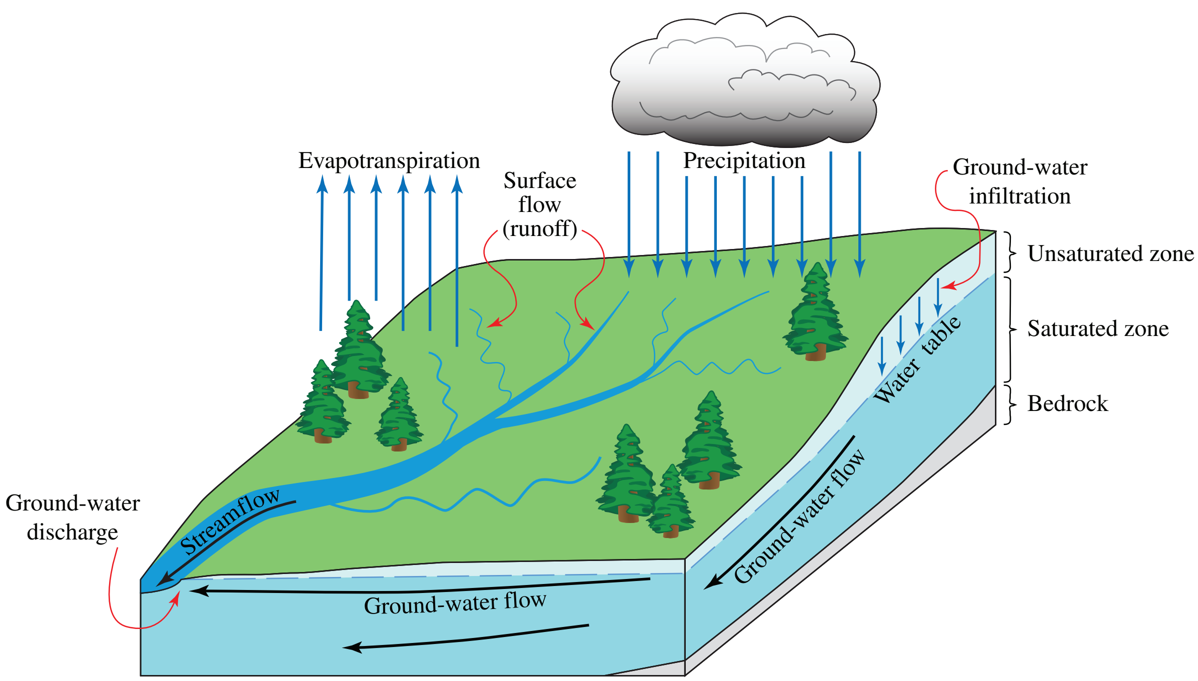


Figure 3-1. The water cycle.

Evapotranspiration

Most precipitation is returned directly to the atmosphere through the combined processes of evaporation and transpiration, termed evapotranspiration or ET. Evaporation is the process by which water changes from the liquid state to the vapor or gaseous state. Temperature, humidity, and wind are the principal environmental factors affecting evaporation rates. Energy from the sun drives the hydrologic cycle and is especially important to the process of evaporation. Solar radiation increases air and water temperatures at different rates; water molecules on the surface of soil, water, and plants heat faster than air molecules. This temperature difference causes higher vapor pressure in the water than in the air, and, to equalize the pressure, liquid water vaporizes and moves into the atmosphere. In general, increasing the vapor-pressure differential between water and air increases the rate of evaporation.

Evaporation rates also are affected by the relative humidity, a measure of the moisture content of air. The relative humidity is simply the ratio of water vapor in the air to the amount of water needed to saturate the air at a particular temperature, expressed as a percentage. As water molecules gradually saturate the air near the site of evaporation, relative humidity adjacent to the site increases, and the rate of evaporation decreases. When the relative humidity reaches 100 percent, evaporation stops.

The mixing influence of the wind can greatly accelerate evaporation. Where the saturated layer of air above an evaporating water body is disturbed by wind and is replaced with drier air, evaporation will continue.

Water also is lost to the atmosphere by transpiration from plants. Plants require large quantities of water for the transport of nutrients and food (sugars), formation of plant cells, photosynthesis, and gas exchange. Water enters plants through the root system, moves through the plant to the leaves, and is then transpired into the atmosphere through stomata, tiny openings on the underside of leaves.

Transpiration is more variable than evaporation because the water molecules pass through living organisms before entering the atmosphere. These water molecules are subject to the same physical factors as in evaporation (temperature, wind, and humidity) and, additionally, are subject to the numerous chemical and biological processes within the plant. Transpiration rates depend on the plant species, time of day, season, and on the availability of water in the root zone.

Ground-Water Infiltration

Precipitation that does not evaporate, transpire, or fall directly on surface-water bodies may infiltrate the earth's crust and contribute to soil moisture and ground-water storage. The rate of ground-water infiltration depends on the soil characteristics and moisture, the type and extent of vegetative cover, and the topography of the terrain. Some water that enters the soil moves downward to recharge underlying ground-water reserves, but much of the water is retained as droplets and films attached to soil particles near the surface. This soil moisture is easily driven into the atmosphere by evaporation and plant transpiration, and soil moisture must be replaced regularly to sustain vegetation. Soil moisture also affects the rate and quantity of infiltration to underlying water-table aquifers. Soil particles accumulate water on their surfaces by molecular attraction until the force of gravity acting on the water exceeds the forces of attraction in the soil; the saturation of soils and storage of ground water occur only after the volume and weight of percolating water exceed the soil's capacity to retain water by molecular attraction. The ground water discharges to the surface where aquifers are incised by stream channels, and that ground water represents the base flow to streams and rivers.

Surface Runoff

Precipitation that does not return to the atmosphere through evaporation and transpiration and cannot infiltrate the earth because the soil is saturated or the precipitation rate exceeds the soil's infiltration capacity becomes surface runoff. This excess water pools on the surface and is diverted to surface streams. The amount of runoff available to streamflow depends on rainfall intensity and duration, type and extent of vegetative cover, soil-moisture state, and the slope and area of the stream-drainage basin. Surface runoff, or overland flow, is a brief and typically small component of total streamflow but can be a major contributor to flooding as stream-basin soils become saturated.

SURFACE-WATER RESOURCES

Historically, the State's numerous rivers served as transportation routes, fishing-and-hunting grounds, and drinking water for Native Americans and Europeans settling along their shores. Later these streams were used to irrigate rice plantations, power grist and textile mills, and transport people and goods. More recent water development includes hydroelectric- and thermoelectric-power plants, flood-control projects, and increased withdrawals for established uses such as public supply, industry, and irrigation. Presently, surface water is used to meet most of the water demand in the State.

River Systems

On the basis of hydrologic drainage characteristics, the State contains all or parts of four major basins: the Pee Dee, Santee, Ashley-Combahee-Edisto (ACE), and Savannah (Figure 3-2). The U.S. Water Resources Council, in cooperation with the U.S. Geological Survey, has subdivided these major basins into several hydrologic units (U.S. Geological Survey, 1974). The 15 subbasins discussed in this report were derived from these hydrologic units, and are listed below under their respective major drainage basins.

- **Pee Dee River basin**
  Pee Dee River subbasin
  Lynches River subbasin
  Little Pee Dee River subbasin
  Black River subbasin
  Waccamaw River subbasin

- **Santee River basin**
  Broad River subbasin
  Saluda River subbasin
  Catawba-Wateree River subbasin
  Congaree River subbasin
  Santee River subbasin

- **Ashley-Combahee-Edisto (ACE) River basin**
  Ashley-Cooper River subbasin
  Edisto River subbasin
  Combahee-Coosawhatchie River subbasin

- **Savannah River basin**
  Upper Savannah River subbasin
  Lower Savannah River subbasin

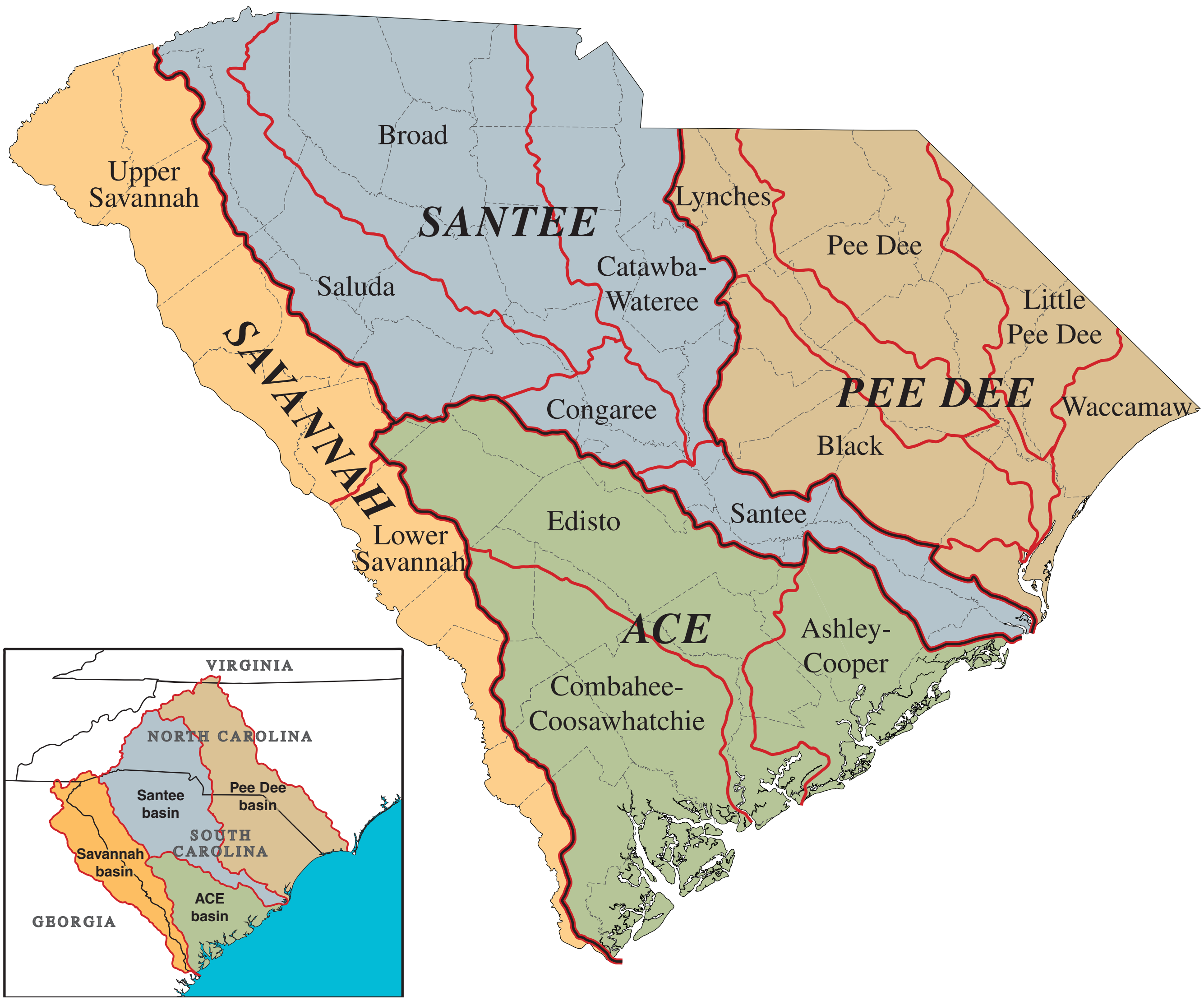


Figure 3-2. Major stream basins and subbasins of South Carolina.

Streamflow Monitoring

The U.S. Geological Survey (USGS) conducts most of the streamflow monitoring in South Carolina, with the South Carolina Department of Natural Resources (DNR), South Carolina Department of Health and Environmental Control (DHEC), and other agencies providing matching funds for most hourly-measured gaging stations. The monitoring network consists of streamflow gages, stage-only gages, and crest-stage gages (Figures 3-3, 3-4, and 3-5). Streamflow gages measure stages hourly, and their data are combined with stream-bottom profiles and periodic flow-velocity profiles to calculate flow volumes. Stage-only stations record lake and stream levels but are not used to calculate flows; crest gages record peak levels during flood events.

The USGS identifies each streamflow gaging station with an eight-digit number. The number reflects the downstream-order position of the station in relation to the main stream and other gaging stations. The complete eight-digit number, such as 02175000, includes the two-digit hydrologic part number (02) plus a six-digit downstream order number (175000) (U.S. Geological Survey, 1980). The gaging-station numbers used in this report are an accepted abbreviated version of the complete eight-digit number. In general, the first two digits (02) referring to South Atlantic Slope basins were deleted, and the last two digits were deleted if equal to zero but follow a decimal point if greater than zero (02172020 becomes 1720.2).

About 100 cooperatively and federally funded continuous-recording stations monitor streamflow. DHEC

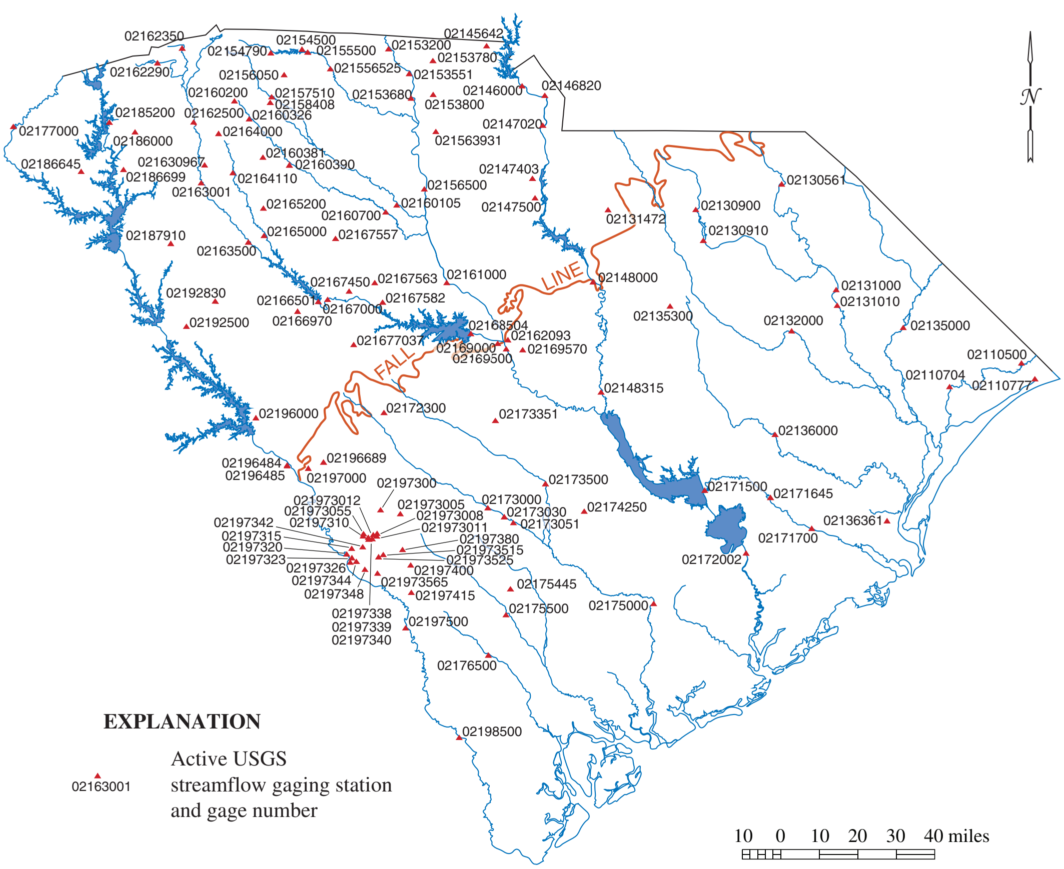


Figure 3-3. USGS streamflow gaging stations.

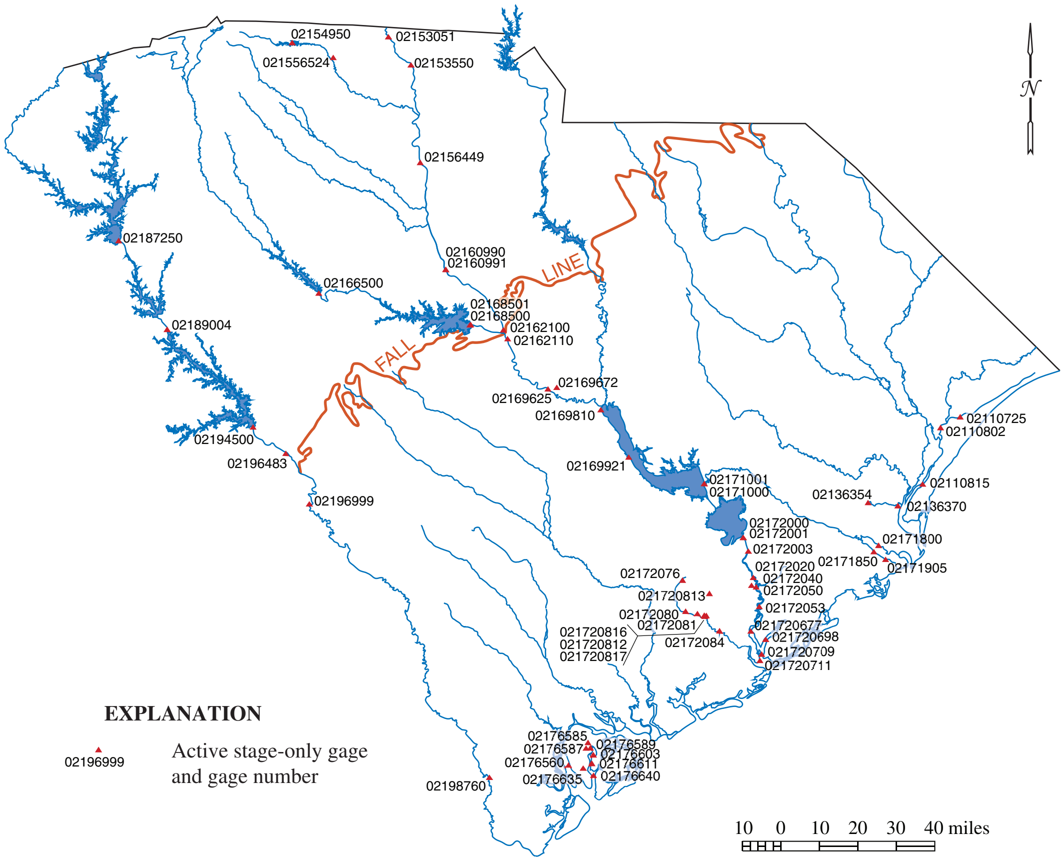


Figure 3-4. USGS stage-only gaging stations.

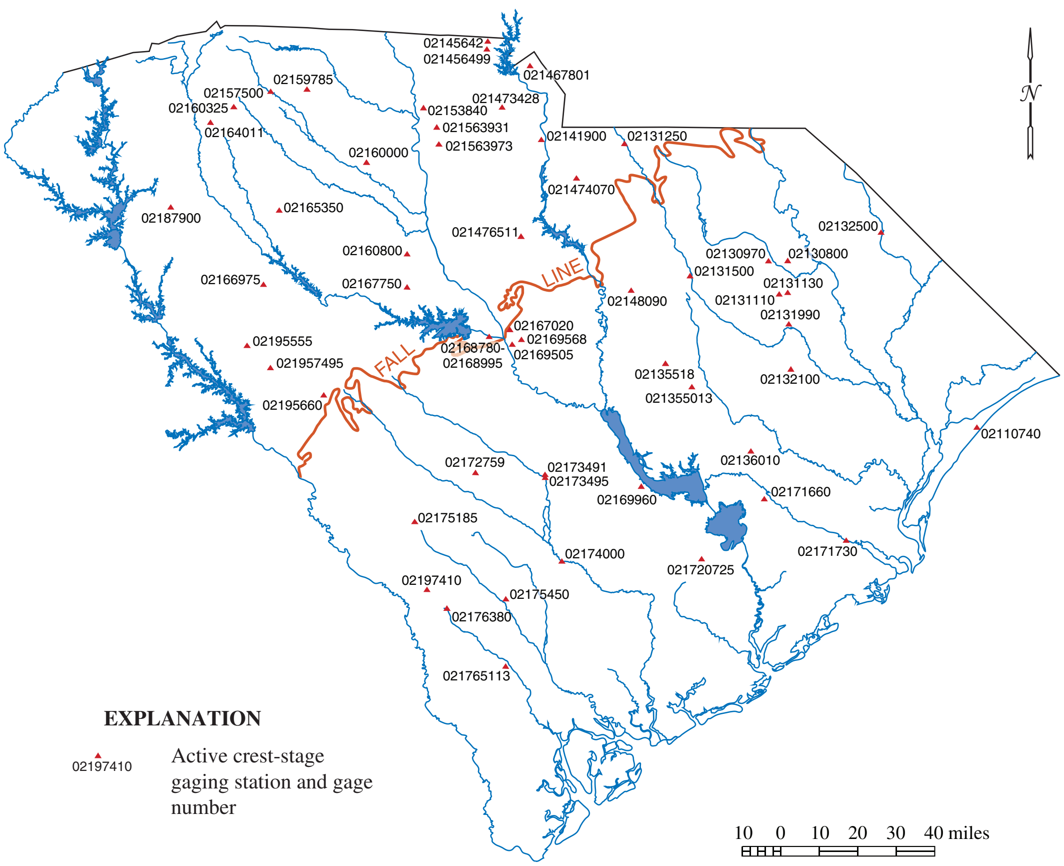


Figure 3-5. USGS crest-gage stations.

periodically measures streamflow at 314 primary water-quality sampling stations and uses those data to calculate waste-load allocation for streams. DNR operates temporary stage-only stations for saltwater-intrusion studies and salt-marsh restoration projects.

Effective monitoring and interpretation of stage data depend on adequate and consistent funding, because the number, distribution, and duration of gage-station records affect the timeliness and quality of streamflow predictions. In particular, statistically meaningful flow histories and accurate trend predictions require record durations of more than 20 years. Multiple gage sites and real-time access to recorded data likewise affect the quality and utility of flow predictions. The need for more and better data increases as the State's population grows, but the number of stations has diminished owing to funding reductions during recent years.

SURFACE WATER OVERVIEW

Average streamflow in South Carolina is about 33 billion gallons per day. The Santee River in its original state had the highest average streamflow in South Carolina with 18,700 cfs (cubic feet per second). This discharge was the third largest on the East Coast, with only the Susquehanna (37,190 cfs) and Hudson (19,500 cfs) Rivers discharging more water to the Atlantic Ocean. Before the completion of the Cooper River rediversion project, most of the Santee River flow, about 15,000 cfs, was diverted to the Cooper River. Since completion of the project, flow of 5,500 to 7,500 cfs is rediverted to the Santee River, and the Cooper River flow is about 4,500 cfs. Other major rivers in the State are the Great Pee Dee River, with an average discharge of 15,600 cfs, and the Savannah River, which discharges about 12,100 cfs.

Throughout the State, streamflow is generally highest

SUPPLEMENTAL INFORMATION BOX 3-1

Surface-Water Analyses

In this report, analyses of surface-water hydrology for the State's streams (except the Ashley-Cooper subbasin) consist of streamflow-characteristics tables and flow-duration hydrographs. The records used to construct these tables and hydrographs are from USGS gaging stations. Gaging-station records and status are available from the U.S. Geological Survey.

Each streamflow-characteristics table consists of the gaging-station number, name, and location; drainage area; average daily flow; 90th percentile flow; minimum daily flow and year of occurrence; maximum daily flow and year of occurrence; and highest peak flow and year of occurrence.

Hydrographs are plots of streamflow against time or date. Duration hydrographs are plots of selected flow percentiles versus date, and help resource managers to statistically quantify the variability of streamflow at a gaging station. Each duration hydrograph contains bands that show the low-, normal-, and high-streamflow conditions for each day of the year. Daily average flows are used to construct these bands for nonregulated streams, and 7-day average flows are used to construct these bands for regulated streams. Duration hydrographs are constructed only for gages with at least 30 years of record.

Surface-Water Terminology

7-day average flow: the flow of a stream averaged over a 7-day period. Hydrographs made using 7-day running averages (rather than daily averages) are often used for regulated streams in order to smooth out highly variable flows caused by widely fluctuating reservoir releases.

Continuous-discharge station: a site at which (a) stage or streamflow is recorded on a continuous basis or (b) water-quality, sediment, or other hydrologic measurements are recorded at least daily.

Crest gage: measures the peak state of a rising stream or impoundment. A crest gage commonly consists of a wooden stick and powdered cork inside a vertical, perforated pipe. The cork adheres to the stick at the highest point of a flood stage, and the cork level is compared with a known elevation datum to calculate peak stage.

Cubic foot per second (cfs): the discharge rate representing 1 cubic foot passing a given point in 1 second—about 7.5 gallons per second, 450 gallons per minute, or 646,000 gallons per day.

Cubic foot per second per square mile (cfsm): the discharge in cubic feet per second divided by the drainage area in square miles.

Discharge: flow, as the volume of water that passes a given point in a given period—commonly stated as cubic feet per second.

Flow percentile: the percentage of time for which a flow is not exceeded at a particular gaging station. For example, the 90th percentile flow is equal to or greater than 90 percent of the discharge values recorded at that gage. In general, a percentile greater than 75 is considered above normal (high), a percentile between 25 and 75 is considered normal, and a percentile less than 25 is considered below normal (low).

Stage-only gaging station: a continuous gaging station used only for determination of stream and lake levels.

Streamflow gaging station: site at which the stream-elevation records, stream-bottom profile, and periodic stream-velocity measurements are used to calculate flow.

during late winter and early spring and lowest during late summer and fall. Minimum flows generally occur only during the summer and fall, but maximum flows may occur at any time during the year.

Streams in the Blue Ridge and upper Coastal Plain provinces generally exhibit greater flow per square mile of drainage area and well-sustained base flow. High average rainfall with little variation year round and substantial ground-water reserves ensure reliable flows in the Blue Ridge streams. Reliable streamflows in the upper Coastal Plain are attributed primarily to discharge from ground-water storage. Lower Piedmont and lower Coastal Plain streams exhibit highly variable flows, small flow per square mile of drainage area, and poorly sustained low flow. Seasonal streamflow variation in these streams is substantial owing to their dependence on rainfall and runoff. Dry conditions during late summer and fall result in minimum-flow conditions with some streams periodically experiencing no-flow conditions.

FACTORS AFFECTING STREAMFLOW

South Carolina's abundant surface-water resource is not geographically and temporally uniform. Streamflow is influenced by natural and man-induced conditions. Physiographic characteristics of the watershed, which affect the seasonal, yearly, and geographical variation in precipitation and evaporation, greatly affect flow. Modification of watercourses for hydroelectric-power generation, navigation, flood control, and water withdrawal also impacts streamflow.

Physiography

Characteristics of the land surface greatly affect local and regional hydrology. Streams in each of the State's provinces —Blue Ridge, Piedmont, and Coastal Plain—exhibit flow characteristic of the province. The following sections describe general surface-water characteristics in each of these provinces.

Blue Ridge. This mountainous region of the State has steep terrain with some stream gradients greater than 250 feet per mile (Bloxham, 1979). The geology of this region significantly affects surface-water flow. Surface fractures in crystalline rock provide channels for runoff. Because of this, stream channels are often angular and local drainage patterns are often rectangular (Acker and Hatcher, 1970). These fractures also provide avenues for ground-water flow and storage. As the deeply incised streams of this region intercept the crystalline-rock aquifers, relatively large quantities of ground water contribute to the streamflow. Overlying the crystalline rock is a layer of weathered bedrock termed saprolite. This layer of semipermeable material stores ground water for release later to crystalline-rock aquifers and to streams. Although some rainfall infiltrates the saprolite layer, the steep terrain and semipermeable soils cause much of the rainfall to run off rapidly into stream channels. Blue Ridge province streams, therefore, typically exhibit rapidly fluctuating flows dependent on rainfall and ensuing runoff but have well-sustained base flow due to substantial ground-water discharge.

Piedmont. The rolling hills of the Piedmont range in elevation from 1,000 feet near the mountains to 400 feet at the Fall Line. Stream gradients range from 60 feet per mile in the mountain foothills to about 5 feet per mile near the Fall Line (Bloxham, 1981). Bedrock in this province is jointed and fractured similarly to that in the Blue Ridge province, but ground-water storage and base flow generally decrease downslope across the Piedmont for two reasons: (1) saprolite permeability decreases from the upper Piedmont to the lower Piedmont, retarding rainwater infiltration and causing more surface-water runoff; and (2) stream channels are less deeply incised than in the Blue Ridge province, which decreases the number of intercepted fracture zones available to support base flow. Piedmont streamflow is, therefore, highly dependent on rainfall and runoff with little ground-water support. No-flow conditions during summer and fall months are common for smaller streams, especially in the lower Piedmont region, and even basins of several hundred square miles may experience no flow under extreme conditions.

Upper Coastal Plain. The upper Coastal Plain extends southeastward from the Fall Line to the Citronelle Escarpment (Cooke, 1936) and is characterized by moderately sloped, irregularly shaped, and rounded terrain. Stream gradients range from 5 to 20 feet per mile (Bloxham, 1979). This region includes outcrops of the Middendorf, Barnwell, and McBean Formations that are composed of loosely consolidated sediments overlain by coarse sand to sandy loam soils. Streams deeply incise these porous materials, resulting in shallow ground-water aquifers above stream level. These aquifers discharge into streambeds to support flow, especially during periods of low rainfall. In addition, these shallow aquifers absorb large quantities of rainfall, thus reducing peak runoff to streams. Upper Coastal Plain streamflows are, therefore, supported primarily by discharge from ground-water storage and typically exhibit less variable flow year round with well-sustained base flow.

Middle and Lower Coastal Plain. The middle and lower Coastal Plain extends from the Citronelle Escarpment to the coast, an area approximately 80 miles wide. This region has moderate to low relief, shallow stream incisement, stream gradients of about 3.5 feet per mile (Bloxham, 1979), and extensive swamplands associated with large segments of the river systems. Middle and lower Coastal Plain streams depend more on rainfall and runoff than on ground-water discharge to support flow. The highly permeable soils in this region are similar to those of the upper Coastal Plain, which readily absorb rainfall and retard runoff to streams. Streamflows, therefore, rise and fall gradually. The low relief and shallow stream incisement of the region allows little ground-water storage area above stream channels. Therefore, ground water provides less support than in the upper Coastal Plain, and these streams typically have poorly sustained base flows. No-flow conditions in the middle and lower Coastal Plain are common during dry periods.

Precipitation and Evapotranspiration

Average annual rainfall is greatest in the Blue Ridge province (up to 80 inches), decreases to about 45 inches over most of the Piedmont and Coastal Plain regions, and increases to about 52 inches near the coast (Figure 3-6). Rainfall amounts vary seasonally, with peaks generally occurring in the winter and summer and minimums in the fall.

The potential evapotranspiration (PET) rate increases from north to south across South Carolina, and the average annual ET rates range from 29.6 inches near Spartanburg to 46.6 inches at Savannah, Ga. (Figure 3-7). Evapotranspiration mainly is controlled by air temperature but is modified by relative humidity and wind speed. Marked seasonal variation occurs, with the highest monthly rates occurring during the summer (3.5–4.9 inches per month) and the lowest rates occurring during the winter (0.35–1.0 inches per month).

The amount of runoff and ground-water base flow contributing to streamflow equals total rainfall minus the amount contributed to evapotranspiration, and combined runoff and base flow ranges from approximately 10 to 35 inches per year (Figure 3-8). Where ground-water infiltration is negligible, as in the Piedmont and lower Coastal Plain, the interaction of rainfall and evapotranspiration are major factors affecting streamflow. Flow characteristics in Piedmont and lower Coastal Plain streams primarily depend on rainfall and runoff, and flows reflect seasonal variations in precipitation and evapotranspiration (Figure 3-9).

Where ground-water base flow is significant, as in the upper Coastal Plain and Blue Ridge provinces, flows are more regular throughout the year. The interaction of rainfall and evapotranspiration and the resulting runoff are greatly impacted by porous soil and substratum in the two provinces. Average annual streamflow may vary considerably, as Figure 3-10 illustrates, but the variation primarily is caused by differences in yearly precipitation.

SURFACE-WATER DEVELOPMENT

Alteration of the State's streams dates to early colonialism. Canals were built; streams were cleared and dredged to improve navigation; and numerous watersheds were modified to drain agricultural land and minimize flooding. Many of these developments also provided stillwater habitat for fish and wildlife and provided areas for recreational activities.

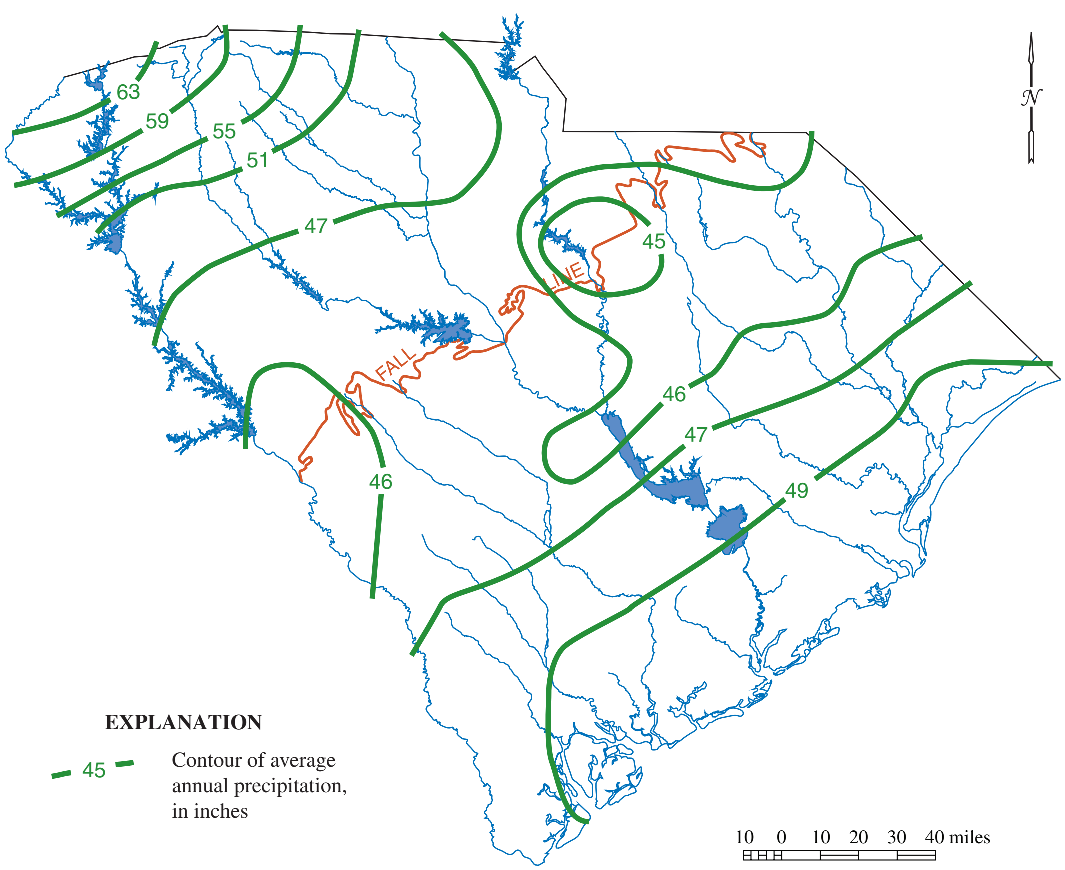


Figure 3-6. Distribution of average annual precipitation in South Carolina, 1948–1990 (Badr and others, 2004).

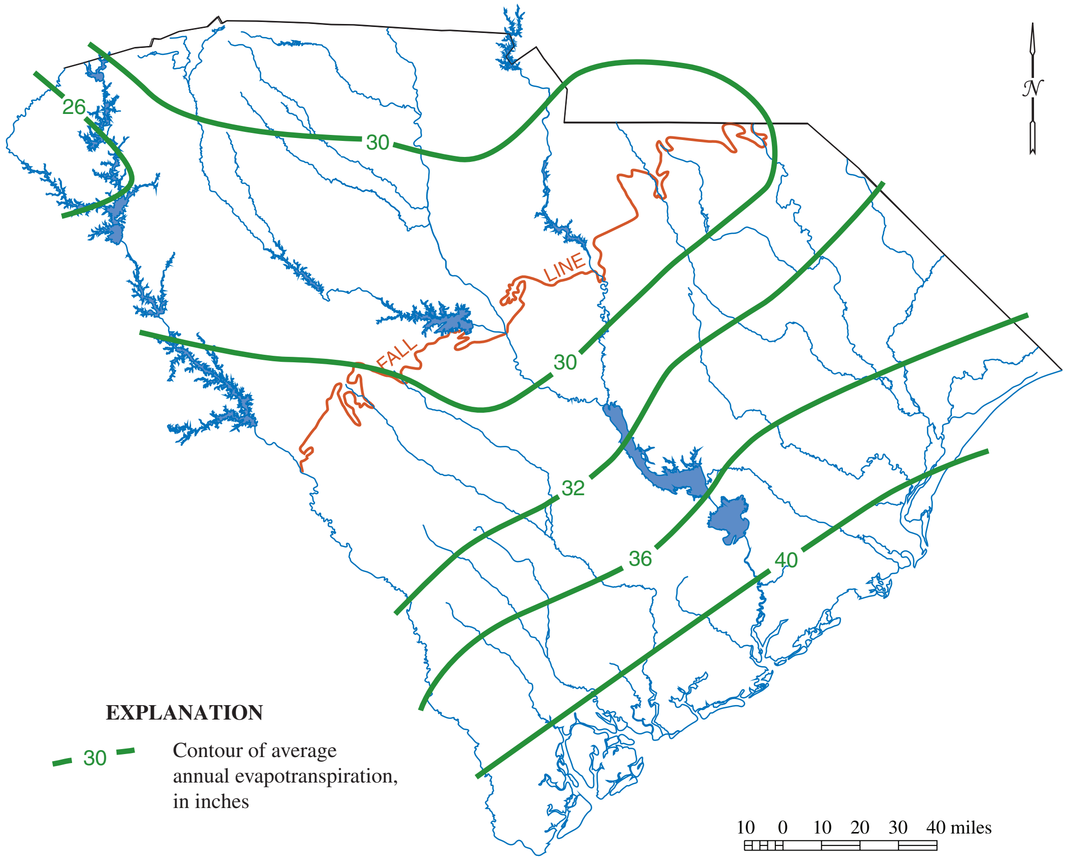


Figure 3-7. Distribution of average annual evapotranspiration in South Carolina, 1948–1990 (Badr and others, 2004).

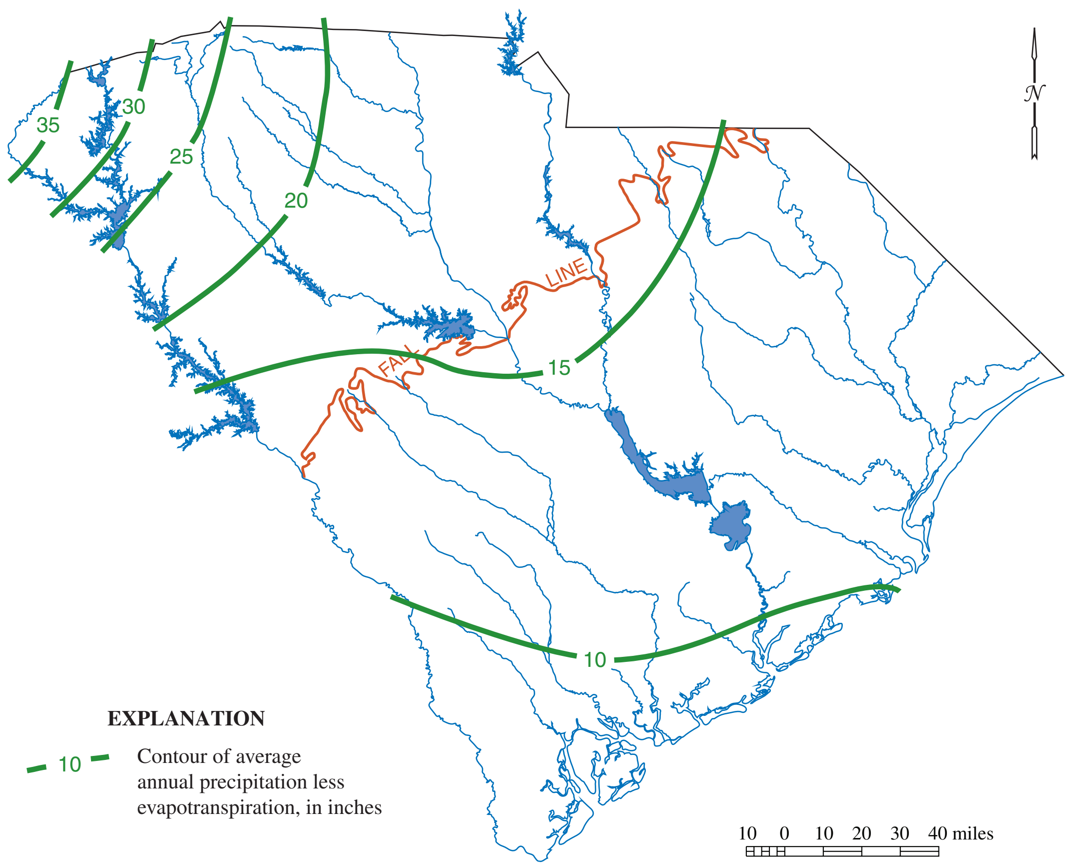


Figure 3-8. Distribution of average annual runoff and base flow in South Carolina, 1948–1990 (Badr and others, 2004).

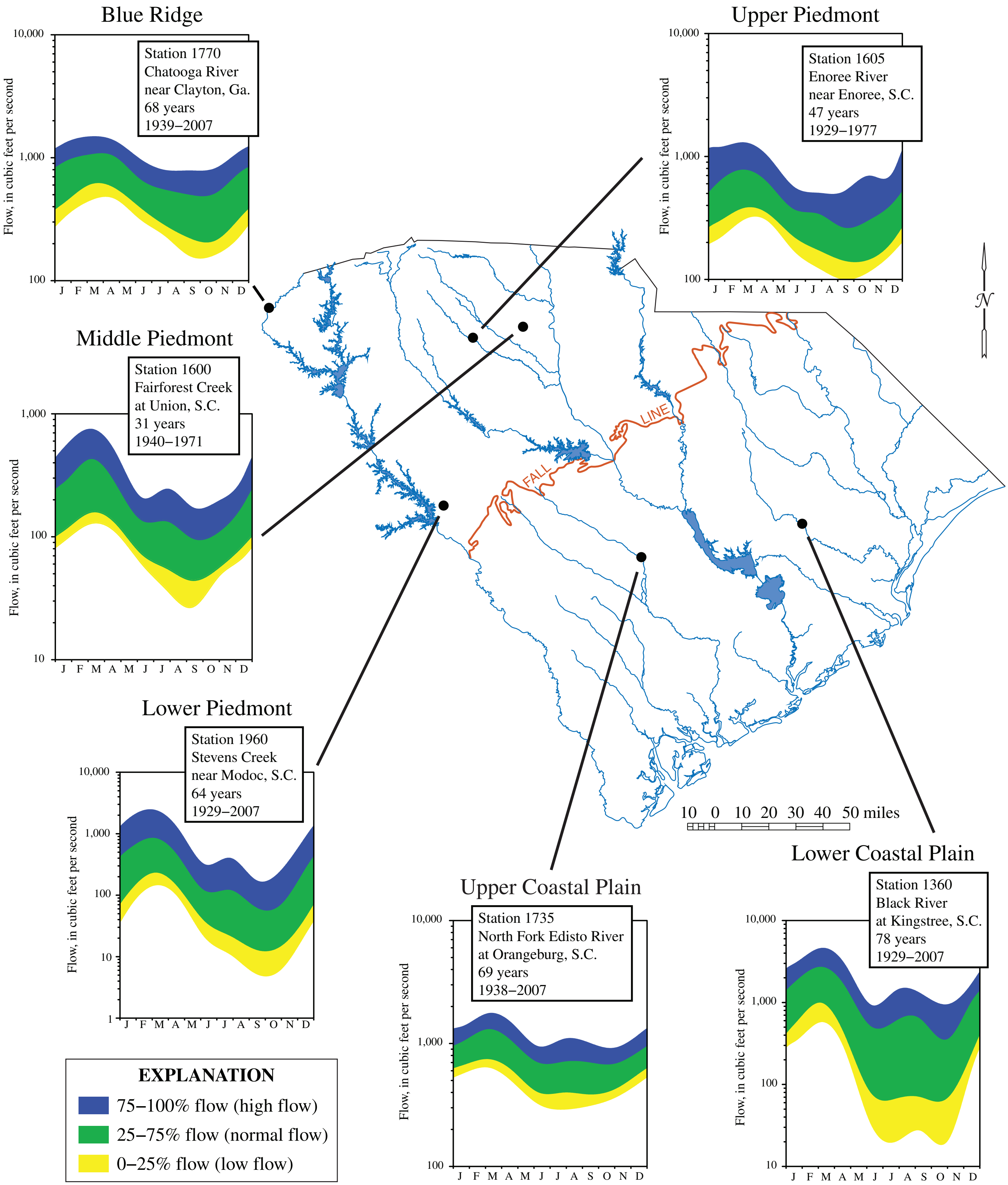


Figure 3-9. Typical flow-duration hydrographs for the physiographic provinces of South Carolina.

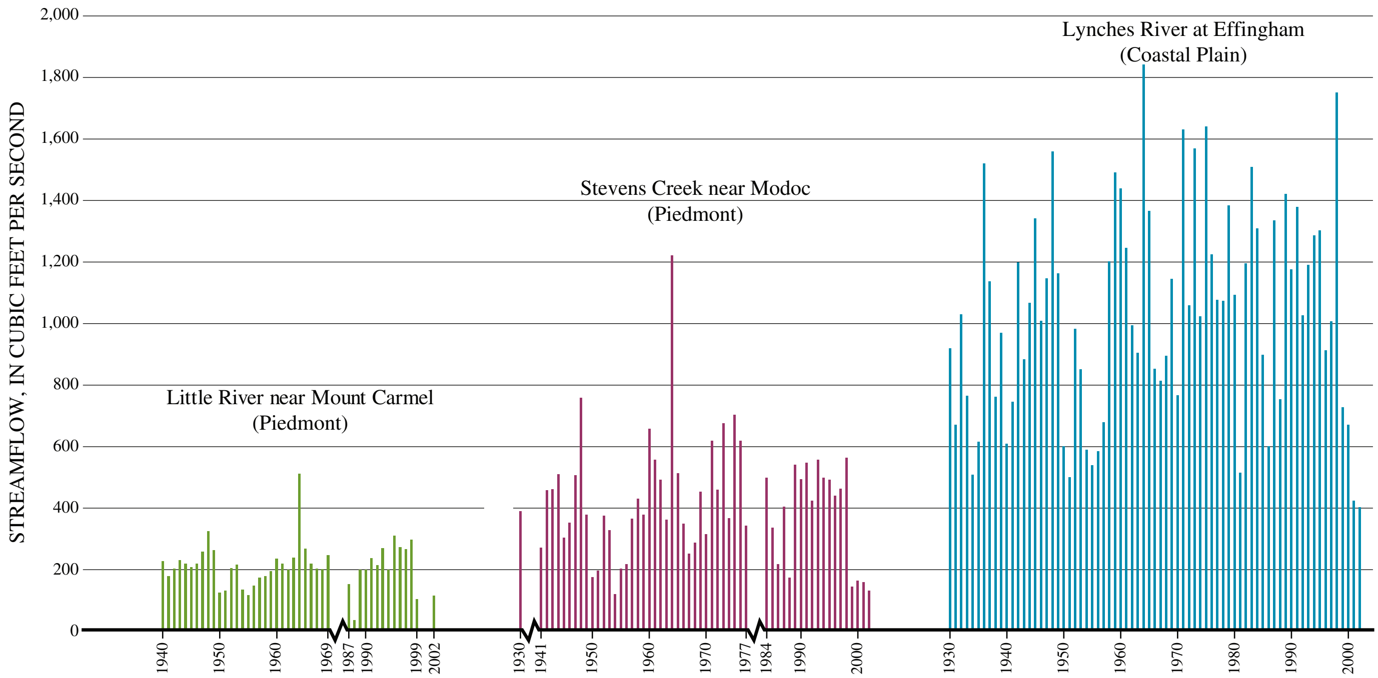


Figure 3-10. Average yearly streamflow of typical streams in the Piedmont and Coastal Plain of South Carolina.

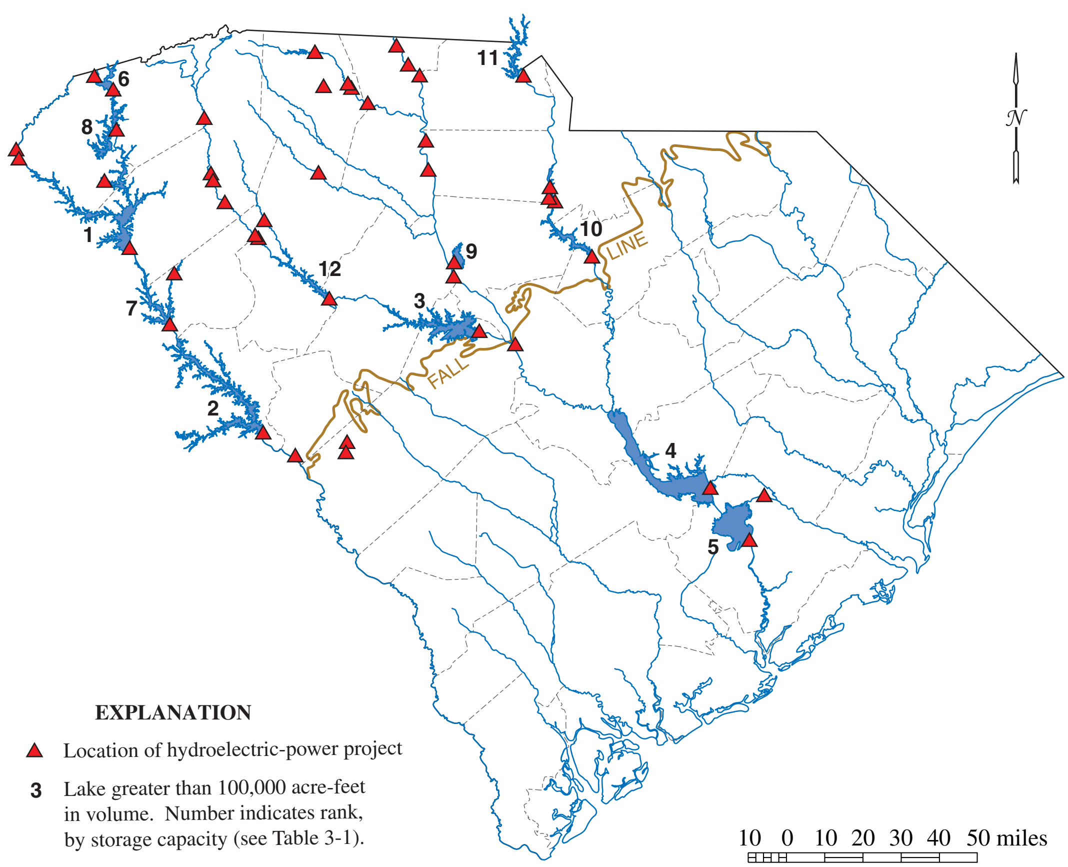


Figure 3-11. Location of hydroelectric-power projects and major lakes in South Carolina.

Forty-six hydroelectric-power projects of varying generating capacity and reservoir size are located in South Carolina (Figure 3-11). Eighty-seven percent of these projects and most potential hydroelectric power sites are in the Piedmont, where high relief and steep stream gradients are naturally suited for reservoir development. Few reservoirs are located in the Coastal Plain region, and impoundments in the region typically are broad and shallow. The 12 largest reservoirs in the State are listed in Table 3-1 by storage capacity. No major reservoirs have been constructed since the completion of the Russell Dam in 1984.

Table 3-1. Largest lakes in South Carolina, by storage capacity

Rank (by capacity)	Name	Surface area (acres)	Storage capacity (acre-feet)	Use*
1	Lake Hartwell	56,000	2,549,000	P R W
2	Lake Thurmond	70,000	2,510,000	P R W F
3	Lake Murray	51,000	2,114,000	P R W
4	Lake Marion	110,600	1,400,000	P R W
5	Lake Moultrie	60,400	1,211,000	P R W
6	Lake Jocassee	7,560	1,186,000	P R
7	Lake Russell	26,650	1,026,000	P F R
8	Lake Keowee	18,370	1,000,000	P R W
9	Lake Monticello	6,800	431,000	P R
10	Lake Wateree	13,700	310,000	P R W
11	Lake Wylie	12,460	281,900	P R W
12	Lake Greenwood	11,400	270,000	P R W

*P, power; R, recreation; F, flood control; W, public water supply.

Controlled releases from hydroelectric dams above the licensed minimum releases depend on electric-power demand and may be highly variable. Generally, extreme maximum and minimum flows are modified by these facilities; however, in some instances (Wateree River, Santee River, Saluda River, Broad River) low-flow conditions may be aggravated due to insufficient discharge while reservoir supplies are replenished or power demand is low.

Approximately 2,000 miles of river channel have been cleared and dredged for navigation, but maintenance on most of these channel miles has been discontinued for various reasons. Currently, fewer than 500 miles of navigation channel are maintained by the U.S. Army Corps of Engineers. Most of these navigation projects are in the lower Coastal Plain region of the State and include the Intracoastal Waterway (ICW), Charleston Harbor, Winyah Bay, and the Savannah River between Savannah and Augusta, Ga. Dredging of the ICW has diminished owing to declining commercial shipping and consequent reductions in Congressional funding.

Modification of watersheds for flood control may entail diking, straightening, clearing, dredging, and damming of stream channels. Flood-control projects in the Piedmont province are made necessary by relatively impermeable soils that cause rapid runoff and subsequent flooding during heavy rainfall. Flood-control projects in the middle and lower Coastal Plain provinces mainly are related by low elevations and relief and the resultant poor drainage and pooling.

SURFACE-WATER QUALITY

The chemical, physical, and biological integrity of surface water greatly affects man's use of this important resource. While water of high quality is suitable for all activities, including swimming, fishing, and drinking (after treatment), less pure water might safely serve only industrial and agricultural needs. The maintenance of a healthy community of aquatic organisms requires a suitable chemical and physical environment. The introduction of toxic substances or the presence of essential constituents outside acceptable ranges can adversely alter aquatic populations and, in turn, adversely impact human water-use activities.

Factors Affecting Water Quality

Pollution occurs where chemical, physical, or biological constituents are present at levels detrimental to human use or to aquatic life. These contaminants can be of natural origin and enter surface water by precipitation or runoff. The impact of this non-point source pollution depends upon the amount of precipitation, watershed characteristics, pollutant type, and assimilative capacity of the water body. Man's modification of watersheds for agriculture, silviculture, mining, waste disposal, and other activities is the main cause of non-point source pollution. Typical non-point source pollutants include sediment, organic material, nutrients, metals, pesticides, oil and grease, and acids. In the Coastal Plain watersheds, tannins from naturally decomposing swamp vegetation stain the water of many streams: the dark brown color is a natural characteristic of the State's blackwater streams and is not a water-quality problem.

Pollutants also originate from industrial, municipal, and domestic wastewater discharges. The impact of these point-source pollutants depends upon the volume and composition of the discharged effluent and the assimilative capacity of the water body. The uncontrolled release of a wide variety of toxic and non-toxic chemical substances, nutrients, oxygen-demanding substances, and waste heat from point-source discharges can severely impact the State's surface water.

Water-Quality Management

The Federal Clean Water Act states: "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water shall be achieved by July 1, 1983."

The State of South Carolina has promulgated S.C. Regulation 61-68, Water Classifications and Standards and S.C. Regulation 61-69, Classified Water, which designates classified uses for each water body and establishes standards and rules to protect and maintain these uses. It is the intent and purpose of the regulations that water that meets standards shall be maintained and water that does not meet standards shall be improved. The agency primarily responsible for protecting and maintaining the quality of South Carolina's water resources is the South Carolina Department of Health and Environmental Control (DHEC). In pursuit of the national goals and in accordance with state and federal regulations, DHEC established a water classification and standards system, a statewide water-quality monitoring network, and several water-quality control programs. Other local, state, and federal agencies that have interests and programs involving water-quality protection include the South Carolina Department of Natural Resources (DNR), U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (USACE), U.S. Geological Survey, the regional planning councils, and local governments.

Classification and Standards

The surface-water bodies of the State have been classified in regulation based on the desired uses of each water body. State standards for various parameters have been established to protect all uses within each classification. The water-use classifications that apply to surface water in South Carolina are as follows:

1. Class ORW (outstanding resource water): freshwater or saltwater that constitutes an outstanding recreational or ecological resource, or freshwater suitable as a source for drinking water supply purposes, with treatment levels specified by DHEC.
2. Class FW (freshwater): freshwater that is suitable for primary and secondary contact recreation and as a source for drinking-water supply after conventional treatment, in accordance with the requirements of DHEC. These water bodies are suitable for fishing and for the survival and propagation of a balanced indigenous aquatic community of fauna and flora. This class also is suitable for industrial and agricultural use.
3. Class SFH (shellfish harvesting) water: tidal saltwater protected for shellfish harvesting and also suitable for the uses intended for Classes SA and SB water.
4. Class SA (tidal saltwater): suitable for primary and secondary contact recreation and for crabbing and fishing. Class SA water must maintain daily DO (dissolved oxygen) averages not less than 5.0 mg/L, with a minimum DO of 4.0 mg/L. These water bodies are not protected for harvesting of clams, mussels, or oysters for market purposes or human consumption. The water is suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.
5. Class SB (tidal saltwater): suitable for the same uses intended for SA water, but with DO levels not less than 4.0 g/L.
6. Class TN (trout natural) water: freshwater suitable for supporting reproducing trout populations and a cold-water, balanced, indigenous, aquatic community of fauna and flora.
7. Class TPGT (trout put, grow, and take) water: freshwater suitable for supporting the growth of stocked trout populations and a balanced, indigenous aquatic community of fauna and flora.
8. Class TPT (trout put and take) water: freshwater protected by the standards of Class FW.

All water in South Carolina falls within one of the preceding classes and must meet associated quality standards. Some classified water bodies are identified by name, while all other water bodies assume the classification of the water body into which they flow.

Numeric standards are used as instream water-quality goals to maintain or improve water quality. They are used to determine permit limits for treated wastewater discharges and other activities that might impact water quality. All discharges to the waters of the State are required to have a National Pollutant Discharge Elimination System (NPDES) permit and must abide by those limits, under penalty of law.

Classifications are based on desired uses and are a legal means to obtain the necessary treatment of discharged wastewater to protect the designated uses. Actual water quality may not have a bearing on a water body's classification. A water body may be reclassified if existing public uses justify the reclassification and if the water quality necessary to protect those uses is attainable. A classification change requires an amendment to State regulation and requires public participation, DHEC Board approval, and General Assembly approval.

Natural conditions may prevent water from meeting the water-quality goals set forth in the standards. The fact that a water body does not meet the standards for a particular classification does not mean the water body is polluted or of poor quality. Certain types of water bodies (e.g., some swamps, lakes, and tidal creeks) naturally have water quality lower than the numeric standards. A water body can have water-quality conditions below standards due to natural causes and yet meet its use classification.

Monitoring Programs

The South Carolina Department of Health and Environmental Control (DHEC) routinely assesses and reports on the quality of the State's waterways in eight basins (Figure 3-12). Water-quality monitoring data are important in determining current conditions and identifying long-term trends and in determining that water-quality standards and use classifications are being met. Toward this end, DHEC has established the Ambient Surface Water Quality Monitoring Network to provide physical, chemical, and biological data about the State's streams, reservoirs, and estuaries.

The network is composed of five sampling categories. Integrator sites are 320 permanent fixed-location monitoring sites (Figure 3-13). The sites are sampled monthly to provide uniform baseline data. Special-purpose sites (33) are semipermanent stations for areas of special interest (e.g., ground-water remediation sites) and for supplementing integrator-site data. A few special-purpose sites are sampled monthly in summer only, but most are sampled monthly year round. Watershed water-quality management sites are sampled monthly for 1 year once every 5 years and supplement integrator sites. Probability-based monitoring sites augment the integrator baseline sites and are small sample sets used to estimate conditions for large areas: each year about 90 sites are randomly selected and are sampled monthly for 12 consecutive months. Sediment samples are collected once per year at 87 permanent sampling sites and at all probability-based monitoring sites.

Point-Source Management

Point-source wastewater discharge to the State's surface-water bodies is controlled through several DHEC programs. These programs manage the impact of agricultural, industrial, municipal, and domestic waste-water discharges by planning, permitting, enforcement, and pollution-response and -investigation activities.

The National Pollutant Discharge Elimination System (NPDES) directly regulates point-source discharges. A NPDES permit limits the type and amount of materials that may be discharged and establishes monitoring requirements. Discharge limits are based on Federal guidelines and on the treatment needed to prevent contravention of State water-quality standards. NPDES permit requirements for oxygen-demanding substances, ammonia, and phosphorus are determined by evaluating the water quality and assimilative capacity of the receiving water in relation to State water-quality standards. Potential receiving water is designated "effluent limited" or "water-quality limited," depending on the level of wastewater treatment required to maintain standards for dissolved oxygen. The application of secondary-treatment technology is sufficient for effluent discharging into effluent-limited water, whereas discharges to water-quality limited water require more advanced treatment technology.

Non-Point Source Management

In South Carolina, non-point sources, rather than point sources, are most commonly responsible for failures to achieve classified uses. The control of surface-water contamination by runoff from large areas is typically more difficult than for well-defined discharge sites, and control primarily depends on effective land-use practices. DHEC, in conjunction with other State agencies and entities, developed strategies to abate non-point source pollution from several types of land uses, including agriculture, silviculture, mining, and hydrologic modifications. There are nine categories of non-point source pollution: agriculture, forestry, urban areas, marinas and recreational boating, mining, hydrologic modification, wetlands disturbance, land disposal/ground-water impacts, and atmospheric deposition. Technology-based management measures are employed to address these impacts. The NPS (Non-Point Source) Program describes specific management measures and implementation schedules for each category. South Carolina has the legal authority to implement all of the necessary management measures. Solid-waste, hazardous-waste, and air-quality control programs in DHEC, in addition to local zoning and the water- and land-management programs of other local, State, and Federal agencies, help to control non-point source pollution. DHEC's South Carolina NPS

Management Program Update describes a framework for agency coordination and presents a strategy and management measures to control NPS pollution.

Surface-Water Quality Overview

Water-quality conditions are influenced by many natural and man-induced factors. Therefore, water quality can change yearly, seasonally, and even daily depending on the type and location of the water body, natural events and conditions, and human activity within the watershed. Water-quality conditions and problems identified here and in the individual subbasin assessments represent documented conditions at the writing of this report—but these conditions are not static. DHEC periodically publishes monitoring data, water-quality assessments, and the results of special studies.

The quality of surface water in South Carolina is generally adequate for most water-use needs. DHEC estimates that 79 percent of the State's major river miles fully support aquatic-life uses: the predominant cause of partial or non-support is low dissolved-oxygen levels. Eighty-three percent of the State's lakes fully support aquatic-life uses: the predominant cause for partial or non-support is high nutrient levels. Eighty-one percent of the State's estuaries fully support aquatic-life uses, with low dissolved oxygen being the predominant cause of non-support. Recreational use is fully supported in 58 percent of the rivers, 99 percent of the lakes, and 93 percent of the estuaries. High fecal-coliform bacteria levels are the predominant cause for the water bodies to be classified as partially or not supportive.

The most widespread water-quality problem is fecal-coliform bacteria contamination. The bacteria primarily impair shellfish harvest and recreational water-use activities, and the bacteria typically are associated with municipal wastewater discharges and non-point source runoff from urban and agricultural areas.

Physiography and climate also influence water quality. Widespread contravention of standards occurs in Coastal Plain wetlands during the summer months. Decomposition of large quantities of organic matter in swamps, coupled with little or no streamflow and high water temperatures, often results in water with low dissolved oxygen concentrations, low pH, and high nutrient levels. Low dissolved oxygen

Figure 3-12. South Carolina Department of Health and Environmental Control water-quality management basins.

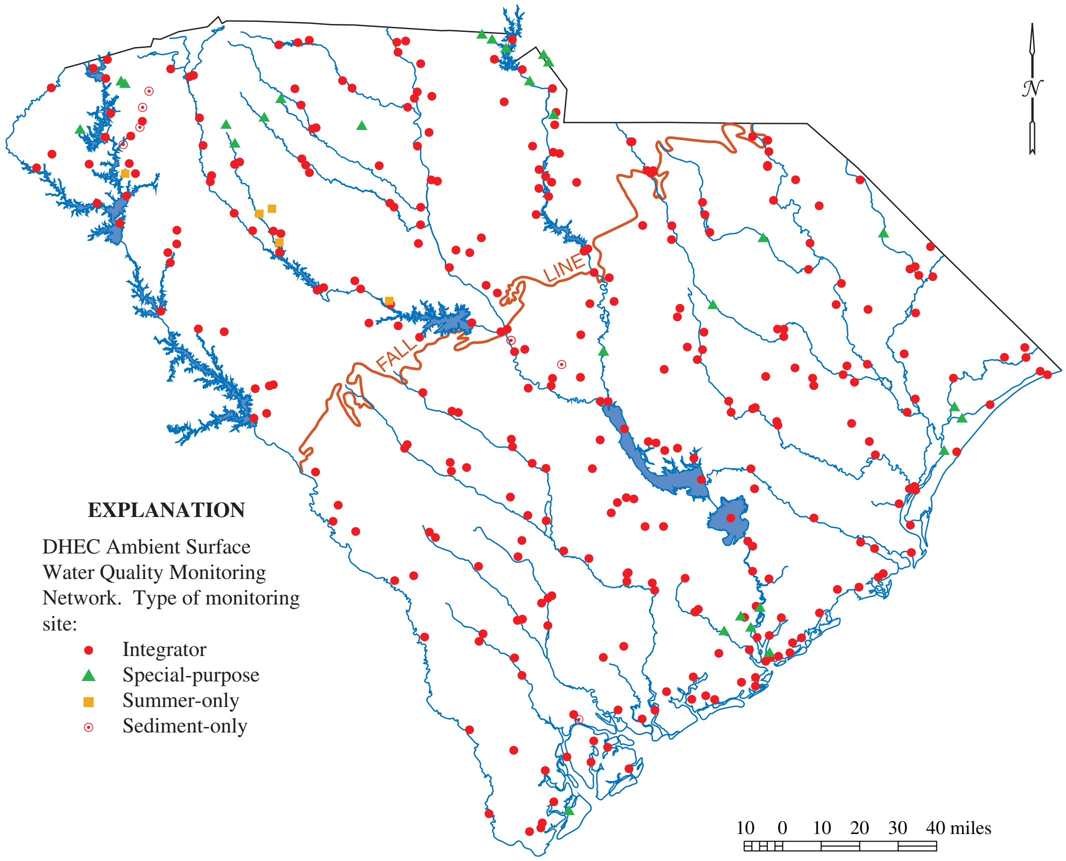


Figure 3-13. DHEC ambient surface-water quality monitoring network (DHEC, 2003b).

levels occur in all impaired waters of the Pee Dee and ACE basins. Fish-consumption advisories have been issued for many of the major rivers and lakes in the Coastal Plain because of high mercury concentrations: the source of mercury contamination is believed to be general aerial deposition.

Piedmont water bodies exhibit somewhat different naturally occurring water-quality problems. The province's high topographic relief and impermeable soil contribute to rapid runoff and cause high levels of suspended solids, turbidity, and fecal coliform bacteria.

Although natural conditions affect water quality statewide, it is generally man's activities that adversely impact surface water to the point of impaired use. Elevated fecal coliform bacteria, nutrients, biochemical oxygen demand, and metals all have been attributed to industrial and municipal wastewater discharges. These same problems, in addition to increased sedimentation, poor macroinvertebrate structure, and dissolved oxygen levels, have been attributed to non-point sources of pollution commonly caused by man's alteration of the watershed.

In the Santee basin, an average of 71 percent of water from all subbasins fully supports aquatic-life uses, but only 67 percent supports recreational uses. Impaired water exhibits poor macroinvertebrate populations, elevated metals, and high fecal coliform levels. The highly developed Saluda subbasin exhibits the State's poorest water quality, with only 58 percent of water supporting aquatic-life uses and 57 percent supporting recreational uses. The Saluda watershed and adjacent Catawba watershed are two of five basins designated as high priority for water-quality restoration.

The Pee Dee and Waccamaw watersheds also are among the five basins in need of restoration because of poor water quality (South Carolina Department of Health and Environmental Control and U.S. Department of Agriculture, 1998). Approximately 70 percent of waterways in the Pee Dee basin meet aquatic-life standards while more than 75 percent support recreational uses; however, many water bodies in this Coastal Plain basin suffer from naturally occurring low dissolved-oxygen levels and high fecal coliform counts. High mercury levels in some game fish have prompted fish-consumption advisories for many lakes and rivers. A nationwide analysis of vulnerable fish and mussel species found the Waccamaw subbasin to be a "Watershed Hot Spot" because ten or more freshwater fish and mussel species were considered at risk (South Carolina Department of Health and Environmental Control and U.S. Department of Agriculture, 1998).

Most water bodies in the ACE basin support aquatic-life and recreational uses, but the basin exhibits the poorest quality in the State owing to exceptionally low compliance in the Ashley-Cooper subbasin (61 percent). As in other Coastal Plain basins, naturally occurring low dissolved-oxygen levels and high fecal coliform levels impair full compliance. Fish-consumption advisories and shellfish advisories have been issued for major waterways throughout this basin.

The Savannah basin has the best water quality overall, with an average of 80 percent of lakes and streams fully supporting aquatic-life uses and 75 percent supporting recreational uses. Impaired water in the Savannah basin tends to have low pH, poor macroinvertebrate communities, and high fecal coliform levels. Fish-consumption advisories have been issued for part of the Savannah River due to high mercury levels and for Lake Hartwell due to high PCB levels. The Seneca-Keowee watershed, in the upper Savannah basin, is one of the State's five basins most in need of restoration (South Carolina Department of Health and Environmental Control and U.S. Department of Agriculture, 1998).

GROUND-WATER RESOURCES

South Carolina's ground water occurs in fractured crystalline rocks of Paleozoic age that are exposed in the Piedmont region and in sand and limestone aquifers in the Cretaceous, Tertiary, and Quaternary formations of the Coastal Plain. Three distinct aquifer types are present: (1) cracks in the crystalline rock of the Piedmont and the Coastal Plain basement, (2) sand beds in several formations of the Coastal Plain, and (3) permeable limestone units of the southern coastal area. The principal geologic and hydrologic units of the Coastal Plain and their correlation with the terminology of the 1983 *State Water Assessment* are shown in Table 3-2. The hydrogeologic units discussed in this assessment are based on the delineations published by Aucott and others (1986) for the USGS Regional Aquifer Systems Analysis project. Schematic representations of the principle Coastal Plain aquifers are shown in Figure 3-14.

The number, size, and shape of openings in an aquifer determine its porosity, and the degree of interconnection of the openings determines the ground-water transmitting capacity. High porosity does not guarantee pore interconnection and high permeability; clay and limestone have porosities two to four times greater than most sand formations, but clay and most limestone store and confine water rather than yielding it to wells.

Table 3-2. Former, present, and proposed hydrostratigraphic systems used by the South Carolina Department of Natural Resources

<table>
<tr><th>Geologic system (1983 assessment)</th><th>Aquifer (1983 assessment)</th><th>Geologic system (2009 assessment)</th><th>Aquifer (Aucott and others, 1986)</th><th>Aquifer delineation system (modified from Aadland and others, 1995)</th></tr>
<tr><td>Post Oligocene</td><td>Shallow</td><td>Middle Miocene to Recent</td><td>Shallow</td><td>Surficial aquifer
Upper Floridan confining unit</td></tr>
<tr><td>Cooper Fm.
Ocala Limestone
Santee Limestone</td><td>Floridan</td><td>Ashley Formation
Harleyville Formation
Ocala Limestone
Santee Limestone</td><td>Floridan</td><td>Upper Floridan aquifer
Middle Floridan confining unit
Middle Floridan aquifer</td></tr>
<tr><td>Orangeburg Group</td><td>Tertiary sand</td><td rowspan="3">Upland Unit
Barnwell Group
McBean Formation
Green Clay
Congaree Formation
Williamsburg Formation
Ellenton Formation</td><td rowspan="3">Tertiary sand</td><td rowspan="3">Steel Pond aquifer
Upper Three Runs aquifer
Gordon confining unit
Gordon aquifer
Crouch Branch confining unit</td></tr>
<tr><td>Black Mingo Fm.</td><td>Black Mingo</td></tr>
<tr><td>Ellenton Fm.</td><td>Ellenton</td></tr>
<tr><td>Peedee Fm.</td><td>Peedee</td><td>Peedee Formation</td><td rowspan="2">Black Creek</td><td rowspan="2">Crouch Branch confining unit
Crouch Branch aquifer
McQueen Branch confining unit</td></tr>
<tr><td>Black Creek Fm.</td><td>Black Creek</td><td>Donoho Creek Formation
Bladen Formation
Tar Heel Formation
Cane Acre Formation
Caddin Formation</td></tr>
<tr><td>Middendorf Fm.</td><td rowspan="2">Middendorf</td><td>Shepherd Grove Formation
Middendorf Formation</td><td>Middendorf</td><td>McQueen Branch aquifer</td></tr>
<tr><td>Cape Fear Fm.</td><td>Cape Fear Formation</td><td>Cape Fear</td><td>Unnamed confining unit</td></tr>
</table>

Fm, Formation

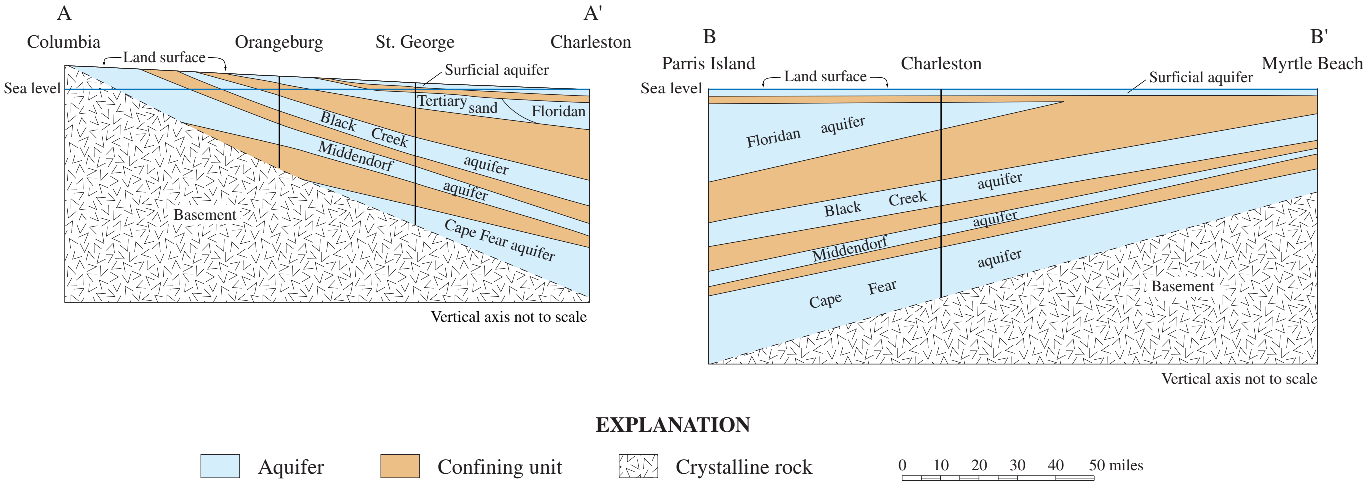


Figure 3-14. General hydrogeologic sections across the South Carolina Coastal Plain (after Aucott and others, 1986).

Ground water may occur under unconfined (water-table) or confined (artesian) conditions. Where unconfined conditions exist, the surface of the saturated zone is at atmospheric pressure and the water table is free to rise and fall in response to gravity. Water levels in wells penetrating unconfined aquifers define the water table. Unconfined aquifers are directly recharged by precipitation percolating downward through the soil column.

Confined conditions exist where aquifers are overlain and underlain by relatively impermeable confining beds. Ground water in such aquifers is under hydrostatic (artesian) pressure, and water levels in wells completed in a confined aquifer will rise above the top of the aquifer. These water levels define the potentiometric surface of the aquifer. Where the potentiometric surface is above ground level, the wells will flow. Confined aquifers receive recharge from precipitation on their outcrop areas and from leakage through adjacent confining beds in their downdip regions.

Ground-water occurrence and availability are directly related to the geology of a region, and well yields differ significantly between the Blue Ridge and Piedmont and the Coastal Plain. Blue Ridge and Piedmont crystalline rocks have little or no permeability except where fractures occur and are enhanced by weathering. Well yields depend on intercepting fractures formed by joints, faults, and partings along bedding and cleavage planes, on the number and size of fracture zones, on saprolite thickness, and on topography. Valleys typically are areas of intense fracturing and exhibit higher ground-water yields than topographically high areas; hilltops and their upper slopes commonly are underlain by thin saprolite and harder, less-fractured rocks with lower permeability.

The saprolite, a 0- to 100-foot thick zone of clayey, weathered rock, overlies the igneous and metamorphic rock. Most of the saprolite is saturated and, although the water seeps only slowly into bedrock fractures, there is a significant transfer of water when considered on a regional scale. The saprolite also can yield water to dug and bored wells that depend on large well diameters for storage, but saprolite wells commonly capture less than 1 gpm (gallons per minute), are drought sensitive, and are less common owing to improved drilling technology and increased household water demands.

Aquifers in the Coastal Plain are basically sand or limestone. The sand aquifers, some with significant amounts of shell or gravel, represent the shallow, Tertiary sand, and Cretaceous aquifers. Ground water in these unconsolidated aquifers is stored in and moves through the pore spaces among sand and gravel. Ground water in limestone aquifers is stored in and moves through diffuse networks of small fractures and poorly consolidated fossil shell or through local networks of pipe-like solution channels. Most limestone aquifers in the State are confined, and the ground water is under pressure. The Floridan aquifer, a sequence of limestone formations that extends from the Santee River to south Florida, is the most productive aquifer system in the United States. There is substantial pumping from the Floridan in southern South Carolina and coastal Georgia.

Near ground surface, ground water commonly occurs under water-table conditions. Water levels in these shallow aquifers fluctuate seasonally, and their well yields are modest because of the small available drawdown. Most Coastal Plain ground water, however, occurs in confined aquifers under artesian pressure. Water levels in these aquifers remain fairly constant, except where influenced by pumping.

An aquifer's capacity to transmit ground water and to yield water to wells is related to rock permeability, termed hydraulic conductivity (K), thickness (m), and storage coefficient (s). Hydraulic conductivity in the aquifers of South Carolina ranges from about 100 gpd/ft^2 (gallons per day per square foot) in fine, poorly sorted sand, to more than 3,000 gpd/ft^2 in some limestone aquifers. Hydraulic conductivity is greatest in and just downdip of aquifer outcrop areas but generally diminishes and falls within a fairly narrow range coastward of outcrop areas. Thickness, however, ranges widely, typically increasing as formations thicken toward the coast and thinning near the Fall Line where eroded in the geologic past, with increasing proportions of fine-grained sediment, and along lateral transitions in rock type.

Transmissivity defines the total capacity of an aquifer and is determined by hydraulic conductivity and aquifer thickness (K x m). It tends to be high in the upper Coastal Plain where there are great thicknesses of coarse sand and gravel; low to moderate across the middle Coastal Plain where medium- to fine-grained sand predominates; and high in the southern Coastal Plain where the stratigraphic column is 2,000 to 4,000 feet in thickness. Ground-water definitions and formulae used to describe and quantify ground-water availability are given in Supplemental Information Box 3-2.

GROUND-WATER PROGRAMS

Monitoring Programs

Ground-water levels and ground-water quality are routinely monitored statewide. Continuous ground-water level monitoring provides both long-term and short-term benefits. Hourly measurements track water-level and water-quality trends daily, yearly, and across decades. Many observation sites, particularly in the middle and lower Coastal Plain, show that artesian levels have declined as the State's population has grown and has concentrated near the coast. Regular measurements are used to predict drawdown and well interference caused by future ground-water use, to estimate changes in ground-water storage, and to observe how particular hydrogeologic settings affect artesian levels during drought. Hourly data can reflect local and regional well interference, the presence or absence of local recharge, daily and seasonal changes in evapotranspiration, and periods of peak ground-water use. Individual observations are made in about 600 wells in the Cretaceous- and Tertiary-age aquifers every 5 to 6 years and are used to construct potentiometric maps. These potentiometric maps reveal changes in the direction and rate of ground-water flow and identify new and expanding pumping centers. Such maps are essential for the calibration of predictive ground-water flow models. Water-quality monitoring includes ambient ground-water quality and water-quality changes caused by active saltwater intrusion.

Long-term ground-water monitoring is conducted by the USGS, DNR, and DHEC. The USGS has collected data since 1945, and it operated hourly water-level recorders on 19 wells during 2006. USGS sites typically have been monitored in cooperation with DNR and the former Water Resources Commission on a matching-funds basis. DNR expanded the statewide network after 1999 (Figure 3-15), and the DNR staff maintained 74 manually and hourly logged water-level sites during 2006. The base network operated by the USGS and DNR increased from 32 wells in 1980 to 109 wells in 2008.

About 150 well sites are monitored for water quality as part of regional or statewide programs. Twenty-seven permanent and temporary sites were monitored for ground-water levels and specific conductance by DHEC in Beaufort and Jasper Counties. The DHEC network is devoted to monitoring the impact of Floridan aquifer pumping at Savannah, Ga., and southern Beaufort County, S.C., a region of substantial water-level decline and widespread saltwater intrusion. DHEC also samples a network of wells open to the major aquifers of the Blue Ridge, Piedmont, and Coastal Plain: this ambient water-quality network began with 19 wells sampled in 1987 and expanded to 117 wells by 2002. The USGS operates a real-time (satellite transmission) specific-conductance station on northern Hilton Head Island for DNR and monitors saltwater intrusion there. DNR maintains a pair of specific-conductance stations near Edisto Beach to monitor saltwater upconing (Figure 3-16).

Management Programs

Water-Quality Management. DHEC has regulatory responsibility for protecting the quality of the State's ground-water resources. Its programs include the permitting of public water-supply systems and well construction, regulation of existing and potential ground-water contamination sites, and management of saltwater intrusion. These programs encompass:

- Reviews and permits for public-supply wells to insure proper design and construction;
- Delineation of well-head protection areas for public-supply wells;
- Regulation of the location, design, and construction of commercial-, domestic-, and irrigation-supply wells;
- Regulation and monitoring of underground storage tanks (UST Program);
- Regulation of pits, ponds, lagoons, and feedlots;
- Reviews and permits for the Underground Injection Control Program, including subsurface-storage wells and geothermal heat-pump return wells; and

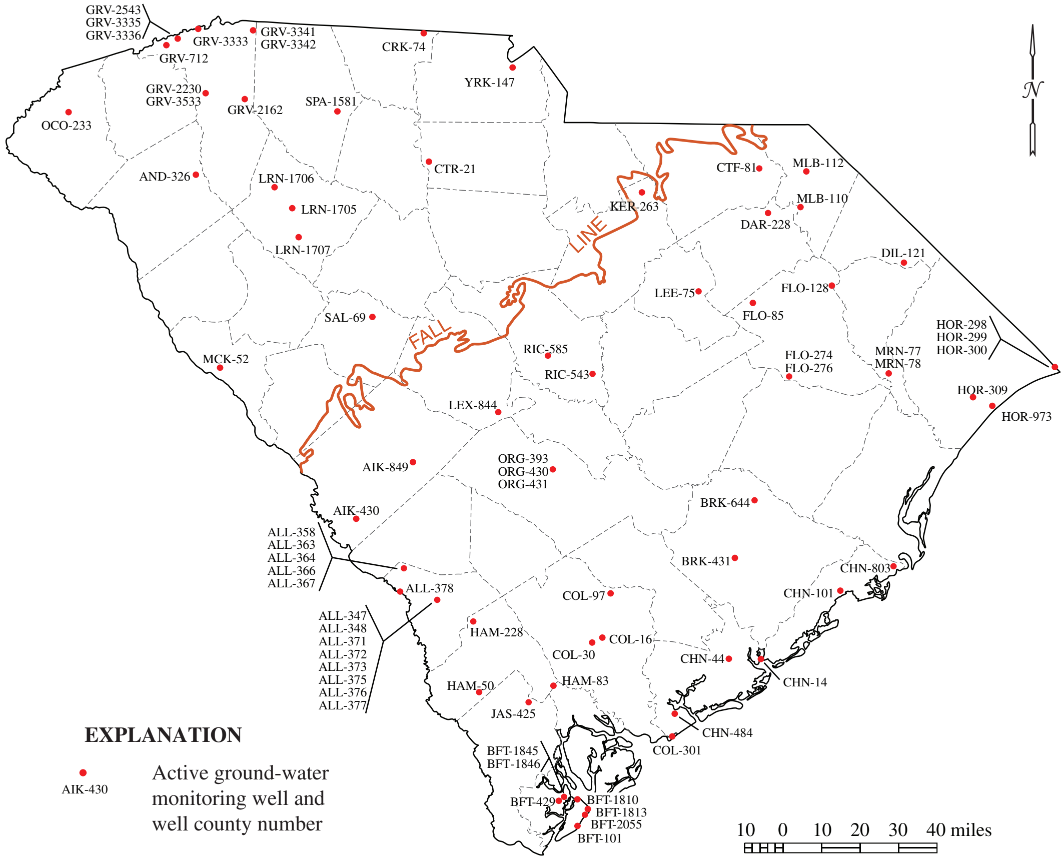


Figure 3-15. Distribution of permanent DNR and USGS–DNR cooperative ground-water level records.

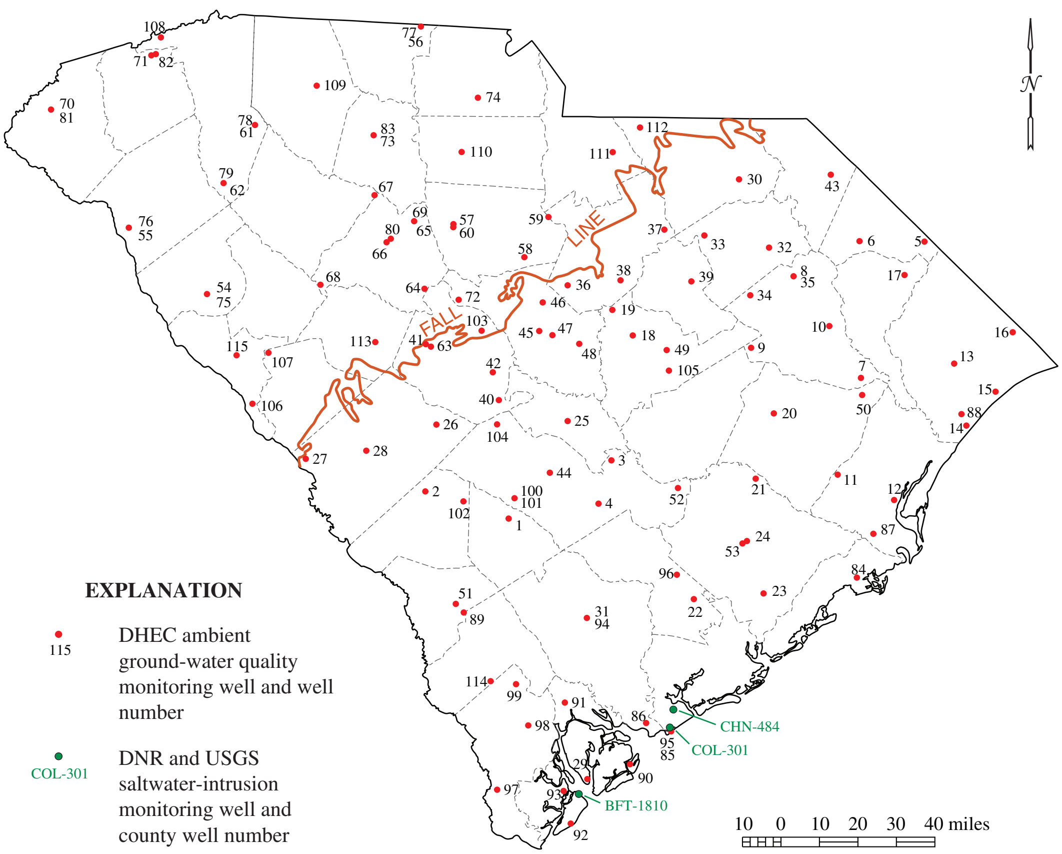


Figure 3-16. Distribution of permanent DNR, USGS, and DHEC ground-water quality monitoring sites.

- Mitigation of well interference and saltwater intrusion through the issuance of ground-water use permits.

Water-Quantity Management. Ground-water withdrawals are regulated in designated areas of the State under authority of the Ground-Water Use and Reporting Act (revised 2000). The former Water Resources Commission managed the State's first two Capacity Use Areas between 1978 and 1994. In 1994, DHEC assumed responsibility for Capacity Use Areas following State-government reorganization and has since designated two additional Capacity Use Areas. A Notice of Intent (NOI) to install a well that will withdraw more than 3 million gallons per month was required after 2000 for Coastal Plain counties outside of the Capacity Use Areas (Figure 3-17). The four Capacity Use Areas span the South Carolina coast and address multi-county ground-water problems:

- Waccamaw Capacity Use Area (Horry and Georgetown Counties)—declared in 1978 to address water-level declines greater than 100 feet in the Black Creek aquifers between North Carolina and Georgetown; to minimize public-supply well and irrigation-well interference; to prevent interconnection of brackish-water and freshwater aquifers within well bores; and to mitigate brackish-water intrusion from the Cape Fear Arch toward Myrtle Beach;
- Low Country Capacity Use Area (Beaufort, Jasper, Hampton, and Colleton Counties)—declared in 1982 to control saltwater intrusion in the Floridan aquifer at Edisto Island; around the Sea Islands of Beaufort County; and from Port Royal Sound toward Hilton Head Island;
- Trident Capacity Use Area (Charleston, Berkeley, and Dorchester Counties)—declared in 2003 to mitigate water-level declines greater than 200 feet and pumping-level interference among industrial and public-supply wells that rely on the Black Creek and Middendorf aquifers;
- Pee Dee Capacity Use Area (Marlboro, Darlington, Florence, Williamsburg, Dillon, and Marion Counties)—declared in 2004 to address water-level declines in the Middendorf and Black Creek aquifers.

Capacity Use permits are required for users who withdraw more than 3 million gallons per month in any month from any combination of wells. Applicants must plan water-conserving measures and consider water sources that are alternatives (e.g., treated effluent and ponds) to the principal aquifer in the Capacity Use Area. Certain uses of the area's principal aquifer, such as golf-course irrigation, might be limited with nonrenewable permits or can be prohibited. Total average-daily withdrawals from the area's principal aquifer may be capped.

SUPPLEMENTAL INFORMATION BOX 3-2

Ground-Water Terminology

Head (h): the height of a water column, or its water pressure, relative to a reference point.

Hydraulic conductivity (K): permeability. The rate at which ground water is transmitted through a unit-squared section of aquifer under a unit hydraulic gradient, expressed in gallons per day per square foot (gpd/ft^2) or in feet per day (ft/day) where cubic feet are used instead of gallons.

Potentiometric surface: the distribution of potentiometric water levels above or within an aquifer and commonly illustrated by contour maps showing potentiometric elevations relative to sea level.

Specific capacity of wells: the rate of discharge from a pumped well divided by the drawdown in water level after a specified period of time (usually 24 hours) and expressed in gallons per minute per foot (gpm/ft) of drawdown.

Specific yield (Sy): the volume of water an unconfined aquifer releases from storage by gravity drainage relative to the volume of the aquifer. The term is dimensionless, and values typically range from 0.01 to 0.1, e.g., 0.1 times one cubic foot (ft^3) of aquifer equals 0.1 ft^3, or 0.75 gallon per cubic foot of aquifer.

Storage coefficient (S): the volume of water a confined aquifer releases from storage per unit surface area per unit change in head. The term is dimensionless, and values for confined Coastal Plain aquifers typically are about 0.0002 (2×10^{-4}), e.g., 0.0002 times 100 ft of water-level decline equals 0.02 ft^3, or 0.15 gallon per square foot of aquifer.

Transmissivity (T): the rate at which ground water is transmitted through a unit width of aquifer under a unit hydraulic gradient, expressed in gallons per day per foot (gpd/ft) or in feet squared per day where cubic feet are used instead of gallons.

Water table: the surface of the saturated section in an unconfined aquifer.

Ground-Water Assistance

Technical assistance is provided to existing and potential ground-water users by DNR, DHEC, and the USGS. The assistance can be as simple as providing tabular data on well depths, yields, and chemistry near a potential well site, or it might be as involved as the inventory and testing of wells where well yield or water quality is unknown or problematic. DNR, DHEC, and the USGS also cooperate on regional studies requested by local governments.

Geologists and hydrologists with the three agencies make geologic interpretations, conduct aquifer testing and sampling, and provide recommendations for well

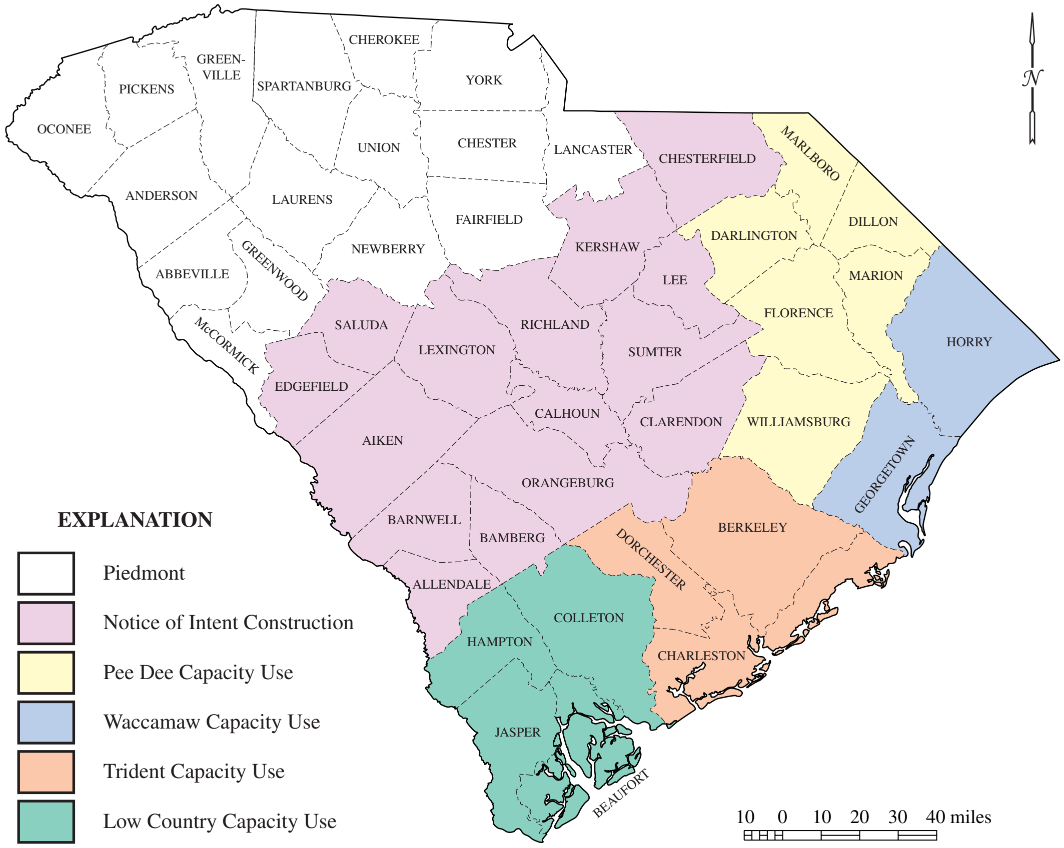


Figure 3-17. Capacity-Use and Notice-of-Intent areas in South Carolina.

design, well spacing, and pumping rates. DHEC, DNR, and the USGS each operate borehole geophysical loggers that measure the radiological, chemical, and geologic characteristics of subsurface formations: these measurements are used to identify rock types, select screen settings, and delineate aquifers. The agencies also operate water-quality laboratories to support their field research. DNR augments geologic and aerial mapping with VLF (very low frequency) technology to locate fracture zones in the crystalline-rock aquifers of the Piedmont and Blue Ridge provinces. VLF surveys greatly reduce the risk of drilling dry holes.

Ground-Water Research and Knowledge

Research. The research of DNR, DHEC, and USGS mainly focuses on projects that have immediate applicability, but it ranges from the utilitarian to the esoteric. Cooperative studies by the former SCWRC and USGS have provided the hydrogeologic and geochemical frameworks used to delineate and manage the State's four Capacity Use Areas. The congressionally-mandated RASA (Regional Aquifer Systems Analysis) projects require the USGS to quantify the nation's ground-water resources, and the USGS published aquifer-distribution maps, potentiometric maps, and flow models of the State's Coastal Plain aquifers during the 1980's—congressionally-funded updates of RASA began in 2004. DNR published ground-water summaries covering 18 counties between 1983 and 2008, completing at least basic coverage of 28 Fall Line and Coastal Plain counties. DHEC publishes a wide range of reports and atlases, particularly concerning water quality, and has extensive experience in mapping isotopes and age-dating rock and water. Research done locally, but having future and outside applications, also is done by Federal and State agencies and by State universities, particularly in the fields of subsurface microbiology, geochemistry, and ground-water remediation.

Knowledge. Judging the adequacy of ground-water knowledge largely depends on how the knowledge is to be used. Estimating the yield and quality of water beneath a potential well site typically requires little more than well-construction records and chemical analyses from nearby wells. Determining the radius of a well-head protection area requires data on geology, aquifer hydraulics, and potential contaminant sources, and calculation of the well's radius of capture. Predicting the impact of multiple wells on water levels or saltwater movement typically involves a computer model that depends on extensive knowledge of geology, transmissivity, water levels, and water use. The following criteria are used to categorize the level of ground-water knowledge in South Carolina's 46 counties (Figure 3-18):

File-data level—

- No systematic, countywide ground-water investigation has been published; or a published investigation is outdated owing to increased water demand, identification of water-supply problems and opportunities since publication, or otherwise limited data relative to the present need.
- Data exist mainly in the form of geophysical logs, pumping tests, water-chemistry analyses, and unverified water-well contractors' reports.
- Data generally are not suitable for planning well design as regards open intervals, drawdown, and specific requirements for well yield and chemical quality.

Planning level—

- Extensive file data are available from contractors' reports and field surveys, the geographic positions of significant well-data points are known, and systematic county or multicounty ground-water investigations have been published. One or more references:
  - o define a hydrogeologic framework; summarize geologic, hydraulic, and water-quality characteristics; and calculate water use.
  - o identify sources of additional water supply and impediments to ground-water development.

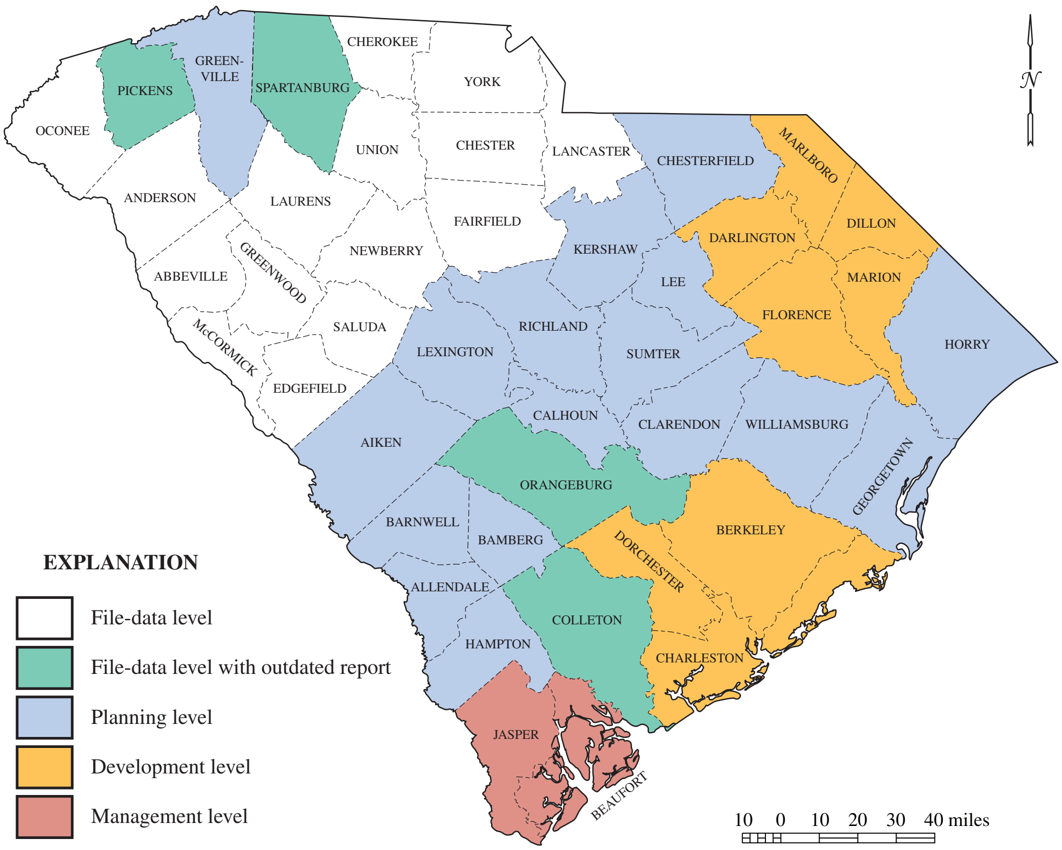


Figure 3-18. Levels of ground-water knowledge in South Carolina.

- Reports used in conjunction with file data can be used to plan approximate well-casing design, well-screen locations, and pump requirements, and to anticipate individual well yield, drawdown, and water quality for the most commonly used aquifer(s).

Development level—

- Summary reports define the hydrogeologic framework and describe significant physical conditions, water-supply problems and alternatives, and regulatory issues.
- The general hydrologic, hydraulic, and water-quality conditions in the principal aquifer(s) are well mapped and understood.
  - o Well design, maximum well yield, and water chemistry typically can be predicted with good confidence in most of the area.

- o Hydraulic and potentiometric data are adequate to identify recharge and discharge areas, to estimate regional flow rate and direction, and to calculate the drawdown and capture radius of individual wells and well fields.

- Information provides a framework for planning digital ground-water models. A digital model already may be available as a tool to identify knowledge gaps and plan future modeling efforts.

Management level—

- Ground-water conditions in one or more principal aquifers are described in digital models.
- The model may be used to predict ground-water conditions under various scenarios, and the model accuracy and the level of knowledge support water-supply management and regulatory decisions.
- Management plans are in progress or in place that encompass water-supply limitations and alternatives and address the nature, scope, and necessity of ground-water regulation.

GROUND-WATER OVERVIEW

Vast amounts of water are stored in the aquifers of South Carolina, and even greater quantities are stored in the thicker and more porous confining units. The availability and quality of this ground water depend on the geology and physiography and, in some places, on the activities of man. Permeable sand and limestone formations in the Coastal Plain contain large quantities of water (Figure 3-19) and readily yield water to wells. The crystalline rocks and saprolite of the Blue Ridge and Piedmont store large water quantities, but yield water reluctantly. Ground-water quality is good nearly everywhere, but local naturally occurring and manmade problems are found in most major aquifers.

Blue Ridge and Piedmont Provinces

Aquifers of the Blue Ridge and Piedmont provinces are weathered zones or fracture zones in the otherwise impermeable igneous and metamorphic rocks. Only limited quantities of ground water can be obtained in this region. The highest yields are from wells constructed in the fracture zones of the Piedmont's igneous and metamorphic rocks.

Until the mid-twentieth century, ground water in the Blue Ridge and Piedmont was developed predominantly from springs and from dug wells 2 or 3 feet in diameter. Water at these sources was obtained from the saprolite or from the top of the underlying hard-rock layer. Dug wells often went dry during droughts as the water table declined below the bottom of the well.

Ground-water supplies mainly are obtained from 4- to 8-inch diameter wells drilled into rock fractures.

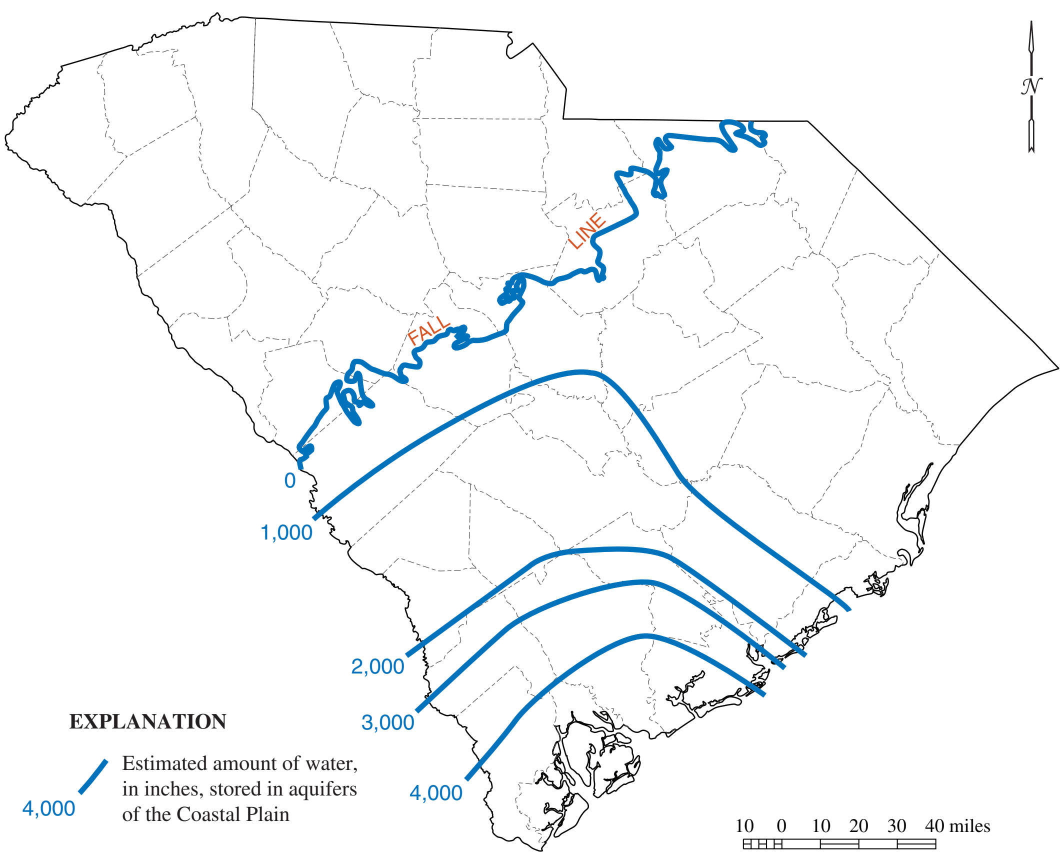


Figure 3-19. Estimated quantity of ground water in South Carolina Coastal Plain aquifers (Cherry and others, 2001).

Yields range from less than 1 gallon per minute to several hundred gallons per minute, and yields can vary greatly among wells located within several yards of one another. Recharge to the fractures that supply wells occurs directly from precipitation if the fracture extends to the land surface and indirectly from water stored in the saprolite. Well-water levels, therefore, usually rise during winter and spring when rainfall is greatest and ET is least, and levels decline during the summer and early fall months when rainfall is least and ET is greatest. Water-level changes in rock fractures can lag months behind drought and wet periods because saprolite clay stores large amounts of water but absorbs and releases it slowly.

Well-site selections and well designs typically are based on convenience and economy rather than hydrogeologic principles, and most domestic-supply wells do not penetrate the full thickness of potential aquifers. Consequently, specific aquifer and hydrogeologic units are not well delineated throughout the Blue Ridge and Piedmont: good databases are available for the more populated areas, such as Greenville and York Counties and, to a lesser extent, Abbeville, Anderson, Laurens, Newberry, Pickens, and Spartanburg Counties.

Ground-water quality in the Blue Ridge and Piedmont is of two general types. The first type includes water from the quartzose, micaceous, and light-colored silicate rocks—the water is generally soft and low in total dissolved solids. The second type includes water from gabbros, hornblende, and dark-colored calcic-magnesium rocks—the water is moderately-hard to hard and commonly has higher dissolved solids and iron concentrations than water in silicate rocks.

Water quality is generally good in crystalline-rock aquifers, but high concentrations of dissolved solids, iron, and hardness are prevalent in some areas. Hard ground water is common in Saluda County and parts of Edgefield and Union Counties; high dissolved-solids concentrations are common in parts of Union, York, Saluda, Newberry, and Greenwood Counties.

Naturally occurring radionuclides exceed recommended drinking water standards in isolated areas. Well samples containing uranium above the 30 µg/L (micrograms per liter) mcl (maximum contaminant level) are scattered through southeastern Greenville County and adjacent areas. The highest measured concentration exceeded 10,000 µg/L, and several others were above 1,000 µg/L. High concentrations of radium and radon also are present. The State Geological Survey and DHEC are working to determine the uranium source, and residents of the most-affected area now are served by municipal water systems.

Sodium, magnesium, and chloride concentrations, and alkalinity and hardness, are generally high in the geologic belts formed by low-grade metamorphism—the Carolina slate belt and, to a lesser extent, the Kings Mountain belt. Other water-quality constituents do not necessarily correlate with these belts. Ground-water quality in Piedmont and Blue Ridge aquifers typically is within drinking-water standards for most constituents (Moody and others, 1988). Concentrations of dissolved solids range from 22 to 1,100 mg/L but exceed the 500-mg/L secondary EPA Drinking Water standard only in limited areas. Ground-water data from the National Uranium Resource Evaluation program indicate a maximum of 1,260 mg/L for dissolved solids with an average in the Piedmont of 89 mg/L and a median value of 58 mg/L. The higher concentrations of dissolved solids are predominantly in the Carolina slate belt and in or near gabbroic plutons. The standard most often exceeded is the 50-µg/L limit for manganese (Patterson and Padgett, 1984), although the median concentration is only 17 µg/L. Manganese concentrations above 50 µg/L tend be located in the Carolina slate belt and near plutons, particularly gabbroic plutons. Water typically is soft in most Piedmont and Blue Ridge aquifers, although moderately-hard to very-hard water does occur locally (Moody and others, 1988). Alkalinity is generally low, ranging from 0.5 mg/L to 300 mg/L, with a median of 17 mg/L. Drinking-water standards for pH, chloride, fluoride, and nitrate are exceeded in some areas (Moody and others, 1988).

Coastal Plain Province

Cape Fear Aquifer. The Cape Fear aquifer consists principally of the Cape Fear Formation and is the basal aquifer of the South Carolina Coastal Plain. It consists of sand-and-gravel beds separated by thick sections of silt-and-clay. It is thought to occur mainly in the lower Coastal Plain and eastern part of the upper Coastal Plain. The type locality of the Cape Fear Formation is in North Carolina, and no part of the formation crops out in South Carolina. Structure contours on the top of the aquifer are shown in Figure 3-20.

Few wells penetrate the aquifer, hence hydraulic and water-quality data are scarce. In general, the aquifer is less permeable and productive than the overlying Middendorf aquifer, and the Cape Fear commonly contains more mineralized water. Those few wells completed exclusively in the Cape Fear exist mainly for test and observation purposes. DNR monitors Cape Fear observation wells near the Savannah River Site and at Calabash, N.C. Water-level observations show only small seasonal water-level fluctuations and little response to drought, mainly owing to its great depth and the small number of pumping wells. Cape Fear/Middendorf aquifer wells at Myrtle Beach and at Hilton Head Island have been constructed as tests for aquifer storage and recovery and for water-supply potential, respectively. The several wells that obtain water supply from the aquifer, at Mount Pleasant, Seabrook Island, and Hilton Head Island, also are screened in the Middendorf aquifer and obtain most of their water from that unit.

Water-quality data mainly are obtained from wells near the N.C.-S.C. border, where Cape Fear aquifers overlie the southwest flank of the Cape Fear Arch and are relatively shallow. Dissolved solids concentrations exceed 1,500 mg/L along the coast, increasing to more than 5,000 mg/L in northeastern Horry County, and generally reflect the trend seen in sodium and chloride concentrations. The distribution of the principal properties and constituents is shown in Figure 3-21.

Middendorf Aquifer. The Middendorf aquifer is composed mostly of Middendorf Formation sediment, but locally it includes parts of adjacent formations. In the updip areas, the aquifer is interbedded sand and clay lenses that were deposited in an upper delta-plain environment. Near the coast, the aquifer encompasses thin- to thick-bedded sand and clay deposited in marginal marine or lower delta-plain environments. In general, the Middendorf aquifer has coarser sand and less clay in the western part of the Coastal Plain than in the eastern part.

The Middendorf crops out along the Fall Line from Chesterfield County to Edgefield County, except for some areas of Aiken County where it not exposed (Figure 3-22). The aquifer dips southeastward near the Fall Line and southward along the coast. The top of the aquifer is at elevation 100, -700, and -1,700 feet msl (mean sea level) at Aiken, Little River, and Charleston, respectively. Thickness ranges from 0 feet at the Fall Line to more than 300 feet in Dorchester County.

Wells that tap the Middendorf can be found in nearly all of South Carolina's Coastal Plain counties, and it is the State's most widely used artesian aquifer. Well depths range from a few tens of feet in its subcrop area, where it locally is unconfined, to more than 2,700 feet in Beaufort County. Individual well yields that locally exceed 2,000 gpm and commonly exceed 500 gpm are reported. Transmissivities of up to 500,000 gpd/ft and specific capacities as great as 75 gpm/ft (gallons per minute per foot of drawdown) occur, but mainly in the upper Coastal Plain. Average hydraulic conductivities generally range between 200 and 500 gpd/ft^2, with the highest averages occurring in Aiken, Orangeburg, Chesterfield, and Marlboro Counties. Coarse sand-and-gravel formations occur in the aquifer in its subcrop area: where incised by stream erosion, these formations substantially contribute to the base flow of both upper Coastal Plain and through-flowing streams.

Pumping from the Middendorf has had a significant impact on potentiometric heads (water levels) near Charleston and in the region to the northeast. Figure 3-23 shows estimated water levels prior to ground-water development and in 2004. Declines of about 200 feet and 150 feet have occurred in Charleston and Florence Counties. Modern pumping, mainly in those two areas and in combination with modest aquifer transmissivity, has reversed ground-water flow from east to southwest.

Water from the Middendorf aquifer generally is of good quality, soft with low concentrations of dissolved solids, hardness, nitrate, and fluoride (Figure 3-24). Middendorf water becomes increasingly mineralized down gradient. Near the outcrop, the water is soft, acidic, and low in dissolved solids. Alkalinity (expressed as calcium carbonate), total dissolved solids, and sodium concentrations increase southeastward to more than 1,000, 2,500, and 1,000 mg/L, respectively. The pH increases from as low as 4.5 to more than 8.5. Dissolved-silica concentration exceeds 40 mg/L in eastern Florence, central Marion, and western Horry Counties. Ground water is highly mineralized or brackish beneath some areas near the coast and cannot be used for public supply without reverse-osmosis treatment.

Dissolved-iron concentrations commonly exceed 1 mg/L in a 25-mile wide band across Allendale, Bamberg, Orangeburg, Sumter, Florence, and Marion Counties. Southeast of this zone, dissolved iron decreases to less than 0.05 mg/L.

Middendorf water-quality variations reflect the geochemical and microbial reactions occurring in the aquifer. Water entering the aquifer is low in dissolved solids, and the sandy sediments of the upper Coastal Plain are less reactive than the clay and carbonate marine sediment near the coast. Mineral content therefore increases as groundwater flows coastward.

Major geochemical processes and trends that occur in the aquifer include:

- decomposition of organic matter;
- exchange of calcium from the dissolution of calcium carbonate minerals for sodium in sodium-rich marine clay minerals;
- the occurrence of dilute seawater near the coast.

Microbial processes also influence ground water chemistry. Dissolved oxygen decreases with increasing distance from recharge areas, iron-reducing bacteria generate soluble ferrous iron, and dissolved-iron concentrations increase. The ground water continues generally coastward, encountering sediment of increasingly marine origin and decreasing oxyhydroxide as the ground water approaches the coast, causing further sulfate reduction, formation of sulfide, and decreasing iron concentration as ferrous sulfide precipitates.

Black Creek Aquifer. The Black Creek aquifer is the youngest of the Cretaceous aquifers. It is composed mostly of permeable sediments of the Black Creek Formation but locally includes sediment of the overlying Peedee Formation. The aquifer encompasses thin- to thick-bedded sand and clay beds that were deposited in marginal-marine or delta-plain environments. The coarsest sand and least clay content are found in the western part of the Coastal Plain.

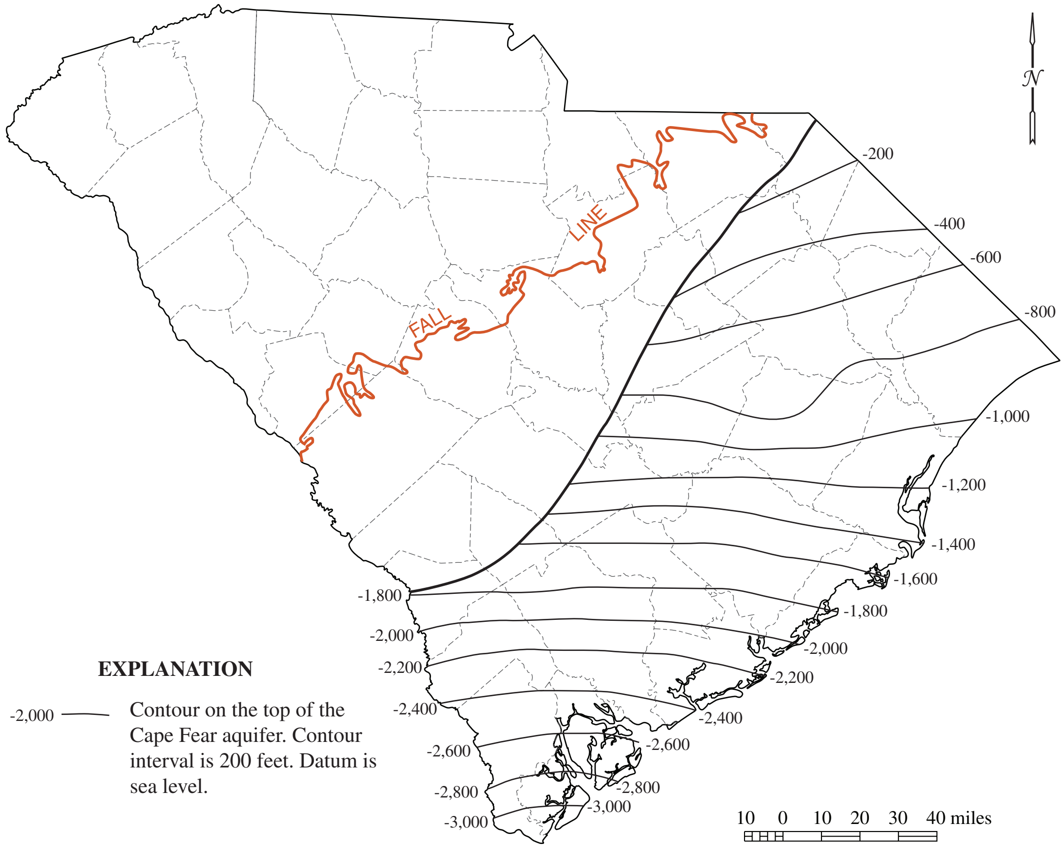


Figure 3-20. Structure contours on top of the Cape Fear aquifer (Aucott and others, 1986).

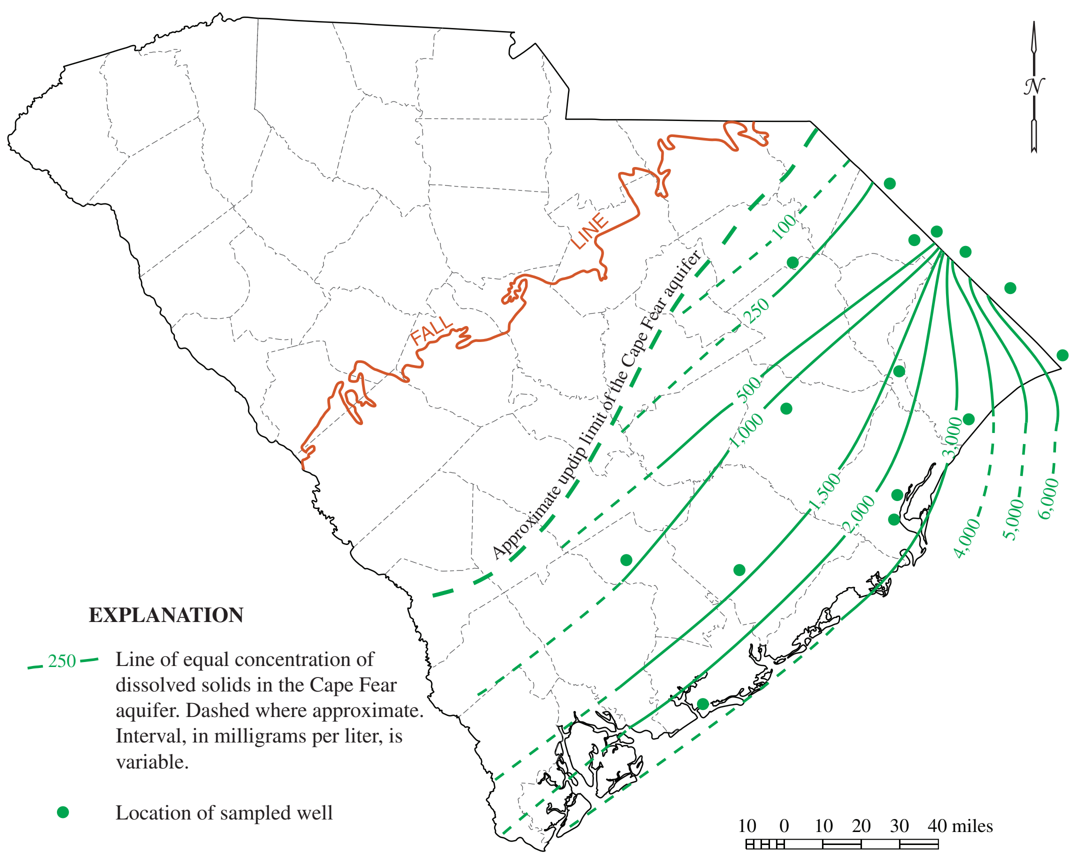


Figure 3-21. (a) Distribution of dissolved solids in the Cape Fear aquifer (Speiran and Aucott, 1994).

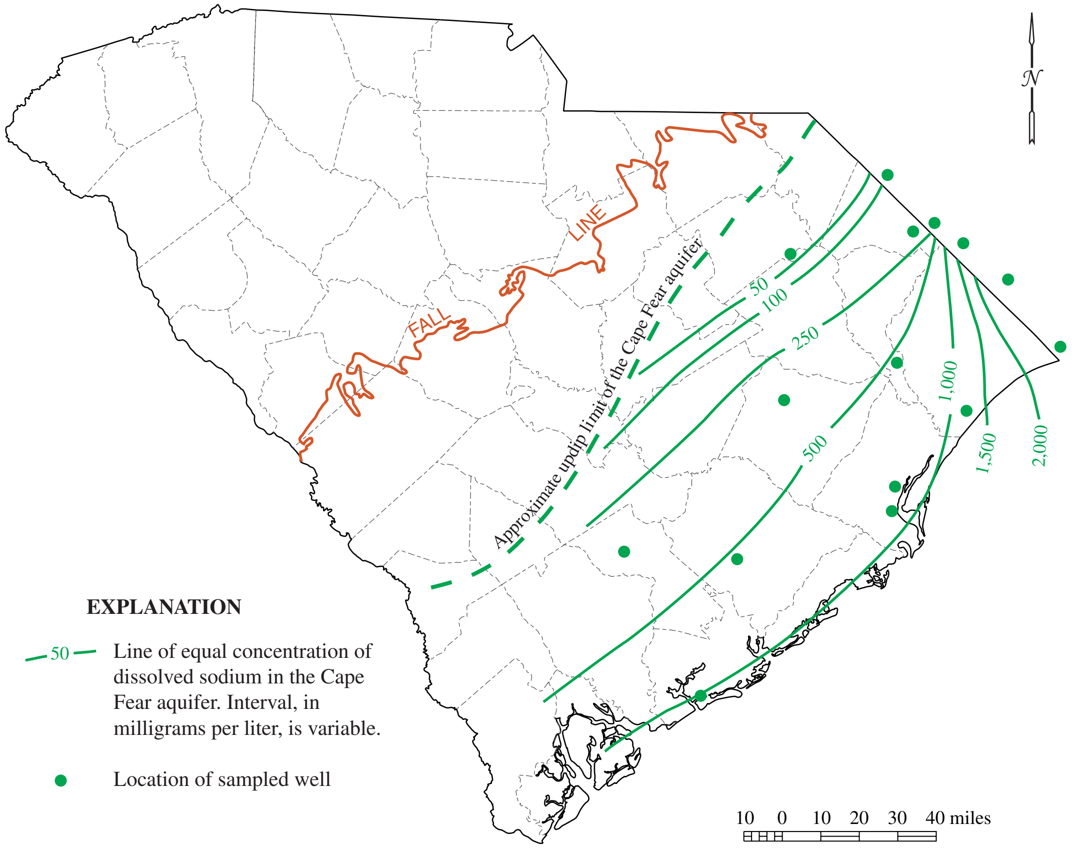


Figure 3-21. (b) Distribution of sodium in the Cape Fear aquifer (Speiran and Aucott, 1994).

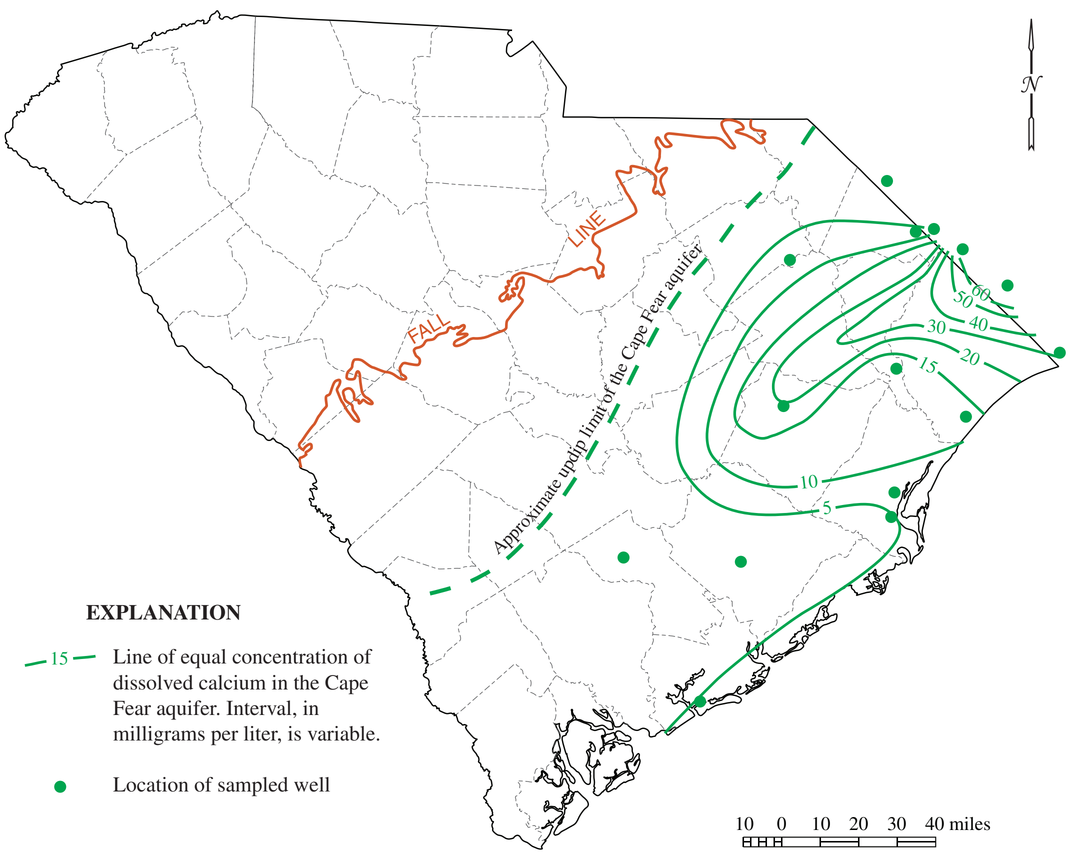


Figure 3-21. (c) Distribution of calcium in the Cape Fear aquifer (Speiran and Aucott, 1994).

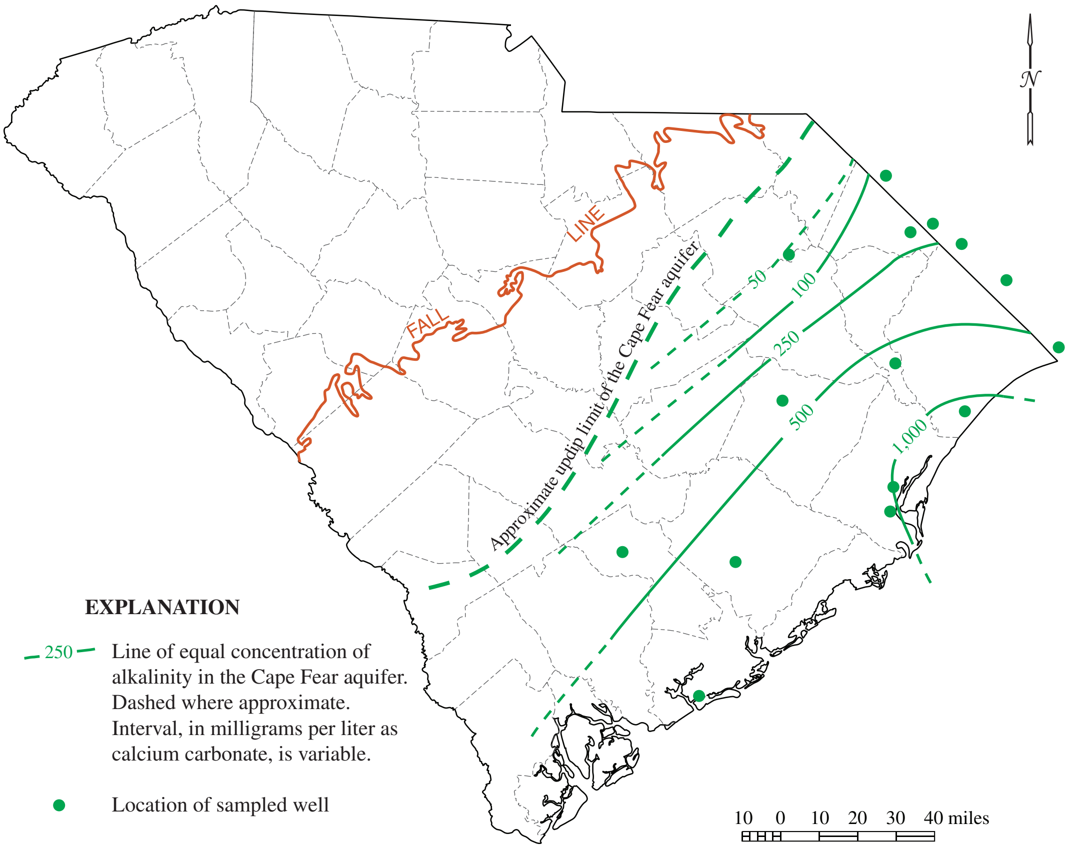


Figure 3-21. (d) Distribution of alkalinity in the Cape Fear aquifer (Speiran and Aucott, 1994).

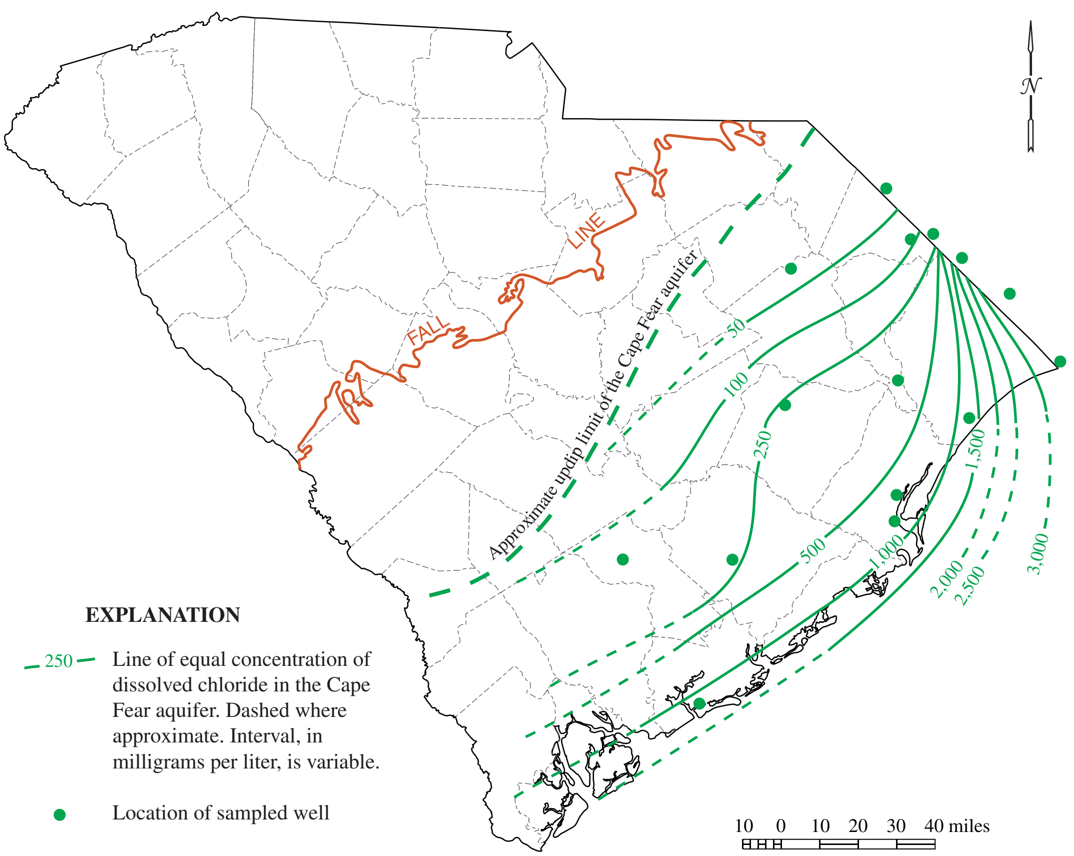


Figure 3-21. (e) Distribution of chloride in the Cape Fear aquifer (Speiran and Aucott, 1994).

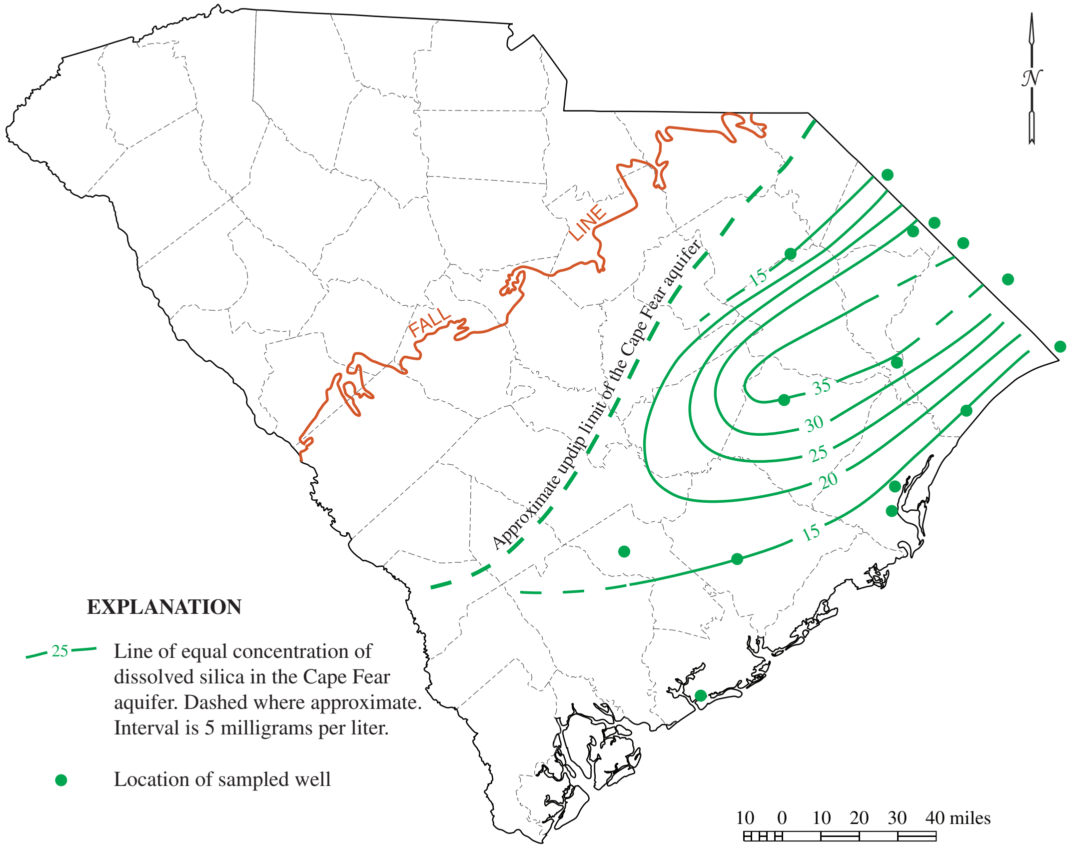


Figure 3-21. (f) Distribution of silica in the Cape Fear aquifer (Speiran and Aucott, 1994).

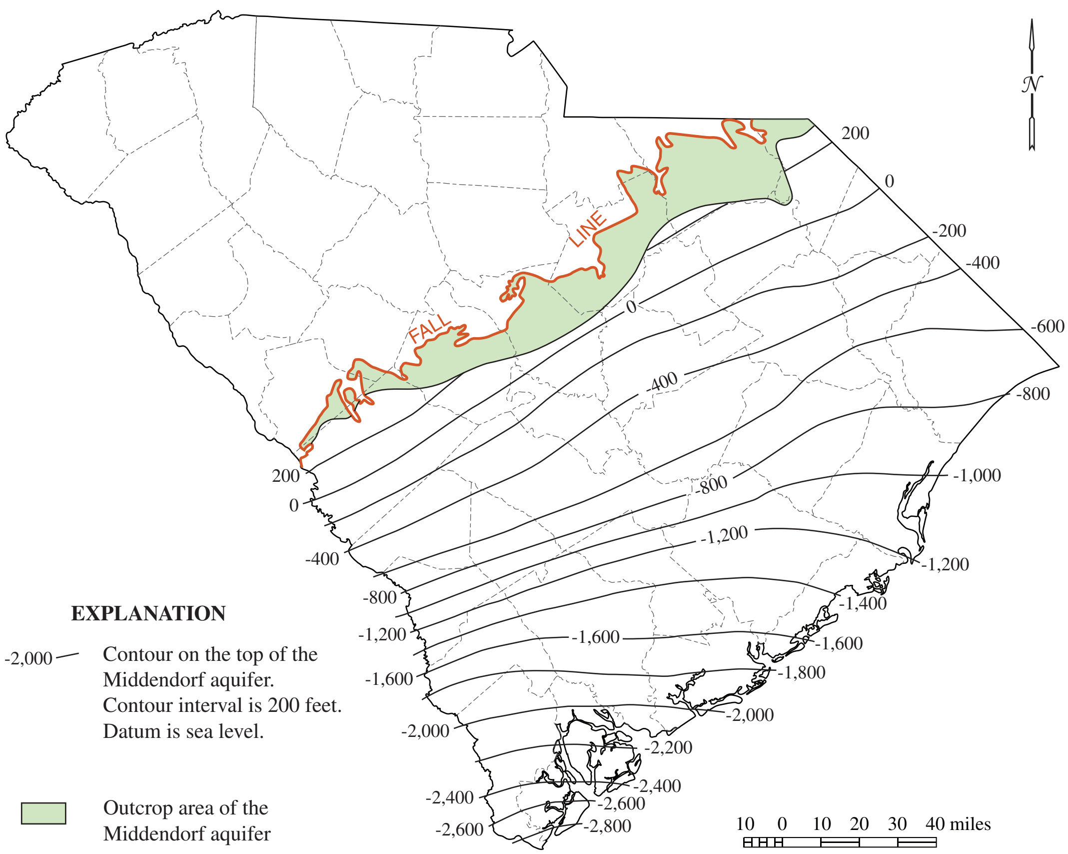


Figure 3-22. Structure contours on top of the Middendorf aquifer (Aucott and others, 1986).

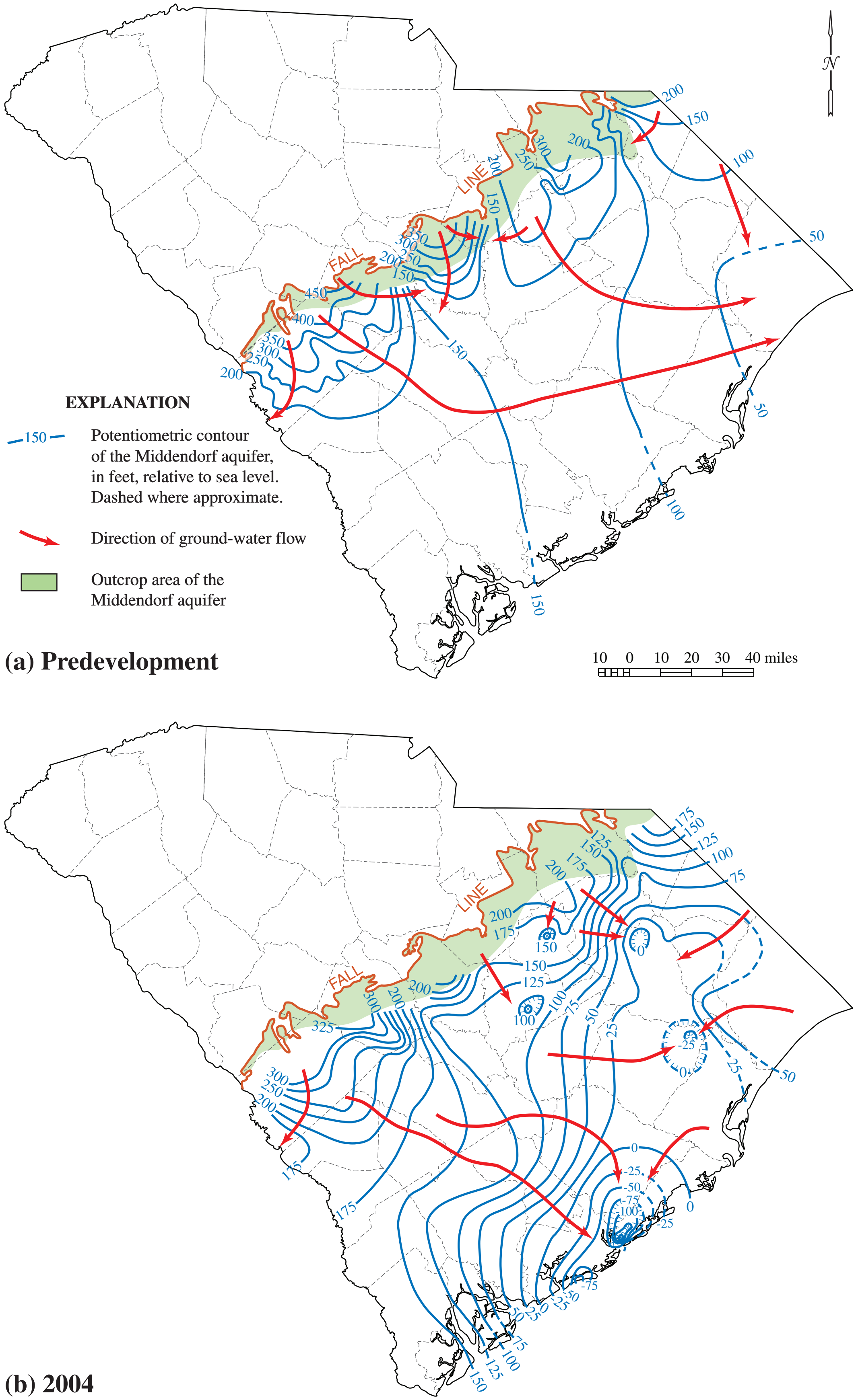


Figure 3-23. Predevelopment (a) and 2004 (b) water levels in the Middendorf aquifer. (Aucott and Speiran, 1985; Hockensmith, 2008a)

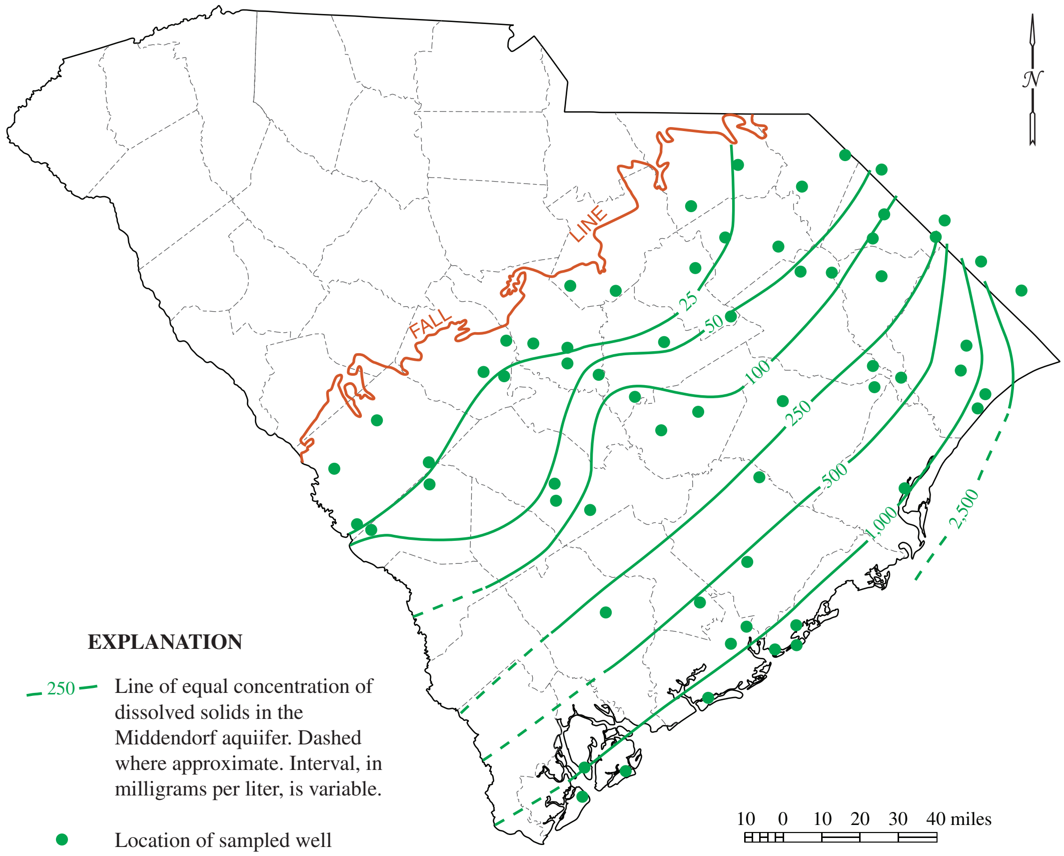


Figure 3-24. (a) Distribution of dissolved solids in the Middendorf aquifer (Speiran and Aucott, 1994).

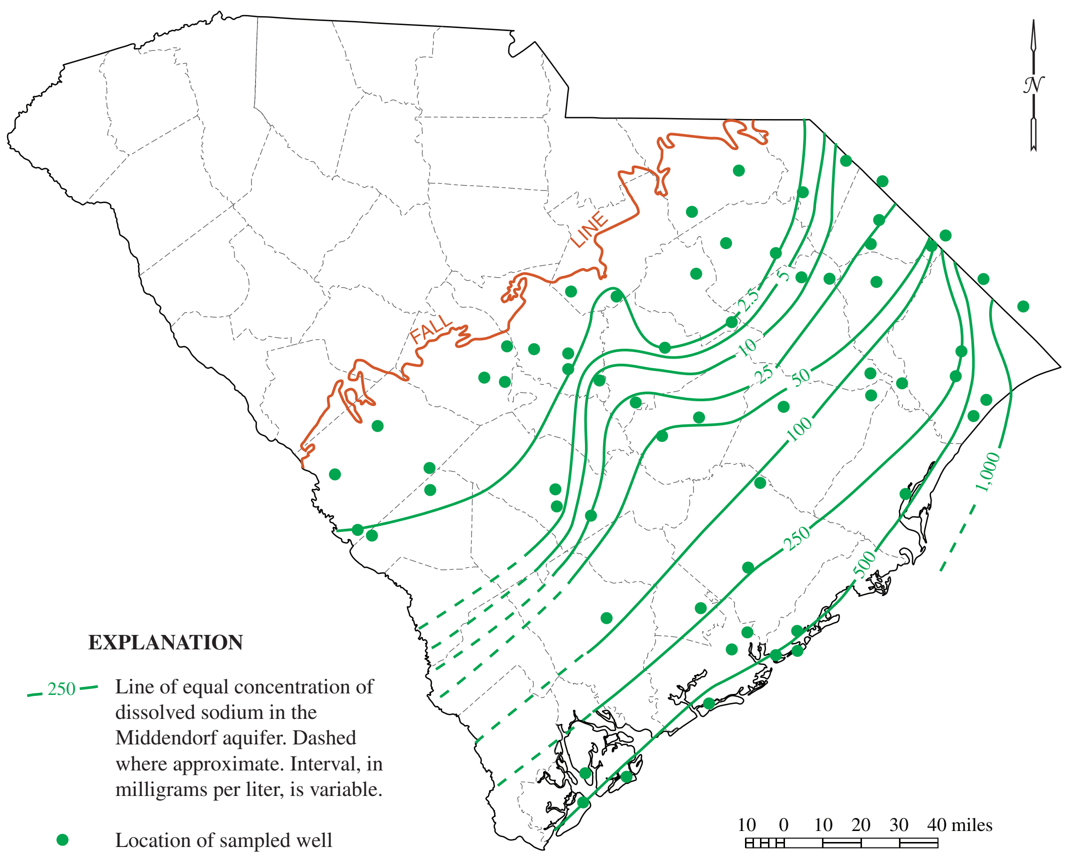


Figure 3-24. (b) Distribution of sodium in the Middendorf aquifer (Speiran and Aucott, 1994).

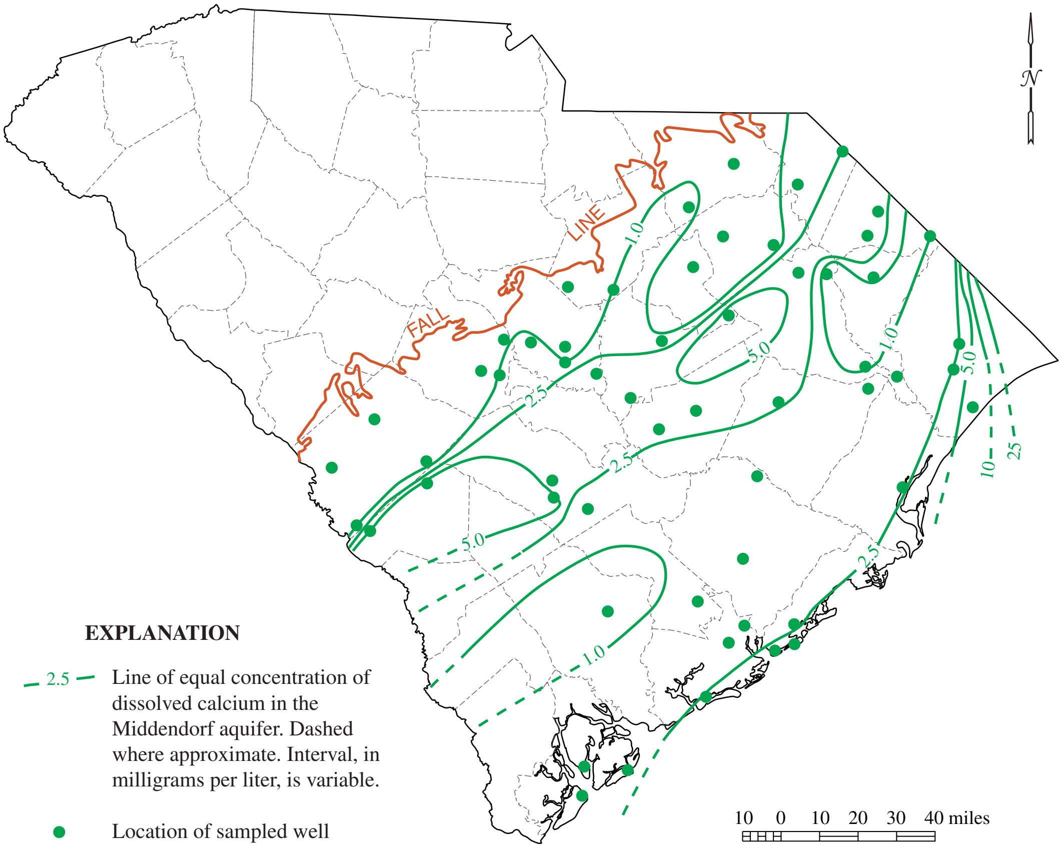


Figure 3-24. (c) Distribution of calcium in the Middendorf aquifer (Speiran and Aucott, 1994).

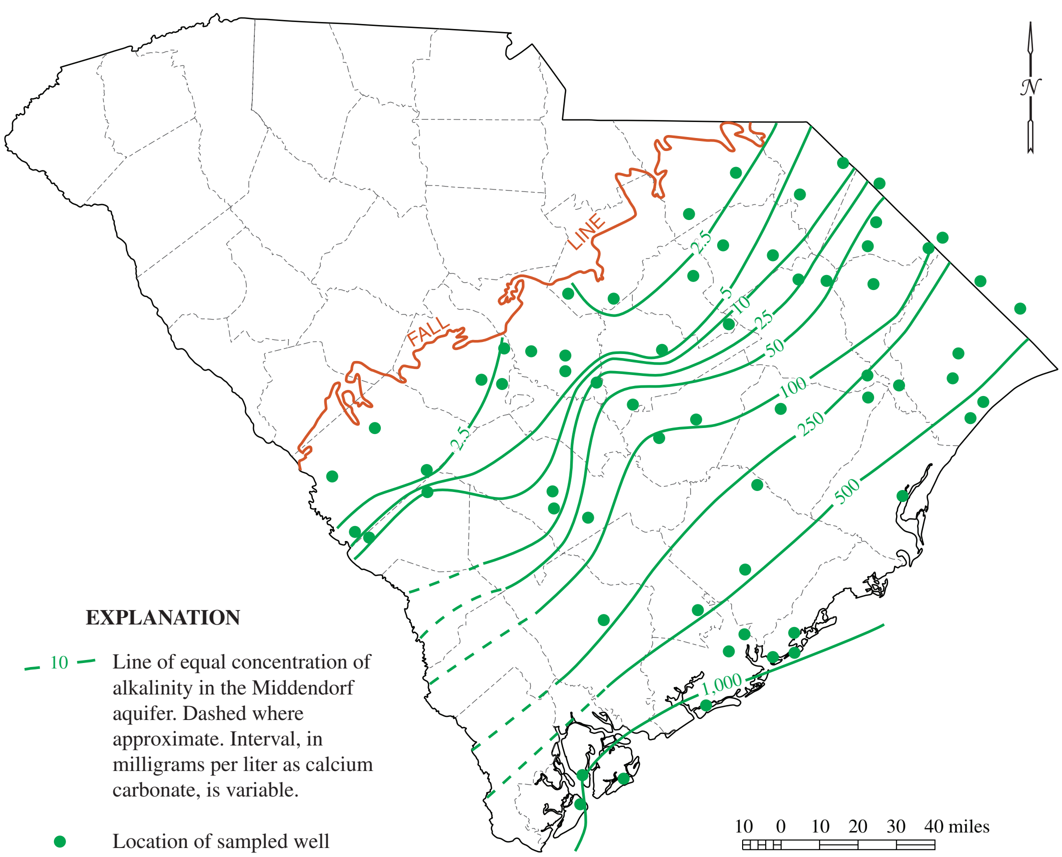


Figure 3-24. (d) Distribution of alkalinity in the Middendorf aquifer (Speiran and Aucott, 1994).

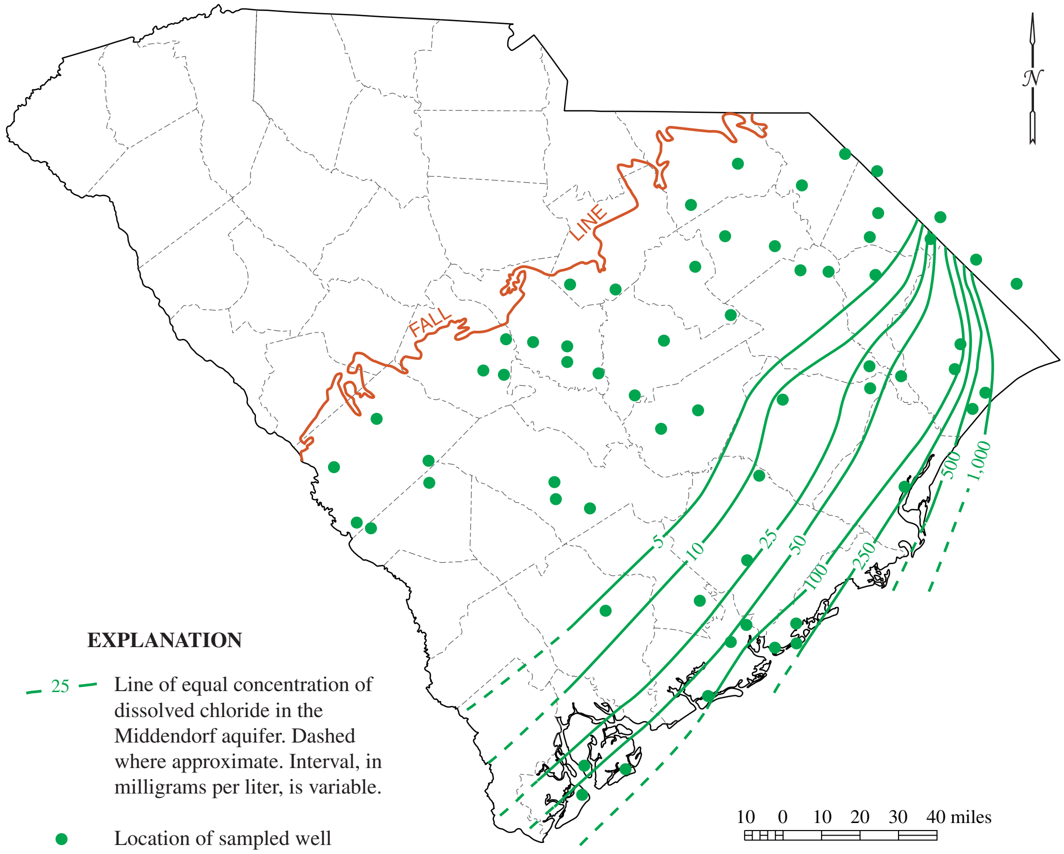


Figure 3-24. (e) Distribution of chloride in the Middendorf aquifer (Speiran and Aucott, 1994).

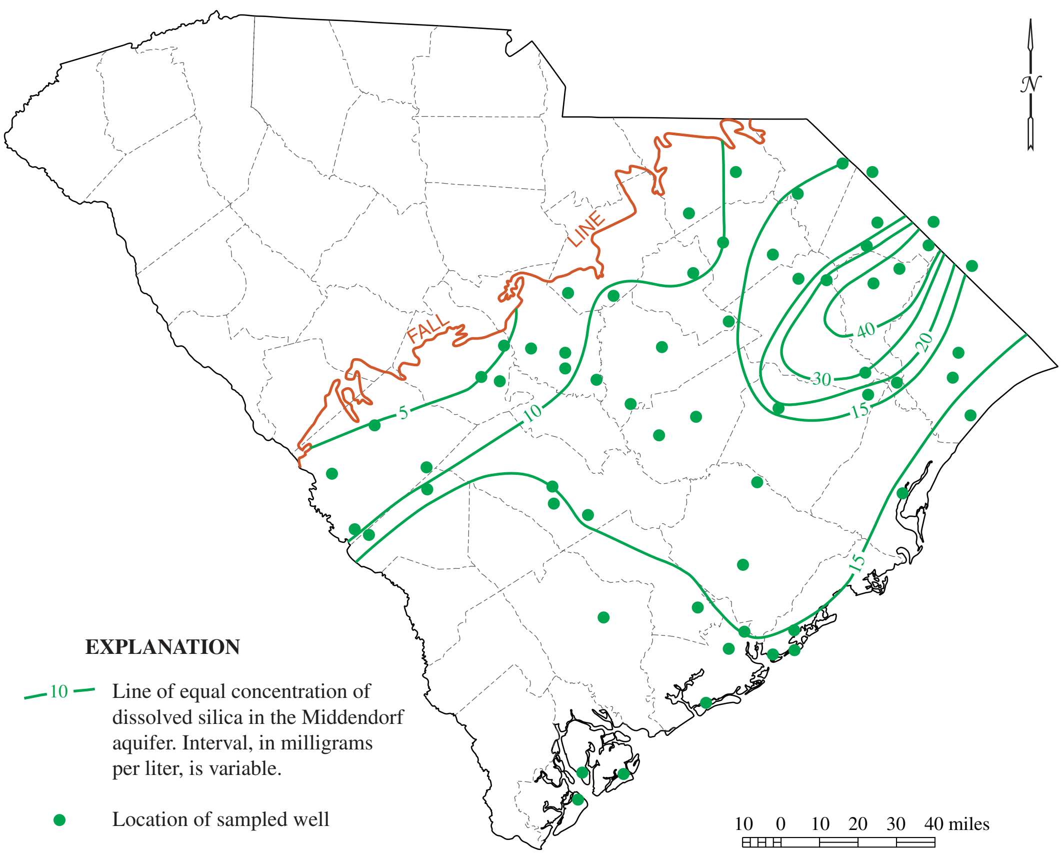


Figure 3-24. (f) Distribution of silica in the Middendorf aquifer (Speiran and Aucott, 1994).

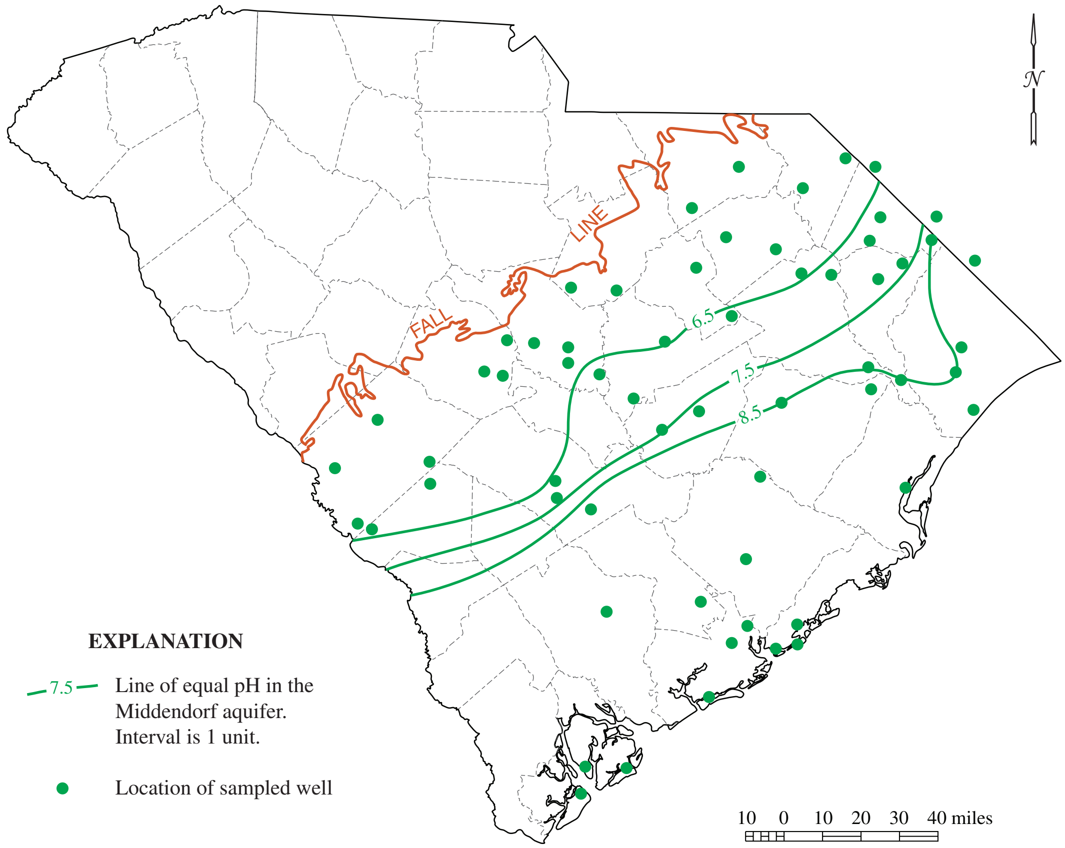


Figure 3-24. (g) Distribution of pH in the Middendorf aquifer (Speiran and Aucott, 1994).

The aquifer crops out in the eastern Coastal Plain along a narrow band extending from Lexington County to Sumter County, thence along a wider band from Sumter County to Dillon County. It dips southeastward toward the coast. The top of the aquifer is at elevation 300, -250, and -1,000 feet msl at Aiken, Little River, and Charleston, respectively. Thickness ranges from about 100 feet near Aiken to more than 400 feet at the coast. Its subcrop area and structure, contoured in feet above msl, are delineated in Figure 3-25.

The Black Creek aquifer is an important source of water supply in, and downdip from, its subcrop area. Well yields are greatest in the counties of the upper and middle Coastal Plain and are least in the coastal counties of Charleston and Beaufort. The average hydraulic conductivites are about 100 gpd/ft^2 between Berkeley and Horry Counties; are between 200 and 320 gpd/ft^2 between Richland and Marion Counties; and are between 360 and 640 gpd/ft^2 in Aiken, Allendale, and Orangeburg Counties. Where the highest possible well yields are desired, the Black Creek is screened in conjunction with the underlying Middendorf aquifer. These multiaquifer-system wells are commonly used by major industrial and public-supply systems in Sumter, Florence, Horry, and Georgetown Counties.

The greatest declines in Black Creek water levels have occurred in the eastern part of the Coastal Plain, mainly in Marion, Georgetown, and Horry Counties. The greatest drawdowns occurred along the coast of Horry County prior to the 1990's as public-supply systems increased their withdrawals to satisfy rapidly-increasing population and tourism: water levels recovered after the region's major utilities converted to surface-water sources but resumed decline with increasing golf-course irrigation. Predevelopment and recent levels are compared in Figure 3-26.

Water from the Black Creek aquifer generally is soft, alkaline, low in dissolved iron, and high in pH and dissolved solids. Total dissolved solids and sodium concentrations commonly exceed EPA's secondary water-quality standards. In the coastal counties, fluoride exceeds the recommended contaminant limits.

Ground water becomes increasingly mineralized downgradient, as in the case of the Middendorf aquifer (Figure 3-27). Concentrations of dissolved solids range from less than 25 mg/L near the outcrop to more than 2,500 mg/L at the coast. Alkalinity, sodium, and chloride range from less than 2.5 mg/L to more than 1,000 mg/L between the outcrop and the coast, and pH ranges between 4.5 and 8.5. The increase in sodium concentration across the Coastal Plain mainly is due to the natural exchange of calcium ions in the water for sodium ions in clay; however, the greatest sodium concentrations occur at the coast where saltwater is not fully flushed from the aquifer. Along the extreme northern coast and the Charleston County coast, concentrations of chloride exceed the 250-mg/L secondary standard: along the southern coast, chloride concentrations locally exceed 1,000 mg/L.

High silica concentrations are found in eastern Sumter County, Florence County, and central Marion County, where dissolved silica locally exceeds 35 mg/L. Turbid water has been reported from Black Creek wells in a belt between Horry and Hampton Counties, but the turbidity, probably caused by the aragonitic form of calcium carbonate precipitate, is uncommon, and usually is temporary. Fluoride concentrations, which are negligible near the subcrop area, increase significantly across the lower Coastal Plain, and they exceed the 4.0 mg/L secondary limit in parts of Horry, Georgetown, and Charleston Counties.

Iron concentrations typically exceed the 300-µg/L secondary drinking-water standard in a broad band across the northern upper Coastal Plain, and iron concentrations there are as great as 3,000 µg/L. Dissolved-iron concentrations greater than 300 µg/L are rare in the middle and lower Coastal Plain.

In the lower Coastal Plain, ground water is predominately a sodium bicarbonate type caused by dissolution of calcium carbonate material and subsequent exchange of sodium for calcium. The pH ranges from 8.0 to 9.2, and exceeds the 8.5 drinking-water standard in much of the area. Dissolved-solids and fluoride concentrations exceed the secondary standards (500 mg/L and 2.0 mg/L, respectively) along the coast. In most of the lower Coastal Plain, dissolved-sodium concentrations are several hundred milligrams per liter.

Tertiary Sand Aquifer. Aucott and others (1986) divided the Tertiary sand aquifer into two parts. The upper part consists of fine- to coarse-grained sand of the Barnwell Group, McBean Formation, and Congaree Formation. They are the sand-facies equivalent of the Floridan aquifer and extend from the vicinity of the Fall Line to the updip limit of the Floridan aquifer. In Allendale, Bamberg, Barnwell, and Aiken Counties, the Congaree Formation is the principal water-bearing unit, and the Barnwell Group and McBean Formation tend to be poorly productive and more significant as confining units. The SCWRC reported a median hydraulic conductivity of 35 gpd/ft^2 (about 4.7 ft^2/day) for the Congaree: individual wells completed in the unit yield up to 660 gpm, and reported specific capacities are about 10 gpm/ft.

The lower part of the Tertiary sand aquifer underlies all of the Floridan aquifer, extends westward into the middle Coastal Plain, and consists principally of the Paleocene-age Black Mingo Formation. The upper 50 to 100 feet of the

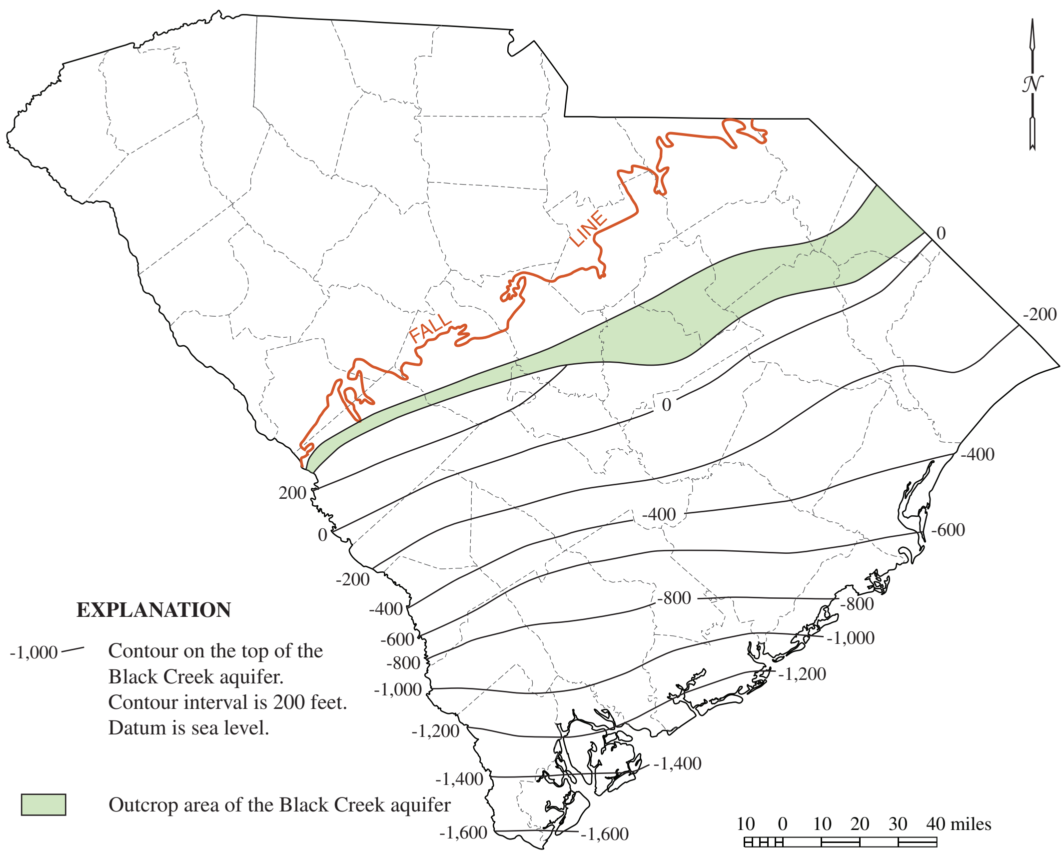


Figure 3-25. Structure contours on top of the Black Creek aquifer (Aucott and others, 1986).

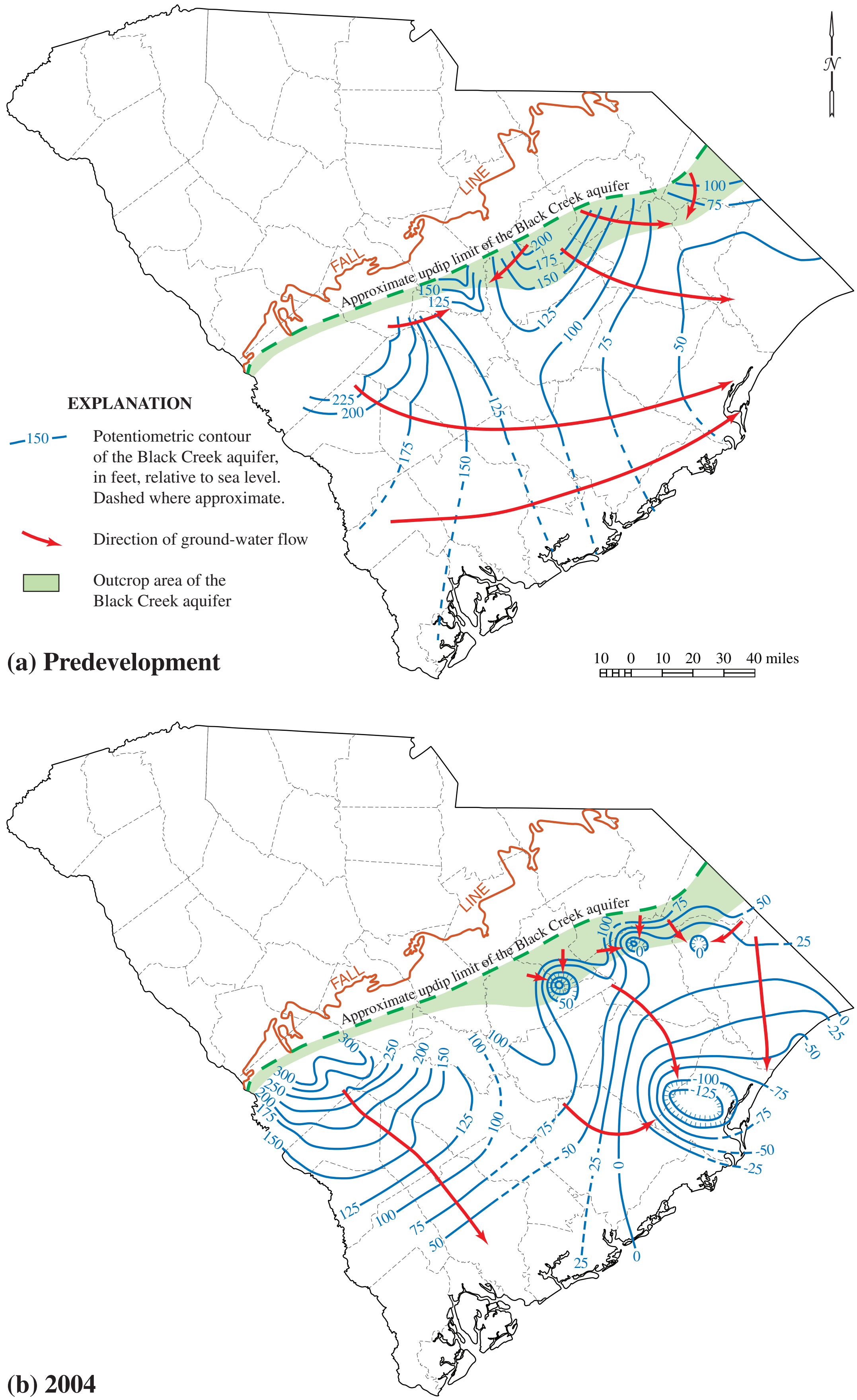


Figure 3-26. Predevelopment (a) and 2004 (b) water levels in the Black Creek aquifer (Aucott and Speiran, 1985; Hockensmith, 2008b).

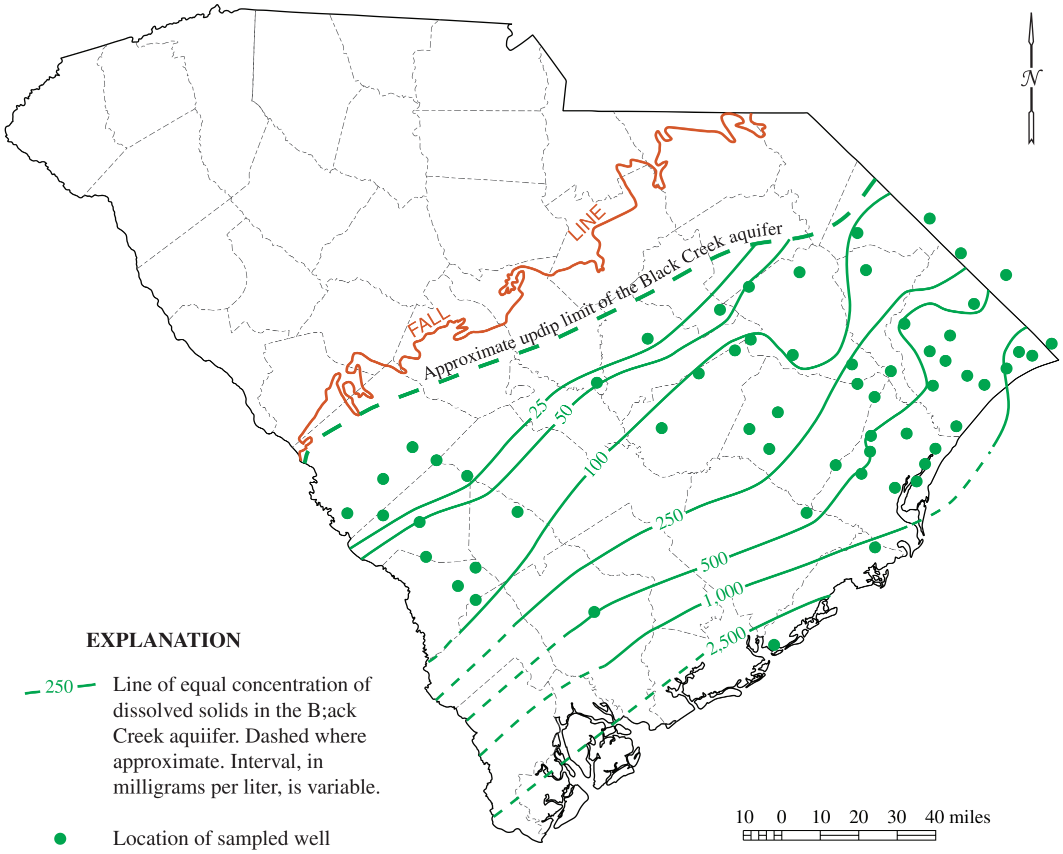


Figure 3-27. (a) Distribution of dissolved solids in the Black Creek aquifer (Speiran and Aucott, 1994).

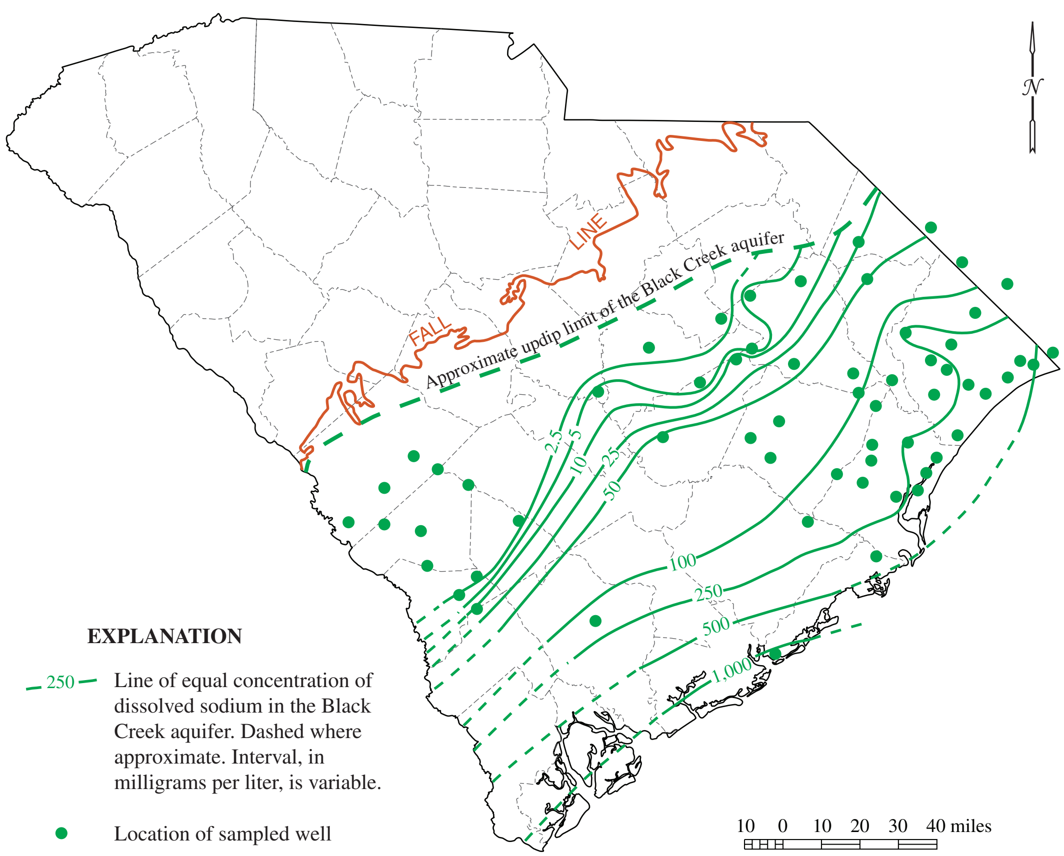


Figure 3-27. (b) Distribution of sodium in the Black Creek aquifer (Speiran and Aucott, 1994).

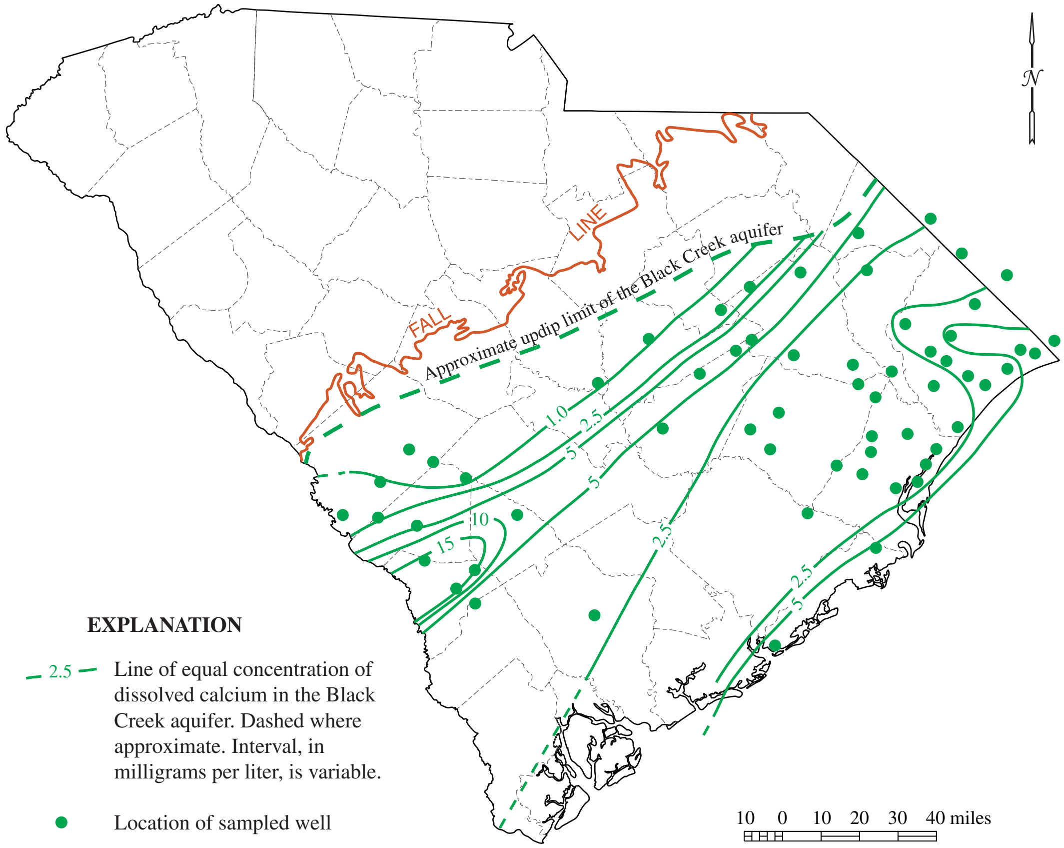


Figure 3-27. (c) Distribution of calcium in the Black Creek aquifer (Speiran and Aucott, 1994).

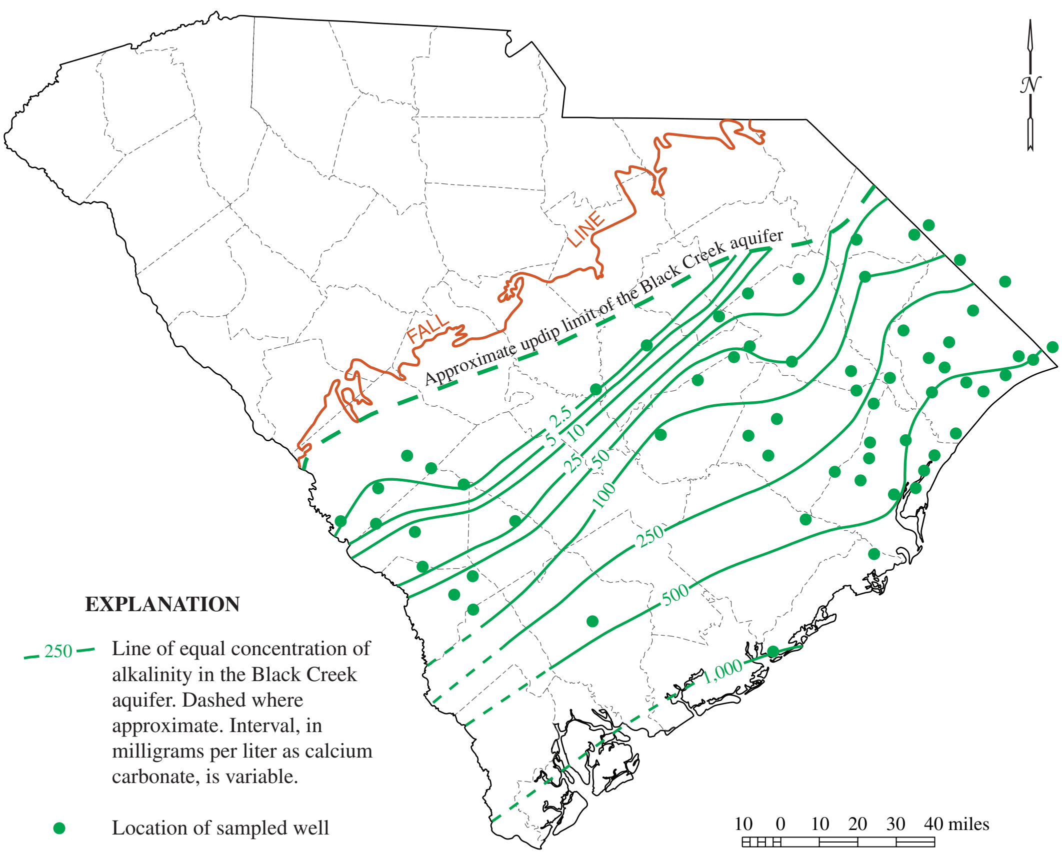


Figure 3-27. (d) Distribution of alkalinity in the Black Creek aquifer (Speiran and Aucott, 1994).

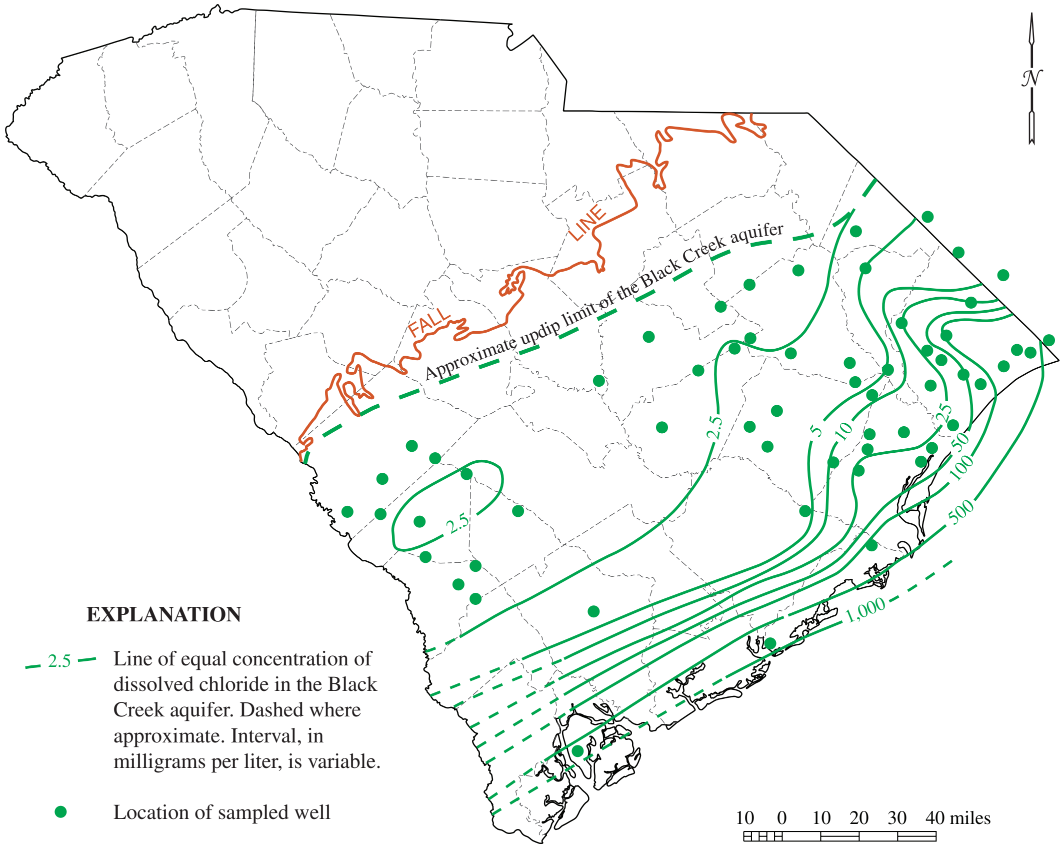


Figure 3-27. (e) Distribution of chloride in the Black Creek aquifer (Speiran and Aucott, 1994).

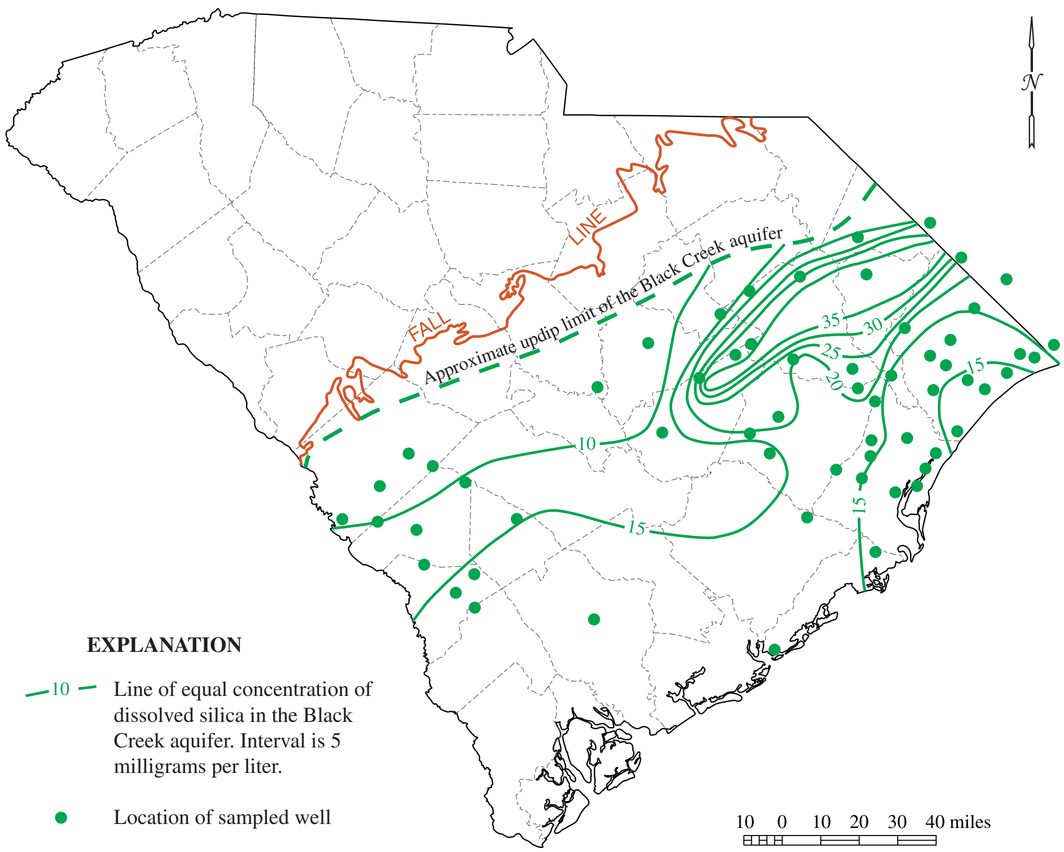


Figure 3-27. (f) Distribution of silica in the Black Creek aquifer (Speiran and Aucott, 1994).

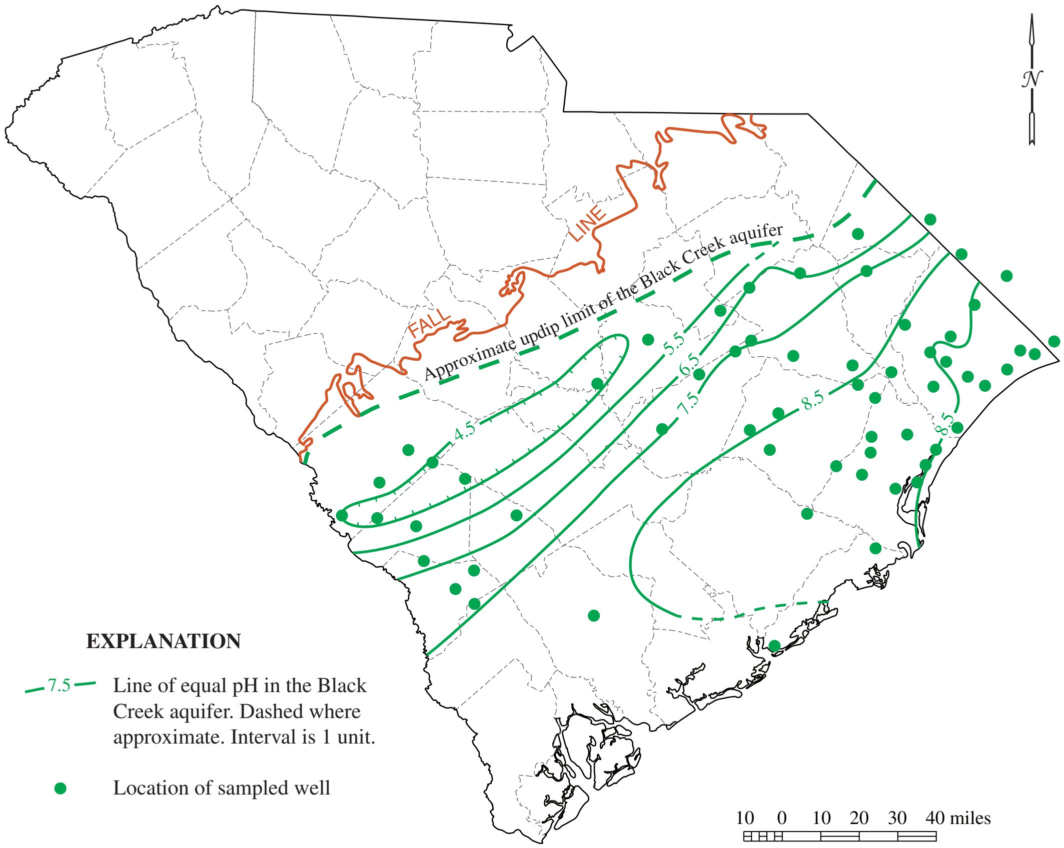


Figure 3-27. (g) Distribution of pH in the Black Creek aquifer (Speiran and Aucott, 1994).

formation consists of interbedded fine- to medium-grained sand and silty sand, carbonaceous and silty clay, sandstone, and sandy limestone. The section is the only significant water-bearing unit in the Tertiary sand aquifer east of its subcrop area. In conjunction with the overlying Floridan aquifer, this unit is widely used in Berkeley, Charleston, Dorchester, Colleton, and eastern Hampton Counties. Open-hole Floridan/Tertiary-sand wells there commonly yield several hundred gallons per minute. Wells open only to the Black Mingo are rare and typically produce less than 300 gpm. Because its transmissivity is low, the formation mainly is used where the overlying Floridan aquifer is poorly productive.

There is wide variation in the water quality of the Tertiary-sand aquifer—variation that stems from the many geologic formations encompassed and the consequent diversity of mineralogy and depositional environment. Within its outcrop region it receives recharge directly from precipitation: the water has dissolved-solids concentrations less than 100 mg/L and is very soft, pH's typically are less than 6.5, and iron concentrations commonly are greater than 300 μg/L. In these areas, the combination of low solids and low pH is corrosive to steel screen and casing.

An increase in calcium carbonate content and the interfingering of the Tertiary sand aquifer with Floridan aquifer limestone alters the water chemistry across the middle Coastal Plain, beginning in lower Barnwell County. The pH generally increases eastward where calcium carbonate has dissolved, and hard water and dissolved solids concentrations above 250 mg/L become increasingly common. Farther down gradient, between the Santee and Savannah Rivers, Tertiary sand aquifers yield sodium bicarbonate type water with pH's near 8.0, dissolved solids above 300 mg/L, and hardness varying from soft to moderately hard. Characteristic of water in the coastal region is low iron concentration and dissolved-silica concentrations between 25 and 50 mg/L; fluoride concentrations of 2.0 mg/L to 5.0 mg/L are reported in the area south of Charleston. Saltwater encroachment also is present south of Charleston, and chloride concentrations there exceed 1,000 mg/L.

Natural radioactivity in excess of acceptable drinking-water standards occurs in isolated areas of Lexington, Orangeburg, and Aiken Counties. The problem has caused some public water suppliers to consider advanced treatment technologies and alternate sources.

Floridan Aquifer. The Floridan aquifer in South Carolina is the northernmost part of one of the most extensive and prolific ground-water sources in North America. It primarily consists of the middle-Eocene Santee Limestone and, in southern and southwestern South Carolina, the upper-Eocene Ocala Limestone. It also encompasses, and is confined by, the Oligocene Cooper Formation in Charleston, Berkeley, Dorchester, and Colleton Counties. The top of the aquifer occurs within 100 feet of land surface, except in southernmost Beaufort and Jasper Counties. Typically, more than 80 percent of the Floridan's thickness acts as confining material owing to the widespread occurrence of impure clayey to sandy limestone and of limestone having interstitial-calcite precipitate; however, sections of clean, permeable, bioclastic limestone are found throughout the Floridan's range of occurrence. These permeable sections almost everywhere yield adequate water for domestic use, small public-supply systems, and light industry, and, locally, they can yield 1 to 3 million gallons per day to individual wells.

The Floridan aquifer subcrops along the Santee River and Wateree River valleys and from eastern Orangeburg County through western Allendale County. The limestone there commonly exceeds 95-percent calcium carbonate, has enlarged secondary porosity owing to dissolution, and locally exhibits cavern and sinkhole formation. The surfaces of the Santee Limestone and Ocala Limestone and the permeable units associated with them dip gently southeastward from 100 feet msl to -200 feet msl. The low-permeability, arenaceous limestone of the Oligocene Cooper Formation overlies the Santee in most of Charleston, Berkeley, and Dorchester Counties, grades into the Ocala Limestone to the southeast, and thickens to more than 250 feet in southern Charleston County. Owing to this geologic complexity, four important and distinct permeable zones occur in the Floridan aquifer.

Limestone in the subcrop area is a major avenue for recharge. Mildly acidic meteoric (from precipitation) water has circulated through the pure limestone at shallow depth, secondary porosity is common and well developed, hydraulic conductivity is high, and water-table to poorly-confined conditions predominate. The limestone downdip of the subcrop region becomes increasingly arenaceous (sandy) and confining, and ground water is obtained from two typically thin and well-separated permeable zones.

The northern zone, underlying Charleston, Berkeley, Dorchester, Colleton, and eastern Hampton Counties, occurs near the base of the Santee Limestone at 50 to -500 feet msl: it typically is 5 to 20 feet thick, is moderately permeable, and, in conjunction with underlying sand of the Tertiary sand aquifer, yields 100 to 400 gpm to individual wells. The southern zone, underlying Jasper County, western Hampton County, and southern Beaufort County, occurs at the top of the Santee Limestone at 0 to -500 feet msl: it typically is 20 to 40 feet thick, has transmissivities as great as 200,000 gpd/ft, and can provide up to 1,000 gpm to individual wells. The geographic distribution of the southern zone roughly coincides with the upper permeable zone of the Ocala Limestone.

The upper permeable zone is the principal source of ground-water supply in Beaufort, Jasper, Hampton, and Allendale Counties. It occurs within the upper 100 feet of the Ocala Limestone and is the most productive aquifer in South Carolina. The top of the unit ranges from -20 feet msl at Beaufort to -250 feet msl near Savannah, Ga. It is more than 100 feet thick in southern Jasper County, has hydraulic conductivities of 1,500 to 3,000 gpd/ft^2, and has transmissivities up to 450,000 gpd/ft. Yields as great as 3,000 gpm are reported, and those exceeding 500 gpm are common.

Floridan aquifer water levels have declined throughout the aquifer's area of occurrence, but the declines are most pronounced along the coast. Levels in the Santee Limestone section (lower Floridan aquifer) are -10 to -50 feet msl in the area of Summerville, Charleston, and Edisto Beach and are about -100 feet msl at Savannah, Ga. Predevelopment levels are not known north of Beaufort, but they probably were 10 to 20 feet above sea level across coastal Charleston and Colleton Counties.

Water levels in the Ocala Limestone section (upper Floridan aquifer) are below sea level everywhere south of Port Royal Sound and have declined to more than -100 feet msl at Savannah, Ga.

Predevelopment levels in the upper Floridan aquifer in Beaufort and Jasper Counties and 2004 levels in the lower and upper Floridan across southern South Carolina are shown in Figure 3-28.

The Floridan's water chemistry is typically the calcium bicarbonate type produced by the dissolution of limestone. The water is moderately hard to very hard, somewhat alkaline, and commonly has dissolved solids concentrations less than 500 mg/L. High iron concentrations are common in permeable zones that are shallow, poorly confined, and recharged by the overlying water table—localities that include the principal subcrop area between Charleston County and Allendale County and a structural uplift in central Beaufort County. Iron concentrations typically are less than 300 µg/L elsewhere in the aquifer.

Water chemistry that is atypical of limestone aquifers occurs mainly in the base of the aquifer between Charleston and southern Hampton Counties and in areas where saltwater encroachment occurs. The lowermost aquifers southwest of Charleston and Berkeley Counties contain water similar to that of the underlying Tertiary sand aquifer—predominantly a sodium bicarbonate water with dissolved silica concentrations up to 50 mg/L and fluoride concentrations up to about 4.0 mg/L.

Saltwater encroaches the Floridan in several areas at and southwest of Charleston. Chloride concentrations above 500 mg/L occur at the base of the aquifer beneath the barrier islands of Charleston County, and concentrations of 500 to 1,000 mg/L are present at Edisto Beach. Concentrations of several thousand milligrams per liter occur in the 500-foot deep middle permeable unit beneath Port Royal Sound, although water in the unit freshens to the south. The most significant contamination occurs at the north end of Hilton Head Island and adjacent part of Beaufort County. Ground water containing more than 10,000 mg/L chloride, or more than 50 percent seawater, now flows southwestward toward pumping areas at Bluffton and Hilton Head Island and at Savannah, Ga. Saltwater-intrusion rates of more than 200 feet per year occur there.

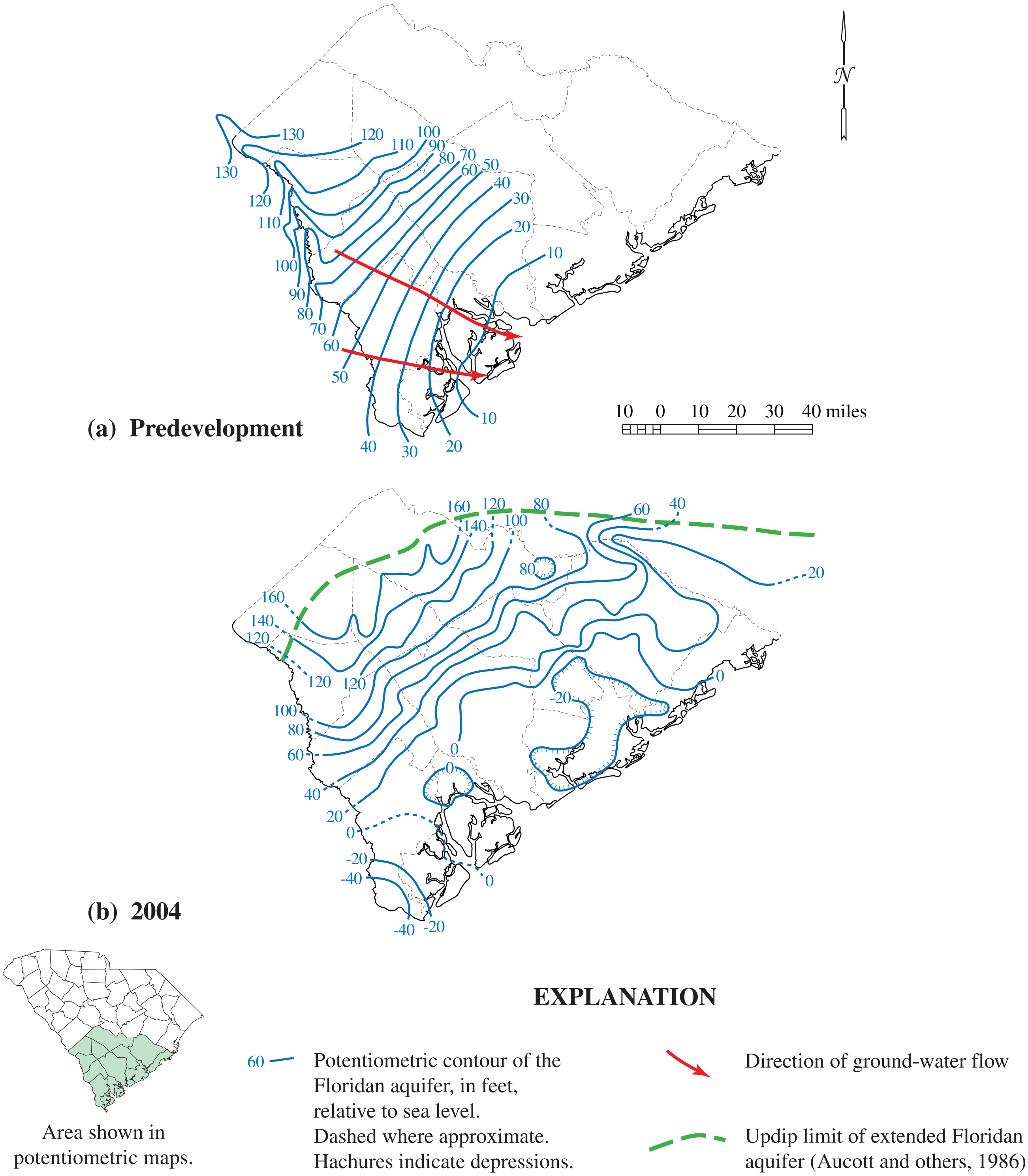


Figure 3-28. Predevelopment (a) and 2004 (b) water levels in the Floridan aquifer (Aucott and Speiran, 1985; Hockensmith, 2009).

<u>Shallow Aquifer.</u> "Shallow aquifer" or "surficial aquifer" is a term of convenience applied to the complex of materials between land surface and the major aquifers of the Blue Ridge, Piedmont, and Coastal Plain. Northwest of the Fall Line, the aquifer comprises saprolite and scattered alluvial deposits: there, the lithologic and hydrologic contrast between bedrock and overlying formations simplifies distinction of the shallow aquifer.

Blue Ridge and Piedmont—The shallow aquifer in the Blue Ridge and Piedmont consists of porous materials overlying the fractured crystalline rock. Saprolite, the residual material from the weathering of bedrock, forms the most geographically extensive shallow unit above the Fall Line. The saprolite typically is 35 to 100 feet thick but thin to absent in some mountainous areas and well over 100 feet in some lower areas. Saprolites are commonly clay rich, but clay content may be low where the parent rock is mainly quartz. It is a source of water to bored wells—augered or dug wells that must be constructed with large diameters owing to low permeability and the consequent need to store large volumes of water. Such wells may yield ground water from the clay-rich saprolite; from relict bedrock fractures and intrusive rock; and from the transition zone, a zone of fractured but relatively unweathered rock debris above the unaltered parent rock. Sustained yields typically are no more than a few gallons per minute; however, the saprolite is the main source of ground-water storage in the region and the main source of ground water in the underlying crystalline-rock aquifer. Where the saprolite is thick, water levels usually respond slowly to precipitation because the low permeability of clay inhibits recharge. Water levels also respond slowly to drought because clay will store large volumes of water and release it slowly.

Shallow aquifers above the Fall Line also include modern and relict alluvial deposits. These alluvial aquifers commonly are unconfined, widely dispersed, and small in extent. Because of the energy of their source streams, Blue Ridge and Piedmont alluvial aquifers tend to be coarser but less uniform than their Coastal Plain counterparts. Consequently, well yields can vary widely, even within distances of a few hundred feet.

Coastal Plain—The shallow aquifer in the Coastal Plain encompasses wide geologic variability. It includes rocks of the principal Cretaceous and Tertiary formations, where water-table conditions occur in their outcrop areas, and the thinner and younger Miocene- to Recent-age rocks. Unconfined conditions, where the surface of the water table is subject only to atmospheric pressure, predominate. Flow direction and flow rate are mainly controlled by topography: the water-table surface subtly imitates that of the land, and flow directions generally are from stream interfluves toward creeks and rivers. The thickness of shallow Coastal Plain aquifers typically are a few tens of feet or less, and their material generally fines coastward from the Fall Line and southwestward into the Georgia Embayment. Consequently, transmissivities generally are less than 3,000 gpd/ft.

Well depths range from about 20 to 100 feet, and well yields are limited by the small amount of drawdown available. Yields of 5 to 20 gpm are the norm, although 100 to 250 gpm are reported from a few upper Coastal Plain wells where well-sorted sand and gravel alluvium are present and hydraulically connected to streams. The shallow aquifer is widely used for domestic and light commercial purposes, and ponds open to shallow aquifers are sources of water for golf course and agricultural irrigation.

Shallow wells typically produce water of good quality, although iron concentrations in excess of the 300 μg/L secondary standard are ubiquitous. Where shell material is absent from the aquifer, as in much of the upper and middle Coastal Plain, shallow water is a soft, acidic, sodium chloride type with total dissolved solids concentrations less than 100 mg/L. Where fossil-shell material is abundant, as in many areas near the coast, hard, alkaline, calcium bicarbonate water is present, and total dissolved solids concentrations of 200 to 300 mg/L occur. The odor of hydrogen sulfide also is common in the lower Coastal Plain, particularly in the sea-island region, and saltwater is present in shallow aquifers in areas near tidal water bodies. Water-quality problems in shallow aquifers are, in the main, the result of man's activities, and, because there is little separation between shallow water and land surface, the shallow aquifer is readily affected by land-use practices.

Manmade Ground-Water Problems

The quantity of water affected by manmade ground-water problems is small relative to the volume of water available to, and used by, South Carolinians. There are, nonetheless, widely scattered, manmade incidents that make ground water unsuitable for our consumption and that restrict the quantity available for our use. The introduction of chemical compounds into a shallow aquifer is the most common problem, but the extent of chemical contamination usually is confined to a few acres. Problems arising from pumping and subsequent water-level declines are less common, but their impacts extend over many square miles.

DHEC began its first Ground-water Contamination Inventory (GCI) of 60 releases in 1980. The number of recorded sites increased to more than 4,100 by 2000 (Figure 3-29), mainly owing to increased effort, Federal funding, and passage of the UST (Underground Storage Tank) Regulations. About 85 percent of the cases are the result of petroleum products leaked from commercial storage tanks, but petroleum-leak sites are more prevalent than indicated by the GCI. Domestic oil-furnace use was common through the 1950's, and many fuel-oil tanks remain buried and corroding and are neither inventoried nor regulated. Other contaminants are derived from solid-waste disposal sites that leach metallic salts and nitrogen and from septic tanks, sewage lagoons, and animal feedlots that release pathogens and nitrogen. Radionuclides are identified in aquifers beneath the Savannah River Site. The distribution of contamination sites in the 2008 GCI is shown in Figure 3-30.

Most of the contaminants identified in the GCI occur in the upper 50 feet of the hydrostratigraphic column, and the potential for deeper and farther-spread contamination would remain if sites were not remediated. The potential for further dispersal is particularly acute in the Piedmont and Blue Ridge, where a contaminant plume might enter bedrock fractures that rapidly conduct ground water away from a site. Contamination also is caused by improper well construction. The most typical well-construction failures are poorly sealed wellheads and faulty grout emplacement around well casings. Either failure can result in surface water entering the well bore and the consequent introduction of fecal-coliform bacteria to drinking-water supplies. Contaminants from septic systems, feed lots, chemical handling areas, and other sources also may enter improperly grouted wells through the subsurface. Contamination within well bores can occur where multiple well screens interconnect aquifers of differing pressure; saltwater contamination can occur in coastal areas where deep, high-pressure brackish-water zones are connected with overlying freshwater zones.

Pumping-related problems occur in the form of land-surface collapse, well interference, and saltwater intrusion. Both sudden and gradual land collapses are documented in Horry, Georgetown, Berkeley, Dorchester, and Orangeburg Counties where limestone deposits were dewatered for mining. Sinkholes occurred locally as pore-water pressure declined in the overburden or fluctuated to cause the spalling of overburden into limestone cavities. Sinkhole diameters usually range from a few feet to tens of feet and are about equal to the overburden thickness.

Well interference—water-level decline caused by pumping of neighboring wells—can occur everywhere. Complaints of well interference are more numerous during droughts, but a well disabled by drought- and pumping-induced water-level declines can be restored if its design permits a deeper pump setting. The main impact of interference is a nominal increase in energy consumption as water must be lifted greater distances to the wellhead.

The most severe interference cases are found in Cretaceous aquifer wells in Charleston County. The growth in ground-water use and potential for interference were not anticipated when designing pump-casing lengths for early wells. Where pump intakes can be lowered no farther owing to casing design, each additional foot of interference reduces a well's potential yield by 10,000 to 20,000 gallons per day. Pump engineering presents another problem where the demand for additional water, the need for maximum available drawdown, and continued static-level decline combine—at some point, increasing horsepower and extending column length are no longer feasible.

Pumping-induced saltwater intrusion occurs along the South Carolina coast, gradually reducing the amount of freshwater available in some of the State's principal artesian aquifers (see the *Special Topics* chapter). Pumping from the Black Creek aquifer around Myrtle Beach and the Middendorf and Floridan aquifers near Charleston captures ancient brackish water and draws it toward the centers of pumping. Both modern and ancient seawater are captured by pumping from the Floridan aquifer at Hilton Head Island and Savannah, Ga., causing intrusion at rates of more than 200 feet per year. Lateral and upward brackish-water intrusions probably are occurring in the Floridan aquifer at Edisto Beach.

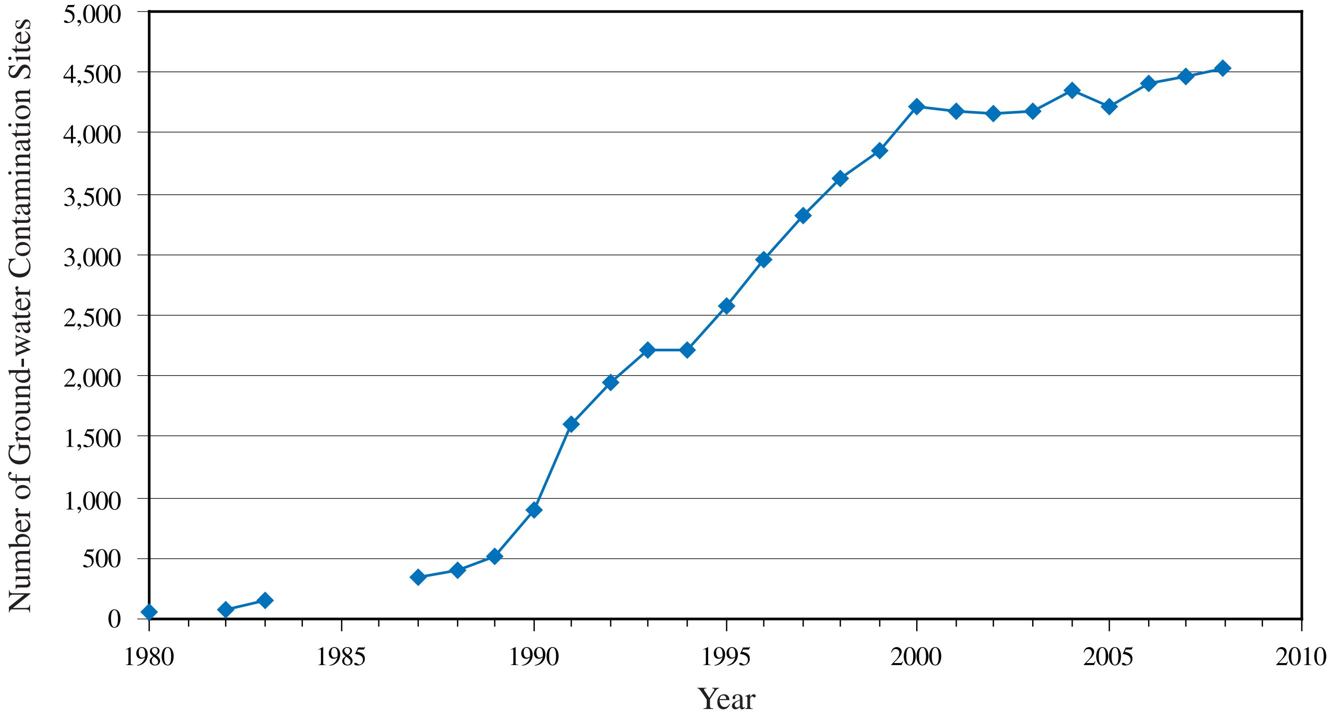


Figure 3-29. Number of known ground-water contamination sites in South Carolina, 1980-2008 (DHEC, 2008).

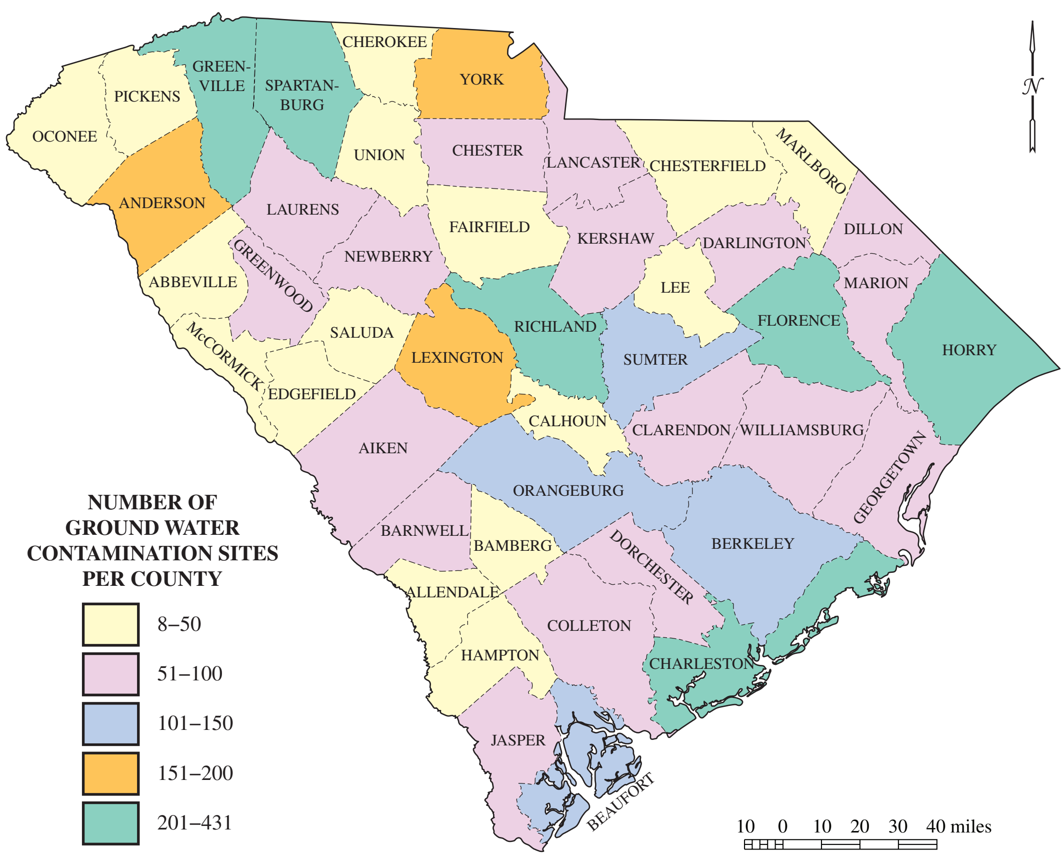


Figure 3-30. Distribution of ground-water contamination sites, 2008 (DHEC, 2008).

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 ground-water 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. Ground-water 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**

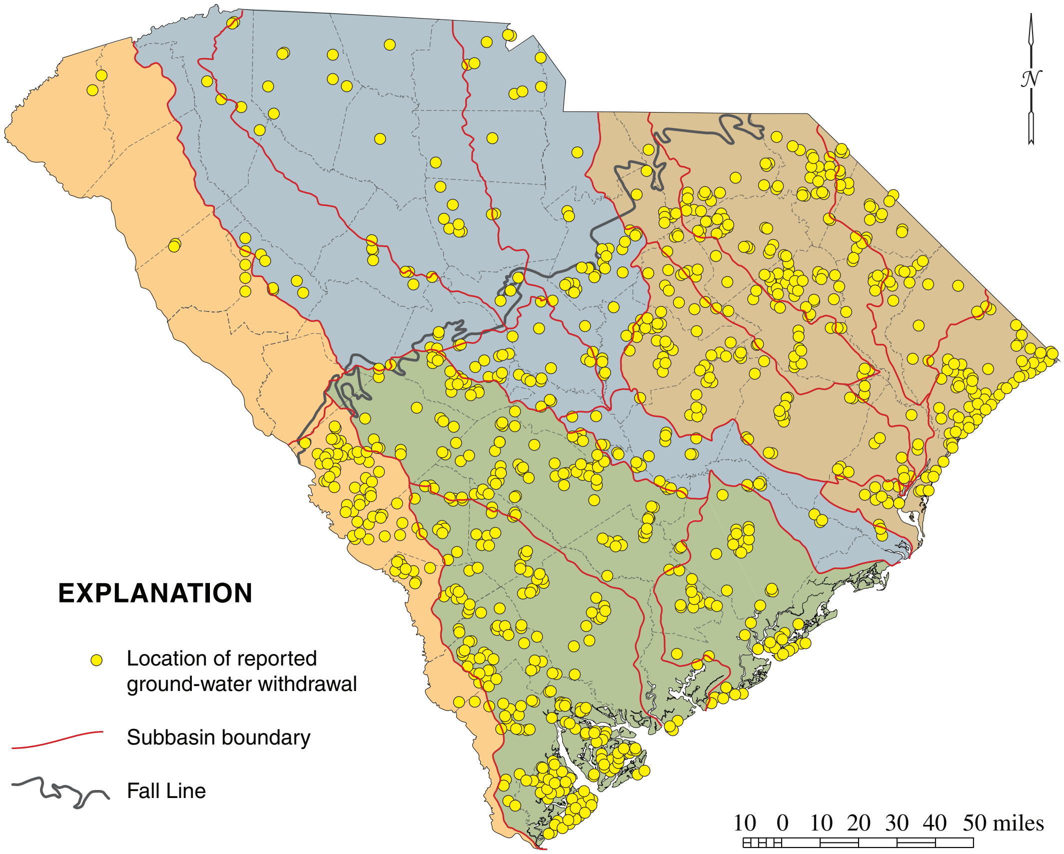


Figure 4-1. Location of reported ground-water withdrawals in the year 2006.

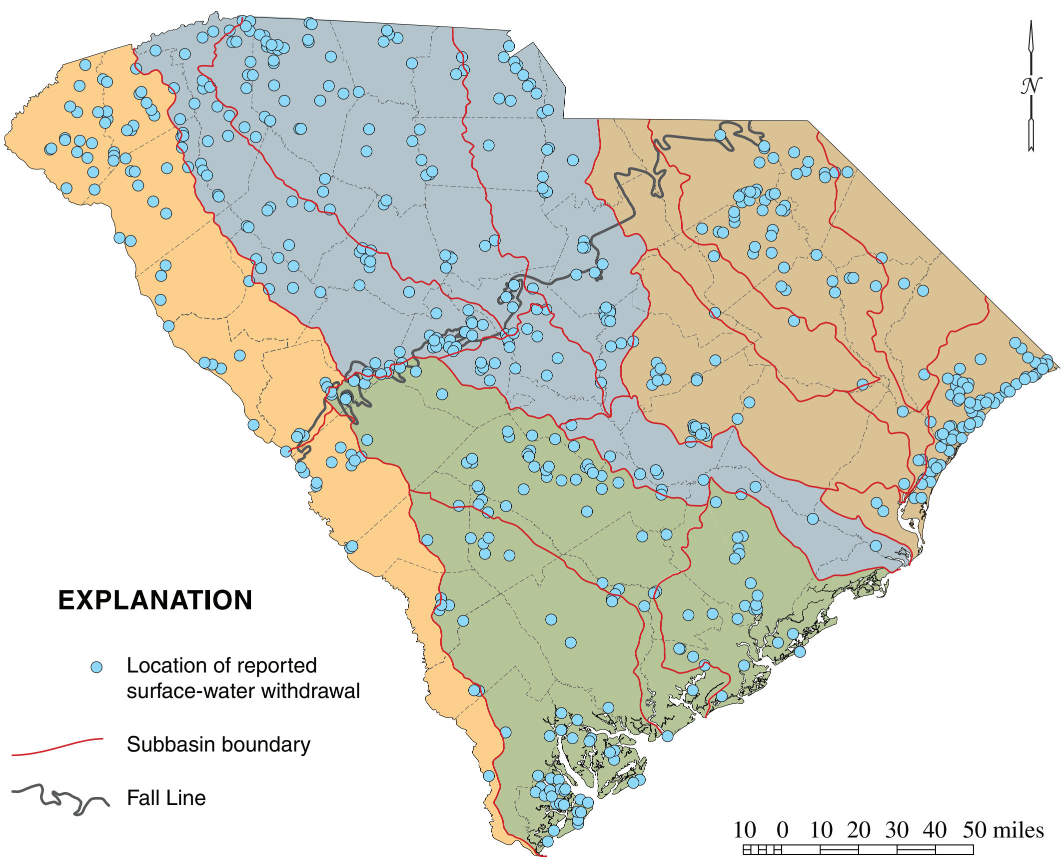


Figure 4-2. Location of reported surface-water withdrawals in the year 2006.

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**	

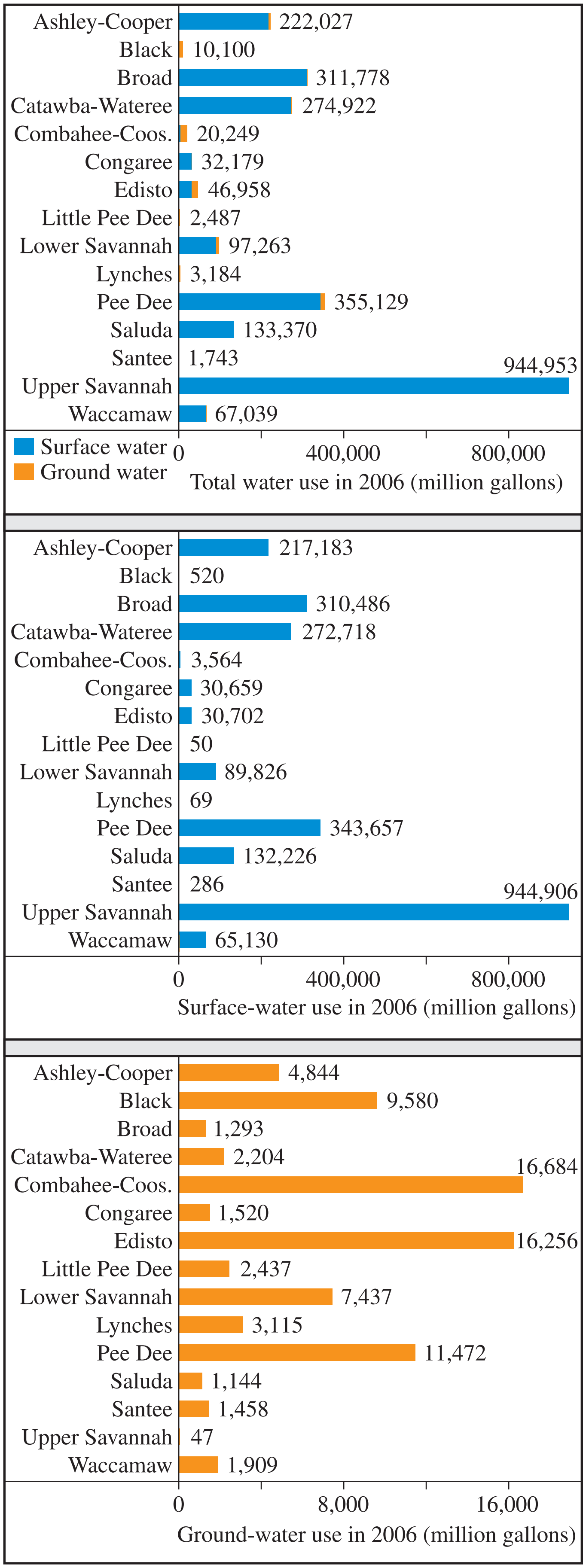


Figure 4-3. Offstream water use in 2006, by subbasin (modified from Butler, 2007).

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.

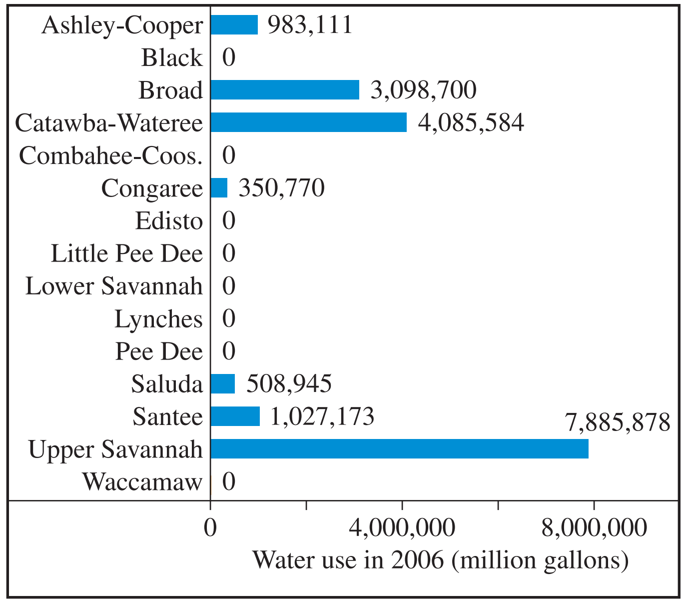
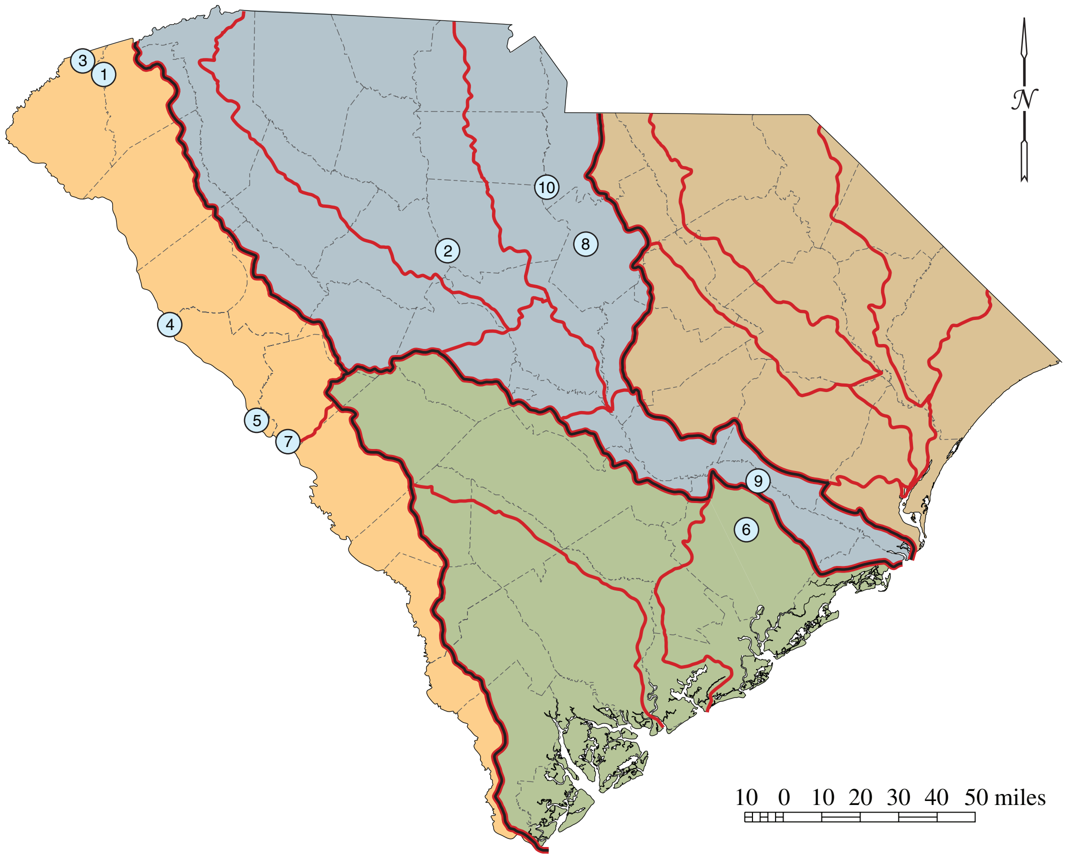


Figure 4-4. Hydroelectric water use in 2006, by subbasin.

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.

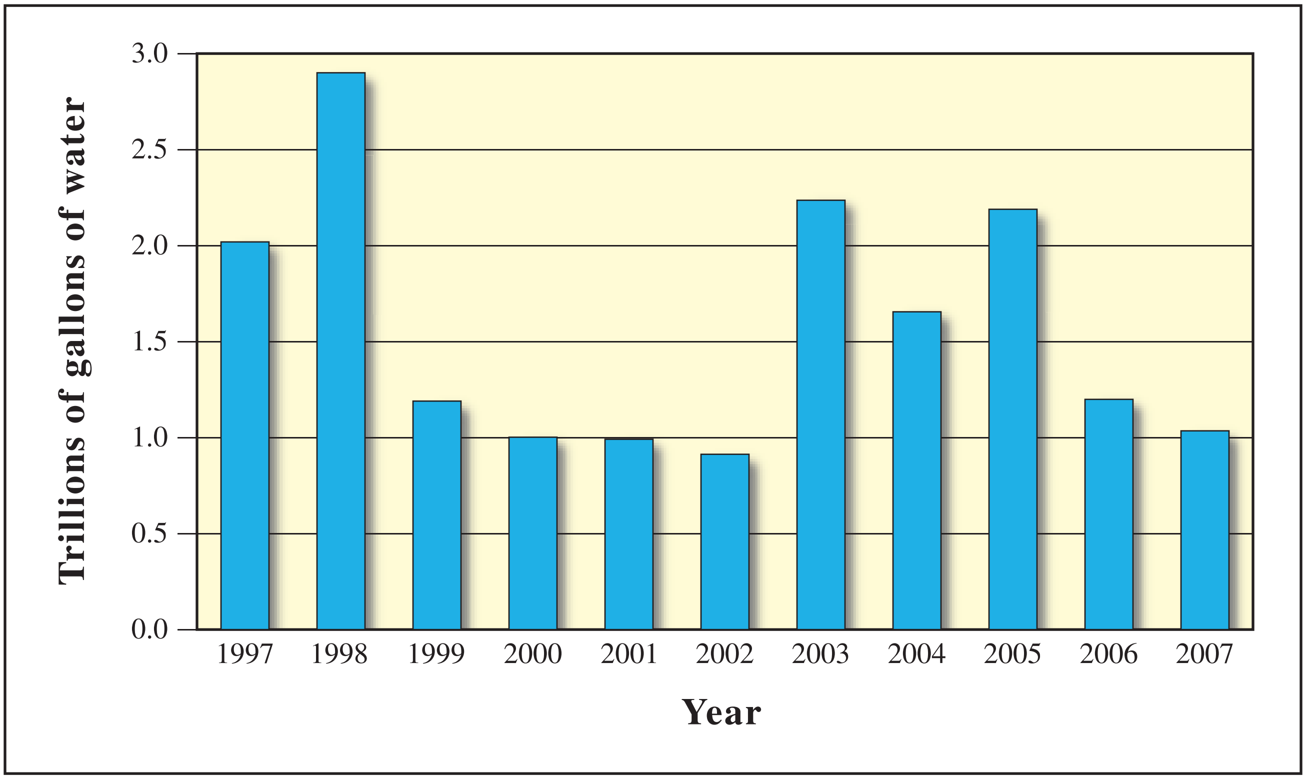


Figure 4-6. Total annual volume of water released from Lake Thurmond, 1997–2007.

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

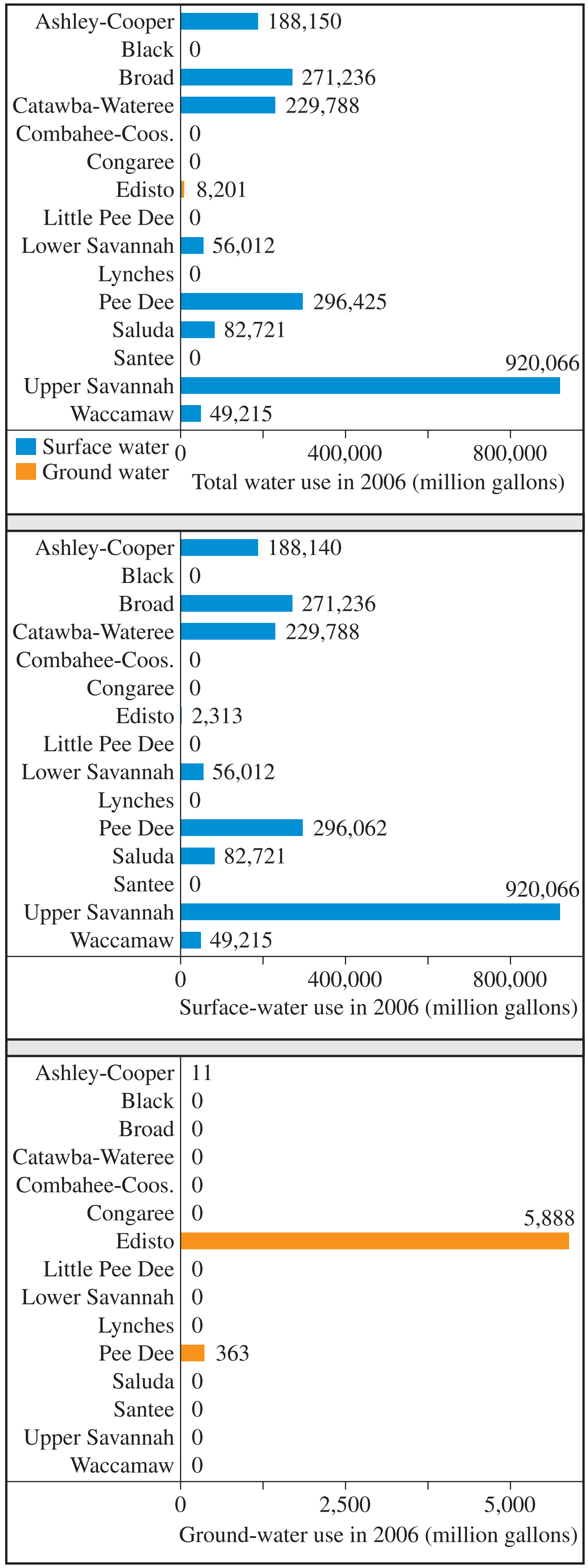
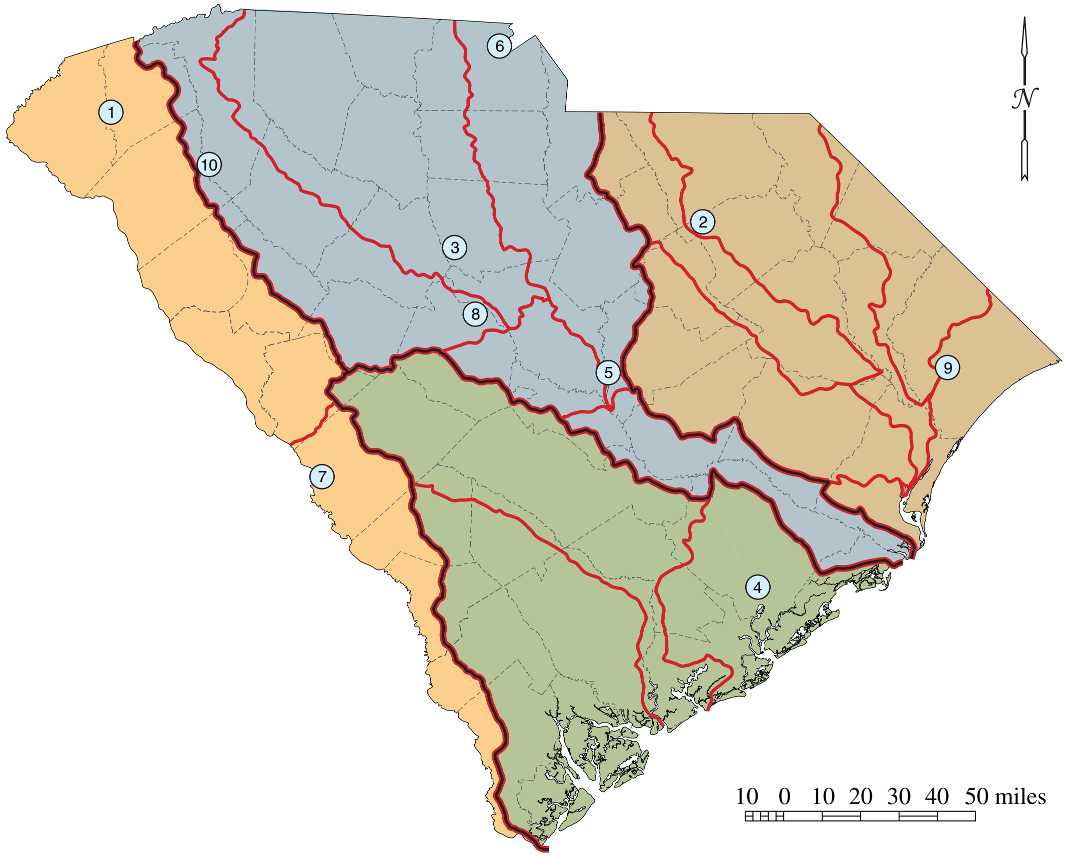


Figure 4-7. Thermoelectric water use in 2006, by subbasin (modified from Butler, 2007).



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.

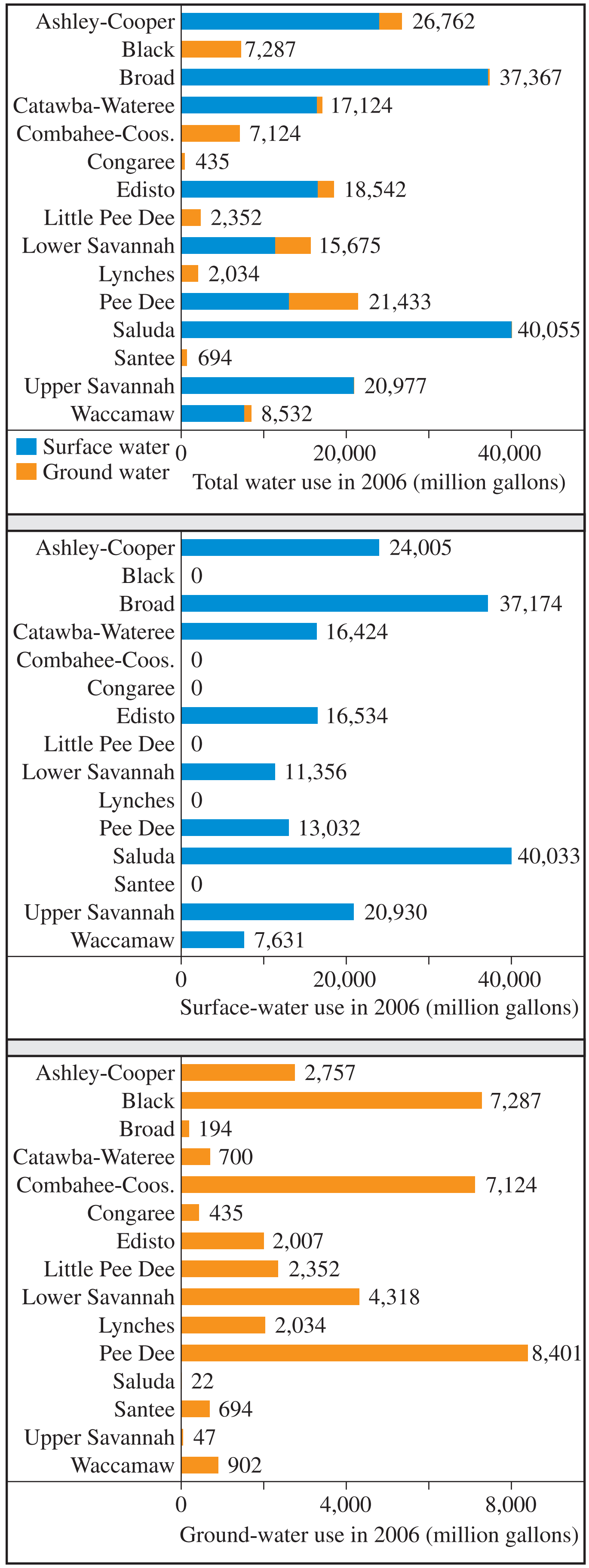


Figure 4-9. Water-supply water use in 2006, by subbasin (modified from Butler, 2007).

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.

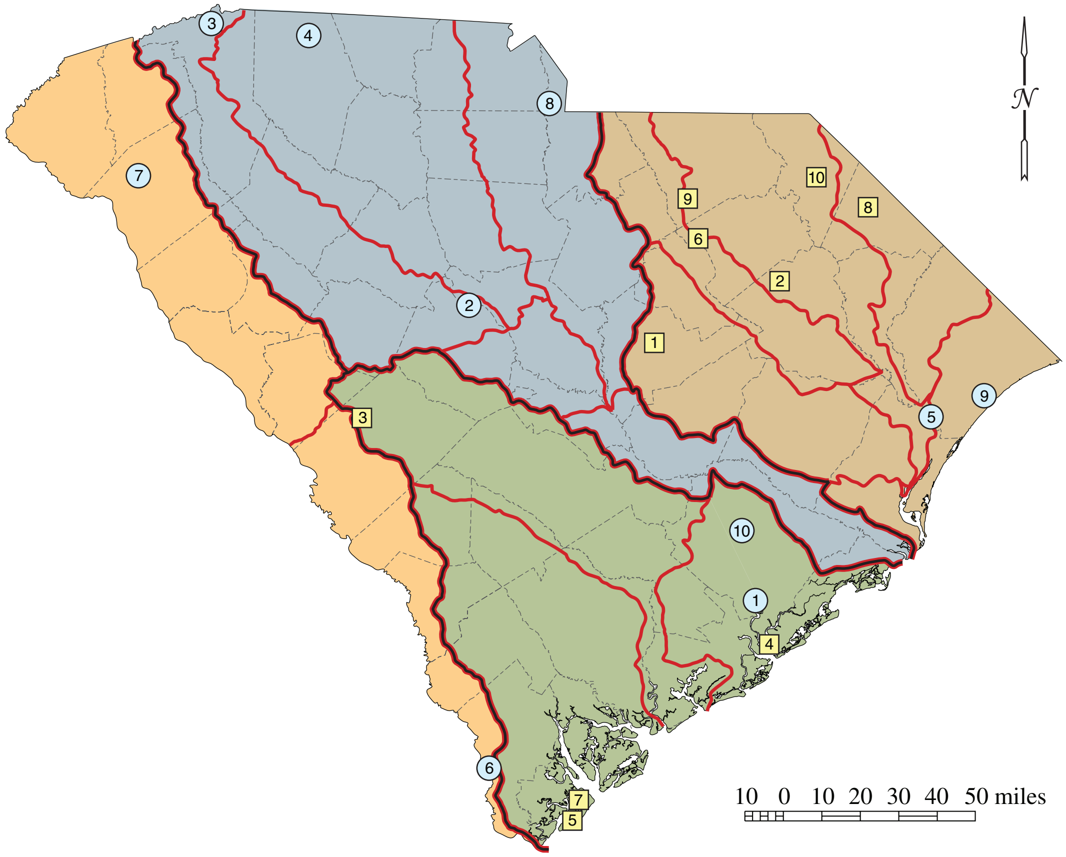
Crop irrigation occurs throughout the State, from peach and apple orchards in the upper Piedmont to tobacco, corn, and soybean fields in the lower Coastal Plain. In 2007, 25,897 farms were in operation in South Carolina, a total of 4,889,339 acres of land were in farms and a total of 1,551,670 acres 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.

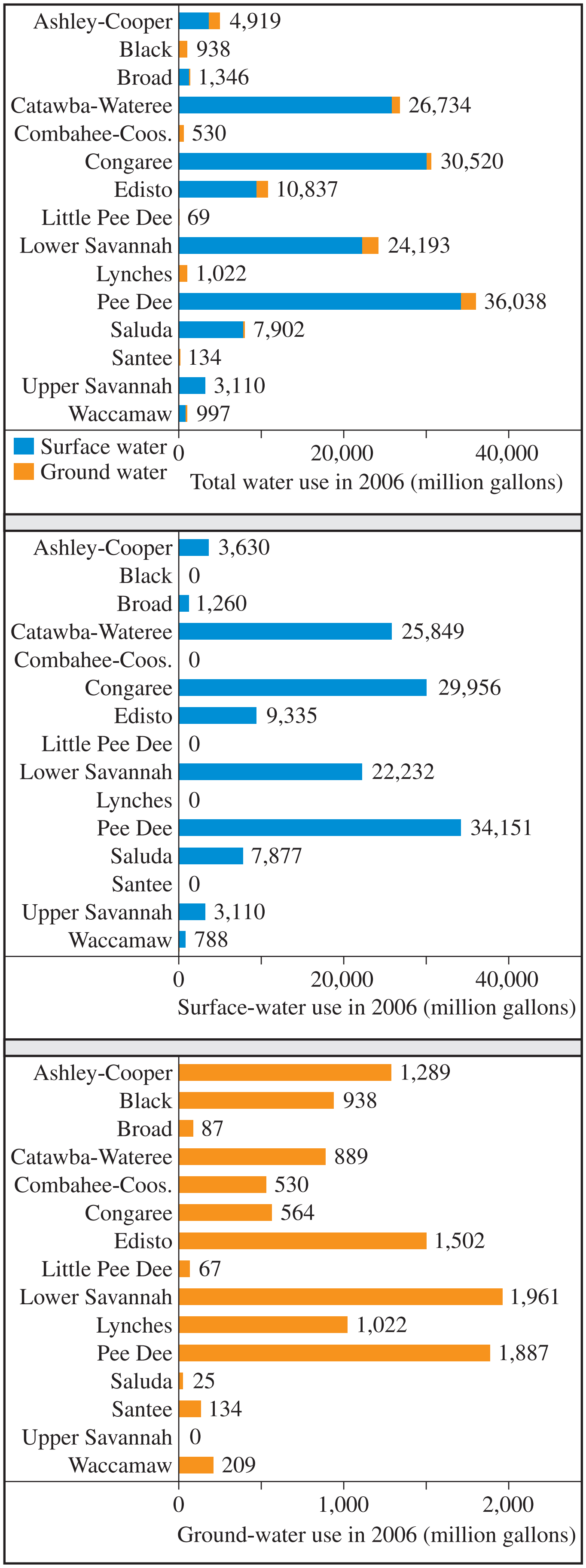


Figure 4-11. Industrial water use in 2006, by subbasin (modified from Butler, 2007).

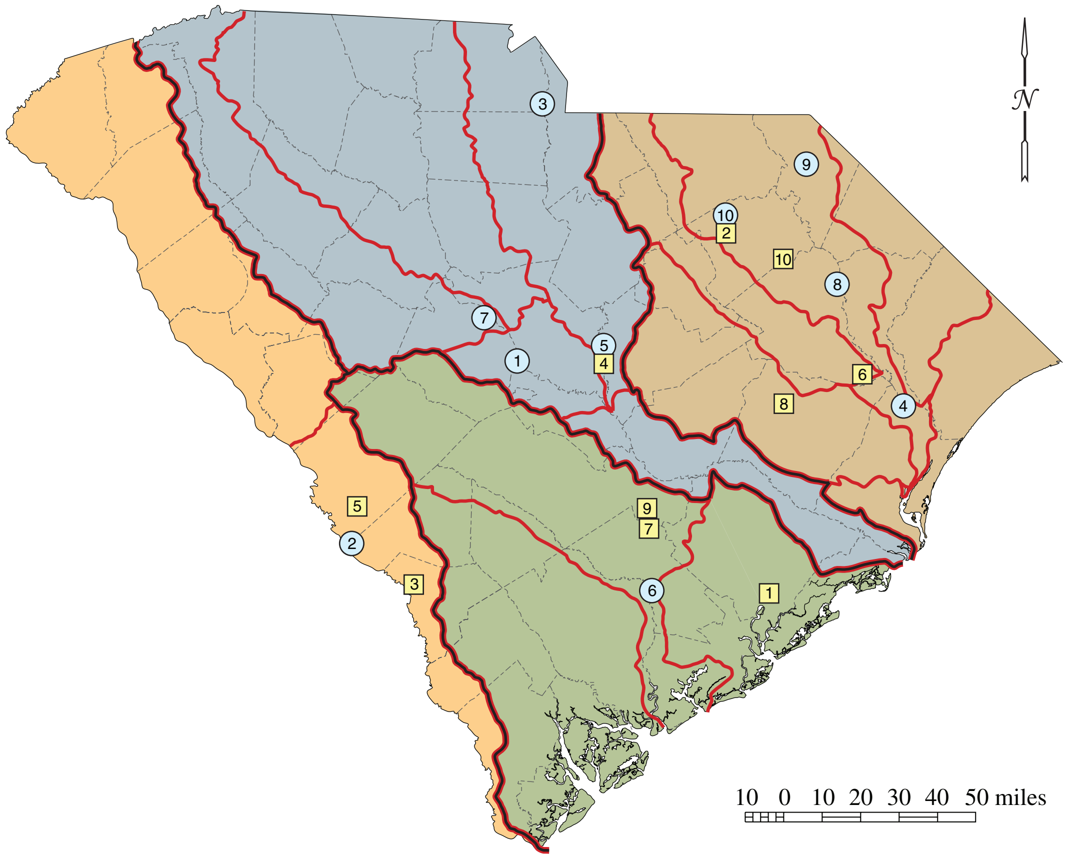
irrigation use in 2006 (Figure 4-13). Withdrawals from the Combahee-Coosawhatchie totaled 9,024 million gallons (31 percent of the statewide total) and those from the Edisto totaled 7,348 million gallons (25 percent). Irrigation use was lowest in the Lynches River subbasin (27 million gallons) and the 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.

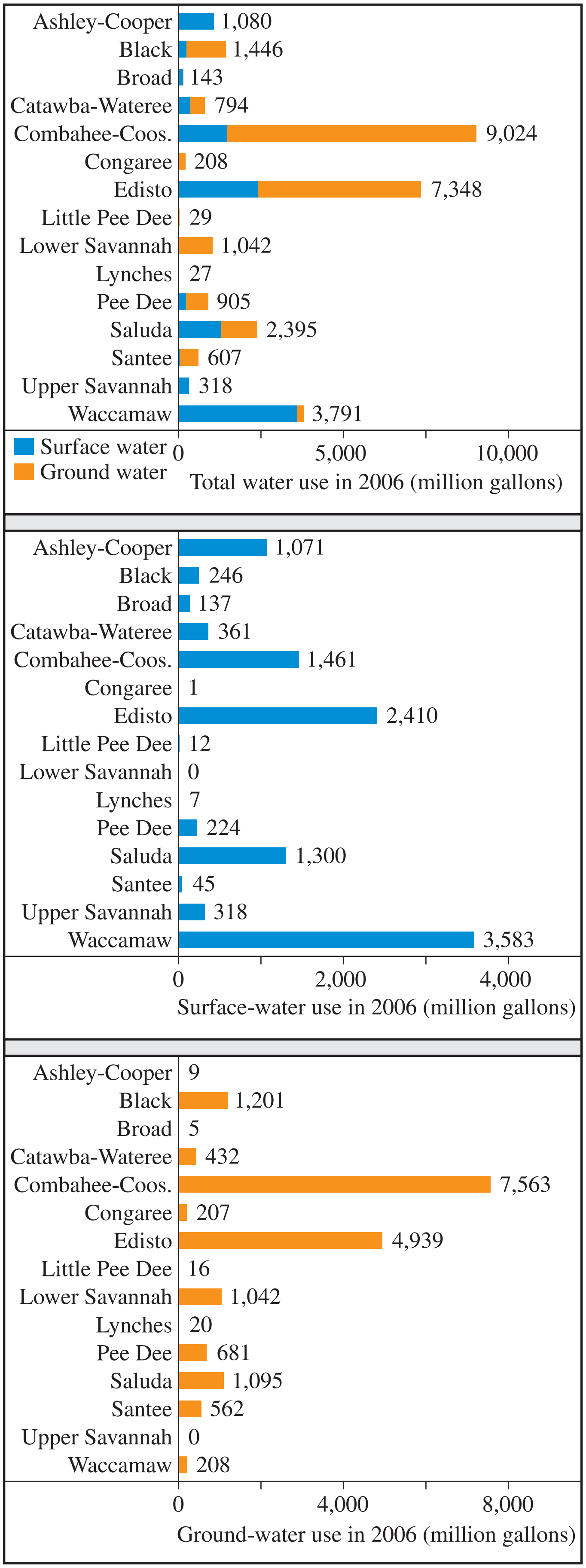


Figure 4-13. Irrigation water use in 2006, by subbasin (modified from Butler, 2007).

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**

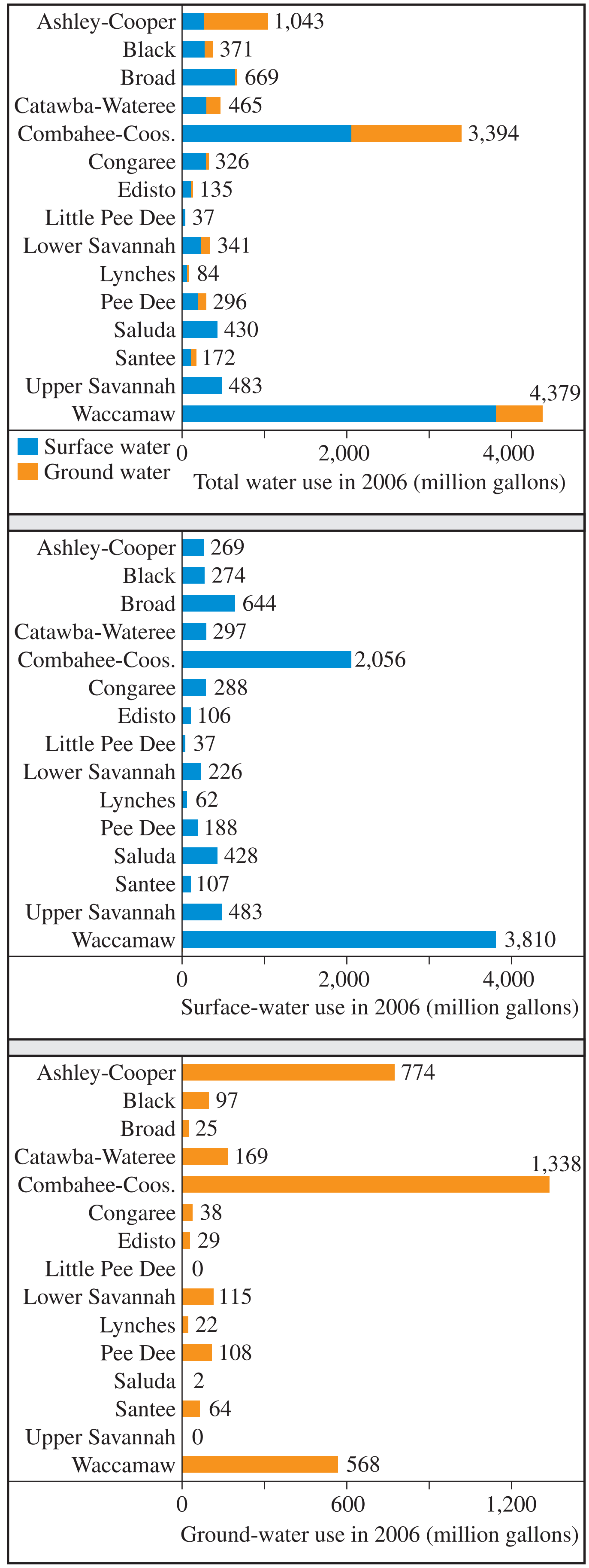


Figure 4-14. Golf course water use in 2006, by subbasin (modified from Butler, 2007).

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*

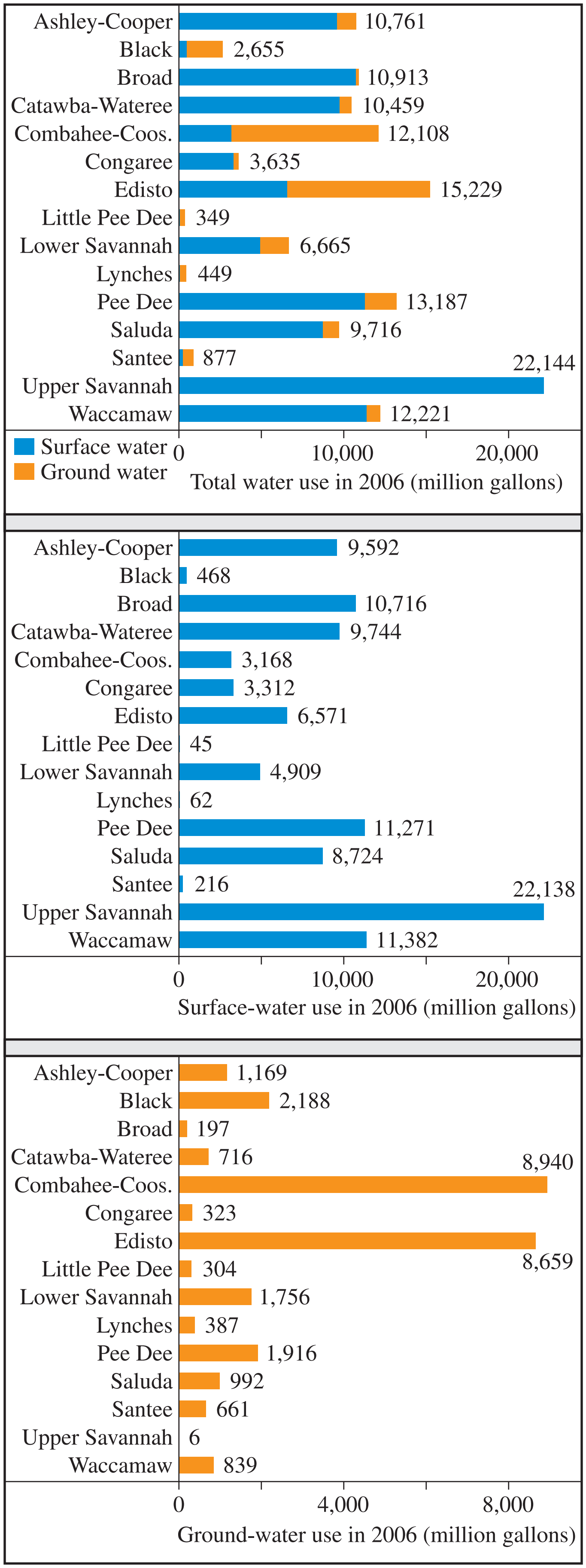
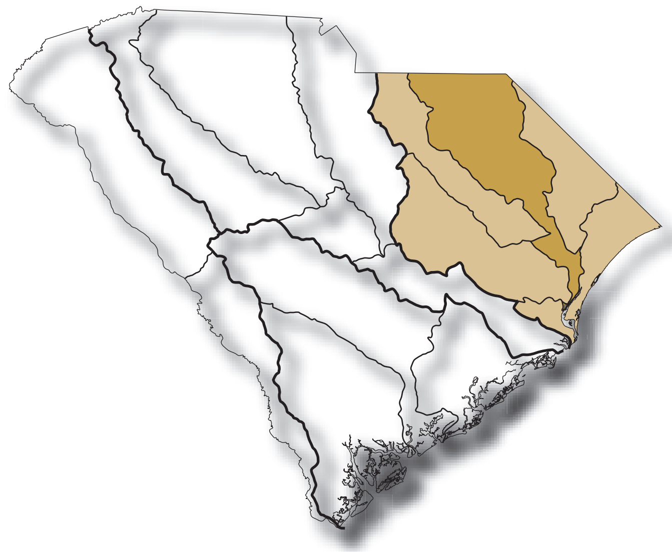


Figure 4-15. Consumptive water use in 2006, by subbasin.

WATERSHED CONDITIONS: PEE DEE RIVER BASIN

PEE DEE RIVER SUBBASIN



PEE DEE RIVER SUBBASIN

The Pee Dee River subbasin extends from the North Carolina border southeast to Winyah Bay and encompasses parts of eight South Carolina counties, including most of Chesterfield, Darlington, Florence, and Marlboro Counties, approximately half of Marion County, and small parts of Dillon, Georgetown, and Williamsburg Counties (Figure 5-1). The subbasin area is approximately 2,350 square miles, 7.8 percent of South Carolina's land area.

DEMOGRAPHICS

The 2000 subbasin population was estimated at 227,200, which is about 5.7 percent of the State's total population. By the year 2020 the population in the subbasin is expected to reach 271,000. The counties expected to exhibit the largest population increases from 2000 to 2025 are Georgetown, with a projected increase of 27 percent, and Florence, with an increase of 12 percent.

The counties in the Pee Dee River subbasin are predominantly rural in character and population. Florence County overall is classified as urban, Georgetown County is classified as rural, and the remaining subbasin counties are classified as very rural. The major population centers in the subbasin are Florence (30,248), Bennettsville (9,425), Darlington (6,720), Marion (7,622), Hartsville (7,556), and Cheraw (5,524). Bennettsville, Darlington, Marion, and Cheraw saw population declines of 0.5 to 8.1 percent between 1990 and 2000.

The 2005 per capita income in the subbasin counties ranged from a low of $20,005 in Williamsburg County to $30,399 in sixth-ranked Georgetown County. The 2005 per capita income in South Carolina averaged $28,285. Median household income for 1999 ranged from $28,205 in Williamsburg County to $35,312 in Georgetown County, all below the State median household income of $37,082.

The 2000 annual-average employment of non-agricultural wage and salary workers in the subbasin's counties was about 130,000. The distribution by type of employment included management, professional, and related, 26 percent; production, transportation, and materials moving, 25 percent; sales and office, 24 percent; service, 14 percent; and construction, extraction, and maintenance, 11 percent.

In the sectors of manufacturing, mining, and public utilities, the combined annual product value from the subbasin counties exceeded $8 billion in 1997. Major employers in those counties included Sonoco Products, Wellman Incorporated, and Galey and Lord.

Agriculture remains important in this section of the State, and crops and livestock have a cash value of more than $325 million. Florence County ranked fifth in the State for cash-crop and livestock receipts from farm marketing, and Dillon and Darlington Counties ranked twelfth and fourteenth, respectively. The delivered value of timber in the subbasin counties ranged from $10 million to $36 million in 2005, when Georgetown, Williamsburg, and Florence Counties ranked fourth, eighth, and tenth in delivered value (South Carolina Forestry Commission, 2008).

SURFACE WATER

Hydrology

The main stem of the Great Pee Dee River is the dominant hydrologic feature of the subbasin. This river originates in North Carolina and receives most of its flow from drainage in North Carolina. (Although its formal name is the Great Pee Dee River, it is often referred to simply as the Pee Dee River and will be referred to as such herein.) Major tributary streams in South Carolina

Figure 5-1. Map of the Pee Dee River subbasin.

include Black Creek, Catfish Creek, Jefferies Creek, and Thompson Creek. Black Creek, the largest of these tributaries, flows through the more urbanized (Hartsville, Darlington, Florence) part of the subbasin. Streams in the upper part of the subbasin originate in or traverse the upper Coastal Plain. Most streams in this subbasin are associated with extensive swamp areas and follow indistinct channels that often divide and recombine.

A 70-mile segment of the Pee Dee River from the US 378 bridge to Winyah Bay was designated as a State Scenic River in 2002. (See the *River Conservation* section of Chapter 9, *Special Topics*.)

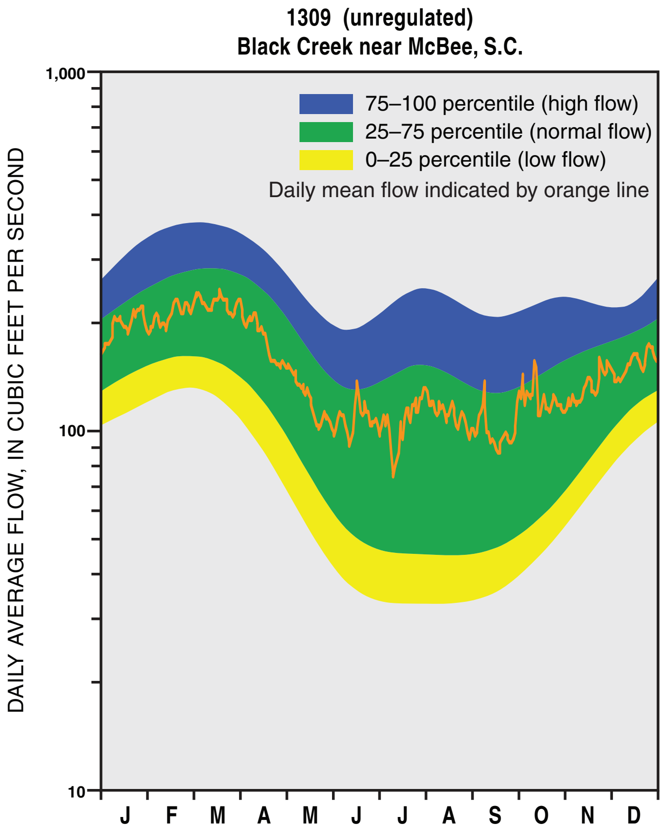
Although the Pee Dee River in South Carolina is free-flowing, in North Carolina it is heavily regulated by a series of six large reservoirs, the last of which, Blewett Falls Lake, is located about 15 miles upstream from the state border. The operation of these reservoirs, primarily for hydroelectric power generation, strongly influences the behavior of the Pee Dee River in South Carolina, particularly during periods of low flow.

Six U.S. Geological Survey (USGS) streamflow monitoring sites are active within this subbasin, three on the Pee Dee River and three on Black Creek. A gaging station on the Pee Dee River outside the subbasin near Rockingham, N.C., also provides useful flow data. The entire period of record on the main stem reflects regulated flows by hydroelectric-power facilities in North Carolina. Black Creek streamflow is affected by two impoundments, Lake Robinson and Prestwood Lake. Streamflow statistics for seven active and four discontinued gaging stations are presented in Table 5-1.

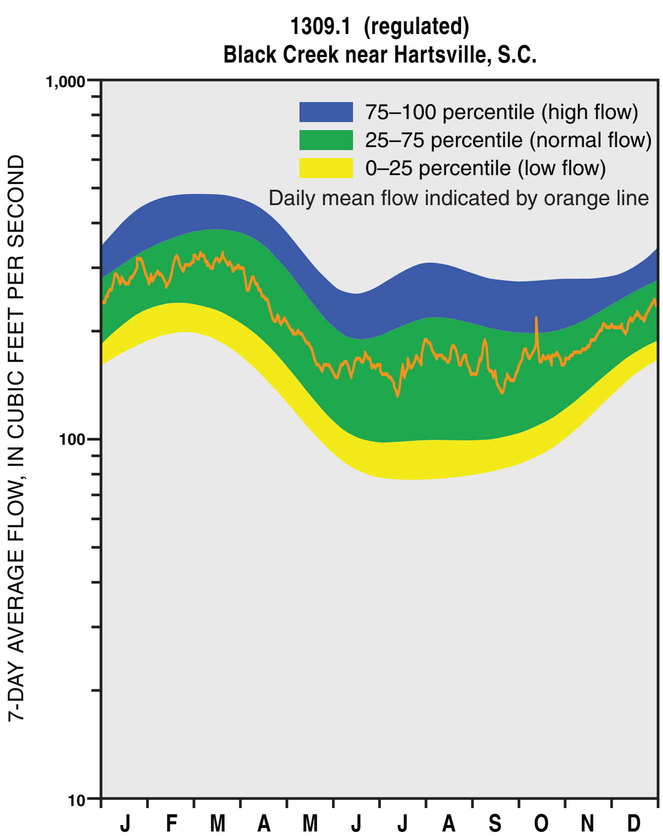
Table 5-1. Selected streamflow characteristics at USGS gaging stations in the Pee Dee River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Pee Dee River near Rockingham, N.C. 1290	1927 to 2007*	6,863	7,903	1.15	1,490	58 1951	242,000 1945	270,000 1945
Whites Creek near Wallace 1295.9	1979 to 1995	26.4	29.2	1.11	4.7	0.0 1990	732 1987	911 1992
Juniper Creek near Cheraw 1305	1940 to 1958	64	72.6	1.13	18.0	0.0 1945, 51, 55, 56	– – –	3,910 1945
Pee Dee River near Bennettsville 1305.61	1990 to 2007*	7,600	7,456	0.98	1,160	48 2000	118,000 2003	124,000 2003
Cedar Creek at Society Hill 1306	1970 to 1981	58.2	92.8	1.59	32.0	8.7 1981	850 1979	1,030 1971
Black Creek near McBee 1309	1959 to 2007*	108	150	1.38	44	9.7 2002	2,460 1990	4,500 1990
Black Creek near Hartsville 1309.1	1960 to 2007*	173	213	1.23	89	6.1 2002	2,890 1990	4,450 1990
Black Creek near Quinby 1309.8	2001 to 2007*	438	400	0.91	148	48 2002	6,090 2004	6,450 2004
Pee Dee River at Peedee 1310	1938 to 2007*	8,830	9,655	1.09	2,810	653 2001	217,000 1945	220,000 1945
Pee Dee River below Peedee 1310.1	1996 to 2007*	8,850	8,069	0.91	1,720	671 2001	96,600 2003	99,000 2003
Catfish Canal at Sellers 1311.5	1966 to 1992	27.4	26.3	0.96	2.0	0.0 1978	755 1971	890 1971

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*



Where it enters South Carolina from North Carolina, the Pee Dee River has an average annual streamflow of about 8,000 cfs (cubic feet per second). At Peedee, in northwestern Marion County, the river has an average annual streamflow of 9,655 cfs and can be expected to be at least 2,810 cfs 90 percent of the time. Streamflow in this river is reasonably steady as indicated by the relatively flat flow-duration curve (Figure 5-2). Flow in the upper portion of the Pee Dee River may be quite variable on a weekly basis due to hydropower discharges upstream in North Carolina; however, discharges from hydropower facilities, in addition to ground-water support from the upper Coastal Plain, sustain relatively steady long-term flows. The lowest flow of record of the Pee Dee River at Peedee is 653 cfs and occurred during July 2007. The highest flow (220,000 cfs) was the result of an unnamed tropical storm in 1945 that caused flooding in much of the eastern part of the State.



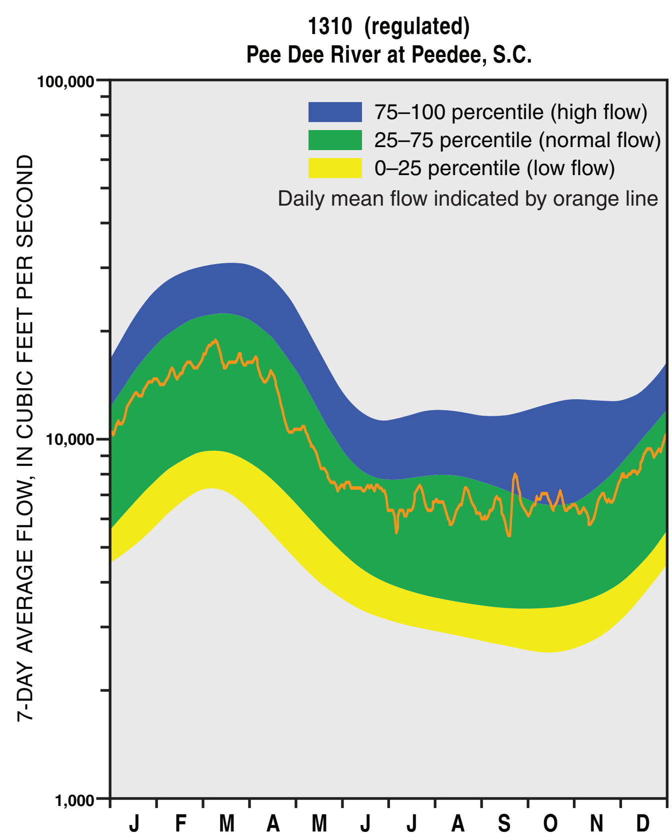


Figure 5-2. Duration hydrographs for selected gaging stations in the Pee Dee River subbasin.

Average annual flows in the gaged tributary streams are 72.6 cfs for Juniper Creek, 92.8 cfs for Cedar Creek, 150 cfs for Black Creek near McBee, 213 cfs for Black Creek near Hartsville, and 27.4 cfs for Catfish Canal. Streamflows in these tributaries equal or exceed 18 cfs, 32 cfs, 44 cfs, 89 cfs, and 2.0 cfs, respectively, 90 percent of the time. Tributaries in the upper Coastal Plain, such as Black Creek and Cedar Creek, exhibit steady flows that are maintained by discharge from ground-water storage, particularly during periods of low rainfall. Lower Coastal Plain streams, such as Catfish Canal, exhibit more variable flow and typically are more dependent on rainfall and runoff than on ground-water discharge to support flows.

The Pee Dee River has a large and well-sustained streamflow year round (Figure 5-2). This river provides a reliable source of freshwater for activities requiring large quantities of water. The recent multiyear drought showed it to be vulnerable, however, to extended low-rainfall periods when the portion of the river in North Carolina is also severely affected by drought. Tributary streams in the upper Coastal Plain, such as Black Creek and Cedar Creek, also provide reliable flows but of much lower volume. Catfish Canal, and probably other lower Coastal Plain streams, provide somewhat less reliable streamflow, and use of these streams may require provision for water storage to ensure adequate availability during summer and fall low-flow periods.

Development

The Pee Dee River subbasin has experienced limited surface-water development in South Carolina, consisting primarily of small-scale flood-control projects. The largest reservoir, Lake Robinson, is owned and operated by Progress Energy and has a surface area of 2,250 acres and a volume of approximately 31,000 acre-ft. Located on Black Creek a few miles northwest of Hartsville, the lake was constructed in 1959 to provide cooling water for the 174-megawatt H.B. Robinson coal-fired power plant. The H.B. Robinson nuclear plant, completed in 1971 and capable of 710 megawatts, also draws cooling water from the lake. Collectively, the two power facilities generate enough power to serve about 400,000 homes. The lake also serves industrial and recreational needs.

Lakes greater than 10 acres in the subbasin have a combined surface area greater than 7,000 acres and a total volume of about 57,000 acre-ft. Lakes greater than 200 acres are listed in Table 5-2.

Table 5-2. Lakes 200 acres or more in the Pee Dee River subbasin (see Figure 5-1 for location of lakes)

Number on map	Name	Stream	Surface area (acres)	Storage capacity (acre-feet)	Purpose
1	Lake Robinson	Black Creek	2,250	31,000	Industry, power, and recreation
2	Lake Wallace	Crooked Creek	416	1,661	Irrigation, recreation, and water supply
3	Prestwood Lake	Black Creek	300	1,800	Industry and recreation
4	Eureka Lake	Sandy River	260	1,660	Recreation
5	Drakes Mill Pond	Three Creeks	250	7,000	Irrigation and recreation

Source: U.S. Army Corps of Engineers (1991)

There are no active U.S. Army Corps of Engineers navigation projects in the subbasin. The Natural Resources Conservation Service completed flood-control, drainage, and erosion projects in the Carters Branch-Muddy Creek and Back Swamp watersheds in the early 1970's; the former project included 33 miles of channel improvement. A Corps of Engineers project near Cheraw developed nonstructural flood control in the Wilson Branch watershed and was completed in 1985.

Surface-Water Quality

All water bodies in the Pee Dee River subbasin, except Winyah Bay, are designated "Freshwater" (Class FW) (DHEC, 2007b). This water-use classification is assigned to water that is suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses.

Winyah Bay is designated "Tidal Saltwater" (Class SB). Class SB water is suitable for primary- and secondary-contact recreation, crabbing, and fishing. Dissolved-oxygen levels in Class SB water must be at least 4.0 mg/L (milligrams per liter). This water is not protected for harvesting clams, mussels, or oysters for market purposes or human consumption.

Figure 5-3. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 5-3 (DHEC, 2007b).

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 71 surface-water sites in the Pee Dee River subbasin in 2003 in order to assess the water's suitability for aquatic life and recreational use (Figure 5-3). Aquatic-life uses were fully supported at 53 sites, or 75 percent of the water bodies sampled in this subbasin; water at many of the impaired sites exhibited pH excursions and dissolved-oxygen levels below the concentrations needed to support aquatic life. Recreational use was fully supported in 75 percent of the sampled water bodies; the water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2007b). Water-quality impairments in the subbasin are listed in Table 5-3.

Table 5-3. Water-quality impairments in the Pee Dee River subbasin (DHEC, 2007b)

Water-body name	Station number	Use	Status	Water-quality indicator
Clay Creek	RS-02305	Aquatic life	Nonsupporting	Dissolved oxygen
Thompson Creek	PD-673	Aquatic life	Partially supporting	Macroinvertebrates
	PD-246	Recreation	Nonsupporting	Fecal coliform
	PD-247	Recreation	Nonsupporting	Fecal coliform
Deep Creek	RS-01013	Aquatic life	Nonsupporting	Turbidity
		Recreation	Partially supporting	Fecal coliform
North Prong Creek	PD-677	Aquatic life	Partially supporting	Macroinvertebrates
Eureka Lake	RL-03346	Aquatic life	Nonsupporting	pH
Juniper Creek	PD-340	Aquatic life	Nonsupporting	pH
Westfield Creek	PD-339	Aquatic life	Partially supporting	Macroinvertebrates, dissolved oxygen, pH
Great Pee Dee River	PD-015	Recreation	Partially supporting	Fecal coliform
Cedar Creek	PD-151	Aquatic life	Nonsupporting	pH
Lake Robinson	RL-03342	Aquatic life	Nonsupporting	pH
Black Creek	PD-021	Recreation	Partially supporting	Fecal coliform
	RS-01043	Aquatic life	Nonsupporting	Copper
	PD-025	Recreation	Partially supporting	Fecal coliform
Snake Branch	PD-258	Aquatic life	Nonsupporting	pH
		Recreation	Nonsupporting	Fecal coliform
Boggy Swamp	RS-03507	Recreation	Partially supporting	Fecal coliform
Tilefield to Swift Creek	PD-141	Recreation	Nonsupporting	Fecal coliform
Swift Creek tributary	RS-01023	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Three Creeks	PD-341	Aquatic life	Nonsupporting	pH
Jeffries Creek	PD-256	Recreation	Nonsupporting	Fecal coliform
Gulley Branch	PD-065	Aquatic life	Partially supporting	pH
		Recreation	Nonsupporting	Fecal coliform
Middle Swamp	PD-230	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Willow Creek	PD-167	Recreation	Partially supporting	Fecal coliform
Smith Swamp	PD-320	Recreation	Nonsupporting	Fecal coliform
	PD-187	Recreation	Partially supporting	Fecal coliform
Catfish Creek	PD-097	Aquatic life	Nonsupporting	Dissolved oxygen
Great Pee Dee River	PD-060	Aquatic life	Nonsupporting	Copper
	MD-275	Aquatic life	Nonsupporting	Dissolved oxygen

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, DHEC issued fish-consumption advisories for the Great Pee Dee River, Black Creek, and Lake Robinson. The advisories are issued where fish contaminated with mercury have been found: the contamination is only in the fish and does not make the water unsafe for skiing, swimming, or boating.

GROUND WATER

Hydrogeology

Almost all of the Pee Dee River subbasin is in the Coastal Plain province. A small part of Chesterfield County, in the northwestern part of the subbasin, is in rocks of the Carolina terrane of the Piedmont province, where ground water occurs in the overlying mantle of saprolite and in joint systems and fracture zones of crystalline bedrock.

East of the Fall Line, the Coastal Plain sediments reach a thickness of 650 feet along the southern border of Marlboro County. The area is underlain by the Middendorf aquifer, which can yield as much as 1,000 gpm (gallons per minute) to individual wells. Gravel mines in alluvial deposits along the Great Pee Dee River and test wells drilled in the Cheraw area by the U.S. Geological Survey indicate a potentially favorable situation for infiltration wells if the water-bearing sand beds are hydraulically connected to the river. Several wells have been drilled successfully into the alluvial and terrace deposits on the east bank of the Great Pee Dee River near Wallace.

In the vicinity of Darlington, the Black Creek and Middendorf aquifers lie beneath a thin veneer of Pleistocene sand and clay and the Duplin Marl. Total thickness of the unconsolidated material overlying the basement rock ranges between 500 and 650 feet.

In Florence County, the Peedee Formation, within the top of the Black Creek aquifer, has a thickness of about 200 feet and reported well yields of about 20 gpm. Yields elsewhere, however, are normally much higher. Selected data on well yields are listed in Table 5-4. The Black Creek aquifer has a thickness of about 250 feet, and the transmissivity calculated from wells screened in Black Creek sand beds and the upper sand beds of the Middendorf ranges between about 1,600 and 2,000 ft^2/day near Florence. Aucott (1988) used a transmissivity range of 2,000 to 5,000 ft^2/day across the subbasin; however, Newcome (1993) reported a Black Creek aquifer transmissivity of almost 10,000 ft^2/day at Lake City, southwest of the subbasin. Where the maximum yield is desired, wells are screened in both the Middendorf and Black Creek aquifers.

Table 5-4. Selected ground-water data for the Pee Dee River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Cheraw-Patrick	Black Creek	135–240	105
Bennettsville-McColl-Clio	Middendorf	105–415	150–625
Wallace	Pee Dee River alluvium	45–98	720
Darlington	Middendorf	141–665	825
Florence	Black Creek	200–500	400–1,300
	Black Creek/ Middendorf	400–740	250–1,060
	Middendorf	400–720	500–2,100
Pamplico	Black Creek	190–300	100–540
Hartsville	Middendorf	215–315	260–1,020

The principal source of ground water in the Florence County section of the subbasin is the deeper Middendorf aquifer, in which transmissivity generally increases south to north. Aucott (1988) based his predevelopment water-level simulations on transmissivity ranges of 2,000 to 5,000 ft^2/day across most of Florence, Dillon, and Marion Counties and 5,000 to 10,000 ft^2/day across Darlington and Marlboro Counties. Newcome (2005b) reported a Middendorf transmissivity range of 1,000 to 6,000 ft^2/day in the Florence area.

Ground-Water Quality

The Middendorf and Black Creek aquifers are the most widely used in the subbasin. A unit of the Tertiary sand aquifer is present but mainly southeast of Brittons Neck and only as a thin section of muddy, fine-grained sand and shale assigned to the Rhems Formation. The upper reach of the subbasin, in Chesterfield, western Darlington, and Marlboro Counties, is in the outcrop area of the Middendorf aquifer. There, Middendorf water is characterized by high dissolved oxygen, low TDS (total dissolved solids), low pH, and low alkalinity and is soft and corrosive. Total dissolved-solids concentrations less than 50 mg/L (milligrams per liter) and pH values below 6.5 are typical.

In the middle reach of the subbasin, in eastern Marlboro, northern Florence, and western Marion Counties, both Black Creek and Middendorf aquifers are used. Water of the Middendorf aquifer in this reach is low in dissolved oxygen, acidic, and high in dissolved iron: TDS are about 60 mg/L. Water of the Black Creek aquifer is low in dissolved oxygen, slightly acidic to slightly alkaline, and high in dissolved iron: TDS are about 140 mg/L. A black precipitate has been reported in some wells and indicates sulfides in the aquifer

(Rodriguez and others, 1994). Some constituents locally exceed secondary water-quality standards, including iron, magnesium, fluoride, and turbidity.

In the lower reaches of the subbasin, in northeastern Williamsburg and northern Georgetown Counties, the Black Creek aquifer is the main source of ground-water supply. Water in the Black Creek is low in dissolved oxygen, TDS are greater than 250 mg/L, and pH is generally above 8.5. Water in the Middendorf is similar to that of the Black Creek.

The major units of the shallow aquifer include outcrops of the Middendorf and Black Creek aquifers where they are poorly confined and Pleistocene and Pliocene terrace deposits that occur southeast of Chesterfield and northern Marlboro Counties. Water in the outcrop areas typically is a soft, acidic, sodium chloride type and has TDS concentrations less than 100 mg/L. Alkalinity, pH, and TDS are, on average, slightly greater at the subbasin's southeastern end, but they range widely. DHEC reported alkalinities of 0.0 to 360 mg/L, pH's of 4.3 to 8.2, and TDS concentrations of 50 to 400 mg/L. Iron concentrations above 300 µg/L (micrograms per liter) are common.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR, USGS, and DHEC in 13 wells in the Pee Dee River subbasin in order to help assess trends or changes in water levels and to monitor areas with known water-level problems (Table 5-5). Water levels in other wells are sometimes measured to help develop potentiometric maps of the Middendorf and Black Creek aquifers.

Pumping ground water faster than it can be replenished results in the development of an area of locally or regionally lower ground-water levels called a cone of depression, which can, if severe enough, limit the availability of ground water within that area. There are at least two known cones of depression in each of the two major aquifers in the Pee Dee River subbasin (Figures 5-4 and 5-5).

Table 5-5. Water-level monitoring wells in the Pee Dee River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
CTF-56	DHEC	34 37 34 79 56 25	Middendorf	Cheraw State Park	141	undetermined
CTF-57	DHEC	34 37 36 79 56 26	Middendorf	Cheraw State Park	141	undetermined
CTF-81	DNR	34 38 35 79 54 41	Crystalline rock	Cheraw State Park	190	231–244
CTF-211	USGS	34 30 23 80 13 06	Middendorf	3 miles northeast of McBee	410	undetermined
DAR-96	DHEC	34 30 27 79 51 22	Middendorf	Society Hill	189	175–373
DAR-228	DNR	34 27 32 79 52 48	Middendorf	Lake Darpo	170	175–185
FLO-128	USGS	34 11 44 79 34 49	Middendorf	10 miles east of Florence	96	264–690
FLO-473	DHEC	34 12 11 79 50 26	Middendorf	Florence	130	undetermined
FLO-475	DHEC	34 01 01 79 45 16	Black Creek	12 miles southeast of Florence	108	undetermined
MLB-110	USGS	34 29 35 79 43 10	Middendorf	8 miles south of Bennettsville	135	75–115
MLB-112	USGS	34 37 35 79 41 22	Middendorf	Bennettsville	135	320–335
MRN-77	DNR	33 51 42 79 19 50	Black Creek	Brittons Neck	34	325–355
MRN-78	DNR	33 51 42 79 19 49	Middendorf	Brittons Neck	35	1,008–1,028

* *DHEC, South Carolina Department of Health and Environmental Control; DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

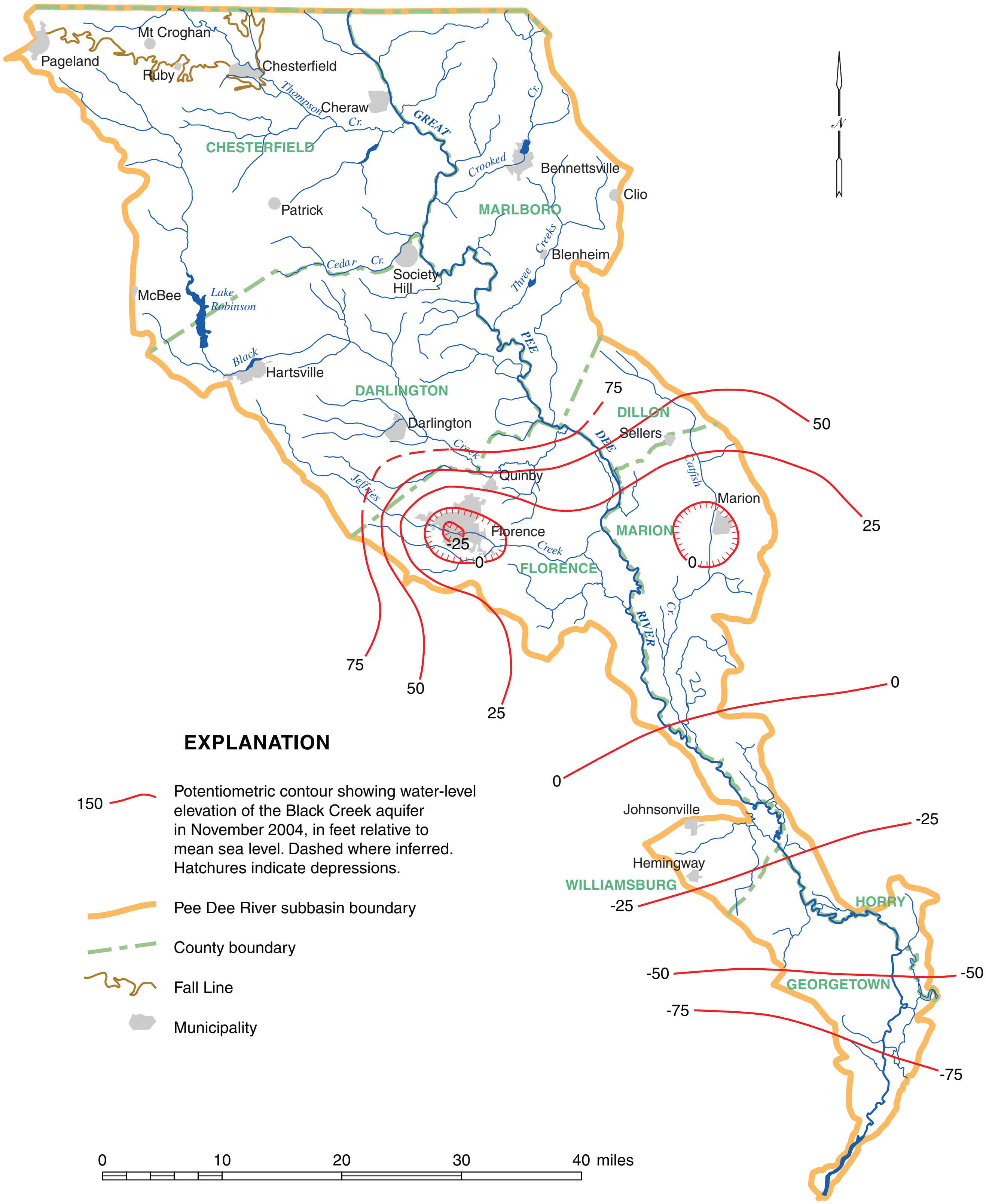


Figure 5-4. Potentiometric contours of the Black Creek aquifer in the Pee Dee River subbasin, November 2004 (from Hockensmith, 2008b).

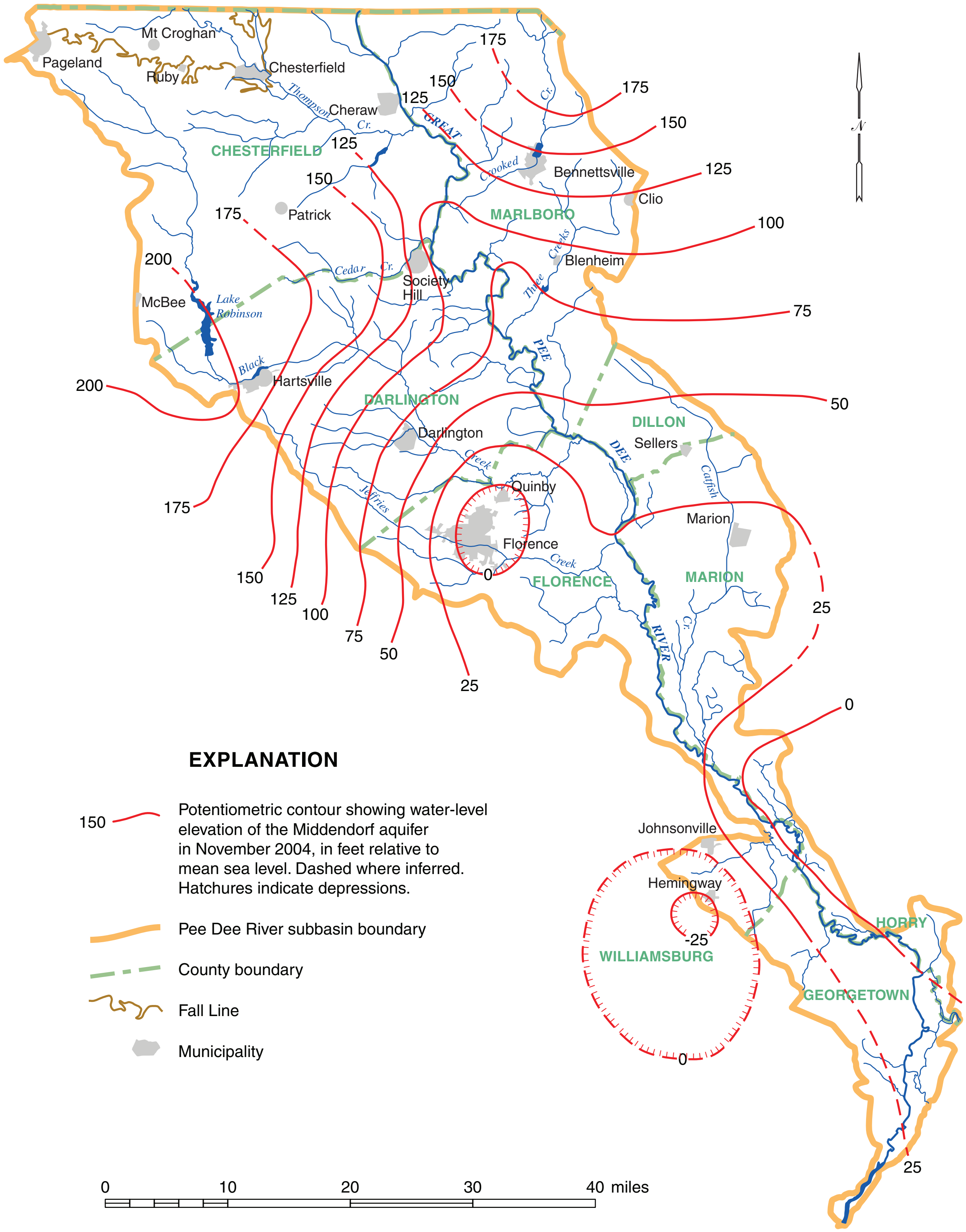


Figure 5-5. Potentiometric contours of the Middendorf aquifer in the Pee Dee River subbasin, November 2004 (from Hockensmith, 2008a).

The most significant cone of depression in the Black Creek aquifer is centered in northern Florence County and is a result of ground-water pumping by the city of Florence. At the center of this cone of depression, the water level is more than 100 feet lower than the predevelopment level. Water levels in this area have shown signs of recovery since the city began supplementing its water supply with surface-water withdrawals from the Pee Dee River in 2004 (Hockensmith, 2008b). Another cone of depression appears to be developing in the Black Creek aquifer in the vicinity of the city of Marion, where water levels have declined as much as 75 feet from predevelopment levels (Hockensmith, 2008b).

There is also a cone of depression centered in northern Florence County in the Middendorf aquifer, also the result of ground-water pumping by the city of Florence. Although the water level at the center of this cone is still more than 100 feet lower than the predevelopment level, water levels in the city of Florence area have recovered significantly since the city began supplementing its water supply with withdrawals from the Pee Dee River (Hockensmith, 2008a). A second cone of depression in the Middendorf aquifer, with a water-level decline of as much as 80 feet from the predevelopment level, has been mapped near the town of Hemingway, in eastern Williamsburg County (Hockensmith, 2008a).

In addition to these site-specific water-level concerns, years of ground-water pumping from wells in this and neighboring subbasins have resulted in regional water-level declines of as much as 50 feet from predevelopment levels in both aquifers in the southern portion of the subbasin.

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Pee Dee River subbasin for the year 2006 is summarized in Table 5-6 and Figure 5-6. Total offstream water use in the subbasin was 355,129 million gallons, ranking it second among the 15 subbasins. Of this amount, 343,657 million gallons were surface water (97 percent) and 11,472 million gallons were ground water (3 percent). Thermoelectric use accounted for 83 percent of this total, followed by industry (10 percent) and water supply (6 percent). Consumptive use in this subbasin is estimated to be 13,187 million gallons, or about 4 percent of the total offstream use.

Table 5-6. Reported water use in the Pee Dee River subbasin for the year 2006 (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	0	0.0	33	0.3	33	0.0
Golf course	188	0.1	108	0.9	296	0.1
Industry	34,151	9.9	1,887	16.5	36,038	10.1
Irrigation	224	0.1	681	5.9	905	0.3
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	296,062	86.1	363	3.2	296,425	83.5
Water supply	13,032	3.8	8,401	73.2	21,433	6.0
Total	343,657		11,472		355,129	

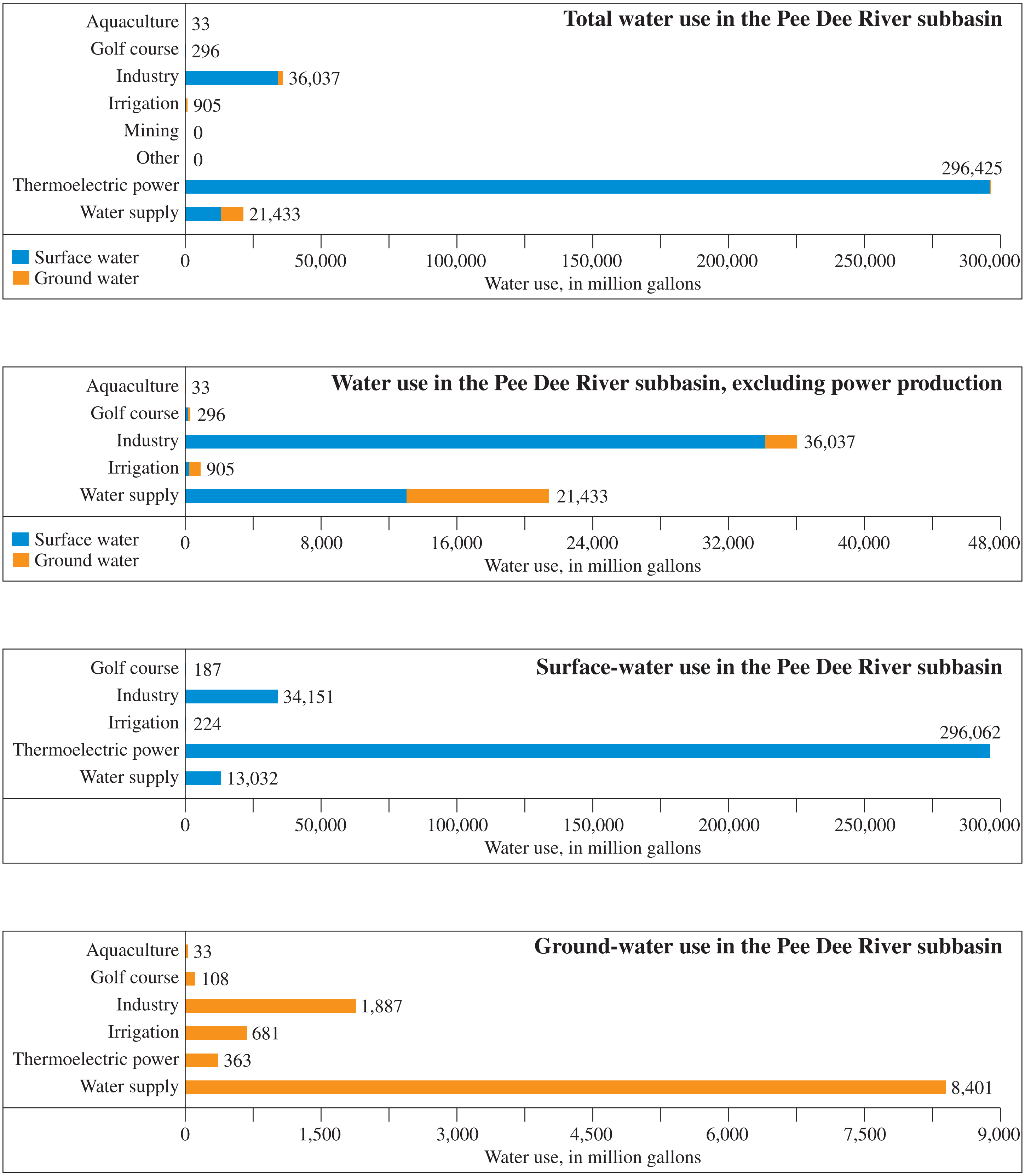


Figure 5-6. Reported water use in the Pee Dee River subbasin for the year 2006 (modified from Butler, 2007).

By far, the largest water user in this subbasin is Progress Energy's H.B. Robinson electrical generating station, which consists of side-by-side coal-fired thermoelectric and nuclear plants, located adjacent to Lake Robinson near Hartsville in Darlington County. In 2006, a total of 296,062 million gallons of surface water (from Lake Robinson) and 362 million gallons of ground water were used by the plants.

Industrial water use was greater in the Pee Dee subbasin than in any other subbasin in the State. Thirteen industries used a total of 36,038 million gallons of water in 2006. Of this amount, 34,151 million gallons were surface water (95 percent) and 1,887 million gallons were ground water (5 percent). Surface water came mainly from the Pee Dee River, and ground water from the Middendorf aquifer. Several of the largest industrial surface-water and ground-water users in the State, such as International Paper Co. and Sonoco Products Co., reside in the subbasin. International Paper Co. in Georgetown County, the fourth largest industrial surface-water user, withdrew 11,400 million gallons from the Sampit River, and Sonoco Products Co. in Darlington County, the second largest industrial ground-water user, withdrew 860 million gallons from the Middendorf aquifer.

Water-supply use in the subbasin totaled 21,433 million gallons. Surface water accounted for 13,032 million gallons (61 percent) and ground water for 8,401 million gallons (39 percent). The largest surface-water user was Grand Strand Water and Sewer Authority, which withdrew 9,904 million gallons from Bull Creek in the southeastern corner of the subbasin. Other large surface-water users include the cities of Florence (1,343 million gallons from the Pee Dee River), Cheraw (737 million gallons from the Pee Dee River), Georgetown (654 million gallons from the Pee Dee River), and Bennettsville (393 million gallons from Lake Wallace).

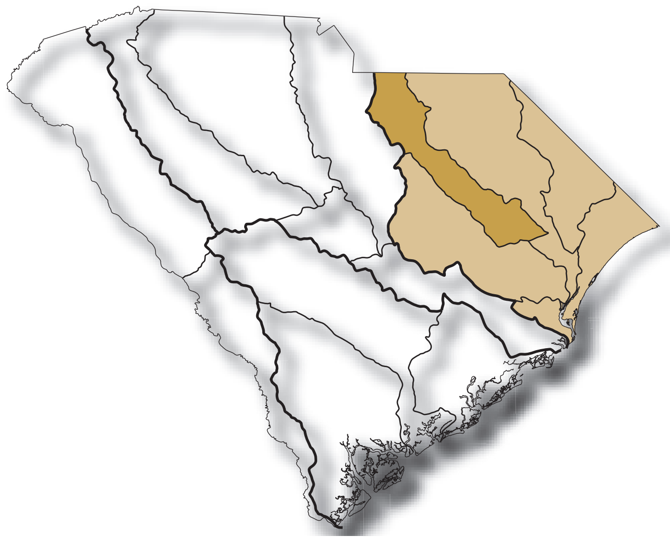
Among water-supply systems using ground water, the city of Florence was the largest user, withdrawing 3,445 million gallons in 2006. Second in ground-water use was Darlington County Water and Sewer Authority (1,367 million gallons), followed by the city of Bennettsville (636 million gallons), and Alligator Rural Water Co. (620 million gallons). Alligator Rural Water Co., which supplies most of Chesterfield County, also has several wells in the Lynches River subbasin to the west. In all, Alligator pumped about 937 million gallons in 2006. Darlington County Water and Sewer Authority also has a few wells in the Lynches subbasin that pumped an additional 219 million gallons. Most of the ground water in the Pee Dee subbasin is from the Middendorf aquifer, the most productive aquifer in the area, but some water is also pumped from the Black Creek and Cape Fear aquifers. It is worth noting that more ground water was used in the Pee Dee subbasin for water-supply use than in any other subbasin in the State.

Irrigation water use totaled 905 million gallons, which is 0.3 percent of the total water used in the subbasin in 2006. Of this amount, 681 million gallons were from ground-water sources (75 percent) and 224 million gallons were from surface-water sources (25 percent). McLeod Farms, in Chesterfield County, was the largest ground-water user. Renowned for its peach orchards, McLeod Farms used 329 million gallons in 2006. Most of this water was from the Middendorf aquifer. Lawson Turf Farms, near Darlington, was the largest surface-water irrigator, using 98 million gallons.

Golf-course water use totaled 296 million gallons, which is about 0.1 percent of the total water used in the subbasin in 2006. Of this amount, 188 million gallons came from surface water and 108 million from ground water. The largest user was Cheraw State Park Golf Course, which withdrew 58 million gallons of water from the Pee Dee River. Hartsville Country Club withdrew 40 million gallons from Prestwood Lake. Only one golf course—Goodson Inc. DBA Traces, located west of Florence—used ground water. It has seven wells, all of which probably produce from the Black Creek aquifer.

A minor amount of ground water (33 million gallons) was also used for aquaculture at one facility in this subbasin. No water use was reported for mining activities.

LYNCHES RIVER SUBBASIN



Kershaw and Florence Counties had per capita incomes of $28,595 and $28,486 in 2005, slightly above the State average ($28,285), and respectively ranked eighth and tenth among South Carolina's 46 counties. The per capita incomes of Lee and Williamsburg Counties were $20,307 and $20,005, respectively, ranking 43rd and 45th in the State.

During 2000 the combined annual average employment of nonagricultural wage and salary workers in Florence and Lee Counties was about 63,000. Labor distribution in the subbasin counties included management, professional, and technical services, 25 percent; sales and office, 22 percent; production, transportation, and materials moving, 21 percent; service, 14 percent; construction, extraction, and maintenance, 11 percent; and farming, fishing, and forestry, 1 percent.

In the sectors of manufacturing, mining, and public utilities, the combined annual product value from the counties of the subbasin exceeded $10 billion in 2000. Major employers in those counties included Sonoco Products, Wellman Incorporated, Gold Kist, and Bosch Braking Systems.

The counties of the subbasin generally ranked high with respect to agricultural production, and crops-and-livestock cash value was about $308 million in 2000. Florence, Kershaw, and Sumter Counties ranked fifth, seventh, and eighth for crops-and-livestock cash receipts. The delivered value of timber in the subbasin counties ranged from about $7.6 million in Lee County to $28.2 million in Williamsburg County in 2005 (South Carolina Forestry Commission, 2008).

LYNCHES RIVER SUBBASIN

The Lynches River subbasin is a long, narrow basin transecting the heart of the Pee Dee region. The basin shares a northern border with North Carolina and encompasses parts of eight South Carolina counties: Chesterfield, Lancaster, Kershaw, Florence, Lee, Darlington, Sumter, and Williamsburg (Figure 5-7). The subbasin area is about 1,370 square miles, 4.4 percent of South Carolina's land area.

DEMOGRAPHICS

The 2000 population of the subbasin was estimated at 85,600, about 2.1 percent of the State's total population and a 3.6 percent increase since 1980. The largest increases in population are expected to occur in Lancaster and Florence Counties.

The eight counties included in the subbasin have a predominantly rural population, with the exception of two counties that are classified as being slightly over 50 percent urban. A majority of the urban residents live outside the subbasin boundary. The major population center in the subbasin is Lake City (6,478) in Florence County, but the urban areas of Florence (30,248) and Lancaster (8,177) lie near the basin boundaries.

SURFACE WATER

Hydrology

The Lynches River flows across the Piedmont and Coastal Plain provinces, both of which influence streamflow of the tributary streams draining these regions and therefore the main river. Headwaters of the Lynches River and the tributary Little Lynches River originate in the lower Piedmont of South Carolina and North Carolina. The dendritic drainage pattern of this river extends through the upper Coastal Plain but exhibits characteristics of a trellis drainage pattern in the middle and lower Coastal Plain. Three other moderately-sized tributary streams in the

Figure 5-7. Map of the Lynches River subbasin.

subbasin, all in the lower Coastal Plain, are Bay Swamp, Lake Swamp, and Sparrow Swamp. Most large stream channels in the Coastal Plain are bordered by swamps, and associated streams break up into braided, indistinct channels.

A 54-mile segment of the river between US Highway 15 in Lee County and the eastern boundary of Lynches River County Park became a State Scenic River in 1994. In 2008, an additional 57 miles—from Lynches River County Park to the Pee Dee River—were also designated, making the Lynches River the longest State Scenic River at 111 miles. (See the *River Conservation* section of Chapter 9, *Special Topics*.)

The flow of the Lynches River is presently monitored at two gaging stations: near Bishopville, in Lee County, near the boundary of the upper and middle Coastal Plain; and at Effingham, in Florence County, in the middle Coastal Plain. Discontinued gages were located in the upper portion of the subbasin, near the Fall Line, on Fork Creek and Little Fork Creek in Chesterfield County and on Hanging Rock Creek in Lancaster County (Figure 5-7). No significant streamflow regulation occurs in the subbasin. Streamflow statistics for the active and inactive gages are presented in Table 5-7.

Table 5-7. Selected streamflow characteristics at USGS gaging stations in the Lynches River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi²)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Fork Creek at Jefferson 1313.09	1976 to 1997	24.3	25.7	1.06	1.3	0.0 1983, 86, 87, 88	2,600 1990	8,960 1990
Little Fork Creek at Jefferson 1313.2	1990 to 2000	15	16.2	1.08	1.5	0.14 1999	1,400 1990	2,440 1990
Hanging Rock Creek near Kershaw 1314.72	1980 to 2003	23.9	24.2	1.01	1.7	0.13 1986	1,080 1990	3,760 1990
Lynches River near Bishopville 1315	1942-71 and 2002-07*	675	750	1.11	218	33 2002	27,300 1945	29,400 1945
Lynches River at Effingham 1320	1929 to 2007*	1,030	1,023	0.99	245	69 2002	24,500 1945	25,000 1945

mi², square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Average annual streamflow at gaging stations on the Lynches River is 750 cfs (cubic feet per second) near Bishopville and 1,023 cfs at Effingham, and 90 percent of the time the streamflow at these gages equals or exceeds 218 cfs and 245 cfs, respectively. The lowest flows of record on the Lynches River are 33 cfs near Bishopville and 69 cfs at Effingham, both occurring in August 2002 near the end of the severe 1998–2002 drought. The highest flow of record is 29,400 cfs near Bishopville and was the result of runoff from a tropical storm in September 1945.

Tributary streams in the upper part of the subbasin typically have flows of less than 100 cfs and rarely exceed 1,000 cfs. These Piedmont and upper Coastal Plain streams exhibit a combination of streamflow characteristics of both provinces.

Average and above-average streamflows in the Lynches River are greatly dependent on direct runoff of rainfall, and low flows are well sustained by discharges from ground-water storage. In the upper Coastal Plain, the Lynches River near Bishopville exhibits better sustained base flow than farther downstream in the middle and lower Coastal Plain regions. Typically, middle and lower Coastal Plain streams do not have well-sustained low flows and have much more variable streamflow than upper Coastal Plain streams. This characteristic behavior can be seen at the Effingham gage, in the middle Coastal Plain (Figure 5-8).

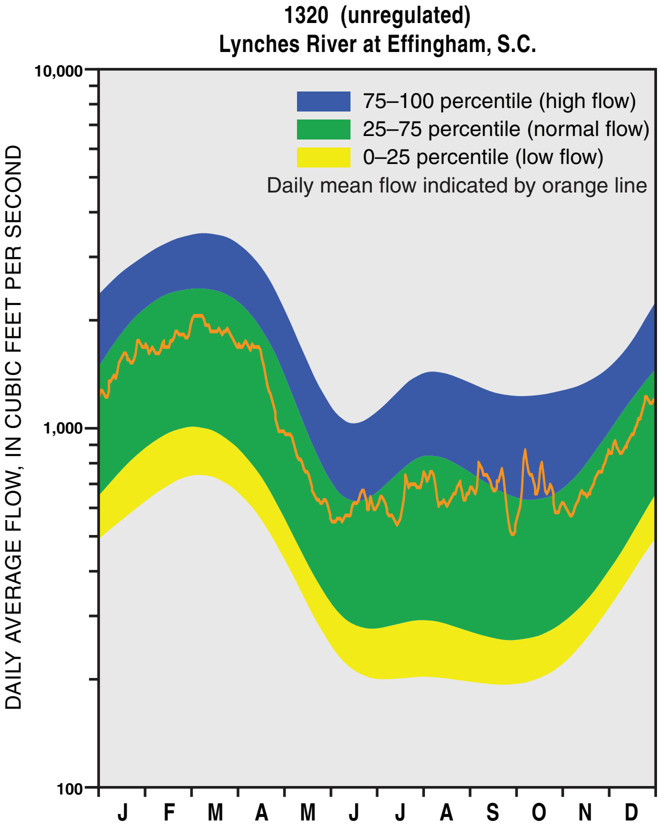


Figure 5-8. Duration hydrograph for the Lynches River at Effingham, S.C., gaging station.

Development

Surface-water development in the Lynches River subbasin is very limited and consists of small lakes and a few navigation and flood-control projects. There are no major reservoirs.

The largest lake has a surface area of 150 acres and a volume of 480 acre-ft. The aggregate surface area and volume of all lakes greater than 10 acres are approximately 1,840 acres and 8,550 acre-ft, respectively. Most of these lakes are used for recreational purposes, but many also are used for golf-course irrigation.

In 1982, the U.S. Army Corps of Engineers completed a navigation project on the Lynches River from S.C. Highway 41 downstream to Clarks Creek and on Clarks Creek from the Lynches River to the Great Pee Dee River.

Four flood-control projects were completed by the Natural Resources Conservation Service during the 1960's; work included drainage, 25 miles of channel improvement, one floodwater-retarding structure, and land-treatment practices to reduce erosion and sediment problems. Erosion-control, flood-control, and drainage work near the Salem community was authorized in 1986 but has been inactive.

Surface-Water Quality

All classified streams in the Lynches River subbasin are designated as “Freshwater” (Class FW). Class FW water is suitable for survival and propagation of aquatic life, primary- and secondary-contact recreation, a source for drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2007b).

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 49 surface-water sites in the Lynches River subbasin in 2003 in order to assess the water's suitability for aquatic life and recreational use (Figure 5-9). Aquatic-life uses were fully supported at 30 sites, or 61 percent of the water bodies sampled in this subbasin; water at the impaired sites exhibited low dissolved-oxygen levels, poor macroinvertebrate-community structure, pH excursions, or high copper levels. Recreational use was fully supported in 58 percent of the sampled water bodies; the water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2007b). Water-quality impairments in the subbasin are listed in Table 5-8.

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, DHEC issued a fish-consumption advisory for the Lynches River from US Highway 15 to the Great Pee Dee River. Fish-consumption advisories are issued in areas where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for skiing, boating, or swimming.

GROUND WATER

Hydrogeology

Most of the Lynches River subbasin is in the Coastal Plain province of South Carolina. Only the northern part of the subbasin is in the Piedmont province. The eastern half of Lancaster County and the extreme northwest corner of Chesterfield County are in rocks of the Carolina terrane, in which ground water occurs in fractures and along bedding and cleavage planes of the rocks or in the mantle of overlying weathered rock (saprolite). Owing to the conditions of ground-water occurrence in crystalline-rock aquifers, it is not unusual to have wells with high yields in close proximity to “dry holes.”

There are two granite plutons in the Piedmont part of the subbasin. A large pluton occurs in the southern part of Lancaster County and covers only a small part of the northwest edge of the subbasin. A smaller pluton is in the eastern corner of Lancaster County and a portion of northwestern Chesterfield County. This area of Chesterfield

Figure 5-9. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 5-8 (DHEC, 2007b).

Table 5-8. Water-quality impairments in the Lynches River subbasin (DHEC, 2007b)

Water-body name	Station number	Use	Status	Water-quality indicator
Hills Creek	PD-333	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Lynches River	PD-113	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
North Branch Wildcat Creek	PD-179	Recreation	Nonsupporting	Fecal coliform
	PD-679	Aquatic life	Partially supporting	Macroinvertebrates
South Branch Wildcat Creek	PD-180	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Partially supporting	Fecal coliform
Flat Creek	PD-182	Aquatic life	Partially supporting	Macroinvertebrates
	PD-342	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Little Lynches River	PD-640	Aquatic life	Partially supporting	Macroinvertebrates
	PD-006	Aquatic life	Nonsupporting	Copper
		Recreation	Nonsupporting	Fecal coliform
	PD-632	Aquatic life	Partially supporting	Macroinvertebrates
	PD-344	Aquatic life	Nonsupporting	pH
Horton Creek	PD-335	Recreation	Partially supporting	Fecal coliform
Todds Branch	PD-005	Recreation	Nonsupporting	Fecal coliform
Lick Creek	PD-329	Recreation	Partially supporting	Fecal coliform
Hanging Rock Creek	PD-328	Recreation	Partially supporting	Fecal coliform
	PD-669	Aquatic life	Partially supporting	Macroinvertebrates
Lynches River	PD-066	Recreation	Partially supporting	Fecal coliform
Little Fork Creek	PD-647	Aquatic life	Partially supporting	Macroinvertebrates
	PD-215	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Fork Creek	PD-067	Recreation	Nonsupporting	Fecal coliform
	PD-068	Recreation	Nonsupporting	Fecal coliform
Newman Swamp	PD-229	Recreation	Partially supporting	Fecal coliform
Sparrow Swamp	PD-072	Recreation	Partially supporting	Fecal coliform
Cousar Branch	PD-112	Aquatic life	Nonsupporting	pH
Lynches River	PD-364	Aquatic life	Nonsupporting	pH
	PD-319	Aquatic life	Partially supporting	pH
	PD-093	Aquatic life	Partially supporting	pH
Lake Swamp	PD-086A	Aquatic life	Nonsupporting	Dissolved oxygen
Lynches River	PD-281	Aquatic life	Nonsupporting	Copper
Big Swamp	PD-169	Recreation	Partially supporting	Fecal coliform

County also has a Triassic basin (indurated sedimentary rocks) exposed at the surface. The part of Kershaw County in the subbasin is completely overlain by Coastal Plain sediments, but many wells in the northeastern part of the county are drilled through the sediments and into the crystalline bedrock. Drilled bedrock wells in the northern (Piedmont) section of the subbasin range in depth from 45 to 600 feet, with an average depth of 205 feet (Table 5-9). Well yields are as great as 330 gpm (gallons per minute) locally; the average yield is 27 gpm. DNR has no records of bored wells in the Piedmont reaches of the subbasin.

Table 5-9. Well depths and yields for drilled bedrock wells in the northwest area of the Lynches River subbasin

County	Well depth (feet)		Well yield (gpm)	
	Average	Maximum	Average	Maximum
Chesterfield	196	420	29	50
Kershaw	455	550	135	330
Lancaster	196	600	24	200
Total	205	600	27	330

The southern part of the subbasin is underlain by rocks that range in age from Late Cretaceous to Holocene, and typical well depths and yields are shown in Table 5-10. The top of the Middendorf aquifer is 250 feet below sea level in the vicinity of Lynchburg and 440 feet below sea level at Lake City. An 800-foot test hole near Lynchburg did not penetrate the entire aquifer. Well yields of 800 gpm have been obtained in this area. Values for transmissivity as great as 13,000 ft^2/day and hydraulic conductivity of about 65 ft/day are calculated from pumping tests.

Table 5-10. Selected ground-water data for the Lynches River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Jefferson	Carolina slate belt	150–420	50
Kershaw	Granite	125–600	110
Bethune	Middendorf	94–218	500
Olanta	Black Creek	175–340	300–450
Lake City	Black Creek/ Middendorf	120–700	75–1,275

The top of the Black Creek aquifer is about 50 feet above sea level at Lynchburg and 100 feet below sea level at Lake City. The thickness of the aquifer increases from about 300 to 370 feet between the two sites. Wells with 8- and 10-inch casings in Florence County yield as much as 1,300 gpm with specific capacities of 20 gpm/ft or more. The transmissivity of the Black Creek aquifer at Pamplico is 4,000 ft^2/day. Hydraulic-conductivity values in eastern Florence County are in the range of 10 to 60 ft/day.

The Peedee Formation underlies the southeastern part of the Lynches River subbasin and mainly is a confining unit for the Black Creek aquifer. Its thickness is estimated to range from 20 feet in Lynchburg to 130 feet in the Lake City area. The formation probably yields sufficient water to supply domestic and light industrial needs, with well specific capacities of less than 5 gpm/ft.

The Black Mingo Formation, a component of the Tertiary sand aquifer, is at a shallow depth and generally is not differentiated from the shallow aquifer in the subbasin. The shallow aquifer there mainly is composed of the Duplin Formation and terrace deposits. Specific water-bearing characteristics of this aquifer are unknown in the Lynches River subbasin, although general well data indicate that yields are sufficient for domestic and light-industrial purposes.

Ground-Water Quality

The upper reaches of the subbasin lie in the Carolina slate belt, where the ground water is generally a calcium bicarbonate type, soft, and with low TDS (total dissolved solids), iron, and pH. Bedrock wells in Kershaw County are generally of good quality, with TDS less than 200 mg/L (milligrams per liter), pH between 7 and 8, and hardness variable from very soft to hard (Newcome, 2002). Crystalline-rock wells in the subbasin part of Lancaster and Chesterfield Counties show similar properties. Overall, TDS in the Piedmont segment of this subbasin have a median concentration of 54 mg/L. The pH of the ground water ranges from 5.8 to 8.7, with a median value of 6.7, and the alkalinity ranges from 0.04 to 2.40 meq/L (milliequivalents per liter), with a median of 0.4 meq/L.

The Middendorf and the Black Creek are the two most widely used aquifers in the middle and lower reaches of the subbasin. The middle reach of the basin, in eastern Lee and Kershaw Counties and western Darlington County, is in the outcrop area of the Middendorf aquifer, where the water is characterized by low TDS, low pH, low alkalinity, and is soft and corrosive. Sand wells in Kershaw County rarely have TDS greater than 30 mg/L, hardness is usually less than 10 mg/L, and pH ranges generally between 4 and 6. Iron-reducing bacteria are a problem in some wells; however, use of plastic pipe and proper well sanitation reduces the likelihood of bacteriological problems. The water quality for this aquifer ranges from a sodium chloride to a calcium bicarbonate type.

In the lower reach of the basin, in southern Florence County and part of northern Williamsburg County, the Black Creek aquifer is the primary ground-water source. Water of that aquifer is slightly acidic to alkaline and has TDS generally less than 200 mg/L. Some constituents locally exceed water-quality standards, including iron, magnesium, and fluoride. Water from the Cretaceous aquifers in this basin reach is a sodium bicarbonate type and becomes more mineralized toward the coast. Water in the Middendorf aquifer has low alkalinity and has TDS concentrations greater than 250 mg/L.

Shallow aquifers in the subbasin contain water having little mineral content. Total dissolved solids are usually less than 100 mg/L, with 30 mg/L or less being typical in Kershaw County and 50 mg/L or less in Sumter County. Values for pH are generally less than 6.5, and values between 4.0 and 5.0 occur locally.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR, USGS, and DHEC in 10 wells within the Lynches River subbasin to help assess trends or changes in water levels and to monitor areas with known water-level problems (Table 5-11). Water levels in other wells in the subbasin are sometimes measured to help develop potentiometric maps of the Middendorf and Black Creek aquifers.

Table 5-11. Water-level monitoring wells in the Lynches River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
CTF-189	DHEC	34 31 05 80 17 22	Middendorf	4 miles northwest of McBee	304	50–85
CTF-197	USGS	34 39 07 80 16 44	Middendorf	7 miles east of Jefferson	564	100–130
CTF-221	DHEC	34 25 44 80 16 58	Middendorf	3 miles southwest of McBee	395	235–255
CTF-222	USGS	34 25 44 80 16 58	Black Creek	3 miles southwest of McBee	395	150–170
FLO-85	USGS	34 08 06 79 56 31	Middendorf	Timmonsville	145	235–515
FLO-274	DNR	33 51 20 79 45 59	Middendorf	Lake City Airport	79	540–560
FLO-276	DNR	33 51 22 79 46 00	Black Creek	Lake City Airport	79	230–250
FLO-474	DHEC	34 01 01 79 45 16	Black Creek/ Middendorf	3 miles north of Coward	80	undetermined
KER-263	DNR	34 33 30 80 26 37	Crystalline rock	Mt. Pisgah	470	103–455
LEE-75	DNR	34 12 08 80 10 30	Middendorf	Lee State Park	195	306–356

* *DHEC, South Carolina Department of Health and Environmental Control; DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

While there are currently no site-specific water-level problems in the Lynches River subbasin, a small cone of depression has developed in the Middendorf aquifer, centered in Lee County near Bishopville (in the Black River subbasin), and has lowered Middendorf water levels in the Bishopville area by about 60 feet (Hockensmith, 2008a). Water-level declines observed in both the Black Creek and Middendorf aquifers in the Florence area (Pee Dee River subbasin) do not appear to be significantly impacting water levels within the Lynches River subbasin. Similarly, lowered ground-water levels caused by pumping in Sumter County and near the town of Hemingway in Williamsburg County (both in the Black River subbasin) do not appear to be influencing ground-water levels within the Lynches River subbasin.

Years of pumping from wells in this subbasin and in neighboring subbasins have caused regional declines in water levels in both the Black Creek and Middendorf aquifers, particularly in the southernmost part of the subbasin. In southern Florence County, water levels in the Black Creek aquifer are about 50 feet lower than predevelopment levels, and water levels in the Middendorf aquifer have declined as much as 75 feet from predevelopment levels (Hockensmith, 2008a and 2008b).

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Lynches River subbasin is summarized in Table 5-12 and Figure 5-10. Total offstream water use in the Lynches River subbasin was 3,184 million gallons in 2006, ranking it thirteenth among the 15 subbasins. Of this amount, 3,115 million gallons came from groundwater sources (98 percent) and 69 million gallons came from surface-water sources (2 percent). Water-supply use accounted for 64 percent of this total, followed by industry (32 percent) and golf course irrigation (3 percent). Consumptive use in this subbasin is estimated to be 449 million gallons, or about 14 percent of the total offstream use.

Table 5-12. Reported water use in the Lynches River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	62	89.4	22	0.7	84	2.6
Industry	0	0.0	1,022	32.8	1,022	32.1
Irrigation	7	10.6	20	0.7	27	0.9
Mining	0	0.0	17	0.5	17	0.5
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	0	0.0	0	0.0	0	0.00
Water supply	0	0.0	2,034	65.3	2,034	63.9
Total	69		3,115		3,184	

All of the 2,034 million gallons used for water-supply in this subbasin in 2006 were provided entirely by ground water. Of the 14 water-supply systems that have wells in the basin, Lake City is the largest and pumped 451 million gallons, all from the Middendorf aquifer. It was followed by the city of Bishopville, which pumped 429 million gallons (Middendorf aquifer); Alligator Rural Water Company in Chesterfield County, which pumped 317 million gallons (Middendorf aquifer); Darlington Water and Sewer Authority, which pumped 219 million gallons (Middendorf aquifer); and the town of Timmonsville in Florence County, which pumped 158 million gallons (Middendorf and Black Creek aquifers). Alligator Rural Water Company and Darlington Water and Sewer Authority have a number of wells in the Pee Dee River subbasin to the east, and Bishopville has two supply wells in the Black River subbasin to the west.

Industrial water use totaled 1,022 million gallons in the Lynches subbasin in 2006, all of it from wells. Wellman, Inc., near Johnsonville, had the highest use, pumping 635 million gallons from the Middendorf and Black Creek aquifers. BBA Fiberweb, near Bethune in Kershaw County, used 333 million gallons, pumping from the Middendorf aquifer.

Golf-course water use totaled 84 million gallons in 2006. Of this amount, 62 million gallons were surface water (74 percent) and 22 million gallons were ground water (26 percent). All of the irrigation was done at Fox Creek Golf Course in Darlington County near the town of Lydia. Water is pumped from a pond located on the golf course and from several wells.

Irrigation water use totaled 27 million gallons, which is 1 percent of the total water use in the subbasin. Of this amount, 20 million gallons came from wells (73 percent) and 7 million gallons were from surface-water sources (27 percent). Small amounts of ground water (17 million gallons) were used for mining activities in the subbasin.

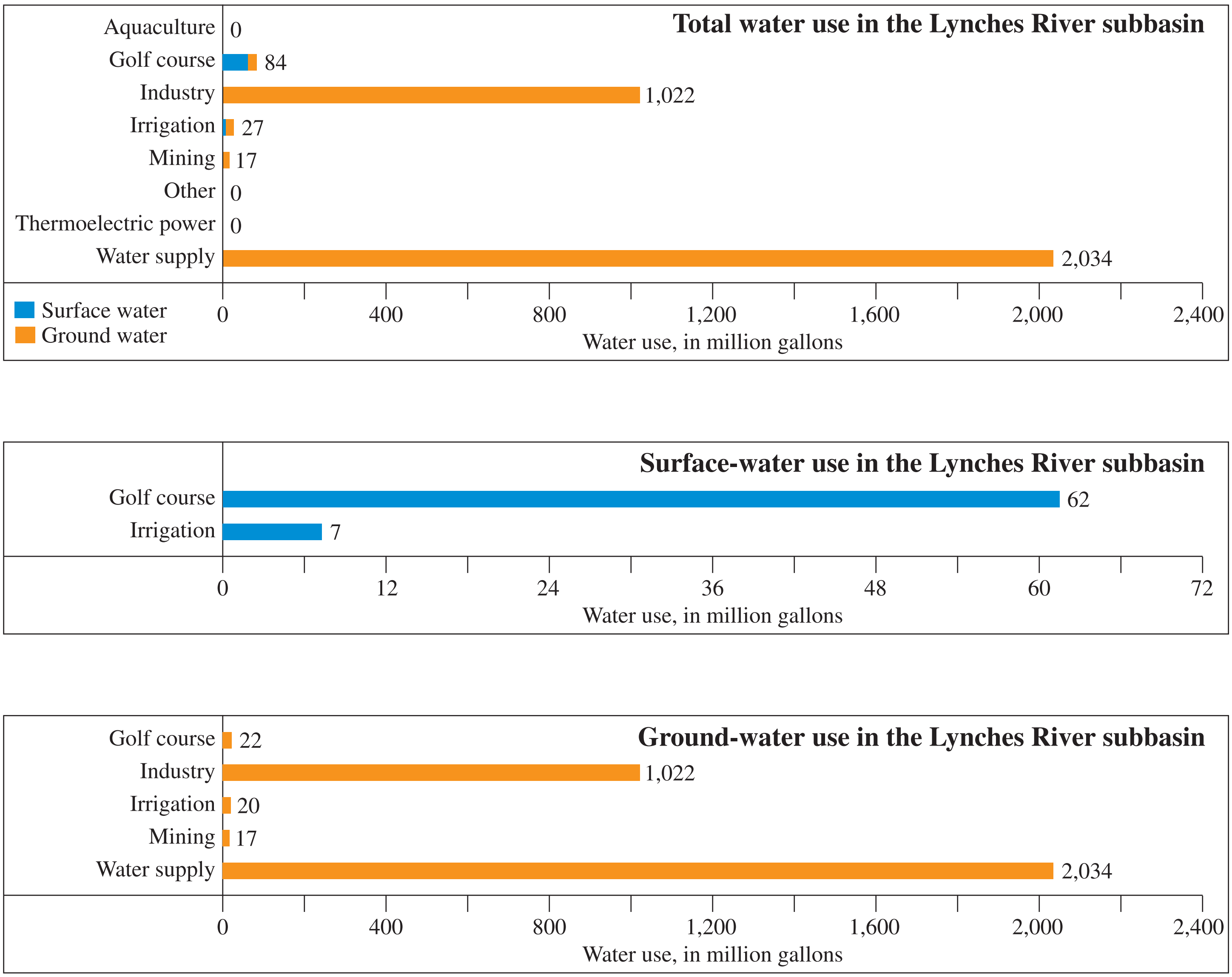
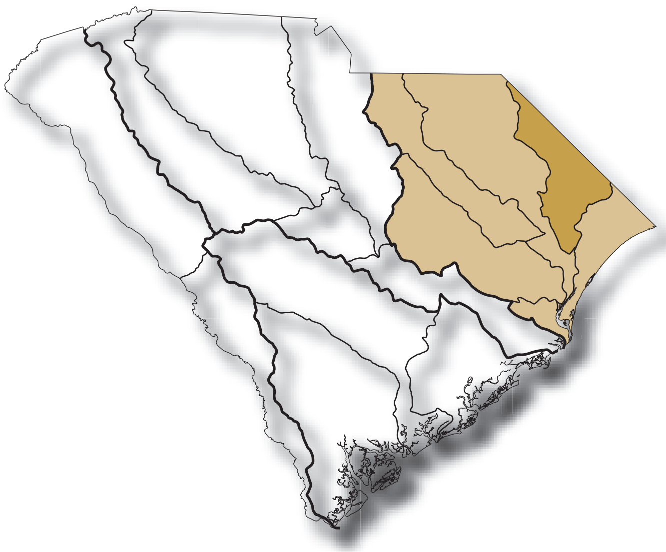


Figure 5-10. Reported water use in the Lynches River subbasin for the year 2006 (modified from Butler, 2007).

LITTLE PEE DEE RIVER SUBBASIN



LITTLE PEE DEE RIVER SUBBASIN

The Little Pee Dee River subbasin is in the northeastern part of the Pee Dee region of South Carolina. This subbasin shares a common border with North Carolina and encompasses parts of four South Carolina counties: Dillon, Marion, Horry, and Marlboro (Figure 5-11). The subbasin area is approximately 1,100 square miles, 3.5 percent of the State's land area.

DEMOGRAPHICS

The 2000 population of the subbasin was estimated at 75,500, less than 2 percent of the State's total population. The subbasin population is expected to reach almost 86,000 by the year 2020. The largest population increases from 2000 to 2020 are expected in Horry County (40 percent).

The four counties, where encompassed by the subbasin, have predominantly rural populations, with Dillon County being classified as over 65 percent rural. Although Horry County is about 40 percent rural overall, most of the rural population is in the Little Pee Dee subbasin whereas its urban population is in the Waccamaw subbasin to the east. The major centers of population in the subbasin are Dillon (6,316) in Dillon County and Mullins (5,029) in Marion County: both centers experienced population declines during the previous decade. The subbasin boundary is near the urban areas of Conway (11,788) on the east and Bennettsville (9,425) on the northwest.

All four counties in the subbasin had a year 2005 per capita personal income below the State average ($28,285). Horry County was closest, with a per capita income of $26,789, ranking 15th among the 46 counties. Marion County ranked 44th, with a per capita income of $20,299; Marlboro County ranked 41st, with $20,485; and Dillon County ranked 39th, with $20,850. The 1999 median household income ranged from $36,470 in Horry County to $26,526 in Marion County.

In 2000, the annual average employment of nonagricultural wage and salary workers in Dillon, Horry, and Marion Counties was about 124,000. Labor distribution in the subbasin counties included sales and office, 28 percent; management, professional, and technical services, 24 percent; service, 18 percent; production, transportation, and materials moving, 16 percent; construction, extraction, and maintenance, 13 percent; and farming, fishing, and forestry, 1 percent.

In the sectors of manufacturing, mining, and public utilities, the combined annual product value from the counties of the subbasin was $2.8 billion in 1997 (South Carolina Budget and Control Board, 2005), but most production occurred outside the Little Pee Dee subbasin boundaries.

Agriculture remained important in this section of the State, and crops and livestock produced a cash value of about $200 million in 2000. Timber production in the area generated $76.7 million in 2005, with Horry County accounting for nearly half of timber sales in the region (South Carolina Forestry Commission, 2008).

Figure 5-11. Map of the Little Pee Dee River subbasin.

SURFACE WATER

Hydrology

The two major watercourses in this subbasin are the Little Pee Dee River and a major tributary, the Lumber River. Headwaters for both streams are in the Sandhills region of North Carolina. Several small to moderately sized tributary streams drain the subbasin, including Buck Swamp, Bear Swamp, and Lake Swamp. Typical of many Coastal Plain streams, extensive swamplands are associated with much of the main stem and tributary streams, resulting in meandering and often ill-defined stream channels.

The General Assembly designated 14 miles of the Little Pee Dee River from Highway 378 to the confluence with the Great Pee Dee River as a State Scenic River in 1990. An additional 64 miles of the river extending upstream from Highway 378 were determined eligible for scenic-river status in 1997 but have not yet been formally designated. Lastly, in the upper portion of the Little Pee Dee River, a 46-mile segment in Dillon County that begins at Parish Mill Bridge on State Road 363 near the Marlboro County line and extends southeast to the State Road 72 bridge near the Marion County line was designated as a State Scenic River in 2005. (See the *River Conservation* section of Chapter 9, *Special Topics*.)

Streamflow is currently monitored at only one site in this subbasin, Galivants Ferry on the Little Pee Dee River. A discontinued streamflow-gaging station on the Little Pee Dee River near Dillon presently monitors only crest-stage data. The Lumber River is monitored by three gaging stations in North Carolina: near Maxton, at Lumberton, and at Boardman. One gaging station is active in North Carolina for a tributary stream of the Little Pee Dee River, Big Shoe Heel Creek near Laurinburg. There are also two streamflow gages on tributary streams, Drowning Creek near Hoffman and Big Swamp near Tarheel. Streamflow statistics for some of these stations are presented in Table 5-13.

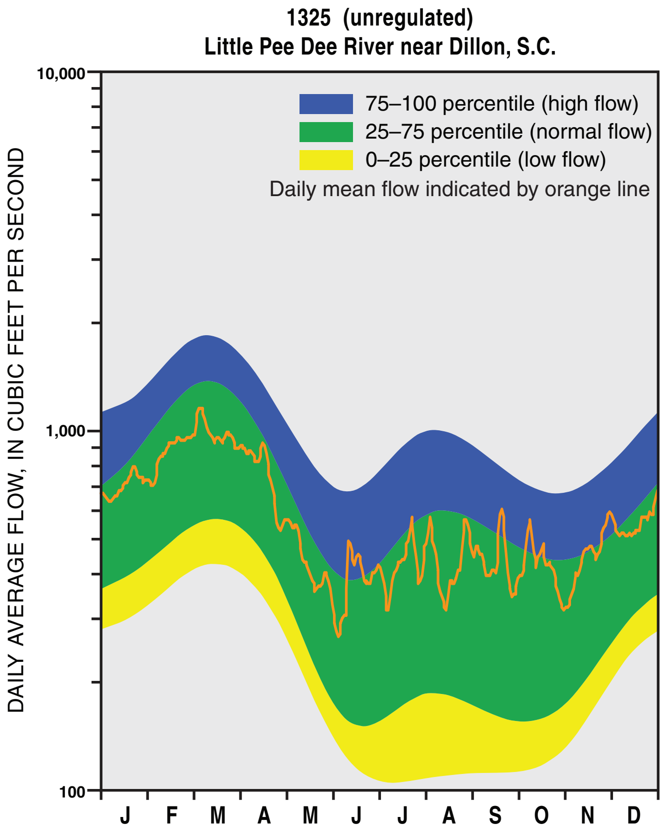
Table 5-13. Selected streamflow characteristics at USGS gaging stations in the Little Pee Dee River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Little Pee Dee River near Dillon 1325	1939 to 1971	524	577	1.10	155	24 1954	– – –	9,810 1945
Lumber River at Boardman, N.C. 1345	1929 to 2007*	1,228	1,308	1.07	290	42 2002	13,400 1945, ’99	13,400 1945, ’99
Little Pee Dee River at Galivants Ferry 1350	1942 to 2007*	2,790	3,033	1.09	588	73 2002	27,500 1964	27,600 1964

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

At the two gaging sites on the Little Pee Dee River, streamflow characteristics are similar and suggest somewhat variable and potentially limited surface-water availability (Figure 5-12). The unit-average discharges at the gages are nearly equal and similar to the regional unit-average discharge. Flows are mainly dependent on rainfall and direct runoff, with lower streamflows partially supplemented by base flow from ground-water storage. Average flow of the Little Pee Dee River is almost 600 cfs (cubic feet per second) near Dillon and more than 3,000 cfs at Galivants Ferry. The lowest flows of record were 24 cfs near Dillon in 1954 and 73 cfs at Galivants Ferry in 2002. The flood flow of record occurred in 1964 at Galivants Ferry (27,600 cfs) due to runoff from tropical storm Hilda that produced localized flooding.

Streamflow in the Little Pee Dee River is fairly reliable; however, surface-water storage would be needed to ensure adequate water supplies during periodic low-flow conditions. The similarity of streamflow characteristics at the main-stem gaging stations suggests similar characteristics for tributary streams in the same physiographic province in the subbasin.



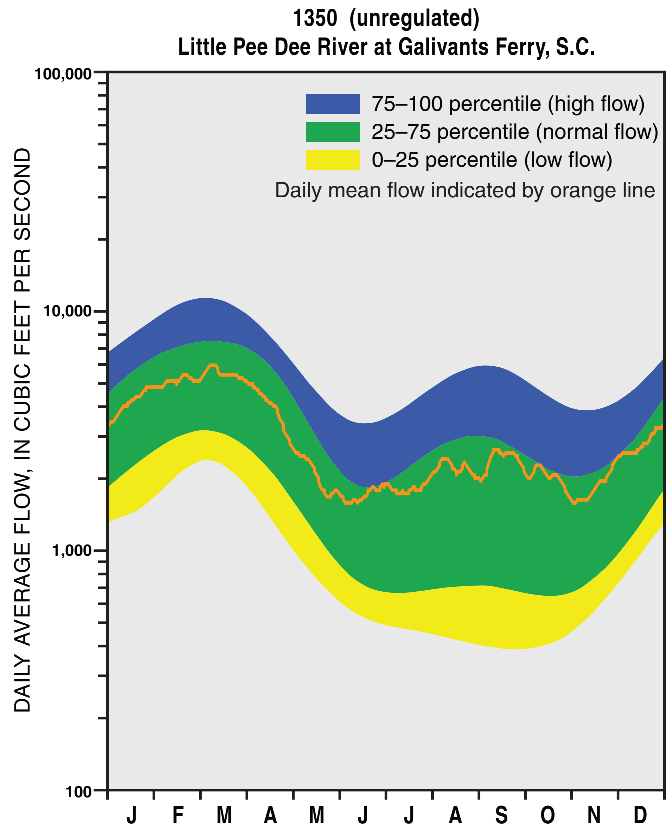


Figure 5-12. Duration hydrographs for selected gaging stations in the Little Pee Dee River subbasin.

Development

Surface-water development in the Little Pee Dee River subbasin is not extensive. Pages Mill Pond, near Lake View in Dillon County, is the largest body of water, with a surface area of 200 acres and a volume of 640 acre-ft. The aggregate surface area of all lakes of 10 acres or more is 1,310 acres, and the total volume is about 4,300 acre-ft.

The U.S. Army Corps of Engineers (COE) navigation projects for the Little Pee Dee River and Lumber River were deauthorized by Congress in 1977. Flood-control work in Gapway Swamp was completed by the COE in 1968. Natural Resources Conservation Service (NRCS) projects for the Cartwheel community and Maple Swamp were completed in the late 1960's; the later project included 10 miles of channel work. In 2006, the NRCS was authorized to plan flood control in the Latta watershed in Dillon County.

Surface-Water Quality

Most of the water bodies in the Little Pee Dee River subbasin are designated as "Freshwater" (Class FW). This class of water is suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2007b).

A part of the Little Pee Dee River and Cedar Creek are designated "Outstanding Resource Water" (Class ORW). These freshwater streams constitute outstanding recreational or ecological resources and are suitable as a drinking-water source with minimal treatment.

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 29 surface-water sites in the Little Pee Dee River subbasin in 2003 in order to assess the water's suitability for aquatic life and recreational use (Figure 5-13). Aquatic-life uses were fully supported at 21 sites, or 72 percent of the water bodies sampled in this subbasin; most of the impaired water exhibited dissolved-oxygen levels below the concentrations needed to support aquatic life. Recreational use was fully supported in 78 percent of the sampled water bodies; the water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2007b). Water-quality impairments in the subbasin are listed in Table 5-14.

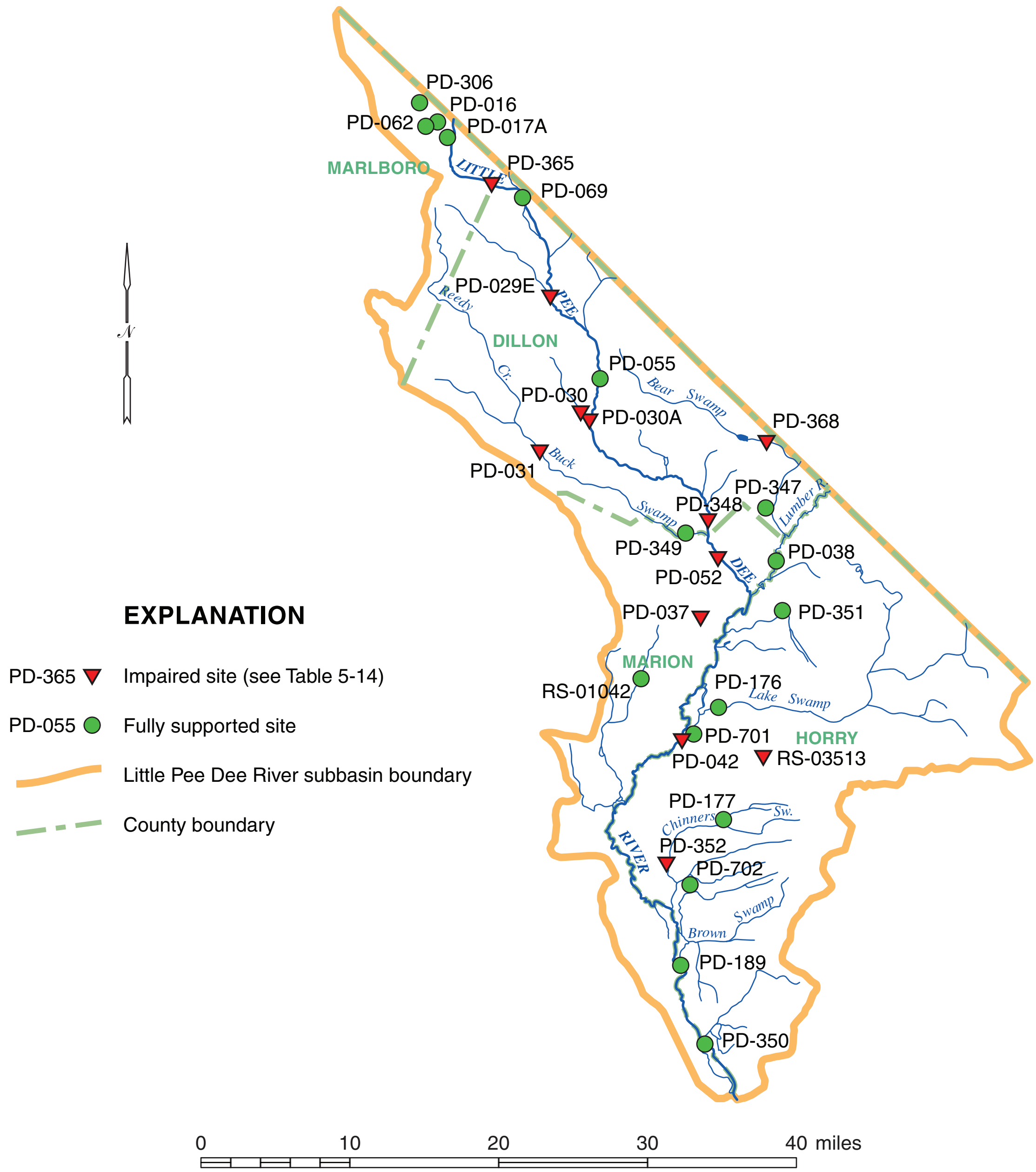


Figure 5-13. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 5-14 (DHEC, 2007b).

Table 5-14. Water-quality impairments in the Little Pee Dee River subbasin (DHEC, 2007b)

<table>
<tr><th>Water-body name</th><th>Station number</th><th>Use</th><th>Status</th><th>Water-quality indicator</th></tr>
<tr><td>Bear Swamp</td><td>PD-368</td><td>Aquatic life</td><td>Nonsupporting</td><td>Dissolved oxygen</td></tr>
<tr><td>Little Pee Dee River</td><td>PD-365</td><td>Aquatic life</td><td>Nonsupporting</td><td>pH</td></tr>
<tr><td>Buck Swamp</td><td>PD-031</td><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td rowspan="5">Little Pee Dee River</td><td>PD-029E</td><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td rowspan="2">PD-030A</td><td>Aquatic life</td><td>Nonsupporting</td><td>Dissolved oxygen</td></tr>
<tr><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td>PD-348</td><td>Aquatic life</td><td>Nonsupporting</td><td>pH</td></tr>
<tr><td>PD-052</td><td>Aquatic life</td><td>Partially supporting</td><td>Copper</td></tr>
<tr><td>Maple Swamp</td><td>PD-030</td><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td>Loosing Swamp</td><td>RS-03513</td><td>Aquatic life</td><td>Nonsupporting</td><td>Dissolved oxygen</td></tr>
<tr><td>Chinners Swamp</td><td>PD-352</td><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td rowspan="2">White Oak Creek</td><td rowspan="2">PD-037</td><td>Aquatic life</td><td>Partially supporting</td><td>Dissolved oxygen</td></tr>
<tr><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td>Little Pee Dee River</td><td>PD-042</td><td>Aquatic life</td><td>Nonsupporting</td><td>Dissolved oxygen, pH</td></tr>
</table>

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, DHEC issued fish-consumption advisories for the Little Pee Dee River and the Lumber River from the North Carolina/South Carolina state line to the Great Pee Dee River. Fish-consumption advisories are issued where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for skiing, swimming, or boating.

GROUND WATER

Hydrogeology

The Little Pee Dee River subbasin is entirely in the Coastal Plain. The northwestern part of the subbasin obtains much of its ground-water supply from the Middendorf and Black Creek aquifers. This part of the subbasin is underlain by approximately 600 feet of unconsolidated sediments, mostly of the Middendorf and Black Creek Formations. Selected ground-water data for the subbasin are presented in Table 5-15.

The southeastern part of the subbasin is underlain by about 1,500 feet of sediment, predominantly of the Cape Fear, Middendorf, Black Creek, and Peedee Formations. The Black Creek is used almost exclusively as the ground-water source for large-capacity wells. In this area, the Middendorf is deep and increasingly mineralized with depth. The Peedee Formation is not a consistently good aquifer and principally confines the Black Creek aquifer. With the exception of one well in Loris, there are no large-capacity wells in the Peedee Formation.

Table 5-15. Selected ground-water data for the Little Pee Dee River subbasin

<table>
<tr><th>Vicinity</th><th>Aquifer</th><th>Well depth (feet)</th><th>Major well yield (gpm)</th></tr>
<tr><td>Dillon</td><td>Black Creek/ Middendorf</td><td>210–485</td><td>360–1,150</td></tr>
<tr><td>Mullins</td><td>Black Creek</td><td>320–390</td><td>370–1,500</td></tr>
<tr><td>Aynor</td><td>Black Creek</td><td>300–350</td><td>150–800</td></tr>
<tr><td rowspan="2">Loris</td><td>Black Creek (Peedee Formation)</td><td>100–200</td><td>250–500</td></tr>
<tr><td>Black Creek</td><td>320–460</td><td>250–800</td></tr>
</table>

Ground-Water Quality

Both the Middendorf and Black Creek aquifers are important ground-water sources in the Little Pee Dee subbasin. In the upper reach, both aquifers are used, and the water of both is of good quality. It is low in dissolved solids, with TDS (total dissolved solids) of about 150 mg/L (milligrams per liter), and is slightly acidic to slightly alkaline (Rodriguez and others, 1994; Speiran and Aucott, 1994). Locally, concentrations of manganese and iron exceed recommended limits. In Dillon County, water from these aquifer systems tends to be a sodium bicarbonate type (Newcome, 1989).

In the lower reach, in eastern Marion and western Horry Counties, the Black Creek is the principal aquifer system. Water from the Black Creek aquifer in Marion County is a sodium bicarbonate type with pH in the range of 7.0 to 8.0 and with high concentrations of TDS, manganese, fluoride, and sodium (Rodriguez and others, 1994). Water in western Horry County is similar in quality, although with pH greater than 8.5 and with TDS increasing to the east.

The Middendorf is generally unused in the lower reach of the subbasin, where it becomes increasingly mineralized with proximity to the coast and with depth. Total dissolved solids and bicarbonate concentrations exceed 500 mg/L at the southeast end. The toe of a diffuse saltwater wedge underlies southeast Marion County and northwestern Horry County, where chloride concentrations increase from less than 10 mg/L to about 100 mg/L (Speiran and Aucott, 1994).

Water-Level Conditions

Ground-water levels are continuously monitored by the DNR in only one well within the Little Pee Dee River subbasin, in Dillon County (Table 5-16). Water levels in other wells in the subbasin are sometimes measured to help develop potentiometric maps of the Middendorf and Black Creek aquifers.

Although there are no known site-specific water-level problems in this subbasin, years of pumping from wells in this subbasin and in neighboring subbasins have resulted in a regional lowering of water levels in the Black Creek aquifer throughout the southern half of the subbasin. In the Brittons Neck area of southern Marion County, water levels have declined nearly 60 feet from predevelopment levels (Hockensmith, 2008b).

Table 5-16. Water-level monitoring wells in the Little Pee Dee River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
DIL-121	DNR	34 19 58 79 16 48	Middendorf	Little Pee Dee State Park	95	269–284

* *DNR, South Carolina Department of Natural Resources*

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

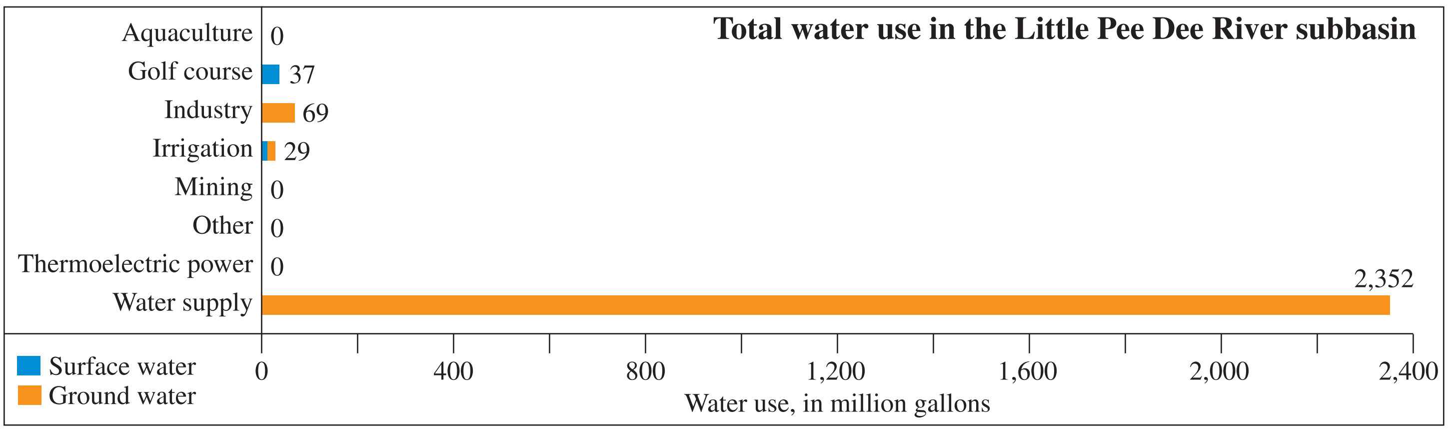
Water use in the Little Pee Dee River subbasin is summarized in Table 5-17 and Figure 5-14. Offstream water use totaled 2,487 million gallons in 2006, ranking it fourteenth among the 15 subbasins. Of this amount, 2,437 million gallons were from ground-water sources (98 percent) and 50 million gallons were from surface-water sources (2 percent). Water-supply use (2,352 million gallons) accounted for almost 95 percent of the total, followed by industry (3 percent), golf course use (2 percent), and irrigation (1 percent). Consumptive use in this subbasin is estimated to be 349 million gallons, or about 14 percent of the total offstream use.

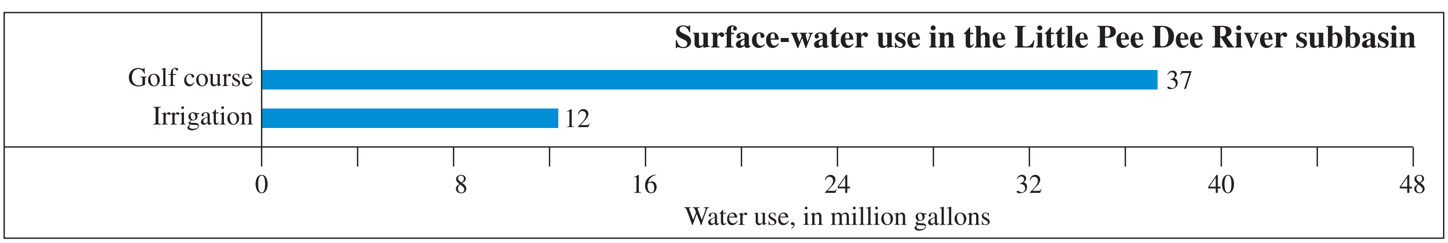
Water-supply use in the subbasin was provided entirely by ground water. Of the 10 water-supply systems that have wells in the basin, Trico Water Company, Inc. in Dillon County was the largest user. It pumped 870 million gallons from 13 wells completed in the Middendorf aquifer. It was followed by the city of Dillon, which pumped 430 million gallons (Middendorf aquifer); the city of Mullins, which pumped 292 million gallons (Middendorf and Black Creek aquifers); and Marco Rural Water Company, Inc., which pumped 237 million gallons (Middendorf aquifer).

Industrial water use in the subbasin totaled 69 million gallons in 2006, all of it from ground-water sources. Golf-course water use totaled 37 million gallons, all of it from surface-water sources. Irrigation use totaled 29 million gallons, slightly more than half of which came from wells.

Table 5-17. Reported water use in the Little Pee Dee River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	37	75.1	0	0.0	37	1.5
Industry	0	0.0	69	2.8	69	2.8
Irrigation	12	24.9	16	0.7	29	1.2
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	0	0.0	0	0.0	0	0.0
Water supply	0	0.0	2,352	96.5	2,352	94.6
Total	50		2,437		2,487	





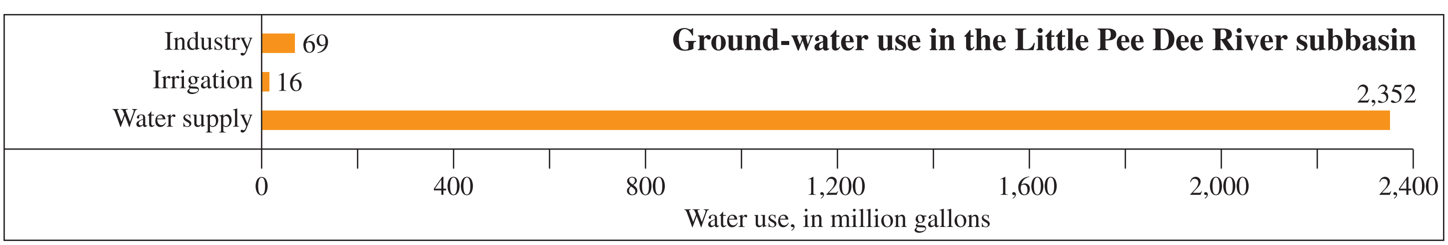
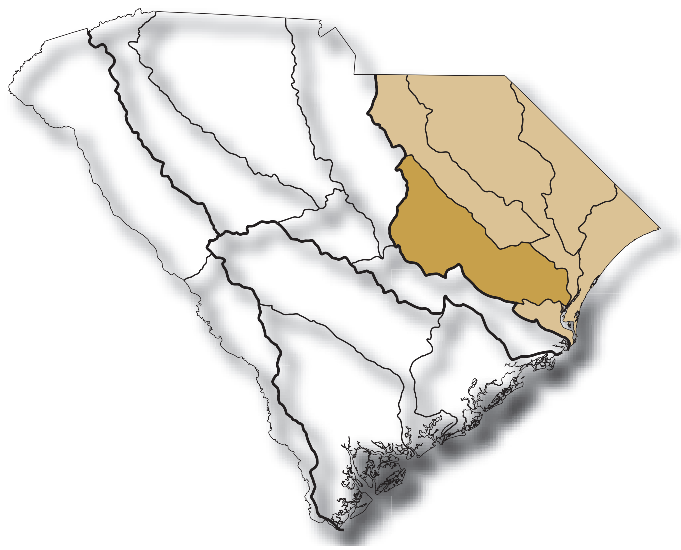


Figure 5-14. Reported water use in the Little Pee Dee River subbasin for the year 2006 (modified from Butler, 2007).

BLACK RIVER SUBBASIN



BLACK RIVER SUBBASIN

The Black River subbasin transects the central part of South Carolina from the western fringe of the Pee Dee region southeast to the upper extent of Winyah Bay. With a northwest-southeast orientation, the subbasin extends into the west edge of Kershaw County and encompasses parts of six additional counties, Sumter, Williamsburg, Georgetown, Clarendon, Lee, and Florence (Figure 5-15). The area of the subbasin is 2,045 square miles, 6.6 percent of the State's land area.

DEMOGRAPHICS

The 2000 subbasin population was estimated at 175,200, about 4.4 percent of the State's total population. The population in the subbasin is projected to increase by about 5 percent by the year 2020. In contrast, the total population of South Carolina is expected to increase 20 percent during this period, and Georgetown and Sumter Counties are expected to increase about 23 percent.

The Black River subbasin population is predominantly very rural, with the exception of Sumter County, in which over half of the residents are classified as urban. The city of Sumter contains more than half of Sumter County's urban population.

The major population centers are Sumter (39,643), Manning (4,025), Kingstree (3,496), Bishopville (3,670), and Andrews (3,068).

In the subbasin, year 2005 per capita income ranged from $30,399 in Georgetown County, which ranked sixth among the 46 counties, to $20,005 in Williamsburg County, which ranked 45th in the State. The 2005 per capita income in South Carolina averaged $28,285. Williamsburg County also had the lowest 1999 median household income ($24,214), about $13,000 lower than the State's median household income of $37,082. The median household incomes in Sumter and Georgetown Counties were $33,278 and $35,312, respectively.

The 2000 annual average employment of non-agricultural wage and salary workers in the counties of the subbasin totaled 158,000, almost 9 percent of the State's total. Labor distribution in the subbasin counties included management, professional, and technical services, 26 percent; sales and office, 24 percent; production, transportation, and materials moving, 21 percent; service, 16 percent; construction, extraction, and maintenance, 12 percent; and farming, fishing, and forestry, 1 percent.

Manufacturing, mining, and utilities in the principal counties of the subbasin produced about $6 billion in 1997. Florence and Sumter Counties accounted for more than two-thirds of that output, and the two counties ranked eighth and ninth in the State, respectively.

Agricultural output was nearly $300 million in 2000. Florence and Sumter Counties ranked fifth and eighth in the State, and all but Georgetown County ranked in the top one-third. The production of timber products exceeded $114 million in 2005, with Georgetown, Williamsburg, and Florence Counties ranking fourth, eighth, and tenth, respectively (South Carolina Forestry Commission, 2008).

SURFACE WATER

Hydrology

The dominant watercourse draining the subbasin is the Black River. The principal tributaries draining into the Black River include the Pocotaligo River, Scape Ore Swamp, Pudding Swamp, and Black Mingo Creek. The Black River discharges directly into Winyah Bay at the

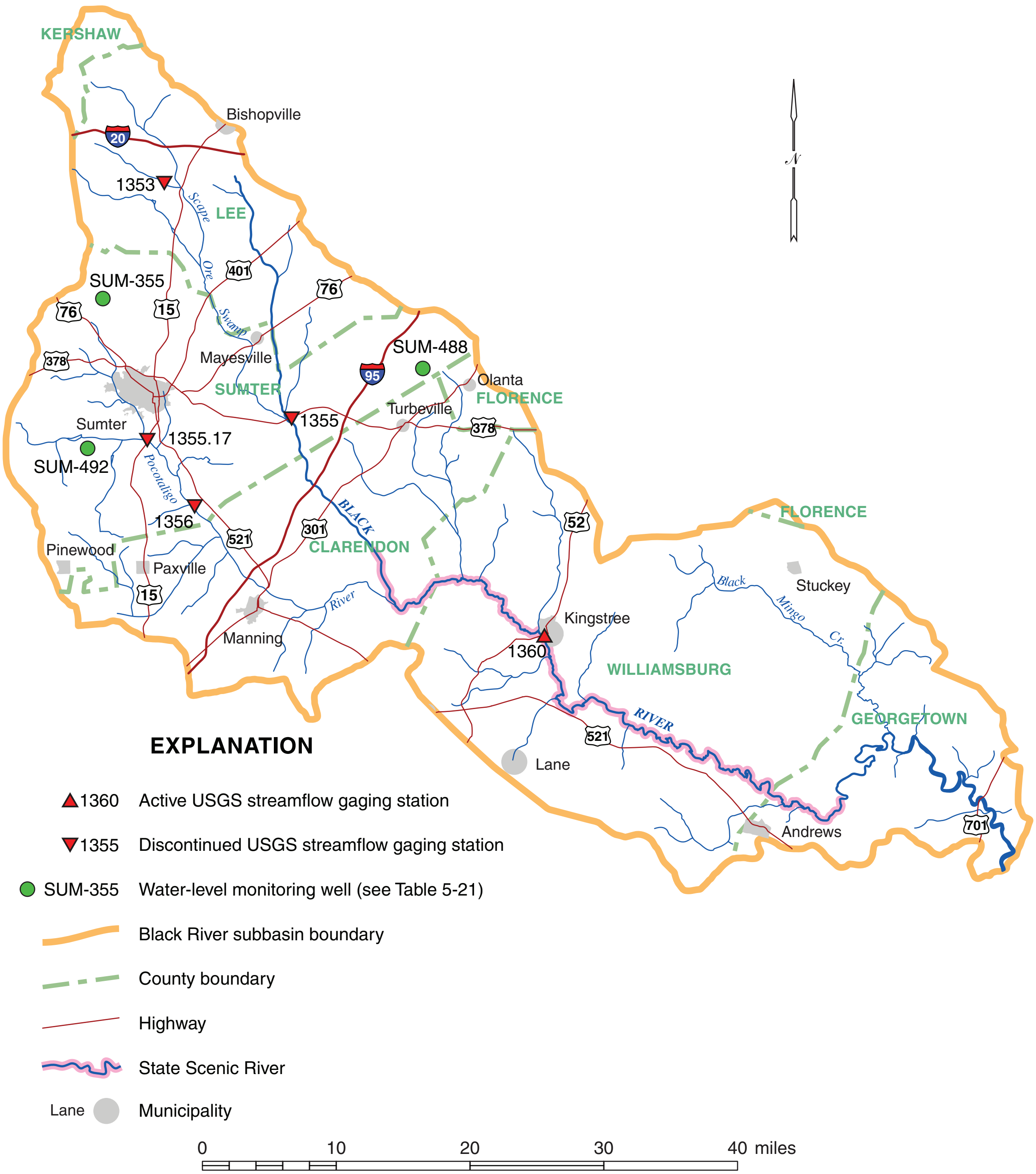


Figure 5-15. Map of the Black River subbasin.

southwest end of the Waccamaw subbasin. Most of the streams are entirely within the middle and lower Coastal Plain regions, with only Scape Ore Swamp located in the upper Coastal Plain region. Extensive swamplands border much of the Black River and its tributaries, frequently resulting in ill-defined and meandering stream channels.

A 75-mile segment of the Black River from County Road 40 in Clarendon County through Williamsburg County to Pea House Landing at the end of County Road 38 in Georgetown County became a State Scenic River in 2001. (See the *River Conservation* section of Chapter 9, *Special Topics*.)

Streamflow in the Black River is currently monitored at only one site, at Kingstree, although high flows are monitored at three crest-stage stations. Another Black River gage located near Gable in Sumter County was discontinued in 1992. Three other gages, two on the Pocotaligo River near Sumter and one in Scape Ore Swamp near Bishopville, are no longer in service (Figure 5-15). Streamflow statistics for these gages are presented in Table 5-18.

Table 5-18. Selected streamflow characteristics at USGS gaging stations in the Black River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Scape Ore Swamp near Bishopville 1353	1968 to 2003	96	97.5	1.02	17	3.5 1986	4,150 1990	4,500 1990
Black River near Gable 1355	1951-66 and 1972-92	401	381	0.95	25	0.0 1954, ’56, ’57	7,590 1965	12,500** 1971
Pocotaligo River at Sumter 1355.17	1992 to 1995	134	155	1.16	21	6.2 1994	4,550 1994	5,080 1994
Pocotaligo River near Sumter 1356	1992 to 1995	185	201	1.09	41	11 1993	2,690 1994	2,790 1994
Black River at Kingstree 1360	1929 to 2007*	1,252	948	0.76	48	2.0 1954	52,800 1973	58,000 1973

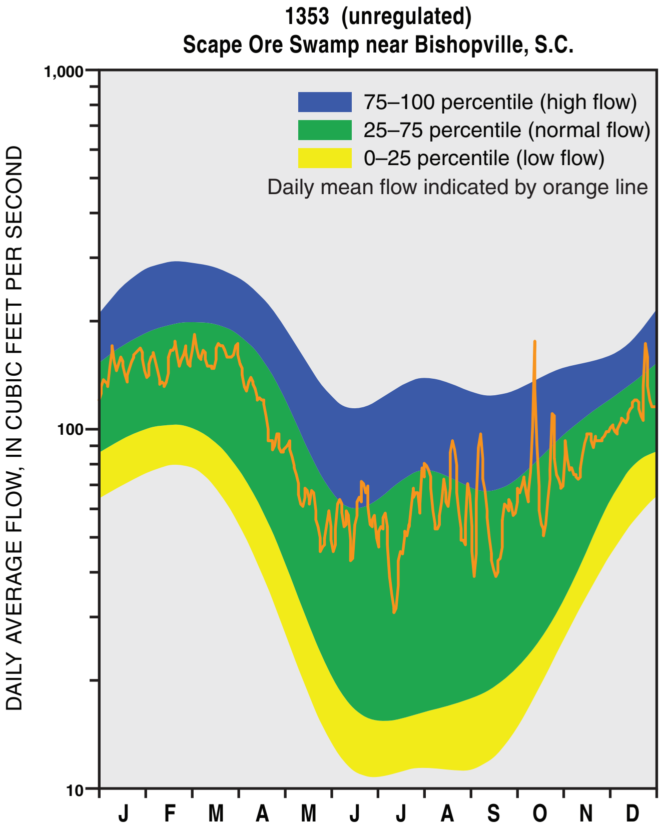
mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*
*** calculated from peak stage measurement recorded by a crest-stage station installed at the site of this gage*

Average annual streamflow for gaged sites on the Black River is 381 cfs (cubic feet per second) near Gable and 948 cfs at Kingstree. Streamflow at these sites equals or exceeds 25 cfs and 48 cfs, respectively, 90 percent of the time.

The duration hydrographs (Figure 5-16) indicate highly variable streamflow in the Black River, which is dependent primarily on rainfall and ensuing runoff rather than ground-water discharge to maintain flows. Base flows at Kingstree appear to receive some ground-water support, whereas low flows at Gable receive little or no support from ground-water storage. Owing to the location of Scape Ore Swamp in the upper Coastal Plain, low flows are well-sustained by ground-water reserves.

The lowest flows of record for the Black River were recorded at Gable where zero-flow conditions occurred for several days in 1954, 1956, and 1957. The highest flow of record (52,800 cfs) was recorded at Kingstree in 1973. Occasional high flows in the Black River cause flood damage in the cities of Sumter, Kingstree, and Andrews. Flooding of the Pocotaligo River occasionally impacts the city of Manning.

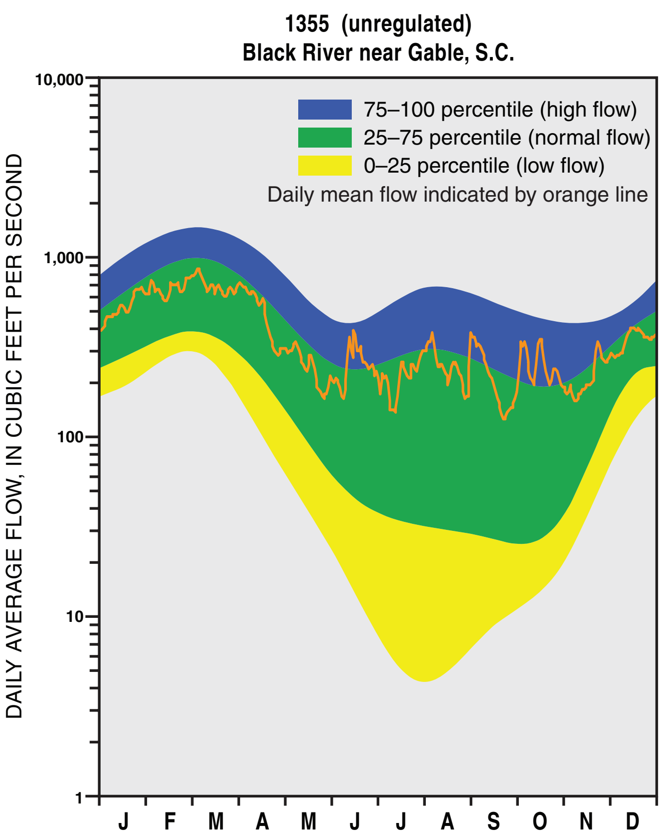
Streamflow in the Black River is highly variable and is not a reliable source of water, especially during the summer months. Water-storage facilities would enhance surface-water-dependent development on this river by providing adequate year-round water supplies. Although average streamflow in Scape Ore Swamp is less than in the Black River, the reliability of flow is greater. During periods of low rainfall, streamflow in Scape Ore Swamp may exceed that in the main river.



Development

Little surface-water development has occurred in the Black River subbasin, and most existing development consists of flood-control projects. The largest lake has a surface area of 150 acres and a volume of 600 acre-ft. The aggregate surface area of all lakes of 10 acres or more is about 1,700 acres and the total volume is about 4,000 acre-ft.

While there are no active navigation projects in this subbasin, the U.S. Army Corps of Engineers once had a project on Mingo Creek in Georgetown County. The Corps has also completed three flood-control projects. The Shot Pouch Creek Project in Sumter County included land enhancement and recreation. Numerous other flood-problem areas have been identified in the subbasin, and the Natural Resources Conservation Service has completed one project and has recently begun planning two others.



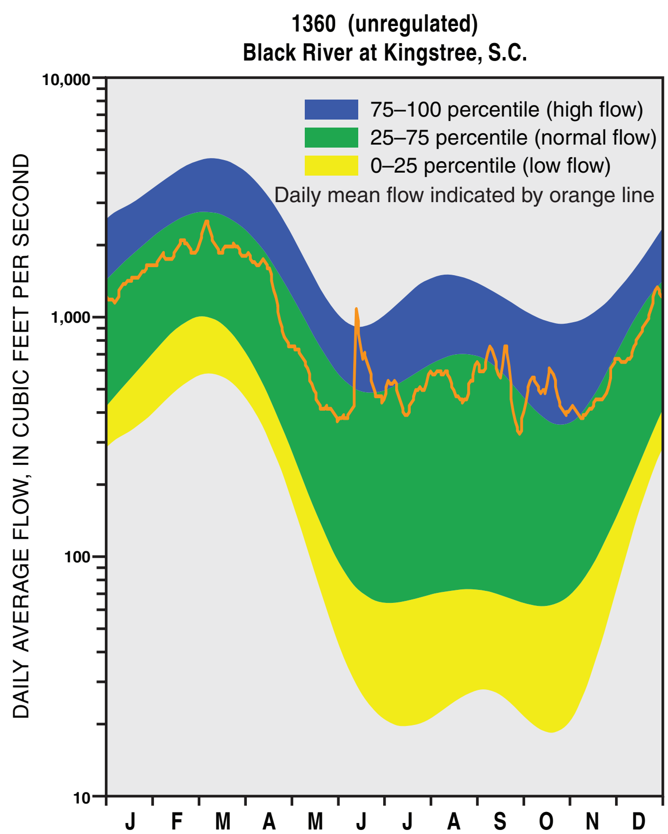


Figure 5-16. Duration hydrographs for selected gaging stations in the Black River subbasin.

Surface-Water Quality

All water bodies, but one, in the Black River subbasin are designated “Freshwater” (Class FW). This water-use classification is assigned to water that is suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2007b).

A section of the Black River (4 miles northeast of Georgetown) is designated “Tidal Saltwater” (Class SA). Class SA water bodies encompass tidal saltwater suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora, suitable for primary- and secondary-contact recreation, crabbing, and fishing. This water is not protected for harvesting of clams, mussels, or oysters for market purposes or human consumption.

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 43 surface-water sites in the Black River subbasin in 2003 in order to assess the water’s suitability for aquatic life and recreational use (Figure 5-17). Aquatic-life uses were fully supported at 29 sites, or 67 percent of the water bodies sampled in this subbasin; most of the impaired water exhibited dissolved-oxygen levels below the concentrations needed to support aquatic life. Recreational use was fully supported in 76 percent of the sampled water bodies; water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2007b). Water-quality impairments in the subbasin are listed in Table 5-19.

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

Table 5-19. Water-quality impairments in the Black River subbasin (DHEC, 2007b)

Water-body name	Station number	Use	Status	Water-quality indicator
Scape Ore Swamp	PD-355	Recreation	Partially supporting	Fecal coliform
McGrits Creek	RS-01017	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Lake Ashwood	CL-077	Aquatic life	Nonsupporting	Total nitrogen, Chlorophyll-*a*
Mechanicsville Swamp	PD-356	Aquatic life	Nonsupporting	Dissolved oxygen
Canal to Atkins drainage canal	PD-354	Aquatic life	Nonsupporting	Dissolved oxygen
Brunson Swamp	RS-03345	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Nasty Branch	PD-239	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Green Swamp	PD-039	Aquatic life	Nonsupporting	Dissolved oxygen
Pocotaligo River	PD-091	Aquatic life	Nonsupporting	Dissolved oxygen
Turkey Creek	PD-098	Recreation	Nonsupporting	Fecal coliform
	PD-040	Recreation	Partially supporting	Fecal coliform
Big Branch	PD-627	Aquatic life	Partially supporting	Macroinvertebrates
Deep Creek	PD-693	Aquatic life	Nonsupporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Black River	PD-116	Aquatic life	Partially supporting	Dissolved oxygen
Clapp Swamp	RS-02325	Aquatic life	Nonsupporting	Dissolved oxygen
Black River	PD-170	Aquatic life	Nonsupporting	Dissolved oxygen, copper
	PD-325	Aquatic life	Partially supporting	Dissolved oxygen
Green Creek	RS-03353	Recreation	Partially supporting	Fecal coliform

Figure 5-17. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 5-19 (DHEC, 2007b).

In 2008, as in several prior years, DHEC issued fish-consumption advisories for the entire reaches of the Black River, Pocotaligo River, and Black Mingo Creek. Fish-consumption advisories are issued in areas where fish are contaminated with mercury; the contamination is only in the fish and does not make the water unsafe for swimming or boating.

GROUND WATER

Hydrogeology

The Black River subbasin is wholly within the Coastal Plain. The Lee County area of the subbasin is underlain by the Middendorf aquifer, which is the principal source of ground water in this area. Selected ground-water data for the subbasin are presented in Table 5-20.

Table 5-20. Selected ground-water data for the Black River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Lee County	Middendorf	260–535	700–2,000
City of Sumter	Middendorf/ Black Creek	90–750	1,000–2,500
Sumter County	Black Creek	100–410	50–650
Clarendon/ Williamsburg Counties	Black Creek	100–800	100–750
Manning	Black Creek/ Middendorf	400–765	80–755
Andrews	Black Creek	770–825	210–500
	Shallow	22–60	150

Pumping tests indicate that the transmissivity of the Middendorf aquifer in the Bishopville area averages about 11,000 ft^2/day. The total thickness of sediments overlying the crystalline bedrock ranges from about 250 feet at the north end of Lee County to 800 feet at the south end.

The total thickness of sediments overlying the crystalline rocks in Sumter County ranges from about 350 feet in the northwestern part of the county to about 900 feet on the border with Clarendon County. About 20 miles northwest of Sumter, at the Kershaw County line, the top of the Middendorf lies at a depth of 200 feet. Beneath the city of Sumter, it is at a depth of 470 feet.

Sumter's municipal water supply is the largest ground-water user in the State. Its pumpage in 2006 averaged 12.4 million gallons per day, drawn from the Middendorf and Black Creek aquifers. Water levels in the Sumter area are generally between 90 and 115 feet above sea level. Aquifer transmissivity at Sumter is indicated by numerous pumping tests to range between 2,500 and 10,000 ft^2/day, depending on the number of sand beds screened.

Productive sand and gravel beds compose most of the Middendorf aquifer in Sumter County, and it is the area's best source of ground-water supply. The top of the aquifer occurs between sea level and 400 feet below sea level. The Black Creek aquifer also underlies most of Sumter County. The top of the aquifer ranges from about 250 feet above sea level at the north border to sea level at the south border. The thickness is as great as 300 feet, and many water systems in the county include wells that tap the Black Creek aquifer.

The shallow aquifer in Sumter County supplies domestic wells ranging in depth from 10 to more than 100 feet. Shallow wells developed in alluvial deposits along the Black River may be able to obtain substantial amounts of water transmitted from the river through these deposits.

Clarendon and Williamsburg Counties, in the center of the Black River subbasin, are entirely underlain by the Cape Fear, Middendorf, and Black Creek aquifers. The top of the Cape Fear dips southward and ranges from 500 to 1,100 feet below sea level. In the vicinity of Turbeville the top of the Middendorf occurs at a depth of 500 feet, and the aquifer is about 150 feet thick. A pumping test of a Middendorf well at Manning indicated an aquifer transmissivity of 5,300 ft^2/day. The Black Creek aquifer underlying Clarendon and Williamsburg Counties is 300 to 350 feet thick, and its top is between sea level and 400 feet below sea level. Measurements of transmissivity range from 460 to 3,600 ft^2/day. The lower part of the Peedee Formation is included in the Black Creek aquifer in the lower reaches, and upper Peedee sediment generally confines the Black Creek system. Sandy intervals that occur in the upper section of the Peedee along the southeastern boundary of the subbasin are grouped in the Tertiary sand aquifer and produce yields adequate for domestic supply. The shallow aquifer in these counties also supplies domestic needs in rural areas.

In Georgetown County the top of the Middendorf aquifer is about 1,000 feet below sea level, and the aquifer is not widely used as a source of water supply. The Black Creek aquifer, with its top between 350 and 650 feet, and the upper part of the Middendorf aquifer are tapped by a number of public-supply wells, such as those at Andrews. Domestic water supplies are obtained from the shallow aquifer and Tertiary sand aquifers by wells that are less than 100 feet deep. A few shallow wells are known to produce as much as 150 gallons per minute, but yields are usually much smaller.

Ground-Water Quality

The Black Creek and Middendorf aquifers are widely used in the Black River subbasin. Water quality of both aquifers is generally good. The quality varies considerably in the aquifers, with a general trend of increasing mineralization downgradient and with depth.

Water from the Middendorf is low in TDS (total dissolved solids), chloride, fluoride, and pH and is soft and corrosive in the upper reaches of the subbasin. High iron concentrations are common. Total dissolved solids, sodium, and alkalinity increase to more than 500, 250, and 500 mg/L (milligrams per liter), respectively, near the coast (Speiran and Aucott, 1994), and pH increases to 8.5. The electrical-resistivity log of a 1,318-foot test hole near Kingstree indicates brackish or salty water in the underlying Cape Fear aquifer at 1,180 feet below land surface. Iron-reducing bacteria are known to cause problems in wells where iron concentrations are high (Park, 1980).

Water from the Black Creek aquifer is a soft, sodium bicarbonate type. TDS range from about 20 mg/L in the upper reaches to more than 500 mg/L near the coast (Speiran and Aucott, 1994). The pH ranges from 5.0 to 6.0 in Sumter County and from 8.0 to 9.0 in Georgetown County. Excessive iron is a widespread problem in Sumter County (Park, 1980), and fluoride concentrations commonly exceed recommended levels near the coast (Johnson, 1978). Turbidity, caused by a colloidal suspension of the calcium carbonate mineral aragonite, has occurred in some wells in Clarendon, Williamsburg, and Georgetown Counties (Johnson, 1978; Pelletier, 1985).

The Tertiary sand aquifer, where present in Clarendon, Williamsburg, and Georgetown Counties, yields water of good quality for rural domestic needs; however, it commonly contains high iron concentrations (Johnson, 1978). The typical water quality in Georgetown and Williamsburg Counties is a calcium bicarbonate type.

Water-Level Conditions

DNR regularly monitors ground-water levels in three wells in the Black River subbasin, all in Sumter County (Table 5-21). Water levels in other wells in the subbasin are sometimes measured to help develop potentiometric maps of the Middendorf and Black Creek aquifers.

Pumping ground water at a rate faster than it is naturally replenished results in cones of depressions—localized areas of lower ground-water levels—and can also result in regionally lower ground-water levels. Several areas with known pumping-related water-level problems occur in the Black River subbasin, affecting both the Black Creek and Middendorf aquifers.

Table 5-21. Water-level monitoring wells in the Black River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
SUM-355	DNR	34 00 59 80 24 07	Surficial	Ebenezer Elementary School	190	undetermined
SUM-488	DNR	33 52 28 80 26 16	Middendorf	4 miles southwest of Sumter	183	511–541
SUM-492	DNR	33 56 44 79 58 48	Middendorf	Woods Bay State Park	125	502–517

* *DNR, South Carolina Department of Natural Resources*

The Black River subbasin contains two major cones of depression in the Black Creek aquifer (Figure 5-18) (Hockensmith, 2008b). Pumping in and around the city of Sumter has created a cone of depression east of the city, the center of which represents a water-level decline of 165 feet from predevelopment conditions. In the southern end of the subbasin, a widespread cone of depression has formed around Andrews and Georgetown, with water-level declines as great as 200 feet from predevelopment levels.

At least three known cones of depression occur in the Middendorf aquifer in the Black River subbasin (Figure 5-19) (Hockensmith, 2008a). Pumping in and around the city of Sumter has created a cone of depression southwest of the city, with water levels as much as 50 feet lower that predevelopment conditions. A small cone of depression centered near Bishopville in Lee County has resulted from local water levels declining as much as 60 feet. A more widespread cone of depression has developed near the town of Hemingway in Williamsburg County, with water levels as much as 80 feet lower than predevelopment levels.

In addition to these site-specific water-level concerns, years of ground-water pumping in this and neighboring subbasins have caused regional declines in water levels in both the Black Creek and Middendorf aquifers throughout the subbasin by as much as 75 feet from predevelopment conditions.

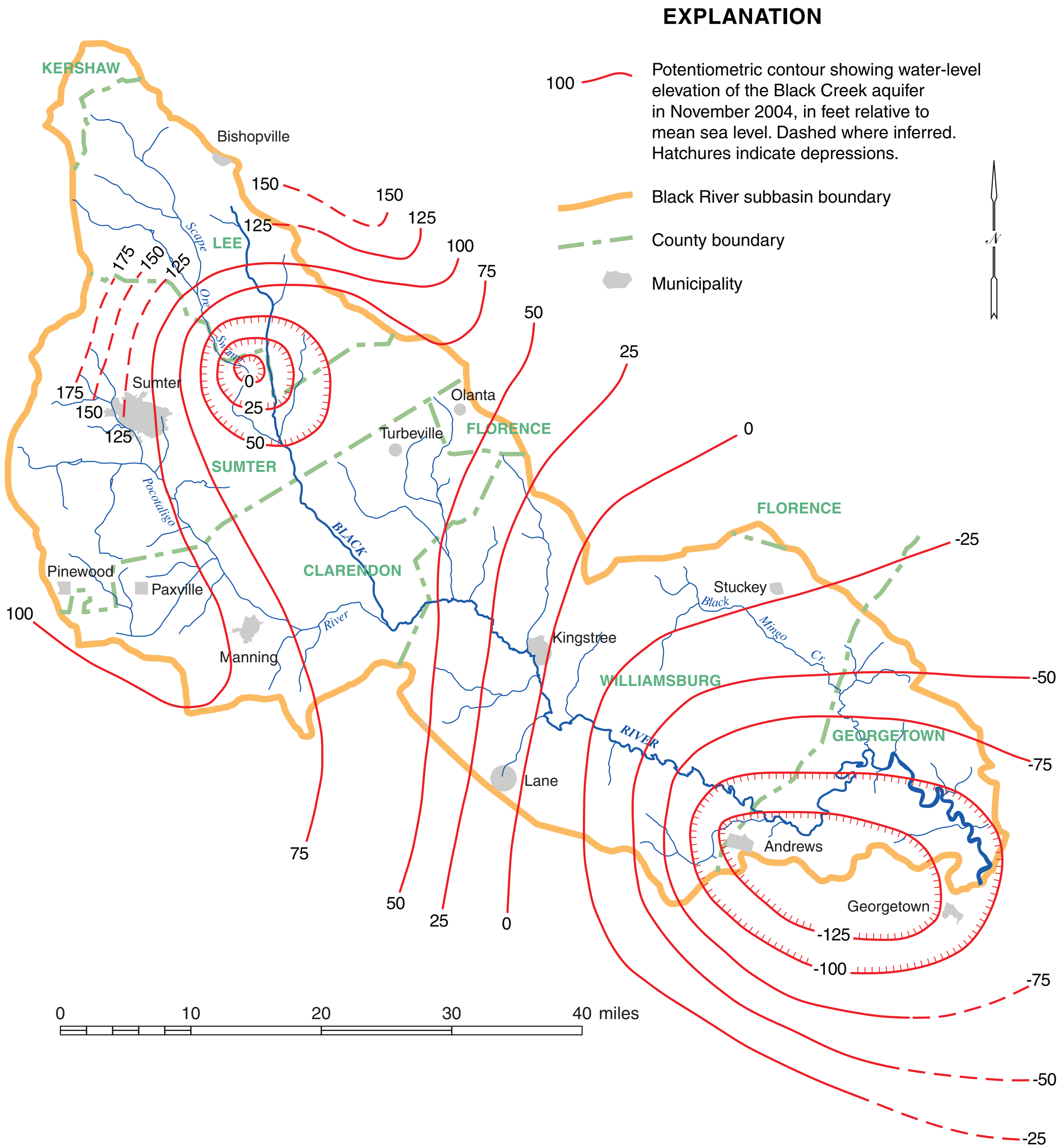


Figure 5-18. Potentiometric contours of the Black Creek aquifer in the Black River subbasin, November 2004 (from Hockensmith, 2008b).

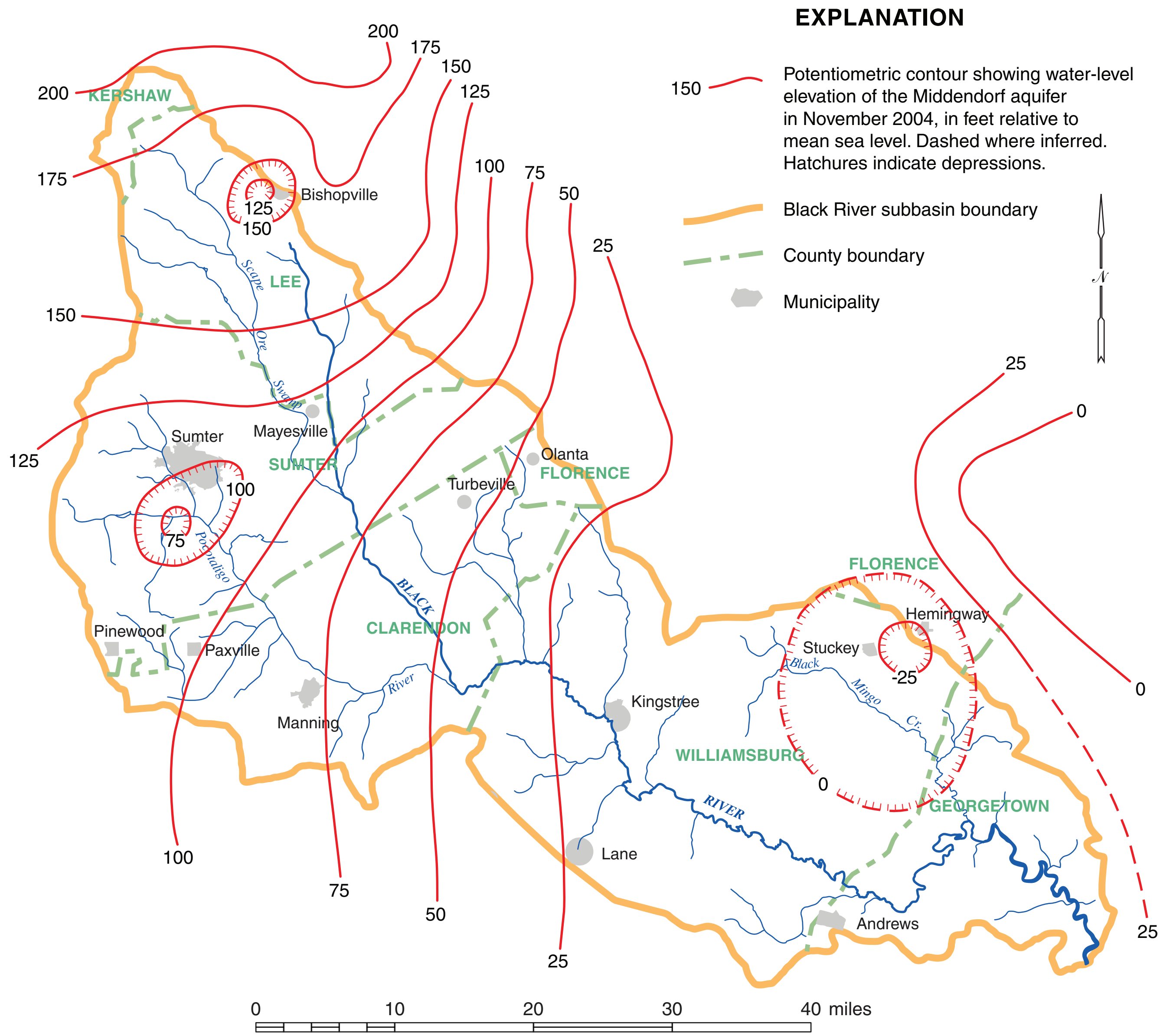


Figure 5-19. Potentiometric contours of the Middendorf aquifer in the Black River subbasin, November 2004 (from Hockensmith, 2008a).

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Black River subbasin is summarized in Table 5-22 and Figure 5-20. Offstream water use in the Black River subbasin was 10,100 million gallons in 2006, ranking it twelfth among the 15 subbasins. Of this amount, 9,580 million gallons were from ground-water sources (95 percent) and 520 million gallons were from surface-water sources (5 percent). Water-supply use accounted for 73 percent of the total use, followed by irrigation (15 percent) and industry (9 percent). Consumptive use in this subbasin is estimated to be 2,655 million gallons, or about 26 percent of the total offstream use.

Water-supply use in the subbasin was provided entirely by ground water. At 7,287 million gallons, this basin ranked second behind the Pee Dee River subbasin in terms of the amount of ground water used for water supply. Twenty-three ground-water supply systems have wells in the subbasin. Some of these wells are located just inside the boundary of the subbasin and actually supply water to regions in adjacent subbasins. For example, although the city of Bishopville is located primarily in the Lynches River subbasin, its wells are located in both the Lynches and Black subbasins. This is not uncommon. Often, water-supply wells are drilled near elevated water-storage tanks, and storage tanks are typically located at high points so that water can be gravity-fed to customers. Likewise, watershed boundaries are located along locally high topography and, as a result, water-supply wells are commonly located very close to basin boundaries.

Table 5-22. Reported water use in the Black River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	274	52.7	97	1.0	371	3.7
Industry	0	0.0	938	9.8	938	9.3
Irrigation	246	47.3	1,257	13.1	1,503	14.9
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	0	0.0	0	0.0	0	0.0
Water supply	0	0.0	7,287	76.1	7,287	72.1
Total	520		9,580		10,100	

The city of Sumter has the largest ground-water public-supply system in the State. In 2006, 4,525 million gallons were pumped from 17 wells located in and around the city. Most of the water is from the Middendorf aquifer, although screens in some wells are set adjacent to both the Middendorf and Black Creek aquifers. The second largest user was High Hills Rural Water Company, which supplies water to rural areas of Sumter County. It withdrew 490 million gallons in 2006 from the Black Creek and Middendorf aquifers. Also of note are the city of Manning (391 million gallons from the Middendorf and Cape Fear aquifers), Shaw Air Force Base in Sumter County (377 million gallons from the Black Creek and Middendorf aquifers), and the town of Kingstree (366 million gallons from the Black Creek and Middendorf aquifers).

Irrigation water use totaled 1,503 million gallons in the subbasin in 2006. Of this amount, 1,257 million gallons were from ground-water sources (84 percent) and 246 million gallons were from surface-water sources (16 percent). Edens Farms, in Sumter County, was the largest ground-water irrigator (500 million gallons from the Black Creek and Middendorf aquifers) and Black Crest Farms, also in Sumter County, was the largest surface-water irrigator (195 million gallons).

Industrial water use totaled 938 million gallons in 2006, all of it from ground-water sources. The largest user was Martek Biosciences Kingstree Corp. in Williamsburg County, which withdrew 607 million gallons from the Middendorf aquifer. Golf-course water use totaled 371 million gallons in 2006, 274 million from surface-water sources (74 percent) and 97 million from ground-water sources (26 percent).

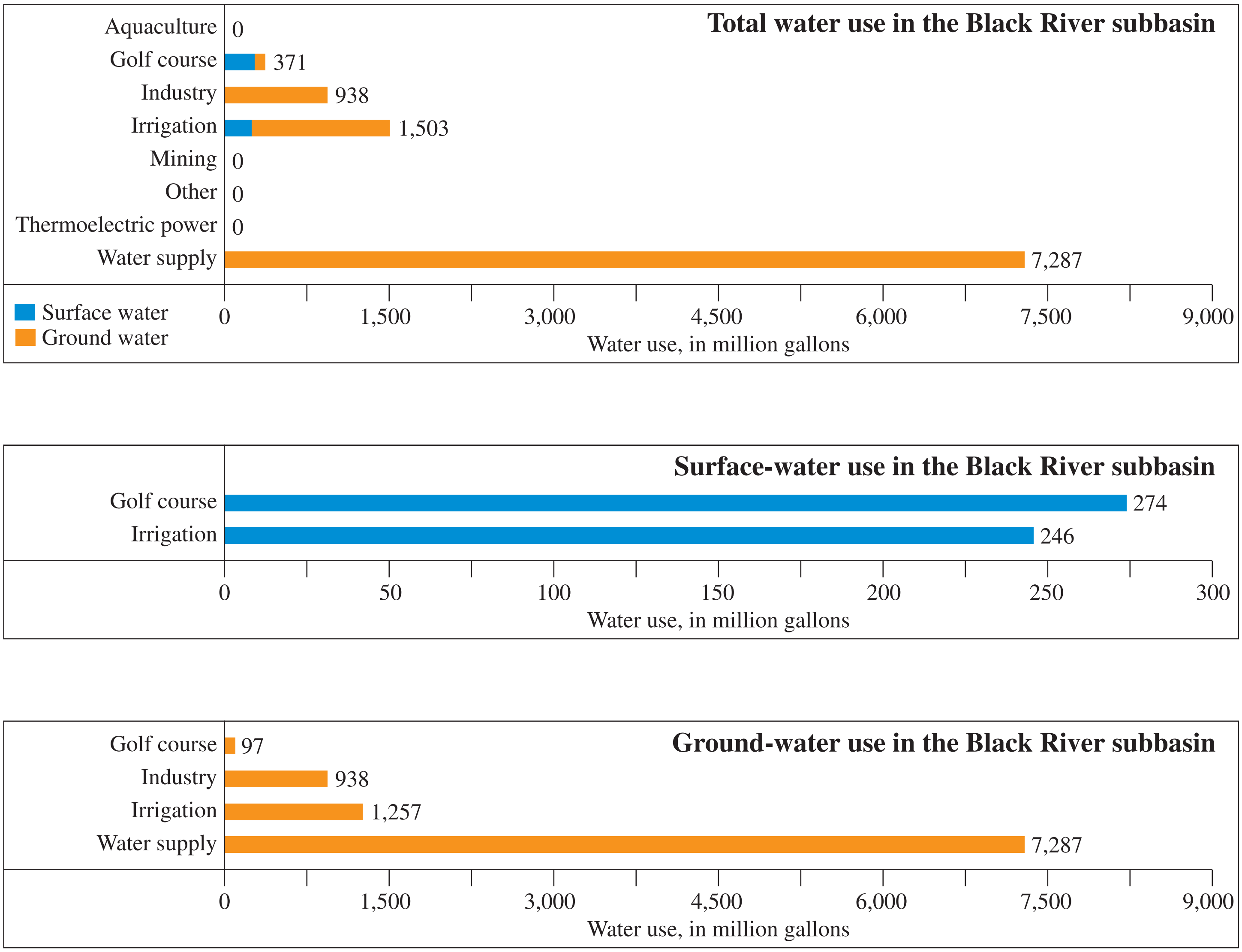
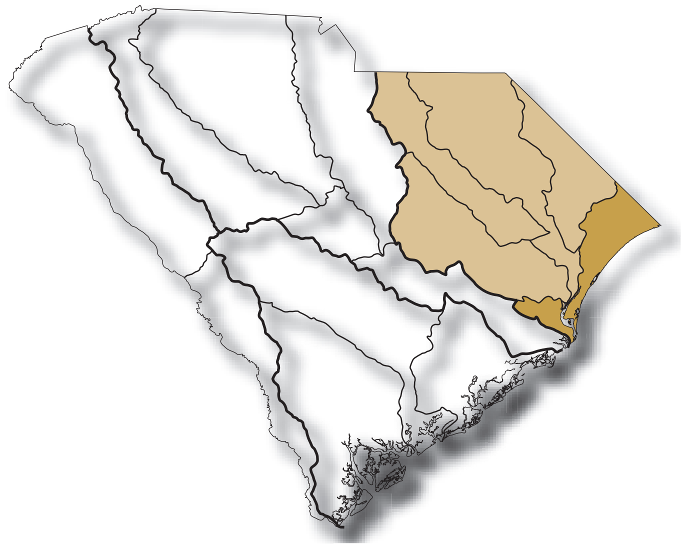


Figure 5-20. Reported water use in the Black River subbasin for the year 2006 (modified from Butler, 2007).

WACCAMAW RIVER SUBBASIN



WACCAMAW RIVER SUBBASIN

The Waccamaw River subbasin is in the easternmost part of the State and runs roughly parallel with the coast, which forms the eastern boundary of the basin. Sharing a 30-mile northern border with North Carolina, the basin includes all of Winyah Bay and the city of Georgetown at its southern extreme. The subbasin encompasses most of Horry County and a part of Georgetown County (Figure 5-21). Within the boundary of the basin is the popular seashore vacation area known as the Grand Strand. This coastal strip comprises a series of towns extending from Cherry Grove near the North Carolina border to Pawleys Island near Georgetown, S.C. The area of the subbasin is about 995 square miles, or 3.2 percent of the State's land area.

DEMOGRAPHICS

The 2000 population of the subbasin was estimated at 206,700, 5.2 percent of the State's total population, but this is a rapidly growing region. The total population of Horry County is projected to increase 30 percent from 2000 to 2020, and Georgetown County's population is projected to increase 19 percent, with most of that growth occurring in the Waccamaw subbasin. By the year 2020 the subbasin population is expected to reach about 261,000, a 26-percent increase in just 20 years.

Horry County has a 40-percent rural population, but most of its urban population is in the Waccamaw subbasin. Rural and urban population growths were 33 percent and 39 percent, respectively, between 1990 and 2000.

The major centers of population in the subbasin are Myrtle Beach (22,759) and Conway (11,788) in Horry County and Georgetown (8,950) in Georgetown County. The transient population of the coastal Grand Strand area of Horry County increases dramatically during the summer months; for example, the population in Myrtle Beach increases nearly tenfold during the peak of the tourist season.

The 2005 per capita income was $30,399 in Georgetown County and $26,789 in Horry County, ranking them 6th and 15th among South Carolina's 46 counties. In that year, South Carolina's per capita income was $28,285. The 1999 median household income in Horry and Georgetown Counties was $36,470 and $35,312, respectively.

In 2000, the annual-average employment of nonagricultural wage and salary workers in Horry and Georgetown Counties was 97,600 and 23,600, respectively. Labor distribution in the subbasin counties included sales and office, 28 percent; management, professional, and technical services, 26 percent; service, 20 percent; construction, extraction, and maintenance, 13 percent; production, transportation, and materials moving, 2 percent; and farming, fishing, and forestry, 1 percent. Employment in service and in sales and offices was 4 to 5 percent greater than the State averages, and employment in production, transportation, and materials moving was 7 percent below the State average. The marked differences in employment reflect the importance of tourism in this subbasin.

Manufacturing output was $2 billion, equally divided between Horry and Georgetown Counties and reflecting the tourism-oriented economies of the area. Crops and livestock production generated $93.5 million, mainly in Horry County. Timber products generated more than $70 million in 2005 (South Carolina Forestry Commission, 2008).

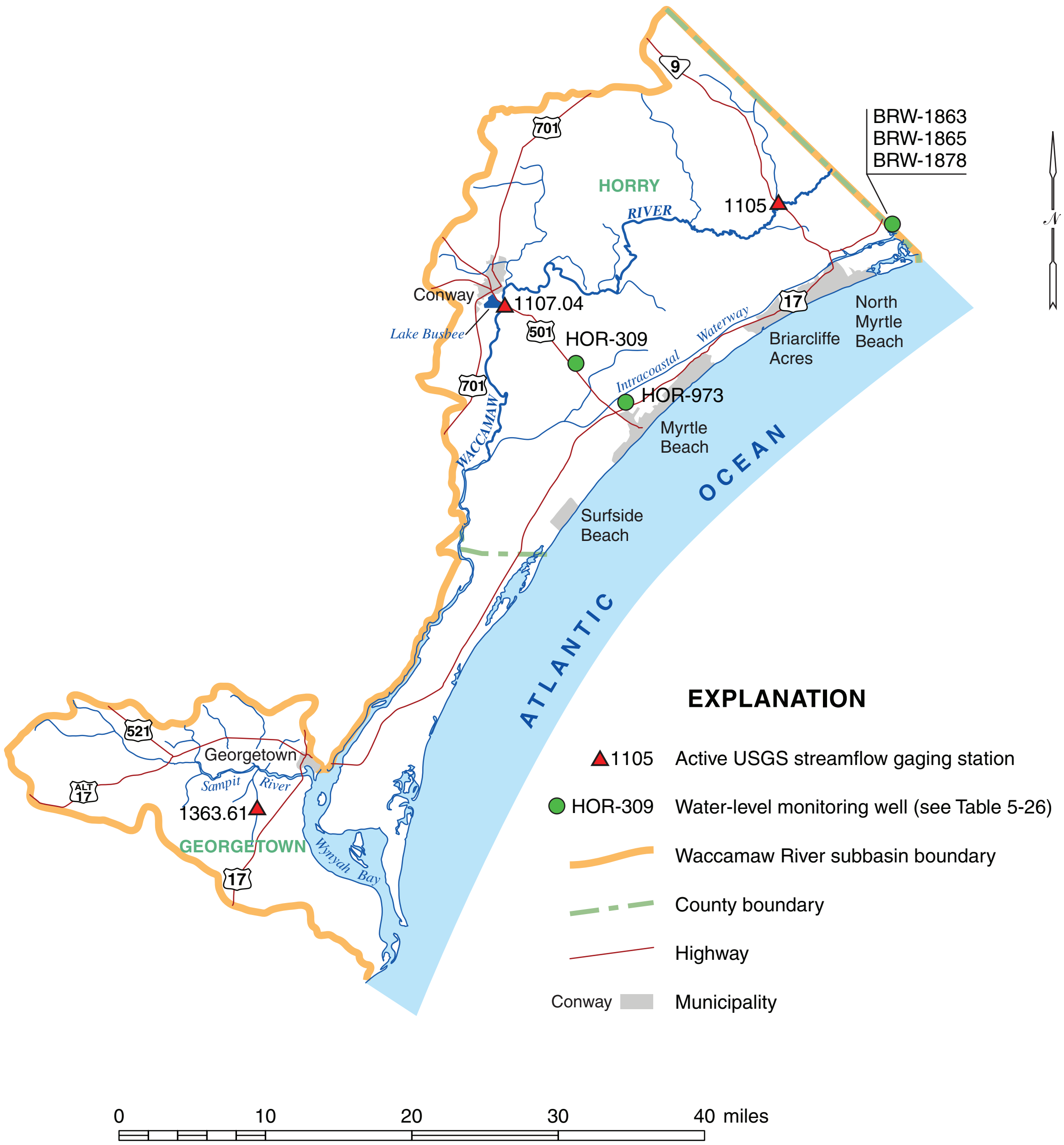


Figure 5-21. Map of the Waccamaw River subbasin.

SURFACE WATER

Hydrology

The Waccamaw River, Intracoastal Waterway, Sampit River, and Winyah Bay constitute the subbasin's major water bodies. Much of the subbasin is occupied by cypress and hardwood swamps and small tributary-stream valleys. The Waccamaw River is entirely in the lower Coastal Plain and has its headwaters and over half of its drainage area in North Carolina. The Waccamaw River and Sampit River flow directly into Winyah Bay. This large and important estuary also receives freshwater inflow directly from the Black and Pee Dee Rivers. The cities of Georgetown and Conway rely heavily on these streams for commercial transportation.

Streamflow of the Waccamaw River is currently monitored at two gaging stations in South Carolina, near Longs and at the Conway Marina at Conway (Figure 5-21). A gaging station also exists on the Waccamaw River outside the subbasin, at Freeland, N.C. A gaging station is also active on Turkey Creek, a tributary of the Sampit River, in Georgetown County. Streamflow statistics for these stations are presented in Table 5-23. Streamflow statistics for the gage at Conway are not presented because at that location the Waccamaw River is heavily influenced by astronomical tides during periods of low and medium flow.

Table 5-23. Selected streamflow characteristics at USGS gaging stations in the Waccamaw River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Waccamaw River at Freeland, N.C. 1095	1939 to 2007*	680	728	1.07	27	0.10 1954	30,600 1999	31,200 1999
Waccamaw River near Longs 1105	1950 to 2007*	1,110	1,258	1.13	53	1.0 1954	28,100 1999	28,200 1999
Waccamaw River at Conway Marina at Conway 1107.04	1994 to 2007*	Indeter-minate	– – –	– – –	– – –	– – –	24,100 1999	– – –
Turkey Creek near Maryville 1363.61	1993 to 2007*	4.7	6.4	1.36	0.37	0.03 1997	1,350 1995	1,500 1995

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Average annual flow of the Waccamaw River near Longs is 1,258 cfs (cubic feet per second), with streamflow at this location equal to or exceeding 53 cfs 90 percent of the time. The flow-duration curve (Figure 5-22) indicates highly variable streamflows in this river. Such poorly sustained streamflows are typical of streams in the lower Coastal Plain owing to diminished base-flow support from shallow ground-water sources.

The lowest flow of record at the Longs gage is 1.0 cfs and occurred during the drought of 1954. The record flood flow (28,100 cfs) was the result of Hurricane Floyd in 1999. Occasional high flows in the Waccamaw River and poor drainage cause flooding in the vicinity of Conway.

Surface-water availability in the Waccamaw River is variable and generally unreliable as a major source of supply. Adequate surface-water supplies can be guaranteed only if provisions for storage are developed.

Development

Surface-water development in the Waccamaw River subbasin includes few impoundments and no hydropower facilities, but there are numerous navigation and flood-control projects. The only impoundment with a surface area greater than 200 acres is Lake Busbee, at Conway, with a surface area of 400 acres and a volume of 1,100 acre-ft. This lake is used for recreation and as a source of cooling water for the Grainger Steam Plant, a thermoelectric power plant currently owned by the Central Electric Power Cooperative and operated by Santee Cooper.

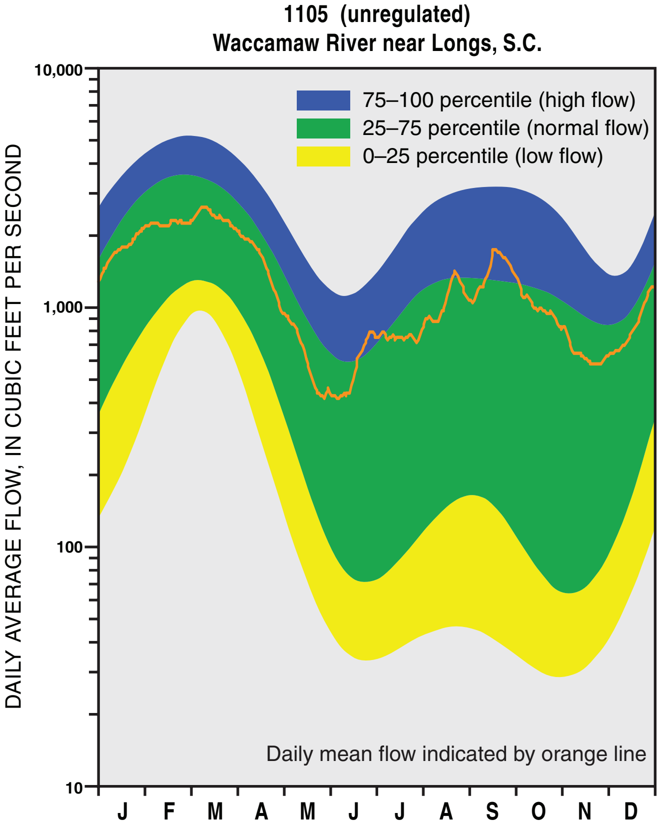


Figure 5-22. Duration hydrograph for the Waccamaw River near Longs, S.C., gaging station.

The U.S. Army Corps of Engineers (COE) has a continuing navigation project in Georgetown Harbor, where a channel is maintained from the ocean through Winyah Bay and into the Sampit River; the Steel Mill Channel was dredged in 2004. The Murrells Inlet navigation project was completed in 1980, and the most recent maintenance dredging was completed in 2002. A survey of the Atlantic Intracoastal Waterway between Winyah Bay and Charleston was made during 2005.

The COE completed five flood-control projects in the subbasin during the 1950's and 1960's, and the Natural Resources Conservation Service has two active flood-control projects.

Surface-Water Quality

Most of the water bodies in the Waccamaw River subbasin are designated "Freshwater" (Class FW). Class FW is freshwater suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, and for drinking-water supply, fishing, and industrial and agricultural use (DHEC, 2007b).

Parts of Little River and the Atlantic Intracoastal Waterway and its tributaries (from the crossing of S.C. highway 9 to the North Carolina line) are designated "Tidal Saltwater" (Class SA). This water is suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora. Average dissolved oxygen in these waters should not be less than 5.0 mg/L (milligrams per liter), with a minimum of 4.0 mg/L. Class SA water is not protected for harvesting clams, mussels, or oysters for market purposes or human consumption.

Winyah Bay and the Sampit River are designated "Tidal Saltwater" (Class SB). Class SB water is the same as Class SA water except that Class SB water must maintain dissolved-oxygen averages above 4.0 mg/L (DHEC, 2007b).

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 42 surface-water sites in the Waccamaw River subbasin in 2003 in order to assess the water's suitability for aquatic life and recreational use (Figure 5-23). Aquatic-life uses were fully supported at 23 sites, or 55 percent of the water bodies sampled in this subbasin; most of the impaired water exhibited dissolved-oxygen levels below the concentrations needed to support aquatic life. Recreational use was fully supported in 95 percent of the sampled water bodies; the two water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2007b). Water-quality impairments in the subbasin are listed in Table 5-24.

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in previous years, DHEC issued a fish-consumption advisory for the Waccamaw River (from the North Carolina/South Carolina state line to Winyah Bay) and the Intracoastal Waterway in Horry County. Fish-consumption advisories are issued in areas where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for skiing, swimming, or boating.

GROUND WATER

Hydrogeology

The Waccamaw River subbasin is wholly within the Coastal Plain. Basement rocks lie at a depth of about 1,000 feet below sea level at the North Carolina/South Carolina border and dip southward to 2,000 feet at Winyah Bay. The top of the Cape Fear aquifer dips southward and ranges from 750 to 1,300 feet below sea level. The Middendorf aquifer overlies the Cape Fear, and its surface is between 550 and 1,000 feet below sea level. Above the Middendorf aquifer lies the Black Creek aquifer, which has a thickness greater than 300 feet throughout most of the subbasin. A confining layer between the Black Creek and the Middendorf hydraulically separates the two aquifers. Selected ground-water data for the subbasin are presented in Table 5-25.

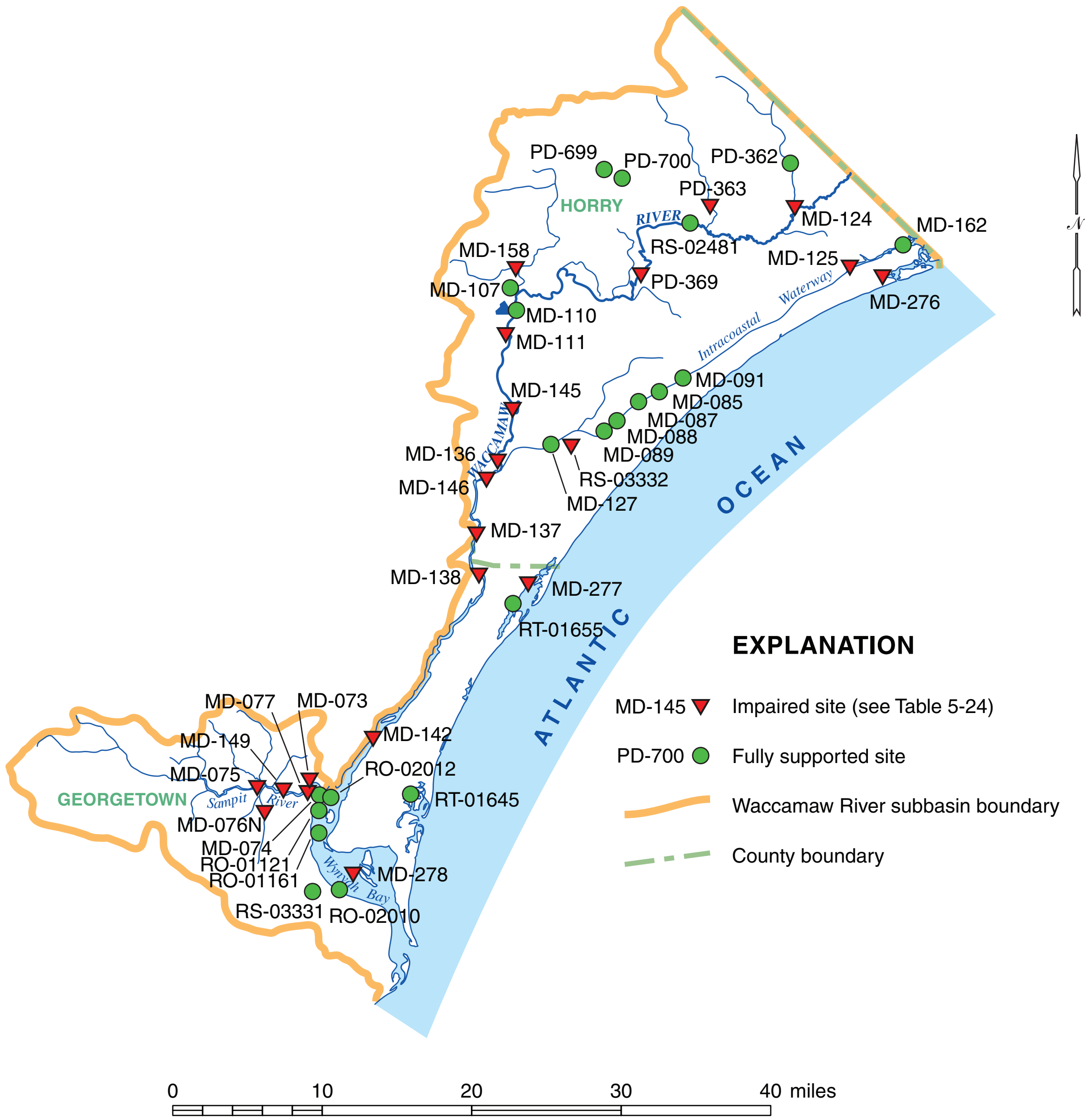


Figure 5-23. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 5-24 (DHEC, 2007b).

Table 5-24. Water-quality impairments in the Waccamaw River subbasin (DHEC, 2007b)

Water-body name	Station number	Use	Status	Water-quality indicator
Sampit River	MD-075	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-077	Aquatic life	Partially supporting	Dissolved oxygen
	MD-073	Aquatic life	Partially supporting	Dissolved oxygen
Turkey Creek	MD-076N	Aquatic life	Nonsupporting	pH
Whites Creek	MD-149	Aquatic life	Nonsupporting	Dissolved oxygen, copper
Winyah Bay	MD-278	Aquatic life	Partially supporting	Dissolved oxygen
Waccamaw River	MD-124	Aquatic life	Nonsupporting	Copper
Simpson Creek	PD-363	Aquatic life	Nonsupporting	Zinc
Crab Tree Swamp	MD-158	Recreation	Partially supporting	Fecal coliform
Waccamaw River	PD-369	Aquatic life	Partially supporting	Dissolved oxygen
	MD-111	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-145	Aquatic life	Partially supporting	Dissolved oxygen
	MD-136	Aquatic life	Nonsupporting	Dissolved oxygen
Atlantic Intracoastal Waterway tributary	RS-03332	Recreation	Partially supporting	Fecal coliform
Waccamaw River	MD-146	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-137	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-138	Aquatic life	Partially supporting	Dissolved oxygen
	MD-142	Aquatic life	Partially supporting	Dissolved oxygen
Atlantic Intracoastal Waterway	MD-125	Aquatic life	Nonsupporting	Copper
House Creek	MD-276	Aquatic life	Nonsupporting	Dissolved oxygen, copper
Parsonnage Creek	MD-277	Aquatic life	Partially supporting	Dissolved oxygen

Table 5-25. Selected ground-water data for the Waccamaw River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Myrtle Beach	Black Creek	265–770	200–1,000
Bucksport	Black Creek	500–710	165–1,000
Georgetown	Black Creek	650–884	520

The Black Creek aquifer is the main source of ground water for municipal, industrial, and domestic water supply in Horry and Georgetown Counties. Aquifer tests in the Myrtle Beach area indicate a value of 15 ft/day for the average hydraulic conductivity, 2,000 ft^2/day for the transmissivity, and 0.0002 for the storage coefficient. In the Bucksport area, pumping tests of wells screened in the Black Creek aquifer indicate a transmissivity of 1,300–2,500 ft^2/day. At Georgetown the transmissivity is less, ranging from 150 to 600 ft^2/day.

The Tertiary sand aquifer occurs in Georgetown County but is absent in most of Horry County. The confining unit that separates the Black Creek aquifer from the Tertiary sand aquifer in Georgetown County and from the shallow aquifers in Horry County consists mainly of the Peedee Formation. Because of a large percentage of clay and fine-grained sand, the hydraulic conductivity of this aquifer is low but sufficient to meet domestic requirements.

Throughout the Waccamaw River subbasin, thin beds of fine clayey sand, fine calcareous sand, and coquina of Tertiary and Quaternary ages overlie the Peedee Formation. This shallow aquifer is often used for domestic water supply where the contained water is of good quality.

Ground-Water Quality

The primary source of ground water for public supplies is the Black Creek aquifer system. Water from the Black Creek is a soft, alkaline, low-iron, sodium bicarbonate type and is generally suitable for most purposes.

Chloride concentrations vary with depth and area. They are greatest and occur at the shallowest depths in eastern Horry County, where concentrations exceed 250 mg/L (milligrams per liter) (Pelletier, 1985; Zack and

Roberts, 1988). These high levels of chloride represent incompletely flushed seawater over the southern flank of the Cape Fear Arch. The minimum, mean, and maximum chloride concentrations recorded in Horry County are 7.0, 140, and 490 mg/L, respectively (Hockensmith and Castro, 1993). Chlorides ranged between 40 and 500 mg/L in Georgetown County (Zack and Roberts, 1988).

Sodium levels in the Black Creek aquifer range from 250 mg/L near Garden City to 700 mg/L near Little River (Pelletier, 1985). They average about 300 mg/L in Horry County (Hockensmith and Castro, 1993).

Fluoride levels commonly exceed the recommended 2.0 mg/L limit. Concentrations range from 0.9 to 6.9, with a mean of 4.1 mg/L in Horry County (Hockensmith and Castro, 1993). The fluoride is attributed to the fluorapatite of fossilized shark teeth—fossils that are abundant in the sediment of the Black Creek aquifer (Zack, 1980).

Total dissolved solids (TDS) concentrations are greatest near the North Carolina/South Carolina border, exceeding 1,500 mg/L; TDS decrease to about 600 mg/L at the Horry-Georgetown county boundary (Pelletier, 1985) and average about 800 mg/L (Hockensmith and Castro, 1993). The excessive turbidity found intermittently throughout the subbasin, presumably caused by aragonite in suspension, generally dissipates with pumping (Pelletier, 1985).

The Middendorf aquifer contains water that is mineralized and unsuitable for public supplies. Concentrations of TDS, sodium, alkalinity, and chloride exceed 500, 250, 500, and 100 mg/L, respectively, throughout most of the subbasin. The distribution of these properties and constituents, is, in part, related to the diffuse saltwater wedge underlying the region, and their concentrations decrease toward the subbasin's northwest boundary (see the *Saltwater Contamination* section of Chapter 9, *Special Topics*).

The shallow aquifers that overlie the Black Creek aquifer consist mainly of Pleistocene and Pliocene terrace deposits that also are important sources of water. They supply domestic water needs in rural areas and, by means of ponds, provide irrigation water for many golf courses in the Grand Strand area. The water quality is variable, ranging from good to very poor. Calcium and bicarbonate are the predominant ions owing to the abundance of fossil-shell. TDS concentrations locally exceed several hundred milligrams per liter, hardness ranges from negligible to 200 mg/L (as calcium carbonate) and pH values range from about 5.0 to 7.0 (Glowacz and others, 1980). Elevated levels of hydrogen sulfide and color occur locally. Iron concentrations range from 5 to 35,000 µg/L (micrograms per liter), but are usually less than 2,000 µg/L (Speiran and Lichtler, 1986). Chlorides are high where the aquifer is in contact with saltwater bodies.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR in five wells in the Waccamaw River subbasin in order to help assess trends or changes in water levels and to monitor areas with known water-level problems (Table 5-26). Water levels in other wells are sometimes measured to help develop potentiometric maps of the Middendorf and Black Creek aquifers.

Table 5-26. Water-level monitoring wells in the Waccamaw River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
BRW-1863	DNR	33 53 33 78 35 22	Black Creek	Calabash, N.C.	48	496–506
BRW-1865	DNR	33 53 30 78 35 23	Middendorf	Calabash, N.C.	48	810–820
BRW-1878	DNR	33 53 35 78 35 20	Cape Fear	Calabash, N.C.	48	1,042–1,052
HOR-309	DNR	33 46 05 78 57 59	Black Creek	Conway	43	360–375
HOR-973	DNR	33 43 17 78 54 10	Middendorf	Myrtle Beach	20	1,012–1,328

* *DNR, South Carolina Department of Natural Resources*

Extensive development and over-pumping of the Black Creek aquifer in the Grand Strand area during the 1970's and 1980's lowered water levels nearly 200 feet below predevelopment levels, and declines of more than 10 feet per year were observed in some wells during the mid-1980's (Pelletier, 1985). Had this water-level depression continued into the 1990's, water levels would have reached the top of the aquifer, possibly resulting in aquifer compaction—the loss of storage capacity because of particle rearrangement. Beginning in 1988, with the prospect of permanently damaging the aquifer, public water suppliers in Horry County began switching from ground-water to surface-water sources, allowing Black Creek water levels to recover somewhat. Since 1988, the water level in one well in Myrtle Beach has recovered more than 100 feet from its lowest measured level (Figure 5-24).

The effect on water quality of the large regional withdrawals from the Black Creek aquifer prior to 1988 and the subsequent pumping reduction are not specifically known. There was intrusion of the saltwater/freshwater interface inland while withdrawals occurred, but with little observed impact because the shallow hydraulic gradients and low hydraulic conductivity caused slow rates of ground-water flow. Saltwater upconing and cross-contamination also occurred before 1988, but those avenues of contamination have been in part mitigated by water-level recovery and shifts in pumping centers and by regulation of well-screen placement.

Although water levels in most of Horry County have recovered substantially in the last two decades, a significant cone of depression has developed around the town of Andrews and city of Georgetown in Georgetown County (Figure 5-25). This depression, which reflects a

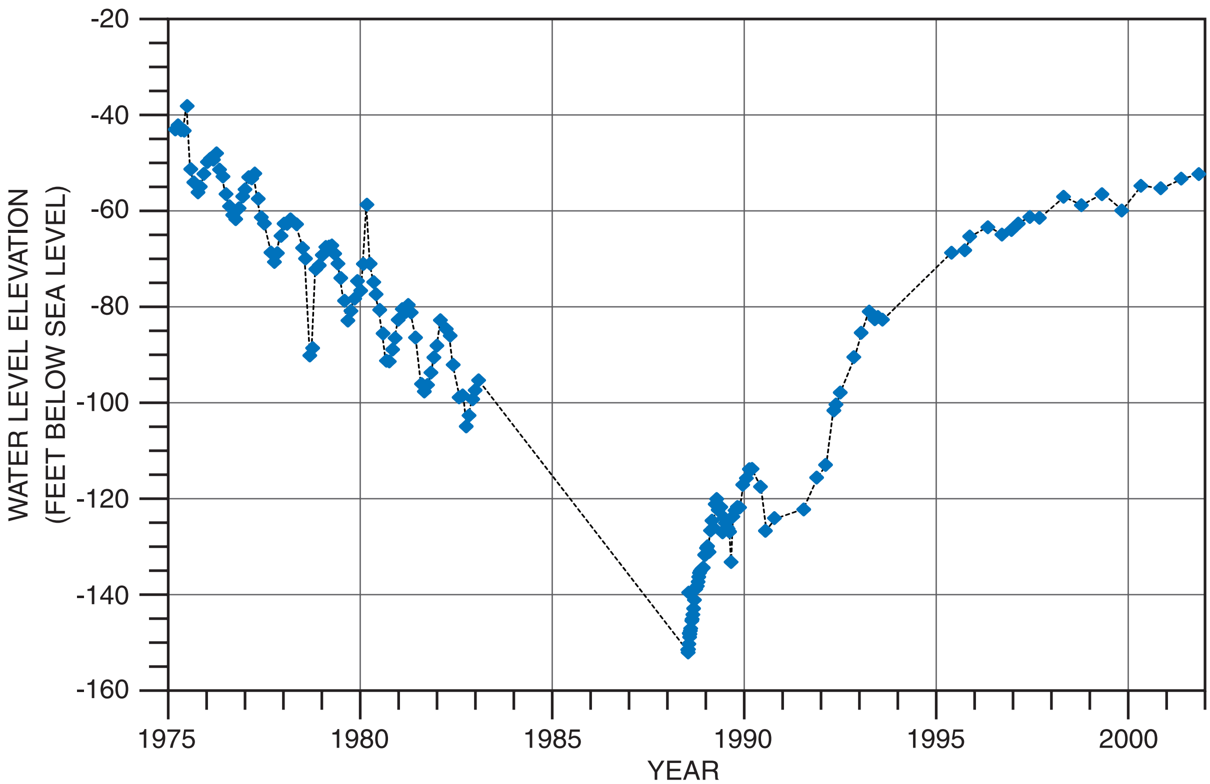


Figure 5-24. Water levels measured in a Black Creek aquifer well (HOR-290) at Myrtle Beach. Water-level declines caused by excessive pumping recovered significantly after regional ground-water pumping was reduced in the late 1980's.

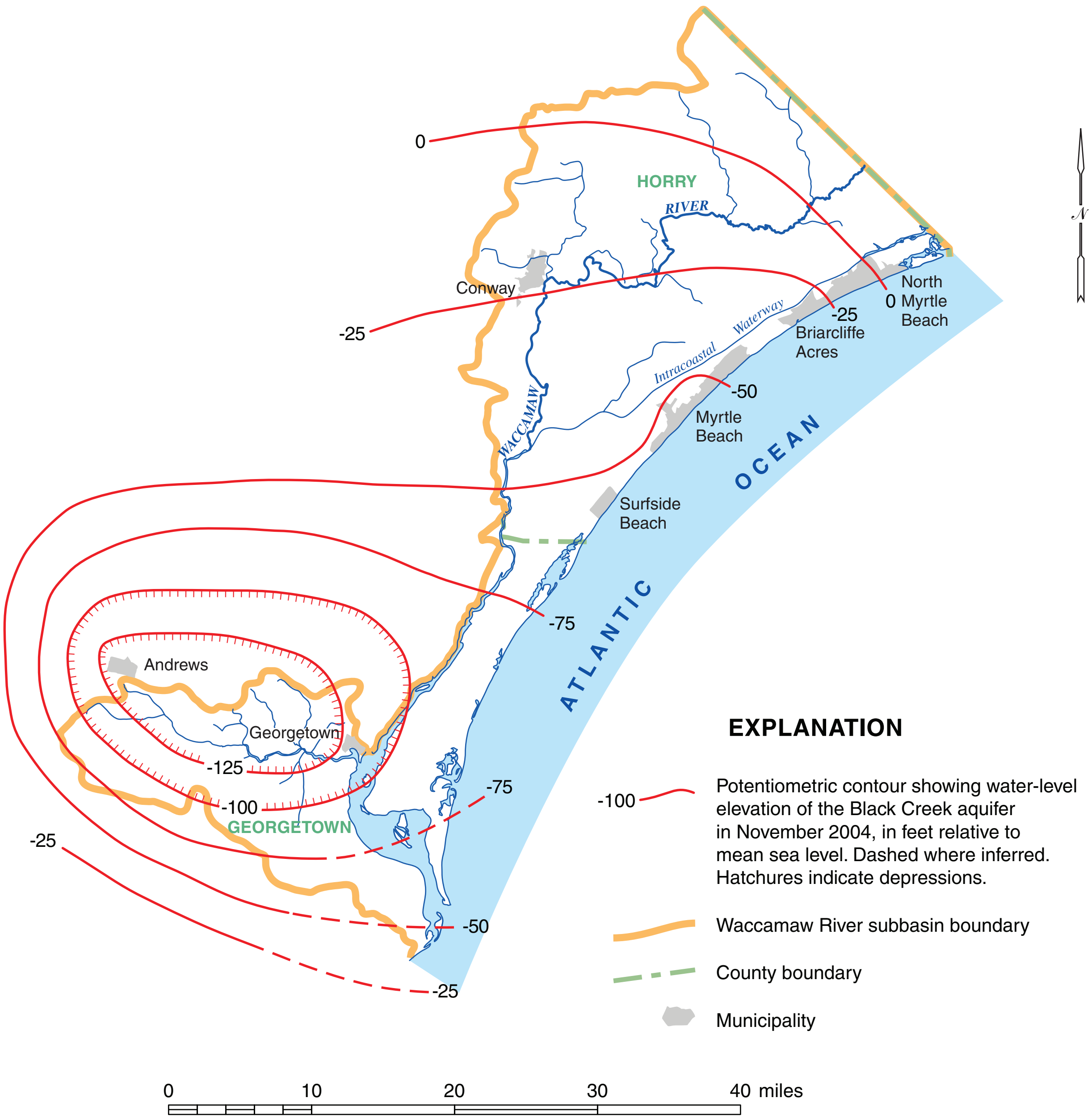


Figure 5-25. Potentiometric contours of the Black Creek aquifer in the Waccamaw River subbasin, November 2004 (from Hockensmith, 2008b).

decline of about 200 feet from predevelopment levels, contains the lowest point on the potentiometric surface of the Black Creek aquifer (Hockensmith, 2008b). Outside of this cone of depression, Black Creek aquifer water levels in this subbasin are generally 50 to 100 feet lower than estimated predevelopment levels.

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Waccamaw River subbasin is summarized in Table 5-27 and Figure 5-26. Offstream water use in this subbasin was 67,039 million gallons in 2006, ranking it eighth among the 15 subbasins. Of this amount, 65,130 million gallons were from surface-water sources (97 percent) and 1,909 million gallons were from ground-water sources (3 percent). Thermoelectric power production accounted for 73 percent of this total use, followed by water supply (13 percent) and golf course (7 percent). Consumptive use in this subbasin is estimated to be 12,221 million gallons, or about 18 percent of the total offstream use.

By far, the largest water user in this subbasin is Santee Cooper's Grainger electrical generating station, located adjacent to Lake Busbee at Conway in Horry County. This facility used 44,499 million gallons in 2006, which is about 90 percent of water used for power generation in the subbasin, and about two-thirds of the total reported water use for the entire subbasin. The subbasin's only other thermoelectric power plant, Santee Cooper's Winyah generating station, located near Georgetown, used 4,715 million gallons of surface water in 2006. Both are coal-fired plants that use steam to drive turbines and produce electricity.

Table 5-27. Reported water use in the Waccamaw River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	3,810	5.9	568	29.8	4,379	6.5
Industry	788	1.2	209	11.0	997	1.5
Irrigation	3,583	5.5	208	10.9	3,791	5.7
Mining	104	0.2	0	0.0	104	0.2
Other	0	0.0	21	1.1	21	0.0
Thermoelectric power	49,214	75.6	0	0.0	49,214	73.4
Water supply	7,631	11.7	902	47.2	8,533	12.7
Total	65,130		1,909		67,039	

Water-supply use in the subbasin totaled 8,533 million gallons in 2006. Surface water accounted for 7,631 million gallons (89 percent) and ground water for 902 million gallons (11 percent). The largest surface-water user was the city of Myrtle Beach, which withdrew 5,964 million gallons from the Atlantic Intracoastal Waterway in 2006. Georgetown Water and Sewer District was the other major surface-water supplier in the subbasin, withdrawing 1,667 million gallons from the Waccamaw River. Some of the larger water suppliers that used ground water were the Grand Strand Water and Sewer Authority (231 million gallons); the city of Georgetown (140 million gallons); Georgetown County Water and Sewer District (135 million gallons); and North Myrtle Beach (116 million gallons). Most of the ground water is pumped from the Black Creek aquifer.

Because of the large number of golf courses in Horry and Georgetown Counties, golf-course irrigation is a major use of water in the subbasin, ranking first among the 15 subbasins in this category. A total of 4,379 million gallons of water were used at 67 golf courses in 2006. Of this amount, 3,810 million gallons were from surface-water sources (87 percent) and 568 million gallons were from ground-water sources (13 percent). Most ground water is pumped from the surficial aquifer, within 100 feet of land surface. Some wells also tap the deeper Black Creek aquifer. Some of the larger users included the Reserve at Litchfield (340 million gallons) and Burroughs and Chapin Grande Dunes in Myrtle Beach (260 million gallons).

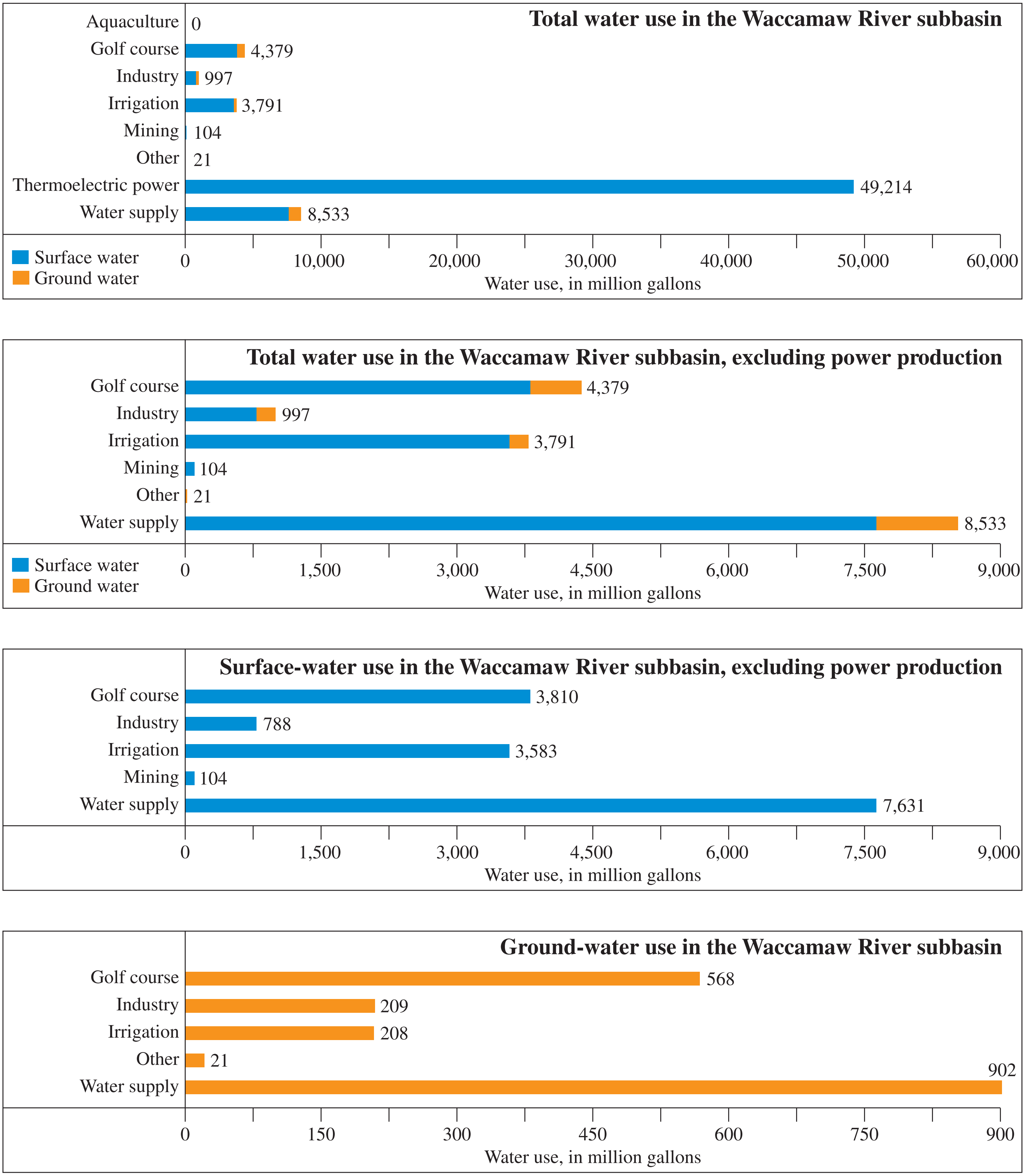


Figure 5-26. Reported water use in the Waccamaw River subbasin for the year 2006 (modified from Butler, 2007).

Irrigation water use totaled 3,791 million gallons, which was 5.7 percent of the water used in the subbasin in 2006. Of this amount, 3,583 million gallons were from surface-water sources (94 percent) and 208 million gallons were from ground-water sources (6 percent). By far the greatest user was Debordieu Colony Community Association in Georgetown, which used 3,517 million gallons.

Industrial water use in the subbasin was 997 million gallons in 2006. Of this amount, 788 million gallons were from surface-water sources (79 percent) and 209 million gallons were from ground-water sources (21 percent). The largest user was 3V, Inc. in Georgetown, which used 780 million gallons.

About 104 million gallons of surface water were used for mining purposes. This represents about 0.2 percent of the total reported water use in the subbasin.

AQUIFER STORAGE AND RECOVERY PROGRAM

In the Grand Strand area, the demand for water increases as much as 70 percent during the summer months, when the population swells because of an influx of tourists (Castro, 1995). In order to provide adequate amounts of drinking water in the summer, water suppliers need water treatment plants whose capacities greatly exceed the average daily demand; most days of the year, however, the treatment plants would operate much below their optimum capacities. As a way to operate their treatment plants more efficiently, and to provide additional water for high-demand summer days, the city of Myrtle Beach began an aquifer storage and recovery (ASR) program in the 1990's.

The concept of an ASR program is to treat more surface water than is needed during times of low demand, inject the excess treated water into an aquifer and store it in the ground until the demand for water is high, and then pump the water out of the ground when it can be used to supplement surface-water supplies. ASR wells can provide water for short-term, high-demand periods, which can allow water systems to meet user demands with smaller treatment plants, thereby reducing the overall cost of providing the water. Additionally, the use of an ASR system can reduce water-production costs by allowing treatment plants to operate more efficiently by stabilizing plant production to an optimum flow rate and by treating more surface water in the winter, when the water quality is better than in the summer, and is thus less expensive to treat.

Begun in the mid-1990's, the Myrtle Beach ASR program was the first of its kind in South Carolina. The Grand Strand Water and Sewer Authority, which recently took over operation of the Myrtle Beach water-treatment plants, now operates this ASR program that currently consists of 15 ASR wells in operation or under development. The combined storage volume is nearly two billion gallons and treated water can be withdrawn from these ASR wells at a rate of 14.9 million gallons per day.

WATERSHED CONDITIONS: SANTEE RIVER BASIN

BROAD RIVER SUBBASIN

BROAD RIVER SUBBASIN

The Broad River subbasin dominates the central Piedmont of South Carolina. Sharing a long northern border with North Carolina, the basin tapers in a southeasterly direction and terminates at its confluence with the Saluda River near Columbia. The subbasin encompasses all or parts of 11 South Carolina counties, including all of Cherokee, Spartanburg, and Union Counties and portions of Chester, Fairfield, Greenville, Laurens, Lexington, Newberry, Richland, and York Counties (Figure 6-1). This is the largest subbasin in the State, representing 12.2 percent of its area and encompassing 3,800 square miles.

DEMOGRAPHICS

This is the most populated subbasin in the State, with an estimated 2000 population of 700,300, or 17.5 percent of the State's total population. The largest population increases are expected to occur in Greenville and Spartanburg Counties, while the slowest growth is expected in Chester County.

The northern part of the subbasin contains the major urban centers, with the cities of Spartanburg and Greenville composing part of the industrialized Interstate-85 corridor. A rural population and agricultural economy predominate in the subbasin south of the Interstate-85 corridor.

The largest population centers are Spartanburg (about 150,000 in the metropolitan area), Gaffney (12,968), and York (6,985) in the north; Laurens (9,916) and Clinton (8,091) in Laurens County near the western boundary; and Union (8,793) in the heart of the subbasin. The northwest corner and south end of the subbasin encompass parts of the Greenville and Columbia metropolitan areas.

Per capita income in the subbasin ranged from $22,651 in Cherokee County to $30,399 in Greenville County in 2005. Per capita income in Greenville, Lexington, Richland, and York Counties ranked third, fourth, fifth, and seventh, respectively, among South Carolina counties. The 1999 median household income ranged from $31,441 in Union County to $44,659 in Lexington County. Median household incomes in five counties were above the State average of $37,082.

During 2000, the counties of the subbasin had combined annual average employment of non-agricultural wage and salary workers of 750,000. Labor distribution in the subbasin counties included management, professional, and technical services, 31 percent; sales and office, 26 percent; production, transportation, and materials moving, 18 percent; service, 13 percent; construction, extraction, and maintenance, 10 percent; and farming, fishing, and forestry, 1 percent.

The sector of manufacturing, mining, and public utilities had an annual product value of $30 billion in 2000. Greenville and Spartanburg Counties accounted for 56 percent of manufacturing output of the subbasin's 11 counties. Manufacturing dominated the economic output of the region, but crop, livestock, and timber-related production were nonetheless substantial. In 2001, crop and livestock value approached $340 million, and delivered-timber value was nearly $190 million (South Carolina Budget and Control Board, 2005).

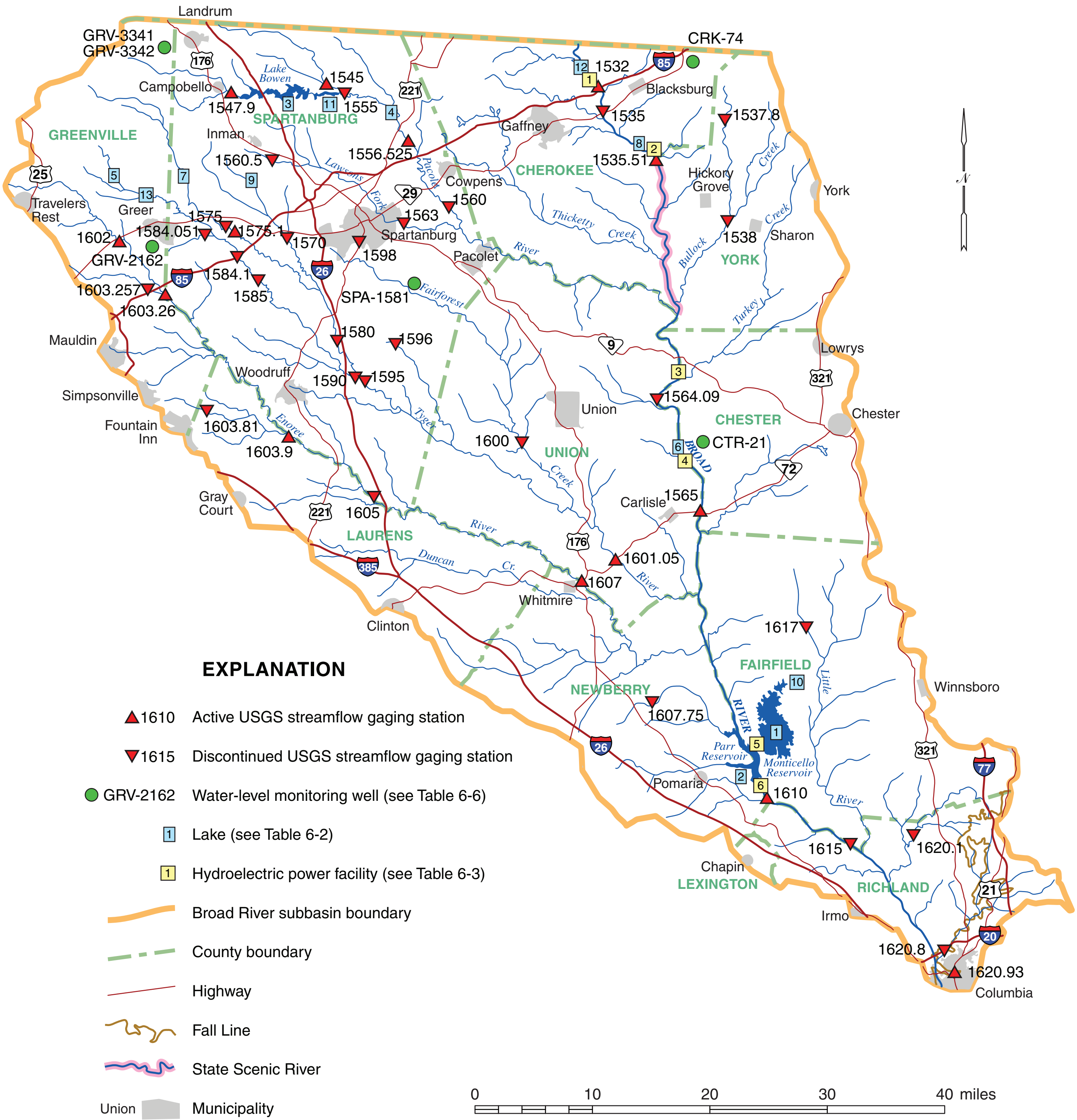


Figure 6-1. Map of the Broad River subbasin.

SURFACE WATER

Hydrology

The Broad River, with its headwaters originating in North Carolina, constitutes the main stem of this large drainage system. Three major tributaries—the Pacolet, Tyger, and Enoree Rivers—originate primarily in South Carolina and discharge into the main stem. Smaller tributaries include Lawsons Fork Creek, Fairforest Creek, Bullock Creek, Turkey Creek, Sandy River, Little River, and Cedar Creek. Several urban areas, including Spartanburg, Columbia, Greer, Gaffney, Union, York, and Winnsboro, utilize these streams. The entire drainage is in the Piedmont physiographic province, except for the extreme headwaters of the Pacolet and Tyger Rivers, which rise in the Blue Ridge, and the southeast edge of the subbasin, which is in the Coastal Plain.

In May of 1991, a 15-mile stretch of the Broad River from Ninety-Nine Islands Dam to the confluence with the Pacolet River was officially designated by the South Carolina General Assembly as a State Scenic River. (See the *River Conservation* section of Chapter 9, *Special Topics*.)

Many U.S. Geological Survey (USGS) streamflow-gaging stations have been established or discontinued in this subbasin since the publication of the *State Water Assessment* in 1983. Streamflow is presently monitored at 14 gaging stations: four on the Broad River, four on the Enoree River, one each on the Pacolet, North Pacolet, South Pacolet, Tyger, and Middle Tyger Rivers and one on Smith Branch in Columbia (Figure 6-1). Streamflow statistics from active and discontinued gaging stations are presented in Table 6-1. Streamflow data for the Broad River near Boiling Springs, N.C., are also presented.

Table 6-1. Selected streamflow characteristics at USGS gaging stations in the Broad River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Broad River near Boiling Springs, N.C. 1515	1925 to 2007*	875	1,473	1.68	552	83 2002	63,900 1928	73,300 1928
Broad River near Blacksburg 1532	1997 to 2007*	1,290	1,738	1.35	504	41 2002	48,000 2004	– – –
Broad River near Gaffney 1535	1938-71 and 1985-90	1,490	2,461	1.65	954	224 1954	80,600 1940	119,000 1940
Broad River below Cherokee Falls 1535.51	1998 to 2007*	1,550	1,983	1.28	518	138 2002	60,000 2004	– – –
Clarks Fork Creek near Smyrna 1537.8	1980 to 2002	24.1	20.7	0.86	3.3	0.0 2002	1,000 1985	2,100 1995
Bullock Creek near Sharon 1538	2000 to 2003	84.3	87.8	1.04	0.0	0.0 2001	2,820 2003	7,160 2003
North Pacolet River at Fingerville 1545	1930 to 2007*	116	203	1.75	79	14 2002	8,110 1964	12,500 1940
South Pacolet River near Campobello 1547.9	1989 to 2007*	55.4	96.6	1.74	33	7.8 2002	3,500 1995	5,170 1995
Pacolet River near Fingerville 1555	1929 to 2006	212	329	1.55	106	26 2002	13,500 1940	22,800 1940
Pacolet River near Cowpens 1556.525	1993 to 2007*	273	345	1.26	78	44 2002	11,800 2003	14,300 2004
Pacolet River near Clinton 1560	1939 to 1971	320	488	1.53	178	17 1941	18,200 1940	26,800 1940

Table 6-1. Continued

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Lawsons Fork Creek near Inman 1560.5	1979 to 2006	6.46	9.3	1.44	3.3	0.37 2002	420 2003	564 2003
Lawsons Fork Creek at Spartanburg 1563	1966 to 1970	74.7	107	1.43	49	28 1970	2,010 1969	7,650 1969
Broad River near Lockhart 1564.09	1992 to 1999	2,720	3,852	1.42	1,410	200 1999	57,600 1995	59,300 1995
Broad River near Carlisle 1565	1938 to 2007*	2,790	3,885	1.39	1,270	44 1956	114,000 1976	123,000 1976
North Tyger River near Fairmont 1570	1950 to 1988	44.4	63.9	1.44	22	4.6 1988	2,130 1959	3,610 1959
Middle Tyger River at Lyman 1575	1937 to 1967	68.3	103	1.51	36	5.0 1955	3,110 1940	4,800 1940
Middle Tyger River near Lyman 1575.1	2000 to 2007*	69.0	82.9	1.20	14	0.66 2002	2,880 2005	– – –
North Tyger River near Moore 1580	1933 to 1967	162	233	1.44	76	16 1954	9,340 1940	12,300 1940
Maple Creek near Duncan 1584.051	1993 to 1994	10.2	13.3	1.31	7.1	5.5 1993	235 1994	– – –
South Tyger River below Lyman 1584.1	1993 to 1995	96.3	160	1.66	59	15 1993	1,020 1994	1,120 1994
South Tyger River near Reidville 1585	1934 to 1937	106	160	1.51	20	5.5 1941	3,850 1949	6,420 1949
South Tyger River near Woodruff 1590	1933 to 1971	174	236	1.36	69	12 1955	7,480 1936	9,510 1936
Tyger River near Woodruff 1595	1929 to 1956	351	465	1.32	146	29 1954	18,000 1929	28,000 1929
Dutchman Creek near Pauline 1596	1966 to 1969	8.9	11.7	1.31	6.0	3.8 1966	242 1968	4,500 1968
Fairforest Creek at Spartanburg 1598	1966 to 1970	17.0	29.9	1.76	11	0.0 1966	567 1967	– – –
Fairforest Creek near Union 1600	1940 to 1971	183	212	1.16	51	5.0 1954	6,740 1964	7,720 1964
Tyger River near Delta 1601.05	1973 to 2007*	759	986	1.30	272	28 2002	26,000 1979	37,500 1976

Table 6-1. Continued

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Enoree River at Taylors 1602	1998 to 2007*	49.7	71.4	1.47	18	2.3 2002	2,000 2003	5,600 2003
Brushy Creek near Pelham 1603.257	1995 to 1997	13.8	26.4	1.91	10	3.9 1997	414 1996	1,150 1996
Enoree River at Pelham 1603.26	1993 to 2007*	84.2	153	1.82	50	16 1999	8,500 1995	11,300 1995
Durbin Creek above Fountain Inn 1603.81	1994 to 2006	14.0	15.9	1.14	4.4	0.15 2002	800 1995	– – –
Enoree River near Woodruff 1603.9	1993 to 2007*	249	362	1.46	116	34 2002	20,000 1995	52,200 1995
Enoree River near Enoree 1605	1929 to 1977	307	432	1.41	136	20 1954	18,300 1929	30,000 1929
Enoree River at Whitmire 1607	1973 to 2007*	444	543	1.22	161	30 2002	22,700 1995	31,200 1995
Hellers Creek near Pomaria 1607.75	1980 to 1994	8.16	7.1	0.87	1.4	0.42 1988	360 1992	888 1992
Broad River at Alston 1610	1896-1907 and 1980-2007*	4,790	5,524	1.15	1,330	48 2002	130,000 1903	140,000 1903
Broad River at Richtex 1615	1925 to 1983	4,850	6,158	1.27	1,890	149 1935, 1937	211,000 1929	228,000 1929
West Fork Little River near Salems Crossroad 1617	1980 to 1997	25.5	25.8	1.01	1.4	0.0 1982	1,810 1991	5,470 1991
Cedar Creek near Blythewood 1620.1	1966 to 1996	48.9	43.3	0.89	3.3	0.07 1986	2,910 1994	4,870 1968
Crane Creek at Columbia 1620.8	1968 to 1974	66.5	64.3	0.97	5.0	0.1 1970	1,500 1968	– – –
Smith Branch at N. Main St. at Columbia 1620.93	1976 to 2007*	5.67	9.1	1.61	1.7	0.74 2001	335 1995	2,180 2004

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Average annual flow of the Broad River ranges from about 1,500 cfs (cubic feet per second) near the North Carolina border to more than 6,000 cfs at the confluence with the Saluda River at Columbia. This main-stem river reflects streamflow characteristics typical of Piedmont streams that depend primarily on precipitation and surface runoff to support flow (Figure 6-2). In the upper portion of this river, near Gaffney, where annual rainfall is higher and ground-water discharges are more significant, flows are well sustained and moderately variable. With distance downstream, flow becomes progressively more variable as rainfall and ground-water support in this lower portion of the subbasin decrease.

Low flows of record for the Broad River occurred during the mid-1950's and in 2002, with average daily flows less than 50 cfs measured at the Blacksburg (1532), Carlisle (1565), and Alston (1610) gaging stations. The highest recorded flow—228,000 cfs—was measured at the Richtex (1615) gage north of Columbia in 1929.

The Broad River typically receives from several hundred to about 1,000 cfs from each of its three main tributaries, the Pacolet, Tyger, and Enoree Rivers. At their most-downstream gages, these rivers have average annual streamflows of 488 cfs on the Pacolet River near Clinton (discontinued gage 1560), 986 cfs on the Tyger River near Delta (1601.05), and 543 cfs on the Enoree River at Whitmire (1607). Ninety percent of the time, flows at these sites equal or exceed 178 cfs, 272 cfs, and 161 cfs, respectively, while the highest flow recorded at each of these sites exceeded 20,000 cfs (Table 6-1).

Streamflow characteristics in the tributary streams are similar to those of the main stem (Figure 6-2). Flow is least variable in streams that drain the upper portion of the subbasin where rainfall and ground-water support are greatest. Flow in streams that drain the lower portion of the subbasin near Columbia shows the greatest variability.

The lowest flows of record for tributary streams occurred primarily during the droughts of 1954–56 and 1998–2002, especially in 2002. Flood flows of record are attributed primarily to major storm events occurring in 1929, 1940, and 1976. Storm events producing peak flows appear to impact limited areas of the subbasin.

Several small water-supply and hydropower reservoirs on the Broad, Pacolet, and Enoree Rivers generally have little effect on streamflow except during low-flow conditions. These developments were built prior to streamflow monitoring.

The Broad River provides reliable quantities of surface water along its entire length, although low flows are best sustained in the upper reaches. Reliable sources of surface-water supplies also exist in tributary streams in the upper portion of the subbasin, such as the Pacolet, Tyger, and Enoree Rivers. Streams that originate in the lower portion of the subbasin near Columbia, such as Little River and Cedar Creek, require storage to provide reliable year-round water supplies.

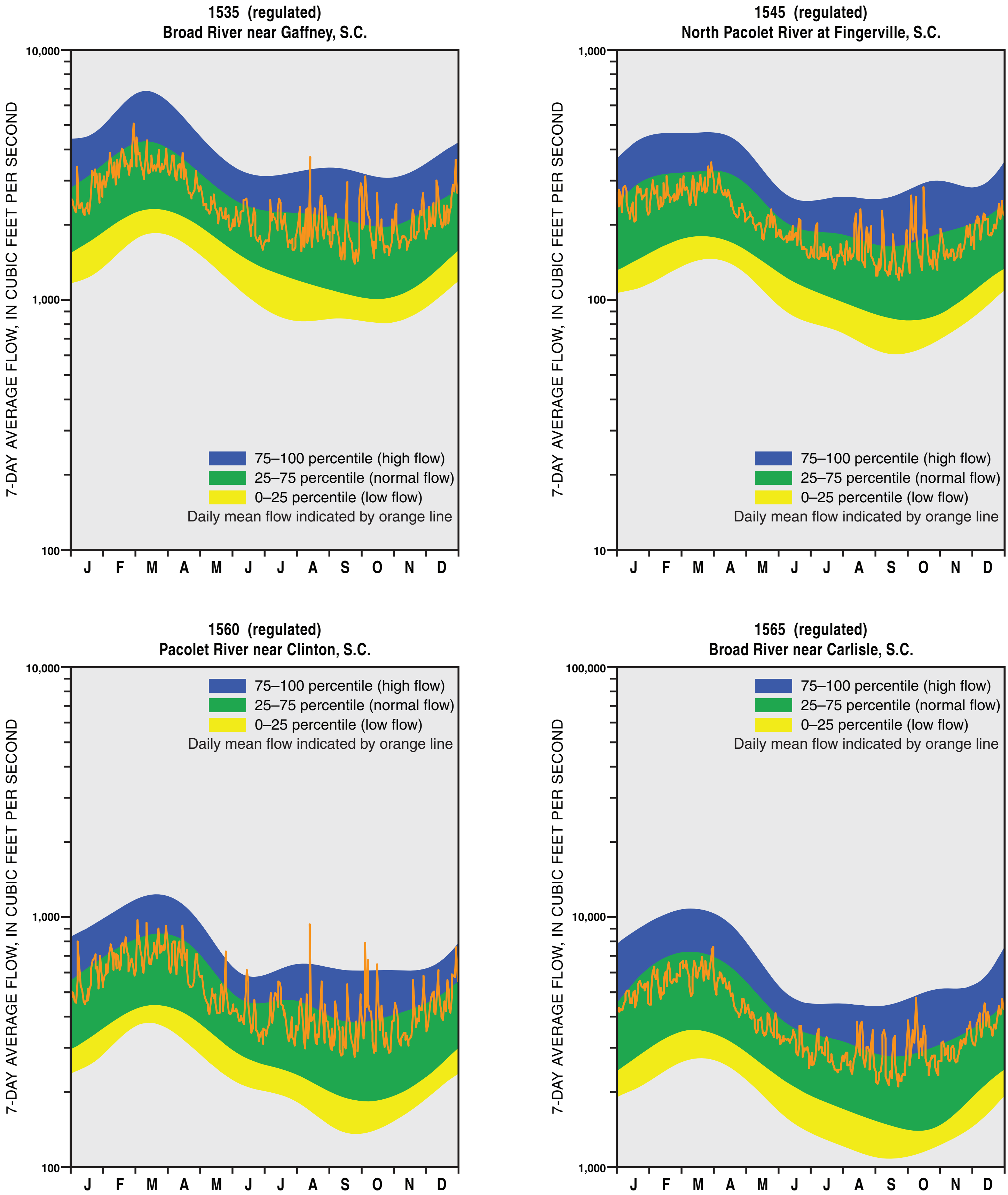


Figure 6-2. Duration hydrographs for selected gaging stations in the Broad River subbasin.

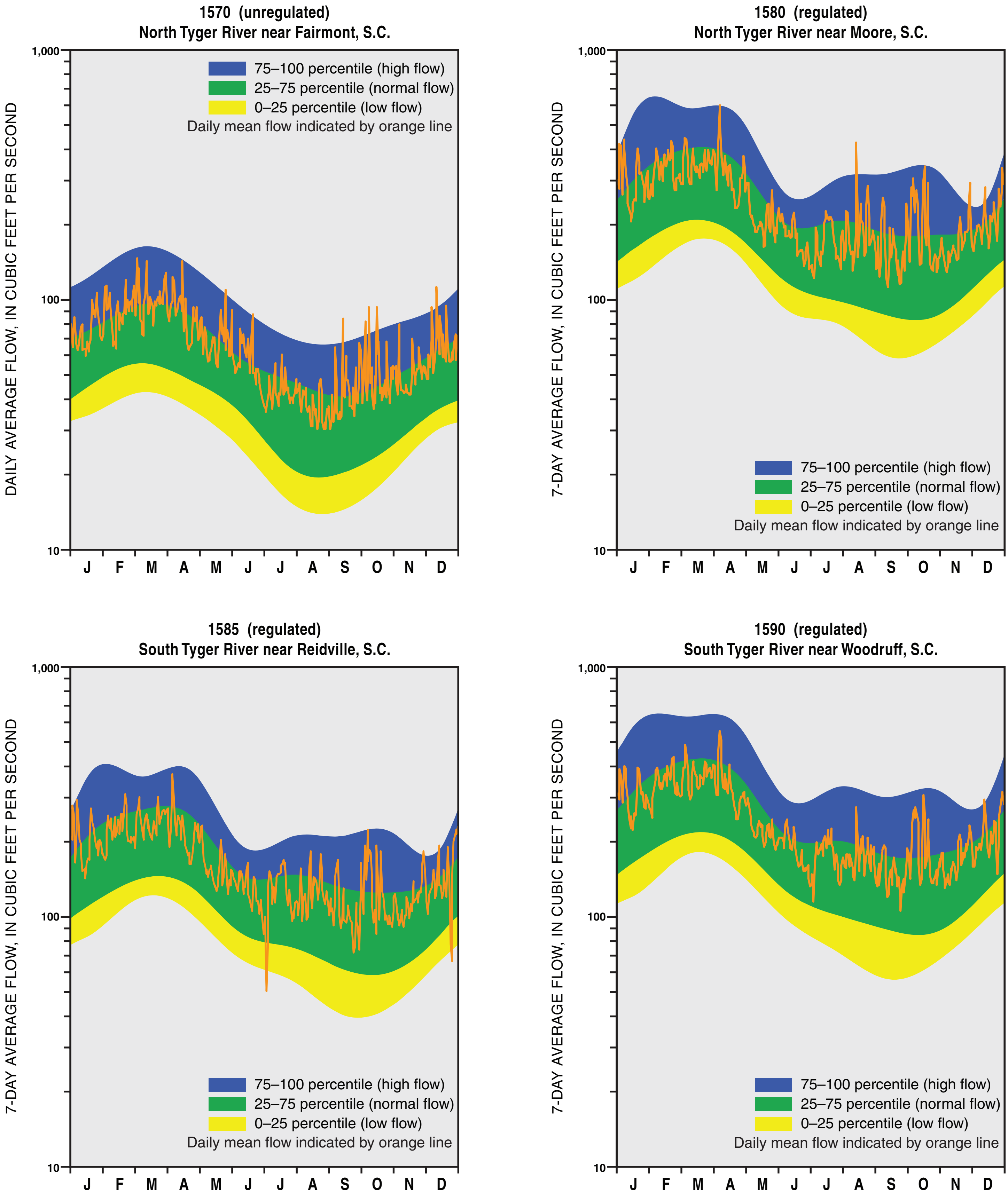


Figure 6-2. Duration hydrographs for selected gaging stations in the Broad River subbasin (continued).

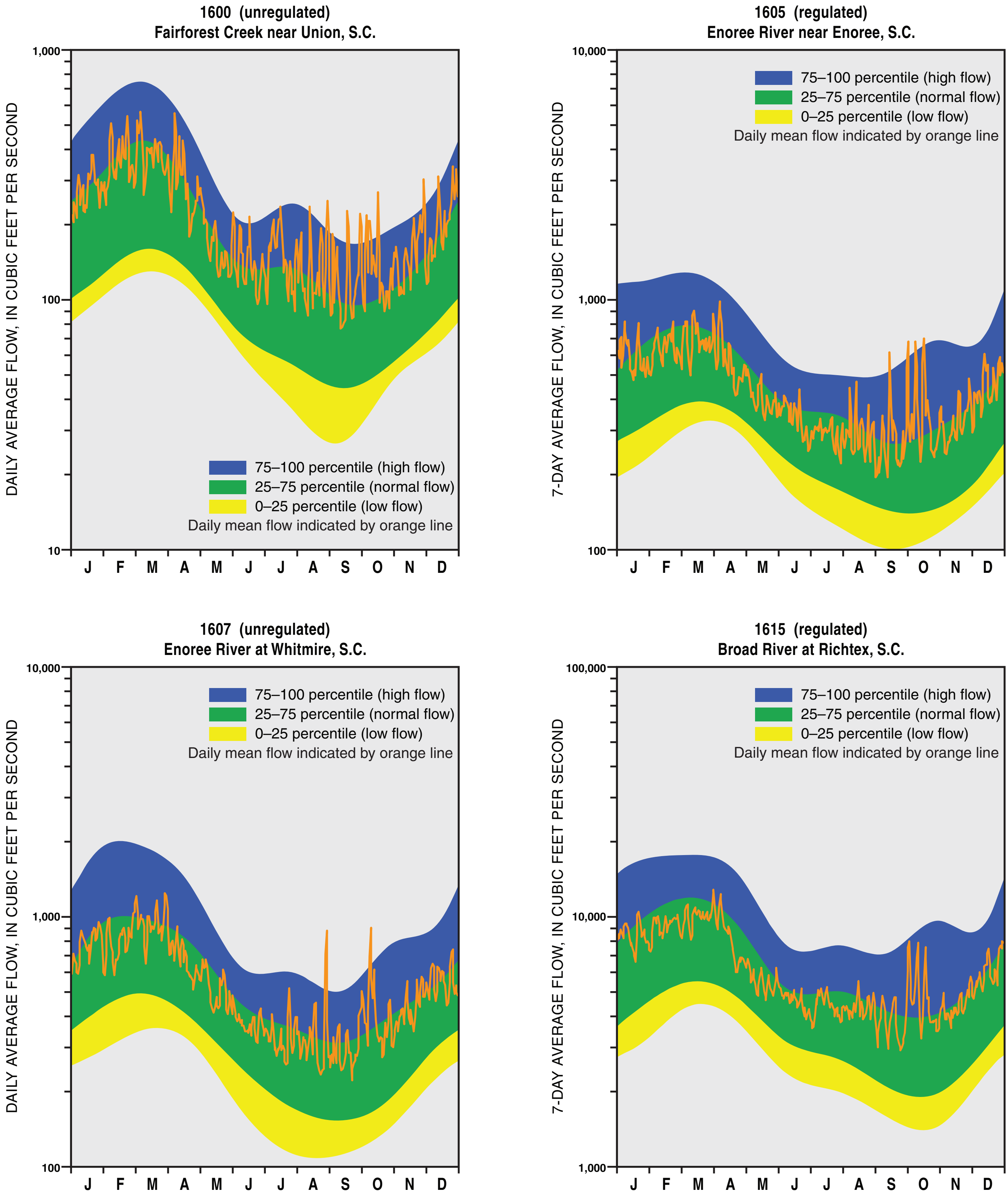


Figure 6-2. Duration hydrographs for selected gaging stations in the Broad River subbasin (continued).

Development

Surface-water development has been extensive in the Broad River subbasin. Most of this development has been for the production of hydroelectric power, although several large reservoirs have been built to provide municipal water supplies (Table 6-2). The larger hydropower facilities located within the subbasin are summarized in Table 6-3 and shown on Figure 6-1. Hundreds of small dams, most privately owned, create small impoundments on many tributaries of the Broad River, particularly in the upper reaches of the subbasin. The three major reservoirs in the subbasin are Lake Monticello, Parr Shoals Reservoir, and Lake William C. Bowen.

Lake Monticello and Parr Shoals Reservoir are 26 miles northwest of Columbia, on Frees Creek and Broad River, respectively. Parr Reservoir, constructed in 1914 for hydroelectric power, has a surface area of 4,400 acres. The lake provides cooling water for steam-electric generating facilities and provided cooling water to the experimental Parr Nuclear Power Plant during the 1960's. In 1976, the dam was heightened 9 feet for conjunctive use with Lake Monticello and provides water for the Fairfield pumped-storage facility on Lower Frees Creek.

Lake Monticello has a surface area of 6,800 acres and a volume of 431,000 acre-ft. The lake was built in 1977 to

Table 6-2. Lakes 200 acres or more in the Broad River subbasin (shown on Figure 6-1)

Number on map	Name	Stream	Surface area (acres)	Storage capacity (acre-feet)	Purpose
1	Monticello Reservoir	Frees Creek	6,800[a]	431,000[a]	Power and recreation
2	Parr Shoals Reservoir	Broad River	4,400[a]	32,500[a]	Power and recreation
3	Lake William C. Bowen	South Pacolet River	1,534[e]	22,700[d]	Recreation and water supply
4	Lake H. Taylor Blalock	Pacolet River	1,100[c]	16,000[c]	Recreation and water supply
5	Lake John A. Robinson	Barton Creek	800[a]	14,000[a]	Recreation and water supply
6	Neal Shoals Reservoir	Broad River	575[f]	1,492[d]	Power
7	Lyman Lake	Middle Tyger River	500[a]	6,200[a]	Industry, recreation, and water supply
8	Ninety-Nine Islands Lake	Broad River	388[b]	undetermined	Power and recreation
9	Lake Cooley	Jordan Creek	330[a]	1,320[a]	Recreation and flood control
10	Monticello Recreation Lake	Frees Creek	300[a]	6,000[a]	Power and recreation
11	Spartanburg Municipal Reservoir #1	South Pacolet River	271[c]	3,388[d]	Recreation and water supply
12	Gaston Shoals Lake	Broad River	251[b]	2,500	Power, recreation, and water supply
13	Lake Cunningham	South Tyger River	250[a]	2,200[a]	Recreation and water supply

Sources: (a) U.S. Army Corps of Engineers (1991)
(b) Duke Energy website http://www.duke-energy.com/lakes/facts-and-maps.asp (2008)
(c) Spartanburg Water System
(d) U.S. Geological Survey (2008)
(e) Journey and Abrahamsen (2008)
(f) South Carolina Electric & Gas Company (2005)

Table 6-3. Major hydroelectric power generating facilities in the Broad River subbasin (shown on Figure 6-1)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Gaston Shoals Duke Energy	Broad River	Gaston Shoals Lake	6.7	213,600
2	Ninety-Nine Islands Duke Energy	Broad River	Ninety-Nine Islands Lake	18	32,949
3	Lockhart Lockhart Power Co.	Broad River	Lockhart Canal	18	583
4	Neal Shoals SCE&G	Broad River	Neal Shoals Reservoir	5.2	326,592
5	Fairfield Pumped Storage SCE&G	Frees Creek	Monticello Reservoir	511.2	1,920,104
6	Parr SCE&G	Broad River	Parr Shoals	14.4	593,019

supply cooling water to the V.C. Summer Nuclear power plant and to serve as the upper-storage reservoir of the Fairfield pumped-storage hydroelectric facility. During periods of peak electrical demand, water is drained through generating turbines from Lake Monticello into Parr Reservoir; during periods when electricity demand is low, part of the V.C. Summer facility's output is used to pump water back into Lake Monticello. Parr Shoals Reservoir and Lake Monticello also serve recreational needs.

Lake William C. Bowen is northwest of Spartanburg on the South Pacolet River. This 1,534-acre lake is one of three reservoirs used by the city of Spartanburg as a water supply and a recreational area.

The inactive Columbia Canal, which takes in water from the Broad River and discharges it into the Congaree River, is the only navigation project in the subbasin. Initially constructed in 1824 to provide a navigable route around rapids at the confluence of the Broad and Saluda Rivers, the Columbia Canal was used by barge traffic into the mid-1800's. A hydroelectric power station constructed at the lower end of the canal in 1891 is still in operation today. The city of Columbia also uses the canal for water supply.

The NRCS (Natural Resources Conservation Service) assisted in the planning and installation of several flood-control projects in the subbasin. Work has been completed on 9 of 12 projects authorized since 1962; three projects have been terminated or have become inactive since their authorizations. Work completed through 2005 included 45 flood-retarding structures, 13 miles of channel improvements, erosion-control treatments, and sediment-damage reduction.

Surface-Water Quality

The Broad River main stem and most of its tributaries are designated as "Freshwater" (Class FW). Class FW encompasses freshwater that is suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses. Vaughn Creek, in the northeastern corner of Greenville County, is designated as "Outstanding Resource Water" (Class ORW)—freshwater that constitutes an outstanding recreational or ecological resource and is suitable as a drinking-water source with minimal treatment (DHEC, 2001).

Water quality in the Broad River subbasin is characterized as generally good. This basin has shown improvement in water-quality indicators since the mid-1990's, and the major lakes meet the minimum water-quality criteria for recreational uses.

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 179 surface-water sites in the subbasin in the late 1990's in order to assess the water's suitability for aquatic life and recreational use (Figure 6-3). Aquatic-life uses were fully supported at 134 sites, or 75 percent of the water bodies sampled; water at the impaired sites exhibited poor macroinvertebrate-community structure, high metals concentrations, pH excursions, or low dissolved-oxygen levels. In the Enoree River, contaminated ground water from an industrial site point-source has been identified as the cause of excessive zinc concentrations. Recreational use was fully supported in 19 percent of the sampled water bodies; the water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2001). Water-quality impairments in the subbasin are listed in Table 6-4.

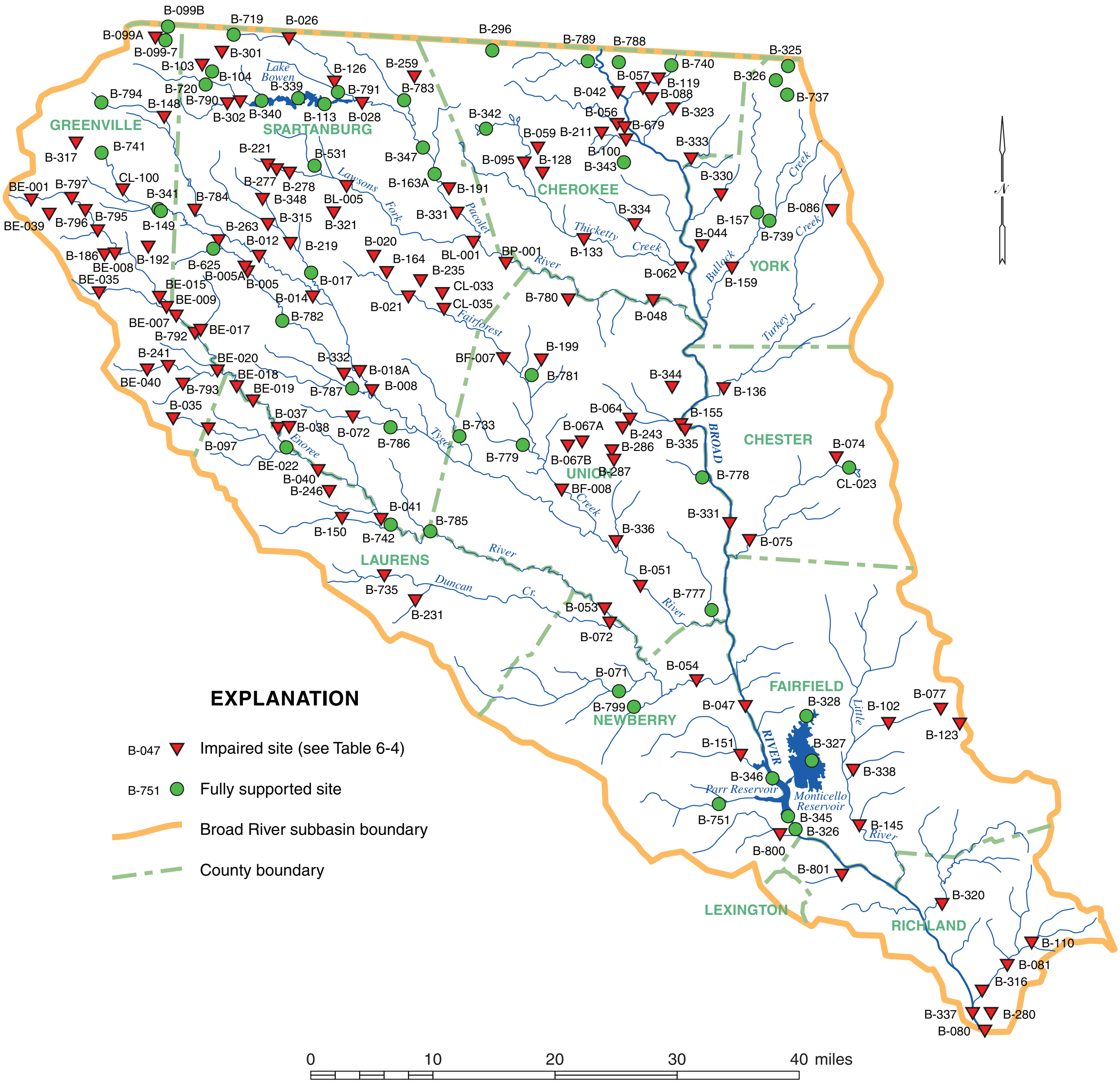


Figure 6-3. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 6-4 (DHEC, 2001).

Table 6-4. Water-quality impairments in the Broad River subbasin (DHEC, 2001)

Water-body name	Station number	Use	Status	Water-quality indicator
Beaverdam Creek	BE-039	Recreation	Nonsupporting	Fecal coliform
	B-769	Aquatic life	Partially supporting	Macroinvertebrates
Buckhorn Creek	B-795	Aquatic life	Partially supporting	Macroinvertebrates
Mountain Creek	B-186	Recreation	Nonsupporting	Fecal coliform
	BE-008	Aquatic life	Partially supporting	Macroinvertebrates
Princess Creek	B-192	Aquatic life	Nonsupporting	Zinc
		Recreation	Nonsupporting	Fecal coliform
Brushy Creek	BE-035	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
	BE-009	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Rocky Creek	BE-007	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Abner Creek	B-792	Aquatic life	Partially supporting	Macroinvertebrates
Horsepen Creek	B-793	Aquatic life	Partially supporting	Macroinvertebrates
Gilder Creek	BE-040	Recreation	Nonsupporting	Fecal coliform
	B-241	Recreation	Nonsupporting	Fecal coliform
	BE-020	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Lick Creek	B-038	Recreation	Nonsupporting	Fecal coliform
Durbin Creek	B-035	Recreation	Nonsupporting	Fecal coliform
Enoree River	B-097	Recreation	Nonsupporting	Fecal coliform
	BE-001	Aquatic life	Nonsupporting	Zinc
		Recreation	Nonsupporting	Fecal coliform
	B-797	Aquatic life	Partially supporting	Macroinvertebrates
	BE-015	Recreation	Nonsupporting	Fecal coliform
	BE-017	Aquatic life	Nonsupporting	Copper
		Recreation	Nonsupporting	Fecal coliform
	BE-018	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
	BE-019	Aquatic life	Partially supporting	Macroinvertebrates
	B-037	Recreation	Nonsupporting	Fecal coliform
	B-040	Recreation	Partially supporting	Fecal coliform
	B-041	Aquatic life	Nonsupporting	Zinc
		Recreation	Partially supporting	Fecal coliform
	B-053	Recreation	Nonsupporting	Fecal coliform
Beaverdam Creek	B-246	Recreation	Nonsupporting	Fecal coliform
Warrior Creek	B-150	Recreation	Nonsupporting	Fecal coliform
Beards Fork Creek	B-231	Aquatic life	Nonsupporting	Dissolved oxygen
Duncan Creek Reservoir	B-735	Aquatic life	Partially supporting	pH
Duncan Creek	B-072	Recreation	Nonsupporting	Fecal coliform
Enoree River	B-054	Aquatic life	Nonsupporting	Chromium
		Recreation	Nonsupporting	Fecal coliform

Table 6-4. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Mush Creek	B-317	Recreation	Nonsupporting	Fecal coliform
Lake Robinson	CL-100	Aquatic life	Partially supporting	pH
South Tyger River	B-263	Recreation	Partially supporting	Fecal coliform
	B-005A	Aquatic life	Partially supporting	Macroinvertebrates
	B-005	Recreation	Nonsupporting	Fecal coliform
	B-332	Recreation	Partially supporting	Fecal coliform
Lake Cooley	B-348	Aquatic life	Partially supporting	pH
North Tyger River tributary	B-315	Recreation	Nonsupporting	Fecal coliform
North Tyger River	B-219	Aquatic life	Nonsupporting	Zinc
		Recreation	Nonsupporting	Fecal coliform
North Tyger River	B-018A	Recreation	Nonsupporting	Fecal coliform
Beaverdam Creek	B-784	Aquatic life	Partially supporting	Macroinvertebrates
Middle Tyger River	B-148	Recreation	Nonsupporting	Fecal coliform
	B-012	Recreation	Nonsupporting	Fecal coliform
	B-014	Recreation	Nonsupporting	Fecal coliform
Tyger River	B-008	Recreation	Nonsupporting	Fecal coliform
	B-051	Recreation	Nonsupporting	Fecal coliform
Jimmies Creek	B-072	Recreation	Nonsupporting	Fecal coliform
Fairforest Creek	B-020	Recreation	Nonsupporting	Fecal coliform
	B-164	Recreation	Nonsupporting	Fecal coliform
	B-021	Aquatic life	Nonsupporting	Macroinvertebrates, chromium, zinc, copper
		Recreation	Nonsupporting	Fecal coliform
	BF-007	Recreation	Nonsupporting	Fecal coliform
	BF-008	Recreation	Nonsupporting	Fecal coliform
Fairforest Creek tributary	B-321	Aquatic life	Nonsupporting	Chromium, zinc, copper
		Recreation	Nonsupporting	Fecal coliform
Kelsey Creek	B-235	Recreation	Nonsupporting	Fecal coliform
Lake Johnson	CL-035	Aquatic life	Nonsupporting	pH
Lake Craig	CL-033	Aquatic life	Partially supporting	pH
Mitchell Creek	B-199	Recreation	Nonsupporting	Fecal coliform
Toschs Creek	B-067A	Recreation	Nonsupporting	Fecal coliform
	B-067B	Recreation	Nonsupporting	Fecal coliform
Tinkers Creek	B-286	Recreation	Nonsupporting	Fecal coliform
	B-287	Recreation	Nonsupporting	Fecal coliform
	B-336	Recreation	Nonsupporting	Fecal coliform
Canoe Creek	B-088	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Peoples Creek	B-211	Recreation	Nonsupporting	Fecal coliform
Furnace Creek	B-100	Recreation	Nonsupporting	Fecal coliform
Doolittle Creek	B323	Recreation	Nonsupporting	Fecal coliform
Guyonmoore Creek	B-330	Recreation	Partially supporting	Fecal coliform

Table 6-4. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Broad River	B-042	Recreation	Partially supporting	Fecal coliform
	B-044	Recreation	Partially supporting	Fecal coliform
Buffalo Creek	B-119	Recreation	Nonsupporting	Fecal coliform
	B-057	Aquatic life	Partially supporting	Copper
		Recreation	Nonsupporting	Fecal coliform
Cherokee Creek	B-056	Aquatic life	Partially supporting	Macroinvertebrates
	B-679	Recreation	Nonsupporting	Fecal coliform
Kings Creek	B-333	Recreation	Partially supporting	Fecal coliform
Irene Creek	B-059	Recreation	Nonsupporting	Fecal coliform
Limestone Creek	B-128	Recreation	Nonsupporting	Fecal coliform
Gilkey Creek	B-334	Recreation	Nonsupporting	Fecal coliform
Thicketty Creek	B-095	Recreation	Nonsupporting	Fecal coliform
	B-133	Recreation	Nonsupporting	Fecal coliform
	B-062	Recreation	Nonsupporting	Fecal coliform
Bullock Creek	B-159	Recreation	Nonsupporting	Fecal coliform
Lake Lanier	B-099A	Recreation	Partially supporting	Fecal coliform
Page Creek	B-301	Recreation	Nonsupporting	Fecal coliform
North Pacolet River	B-026	Recreation	Nonsupporting	Fecal coliform
	B-126	Recreation	Nonsupporting	Fecal coliform
Spivey Creek	B-103	Recreation	Partially supporting	Fecal coliform
Motlow Creek	B-790	Aquatic life	Partially supporting	Macroinvertebrates
South Pacolet River	B-302	Recreation	Nonsupporting	Fecal coliform
Little Buck Creek	B-259	Recreation	Nonsupporting	Fecal coliform
Potter Branch	B-191	Recreation	Nonsupporting	Fecal coliform
Pacolet River	B-028	Recreation	Nonsupporting	Fecal coliform
	B-331	Recreation	Partially supporting	Fecal coliform
Lawsons Fork Creek	B-221	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
	B-277	Recreation	Nonsupporting	Fecal coliform
	B-278	Recreation	Nonsupporting	Fecal coliform
	BL-005	Recreation	Nonsupporting	Fecal coliform
	BL-001	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Mill Creek	B-780	Aquatic life	Partially supporting	Macroinvertebrates
Pacolet River	BP-001	Recreation	Nonsupporting	Fecal coliform
	B-048	Recreation	Nonsupporting	Fecal coliform
John D. Long Lake	B-344	Aquatic life	Nonsupporting	pH
Broad River	B-331	Recreation	Partially supporting	Fecal coliform
Ross Branch	B-086	Recreation	Nonsupporting	Fecal coliform
Turkey Creek	B-136	Recreation	Partially supporting	Fecal coliform
Meng Creek tributary	B-243	Recreation	Nonsupporting	Fecal coliform
Meng Creek	B-064	Recreation	Nonsupporting	Fecal coliform

Table 6-4. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Browns Creek	B-155	Recreation	Partially supporting	Fecal coliform
Gregorys Creek	B-335	Recreation	Nonsupporting	Fecal coliform
Dry Fork	B-074	Recreation	Nonsupporting	Fecal coliform
Sandy River	B-075	Recreation	Nonsupporting	Fecal coliform
Broad River	B-047	Recreation	Partially supporting	Fecal coliform
Hellers Creek	B-151	Aquatic life	Partially supporting	Macroinvertebrates
Crims Creek	B-800	Aquatic life	Partially supporting	Macroinvertebrates
Wateree Creek	B-801	Aquatic life	Partially supporting	Macroinvertebrates
Elizabeth Lake	B-110	Recreation	Partially supporting	Fecal coliform
Cranes Creek	B-081	Aquatic life	Partially supporting	Macroinvertebrates
	B-316	Aquatic life	Nonsupporting	Zinc
		Recreation	Partially supporting	Fecal coliform
Smith Branch	B-280	Aquatic life	Nonsupporting	Macroinvertebrates, zinc
		Recreation	Nonsupporting	Fecal coliform
Broad River	B-337	Recreation	Partially supporting	Fecal coliform
	B-080	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Little River	B-145	Recreation	Nonsupporting	Fecal coliform
Winnsboro Branch	B-123	Recreation	Nonsupporting	Fecal coliform
	B-077	Aquatic life	Nonsupporting	Copper, zinc
		Recreation	Nonsupporting	Fecal coliform
Jackson Creek	B-102	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Partially supporting	Fecal coliform
Mill Creek	B-338	Recreation	Nonsupporting	Fecal coliform
Big Cedar Creek	B-320	Recreation	Partially supporting	Fecal coliform

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

GROUND WATER

Hydrogeology

The Broad River subbasin is almost entirely in the Piedmont physiographic province, where ground water occurs principally in bedrock fractures formed by fault-and-joint systems and in the saprolite. Cretaceous-age Coastal Plain sediments occupy the extreme southern reach of the subbasin and constitute a shallow, sandy aquifer.

The subbasin includes six geologic units of the Piedmont geologic province trending northeast-southwest. From north to south, these are the extreme eastern edge of the Walhalla thrust sheet (Greenville County), the Sixmile thrust sheet (Greenville, Spartanburg, and Cherokee Counties), and the Laurens thrust sheet (Greenville, Spartanburg, and Cherokee Counties). To the southeast, separated by the Cross Anchor fault and the Kings Mountain shear zone, lie the Kings Mountain terrane (Spartanburg, Union, Cherokee, and York Counties), the Charlotte terrane (Laurens, Spartanburg, Union, Cherokee, York, Chester, Fairfield, and Newberry Counties), and the Carolina terrane (Newberry, Fairfield, and Richland Counties). Some gabbro and granite intrusions exist in the subbasin; an especially large granite pluton occurs in northeastern Union County and southern Cherokee County.

Saprolite is as thick as 150 feet and serves as a medium for the collection of rainfall and subsequent recharge to fractures in the underlying crystalline rocks. The number and size of fractures usually diminish with depth, and crystalline-rock composition appears to have little effect on well yields. The water supply from wells penetrating these rocks is reliable but limited, and well yields are usually less than 50 gpm (gallons per minute).

Topography also impacts wells yields. Valleys provide basins that capture recharge water and commonly are areas of rock weakness and more numerous fractures. Wells in valleys tend to have larger yields than wells in topographically high areas.

The full ground-water potential of the region is not known, and specific aquifer or hydrogeologic units are not well delineated. Generally, ground water in the subbasin is somewhat limited but typically is present in quantities adequate for domestic use. Average well yields are about 18 gpm; however, wells that are carefully sited with regard to topography and geology can produce much more than the average. About 70 percent of reported wells are 300 feet deep or less, although a few are deeper than 1,000 feet. The available data indicate that 100 to 250 feet are optimum depths for maximum yields. Wells drilled in crystalline-rock fracture zones can produce 100 to 300 gpm, whereas wells near the fringes of fracture zones produce 2 to 50 gpm. Two geologic-core holes in Fairfield County were drilled deeper than even the deepest water-supply wells: the first well was deeper than 3,500 feet and produced more than 1,100 gpm, and the second well exceeded 3,900 feet and produced about 600 gpm. The average and maximum well depths and well yields in the subbasin sections of each county are listed in Table 6-5. The table data indicate there generally is little difference in the depths required of drilled bedrock wells if only modest well yields are needed.

Table 6-5. Well depths and yields for drilled bedrock wells in the Broad River subbasin

County	Well depth (feet)		Well yield (gpm)	
	Average	Maximum	Average	Maximum
Cherokee	236	1,185	15	200
Chester	213	585	17	360
Fairfield	251	610	21	200
Greenville	265	1,085	17	200
Laurens	273	905	16	150
Lexington	274	325	26	40
Newberry	234	880	15	250
Richland	292	884	24	200
Spartanburg	278	1,200	20	370
Union	276	1,000	14	100
York	220	745	16	300

Bored wells represent about 11 percent of all water-producing wells in the Broad River subbasin. They commonly have a 24-inch diameter but range from 12 inches to 60 inches. The wells are generally shallow, do not penetrate bedrock, and draw water from the saprolite. Old hand-dug wells range from 8 feet to 100 feet in depth and average 47 feet in depth. Yields are rarely reported by drillers, but sustained yields are believed to be less than 5 gpm.

The northwestern area of Richland County in the Broad River subbasin is underlain mostly by argillite of the Carolina slate belt, but near the southeast edge of the subbasin the bedrock is overlain by about 50 feet of unconsolidated Middendorf sand, gravel, and clay. Rock-well depths range from 100 to 884 feet deep, and yields are 2 to 50 gpm.

Ground-Water Quality

Chemical quality of the ground water in the Broad River subbasin is generally good, although in some areas the water is rather hard. Water from acidic rocks such as granite, granite-gneiss, and mica-schist is soft, slightly acidic, and contains low concentrations of TDS (total dissolved solids). Water from hornblende, gneiss or schist, diorite, gabbro, and diabase is slightly alkaline, fairly hard, and relatively high in dissolved solids. This water also can contain high amounts of dissolved iron. Ground water in the subbasin has TDS concentrations ranging from 8 to 658 mg/L (milligrams per liter); pH ranges from 5.1 to 9.1, with a median of 6.8. The higher pH values (above 7.5) are generally in the Charlotte belt in Union County and in the Kings Mountain belt in Cherokee County. Alkalinity ranges from 0.5 to 300 mg/L (National Uranium Resource Evaluation program, 1997).

DHEC has found that Ra-226 and Pb-214 (radioactive isotopes of radium and lead) are present in two wells in Jenkinsville (southern Fairfield County) and that concentrations exceed acceptable drinking-water standards. These wells are completed in rocks of the Charlotte belt.

Water-Level Conditions

Ground-water levels are routinely monitored by DNR and USGS in six wells in the Broad River subbasin to help assess trends or changes in hydrologic conditions (Table 6-6). Water levels in these wells are often indicative of local hydrologic conditions that impact the surface-water systems to which the ground water is connected. Changes in observed water levels are almost always a reflection of changes in above-ground hydrologic conditions.

Table 6-6. Water-level monitoring wells in the Broad River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
CRK-74	USGS	35 09 18 81 26 34	Crystalline rock	4 miles northeast of Blacksburg	825	99–265
CTR-21	USGS	34 40 27 81 24 55	Crystalline rock	6 miles north-north-east of Carlisle	665	40–93
GRV-2162	DNR	34 54 16 82 15 49	Crystalline rock	East Riverside Park, Greer	875	83–169
GRV-3341	DNR	35 09 38 82 13 29	Shallow	Oak Grove Road Fire Station, Gowansville	1,030	70–80
GRV-3342	DNR	35 09 38 82 13 29	Crystalline rock	Oak Grove Road Fire Station, Gowansville	1,030	132–334
SPA-1581	USGS	34 51 45 80 50 29	Crystalline rock	Croft State Park	605	54–225

* *DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

Because ground-water use in this subbasin is very limited, no areas within the subbasin are experiencing significant water-level declines caused by overpumping.

WATER USE

Water-withdrawal information presented here is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Broad River subbasin, exclusive of hydroelectric power production, is summarized in Table 6-7 and Figure 6-4. Offstream water use in this subbasin totaled 311,778 million gallons in 2006, ranking it third among the 15 subbasins. Of this amount, more than 99 percent (310,485 million gallons) came from surface-water sources and less than one percent (1,293 million gallons) came from ground-water sources. Thermoelectric power production accounted for 87 percent of this total, and water supply accounted for 12 percent. Relatively small amounts of water were also used for industry, mining, golf courses, irrigation, and aquaculture. Consumptive use in this subbasin is estimated to be 10,913 million gallons, or about 4 percent of the total offstream use.

The Virgil C. Summer Nuclear Station, located on Lake Monticello in Fairfield County, about 26 miles northwest of Columbia, is the only thermoelectric power plant in the subbasin. It is jointly owned by SCE&G and the South Carolina Public Service Authority (Santee Cooper) and is operated by SCE&G. It contains one turbine that has a capacity of 953.9 MW (megawatts). In 2006, the facility used 271,236 million gallons of water for cooling and steam.

Table 6-7. Reported water use in the Broad River subbasin for the year 2006 (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	35	0.0	0	0.0	35	0.0
Golf course	644	0.2	25	1.9	669	0.2
Industry	1,259	0.4	87	6.7	1,346	0.4
Irrigation	137	0.0	5	0.4	143	0.1
Mining	0	0.0	982	76.0	982	0.3
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	271,236	87.4	0	0.0	271,236	87.0
Water supply	37,173	12.0	194	15.0	37,367	12.0
Total	310,485		1,293		311,778	

Water-supply use in the Broad River subbasin totaled 37,367 million gallons in 2006, which ranked it second behind the Saluda River subbasin. Surface water accounted for 37,173 million gallons (99.5 percent) and ground water for 194 million gallons (0.5 percent). The largest surface-water system was the city of Columbia, which withdrew 12,096 million gallons from the Columbia Canal on Broad River. Columbia's other water-supply facility is in the Saluda subbasin at Lake Murray. The city of Spartanburg withdrew 12,092 million gallons from Lake Bowen, Lake Blalock, and Municipal Reservoir #1. Other systems of note include Greer Commission of Public Works (2,883 million gallons from the South Tyger River), Gaffney Board of Public Works (2,582 million gallons from Lake Welchel and Broad River), and Startex-Jackson-Wellford-Duncan Water District (2,454 million gallons from Lyman Lake on the Middle Tyger River). Despite its limited availability, ground water is used by several smaller water-supply systems. Jenkinsville Water District had the largest ground-water system in the subbasin, with a withdrawal of 49 million gallons from the crystalline rock aquifer.

Industrial water use was 1,346 million gallons in 2006. Of this amount, 1,259 million gallons were from surface-water sources (94 percent) and 87 million were from wells (6 percent). Milliken & Company in Cherokee County and Cone Mills Corp. in Union County were among the largest users in the subbasin, withdrawing 621 and 458 million gallons, respectively.

Mining water use was 982 million gallons in the subbasin, all of it ground water. All of the water was pumped at the Martin Marietta Aggregates quarry in Columbia to dewater the quarry. Golf-course water use was 669 million gallons, ranking it fourth among the 15 subbasins in this category. Most of the water used was surface water (96 percent). Of the seventeen golf courses reporting water use in 2006, the Cliffs at Glassy in Greenville County was the largest user, withdrawing 274 million gallons.

Eight hydroelectric facilities operating in this subbasin reported total instream water use of 3,098,700 million gallons in 2006 (see Table 6-3). The largest water use was by the Fairfield Pumped Storage facility, which is owned and operated by SCE&G and is located at Lake Monticello in Fairfield County off the main stem of the Broad River. Water that is released from the lake to produce hydroelectric power flows into Parr Shoals Reservoir, where it can then be pumped back into Lake Monticello and reused. In 2006, the facility used 1,920,104 million gallons of water, second only to Duke Energy's pumped-storage facility at Lake Jocassee in the Upper Savannah subbasin. Water is also released through turbines at Parr Shoals Reservoir to produce hydroelectric power. The amount of water used at Parr Shoals was 593,019 million gallons. Together, the two facilities operate 14 turbines and have a capacity of about 525 MW. SCE&G also owns and operates the Neal Shoals facility on the Broad River, which contains four turbines and has a capacity of 5.2 MW. It used 326,592 million gallons in 2006.

Duke Energy owns and operates the Gaston Shoals and Ninety-Nine Islands hydroelectric facilities located on the Broad River in Cherokee County. Gaston Shoals used 213,600 million gallons and Ninety-Nine Islands used 32,949 million gallons in 2006. The two plants house 10 turbines with a total capacity of 24.7 MW. Lockhart Power Company owns and operates two hydroelectric facilities, the Lockhart plant on the Broad River in Union County, and the Pacolet plant on the Pacolet River in Spartanburg County. The Lockhart plant used 583 million gallons and the Pacolet plant used 35 million gallons. The plants operate seven turbines with a capacity of 18.8 MW. The city of Spartanburg Commissioners of Public Works operates a small 1 MW unit at Lake Bowen in Spartanburg County. It used 11,818 million gallons in 2006.

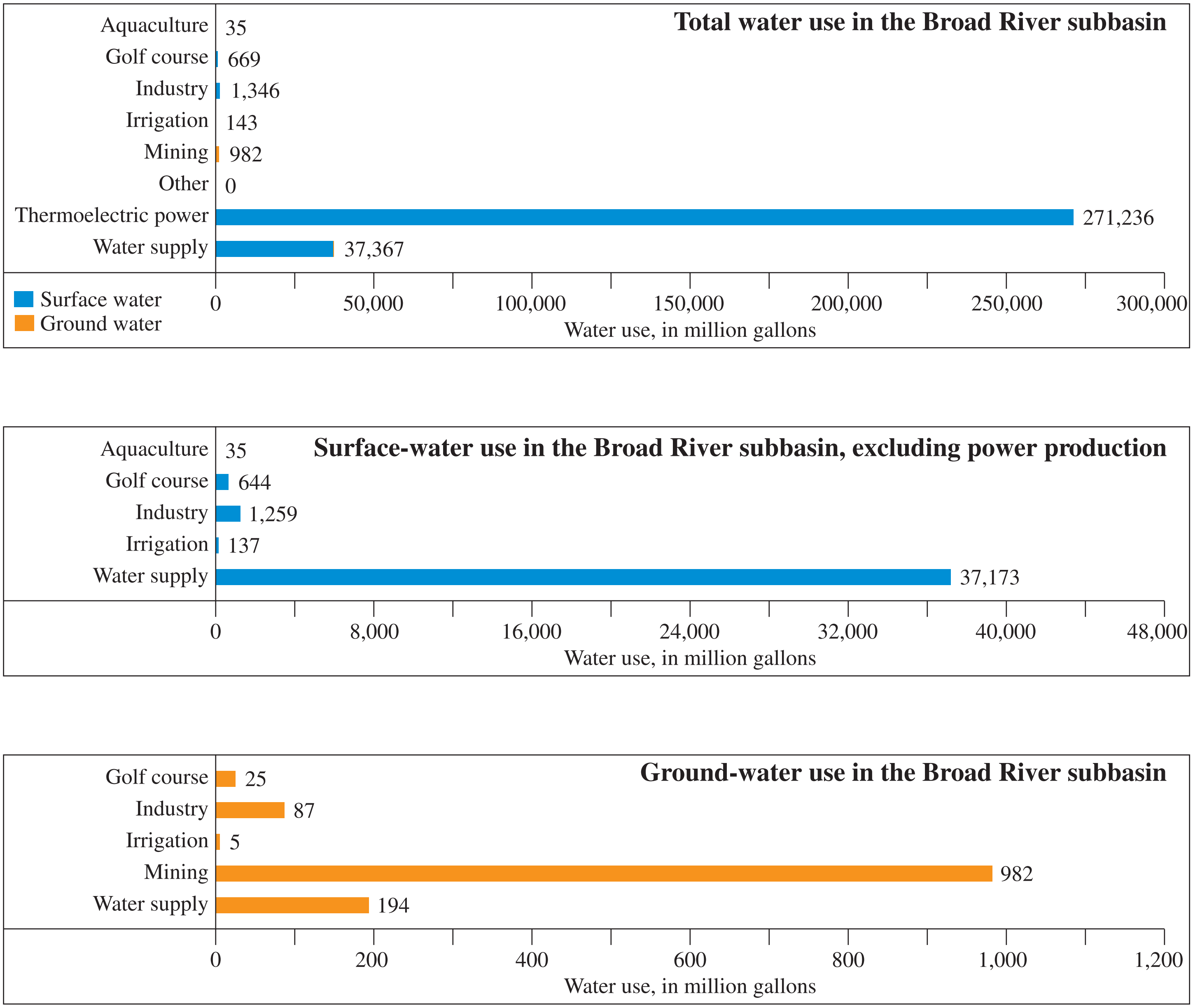


Figure 6-4. Reported water use in the Broad River subbasin for the year 2006 (modified from Butler, 2007).

SALUDA RIVER SUBBASIN

SALUDA RIVER SUBBASIN

The Saluda River subbasin is a long, narrow basin transecting the Blue Ridge and Piedmont of South Carolina and extending southeast to the Fall Line in the central part of the State. With a northwest-southeast orientation, the subbasin shares a common northern boundary with North Carolina on the north and encompasses parts of 12 South Carolina counties, including most of Greenville, Greenwood, Laurens, Newberry, and Saluda Counties, and smaller parts of Abbeville, Aiken, Anderson, Edgefield, Lexington, Pickens, and Richland Counties (Figure 6-5). The subbasin area is approximately 2,505 square miles, 8.1 percent of the State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 541,600, which was 13.5 percent of the State's total. The greatest population growth by the year 2020 is anticipated in Lexington County (34 percent), Pickens County (28 percent), and Aiken County (25 percent). Aiken, Anderson, Lexington, and Richland Counties are classified as urban, and Saluda County is classified as very rural.

The major cities and population centers include: Greenville (about 300,000 in the urban area), Greenwood (22,071), Easley (17,754), Laurens (9,916), Newberry (10,580), Simpsonville (14,352), and Mauldin (15,224). The major urban center of Columbia is immediately outside the eastern boundary.

There are four subbasin counties with a year-2005 per capita income above the State's average of $28,285: Aiken, Greenville, Lexington, and Richland. The 1999 median household income ranged from $44,659 in Lexington County to $32,635 in Abbeville County. Only four of the subbasin's 12 counties have median household incomes above the State average of $37,082.

During 2000, the counties of the subbasin had combined annual-average employment of non-agricultural wage and salary workers of 275,000. Labor distribution in the subbasin counties included management, professional, and technical services, 30 percent; sales and office, 25 percent; production, transportation, and materials moving, 21 percent; service, 13 percent; construction, extraction, and maintenance, 10 percent; and farming, fishing, and forestry, 1 percent. In the sector of manufacturing and public utilities, the average annual product value of the area was $29.9 billion in 2000.

Agriculture-related production played a relatively modest role in the subbasin's economy. Crop and livestock production generated $414 million, with Lexington and Saluda Counties having product values of $87 million and $67 million, respectively. The delivered value of timber exceeded $270 million in 2001, with Newberry County generating more than $40 million (South Carolina Budget and Control Board, 2005).

SURFACE WATER

Hydrology

The Saluda River is the major watercourse in the subbasin. This stream has its headwaters in the Blue Ridge physiographic province of South Carolina, and it flows southeasterly across the Piedmont before joining the Broad River to form the Congaree River near Columbia. Major tributaries include the Reedy River, Rabon Creek, Little River, Bush River, and Little Saluda River. These streams serve water-use needs for the cities of Greenville, Greenwood, and Laurens.

Figure 6-5. Map of the Saluda River subbasin.

A 5-mile segment of the Middle Saluda River in Greenville County became the first river protected under the Scenic Rivers Program in South Carolina in 1978. In addition, a 10-mile segment of the Saluda River from one mile below the Lake Murray Dam to its confluence with the Broad River was designated as a State Scenic River in 1991.

Streamflow is presently monitored at 13 sites, 6 on the Saluda River and 7 on tributary streams (Figure 6-5). Streamflow statistics for these gaging stations and 9 discontinued stations are presented in Table 6-8. Surface-water data are also available for six crest-stage stations as well as lake-level stations on Lakes Greenwood and Murray. Streamflow in the upper part of the Saluda River has been affected for the entire period of record by two small water-supply reservoirs, Table Rock Reservoir and Poinsett (North Saluda) Reservoir. Controlled releases from Lakes Murray and Greenwood have modified streamflows in the lower portion of the Saluda River since the 1930's.

Table 6-8. Selected streamflow characteristics at USGS gaging stations in the Saluda River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
South Saluda River near Cleveland 1622.9	2000 to 2005	17.8	28.1	1.57	3.7	1.3 2000	2,730 2004	3,720 2004
Middle Saluda River near Cleveland 1623.5	1980 to 2003	21.0	57.2	2.72	18	6.6 2002	1,160 1994	5,190 1986
Saluda River near Greenville 1625	1941-78 and 1990-2007*	295	623	2.11	231	36 1998	8,580 1949	11,000 1949
Hamilton Creek near Easley 1625.25	1981 to 1986	1.6	3.1	1.91	0.8	0.09 1986	77 1985	– – –
Saluda River near Pelzer 1630	1929 to 1971	405	783	1.93	290	57 1954	– – –	13,600 1949
Saluda River near Williamston 1630.01	1995 to 2007*	414	640	1.55	202	6.3 2000	12,000 1995	– – –
Grove Creek near Piedmont 1630.967	1994 to 2007*	19.1	22.8	1.19	5.5	0.44 2007	1,000 1995	– – –
Saluda River near Ware Shoals 1635	1938 to 2007*	580	975	1.68	313	11.0 1941	16,100 1995	20,900 1995
Reedy River near Greenville 1640	1941-71 and 1987-2007*	48.6	80.8	1.66	24	5.3 1999	4,120 1995	5,830 2004
Reedy River above Fork Shoals 1641.1	1993 to 2007*	104	204	1.96	81	39 2002	6,260 1995	8,200 1995
Reedy River near Ware Shoals 1650	1939 to 2004	236	353	1.50	94	4.8 1973	8,800 1963	11,000 1973
South Rabon Creek near Gray Court 1652	1967-81 and 1990-2007*	29.5	35.4	1.20	9.8	0.20 2007	2,520 1973	4,100 1973
Ninety-Six Creek near Ninety-Six 1669.7	1980 to 2001	17.4	15.6	0.90	0.36	0.0 2002	810 1982	– – –

Table 6-8. Continued

Gaging station name, location, station number	Period of record	Drainage area (mi²)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Saluda River at Chappells 1670	1926 to 2007*	1,360	1,869	1.37	518	8.0 1939	56,700 1929	63,700 1929
Little River near Silverstreet 1674.5	1990 to 2007*	230	178	0.77	27	0.71 2002	5,600 1996	– – –
Saluda River near Silverstreet 1675	1929 to 1966	1,620	2,227	1.37	710	49 1940	– – –	83,800 1929
Bush River near Joanna 1675.57	1995 to 2005	11.1	14.5	1.31	0.73	0.0 2001, 02, 04, 05	730 2003	1,160 1996
Bush River at Newberry 1675.63	1999 to 2007*	62.2	45.3	0.73	4.3	0.0 2002	1,880 2003	– – –
Bush River near Prosperity 1675.82	1990 to 2007*	115	102	0.89	14	3.2 2002	4,330 1995	5,570 1995
Little Saluda River at Saluda 1677.037	1992 to 2001	90	84.1	0.93	0.73	0.0 2001	4,720 1994	6,340 1994
Saluda River below Lake Murray 1685.04	1988 to 2007*	2,386	2,495	1.07	441	155 1989	21,800 1995	22,400 1995
Saluda River near Columbia 1690	1925 to 2007*	2,520	2,762	1.10	426	12.0 1930	62,300 1929	67,000 1929

mi², square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Average-annual streamflow in the Saluda River varies from 623 cfs (cubic feet per second) near Greenville to 2,762 cfs near Columbia. Ninety percent of the time, flow at these sites equals or exceeds 231 cfs and 426 cfs, respectively. Streamflows in the Blue Ridge portion of the subbasin are relatively steady and have well-sustained base flow supported by ground-water discharge from exposed fracture zones. High rainfall and runoff in this region also contribute significantly to flow. Streamflow in the upper reach of the Saluda River is well-sustained throughout the year (Figure 6-6). Streamflow in the Saluda River becomes increasingly more variable in the Piedmont region with distance downstream, because of hydropower facilities and progressively decreasing annual precipitation and ground-water support in watersheds away from the mountains.

The most variable flows in the Saluda River occur immediately below Lake Greenwood, where regulated discharges from the Buzzard's Roost Hydroelectric Plant greatly influence flow. Use of this facility only during periods of peak electric demand results in highly fluctuating flows downstream with frequent periods of extreme low flow. These low-flow conditions limit navigation, fish migration, and suitable fish habitat.

Tributary streams are subject to the same flow-controlling factors as the main stem; however, most tributaries do not benefit from having headwater bodies in regions of high rainfall and ground-water discharge to partially sustain streamflows during periods of low rainfall. Streamflow characteristics of the Reedy River indicate the same main-stem trend of increased flow variability with progression downstream (Figure 6-6). Average annual streamflow in the Reedy River is 80.8 cfs near Greenville and 353 cfs near Ware Shoals. Streamflow at these sites is at least 24 cfs and 94 cfs, respectively, 90 percent of the time.

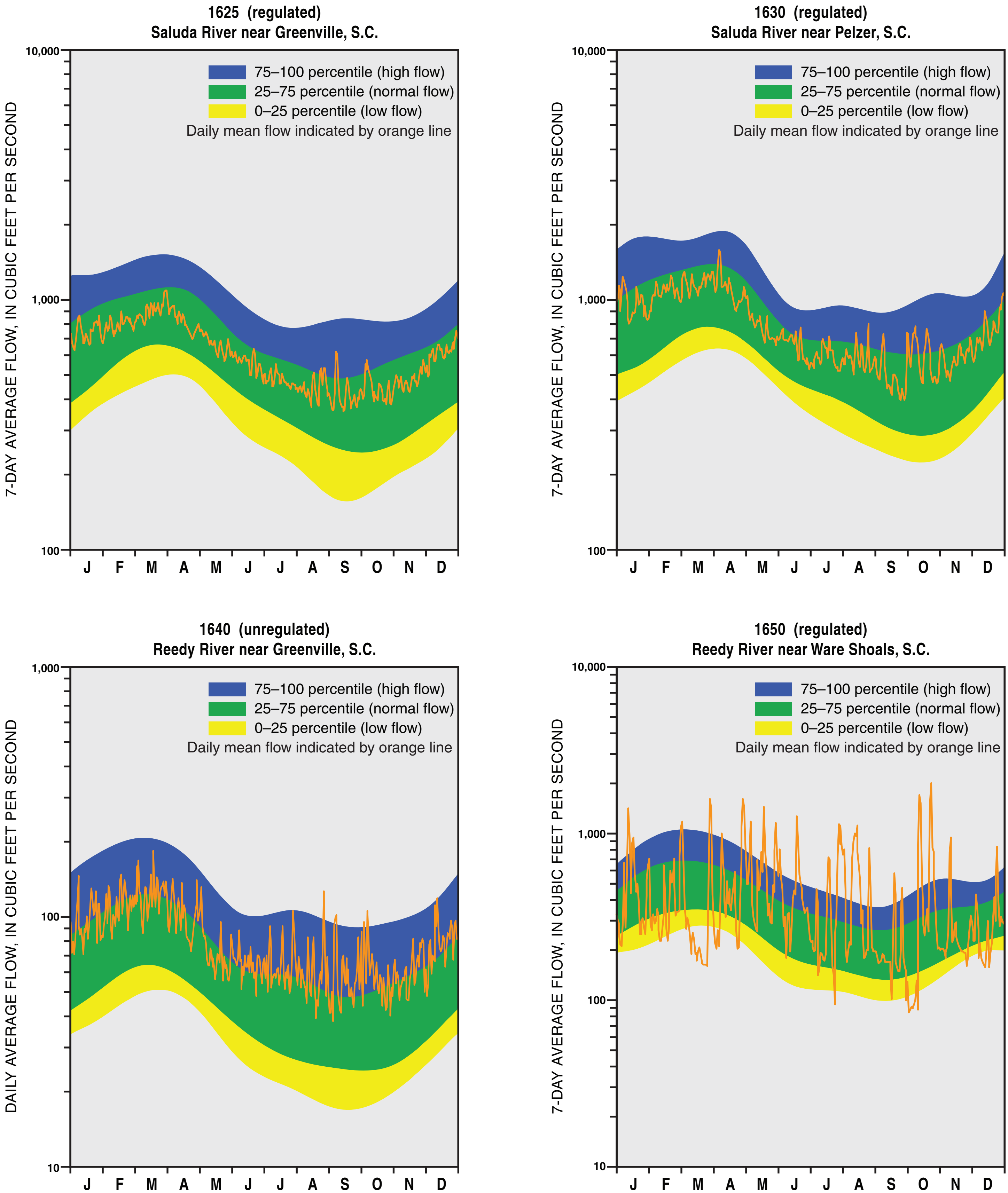


Figure 6-6. Duration hydrographs for selected gaging stations in the Saluda River subbasin.

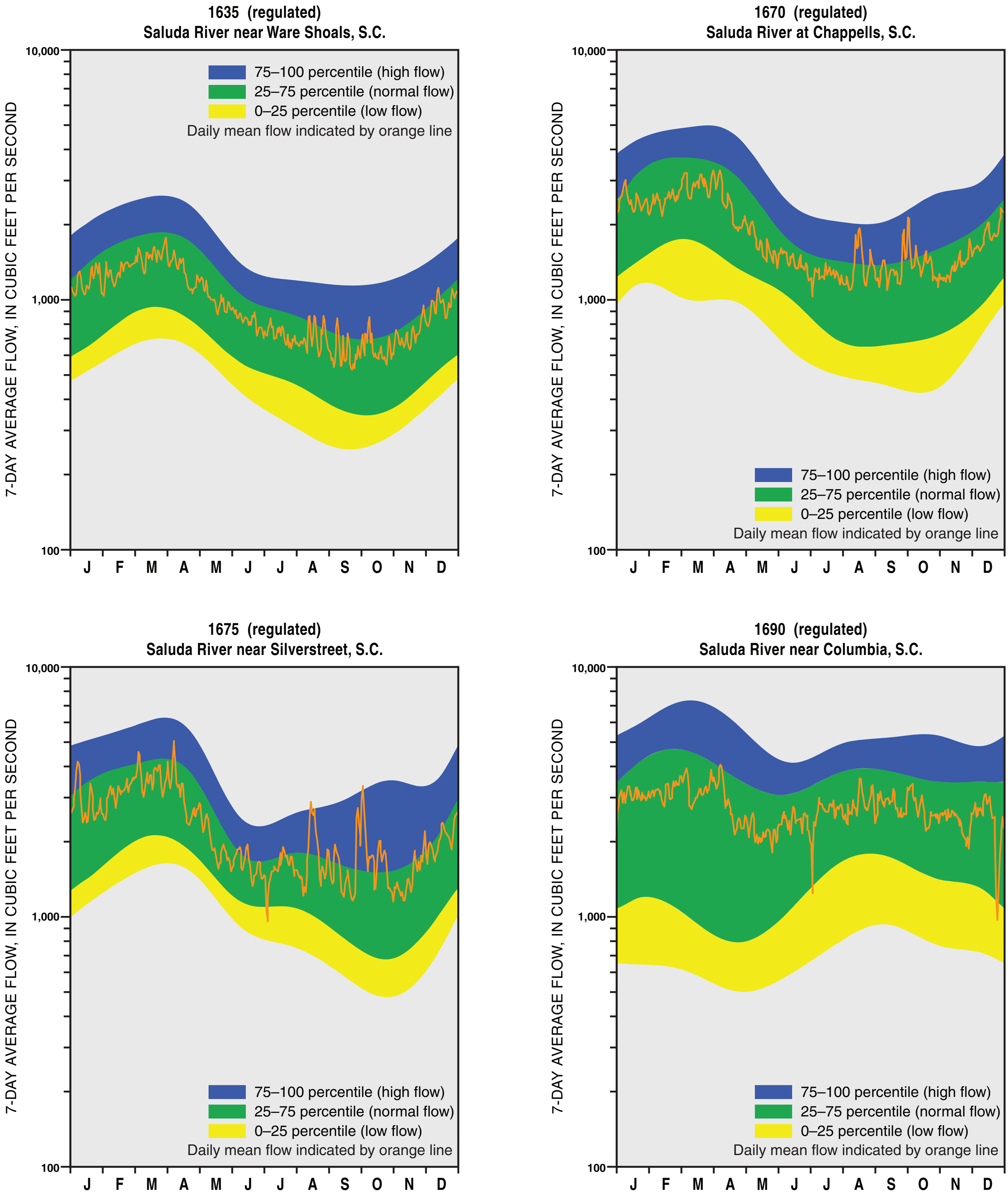


Figure 6-6. Duration hydrographs for selected gaging stations in the Saluda River subbasin (continued).

The lowest recorded flow of the Saluda River is 6.3 cfs (estimated) and occurred in 2000 near Williamston. Record flood flows were primarily because of three storms occurring in 1929, 1949, and 1973. The highest peak flow of the Saluda River (83,800 cfs) was recorded near Silverstreet in 1929.

In general, available streamflows in the upper part of the subbasin are well-sustained and provide a reliable surface-water supply source. While flow is more variable in the lower portion of the Saluda River, minimum flow still provides a substantial supply. Tributaries in the lower part of the subbasin may experience significant low-flow conditions during periods of low rainfall and, if used as a water source, may require storage facilities to ensure a reliable year-round supply.

Development

Extensive surface-water development exists to meet the needs of industry and municipalities in the Saluda River subbasin. There are several large reservoirs on the Saluda River, including Lake Murray, Lake Greenwood, and Poinsett (North Saluda) Reservoir. Just in the upper part of the subbasin that drains into Lake Greenwood, there are more than 150 State- or Federally-regulated dams and more than 2,500 non-regulated dams, most of which are privately owned (Saluda-Reedy Watershed Consortium, 2005a). The aggregate surface area of all lakes larger than 200 acres is approximately 65,000 acres, and the total volume is about 2,500,000 acre-ft (Table 6-9).

Table 6-9. Lakes 200 acres or more in the Saluda River subbasin (shown on Figure 6-5)

Number on map	Name	Stream	Surface area (acres)	Storage capacity (acre-feet)	Purpose
1	Lake Murray	Saluda River	51,000[a]	2,114,000[a]	Power, recreation, and water supply
2	Lake Greenwood	Saluda River	11,400[a]	270,000[a]	Power, recreation, and water supply
3	Poinsett (North Saluda) Reservoir	North Saluda River	1,034[b]	33,000[b]	Water supply
4	Lake Rabon	Rabon Creek	562[b]	6,832[b]	Water supply, flood control, and recreation
5	Table Rock Reservoir	South Saluda River	485[b]	15,000[b]	Water supply
6	Saluda Lake	Saluda River	305[b]	7,228[b]	Power, water supply, and industry
7	Boyd Mill Pond	Reedy River	203[b]	3,000[b]	Power and recreation

Sources: (a) U.S. Army Corps of Engineers (1991)
(b) Saluda-Reedy Watershed Consortium (2005b)

Statewide, Lake Murray ranks fifth in surface area and third in volume, with 51,000 acres and 2,114,000 acre-ft, respectively. Located 11 miles west of Columbia, Lake Murray is owned and operated by South Carolina Electric and Gas Company (SCE&G). The lake was constructed in 1930 for the production of hydroelectric power, but now also provides recreational opportunities and water supply.

Lake Greenwood, 18 miles east of Greenwood, is currently owned by Greenwood County, but Santee Cooper operates the hydroelectric plant (Buzzard's Roost). Constructed in 1940 for the production of hydroelectric power, the lake also serves as a municipal water supply and is used for recreation. With a surface area of 11,400 acres and a volume of 270,000 acre-ft, Lake Greenwood ranks tenth in surface area among the State's lakes.

Poinsett (North Saluda) Reservoir is owned by the City of Greenville and is used solely as a municipal water supply. It has a surface area of 1,034 acres and a volume of 33,000 acre-ft.

The three largest hydroelectric power plants in the subbasin are listed in Table 6-10 and shown on Figure 6-5. With a generating capacity of 197.5 megawatts, the SCE&G Saluda plant at Lake Murray is the largest. Several other hydroelectric power plants on the Saluda River have capacities of less than 5 megawatts.

The subbasin contains no navigation projects, but the subbasin is the site of some of the earliest flood-control

Table 6-10. Major hydroelectric power generating facilities in the Saluda River subbasin (shown on Figure 6-5)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Ware Shoals Chi Energy, Inc.	Saluda River	– – –	6.2	0
2	Buzzard's Roost Santee Cooper	Saluda River	Lake Greenwood	15	93,433
3	Saluda SCE&G	Saluda River	Lake Murray	197.5	149,244

projects in South Carolina. Eighteen flood- and erosion-control projects have been given Federal authorization. Since 1957, eight projects that involved more than 30 miles of channel improvement and 20 flood-retarding structures were completed by the U.S. Army Corps of Engineers (COE) or the Natural Resources Conservation Service (NRCS).

Surface-Water Quality

The Saluda River subbasin contains water bodies with a variety of water-use classifications, but most are designated as "Freshwater" (Class FW). Class FW lakes and streams are suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking water, fishing, and industrial and agricultural uses (DHEC, 2004a).

A large number of water bodies in the subbasin are designated as "Outstanding Resource Waters" (Class ORW). These are freshwater bodies that constitute an outstanding recreational or ecological resource and are suitable as a drinking-water source with minimal treatment. Class ORW water bodies in this basin include part of the North Saluda River, with the Poinsett Reservoir, and the South Saluda River including Table Rock Reservoir, Julian Creek, Matthews Creek, Coldstream Branch, Middle Saluda River, Head Foremost Creek, and Oil Camp Creek. Other ORW-designated water bodies are Falls Creek from its headwaters to Lake Trammell; Willis and Emory Creeks from their headwaters to the north boundary of Table Rock Resort property; Green Creek; the Carrick Creek headwater; and Pinnacle Lake.

Several streams are designated as "Trout Natural Waters" (Class TN). These are freshwater bodies suitable for supporting reproducing-trout populations and a cold-water balanced indigenous aquatic community of fauna and flora. Water bodies with this designation include parts of Oil Camp Creek; Lake Trammell, and part of Falls Creek; Gap Creek, Rock Branch, Buck Hollow, and the Middle Saluda River from the end of State land to Oil Camp Swamp.

The South Saluda River from Table Rock Reservoir dam to the crossing of S.C. Highway 8 and the main stem of the Saluda River and Saluda River tributaries from the Lake Murray dam to the confluence with the Broad River are classified as "Trout Put, Grow and Take Waters" (Class TPGT). These are freshwater bodies suitable for supporting the growth of stocked-trout populations and a balanced indigenous aquatic community of fauna and flora.

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 128 surface-water sites between 1997 and 2001 within the subbasin in order to assess the water's suitability for aquatic life and recreational uses (Figure 6-7). Aquatic-life uses were fully supported in 78 sites, or 61 percent of the water bodies sampled. Water was considered partially or fully impaired primarily because of poor macroinvertebrate-community structures or high phosphorus or metals concentrations. Aquatic life is not supported in Mill Creek, near Greenville, because of chromium and copper, and human health standards for chromium are consistently exceeded; these contaminants are transported by ground water from a nearby industrial site. Signs advise the public to avoid swimming, wading, drinking, or other contact with water from this creek, and the public is also advised not to consume fish from Mill Creek. Recreational use was fully supported in 55 percent of the sampled water bodies; water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2004a). Water-quality impairments in the subbasin are summarized in Table 6-11. DHEC publishes the most recently observed impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, DHEC issued a fish-consumption advisory for the Saluda River between Lake Greenwood and Lake Murray, and from Lake Murray to the Congaree River. Fish-consumption advisories are issued in areas where fish are contaminated with mercury; the contamination is only in the fish and does not make the water unsafe for swimming or boating.

The Reedy River and Bushy River arms of Lake Murray are listed as two of the most eutrophic lake embayments

Figure 6-7. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 6-11 (DHEC, 2004a).

Table 6-11. Water-quality impairments in the Saluda River subbasin (DHEC, 2004a)

Water-body name	Station number	Use	Status	Water-quality indicator
North Saluda River	S-004	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
	S-773	Aquatic life	Nonsupporting	Macroinvertebrates
South Saluda River	S-087	Recreation	Partially supporting	Fecal coliform
	S-299	Recreation	Partially supporting	Fecal coliform
Middle Saluda River	S-077	Aquatic life	Nonsupporting	Copper
Oolenoy River	S-103	Recreation	Partially supporting	Fecal coliform
Saluda River	S-250	Recreation	Partially supporting	Fecal coliform
	S-007	Recreation	Partially supporting	Fecal coliform
Mill Creek	S-315	Aquatic life	Nonsupporting	Chromium, copper
		Drinking water	Nonsupporting	Chromium
		Recreation	Nonsupporting	Fecal coliform
Saluda River tributary	S-267	Recreation	Partially supporting	Fecal coliform
Grove Creek	S-171	Recreation	Nonsupporting	Fecal coliform
	S-774	Aquatic life	Partially supporting	Macroinvertebrates
Georges Creek	S-300	Recreation	Nonsupporting	Fecal coliform
Georges Creek tributary	S-005	Recreation	Nonsupporting	Fecal coliform
Big Brushy Creek	S-301	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Partially supporting	Fecal coliform
Saluda River	S-125	Recreation	Partially supporting	Fecal coliform
Turkey Creek	S-858	Aquatic life	Partially supporting	Macroinvertebrates
Lake Greenwood	S-024	Aquatic life	Partially supporting	pH
	S-131	Aquatic life	Nonsupporting	Total phosphorus
Cane Creek	S-097	Aquatic life	Nonsupporting	Dissolved oxygen, total phosphorus
Broad Mouth Creek	S-289	Recreation	Nonsupporting	Fecal coliform
	S-010	Recreation	Nonsupporting	Fecal coliform
	S-304	Recreation	Partially supporting	Fecal coliform
Broad Mouth Creek tributary	S-776	Aquatic life	Partially supporting	Macroinvertebrates
Reedy River	S-073	Recreation	Nonsupporting	Fecal coliform
	S-928	Aquatic life	Partially supporting	Macroinvertebrates
	S-319	Recreation	Nonsupporting	Fecal coliform
	S-013	Recreation	Nonsupporting	Fecal coliform
	S-018	Recreation	Nonsupporting	Fecal coliform
	S-323	Aquatic life	Nonsupporting	Copper
		Recreation	Nonsupporting	Fecal coliform
	S-072	Recreation	Partially supporting	Fecal coliform
Langston Creek	S-264	Recreation	Nonsupporting	Fecal coliform
Brushy Creek	S-067	Aquatic life	Partially supporting	Macroinvertebrates
	S-867	Recreation	Nonsupporting	Fecal coliform
Rocky Creek	S-091	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform

Table 6-11. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Huff Creek	S-863	Recreation	Nonsupporting	Fecal coliform
	S-178	Aquatic life	Partially supporting	Macroinvertebrates
Reedy River	S-778	Recreation	Partially supporting	Fecal coliform
	S-070	Aquatic life	Partially supporting	Macroinvertebrates
Boyd Mill Pond	S-311	Aquatic life	Nonsupporting	Total phosphorus, pH
Reedy River arm of Lake Greenwood	S-308	Aquatic life	Nonsupporting	Total phosphorus, pH
	S-022	Aquatic life	Nonsupporting	Total phosphorus, pH
North Rabon Creek	S-321	Recreation	Nonsupporting	Fecal coliform
South Rabon Creek	S-322	Recreation	Nonsupporting	Fecal coliform
Rabon Creek	S-096	Recreation	Partially supporting	Fecal coliform
Rabon Creek arm of Lake Greenwood	S-307	Aquatic life	Partially supporting	pH
Ninety Six Creek	S-856	Aquatic life	Partially supporting	Macroinvertebrates
Coronaca Creek	S-184	Aquatic life	Partially supporting	Macroinvertebrates
	S-092	Aquatic life	Nonsupporting	Dissolved oxygen, pH
Wilson Creek	S-235	Aquatic life	Partially supporting	Macroinvertebrates
Saluda River	S-186	Aquatic life	Partially supporting	Copper
	S-295	Aquatic life	Nonsupporting	Copper
	S-047	Aquatic life	Partially supporting	pH
Saluda River arm of Lake Murray	S-310	Aquatic life	Nonsupporting	pH
	S-223	Aquatic life	Nonsupporting	Total phosphorus, pH
Beaverdam Creek	S-852	Aquatic life	Partially supporting	Macroinvertebrates
Bush River	S-042	Aquatic life	Nonsupporting	Dissolved oxygen
	S-046	Recreation	Partially supporting	Fecal coliform
	RS-01044	Aquatic life	Partially supporting	Macroinvertebrates
	S-102	Recreation	Partially supporting	Fecal coliform
Scott Creek	S-044	Recreation	Nonsupporting	Fecal coliform
Bush River arm of Lake Murray	S-309	Aquatic life	Nonsupporting	Total phosphorus, pH
Little River	S-034	Recreation	Nonsupporting	Fecal coliform
	S-297	Recreation	Nonsupporting	Fecal coliform
	S-305	Aquatic life	Partially supporting	pH
North Creek	S-135	Recreation	Nonsupporting	Fecal coliform
Little Saluda River	S-050	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
	S-123	Aquatic life	Nonsupporting	Dissolved oxygen
Little Saluda River arm of Lake Murray	S-222	Aquatic life	Nonsupporting	Total phosphorus, pH
Clouds Creek	S-255	Aquatic life	Nonsupporting	Dissolved oxygen, pH
	S-324	Aquatic life	Partially supporting	pH
Lake Murray	S-279	Aquatic life	Nonsupporting	Total phosphorus, pH
	S-211	Aquatic life	Partially supporting	pH
	S-212	Aquatic life	Partially supporting	pH
	CL-083	Aquatic life	Partially supporting	pH

Table 6-11. Continued

<table>
<tr><th>Water-body name</th><th>Station number</th><th>Use</th><th>Status</th><th>Water-quality indicator</th></tr>
<tr><td>Camping Creek</td><td>S-290</td><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
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<tr><td>Recreation</td><td>Nonsupporting</td><td>Fecal coliform</td></tr>
<tr><td rowspan="3">Saluda River</td><td>S-152</td><td>Aquatic life</td><td>Partially supporting</td><td>Dissolved oxygen, pH</td></tr>
<tr><td rowspan="2">S-149</td><td>Aquatic life</td><td>Partially supporting</td><td>Dissolved oxygen</td></tr>
<tr><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td rowspan="3">Rawls Creek</td><td rowspan="2">RS-01012</td><td>Aquatic life</td><td>Partially supporting</td><td>Macroinvertebrates</td></tr>
<tr><td>Recreation</td><td>Partially supporting</td><td>Fecal coliform</td></tr>
<tr><td>S-287</td><td>Recreation</td><td>Nonsupporting</td><td>Fecal coliform</td></tr>
<tr><td>Lorick Branch</td><td>S-150</td><td>Recreation</td><td>Nonsupporting</td><td>Fecal coliform</td></tr>
<tr><td rowspan="2">Kinley Creek</td><td rowspan="2">S-260</td><td>Aquatic life</td><td>Partially supporting</td><td>Macroinvertebrates, dissolved oxygen</td></tr>
<tr><td>Recreation</td><td>Nonsupporting</td><td>Fecal coliform</td></tr>
<tr><td>Twelvemile Creek</td><td>S-294</td><td>Recreation</td><td>Nonsupporting</td><td>Fecal coliform</td></tr>
<tr><td>Fourteenmile Creek</td><td>S-848</td><td>Aquatic life</td><td>Partially supporting</td><td>Macroinvertebrates</td></tr>
</table>

in the State. These areas have high densities of algae and high phosphorus concentrations. Boyd Mill Pond is one of the most eutrophic small lakes in South Carolina owing to algae and phosphorus concentrations. The upper end of Lake Murray has been classified as one of the most eutrophic sites on a large lake in South Carolina because of a high algae density. Large lakes characterized as having intermediate trophic conditions are Lake Greenwood, the Rabon Creek arm of Lake Greenwood, the Saluda River arm of Lake Murray, and the Little Saluda River arm of Lake Murray. Oolenoy Lake is characterized as one of the least eutrophic small lakes in the State because of its low nutrient concentration and clear water. Saluda Lake also is listed as one of the least eutrophic small lakes, mainly owing to low phosphorus concentrations and high levels of dissolved oxygen. Lake Murray is characterized as one of the least eutrophic large lakes in South Carolina. The lake is a source of public water supply and a major recreation area, and, in 2000, DHEC designated it as a no-discharge lake for marine toilets (DHEC, 2004a).

GROUND WATER

Hydrogeology

The Saluda River subbasin lies almost entirely within the Piedmont province; only the extreme southern portion is in the Coastal Plain province. The extreme northwestern tip of Greenville County and the extreme northeastern tip of Pickens County are in the Chauga belt, which is the northwest-most belt of the Piedmont province. The subbasin is crossed by five more geologic units trending northeast to southwest. From north to south, these are the Walhalla thrust sheet (Pickens and Greenville Counties), the Sixmile thrust sheet (Anderson, Pickens, and Greenville Counties), the Laurens thrust sheet (Anderson, Greenville, Abbeville, Laurens, and Greenwood Counties), the Charlotte terrane (Greenwood, Laurens, and Newberry Counties) and the Carolina terrane (Greenwood, Newberry, Saluda, Lexington, and Richland Counties). To the south is the Modoc Shear zone (Saluda and Lexington Counties), which separates the metamorphic and igneous rocks of the Piedmont from the sediments of the Coastal Plain to the south. Another shear zone, the Lowndesville, partially separates the Charlotte and the Carolina terranes in Greenwood and Laurens Counties. Scattered gabbro and granite intrusions occur in the subbasin as well.

Ground-water availability in the subbasin is generally limited to zones of substantial fracturing. Well records for the subbasin counties range from numerous in the northwestern part of the subbasin, especially in Greenville County, to sparse in the southeastern part. Reported well depths range from 29 to 1,103 feet, with the majority of wells less than 350 feet deep. Yields generally are 20 gpm (gallons per minute) or less but can be as much as 400 gpm. Table 6-12 summarizes drilled bedrock-well depths and yields in the Piedmont portion of the subbasin.

Boyter (1979) compared well data in relation to more than 100 linear fracture zones mapped in parts of Oconee, Pickens, and Anderson Counties. He found that wells drilled into fracture zones yield 10 to 500 gpm, whereas wells outside of fracture zones commonly yield 1 gpm or less. Boyter also observed that wells drilled in valleys

Table 6-12. Well depths and yields for drilled bedrock wells in the Saluda River subbasin

County	Well depth (feet)		Well yield (gpm)	
	Average	Maximum	Average	Maximum
Abbeville	237	455	8	20
Anderson	303	730	32	400
Greenville	243	1,057	18	200
Greenwood	264	642	21	150
Laurens	277	750	17	300
Lexington	194	540	15	150
Newberry	229	725	16	200
Pickens	268	705	20	200
Richland	227	400	17	40
Saluda	236	1,103	15	90
Total	250	1,103	18	400

with linear features generally provide greater than average yields and that metamorphic- and igneous-rock fracture zones offer the best opportunity for maximum yields.

Ground water occurs in the Middendorf aquifer (about 200 feet thick) and the bedrock aquifer in northern Lexington County. In Gilbert and Summit, public-supply wells screened in the Middendorf produce as much as 250 gpm. Pumping tests of 60- to 100-foot deep Middendorf aquifer wells at the Michelin Tire plant indicate that well yields of 200–300 gpm are possible near Red Bank. The highest reported yield from a bedrock well is about 150 gpm.

About 25 percent of DNR's well records for the Piedmont part of the subbasin include reports of large-diameter bored wells. Their depths range between 6 and 88 feet and average 50 feet. Yields commonly are but a few gallons per minute, and the shallowest wells may be unreliable during droughts.

Ground-Water Quality

In the rock aquifers of this subbasin, ground-water pH ranges from 5.1 to 8.3, alkalinity ranges from 5 to 275 mg/L (milligrams per liter), and TDS (total dissolved solids) concentrations range from 5 to 950 mg/L (National Uranium Resource Evaluation program, 1997). The few wells with TDS above 500 mg/L are in the Carolina slate belt.

Radiochemical analyses of ground water from the Tertiary sand aquifer near Leesville, in Lexington County, indicate naturally high concentrations of gross-alpha particle activity up to 45 pCi/L (picoCuries per liter) and radium-226 activity to 23.0 pCi/L. These levels locally exceed acceptable drinking-water standards (Moore and Michel, 1980). The source of the radium, a disintegration product of thorium, is thought to be the granitic rocks cropping out near the Fall Line, and its occurrence appears to be concentrated in the crystalline rocks and sediment in a narrow zone adjoining the Fall Line.

Water-Level Conditions

Ground-water levels are routinely monitored by DNR and USGS in 10 wells in the Saluda River subbasin to help assess trends or changes in hydrologic conditions (Table 6-13). Water levels in these wells are often indicative of local hydrologic conditions that impact the surface-water systems to which the ground water is connected. Changes in observed water levels are almost always a reflection of changes in above-ground hydrologic conditions.

Because ground-water use in this subbasin is very limited, no areas within the subbasin are experiencing significant water-level declines caused by overpumping.

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Saluda River subbasin is summarized in Table 6-14 and Figure 6-8. Offstream water use totaled 133,370 million gallons in 2006, ranking it sixth among the 15 subbasins. Of this amount, 132,226 million gallons were from surface-water sources (99 percent) and 1,144 million gallons were from ground-water sources (1 percent). Thermoelectric power production accounted for 62 percent of this total use, followed by water supply (30 percent) and industry (6 percent). Minor amounts of water were also used for agricultural irrigation and golf-course irrigation. Consumptive use in this subbasin is estimated to be 9,716 million gallons, or about 7 percent of the total offstream use.

The two thermoelectric power plants operating in the subbasin used a total of 82,721 million gallons in 2006. SCE&G's McMeekin Station is a coal-fired power plant located adjacent to the Lake Murray Dam in Lexington County. The plant contains two turbines capable of generating 293.6 MW (megawatts) of power (South Carolina Energy Office, 2005). In 2006, it used 50,964 million gallons of water for cooling and steam, drawing its water from the bottom of Lake Murray. It was the largest user in the subbasin.

The Lee Steam Station is a coal-fired power plant owned and operated by Duke Energy. Located on the Saluda River in Anderson County, the plant contains three turbines capable of generating 355 MW of power

Table 6-13. Water-level monitoring wells in the Saluda River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
AND-326	USGS	34 37 14 82 28 56	Crystalline rock	Williamston	785	75–398
GRV-712	USGS	35 06 22 82 37 36	Crystalline rock	Ceasars Head State Park	3,150	28–450
GRV-2543	DNR	35 07 34 82 34 17	Crystalline rock	Jones Gap State Park	1,329	undetermined
GRV-3333	DNR	35 09 57 82 28 17	Crystalline rock	Highway 25, near N.C. state line	1,867	58–260
GRV-3335	DNR	35 07 30 82 34 26	Crystalline rock	Jones Gap State Park	1,352	62–110
GRV-3336	DNR	35 07 30 82 34 26	Shallow	Jones Gap State Park	1,352	14–19
LRN-1705	DNR	34 29 26 82 02 35	Shallow	Joe Adair Outdoor Center, Laurens	641	29–39
LRN-1706	DNR	34 34 14 82 06 50	Crystalline rock	Big Knob Fire Tower	840	undetermined
LRN-1707	DNR	34 22 52 82 00 23	Crystalline rock	Mountville Fire Tower	660	undetermined
SAL-69	DNR	34 05 17 81 40 13	Crystalline rock	Hollywood Elementary School	445	92–480

* *DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

(South Carolina Energy Office, 2005). It also houses three combustion turbine units capable of generating an additional 105.3 MW. In 2006, it used 31,757 million gallons of water from the Saluda River for cooling and steam.

Water-supply use in the Saluda River subbasin was greater than in any other subbasin in the State. Eleven water-supply systems used a total of 40,055 million gallons of water in 2006. Of this amount, 40,033 million gallons were from surface-water sources (99.95 percent) and 22 million gallons were from wells (0.05 percent). The City of Greenville had the largest use, withdrawing 15,019 million gallons from the North Saluda River and Table Rock Reservoir. Greenville operates another surface-water facility in the Upper Savannah River subbasin at Lake Keowee. The City of Columbia facility at Lake Murray withdrew 10,814 million gallons. Other systems of note include Greenwood Commission of Public Works (4,238 million gallons from Lake Greenwood and the Saluda River), Easley Combined Utility (2,762 million gallons from Saluda Lake), and West Columbia (2,599 million gallons from the Saluda River and Lake Murray). Gilbert-Summit Rural Water District had the largest ground-water supply system in the subbasin with withdrawals of 16 million gallons from the crystalline rock and surficial aquifers.

Industrial water use totaled 7,850 million gallons in 2006. Of this amount, 7,825 million gallons were from surface-water sources (99.7 percent) and 25 million gallons were from ground-water sources (0.3 percent). Shaw Industries Group, Inc. in Lexington County was the largest user, having withdrawals totaling 7,788 million gallons.

Irrigation water use totaled 2,314 million gallons in the subbasin. Of this amount, 1,219 million gallons were from surface-water sources (53 percent) and 1,095 million gallons were from ground-water sources (47 percent). Large surface-water users include Mt. Airy Farms in Saluda County (420 million gallons) and Walter P. Rawl & Sons, Inc. in Lexington County (350 million gallons). Walter P. Rawl & Sons, Inc. also used 1,045 million gallons of ground water from the crystalline rock and surficial aquifers.

The total instream water use for hydroelectric power generation was 508,945 million gallons in 2006. Seven hydroelectric power facilities operate in the subbasin, all on the Saluda River. The Saluda Dam Hydroelectric Station at Lake Murray is SCE&G's largest conventional hydroelectric power plant, with five turbines and a capacity of 197.5 MW. In 2006, it used 149,244 million gallons

Table 6-14. Reported water use in the Saluda River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	428	0.3	2	0.2	430	0.3
Industry	7,825	5.9	25	2.2	7,850	5.9
Irrigation	1,219	0.9	1,095	95.7	2,314	1.7
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	82,721	62.6	0	0.0	82,721	62.0
Water supply	40,033	30.3	22	1.9	40,055	30.0
Total	132,226		1,144		133,370	

of water. The Buzzard's Roost hydroelectric facility at Lake Greenwood, operated by Duke Energy, has three turbines and a capacity of 15 MW. It used 93,433 million gallons in 2006.

Other hydroelectric plants in the subbasin include Holiday Bridge in Anderson County (92,268 million gallons); Lower Pelzer in Anderson County (83,000 million gallons); Piedmont Hydroelectric Power Project in Greenville County (56,000 million gallons); Upper Pelzer in Anderson County (35,000 million gallons); and Ware Shoals in Laurens County (reported no water use in 2006).

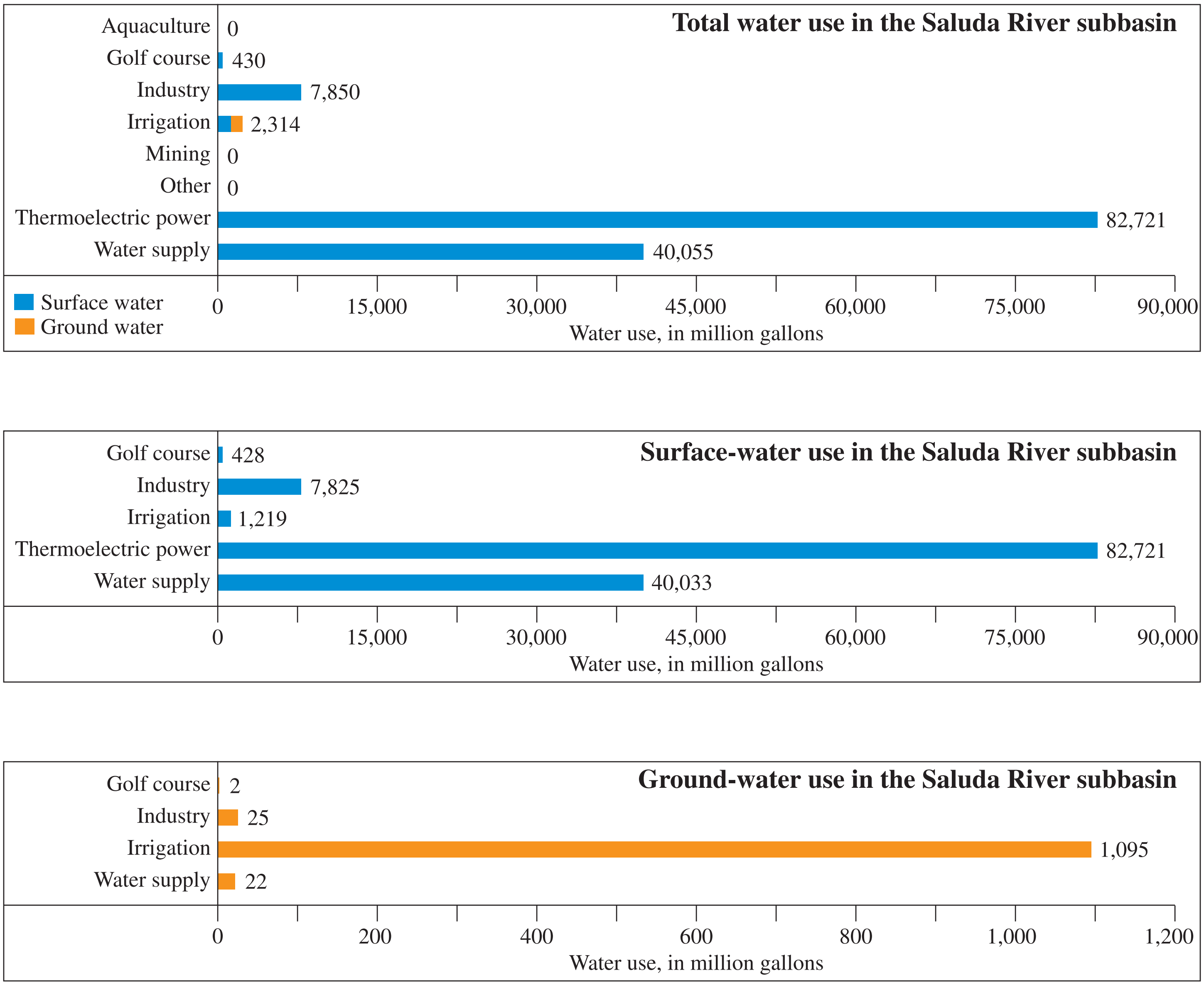


Figure 6-8. Reported water use in the Saluda River subbasin for the year 2006 (modified from Butler, 2007).

CATAWBA-WATEREE RIVER SUBBASIN

CATAWBA-WATEREE RIVER SUBBASIN

The Catawba-Wateree River subbasin bisects the north-central portion of South Carolina. The subbasin parallels the course of the Catawba-Wateree River from the North Carolina border south to the confluence with the Congaree River. Parts of eight South Carolina counties are in the subbasin, including most of Chester, Kershaw, Lancaster, and York Counties, the eastern third of Fairfield County, and small portions of Lee, Richland, and Sumter Counties (Figure 6-9). The subbasin area is approximately 2,315 square miles, 7.5 percent of the State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 305,900, or 7.6 percent of the State's total population. Significant population increases are expected by the year 2020, with the largest increases anticipated in York and Lancaster Counties. This area of the subbasin encompasses the metropolitan areas of Rock Hill, York, and Lancaster and is influenced by Charlotte, N.C.

In general, the upper part of the Catawba-Wateree subbasin is well developed and urbanized, whereas the lower part is relatively sparsely populated and rural. The major population centers in the South Carolina portion of the subbasin are Rock Hill (49,765), Lancaster (8,177), Camden (6,682), Chester (6,476), and York (6,700).

Year-2005 per capita income in the subbasin ranged from $31,518 in Richland County to $20,307 in Lee County. Richland, York, and Kershaw Counties ranked fifth, seventh, and eighth in the State and were the only subbasin counties with per capita incomes above the State average of $28,285. The 1999 median household incomes ranged from $44,539 in York County to $26,907 in Lee County.

During 2000, the subbasin's counties had combined annual-average employment of non-agricultural wage and salary workers of 160,000. Labor distribution in the subbasin counties included management, professional, and technical services, 26 percent; sales and office, 25 percent; production, transportation, and materials moving, 23 percent; service, 13 percent; construction, extraction, and maintenance, 13 percent; and farming, fishing, and forestry, 1 percent.

In the sectors of manufacturing and public utilities, the counties overlapping the subbasin had an annual product value of $10.6 billion in 2000. Crop and livestock production was $166 million, and the delivered value of timber exceeded $120 million (South Carolina Budget and Control Board, 2005).

SURFACE WATER

Hydrology

The major watercourse draining this subbasin is the Catawba-Wateree River. The headwater streams and much of the drainage area of the Catawba River are in North Carolina. At its confluence with Big Wateree Creek near Lake Wateree in the middle of the subbasin, the Catawba River changes in name to the Wateree River. Major tributaries in the Piedmont portion of the subbasin include Fishing Creek, Rocky Creek, Big Wateree Creek, Sugar Creek, and Cane Creek. Streams draining the upper Coastal Plain below Lake Wateree include Spears Creek, Colonels Creek, and Swift Creek.

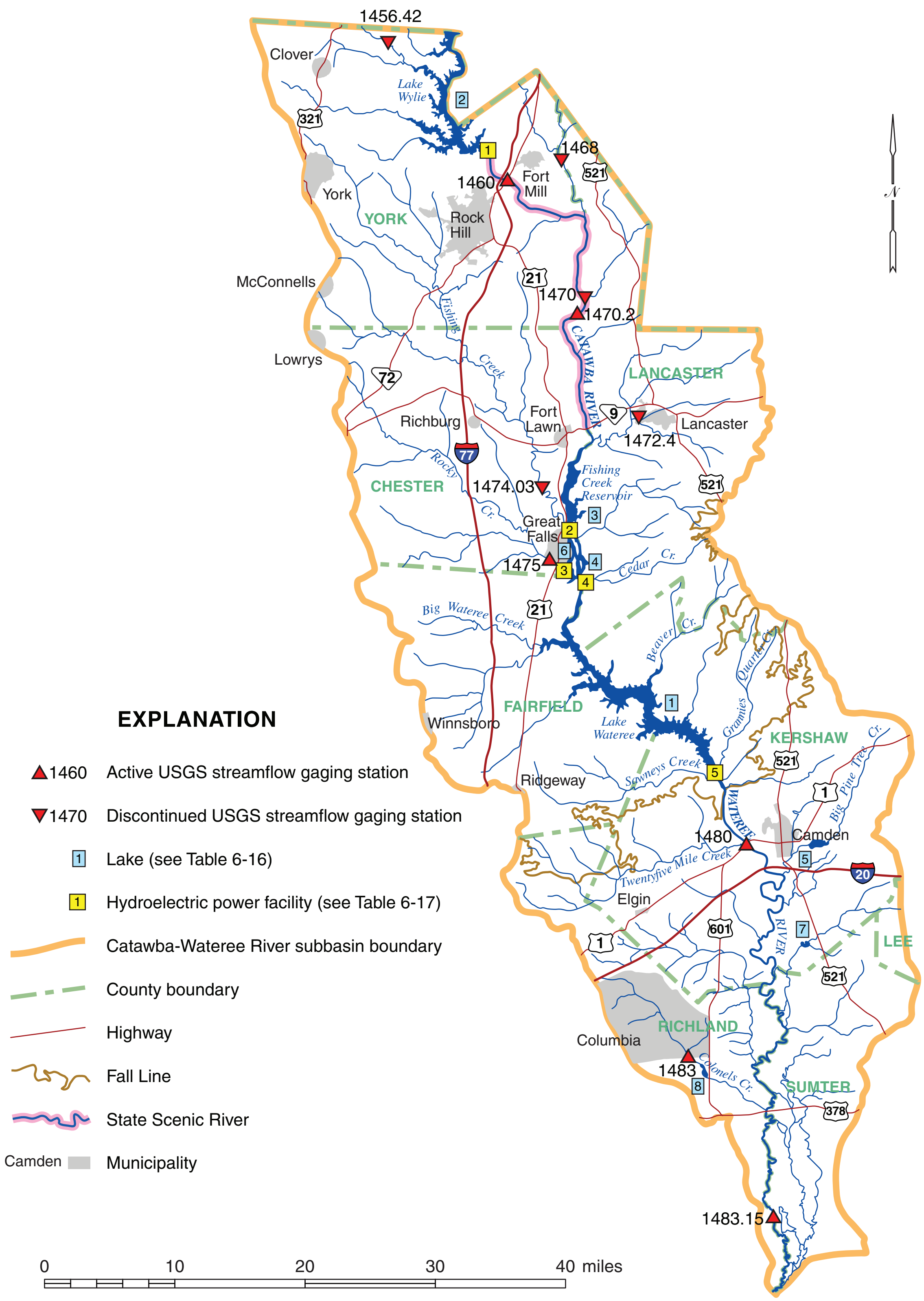


Figure 6-9. Map of the Catawba-Wateree River subbasin.

Controlled releases from a series of six hydroelectric reservoirs in North Carolina and five in South Carolina greatly affect streamflow of the Catawba-Wateree River. Duke Energy owns and operates all the reservoirs and hydroelectric power plants along the river in North and South Carolina.

Streamflow is currently monitored at six gaging stations, four of which are on the Catawba-Wateree River main stem and two on tributary streams (Figure 6-9). Streamflow statistics for these active gages and five discontinued gages are presented in Table 6-15. Streamflow at all main-stem stations has been subject to regulated releases for nearly all of the period of record because of numerous hydroelectric power facilities in North and South Carolina. The gaging station on the Wateree River below Eastover accurately monitors streamflow only below 10,000 cfs (cubic feet per second); the full range of flow is monitored at all other gaging stations.

The Catawba River is well developed by the time it enters South Carolina at Lake Wylie. Average annual flow of the Catawba-Wateree River ranges from 4,226 cfs near Rock Hill to 6,080 cfs near Camden. Streamflow can be expected

Table 6-15. Selected streamflow characteristics at USGS gaging stations in the Catawba-Wateree River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Crowders Creek near Clover 1456.42	1991-92 and 2000-01	89.0	58.5	0.66	21.0	11.0 2001	2,350 1991	– – –
Catawba River near Rock Hill 1460	1895-1903 and 1942-2007*	3,050	4,226	1.39	894	132 2002	127,000 1901	151,000 1901
Sugar Creek near Fort Mill 1468	1974 to 1979	262	461	1.76	98.0	24.0 1979	– – –	22,700 1976
Catawba River near Catawba 1470	1968 to 1992	3,530	5,183	1.47	1,060	480 1986	66,800 1989	73,600 1976
Catawba River below Catawba 1470.2	1992 to 2007*	3,540	4,317	1.22	1,100	451 2003	49,800 2003	– – –
Bear Creek at Lancaster 1472.4	1978 to 1982	66.6	53.9	0.81	2.1	0.7 1981	1,990 1980	3,610 1980
Fishing Creek below Fort Lawn 1474.03	2001 to 2003	134	272	2.03	5.8	3 2001	5,490 2003	– – –
Rocky Creek at Great Falls 1475	1951 to 2007*	194	175	0.90	15	0.0 2002	21,100 1967	31,300 1967
Wateree River near Camden 1480	1904-10 and 1929-2007*	5,070	6,080	1.20	1,230	143 1980	149,000 1929	366,000† 1908
Colonels Creek near Leesburg 1483	1966-80 and 2004-07*	38.1	43.4	1.14	18	5.6 2006	893 1967	1,350 1967
Wateree River below Eastover 1483.15	1968 to 2007*	5,590	Indeter-minate	– – –	– – –	549 1986	– – –	unknown‡ 1989

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*
† A flow estimated at 400,000 cfs occurred at this site in 1916 (outside period of record)
‡ Discharge measured only in main channel; flows greater than 10,000 cfs not recorded

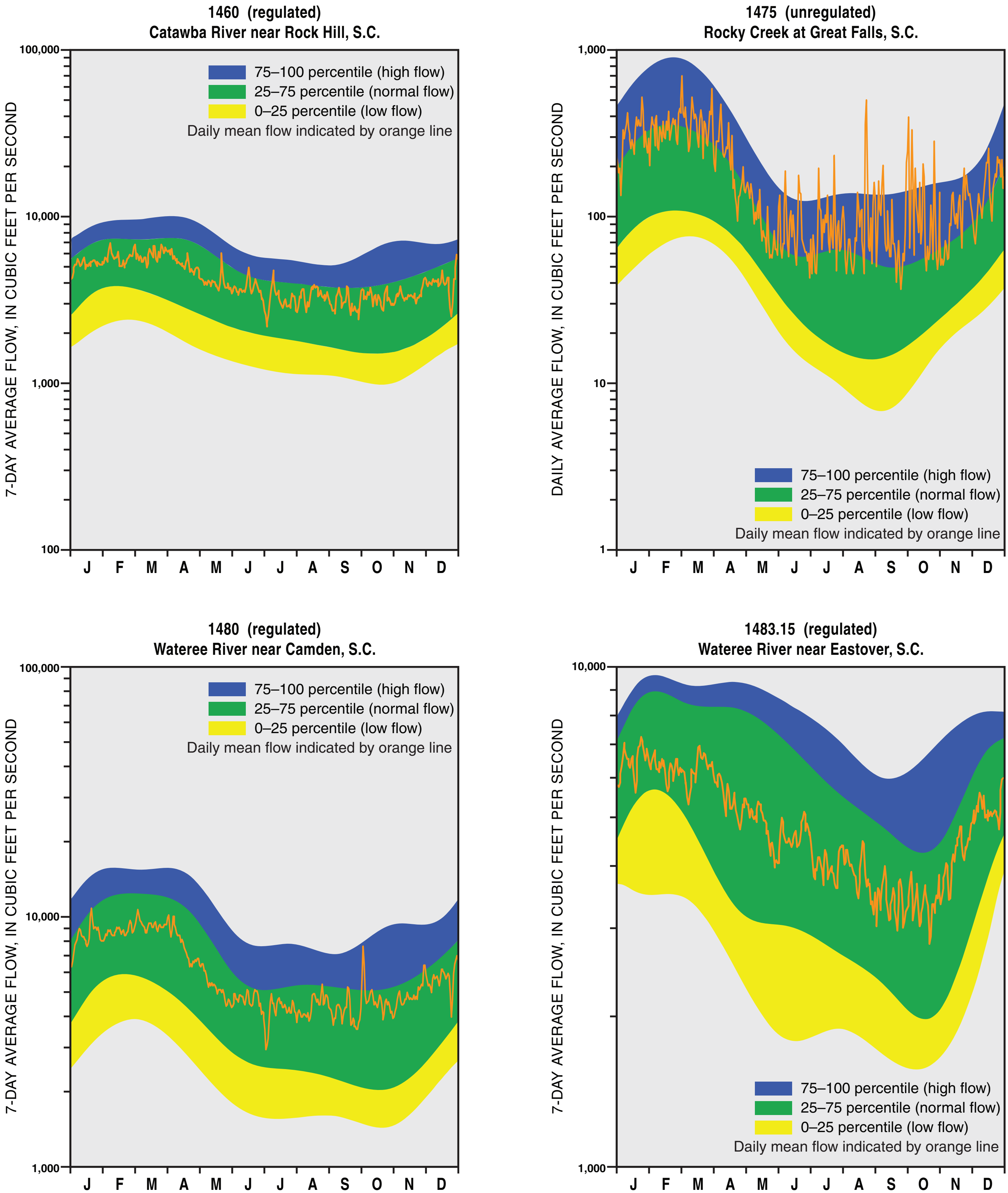


Figure 6-10. Duration hydrographs for selected gaging stations in the Catawba-Wateree River subbasin.

to equal or exceed 894 cfs near Rock Hill and 1,230 cfs near Camden 90 percent of the time. The lowest recorded flow on the main stem (132 cfs) occurred near Rock Hill in 2002 during the 1998–2002 drought. The highest flood flow of record (estimated at 400,000 cfs) was recorded near Camden in 1916. Daily streamflows near Camden are more variable than elsewhere along the river because of fluctuating releases from Lake Wateree (Figure 6-10).

Unlike the main stem, tributary streams are largely unregulated, and flows in these streams rarely exceed 1,000 cfs. Average annual streamflow of one actively-gaged tributary, Rocky Creek at Great Falls, is 175 cfs, with flow in this stream equal to or exceeding 15 cfs 90 percent of the time. At the other active tributary gage, on Colonels Creek near Leesburg, the average annual streamflow is 43 cfs and streamflow is expected to equal or exceed 18 cfs 90 percent of the time. Differing geomorphological characteristics of two major physiographic provinces greatly influence streamflow in these and other tributaries. Colonels Creek is in the upper Coastal Plain, where highly permeable soils, subsurface sediments, and deeply incised streams result in well-sustained flows during periods of low rainfall. Rocky Creek is in the Piedmont, where high relief and impermeable soils result in rapid runoff and limited ground-water storage. It and other Piedmont streams are, therefore, characterized by highly variable flows dependent primarily on rainfall and runoff rather than discharge from ground-water storage (Figure 6-10).

Streamflow in the upper portion of the Catawba-Wateree River is well-sustained throughout the year and provides a reliable source of supply. Although surface-water availability in the portion of the river below Wateree Dam is relatively constant, daily fluctuations and resultant low flows may limit some water-use activities. Larger water users may require storage facilities in this lower stretch of the river to help ensure more reliable surface-water supplies.

Tributary streams in the upper Coastal Plain, such as Colonels Creek, support relatively constant streamflows and provide a reliable surface-water flow if adequate in volume. Tributary streams in the Piedmont are not reliable water-supply sources, however, owing to widely fluctuating flows and low flows during periods of low rainfall. Unregulated Piedmont streams require provisions for storage to ensure sustained surface-water availability.

Development

The Catawba-Wateree River subbasin is intensely developed. Surface-water development consists primarily of dams and reservoirs for hydroelectric power production but also includes several flood-control projects. Before entering South Carolina, the Catawba River passes through six hydroelectric power projects and provides water for one nuclear and three coal-fired thermoelectric power plants.

In the South Carolina portion of the subbasin, the aggregate surface area of all lakes greater than 10 acres is approximately 34,400 acres, with a total volume of 734,800 acre-ft. The three largest reservoirs, all owned and operated by Duke Energy, are Lake Wateree, Lake Wylie, and Fishing Creek Reservoir (Table 6-16). By surface

Table 6-16. Lakes 200 acres or more in the Catawba-Wateree River subbasin (shown on Figure 6-9)

Number on map	Name	Stream	Surface area (acres)	Storage capacity (acre-feet)	Purpose
1	Lake Wateree	Wateree River	13,864[b]	310,000[a]	Power, recreation, and water supply
2	Lake Wylie	Catawba River	13,443[b]	281,900[a]	Power, recreation, industry, and water supply
3	Fishing Creek Reservoir	Catawba River	3,112[b]	80,000[a]	Power, recreation, industry, and water supply
4	Rocky Creek Lake (Cedar Creek Reservoir)	Catawba River	847[b]	23,000[a]	Power, recreation, and water supply
5	Hermitage Mill Pond	Big Pine Tree Creek	600[a]	1,800[a]	Power, recreation, industry, and water supply
6	Great Falls Lake	Catawba River	477[b]	16,000[a]	Power
7	Boykin Mill Pond	Swift Creek	200[a]	640[a]	Recreation
8	Murray Pond	Colonels Creek	200[a]	600[a]	Recreation

Sources: (a) U.S. Army Corps of Engineers (1991)
(b) Duke Energy website http://www.duke-energy.com/lakes/facts-and-maps.asp (2008)

area, Lake Wateree and Lake Wylie are the eighth and ninth largest lakes in the State, respectively. Lake Wateree is the tenth largest reservoir in the State by volume.

Lake Wateree is 8 miles northwest of Camden on the Wateree River. Constructed in 1920 and enlarged in 1925, it is used for power generation, municipal water supplies, industry, and recreation.

Lake Wylie is on the North Carolina-South Carolina border, 5 miles north of Rock Hill. Constructed in 1904 for the generation of hydroelectric power, it is one of the oldest major impoundments in the State. Lake Wylie was enlarged to its present capacity in 1924 and also serves water supply, industrial, and recreational needs.

Fishing Creek Reservoir was built for the production of hydroelectric power in 1916. In addition to power generation, it is used as a municipal water supply and for industrial and recreational needs.

In addition to the hydroelectric power plants at Lake Wylie, Lake Wateree, and Fishing Creek Reservoir, four other hydropower plants are located just downstream from Fishing Creek Reservoir (Table 6-17). The Great Falls and Dearborn Hydroelectric Stations are both located on Great Falls Lake; the powerhouse for Great Falls is on the west side of the dam and the powerhouse for Dearborn is on the east side. The Cedar Creek and Rocky Creek Hydroelectric Stations are both located on Rocky Creek Lake (Cedar Creek Reservoir); Rocky Creek is on the west side of the dam and Cedar Creek is on the east side.

Table 6-17. Hydroelectric power generating facilities in the Catawba-Wateree River subbasin (shown on Figure 6-9)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Wylie Duke Energy	Catawba River	Lake Wylie	60	679,938
2	Fishing Creek Duke Energy	Catawba River	Fishing Creek Lake	36.7	783,749
3	Great Falls Duke Energy	Catawba River	Great Falls Lake	24	23,821
3	Dearborn Duke Energy	Catawba River	Great Falls Lake	45	810,158
4	Rocky Creek Duke Energy	Catawba River	Rocky Creek Lake	28	5,377
4	Cedar Creek Duke Energy	Catawba River	Rocky Creek Lake	45	859,455
5	Wateree Duke Energy	Wateree River	Lake Wateree	56	923,086

The Wateree River is the site of the only U.S. Army Corps of Engineers project in the subbasin. In the late 1800's and early 1900's, a 4-foot navigation channel was maintained from the mouth of the river to Camden. The project remains authorized but is no longer active.

The NRCS (Natural Resources Conservation Service) has completed four flood-control and drainage projects in the subbasin. These projects include 18.3 miles of channel improvement, 29 floodwater-retarding structures, and land treatment for erosion control and sediment reduction.

In 2008, American Rivers, a national river conservation group, declared the Catawba-Wateree River to be *America's Most Endangered River*. Rapid population growth, particularly in the Charlotte metropolitan area, and inadequate and outdated water-management practices and legislation in both North and South Carolina threaten to impair the river's health and its ability to provide for residents in the future (American Rivers, 2008).

Surface-Water Quality

All water bodies in the Catawba-Wateree subbasin are designated “Freshwater” (Class FW). This class of water bodies is suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2005a).

As part of its ongoing Watershed Water Quality Assessment program, DHEC sampled 113 surface-water sites in the Catawba-Wateree subbasin during 1998 and 2002 in order to assess the water's suitability for aquatic life and recreational uses (Figure 6-11). Aquatic-life uses

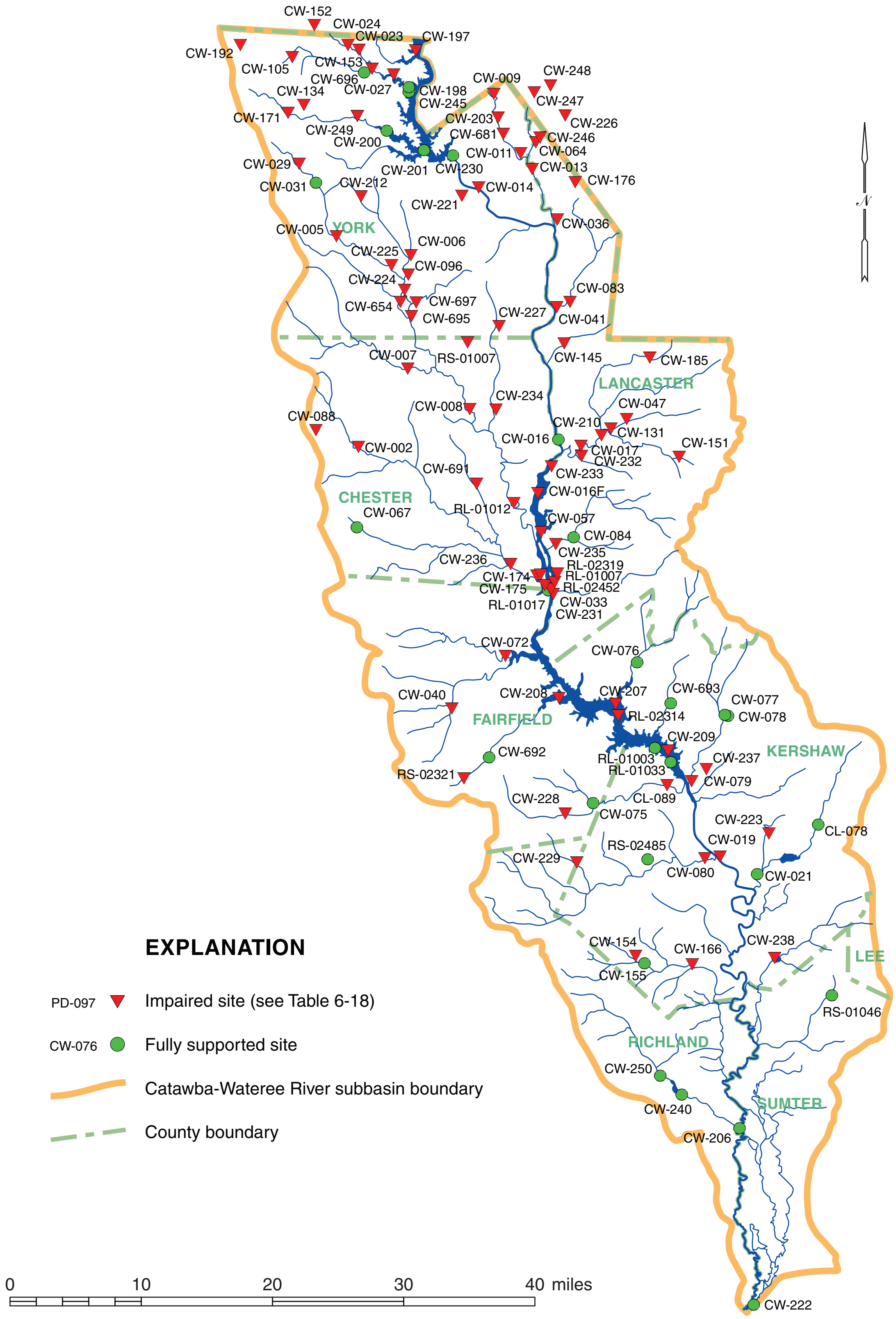


Figure 6-11. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 6-18 (DHEC, 2005a).

Table 6-18. Water-quality impairments in the Catawba-Wateree River subbasin (DHEC, 2005a)

Water-body name	Station number	Use	Status	Water-quality indicator
Lake Wylie	CW-197	Aquatic life	Nonsupporting	Copper
	CW-027	Recreation	Partially supporting	Fecal coliform
South Fork	CW-192	Recreation	Nonsupporting	Fecal coliform
Crowders Creek	CW-152	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
	CW-023	Recreation	Nonsupporting	Fecal coliform
	CW-024	Aquatic life	Nonsupporting	Macroinvertebrates
		Recreation	Partially supporting	Fecal coliform
Brown Creek	CW-105	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Beaverdam Creek	CW-153	Recreation	Partially supporting	Fecal coliform
Allison Creek	CW-171	Recreation	Nonsupporting	Fecal coliform
	CW-249	Recreation	Nonsupporting	Fecal coliform
Calabash Creek	CW-134	Recreation	Nonsupporting	Fecal coliform
Hidden Creek	CW-221	Recreation	Nonsupporting	Fecal coliform
Catawba River	CW-014	Recreation	Partially supporting	Fecal coliform
	CW-041	Aquatic life	Nonsupporting	Copper
Fishing Creek Reservoir	CW-016F	Aquatic life	Nonsupporting	Turbidity, total phosphorus
	RL-01012	Aquatic life	Nonsupporting	Chlorophyll-*a*
	CW-057	Aquatic life	Nonsupporting	Total phosphorus
Cedar Creek Reservoir	CW-174	Aquatic life	Nonsupporting	Dissolved oxygen, total phosphorus, total nitrogen
		Recreation	Partially supporting	Fecal coliform
	RL-02319	Aquatic life	Nonsupporting	Total phosphorus
	RL-01007	Aquatic life	Nonsupporting	Chlorophyll-*a*, dissolved oygen
	RL-02452	Aquatic life	Nonsupporting	Total phosphorus
	CW-033	Aquatic life	Nonsupporting	Total phosphorus
Sugar Creek	CW-247	Aquatic life	Nonsupporting	Cadmium, copper
		Recreation	Partially supporting	Fecal coliform
	CW-246	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
	CW-013	Recreation	Nonsupporting	Fecal coliform
	CW-036	Aquatic life	Nonsupporting	Copper
		Recreation	Nonsupporting	Fecal coliform
Little Sugar Creek	CW-248	Recreation	Nonsupporting	Fecal coliform
McAlpine Creek	CW-226	Recreation	Nonsupporting	Fecal coliform
	CW-064	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Steel Creek	CW-009	Recreation	Nonsupporting	Fecal coliform
	CW-203	Recreation	Nonsupporting	Fecal coliform
	CW-681	Aquatic life	Partially supporting	Macroinvertebrates
	CW-011	Recreation	Partially supporting	Fecal coliform

Table 6-18. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Sixmile Creek	CW-176	Recreation	Nonsupporting	Fecal coliform
Twelvemile Creek	CW-083	Aquatic life	Nonsupporting	Turbidity, copper
		Recreation	Partially supporting	Fecal coliform
Waxhaw Creek	CW-145	Aquatic life	Nonsupporting	Copper
		Recreation	Nonsupporting	Fecal coliform
Cane Creek	CW-185	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
	CW-210	Aquatic life	Partially supporting	Macroinvertebrates
	CW-017	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Bear Creek	CW-151	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
	CW-131	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Gills Creek	CW-047	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Rum Creek	CW-232	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Fishing Creek	CW-029	Recreation	Nonsupporting	Fecal coliform
	CW-005	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
	CW-225	Aquatic life	Nonsupporting	Copper
		Recreation	Nonsupporting	Fecal coliform
Wildcat Creek	CW-006	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
	CW-096	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Tools Fork	CW-212	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Fishing Creek	CW-224	Recreation	Nonsupporting	Fecal coliform
	CW-654	Aquatic life	Partially supporting	Macroinvertebrates
	CW-008	Recreation	Partially supporting	Fecal coliform
	CW-233	Recreation	Partially supporting	Fecal coliform
Stoney Fork	CW-697	Aquatic life	Partially supporting	Macroinvertebrates
Taylor Creek	CW-695	Aquatic life	Partially supporting	Macroinvertebrates
South Fork Fishing Creek	CW-007	Aquatic life	Partially supporting	Macroinvertebrates
McFadden Branch	RS-01007	Recreation	Nonsupporting	Fecal coliform
Lake Oilphant	CL-021	Aquatic life	Nonsupporting	Ph, chlorophyll-*a*
Neelys Creek	CW-227	Recreation	Partially supporting	Fecal coliform
Tinkers Creek	CW-234	Aquatic life	Nonsupporting	Macroinvertebrates, turbidity
		Recreation	Partially supporting	Fecal coliform
Camp Creek	CW-235	Recreation	Nonsupporting	Fecal coliform

Table 6-18. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Grassy Run Branch	CW-088	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Rocky Creek	CW-002	Aquatic life	Nonsupporting	Macroinvertebrates, copper
		Recreation	Nonsupporting	Fecal coliform
	CW-236	Recreation	Nonsupporting	Fecal coliform
Beaverdam Creek	CW-691	Aquatic life	Partially supporting	Macroinvertebrates
Rocky Creek arm of Cedar Creek Reservoir	CW-175	Aquatic life	Nonsupporting	Dissolved oxygen, turbidity, total phosphorus
		Recreation	Nonsupporting	Fecal coliform
Lake Wateree	CW-231	Aquatic life	Nonsupporting	Turbidity, total phosphorus
	CW-208	Aquatic life	Nonsupporting	pH, total phosphorus, chlorophyll-*a*
	RL-02134	Aquatic life	Nonsupporting	pH, total phosphorus
	CW-207	Aquatic life	Nonsupporting	pH, total phosphorus
	CW-209	Aquatic life	Nonsupporting	pH, total phosphorus
	CL-089	Aquatic life	Partially supporting	pH
Little Wateree Creek	CW-040	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Dutchmans Creek	RS-02321	Recreation	Nonsupporting	Fecal coliform
Big Wateree Creek	CW-072	Aquatic life	Partially supporting	Dissolved oxygen, pH
		Recreation	Nonsupporting	Fecal coliform
Wateree River	CW-019	Aquatic life	Partially supporting	Dissolved oxygen
Grannies Quarter Creek	CW-237	Aquatic life	Partially supporting	pH
		Recreation	Partially supporting	Fecal coliform
Sawneys Creek	CW-228	Recreation	Nonsupporting	Fecal coliform
	CW-079	Recreation	Partially supporting	Fecal coliform
Bear Creek	CW-229	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Twentyfive Mile Creek	CW-080	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Partially supporting	Fecal coliform
Little Pine Tree Creek	CW-223	Recreation	Partially supporting	Fecal coliform
Swift Creek	CW-238	Aquatic life	Nonsupporting	Dissolved oxygen
Kelly Creek	CW-154	Recreation	Partially supporting	Fecal coliform
Spears Creek	CW-166	Recreation	Nonsupporting	Fecal coliform

were fully supported at 58 sites, or 51 percent of the water bodies sampled (DHEC, 2005a). The main reasons these water bodies did not meet minimum standards to support aquatic life are low dissolved-oxygen levels, poor macroinvertebrate-community structures, and high phosphorus concentrations. Thirty-eight percent of the sampled water bodies fully supported recreational use; water bodies not fully supporting recreational use exhibited high levels of fecal-coliform bacteria. Table 6-18 summarizes these water-quality impairments.

Although present Lake Wylie water quality is generally good, the potential exists for future water-quality degradation owing to urbanization and industrial growth. Special measures are needed to insure that present water-quality conditions are maintained.

The South Fork Catawba River (which drains into Lake Wylie in North Carolina) has an average total-phosphorus concentration that is several times greater than the EPA goal and is a significant source of phosphorus in downstream lakes (USGS National Water-Quality Assessment Program: *http://sc.water.usgs.gov/nawqa*).

DHEC publishes the most recently observed impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in earlier years, DHEC issued a fish-consumption advisory for the Wateree River between Lake Wateree and the Congaree River. Fish-consumption advisories are issued in areas where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for skiing, boating, or swimming.

GROUND WATER

Hydrogeology

The Catawba-Wateree River subbasin is partially in the Piedmont and partially in the upper Coastal Plain, creating wide variations in ground-water availability.

The Piedmont portion of the subbasin is predominantly underlain by Charlotte terrane rocks, and includes parts of York, Chester, and Fairfield Counties. The extreme northwest corner of the subbasin, north-central York County, is in the Kings Mountain terrane. Kershaw County is underlain by rocks of the Carolina terrane, and Lancaster County is underlain by the Charlotte terrane to the northwest and the Carolina terrane to the southeast. Both terranes are generally oriented northeast-southwest, with the Charlotte terrane transecting the northernmost part of the subbasin. Some gabbro and granite plutons are scattered throughout the subbasin. The Gold Hill/Silver Hill Shear Zone cuts northeast-southwest across the panhandle of Lancaster County and the northeast corner of Chester County.

Little difference is observed between the yields of drilled wells in the two crystalline-rock terranes. Well yields usually are less than 20 gpm (gallons per minute), although yields greater than 300 gpm have been reported. Well depths range from 40 to 810 feet, but commonly are around 200 feet (Table 6-19). DNR well records show significantly higher average yields in Kershaw County—a statistical bias caused by the disproportionately high number of public-supply and industrial wells inventoried. Such wells are constructed with the intent to obtain the maximum possible yields.

Table 6-19. Well depths and yields for drilled bedrock wells in the Catawba-Wateree River subbasin

County	Well depth (feet)		Well yield (gpm)	
	Average	Maximum	Average	Maximum
Chester/ Cherokee	192	645	16	90
Fairfield	230	585	20	120
Kershaw	316	625	62	275
Lancaster	240	780	16	145
Richland	321	604	14	30
York	206	810	19	400
Total	209	810	19	400

Southeast of the Fall Line in Richland, Kershaw, and Sumter Counties, the sedimentary deposits of the upper Coastal Plain provide a good source of ground water. This part of the subbasin is underlain by the Middendorf, Black Creek, and Tertiary sand aquifers, which dip southeastward and thicken to about 650 feet at the lower end of the subbasin. Southeastern Kershaw County, eastern Richland County, and northwestern Sumter County are in the outcrop area of the Middendorf Formation and therefore the recharge area of the Middendorf aquifer.

Near the town of Wateree, in southeastern Richland County, the total thickness of sedimentary deposits is about 550 feet. The Middendorf aquifer occurs between the depths of 350 and 550 feet and directly overlies the bedrock. From 0 to 350 feet, a series of sand and clay beds represents the Black Creek aquifer. The Tertiary sand aquifer overlies the Black Creek and is the principal source of water for domestic supplies in the high-elevation areas outside the river valley. The transmissivity of the Middendorf aquifer near Eastover has been calculated to be as much as 8,700 ft^2/day, and hydraulic conductivities of 35 to 79 ft/day are indicated.

In northwestern Sumter County, the area around Rembert and Hagood is underlain by alluvial deposits of sand, silt, clay, and gravel along the Wateree River and by the Middendorf aquifer elsewhere. Wells in the Wedgefield area are used primarily for domestic supplies. Shallow industrial wells in the Wateree River valley capture water from that stream and yield as much as 300 gpm. Selected ground-water data for the Coastal Plain portion of the subbasin are presented in Table 6-20.

Table 6-20. Selected Coastal Plain ground-water data for the Catawba-Wateree River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Camden-Lugoff	Middendorf/ crystalline rock	50–560	350
Cassatt	Middendorf	92–182	305
Eastover	Middendorf	250–600	2,000
Rembert-Hagood	Black Creek/ Middendorf	155–320	1,200
Elgin	Middendorf	115–210	350
Wedgefield	Tertiary sand/ Black Creek	74–250	250
Wateree River at Lugoff	Shallow sand and gravel deposits in flood plain	40	300

Ground-Water Quality

In the Piedmont section of the Catawba-Wateree River subbasin, ground water locally has high iron and magnesium concentrations, excessive hardness, and taste problems. The pH ranges from 4.3 to 8.4, alkalinity is less than 250 mg/L (milligrams per liter) and TDS (total dissolved solids) concentrations range between 16 and 1,260 mg/L (National Uranium Resource Evaluation program, 1997).

Both bedrock and Middendorf wells are used in Kershaw County. Water from bedrock wells is generally of good quality; TDS concentrations are less than 200 mg/L; pH is between 7.0 and 8.0; and hardness ranges from very soft to hard. Water from sand wells in the Middendorf is characterized by low TDS, pH, and alkalinity, and is soft and corrosive. Sand wells in Kershaw County rarely have TDS greater than 30 mg/L and hardness greater than 10 mg/L. The pH commonly is between 4.0 and 5.0 (Newcome, 2002).

Newcome (2003) also noted a distinct water-quality contrast between bedrock- and sand-aquifer wells in Richland County. Rock wells commonly produce water having a pH greater than 7.0, and the median concentrations of TDS and hardness are 250 mg/L and 130 mg/L, respectively. Sand wells generally produce water with a pH less than 7.0, and the median concentrations of TDS and hardness are 30 mg/L and 5 mg/L, respectively.

High iron concentrations are common in the Middendorf aquifers of Sumter County, and iron-reducing bacteria are known to cause well problems in both Sumter and Richland Counties (Park, 1980; Newcome, 2003). Steel and brass well screens can corrode because the pH is low, and well screens may be blocked if iron-reducing bacteria thrive; both problems are aggravated where pumps are set inside the well screen. The latter situation also can produce “red water” and probably accounts for many reports of high iron in well water.

Water-Level Conditions

Ground-water levels in this subbasin are not routinely measured by USGS, DNR, or DHEC in any wells within this subbasin.

Because ground-water use in this subbasin is very limited, and because most of the lower part of the subbasin falls within recharge areas for the Middendorf and Black Creek aquifers, no known ground-water-level problems are associated with pumping from these aquifers. Water-level variations within the Coastal Plain aquifers in this subbasin are likely the result of variations in surface-water availability and subsequent recharge rates.

WATER USE

Water-withdrawal information presented here is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Offstream water use in the Catawba-Wateree River subbasin, summarized in Table 6-21 and Figure 6-12, totaled 274,922 million gallons in 2006, ranking it fourth among the 15 subbasins. Of this amount, 272,718 million gallons were from surface-water sources (99 percent) and 2,204 million gallons were from ground-water sources (1 percent). The subbasin’s two thermoelectric power plants accounted for 84 percent of the total use, followed by industry (10 percent) and water supply (6 percent). Small quantities of water were also used for agricultural irrigation, golf courses, and mining. Consumptive use in this subbasin is estimated to be 10,459 million gallons, or about 4 percent of the total offstream use.

The Wateree Station, SCE&G’s largest coal-fired power plant, was the largest water user in the subbasin in 2006. Located at the lower end of the subbasin in Richland County, this plant contains two turbines capable of generating 700 MW (megawatts) of power. In 2006, it withdrew 146,349 million gallons of water from the Wateree River for cooling and steam. A closed-cycle cooling-water system was installed in 2006 to reduce withdrawals.

The Catawba Nuclear Station, located adjacent to Lake Wylie in York County, is jointly owned by Duke Energy, North Carolina Electric Membership Corp., and Saluda River Electric Cooperative. Its two turbines have a total capacity of 2,258 MW. In 2006, the station used 83,439 million gallons of water for cooling and steam.

The Catawba-Wateree subbasin ranked third behind the Pee Dee and Congaree subbasins in industrial water use in 2006. A total of 26,738 million gallons were used, 25,849 million gallons (97 percent) from surface-water sources and 889 million gallons (3 percent) from ground-water sources. Bowater, Inc. and International Paper are two of the largest industrial users in the State. Bowater withdrew 12,303 million gallons from the Catawba River, and International Paper in Eastover withdrew 10,516 million from the Wateree River. International Paper also reported withdrawals of 701 million gallons from the Middendorf aquifer.

Water-supply use in the subbasin was 17,124 million gallons, of which surface water accounted for 16,424 million gallons (96 percent) and ground water for 700 million gallons (4 percent). The largest surface-water system was the Catawba River Water Treatment Plant, which withdrew 6,354 million gallons from the Catawba River in York County in 2006. The next largest surface-water supplier was the City of Rock Hill, which withdrew 5,534 million gallons from Lake Wylie. Cassatt Water Company, Inc., which serves rural areas in mainly Kershaw County, reported the largest ground-water withdrawals, at 292 million gallons from the Middendorf aquifer.

Instream water use for the seven Duke Energy hydroelectric power facilities on the Catawba-Wateree River in South Carolina totaled 4,085,584 million gallons in 2006 (Table 6-17).

Table 6-21. Reported water use in the Catawba-Wateree River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	297	0.1	169	7.7	465	0.2
Industry	25,849	9.5	889	40.3	26,738	9.7
Irrigation	361	0.1	432	19.6	794	0.3
Mining	0	0.0	14	0.6	14	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	229,787	84.3	0	0.0	229,788	83.6
Water supply	16,424	6.0	700	31.8	17,124	6.2
Total	272,718		2,204		274,922	

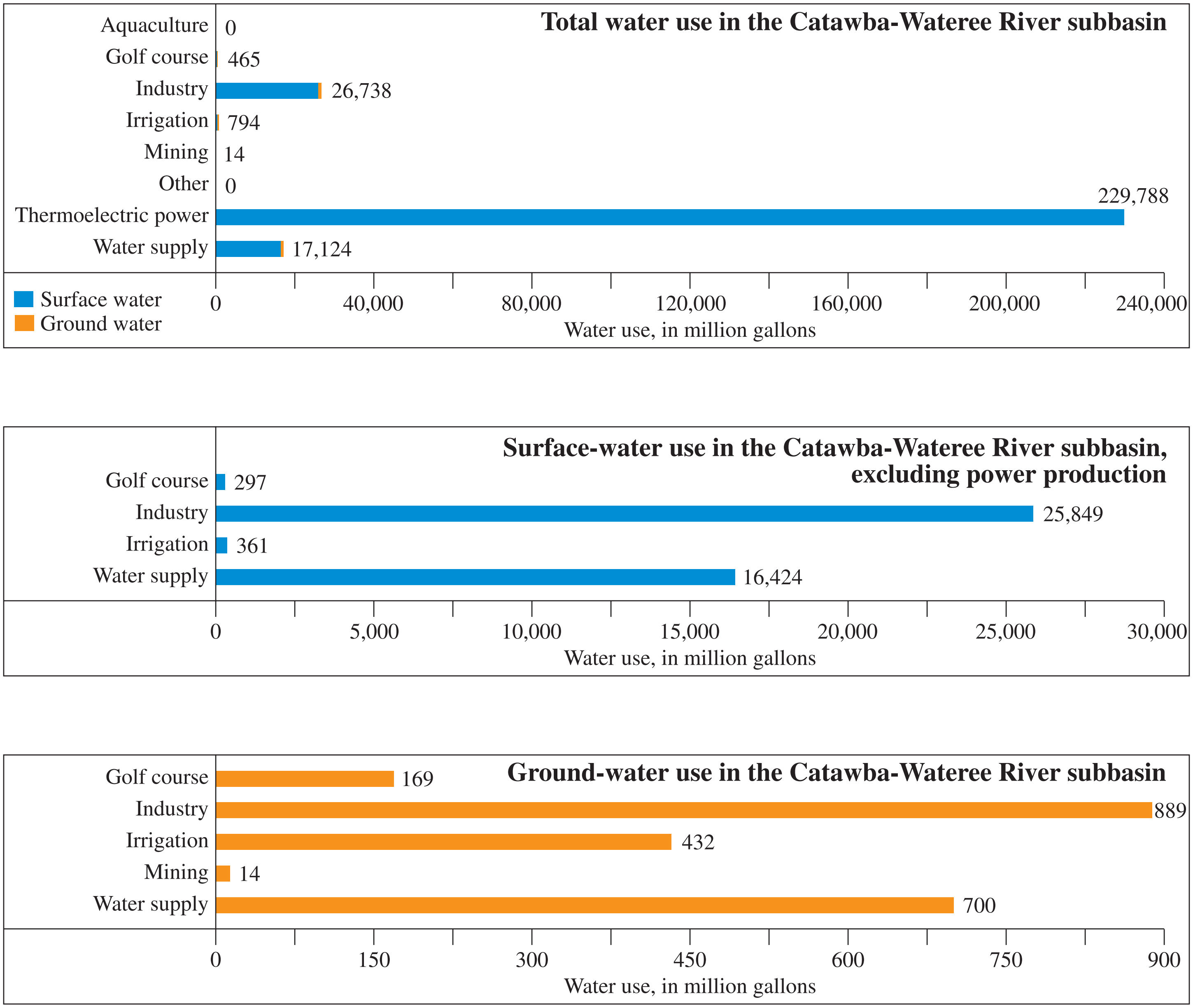


Figure 6-12. Reported water use in the Catawba-Wateree River subbasin for the year 2006 (modified from Butler, 2007).

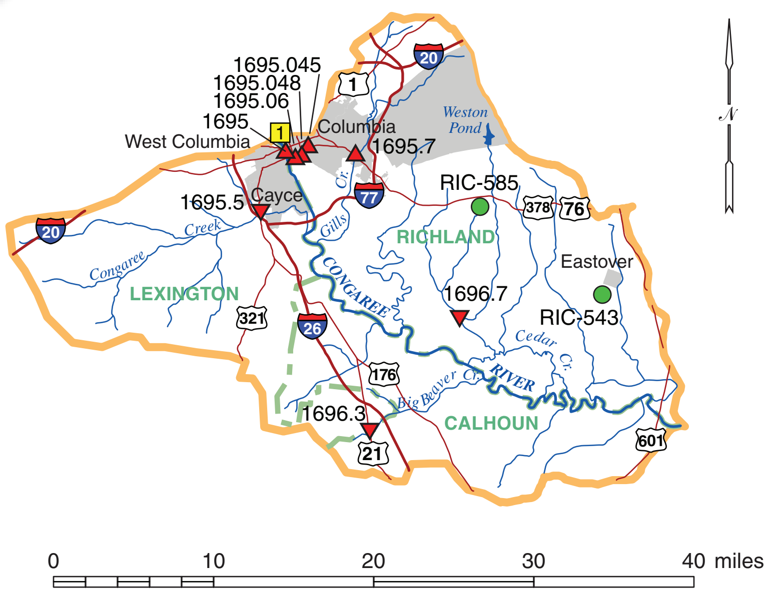
CONGAREE RIVER SUBBASIN

CONGAREE RIVER SUBBASIN

Located in the geographical center of the State, the Congaree River subbasin is the smallest of the State's 15 subbasins. It encompasses parts of Richland, Lexington, and Calhoun Counties (Figure 6-13). The subbasin area is approximately 705 square miles, 2.3 percent of the State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at approximately 252,400, which was 6.3 percent of the State's total population. The largest growth is anticipated in Lexington County, where population is expected to increase by almost 30 percent by 2020.



EXPLANATION

▲1695	Active USGS streamflow gaging station		County boundary
▼ 1696.3	Discontinued USGS streamflow gaging station		Highway
● RIC-543	Water-level monitoring well (see Table 6-26)		Congaree River subbasin boundary
1	Hydroelectric power facility (see Table 6-23)	Columbia	Municipality

Figure 6-13. Map of the Congaree River subbasin.

The southeastern reach of the subbasin is predominantly rural, whereas the northwestern reach is one of the most densely populated areas of the State. The main center of population is Columbia (116,278). Other major urban areas are Cayce (12,150), West Columbia (13,064), and Forest Acres (10,558), all of which are Columbia suburbs. Fort Jackson, the U.S. Army's largest basic-training center, is located at Columbia.

The year 2005 per capita personal income for the subbasin ranged from $31,575 in Lexington County, which ranked fourth among the State's 46 counties, to $28,429 in Calhoun County, which ranked eleventh. Median household income in 1999 ranged from $44,659 in Lexington County, second in the State, to $32,736 in Calhoun County, which was about $4,000 less than the State's median household income.

During 2000, the counties of the subbasin had combined annual-average employment of non-agricultural wage and salary workers of 267,000. Labor distribution in the subbasin counties included management, professional, and technical services, 37 percent; sales and office, 28 percent; service, 14 percent; production, transportation, and materials moving, 11 percent; construction, extraction, and maintenance, 9 percent; and farming, fishing, and forestry, 1 percent. Because the State capital is Columbia, the number of government employees is disproportionately high in the region: management, professional, and technical employment is 27 percent greater than the State average.

In the sector of manufacturing and public utilities, the subbasin counties had an annual product value of $5.4 billion. Crop and livestock production was $117 million, with first-ranked Lexington County accounting for more than $87 million. All three subbasin counties ranked in the lower half of the State in timber-product output, with an aggregate delivered-timber value of $34 million in 2001 (South Carolina Budget and Control Board, 2005).

SURFACE WATER

Hydrology

The major watercourse in the subbasin is the Congaree River, formed by the confluence of the Saluda and Broad Rivers at Columbia. Several small- to moderately-sized tributaries discharge into the main stem; the largest of these are Congaree Creek, Gills Creek, Cedar Creek, and Toms Creek. This subbasin is mostly in the upper Coastal Plain, with portions of the eastern region in the middle Coastal plain. Much of the Congaree River and lower portions of tributary streams are associated with swamplands. The Columbia metropolitan area makes extensive use of surface water in the upper portion of the subbasin.

Currently, streamflow in the subbasin is monitored at five sites (Figure 6-13). Two gaging stations—one on the Congaree River (1695) and one on Gills Creek (1695.7)—have been in service for more than 40 years. The other three stations were installed in 2007 on Rocky

Table 6-22. Selected streamflow characteristics at USGS gaging stations in the Congaree River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Congaree River at Columbia 1695	1939 to 2007*	7,850	8,872	1.13	2,820	576 2007	150,000 1976	155,000† 1976
Congaree Creek at Cayce 1695.5	1959 to 1980	122	222	1.82	148	111 1970	1,600 1959	1,840 1959
Gills Creek at Columbia 1695.7	1966 to 2007*	59.6	72.2	1.21	13	1.1 2007	1,730 1986	2,880 1979
Big Beaver Creek near St. Matthews 1696.3	1966 to 1993	10.0	13.6	1.36	7.1	3.9 1988	285 1971	1,360 1971
Cedar Creek near Hopkins 1696.7	1981 to 1985	66.9	66.2	0.99	26.0	4.2 1982	372 1983	– – –

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*
† About 364,000 cfs occurred at this site in 1908 (outside period of record)

Branch, a small creek that flows through Columbia. There are also two stage-only gaging stations in the lower reaches of the subbasin, one on the main stem and one on Cedar Creek. Streamflow statistics for two active and three discontinued streamflow gaging stations are presented in Table 6-22.

Average annual flow of the Congaree River at Columbia is 8,872 cfs (cubic feet per second) and should be at least 2,820 cfs 90 percent of the time. The lowest flow of record (576 cfs) occurred in August 2007. Although the greatest flow measured at the Congaree River at Columbia gage is 155,000 cfs, which occurred in October 1976, the flow of the river is believed to have exceeded 200,000 cfs in six different years between 1908 and 1939, before the current gaging station was established. Streamflow at this site during a 1908 flood event is estimated to have peaked at 364,000 cfs. Although the daily flow of the Congaree River may be highly variable because of fluctuating releases from hydroelectric-power facilities upstream on the Saluda and Broad Rivers, the minimum available flow is still significant and reliable the year around (Figure 6-14).

Tributary streams on opposite sides of the Congaree River exhibit different streamflow characteristics. Streams draining the western side of the subbasin, such as Congaree Creek and Big Beaver Creek, have nearly constant streamflows and provide an excellent source of water supply. Congaree Creek has the most-regular year-round streamflow of any gaged stream in the State. Big Beaver Creek also indicates well-sustained year-round flow with little significant variation.

Streams draining the eastern side of the subbasin are typical of most middle Coastal Plain streams and exhibit moderately-sustained flow. They originate in an area of nearly impermeable, red, clayey sand and are therefore characterized by limited steady flow. Streamflow characteristics of Gills Creek (Figure 6-14) reflect

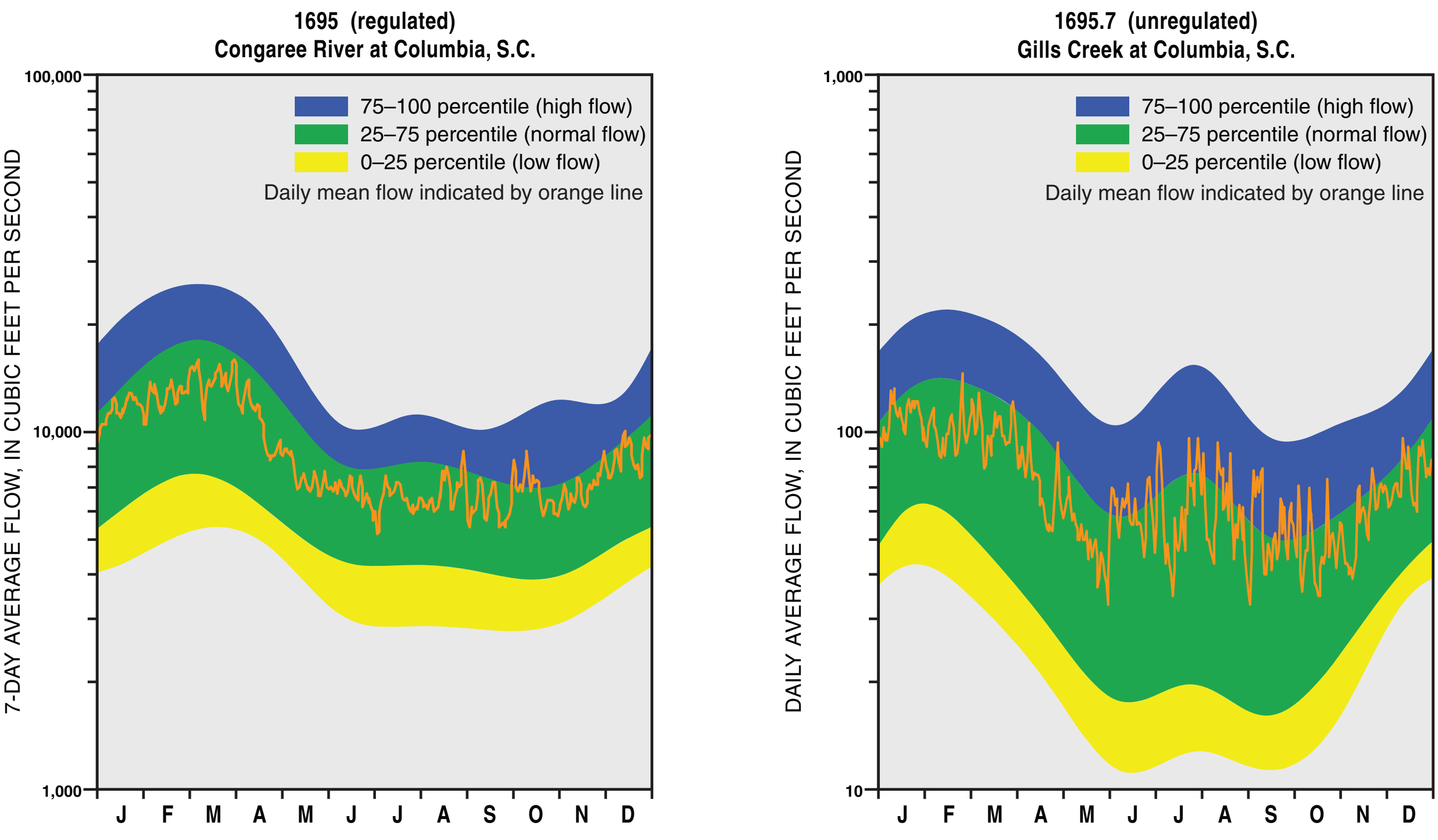


Figure 6-14. Duration hydrographs for selected gaging stations in the Congaree River subbasin.

the more variable, less well-sustained flows of these eastern tributaries. Several flood-control and recreational impoundments along Gills Creek also affect natural streamflow in this tributary. Although streamflow on the eastern side of the subbasin is more variable, some base-flow support from ground-water reserves should ensure limited year-round surface-water availability.

Development

There is little surface-water development in the Congaree River subbasin. With a surface area of 240 acres and a volume of 2,300 acre-ft, Weston Pond, on the U.S. Army training facility at Fort Jackson, is the only lake greater than 200 acres in area in the subbasin. Lakes larger than 10 acres have an aggregate surface area of 3,045 acres and a total volume of 16,607 acre-ft.

The lowermost portion of the inactive Columbia Canal, which takes in water from the Broad River and discharges it into the Congaree River, is in the Congaree River subbasin. The subbasin's only hydroelectric power station is located at the lower end of the canal (Table 6-23). The city of Columbia also uses the canal for water supply.

The U.S. Army Corps of Engineers (COE) has no active navigation projects in the subbasin. At one time there were plans for a navigation channel along the entire length of the Congaree River. Approximately 70 percent of the project was completed before it was deauthorized by Congress in 1977.

The Natural Resources Conservation Service (NRCS) started work on a flood-control project in the Cabin Branch watershed near Hopkins in 1997, but the project was not completed as of 2008.

Congaree National Park, at the southeast end of the subbasin, is among the State's most significant land- and water-conservation areas. The 22,200-acre park protects the largest contiguous tract of old-growth bottomland hardwood forest remaining in the United States. Blanketed by giant hardwoods and towering pines, the park's flood-plain forest includes one of the highest canopies in the world and contains some of the tallest trees in the eastern United States. Congress approved National Park status for the former National Monument in 2003.

Table 6-23. Hydroelectric power generating facilities in the Congaree River subbasin (shown on Figure 6-13)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Columbia SCE&G	Broad / Congaree River	Columbia Canal	10.6	350,770

Surface-Water Quality

All water bodies in the Congaree River subbasin are designated "Freshwater" (Class FW). Class FW are freshwater bodies that are suitable for survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking water, fishing, and industrial and agricultural uses (DHEC, 2004a).

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 30 surface-water sites between 1997 and 2001 in order to assess the water's suitability for aquatic life and recreational uses (Figure 6-15). Aquatic-life uses were fully supported in 23 sites, or 77 percent of the water bodies sampled in this subbasin. Water at impaired sites did not support, or only partially supported, aquatic life primarily because of low dissolved-oxygen levels. Recreational use was fully supported in 52 percent of the sampled water bodies; water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2004a). Water-quality impairments in the subbasin are summarized in Table 6-24. DHEC publishes the most recently observed impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in previous years, DHEC issued a fish-consumption advisory for the entire Congaree River and for Windsor, Carys, and Forest Lakes (all on Gills Creek). Fish-consumption advisories are issued in areas where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for skiing, boating, or swimming.

GROUND WATER

Hydrogeology

The entire Congaree River subbasin is in the Coastal Plain and is underlain everywhere by the Middendorf aquifer. In the southern part of Richland and Lexington Counties, rocks of the Black Creek Formation overlie the Middendorf aquifer and constitute most of the Black Creek aquifer. Near the Fall Line, the Black Creek is absent and the Middendorf is directly overlain by Tertiary sand aquifers of younger age. The Coastal Plain sediments commence at the Fall Line and thicken in a southeasterly direction to 650 feet near Wateree.

At sites near the Fall Line, ground water is usually obtained from the underlying crystalline-rock aquifers of the Carolina slate belt, and well yields are highly variable.

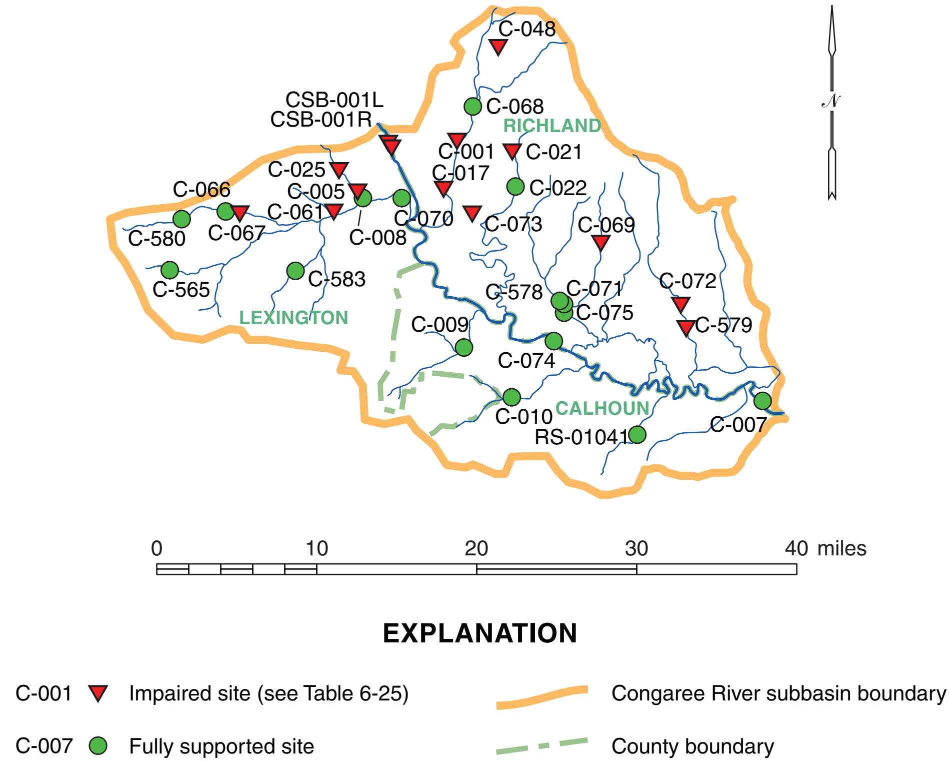


Figure 6-15. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 6-24 (DHEC, 2004a).

Table 6-24. Water-quality impairments in the Congaree River subbasin (DHEC, 2004a)

Water-body name	Station number	Use	Status	Water-quality indicator
Congaree River	CSB-001L	Recreation	Partially supporting	Fecal coliform
	CSB-001R	Aquatic life	Nonsupporting	Zinc
Mill Creek	C-021	Recreation	Partially supporting	Fecal coliform
Reeder Point Branch	C-073	Aquatic life	Nonsupporting	Dissolved oxygen, pH
		Recreation	Nonsupporting	Fecal coliform
Red Bank Creek	C-067	Recreation	Partially supporting	Fecal coliform
Savana Branch	C-061	Recreation	Partially supporting	Fecal coliform
Sixmile Creek	C-005	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Lake Caroline	C-025	Aquatic life	Nonsupporting	Total phosphorus
		Recreation	Nonsupporting	Fecal coliform
Gills Creek	C-001	Recreation	Nonsupporting	Fecal coliform
	C-017	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Windsor Lake	C-048	Aquatic life	Partially supporting	Dissolved oxygen, pH
Cedar Creek	C-069	Recreation	Partially supporting	Fecal coliform
Toms Creek	C-579	Aquatic life	Partially supporting	Macroinvertebrates
	C-072	Recreation	Partially supporting	Fecal coliform

For example, two rock wells in West Columbia are 385 feet and 95 feet deep and produce 12 gpm (gallons per minute) and 56 gpm, respectively. These wells were obtained only after three dry holes had been drilled at the same location. Nearby, wells 240 and 400 feet deep yield 150 and 15 gpm, respectively.

The Town of Eastover is supplied by ground water from wells, about 100 feet deep, that tap the Black Creek aquifer. This aquifer is separated from the deeper Middendorf aquifer by several confining beds composed of clay or silty clay. Table 6-25 contains selected well data for two areas of the Congaree River subbasin.

Table 6-25. Selected ground-water data for the Congaree River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Columbia	Middendorf	50–300	75–250
Eastover	Black Creek/ Middendorf	60–500	100–500

Ground-water levels are regularly monitored in two wells by DNR in this subbasin (Table 6-26 and Figure 6-13). Water levels in other wells in the subbasin are sometimes measured to help develop potentiometric maps of the Middendorf aquifer.

Table 6-26. Water-level monitoring wells in the Congaree River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
RIC-543	DNR	33 52 30 80 42 08	Middendorf	Webber School, Eastover	184	370–410
RIC-585	DNR	33 56 56 80 50 27	Middendorf	Horrel Hill Elementary School	328	263–293

* *DNR, South Carolina Department of Natural Resources*

Ground-Water Quality

The upper reaches of this subbasin (in eastern Lexington and southern Richland Counties) are in the outcrop areas of the Middendorf and Black Creek aquifers. Water from the Black Creek aquifer generally has TDS (total dissolved solids) concentrations less than 50 mg/L (milligrams per liter) and a pH less than 5.5. Water from the Middendorf aquifer generally has TDS less than 100 mg/L and pH less than 7 (Speiran and Aucott, 1994). Water quality is similar but more mineralized in the lower reaches (Greaney, 1993).

The Tertiary sand aquifer, where it crops out in Calhoun County, yields good water. It is generally a soft, calcium bicarbonate type with a low TDS (less than 100 mg/L) and nearly neutral pH. Iron concentrations locally exceed the recommended limit of 0.3 mg/L and may stain clothing and fixtures (Greaney, 1993).

Naturally occurring radioactive ground water has been found in the subbasin. In the Cayce-West Columbia area of Lexington County, gross alpha-particle activity was measured as great as 105 picoCuries per liter.

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Offstream water use in the Congaree River subbasin is summarized in Table 6-27 and Figure 6-16. Offstream water withdrawals in the Congaree River subbasin totaled 32,179 million gallons in 2006, ranking it tenth among the 15 subbasins. Of this amount, 30,659 million gallons were from surface-water sources (95 percent) and 1,520 million gallons were from ground-water sources (5 percent). Industrial use accounted for 95 percent, followed by mining (2 percent) and water supply (1 percent). Small amounts of ground and surface water were also withdrawn for golf course, irrigation, and aquaculture uses. Consumptive use in this subbasin is estimated to be 3,635 million gallons, or about 11 percent of the total offstream use.

With a total of 30,520 million gallons in 2006, the Congaree River subbasin ranked second behind the Pee Dee subbasin for industrial water use in the State. Surface-water sources accounted for 29,956 million gallons (98 percent) and ground-water sources for 564 million gallons (2 percent). Eastman Chemical Co., the largest industrial user in the State, withdrew 28,262 million gallons from the Congaree River. U.S. Silica Co. had withdrawals of 375 million from ground-water sources (Black Creek and Middendorf aquifers).

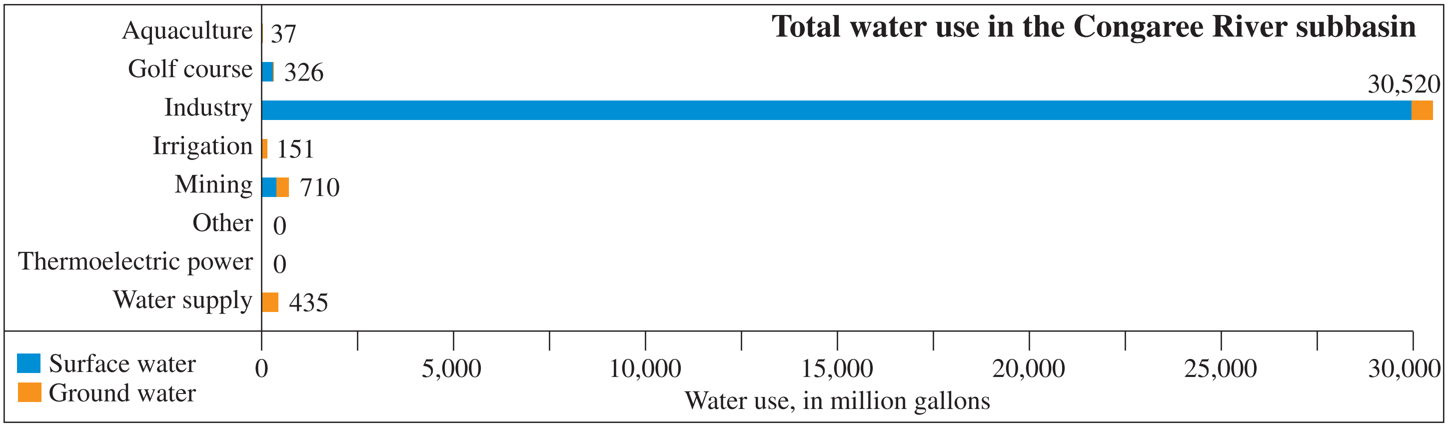
Mining water use was 710 million gallons in 2006. Of this amount, 392 million was from surface-water sources (55 percent) and 318 million was from ground-water sources (45 percent). Most of this water (664 million gallons) was pumped at the Martin Marietta Aggregates quarry in Cayce to dewater the quarry.

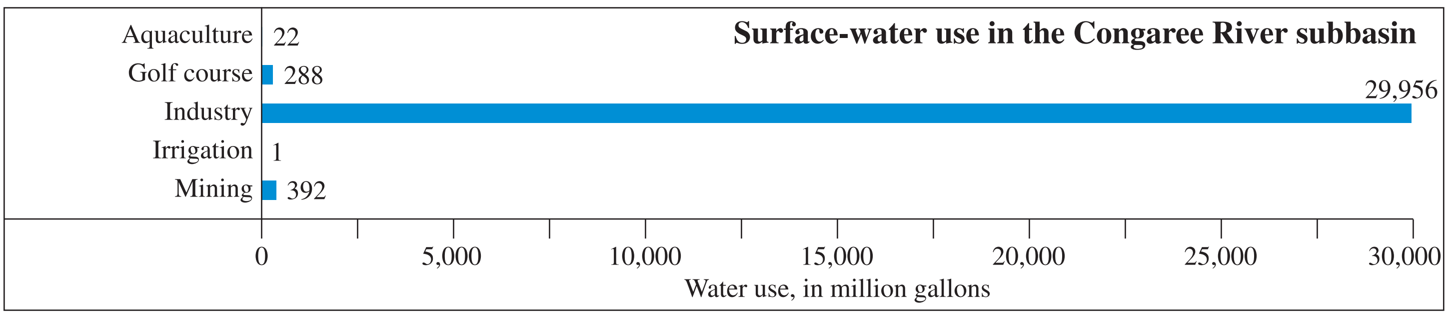
Water-supply use totaled 435 million gallons and was provided entirely by ground water. Of the four water-supply systems that have wells in this subbasin, the Gaston Rural Community Water District was the largest user, pumping 247 million gallons from the Black Creek and Middendorf aquifers. Most of this subbasin's population, in the metropolitan Columbia and West Columbia areas, use surface water drawn from the Broad and Saluda subbasins.

Instream water use for hydroelectric power generation totaled 350,770 million gallons in 2006, all at the only hydroelectric facility in the subbasin, the Columbia Canal Hydroelectric facility. Located at the downstream end of the Columbia Canal, this power plant, owned by the city of Columbia and operated by SCE&G, contains seven turbines with a total generating capacity of 10.6 megawatts.

Table 6-27. Reported water use in the Congaree River subbasin for the year 2006 (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	22	0.1	15	1.0	37	0.1
Golf course	288	0.9	38	2.5	326	1.0
Industry	29,956	97.7	564	37.1	30,520	94.8
Irrigation	1	0.0	150	9.9	151	0.5
Mining	392	1.3	318	20.9	710	2.2
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	0	0.0	0	0.0	0	0.0
Water supply	0	0.0	435	28.6	435	1.4
Total	30,659		1,520		32,179	





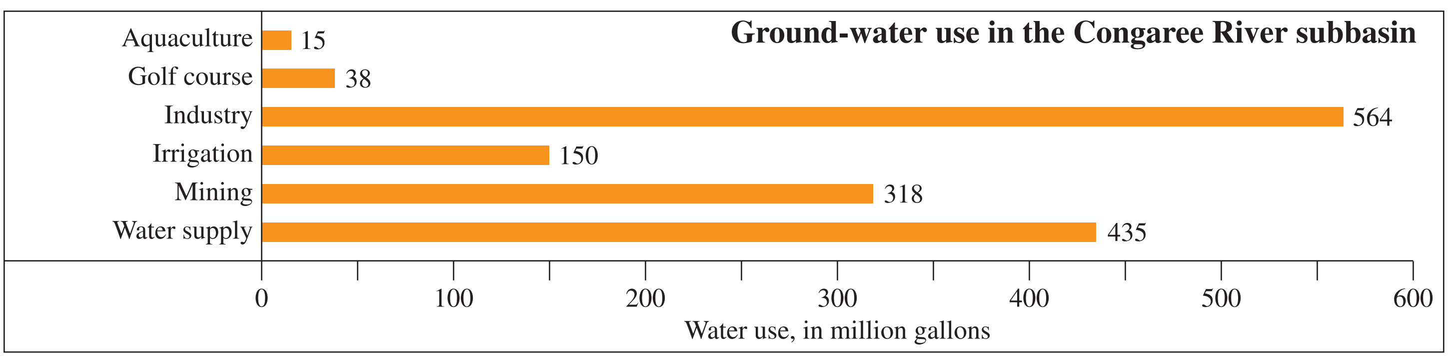


Figure 6-16. Reported water use in the Congaree River subbasin for the year 2006 (modified from Butler, 2007).

SANTEE RIVER SUBBASIN

SANTEE RIVER SUBBASIN

The Santee River subbasin transects the middle and lower parts of the Coastal Plain, extending from the confluence of the Congaree and Wateree Rivers southeast to the Atlantic Ocean. With a northwest-southeast orientation, this basin encompasses parts of eight South Carolina counties: Berkeley, Calhoun, Charleston, Clarendon, Georgetown, Orangeburg, Sumter, and Williamsburg (Figure 6-17). The subbasin area is approximately 1,275 square miles, 4.1 percent of the State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 39,100, just 1.0 percent of South Carolina's total population. The largest population increases by 2020 are expected to occur near the coast, in Berkeley and Georgetown Counties. The subbasin is primarily rural and contains no major urban areas or centers of population, although there are a number of small towns. The largest of these towns in 2000 were St. Matthews (2,107), St. Stephen (1,776), and Summerton (1,016); all three towns had larger reported populations in 1980 than in 2000.

Economically, this is one of the most disadvantaged areas of South Carolina. Average county per capita incomes in 2005 ranged from $20,005 in Williamsburg County, ranking 45th of 46 counties, to $34,158 in Charleston County, ranking second. Three counties in the subbasin—Charleston, Georgetown, and Calhoun—had per capita incomes above the State average of $28,285. Of the other five subbasin counties, only Berkeley County approached the State average. Median household incomes in 1999, the most recent report available, ranged from $24,214 in Williamsburg County, ranking 44th in the State, to $39,908 in Berkeley County, which ranked seventh. Only Charleston and Berkeley Counties had median household incomes above the State average of $37,082.

During 2000, the counties of the subbasin had combined annual-average employment of non-agricultural wage and salary workers of 314,000. Labor distribution in the subbasin counties included management, professional, and technical services, 30 percent; sales and office, 25 percent; service, 16 percent; production, transportation, and materials moving, 16 percent; construction, extraction, and maintenance, 11 percent; and farming, fishing, and forestry, 1 percent.

Manufacturing output by the subbasin's seven principal counties totaled $12.7 billion in 1997, with Sumter, Berkeley, and Charleston Counties accounting for nearly two-thirds of the region's product value. Crop and livestock production was valued at $337.5 million in 2000.

SURFACE WATER

Hydrology

The Santee River, formed by the confluence of the Congaree and Wateree Rivers in the upper Coastal Plain, is the dominant watercourse in this subbasin. In its original form, the 144-mile long Santee River had the fourth-largest average flow of any river on the Atlantic coast of the United States, and periodic flooding nourished extensive swamplands along its entire length. With the construction of the Santee Dam (also known as Wilson Dam) in 1941, much of upper reach of the Santee River became part of Lake Marion, which is the dominant hydrologic feature in this subbasin. About 10 miles from its mouth, the river bifurcates into two channels, the North Santee River and

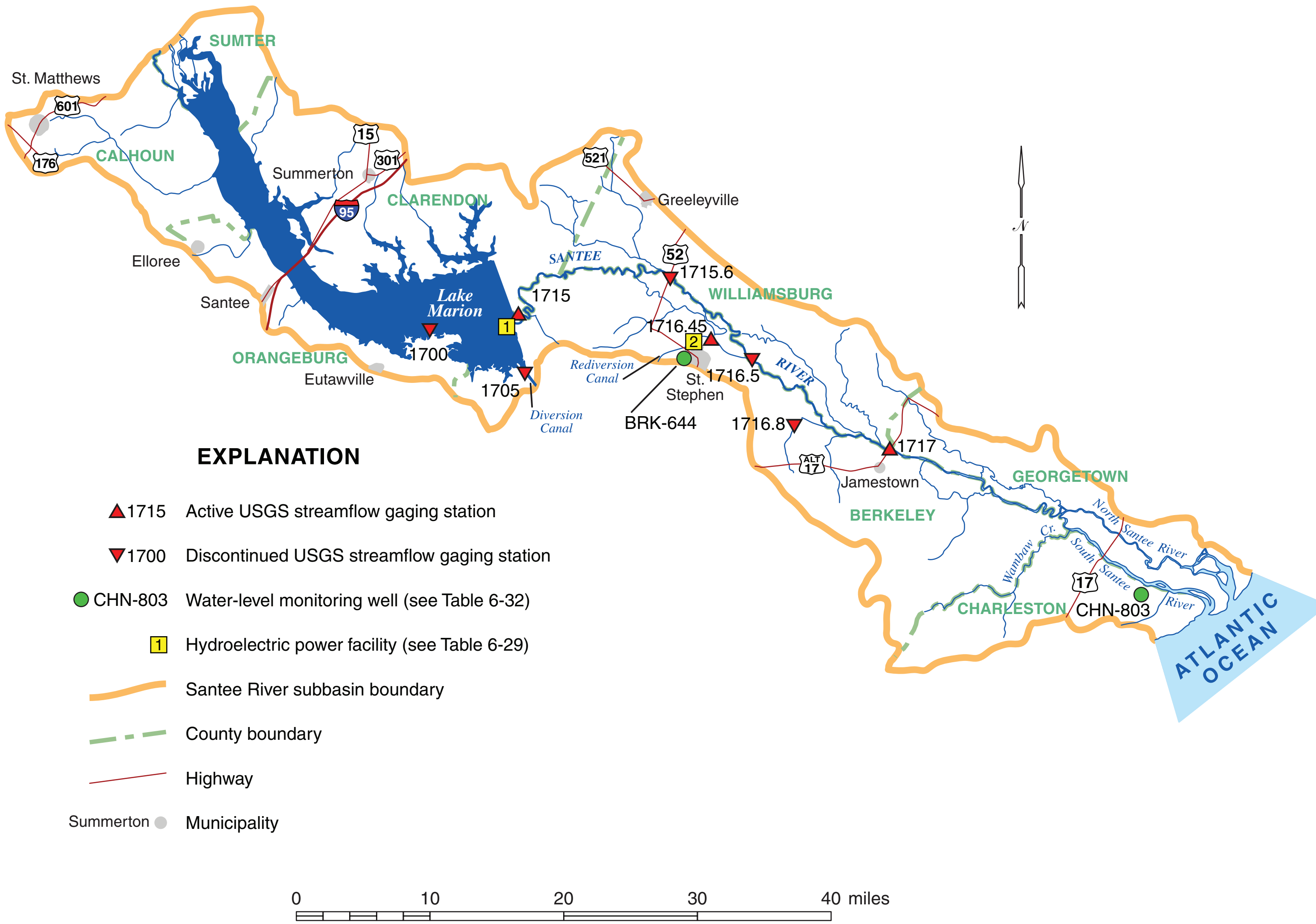


Figure 6-17. Map of the Santee River subbasin.

the South Santee River, that are roughly parallel and separated by about 2 miles. The two channels reach the ocean at Santee Point, a few miles south of Winyah Bay.

Lake Marion was created in conjunction with Lake Moultrie, in the Ashley-Cooper River subbasin, to provide a major source of hydropower for the State. The original operation of Lake Marion diverted almost all of the Santee River flow through a canal into Lake Moultrie, which discharges into the Cooper River. Under normal conditions, only a small amount of water—often as little as 500 cfs (cubic feet per second)—passed Santee Dam and continued into the Santee River.

The construction of Lake Marion and the subsequent diversion of most of the Santee River into the Cooper River changed the character of both rivers. The lower Santee River, deprived of much of its flow, became more saline near the coast, while the increased flow of the Cooper River decreased its salinity near the Charleston Harbor but greatly increased its sediment load, which caused shoaling problems and thus a need for more dredging to keep the harbor functional. To mitigate these problems, in 1985 the U.S. Army Corps of Engineers (COE) began operating a rediversion canal to return water from Lake Moultrie back to the Santee River. The normal operation of Lake Moultrie releases enough water—usually 4,500 cfs—into the Cooper River to keep its salinity low, while returning the remaining flow back into the Santee River. Flow from the rediversion canal enters the Santee River near St. Stephen, about 35 river miles downstream from Santee Dam.

Several small tributary streams drain the subbasin, the largest of these being Halfway Swamp Creek and Wambaw Creek.

Historical streamflow data for the undeveloped Santee River are available from one discontinued gaging station (1700), which was inundated by Lake Marion. Before development of the Santee Cooper lake system, year-round flow in the Santee River at that site was well-sustained (Figure 6-18). Average annual streamflow was 15,400 cfs and could be expected to equal or exceed 7,000 cfs 90 percent of the time.

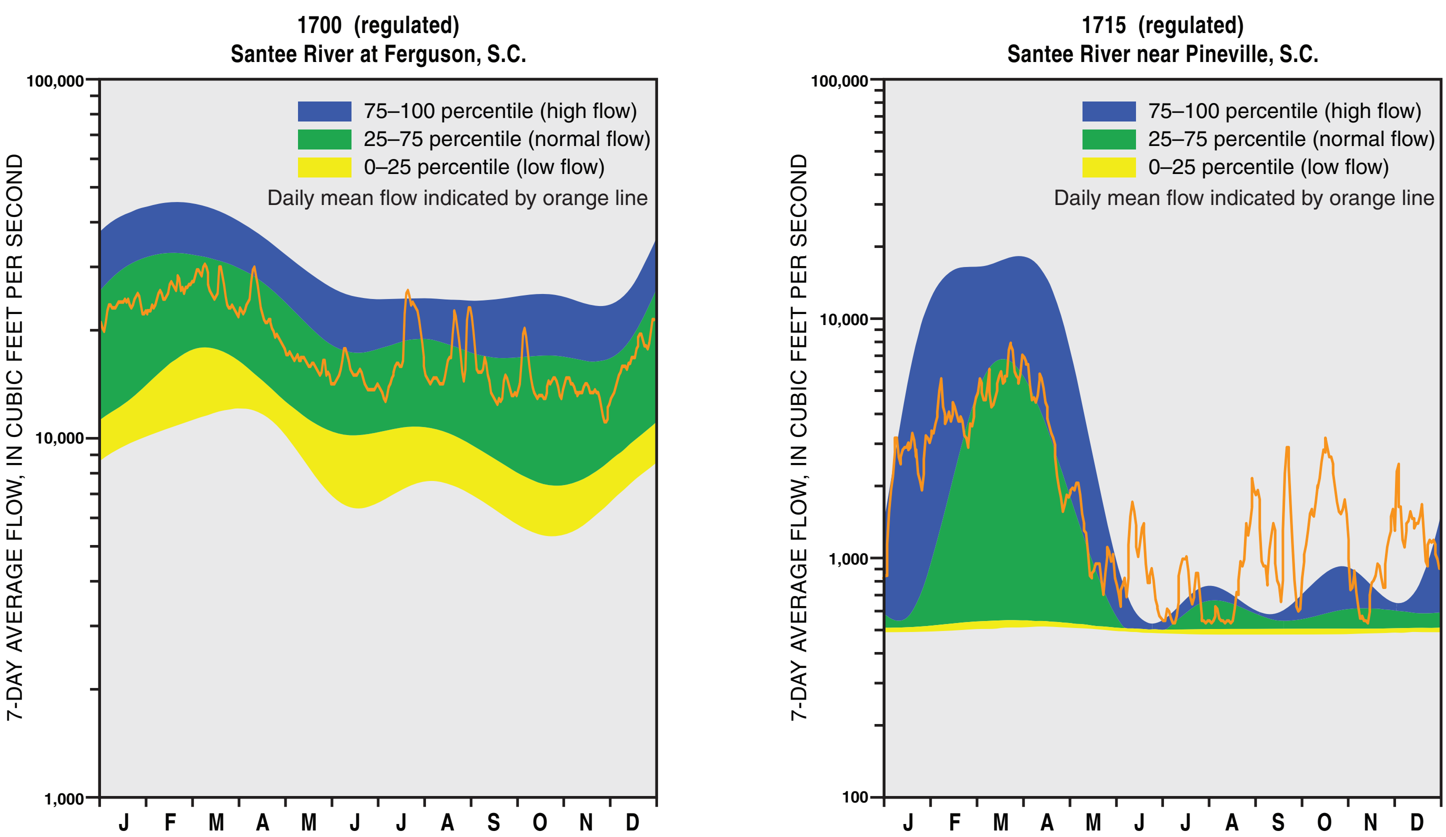


Figure 6-18. Duration hydrographs for selected gaging stations in the Santee River subbasin.

Three gaging stations currently monitor streamflow in the Santee River subbasin, two on the Santee River and one on the rediversion canal (Figure 6-17). No gaging stations are active on tributary streams. Five stage-only gaging stations monitor river elevation continuously, and Lake Marion's surface elevation is also monitored by two lake-level gages. Statistics for active and discontinued streamflow gaging stations are presented in Table 6-28.

Currently, average annual streamflow in the Santee River is 2,121 cfs near Pineville (just below Santee Dam) and 10,610 cfs near Jamestown (below the rediversion canal). Ninety percent of the time, flow at these sites should be at least 489 cfs and 934 cfs, respectively. Annual average flow in the rediversion canal is 8,741 cfs. Contribution from tributary streams in the lower portion of the Santee River is small and only slightly increases main-stem flow. Before the completion of the rediversion canal, most streamflow in the lower portion of the Santee River was contributed by discharges from Santee Dam. From February through May, very high flow occurs; the rest of year, flow is fairly steady (Figure 6-18). Occasional discharge of large volumes of water helps to relieve Lake Marion of floodwater inflow from upstream, and withholding discharge sustains adequate water levels in Lake Marion for recreation, hydroelectric power, and other uses. During periods of excessive rainfall, the level of the Santee River near Jamestown frequently exceeds its flood stage.

Table 6-28. Selected streamflow characteristics at USGS gaging stations in the Santee River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Santee River at Ferguson 1700	1907 to 1941	14,600	15,400	1.05	7,000	2,630 1925	– – –	168,000 1916
Diversion Canal near Pineville 1705	1943 to 1986	Indeterminate	14,684	– –	6,086	– – –	– – –	40,300 1983
Santee River near Pineville 1715	1942 to 2007*	Indeterminate	2,121	– –	489	9.0 1947	153,000 1945	155,000 1945
Santee River near Russellville 1715.6	1979 to 1996	Indeterminate	45.2	– –	469	– – –	120,000 1979	– – –
Rediversion Canal near St. Stephen 1716.45	1986 to 2007*	Indeterminate	8,741	– –	14	– – –	31,200 1989	31,200 1989
Santee River below St. Stephen 1716.5	1970 to 1981	14,900	2,871	0.19	568	481 1981	97,100 1975	98,900 1975
Wedboo Creek near Jamestown 1716.8	1966-72 and 1973-92	17.4	13.1	0.75	0.43	0.0 many years	1,220 1987	– – –
Santee River near Jamestown 1717	1986 to 2007*	Indeterminate	10,610	– –	934	460 1986	90,600 2003	102,000 2003

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Since Lake Marion was created, the lowest flow of record for the Santee River (9 cfs at Pineville) occurred in 1947 because of repair work on the spillway, and the greatest flow recorded (155,000 cfs at Pineville) resulted from a tropical storm in 1945 that caused extensive flooding throughout the eastern portion of South Carolina.

The only streamflow gaging station on a tributary stream, Wedboo Creek near Jamestown, was discontinued in 1992. Average annual streamflow was 13.1 cfs, and flow equaled or exceeded 0.43 cfs 90 percent of the time. This stream exhibited highly variable flow and occasional no-flow conditions typical of lower Coastal Plain streams.

Although flow in the Santee River is somewhat variable, the river still generally provides a good supply of surface water, particularly below the rediversion canal. Tributary streams probably are unreliable supply sources because of highly-fluctuating flows and possible no-flow conditions during periods of low rainfall. Streamflow in tributaries in the upper reaches of the subbasin near the upper Coastal Plain region may be less variable because of ground-water support and may provide a more reliable supply source.

Development

Other than the creation of Lake Marion, surface-water development in the subbasin is very limited. Excluding Lake Marion, the aggregate surface area of all lakes greater than 10 acres in the subbasin is 1,400 acres, and the total volume is 5,000 acre-ft. Two hydroelectric power facilities are located within this subbasin (Figure 6-17; Table 6-29).

The nearly eight-mile long Santee Dam, on the Santee River 17 miles south of Manning, forms Lake Marion. Completed in 1941, the lake extends nearly 40 miles upstream, almost to the confluence of the Congaree and Wateree Rivers. Although it is the State's largest reservoir by surface area, at 110,600 acres, Lake Marion averages a depth of only about 12.5 feet and ranks fourth in volume (1,400,000 acre-ft). It is owned and operated by the South Carolina Public Service Authority (Santee Cooper). The 1.92-megawatt capacity of the Santee Dam is negligible, but the dam's 62 spillway gates are important flood-control structures. Lake Marion also is a major economic asset by virtue of its recreational attractions, and part of the lake is in the Santee National Wildlife Refuge.

Table 6-29. Hydroelectric power generating facilities in the Santee River subbasin (shown on Figure 6-17)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Santee Spillway Santee Cooper	Santee River	Lake Marion	2	148,325
2	St. Stephen Santee Cooper	Lake Moultrie Rediversion Canal	Lake Moultrie	84	878,848

An 84-megawatt hydroelectric power station is located on the rediversion canal at St. Stephen, near the Santee River flood plain. A fish lift, built by the COE and operated by DNR, is part of the St. Stephen project and permits inland migration of anadromous shad, bass, and sturgeon from the Santee River into Lake Moultrie.

Prior to the construction of Santee Dam, the COE maintained the entire river for navigation. After construction of the dam, direct navigation from the lower reaches of the Santee River to the upper reaches was discontinued.

Surface-Water Quality

All classified streams in the Santee River subbasin are designated "Freshwater" (Class FW). This class of water is suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2005b).

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 63 surface-water sites in the Santee River subbasin in 1998 and 2002 in order to assess the water's suitability for aquatic life and recreational use (Figure 6-19). Aquatic-life uses were fully supported at 44 sites, or 70 percent of the water bodies sampled in this subbasin; most of the impaired water exhibited pH problems or high phosphorus concentrations. Recreational use was fully supported in 75 percent of the sampled water bodies; water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2005b). Water-quality impairments in the subbasin are listed in Table 6-30.

The herbicides atrazine, simazine, and tebuthiuron have been detected in almost every stream in the Santee subbasin, including those in forested areas; however, concentrations are below the guideline levels that protect aquatic life and drinking water (USGS National Water-Quality Assessment Program: *http://sc.water.usgs.gov/nawqa*).

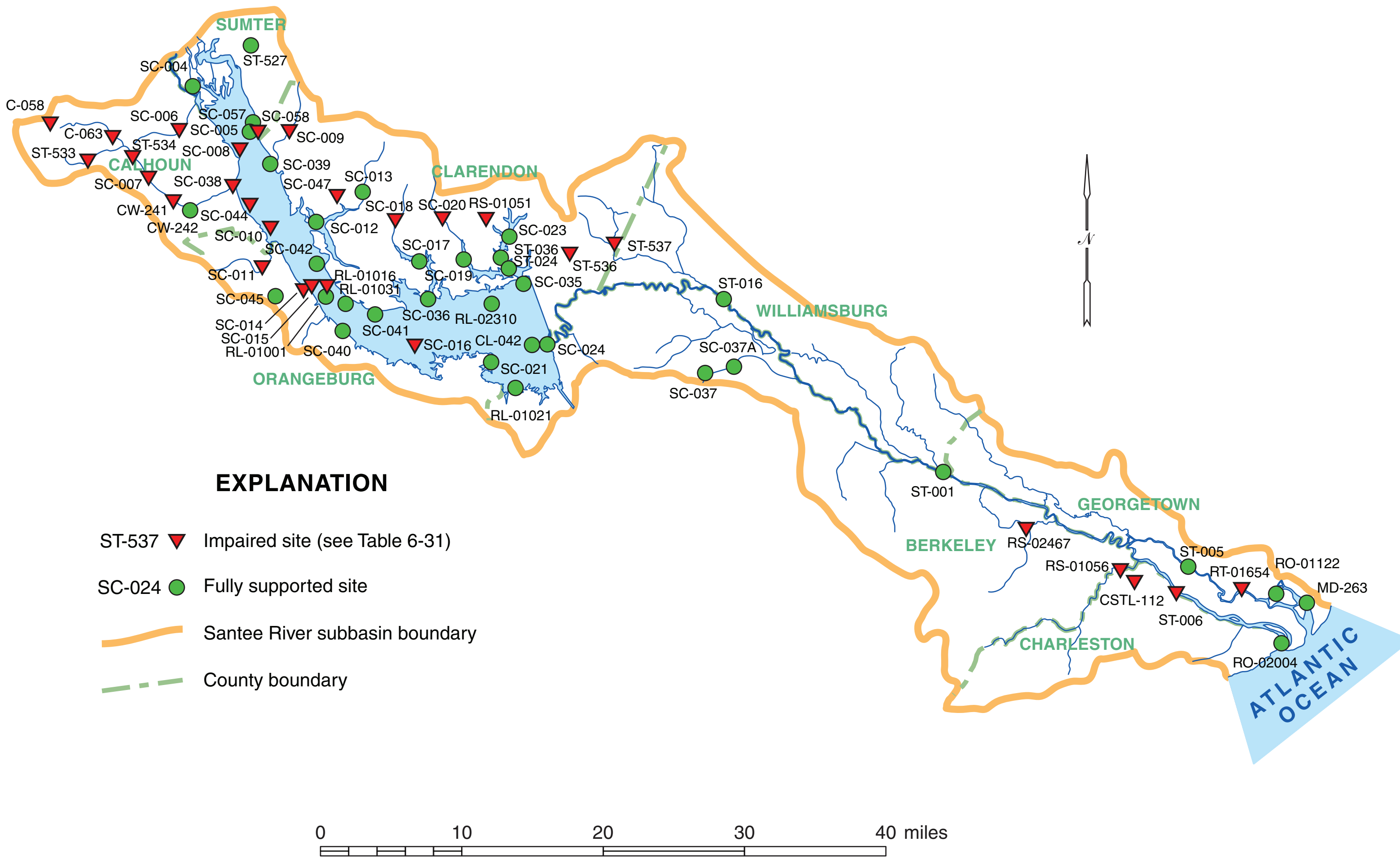


Figure 6-19. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 6-30 (DHEC, 2005b).

Table 6-30. Water-quality impairments in the Santee River subbasin (DHEC, 2005b)

Water-body name	Station number	Use	Status	Water-quality indicator
Warley Creek	SC-006	Recreation	Nonsupporting	Fecal coliform
Stream upstream of Safety Kleen, Pinewood	SC-058	Aquatic life	Nonsupporting	pH
Lake Marion	SC-008	Aquatic life	Nonsupporting	Total phosphorus
	SC-044	Aquatic life	Partially supporting	pH
	SC-010	Aquatic life	Nonsupporting	Total phosphorus
	SC-014	Aquatic life	Nonsupporting	Total phosphorus, total nitrogen, pH, chlorophyll-*a*
	SC-015	Aquatic life	Nonsupporting	pH
	RL-01016	Aquatic life	Partially supporting	pH
	SC-016	Aquatic life	Partially supporting	pH
Spring Grove Creek	SC-009	Recreation	Nonsupporting	Fecal coliform
Big Poplar Creek	SC-011	Recreation	Nonsupporting	Fecal coliform
Lake Inspiration	C-058	Aquatic life	Nonsupporting	Dissolved oygen, total phosphorus, total nitrogen, pH, turbidity
		Recreation	Partially supporting	Fecal coliform
Halfway Swamp Creek	C-063	Recreation	Nonsupporting	Fecal coliform
	ST-534	Aquatic life	Partially supporting	Marcoinvertebrates
	SC-007	Recreation	Nonsupporting	Fecal coliform
	CW-241	Recreation	Nonsupporting	Fecal coliform
Lyons Creek	ST-533	Aquatic life	Partially supporting	Marcoinvertebrates
Halfway Swamp Creek arm of Lake Marion	SC-038	Aquatic life	Nonsupporting	Total phosphorus
Big Branch	SC-047	Aquatic life	Nonsupporting	Dissolved oygen
		Recreation	Nonsupporting	Fecal coliform
Tawcaw Creek	SC-018	Aquatic life	Nonsupporting	Dissolved oygen
		Recreation	Nonsupporting	Fecal coliform
Potato Creek	SC-020	Aquatic life	Nonsupporting	Dissolved oygen, pH
		Recreation	Partially supporting	Fecal coliform
White Oak Creek	RS-01051	Recreation	Partially supporting	Fecal coliform
Doctor Branch	ST-537	Aquatic life	Partially supporting	Marcoinvertebrates
Bennetts Branch	ST-536	Aquatic life	Partially supporting	Marcoinvertebrates
Echaw Creek	RS-02467	Recreation	Nonsupporting	Fecal coliform
Wambaw Creek	CSTL-112	Recreation	Partially supporting	Fecal coliform
Minim Creek	RT-01654	Aquatic life	Partially supporting	Turbidity
Cedar Creek	RS-01056	Recreation	Nonsupporting	Fecal coliform
South Santee River	ST-006	Aquatic life	Nonsupporting	Turbidity
		Recreation	Partially supporting	Fecal coliform

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in earlier years, DHEC issued a fish-consumption advisory for mercury in several areas of the Santee River subbasin, including Lake Marion, the diversion canal, the rediversion canal, the Santee River (from Lake Marion to the South Santee River), both the North and South Santee Rivers (from the Santee River to the U.S. Highway 17 bridge) and Wambaw Creek in Charleston County and Wadmacon Creek in Georgetown County. Fish-consumption advisories are issued in areas where fish are contaminated with mercury; the contamination is only in the fish and does not make the water unsafe for swimming or boating.

GROUND WATER

Hydrogeology

The Santee River subbasin is in the middle and lower Coastal Plain. The northwestern portion of the subbasin is underlain by more than 1,000 feet of unconsolidated sediments. The thickness increases to approximately 2,500 feet at the southeastern limit. The Middendorf aquifer underlies the entire subbasin and can support large wells; however, it is too deep to be employed as a water source by most users. Transmissivities of 3,100 and 5,300 ft^2/day have been indicated by pumping tests.

The Black Creek aquifer is the major source of ground water throughout Clarendon, Williamsburg, and Georgetown Counties. The top of this aquifer is 300 feet deep at Summerton and about 800 feet deep at the mouth of the Santee River. Wells can be expected to yield 100 to 1,000 gpm (gallons per minute); the highest yields probably will be attained in the upper part of the basin.

The top of the Peedee Formation, comprising the lower part of the Tertiary sand aquifer, is 100 to 250 feet below land surface and deepens to the south through Clarendon and Williamsburg Counties.

The Black Mingo Formation, part of the Tertiary sand aquifer, and surficial deposits cover the Peedee Formation in Clarendon and Williamsburg Counties. Wells in these deposits commonly produce 20 to 50 gpm.

The Orangeburg County area is underlain by the Middendorf, Black Creek, Tertiary sand, and Floridan aquifers. Together, these aquifers have a total thickness of 1,150 to 1,850 feet, thickening in a southerly direction. All but the Middendorf are tapped by wells in the area. On pumping tests, wells yielding 73 to 620 gpm indicated aquifer transmissivities of 1,100 to 33,000 ft^2/day. It is common for wells to be screened in two of the aquifers. The Tertiary sand and Floridan aquifers are the most commonly used at the eastern end of the subbasin.

In the Jamestown area of Berkeley County, all the aquifers mentioned above are available for water supply. Jamestown uses wells in the Black Creek aquifer at nearly 900 feet, and St. Stephen taps the Middendorf at about 1,250 feet. Selected well data for the subbasin are presented in Table 6-31.

Table 6-31. Selected ground-water data for the Santee River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Clarendon County	Middendorf	725–950	500–1,000
	Black Creek	250–675	90–675
	Peedee	100–250	150
Calhoun County	Tertiary sand/ Black Creek/ Middendorf/	100–800	30–1,400
Eutawville	Floridan	80–100	425–620
	Tertiary sand	180–460	200–2,800
Jamestown	Black Creek	700–900	100–375
St. Stephen	Black Creek/ Middendorf	1,050–1,260	300–500
Mullins	Black Creek	320–390	370–1,500
Aynor	Black Creek	300–350	150–800
Loris	Tertiary sand (Peedee)	100–200	250–500
	Black Creek	320–460	250–800

The Jamestown area in northeastern Berkeley County, like the area south of Lake Marion, exhibits a covered karst topography underlain at shallow depths by the Floridan aquifer. This aquifer is the most important source of ground water for domestic use in the area. Ground-water pumping from limestone quarries resulted in instances of land-surface collapse and water-level declines in wells more than a mile from the center of pumping.

Ground-Water Quality

Water from the Middendorf aquifer is generally low in TDS (total dissolved solids), chloride, fluoride, and pH and is soft and corrosive in the upper reaches of the subbasin (Greaney, 1993). Iron concentrations may exceed recommended limits (Greaney, 1993; Johnson, 1978). The aquifer becomes more mineralized toward the coast, where the concentrations of TDS, sodium, and chloride increase to more than 1,000, 500, and 250 mg/L (milligrams per liter), respectively (Speiran and Aucott, 1994).

The Black Creek aquifer is the principal aquifer for the Santee River subbasin. The water generally is soft and a sodium bicarbonate type, and mineralization increases toward the coast. Total dissolved solids concentrations range from 50 mg/L in the upper reaches to more than 1,000 mg/L near the coast (Speiran and Aucott, 1994). The pH ranges from 4.5 in the upper reaches to greater than 8.5 in the lower reaches. Iron concentrations commonly exceed standards (Johnson, 1978; Greaney, 1993). Sodium concentrations are greater than 250 mg/L near the coast. Fluoride exceeds recommended drinking-water levels in eastern Williamsburg and Georgetown Counties. Turbidity, caused by a colloidal suspension of the calcium carbonate mineral aragonite, has been reported in a few wells in Clarendon, Williamsburg, and Georgetown Counties (Johnson, 1978; Pelletier, 1985).

The Tertiary sand and extended Floridan aquifers, where present in Calhoun, Clarendon, and Williamsburg Counties, yield water of good quality. In Calhoun County, it is generally a soft, calcium bicarbonate type with a low TDS, nearly neutral pH, and locally high iron concentrations (Greaney, 1993). In northern Berkeley County, water is usually obtained from both the Floridan aquifer and Tertiary sand aquifer and is a hard, calcium bicarbonate or sodium bicarbonate type. TDS and chloride usually are less than 350 and 30 mg/L, respectively, and pH is between 7 and 8 (Meadows, 1987).

Water-Level Conditions

Ground-water levels are regularly monitored by DNR in two Floridan-aquifer wells in the Santee River subbasin in order to help assess trends or changes in water levels within that aquifer (Table 6-32). Water levels in other wells are sometimes measured to help develop potentiometric maps of the Middendorf, Black Creek, and Floridan aquifers.

Table 6-32. Water-level monitoring wells in the Santee River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
BRK-644	DNR	33 24 16 79 56 03	Floridan	St. Stephen Middle School	75	53–93
CHN-803	DNR	33 09 10 79 21 30	Floridan	Santee Coastal Reserve	11	48–113

* *DNR, South Carolina Department of Natural Resources*

Water levels in the Middendorf aquifer are about 25 feet below estimated predevelopment levels in the upper part of the subbasin and about 75 feet below estimated predevelopment levels in the lower part of the subbasin (Hockensmith, 2008a). These declines are primarily the result of regional lowering of water levels throughout the aquifer, rather than from pumping of wells within this subbasin.

In the lower part of the subbasin, in southern Georgetown County and in the northeastern corners of Berkeley and Charleston Counties, water levels in the Black Creek aquifer are influenced by the large cone of depression that has developed around Andrews and Georgetown (in the Black and Waccamaw subbasins; see Figure 5-25). In this area, Black Creek water levels are as much as 100 feet lower than estimated predevelopment levels. In the upper portion of this subbasin, Black Creek water levels are less than 25 feet lower than estimated predevelopment levels (Hockensmith, 2008b).

In the Floridan/Tertiary sand aquifer, a small cone of depression has developed around Eutawville, near Lake Marion in eastern Orangeburg County, with water levels having declined 45 feet since 1965 (Hockensmith, 2009). Elsewhere in this subbasin, water levels in this aquifer are not significantly lower than estimated predevelopment levels.

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Santee River subbasin is summarized in Table 6-33 and Figure 6-20. Reported offstream water use in the Santee River subbasin was 1,743 million gallons in 2006, the least of the State's 15 subbasins. Of this amount, 1,457 million gallons were from ground-water sources (84 percent) and 286 million gallons were from surface-water sources (16 percent). Water-supply and irrigation uses each accounted for about 40 percent of the total use, and industry and golf-course uses each accounted for about 10 percent. Consumptive use in this subbasin is estimated to be 877 million gallons, or about 50 percent of the total offstream use.

All of the 694 million gallons withdrawn for water-supply use were provided by ground water. Of the 11 water-supply systems that have wells in the subbasin, the town of Santee in Orangeburg County was the largest user, pumping 137 million gallons from two wells, both completed in the Black Creek aquifer. It was followed by the town of St. Matthews, which pumped 122 million gallons (Black Creek aquifer), and the town of Summerton, which pumped 115 million gallons (Middendorf aquifer).

In 2008, the Lake Marion Regional Water Agency opened a water treatment plant capable of treating 8 million gallons a day from Lake Marion, which will serve parts of Berkeley, Calhoun, Clarendon, Dorchester, Orangeburg, and Sumter Counties and several municipalities; most of this use is outside the subbasin. The treatment plant will be owned, operated, and maintained by Santee Cooper.

Irrigation water use totaled 688 million gallons in the subbasin in 2006. Of this amount, 562 million gallons were from ground-water sources (82 percent) and 126 million gallons were from surface-water sources (18 percent). Haigler Farms, Inc. in Calhoun County was the largest irrigator, pumping 417 million gallons from 10 wells, most of which tap the Black Creek aquifer.

Industrial water use in the subbasin was 186 million gallons in 2006. Of this amount, 134 million gallons were from ground-water sources (72 percent) and 52 million gallons were from surface-water sources (28 percent). The largest user was Georgia Pacific Corp. in Berkeley County, which used 101 million gallons pumped from the Black Creek aquifer.

Golf-course water use totaled 172 million gallons, about 10 percent of the total water used in the subbasin in 2006. Of this amount, 107 million gallons came from surface water (74 percent) and 65 million came from ground water (26 percent). The largest user was Santee Cooper Resort, which withdrew 81 million gallons of surface water.

Instream water use for the two hydroelectric power generating facilities—St. Stephen on the Lake Moultrie rediversion canal and the Santee Spillway Hydroelectric Station—totaled 1,027,173 million gallons in 2006. The St. Stephen plant used 878,848 million gallons and the Santee Spillway Hydroelectric Station used 148,325 million gallons.

Table 6-33. Reported water use in the Santee River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	107	37.6	65	4.4	172	9.8
Industry	52	18.1	134	9.2	186	10.7
Irrigation	126	44.3	562	38.6	688	39.5
Mining	0	0.0	3	0.2	3	0.2
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	0	0.0	0	0.0	0	0.0
Water supply	0	0.0	694	47.6	694	39.8
Total	286		1,457		1,743	

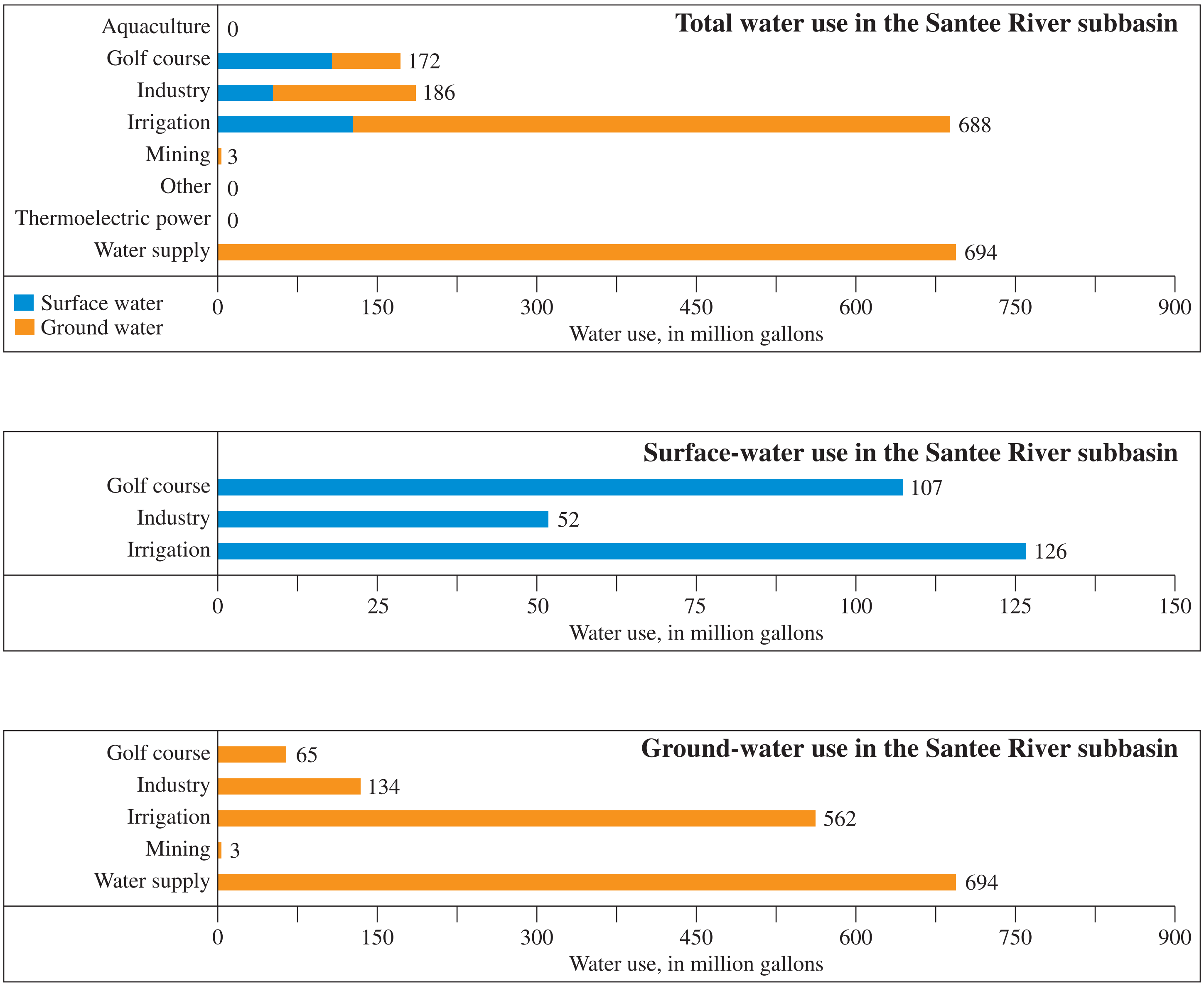
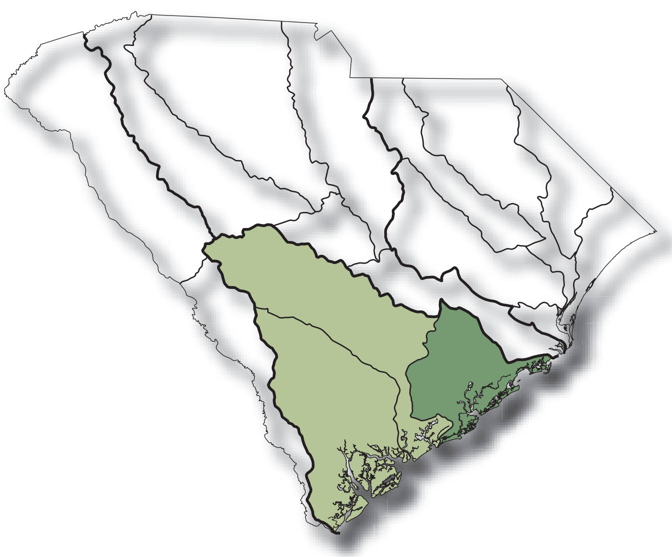


Figure 6-20. Reported water use in the Santee River subbasin for the year 2006 (modified from Butler, 2007).

WATERSHED CONDITIONS: ACE BASIN

ASHLEY-COOPER RIVER SUBBASIN



ASHLEY-COOPER RIVER SUBBASIN

The Ashley-Cooper River subbasin is in the central southeastern section of the lower Coastal Plain. The subbasin extends inland approximately 45 miles, encompassing Lake Moultrie and parts of Berkeley, Charleston, and Dorchester Counties (Figure 7-1). The subbasin surface area is approximately 1,710 square miles, 5.5 percent of the State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 503,400, which was 12.5 percent of South Carolina's total population. By the year 2020, the subbasin population is expected to reach 600,000, an increase of almost 20 percent. Berkeley County is expected to have the most rapid growth (36 percent) during this period, primarily along the corridor between Goose Creek and Moncks Corner. Most of the population in the three counties is classified as urban, and Charleston forms the principal population hub.

The major population centers in 2000 were Charleston (96,650), North Charleston, including Charleston Heights (79,641), Mount Pleasant (47,609), Summerville (27,752), St. Andrews (21,814), and Hanahan (12,937).

The year 2005 per capita income in the subbasin ranged from $26,207 in Dorchester County, which ranked 17th in the State, to $34,158 in Charleston County, which ranked second. In 1999, median household income in the subbasin ranged from $37,810 in Charleston County to $43,316 in Dorchester County. Median household income in the three counties ranked between tenth and fourth in the State, well above the South Carolina average of $37,082 (South Carolina Budget and Control Board, 2005).

During 2000, the counties of the subbasin had combined annual average employment of nonagricultural wage and salary workers of about 248,000. Labor distribution in the subbasin counties included management, professional, and technical services, 33 percent; sales and office, 26 percent; service, 16 percent; production, transportation, and materials moving, 13 percent; construction, extraction, and maintenance, 11 percent; and farming, fishing, and forestry, 1 percent. Management, professional, and technical employment was about 10 percent above the State average, and production, transportation, and materials moving employment was about 30 percent below the State average.

Manufacturing output from the three subbasin counties was $6.6 billion in 1997, with $3.0 billion produced in Charleston County and $2.8 billion produced in Berkeley County. Overall, year 2003 crop and livestock production was $124.5 million, and 2001 timber production was $48 million (South Carolina Forestry Commission, 2008).

SURFACE WATER

Hydrology

The two major streams draining this subbasin are the Ashley River and the Cooper River. These tidally-influenced rivers, along with several saltwater tidal creeks and rivers, discharge into Charleston Harbor. Numerous tidal streams draining developed and undeveloped areas along the coast discharge into the Atlantic Ocean. All streams in the subbasin are entirely within the lower Coastal Plain. The Charleston metropolitan area makes extensive use of these surface-water resources.

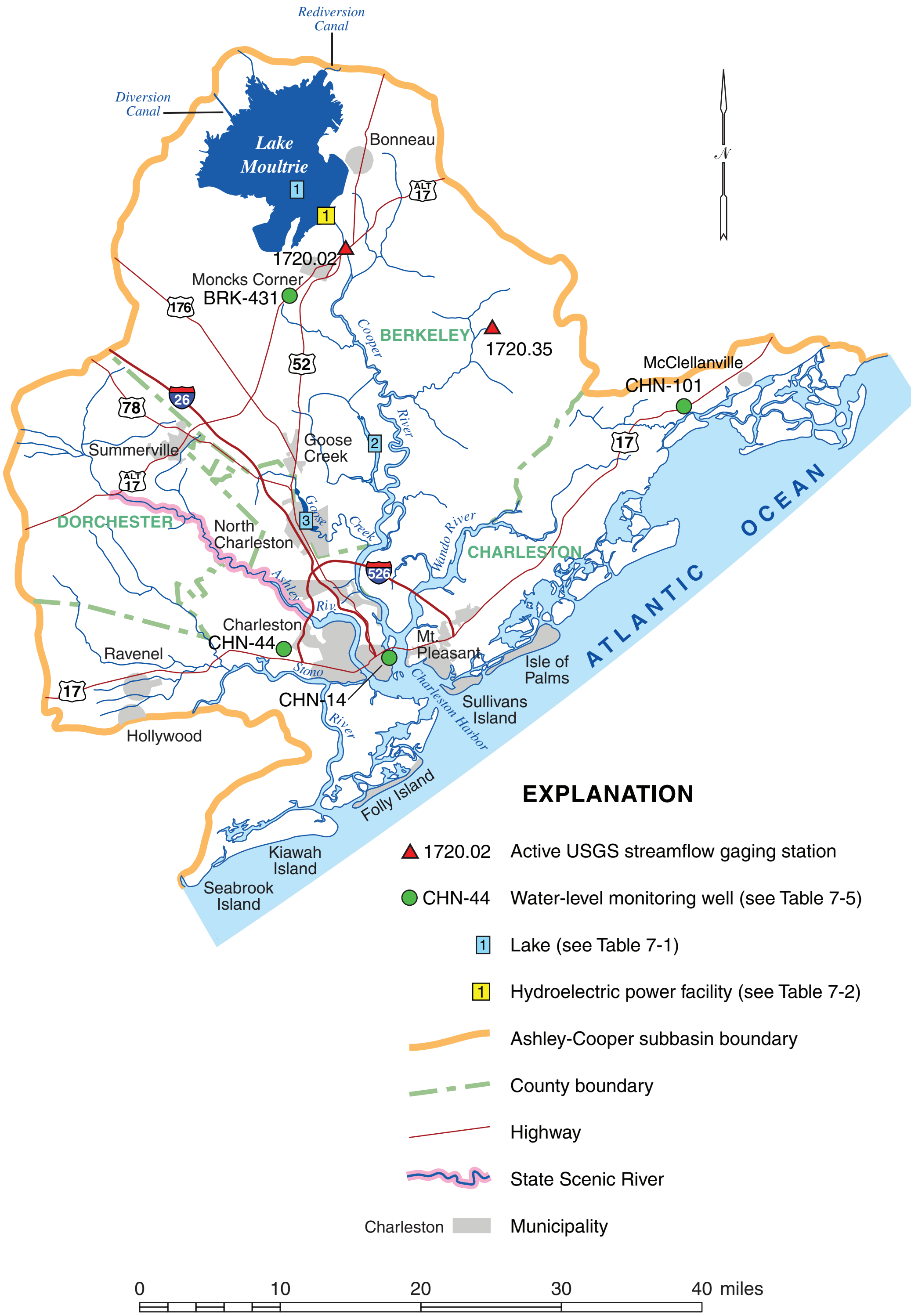


Figure 7-1. Map of the Ashley-Cooper River subbasin.

A 24-mile segment of the Ashley River—from Slands Bridge (U.S. Highway 17-A) near Summerville to the Mark Clark Expressway (I-526) bridge in Charleston—was designated as a State Scenic River in 1998. (See the *River Conservation* section of Chapter 9, *Special Topics*.)

Streamflow data in this subbasin are somewhat limited. Routine streamflow monitoring is done by the U.S. Geological Survey at only two sites (Figure 7-1), because discharge from most coastal streams is influenced by tides. The Lake Moultrie Tailrace Canal at Moncks Corner gage (Station 1720.02) on the West Branch Cooper River reports discharges from Lake Moultrie. Another gage, Turkey Creek above Huger (Station 1720.35), was installed in 2004 on a small creek in the Francis Marion National Forest. Currently, 12 stage-only gaging stations also operate in the subbasin. Discharge values are computed, rather than physically measured, for two other streams using data from stage-only gaging stations. Some of these stations also measure electrical conductivity.

Streamflow in this subbasin provides a limited source of freshwater. The impoundment of freshwater streams in the subbasin and the transfer of water from outside the subbasin provide most available surface-water supplies.

Development

Most surface-water development in this coastal subbasin consists of navigation projects in and around the port of Charleston and flood-control projects in urbanized areas. The subbasin contains only three significant reservoirs (Table 7-1), including one of South Carolina's largest lakes, Moultrie, which was created for hydroelectric-power development in 1941.

Lake Moultrie is formed by the Jefferies (formerly Pinopolis) Dam, which is on the Cooper River north of Moncks Corner, and is managed by the South Carolina Public Service Authority (Santee Cooper). It is the largest lake in the subbasin and the fourth largest lake in the State, having a surface area of 60,400 acres. Its volume of 1,211,000 acre-ft ranks it fifth among the State's lakes by volume. The Jefferies Hydroelectric Station is the only hydroelectric power plant in the ACE basin (Table 7-2).

Table 7-1. Lakes 200 acres or more in the Ashley-Cooper River subbasin (shown on Figure 7-1)

Number on map	Name	Stream	Surface area (acres)	Storage capacity (acre-feet)	Purpose
1	Lake Moultrie	Cooper River	60,400	1,211,000	Power, recreation, and water supply
2	Bushy Park Reservoir (Back River Reservoir)	Back River	850	8,500	Water supply, industry, recreation, and power
3	Goose Creek Reservoir	Goose Creek	600	4,800	Water supply and recreation

Source: U.S. Army Corps of Engineers (1991)

Table 7-2. Hydroelectric power generating facilities in the Ashley-Cooper River subbasin (shown on Figure 7-1)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Jeffries Hydroelectric Santee Cooper	Cooper River	Lake Moultrie	128	983,111

Between 1943 and 1985, most of the natural flow of the Santee River—an average of about 15,000 cfs (cubic feet per second)—was diverted into Lake Moultrie and discharged into the Cooper River, which resulted in severe silting in the Cooper River and Charleston Harbor during that period. To alleviate this problem, in 1985 the U.S. Army Corps of Engineers (COE) constructed another canal to redivert water from Lake Moultrie back into the Santee River. The normal operation of Lake Moultrie releases a daily average of 4,500 cfs into the Cooper River—enough to keep the salinity of the river low—and returns the remainder of its discharge—on average about 10,000 cfs—to the Santee River.

In addition to electric-power production, Lake Moultrie is used for water supply and recreation and is partially within Santee National Wildlife Refuge. Santee Cooper owns and operates a 24-mgd (million gallons per day) water-treatment plant and 26 miles of transmission pipeline. The water is distributed to the Lake Moultrie Water Agency, which is owned by and supplies water to the Moncks Corner Public Works Commission, Summerville Commissioners of Public Works, city of Goose Creek, and Berkeley County Water and Sanitation Authority.

The city of Charleston owns two reservoirs, Bushy Park Reservoir (also known as the Back River Reservoir), and Goose Creek Reservoir, from which it obtains municipal and industrial water supplies. Both streams were tidally influenced until they were impounded for freshwater storage. The Bushy Creek Reservoir receives water primarily from the Cooper River and supplies industrial customers, although it serves as an alternate municipal-supply source. Goose Creek Reservoir is used for recreational purposes and as a backup municipal-supply source. Together, the two reservoirs have a total surface area of 1,450 acres and an approximate volume of 13,000 acre-ft.

The total surface area of all lakes 10 acres or more is 66,281 acres; the total volume is approximately 1,250,000 acre-ft (U.S. Army Corps of Engineers, 1991).

Numerous and extensive navigation projects have been undertaken by the COE in the subbasin. Most of the work has been related to the Charleston Harbor, the Atlantic Intracoastal Waterway, and inlet navigation. The COE completed flood-control projects on Sawmill Branch in 1971 and Eagle Creek in 1986, but has had no similar projects since then. Renourishment at Folly Beach was completed in 2005, and five streambank-erosion control projects were completed in Charleston Harbor, the Cooper River, and the Ashley River between 1987 and 1996. In 2006, the Natural Resources Conservation Service began planning for flood-control projects in the Isaac German area of Mount Pleasant and at Moncks Corner.

Surface-Water Quality

There are five designated classes of water bodies in the Ashley-Cooper River subbasin (DHEC, 2005b). Copahee Sound, Bullyard Sound, Capers Inlet, Mark Bay, Price Inlet, Bulls Bay, and Cape Romain Harbor are all designated as "Outstanding Resource Water" (Class ORW). These are water bodies that constitute an exceptional recreational or ecological resource or are suitable as a drinking-water source with minimal treatment.

Portions of the Wando and Ashley Rivers, Bulls Creek, and the Dick Island Canal are designated "Tidal Saltwater" (Class SA). Class SA comprises tidal saltwater bodies suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora, suitable for primary- and secondary-contact recreation, crabbing, and fishing. Class SA water bodies must maintain daily dissolved-oxygen averages of not less than 5.0 mg/L (milligrams per liter), with a minimum concentration of 4.0 mg/L. These water bodies are not protected for harvesting clams, mussels, or oysters for market purposes or human consumption.

Several water bodies are designated as "Tidal Saltwater" (Class SB), including the Cooper River, Tidal Creek, Grove Creek, the Back River watershed, Flag Creek, Slack Reach, Yellow Horse Creek, the Goose Creek watershed, Filbin Creek, Noisette Creek, Clouter Creek, Shipyard Creek, Newmarket Creek, the Wando River watershed, Turkey Creek, Eagle Creek, Brickyard Creek, Wappoo Creek, and the Charleston Harbor. Class SB water bodies are the same as Class SA water bodies except for the dissolved oxygen standards: Class SB water bodies must maintain dissolved-oxygen averages at or above 4.0 mg/L.

Part of the Wando River, part of the Stono River, Gray Sound, Hamlin Sound, Dewees Inlet, Sewee Bay, Five Fathom Creek, and Folly River are designated as "Shellfish Harvesting" (Class SFH) waters. These are tidal saltwater bodies protected for shellfish harvesting and have the most stringent bacterial standards.

All other water bodies in the basin are designated "Freshwater" (Class FW). Class FW are freshwater bodies that are suitable for survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses.

As part of its ongoing Watershed Water Quality Assessment program, DHEC sampled 97 surface-water sites in the Ashley-Cooper subbasin between 1997 and 2001 in order to assess the water's suitability for aquatic life and recreational use (Figure 7-2). Aquatic-life uses were fully supported at 70 sites, or 72 percent of the water bodies sampled in this subbasin; most of the impaired sites exhibited low dissolved-oxygen levels or excessive concentrations of heavy metals. Recreational use was fully supported in 78 percent of the sampled water bodies; water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2005b). Water-quality impairments in the subbasin are summarized in Table 7-3.

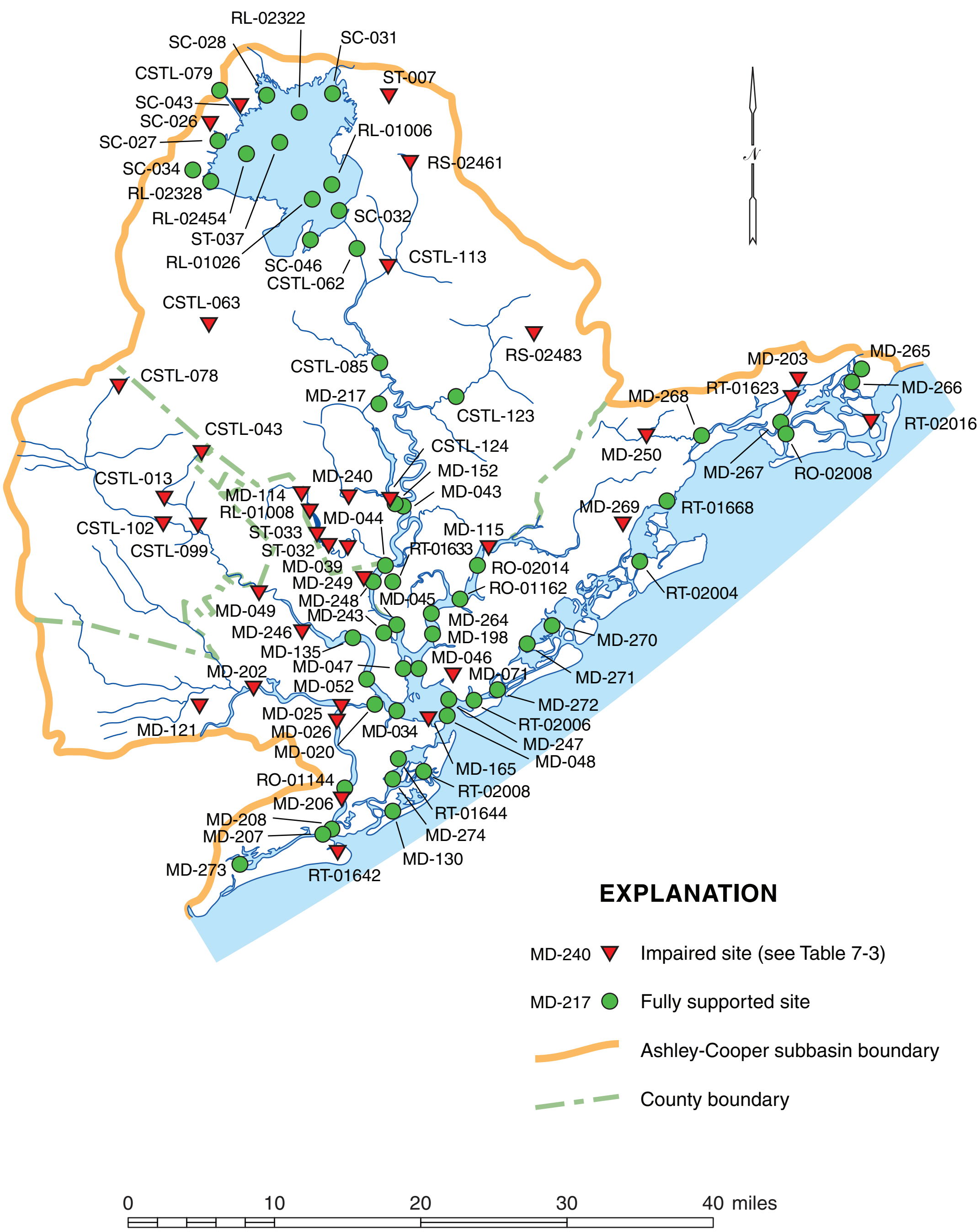


Figure 7-2. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 7-3 (DHEC, 2005b).

Table 7-3. Water-quality impairments in the Ashley-Cooper River subbasin (DHEC, 2005b)

Water-body name	Station number	Use	Status	Water-quality indicator
Lake Moultrie tributary	SC-043	Recreation	Nonsupporting	Fecal coliform
Lake Moultrie tributary	SC-026	Recreation	Nonsupporting	Fecal coliform
Walker Swamp	ST-007	Recreation	Nonsupporting	Fecal coliform
Wadboo Creek	RS-02461	Recreation	Partially supporting	Fecal coliform
	CSTL-113	Recreation	Partially supporting	Fecal coliform
Turkey Creek	RS-02483	Aquatic life	Nonsupporting	Dissolved oxygen, pH
		Recreation	Partially supporting	Fecal coliform
Filbin Creek	MD-249	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Foster Creek	MD-240	Aquatic life	Nonsupporting	Dissolved oxygen
Back River Reservoir	CSTL-124	Aquatic life	Nonsupporting	Dissolved oxygen
Goose Creek	MD-114	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
	MD-039	Recreation	Nonsupporting	Fecal coliform
Goose Creek Reservoir	RL-01008	Aquatic life	Partially supporting	Dissolved oxygen
	ST-033	Aquatic life	Nonsupporting	pH, total phosphorus, Chlorophyll-*a*, copper
	ST-032	Aquatic life	Nonsupporting	pH, total phosphorus, Chlorophyll-*a*
Wando River	MD-115	Aquatic life	Partially supporting	Copper
Wassamassaw Swamp	CSTL-063	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Cypress Swamp	CSTL-078	Aquatic life	Nonsupporting	Zinc
		Recreation	Partially supporting	Fecal coliform
Ashley River	CSTL-102	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Sawmill Branch	CSTL-043	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Dorchester Branch	CSTL-013	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Eagle Creek	CSTL-099	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Ashley River	MD-049	Aquatic life	Nonsupporting	Dissolved oxygen, turbidity, copper, nickel
		Recreation	Nonsupporting	Fecal coliform
Church Creek	MD-246	Recreation	Partially supporting	Fecal coliform
Log Bridge Creek	MD-121	Recreation	Partially supporting	Fecal coliform
Stono River	MD-202	Aquatic life	Nonsupporting	Dissolved oxygen, copper
Elliot Cut	MD-025	Aquatic life	Partially supporting	Dissolved oxygen
Devils Den Creek	RT-02016	Aquatic life	Nonsupporting	Copper
Jeremy Creek	MD-203	Aquatic life	Nonsupporting	Dissolved oxygen, turbidity
		Recreation	Partially supporting	Fecal coliform
Matthews Creek tributary	RT-01623	Aquatic life	Nonsupporting	Turbidity

Table 7-3. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Awendaw Creek	MD-250	Recreation	Nonsupporting	Fecal coliform
Atlantic Intracoastal Waterway	MD-269	Aquatic life	Nonsupporting	Copper
Shem Creek	MD-071	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Charleston Harbor	MD-165	Aquatic life	Nonsupporting	Dissolved oxygen, copper
Stono River	MD-026	Aquatic life	Nonsupporting	Copper
	MD-206	Aquatic life	Partially supporting	Dissolved oxygen
Stono Inlet tributary	RT-01642	Aquatic life	Nonsupporting	Turbidity

The water quality of Wappoo Creek, Elliott Cut, and Stono River is influenced by water entering from Charleston Harbor on the rising tide. Shipyard Creek has sediment contamination and a shellfish-consumption ban because of point source-contamination (DHEC, 2002).

Water quality conditions can change significantly from year to year and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in previous years, DHEC issued a fish-consumption advisory for the Diversion Canal, Lake Moultrie, the Rediversion Canal, the Cooper River (from Lake Moultrie to Bushy Park), Wadboo Creek, Durham Creek, and the lower part of the Ashley River. Fish-consumption advisories are issued in areas where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for swimming or boating.

GROUND WATER

Hydrogeology

The Ashley-Cooper River subbasin is entirely in the lower Coastal Plain and is underlain by six aquifers: the Cape Fear, Middendorf, Black Creek, Tertiary sand, Floridan, and shallow aquifers. The thickness of sediments ranges from about 1,700 to 2,800 feet. The principal sources of ground-water supply are the Middendorf aquifer, the Black Mingo Formation of the Tertiary sand aquifer, and the Santee Limestone section of the Floridan aquifer. Selected ground-water data for the subbasin are presented in Table 7-4.

Table 7-4. Selected ground-water data for the Ashley-Cooper River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Moncks Corner	Floridan / Tertiary sand	140–340	55–480
Summerville	Middendorf	1,580–1,800	500
	Floridan / Tertiary sand	250–570	70–510
McClellanville	Floridan / Tertiary sand	100–240	50–200
Seabrook Island	Middendorf	1,840–2,510	1,600
Charleston / Mount Pleasant	Middendorf	1,830–2,030	720–1,400

The Middendorf aquifer has been the principal ground-water source for public supply. Municipal systems in the Mount Pleasant area are the largest users. The town of Summerville used the Middendorf aquifer as its main source until 1994, when it began purchasing surface water from Santee Cooper and the Lake Moultrie Water Agency; the town maintains these wells on standby. Sullivan's Island discontinued well use in 1996. Middendorf wells at Mount Pleasant and Charleston are capable of 700 to 1,400 gpm (gallons per minute) with specific capacities ranging from 5 to 14 gpm/ft (gallons per minute per foot of water-level drawdown). Similarly-constructed wells in the Summerville area produced about 500 gpm with specific capacities less than 5 gpm/ft. Middendorf wells also are used at Kiawah Island for supplemental public supply and for golf-course irrigation.

The Tertiary sand and Floridan aquifers are the most commonly used ground-water sources, particularly in the areas south and west of Charleston. The aquifers are used conjunctively by open-hole wells that tap permeable sections in the Santee Limestone unit of the Floridan aquifer and a Black Mingo Formation sand in the top of the Tertiary sand aquifer: wells are rarely completed in either aquifer alone. The wells mainly are used for domestic and light-commercial purposes, range from 250 to 400 feet in depth, and provide reliable yields up to about 250 gpm. Former industrial wells are known to have produced more than 400 gpm locally. Specific capacities are commonly 4 to 6 gpm/ft but can exceed 10 gpm/ft. Moderately-brackish water occurs in these aquifers at Charleston and in the subbasin area to the north and northwest, and few Tertiary sand and Floridan wells have been used there.

Shallow-aquifer use is scattered throughout the eastern end of the subbasin and generally occurs where the Floridan aquifer and Tertiary sand aquifer are brackish and where public water supply is absent. The largest number of shallow wells is around Johns Island and Wadmalaw Island, where 30- to 50-foot wells yield about 10 gpm. Shallow wells were more widely used on the Sea Islands before public water-supply systems were constructed. The greatest shallow-well yields occur at Mount Pleasant, where former municipal wells produced 30 to 50 gpm. Poor yields are reported west of Charleston where silt and clay predominate: aquifer thinning, commonly between 0 and 30 feet, also reduces potential shallow-well yields in the upper reaches of the subbasin.

Ground-Water Quality

The Cretaceous- and Tertiary-age aquifers are important sources for public-supply, industrial, and irrigation uses in this subbasin. Water in these aquifers becomes increasing mineralized toward the coast and with depth.

The water quality of the Middendorf aquifer is alkaline, very soft, and generally a sodium bicarbonate type that is high in TDS (total dissolved solids) and fluoride. TDS range from 250 to 2,800 mg/L; sodium concentrations range from 20 to 800 mg/L; alkalinity ranges from 500 to 1,300 mg/L; chlorides range from less than 250 to more than 1,400 mg/L; and iron concentrations are variable, ranging from 0.010 to 0.950 mg/L (Park, 1985; Speiran and Aucott, 1994). Fluoride concentrations range from 2.0 to 11.1 mg/L, all above recommended drinking-water limits (Park, 1985). Because of the high concentrations of fluoride, sodium, and chloride, water from the Middendorf aquifer is treated by reverse osmosis for public supplies in Mount Pleasant and for irrigation on Kiawah Island.

Water from the Black Creek aquifer is a sodium bicarbonate type and is soft and alkaline in northern Berkeley and Charleston Counties. Black Creek aquifer water becomes more mineralized to the south in coastal areas, where it becomes a sodium chloride type (Park, 1985). From northwest to southeast in the subbasin, TDS increase from 250 to 2,500 mg/L, sodium increases from 100 to 1,000 mg/L, chloride increases from less than 5 to 1,000 mg/L, and alkalinity increases from 250 to 1,000 mg/L, (Speiran and Aucott, 1994). Fluoride levels in this aquifer range from 1.3 to 6.5 mg/L, with concentrations increasing generally southward.

Water quality in the Tertiary sand is generally good in northern Berkeley County and Charleston County, but it becomes increasingly mineralized to the southeast and with depth. It varies from a sodium bicarbonate type in Berkeley County to a sodium chloride type in south-coastal Charleston County. Chloride and fluoride concentrations range from about 10 mg/L to more than 1,000 mg/L and from 0.1 to 5.0 mg/L, respectively, from northwest to southeast across the subbasin. Hardness ranges from 1 to 250 mg/L and alkalinity ranges from 100 to 700 mg/L. High concentrations of dissolved silica are present in the Tertiary sand aquifer, averaging 30 mg/L and locally exceeding 40 mg/L (Park, 1985).

Water quality in the Floridan aquifer is a calcium bicarbonate type that is moderately-hard to hard with iron concentrations commonly exceeding secondary drinking-water limits. Chloride increases toward the southeast from less than 25 to more than 500 mg/L, locally exceeding 1,000 mg/L (Park, 1985). Silica concentration averages about 20 mg/L but is present at concentrations greater than 40 mg/L.

Water from the Floridan aquifer tends to be less mineralized than that from the Tertiary sand aquifer; however, interaquifer contamination is common in the subbasin as a result of well-construction practices and regional ground-water withdrawals.

Shallow-aquifer water quality varies widely in the subbasin and is generally good for domestic and irrigation use, but is the most vulnerable to contamination. It is usually low in TDS, acidic to slightly alkaline, and can contain high iron concentrations and hardness (Park, 1985). Shallow aquifers in contact with saltwater bodies may become more saline during drought; former Folly Beach wells are reported to have captured seawater shortly after being placed into service.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR and USGS in four wells in the Ashley-Cooper subbasin in order to help assess trends or changes in water levels (Table 7-5). Water levels in other wells are sometimes measured to help develop potentiometric maps of the Middendorf, Black Creek, and Floridan aquifers.

The long-term and ever-increasing use of ground water in this subbasin has led to the development of significant cones of depression in both the Middendorf and Floridan aquifers, the subbasin's two most important aquifers.

The potentiometric surface of the Middendorf aquifer in this subbasin is dominated by a large cone of depression centered at Mount Pleasant, in Charleston County (Figure 7-3). This cone of depression, the center of which is the lowest point on the Middendorf aquifer's potentiometric surface in South Carolina, has continued to expand and deepen in recent years (Hockensmith, 2008a). At Mount

Table 7-5. Water-level monitoring wells in the Ashley-Cooper River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
BRK-431	USGS	33 10 22 80 02 18	Middendorf	Moncks Corner	67	1,602–1,607
CHN-14	USGS	32 47 29 79 47 20	Middendorf	Charleston	7	1,805–2,007
CHN-44	DNR	32 47 47 80 04 12	Floridan	Charleston	10	180–425
CHN-101	USGS	33 02 47 79 34 03	Floridan	Awendaw	22	82–91

* *DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

Pleasant, Middendorf water levels are as much as 300 feet lower than predevelopment levels, which ranged from approximately 100 to 150 feet above sea level in this subbasin.

A second, smaller Middendorf cone of depression in southern Charleston County, around Kiawah and Seabrook Islands, has also grown in recent years. Middendorf aquifer water-levels at Seabrook Island have declined as much as 260 feet from predevelopment levels (Hockensmith, 2008a).

The potentiometric map of the Floridan/Tertiary sand aquifer shows a widespread cone of depression encompassing eastern Dorchester County and much of the southern and central parts of Charleston County (Figure 7-4). Within this large depression, smaller, deeper depressions exist around Summerville, North Charleston, and near Mount Pleasant. The depression around Summerville represents a water-level decline of more than 80 feet from predevelopment levels (Hockensmith, 2009).

Primarily in response to increasing Middendorf aquifer use and the consequent water-level decline, in 2002 DHEC declared Charleston, Berkeley, and Dorchester Counties to be the Trident Capacity Use area. In these counties, ground-water withdrawals of 3 million gallons or more in any month are regulated and require a permit from DHEC.

WATER USE

Water use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Ashley-Cooper subbasin is summarized in Table 7-6 and Figure 7-5. Offstream water use in the Ashley-Cooper subbasin was 222,027 million gallons in 2006, ranking it fifth among the 15 subbasins. Of this amount, 217,183 million gallons were from surface-water sources (98 percent) and 4,844 million gallons were from ground-water sources (2 percent). Thermoelectric water use accounted for 85 percent of this total, followed by water supply (12 percent) and industry (2 percent). Consumptive use in this subbasin is estimated to be 10,761 million gallons, or about 5 percent of the total offstream use.

Three thermoelectric power plants operate in the subbasin. Collectively, they used 188,150 million gallons of water in 2006. Williams Station is owned by SCE&G and operated by the South Carolina Power Generating Company. Located near Charleston, Williams Station is a coal-fired plant with a capacity of 650 MW (megawatts). It can also generate 50 MW of electricity from two natural gas combustion turbines. In 2006, the plant used 172,369 million gallons from the Cooper River. The plant utilizes a once-through cooling system.

Jefferies Generating Station is an oil- and coal-fired plant owned and operated by Santee Cooper. Located in Berkeley County on the Tailrace Canal near Lake Moultrie, it has a capacity of 398 MW and used 13,402 million gallons in 2006. This plant utilizes a once-through cooling system.

Cross Generating Station, also owned and operated by Santee Cooper, is a coal-fired plant located adjacent to the Diversion Canal between Lakes Marion and Moultrie. The plant, which has a capacity of 1,160 MW, used 2,379 million gallons in 2006.

Water-supply use in the subbasin was 26,762 million gallons. Surface water accounted for 24,005 million gallons (90 percent) and ground water for 2,757 million gallons (10 percent). Charleston Water System was the largest user, withdrawing 18,347 million gallons from Bushy Park Reservoir. Charleston Water System also draws water from the Edisto River in the Edisto River subbasin. The Lake

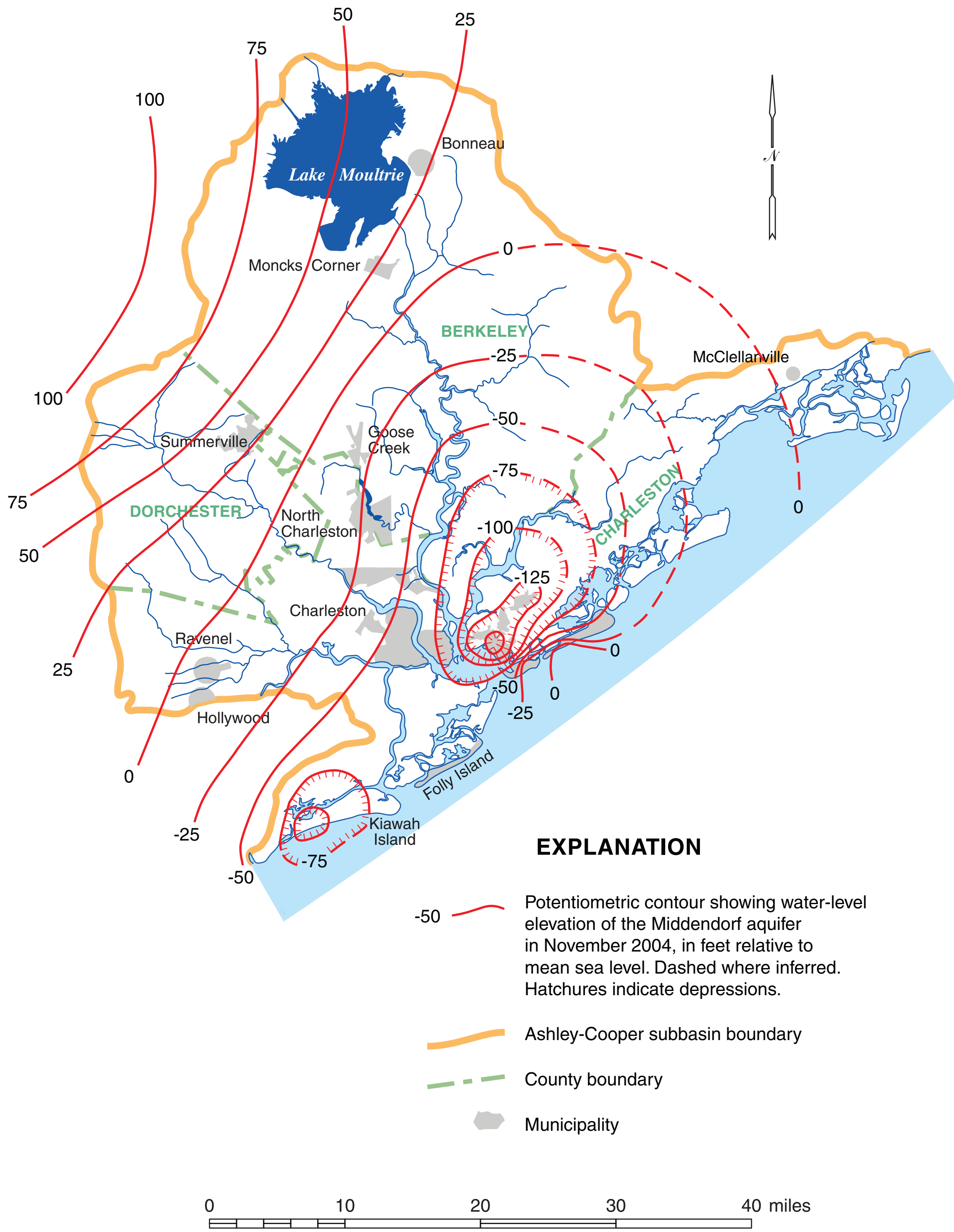


Figure 7-3. Potentiometric contours of the Middendorf aquifer in the Ashley-Cooper River subbasin, November 2004 (from Hockensmith, 2008a).

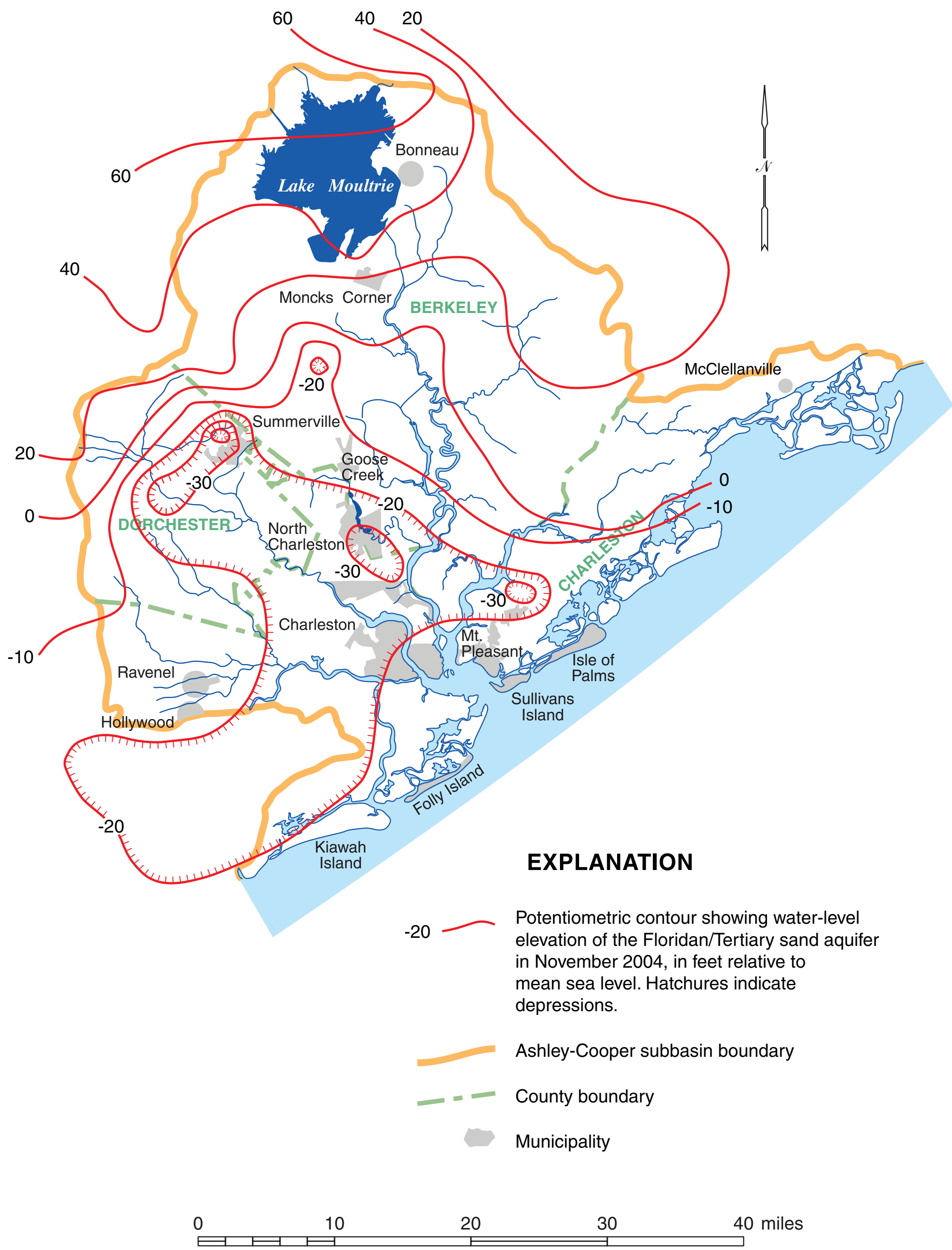


Figure 7-4. Potentiometric contours of the Floridan aquifer in the Ashley-Cooper River subbasin, November 2004 (from Hockensmith, 2009).

Moultrie Water Agency, which serves the Berkeley County Water and Sanitation Authority, the city of Goose Creek, the Moncks Corner Public Water Works Commission, and the Summerville Commissioners of Public Works, had withdrawals of 5,658 million gallons from Lake Moultrie. Thirteen ground-water supply systems have wells in the subbasin. The largest system is Mt. Pleasant in Charleston County, which used 1,783 million gallons in 2006, pumping from the Middendorf aquifer.

Industrial water use was 4,919 million gallons in the subbasin. Of this amount, 3,630 million gallons were from surface-water sources (74 percent) and 1,289 million gallons were from ground-water sources (26 percent). BP Amoco Cooper River chemicals plant near Charleston had the greatest surface-water use, withdrawing 2,619 million gallons from the Cooper River. Nucor Steel in Berkeley County had the greatest ground-water use, withdrawing 1,065 million gallons, mainly from the Middendorf aquifer.

Table 7-6. Reported water use in the Ashley-Cooper River subbasin for the year 2006 (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	68	0.0	4	0.1	72	0.0
Golf course	269	0.1	774	16.0	1,043	0.5
Industry	3,630	1.7	1,289	26.6	4,919	2.2
Irrigation	1,071	0.5	9	0.2	1,080	0.5
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	188,140	86.7	11	0.2	188,150	84.7
Water supply	24,005	11.1	2,757	56.9	26,762	12.1
Total	217,183		4,844		222,027	

Instream water use for hydroelectric power generation totaled 983,111 million gallons in 2006, all by the Jefferies Hydroelectric Station, the only hydroelectric power facility in the subbasin. The plant, owned and operated by Santee Cooper, is located in Berkeley County at Lake Moultrie and has a total capacity of 128 MW (see Table 7-2).

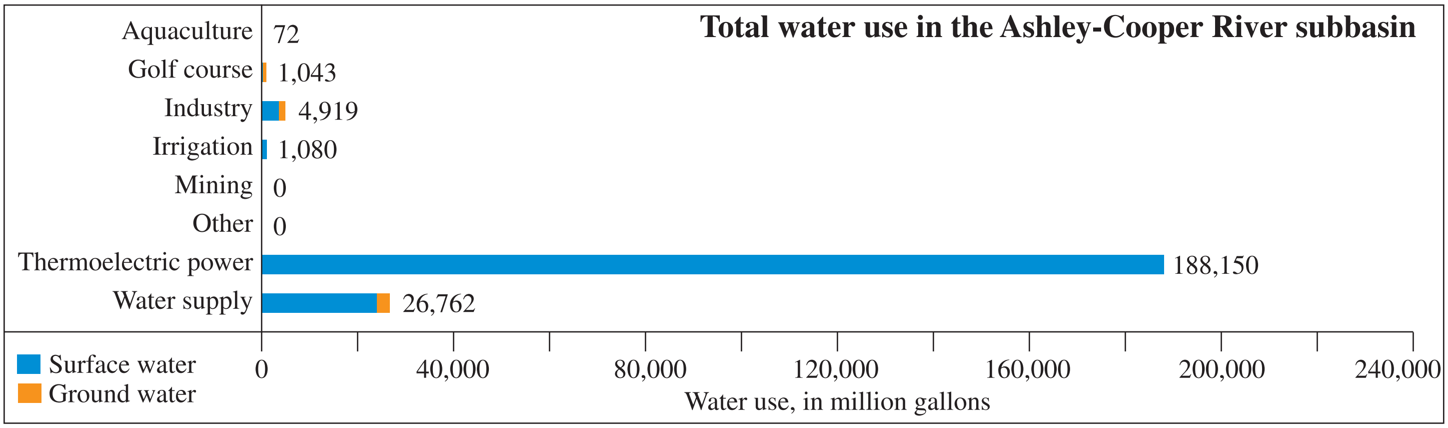
AQUIFER STORAGE AND RECOVERY PROGRAMS

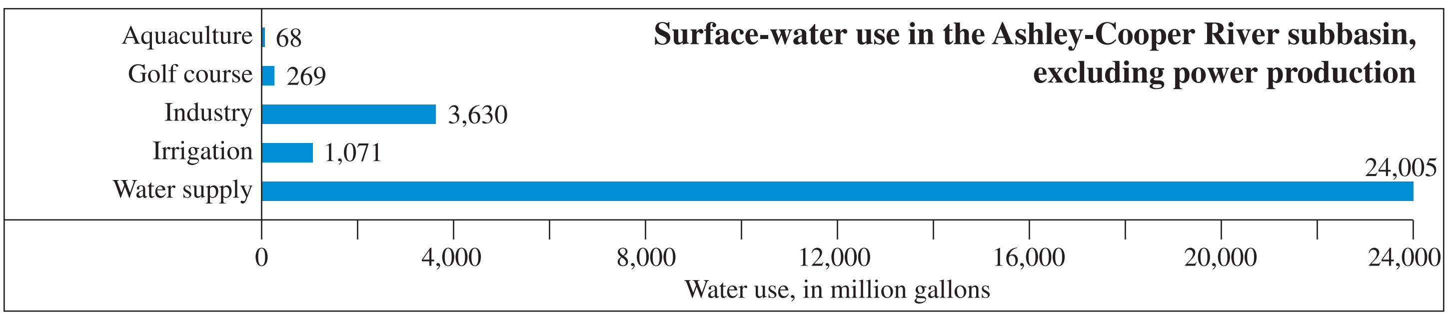
The concept of an aquifer storage and recovery (ASR) program is to treat more surface water than is needed during times of low demand, inject the excess treated water into an aquifer, store it in the ground until the demand for water is high, and then pump the water out of the ground when it can be used to supplement surface-water supplies. ASR wells can provide water for short-term, high-demand periods, which can allow water systems to meet user demands with smaller treatment plants, thereby reducing the overall cost of providing the water. Additionally, the use of an ASR system can reduce water-production costs by allowing treatment plants to operate more efficiently by stabilizing plant production to an optimum flow rate and by treating more surface water in the winter, when the water quality is better than in the summer and is thus less expensive to treat.

Two of the four active ASR programs in South Carolina are located within the Ashley-Cooper subbasin.

Mount Pleasant Waterworks, in Charleston County, has four ASR wells in operation, all of them completed in aquifers of the Black Mingo Formation. Treated surface water is stored underground during off-peak periods and recovered to supplement drinking-water supplies during periods of peak demand, typically during the spring and summer months. During recovery, the wells each produce between 0.5 and 1.0 million gallons per day.

Kiawah Island Utility, Inc. (KIU), which buys its treated water from Charleston Water System, utilizes two ASR wells to help meet their water demands. Both wells are completed in aquifers of the Black Mingo Formation. The first well was installed in 2002 at their Sora Rail facility near the west end of the island for use during emergencies and peak demand periods (KIU, 2009). Approximately 60 million gallons of treated surface water are stored during non-peak periods for use throughout the peak-demand season. The second well was installed at the east end of Kiawah Island and is used to help satisfy early morning demands. It has a storage-volume target of 60 million gallons (Becky Dennis, KIU, personal communication, 2009). The combined yield of the two wells is about 2.5 million gallons per day.





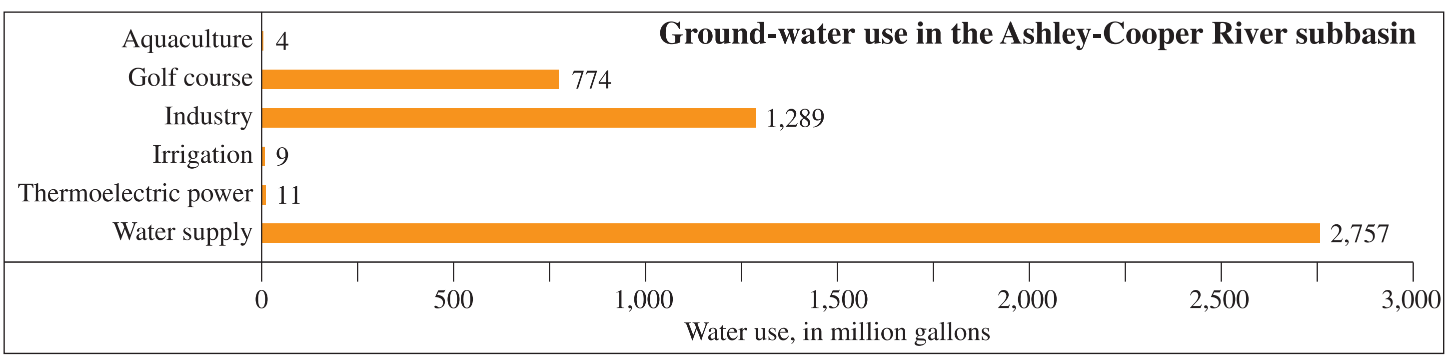
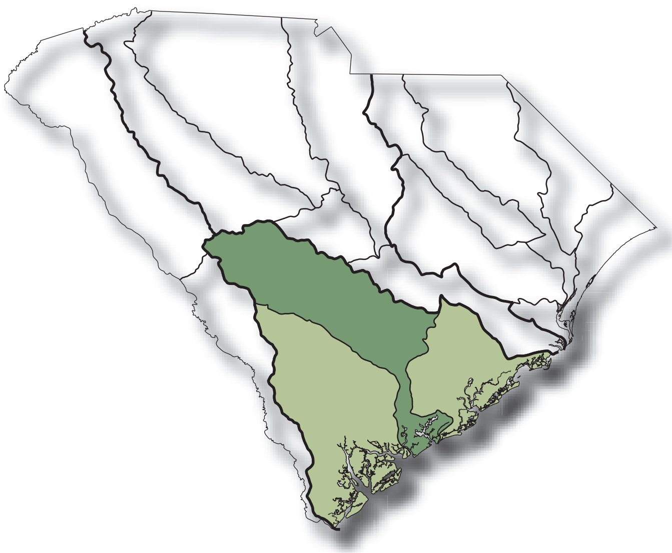


Figure 7-5. Reported water use in the Ashley-Cooper River subbasin for the year 2006 (modified from Butler, 2007).

EDISTO RIVER SUBBASIN



EDISTO RIVER SUBBASIN

The Edisto River subbasin is in south central South Carolina. From its western extreme in eastern Edgefield County, the subbasin extends southeastward to the coast and follows the course of the Edisto River. The subbasin encompasses parts of 12 South Carolina counties, including most of Colleton and Orangeburg counties and smaller parts of Aiken, Bamberg, Barnwell, Berkeley, Calhoun, Charleston, Dorchester, Edgefield, Lexington, and Saluda Counties (Figure 7-6). The subbasin area is approximately 3,120 square miles, 10.0 percent of the State's area.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 199,000, 5.0 percent of South Carolina's total population. By 2020, the subbasin population is expected to reach 206,000, an increase of 4 percent. The highest rate of population growth is anticipated in Dorchester County, which is projected to have a population increase greater than 30 percent.

The subbasin is primarily rural in character with the city of Orangeburg (population 12,765) being the only sizable urban area. Small towns in the subbasin have experienced negative or little population growth in the past 20 years, including Bamberg (3,733), Denmark (3,328), Johnston (2,336), St. George (2,092), Holly Hill (1,281), and Bowman (1,198).

The year 2005 per capita income for the counties in the subbasin ranged from $20,409 in Barnwell County, which ranked 42nd among the State's 46 counties, to $34,158 in Charleston County, which ranked second. The 1999 median household income ranged from $24,007 in Bamberg County (the lowest in the State) to $44,659 in Lexington County. The median household income was above the State average in five of the 12 subbasin counties (South Carolina Budget and Control Board, 2005).

During 2000, the counties of the subbasin had combined annual average employment of non-agricultural wage and salary workers of about 165,000. Labor distribution in the subbasin counties included management, professional, and technical services, 29 percent; sales and office, 24 percent; production, transportation, and materials moving, 19 percent; service, 15 percent; construction, extraction, and maintenance, 12 percent; and farming, fishing, and forestry, 1 percent.

In the sectors of manufacturing and public utilities, the subbasin counties had an annual product value of about $12 billion in 1997. Agriculture was important in most sections of the subbasin, and total crop and livestock production in the subbasin counties exceeded $500 million in 2003; 2001 timber-product value was about $175 million.

SURFACE WATER

Hydrology

The Edisto River subbasin is drained by four major streams: South Fork Edisto River, North Fork Edisto River, Edisto River, and Four Hole Swamp. The Edisto River is the longest and largest river system completely contained within the borders of South Carolina. The North and South Fork Edisto Rivers originate in and pass through the upper Coastal Plain region before joining to form the Edisto River in the middle Coastal Plain near the

Figure 7-6. Map of the Edisto River subbasin.

town of Branchville. The blackwater Four Hole Swamp, a major tributary originating in Calhoun and Orangeburg Counties, is unique in that it consists of multiple braided channels rather than one well-defined channel. Much of the Edisto River and its tributary streams are associated with extensive swamplands. Near the coast, the Edisto River divides to form the North and South Edisto Rivers, which surround Edisto Island. Near the coast, these tidally-influenced saltwater streams also receive drainage from bordering salt marshes and tidal creeks.

Within this subbasin, the U.S. Geological Survey (USGS) has seven active streamflow gaging stations: one on the Edisto River, one on the North Fork Edisto River, three on the South Fork Edisto River, and one each on McTier Creek and Cow Castle Creek (Figure 7-6). Streamflow statistics for these active stations and three discontinued stations are presented in Table 7-7.

Average annual flow of the South Fork Edisto River is 738 cfs (cubic feet per second) near Denmark, 694 cfs near Cope, and 892 cfs near Bamberg. Ninety percent of the time, streamflow at these sites should be at least 323, 266, and 287 cfs, respectively. For the North Fork Edisto River, average annual flow is 753 cfs at Orangeburg and streamflow should be at least 358 cfs 90 percent of the time. Characteristic of upper Coastal Plain streams, these streamflows are steady, with well-sustained low flows (Figure 7-7).

Table 7-7. Selected streamflow characteristics at USGS gaging stations in the Edisto River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
McTier Creek near Monetta 1723	1995-97 and 2001-07*	15.3	17.5	1.14	5.2	1.4 2002	248 1996	536 1996
South Fork Edisto River near Montmorenci 1725	1940 to 1996	198	244	1.23	110	40 1954	4,260 1964	5,010 1964
South Fork Edisto River near Denmark 1730	1931-71 and 1980-2007*	720	738	1.03	323	110 2002	12,700 1936	13,500 1936
Sout Fork Edisto River near Cope 1730.3	1991 to 2007*	757	694	0.92	266	87 2002	6,510 1998	7,610 1998
South Fork Edisto River near Bamberg 1730.51	1991 to 2007*	807	892	1.11	287	110 2002	8,080 1998	8,640 1998
Bull Swamp Creek below Swansea 1733.51	2001 to 2003	34.4	8.9	0.26	3.5	3.1 2002	80 2001	93 2002
North Fork Edisto River at Orangeburg 1735	1938 to 2007*	683	753	1.10	358	113 2002	8,850 1945	9,500 1945
Edisto River near Branchville 1740	1945 to 1996	1,720	1,991	1.16	820	325 1990	14,400 1964	14,600 1964
Cow Castle Creek near Bowman 1742.5	1971-81 and 1995-2007*	23.4	19.5	0.83	1.5	0.0 2002	1,030 2003	2,340 1979
Edisto River near Ghivans 1750	1939 to 2007*	2,730	2,522	0.92	684	150 2002	24,100 1973	24,500 1973

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

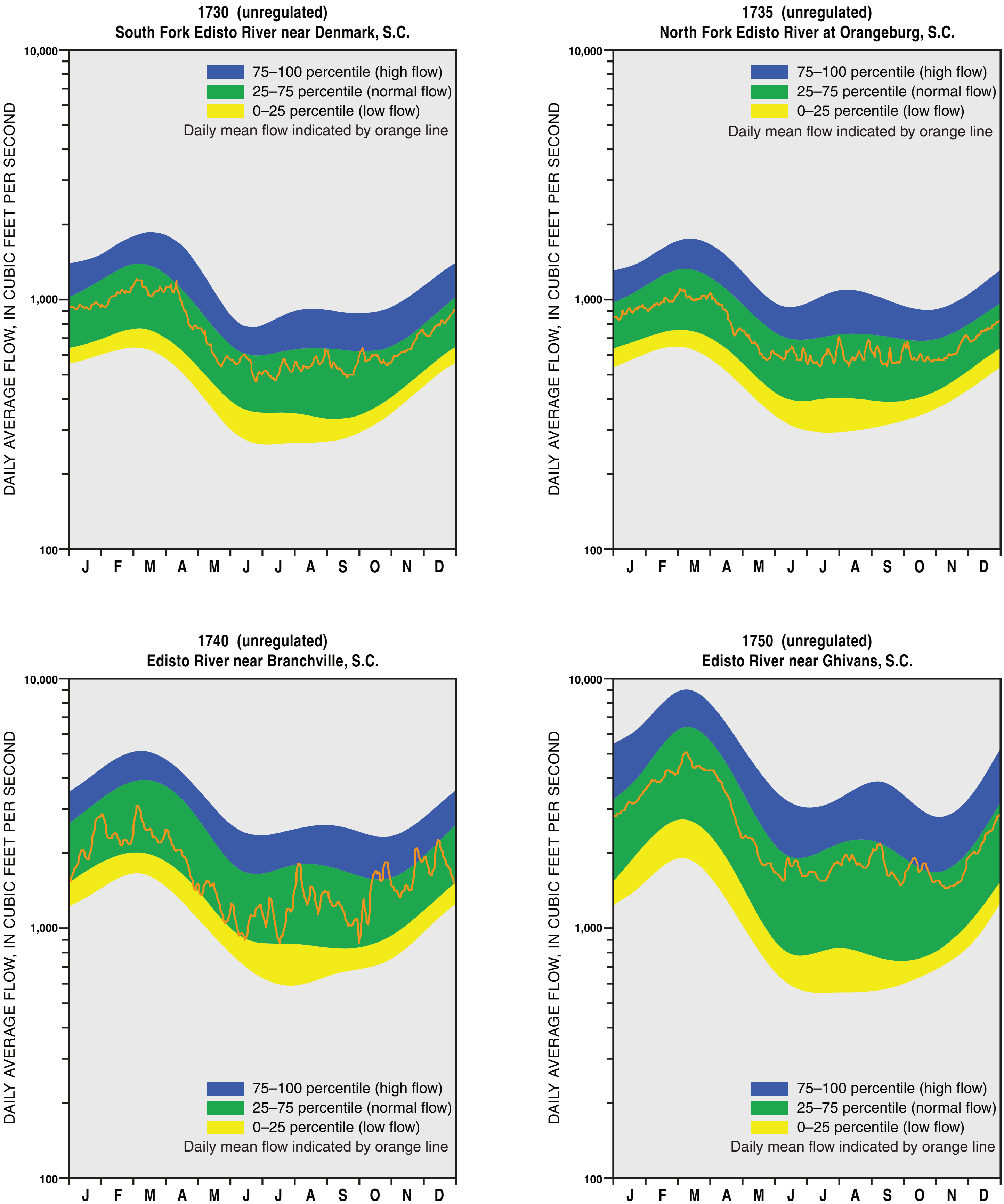


Figure 7-7. Duration hydrographs for selected gaging stations in the Edisto River subbasin.

By contrast, Cow Castle Creek near Bowman, a small tributary of Four Hole Swamp, exhibits more variable flows typical of middle and lower Coastal Plain streams, where flow is more dependent on rainfall and direct runoff. Average annual flow of this stream is 19.5 cfs and should be at least 1.5 cfs 90 percent of the time.

Streamflow on the Edisto River is substantial and fairly consistent (Figure 7-7). These well-sustained flows are caused primarily by discharge from ground-water reserves in the upper Coastal Plain region, in which more than half the drainage area is located. Average annual flow of the Edisto River at the discontinued gage near Branchville is 1,991 cfs and at the gage near Givhans is 2,522 cfs. Streamflow at these sites can be expected to be at least 820 and 684 cfs, respectively, 90 percent of the time. Although large withdrawals by the city of Charleston upstream of the Givhans gage may lower the 90-percent exceedance flow value at this site, those withdrawals alone do not account for the lower exceedance values at the downstream gage.

The highest flow of record for the Edisto River at the Branchville gage is 14,400 cfs, measured in September 1964, and the highest flow of record at the Givhans gage is 24,100 cfs, measured in June 1973. A flow of 25,700 cfs at the location of the Branchville gage has been estimated for a flood event that occurred in September 1928.

The multiyear drought of 1998–2002 broke record low flows previously measured during the drought of the 1950's. A new lowest flow of record for most of the gages was measured in August of 2002.

The Edisto River and tributary streams in the upper Coastal Plain exhibit well-sustained year-round flows and provide a reliable water-supply source. Tributary streams in the middle and lower Coastal Plain region, however, have more variable flows and provide limited surface-water availability during periods of low rainfall.

Development

Surface-water development in the Edisto River subbasin is very limited, consisting of primarily a few navigation and flood-control projects in the southern reach. The Edisto River is completely undammed and unleveed, and no large impoundments occur in the subbasin. Lakes having surface areas of 10 acres or more have an aggregate area of 6,000 acres and a total volume of 29,000 acre-ft (U.S. Army Corps of Engineers, 1991).

The U.S. Army Corps of Engineers (COE) has been involved in four navigation projects and three flood-control projects in the subbasin, none of which are active. The NRCS (Natural Resources Conservation Service), in conjunction with the Horse Range Watershed and Orangeburg Soil and Water Conservation District, completed a flood-control project on Horse Range Swamp in 1975; the project improved 20 miles of channel. The NRCS also has an active flood-control project near Holly Hill in Orangeburg County.

Surface-Water Quality

Most of the water bodies in the Edisto River subbasin are designated "Freshwater" (Class FW). Class FW waters are freshwater bodies suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2004b).

A few water bodies are designated as "Outstanding Resource Water" (Class ORW). These constitute an exceptional recreational and ecological resource or are suitable as a drinking-water source with minimal treatment. Parts of Church Creek and the North Edisto River, and all of Townsend Creek, Frampton Inlet, Dawho River, and Bohicket Creek are classified as ORW.

The South Edisto River and Church Creek from Raven Point Creek to Hoopstick Island are designated as "Shellfish Harvesting" (Class SFH). These tidal saltwater bodies are protected for shellfish harvesting and have the most stringent bacterial standards.

As part of its ongoing Watershed Water Quality Assessment program, DHEC sampled 80 surface-water sites in the Edisto River subbasin between 1997 and 2001 in order to assess the water's suitability for aquatic life and recreational use (Figure 7-8). Aquatic-life uses were fully supported at 58 sites, or 72 percent of the water bodies sampled; most of the impaired sites exhibited low dissolved-oxygen levels. Recreational use was fully supported in 76 percent of the sampled water bodies; water bodies that did not fully support recreational use exhibited high levels of fecal coliform bacteria (DHEC, 2004b). Water-quality impairments in the subbasin are summarized in Table 7-8.

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in previous years, DHEC issued a fish-consumption advisory for the South Fork Edisto River from Aiken State Park to the Edisto River, the North Fork Edisto River in Orangeburg County, all of Four Hole Swamp, the Edisto River above Willtown Bluff (near Edisto Island), and Penny Creek in Charleston County. Fish-consumption advisories are issued in areas where fish contaminated with mercury have been found. The contamination is only in the fish and does not make the water unsafe for swimming or boating.

Figure 7-8. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 7-8 (DHEC, 2004b).

Table 7-8. Water-quality impairments in the Edisto River subbasin (DHEC, 2004b)

Water-body name	Station number	Use	Status	Water-quality indicator
Chinquapin Creek	E-091	Recreation	Nonsupporting	Fecal coliform
Horsepen Creek	RS-01004	Recreation	Nonsupporting	Fecal coliform
Bull Swamp Creek	E-034	Aquatic life	Nonsupporting	Dissolved oxygen
North Fork Edisto River	E-099	Recreation	Partially supporting	Fecal coliform
	E-007	Aquatic life	Nonsupporting	pH
	E-007A	Recreation	Partially supporting	Fecal coliform
	E-007C	Aquatic life	Nonsupporting	pH
Shaw Creek	E-094	Aquatic life	Nonsupporting	pH
Windy Hill Creek	E-029	Aquatic life	Partially supporting	Macroinvertebrates
Goodland Creek	E-036	Recreation	Nonsupporting	Fecal coliform
Roberts Swamp	E-039	Aquatic life	Partially supporting	Macroinvertebrates
Cattle Creek	E-108	Recreation	Partially supporting	Fecal coliform
Indian Field Swamp	E-032	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Polk Swamp	E-016	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
	E-109	Aquatic life	Nonsupporting	Dissolved oxygen, macroinvertebrates
		Recreation	Partially supporting	Fecal coliform
South Edisto River	RO-01123	Aquatic life	Nonsupporting	Turbidity
Younges Island Creek	MD-261	Aquatic life	Nonsupporting	Turbidity
Dawho River	RT-01665	Aquatic life	Nonsupporting	Dissolved oxygen, turbidity
	MD-120	Aquatic life	Nonsupporting	Dissolved oxygen, turbidity
Church Creek	MD-195	Aquatic life	Nonsupporting	Dissolved oxygen
Bohicket Creek	MD-209	Aquatic life	Nonsupporting	Dissolved oxygen
Gramling Creek	E-022	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Little Bull Swamp	E-076	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
	E-589	Aquatic life	Partially supporting	Macroinvertebrates
Four Hole Swamp	E-059	Recreation	Partially supporting	Fecal coliform
	E-111	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Partially supporting	Fecal coliform
Goodbys Swamp	RS-01036	Recreation	Nonsupporting	Fecal coliform
Cow Castle Creek	E-050	Recreation	Partially supporting	Fecal coliform
Four Hole Swamp	E-112	Aquatic life	Nonsupporting	Dissolved oxygen
Providence Swamp	E-051	Aquatic life	Partially supporting	Dissolved oxygen
Horse Range Swamp	E-052	Recreation	Partially supporting	Fecal coliform
Four Hole Swamp	E-100	Aquatic life	Partially supporting	Chromium
		Recreation	Partially supporting	Fecal coliform

GROUND WATER

Hydrogeology

The Edisto River subbasin lies completely within the Coastal Plain. The basement (Piedmont) rocks occur at a depth of about 100 feet below land surface at the northwest border of the subbasin, which approximates the Fall Line. Piedmont rocks crop out in riverbeds in the extreme upper reaches of the subbasin, and in a few erosional windows. Near the coast, the sedimentary column is about 3,000 feet thick. Selected ground-water data for the subbasin are presented in Table 7-9.

Ground-water availability in Lexington County is variable. At sites along the Fall Line, water usually must be obtained from the underlying crystalline-rock aquifers where yields are generally low—usually less than 15 gpm (gallons per minute)—and dry holes are common. The southern part of Lexington County is underlain by the Middendorf, Black Creek, and Tertiary sand aquifers. Their combined thickness is 550 feet at Swansea.

The northeastern half of Aiken County is in the subbasin, and the city of Aiken is on the divide between the ACE and Savannah River basins. Near Aiken, where land-surface elevations are about 500 feet above mean sea level, the Coastal Plain sediments are 500 feet thick. Major wells are usually completed in the Middendorf aquifer at depths below 400 feet. Elsewhere in Aiken County, wells are in the Middendorf, Black Creek, or Tertiary sand aquifers and are 70 to 700 feet deep, and yields are 80 to 700 gpm.

The Cretaceous and Tertiary sediments in much of Orangeburg County provide large quantities of good-quality water. Most wells in the upper Coastal Plain of Orangeburg County are developed in the Orangeburg Group, part of the Tertiary sand aquifer, whereas wells in the lower Coastal Plain are developed primarily in the Floridan, Black Creek, and Middendorf aquifers.

Table 7-9. Selected ground-water data for the Edisto River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Pelion-Gaston-Swansea	Middendorf / Black Creek	225–430	70–1,000
Aiken	Middendorf / Black Creek	70–485	120–1,500
Orangeburg	Middendorf / Black Creek / Tertiary sand	105–970	200–1,500
Bowman	Middendorf / Black Creek	350–950	200–1,100
Cope	Middendorf / Black Creek	200–965	300–2,300
Norway	Black Creek / Black Creek	230–350	125–710
North	Middendorf / Black Creek / Tertiary sand	125–480	100–760
Edisto Island	Floridan / Tertiary sand	400–550	200–500

The middle and lower Coastal Plain area of Orangeburg County is underlain by the Cape Fear, Middendorf, Black Creek, Tertiary sand, and Floridan aquifers. The top of the Middendorf aquifer occurs at a depth of 650 feet at Orangeburg and dips southeast to about 1,100 feet at the county boundary. Large-diameter wells screened in this aquifer yield more than 2,000 gpm at Cope. The transmissivity of the aquifer at Orangeburg, Cope, and Eutawville is 20,000 to 27,000 ft^2/day. Hydrologic data for the Black Creek aquifer in the Orangeburg area indicate transmissivities similar to those for the Middendorf. A well at Holly Hill in southern Orangeburg County yielded 1,067 gpm from the Black Creek aquifer.

Wells in the Tertiary sand aquifer yield up to 1,000 gpm. Several wells near the towns of Eutawville and North are screened in both the Tertiary sand and Black Creek aquifers. North and west of the city of Orangeburg, wells in the Tertiary sand aquifer are 200 to 300 feet deep and yield 50 to 400 gpm.

The Floridan aquifer is formed by the Santee Limestone in the middle Coastal Plain and the Santee Limestone and overlying Cooper Formation in the lower Coastal Plain. The Floridan is very transmissive in the Eutawville area in Orangeburg County: transmissivity values of 24,000 and 33,000 ft^2/day have been calculated from tests, and yields as high as 600 gpm have been reported. Transmissivities less than 2,000 ft^2/day are more typical of the lower Coastal Plain section. Shallow aquifers in the Duplin Formation and Pleistocene deposits overlie the Floridan aquifer.

The shallow, Floridan, and Tertiary sand aquifers are the principal sources of ground-water supply where the subbasin includes parts of Dorchester, Colleton, and

Charleston Counties. The underlying Cretaceous aquifers are unused there owing to their great depths and to brackish-water occurrence near the coast.

At Edisto Island, open-hole wells tapping both the base of the Floridan and the upper 20 to 50 feet of the Tertiary sand aquifer are the predominant water source: well depths are between about 200 and 550 feet. Yields are everywhere adequate for domestic and light-commercial use, and public-supply wells at Edisto Beach produce about 500 gpm. Shallow wells also are common around Edisto Island, where Pleistocene deposits are as thick as 60 feet.

The ground-water supply potential of the Edisto River subbasin is at or near the greatest in South Carolina. Multiple, highly-transmissive aquifers in a complex of sediments that contain freshwater to depths as great as 2,000 feet ensure reliable water supplies for towns, industries, and farms.

Ground-Water Quality

The Middendorf and Black Creek aquifers encompass a wide range of water quality. The water in both aquifers tends to be soft, alkaline, and a sodium bicarbonate type grading to a sodium chloride type with depth and proximity to the coast. Both aquifers become more mineralized from the upper reaches to the coast. In the Middendorf aquifer, total dissolved solids (TDS) are 25 to more than 1,000 mg/L (milligrams per liter), sodium ranges from 2.5 to 800 mg/L, chloride ranges from 5 to more than 100 mg/L, alkalinity ranges from 2.5 to more than 1,300 mg/L, fluoride ranges from 2.0 to 11 mg/L, and pH values are between 6.5 and 8.5. A zone of iron concentrations greater than 1.0 mg/L has been noted in these aquifers in Bamberg County. Iron concentrations diminish northwest and southeast of this zone to less than 0.1 mg/L (Lee, 1988).

In the Black Creek aquifer, TDS range between 25 and 2,500 mg/L, sodium ranges between 2.5 and 1,000 mg/L, and chloride ranges between 2.5 and 1,000 mg/L. Alkalinity is as great as 1,000 mg/L at the coast. The pH increases from about 4.5 to more than 9.3 along the subbasin (Park, 1985; Speiran and Aucott, 1994).

At the northwest end of the subbasin, water of the Tertiary sand aquifer is acidic, low in dissolved solids, and usually high in iron. Sodium chloride type water predominates, and hydrogen sulfide occurs locally. Downdip, TDS increase and pH increases to about 7.0 as aquifer sediments become more calcareous (Logan and Euler, 1989; Siple, 1975). Naturally-occurring sodium and chloride are usually the dominant ions. Radioactive ground water has been found in the Leesville area of Lexington County, where gross alpha-particle activity was measured as high as 39 pCi/L (picoCuries per liter). Radium-226 levels in water from wells at North, in Orangeburg County, ranged from 4.6 to 7.1 pCi/L (Scott and Barker, 1962; Siple, 1975).

Along the Colleton County and Dorchester County reach, the Tertiary sand aquifer contains a more mineralized sodium bicarbonate water, which in turn becomes a sodium chloride type across Charleston and northeastern Colleton Counties. Fluoride concentrations increase from about 1.0 mg/L to 5.0 mg/L along the lower third of the subbasin. Brackish water is present at the coast, and chloride concentrations increase along the Colleton and Charleston Counties reach. A chloride concentration of 8,000 mg/L has been reported in a Tertiary sand well at Botany Bay Island north of Edisto Beach.

The Tertiary sand aquifer grades and interfingers southeastward into the Santee Limestone section of the Floridan aquifer. Water in the Floridan aquifer generally is typical of carbonate aquifers. It is a calcium bicarbonate type, has pH between 7.5 and 8, has TDS generally less than 200 mg/L, and is moderately hard to hard. Down the length of the subbasin, TDS concentrations range from 50 to 1,850 mg/L, and high iron concentrations and hydrogen sulfide are common. Chloride concentrations inland of Charleston County are less than 40 mg/L, but are as great as 1,000 mg/L at Edisto Beach.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR and DHEC in 15 wells in the Edisto River subbasin in order to help assess trends or changes in water levels (Table 7-10). Water levels in other wells are sometimes measured to help develop potentiometric maps of the Middendorf, Black Creek, and Floridan aquifers.

No site-specific water-level problems occur in the Middendorf aquifer in this subbasin. Water-level elevations range from more than 300 feet above sea level in the northwest corner of the subbasin to 50 feet below sea level at the southeast edge of the subbasin (Hockensmith, 2008a). In the upper part of this subbasin, near the Middendorf recharge area, water levels are not significantly lower than estimated predevelopment levels. In the lower half of the subbasin, water levels have been lowered because of the large cone of depression surrounding the Charleston area (see Figure 7-3). In Charleston County, near Edisto Island, Middendorf water levels may be as much as 200 feet lower than predevelopment levels (Hockensmith, 2008a).

The potentiometric surface of the Floridan/Tertiary sand aquifer slopes fairly uniformly down toward the southeast, from a high elevation of about 160 feet in central Orangeburg County to about 20 feet below sea level at Edisto Island. A small but deep cone of depression exists around Holly Hill, and the much larger depression that encompasses much of southern Charleston County (see Figure 7-4) impacts water levels near the coast in this subbasin. Water levels in Orangeburg and Bamberg Counties are generally stable and not much lower than estimated predevelopment levels, but

Table 7-10. Water-level monitoring wells in the Edisto River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
AIK-826	DNR	33 32 35 81 29 08	Middendorf	DNR cluster site C-3, Aiken State Park	295	485–495
AIK-845	DNR	33 32 35 81 29 08	Middendorf	DNR cluster site C-3, Aiken State Park	297	341–351
AIK-846	DNR	33 32 34 81 29 08	Black Creek	DNR cluster site C-3, Aiken State Park	298	240–250
AIK-847	DNR	33 32 33 81 29 07	Black Creek	DNR cluster site C-3, Aiken State Park	299	178–188
AIK-848	DNR	33 32 33 81 29 07	Black Creek	DNR cluster site C-3, Aiken State Park	300	116–126
AIK-849	DNR	33 32 32 81 29 06	Shallow	DNR cluster site C-3, Aiken State Park	302	82–92
CHN-484	DNR	32 34 55 80 18 22	Floridan	Blue House Plantation, Edisto Island	14	280–548
COL-97	DNR	33 02 51 80 35 51	Floridan	near Canadys	84	134–342
COL-301	DNR	32 30 42 80 17 58	Floridan	Edisto Beach State Park	10	516–545
LEX-844	DNR	33 44 45 81 06 27	Middendorf	Swansea Primary School	360	392–502
ORG-202	DHEC	33 26 53 81 07 30	Tertiary sand	Norway	237	undetermined
ORG-385	DHEC	33 22 09 81 01 50	Black Creek	near Cope	175	475–535
ORG-393	DNR	33 30 29 80 51 54	Black Creek	Clark Middle School, Orangeburg	256	423–463
ORG-430	DNR	33 30 29 80 51 54	Tertiary sand	Clark Middle School, Orangeburg	256	205–265
ORG-431	DNR	33 30 29 80 51 54	Floridan	Clark Middle School, Orangeburg	256	83–88

* *DHEC, South Carolina Department of Health and Environmental Control;*
DNR, South Carolina Department of Natural Resources

water levels in the lower part of the subbasin have declined 10 to 20 feet since 1985 and as much as 40 feet from predevelopment levels. Near Edisto Beach, the increasing specific conductivity measured in wells having declining water levels suggests that saltwater intrusion is occurring (Hockensmith, 2009).

WATER USE

Water use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Edisto River subbasin for the year 2006 is summarized in Table 7-11 and Figure 7-9. Total offstream water use in the subbasin was 46,958 million gallons in 2006, ranking it ninth among the 15 subbasins. Of this amount, 30,702 million gallons came from surface-water sources (65 percent) and 16,256 million gallons came from ground-water sources (35 percent). Water-supply use accounted for 39 percent of this total, followed by industry (23 percent), thermoelectric power (17 percent), and irrigation (16 percent). Consumptive use in this subbasin is estimated to be 15,299 million gallons, or about 32 percent of the total offstream use.

Surface-water sources provided most of the water for water-supply use in the subbasin (16,534 million gallons, or 89 percent). Ground-water sources supplied 2,007 million gallons (11 percent). Charleston Water System, which serves the city of Charleston and some surrounding areas, was the largest user, withdrawing 11,900 million gallons from the Edisto River in 2006. Orangeburg Department of Public Utilities used 3,485 million gallons from the North Fork Edisto River and the city of Aiken used 743 million gallons from Shaw Creek.

Twenty-nine water supply systems use ground water in the subbasin. The city of Aiken, which has most of their public-supply wells in the Lower Savannah River subbasin, has one well in the Edisto subbasin, which produced 461 million gallons from the Middendorf aquifer in 2006. The town of Edisto Beach used 191 million gallons from a 50-foot thick sandy-limestone formation at the base of the Floridan aquifer system, which is about 550 feet deep. Gilbert-Summit Rural Water District pumped 164 million gallons from shallow sand beds (less than 150 feet deep)—probably part of the outcropping Middendorf and/or Black Creek aquifers—and from the deeper crystalline-rock aquifer.

Table 7-11. Reported water use in the Edisto River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	106	0.3	29	0.2	135	0.3
Industry	9,335	30.4	1,502	9.2	10,837	23.1
Irrigation	2,410	7.8	4,938	30.4	7,348	15.7
Mining	3	0.0	1,891	11.6	1,894	4.3
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	2,313	7.5	5,888	36.2	8,201	17.5
Water supply	16,534	53.9	2,007	12.4	18,542	39.5
Total	30,702		16,256		46,958	

Industrial water use totaled 10,837 million gallons in 2006. Of this amount, 9,335 million gallons (86 percent) came from surface-water sources and 1,502 million gallons (14 percent) came from ground-water sources. MeadWestvaco Corporation in North Charleston was the largest surface-water user, withdrawing 9,168 million gallons. The cement manufacturer Holcim, in Orangeburg County, was the largest ground-water user, pumping 623 million gallons, mostly to dewater their limestone quarries.

Two thermoelectric power plants operate in the subbasin, both owned and operated by SCE&G. Cope Station is a coal-fired plant located in Orangeburg County along the South Fork Edisto River. It has a capacity of 430 MW (megawatts). In 2006, the Cope plant used 5,887 million gallons of water from the Black Creek and Middendorf aquifers, making it the single largest ground-water withdrawer in the State in 2006. Canadys Station is a coal-fired plant located in Colleton County along the Edisto River. It has a capacity of 470 MW. In 2006, it used 2,313 million gallons of water from the Edisto River and a small amount of ground water (0.7 million gallons).

Irrigation water use was 7,348 million gallons in the subbasin, the second highest total in this category behind the Combahee-Coosawhatchie subbasin. Of this amount, 4,938 million gallons came from ground-water sources (67 percent) and 2,410 million gallons came from surface-water sources (33 percent). Super Sod Patten Seed Co. in Orangeburg County had the highest use, pumping 1,995 million gallons, most from the Black Creek aquifer. Millwood Farms in Orangeburg County had the greatest surface-water use, withdrawing 708 million gallons.

Mining water use was 1,894 million gallons in the subbasin, the highest in the State. Nearly this entire amount—1,891 million gallons—came from ground-water sources. All of the ground water was used by Martin Marietta Aggregates at their Orangeburg County quarry, mainly for dewatering operations.

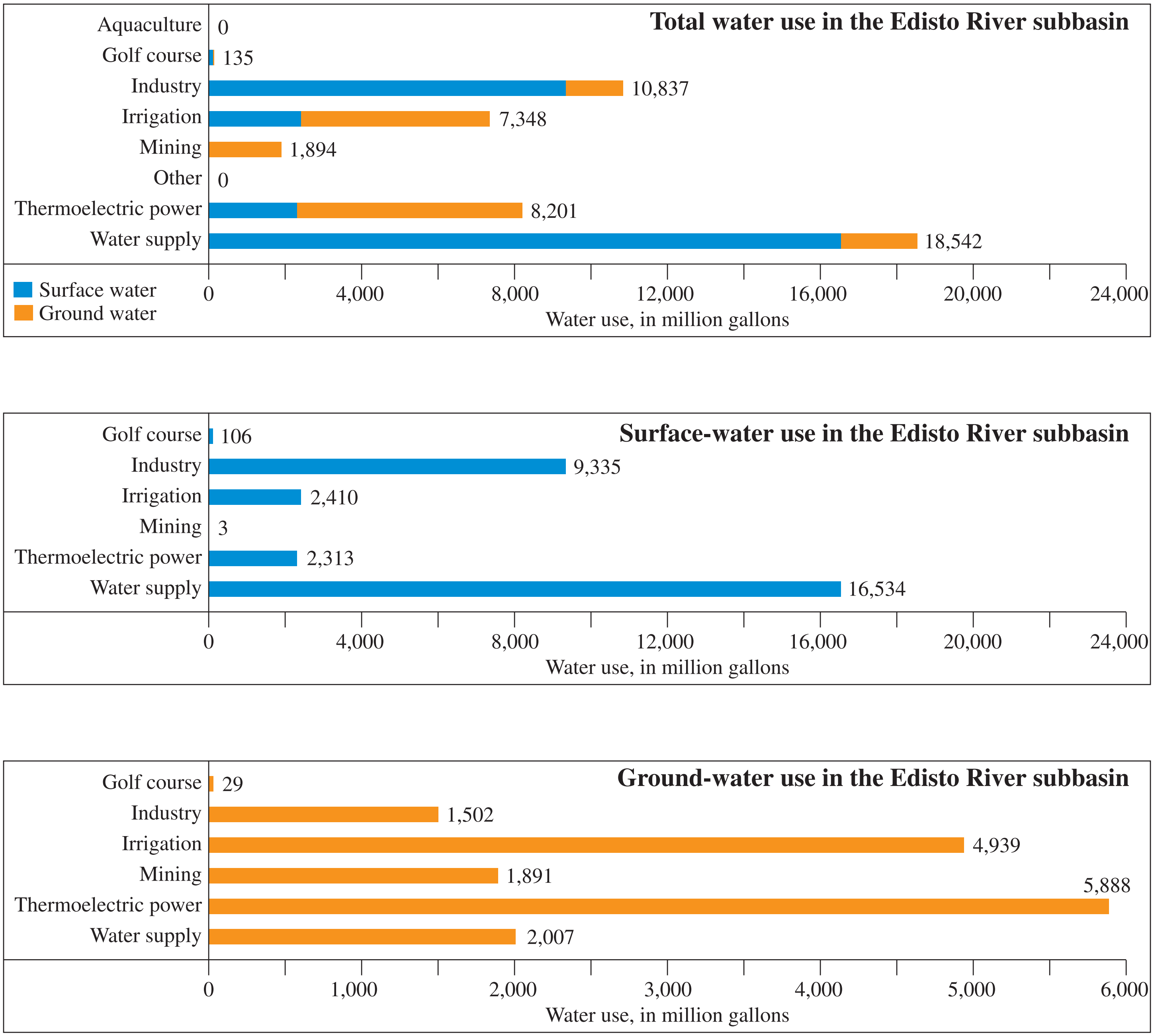
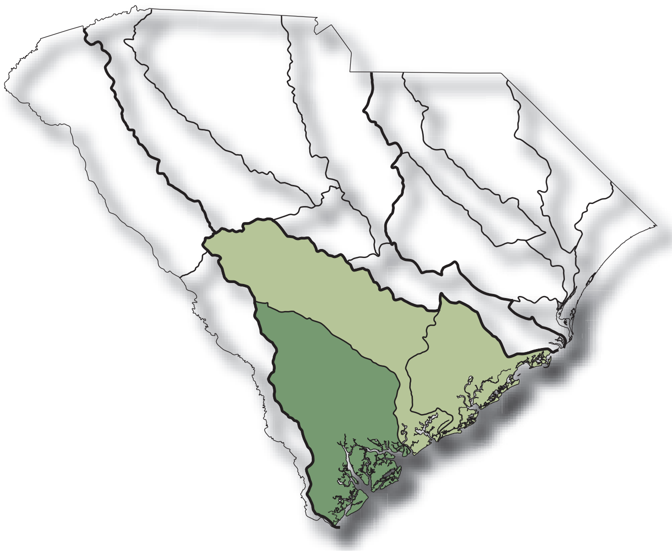


Figure 7-9. Reported water use in the Edisto River subbasin for the year 2006 (modified from Butler, 2007).

COMBAHEE-COOSAWHATCHIE RIVER SUBBASIN



COMBAHEE-COOSAWHATCHIE RIVER SUBBASIN

The Combahee-Coosawhatchie River subbasin is in the southern Coastal Plain region of the State. The subbasin extends 95 miles inland from the Atlantic Ocean and includes all of Beaufort County and parts of Aiken, Allendale, Bamberg, Barnwell, Colleton, Hampton, and Jasper Counties (Figure 7-10). The subbasin area is approximately 3,270 square miles, 10.5 percent of State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 229,300, 5.7 percent of the State's total population. By the year 2020, the subbasin population is expected to reach 273,000, an increase of 19 percent. The highest rate of population growth during this time period is anticipated for Beaufort County, which grew 37 percent between 1990 and 2000.

In general, the subbasin is rural outside of Beaufort County, which is becoming increasingly urbanized. The county includes the affluent retirement and resort community of Hilton Head Island, the State's ninth largest city in 2000. Substantial growth now occurs in the area between Hilton Head Island and Beaufort.

The major centers of 2000 population in the subbasin were Hilton Head Island (33,862), Beaufort (12,950), Laurel Bay (6,625), Barnwell (5,556), Walterboro (5,153), Allendale (4,410), Bamberg (3,733), Denmark (3,328), and Hampton (2,837).

The per capita income of the region in 2005 ranged from $39,308 in Beaufort County, which ranked first among the State's 46 counties, to $18,871 in Allendale County, which ranked last. Of the remaining subbasin counties, only Aiken County had a per capita income as high as the State average ($28,285). Median household incomes for 1999 ranged from the State's highest, $46,992 in Beaufort County, to the State's lowest, $20,898 in Allendale County. Six of the eight counties ranked below the State average ($37,082).

During 2000, the counties of the subbasin had combined annual average employment of nonagricultural wage and salary workers of about 98,000. Labor distribution in the subbasin counties included management, professional, and technical services, 27 percent; sales and office, 25 percent; service, 18 percent; production, transportation, and materials moving, 15 percent; construction, extraction, and maintenance, 14 percent; and farming, fishing, and forestry, 1 percent. Farming, fishing, and forestry employment averaged about four times as great as the State average; management, professional, and technical employment and production-related employment were significantly below State averages.

In the sectors of manufacturing and public utilities, the subbasin counties had a relatively low annual product value of $5.7 billion in 1997, when Aiken County provided nearly 75 percent of manufacturing output. Agricultural production in individual counties was generally less than $15 million, although Aiken County accounted for $59 million. The year 2003 delivered value of timber was about $125 million in the eight subbasin counties; Colleton County, which ranked fourth in the State, delivered $32.4 million (South Carolina Budget and Control Board, 2005).

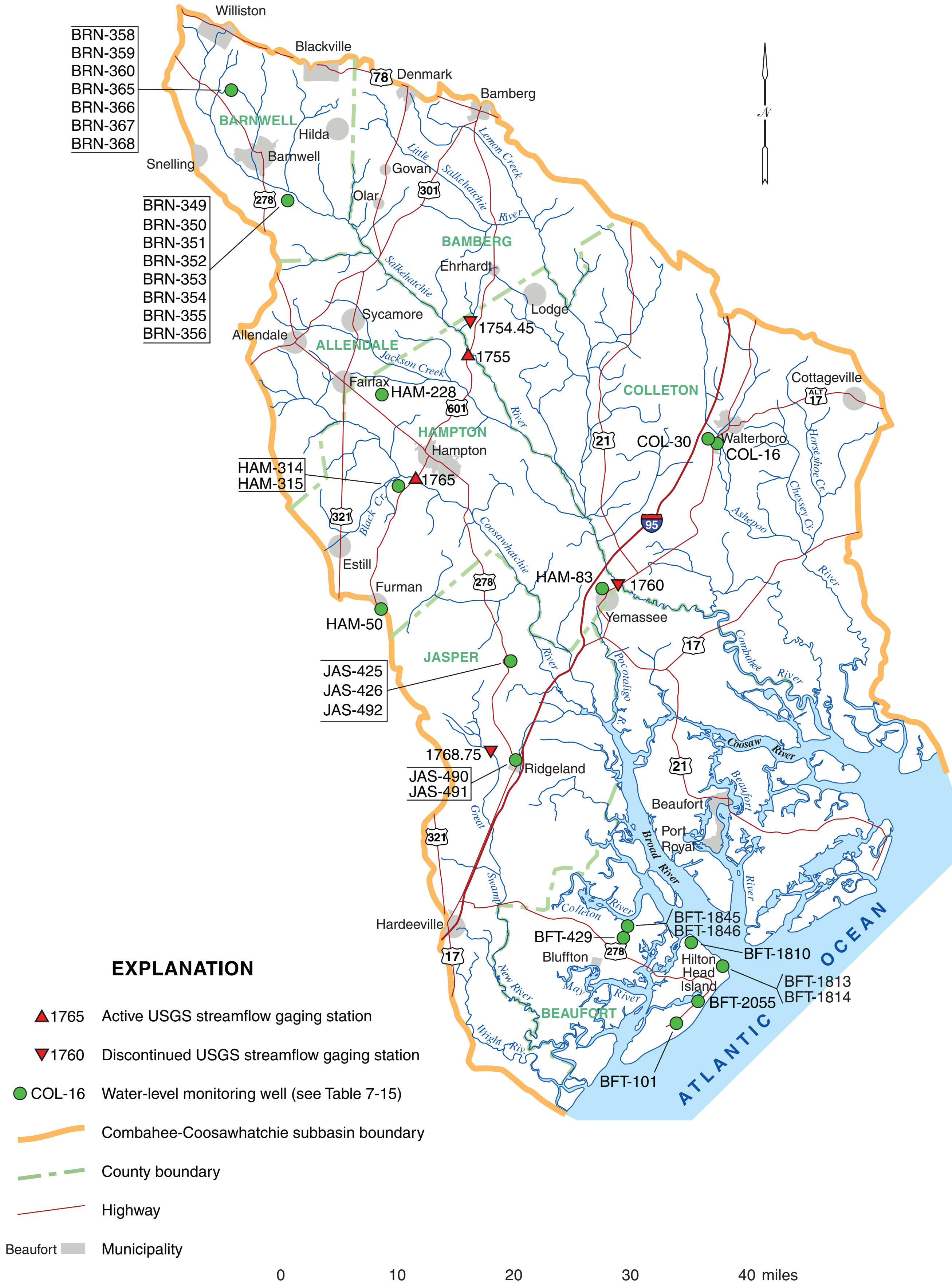


Figure 7-10. Map of the Combahee-Coosawhatchie River subbasin.

SURFACE WATER

Hydrology

The major streams draining this mostly middle and lower Coastal Plain subbasin are the Salkehatchie River, Coosawhatchie River, and Ashepoo River. The Salkehatchie and Little Salkehatchie Rivers join to form the tidally-influenced Combahee River. The Coosawhatchie River discharges into the Broad River, a tidal saltwater river that also receives drainage from surrounding marshlands. The coastal area of this subbasin contains the most extensive estuarine water bodies in the State. These coastal water bodies are dominated by St. Helena Sound and Port Royal Sound and include numerous, often interconnecting, tidal creeks and rivers.

Streamflow has been monitored on the Salkehatchie and Coosawhatchie Rivers since 1951. A gage was also in operation for several years in the 1950's on the Combahee River near Yemassee. Another gage was in operation on Great Swamp from 1977 to 1984. Streamflow statistics of these active and discontinued gaging stations are presented in Table 7-12. Several stage-only gages are in operation on the Broad River.

Table 7-12. Selected streamflow characteristics at USGS gaging stations in the Combahee-Coosawhatchie River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Savannah Creek at Ehrhardt 1754.45	2001 to 2003	2.2	4.3	1.96	0.23	0.11 2002	96 2003	– – –
Salkehatchie River near Miley 1755	1951 to 2007*	341	337	0.99	91	2.9 2002	3,390 1992	4,360 1992
Combahee River near Yemassee 1760	1951 to 1957	1,100	483	0.44	60	9.0 1954	5,070 1955	– – –
Coosawhatchie River near Hampton 1765	1951 to 2007*	203	169	0.83	2.2	0.0 many years	6,590 1969	8,910 1992
Great Swamp near Ridgeland 1768.75	1977 to 1984	48.8	31	0.64	0.0	0.0 many years	1,950 1984	– – –

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Average-annual streamflow of the Salkehatchie River near Miley is 337 cfs (cubic feet per second) and can be expected to be at least 91 cfs 90 percent of the time. Streamflow at this site is relatively steady and well-sustained (Figure 7-11), probably due to discharges from ground-water storage and from several headwater streams in the upper Coastal Plain region. Flow at this site rarely exceeds 1,000 cfs; the maximum flood flow of record—4,360 cfs—was recorded in 1992.

Streamflow in the Coosawhatchie River is more variable than in the Salkehatchie River (Figure 7-11). Average annual flow of this river near Hampton is 169 cfs, and the flow can be expected to equal or exceed 2.2 cfs 90 percent of the time. This stream is entirely contained in the middle and lower Coastal Plain and is, therefore, dependent on rainfall and runoff from the area's low-lying and highly-permeable terrain to support streamflow. Flow in the Coosawhatchie River can diminish greatly during summer months, and periods of no flow have been recorded numerous times since 1951. Flow at this site rarely exceeds 1,000 cfs; the maximum flood flow of record—8,910 cfs—was recorded in 1992.

Although the period of record for streamflow data on Great Swamp is short, the data collected indicate characteristics typical of lower Coastal Plain streams, including several periods of no flow during summer months.

The quantity of fresh surface water available in this subbasin is limited. Available streamflow in the upper portion of the Salkehatchie River is reliable, but flow downstream in the middle and lower Coastal Plain region

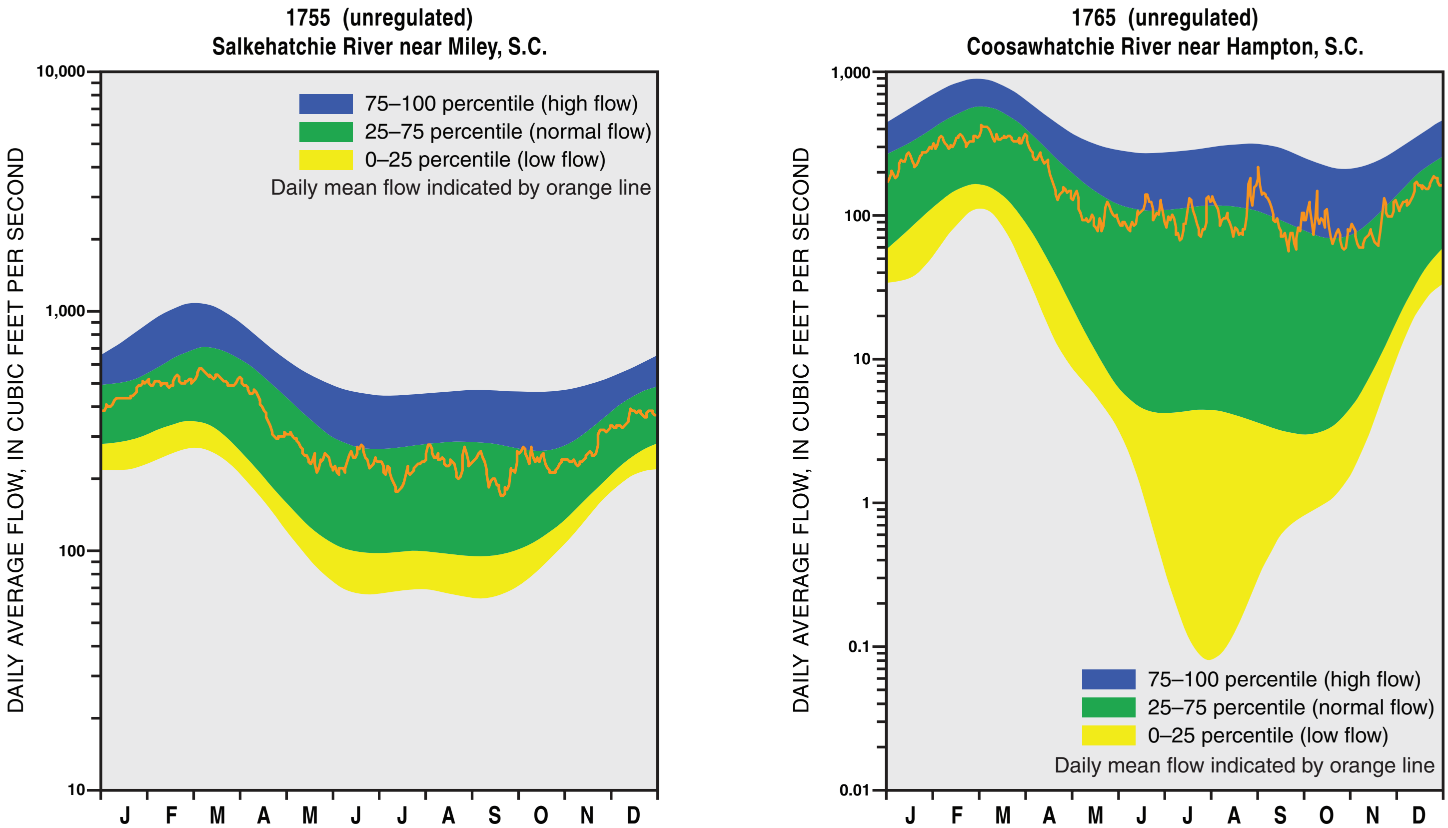


Figure 7-11. Duration hydrographs for selected gaging stations in the Combahee-Coosawhatchie River subbasin.

may be subject to greater variability. Available streamflow in the Coosawhatchie River and Great Swamp is extremely limited and unreliable since flow is often nonexistent during summer and fall months.

Development

Surface-water development in the Combahee-Coosawhatchie River subbasin consists primarily of navigation projects in tidal water bodies and some flood-control projects.

The subbasin contains no large reservoirs, and the largest lake is an unnamed pond near the Ashepoo River with a surface area of 800 acres and a volume of 2,400 acre-ft. Lake Warren on Black Creek near the town of Hampton has a surface area of 600 acres and a volume of 3,600 acre-ft. The total surface area of all lakes larger than 10 acres is about 7,000 acres, and total volume is approximately 29,000 acre-ft (U.S. Army Corps of Engineers, 1991). No hydroelectric-power facilities occur in the subbasin.

The U.S. Army Corps of Engineers (COE) has conducted extensive navigation projects in the subbasin, concentrated primarily near the coast. Channels are maintained through Port Royal Sound, the Beaufort River, and Battery Creek for the port of Port Royal. The COE also maintains a long section of the Atlantic Intracoastal Waterway.

The Willow Swamp watershed of Colleton and Bamberg Counties and upper New River in Jasper County are areas of past Natural Resources Conservation Service flood-control projects. Willow Swamp has had 37 miles of channel improvement and the New River has had 28 miles of channel improvement. Beaufort County has undertaken many smaller-scale flood-control projects.

Surface-Water Quality

Surface-water bodies in the Combahee-Coosawhatchie River subbasin encompass five water-use classifications (DHEC, 2003d). Parts of the Colleton River and the mouth of the May River are designated as "Outstanding Resource Water" (Class ORW), which are saltwater bodies that constitute outstanding recreational or ecological resources.

Portions of the New River and the Beaufort River are designated "Tidal Saltwater" (Class SA). Class SA water bodies are tidal saltwater bodies suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora and for primary- and secondary-contact recreation, crabbing, and fishing. These water bodies are not protected for harvesting clams, mussels, or oysters for market purposes or human consumption. Class SA waters must always have dissolved-oxygen concentrations at or greater than 4.0 mg/L (milligrams per liter) and have daily average dissolved-oxygen levels of at least 5.0 mg/L.

A portion of Bees Creek is classified as "Tidal Saltwater" (Class SB). Class SB water bodies are the same as Class SA water bodies, except that Class SB waters must only maintain dissolved-oxygen concentrations of at least 4.0 mg/L.

A large number of water bodies in the coastal reaches of the subbasin are designated "Shellfish Harvesting" (Class SFH). These tidal saltwater bodies are protected for shellfish harvesting and have the most stringent bacterial standards. Class SFH water bodies include parts of the Combahee River, the lower Ashepoo River, Coosawhatchie River, Pocotaligo River, Chechessee River, Whale Branch, Coosaw River, Beaufort River, Calibogue Sound, Broad Creek, part of Port Royal Sound, the mouth of Skull Creek, and the mouth of May River.

All other water bodies in this subbasin are designated "Freshwater" (Class FW). Class FW water bodies are suitable for survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses.

As part of its ongoing Watershed Water Quality Assessment program, DHEC sampled 68 sites in the Combahee-Coosawhatchie subbasin between 1996 and 2000 in order to assess the water's suitability for aquatic life and recreational use (Figure 7-12). Aquatic life was fully supported at 49 sites, or 72 percent of the water bodies sampled; most of the impaired sites exhibited low dissolved-oxygen levels. Recreational use was fully supported in 61 percent of the sampled water bodies; water bodies that did not fully support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2003d). Water-quality impairments in the subbasin are summarized in Table 7-13. Because of high phosphorus levels, Lake Edgar Brown in Barnwell County is one of the most eutrophic small lakes in South Carolina.

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes the most recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in several prior years, DHEC issued fish-consumption advisories for the Coosawhatchie River in Jasper County; the Salkehatchie River from U.S. Highway 301 to the Combahee River; the entire Little Salkehatchie River; the Combahee River from the Salkehatchie River to U.S. Highway 17; the Ashley River from Walterboro to U.S. Highway 17; part of New River (Great Swamp) in Jasper County; and Cuckolds, Chessey, and Horseshoe Creeks in Colleton County. Fish-consumption advisories are issued in areas where fish are contaminated with mercury; the contamination is only in the fish and does not make the water unsafe for swimming or boating.

GROUND WATER

Hydrogeology

The Combahee-Coosawhatchie River subbasin is in the lower Coastal Plain. Ground water in the subbasin is available from six aquifers: the Cape Fear, Middendorf, Black Creek, Tertiary sand, Floridan, and shallow aquifers. Table 7-14 lists the depths and yields of major wells in the subbasin. This subbasin is part of the most intensely studied and monitored region of South Carolina, outside of the Savannah River Site.

The Cape Fear and Middendorf aquifers are not generally used for water supply, primarily because of their depths and the availability of water from shallower aquifers. The top of the Middendorf extends from about 600 feet below land surface at Williston to nearly 3,000 feet on the coast. At Walterboro, in Colleton County, two wells screened between the depths of 1,602 and 1,760 feet flowed at a rate of more than 1,000 gpm (gallons per minute) in the 1970's. A 3,400-foot public-supply well on Hilton Head Island is screened in the Cape Fear and Middendorf aquifers and produces about 2 million gallons per day; water from this well is treated by reverse osmosis and blended with water from the Floridan aquifer.

The Black Creek aquifer has been tapped by a few wells near the upper end of the subbasin where the top of this aquifer is at a depth of approximately 400 feet. It is below 2,000 feet near the coast. In Beaufort County, the Black Creek aquifer consists of about 800 feet of sediment that is mostly clay. In Allendale, Barnwell, Colleton, and Hampton Counties, several large-diameter municipal and irrigation wells withdraw water from this aquifer, with yields in excess of 1,000 gpm.

The Tertiary sand aquifer beneath the subbasin mainly consists of the Black Mingo Formation. The top of the Tertiary sand aquifer ranges in depth from 400 feet in Allendale County to 1,200 feet near Beaufort, where the aquifer is about 250 feet thick. Fine-grained sediments such as clay or clayey limestone comprise much of the aquifer in coastal areas. In Hampton and Colleton Counties, the top of the aquifer ranges from 500 to 1,000 feet in depth and wells usually yield less than 500 gpm.

The Floridan aquifer is the main source of ground water in all but the upper end of the subbasin. Wells 50 to 900 feet deep tap this aquifer and provide most of the ground water used. The thickness of the Floridan aquifer ranges from 500 feet in Hampton and Colleton Counties to 1,000 feet at Hilton Head Island.

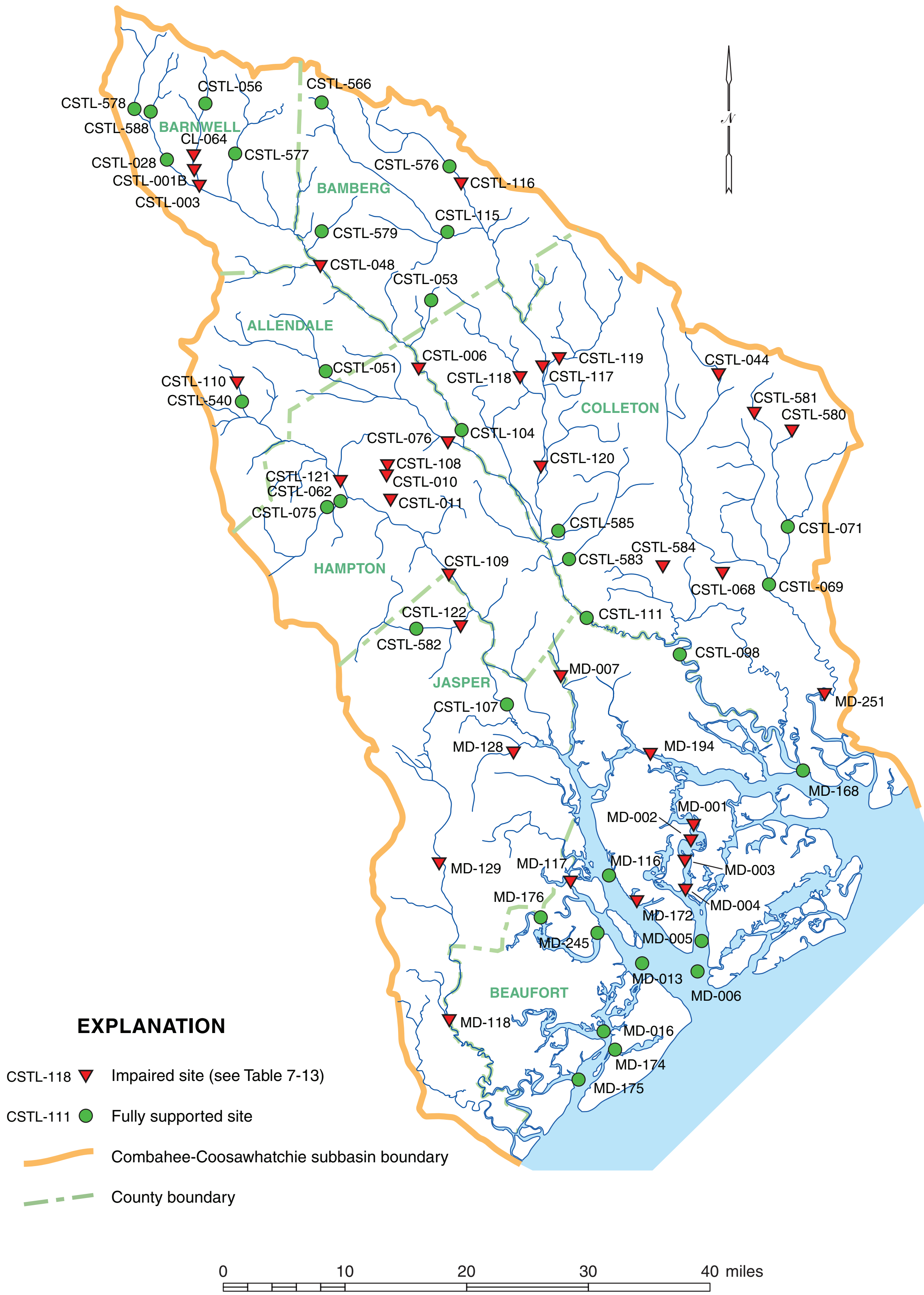


Figure 7-12. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 7-13 (DHEC, 2003d).

Table 7-13. Water-quality impairments in the Combahee-Coosawhatchie River subbasin (DHEC, 2003d)

Water-body name	Station number	Use	Status	Water-quality indicator
Turkey Creek	CSTL-001B	Recreation	Partially supporting	Fecal coliform
Lake Edgar Brown	CL-064	Aquatic life	Nonsupporting	Chlorophyll-*a*
Salkehatchie River	CSTL-003	Recreation	Partially supporting	Fecal coliform
	CSTL-048	Recreation	Partially supporting	Fecal coliform
	CSTL-006	Recreation	Partially supporting	Fecal coliform
Whippy Swamp	CSTL-076	Recreation	Partially supporting	Fecal coliform
Lemon Creek	CSTL-116	Recreation	Partially supporting	Fecal coliform
Little Salkehatchie River	CSTL-117	Recreation	Partially supporting	Fecal coliform
Buckhead Creek	CSTL-119	Recreation	Nonsupporting	Fecal coliform
Willow Swamp	CSTL-118	Recreation	Nonsupporting	Fecal coliform
Little Salkehatchie River	CSTL-120	Recreation	Partially supporting	Fecal coliform
Ireland Creek	CSTL-044	Recreation	Nonsupporting	Fecal coliform
Bluehouse Swamp	CSTL-584	Aquatic life	Nonsupporting	Macroinvertebrates
Fuller Swamp Creek	CSTL-581	Aquatic life	Nonsupporting	Macroinvertebrates
Chessey Creek	CSTL-580	Aquatic life	Nonsupporting	Macroinvertebrates
Ashepoo River	CSTL-068	Recreation	Partially supporting	Fecal coliform
	MD-251	Aquatic life	Nonsupporting	Turbidity
Coosawhatchie River	CSTL-110	Aquatic life	Partially supporting	Dissolved oxygen
	CSTL-121	Aquatic life	Nonsupporting	Dissolved oxygen
Sanders Branch	CSTL-108	Recreation	Nonsupporting	Fecal coliform
	CSTL-010	Recreation	Partially supporting	Fecal coliform
	CSTL-011	Aquatic life	Partially supporting	Macroinvertebrates, dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Coosawhatchie River	CSTL-109	Aquatic life	Nonsupporting	Dissolved oxygen, pH
Bees Creek	MD-128	Aquatic life	Partially supporting	Dissolved oxygen, pH
		Recreation	Partially supporting	Fecal coliform
Cypress Creek	CSTL-122	Recreation	Partially supporting	Fecal coliform
Pocotaligo River	MD-007	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Broad River	MD-172	Aquatic life	Partially supporting	Dissolved oxygen
Chechessee River	MD-117	Aquatic life	Nonsupporting	Dissolved oxygen
Beaufort River	MD-001	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-002	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-003	Aquatic life	Nonsupporting	Dissolved oxygen
	MD-004	Aquatic life	Nonsupporting	Dissolved oxygen
Whale Branch	MD-194	Aquatic life	Nonsupporting	Dissolved oxygen
Great Swamp	MD-129	Recreation	Partially supporting	Fecal coliform
New River	MD-118	Aquatic life	Nonsupporting	pH
		Recreation	Nonsupporting	Fecal coliform

Table 7-14. Selected ground-water data for the Combahee-Coosawhatchie River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Allendale-Fairfax	Floridan (shallow wells), Tertiary sand or Black Creek (deep wells)	350–1,040	400–1,250
Barnwell		270–320	250–500
Blackville		300–470	300–2,000
Bamberg-Denmark		160–1,000	200–2,150
Williston		450–900	1,350
Hampton	Tertiary sand	700–1,000	400–3,000
Estill	Floridan	180–300	500–2,050
	Black Creek	1,015	800
Walterboro	Floridan (lower) / Tertiary sand	492–563	280–300
	Middendorf	1,680–1,760	1,200–1,430
Edisto Beach	Floridan (lower)	514–570	390–450
Hilton Head Island	Floridan (upper)	195–240	920–1,500
	Middendorf / Cape Fear	3,832	1,209

Many large wells in southwestern Beaufort, Hampton, and Jasper Counties produce water from the Ocala Limestone section of the Floridan aquifer. They range in depth from 40 to 500 feet. Beaufort County has, by far, the most wells in the Floridan aquifer. Nearly 70 pumping tests, at discharge rates of 40 to 2,900 gpm, indicated transmissivity as high as 106,000 ft^2/day. More than half of the tests showed transmissivity greater than 10,000 ft^2/day. Six Floridan-aquifer pumping tests from wells in Hampton County indicate transmissivity values from 1,200 to 12,000 ft^2/day and yields from 100 to 1,500 gpm. Jasper County, with 11 pumping tests, had the consistently highest transmissivity values, all between 35,000 and 67,000 ft^2/day, and well yields of 260 to 1,600 gpm.

The shallow aquifer encompasses the Hawthorn and Duplin Formations and various Pleistocene deposits and is developed by 25- to 60-foot wells. Ten pumping tests yielded transmissivity values from 150 to 2,100 ft^2/day. Well yields were 75 gpm or less. This aquifer is a source of domestic water supplies in coastal areas where the underlying Floridan aquifer is brackish.

Ground-Water Quality

Water quality in the Middendorf aquifer varies throughout the subbasin. In the upper reaches, the water quality is good; the water is a dilute sodium chloride type with a TDS (total dissolved solids) concentration near 50 mg/L (milligrams per liter) and pH of about 6.5. Downdip, the ground water becomes increasingly mineralized and alkaline; TDS concentrations exceed 1,000 mg/L and pH values are between 8.0 and 8.5. Chloride concentrations exceed 250 mg/L and a fluoride concentration of 8.5 mg/L was found in a Fripp Island well in Beaufort County (Speiran and Aucott, 1994).

Water quality in the Black Creek aquifer is similar to that of the Middendorf aquifer, and, like the Middendorf, it becomes more mineralized downgradient. Total dissolved solids range from 50 mg/L in the upper part of the subbasin to 200 mg/L in southern Allendale County and greater than 2,500 mg/L near the coast. Sodium and chloride concentrations increase from about 3 to 1,000 mg/L, alkalinity increases from less than 25 to more than 1,000 mg/L, and pH values increase from about 5.5 to more than 7.5 (Speiran and Aucott, 1994; Logan and Euler, 1989). Samples taken during drilling projects showed chloride concentrations of 440 and 1,100 mg/L at Parris Island and Fripp Island, respectively (Siple, 1956; Hayes, 1979).

Dissolved-iron concentrations of 1.0 mg/L are present in Cretaceous aquifers in Bamberg County. Iron concentrations diminish southeast of this zone to less than 0.1 mg/L between Walterboro and the coast (Lee, 1988).

The Tertiary sand aquifer is present in the upper reaches of the subbasin. Water from this aquifer has low TDS (usually less than 50 mg/L), is acidic, and locally is high in iron. Hydrogen sulfide gas is present in some areas. Downdip, the water evolves into a calcium bicarbonate type as sediments become more calcareous and TDS, alkalinity, and pH increase (Logan and Euler, 1989).

The Floridan aquifer is the most widely-used aquifer in the middle and lower reaches of the subbasin. Its water is a calcium bicarbonate type with a pH between 7.5 and 8, TDS concentration less than 200 mg/L, and hardness usually less than 140 mg/L (as $CaCO_3$) (Hayes, 1979). Dissolved solids tend to increase downdip except near Allendale, where TDS decrease because of local recharge (Logan and Euler, 1989).

In the coastal areas, water quality in the Floridan aquifer varies with proximity to saltwater. In Beaufort County, chloride concentrations are 100 to 7,000 mg/L in the lower and middle Floridan permeable zones (Hughes and others, 1989). In the upper permeable zone, chloride concentrations are less than 10 mg/L inland of the Sea Islands and 25 to 100 mg/L beneath most of St. Helena and Hilton Head Islands, but exceed 10,000 mg/L beneath areas of the Port Royal Sound estuary (see the *Special Topics* chapter). Brackish water is present beneath the tidal streams between St. Helena Sound and Port Royal Sound; the islands are underlain by freshwater lenses that have low TDS concentrations, are moderately hard, and commonly contain dissolved iron in concentrations above 0.3 mg/L and hydrogen sulfide.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR, DHEC, and USGS in 35 wells within the Combahee-Coosawhatchie subbasin (Table 7-15). Water levels in other wells in the subbasin are sometimes measured to help develop potentiometric maps of the Middendorf, Black Creek, and Floridan aquifers.

The Floridan aquifer is the source of most ground water in this subbasin, and years of pumping from this aquifer have significantly changed the aquifer's potentiometric surface in the lower part of the subbasin. Whereas predevelopment water levels were estimated to be above sea level throughout the subbasin, water levels are now at or below sea level in most of the coastal areas (Figure 7-13). Although some of this water-level decline stems from pumping in Beaufort, Colleton, and Charleston Counties, much of the decline is due to pumping from the Floridan aquifer at Savannah, Georgia. A large cone of depression has developed around Savannah, where water levels in the aquifer that were originally 10 to 35 feet above sea level in 1880 were as low as 140 feet below sea level in 2004. In 2004, the lowest point on the Floridan potentiometric surface in South Carolina, in southern Jasper County, was 57 feet below sea level, about 80 feet below the predevelopment level (Hockensmith, 2009).

The Floridan water-level decline has changed the original direction of ground-water movement from a southeasterly flow toward Port Royal Sound to a southwesterly flow toward Savannah. Lower water levels in the aquifer along the coast and the change in ground-water flow direction have allowed for the lateral and vertical movement of saltwater into the aquifer beneath Edisto Beach, Hilton Head Island, and in Port Royal Sound in southern Beaufort County. Research by DHEC and the USGS has shown that brackish water is moving from marshlands and tidal streams toward the top of the Floridan aquifer in areas northeast of Savannah. This vertical contamination will affect water quality at Savannah well in advance of the lateral saltwater migration from Port Royal Sound (see the *Special Topics* chapter). Continued pumping of the Floridan aquifer near the Savannah cone of depression may also lead to permanent degradation of the aquifer by causing compaction of overlying confining beds.

WATER USE

Water-use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Combahee-Coosawhatchie subbasin is summarized in Table 7-16 and Figure 7-14. Offstream water use in the subbasin was 20,249 million gallons in 2006, ranking it eleventh among the 15 subbasins. Of this amount, 16,684 million gallons were from ground-water sources (82 percent) and 3,564 million gallons were from surface-water sources (18 percent). Irrigation accounted for 45 percent of the total use, followed by water supply (35 percent) and golf course (17 percent). Consumptive use in this subbasin is estimated to be 12,108 million gallons, or about 60 percent of the total offstream use.

Irrigation water use in the subbasin was 9,024 million gallons in 2006, the highest in the State. Of this amount, 7,563 million gallons were from ground-water sources (84 percent) and 1,461 million gallons were from surface-water sources (16 percent). Sixty-two withdrawers reported water use in 2006. Williams Farms, in Colleton County, was the largest ground-water irrigator, withdrawing 1,877 million gallons. Using almost as much was Oswald Farms, in Allendale County, which pumped 1,843 million gallons, mainly from the Black Creek aquifer. Sharp and Sharp Certified Seed, in Allendale County, withdrew 474 million gallons from surface-water sources.

Water-supply use in the subbasin was 7,125 million gallons, all of it supplied by ground water. Several facilities operated by the South Island Public Service District in Beaufort County collectively used about 2,400 million gallons from the Floridan aquifer, and the Hilton Head Public Service District used 1,112 million gallons from the Floridan aquifer. Other ground-water systems of note are Broad Creek Public Service District (568 million gallons from the Floridan aquifer), the city of Walterboro (555 million gallons from the Floridan and Middendorf aquifers), and the city of Barnwell (393 million gallons from the Tertiary sand aquifer).

Golf-course irrigation is a major use of water in the subbasin, ranking second only to the Waccamaw River subbasin in this category. A total of 3,394 million gallons were used at 41 golf courses in 2006. Of this amount, 2,056 million gallons came from surface-water sources (61 percent) and 1,338 million gallons came from ground-water sources (39 percent). Most of the ground water was

Table 7-15. Water-level monitoring wells in the Combahee-Coosawhatchie River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
BFT-101	DNR	32 10 05 80 44 26	Floridan	Hilton Head Island	14	129–470
BFT-429	DNR	32 15 50 80 49 11	Floridan	Victoria Bluff Wildlife Mgmt. Area, Bluffton	22	119–300
BFT-1810	USGS	32 16 03 80 43 22	Floridan	Hilton Head Island	14	105–199
BFT-1813	DNR	32 13 58 80 40 38	Floridan	Hilton Head Island	12	280–600
BFT-1814	DNR	32 13 58 80 40 38	Floridan	Hilton Head Island	12	120–210
BFT-1845	DNR	32 16 49 80 49 17	Floridan	Waddell Mariculture Center, Bluffton	12	320–600
BFT-1846	DNR	32 16 50 80 49 18	Floridan	Waddell Mariculture Center, Bluffton	12	85–180
BFT-2055	DNR	32 11 28 80 42 15	Cape Fear	Hilton Head Island	10	2,782–3,688
BRN-349	DNR	33 10 44 81 18 51	Middendorf	DNR cluster site C-6, near Kline	209	1,030–1,040
BRN-350	DNR	33 10 45 81 18 54	Tertiary sand	DNR cluster site C-6, near Kline	207	155–165
BRN-351	DNR	33 10 43 81 18 53	Tertiary sand	DNR cluster site C-6, near Kline	207	80–90
BRN-352	DNR	33 10 44 81 18 53	Tertiary sand	DNR cluster site C-6, near Kline	207	278–288
BRN-353	DNR	33 10 43 81 18 54	Black Creek	DNR cluster site C-6, near Kline	208	573–583
BRN-354	DNR	33 10 44 81 18 54	Gordon	DNR cluster site C-6, near Kline	208	396–406
BRN-355	DNR	33 10 44 81 18 55	Crouch Branch	DNR cluster site C-6, near Kline	208	686–696
BRN-356	DNR	33 10 43 81 18 56	McQueen Branch	DNR cluster site C-6, near Kline	209	914–924
BRN-358	DNR	33 19 14 81 24 28	Middendorf	DNR cluster site C-5, near Barnwell	266	832–842
BRN-359	DNR	33 19 16 81 24 27	Tertiary sand	DNR cluster site C-5, near Barnwell	266	199–209
BRN-360	DNR	33 19 15 81 24 27	Tertiary sand	DNR cluster site C-5, near Barnwell	264	125–134
BRN-365	DNR	33 19 15 81 24 28	Black Creek	DNR cluster site C-5, near Barnwell	264	524–534
BRN-366	DNR	33 19 14 81 24 28	Black Creek	DNR cluster site C-5, near Barnwell	267	700–710
BRN-367	DNR	33 19 15 81 24 28	Tertiary sand	DNR cluster site C-5, near Barnwell	264	270–280
BRN-368	DNR	33 19 14 81 24 28	Black Creek	DNR cluster site C-5, near Barnwell	265	428–438
COL-16	DNR	32 53 55 80 39 57	Floridan	Walterboro	62	68–528
COL-30	DNR	32 53 45 80 40 40	Black Creek	Walterboro	61	undetermined

Table 7-15. Continued

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
HAM-50	DNR	32 40 48 81 11 20	Black Mingo	Furman	110	undetermined
HAM-83	USGS	32 41 52 81 51 04	Floridan	Yemassee	46	86–156
HAM-228	DNR	32 56 52 81 11 50	Floridan	Brunson	128	undetermined
HAM-314	DHEC	32 49 49 81 09 57	Floridan	Lake Warren State Park	112	88–122
HAM-315	DHEC	32 49 49 81 09 57	Floridan	Lake Warren State Park	112	200–568
JAS-425	DNR	32 37 04 80 59 45	Floridan	DNR cluster site C-15, Gillisonville	65	150–255
JAS-426	DNR	32 37 06 80 59 45	Middendorf	DNR cluster site C-15, Gillisonville	63	1,949–1,994
JAS-490	DHEC	32 28 54 80 58 22	Floridan	Ridgeland	40	288–558
JAS-491	DHEC	32 28 54 80 58 22	Floridan	Ridgeland	40	144–220
JAS-492	DNR	32 37 06 80 59 45	Floridan	DNR cluster site C-15, Gillisonville	65	300–600

* *DHEC, South Carolina Department of Health and Environmental Control; DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

pumped from the Floridan aquifer. Some of the larger users are the Colleton River Plantation Nicholas Golf Course in Beaufort County (290 million gallons), Belfair Plantation in Beaufort County (219 million gallons), and Dataw Island Club in Beaufort County (169 million gallons).

AQUIFER STORAGE AND RECOVERY PROGRAMS

The concept of an aquifer storage and recovery (ASR) program is to treat more surface water than is needed during times of low demand, inject the excess treated water into an aquifer, store it in the ground until the demand for water is high, and then pump the water out of the ground when it can be used to supplement surface-water supplies. ASR wells can provide water for short-term, high-demand periods, which can allow water systems to meet user demands with smaller treatment plants, thereby reducing the overall cost of providing the water. Additionally, the use of an ASR system can reduce water-production costs by allowing treatment plants to operate more efficiently by stabilizing plant production to an optimum flow rate and by treating more surface water in the winter, when the water quality is better than in the summer and is thus less expensive to treat.

The Beaufort-Jasper Water and Sewer Authority (BJWSA), which provides water to much of Beaufort and Jasper Counties, has one of the four active ASR programs in South Carolina. BJWSA, which primarily uses surface water from the Savannah River, has three ASR wells as part of its water system, all completed in the Floridan aquifer. Two of the wells are located at their Chelsea Water Treatment Plant; at this site, one well is used for injection and both wells are used for recovery. Combined, the two wells yield 3.0 million gallons per day. A third ASR well, with a capacity to yield 2.5 million gallons per day, is located at their Purrysburg Water Treatment Plant. BJWSA injects treated surface water during the fall and winter, and withdraws water to meet peak demands during the spring and summer months. A total of 300 million gallons of treated water from the Savannah River is injected and stored in the aquifer each year.

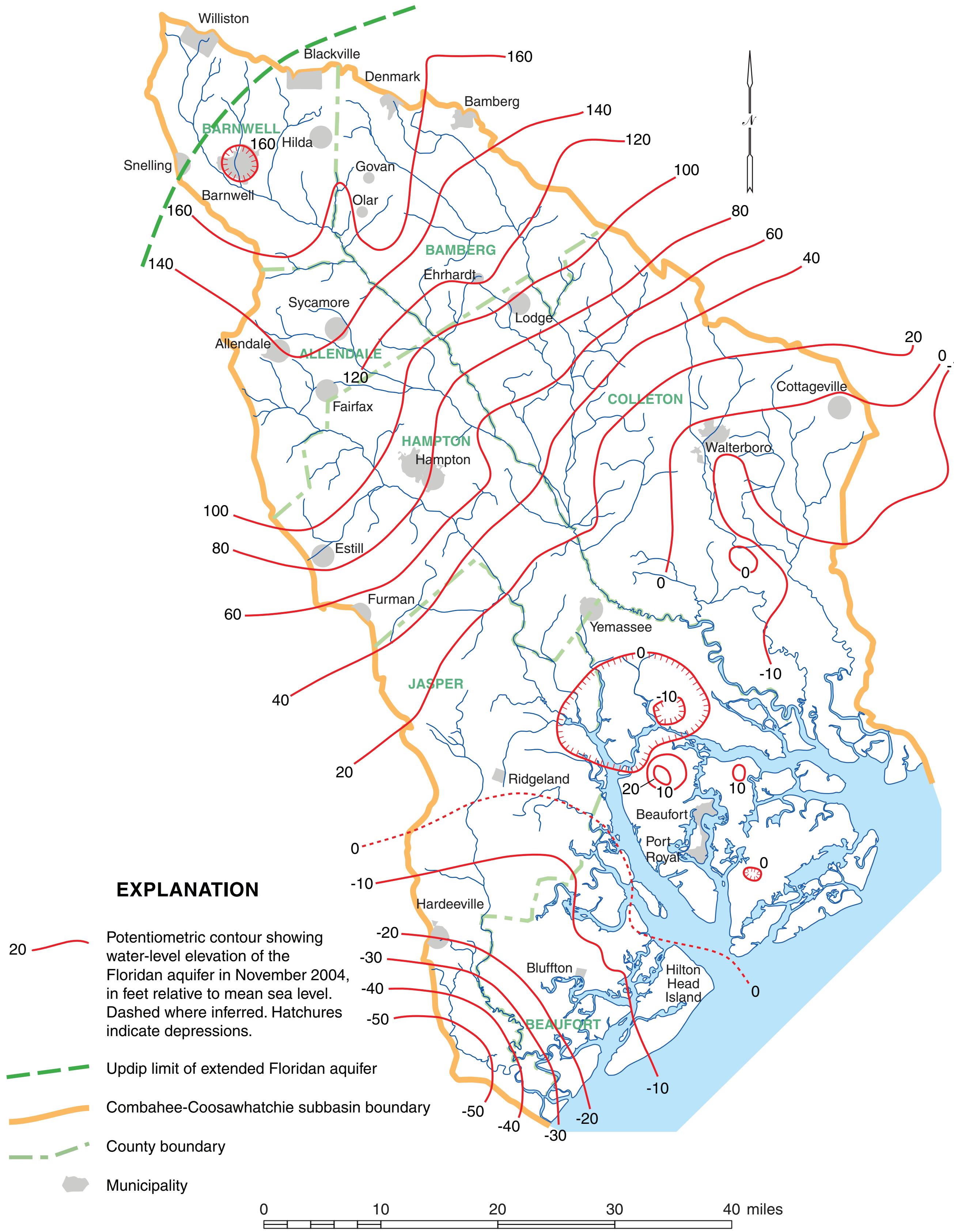


Figure 7-13. Potentiometric contours of the Floridan aquifer in the Combahee-Coosawhatchie River subbasin, November 2004 (from Hockensmith, 2009).

Table 7-16. Reported water use in the Combahee-Coosawhatchie River subbasin for the year 2006 (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	47	1.3	95	0.6	143	0.7
Golf course	2,056	57.7	1,338	8.0	3,394	16.8
Industry	0	0.0	530	3.2	530	2.6
Irrigation	1,461	41.0	7,563	45.3	9,024	44.6
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	33	0.2	33	0.2
Thermoelectric power	0	0.0	0	0.0	0	0.0
Water supply	0	0.0	7,125	42.7	7,125	35.2
Total	3,564		16,684		20,249	

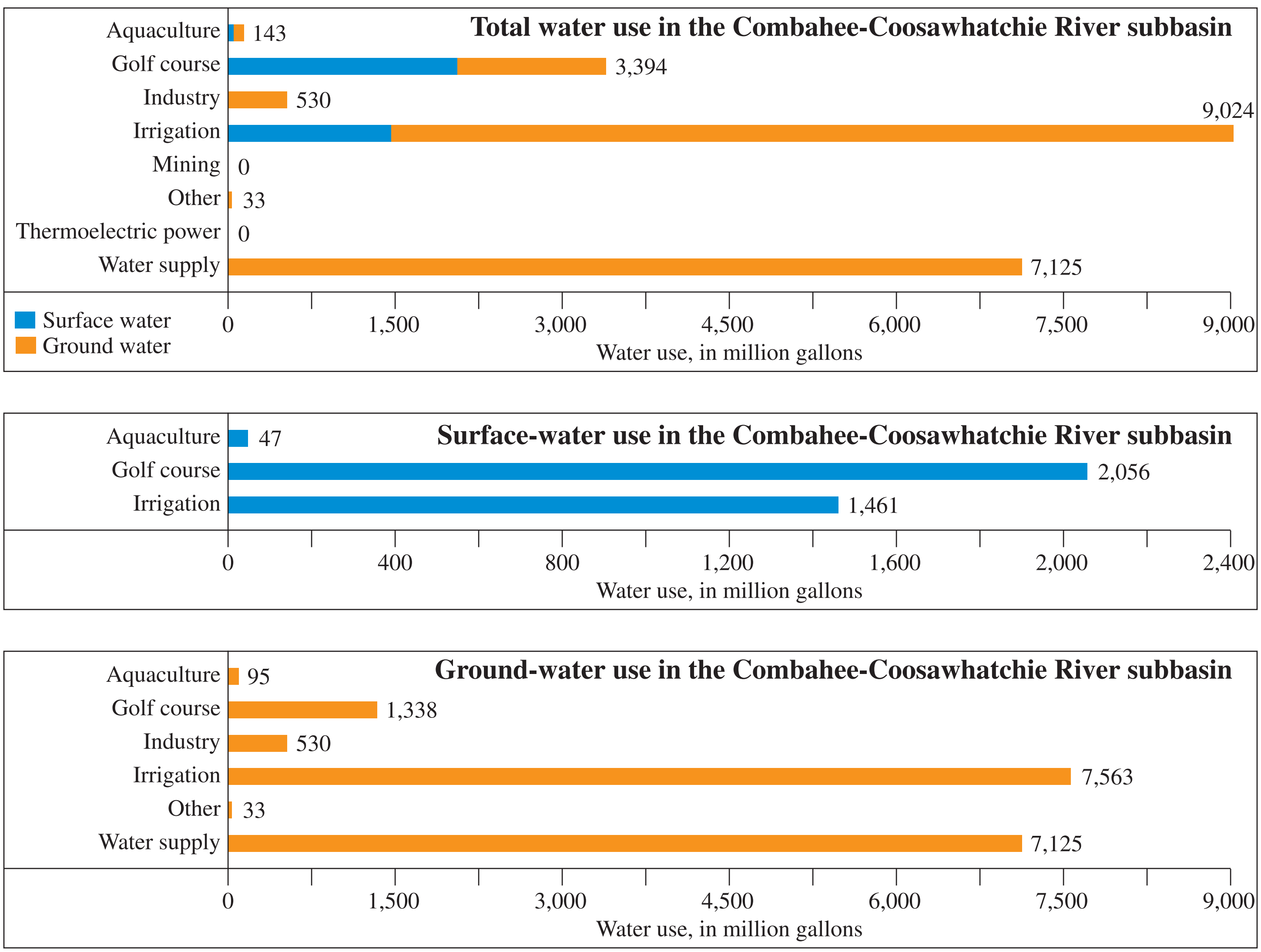


Figure 7-14. Reported water use in the Combahee-Coosawhatchie River subbasin for the year 2006 (modified from Butler, 2007).

WATERSHED CONDITIONS: SAVANNAH RIVER BASIN

UPPER SAVANNAH RIVER SUBBASIN

UPPER SAVANNAH RIVER SUBBASIN

The Upper Savannah River subbasin is located in northwestern South Carolina and extends 140 miles southeast from the North Carolina state line to the Edgefield-Aiken county line. It shares its western border with Georgia along reaches of the Chattooga, Tugaloo, and Savannah Rivers and encompasses McCormick and Oconee Counties and much of Abbeville, Anderson, Edgefield, Greenwood, Pickens, and Saluda Counties (Figure 8-1). The subbasin area is approximately 3,200 square miles, 10.3 percent of the State.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 343,100, 8.6 percent of the State's total population. By the year 2020, the subbasin population is expected to reach 428,000, an increase of 25 percent. Oconee and Pickens Counties are projected to experience the greatest population change between 2000 and 2020, both increasing about 26 percent. Edgefield and Saluda Counties are projected to lose 6 and 9 percent of their respective populations.

The region is predominantly rural, and its principal population centers are dispersed along its length. The major towns in 2000 were Anderson (25,514), Greenwood (22,071), Easley (17,754), Clemson (11,939), Seneca (7,652), and Abbeville (5,840).

The year 2005 per capita income for the subbasin counties ranged from \$20,643 in McCormick County, which ranked 40th in the State, to \$28,561 in Oconee County, which ranked ninth. All of the counties in the subbasin had 1999 median household incomes below the State average of \$37,082. Abbeville and McCormick Counties had median household incomes more than \$4,000 below the State average (South Carolina Budget and Control Board, 2005).

During 2000, the counties of the subbasin had combined annual average employment of non-agricultural wage and salary workers of about 216,000. Labor distribution within the subbasin counties included management, professional, and technical services, 26 percent; production, transportation, and materials moving, 25 percent; sales and office, 22 percent; service, 14 percent; construction, extraction, and maintenance, 13 percent; and farming, fishing, and forestry, 1 percent.

In the sector of manufacturing and public utilities, the 1997 annual product value for the subbasin's counties was \$10.4 billion. Crop and livestock production in 2003 was valued at \$214 million, and the delivered-timber value in 2001 totaled \$135 million (South Carolina Budget and Control Board, 2005).

SURFACE WATER

Hydrology

The upper part of the Savannah River is the main watercourse of this drainage system. With headwaters in the Blue Ridge province of North Carolina and Georgia, the Tugaloo and Seneca Rivers converge to form the Savannah River. Several other tributaries drain South Carolina and Georgia watersheds and contribute to streamflow in the Savannah River. Those streams in South Carolina include the Chattooga River, Twelvemile Creek, Rocky River, Little River, and Stevens Creek. Since 1950, five large reservoirs have been built on the upper Savannah River and its major headwater tributaries

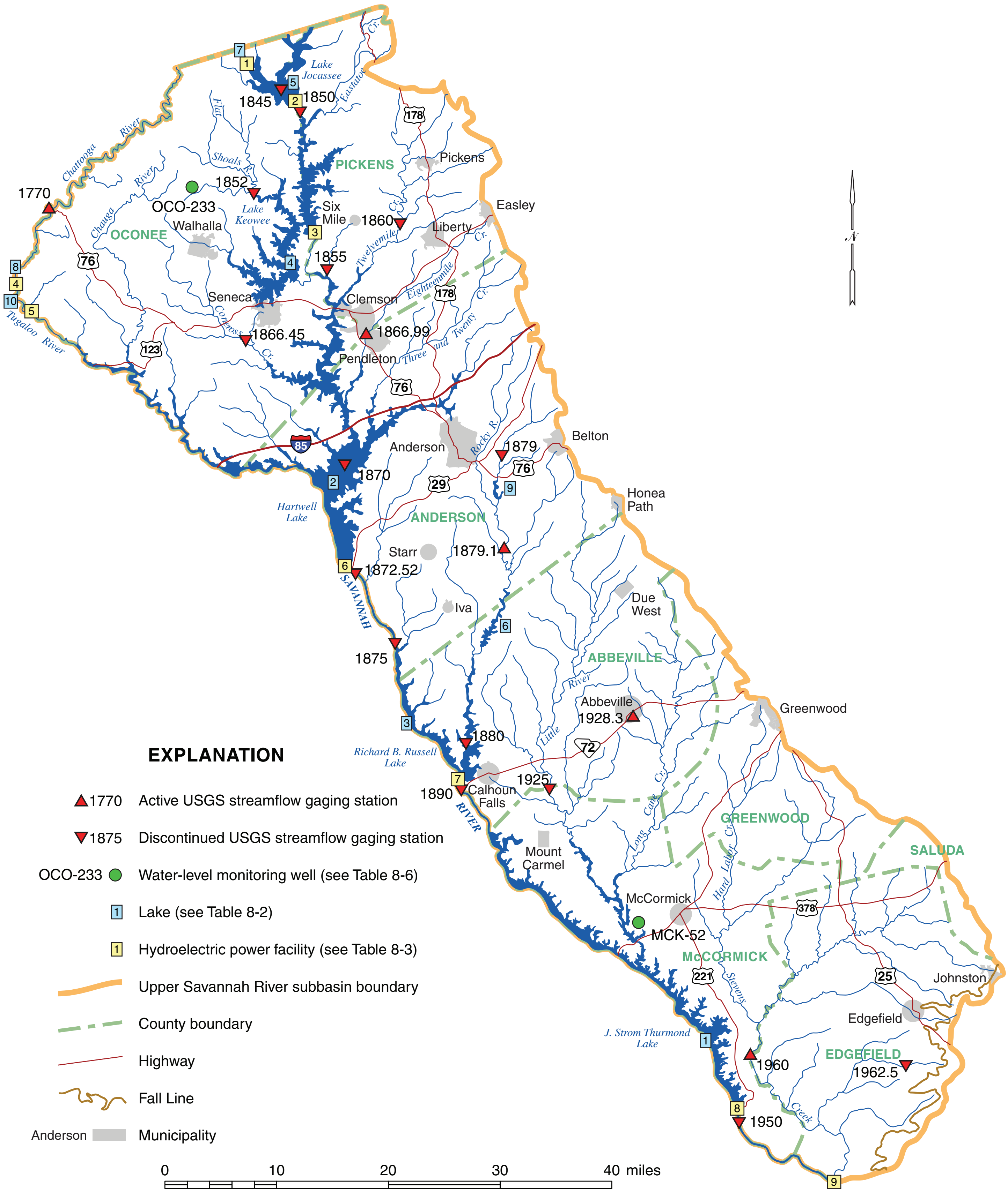


Figure 8-1. Map of the Upper Savannah River subbasin.

in South Carolina, inundating virtually all of the upper reach of the Savannah River valley. Controlled discharges from hydroelectric-power facilities associated with these reservoirs greatly affect streamflow in the main stem.

Streamflow is currently monitored at five U.S. Geological Survey (USGS) gaging stations, all on tributary streams. Gages on the Savannah River have all been discontinued. Streamflow statistics for these five active and 15 discontinued gaging stations are presented in Table 8-1.

Table 8-1. Selected streamflow characteristics at USGS gaging stations in the Upper Savannah River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow		90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
			(cfs)	(cfsm)				
Chattooga River near Clayton, Ga. 1770	1939 to 2007*	207	646	3.12	221	85 2007	18,500 2004	33,300 2004
Whitewater River at Jocassee 1845	1951 to 1968	47.3	177	3.74	56	24 1954	3,140 1964	6,900 1964
Keowee River near Jocassee 1850	1950 to 1968	148	488	3.30	159	57 1954	10,600 1964	21,000 1964
Little River near Walhalla 1852	1967 to 2003	72.0	173	2.40	61	8.0 2002	10,000 1967	12,800 1967
Keowee River near Newry 1855	1939 to 1961	455	1,153	2.53	376	152 1954	19,600 1940	25,200 1940
Twelvemile Creek near Liberty 1860	1954-64 and 1989-2001	106	192	1.81	64	23 2000	5,120 1998	6,730 1998
Coneross Creek near Seneca 1866.45	1989 to 2003	65.4	115	1.76	37	3.1 2002	2,800 1990	3,590 1994
Eighteenmile Creek above Pendleton 1866.99	1998 to 2007*	47	58	1.23	20	3.3 2002	2,980 2003	3,470 2003
Seneca River near Anderson 1870	1928 yo 1959	1,026	1,997	1.95	735	170 1931	76,000 1928	81,100 1928
Savannah River below Lake Hartwell 1872.52	1984 to 1999	2,090	2,879	1.38	102	10 1996	21,000 1998	– – –
Savannah River near Iva 1875	1950 to 1981	2,231	4,469	2.00	573	78 1961	47,200 1952	54,400 1952
Broadway Creek near Anderson 1879	1967 to 1970	26.4	25.6	0.97	– – –	7.0 1970	337 1967	904 1967

Table 8-1. Continued

Gaging station name, location, station number	Period of record	Drainage area (mi²)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Rocky River near Starr 1879.1	1989-96; 1996-2001; 2003-07*	111	128	1.16	37	6.0 2007	3,810 1998	6,260 1998
Rocky River near Calhoun Falls 1880	1950 to 1966	267	307	1.15	103	9.0 1954	8,440 1964	10,900 1964
Savannah River near Calhoun Falls 1890	1896-1900; 1930-32; 1938-79	2,876	5,428	1.89	1,700	300 1961	– – –	96,500 1940
Little River near Mount Carmel 1925	1939-70 and 1986-2003	217	207	0.96	35	1.0 1954	15,200 1940	20,800 1940
Blue Hill Creek at Abbeville 1928.3	1998 to 2007*	3.2	2.9	0.91	0.47	0.0 2007	111 2003	294 2000
Savannah River near Clarks Hill 1950	1940 to 1954	6,150	8,479	1.38	3,130	1,120 1941	185,000 1940	– – –
Stevens Creek near Modoc 1960	1929-31; 1940-78; 1983-2007*	545	393	0.72	14	0.0 1954	31,700 1940	35,100 1940
Horn Creek near Colliers 1962.5	1981 to 1994	13.9	14.1	1.01	3.4	0.8 1982	530 1981	3,680 1985

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*

Extensive development on the Savannah River has eliminated most of the free-flowing streams in this region. Average streamflow of the Savannah River, measured at now-discontinued gaging stations, was 4,469 cfs (cubic feet per second) near Iva (below Lake Hartwell) and 5,428 cfs near Calhoun Falls (below Lake Russell); flow at these sites was at least 573 cfs and 1,700 cfs, respectively, 90 percent of the time. Although daily flows were variable due to fluctuating discharges from upstream hydroelectric power plants, minimum flows were well sustained because of reservoir releases.

Unregulated streams in the subbasin are heavily dependent on direct precipitation, surface runoff, and ground-water discharge to support flows. Streams in the Blue Ridge region, where average annual rainfall is high and ground-water storage is substantial, exhibit generally uniform year-round flows with well-sustained base flows (Figure 8-2). With increasing distance from the mountains, rainfall diminishes, ground-water discharge decreases, and streamflow becomes progressively more variable. Stevens Creek, the farthest gaged stream from the Blue Ridge region, exhibits the most variable flow and most poorly-sustained base flow among gaged tributary streams in this portion of the subbasin. No-flow conditions were recorded in this stream on numerous occasions during the drought of 1954.

The Savannah River main stem provides large quantities of water throughout the year. Although flow may be variable, minimum flows are uniform and substantial. Tributary streams in the upper part of the subbasin support well-sustained flows and are reliable water-supply sources, provided the quantity is adequate for the intended use. Tributary streams in the middle and lower parts of the subbasin are progressively less reliable sources of water because flows in these streams decline dramatically during the summer and fall months.

Development

The Upper Savannah River subbasin is one of the most intensely developed subbasins in the State and is a region of numerous flood-control projects and hydroelectric power facilities. Five of the largest reservoirs in South

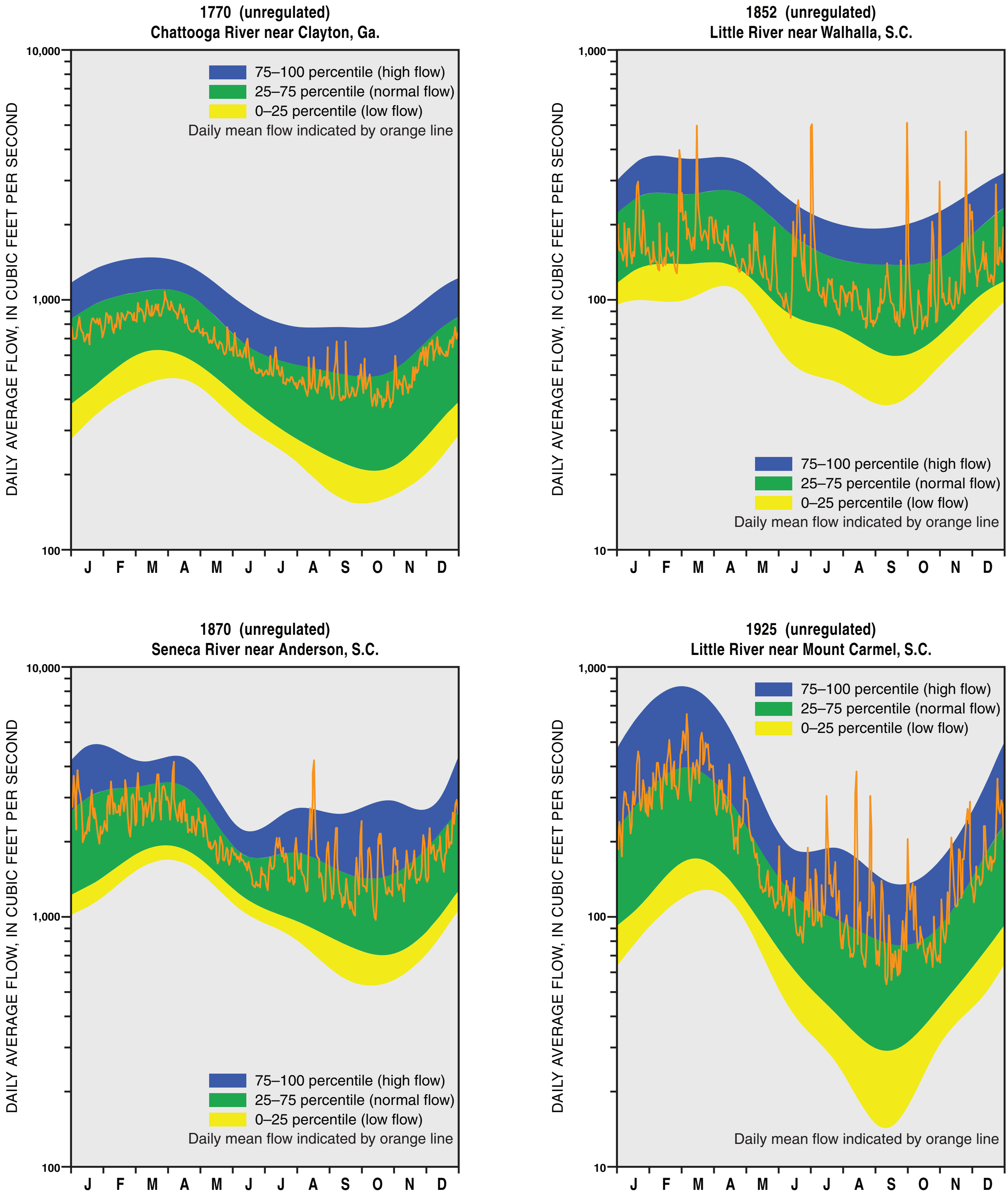


Figure 8-2. Duration hydrographs for selected gaging stations in the Upper Savannah River subbasin.

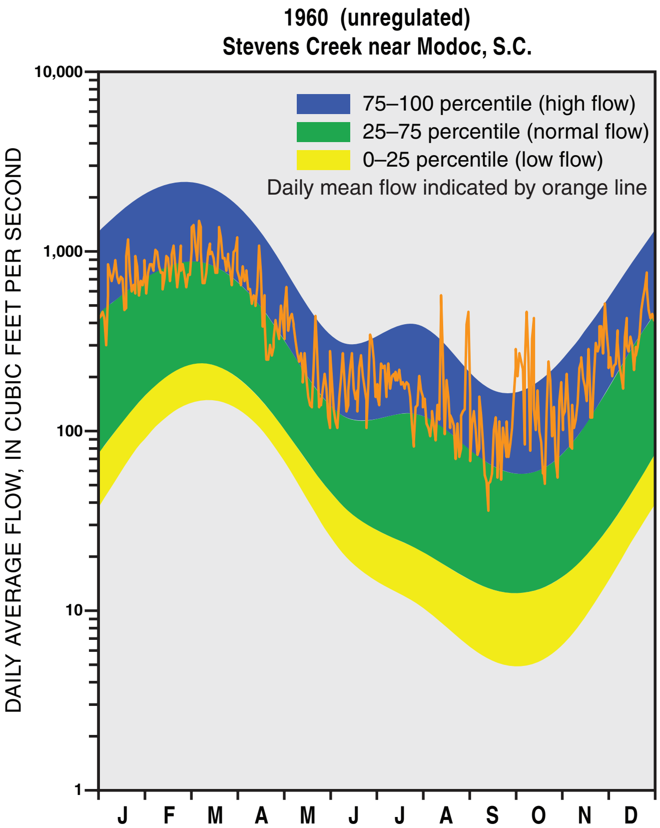


Figure 8-2. Continued.

Carolina—Jocassee, Keowee, Hartwell, Russell, and Thurmond—dominate the hydrology of this subbasin (Table 8-2).

Lake Jocassee, on the Keowee River near the northern edge of the subbasin, extends up the Toxaway and Whitewater Rivers. Completed in 1975, Lake Jocassee holds 1,185,000 acre-ft of water and has a surface area of 7,565 acres; it is the State's sixth-largest lake by volume. The Jocassee Hydroelectric Station is a pumped-storage generating facility that discharges into Lake Keowee. During periods of low electrical demand, reversible turbines pump water up from Lake Keowee back into Lake Jocassee, to be used again to generate power during periods of high electrical demand. The lake and generating facilities are owned and operated by Duke Energy, and the lake is a popular recreation area.

Immediately downstream from Lake Jocassee is Lake Keowee. Created in 1971 by damming the Keowee and Little Rivers, the lake contains nearly 1,000,000 acre-ft of water and has a surface area of 18,372-acres. Lake Keowee ranks seventh in area and eighth in volume among South Carolina lakes. In addition to providing water for Duke Energy's Keowee hydropower plant, the lake serves as a source of cooling water for the adjacent Oconee Nuclear Station, as a reservoir for the pumped-storage facility at Jocassee Dam, as a water-supply reservoir for the city of Greenville, and as a popular recreational area.

Table 8-2. Lakes 200 acres or more in the Upper Savannah River subbasin (shown on Figure 8-1)

Number on map	Name	Stream	Surface area (acres)	Storage capacity (acre-feet)	Purpose
1	Lake Thurmond	Savannah River	70,000	2,510,000	Power, recreation, flood control and water supply
2	Lake Hartwell	Savannah River	56,000	2,549,000	Power, recreation and water supply
3	Lake Russell	Savannah River	26,650	1,026,000	Power, recreation, flood control and water supply
4	Lake Keowee	Keowee River	18,372	1,000,000	Power, recreation and water supply
5	Lake Jocassee	Keowee River	7,565	1,185,000	Power, recreation and water supply
6	Lake Secession	Rocky River	880	19,360	Power, recreation and water supply
7	Bad Creek Reservoir	Bad Creek	310	24,650	Power
8	Lake Tugaloo	Tugaloo River	300	18,000	Power and recreation
9	Broadway Lake	Rocky River	300	1,800	Recreation
10	Lake Yonah	Tugaloo River	200	6,400	Power and recreation

Source: U.S. Army Corps of Engineers (1991)

Lake Hartwell, located west of Anderson on the Savannah River, was constructed by the U.S. Army Corps of Engineers (COE). The lake, completed in 1963, extends up the Savannah, Tugaloo, and Seneca Rivers and has a surface area of 56,000 acres and a volume of 2,549,000 acre-ft. It ranks fourth in surface area and first in volume among lakes in the State. The lake is an important source of water for hydroelectric power production, public water supplies, and recreation.

Almost immediately below Lake Hartwell on the Savannah River is Richard B. Russell Lake. With a surface area of 26,650 acres and volume of 1,026,000 acre-ft, it ranks sixth and seventh, respectively, among South Carolina lakes. It was constructed by the COE in 1985 primarily for hydroelectric-power production and flood control, but it also is used for recreation and water supply.

Immediately below Lake Russell is J. Strom Thurmond Lake, which occupies most of the western border of McCormick County. (Before 1988, this reservoir was named Clarks Hill Lake, and it is still officially referred to as such by the State of Georgia.) With a surface area of 70,000 acres and a volume of 2,510,000 acre-ft, this lake is the second largest in both surface area and volume of all lakes in the State. Completed in 1954, this was the COE's first reservoir on the Savannah River. Originally constructed for hydropower, flood control, and to assist with downstream navigation, the reservoir is now also important for water supply and recreation. Releases from Lake Thurmond control the behavior of the lower Savannah River, particularly in the upper reaches of the Lower Savannah River subbasin.

The ten largest lakes in the subbasin are listed in Table 8-2. The total surface area of all lakes larger than 10 acres in the subbasin is about 196,000 acres and the total volume is approximately 9,000,000 acre-ft (U.S. Army Corps of Engineers, 1991).

In addition to the hydroelectric power projects associated with these large reservoirs, the subbasin contains several other hydroelectric projects (Table 8-3), including Duke Energy's Bad Creek pumped-storage facility above Lake Jocassee and SCE&G's Stevens Creek project, which helps to mitigate the downstream effects of widely-varying releases from Lake Thurmond.

There are no navigation projects in the subbasin. The COE reservoirs serve as important flood-control projects by virtue of their large floodwater-storage capacities. Many smaller flood-control projects have been constructed by the NRCS (Natural Resources Conservation Service). Most projects are in the upper reaches of the subbasin, mainly in Oconee, Pickens, and Anderson Counties. In 1954, the NRCS (formerly the U.S. Soil Conservation Service) completed the State's first floodwater-retarding

Table 8-3. Major hydroelectric power generating facilities in the Upper Savannah River subbasin (shown on Figure 8-1)

Number on map	Facility name and operator	Impounded stream	Reservoir	Generating capacity (megawatts)	Water use in year 2006 (million gallons)
1	Bad Creek pumped-storage Duke Energy	Bad Creek	Bad Creek Reservoir	1,065	1,412,404
2	Jocassee pumped-storage Duke Energy	Keowee River	Lake Jocassee	662.5	2,168,735
3	Keowee Duke Energy	Keowee River	Lake Keowee	158	155,852
4	Tugalo Georgia Power	Tugaloo River	Lake Tugaloo	45	unavailable
5	Yonah Georgia Power	Tugaloo River	Lake Yonah	23	unavailable
6	Hartwell Corps of Engineers	Savannah River	Lake Hartwell	420	686,485
7	Richard B. Russell Corps of Engineers	Savannah River	Lake Russell	628	1,297,653
8	J. Strom Thurmond Corps of Engineers	Savannah River	Lake Thurmond	280	1,199,816
9	Stevens Creek SCE&G	Savannah River	Stevens Creek Reservoir	18	939,326

structure on Twelvemile Creek as a pilot program. The project succeeded and prompted many others.

Surface-Water Quality

Water bodies in the upper Savannah River subbasin encompass three water-use classifications. Most are designated "Freshwater" (Class FW). Class FW are freshwater bodies that are suitable for survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2003c).

Eastatoe Creek, Rocky Bottom Creek, and parts of the Chauga and Chattooga Rivers are designated "Outstanding Resource Water" (Class ORW). These freshwater bodies constitute an outstanding recreational or ecological resource and are suitable as a drinking-water source with minimal treatment.

Lake Jocassee is designated as "Trout Put, Grow and Take Water" (Class TPGT). These are freshwater bodies suitable for supporting the growth of stocked-trout populations and a balanced indigenous aquatic community of fauna and flora. This lake is also listed as one of the least eutrophic large lakes in South Carolina, and it is characterized by low nutrient concentrations and very clear water.

As part of its ongoing Watershed Water-Quality Assessment program, DHEC sampled 115 surface-water sites within the subbasin in order to assess the water's suitability for aquatic life and recreational uses (Figure 8-3). Aquatic-life uses were fully supported in 99 sites, or 84 percent of the water bodies sampled. Water was considered partially or fully impaired primarily because of poor macroinvertebrate-community structures or high concentrations of heavy metals. Recreational use was fully supported in 75 percent of the sampled water bodies; water bodies that did not support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2003c). Water-quality impairments in the subbasin are summarized in Table 8-4. DHEC publishes recently observed impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

Lake Keowee is listed as the least eutrophic large lake in South Carolina and is characterized by low nutrient concentrations. Lake Yonah is listed as one of the least eutrophic small lakes in the State.

In 2008, as in previous years, DHEC issued a fish-consumption advisory for Lakes Yonah, Jocassee, Russell, and Thurmond because of mercury contamination. A fish consumption advisory for Lake Hartwell was issued because of polychlorinated biphenyl (PCB) contamination that originated from an industrial site near Pickens. Fish-consumption advisories are issued in areas where contaminated fish are found; the contamination is only in the fish and does not make the water unsafe for swimming or boating.

GROUND WATER

Hydrogeology

The Upper Savannah River subbasin occupies part of the Blue Ridge and Piedmont physiographic provinces and is crossed by several geologic belts or terranes trending northeast to southwest. From northwest to southeast, these begin with the Blue Ridge, composed of the Toxaway Gneiss and the Tallulah Falls Formation. The Brevard zone, a narrow unit of cataclastic rocks that extends from North Carolina to Alabama, separates the Blue Ridge to the northwest, in Oconee County, from the rocks of the Piedmont to the southeast. Immediately southeast of the Brevard zone is the Chauga belt (Oconee, Pickens, and northwestern Greenville Counties), which is overlain to the southeast by the Walhalla thrust sheet (Oconee and Pickens Counties). The Walhalla thrust sheet is, in turn, overlain by the Sixmile thrust sheet (Anderson, Oconee, and Pickens Counties), followed by the Laurens thrust stack in southeastern Anderson County and northwestern Abbeville County.

To the southeast, separated by the Lowndesville shear zone, lie the Charlotte terrane (Abbeville, Greenwood, and McCormick Counties) and the Carolina terrane (McCormick, Edgefield, southern Greenwood, and western Saluda Counties). Finally, the Modoc shear zone separates the Carolina terrane from the rocks of the Savannah River terrane and the Augusta terrane at the southernmost extent of the Upper Savannah River subbasin. Additionally, a few gabbro intrusions occur in Abbeville and McCormick Counties and a small granite intrusion occurs on the Edgefield-McCormick county line.

Most of the subbasin ground water occurs in the saprolite, which stores rainfall and provides recharge to fractures in the underlying rock. The saprolite is as thick as 150 feet in places. About a quarter of the wells in the subbasin are domestic wells bored into the saprolite.

The number and size of bedrock fractures beneath the saprolite diminish with depth, and most wells are less than 300 feet deep. The greatest depth is 1,100 feet. Water supplies from fractured rocks are reliable but limited. Well yields, although locally as great as 600 gpm (gallons per minute), usually are less than 50 gpm.

Topography and well yields generally are related. Because valleys and draws provide large areas for aquifer recharge and usually are areas of weak rock where fractures are common, wells located in low areas tend to have larger yields than those in topographically high areas. Wells carefully sited with regard to topography and geology produce yields that are much above the average. The ground-water potential is not well known in much of this subbasin, and specific aquifer or hydrogeologic units are not delineated. Table 8-5 summarizes the drilled-well depths and yields for the subbasin.

Figure 8-3. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 8-4 (DHEC, 2003c).

Table 8-4. Water-quality impairments in the Upper Savannah River subbasin (DHEC, 2003c)

Water-body name	Station number	Use	Status	Water-quality indicator
Lake Yonah	SV-358	Aquatic life	Nonsupporting	Total phosphorus
Chauga River	SV-344	Recreation	Partially supporting	Fecal coliform
Norris Creek	SV-301	Recreation	Nonsupporting	Fecal coliform
Choestoea Creek	SV-108	Recreation	Nonsupporting	Fecal coliform
Beaverdam Creek	SV-345	Recreation	Nonsupporting	Fecal coliform
Little Eastatoe Creek	SV-341	Recreation	Partially supporting	Fecal coliform
Sixmile Creek	SV-205	Recreation	Partially supporting	Fecal coliform
Six and Twenty Creek	SV-181	Recreation	Partially supporting	Fecal coliform
Little Cane Creek	SV-343	Recreation	Nonsupporting	Fecal coliform
Cane Creek	SV-342	Recreation	Nonsupporting	Fecal coliform
North Fork	SV-206	Recreation	Partially supporting	Fecal coliform
Twelvemile Creek	SV-015	Recreation	Nonsupporting	Fecal coliform
	SV-137	Recreation	Partially supporting	Fecal coliform
Twelvemile Creek tributary	SV-136	Recreation	Partially supporting	Fecal coliform
Golden Creek	SV-239	Recreation	Nonsupporting	Fecal coliform
Coneross Creek	SV-333	Aquatic life	Partially supporting	Copper
		Recreation	Partially supporting	Fecal coliform
	SV-004	Aquatic life	Nonsupporting	Copper
		Recreation	Partially supporting	Fecal coliform
Eighteenmile Creek	SV-017	Recreation	Nonsupporting	Fecal coliform
	SV-245	Recreation	Nonsupporting	Fecal coliform
	SV-135	Recreation	Nonsupporting	Fecal coliform
	SV-268	Aquatic life	Nonsupporting	Total phosphorus, pH, Chlorophyll-*a*
		Recreation	Partially supporting	Fecal coliform
Woodside Branch	SV-241	Recreation	Partially supporting	Fecal coliform
Three and Twenty Creek	SV-111	Recreation	Nonsupporting	Fecal coliform
Big Generostee Creek	SV-316	Recreation	Nonsupporting	Fecal coliform
	SV-101	Aquatic life	Partially supporting	Macroinvertebrates
Cupboard Creek	SV-139	Aquatic life	Nonsupporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
	SV-140	Recreation	Nonsupporting	Fecal coliform
Broadway Creek	SV-141	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Betsy Creek	SV-037	Aquatic life	Nonsupporting	Copper
Cherokee Creek	SV-043	Recreation	Nonsupporting	Fecal coliform
Rocky River	SV-031	Recreation	Nonsupporting	Fecal coliform
	SV-041	Recreation	Partially supporting	Fecal coliform
Lake Secession	SV-331	Aquatic life	Nonsupporting	Total phosphorus, pH
Wilson Creek	SV-347	Recreation	Partially supporting	Fecal coliform

Table 8-4. Continued

Water-body name	Station number	Use	Status	Water-quality indicator
Little River	SV-164	Recreation	Partially supporting	Fecal coliform
	SV-348	Recreation	Nonsupporting	Fecal coliform
	SV-192	Recreation	Partially supporting	Fecal coliform
Sawney Creek	SV-052	Aquatic life	Partially supporting	Dissolved oxygen
		Recreation	Nonsupporting	Fecal coliform
Johns Creek	SV-734	Aquatic life	Partially supporting	Macroinvertebrates
Blue Hill Creek	SV-053B	Aquatic life	Nonsupporting	Turbidity
		Recreation	Nonsupporting	Fecal coliform
Double Branch	SV-054	Aquatic life	Partially supporting	Macroinvertebrates
Long Cane Branch	SV-349	Recreation	Nonsupporting	Fecal coliform
Stevens Creek Reservoir	SV-294	Aquatic life	Partially supporting	Dissolved oxygen, pH
Hard Labor Creek	SV-151	Aquatic life	Partially supporting	Macroinvertebrates
		Recreation	Nonsupporting	Fecal coliform
Cuffytown Creek	SV-351	Recreation	Partially supporting	Fecal coliform
Rocky Creek	SV-730	Aquatic life	Partially supporting	Macroinvertebrates

Table 8-5. Well depths and yields for drilled bedrock wells in the Upper Savannah River subbasin

County	Well depth (feet)		Well yield (gpm)	
	Average	Maximum	Average	Maximum
Abbeville	259	730	22	300
Anderson	316	1,100	28	600
Edgefield	232	600	15	100
Greenwood	243	620	21	150
McCormick	220	325	23	47
Oconee	241	565	23	400
Pickens	296	885	21	200
Saluda	323	560	16	60
Total	277	1,100	24	600

Ground-Water Quality

Total dissolved solids (TDS) concentrations in the ground water of this subbasin commonly are less than 100 mg/L (milligrams per liter); concentrations as low as 5 mg/L and as high as 850 mg/L have been recorded. The highest TDS concentrations—greater than 500 mg/L—are found in the Carolina terrane, especially in McCormick County. A pH range of 4.5 to 8.9 suggests a wide range of alkalinity. Alkalinity concentrations also are greater in the Carolina terrane. The lowest pH values—less than 6.0—tend to occur in the Blue Ridge belt and in the Walhalla and Sixmile thrust sheets in Oconee and Pickens Counties.

Water-Level Conditions

Ground-water levels are routinely monitored by the USGS in two wells in the Upper Savannah River subbasin to help assess trends or changes in hydrologic conditions (Table 8-6). Water levels in these wells are often indicative of local hydrologic conditions that impact the surface-water systems to which the ground water is connected. Changes in observed water levels are typically a reflection of changes in above-ground hydrologic conditions.

Because ground-water use in this subbasin is very limited, no areas within the subbasin are known to be experiencing significant water-level declines caused by overpumping.

WATER USE

Water use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Upper Savannah River subbasin for the year 2006 is summarized in Table 8-7 and Figure 8-4. Total offstream water use in the subbasin was 944,953 million gallons in 2006, ranking it first among the 15 subbasins. Of this amount, 944,907 million gallons came from surface-water sources (99.95 percent) and 47 million

Table 8-6. Water-level monitoring wells in the Upper Savannah River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
MCK-52	USGS	33 53 36 82 21 46	Crystalline rock	3 miles west of McCormick	400	54–202
OCO-233	USGS	34 50 51 83 04 18	Crystalline rock	5 miles north of Walhalla	1,080	24–433

* *USGS, United States Geological Survey*

gallons came from ground-water sources (0.05 percent). Thermoelectric power use accounted for 97 percent of this total, followed by water supply (2 percent) and industry (less than 1 percent). Consumptive use in this subbasin is estimated to be 22,144 million gallons, or about 2 percent of the total offstream use.

Almost all of the water used for thermoelectric power, and thus most of the offstream water use in the subbasin, was used by Duke Energy's Oconee Nuclear Station. Located near Seneca in Oconee County, the Oconee Nuclear Station is one of the largest nuclear plants in the nation, with three reactors and a generating capacity of 2,538 MW (megawatts). In 2006, the plant used 919,732 million gallons of water, more than any other single offstream use in the State. The Oconee Nuclear Station withdraws water from Lake Keowee.

The other thermoelectric power facility in the subbasin is Santee Cooper's John S. Rainey Station, a gas-combustion turbine plant that uses natural gas and compressed air to turn turbines and produce electricity. Exhaust heat generated in the process is used to produce additional electrical power from steam. The plant, located in western Anderson County on the Savannah River, used 334 million gallons of water in 2006.

Water-supply use in the Upper Savannah River subbasin totaled 20,977 million gallons. Surface water accounted for 20,930 million gallons (99.8 percent) and ground water for 47 million gallons (0.2 percent). The largest surface-water user was the city of Greenville, which withdrew 7,293 million gallons from Lake Keowee. Greenville also draws water from the North Saluda Reservoir and Table Rock Reservoir in the Saluda River subbasin. Anderson Regional Water System used 7,098 million gallons for public supply from Lake Hartwell. Other systems of note include the city of Seneca (2,394 million gallons from Lake Keowee), Westminster Commission of Public Works in Oconee County (903 million gallons from Chauga River), and the city of Abbeville (858 million gallons from Lake Russell). The town of Salem in Oconee County had the largest ground-water system in the subbasin, with withdrawals from the crystalline rock aquifer totaling 44 million gallons. Water-supply is the only significant ground-water use in the subbasin.

Industrial water use was 3,110 million gallons in 2006, all of it from surface-water sources. Clemson University was the largest user, withdrawing a total of 2,038 million gallons.

Instream water use for hydroelectric power generation totaled 7,885,878 million gallons in 2006, more than any other subbasin. Duke Energy owns and operates both the Jocassee Hydroelectric Station in Pickens County and the Bad Creek Hydroelectric Station in Oconee County. Both stations are pumped-storage facilities that reuse water repeatedly to generate hydroelectric power. The Jocassee Station, with a capacity of 662.5 MW, used more water than any other facility in the State—2,168,735 million gallons (see Table 8-3). The Bad Creek Station, with a capacity of 1,065 MW, had the third highest use in the State—1,412,404 million gallons. Duke Energy also owns and operates the Keowee Hydroelectric Station at Lake Keowee, which has a capacity of 158 MW and used 155,852 million gallons in 2006.

The COE's Lake Russell power plant, a pumped-storage facility with a capacity of 628 MW, used 1,297,653 million gallons in 2006. The Lake Thurmond facility, which has a capacity of 280 MW, used 1,199,816 million gallons, and the Lake Hartwell facility, which has a capacity of 420 MW, used 686,485 million gallons.

SCE&G's Stevens Creek Hydroelectric Station on the Savannah River has a capacity of 18.4 MW and used 939,326 million gallons in 2006.

The city of Abbeville owns and operates the Rocky River hydroelectric plant at Lake Secession. It has a capacity of 2.6 MW and used 15,807 million gallons in 2006. Aquaenergy Systems, Inc. owns Coneross Creek, a 0.9 MW plant located just south of Seneca in Oconee County that used 9,800 million gallons.

Table 8-7. Reported water use in the Upper Savannah River subbasin for the year 2006 (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	0	0.0	0	0.0	0	0.0
Golf course	483	0.1	0	0.0	483	0.1
Industry	3,110	0.3	0	0.0	3,110	0.3
Irrigation	318	0.0	0	0.0	318	0.0
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	920,066	97.4	0	0.0	920,066	97.4
Water supply	20,930	2.2	47.1	100.0	20,977	2.2
Total	944,907		47.1		944,953	

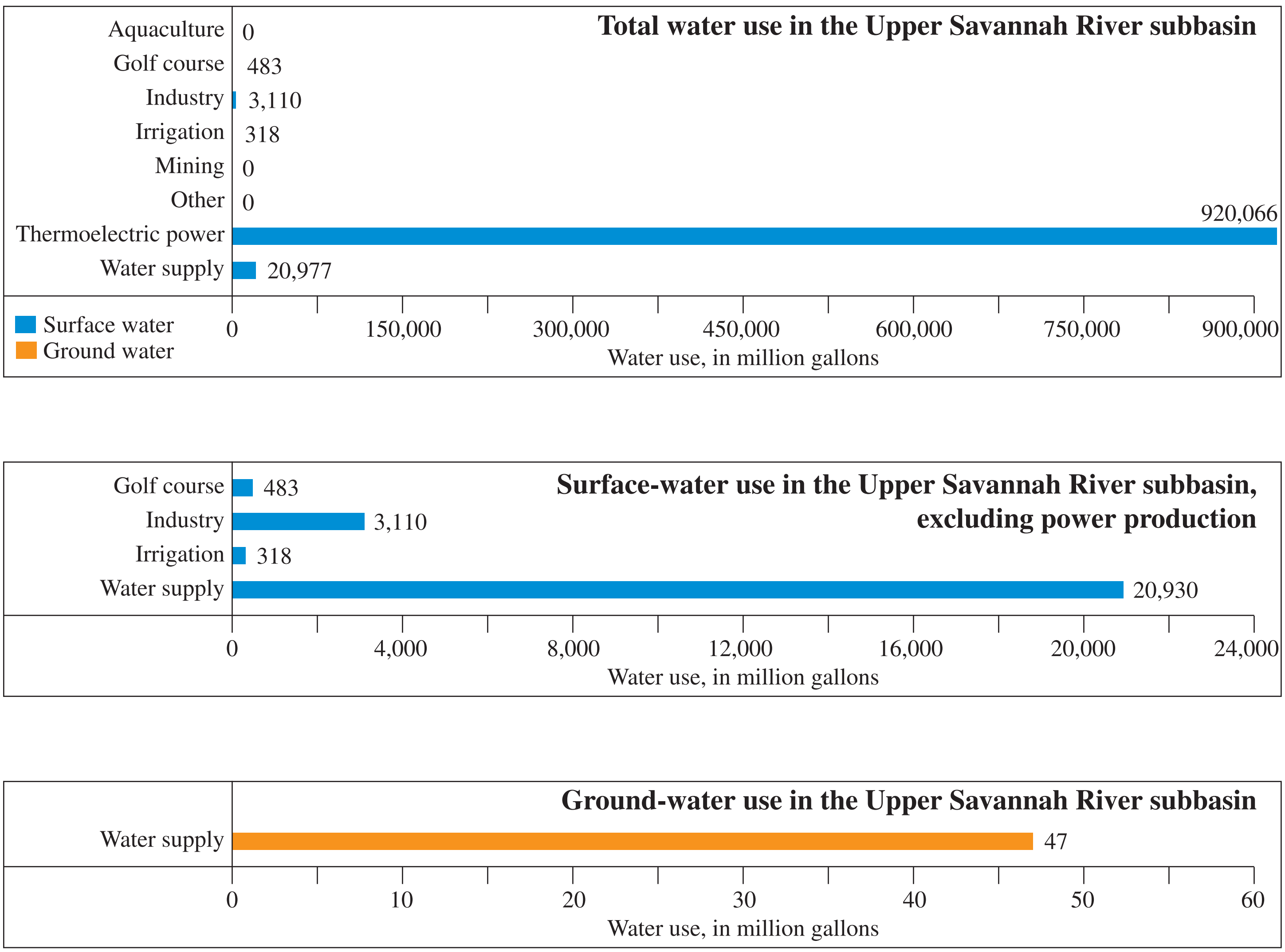


Figure 8-4. Reported water use in the Upper Savannah River subbasin for the year 2006 (modified from Butler, 2007).

LOWER SAVANNAH RIVER SUBBASIN

LOWER SAVANNAH RIVER SUBBASIN

The Lower Savannah River subbasin parallels the State's western boundary with Georgia and is a 125-mile-long subbasin extending south-southeast from the Edgefield-Aiken county line to the coast. Parts of five South Carolina counties are included in the subbasin: Aiken, Allendale, Barnwell, Hampton, and Jasper (Figure 8-5). The subbasin area is approximately 1,295 square miles, 4.2 percent of the State's area.

DEMOGRAPHICS

The year 2000 population of the subbasin was estimated at 127,500, 3.2 percent of the State's total population. The largest population increases by 2020 are expected in Aiken and Allendale Counties, whose populations are projected to increase 22 percent and 16 percent, respectively. Hampton County is projected to experience a population loss.

The subbasin is rural with the exception of Aiken County, where more than 60 percent of the population is classified as urban. Industries and government, such as textiles and the Savannah River Site in Barnwell and Aiken Counties, have created greater employment opportunities at the northern end of the subbasin than at the southern end. The major cities in the subbasin are Aiken (25,337) and North Augusta (17,544), both located in Aiken County.

Aiken County ranked twelfth in the State by per capita income ($28,418) in 2005, whereas Allendale County ranked last with $18,871. The 1999 median household income in Aiken County was $37,889, slightly above the State average. The median household income in the other four counties ranked in the lowest third in the State; median household income in Allendale County was $20,898, the lowest in the State (South Carolina Budget and Control Board, 2005).

During 2000, the counties of the subbasin had combined annual average employment of non-agricultural wage and salary workers of about 76,000. Labor distribution within the subbasin counties included management, professional, and technical services, 29 percent; sales and office, 23 percent; production, transportation, and materials moving, 20 percent; service, 15 percent; construction, extraction, and maintenance, 12 percent; and farming, fishing, and forestry, 1 percent.

In the sector of manufacturing and public utilities, the 1997 product value from all subbasin counties totaled $5.2 billion; about 80 percent of this total, or $4.3 billion, was generated in Aiken County. Crop and livestock value in 2003 totaled $94 million and delivered-timber value in 2001 totaled $97 million, respectively.

SURFACE WATER

Hydrology

The lower portion of the Savannah River from the confluence with Stevens Creek near the Fall Line to the Atlantic Ocean forms the main stem of this drainage system. Several small to moderately-sized tributary streams drain the Lower Savannah River subbasin. The largest of these are in the upper Coastal Plain region and include Horse Creek, Upper Three Runs Creek, and Lower Three Runs Creek. Tributary streams in the middle and lower Coastal Plain region are generally small and associated with swamplands and follow ill-defined, meandering channels. Two large urban areas, Augusta-

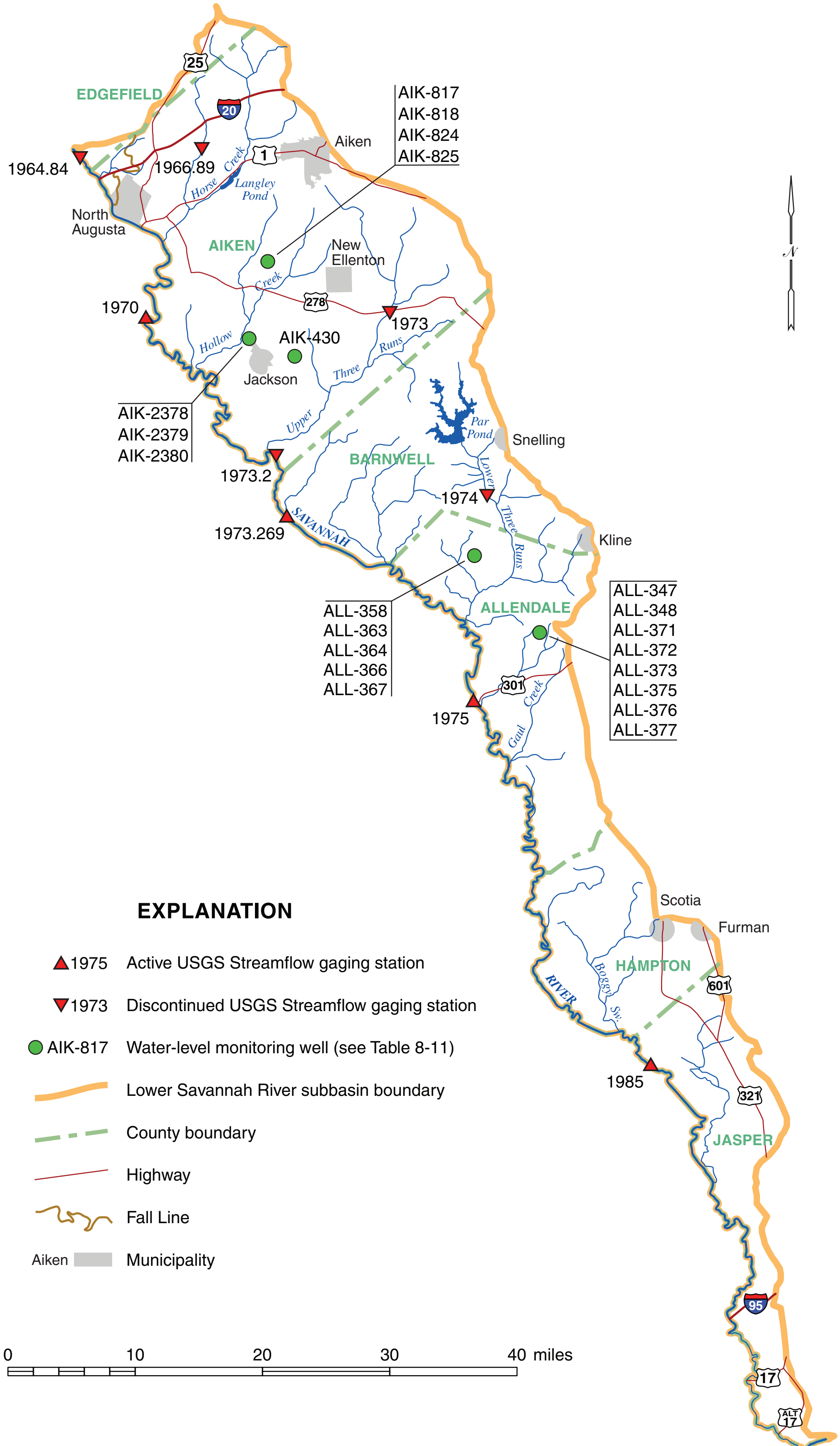


Figure 8-5. Map of the Lower Savannah River subbasin.

North Augusta and Savannah, Georgia, make extensive use of these streams.

Flow in the Savannah River has been regulated since 1951 by controlled releases from Lake Thurmond in the Upper Savannah River subbasin. Streamflow in the subbasin is presently monitored at four gaging stations, all on the Savannah River (Figure 8-5). Three active gaging stations were in place before hydroelectric development upstream and reflect the combination of flow conditions before and after regulation. Several other gages on the Savannah River and its tributaries are no longer active. Streamflow statistics for some of these active and discontinued gaging stations are presented in Table 8-8. In addition to these streamflow gages, several stage-only gages are active near the coast.

Average streamflow in the Savannah River is 9,135 cfs (cubic feet per second) at Augusta, Georgia, and increases to 11,620 cfs downstream near Clyo. Ninety percent of the time, streamflow at these sites should be at least 4,580 cfs and 5,520 cfs, respectively. Releases from Lake Thurmond and subsequent reregulation by the Stevens Creek Dam are such that the flow of the Savannah River at Augusta is almost always at least 3,600 cfs.

Flow characteristics at all main-stem gaging stations reflect controlled discharges from upstream hydroelectric

Table 8-8. Selected streamflow characteristics at USGS gaging stations in the Lower Savannah River subbasin

Gaging station name, location, station number	Period of record	Drainage area (mi^2)	Average flow (cfs)	Average flow (cfsm)	90% exceeds flow (cfs)	Minimum daily flow (cfs), year	Maximum daily flow (cfs), year	Maximum peak flow (cfs), year
Savannah River near North Augusta 1964.84	1988 to 2002	7,150	6,697	0.94	1,790	65 1989	39,000 1993	54,200 1990
Little Horse Creek near Graniteville 1966.89	1989 to 2001	26.6	33.8	1.27	16	4.1 1993	305 1990	593 1990
Savannah River [1] at Augusta, Ga. 1970	1883-91; 1896-1906; 1925-51	7,510	10,640	1.42	3,180	1,040 1927	315,000 1929	350,000 1929
Savannah River [2] at Augusta, Ga. 1970	1951 to 2007*	7,510	9,135	1.22	4,580	1,770 1951	84,500 1964	87,100 1964
Upper Three Runs Creek near New Ellenton 1973	1996 to 2002	87.0	103	1.18	72	46 2002	509 1992	820 1990
Savannah River near Jackson 1973.2	1971 to 2002	8,110	6,277	0.77	4,620	3,220 1981	22,000 1976	– – –
Savannah River near Waynesboro, Ga. 1973.269	2005 to 2007*	8,300	6,484	0.78	4,540	4,000 2006	21,800 2005	21,900 2005
Lower Three Runs Creek near Snelling 1974	1974 to 2002	59.3	78.9	1.33	27	13 1986	743 1990	1,130 2000
Savannah River near Millhaven, Ga. 1975	1937-70 and 1982-2007*	8,650	10,180	1.18	4,960	2,120 1951	138,000 1940	141,000 1940
Savannah River near Clyo, Ga. 1985	1929-33 and 1937-2007*	9,850	11,620	1.18	5,520	1,950 1931	203,000 1929	270,000 1929

mi^2, square miles; cfs, cubic feet per second; cfsm, cubic feet per second per square mile of drainage area
90% exceeds flow: the discharge that has been exceeded 90 percent of the time during the period of record for that gaging station
** 2007 is the most recent year for which published data were available when this table was prepared*
1 *Records from before Lake Thurmond began regulating flow of the Savannah River*
2 *Records from after Lake Thurmond began regulating flow of the Savannah River*

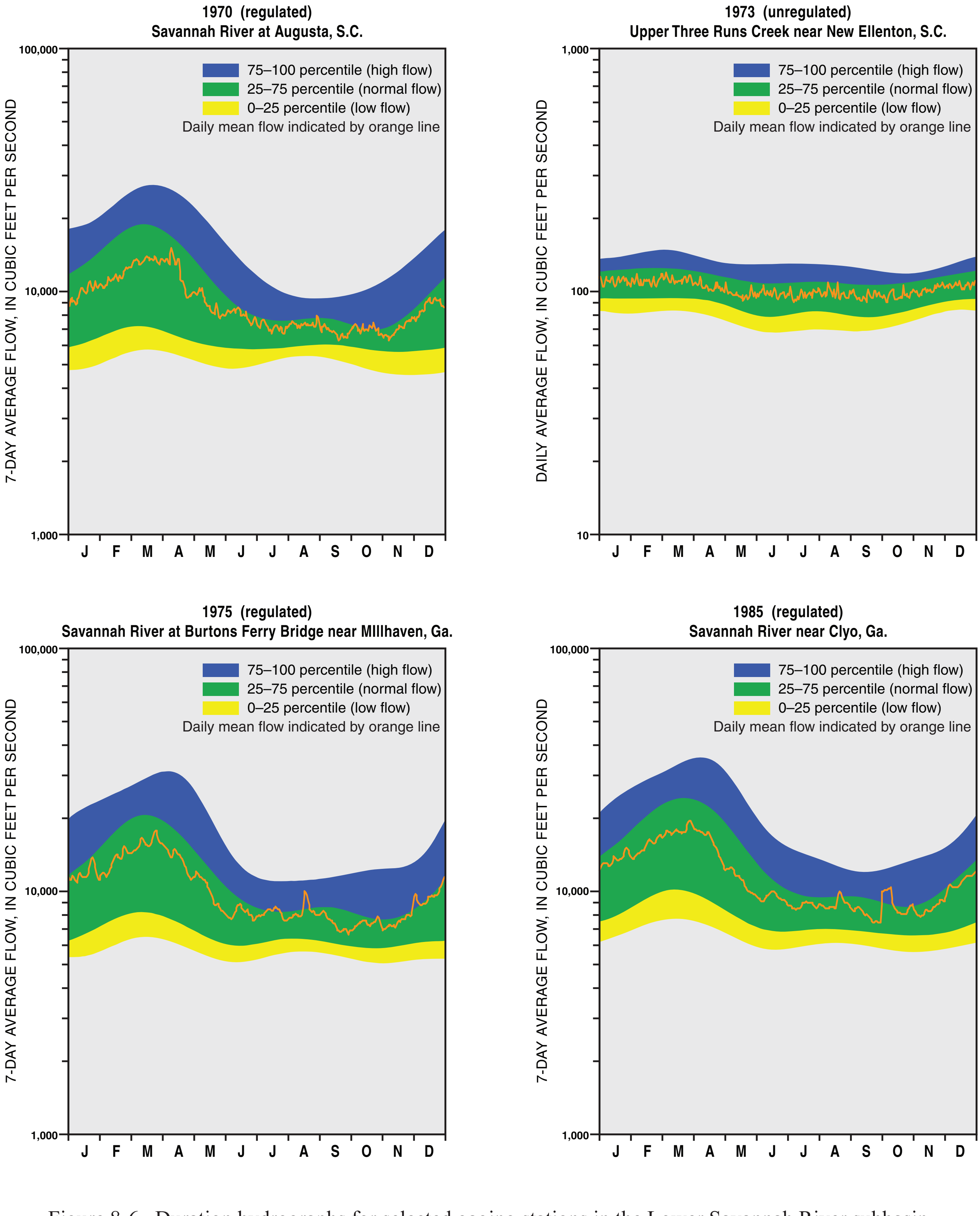


Figure 8-6. Duration hydrographs for selected gaging stations in the Lower Savannah River subbasin.

power facilities (Figure 8-6). This streamflow regulation has resulted in higher and more well-sustained low flows. In the upper portion of the main stem, streamflow is generally more variable due to upstream releases; in the lower portion of the main stem, streamflow becomes more uniform as inflow from tributary streams and the modifying effect of surrounding wetlands stabilize flow.

One gaged tributary stream, Upper Three Runs Creek in Aiken County, is located in the upper Coastal Plain and exhibits the characteristically well-sustained flows of streams in that province (Figure 8-6). Streamflow is uniform and shows well-supported base flow. No data exist for tributary streams in the middle and lower Coastal Plain regions of the subbasin; however, streamflow characteristics for these streams are probably similar to those of other middle and lower Coastal Plain streams that exhibit highly-variable flow and poorly-sustained base flow during periods of low rainfall.

Development

Little surface-water development occurs in the lower Savannah River subbasin. Most development consists of navigation projects in the Savannah River from the Savannah Harbor to Augusta, Georgia.

The only large lake in the subbasin is Par Pond, located on Lower Three Runs Creek on the Savannah River Site in Barnwell County. Par Pond has a surface area of 2,700 acres and a volume of 54,000 acre-ft. The next largest impoundment—Langley Pond, on Horse Creek near Graniteville in Aiken County—has a surface area of 250 acres and a total volume of 1,250 acre-ft.

Nearly all of the lower Savannah River is included in two U.S. Army Corps of Engineers (COE) navigation projects. One project involves maintaining a navigation channel in the Savannah Harbor and the other involves maintaining a navigation channel in the Savannah River from Savannah Harbor to Augusta, Georgia. The channel to Augusta provides the only inland commercial navigation in the State.

The COE actively maintains a 42-foot deep navigation channel in the Savannah Harbor. A plan to deepen the harbor was authorized in 1999 and remains in the planning stage. If completed, it will deepen the Savannah River channel from the ocean bar (Atlantic Ocean and Savannah River entrance) to the Georgia Ports Authority by as much as 6 feet, for a total depth of 48 feet.

The New Savannah Bluff Lock and Dam, located on the Savannah River 13 miles below Augusta, was constructed by the COE in 1937 to improve navigation on the Savannah River between the Savannah Harbor and Augusta. Commercial traffic through the lock ceased in 1979, and maintenance of the facility and its navigation channel was discontinued. Although the lock is no longer used for commercial navigation, the dam creates a relatively stable pool of water in the river that serves as a source for municipal, industrial, and agricultural water supply for the North Augusta area.

There are no completed flood-control projects in the subbasin, although the COE completed reconnaissance studies of two problem areas in Aiken County—Sand River and Horse Creek—many years ago.

Surface-Water Quality

Water bodies in the Lower Savannah River subbasin, except for near the coast, are designated “Freshwater” (Class FW). This water-use classification is assigned to water bodies that are suitable for the survival and propagation of aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses (DHEC, 2003c).

The sections coastward of U.S. Highway 17 are designated as “Tidal Saltwater” (Class SB). Class SB represents tidal saltwater suitable for primary- and secondary-contact recreation, crabbing, and fishing. These water bodies are not protected for harvesting clams, mussels, or oysters for market purposes or human consumption. Class SB waters must maintain dissolved-oxygen concentrations of at least 4.0 mg/L (milligrams per liter).

As part of its ongoing Watershed Water Quality Assessment program, DHEC sampled 29 sites in the subbasin in order to assess the water’s suitability for aquatic life and recreational use (Figure 8-7). Aquatic life was fully supported at 25 sites, or 86 percent of the water bodies sampled; four sites were impaired, mainly because of pH excursions. Recreational use was fully supported in 75 percent of the tested water bodies; water that did not fully support recreational use exhibited high levels of fecal-coliform bacteria (DHEC, 2003c). Water-quality impairments in the subbasin are summarized in Table 8-9.

Water-quality conditions can change significantly from year to year, and water bodies are reassessed every 2 years for compliance with State water-quality standards. DHEC publishes recent impairments and water-quality trends online in their 303(d) listings and 305(b) reports.

In 2008, as in several prior years, DHEC has issued fish-consumption advisories for the entire Savannah River downstream from Stevens Creek and for Langley, Flat Rock, and Vaucluse ponds in Aiken County. Fish-consumption advisories are issued in areas where fish are contaminated with mercury; the contamination is only in the fish and does not make the water unsafe for swimming or boating.

Figure 8-7. Surface-water-quality monitoring sites evaluated by DHEC for suitability for aquatic life and recreational uses. Impaired sites are listed in Table 8-9 (DHEC, 2003c).

Table 8-9. Water-quality impairments in the Lower Savannah River subbasin (DHEC, 2003c)

Water-body name	Station number	Use	Status	Water-quality indicator
Horse Creek	SV-071	Aquatic life	Nonsupporting	pH
	SV-096	Aquatic life	Partially supporting	pH
	SV-072	Recreation	Partially supporting	Fecal coliform
	SV-250	Aquatic life	Nonsupporting	pH
		Recreation	Partially supporting	Fecal coliform
Hollow Creek	SV-350	Recreation	Partially supporting	Fecal coliform
Tims Branch	SV-324	Recreation	Partially supporting	Fecal coliform
Fourmile Creek	SV-326	Recreation	Partially supporting	Fecal coliform
Cypress Creek	SV-356	Aquatic life	Nonsupporting	Dissolved oxygen
Savannah River	SV-191	Recreation	Partially supporting	Fecal coliform

GROUND WATER

Hydrogeology

The Lower Savannah River subbasin is almost entirely in the Coastal Plain and is generally underlain by the same aquifers that occur throughout the Coastal Plain of South Carolina. The aquifers originate southeast of the Fall Line and dip toward the coast. The lowermost aquifer is the Cape Fear, which rarely is tapped by wells. The overlying Middendorf aquifer first occurs at a depth of 50 to 100 feet below the ground surface in the upper extent of the subbasin and deepens to approximately 2,800 feet in southern Jasper County. The Middendorf aquifer ranges in thickness from 0 to 300 feet between the upper and lower ends of the subbasin. Overlying the Middendorf is the Black Creek aquifer, which is in turn overlain by the Black Mingo, Congaree, McBean, and Barnwell Formations of the Tertiary sand aquifer and the shallow aquifer. In the lower Coastal Plain, the Floridan aquifer and shallow aquifer overlay the Tertiary sand aquifer. Selected ground-water data for the subbasin are presented in Table 8-10.

Table 8-10. Selected ground-water data for the Lower Savannah River subbasin

Vicinity	Aquifer	Well depth (feet)	Major well yield (gpm)
Aiken County	Middendorf	120–625	80–1,500
Savannah River Site	Middendorf	400–875	370–2,200
Williston	Tertiary sand/ Black Creek/ Middendorf/	100–700	120–1,350
Scotia	Floridan	54–374	1,250
Hardeeville	Floridan	182–600	1,040

The major aquifers underlying Aiken and Barnwell Counties are the Middendorf, Black Creek, and Tertiary sand aquifers. The Middendorf aquifer underlies the two-county area and is the principal aquifer. At sites close to the Fall Line, where overlying sand deposits become very thin, the Middendorf aquifer produces less water than in the areas farther south and east. A well for the city of Aiken reached basement granite at a depth of 517 feet below land surface; a test hole near the center of the Savannah River Site reached basement at a depth of 985 feet below land surface; and triassic rocks (basement) were reached at 1,240 feet in a well in the southern part of the Savannah River Site.

Transmissivities determined from pumping tests of Middendorf-aquifer wells in Aiken County range from 700 to 31,000 ft^2/day. Pumping tests of two wells screened in both the Middendorf and overlying Black Creek aquifers indicated composite transmissivities of 6,400 and 13,000 ft^2/day; these wells were pumped at 1,550 and 2,200 gpm (gallons per minute), respectively.

The Black Creek aquifer, either screened alone in wells or in combination with the Middendorf, is an important source of supply in the subbasin, and well yields as great as 1,000 gpm have been obtained from the Black Creek aquifer.

In places near the Fall Line, the Black Creek Formation evidently was eroded before deposition of the Black Mingo or equivalent Tertiary sand sediments, thus the latter directly overlies the Middendorf in a limited area. The Black Mingo component of the Tertiary sand aquifer is a minor source of supply in this part of the subbasin.

The Tertiary sand aquifer also encompasses the Congaree, McBean, and Barnwell Formations above the Black Mingo. Their thickness ranges from about 125 feet in the northwestern part of the Savannah River Site to about 400 feet in the southeastern part near the Allendale County line. Yields of Tertiary-sand wells tapping the

McBean and Congaree Formations range from 60 to 660 gpm in the Savannah River Site area. The Barnwell Formation section of the Tertiary sand aquifer thickens southeastward across Aiken and Barnwell Counties from a featheredge to approximately 90 feet and may be in hydraulic continuity with the McBean Formation.

Few wells tap the Cretaceous aquifers in Hampton and Jasper Counties because of the greater depth and, in some cases, poor water quality, especially near the coast. A few large wells in Hampton County withdraw water in excess of 1,000 gpm from the Black Creek aquifer. The top of the Tertiary sand, consisting mainly of the Black Mingo Formation in Hampton County, occurs at a depth of 400 to 600 feet. The Peedee Formation, which principally is a confining unit within and above the Black Creek aquifer, supplies deep wells at Hampton and Varnville in Hampton County.

The Floridan aquifer is the most widely used ground-water source in the Allendale, Hampton, and Jasper County reaches of the lower Savannah River. The Ocala Limestone forms the uppermost and most productive section of the Floridan, and the top of the principal permeable zone generally occurs within 50 to 150 feet of land surface. Transmissivities are highest of any aquifer in the State and exceed 40,000 ft^2/day in Jasper County. Wells capable of 500 to 2,000 gpm are possible nearly everywhere in the subbasin.

Ground-Water Quality

The quality of water in the Middendorf aquifer varies throughout the subbasin. In the upper reaches the water is low in total dissolved solids (TDS), is soft, and has a low pH. Because of its acidity and the appreciable amount of dissolved carbon dioxide, the water is corrosive to steel and brass well screens. Sodium chloride type water predominates in this region (Logan and Euler, 1989). Near the outcrop, TDS, chloride, and alkalinity are about 25, 5.0, and 2.5 mg/L, respectively, and pH is 6.5. These concentrations increase toward the coast, where TDS concentrations exceed 1,000 mg/L and the pH increases to more than 8.5 (Speiran and Aucott, 1994).

Ground-water contamination has been documented at the Savannah River Site. Metals, nitrates, and radioactive materials have been detected in shallow aquifers, and organic contaminants (Triclene, Perclene, and trichloroethylene) were found in wells open to the Middendorf aquifer.

Water quality of the Black Creek aquifer is similar to that of the Middendorf aquifer. Total dissolved solids range from 25 mg/L near the outcrop to 200 mg/L in southern Allendale County and probably are more than 2,500 mg/L at the coast. Chloride concentration increases along the subbasin from 3 to 1,000 mg/L, alkalinity increases from about 20 mg/L to more than 1,000 mg/L, and pH increases from 4.5 to more than 7.5 (Speiran and Aucott, 1994; Logan and Euler, 1989). High iron concentrations are common in Allendale County.

In Aiken and Barnwell Counties, water in the Tertiary sand aquifer is low in dissolved solids (usually less than 50 mg/L), acidic, and high in iron. Water in the lower part of the aquifer commonly contains hydrogen sulfide gas, which causes a "rotten-egg" odor (Logan and Euler, 1989). Downdip, dissolved solids and pH increase as aquifer sediments become more calcareous.

The Floridan aquifer yields calcium bicarbonate type water with pH between 7.5 and 8.8, TDS generally less than 200 mg/L, hardness less than 140 mg/L (as $CaCO_3$), and chloride concentrations less than 15 mg/L (Hayes, 1979).

Freshwater is present in the Floridan aquifer throughout the Jasper County reach; however, this condition is changing. Test wells drilled offshore from the mouth of the Savannah River and next to Bull River, on the Georgia side of the subbasin, show seawater migrating downward into the Floridan aquifer (see the *Special Topics* chapter).

Shallow aquifers vary in water quality depending on the geology and interactions with surface-water bodies. Total dissolved solids typically are less than 100 mg/L, and the greatest TDS usually are associated with the moderately-hard to hard water that occurs where shell material is abundant. High iron concentrations are common.

Water-Level Conditions

Ground-water levels are regularly monitored by DNR and USGS in 21 wells within the Lower Savannah River subbasin (Table 8-11). Water levels in other wells in the subbasin are sometimes measured to help develop potentiometric maps of the Middendorf, Black Creek, and Floridan aquifers.

Because the southern portion of this subbasin (in Jasper County) is very narrow and relatively undeveloped, this part of the subbasin experiences little use of ground water. Despite this, water levels in the Floridan aquifer in this region have declined significantly owing to pumping at Savannah, Georgia. The large cone of depression that has developed around Savannah, where water levels in the aquifer that were originally 10 to 35 feet above sea level in 1880 were as low as 140 feet below sea level in 2004, extends into Jasper County. Water levels estimated to be above sea level before development are now at or below sea level in southern Jasper County (see Figure 7-13). In 2004, the lowest point on the Floridan potentiometric surface in South Carolina, in southern Jasper County, was 57 feet below sea level, about 80 feet below the predevelopment level (Hockensmith, 2009). Research by DHEC and USGS shows that seawater is migrating vertically into the Floridan aquifer from the tidal streams and marshlands in the lower reaches of the subbasin (see the *Special Topics* chapter).

Table 8-11. Water-level monitoring wells in the Lower Savannah River subbasin

Well number	Monitoring agency*	Latitude Longitude (deg min sec)	Aquifer	Well location	Land surface elevation (feet)	Depth (feet) to screen top, bottom; or open interval
AIK-430	USGS	33 19 40 81 44 35	Middendorf	Savannah River Site	357	390–600
AIK-817	DNR	33 26 17 81 46 15	Middendorf	DNR cluster site C-2, New Ellenton	419	520–530
AIK-818	DNR	33 26 17 81 46 14	Middendorf	DNR cluster site C-2, New Ellenton	419	410–420
AIK-824	DNR	33 26 16 81 46 14	Black Creek	DNR cluster site C-2, New Ellenton	419	350–360
AIK-825	DNR	33 26 16 81 46 14	Black Creek	DNR cluster site C-2, New Ellenton	419	216–226
AIK-2378	DNR	33 21 11 81 48 33	Black Creek	DNR cluster site C-1, Jackson	220	170–180
AIK-2379	DNR	33 21 11 81 48 32	Black Creek	DNR cluster site C-1, Jackson	224	251–261
AIK-2380	DNR	33 21 12 81 48 32	Middendorf	DNR cluster site C-1, Jackson	228	370–380
ALL-347	DNR	33 01 28 81 23 03	Middendorf	DNR cluster site C-10, Appleton	282	1,408–1,418
ALL-348	DNR	33 01 29 81 23 05	Cape Fear	DNR cluster site C-10, Appleton	281	1,575–1,600
ALL-358	DNR	33 06 47 81 30 22	Middendorf	DNR cluster site C-7, Martin	243	1,108–1,118
ALL-363	DNR	33 06 48 81 30 22	Floridan	DNR cluster site C-7, Martin	246	90–100
ALL-364	DNR	33 06 48 81 30 22	Floridan	DNR cluster site C-7, Martin	245	210–220
ALL-366	DNR	33 06 47 81 30 22	Floridan	DNR cluster site C-7, Martin	244	385–395
ALL-367	DNR	33 06 47 81 30 22	Black Creek	DNR cluster site C-7, Martin	246	551–561
ALL-371	DNR	33 01 28 81 23 05	Floridan	DNR cluster site C-10, Appleton	282	192–212
ALL-372	DNR	33 01 28 81 23 04	Tertiary sand	DNR cluster site C-10, Appleton	282	140–150
ALL-373	DNR	33 01 28 81 23 03	Floridan	DNR cluster site C-10, Appleton	280	327–367
ALL-375	DNR	33 01 28 81 23 06	Tertiary sand	DNR cluster site C-10, Appleton	283	453–578
ALL-376	DNR	33 01 28 81 23 05	Black Creek	DNR cluster site C-10, Appleton	282	784–989
ALL-377	DNR	33 01 28 81 23 04	Middendorf	DNR cluster site C-10, Appleton	282	1,174–1,194

* *DNR, South Carolina Department of Natural Resources; USGS, United States Geological Survey*

In the upper part of the subbasin (Aiken and Barnwell Counties), water levels in the Middendorf and Black Creek aquifers are not significantly lower than estimated predevelopment levels. Water levels in this area are sensitive to both rainfall and pumping, and the extent to which pumping affects water levels is difficult to determine, owing to the high transmissivity of the aquifers and the effect of natural discharge to the Savannah River (Hockensmith, 2008a and b).

WATER USE

Water use information presented in this chapter is derived from water-use data for the year 2006 that were collected and compiled by DHEC (Butler, 2007) and represents only withdrawals reported to DHEC for that year. Water-use categories and water-withdrawal reporting criteria are described in more detail in the *Water Use* chapter of this publication.

Water use in the Lower Savannah River subbasin for the year 2006 is summarized in Table 8-12 and Figure 8-8. Total offstream water use in the subbasin was 97,263 million gallons in 2006, ranking it seventh among the 15 subbasins. Of this amount, 89,826 million gallons came from surface-water sources (92 percent) and 7,437 million gallons came from ground-water sources (8 percent). Thermoelectric power generation accounted for 58 percent of the total, followed by industry (25 percent) and water supply (16 percent). Consumptive use in this subbasin is estimated to be 6,665 million gallons, or about 7 percent of the total offstream use.

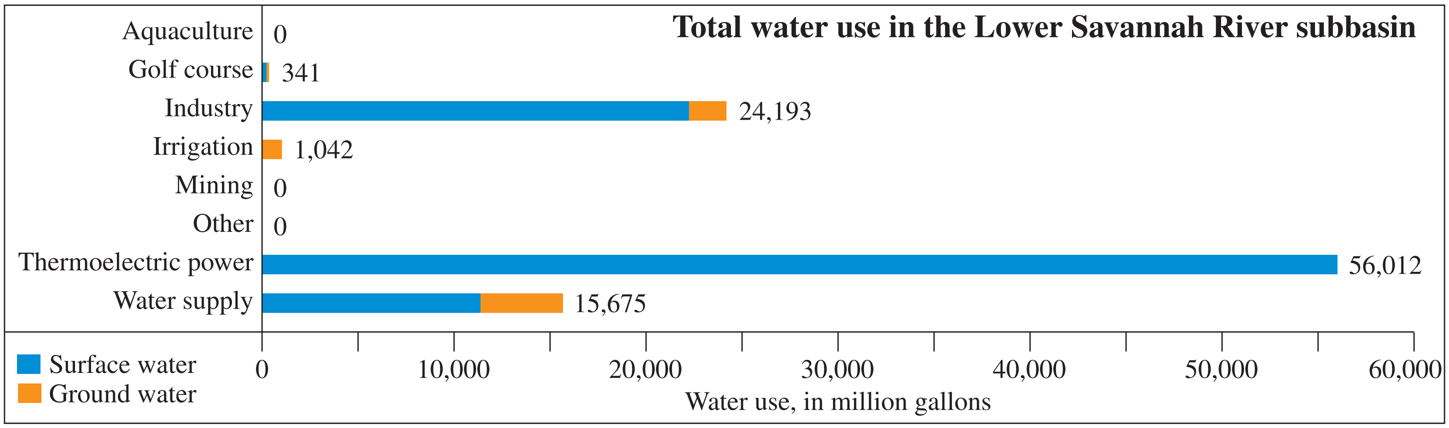
Table 8-12. Reported water use in the Lower Savannah River subbasin for the year 2006 (modified from Butler, 2007)

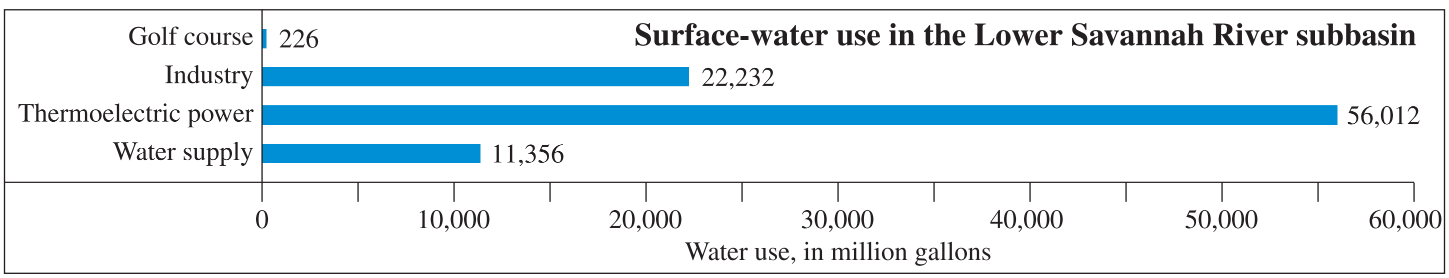
Water-use category	Surface water		Ground water		Total water	
	Million gallons	Percentage of total surface-water use	Million gallons	Percentage of total ground-water use	Million gallons	Percentage of total water use
Aquaculture	0	0.0	0	0.0	0	0.0
Golf course	226	0.3	115	1.6	341	0.3
Industry	22,232	24.7	1,961	26.4	24,193	24.9
Irrigation	0	0.0	1,042	14.0	1,042	1.1
Mining	0	0.0	0	0.0	0	0.0
Other	0	0.0	0	0.0	0	0.0
Thermoelectric power	56,012	62.4	0	0.0	56,012	57.6
Water supply	11,356	12.6	4,319	58.0	15,675	16.1
Total	89,826		7,437		97,263	

The only thermoelectric power plant in the subbasin reporting water use was SCE&G's Urquhart Station. Located near North Augusta on the Savannah River, the plant, which burns both coal and natural gas, has a capacity of 650 megawatts, and is SCE&G's oldest fossil-fuel thermoelectric plant, having been in operation since 1953. In 2006, the station used 56,012 million gallons of water, all from the Savannah River.

Industrial water use totaled 24,193 million gallons in the subbasin, third highest in the State. Of this amount, 22,232 million gallons came from surface-water sources (92 percent) and 1,961 million gallons came from ground-water sources (8 percent). Primesouth, in Aiken County, had the greatest surface-water use, withdrawing 18,184 million gallons from the Savannah River. Primesouth is the second largest industrial user in the State. The Savannah River Site (SRS) used a total of 1,036 million gallons of ground water at four different areas on the site, pumping from the Middendorf aquifer (known as the McQueen Branch aquifer at SRS), Black Creek aquifer (Crouch Branch aquifer at SRS), and the Tertiary sand aquifer (Gordon aquifer at SRS). The Savannah River Site also reported using 1,051 gallons of surface water in 2006. Clariant Corporation in Allendale County is the subbasin's other large industrial user of ground water, withdrawing 850 million gallons from the Black Creek aquifer.

Water-supply use in the Lower Savannah River subbasin totaled 15,675 million gallons. Surface water accounted for 11,356 million gallons (72 percent) and ground water for 4,319 million gallons (28 percent). Beaufort-Jasper Water and Sewer Authority was the largest of the three surface-water users, withdrawing 8,072 million gallons from the Savannah River, much of which is used outside the Lower Savannah River subbasin. Edgefield County Water and Sewer used 1,652 million gallons and the city of North Augusta used 1,632 gallons, both from the Savannah River. The city of Aiken had the largest ground-water system, pumping 2,124 million gallons, primarily from the Middendorf aquifer. Beech Island Water District had withdrawals of 502 million gallons from the Middendorf aquifer.





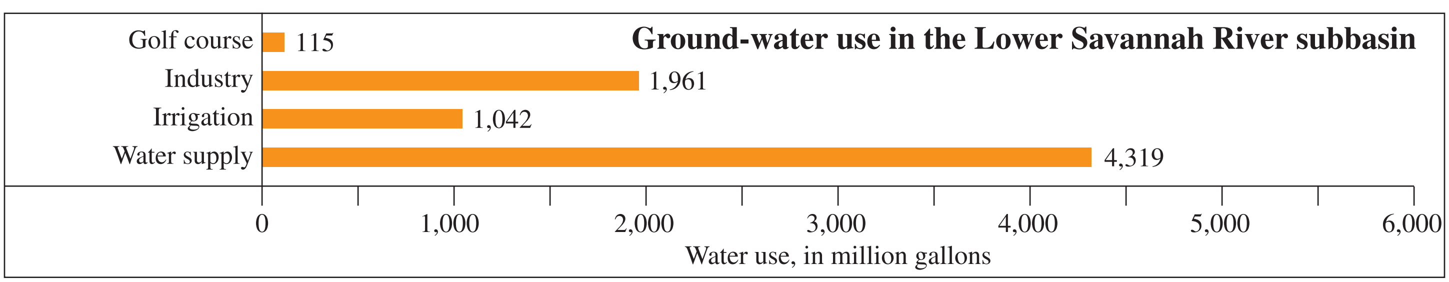
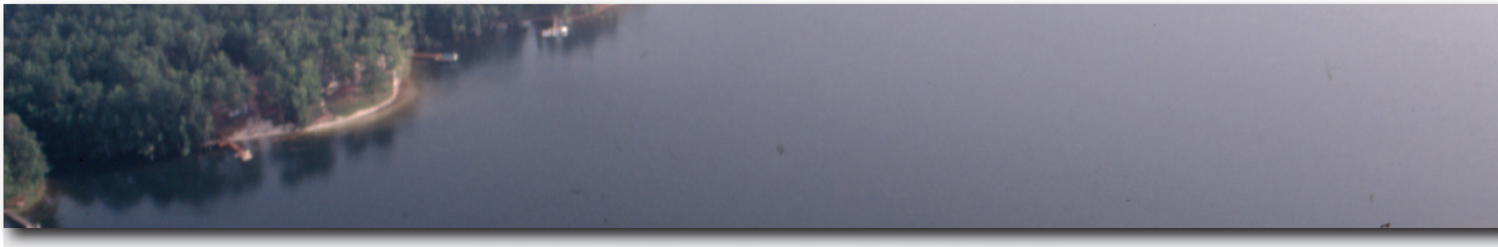


Figure 8-8. Reported water use in the Lower Savannah River subbasin for the year 2006 (modified from Butler, 2007).



SPECIAL TOPICS

SPECIAL TOPICS

Water-resource activities and concerns are numerous and varied. Some have been presented earlier in the statewide overview and the subbasin analyses; however, many water-resource topics require more in-depth coverage and/or do not lend themselves to the statewide or subbasin presentation format. While many topics could be presented in this section, the most important were selected to give the reader a balanced overview of water-resource concerns.

The special topics in order of presentation are:

- Hydroelectric power
- FERC relicensing
- Instream flow needs
- Navigation
- River conservation
- Aquatic nuisances
- Water recreation
- Sedimentation in surface waters
- Unique wetland areas
- Coastal concerns
- Saltwater contamination
- Aquifer storage and recovery
- Water conservation
- Interbasin transfers
- Drought management and mitigation
- Flooding

HYDROELECTRIC POWER

Not until the mid-1800's were turbines developed that could efficiently produce electricity from flowing water. Beginning in the 1880's, the Nation as well as the State saw a dramatic increase in the development of hydroelectric power. The Piedmont region of South Carolina, with its abundance of free-flowing waters and relatively high relief, was ideally suited for this type of development. Industry quickly took advantage of these conditions and built factories with hydropower facilities at many sites, thus providing each factory with its own source of electricity. In 1895, the Columbia Water Power Company became the first company to commercially produce electricity in South Carolina (Kohn, 1910; Federal Power Commission, 1970). Power from the company's Columbia Canal facility was first sold to local mills and then later used to power streetcars and streetlights in the city of Columbia. South Carolina Electric and Gas Company (SCE&G) now operates this facility.

The Lower Pelzer Hydroelectric facility, built in 1895 on the Saluda River in Williamston, a town about 30 miles south of Greenville, is said to be the first facility to use overhead wires to transmit electricity long distances, providing power to the Pelzer Manufacturing Company located a few miles upstream of the project (Enel North America, 2004). The Lower Pelzer project was inducted into the Hydro Hall of Fame for 100 years of continuous operation. Another milestone in South Carolina's hydropower development was the transmission of power from Portman Shoals to Anderson in 1897, the longest distance of electric power transmission in the United States at the time (Confederation of South Carolina Historical Societies, 1978). Such long-distance power transmission allowed for development of remote hydropower sites.

Types of Facilities

Hydropower has experienced tremendous growth and change since its beginnings. Hydroelectric power facilities range in size from small developments with little storage to large dams with several turbines. Smaller facilities often depend entirely on streamflow and are referred to as run-of-river plants; these were the type most frequently constructed in the early days of hydroelectric development. Today, a single hydropower facility may impound thousands of acre-feet of water and produce thousands of mega-watt hours of energy.

Besides the numerous technological improvements that have allowed for more efficient production of electricity, many new concepts in hydropower production have been developed. One of the most important of these is the development of pumped-storage facilities. At a conventional hydropower facility, water released from a reservoir through turbines to produce electricity is lost downstream, whereas at a pumped-storage site, some of the released water is retained in a tailwater pool and is later pumped back into the headwater pool to be used again to generate more electricity. This is made possible by reversible pump turbines, which serve as both generators—creating electricity when water is passed through them from upstream to downstream—and pumps—using electricity to pump water from downstream back into the upper reservoir. During periods of high electrical demand when electricity is relatively expensive, usually weekday mornings and afternoons, electricity is produced by releasing water from the headwater pool through the pump turbines and into the tailwater pool. Later, during periods of low electrical demand when electricity is relatively inexpensive, usually at night or on weekends, the turbines are reversed and used to pump water back into the headwater pool where it is stored until needed during another peak-demand time. Although more energy is required to pump water back into the headwater pool than is generated when the water is released, this process is economically feasible because the cost of electricity is much lower when pumping back water than when releasing water from the upper reservoir. Although pumped-storage facilities allow water to be used more than once to generate electricity, not all water within the tailwater reservoir is retained. Discharges are allowed to satisfy downstream flow requirements and to compensate for inflow, and some water is lost to evaporation. There are currently four pumped-storage facilities in South Carolina: Lake Russell (U.S. Army Corps of Engineers), Fairfield Pumped Storage Facility (SCE&G), Bad Creek (Duke Energy), and Lake Jocassee (Duke Energy) (Table 9-1). These facilities have a total capacity of about 2,800 MW (megawatts).

A modern, sophisticated steam plant may require up to 72 hours to generate enough steam to start producing electricity, making it very expensive to either start or stop operations. These plants are better suited for meeting base load demands. Base load is defined as the mean of the Monday to Friday minimum loads, plus 10 percent. Base load operation of hydropower plants is normally confined to those facilities that lack storage (run-of-river) or those that must be run continually to meet downstream flow requirements. Hydropower plants are well suited for meeting peak loads (defined as the greatest difference between the Monday to Friday daily peak and the daily load equaled or exceeded 12 hours per day) and reserve loads because they have the ability to produce electricity on short notice and to stop quickly once demands are met or reduced. Newer hydropower plants reflect this use as peaking units; they are designed to operate less than 20 percent of the time. The recent and continuing construction of large pumped-storage units also emphasizes the importance placed on hydropower for peaking energy.

The distribution of power generated at hydropower plants in South Carolina depends mainly on plant ownership and location. Hydropower generated by municipalities or cooperatives is usually used in the immediate vicinity of the plant site. Power produced at Federal projects such as Lake Thurmond and marketed by the Southeastern Power Administration is often carried through major transmission lines or "wheeled" to distant users.

Current Facilities

Currently, 46 hydroelectric plants use the waters in or adjacent to South Carolina (Figure 9-1). Plants range in

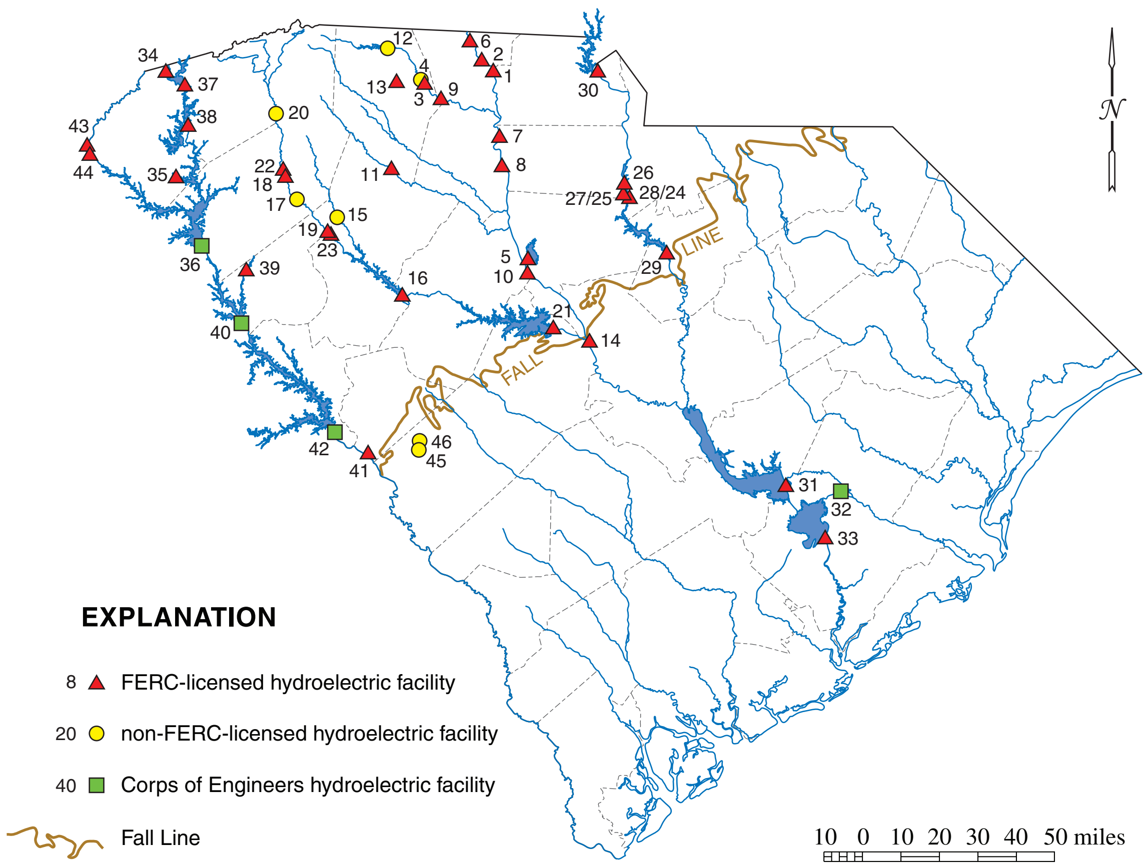


Figure 9-1. Existing hydroelectric power plants in and adjacent to South Carolina. See Table 9-1 for facility information.

capacity from less than 1 MW to 1,065 MW (Table 9-1). The largest conventional hydropower plant is the U.S. Army Corps of Engineers' Hartwell facility, which has a capacity of 420 MW, and the largest pumped-storage plant is Duke Energy's Bad Creek facility, which has a capacity of 1,065 MW. Total generating capacity of all the hydroelectric plants in or adjacent to South Carolina is about 4,600 MW, which is about 20 percent of the total capacity of all electricity-generating facilities in the State. Of the total hydropower generating capacity, 2,800 MW are provided by pumped-storage facilities. Since hydroelectric power plants are generally designed to operate less than 20 percent of the time, yearly outputs are much lower than these numbers indicate. In 2006, hydroelectric plants generated 1,806,948 MWH (megawatt-hours) of energy, which was only 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).

Duke Energy owns the most hydroelectric facilities in or adjacent to South Carolina, with twelve facilities, followed by SCE&G, which owns six (Table 9-1). Most hydroelectric facilities are located in the Piedmont region of the State on the Savannah, Broad, Saluda, and Catawba-Wateree Rivers. The only large facilities outside the Piedmont are those associated with the Santee-Cooper Lakes.

Potential Hydropower Sites

In 1976, Congress authorized the National Hydroelectric Power Resources Study, one objective of which was to identify potential sites for the development of future hydroelectric power facilities. Results of the study indicated that South Carolina has considerable potential for additional hydropower development (Table 9-2). If fully developed, these facilities could provide a total generating capacity of about 4,000 MW and produce an additional 4.8 million MWH of electricity annually (U.S. Army Corps of Engineers, 1982a). At least four of these potential sites have been developed since that study was made: Bad Creek, Richard B. Russell, St. Stephen, and Clifton No. 3.

Potential for hydropower development in the Pee Dee Basin is limited due to the basin's low topographic relief. The dam at Lake Robinson, in the Black River subbasin, is the only existing site having potential for hydropower development. With a power head of 32.6 feet, this site has the potential to generate 1.7 MW and generate 4,860 MWH of energy annually (U.S. Army Corps of Engineers, 1982a).

Most of the State's potential hydroelectric power development is in the Broad River subbasin. Twelve major sites and six alternate sites have been identified on the Broad, Pacolet, and Tyger Rivers (Table 9-2). The maximum potential generating capacity of these sites totals 1,450 MW, which could provide an additional 1.7 million MWH of electricity per year.

Four sites in the Saluda River subbasin have been identified in the National Hydropower Study as being feasible for development. Three sites occur on the Saluda River and one, a retired hydropower plant, is on the Reedy River. These sites have a total potential capacity of 40.5 MW and could provide almost 77,000 MWH of energy annually.

Most of the Catawba River, in the Catawba-Wateree subbasin, has been developed for hydropower production. A head of 88.5 feet, however, remains undeveloped between Duke Energy's existing Lake Wylie and Fishing Creek hydropower plants. Two potential hydroelectric sites have been identified to utilize this remaining head. These sites, Sugar Creek and Courtney Island, could support a total capacity of 77 MW and generate on the average 253,000 MWH of energy annually. Development of these sites would inundate the Catawba River's only remaining free-flowing water and create a chain of hydroelectric reservoirs from the North Carolina boundary to Lake Wateree. Development of Courtney Island may also have significant impacts on Landsford Canal State Park.

Four potential hydroelectric power sites have been identified in the Congaree River subbasin. In 1965, the Charleston District of the U.S. Army Corps of Engineers completed an interim report on navigation for the Santee River System from Charleston to Columbia. Part of this report proposed development of three low-level locks and dams on the Congaree River. These low-level dams were included in the National Hydropower Study with all three being economically favorable. Part of a navigation plan recommended prior to the above plan proposed development of a dam site just above the Gervais Street Bridge in Columbia. Development of this site would renovate the existing Columbia Canal hydropower plant and would inundate the Lower Saluda site. The potential generating capacity of these four sites is almost 107 MW with an average annual energy output of 414,000 MWH.

One site in the upper portion of the Edisto River subbasin is potentially feasible for a pumped-storage hydropower development. The headwater reservoir would be located on Rocky Springs Creek and the tailwater reservoir would be located on the South Fork Edisto River. This development would permit a gross power head of 190 feet with a capacity of 500 MW and average annual energy output of 438,000 MWH.

The 84-MW St. Stephen Hydroelectric Plant, located in the Ashley-Cooper subbasin, was completed in the mid-1980's and is owned by the U.S. Army Corps of Engineers and operated by Santee Cooper.

The Upper Savannah River subbasin has undergone extensive hydropower development in its upper reaches.

Table 9-1. Existing hydroelectric power plants in and adjacent to South Carolina (number on map refers to Figure 9-1)

Subbasin	Number on map	Facility name	Owner	Source of water	Height of dam (feet)	Maximum storage (acre-feet)	Generating capacity (megawatts)	Water use in year 2006 (million gallons)	FERC license number
Broad	1	Ninety-nine Islands	Duke Energy	Broad River	86	2,300	18.0	32,949	P-2331
	2	Cherokee Falls	Broad River Electric Coop.	Broad River	– – –	– – –	4.3	– – –	P-2880
	3	Clifton Mills #1	Clifton Power Corp.	Pacolet River	– – –	– – –	0.8	– – –	P-4632
	4	Clifton Dam #3	Converse Energy	Pacolet River	28	– – –	1.2	– – –	– – –
	5	Fairfield (Pumped Storage)	South Carolina Electric & Gas	Broad River/Frees Creek	180	431,000	511.2	1,920,104	P-1894
	6	Gaston Shoals	Duke Energy	Broad River	64	2,000	8.5	213,600	P-2332
	7	Lockhart	Lockhart Power Co.	Broad River	16	15,000	18.0	583	P-2620
	8	Neal Shoals	South Carolina Electric & Gas	Broad River	33	6,000	5.2	326,592	P-2315
	9	Pacolet	Lockhart Power Co.	Pacolet River	24	100	0.8	35	P-2621
	10	Parr Shoals	South Carolina Electric & Gas	Broad River	50	33,000	14.4	593,019	P-1894
	11	Riverdale	Inman Mills	Enoree River	14	20	1.2	– – –	P-4362
	12	Spartanburg Water	Spartanburg CPW	South Pacolet River	58	4,500	1.0	11,818	– – –
	13	Whitney Mills	Daniel N. Evans	Lawson's Fork Creek	23	30	0.2	– – –	P-10881
Congaree	14	Columbia Hydro	City of Columbia	Broad River	14	1,100	10.6	350,770	P-1895
Saluda	15	Boyd Mill	Northbrook Carolina Hydro	Reedy River	42	3,000	1.4	– – –	– – –
	16	Buzzard's Roost	Greenwood County	Saluda River	82	270,000	15.0	93,433	P-1267
	17	Hollidays Bridge	Northbrook Carolina Hydro	Saluda River	48	7,400	4.0	92,268	– – –
	18	Lower Pelzer	Consolidated Hydro SE	Saluda River	44	300	3.3	83,000	P-10253
	19	Piedmont	AquaEnergy Systems	Saluda River	26	600	1.0	56,000	P-2428
	20	Saluda	Northbrook Carolina Hydro	Saluda River	59	7,500	2.4	– – –	– – –
	21	Saluda (Lake Murray)	South Carolina Electric & Gas	Saluda River	204	2,114,000	202.6	149,244	P-516
	22	Upper Pelzer	Consolidated Hydro SE	Saluda River	27	1,000	2.0	35,000	P-10254
	23	Ware Shoals	AquaEnergy Systems	Saluda River	23	500	6.2	0	P-2416
Catawba-Wateree	24	Cedar Creek	Duke Energy	Catawba River	81	9,600	45.0	859,455	P-2232
	25	Dearborn	Duke Energy	Catawba River	82	2,000	46.0	810,158	P-2232
	26	Fishing Creek	Duke Energy	Catawba River	73	80,000	36.7	783,749	P-2232
	27	Great Falls	Duke Energy	Catawba River	82	2,000	24.0	23,821	P-2232
	28	Rocky Creek	Duke Energy	Catawba River	81	96,000	28.0	5,377	P-2232
	29	Wateree	Duke Energy	Catawba River	106	310,000	56.0	923,086	P-2232
	30	Wylie	Duke Energy	Catawba River	90	282,000	60.0	679,938	P-2232

Table 9-1. Continued

Subbasin	Number on map	Facility name	Owner	Source of water	Height of dam (feet)	Maximum storage (acre-feet)	Generating capacity (megawatts)	Water use in year 2006 (million gallons)	FERC license number
Santee	31	Lake Marion Spillway	Santee Cooper	Santee River	61	14,000	2.0	148,325	P-199
	32	St. Stephen	Corps of Engineers	Rediversion Canal	– – –	– – –	84.0	878,848	– – –
Ashley-Cooper	33	Jefferies (Lake Moultrie)	Santee Cooper	Cooper River	81	1,211,000	132.6	983,110	P-199
Upper Savannah	34	Bad Creek (Pumped Storage)	Duke Energy	Bad Creek	– – –	– – –	1,065.2	1,412,404	P-2740
	35	Coneross	AquaEnergy Systems	Coneross Creek	– – –	– – –	0.9	9,800	P-6731
	36	Hartwell	Corps of Engineers	Savannah River	204	2,549,000	420.0	686,485	– – –
	37	Jocassee (Pumped Storage)	Duke Energy	Keowee River	365	1,185,000	662.5	2,168,735	P-2503
	38	Keowee	Duke Energy	Keowee River	160	1,000,000	157.6	155582	P-2503
	39	Rocky River	City of Abbeville	Rocky River	60	31,200	2.6	15807	P-11286
	40	Russell (Pumped Storage)	Corps of Engineers	Savannah River	210	1,026,000	628.0	1297653	– – –
	41	Stevens Creek	South Carolina Electric & Gas	Savannah River	30	17,700	18.4	939326	P-2535
	42	Thurmond	Corps of Engineers	Savannah River	200	2,510,000	280.0	1199816	– – –
	43	Tugalo	Georgia Power Co.	Tugaloo River	155	43,000	45.0	– – –	P-2354
	44	Yonah	Georgia Power Co.	Tugaloo River	90	11,700	22.5	– – –	P-2354
Lower Savannah	45	Graniteville	Avondale Mills, Inc.	Horse Creek	18	1,000	0.5	– – –	– – –
	46	Vaucluse	Avondale Mills, Inc.	Horse Creek	33	1,000	0.2	– – –	– – –

Sources: *South Carolina Department of Health and Environmental Control*
South Carolina Energy Office
South Carolina Public Service Authority
South Carolina Electric & Gas Company
Duke Energy
U.S. Army Corps of Engineers
U.S. Energy Information Administration
Personal correspondence

Table 9-2. Potential hydroelectric power sites in South Carolina

Subbasin	Site name	Source of water	Average streamflow (cfs)	Surface area (acres)	Net power head (feet)	Generating capacity (megawatts)	Average annual energy (MWH)
Pee Dee	Lake Robinson	Black Creek	242	1,800	32.6	1.7	4,860
Broad	Berry Shoals	Tyger River	140	70	74.0	2.1	6,365
	Blairs	Broad River	5,520	36,900	70.5	109.0	235,166
	Blairs A-	Broad River	5,520	9,224	50.0	63.1	161,743
	Burnt Factory	Tyger River	588	1,460	85.0	9.5	26,835
	Clifton #3	Pacolet River	485	29	27.0	2.6	7,455
	Frost Shoals	Broad River	6,565	8,900	67.2	177.3	268,159
	Greater Cherokee Falls	Broad River	2,342	470	33.0	15.0	47,811
	Greater Gaston Shoals	Broad River	2,357	16,300	111.8	115.8	177,861
	Greater Lockhart	Broad River	3,640	51,150	118.0	149.6	232,911
	Greater Lockhart †	Broad River	3,640	58,600	170.0	1,000.0	876,000
	Greater Lockhart (alternate)	Broad River	3,640	58,600	170.0	284.0	319,000
	Lyles Ford	Broad River	5,310	3,270	35.0	25.0	90,900
	Pacolet River	Pacolet River	453	1,050	60.0	6.6	15,963
	Print Crash	Tyger River	108	32	54.0	1.1	3,178
	Trough	Pacolet River	701	1,340	45.0	6.9	18,362
	Tyger River	Tyger River	1,235	13,190	92.0	21.2	61,024
	W.C. Bowen Reservoir	Pacolet River	145	1,516	50.0	1.5	4,030
	Whitmire	Tyger River	1,200	17,310	86.0	20.4	80,519
Saluda	Fork Shoals	Reedy River	210	51	44.8	2.0	5,278
	Lower Saluda	Saluda River	2,900	1,424	31.2	18.0	48,000
	The Forks	Saluda River	655	7,652	95.0	18.3	37,010
	Upper Ware Shoals	Saluda River	976	1,720	60.0	20.2	34,370
Catawba-Wateree	Courtney Island	Catawba River	5,148	5,400	52.0	50.6	164,301
	Sugar Creek	Catawba River	4,863	2,500	36.5	26.4	88,722
Congaree	Lock & Dam #1	Congaree River	10,140	1,632	16.0	21.5	90,100
	Lock & Dam #2	Congaree River	10,070	1,440	14.0	9.3	62,700
	Lock & Dam #3	Congaree River	9,840	1,648	15.0	19.5	82,000
	Reregulator	Congaree River	9,329	727	35.0	56.5	179,000
Ashley-Cooper	St. Stephen*	Rediversion Canal (Lake Moultrie)	12,600	60,400	49.0	84.0	418,000
Edisto	Rocky Springs †	South Fork Edisto	242	8,100	190.0	500.0	438,000
Upper Savannah	Bad Creek* †	Bad Creek	– – –	– – –	1,230.0	1,000.0	32,000
	Dan River No. 1	Twelvemile Creek	230	– – –	49.0	6.9	14,852
	Dan River No. 2	Twelvemile Creek	150	– – –	37.0	5.5	10,856
	Lower Whitewater	Whitewater River	70	162	890.0	16.7	30,778
	Richard B. Russell*†	Savannah River	5,078	26,650	162.0	600.0	788,400
Lower Savannah	Bull Pen Point	Savannah River	12,000	51	14.0	12.8	80,762
	Dicks Lookout Point	Savannah River	11,800	2,990	14.0	24.9	97,899
	Eagle Point	Savannah River	10,800	3,871	14.0	21.5	84,418
	Low Johnsons Landing	Savannah River	11,300	869	14.0	23.3	91,511
	Low Stokes Bluff	Savannah River	12,100	3,376	14.0	13.3	82,844
	New Savannah Bluff	Savannah River	10,200	– – –	12.2	23.7	71,465
	Steel Creek	Savannah River	11,000	11,672	14.0	22.2	87,349

cfs, cubic feet per second; MWH, megawatt-hours
** Construction completed; † Pumped-storage facility*

Source: U.S. Army Corps of Engineers, 1982a

The 628-MW Richard B. Russell pumped-storage facility was completed in 1985 and the 1,065-MW Bad Creek pumped-storage facility went online in 1991. Three other potential hydropower sites were identified in the Upper Savannah River subbasin: two retired low-head hydroelectric power plants located on Twelvemile Creek and one on the lower portion of Whitewater River. If developed, these additional facilities would have a total capacity potential of 29 MW and could provide an average of 56,500 MWH of energy annually.

A feasibility study to create a 12-foot navigation channel on the Savannah River between the cities of Savannah and Augusta included the development of seven lock-and-dam sites. These sites, identified in Table 9-2, could also produce electricity under run-of-river conditions. The potential generating capacity of these sites is about 142 MW, which could provide an average annual energy contribution of 596,000 MWH.

Water Use and Downstream Impacts

In 2006, 31 conventional and 4 pumped-storage hydroelectric plants reported an annual water use of 17,940,200 million gallons (Table 9-1), which was 87.7 percent of the total reported water use in that year. Unlike most other uses, water for hydroelectric power generation is generally not removed from the stream nor consumed, although offstream channel diversion and interbasin transfers may occur.

Although water for hydropower facilities is never removed from a stream, the operation of many of these facilities greatly impacts water availability and quality downstream. Releases from hydroelectric power plants used for peak power generation are greatly increased during periods of high energy demand—typically brief periods during weekday mornings and afternoons—and greatly reduced during periods of generally low energy demand, which is most of the time. Discharges from peaking-power facilities are periodic and result in highly variable flows downstream. Low and widely-fluctuating flows downstream from hydropower facilities adversely impact future water-dependent development, waste assimilative capacity of streams, and biological communities. Hydropower reservoirs trap sediment and nutrients from upstream water and, depending on the facility design and operation, discharged waters may be significantly colder than ambient water temperatures and may have extremely low dissolved-oxygen concentrations.

Hydroelectric power generation is important to current and future development in South Carolina. As the need for energy increases in the State, potential sites are available for additional hydroelectric power development. The development of any hydropower site, however, will certainly raise questions concerning the environmental, economic, and social impacts that construction of the dam will have. Plant design and operation must maintain the physical, chemical, and biological integrity of the State's waters. Impacts to the environment and quality of life should be carefully weighed against potential economic benefits gained from development of a site.

FERC RELICENSING

The Federal Energy Regulatory Commission (FERC), created by the Federal Power Act of 1920 and formerly known as the Federal Power Commission, is an independent regulatory agency responsible for the licensing and relicensing of nonfederal hydropower projects. The duties of the Commission regarding hydropower include the issuance of licenses for the construction of new projects, the issuance of licenses for the continuance of existing projects (relicensing), and oversight of all ongoing project operations, including dam safety inspections and environmental monitoring. FERC licenses stipulate the operating and management guidelines regarding power generation and the resources affected by a hydropower project and are typically issued for 30 to 50 years. Projects exempted from FERC licensing include small hydropower projects less than or equal to 5 MW (megawatts) built on existing dams, projects that use a natural water feature, or existing projects that have less than or equal to a 5-MW capacity that propose to increase capacity. Also exempted are projects constructed along conduits (canal or canal-like structures) that are used primarily for purposes other than hydropower and have a capacity not greater than 40 MW for municipal projects or 15 MW for non-municipal projects.

Federal FERC licensing is a multi-year process involving a variety of stakeholders including the licensee, state and federal agencies, conservation groups, other nongovernment organizations, and the general public. A licensee must notify FERC of its intention to file for a new license five years before the current license's expiration date, and the licensee must solicit comments and requests for information, surveys, and studies from the various stakeholders. A license application must be submitted by the applicant two years before the current license expires, and the application should consider the results of any surveys and studies and any other information collected during the soliciting period. Based on the application, any existing settlement agreements between the licensee and the various stakeholders, site visits, and any other information gathered, FERC prepares an environmental review of the proposed license or relicense in order to evaluate the impacts of the project. Based on its review, FERC may issue a license with no changes, issue a license with new or modified terms and conditions, or decommission the project.

The development of a flow-release schedule downstream of a hydropower project and the development of a low inflow protocol (LIP) during drought periods are often the most difficult aspects of the licensing process. Balancing the needs of fish and wildlife, the desires of

Table 9-3. FERC-licensed hydroelectric power plants in South Carolina (number on map refers to Figure 9-1)

Number on map	Project name FERC project number	Licensee	River	Year of license issuance and expiration
31, 33	Santee Cooper* 0199	S.C. Public Service Authority	Santee	1979 2006
21	Saluda* 0516	S.C. Electric & Gas	Saluda	1984 2010
16	Buzzard's Roost 1267	Greenwood County	Saluda	1995 2035
10	Parr Shoals 1894	S.C. Electric & Gas	Broad	1974 2020
14	Columbia 1895	City of Columbia	Congaree	2002 2042
24–30	Catawba-Wateree* 2232	Duke Energy	Catawba-Wateree	1958 2008
8	Neal Shoals 2315	S.C. Electric & Gas	Broad	1996 2036
1	99 Islands 2231	Duke Energy	Broad	1996 2036
6	Gaston Shoals 2332	Duke Energy	Broad	1996 2036
43, 44	North Georgia 2354	Georgia Power Co.	Tugaloo	1996 2036
23	Ware Shoals 2416	AquaEnergy Systems, Inc.	Saluda	2002 2032
19	Piedmont 2428	AquaEnergy Systems, Inc.	Saluda	1986 2017
37, 38	Keowee-Toxaway 2503	Duke Energy	Little	1966 2016
41	Stevens Creek 2535	S.C. Electric & Gas	Stevens Creek	1995 2025
7	Lockhart 2620	Lockhart Power Co.	Broad	1999 2040
9	Pacolet 2621	Lockhart Power Co.	Pacolet	1982 2012
34	Bad Creek Pumped Storage 2740	Duke Energy	Bad Creek	1977 2027
2	Cherokee Falls 2880	Broad River Electric Cooperative	Broad	1981 2021
11	Riverdale 4362	Inman Mills	Enoree	1982 2012
3	Clifton Mills #1 4632	Clifton Power Corp.	Pacolet	1986 2016
35	Coneross 6731	AquaEnergy Systems, Inc.	Coneross Creek	1991 2021
13	Whitney Mills 10881	Daniel N. Evans (NC)	Lawson's Fork Creek	1993 2033
18	Pelzer Mills Lower Hydro 10253	Consolidated Hydro SE, Inc.	Saluda	1987 2017
22	Pelzer Mills Upper Hydro 10254	Consolidated Hydro SE, Inc.	Saluda	1987 2017
39	Abbeville 11286	City of Abbeville	Rocky	1997 2027

* *Relicensing in progress*

recreational users in both the river and the reservoir, and the requirements of the hydropower operator to meet peaking, base-load, and reserve demands can be a challenging process. As a result, the licensing or relicensing of large hydropower projects may involve numerous scientific studies and surveys that help facilitate the development of management plans regarding power generation, reservoir elevations, and downstream flows.

Currently 25 FERC-licensed projects are located in South Carolina (Table 9-3) and some FERC projects in Georgia and North Carolina influence streamflow conditions in South Carolina (Table 9-4). Two large FERC projects in North Carolina (No. 2206 and No. 2197), both located in the Yadkin-Pee Dee River basin, directly affect streamflow in South Carolina even though neither of the hydropower plants are physically located in the State. In addition, three FERC projects along Georgia's Augusta Canal (No. 2935, No. 5044, and No. 9988) can affect streamflow locally within the Savannah River, which serves as a border between the two states.

Over the past decade, most of the large FERC projects in South Carolina or in a basin shared with either Georgia or North Carolina have undergone the relicensing process. These projects include the Catawba-Wateree (No. 2232), Yadkin-Pee Dee (No. 2206), Santee Cooper (No. 0199), and Saluda (No. 0516). Though none of these projects has yet received an official relicense, tentative settlement agreements have been completed and are under final review by FERC. Other large projects in the State include Buzzard's Roost (No. 1267), relicensed in 1995; Keowee-Toxaway (No. 2503), whose current license is set to expire in 2016; Bad Creek Pumped Storage (No. 2740), which expires in 2027; and Parr Shoals, which expires in 2020. The above projects are described in more detail below. Other projects in the State regulated by FERC are typically run-of-river projects that have relatively small power generation capacity and limited available reservoir storage. Relicensing issues regarding these smaller projects typically focus on minimum flow requirements in tail races and/or by-pass channels and on LIP protocols during extreme droughts.

Table 9-4. FERC-licensed hydroelectric power plants in North Carolina and Georgia that may impact South Carolina

Project name FERC project number	State	Licensee	River	Year of license issuance and expiration
Yadkin* 2197	N.C.	Alcoa Power Generating Corp.	Yadkin	1958 2008
Yadkin-Pee Dee* 2206	N.C.	Progress Energy Carolinas, Inc.	Pee Dee	1958 2008
Enterprise Mill 2935	Georgia	Melaver/Enterprise Mill, LLC.	Savannah (Augusta Canal)	2005 2055
Sibley Mill 5044	Georgia	Avondale Mills, Inc.	Savannah (Augusta Canal)	2005 2055
John P. King Mill 9988	Georgia	Augusta Canal Authority	Savannah (Augusta Canal)	1989 2009

* *Relicensing in progress*

Catawba-Wateree (Project No. 2232)

The Catawba-Wateree project consists of eleven impoundments and thirteen developments (hydropower projects), all owned and operated by Duke Energy, in the states of South Carolina and North Carolina. Five of the impoundments—Lake Wylie, Fishing Creek Reservoir, Cedar Creek Reservoir, Great Falls Reservoir, and Lake Wateree—and seven of the developments—Wylie, Fishing Creek, Great Falls, Dearborn, Rocky Creek, Cedar Creek, and Wateree—occur in South Carolina. The current Catawba-Wateree FERC license began in 1958 and was scheduled to expire in 2008. The project is in the final stages of the FERC relicensing process (FERC, 2009).

The Wylie Development includes a 12,177-acre impoundment (Lake Wylie), which is the project's farthest upstream impoundment in South Carolina and a hydroelectric station (60 MW installed capacity) at the Wylie Dam. The current target elevation under normal operating conditions is 566.4 feet with an operational range of 2 feet below to 2 feet above this target. The full pool elevation of the reservoir is 569.4 feet. Lake Wylie (and Lake Wateree below) is part of the Spring Reservoir Level Stabilization Program, which seeks to minimize reservoir fluctuations during a 3-week period in the spring to enhance fish spawning in the lake. The current license requirement for a minimum average daily flow is 411 cfs (cubic feet per second), which generates 49 MWH (megawatt-hours) of electricity. The development generally releases higher flows for the benefit of downstream industrial water users (approximately 700 cfs) and for the maintenance of reservoir levels within its normal operating range.

The Fishing Creek Development, approximately 40 miles downstream of the Wylie Development, includes a 3,431-acre reservoir (Fishing Creek) and a hydroelectric station with an installed capacity of 36.7 MW. The normal operating target elevation for the reservoir is 414.2 feet, with a full pool elevation of 417.2 feet, and the elevation may vary within a normal operating range from 2 feet below to 2 feet above the target elevation. This development generates electricity to maintain reservoir levels within this operating range. The minimum average daily flow requirement under the existing license is 440 cfs, and the timing of flow releases is managed to maximize the power generation efficiency of the four developments located immediately downstream. Any additional generation, after required minimum releases and downstream constraints are satisfied, is used to meet peak energy needs.

The Great Falls (24.0 MW capacity) and Dearborn (46.0 MW capacity) Developments are located three miles downstream from the Fishing Creek Development. The hydroelectric stations are on the east and west sides of a canal connected to a 477-acre reservoir (Great Falls). A rediversion dam, 1,500 feet below the Fishing Creek dam, is used to divert water from the original Catawba River channel to a canal leading to the Great Falls reservoir. The dam has a spillway that feeds a 2.25-mile bypass reach (Long Bypassed Reach), which represents the original channel and empties into the north end of Cedar Creek Reservoir. The canal headworks, located 1.4 miles upstream of the Great Falls-Dearborn dam, delineates the boundary between the Great Falls reservoir and a second canal that feeds water to the Great Falls and Dearborn powerhouses. Submerged openings in the canal intake structure are used to regulate flows to the powerhouses. Two spillways are also located at the canal headworks: the main spillway empties into a 0.75-mile bypass reach (Short Bypassed Reach) that empties into the north end of Cedar Creek Reservoir and the canal spillway, which feeds water to the Great Falls and Dearborn powerhouses. These two spillways, along with the upstream diversion dam spillway, are used to regulate flood flows.

The normal operating target elevation for these developments is 353.3 feet with a full pond elevation of 355.8 feet. Reservoir levels vary within a normal operating range from 3.5 feet below to 2 feet above the target elevation. Power is generated primarily to maintain reservoir levels within its normal operating range and for peak energy demand. Since the three Dearborn units are more efficient than those at Great Falls, the Great Falls units are only operated to avoid spilling or during periods of high peaking energy demand. The current license requirement for minimum average daily flow is 444 cfs and is released through one Dearborn unit operated at efficiency load at least once each day, which generates about 53 MWH of electricity.

The Rocky Creek (28 MW installed capacity) and Cedar Creek (45 MW installed capacity) Developments are located immediately downstream of the Great Falls and Dearborn Developments. The development includes a 748-acre reservoir (Cedar Creek) and two powerhouses: the Rocky Creek powerhouse on the west side of the river and the Cedar Creek powerhouse on the east side. The normal operating target elevation for the reservoir is 281.9 feet, with a full pond elevation of 284.4 feet, and the elevation may vary within a normal operating range from 1 foot below to 2 feet above the target elevation. Power is generated from the developments to maintain reservoir levels within the normal operating range, to meet the minimum average daily flow requirement, and for peak energy demand. Units at the Rocky Creek powerhouse are less efficient than those at Cedar Creek and are only operated to avoid spilling or during periods of high peaking energy demand. The minimum flow requirement of 445 cfs is met by operating one Cedar Creek unit at efficiency load at least once each day, which generates about 40 MWH of electricity.

The Wateree Development, located approximately 22.5 miles downstream of the Rocky Creek and Cedar Creek Developments, includes a 13,025-acre reservoir (Lake Wateree) and a powerhouse with a 56-MW installed capacity. Normal operating target elevations for the reservoir are 220.5 feet in December and January and 222.5 feet for the rest of the year except for a three-week refill period in January and February and a six-week draw-down period in November and December. Normal operating ranges are from 2 feet below to 2 feet above the target elevations, and the reservoir has a full pool elevation of 225.5 feet. Electricity is generated as needed to maintain reservoir levels within the normal operating range. The existing minimum average daily flow requirement is 446 cfs, which is met by operating one unit at efficiency load at least once each day. Depending on water availability, continuous flow releases are increased from March 15 to May 31 to support fish spawning, which generates about 312 MWH of electricity per day. Other voluntary releases may be made at various times of the year to support industrial water users downstream, including a steam-electric generating station. Power generation at this development is mainly for peaking energy needs, except for generation from the continuous releases described above.

Higher minimum flow releases and some modifications to reservoir operating ranges are being proposed under the new license for several of the reservoirs discussed above and for those reservoirs located in North Carolina. In addition, a detailed LIP is currently undergoing review for all reservoirs and developments associated with the project in North Carolina and South Carolina (FERC, 2006). The LIP is designed to progressively reduce minimum flow releases and reservoir elevations as low-inflow conditions worsen. A new license is expected to be issued within the next several years.

Yadkin-Pee Dee (Project No. 2206)

The Yadkin-Pee Dee project consists of two developments, Tillery and Blewett Falls, both of which are located in North Carolina and are owned by Progress Energy. The Tillery Development (84 MW capacity) is located on the Yadkin River and impounds a 5,700-acre reservoir (Lake Tillery) and is used as a peaking and load-following facility. The Blewett Falls Development (24.6 MW capacity), located downstream of Tillery along the Pee Dee River, impounds a 2,866-acre reservoir (Blewett Falls Lake) and operates as a re-regulating facility that smoothes out flows from upstream developments. The Yadkin-Pee Dee project was issued a 50-year license in 1958 and was scheduled to expire in 2008; the project is currently nearing the completion of the relicensing process (FERC, 2008).

Under the 1958–2008 license, the Tillery Development typically operated within 4 feet below its normal pool elevation of 278.2 feet, though it was licensed for a 22-foot drawdown, while the Blewett Falls Development typically operated within 2 to 4 feet below its normal pool elevation of 178.1 feet, though it was licensed for a 17-foot drawdown. Continuous, minimum flow requirements under this license were 40 cfs for the Tillery Development and 150 cfs from the Blewett Falls Development. Higher minimum flow releases are being considered under the new license. Both developments would also be subject to an LIP, which would allow for reductions in minimum releases and changes in the normal operating ranges of the lake levels. A new license is expected to be released with the next several years.

Santee Cooper (Project No. 0199)

The Santee Cooper project includes the Santee Spillway Hydroelectric Station (2 MW capacity) on the Santee River and the Jefferies Hydroelectric Station (132.6 MW capacity) on the Cooper River. Both hydroelectric projects are owned and operated by Santee Cooper (South Carolina Public Service Authority). The Santee Spillway is located at the Santee Dam, which impounds a 110,000-acre reservoir (Lake Marion), and the Jefferies Station is located at the Pinopolis Dam, which impounds a 60,000-acre reservoir (Lake Moultrie). The 5-mile long diversion canal that connects Lake Marion to Lake Moultrie has no flow control structure, and any flow not released from the Santee Dam enters Lake Moultrie through this canal. Because it is owned by the U.S. Army Corps of Engineers (although operated by Santee Cooper), the St. Stephen Hydroelectric Station (84 MW capacity), located along the rediversion canal that returns water from Lake Moultrie to the Santee River, is not under FERC jurisdiction.

The Santee Cooper license expired in 2006 and is currently in the final stages of the FERC relicensing process (FERC, 2007). The existing license is being renewed on an annual basis until FERC finalizes the new license. Operational requirements under the existing license include a weekly average release of 4,500 cfs from the Jefferies Station to prevent saltwater intrusion impacts on industries along the Cooper River and to minimize shoaling in the Charleston Harbor, and a continuous minimum flow of 500 cfs from the Santee Spillway into the Santee River. After flow requirements at the Santee and Jefferies stations are met, any remaining flows are discharged through the St. Stephen Station. The existing rule curve for the two lakes ranges from an elevation of 75.5 feet during the summer to a minimum winter drawdown of just above 72.0 feet, which typically occurs in January. A new license is expected to be issued within the next few years and may contain changes in the existing minimum-flow releases.

Saluda (Project No. 516)

The Saluda project, owned and operated by South Carolina Electric & Gas Company (SCE&G), is located on the Saluda River ten miles upstream from its confluence with the Broad River, and includes a 202.6 MW hydroelectric station at the Saluda Dam. The Saluda Dam impounds a 48,000-acre reservoir (Lake Murray). The project was relicensed in 1984 (FERC, 1984), is scheduled to expire in 2010 (after a 3-year extension was granted by FERC), and is currently in the relicensing process. The Saluda project was mainly operated as a peaking facility over the past 30 years; however, a transition from peaking to reserve operations has taken place during the past decade.

The existing guide curve ranges from 356.5 feet during the month of May to 348.5 feet during the month of December. The existing license has no minimum flow requirements; however, a minimum flow of 180 cfs is agreed upon in a Memorandum of Understanding with the S.C. Department of Health and Environmental Control to maintain water quality in the lower Saluda River.

Buzzard's Roost (Project No. 1267)

The Buzzard's Roost project includes a hydroelectric station (15 MW capacity) located along the Saluda River at the Buzzard's Roost dam, which impounds an 11,400-acre reservoir (Lake Greenwood). The owner and current operator of the project is Greenwood County; however, from 1966 to 2006, the project was leased to Duke Power, which operated the station as a peaking facility. The project was relicensed in 1995 and expires in 2035.

The existing license (FERC, 1995) includes a rule curve that ranges from a maximum of 439 feet from April 15 to October 1 to a minimum of 434.5 at the end of January. Minimum flow requirements under the current license, developed to enhance fish habitat and boat navigation, are (1) weekdays (June 15 through October

15): 400 cfs when inflow is greater than 566 cfs; 300 cfs when inflow is between 566 cfs and 466 cfs; 205 cfs when inflow is between 466 cfs and 366 cfs; or 225 cfs or inflow, whichever is less, when inflow is less than 366 cfs; (2) weekdays (October 16 through June 14), weekends and holidays: 400 cfs or inflow, whichever is less; and (3) a flow of at least 833 cfs for six consecutive hours during the months of February through May to enhance fish passage, if, during those months, no flows exceeding 833 cfs are released for at least six consecutive hours in any 72-hour period.

Flows can be modified temporarily due to operational emergencies and for short periods of time upon agreement between the licensee and the S.C. Department of Natural Resources.

Keowee-Toxaway (Project No. 2503)

The Keowee-Toxaway project, located in the Upper Savannah River subbasin, consists of two hydroelectric stations, the Keowee Hydro Facility (157.5 MW capacity) at Lake Keowee and the Jocassee Pumped Storage Facility (662.5 MW) at Lake Jocassee. Both of these stations are owned and operated by Duke Energy, and are primarily used to meet peaking energy demands. Lake Keowee was formed by the construction of dams on the Keowee River and the Little River and is 17,700 acres at full pond. An excavated canal connects the Little River section of Lake Keowee with the Keowee River section of Lake Keowee. Lake Keowee provides cooling water to the Oconee Nuclear Station (2,538 MW capacity), which is also owned by Duke Energy and is adjacent to the Keowee Hydro Facility. Water released from Lake Keowee enters the Seneca River arm of Lake Hartwell, one of three large reservoirs owned and operated by the U.S. Army Corps of Engineers on the Savannah River.

The Jocassee dam is located approximately 15 miles upstream from the Keowee dam. It impounds the Keowee River and forms Lake Jocassee, which is approximately 7,980 acres. Water released from Lake Jocassee enters directly into the northern arm of Lake Keowee. The Jocassee Pumped Storage Project generates electricity to meet peak demands by moving water from Lake Jocassee to Lake Keowee. At off-peak times, the Jocassee turbines are reversed and pump water back up into Lake Jocassee from Lake Keowee. Lake Jocassee also serves as the lower reservoir for the Bad Creek Pumped Storage Facility.

A fifty-year license was issued for this project in 1966 and is set to expire in 2016. The full-pond elevation for Lake Jocassee is 1,100 feet and the maximum licensed drawdown for the lake is 30 feet. Lake Keowee has a full pond elevation of 800 feet and currently has a maximum licensed drawdown of 25 feet (G.A. Galleher, Duke Energy, written communication, 2009). Duke Energy, the Corps of Engineers, and the Southeastern Power Administration (SEPA) are currently evaluating Lake Keowee operating limits that will protect operation of the Oconee Nuclear Station under drought conditions. Duke Energy is required to balance the total remaining useable storage in Lakes Keowee and Jocassee with the total remaining useable storage in the Corps' three Savannah River reservoirs. This storage balance applies when the conservation-pool storage in Lakes Thurmond and Hartwell is less than 90 percent of its total remaining useable storage as compared to that in Lakes Keowee and Jocassee. The agreement requires that up to a maximum volume of 25,000 acre-ft can be transferred each week from Lake Keowee to Lake Hartwell when balancing storage between the lakes. An agreement with the S.C. Water Pollution Control Authority (now S.C. Department of Health and Environmental Control) sets the minimum release from Lake Keowee at a leakage flow of 50 cfs.

Bad Creek Pumped Storage (Project No. 2740)

The Bad Creek Pumped Storage project (1,065 MW) is the largest hydroelectric station owned by Duke Energy. Formed by the damming of Bad Creek and West Bad Creek, the 367-acre Bad Creek Reservoir serves as the upper pool for this pumped-storage facility. Water is released from Bad Creek Reservoir through a discharge portal located on the Whitewater River arm of Lake Jocassee, which serves as the lower reservoir for this project. Water is typically released from Bad Creek to generate electricity during times of high electricity demand and is typically pumped back into Bad Creek during times of low energy demand.

The Bad Creek Pumped Storage Facility was first licensed in 1977; commercial operation began in 1991 (FERC, 1993; G.A. Galleher, Duke Energy, written communication, 2009). The current license is set to expire in 2027. Bad Creek Reservoir has a full pond elevation of 2,310 feet and a minimum elevation of 2,150 feet, which corresponds to a maximum licensed drawdown of 160 feet. Water-level fluctuations during a week are typically less than 40 feet.

Parr Shoals (Project No. 1894)

The Parr Shoals project includes two SCE&G hydroelectric stations, Parr Shoals Hydroelectric Project (14.4 MW installed capacity) and the Fairfield Pumped Storage Facility (FPSF) (511.2 MW installed capacity). The Parr Shoals station is located at the Parr Shoals dam, which impounds the 4,400-acre Parr Reservoir on the Broad River. This reservoir also serves as the lower pool for the FPSF. A 6,800-acre reservoir (Monticello), located nearly one mile east of the Broad River, serves as the upper reservoir for the FPSF and was formed by the damming of Frees Creek. The Monticello Reservoir, which covers nearly the entire Frees Creek watershed, also serves as the source of cooling water for SCE&G's V.C. Summer Nuclear Facility (966 MW installed capacity).

The current license for the Parr Shoals project was issued in 1974 and is scheduled to expire in 2020. The Parr Reservoir is licensed for a water-level range from 266 feet at full pool down to 256 feet, whereas the Monticello Reservoir is licensed for a water-level range from 425 to 420.5 feet (or 418 feet for emergency drawdowns). Owing to the operation of the FPSF, daily reservoir fluctuations can be as much as 10 feet for the Parr Reservoir and 4.5 feet for Monticello (R.R. Ammarell, SCE&G, written communication, 2009). Average daily fluctuations for Parr are approximately 4 feet. Minimum flow releases from Parr Reservoir during March, April, and May are the lesser of a continuous minimum flow of 1,000 cfs or inflow minus evaporation from the two reservoirs. For the rest of the year, required releases are the lesser of an 800 cfs daily average and a 150 cfs continuous release, or inflow minus evaporation from the two reservoirs. During flood events, the license stipulates that the FPSF cannot add to existing flood flows when streamflow at the Broad River at Alston gage exceeds 40,000 cfs. At or above this flow, the FPSF must stop generating or releasing flows.

INSTREAM FLOW NEEDS

Many important instream water uses depend upon the presence of a certain amount of water flowing within natural stream channels. These instream uses differ from typical agricultural, industrial, and domestic water uses in that water is not withdrawn from the stream course but is utilized within the stream itself. Principal instream uses and values include the survival and propagation of aquatic biota, including important fish and wildlife species; assimilation of discharged wastewater; protection of water quality; hydroelectric power generation; navigation; recreational activities; aesthetic appeal of water bodies; preservation of flood-plain wetlands and riparian vegetation; and freshwater inflow to coastal estuaries. Many instream uses involve interests of the general public and the protection of public waters, as well as interests of riparian owners in streams flowing through private property.

Instream flow needs (or requirements) refer to the amount of water that is needed within a stream channel to sustain all relevant instream uses at an acceptable level. Maintenance of desirable aquatic biological populations requires the presence of sufficient volume and depth of water to facilitate all life-cycle functions including feeding and reproduction. Estuaries are important habitats for numerous marine resources, and adequate freshwater inflow to these systems is vital to sustain these ecological functions. Adequate instream flow in coastal rivers is also necessary to protect water-supply intakes from saltwater intrusion.

Protection of water quality requires instream flow at a sufficient level to assimilate waste materials discharged by municipalities and industries. Waste-discharge permits are generally issued on the condition that a stream usually has more than enough flow to adequately dilute discharged pollutants. Very low instream flows may be insufficient to adequately assimilate waste loads and can result in water-quality problems for both instream and offstream uses.

Flow requirements for navigation depend upon the type of navigation that individual streams are capable of supporting. Large streams that sustain commercial navigation have greater instream flow needs than smaller streams, which may support only recreational navigation by small watercraft.

Factors Influencing Instream Flows

Instream flow is affected by several natural and man-induced factors. The amount of precipitation falling on a stream or river basin, the size of the catchment area, watershed topography, rates of evaporation and transpiration, and ground-water discharge are natural factors that affect streamflow. In South Carolina, these natural factors generally result in relatively high flows during winter and spring months and lower flows during summer and fall months. Human activities that have a major impact on instream flow are diversions and withdrawals of water from the stream channel and controlled releases of water from reservoirs.

Withdrawals may be consumptive or non-consumptive. Highly-consumptive uses, such as agricultural irrigation, interbasin transfers, and evaporative losses from thermo-electric power plants, result in a permanent reduction of the instream flow rate for a particular stream. Irrigation withdrawals can be especially detrimental to instream flow because this use is almost entirely consumptive and occurs primarily during dry periods when streamflow may already be at low levels. Most offstream uses, such as public water supply and industry, are typically only 10–15% consumptive, and return almost as much water back to the source stream as was withdrawn. These uses result in small and localized reductions in streamflow.

Controlled releases from large reservoirs associated with hydroelectric generating facilities offer some of the greatest challenges for meeting instream flow needs. Peaking-power facilities typically release water from a reservoir only during times of highest demand for electricity, while reserve-power facilities will release water for power generation on an as-needed basis. Because the frequency of power generation from these facilities can vary greatly, discharges may occur during only a brief period each day or not at all, resulting in highly-variable streamflows or periods of prolonged low flows. A river downstream from a large hydropower project can have a hydrograph that is substantially altered from its natural condition. Adverse impacts of fluctuating hydroelectric releases and hydrograph alteration on downstream biological communities have been documented by numerous studies and are summarized by Walburg and others (1981) and by Poff and others (1997). Smaller hydroelectric projects or run-of-the-river projects generally have much less of an impact on instream flows except during extreme low-flow conditions. Despite these problems, reservoirs can also be very helpful in maintaining minimum flows during prolonged droughts: water released from reservoir storage can sustain minimum streamflows when natural inflows are inadequate.

Releases from hydroelectric plants have not always provided adequate streamflow to sustain all instream uses. State agencies have recently had the opportunity to address instream flow issues as part of the Federal Energy Regulatory Commission (FERC) relicensing of hydropower projects in several of the State's river basins. FERC licenses specify operational plans for hydropower projects, including minimum flow releases, and are typically issued or reissued for periods ranging from 30 to 50 years. Detailed, site-specific Instream Flow Incremental Methodology (IFIM) studies have been conducted on several rivers in the State in the past decade as part of the FERC relicensing process, and IFIM studies have facilitated the development of minimum flow releases in the relicensing of hydropower projects in the Saluda, Catawba-Wateree, and Yadkin-Pee Dee basins.

Another type of controlled release is the intermittent discharge from large wastewater-holding reservoirs at industrial and municipal waste-treatment facilities. Wastewater from such facilities is usually released only when the flow and assimilative capacity of the receiving stream are high; wastewater is stored in holding ponds when the stream's flow and assimilative capacity are low. Where the same stream is used for both water supply and waste assimilation, water may be withdrawn from the stream but not returned while instream flow remains low, thus causing a further reduction of instream flow. Several water users in South Carolina currently use controlled discharges.

Evaporative losses associated with the cooling processes of nuclear and fossil fuel plants may also impact instream flows in South Carolina, primarily during low-flow periods. Most of these plants use a once-through or open-loop cooling system, in which large amounts of water are withdrawn, but most of the water—approximately 98%—is returned. Motivated by concerns over harmful emissions from fossil fuel plants and the expected increase in energy demand in the State, two power companies have recently proposed construction of four new nuclear units in the Broad River basin. These units will use closed-loop cooling systems that allow for a much smaller withdrawal of water, but the consumptive losses associated with the withdrawals will be large. These consumptive losses from the Broad River would be only a small percentage of its mean annual flow and, under normal conditions, may have a negligible impact on the river, but during droughts or low-flow periods, these losses may become a significant stress on the river. If the State's demand for power continues to increase along with its population, other nuclear facilities could be proposed to meet the increasing demand, and thereby cause further stresses on our water resources.

Determination of Instream Flow Needs

In general, instream flow requirements are dependent upon characteristics of individual streams and on the instream uses under consideration, and can only be accurately determined on an individual, case-by-case basis. Frequently, site-specific studies are unavailable and instream flow requirements are developed based on average flow rates.

The U.S. Fish and Wildlife Service has developed methodologies, such as the Instream Flow Incremental Methodology (IFIM), to assess instream flow needs for fish and wildlife populations in individual water bodies (Trihey and Stalnaker, 1985; Stalnaker and others, 1995; Bovee and others, 1998). The IFIM method is a site-specific decision-support system that assesses the benefits or consequences of varying flow-management alternatives.

Water-quality management policies are generally based on having a streamflow equal to or greater than the "7Q10" flow, which represents the lowest seven-consecutive-day average flow rate that occurs with an average frequency of once every ten years. DHEC, the state agency that regulates water quality in South Carolina, generally uses the 7Q10 flow to determine the waste load capacity of a stream. In general, DHEC allows treated waste discharges into a stream only to the extent that, under 7Q10 flow conditions, all water quality standards will be met. Instream flows less than the 7Q10 rate may be insufficient to adequately assimilate waste loads and can result in water-quality standards violations. 7Q10 values have been published for many of the State's rivers and streams (Steinert, 1989; Zalants, 1991); however, for those streams that have additional years of streamflow data, the 7Q10 values should be updated.

The *South Carolina Water Plan* (Badr and others, 2004) recommends that the minimum instream flow should be sufficient to protect each of four types of instream uses: water quality, fish and wildlife habitats, navigation, and estuary maintenance and prevention of saltwater intrusion. The *Water Plan* also recognizes the need to balance the needs of the lake users with the needs of river users when developing minimum flow requirements.

Recently, emphasis has shifted among natural resource managers, fisheries biologists, and stream ecologists from one year-round minimum flow to minimum flows that vary seasonally to reflect the natural hydrograph of a river (Poff and others, 1997 and 2003; Baron and others, 2002). These authors argue that the societal needs for freshwater are strongly linked to sustaining the ecological needs of aquatic ecosystems. Seasonally-based instream flow requirements are sometimes referred to as environmental flows. Though the impacts on river basins with large reservoirs or heavy regulation cannot be completely offset, these efforts have sought to minimize the negative impacts of regulation by reproducing, at least in part, natural flow regimes.

Policy guidelines in South Carolina for determining instream flow requirements for the protection of fish and wildlife can be found in *South Carolina Instream Flow Studies: A Status Report* (Bulak and Jobsis, 1989) and in the *South Carolina Water Plan* (Badr and others, 2004). These guidelines state that, in the absence of an IFIM or other site-specific study, recommended minimum flows should be a seasonally-varying fraction of the stream's mean annual flow (Table 9-5). These recommended minimum flows reflect the seasonality of streamflow: wet periods typically occur during the months of January through April; dry periods typically occur in the months of July through November; and May, June, and December represent transitions between the wetter and drier periods.

Minimum flow recommendations for navigation are detailed in de Kozlowski (1988).

Table 9-5. Recommended seasonally-varying minimum flow requirements for streams in South Carolina

Month	Recommended required flow	
	Piedmont	Coastal Plain
January–April	40% MADF	60% MADF
May, June, December	30% MADF	40% MADF
July–November	20% MADF	20% MADF

MADF, Mean annual daily flow

Interstate Complications

South Carolina shares three of its four major basins with the states of Georgia and North Carolina, and this presents a major challenge to instream flows in the State. The Savannah River serves as the border between South Carolina and Georgia along the western side of the State, and the upper part of the basin contains a series of reservoirs, three of which are controlled by the U.S. Army Corps of Engineers. Balancing the needs for instream flow in the lower Savannah River basin and the needs of reservoir users in the upper Savannah River basin has proved especially problematic over the last decade (1998–2008) due to the preponderance of drought during this period. Instream flow issues in the lower Savannah River include providing adequate flow to support fish and wildlife and flood-plain ecology, the protection of public water-supply intakes from saltwater intrusion, and the protection of water quality that supports estuarine ecology. In addition, 97% of the assimilative capacity in the Savannah River is held by Georgia's water users, which limits South Carolina's potential to use this water resource.

A recent proposal by the North Carolina cities of Concord and Kannapolis to transfer water from the Catawba-Wateree basin to the Yadkin-Pee Dee basin highlights further instream challenges in South Carolina. South Carolina brought litigation against North Carolina to prevent the proposed interbasin transfer, and the case is currently scheduled for review by the United States Supreme Court (*South Carolina v. North Carolina*, U.S. Supreme Court Case #138, original, filed June 7, 2007).

The Yadkin-Pee Dee River is regulated by six reservoirs, all of which occur in North Carolina; thus, flow in the Pee Dee River in South Carolina is heavily dependent on users outside of the State. Recent concerns over the protection of coastal public water supplies from saltwater intrusion in the lower Pee Dee River led to amendments of minimum flow requirements from the upstream reservoirs in North Carolina.

Water Law

Significant conflicts between instream water uses and offstream uses first developed in western states where water supplies are limited and water is allocated among users under the appropriation doctrine of water law. In the past, available water was allocated for those offstream uses that resulted in greatest economic benefit, with little consideration of instream uses. More recently, many western states have recognized the need to protect instream uses and have developed provisions that reserve a portion of available streamflow for these uses. In states east of the Mississippi River, where water is more plentiful, interest in instream flow needs has only recently developed, and conflicts have been localized and usually occur only during low-flow periods. Water law in most Eastern states, including South Carolina, is based on the riparian doctrine, which provides all owners of property adjacent to a stream course an equal right to reasonable use of water in the stream. The riparian doctrine originally did not provide a good mechanism for protecting the general public interest in instream uses and values because the doctrine focused only on riparian owners. In 1995, the Supreme Court of South Carolina established that water is subject to the Public Trust Doctrine and is, therefore, too important to be owned by one person (*Sierra Club v. Kiawah Resort Assoc*., 318 S.C. 119, 456 S.E. 2d 397, 1995).

Historically, two important problems regarding instream flow needs have been a general lack of recognition of the significance of these needs and the absence of an adequate legal and institutional basis to manage instream flow. Interest in instream flow issues has grown steadily over the past few decades. The recognition of instream flow needs in South Carolina appeared as early as 1981 in a water resources management plan for the Yadkin-Pee Dee River basin, which recommended that the States of North Carolina and South Carolina "... develop criteria for protecting all instream uses of water" (U.S. Water Resources Council, 1981). The Water Law Review Committee appointed by Governor Richard W. Riley in 1982 also recognized the importance of instream needs, stating that "a minimum amount of water should be maintained to support in-stream needs in rivers, streams, and lakes. The State should, giving due consideration to existing uses, determine instream flow needs and consider those needs in reviewing present and future development" (Governor's State Water Law Review Committee, 1982). Recommendations by the Committee facilitated the development of a State Water Policy and the enactment of the Drought Response Act and the Interbasin Transfer Act. The State Water Policy was developed in two phases. The first phase was the *South Carolina State Water Assessment* (South Carolina Water Resources Commission, 1983) and the second phase was the *South Carolina Water Plan* (Cherry and Badr, 1998). The *Water Plan* was first published in 1998 by the S.C. Department of Natural Resources and outlines the guidelines and procedures for managing the State's water resources. After one of the worst droughts in South Carolina's history ended in 2002, a second edition of the *Water Plan* (Badr and others, 2004) was published to incorporate the lessons learned from the severe drought into the management strategies presented in the original plan.

Although surface-water withdrawers must report their water use to DHEC, no State legislation requires a permit to withdraw surface water. Renewed interest in such legislation occurred after the drought of 2002. Governor Mark Sanford established a Water Law Review Committee to "conduct a comprehensive review of South Carolina's water laws and recommend changes that would improve those laws" (Executive Order 2003-16, 2003). Some specific recommendations submitted by the Governor's Water Law Review Committee (2004) regarding instream flow needs were as follows:

1. A minimum amount of water should be maintained to support instream needs in rivers and streams. The State should, giving due consideration to existing uses and taking into account the public need for drinking water supply, modify the current common law riparian doctrine by setting an instream flow needed for each river and stream in the State. Such instream flow will guarantee an adequate volume of water to support aquatic life and preserve water quality.
2. The Committee recommends that the State modify current common-law riparian doctrine such that a permit is required for any withdrawal greater than or equal to 3 million gallons per month.
3. The State of South Carolina should consider entering into a Compact with the State of Georgia and the Federal Government concerning the Savannah River. It would be in the interest of South Carolina to take the initiative to make this happen and the time to undertake this activity is now.

NAVIGATION

The importance of navigation in South Carolina dates back to the Colonial period. For early settlers, the waterways were an indispensable means of communication and transportation. As early as 1714, legislation was passed by the Colonial government for the improvement of inland navigation. Settlers slowly moved inland and established settlements at the heads of navigation on the larger rivers in the State. By the 1780's, state legislation required improvements on nearly all of the rivers in South Carolina.

One important event in the improvement of inland navigation was the formation in 1786 of "The Company for the Inland Navigation from Santee to Cooper River," whose purpose was to construct a canal from the Santee River to the Cooper River, thus providing navigation directly from the coastal port of Charleston to inland towns. Completed in 1800, the Santee Canal was 22 miles long, four-feet deep, and 20-feet wide at the bottom. Two double and eight single locks could raise a vessel 34 feet from the Santee River to the summit of the canal and then lower it 69 feet to the Cooper River (Epting, 1936). Although built over a poorly chosen course, the canal was prosperous for over 30 years and did much to improve trade within the State.

In 1818, the South Carolina legislature appropriated $1 million for public works, much of which was for canal construction. By 1820, plans were formed for eight canals, two on the Saluda, one on the Broad, one on the Congaree, and four on the Catawba-Wateree. Navigation was planned to extend all the way up the Catawba to Morganton, North Carolina. All four of South Carolina's canals on the Catawba were completed by 1830. One has been restored for its historical significance at Landsford Canal State Park. The other three were flooded by hydroelectric reservoirs.

Another significant project was the Columbia Canal, which used tolls to meet its construction and operating expenses. Completed in 1823, it enabled river traffic to pass around the shoals in the upper portion of the Congaree River at the confluence of the Broad and Saluda Rivers near Columbia. The canal was three miles long with three locks that overcame a fall of 34 feet (Epting, 1936). The canal was instrumental in the growth of Columbia.

At the height of development of inland navigation within the State, more than 2,000 miles of inland water

Figure 9-2. Greatest extent of commercial navigation in South Carolina (mid-1800's).

were navigable (Epting, 1936) and most of the State was accessible by water (Figure 9-2). The Savannah River was navigable from its mouth to Augusta, Georgia. In addition, smaller vessels were able to descend down the Savannah River from as far up as the Tugaloo and Seneca Rivers. The Santee River was navigable along its entire length and the Wateree River to five miles past Camden. Boat traffic on the Santee River could also go up the Congaree River and then up either the Broad or Saluda Rivers. Two of the major tributaries of the Broad River, the Pacolet and Tyger Rivers, were also navigable. The Saluda River was navigable to 120 miles above Columbia. The entire length of the Pee Dee River in South Carolina was navigable, as was the Little Pee Dee River. Other rivers in the State maintained for navigation included the Combahee, Salkahatchie, Waccamaw, Edisto, Black, Lynches, Ashley, Cooper, and Ashepoo.

When inland navigation was at its height of development and use in the mid-1800's, the rapidly developing railroads quickly replaced inland waterways as the best method of moving people and goods. Soon many of the inland waterways fell into disrepair and became unusable. The introduction of the railroad was the beginning of the end for inland navigation in South Carolina.

Navigation projects up to this time were the responsibility of state or private entities. The first federal involvement began in 1880 with projects on the Pee Dee, Waccamaw, and Salkahatchie Rivers. The federal government's role quickly expanded and soon projects were underway on all of the State's major rivers within the Coastal Plain. The projects continued until boat traffic on the rivers declined to a point not to warrant further maintenance.

Current navigation projects of the federal government satisfy many water use objectives. These objectives may be to assist in the development, conduct, safety, and efficiency of interstate and foreign waterborne commerce; promote the production and harvest of seafood; encourage expansion of existing and development of new industrial and agricultural production; meet the needs of recreational boating; enhance fish and wildlife resources; enhance environmental quality; and enhance social effects. Federal navigation improvements must be in the interest of the general public and must be accessible and available to all on equal terms (U.S. Army Corps of Engineers, 1982b).

Federal practice pertaining to navigation improvements, which has developed over the years on the basis of congressional actions, extends only to providing waterway channels, anchorages, turning basins, locks and dams, harbor areas, and protective jetties and breakwaters of dimension adequate for the movement of vessels efficiently and safely between harbors and other areas of use. The provision docks, terminals, local access channels, and other similar structures are the responsibility of local interests (U.S. Army Corps of Engineers, 1982b).

The maintenance of coastal navigation aids such as lighthouses, buoys, range markers, and charts is the responsibility of the U.S. Coast Guard. These include two systems, the Atlantic Intracoastal Waterway System and the Lateral System for navigation from port through the channel outward to the sea buoy at the mouth of each channel.

Upstream from the coastal harbors, no aids to navigation system exist on the rivers; the S.C. Department of Natural Resources, U.S. Army Corps of Engineers, and private power companies maintain some buoys and markers in the major reservoirs.

While commercial navigation is currently limited primarily to coastal waters and the Savannah River below Augusta, Georgia, navigation for recreational purposes is suitable in lakes and streams throughout the State. Recreational navigation is generally easier in Coastal Plain streams than in Piedmont streams because of reduced stream gradients and shoal obstructions.

A primary problem impacting current and future navigation in South Carolina is the insufficient availability of dredge material disposal sites in coastal areas. Laws preventing the filling of wetlands, coupled with the rapidly increasing value of high ground, restrict the availability and affordability of suitable disposal sites near areas of dredging activity.

RIVER CONSERVATION

Rivers and streams have had a significant role in the natural and cultural heritage of South Carolina. The State contains thousands of miles of rivers and streams that flow from the mountains to the sea, and these streams provide numerous ecological benefits and services to people. Rivers and streams provide water for drinking, manufacturing, irrigation, electricity from hydropower production, transportation, and recreational opportunities. Streams channel floodwaters and assimilate wastes. They also provide essential habitats for fish and wildlife and migration corridors vital to the reproduction of many species. In many places, rivers harbor rare plants and animals, as well as relics of our cultural heritage. As the population and economy of South Carolina continue to expand, our demands on rivers will increase, as will our dependency upon these resources and our interest in conserving them.

Recognizing the functions and values associated with rivers and the need to protect river resources, a variety of public and private initiatives have emerged to target conservation efforts towards specific rivers. Private, non-profit conservation organizations have been formed around particular rivers and watersheds, such as the Reedy, Edisto, Saluda, Congaree, Santee, Waccamaw, Cooper, Ashley, and Catawba, where citizens are working to protect natural and cultural resources through land conservation and/or influencing local policies and practices that affect land use and development.

In these same places and many others, including the Chattooga, Broad, Lynches, Great Pee Dee, Little Pee Dee, Black, Ashepoo, and Combahee, public agencies have had a leadership role, forming partnerships with local community groups and landowners to promote conservation actions around particular rivers.

The River Conservation Program of the DNR (S.C. Department of Natural Resources) has demonstrated ways in which public agencies can form partnerships with local communities to pursue river conservation goals. The DNR's program utilizes a cooperative, non-regulatory, community-based approach that is practiced and promoted through the State Scenic Rivers Program and river-corridor and watershed planning projects.

Scenic Rivers Program

The Scenic Rivers Program's purpose is to protect unique and outstanding river resources throughout South Carolina. The method of river protection is through a cooperative, voluntary management program that involves landowners, community interests, and the DNR working toward common river-conservation goals. The Scenic Rivers Act (established in 1974 and revised in 1989) is the enabling legislation for this program.

The designation of a State Scenic River occurs through legislative action by the General Assembly, which is preceded by a scenic-river eligibility study process conducted by the DNR with the review and input of local citizens and community leaders. The designation progress involves four steps:

1. A local request for scenic-river designation is made, and the DNR conducts a scenic-river eligibility study and develops a proposal for designation.
2. All riparian landowners and the general public are notified of the scenic-river proposal and invited to public meetings to share information, ask questions, and express opinions.
3. Each county council of all river-bordering counties is notified of the scenic-river proposal.
4. The DNR Board approves the proposal and a bill is then introduced in the General Assembly. When

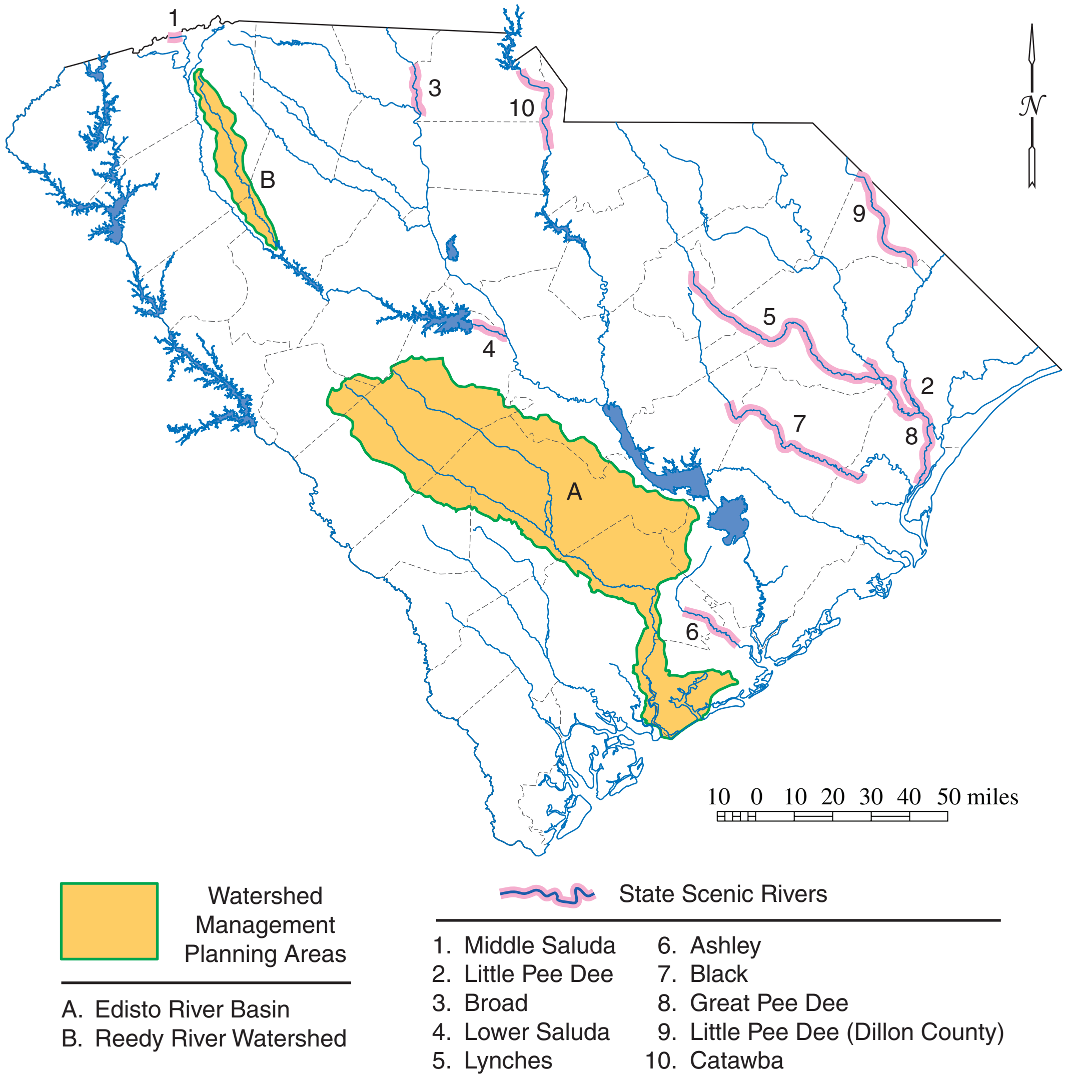


Figure 9-3. Scenic Rivers and Watershed Management Planning Areas in South Carolina.

the bill is passed and signed by the Governor, a new State Scenic River is officially designated.

After the designation is completed, the DNR establishes a Scenic River Advisory Council to oversee the project and assist the DNR in managing the river. Advisory councils are made up of six to ten voting members, the majority of whom are river-bordering landowners, and a DNR staff person serves as chair. Additional *ex officio* members are included on advisory councils to expand input and expertise from individuals and organizations with interests in the river. The Advisory Council is responsible for developing a scenic river management plan to address river issues of interest and concern to the community and to guide ongoing management activities of the Advisory Council and the DNR.

River management issues common to all scenic rivers include protecting and improving water quality, improving recreational access and facilities, supporting stewardship and conservation of river-bordering lands, protecting fish and wildlife resources, and promoting river awareness and stewardship among area citizens and local decision-makers. Management plans for South Carolina's scenic rivers can be accessed on the DNR website.

As of 2009, ten river segments totaling about 400 river miles have been designated as South Carolina State Scenic Rivers (Figure 9-3):

Middle Saluda Scenic River. The Middle Saluda River became the first river protected under the Scenic Rivers Program in 1978. Located in northern Greenville County and within Jones Gap State Park, about 5 miles of the Middle Saluda and its major tributary, Coldspring Branch, are designated as a State Scenic River.

Little Pee Dee Scenic River. The 14-mile segment of the Little Pee Dee River in Marion and Horry Counties from U.S. Highway 378 to the confluence with the Great Pee Dee River was designated a State Scenic River in 1990.

Broad Scenic River. Fifteen miles of the Broad River in Cherokee and York Counties, from 99 Islands Dam to the confluence with the Pacolet River, were designated as a State Scenic River in 1991.

Lower Saluda Scenic River. A ten-mile segment of the Saluda River in Lexington and Richland Counties, from below Lake Murray Dam to the confluence with the Broad River, was designated as a State Scenic River in 1991.

Lynches Scenic River. A 110-mile section of the Lynches River in Lee, Darlington, Florence, and Sumter Counties was designated a Scenic River in two parts. The first portion, designated in 1994, extends 54 miles from the U.S. Highway 15 Bridge near Bishopville to the Lynches River County Park in Florence County. The second section, designated in 2008, extends 56 miles from Lynches River County Park to the confluence with the Great Pee Dee River.

Ashley Scenic River. A 22-mile segment from U.S. Highway 17-A to the I-526 Bridge in Dorchester and Charleston Counties was designated a State Scenic River in two parts in 1998 and 1999.

Black Scenic River. A 75-mile segment of the Black River beginning at the County Road 40 Bridge in Clarendon County and ending at Pea House Landing in Georgetown County was designated a State Scenic River in June 2001.

Great Pee Dee Scenic River. A 70-mile section of the Great Pee Dee River in Marion, Florence, Williamsburg, Horry, and Georgetown Counties was designated a State Scenic River in 2002. The Scenic River section extends from U.S. Highway 378 to U.S. Highway 17.

Little Pee Dee Scenic River (Dillon County). A 48-mile section of the Little Pee Dee River in Dillon County was designated a Scenic River in 2005. The Scenic River extends from the Marlboro County line, just above Parrish Mill Bridge (State Road 363), downstream to the Marion County line, where Buck Swamp enters the Little Pee Dee River.

Catawba Scenic River. A 30-mile section of the Catawba River was designated a State Scenic River in 2008. The Scenic River designation begins below Lake Wylie dam in York County and extends downstream to the S.C. Highway 9 Bridge between Lancaster and Chester Counties.

River Corridor and Watershed Planning Projects

The DNR's River Conservation Program also works in partnership with communities to develop river-corridor and watershed-management plans. Major projects have addressed the lower Saluda River corridor, the Catawba River corridor, the Edisto River watershed, and the Reedy River watershed. The goal of these projects has been to create community-based plans that integrate local interests in natural and cultural resource conservation with community and economic development.

River-corridor planning projects, as conducted by DNR staff, provide an alternative to the formal designation and structure of the Scenic Rivers Program and allow partnering organizations other than the DNR to take the leadership role of plan implementation and advocacy. Two river corridor projects have been conducted resulting in plans: *The Lower Saluda River Corridor Plan* (S.C. Water Resources Commission, 1990) and *The Catawba River Corridor Plan* (S.C. Department of Natural Resources, 1994). Eventually, the local citizens and groups involved with these rivers decided to pursue scenic river designation and now both the lower Saluda and Catawba are designated State Scenic Rivers.

In the early 1990's, the bounds of river-corridor planning in South Carolina were expanded to the watershed level though a comprehensive effort known as the Edisto River Basin Project. More than 200 people participated in the project by serving on a citizen task force (the Edisto River Basin Task Force) and/or its 15 supporting committees, and they contributed to the crafting of a basin-wide plan for the Edisto River Basin, a 2-million-acre watershed. Geographic information system (GIS) technology was used to assess the landscape (its ecological, cultural, and economic assets) and create a series of maps depicting the significance and suitability of basin areas with respect to economic uses, ecological functions, recreational activities, and cultural-resource preservation. Participants used the GIS analysis, personal knowledge, and expertise to collaboratively develop goals and recommendations to address a wide range of issues on economic development and ecological, cultural, and recreational resource conservation. Maps and guidelines were published in a plan entitled *Managing Resources for a Sustainable Future: the Edisto River Basin Project Report* (S.C. Department of Natural Resources, 1996). At project's end, the Edisto River Basin Task Force created a private nonprofit organization, Friends of the Edisto, to promote the goals and ideas of the Edisto plan.

The Reedy River, in Greenville and Laurens Counties, was the target of the DNR River Conservation Program's second watershed-level planning project. As with other planning projects, a citizen task force was formed to assess the issues, create a plan, and examine critical management issues that impact the river and related resources. This project was completed in 2001 and DNR produced a published plan, *The Reedy River Report: Managing a Watershed* (S.C. Department of Natural Resources, 2001). The project has stimulated on-going initiatives among citizens and groups of Greenville and Laurens Counties that address the long-term management and enhancement of the Reedy River.

AQUATIC NUISANCES

Nonnative invasive species cost the economy of the United States an estimated $137 billion annually in lost production and control costs (Pimentel and others, 2000). They are considered one of the greatest threats to biological diversity, exceeded only by habitat loss and degradation. In the absence of native predators and diseases, nonindigenous organisms may develop large populations that create severe ecological and economic problems.

When such invasions occur in our lakes and rivers, they can disrupt entire aquatic ecosystems and impair important municipal, industrial, agricultural, and recreational uses of our waterways. Exotic plant and animal species that threaten the diversity and use of our freshwater bodies are termed Aquatic Nuisance Species (ANS). Estuarine and marine environments are also impacted by aquatic nuisance species; this section will focus on freshwater species. In South Carolina, the principal effort to manage ANS has been directed at nuisance aquatic plants, zebra mussels, and exotic fishes.

Invasive Aquatic Vegetation

Management. South Carolina is one of the few states that provide clear statutory authority for the management of nuisance aquatic vegetation. On May 29, 1990, Governor Carroll Campbell, Jr., approved legislation (Act 498) that established the S.C. Aquatic Plant Management Program, the S.C. Aquatic Plant Management Council, and the S.C. Aquatic Plant Management Trust Fund for the statewide management of nuisance aquatic plants in public water bodies.

The S.C. Water Resources Commission originally administered the Aquatic Plant Management Program until S.C. government was restructured in 1994. Since then, the program has been administered by the Department of Natural Resources (DNR). DNR is responsible for developing an annual Aquatic Plant Management Plan that describes the procedures for problem-site identification and analysis, selection of control methods, operational-program development, and implementation of operational strategies. The Plan also identifies problem areas, prescribes management practices, and sets management priorities.

The Aquatic Plant Management Council is composed of ten representatives from the following agencies: DNR (Land, Water and Conservation Division and the Division of Wildlife and Freshwater Fisheries); S.C. Department of Health and Environmental Control (Bureau of Environmental Quality Control and Office of Coastal Resources Management); S.C. Department of Agriculture; Public Service Authority; S.C. Department of Parks, Recreation and Tourism; Clemson University Department of Pesticide Regulation; and the Governor's Office. The representative from the DNR Land, Water and Conservation Division serves as chairman of the council. The council provides valuable interagency coordination and serves as the principal advisory body to the DNR on all aspects of aquatic-plant management and research. In addition, the council establishes management policies and approves all annual management plans.

The Aquatic Plant Management Trust Fund was created to receive and expend funds to prevent, manage, and conduct research on aquatic-plant problems in public water bodies of the State. The fund is eligible to receive state appropriations, federal and local government funds, and funds from private sources. DNR administers the Trust Fund.

The cost of control operations is shared among federal (U.S. Army Corps of Engineers), state (DNR), and various local sponsors that include counties and water and electric utilities. Since 1981, more than $24 million in federal, state, and local funds have been spent to control the growth of invasive aquatic-plant species in more than 60 public water bodies. The most troublesome aquatic weeds have been hydrilla, water hyacinth, and phragmites.

Hydrilla. Hydrilla (*Hydrilla verticillata*) is a submersed aquatic weed that roots in the lake bottom and grows to the water surface where it forms dense mats (Figure 9-4). First introduced to the State in 1982, hydrilla rapidly expanded to cover more than 48,000 acres in the Santee Cooper lake system (Lakes Marion and Moultrie). In 1991, mats of hydrilla clogged the intake screens of the St. Stephen Hydroelectric Plant on Lake Moultrie and caused it to shut down for several weeks, resulting in over $4 million in lost power and associated costs. The shutdown also caused one of the largest fish kills in state history, resulting in $526,000 in lost game fish.

Figure 9-4. Hydrilla in upper Lake Marion.

Uncontrolled hydrilla growth poses the greatest and most immediate threat to the economic and environmental integrity of South Carolina's public water bodies. Substantial amounts of effort and funding have been directed at its control, with good success. From 1982 to 2008, about $15 million was spent on hydrilla-control efforts, with about 80 percent ($12 million) of that used on the Santee Cooper lakes. Although peak infestations in all South Carolina water bodies combined are estimated to be 55,000 acres, management efforts have eliminated most problem areas for the time being. Hydrilla is currently known to occur in Goose Creek Reservoir, Back River Reservoir, the Cooper River, Lake Moultrie, Lake Marion, Lake Murray, Lake Wateree, Lake Greenwood, Lake Thurmond, and Lake Keowee. Hydrilla is rapidly infesting lakes in the upper Catawba River basin in North Carolina and poses an additional threat to South Carolina water bodies downstream.

Water Hyacinth. Water hyacinth (*Eichhornia crassipes*) is a floating aquatic weed originally from South America (Figure 9-5). It is extremely prolific, with a single plant producing about one acre of plants by the end of the growing season. Water hyacinths have been a problem in South Carolina from the early 1980's or before, but problems have been restricted primarily to the Charleston area in Goose Creek Reservoir, Back River Reservoir, and the Cooper River. Prior to control operations on these water bodies, water hyacinths covered hundreds of acres, blocked public access at boat ramps, impaired recreational boating activities, clogged industrial, municipal, and electric-generation cooling-water intakes, and restricted stormwater runoff with resulting upstream flooding. Recently, water hyacinths have spread to other water bodies in the State, including Lake Marion and the Ashepoo, Waccamaw, and Pee Dee Rivers. Water hyacinth is the second-most troublesome aquatic plant in the State. Since 1982, more than 18,000 acres have been controlled at a total cost of about $1.4 million.

Figure 9-5. Water hyacinth.

Prevention. The most cost-effective way to manage invasive aquatic-vegetation problems is to prevent them from occurring in the first place. Hydrilla, water hyacinth, and other nuisance aquatic plants are so objectionable that they are prohibited from importation, distribution, and sale by federal and state laws. The Plant Protection Act (P.L. 106-224 Title IV), which is enforced by the U.S. Department of Agriculture, prevents the importation of several aquatic-plant species into the United States. Federal law (18 USC 46) also prohibits anyone from knowingly delivering or receiving water hyacinths (*Eichhornia crassipes*), alligatorweed (*Alternanthera philoxeroides*), or water chestnuts (*Trapa natans*) through interstate commerce. To sell, purchase, barter, exchange, give, or receive any of these plants or seeds, or to advertise to sell, purchase, barter, exchange, give, or receive these plants or seeds is forbidden.

Two state laws, the South Carolina Noxious Weed Act (*S.C. Code of Laws*, Section 46-23-10) and the State Crop Pest Act (*S.C. Code of Laws*, Section 46-9-10), minimize the movement of invasive plant species into South Carolina from other states. These laws prohibit the importation, sale, and distribution of certain noxious weed species and plant pests (including many aquatic-plant species) in the State. The Department of Agriculture and the Clemson University State Crop Pest Commission (through the Clemson University Department of Plant Industry) are responsible for enforcing these laws and associated regulations.

Another state law (*S.C. Code of Laws*, Section 50-13-1415) focuses specifically on preventing hydrilla and water-hyacinth problems in public water bodies. It prohibits the possession, sale, or importation of these two species and forbids their introduction into the State's waters. DNR works closely with other agencies to enforce these laws through public education and outreach programs. Table 9-6 lists all aquatic-plant species that are illegal to import, sell, and distribute in South Carolina.

Table 9-6. South Carolina Illegal Aquatic Plant List (includes all aquatic-plant species listed on State Noxious Weed List and State Crop Pest List)

Common name	Scientific name
Alligatorweed	*Alternanthera philoxeroides*
Brazilian elodea	*Egeria densa*
Common reed	*Phragmites australis*
Eurasian watermilfoil	*Myriophyllum spicatum*
Purple loosestrife	*Lythrum salicaria*
Slender naiad	*Najas minor*
Water chestnut	*Trapa natans*
Water hyacinth	*Eichhornia crassipes*
Water lettuce	*Pistia stratiotes*
Water primrose	*Ludwigia hexapetala*
African oxygen weed*	*Lagarosiphon major*
Ambulia*	*Limnophila sessiliflora*
Arrowhead*	*Sagittaria sagittifolia*
Arrow-leaved monochoria*	*Monochoria hastata*
Duck-lettuce*	*Ottelia alismoides*
Exotic bur reed*	*Sparganium erectum*
Giant salvinia*	*Salvinia molesta, S. biloba, S. herzogii, S. auriculata*
Hydrilla*	*Hydrilla verticillata*
Mediterranean clone of caulerpa*	*Caulerpa taxifolia*
Melaleuca*	*Melaleuca quinquenervia*
Miramar weed*	*Hygrophila polysperma*
Mosquito fern*	*Azolla pinnata*
Pickerel weed*	*Monochoria vaginalis*
Rooted water hyacinth*	*Eichhornia azurea*
Water spinach*	*Ipomoea aquatica*
Wetland nightshade*	*Solanum tampicense*

** also on Federal Noxious Weed List*

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are a small bivalve mollusk native to Eastern Europe and western Asia (Figure 9-6). In the 1800's, as international shipping developed and canals were constructed, the zebra-mussel's range spread throughout Europe and into Great Britain. Zebra mussels were introduced into North America in the 1980's in Lake Saint Clair (Michigan and Canada) through ballast-water discharge. Once established, they spread rapidly throughout the Great Lakes, Hudson River, and upper Mississippi River system by 1991. Zebra mussels have exhibited strong genetic plasticity and have tolerated hostile environments beyond traditional environmental ranges in their native area. It was initially thought that water temperatures in the southern United States would prohibit colonization, but by the mid-1990's, zebra mussel colonies were documented as far south as Louisiana on the Mississippi River, as far west as Oklahoma on the Arkansas River, and as far east as Knoxville on the Tennessee River. Recently, zebra mussels were found in Virginia. Currently, they do not occur in South Carolina or the other Atlantic-slope drainages from North Carolina to Florida.

Figure 9-6. Zebra mussel.

Following the introduction of zebra mussels in the Great Lakes, DNR and the Sea Grant Consortium formed the Zebra Mussel Task Force to identify interested parties and to bring focus to this issue. Comprising representatives of the public and private sectors, the Task Force has served as an effective communication and education network for those entities most at risk of being impacted by zebra-mussel infestations. In 1999, the Task Force initiated a statewide water-quality-based study to assess the potential impact of zebra mussels in South Carolina. The study, titled *Zebra Mussels in South Carolina: The Potential Risk of Infestation* (de Kozlowski and others, 2002), is a joint publication of DNR, Clemson University, and the South Carolina Sea Grant Consortium.

The study found that, in general, water-quality conditions in South Carolina are not suitable for zebra-mussel growth and propagation. Ninety percent of the sites had at least one water-quality constituent that made zebra mussel colonization unlikely, and none of the sites provided ideal conditions. Calcium and pH appear to be the most limiting factors. Surface water in our rivers and lakes is generally too soft and pH levels too low to allow good shell formation; however, two regions of the State contain more favorable water-quality characteristics. One area is a small band of streams in the middle Piedmont, extending from York County near Charlotte, N.C., southwest to McCormick County near the Georgia border. The other area includes water just inland from the coast: parts of the Atlantic Intracoastal Waterway, the Sampit River in Georgetown, parts of the Cooper and Ashley Rivers near Charleston, and the Savannah River at Savannah, Georgia. These latter sites are of particular concern because they are near commercial ports that are subject to zebra-mussel introductions from ballast-water discharges and detachment of adults from ship hulls.

The study made the following recommendations: (1) Continue public education and awareness of zebra mussels and aquatic-nuisance species in general; (2) Post signs at boat-launch sites on public water bodies, reminding boaters to take specific precautions to prevent the introduction of zebra mussels; (3) Water-dependent industries located in identified higher-risk areas should monitor for the presence of zebra mussels on a regular basis and prepare management plans to respond to infestations; (4) Precautions should be taken to prevent ballast-water discharges in the Georgetown, Charleston, and Savannah ports; and (5) The State Zebra Mussel Task Force should continue to meet periodically to maintain an effective network of interested parties and stay current on zebra-mussel information.

Exotic Fishes

The introduction of certain nonnative fish to South Carolina water bodies can harm existing fish populations through direct competition and the transmission of diseases. State law (*S.C. Code of Laws*, Section 50-13-1630) prohibits the possession, sale, importation, or release of the following species of fish: (1) carnero or candiru catfish (*Vandellia cirrhosa*); (2) freshwater electric eel (*Electrophorus electricus*); (3) white amur or grass carp (*Ctenopharyngodon idella*); (4) walking catfish or a member of the *Clariidae* family (*Clarias, Heteropneustes*, *Gymnallabes, Channallabes*, or *Heterobranchus* genera); (5) piranha (all members of *Serrasalmus, Rooseveltiella*, and *Pygocentrus* genera); (6) stickleback; (7) Mexican banded tetra; (8) sea lamprey; (9) rudd (*Scardinius erythrophtalmus Linnaeus*); and (10) snakehead (all members of family *Cannidae*).

DNR is charged with issuing rules and regulations or special permits for research regarding these species. Of the species listed, nonreproducing grass carp and grass carp hybrids are legal under special permit by DNR.

WATER RECREATION

Water is the focal point for many recreational activities, including fishing, boating, and swimming. Many other outdoor activities, such as camping, hiking, viewing wildlife, and picnicking, are enhanced when performed near water. Fortunately, South Carolina is well supplied with freshwater and saltwater resources that allow a wide variety of water-oriented recreation for the State's residents and visitors. The attraction of South Carolina's water resources supports a healthy and growing recreation and tourism industry, and about 30 million visitors come to South Carolina each year. In 2007, travelers spent more than $16.7 billion in South Carolina, and travel and tourism generated over $1.1 billion in state and local tax revenues (S.C. Budget and Control Board, 2009). It is estimated that the hospitality and leisure employment sector, with a growth rate of 3.6% in 2007, is outperforming other private sectors. In addition, 12.6% of South Carolina's employment is related to travel and tourism (SCPRT, 2009a).

According to a survey conducted by the S.C. Department of Parks, Recreation and Tourism (SCPRT), the most popular type of water recreation in the State is beach swimming and sunbathing, with nearly two-thirds of the population participating in this activity in 2005 (SCPRT, 2008). Other popular water-related activities were freshwater fishing, motorboating, and lake-and-river swimming. Less popular water-related recreational activities include saltwater fishing, jetskiing, canoeing, kayaking and rafting, waterskiing, and sailing. Both motorboating and canoeing-kayaking-rafting participation increased slightly from 1990 to 2005 and while jetskiing saw an 8% increase in participation, waterskiing experienced an 8% decline in participation. The percentage of population participating in other water-related activities listed above remained relatively constant from 1990 to 2005. Other recreational activities, such as watching wildlife, bird watching, and hiking, have relatively high participation percentages; however, the SCPRT survey does not state whether these activities were associated with water bodies. It is likely that a significant amount of participation in these activities is associated with the State's water resources.

South Carolina has a variety of state, county, and municipal parks, state and national forests, heritage preserves, wildlife refuges, and other sites from which to access and enjoy the State's numerous water resources. Recreational activities associated with the State's major recreational water bodies—lakes, rivers, and coastal waters—are described in the following sections.

Lake Recreation

Although few natural lakes exist in South Carolina, the construction of reservoirs for hydropower, water supply, and flood control has provided the State with more than 1,600 lakes greater than 10 acres in area. Collectively, these lakes cover more than 520,000 acres and impound in excess of 15,000,000 acre-feet of water. Seventeen reservoirs have surface areas larger than 1,000 acres and provide a wide variety of recreational opportunities (Table 9-7); collectively, these seventeen lakes account for more than 450,000 acres of surface water (SCPRT, 2008). Most of the major lakes are located in the Piedmont region of the State, with the exception of Lakes Marion, Moultrie, and Robinson, which are in the Coastal Plain.

While most of these major lakes were originally constructed for the production of electricity, many now serve secondary purposes, including recreation. A wide range of water-based recreational opportunities is available at these lakes, with the most popular being fishing, swimming, and boating-related activities. Lakes near large population centers, such as Lake Murray and Lake Wylie, experience high public use. More information on water-based recreational opportunities can be found at the South Carolina State Parks website, *http://www.southcarolinaparks.com*, and a list of public boat landings can be found at *http://www.dnr.sc.gov/managed/boatramp.html*.

In addition to the sites listed in Table 9-7, lake recreation is also available to the public at smaller lakes contained completely within the following parks and natural areas: Aiken State Park, Andrew Jackson State Park, Barnwell State Park, Cheraw State Park, Chester State Park, Croft State Natural Area, Goodale State Park, Kings Mountain State Park, Little Pee Dee State Park, Oconee State Park, Paris Mountain State Park, Poinsett State Park, Sesquicentennial State Park, Table Rock State Park, and Lake Warren State Park. A list of lakes managed by DNR that are open to the public can be found at *http://www.dnr.sc.gov/managed/lakes.html*.

River Recreation

While stretches of many of South Carolina's permanently-flowing rivers and streams have been impounded, most of the State's rivers still freely flow and offer a variety of recreational opportunities throughout the State. The diversity of the State's waterways provides a variety of riverine environments, from turbulent whitewater streams of the Blue Ridge and Piedmont to tranquil blackwater streams of the lower Coastal Plain.

The types of recreational activities available on any particular stream are influenced by the characteristics of that stream. For example, trout fishing is popular in the cold waters of the Blue Ridge and Piedmont, while striped bass, catfish, and redbreast fishing are more popular in Coastal Plain streams.

Boating, including canoeing, kayaking, and rafting, occurs throughout the State. Most main stem rivers are suitable for canoeing and kayaking, and numerous water trails exist on these rivers and their tributaries. A sampling of water trails that highlight the State's diverse riverine systems is listed in Table 9-8. Additional information on these and other water trails in the State can be found online at *http://www.sctrails.net* and in *Paddling South Carolina: A Guide to Palmetto State River Trails* (Able and Horan, 2001). Motorboating is more popular on lower Coastal Plain streams because these waters are wider and deeper than those of the upper Coastal Plain and Piedmont.

As of 2009, portions of ten rivers totaling about 400 river miles have been designated as South Carolina State Scenic Rivers by the General Assembly. The Scenic Rivers Program has the purpose of protecting unique and outstanding river resources in South Carolina (see the *River Conservation* section of this chapter). River protection is achieved through a cooperative, voluntary management program that includes landowners, community interests, and DNR working toward common river-conservation goals. DNR also manages lands that provide access to several rivers. The following heritage preserves, managed under DNR's Heritage Trust Program, provide access to rivers or creeks of the same name: Congaree Bluffs, Congaree Creek, Eastatoe Creek, Great Pee Dee River, Little Pee Dee River, and Waccamaw River.

The following State Parks provide access to river-oriented recreation as well: Aiken State Natural Area, Colleton State Park, and Givhans Ferry State Park on the Edisto River; Rivers Bridge State Historic Site on the Salkehatchie River; Colonial Dorchester State Historic Site on the Ashley River; Landsford Canal State Park on the Catawba River; Little Pee Dee State Park on the Little Pee Dee River; and Hampton Plantation State Historic Site on the Santee River. The Lee State Natural Area and the Lynches River County Park are both on the Lynches River; the Musgrove Mill Historic Site is on the Enoree River; and the Rose Hill Historic Site is on the Tyger River. Caesars Head State Park includes part of the Middle Saluda River and the scenic Raven Cliff Falls.

Several State and National Forests also provide access to river recreation: Manchester State Forest on the Wateree River; Harbison State Forest on the Broad River; Wee Tee State Forest on the Santee River; and Poe Creek State Forest on Little Eastatoe Creek. The Sumter National Forest's Enoree Ranger District provides access to the Enoree, Tyger, and Broad Rivers; the Andrew Pickens Ranger District provides access to the Chatooga River; and the Long Cane Ranger District provides access to Stevens Creek. Francis Marion National Forest provides access to several creeks including Wambaw Creek, portions of which are a designated Wilderness Area. In addition, the Congaree National Park provides access to Cedar Creek and the Congaree River.

Table 9-7. Recreational overview of South Carolina lakes larger than 1,000 acres in area

Lake **Lake operator**	**Surface area (acres)** **Shoreline length (miles)**	**Recreational overview***
Hartwell Corps of Engineers	56,000 962	Numerous public access points, including two State recreation areas: Sadlers Creek and Lake Hartwell. Georgia also has two State Parks on the lake. All forms of recreation are available, including camping, hiking, boating, and fishing.
Thurmond Corps of Engineers	70,000 1,200	Numerous public recreation sites, including three State Parks: Hickory Knob, Baker Creek, and Hamilton Branch. Georgia also has three State Parks on the lake. All forms of recreation are available, including camping, hiking, boating, and fishing.
Murray SCE&G	51,000 649	Dreher Island State Recreational Area is located on the northern shore. SCE&G maintains nine recreational areas along the lake. All forms of recreation are available.
Marion Santee Cooper	110,000 315	Public access is available at several sites, including Santee State Park on the western shore and Santee National Wildlife Refuge on the northern shore. All forms of recreation are available, the most popular being fishing.
Moultrie Santee Cooper	60,000 135	The lake is connected to Lake Marion via a canal. Public access is available at several boat landings, the diversion canal from Lake Marion, and the Pinopolis lock connected to the Cooper River. The Palmetto Trail also provides access to the lake.
Jocassee Duke Energy	7,565 75	The shoreline is mostly undeveloped, and much of the lake is surrounded by a DNR wildlife management area (Jim Timmerman Natural Resources Area at Jocassee Gorges). Public access is limited and includes Devil's Forks State Park on the southern end of the lake and the Foothills Trail along the upper end of the lake.
Russell Corps of Engineers	26,650 550	The shoreline is largely undeveloped due to federal regulations prohibiting private use of lands surrounding this lake. Public access is available through Calhoun Falls State Park and other recreational areas leased to South Carolina and Georgia. All forms of recreation are available.
Keowee Duke Energy	18,372 300	Public access is available from Keowee-Toxaway State Park on the northern end of the lake and several other recreational areas maintained by Duke Energy or leased to local counties. All forms of recreation are available.
Monticello SCE&G	6,800 ---	Public access is limited to one boat landing on the western side of the lake and to Lake Monticello Park operated by Fairfield County. Limited recreation is available in the form of boating and fishing.
Wateree Duke Energy	13,710 242	In addition to several access areas maintained by Duke Energy, public access is available at the Lake Wateree State Recreational Area and DNR's Beaver Creek Access Area. All forms of recreation are available but somewhat limited.
Wylie Duke Energy	12,455 325	Duke Energy maintains several access areas, and others are leased to local counties. All forms of recreation are available.
Greenwood Greenwood County	11,400 212	Public access is available at the Lake Greenwood State Recreational Area as well as several other recreational areas operated by Greenwood County.
Fishing Creek Reservoir Duke Energy	3,431 61	Public access is available through two recreation facilities maintained by Duke Energy and at DNR's Highway 9 Access Area.
Parr Reservoir SCE&G	4,400 94	Access to the reservoir is limited to two recreational areas maintained by SCE&G. Most recreation consists of boating and fishing.
H.B. Robinson Progress Energy	2,250 ---	Limited access is available through a few public boat landings and a fishing pier.
Bowen Spartanburg Water	1,534 33	Originally created for a municipal water supply, the lake now supports recreation in the form of boating, fishing, and swimming. Public access is available at Lake Bowen Park, which is operated by Spartanburg Water.
Blalock Spartanburg Water	1,105 45	The lake, created to expand Spartanburg's water supply, offers boating, fishing, and swimming. Public access is available through a recreational park provided by Spartanburg Water.

* *Visit* http://www.dnr.sc.gov/managed/boatramp.html *for a list of South Carolina public boat landings and* http://www.southcarolinaparks.com *for more information on South Carolina State Parks.*

Table 9-8. Description of selected water trails in South Carolina

Waterway	Length (miles)	Description
Chatooga River	7–19	Located along the border of South Carolina and Georgia in the Sumter National Forest, this trail is along a 40-mile reach designated as a National Wild and Scenic River. This river is divided into 4 sections, but only sections II and III are included in the river trail described here. This river is one of the best and most dangerous whitewater sites in the Southeast. No boating is allowed in section I above the Highway 28 bridge, where this trail begins. Section II has 20 rapids, is open to boaters and tubers, and is suitable for less-experienced users. Section III should only be attempted by experienced and skilled boaters. Section IV, which begins at the takeout at mile marker 19, also should only be attempted by experienced and skilled boaters. Due to the powerful and dangerous nature of the river, the National Forest Service regulates its use. Several access/take out points along the trail allow for trips of varying lengths.
Turkey Creek / Stevens Creek	4–12	This tributary to the Savannah River is located in Sumter National Forest's Long Cane Ranger District along relatively undeveloped woodlands. Flood-plain forest interspersed with marshy areas and occasional steep hardwood bluffs lie along the lands surrounding this creek. The lack of development and the National Forest buffer make this a good site for close-up wildlife viewing. Several access/take out points along the trail allow for trips of varying lengths.
Tyger River	3–24	This trail is located along the edge of the Sumter National Forest's Enoree Ranger District and consists mainly of moderate, swift-moving flatwater with some whitewater in the upper sections. The land surrounding the river is mainly a pine-hardwood mixed forest beyond sloping banks and some marshy bogs. Caution is warranted on this trail after heavy rains that can produce swift currents and dangerous strainers. Several access/take out points along the trail allow for trips of varying lengths.
Lower Saluda River	3–9.5	This river trail is located just downstream of the Lake Murray dam near the metropolitan area of Columbia. Due to the releases from this dam, the river is subject to large fluctuations in stage and current and remains cold year-round. Due to the cold water, a put, grow, and take trout fishery is managed on the river, and the river also serves as a cold-water refuge for migrating striped bass in the summer months. The river is mainly flatwater above the I-26 intersection and suitable for less experienced paddlers. There are several rapids below the I-26 intersection including Mill Race Rapids near the Riverbanks Zoo, which can reach a Class V rating and should only be attempted by skilled and experienced paddlers. There is a portage area around Mill Race on the right bank at a powerline right-of-way. There are four public access/take out points on the river.
Catawba River	1.7–7.4	Located on the longest stretch of free-flowing water remaining in the Catawba-Wateree basin, this trail begins at Landsford Canal State Park, just upstream of the well-preserved remains of a canal system constructed in the early 1800's. The canal made the river commercially navigable past the rocky shoals that characterize this reach of the Catawba River. This trail runs through one of the largest stands of the rare Rocky Shoals Spider Lily, which blooms in mid-May to early June. Rapids in the shoals are normally rated Class I, but can reach Class II or III due to releases from Lake Wylie upstream. Paddlers should check with Duke Energy for potential flow releases from Wylie before beginning a trip. Under extreme low-flow conditions, this stretch of the river may not be navigable.
Wambaw Creek	5	This trail is located within the boundaries of the Francis Marion National Forest and runs through a designated Wilderness Area, one of only five such areas in the State. The creek, which is a tidally-influenced tributary to the Santee River, is an easy flatwater paddle through the vast swamps of the National Forest. In the early 1700's, slave labor converted some of the swamplands surrounding the creek to rice fields, and the evidence of their associated canals and dikes can still be seen.
Edisto River	13.5–57	This trail resides on the main stem of the Edisto River and begins at the Whetstone Crossroads landing on U.S. Highway 21. The trail is on one of the state's longest blackwater rivers and meanders through large live oaks covered with Spanish moss, bald cypresses, and water tupelos. This trail offers a relatively easy paddle with a steady current, abundant wildlife viewing opportunities and numerous rest stops along its 57-mile length. Several access/take out points allow for trips of varying lengths. Although volunteers work to remove fallen trees and logjams, interested paddlers should watch out for these potential hazards.
Cedar Creek	6	The Cedar Creek Trail, a tributary to the Congaree River, resides in the Congaree National Park, home to the largest remnant of old-growth floodplain forest in the country and holder of Federal and State record-sized trees. Small elevation changes throughout the swamp produce diverse flora and fauna. Although this trail is an easy paddle under normal conditions, paddlers should expect occasional logjams and strainers.
Little Pee Dee Scenic River	8	This river trail is part of a designated State Scenic River that spans 14 miles upstream from the confluence with the Great Pee Dee River. This trail is well-suited for beginners and meanders through vast areas of swampland that provide numerous opportunities for wildlife viewing. This trail is characterized by many side channels and oxbows, so care must be taken to stay on the main channel.
Ashepoo River	6	Located within the ACE basin, one of the last great undeveloped watersheds in the eastern Unites States, the Ashepoo River is tidally influenced, and although the river can be paddled at any time, it is recommended that a trip be undertaken on a falling tide. The first 0.6 miles of the trail are narrow and feature a tree canopy that offers shade and habitat for wildlife. The remaining length of the trail opens up and features old rice fields and plantations, such as the historic Bonnie Doone. The trail is also noted for nesting ospreys and eagles.

Coastal Water Recreation

South Carolina's coastline stretches approximately 190 miles between Little River Inlet and Savannah Harbor. In addition to the open ocean, 240 miles of Intracoastal Waterway and numerous inlets, bays, sounds, and tidal rivers contribute to the diversity of South Carolina's coastal waters. Nearly 3,000 miles of shoreline and more than 450,000 acres of saltwater or brackish marshland make this area one of the State's most important and productive natural resources.

The natural beauty, diversity, and productivity of South Carolina's coastal waters attract numerous resident and out-of-state visitors each year. The most popular recreation areas in the State are along the coast and offer a variety of recreational opportunities. The coast can be divided into three major tourist and recreation areas: the Grand Strand, Charleston, and the lower coastal area near Beaufort.

With nearly 60 miles of unbroken beaches, the Grand Strand area is the most popular recreation site in the State for both residents and out-of-state visitors. While the most popular form of water-based recreation is ocean swimming and sunbathing, camping and fishing are also popular. Fishing piers dot the coast and charter boats are available for ocean gamefishing. Two parks, Huntington Beach State Park and Myrtle Beach State Park, are located in the Grand Strand area, providing natural recreation areas that contrast with the numerous commercial activities present in the area (SCPRT, 2009b). Lewis Ocean Bay Heritage Preserve is a 9,383-acre preserve that contains 23 Carolina bays, the largest number of undisturbed Carolina bays in one place in South Carolina. The 5,347-acre Waccamaw River Heritage Preserve stretches from the North Carolina state line to the Red Bluff boat landing and showcases 30 miles of protected river wetlands and bottomland hardwood forests. The 55,000-acre Waccamaw National Wildlife Refuge, located in portions of Horry, Georgetown, and Marion Counties, includes large sections of the Waccamaw and Great Pee Dee Rivers. Wetland habitats range from historic tidal rice fields to blackwater and alluvial floodplain forested wetlands of the Waccamaw and Great Pee Dee Rivers. These tidal freshwater wetlands are some of the most diverse freshwater wetland systems found in North America and they offer many important habitats for migratory birds, fish, and resident wildlife.

Beaches in the Charleston area are also heavily used by both local and tourist populations. Ocean swimming is the most popular water-based recreational activity; also popular are boating, fishing, and water-skiing. Folly Beach is the closest beach to historic Charleston. Calm and relaxed, Folly Beach is a great place to ride the waves, collect seashells, and walk to the lighthouse. A fishing pier and striking views make Folly Beach one of the last "shabby" beaches in the area. Isle of Palms, just north of Charleston, is bordered by beautiful beaches and a network of marsh creeks. Beach volleyball, bodysurfing, shrimping, and crabbing are favorite pastimes. The Santee Coastal Reserve Wildlife Management Area is a 24,000-acre tract of land in northern Charleston County that offers canoeing opportunities and showcases a boardwalk through the marshland (SCPRT, 2009b). Cape Romain National Wildlife Refuge is a 66,267-acre barrier-island refuge offering great bird watching and a captivating expanse of barrier islands, salt marshes, intricate coastal waterways, long sandy beaches, fresh and brackish water impoundments, and a maritime forest. Capers Island Heritage Preserve is an undeveloped barrier island with 214 acres of beach and 1,090 acres of salt marsh.

Between Charleston and Beaufort are thousands of acres of public land containing pine and hardwood uplands, forested wetlands, fresh, brackish, and saltwater tidal marshes, barrier islands, and beaches. Numerous islands are in private hands and several are developed as resorts with public access. Named for an Indian tribe, Kiawah Island is about 21 miles south of historic Charleston. Although much of Kiawah is privately owned, Beachwalker Park is open to the public, offering 11 miles of unspoiled beach and a wide boardwalk that winds through live oaks, pines, palmettos, and yucca plants. Edisto Beach State Park, located about 30 miles southwest of Charleston, provides a major public access to this section of coast and offers a variety of recreational activities, including boating, surf fishing, oceanfront camping, and bird watching. The Donnelley Wildlife Management Area in Colleton County has two designated nature trails and miles of dirt roads for hikers and bicyclists. Alligators are abundant in the managed wetlands and are most often seen from late February through mid-November. The National Estuarine Research Reserve and the Earnest F. Hollings National Wildlife Refuge offer visitors many opportunities to enjoy the uniqueness of the ACE Basin. Popular activities include hunting, fishing, boating, and bird watching.

South Carolina’s Lowcountry near Beaufort has become a very popular recreational area, with resort development on barrier islands such as Hilton Head and Daufuskie Islands, and the semitropical climate of the area makes water-related recreation possible for most of the year. The largest sea island between New Jersey and Florida, Hilton Head Island has 12 miles of broad beaches, maritime forests, salt marshes, and nine marinas. Hunting Island is South Carolina’s most popular State Park, attracting more than one million visitors a year. The park is home to five miles of beach, thousands of acres of marsh, tidal creeks, a maritime forest, a saltwater lagoon and ocean inlet, and a fishing pier. Fishing, boating, water skiing, and sailing are popular all year round.

Restrictions

Although South Carolina has an abundance of water that is usually clean enough to regularly support recreational uses, some activities may occasionally be restricted due to poor water quality, excessive aquatic vegetation, or other reasons.

In South Carolina, DHEC develops water-quality standards for various types of recreational water use and monitors the State's waters for compliance with these standards. DHEC collects data from a statewide network of surface-water monitoring stations used to evaluate current water-quality conditions and long-term trends. Advisories are issued for waters that do not meet the water-quality standards associated with particular water uses. The most current water classifications and standards can be found on the DHEC website *http://www.scdhec.net/environment/water/regs/r61-68.pdf*.

Fish Consumption Advisories. A variety of fish are routinely collected by DHEC and DNR from streams, lakes, estuaries, and offshore waters and tested to determine if the fish are contaminated. Mercury is the most common and widespread contaminant found in fish in the State, but PCBs are locally found in fish at Lake Hartwell and radioisotopes are sometimes found in fish caught in the Savannah River. If fish are found to be contaminated, DHEC issues fish consumption advisories that describe the water body that is under the advisory, the types of fish that are contaminated, and the amounts of fish that can safely be eaten. Warning signs are posted at public boat landings that access water bodies under an advisory. Current fish consumption advisories are listed on DHEC's website (*http://www.scdhec.net/environment/water/fish/index.htm*).

Shellfish Program. DHEC regularly tests coastal waters that contain beds of oysters, clams, or mussels for the occurrence of bacteria. If standards are not met, or if conditions have changed to make the shellfish unsafe, DHEC closes the shellfish bed, meaning that the shellfish are unsafe to eat and illegal to collect. Maps of shellfish beds and their current water-quality classifications are provided on DHEC's website (*http://www.scdhec.net/environment/water/shellfish.htm*).

Swimming Advisories. DHEC tests rivers, lakes, and streams in the State for the occurrence of potentially harmful bacteria. If standards for contact recreation are exceeded, DHEC posts swimming-advisory signs where high amounts of bacteria have been found and where people commonly swim. Advisories are warnings that the water may contain harmful germs. Because natural waters change often, DHEC can only make general statements about the health risks of swimming in them (see DHEC's website, *http://www.scdhec.net/environment/water/recadvisory.htm*).

Beach Monitoring Program. DHEC routinely tests bacteria levels in water samples collected at 125 locations on South Carolina's beaches. If high bacteria concentrations are found, an advisory is issued for that portion of the beach, meaning that DHEC advises people, especially young children and those with compromised immune systems, not to swim in certain areas. Advisories do not mean that the beach is closed; wading, fishing, and shell collecting do not pose a risk. For the most recent monitoring results, check local newspapers, television news stations, and DHEC's website (*http://www.scdhec.net/environment/water/beachmon.htm*), and look for advisory signs when at the beach.

Wind and Flood Advisories. Water-based recreational activities can be dangerous during inclement weather or in times of unusual water conditions. High surf advisories, lake wind and small-craft advisories, hazardous seas and flood warnings, and severe weather statements are issued by the National Weather Service and can be found on their website (*http://www.nws.noaa.gov/*). The Southeast River Forecast Center, operated by the National Weather Service, provides real time data regarding river flooding in the State (*http://www.srh.noaa.gov/alr/index.shtml*).

SEDIMENTATION IN SURFACE WATERS

Sediment is any particulate material that is transported and deposited by water, wind, or ice. Waterborne sediments may be composed of organic material (plant and animal matter), inorganic material, or, as is usually the case, a mixture of both. The size of sediment particles usually includes a wide range from very-fine clays and sands to large rocks and boulders. However, sediment material can be placed into two general categories based on modes of transport: suspended sediments and bedload sediments (Farnworth and others, 1979). Suspended sediments include small-sized particles (silts and clays) that are maintained in the water column by turbulence and carried with water flow. Bedload sediments usually include large-sized particles (sand, gravel, rocks) that rest on the streambed and are moved along the bottom by streamflow. Some sediment particle sizes may be included in either category depending on water body characteristics and environmental conditions. The ASCE Manual 110 *Sedimentation Engineering* is a comprehensive reference on sediment movement (Garcia, 2008).

Impact on Water Resources

Both water quality and quantity are impacted by heavy sediment loads. Bedload sediment movement impacts primarily stream environments through the scouring and abrading of streambeds, altering habitat structure, and burying bottom-dwelling organisms (Farnworth and others, 1979). Suspended sediments may impact all types of waters but especially slow-moving waters such as lakes and reservoirs. This form of sedimentation is one of the most insidious forms of water pollution because it is widespread, often goes unnoticed, and damage is often permanent (Smith, 1966).

High levels of suspended sediments are not only aesthetically undesirable but are also detrimental to several water-use activities. The efficiency and effectiveness of municipal and industrial water treatment processes are reduced when suspended solids are greater than normal levels (U.S. Environmental Protection Agency, 1976). Agricultural use may be adversely affected. Use of irrigation water with high levels of suspended solids may result in crust formation on soils that inhibits water infiltration, soil aeration, and plant emergence; cause film formation on crops, which blocks sunlight and impairs photosynthesis; and can damage pumps and water-delivery systems (U.S. Environmental Protection Agency, 1976). The safe use of a water body for recreational activities, such as swimming and diving, is impaired by highly turbid waters.

Sediment deposition in drainage ditches, culverts, canals, and other small conveyances restricts their flow capacity. This is also true in streams and lakes. When water turbulence subsides, heavier particles settle to the bottom, causing additional problems. The accumulation of sediments in lakes can greatly reduce storage capacity; almost 3,600 acre-feet of storage are lost annually from the major reservoirs in the Santee River basin in South Carolina, and Lake Marion alone loses about 1,500 acre-feet per year (U.S. Department of Agriculture, 1973). Silted navigation channels hinder boat traffic and increase dredging time and cost. The U.S. Army Corps of Engineers dredges an average of about 15,000 tons of sediment per year from the Intracoastal Waterway between Charleston and Beaufort. The Corps' multi-million dollar Cooper River Rediversion Project was initiated because of heavy sedimentation and shoaling in Charleston Harbor.

In addition to adverse impacts on man's use of water, excess sedimentation is also harmful to all levels of aquatic life. High levels of suspended solids block sunlight and inhibit growth of microscopic plants; clog the filtering structures of mollusks and gill structures of fish; reduce fish growth rates and disease resistance; and modify natural fish movements (Farnworth and others, 1979). Heavy deposition of sediments on the bottom of water bodies may alter existing habitats, smother and kill bottom-dwelling organisms, kill fish eggs, and alter the existing biological community. Organic matter, nutrients, heavy metals, and pesticides are also often associated with sediments and may alter water quality and impact aquatic organisms. A more recent reference for the impact of sediment on quality is the Environmental Protection Agency's *Sediment Classification Methods Compendium* (U.S. Environmental Protection Agency, 1992).

Sources of Sediment

Surface-water sediments come from eroded soil washed off watershed lands during periods of heavy rainfall. An estimated 1.8 billion tons of valuable soil enters the nation's waterways each year (Beck, 1980). In South Carolina, over 18 million tons of soil are eroded each year, contributing to surface-water sedimentation problems (U.S. Department of Agriculture, 1980). The rate at which eroded soils enter water bodies is dependent on precipitation, water flow, land use, slope, soil type, and vegetative cover in the watershed. Land use activities that contribute to soil erosion and subsequent sedimentation include agriculture, silviculture, construction, mining, and hydrologic modification. Agricultural activities are a major cause of soil erosion in South Carolina (4.65 tons per acre per year) (U.S. Department of Agriculture, 1980). The U.S. Department of Agriculture Soil Conservation Service determined that agricultural croplands, which comprise about 18 percent of nonfederal acreage in the State, contribute about 85 percent of total soil erosion (15.5 million tons per year). Soil erosion due to silviculture activities is much less significant (0.18 tons per acre per year). Forest lands that comprise over 59 percent of nonfederal acres in South Carolina contribute only about 11 percent (1.9 million tons per year) of total soil erosion (U.S. Department of Agriculture, 1980). While construction activities generally cause the greatest rate of erosion (20–100 tons per acre per year), the extent of land disturbed by construction is small and can vary significantly from year to year (S.C. Land Resources Conservation Commission, 1978a).

Geological and morphological characteristics of a watershed greatly affect the rate of erosion and sedimentation. Variations in these characteristics are exemplified by the major land-resource areas in South Carolina, which include the Blue Ridge Mountains, Southern Piedmont, Carolina and Georgia Sandhills, Southern Coastal Plain, Atlantic Coast Flatwoods, and Tidewater Areas (see Figure 1-4). In general, erosion is greatest in the Piedmont where slopes are steep and soils contain relatively high percentages of silt and clay. Erosion is least in the Atlantic Coast Flatwoods region where sandy flat terrain allows little runoff. About 56 percent of total State soil loss occurs in the Piedmont, 23 percent occurs in the Southern Coastal Plain, 15 percent occurs in the Sandhills region, and 6 percent occurs in the Atlantic Coast Flatwoods (S.C. Land Resources Conservation Commission, 1978b). It is further estimated that 25 percent of the gross soil movement from agricultural croplands in the Piedmont is delivered to watershed outlets. This estimation is 17.5 percent in the Sandhills, 13 percent in the Southern Coastal Plain, and 10.6 percent in the Atlantic Coast Flatwoods land resources areas (S.C. Land Resources Conservation Commission, 1978b).

Management of the Sedimentation Problem

The S.C. Department of Health and Environmental Control (DHEC) regulates sediment loss due to land disturbance from construction activities. Two programs regulate land-disturbing activities in South Carolina: the S.C. Stormwater Management and Sediment Reduction Act (1991 Act) and the National Pollutant Discharge Elimination System (NPDES) permitting program as authorized by the

Federal Water Pollution Control Act of 1972 and the Clean Water Act of 1977 and delegated to South Carolina by the U.S. Environmental Protection Agency.

The 1991 Act applies to construction sites in South Carolina that result in two acres or more of land disturbance.

The NPDES program consists of coverage of land-disturbing activities equal to or greater than one acre, and sites less than one acre that are part of a larger common plan for development or sale, under the current NPDES General Permit for Storm Water Discharges from Large and Small Construction Activities. In the coastal counties, coverage is also required for projects that disturb less than one acre when the site is located within one-half mile of a receiving water body.

DHEC is assisted in implementing these regulations by many cities and counties that have been delegated to run a stormwater program under provisions of the 1991 Act and/or are owners of a Municipal Separate Storm Sewer System (MS4) and are required to run stormwater management programs under the NPDES program.

Both of these programs require the development and implementation of a plan to control sediment and prevent erosion during site construction and control stormwater runoff rates post-construction. These plans consist of a series of best management practices, or BMPs, such as silt fences, sediment basins, and rock check dams that keep sediment generated during the construction process from entering water bodies or adjacent properties.

UNIQUE WETLAND AREAS

South Carolina's abundant wetland areas, including saltwater and freshwater tidelands, riverine swamps and flood plains, and isolated wetland sites, particularly Carolina bays, are diverse ecosystems that serve a variety of functions beneficial to nature and mankind. The State has approximately 4.5 million acres of wetlands, which corresponds to about 23 percent of the State’s land surface. Although they are found all over the State, the majority of South Carolina’s wetlands occur in the Coastal Plain. Approximately 90 percent of the State’s wetlands are freshwater and are inundated by water from rain, surface runoff, flooding, or groundwater discharge; the remaining 10 percent are salt water and brackish-water marshes along the coast, where flooding or saturation is controlled by ocean tides.

The role of wetlands in maintaining water quality is well known. Serving as buffers between upland areas and receiving streams, wetlands filter runoff from high-ground areas prior to releasing water into adjacent streams, thus playing an important role in reducing sedimentation and water pollution from non-point sources. Wetlands also recharge ground-water systems and serve as floodwater reservoirs by gathering and holding runoff and gradually releasing these waters into streams.

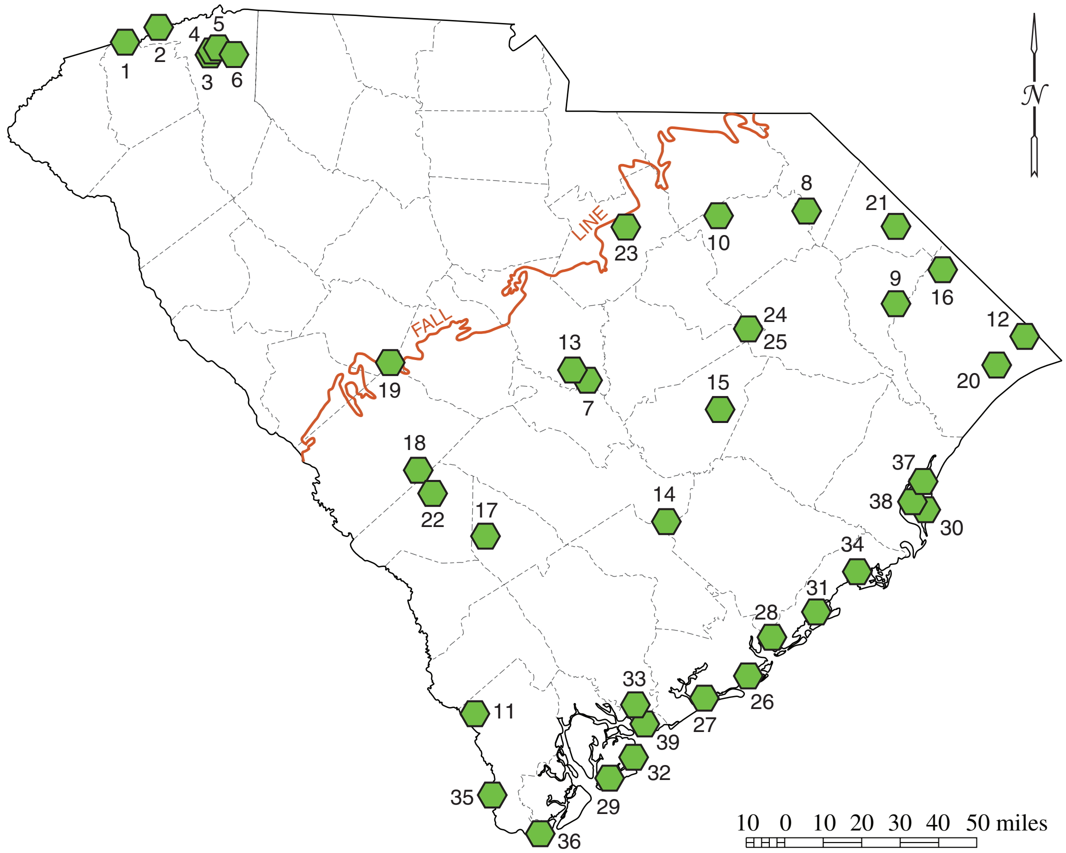
The diversity of South Carolina's wetland resources and the relative inaccessibility of these areas serve to increase the value of wetlands as natural areas by harboring and providing habitat for a variety of animal and plant species. South Carolina’s wetlands also contain numerous animal and plant species listed as federally endangered or threatened species and/or species of state concern. While all of the State's wetlands are valuable for these reasons, the coastal tideland areas, comprising approximately 500,000 acres of tidally-influenced wetlands, are perhaps the most sensitive and productive of all. These tidal areas, which support a great variety of marine life during all or part of their life cycles, are especially important as nursery areas for several commercially-harvested marine organisms such as shrimp, oysters, crabs, clams, and several fish species.

All of South Carolina's wetlands function in a variety of ways to improve the quality of life not only for man, but for many other species. However, every year greater development pressures are placed on the wetlands, particularly in the coastal region, where competition for prime development sites is increasing. Several basic questions concerning wetland loss remain unanswered. The extent and the rate at which wetland losses are occurring are not well documented in South Carolina; however, of all wetland losses in the United States, it is estimated that approximately 89 percent have occurred in the Southeast (DHEC, 2009). More importantly, the economic and environmental impacts of the loss of these sensitive resource areas have yet to be assessed. Wise resource management and protection are imperative to maintain the important functions of the wetlands.

Located throughout the State are specific wetland sites that have special characteristics that have led to their classification as unique or sensitive natural areas. Through its Heritage Trust Program, the DNR (S.C. Department of Natural Resources) has protected many unique and sensitive wetland sites and continually strives to locate other such sites to ensure the protection and preservation of their unique qualities. Some of the wetland-associated natural areas currently protected under the S.C. Heritage Trust Program and by other state, federal, and nongovernment agencies are identified in Figure 9-7 and briefly discussed below.

Blue Ridge Mountains

Two unique wetland areas in the mountains of South Carolina are the Eastatoe Creek Heritage Preserve and the Watson-Cooper Heritage Preserve, both part of the DNR Heritage Trust Program. The streams at Eastatoe support a rainbow trout fishery and occur in rocky gorges that support three rare fern species. The Watson-Cooper Preserve contains one of the few remaining streams in the mountains of South Carolina that supports brown trout,



1. Eastatoe Creek Heritage Preserve
2. Watson-Cooper Heritage Preserve
3. Blackwell Bunched Arrowhead Heritage Preserve
4. Bunched Arrowhead Heritage Preserve
5. Belvue Springs Heritage Preserve
6. Clear Creek Heritage Preserve
7. Congaree Bluffs Heritage Preserve
8. Great Pee Dee River Heritage Preserve
9. Little Pee Dee River Heritage Preserve
10. Segars-McKinnon Heritage Preserve
11. Tillman Sand Ridge Heritage Preserve
12. Waccamaw River Heritage Preserve
13. Congaree National Park
14. Francis Beidler Forest
15. Bennett's Bay Heritage Preserve
16. Cartwheel Bay Heritage Preserve
17. Cathedral Bay Heritage Preserve
18. Ditch Pond Heritage Preserve
19. Janet Harrison High Pond Heritage Preserve
20. Lewis Ocean Bay Heritage Preserve
21. Little Pee Dee State Park Bay Heritage Preserve
22. Long Branch Bay Heritage Preserve
23. Savage Bay Heritage Preserve
24. Woods Bay State Natural Area
25. Woods Bay State Heritage Preserve
26. Bird Key-Stono Heritage Preserve
27. Deveraux Bank Heritage Preserve
28. Crab Bank Heritage Preserve
29. Bay Point Shoal Heritage Preserve
30. Yawkey Wildlife Center Heritage Preserve
31. Capers Island Heritage Preserve
32. Old Island Heritage Preserve
33. St. Helena Sound Heritage Preserve
34. Cape Romain National Wildlife Refuge
35. Savannah National Wildlife Refuge
36. Tybee National Wildlife Refuge
37. Belle W. Baruch Marine Research Institute
38. North Inlet-Winyah Bay National Estuarine Research Reserve
39. ACE Basin National Estuarine Research Reserve

Figure 9-7. Protected sites associated with unique wetlands in South Carolina.

the State's only native trout species. A montane bog, the only one of its kind in South Carolina, is also found at the preserve and contains a rare orchid species.

Piedmont

The Blackwell Bunched Arrowhead, Bunched Arrowhead, Belvue Springs, and Clear Creek Heritage Preserves all contain a rare wetland type known as a Piedmont seepage forest. These wetlands are formed by a network of streams, groundwater seeps, and springs located in the hilly regions adjacent to floodplains of Piedmont streams. These wetlands have extensive areas of saturated soil for much of the year, due to seeps and springs rather than periodic flooding of the river. As several of the names suggest, these seepage forests contain a federally-endangered plant species, the Bunched Arrowhead, as well as a wide variety of ferns and orchids.

Coastal Plain

Bottomland Hardwood Forests. Bottomland hardwoods are lowland forests adjacent to streams and rivers that are periodically flooded. The Waccamaw, Pee Dee, Little Pee Dee, Lynches, Black, Santee, Wateree, Congaree, Edisto, Salkehatchie, and Savannah Rivers are surrounded by an abundance of bottomland hardwoods. Historically, these riparian ecosystems have been threatened by logging and/or conversion to agriculture. DNR has protected several bottomland hardwood sites through the creation of Heritage Preserves including Congaree Bluffs, Great Pee Dee River, Little Pee Dee River, Segars-McKinnon (Black Creek), Tillman Sand Ridge (Savannah River), and Waccamaw River.

Other notable bottomland hardwood sites include the 22,000-acre Congaree National Park, which has the largest remnant of old-growth floodplain forest in the United States and holds federal and state record-sized trees, and the Francis Beidler Forest (Four Hole Swamp), which is managed by the National Audubon Society. Beidler Forest is a 15,000-acre unique blackwater stream/swamp that supports virgin cypress and a large tract of undisturbed bottomland forest.

Carolina Bays. Carolina bays, though of unsure origin, are elliptically-shaped, unique wetlands of the Atlantic Coastal Plain that can harbor a diverse range of animal and plant species. Though found along the Atlantic Coastal Plain from Delaware to Florida, these bays are found predominantly in North and South Carolina. Most Carolina bays have been destroyed or altered by logging and conversion to agriculture, and hence, qualify as sensitive wetland areas. DNR has recognized the importance of Carolina bays and has preserved numerous bays through its Heritage Trust Program. Current Heritage Preserves that feature Carolina bays are Bennett's Bay, Cartwheel Bay, Cathedral Bay, Ditch Pond, Janet Harrison High Pond, Lewis Ocean Bay, Little Pee Dee State Park Bay, Long Branch Bay, and Savage Bay. The S.C. Department of Parks, Recreation and Tourism manages Woods Bay, which is part of the Woods Bay State Natural Area. DNR also manages the Woods Bay State Park Heritage Preserve, which was created to serve as a buffer from any future development around Woods Bay.

Coast

Numerous sites along the coast exemplify the varied estuarine environment of South Carolina. Bird Key-Stono Heritage Preserve is a sandspit island that provides habitat for a variety of sea and shore birds and from the late 1980's to 1994 was the largest rookery island in South Carolina for the once-endangered brown pelican. Other sandspit islands, which are formed by deposits from river systems, are found at Deveaux Bank, Crab Bank, and Bay Point Shoal Heritage Preserves.

The Yawkey Wildlife Center Heritage Preserve is a 17,000-acre complex of barrier islands, impoundments, marsh, and uplands that is dedicated as a wildlife preserve, research center, and waterfowl refuge. Capers Island, Old Island, and St. Helena Sound Heritage Preserves are other barrier-island systems protected by the State that contain wetland habitats ranging from saltwater and freshwater marshes to brackish-water impoundments. Other barrier-island systems that have unique or special characteristics include the Cape Romain, Savannah, and Tybee National Wildlife Refuges and the Belle W. Baruch Marine Research Institute, a research complex owned by the University of South Carolina. All of these properties and their flora and fauna are sensitive to changes in the estuarine environment.

South Carolina has two of the 27 areas nationally-designated as National Estuarine Research Reserves: North Inlet-Winyah Bay and the ACE Basin. These reserves were created under the Coastal Zone Management Act and exist under a partnership with the National Oceanic and Atmospheric Administration and coastal states. These areas are protected for long-term research, water-quality monitoring, education, and coastal stewardship.

COASTAL CONCERNS

Coastal Growth

Coastal population in South Carolina is rapidly increasing, with over 1.15 million people estimated to be living in the eight coastal counties in 2007 (U.S. Census Bureau, 2008). Recent population growth has been concentrated in Beaufort, Dorchester, and Horry Counties, with more than 45 percent of the coastal population living in these counties. The average population density of the coastal zone is 143 people per square mile, with greater densities observed in Charleston, Beaufort, Dorchester, and Horry Counties (U.S. Census Bureau, 2008). The coastal counties support over $40 billion in economic output annually.

Economic activities in the coastal zone of South Carolina are mainly supported by the natural resources that characterize the Lowcountry, such as estuarine systems, sandy beaches, and fisheries. These resources are a major attraction to both citizens of the state and out-of-state visitors, who contribute more than $16.7 billion annually in travel and tourism activity to the State, and commercial fishing landings were valued at $12.9 million in 2007 (National Ocean Economics Program, 2009). In addition to the contribution of natural resources to the economy of the coast, the location of seaports—specifically in the Charleston area—also provides a significant contribution to the economy of the coastal zone. The Port of Charleston has been recognized as one of the nation's most efficient and productive ports in terms of dollar value of international shipments, with cargo valued at more than $60 billion annually (S.C. State Ports Authority, 2009).

Population and economic growth of the coastal zone of South Carolina will continue to increase rapidly in the near future. Population growth will result in associated development of housing, roads, and commercial and industrial infrastructure to supply the needs of the coastal population. This will also generate an increase in the recreational, commercial, and industrial utilization of key resources of the coast, such as the coastal waters, forested areas, and estuarine systems, which may cause significant impacts on South Carolina's coastal habitats.

Shoreline Changes

With 187 miles of Atlantic coastline and nearly 3,000 miles of bays, rivers, and creeks, South Carolina's coast offers unsurpassed natural beauty, habitat, and recreation opportunities. Much of the shoreline experiences chronic erosion due to both natural (e.g., barrier island migration, coastal storms, and sea level rise) and anthropogenic (e.g., jetties, navigation projects, boat wakes) causes. Some shorelines are stable or accretional in the short term, but others erode at rates as high as 15 feet per year. South Carolina has relied on beach renourishment for many years to combat erosion, but renourishment is expensive and is considered by many to be only a medium-term solution to chronic erosion. Hard erosion-control structures such as seawalls are prohibited along ocean shorelines in the State, but they are allowed along estuarine shorelines if high-ground property is being lost to erosion. As beachfront lots become increasingly scarce, estuarine shorelines along rivers and creeks have been targeted for development, which has led to an increasing demand for erosion control structures along these shorelines.

In late 2007, the S.C. Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management established a 23-member Shoreline Change Advisory Committee that includes a broad cross-section of coastal professionals and stakeholders. The Committee is working to identify and explore new ways to resolve shoreline-use conflicts and reduce socioeconomic and environmental vulnerabilities related to shoreline changes in the South Carolina coastal zone. The Committee is considering a wide range of options to improve shoreline management in the State by exploring the pros and cons of past and future approaches to shoreline erosion, beach renourishment planning, structural erosion control alternatives, and intergovernmental coordination in planning and permitting.

Emerging Ocean Activities

Ocean-resource issues are gaining increased attention in South Carolina. Expanding offshore activities and increasing reliance on ocean resources may lead to future conflicts over sand resources, dredged material disposal, military training, ocean outfalls, and offshore energy development. To better prepare for and respond to these challenges, a new ocean-planning effort has been initiated to explore research and planning issues related to ocean resources in South Carolina. In 2008, an Ocean Planning Work Group, with representatives from federal and state agencies and academic institutions, was established to meet with experts and stakeholders on various issues and over the next several years develop a plan to guide future ocean research, data collection and mapping, ocean education programs, and policies and decisions of agencies with ocean authorities.

The Ocean Planning Work Group meets regularly to consider ocean-resource issues associated with offshore energy, sand, aquaculture, mapping, monitoring, and habitat. Ocean-mapping and marine-monitoring workshops have already been held, and future workshops will focus on sand resources and offshore energy. The Work Group will develop a final report that will identify mapping and monitoring priorities for South Carolina and will document the findings and recommendations from all of the workshops. The report will serve as a foundation for ocean planning that could lead to new programs, activities, or projects, and improved interagency coordination.

SALTWATER CONTAMINATION

Dilute seawater occurs as far as 35 miles inland in the principal aquifers of the lower Coastal Plain. Nearly all of this seawater reflects the natural balance between freshwater heads (levels) and the opposing head created by sea-level elevation and seawater's greater density. No sharp differentiation between freshwater and seawater exists in the subsurface. Instead, the transition from fresh water to salt water is diffuse and in well-confined artesian aquifers the zone of diffusion is many miles wide. A chloride concentration of 250 mg/L (milligrams per liter) is the approximate taste threshold of chloride and is commonly used to define the saltwater-freshwater contact. The inland extent of saltwater encroachment into South Carolina's principal aquifers is shown in Figure 9-8. Most of the salt water west of the coastline is less

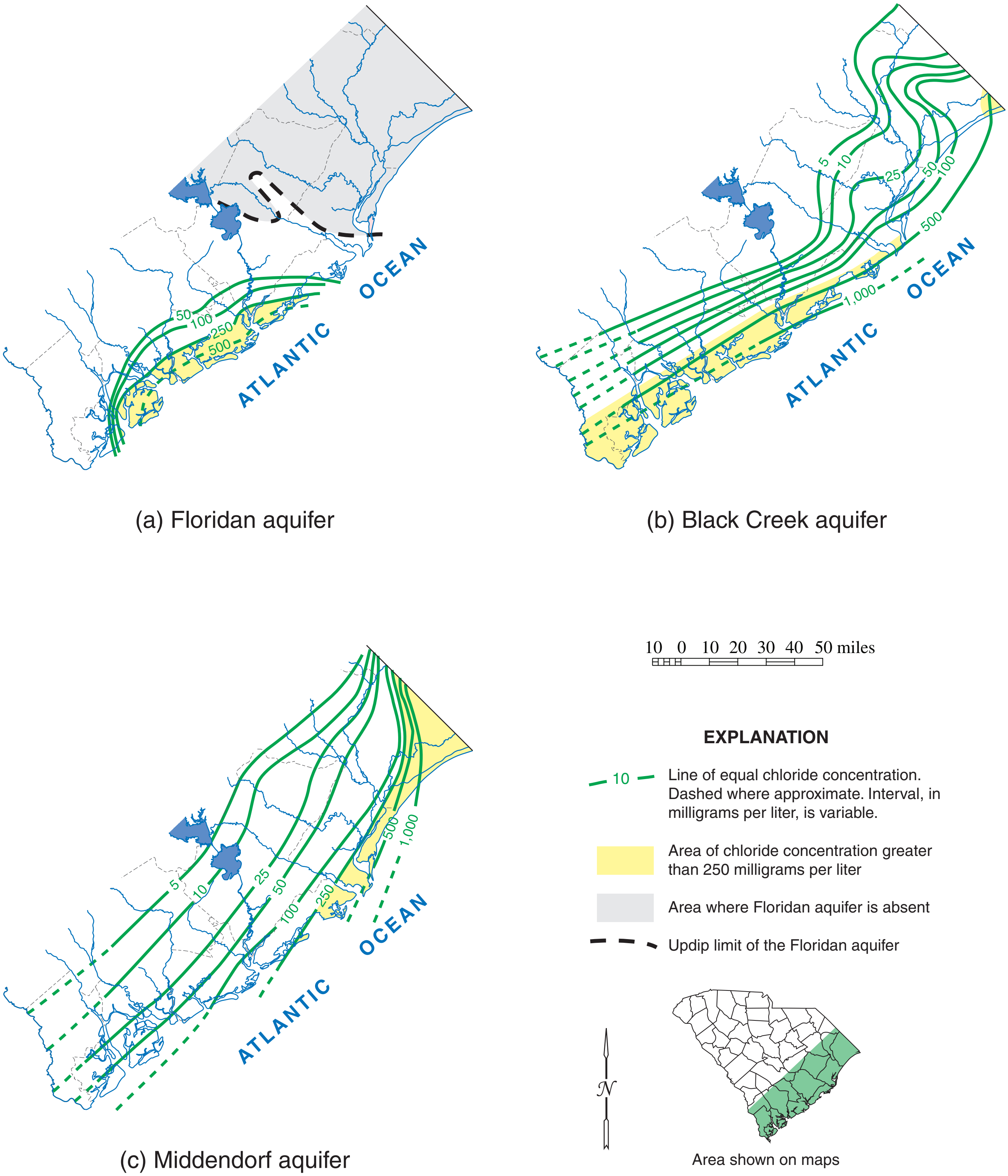


Figure 9-8. Saltwater intrusion into the (a) Floridan, (b) Black Creek, and (c) Middendorf aquifers along the coast of South Carolina (adapted from Hayes, 1979; Park, 1986; and Speiran and Aucott, 1994).

than 10-percent seawater (1,900 mg/L chloride), and broad areas west of the saltwater-freshwater contact (250 mg/L) contain further-diluted seawater.

Because sodium chloride salt is highly soluble and is easily flushed from aquifers except where ground-water flow is negligible, it is rare to find fresh water that has chloride concentrations greater than 10 mg/L; with few exceptions, concentrations greater than 10 mg/L indicate proximity to modern or ancient seawater.

Saltwater Capture

The natural balance between fresh water and salt water in the State's coastal aquifers has been disrupted by pumping. Ground-water withdrawals from the Middendorf, Black Creek, and Floridan aquifers along the coast have lowered freshwater heads, and the diluted seawater near the coastline has been captured. Broad areas of saltwater migration exist seaward of pumping centers along the Grand Strand area (Black Creek aquifer); at Mount Pleasant, Kiawah Island, and Seabrook Island (Black Creek and Middendorf aquifers); at Edisto Beach (lower Floridan aquifer); and at Hilton Head Island and Savannah, Georgia (upper Floridan aquifer).

The rates of lateral saltwater migration in the Middendorf and Black Creek aquifers near the coast generally are less than 10 feet per year, except near well fields, and the transition zones between fresh water and salt water are wide and diffuse. For these reasons, chloride concentrations increase only gradually, and intrusion of salt water to the point where wells yield chloride concentrations greater than 250 mg/L does not appear to be a near-term problem for Middendorf and Black Creek aquifer users.

Saltwater intrusions are near-term threats where water supplies are obtained from the relatively shallow Floridan aquifer. Water quality is more quickly degraded where the distance between pumping wells and saltwater sources is small; Edisto Beach, Hilton Head Island, and Savannah, Georgia, are the areas where this second condition occurs.

Edisto Beach

Chloride concentrations are increasing in the Floridan aquifer at Edisto Beach. Data for the area are scant, but the increase is probably due to high chloride concentrations in the underlying and overlying rocks in combination with declining water levels in the Floridan aquifer.

Wells near the beach are open to the Santee Limestone, which forms the lower Floridan aquifer in South Carolina. A sandy to clayey limestone, the Cooper Formation overlies the Santee Limestone in most of Charleston and Colleton Counties, is part of the Floridan aquifer, and is one of the most effective Coastal Plain confining beds.

The Santee Limestone lies between 300 and 600 feet below sea level at Edisto Beach. Its most productive zone, between 500 and 550 feet below sea level, is about 40 feet thick and yields as much as 500 gpm (gallons per minute) to open-hole wells. Although chloride concentrations are between 500 and 2,000 mg/L, this zone is the water source for the town of Edisto Beach and local private wells. Water levels in the Floridan aquifer and Tertiary sand aquifer have declined during the past 60 years, and heads at Edisto Beach are probably 20 to 25 feet below predevelopment levels.

DNR monitors the specific electrical conductance of Floridan-aquifer water on Edisto Island and Edisto Beach, and specific conductance reflects chloride concentrations. Specific conductance was constant in well CHN-484, 5 miles inland from the beach, but it increased at Edisto Beach (well COL-301) between the years 2000 and 2005. Figure 9-9 shows daily-average specific conductance between January 2001 and December 2005, and the change represents a chloride-concentration increase of about 60 mg/L.

Because heads in the pumped zone are less than in the undeveloped rocks above and below the pumped zone, ground water moves vertically into the lower Floridan aquifer. The rocks below the productive zone contain higher chloride concentrations; the rocks above the productive zone probably contain higher chloride concentrations; and water in those rocks may have to travel less than 200 feet before entering the lower Floridan aquifer. The process will accelerate if additional pumping increases the head difference between the productive zone and surrounding rock.

Hilton Head Island

Ground-water users in Beaufort County primarily depend on wells open to the Ocala Limestone. The Ocala constitutes the upper Floridan aquifer, is 400 feet thick at Hilton Head Island, and can yield more than 2,000 gpm to wells. The top of the Ocala Limestone and its most permeable zone is 20 to 150 feet below sea level between St. Helena Sound and the south end of Hilton Head Island. The upper permeable zone thickens southward from 0 and 150 feet and is poorly confined, especially between St. Helena Sound and Hilton Head Island.

Prior to the year 1900 and major ground-water development, upper Floridan aquifer water levels were 40 feet above sea level at Savannah, Georgia, and approximately 5 feet above sea level at the north shore of Hilton Head Island; ground water in the upper Floridan aquifer flowed northeastward from Georgia and discharged into Port Royal Sound. By 2004, ground-water users in southern Beaufort County, South Carolina, and Chatham and Effingham Counties, Georgia, were pumping more than 90 million gallons per day from the upper Floridan aquifer, mainly from the upper permeable zone. Water levels at Savannah had declined to 140 feet below sea level and water levels across southern Beaufort County were 2 to 20 feet below sea level.

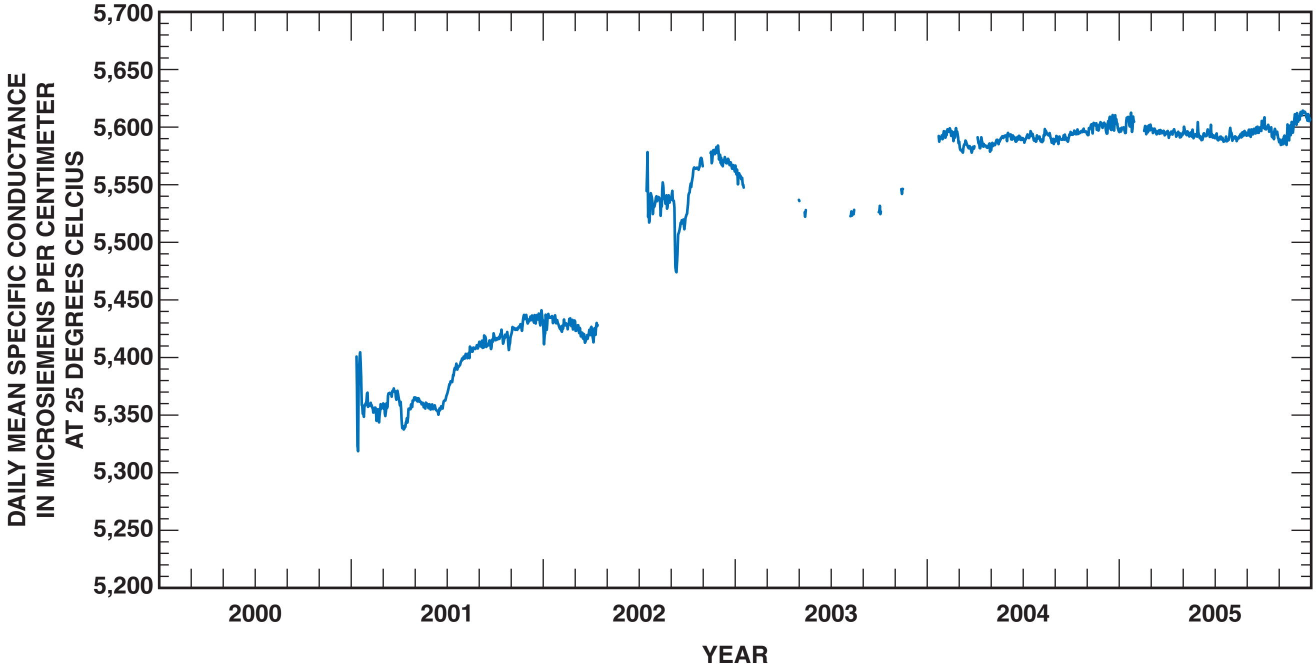


Figure 9-9. Daily mean specific conductance in well COL-301 at Edisto Beach State Park, years 2001–2005.

Ground-water pumping now captures water from the surface, including a 2,500-square-mile area encompassing the Atlantic Ocean and saltwater tidelands. Seawater is migrating from Port Royal Sound and nearby tidelands through the thin confining bed and into the top of the Floridan aquifer (Figure 9-10). Seawater that has entered the aquifer from Port Royal Sound flows toward Hilton Head Island and Bluffton, and ground-water flow rates are 150 to 200 feet per year along the leading edges of the plumes. Hydraulic gradients increase southward, and the plumes accelerate and spread as they move: flow rates will be 250 to 300 feet per year when the plumes reach the south end of the island and Bluffton. About a dozen domestic and public-supply wells have been abandoned because of saltwater contamination in recent years.

Jasper County and southern Beaufort County

The salt water intruding the Floridan aquifer from Port Royal Sound might take more than 900 years to reach wells at Savannah, Georgia, but vertical leakage (recharge) from the Atlantic Ocean and saltwater estuaries will affect areas south of the plumes much sooner. The primary factors controlling leakage rates are the permeability, porosity, and thickness of the confining bed above the Floridan aquifer and the water-level difference between the aquifer and water at the surface. Leakage rates are indirectly proportional to the confining-bed thickness and directly proportional to the head difference.

The S.C. Department of Health and Environmental Control and the U.S. Geological Survey (USGS) began to examine vertical saltwater migration in 2004. Two test holes, one offshore and one inshore, were cored from land surface into the Floridan aquifer, and confining-bed pore-water samples were collected at 5-foot intervals for chloride analysis. The tests showed contamination in the confining bed.

The inshore site was on the bank of Bull River, a tidal stream between Tybee Island and Savannah, Georgia. Chloride concentration near the top of the confining bed (Figure 9-11) almost equaled that in the base of the overlying water-table aquifer (about 8,000 mg/L) and the concentration decreased with depth because of dispersion. Chloride concentrations of about 50 mg/L were found near the base of the confining unit.

Lateral flow through the aquifer and vertical flow into the aquifer contribute about 50 percent each to total flow in the aquifer. (Recharge rates for large areas cannot be directly measured, usually are estimated with ground-water flow models, and are subject to large errors. A 50-percent recharge rate is in general agreement with water budgets published by Smith (1988) and Garza and Krause (1992). In that case, chloride concentrations in the Floridan will exceed 250 mg/L when the water breaking through the confining bed contains about 500 mg/L chloride. Water exiting the confining bed eventually will contain about 8,000 mg/L chloride at the Bull River site

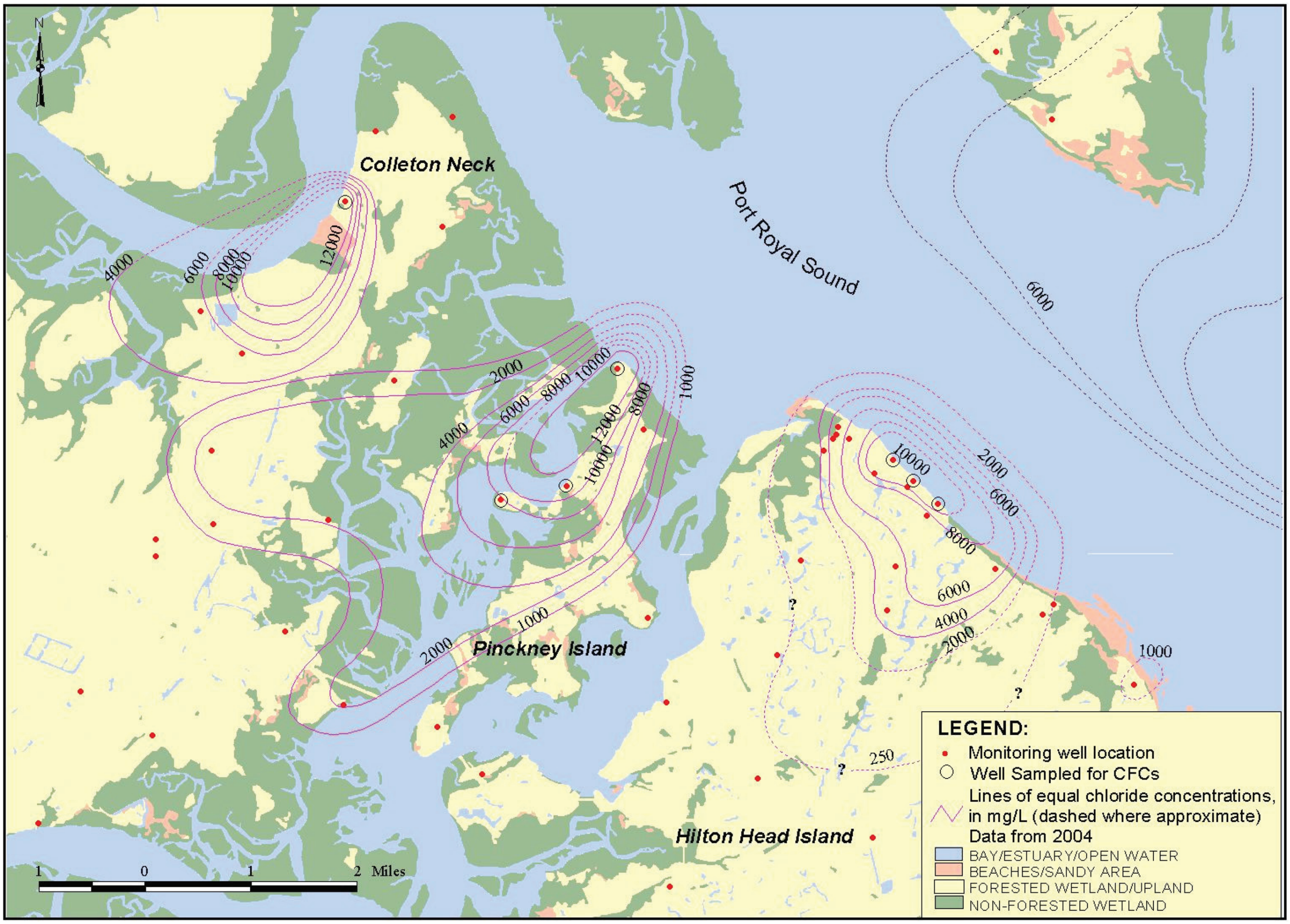


Figure 9-10. Seawater contamination in the upper permeable zone of the Floridan aquifer, Hilton Head Island, S.C., year 2004 (courtesy of S.C. Department of Health and Environmental Control, Bureau of Water).

and will have concentrations near that of seawater (19,000 mg/L) where surficial sediments are overlain by tidal streams.

Floridan aquifer samples from the Bull River test had chloride concentrations between 25 and 100 mg/L, compared to background concentrations of about 6 mg/L. Seven feet below the top of the aquifer, the concentration was 95 mg/L, and concentrations decreased with depth through the upper 80 feet of the aquifer. The concentrations and their distribution indicate that chlorides near 200 mg/L may be entering the aquifer upgradient from the test site. Under predevelopment conditions, the confining bed contained freshwater discharged from the Floridan aquifer. Similar conditions were found in the confining bed and aquifer at the USGS test site 7 miles northeast of Tybee Island.

The conditions at the Bull River site were reproduced in mathematical simulations of the coastal area between Hilton Head Island and Savannah. Figure 9-12 shows the estimated time, from the year 2005, until a 500-mg/L chloride concentration breaks through the confining bed and enters the Floridan aquifer. On the basis of an estimate that half of the water transported by the Floridan aquifer is derived from downward leakage, a mixture of 50-percent recharge water containing 500 mg/L chloride and 50-percent freshwater in the Floridan aquifer would produce an average chloride concentration of about 250 mg/L. According to the estimates, 500 mg/L will be entering the Floridan aquifer in nearly half of the modeled grids by the year 2055.

The core tests and model estimates illustrate that there is little time left for the Floridan aquifer in southern Beaufort County and areas to the south. Tybee Island, Georgia, is a small community and may eventually bear great expense to bring freshwater from the Georgia mainland. Daufuskie Island, South Carolina, has no bridge and cannot obtain water from the mainland; its only

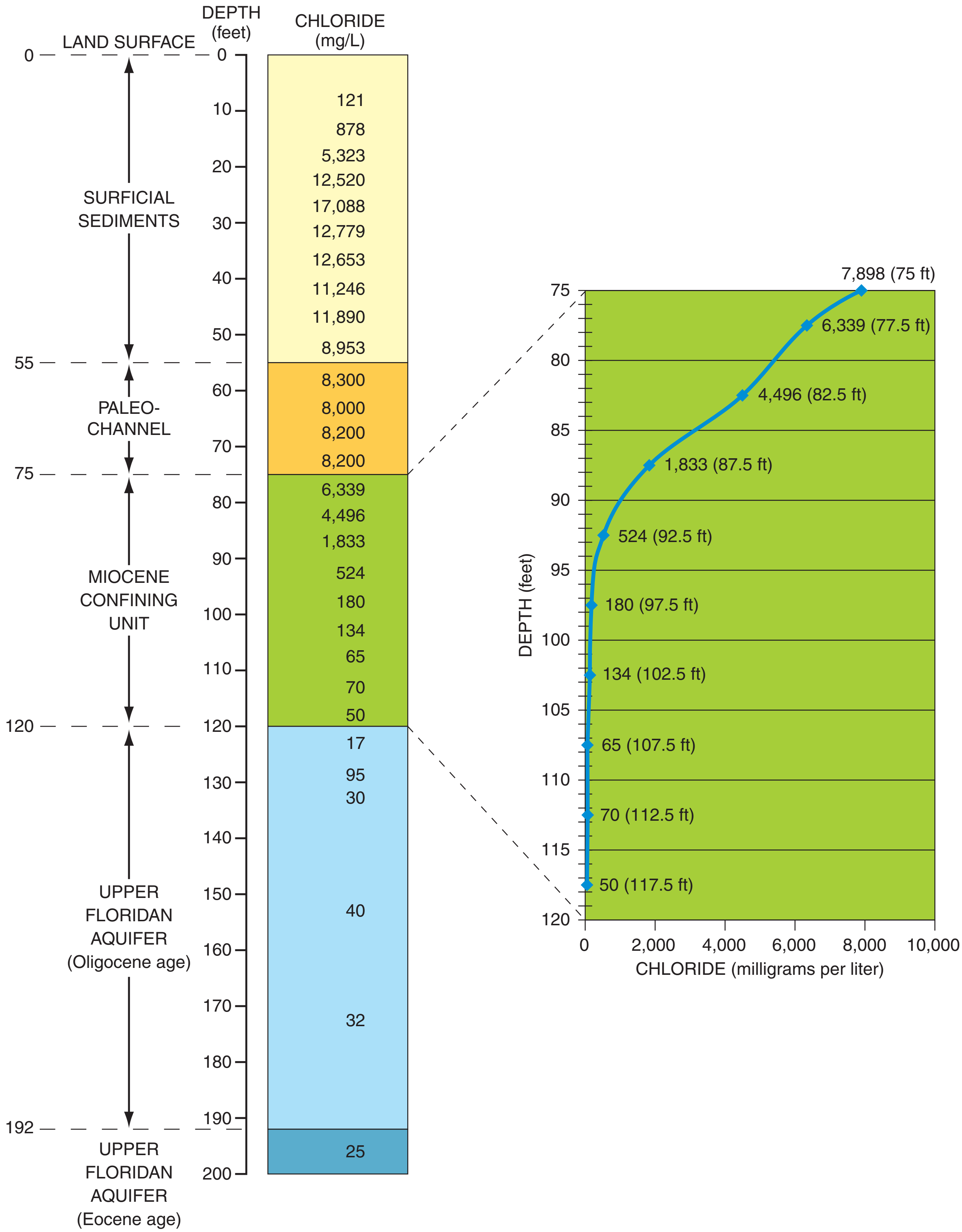


Figure 9-11. Geology and chloride distribution in the Bull River test well near Tybee Island, Ga. (Ransom and others, 2006).

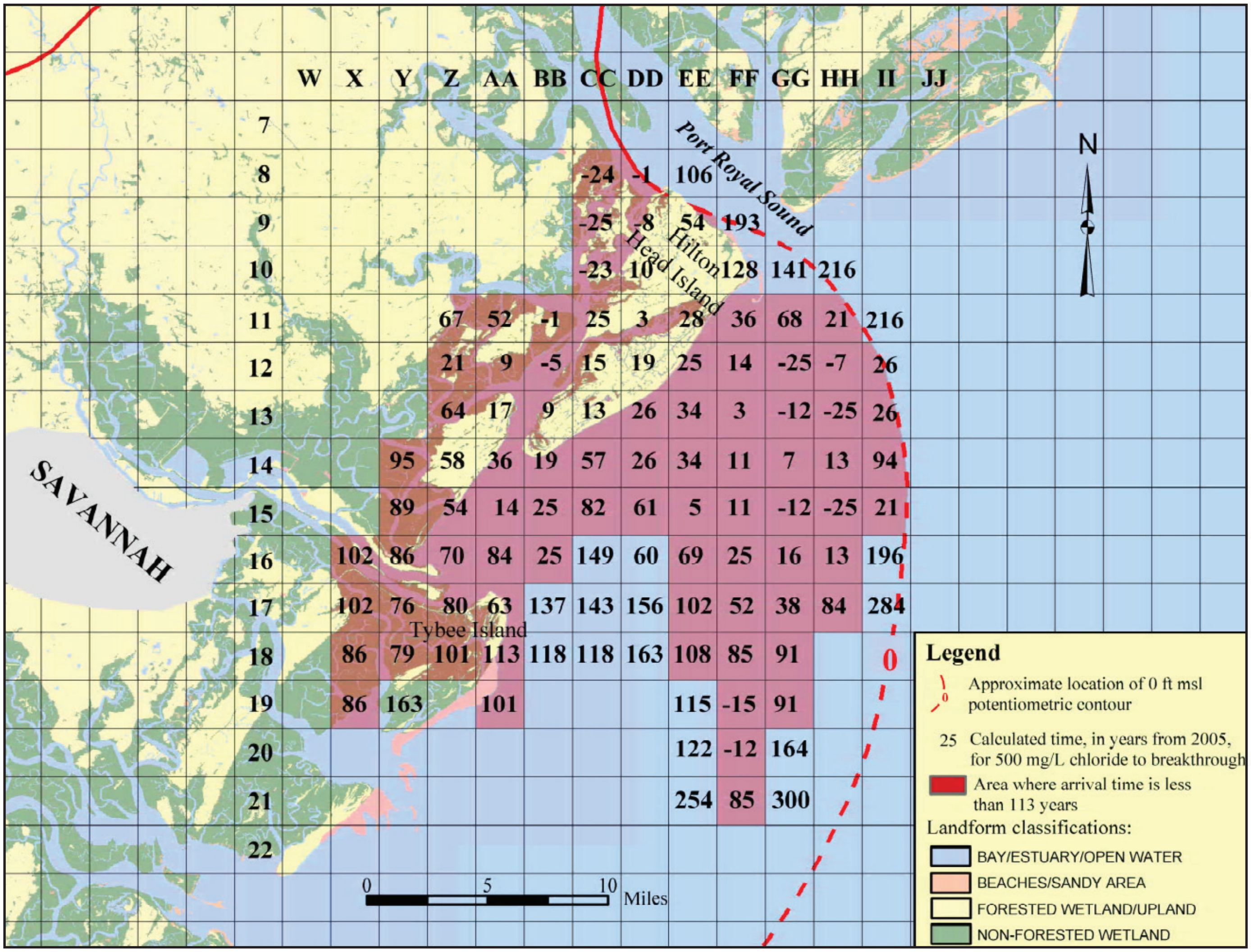


Figure 9-12. Estimated time to 500-mg/L chloride breakthrough in the Floridan aquifer confining unit, Beaufort and Jasper Counties, S.C., and Chatham County, Ga., from the year 2005 (Ransom and others, 2006).

alternative may be 3,000- to 4,000-foot deep Cretaceous-aquifer wells and water treatment by reverse osmosis. Many ground-water users in the region face higher costs as one of the Nation's most productive and economical water sources is lost to saltwater contamination.

AQUIFER STORAGE AND RECOVERY

Aquifer storage and recovery (ASR) systems involve the injection and storage of potable water into an aquifer and the recovery of this water at a later time, usually to supplement drinking water supplies. Most ASR projects in South Carolina are employed in coastal areas to meet high seasonal demands and to provide emergency supplies as needed. Treated surface water is injected into an aquifer during the off-peak season when demands are low and recovered by pumping the treated water out of the aquifer to meet peak seasonal demands.

ASR technology offers an alternative water-management option to the traditional method of storing water in above-ground storage tanks and reservoirs, and to meet water demands that vary widely from season to season. Its advantages over surface-water reservoirs include decreased evaporative losses, low ecological impacts, decreased contamination potential, and reduced land consumption. Disadvantages include the potential for chemical reactions to occur that could alter the chemistry and quality of the native and injected ground water, fracturing of the rock formations (aquifer) during injection, and changes to clay mineralogy that could change the hydraulic properties and permanently damage the aquifer. Comprehensive hydrologic and geochemical studies must be conducted to determine if ASR is feasible at a particular location and to ensure that water quality and aquifer characteristics are not impaired by injection.

Water injected into the aquifer must meet state and federal water-quality standards and ASR wells must be permitted by the S.C. Department of Health and Environmental Control (DHEC) in accordance with the S.C. Underground Injection Control Regulation (R. 61-87).

Currently, four water suppliers operate ASR systems in the State: Grand Strand Water and Sewer Authority in Horry County; Mount Pleasant Waterworks in Charleston County; Kiawah Island Utility, Inc. in Charleston County; and Beaufort-Jasper Water and Sewer Authority in Beaufort and Jasper Counties.

Grand Strand Water and Sewer Authority (GSWSA) was the first to utilize ASR technology in the State (see Castro and others, 1995; Castro, 1995; Castro, 1996; and Castro and others, 1996). They currently have 15 ASR wells in operation or under development for use during emergencies or peak consumption conditions (GSWSA, 2009). Most of these wells were originally water-supply wells that were unused after the utility switched from ground water to surface water owing to significant water-level declines in the Black Creek aquifer. This ASR system has a combined storage volume of nearly two billion gallons. Treated water can be withdrawn for use from ASR wells at a rate of 14.9 mgd (million gallons per day). Most of the wells are completed in the Black Creek aquifer.

Mount Pleasant Waterworks has four ASR wells in operation, all of them completed in the Black Mingo aquifer. Water is stored during off-peak periods and recovered to supplement drinking-water supplies during periods of peak demand, typically during the spring and summer months. The wells each produce between 0.5 and 1.0 mgd.

Kiawah Island Utility, Inc. (KIU) utilizes two ASR wells to meet their water demands. Both wells are completed in the Black Mingo aquifer. The first well was installed in 2002 at their Sora Rail facility near the western end of the island for use during emergencies and peak demand periods (KIU, 2009). Approximately 60 million gallons are stored during non-peak periods for use throughout the peak-demand season. The second well was installed at the eastern end of the Island and is used for peak shaving of early morning demands. It has a storage-volume target of 60 million gallons (Becky Dennis, KIU, personal communication, 2009). The combined yield of the two wells is about 2.5 mgd.

Beaufort-Jasper Water and Sewer Authority (BJWSA) has three ASR wells as part of their water system, all completed in the Upper Floridan aquifer. Two of the wells are located at their Chelsea Water Treatment Plant; one well is used for injection and both wells are used for recovery. Combined, the wells can yield 3.0 mgd. A third ASR well, located at their Purrysburg Water Treatment Plant, has the capacity to yield 2.5 mgd. BJWSA injects during off-peak periods, which are in the fall and winter, and withdraws water during peak demand periods in the spring and summer months. A total of 300 million gallons of treated water from the Savannah River is injected and stored in the aquifer each year.

The Orangeburg Department of Public Utilities, which uses the North Fork Edisto River as its drinking-water source, is in the process of installing two ASR wells, one in the Black Creek aquifer and the other in the Middendorf aquifer. The primary reason for developing this ASR system is to have additional capacity during droughts when streamflows are low, but this ASR system will also improve the efficiency of their water treatment operations. During periods of low streamflow, when treatment of water from the North Fork Edisto River is least expensive, treated water will be injected into the aquifers; during periods of high streamflow, when treatment of surface water is more expensive, the already-treated water stored underground will be recovered and made available for use with minimal additional treatment.

WATER CONSERVATION

Water conservation is more than just a practice to put into place during times of water shortage; water should be conserved and used wisely at all times. Water conservation is not only a wise ethic to follow, it is a matter of economic concern: as competition for water increases, the cost of the water also increases. The benefits of implementing water conservation practices are many and should be carefully considered by all water users.

Even in South Carolina, where clean water is usually available in abundance, there are costs associated with water use. Increased water use can shorten the life of existing water-treatment facilities or cause them to reach their treatment capacity, increasing maintenance costs and often requiring expensive treatment-plant expansions. Increased water use also generally leads to a greater volume of wastewater, which increases waste-treatment costs. Large demands on water resources diminish water availability, requiring increased expenditures to explore for and develop additional sources of water.

The economic impact of the continually-increasing demand for water can be exacerbated by water shortages caused by droughts. Droughts may reduce the availability of surface-water supplies and, if severe enough, can cause ground-water levels to fall below pump levels. A severe drought can have far reaching consequences. Lack of water may cause crops to fail and livestock to lose weight and, in some instances, industries that depend on water for cooling or in production may have to suspend operations and lay off workers. Air conditioning use increases during hot summer droughts, so more electricity is needed, requiring more water for power generation. More water is also used during a drought to water crops, lawns, and gardens.

With increasing demands being placed on the State's water supplies, conservation must play an increasingly larger role in water-resources management decisions in South Carolina. As competition for water increases and the cost of water-resources development continues to escalate, economics will help influence our water-use practices.

Public-Supply Conservation

Managers of public water-supply districts or municipalities can utilize several techniques, either independently or collectively, to reduce the quantity of water needed to satisfy customers or to reduce the demand itself. Among these methods are leakage management, meter management, price structuring, user education, and, in times of emergency, regulation of water use.

Accurate metering is essential to monitoring water use and establishing equitable rate charges. In addition, water use tends to be lower in metered service areas than in unmetered service areas. Meters also allow users to monitor their own use and may encourage conservation efforts. Meter slippage—the underestimate of water use by a meter—can be a serious problem that results in underreporting of water use and subsequent losses of revenue for the water supplier. A routine service and maintenance program is needed to ensure accurate metering.

Price structuring of water rates can be a means to reduce water demand. Rate structures that are commonly used for water pricing are described below. Some rate structures encourage conservation while others encourage water use.

Flat Rate. A fixed price charged per time period, regardless of water quantity. This method does not encourage conservation of water; rather, it encourages water use.

Uniform Rate. A constant price per unit of water charged, regardless of quantity used. This pricing method encourages conservation only slightly.

Declining Block Rate. The price per unit of water decreases as the quantity of use increases. This pricing method subsidizes the larger user at the expense of the smaller user and has an adverse effect on water conservation as it encourages water use.

Increasing Block Rate. The price per unit of water increases as the quantity of use increases. As larger quantities are used, the consumer pays a higher rate for the larger portions used. This pricing method is effective in encouraging water conservation.

Peak Period Rate. The price per unit of water depends on the time of day, with higher rates charged during peak demand periods. This pricing method encourages conservation.

Seasonal Rates. The price per unit of water increases or decreases based on water demand and climatic conditions, with higher prices usually occurring in the summer months. This pricing method encourages conservation.

In a survey of more than 1,200 water-supply systems nationwide conducted by the Environmental Protection Agency (EPA), approximately half of the systems used a uniform rate structure (U.S. Environmental Protection Agency, 2000). Declining block structures were used by 19 percent of the suppliers, while only 9 percent used an increasing block rate structure. These statistics show that a large majority of water suppliers use pricing structures that do not encourage water conservation. Large public utilities in South Carolina typically use a uniform rate or a declining block rate pricing structure. Switching from declining or uniform rate pricing structures to increasing block, peak period, or seasonal rate structures can be an effective way to increase water conservation and should be considered by all water utilities in the State.

The Water and Wastewater Department of the S.C. Office of Regulatory Staff (ORS) regulates the rates and services for private water suppliers. Private utilities in the State are also under the jurisdiction of the Public Service Commission of South Carolina (PSC). Public water utilities in the State are typically operated by elected commissioners or water authorities who set water rates and pricing structures. These public utilities are neither regulated by the ORS nor under the jurisdiction of the PSC.

Public education is necessary for an effective water conservation program. Water users must be kept informed of current and potential water problems and be provided with the information needed to react to these problems. The recent droughts throughout the Southeast have focused attention on the need to instill a conservation ethic in water users. Much has been written during the past few years concerning water conservation and public education and many innovative approaches have been devised. Public water suppliers should contact appropriate state agencies and water organizations to seek effective techniques to educate their users.

During times of drought or other water emergencies, water use may need to be regulated. Water-use regulations can address a broad spectrum of uses and activities, from the large water-using industry or irrigator to the single-family resident. The success of any regulatory program requires both consumer education and regulatory enforcement. The consumer must know that a problem exists and how that problem can affect him, and sufficient enforcement must be exercised to make users aware of the seriousness of the water problem. Water suppliers in South Carolina are currently required by the S.C. Drought Response Act to have a drought response plan.

Residential Water Conservation

During recent droughts, emphasis was placed on the need for domestic water conservation. Although the amount of water saved through one family's conservation efforts is small compared to the enormous amount of water required for power generation, industry, and agriculture, the small savings of thousands of citizens can amount to a substantial overall savings. Conservation efforts should not be restricted only to times of drought; these efforts can benefit water users regardless of the availability of water.

Major steps in water conservation on the domestic level can be accomplished through the installation of new appliances and fixtures that have high water-use efficiencies. More information on water conservation products and methods can be found on the EPA website (*http://www.epa.gov/watersense/*) and many water utilities provide websites and other resources that promote and describe various water conservation practices. Some water conservation practices for home use are described below.

Toilets are one of the largest sources of water use in the home; many conservation measures can be used to save water when flushing. Toilets installed prior to 1992 typically use from 3 to 7 gallons per flush (gpf). These older models can be replaced by newer ones, which are required to use 1.6 gpf or less under the Energy Policy Act of 1992. High efficiency toilets, which use as little as 1.3 gpf, are also on the market. Replacing older toilets with these newer, high-efficiency models can reduce toilet water use by more than 50 percent.

Displacement devices that reduce the amount of water used per flush can be placed in the storage tanks of many older model toilets. Such devices included bags or bottles filled with water and a weighted material, and can reduce water consumption by almost one gallon per flush. Bricks (and other friable material), commonly used in the past, should be avoided to prevent the possibility of granular components damaging or interfering with the flushing components of the toilet. Adjustable ballcock valves or refill valves can also be installed in some toilets to further limit the amount of water used per flush. Care should be taken, however, to follow the manufacturer's recommendations and to use enough water to ensure proper solid waste disposal.

To test for leaks in a toilet, place a few drops of food coloring in the toilet tank and let stand for 15 minutes; if the color has filtered into the toilet bowl, there is a leak.

Bathing also accounts for a large amount of water used in the home. While older model showerheads typically use 3 to 5 gpm (gallons per minute), new showerheads are required to have a flow rate of 2.5 gpm or less under the Energy Policy Act of 1992. Replacing older models with newer ones can be an effective way to save water and can also reduce costs associated with water heating. Various types of shower heads or adapters that conserve water by reducing the flow rate or by producing a shower spray with an adjustable low-flow shower head are also available.

Taking shorter showers is an obvious way to save water as well as using less water when taking a bath. Bath tubs can typically hold from 50 to 75 gallons of water, but adequate bathing can often be accomplished with much less water. A five-minute shower uses from 10 to 25 gallons of water and will typically save more water compared to taking a bath.

Under the Energy Policy Act of 1992, bathroom and kitchen faucets are required to have a flow rate of 2.2 gpm or less. Replacing older conventional faucets, which typically use 3 to 5 gpm, can result in substantial water savings. Aerators can be added to older model kitchen faucets to reduce flow rates to as low as 2 gpm, which is adequate for general washing purposes. Aerators can also be added to bathroom faucets to reduce flow rates to 1 gpm or less, which is suitable for hand washing.

Faucet leaks are a major source of wasted water: a one-drop-per-second leak from a faucet can waste as much as 36 gallons per day. A simple test to determine if leaks exist in the home is to turn off all water-using devices, immediately check the water meter and then recheck the water meter after several hours to verify that no flow has been registered. These checks should be done routinely to minimize water waste.

Other methods of conserving water that require little effort include brushing teeth with the faucet turned off, keeping drinking water in the refrigerator instead of running the tap, watering plants with leftover water, waiting until all food items are peeled before rinsing, scraping dirty dishes clean before washing, and always using full loads when washing dishes or clothes.

The greatest amount of outdoor residential water use is for watering lawns and gardens. Watering should only be done when necessary and during the early morning or evening to avoid excessive evaporation. Watering should also be done slowly to allow seepage into the root zone and to prevent runoff. More than half of landscape water goes to waste due to evaporation or runoff caused by over watering. Heavier and less frequent watering also encourages development of deep-rooted grass. The use of automatic timers and replacement of damaged or leaking sprinklers can reduce the wasteful use of water. Where appropriate, the installation of drip irrigation systems with automatic timers can also save water. Landscaping practices such as using mulch and planting hardy, water-saving plants also promote water conservation. Using a broom rather than a hose to clean driveways, patios, and walks can save a significant amount of water.

Research has indicated that a substantial reduction in domestic use can result from installing water-saving devices. Some new and renovated homes have these devices, but to make an impact in the amount of water conserved statewide, changes are needed in existing plumbing and/or housing codes. An opportunity also exists for progressive local governments to develop conservation-minded ordinances.

Agricultural Water Conservation

Over the course of a year, agriculture uses an average of about 80 million gallons of water daily to irrigate crops and maintain livestock. Irrigation, the dominant agricultural water use, accounts for about 93 percent of agricultural demand.

Irrigation operates on the premise that crop growth can be maximized by maintaining the optimum moisture levels by artificial means, when and where rainfall is deficient. The ability to apply the correct amount of water at the right time can greatly stabilize crop production. Irrigation helps sustain farmers through dry periods and helps to maximize agricultural production.

In the dry western United States, irrigation is often necessary to maintain crops to maturity. However, in the humid southeastern United States, where water is generally plentiful, most farming continues without artificial irrigation. Droughts, sporadic rainfall, and the growing of crops with higher water demands (such as corn) have made irrigation a more common practice in the Southeast, but the high initial cost to install irrigation systems has, at least temporarily, lessened the economic feasibility of irrigation.

For all practical purposes, agricultural irrigation is considered to be a totally consumptive water use, with little water returning directly to its source. For this reason, water conservation will help relieve present and future water-use problems and conflicts.

Specific water-conservation practices depend on the crop, soil type, and lay of the land. Drip or trickle irrigation is the most water-conserving irrigation method, but because this method is equipment intensive and is a permanent system, it requires that the irrigated crops be of a permanent nature, such as peach, apple, or pecan orchards. Drip irrigation systems use pipes and tubes with small outlets near each plant that apply only the amount of water needed to sustain the plant. This eliminates runoff, evaporation, and watering of non-crop vegetation.

Subsurface irrigation is a soil-moisture management method that uses porous pipes or tiles placed in the field. In South Carolina, this system is used primarily in wet fields where excess water is drained off, making unproductive land useful. During dry periods, the system can be reversed to irrigate the fields. Subsurface irrigation systems are expensive to install, but recent developments have helped reduce cost. Row crops can be grown using this system. The elimination of runoff and evaporation makes this a useful water conservation method.

Because the intent of irrigation is to maintain soil moisture for optimum plant growth, the application of water directly to the soil is most simply met by flood or furrow irrigation. This oldest of irrigation methods was improved upon by the use of furrows to direct water to plants. However, surface application methods require more water than is needed by the crop and expose the excess water to evaporative forces.

Sprinkler irrigation systems, including moveable and solid-set pipe systems, center pivots, and traveling guns, are much less labor intensive than furrow or flood irrigation. This irrigation method applies water in a manner similar to natural rainfall. A large portion of the water can be lost to evaporation; on hot, windy days, nearly one-half of the water sprayed by sprinkler irrigation systems evaporates before the water reaches the crop.

Pipelines require less land area than canals and provide more efficient control in water management. Recovery systems and drip and wastewater reclamation programs are also effective methods to conserve water. The reuse of irrigation water captured in tail-water pits conserves water and keeps poor-quality runoff water from degrading receiving streams.

No-till planting and the application of mulch keep plant residues on the soil surface, helping to reduce evaporative loss. The use of narrow row spacing, selection of plants that require less water, application of growing practices that utilize available rainfall, and careful selection of planting dates all assist in reducing water use.

Industrial Water Conservation

Industrial water use, including that for electricity generation at thermoelectric power plants (but excluding hydropower facilities), represents the largest withdrawal use in South Carolina. Withdrawals total about 6,167 mgd (million gallons per day), representing nearly 90 percent of total water withdrawals. Thermoelectric power generation accounts for nearly 83 percent (5,758 mgd) of this use.

Nationally, during the past several decades industries have improved the efficiency of water use in their operations, as can be evidenced by a decrease in the amount of intake water used per unit of production. Much of this water conservation trend may be attributed to wastewater treatment requirements imposed by the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), which mandates the treatment of industrial wastewater to maintain water-quality standards in the nation's water bodies. Because treatment costs can be high and are based on the volume and character of the wastewater, industries were encouraged to reduce production costs by reducing the amount of water used and subsequent wastewater generated. Industries that purchase water for their operations have an additional incentive to improve water-use efficiency.

Some water-conserving measures employed by industries include the reuse and recycling of wastewater; more efficient use of water in industrial processes; the development and use of no-water and low-water industrial process technology; repair and replacement of leaking pipes and equipment; installation of automatic water cut-off valves where practical; and installation of water-saving devices for employee sanitation.

The greatest industrial use of water is for cooling purposes. This is especially true for thermoelectric power plants, some of which individually use several hundred million gallons per day to dissipate waste heat. Significant reductions in industrial water use are possible through the use of alternative cooling methods, such as air cooling devices or dry cooling towers.

Water conservation can reduce overall production costs by decreasing total water intake, pumping costs, and water treatment costs. As process technology improves and the cost of treatment continues to rise, the trend of increased water conservation by industries should continue.

INTERBASIN TRANSFERS

In some areas, the demand for water may exceed its natural availability, resulting in a water shortage. One solution to this problem is to transfer water from an area that has an excess of water to the area that has the deficit. An interbasin transfer is the withdrawal, diversion, or pumping of surface water from one river basin and subsequent use or discharge of all or any of the water into another basin. The losing basin, also referred to as the origin basin, is the river basin from which the water is withdrawn; the receiving basin is the river basin to which the water is transferred. Such a water transfer results in a net loss of water to the losing basin and a net gain of water to the receiving basin.

In South Carolina, a permit is required for interbasin transfers. The Interbasin Transfer Act (Title 49, Chapter 21), which went into effect in 1985, authorizes DHEC to issue permits under S.C. Regulation 121-12. (See Chapter 2, *Water Law*, of this report for more information regarding the act.) Permits are conditioned upon the availability of water in both the losing and receiving basins and whether the transfer will have any detrimental impacts to instream uses such as water quality, fish and wildlife habitat, recreation, hydropower generation, navigation, and aesthetics, or on offstream uses such as agricultural, municipal, and industrial uses. Permits are also conditioned upon whether the use of water in the receiving basin is reasonable and beneficial and whether alternative sources of water within the receiving basin are available. Basin boundaries are defined and delineated in the regulation and coincide closely with the subbasins described in this report.

Normally, the origin basin will have adequate excess water, so that transferring water to another basin will not result in detrimental water shortages in the origin basin. If the origin basin is experiencing a water shortage, there may not be enough water available for transfer without worsening the water shortage in the origin basin. The *South Carolina Water Plan* (Badr and others, 2004) proposes that a trigger mechanism be incorporated into special-permit conditions to make transferrable volumes proportional to the volume of water available in the origin basin—the less water available in the origin basin, the less that can be transferred to the receiving basin. In that way, both the origin and receiving basins share the burden during water shortages.

DHEC recognizes two classes of transfers, based on the amount of water transferred: a Class I permit is issued for any transfer equal to or greater than one million gallons a day on any day of the year, or 5 percent or more of the source stream's 7Q10 flow, whichever is less; a Class II permit is issued for any transfer that is less than one million gallons a day and less than 5 percent of the source stream's 7Q10 flow. Permits are issued for a period of up to 40 years.

Twenty Class I permits are currently active (Table 9-9). The Columbia Canal Hydroelectric facility has the largest permitted transfer—3,878 mgd (million gallons per day); water is diverted from the Broad River into the Columbia Canal and discharged into the Congaree River. The city of Columbia has a permit to withdraw 125 mgd from the Broad River (via the Columbia Canal) and discharge to the Congaree, Saluda, and Catawba-Wateree basins, and another permit to withdraw 125 mgd from the Saluda River basin (Lake Murray) and discharge to the Broad, Congaree, and Catawba-Wateree basins.

Entities already making the equivalent of a Class I interbasin transfer—more than one million gallons of water a day or 5 percent or more of the source stream's 7Q10 flow—prior to December 1, 1984, were allowed to continue their transfers for up to 40 years as registered rather than permitted transfers. The Greenville Water System, Charleston Water System, and Beaufort-Jasper Water and Sewer Authority are each registered for interbasin transfers of 60 mgd or more (Table 9-9).

DROUGHT MANAGEMENT AND MITIGATION

Historically, droughts have had severe, adverse impacts on the people and economy of South Carolina. Droughts affect a wide variety of sectors across divergent time scales, and periods of dry weather have occurred in each decade of the last 200 years. During the past 50 years, droughts have caused South Carolina's third highest economic loss resulting from a natural hazard, surpassed only by Hurricane Hugo and flooding. The most damaging droughts in recent history occurred in 1954, 1986, 1998–2002, and 2007–2008. Adverse impacts to the people and economy were made especially clear during the droughts

Table 9-9. Permitted and registered interbasin transfers in South Carolina

Permitted transfers	Volume (mgd)	Losing basin	Receiving basin	Permit issued	Permit expires
City of Aiken	8.0	Edisto	Lower Savannah	2004	2025
Anderson County Water System	4.0	Upper Savannah	Saluda	1997	2017
Town of Batesbug-Leesville	2.5	Edisto	Saluda	2003	2025
City of Clinton	6.0	Broad	Saluda	2003	2025
Chetser Metropolitan District	7.2	Catawba-Wateree	Broad	2004	2025
Easley Combined Utilities	31.5	Saluda	Upper Savannah	2002	2034
Edgefield County WSA	5.9	Upper Savannah	Edisto	2004	2025
Grand Strand WSA	6.2	Waccamaw	Little Pee Dee	1991	2011
Greenwood CPW	30.0	Saluda	Upper Savannah	1989	2009
Lake Marion Regional Water Authority / Santee Cooper	20.0	Santee	Edisto, Black, Combahee-Coosawhatchie	2003	2025
Lancaster County WSA	20.0	Catawba-Wateree	Lynches, Pee Dee	1989	2012
City of Newberry / Newberry County WSA / Town of Saluda CPW / Saluda County WSA	8.0	Saluda	Broad, Lower Savannah	1996	2016
Saluda County WSA	12.0	Saluda	Lower Savannah, Edisto	2004	2025
Spring Valley Country Club	4.0 (30-day emergency use)	Broad	Congaree	1987	2007
City of West Columbia / Lexington County	12.0 to 48.0	Saluda	Congaree, Edisto	1990	2011
City of York	3.0	Broad	Catawba-Wateree	1988	2008
Town of Winnsboro	3.1	Broad	Catawba-Wateree	2005	2025
Columbia Hydro	3,878.0	Broad	Congaree	2005	2025
Belton-Honea Path WA	4.0	Saluda	Upper Savannah	2006	2028
City of Columbia	125.0	Broad	Congaree, Saluda, Catawba-Wateree	2008	2028
	125.0	Saluda	Broad, Congaree, Catawba-Wateree	2008	2028

Registered transfers	Volume (mgd)	Losing basin	Receiving basin	Effective date	Expiration date
Beaufort-Jasper WSA	60.0	Lower Savannah	Combahee-Coosawhatchie	1985	2015
Charleston CPW	100.0	Edisto	Ashley-Cooper	1985	2022
Greenville WS	32.0	Saluda	Broad	1985	2016
	60.0	Saluda	Broad	1985	2016
	150.0	Upper Savannah	Saluda	1985	2016
International Paper	65.0	Pee Dee	Waccamaw	1985	2005

Source: South Carolina Department of Health and Environmental Control of 1998–2002 and 2007–2008 that affected agriculture, forestry, tourism, power generation, public water supplies, and fisheries.

The persistent drought that impacted South Carolina over much of the past decade reinforced the need to improve coordination and planning within and between levels of government and water users. The State should have a statewide drought management and mitigation plan to help sustain all water uses during water-shortage periods. Water available during dry periods should be allocated among all uses in such a way as to minimize adverse economic and health-related problems, but all users within the drought-affected area should share the burden.

The Drought Response Committee was established by the South Carolina Drought Response Act of 1985 and includes state and local representation. The Committee has the authority to declare a drought based on climatic conditions, soil moisture, streamflow rates, and water levels in lakes and aquifers. The specific drought indices used to declare a drought and determine the appropriate drought level are the responsibility of the Drought Response Committee. Drought declarations should not be made prematurely or so frequently that the public becomes unresponsive. The Committee may request that state and federal water resource agencies provide additional monitoring of streamflows, water levels, and water quality to ascertain the adequacy of drought-mitigation practices. DNR serves as the primary agency to monitor drought conditions throughout the State and coordinate the State's response.

An updated status of soil moisture, streamflows, aquifer water levels, lake levels, and overall climate must be issued periodically for as long as a drought exists. Notification of water-shortage conditions is to be provided by DNR by letter and/or public communication through such media as newspaper, radio, television, and the internet. The Drought Response Committee can recommend that the Governor issue a public statement imposing mandatory water-use restrictions. Economic, social, and environmental considerations should be used to help prioritize water use in order to enhance the recommendations of the Drought Response Committee and the Governor's Office.

A proactive approach to drought management is required to lessen the economic, social, and environmental impacts of drought. Federal and state funds should be used for drought mitigation, and cooperation among federal, state, and local agencies, as well as private interests, is essential for sustaining all uses during dry periods. An assessment is needed of how droughts impact the State and of how vulnerability to droughts can be reduced. The *State Water Plan* (Badr and others, 2004) offers the following drought-mitigation recommendations:

- DHEC and DNR should develop allocation mechanisms for surface water and ground water to maximize water availability and minimize conflicts during water shortages.
- DHEC and DNR should establish and enforce required instream flows and water levels to protect surface-water quality and instream uses.
- All water suppliers should prepare drought response plans, specifying water reduction schedules, alternate supply sources, and backup systems.
- A statewide shallow-ground-water monitoring network should be developed to monitor the effects of drought on water-table aquifers.
- Statistical analyses of water-level data should be made from long-term surface- and ground-water records to determine the relative severity and recurrence interval of droughts.
- The State should utilize the Federal Energy Regulatory Commission's hydropower relicensing process to ensure that low-inflow protocols adequately address drought severity with equitable response by the hydropower projects and other water users.
- The State should promote measures to increase water availability, including increased water conservation, reverse osmosis and desalination water-treatment systems, aquifer storage and recovery programs, and the use of recycled wastewater.
- The State should promote and encourage the protection of water quality through improved watershed management and wetlands preservation.
- Farmers should invest, with federal and state support, in efficient irrigation systems where adequate surface- or ground-water supplies are available. Farmers, especially those not using irrigation systems, should select crop varieties that have a high tolerance for dry weather.
- Federal and state resource agencies should improve research programs to increase the accuracy of drought predictions. Earlier warnings will enhance drought management and mitigation programs.
- Victims of drought should seek relief from all federal programs that have some element of drought relief, primarily for agricultural droughts. Federal and state agencies should improve programs that assist businesses that suffer drought-related losses and help alleviate the impacts of extreme droughts on farmers, ranchers, local businesses, and communities.

FLOODING

Flooding is a natural occurrence. Throughout time, flood-plain landscapes have been continuously altered by the forces of water—either eroded or built by the deposition of sediment. Man has altered the landscape, affecting both the immediate flood plain and shoreline properties downstream. During the early settlement of the State, locations near water provided necessary access to transportation, water supply, and waterpower. These areas also had fertile soils, making them prime agricultural lands.

In recent decades, development along waterways and shorelines has been spurred by the aesthetic and recreational value of these sites. The result has been an increasing exposure to damage and destruction wrought by the natural forces of flooding. Despite the investment of more than $9 billion in dams, levees, and other flood-control structures, flood damage in the United States averaged over $4.5 billion per year by the 1980's.

Flood Damage

Floods affect everyone, even those not directly damaged, because of their ripple effect on the community and the economy.

Human Impact. Floods can kill people. They rob survivors of their dwellings, possessions, and livelihoods. They pose health hazards from polluted water, mildew, and fatigue. They also generate stress and cause mental health strains from property damage and the loss of irreplaceable family treasures. Property damage can be measured in dollars; the losses to people of time, energy, and emotional well-being cannot. Most flood deaths are a result of people driving into floodwater; the threat to life is not limited to flood-plain residents.

Infrastructure Damage. Flooding of streets, highways, and underpasses affects many more people than just those who live in flood plains. Travelers, commuters, and commerce are also affected. Floods can even impact areas where land is not inundated. Flood water entering a water or wastewater treatment plant can cause an entire community to lose its water supply or have its sanitary sewers overloaded. Overloaded sewers can flood streets and homes, and downstream communities may be flooded by polluted water.

Economic Impact. Floods can cause severe damage to the economy. Buildings and inventories are simply lost to water. Income is lost as businesses close or lose customers who cannot get to the establishments, and the loss of income can have a ripple-effect on jobs and other related businesses. When the streets are flooded and when water, sewer, or other utilities are down, businesses cannot operate. Employees, customers, and needed deliveries cannot get in and shipments cannot get out. If down too long, marginal businesses may not be able to reopen. Floods are known for adding one problem too many to struggling businesses and forcing them to close or to relocate out of the area.

Flood Types

Five types of flood events occur in South Carolina. Some are associated with particular physiographic provinces or geographic areas, while others can occur anywhere in the State.

Flash Flooding. Flash floods move fast and offer little warning time. They are the primary hazard in the hilly terrain of the northwest Piedmont region and in cities with large areas of impervious surfaces. Flash floods can occur anywhere, especially during and after heavy thunderstorms that stall or move repeatedly over the same area.

Flash floods are caused by local, heavy rains in areas where the water runs off quickly. The quick runoff may be due to steep terrain, impervious surfaces, or saturated ground. These conditions typically occur in hilly areas, urbanized areas, or anywhere after prolonged periods of rain.

Flash floods are the killer floods. They catch people unaware, often in their vehicles when bridges are washed out—70 percent of flash-flood deaths occur when vehicles are driven into floodwater. Recent flash-flooding reports note damages to cars in parking lots when the owners didn't have time to move them to safety.

South Carolina's largest flood in terms of loss of human life and property damage occurred along the Pacolet River on June 6, 1903. This flood occurred when a low-pressure system stalled over the mountains and upper Piedmont area. Accounts at Pacolet Mills in Spartanburg County reported that the river rose 41 feet in 40 minutes. Damage included destruction of or significant damage to 7 cotton mills, 13 railroad bridges, 17 farmhouses, and crop losses, and was estimated at $3.87 million. Sixty-two people were killed and 4,300 workers were left out of work. A dam failure at Pacolet compounded the flooding.

Riverine Flooding. Both the Piedmont and Coastal Plain are subject to the slower-moving overbank flooding of the State's many streams and rivers. Because these floods usually rise and fall slowly, there is more warning time for riverine flooding on the larger rivers. While there may be less loss of life, the property damage can be extensive because there is often more development in the path of these floods. The danger and damage can be compounded by dam failures, which have occurred with many recent floods.

The worst riverine flooding in recent times occurred on October 10–29, 1990, during Tropical Depression Klaus and Tropical Storm Marco. Eleven of the State's 15 major river basins exceeded flood stage. Within a 24-hour period, some areas of Orangeburg, Sumter, Kershaw, Lancaster, and Chesterfield Counties experienced as much as 10 to 15 inches of rain, exceeding the expected 50- and 100-year rainfall amounts. Streams in Lee and Darlington Counties had flood crests well above the 100-year flood levels. A survey of the impacts reported 17 dam failures and an additional 31 dams overtopped; more than 120 bridges closed or washed away; secondary roads washed out in all impacted counties; and a railroad track flooded in Calhoun County, causing a train to derail. Five people were killed and the total damage was estimated at more than $3 million.

Coastal Storms. Coastal shorelines are subject to extremely destructive flooding, storm surge, wave action, and erosion caused by storms and hurricanes. While there may be plenty of warning time, the concentration of people and development in the large, exposed Lowcountry flood plains makes these storms the State's worst flood hazard. Coastal storms include hurricanes and "nor'easters," winter storms whose winds come from the northeast. The historical record on hurricanes is greater because of their greater impact.

The first recorded hurricane to hit South Carolina occurred in the late summer of 1686, destroying crops, trees, boats, and buildings. Since then, the State has been hit by more than 45 hurricanes or major coastal storms.

Litchfield Beach in Georgetown County was hit hard by a storm in 1893. One house survived because it stood on high ground; the rest were destroyed, and most of the residents drowned. Survivors estimated wave heights of 40 feet.

Flooding from Hurricane Hugo in 1989 dwarfs all other floods in South Carolina's history. The statistics are staggering—in South Carolina alone, 264,000 people were evacuated, and the storm caused 26 deaths and $2 billion in agricultural damage. Hugo resulted in the second-largest claim event in the history of the National Flood Insurance Program at that point in time. Luckily, its worst fury was spent on a relatively undeveloped area north of Charleston. A hurricane like Hugo can be repeated any year.

Local Drainage Problems. Storm-water drainage problems can occur anywhere in the State where the ground is flat, where natural drainage patterns have been disrupted, or where storm sewers, channels, or culverts have not been maintained. Surface-runoff from heavy, localized storms can overwhelm inadequate drainage structures or facilities, causing water to overflow the drainage channel.

Local drainage problems usually produce only shallow flooding in streets and yards; however, this water can enter low-lying houses and cause damage to buildings with floors below grade. Clay soils obstruct percolation, resulting in standing water that covers septic systems and causes health problems.

Few statistics are available for this type of flooding, as it usually does not result in a disaster declaration or a flood-insurance claim. One measure of the problem is the amount of money communities are willing to spend to correct local drainage problems. The town of Hilton Head Island, which found its only evacuation route cut off by such flooding in October 1994, has since embarked on a multimillion-dollar effort to improve local drainage.

Dam Failure. Dam failures cause a type of flash flood. The sudden release of impounded water can occur during a flood that overtops or damages a dam, or it can occur on a clear day if the dam has not been properly constructed or maintained. It is estimated that two or three dam failures occur each year, most of which are small and have little impact on human development.

Dam failures can occur anywhere there is a dam. The Coastal Plain contains relatively few dams because the generally-flat terrain makes reservoirs very costly; where present, the reservoirs commonly are small in area and volume. In the Piedmont, by contrast, dam construction has been widespread. The National Inventory of Dams reports more than 50,000 dams in South Carolina, including 34 federally-regulated dams and more than 2,200 state-regulated dams.

The threat from dam failures increases as dams become older and as more dams are built for retention basins and amenity ponds in new developments. Many dams are located on smaller streams that do not have well-mapped flood plains or are not subject to flood-plain regulations. Even where the flood plain is mapped, it is usually delineated for naturally-occurring floods, not on dam-breach inundation, leaving downstream residents unaware of the potential dangers. Recent dam failures usually have been related to heavy precipitation.

Flood Exposure

The only readily available statistics on the State's exposure to flooding are based on the number of flood-insurance policies. While not a basis for an accurate count of flood-prone buildings, the number of flood-insurance policies does indicate where the hazards are and where the most properties are exposed. South Carolina has 202,000 policies, the sixth most in the nation. The greatest concentration of policies is on the coast. Nearly 90 percent of all policies (and therefore nearly 90 percent of the exposure) are in the three counties—Charleston, Horry, and Beaufort—that contain the coastal population centers of Charleston, Myrtle Beach, and Hilton Head Island. Coastal counties also account for 99 percent of the State's repetitive flood-insurance losses. Inland, the counties with the largest number of policies are Lexington and Richland (around Columbia, the largest population center in the State), followed by Greenville County.

Federal Sources of Assistance and Information

Various types of assistance in flood-plain management are available from federal agencies in South Carolina. Each agency is responsible for a different facet of floodplain management and varies in the assistance it can provide. Those seeking assistance should initially contact all of the relevant agencies to determine which offers the type of help needed.

U.S. Army Corps of Engineers. The Charleston and Savannah Corps Districts and the South Atlantic Division offices provide information and assistance in flood-related matters. They maintain a file of flood-plain information, surveys, and other reports containing flood-plain delineations, flood profiles, data on discharges and hydrographs, and information on operational and planned flood-control projects. Each office provides interpretations as to flood depths, velocities, and durations from existing data; develops new data through field and hydrologic studies for interpretations; and provides guidance on adjustments to minimize the adverse effects of floods and flood-plain development.

The Corps constructs flood-control projects pursuant to congressional authorization. Major projects, such as large dams and reservoirs, are usually also operated by the agency.

The Corps also administers a continuing authorities program to assist local communities with their water-resources problems. These programs include flood control, channel clearing, navigation, beach erosion, and stream-bank stabilization. Projects authorized through these programs are usually cost-shared with a local sponsoring government agency.

During flood emergencies, the Corps can assist the state and local communities by providing materials, equipment, and personnel for flood-fighting and construction of temporary levees or other temporary protective structures. Assistance is also available for rehabilitation of damaged public facilities and protective works.

Further information on assistance available from the Corps can be obtained from the following sources:

U.S. Army Corps of Engineers
South Atlantic Division
60 Forsyth Street. S.W.
Room 9M15
Atlanta, GA 30303-8801
(404) 562-5011

U.S. Army Corps of Engineers
Savannah District
PO Box 889
Savannah, GA 31402-0889
(912) 652-5279

U.S. Army Corps of Engineers
Charleston District
69A Hagood Avenue
Charleston, SC 29403-5107
(843) 329-8123

Federal Emergency Management Agency. The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP) as well as programs for disaster planning and recovery. Specifically, the NFIP is administered by the Federal Insurance Administration (FIA), which works closely with states and communities in an effort to effect wise flood-plain management, including flood-loss prevention.

Another FEMA responsibility is to see that the NFIP's Standard Flood Insurance Policy is properly promoted and written. The Electronic Data Systems Corporation is under contract with the NFIP to assist with these marketing-related responsibilities. Some of FEMA's services include provision of flood hazard maps and data; assistance in developing flood-plain regulations that meet federal criteria; and provisions of disaster relief and recovery assistance.

The FEMA regional office with jurisdictional authority for South Carolina is located at:

Federal Emergency Management Agency
3003 Chamblee Tucker Road
Atlanta, GA 30341
(770) 220-5200

National Weather Service. The National Weather Service issues weather forecasts and flood warnings. It also provides assistance to communities to establish flood-warning systems and conduct flood-hazard analyses. The agency utilizes a network of about 7,900 precipitation and streamflow stations nationwide to support its flood forecast and warning services at about 2,500 communities. Types of information and assistance available include precipitation records and other climatological data; preparation of forecasting materials; assistance in organization and training of observers and those responsible for applying self-help warning systems; equipment installation and calibration; and stream-depth data.

An annual publication entitled *River Forecasts Provided by the National Weather Service* lists locations at which data are compiled and includes the flood stage as well as the maximum stage of record at each location. For further information on available data and assistance, contact:

National Weather Service
Southern Region
819 Taylor Street
Room 10E09
Fort Worth, TX 76102
(817) 978-1100

Storm-surge frequency information is also available. Studies have been completed for the Gulf of Mexico coast from the Alabama-Florida border to southern Florida and along the Atlantic Coast from southern Florida to Cape Henlopen, Delaware. The National Weather Service also provides warnings of storm surges associated with tropical and extratropical storms. For storm surge frequency information and interpretative assistance, contact:

Chief, Hydrologic Science and Modeling Branch
Office of Hydrologic Development
National Weather Service
1325 East-West Highway
Silver Spring, MD 20910
(301) 713-0640

Natural Resources Conservation Service. At the request of local governments, the Natural Resources Conservation Service (NRCS) carries out cooperative flood-plain management studies, which include flood-hazard photomaps, flood profiles, and flood-plain management recommendations. The agency also provides technical and financial assistance to plan, design, and install watershed projects of less than 250,000 acres; and install emergency work such as stream-bank stabilization, debris removal from channels and bridges, and revegetation of denuded and eroded areas to protect life and property after storms and floods.

Types of information available from the NRCS include land-treatment needs; project-planning data; photomosaic maps delineating areas subject to inundation by floods of selected frequency and associated flood profiles; flood-plain management options (structural and nonstructural); design and construction information on flood-prevention works; detailed soil-survey data and maps; and snow-survey data. To assist in the implementation of local flood-plain management programs, the NRCS also provides continuing technical assistance to local governments after the completion of studies it performs.

Information on assistance and the availability of information can be obtained from the following location:

Natural Resources Conservation Service
State Conservationist
1701 Senate Street
Columbia, SC 29201
(803) 253-3975

U.S. Geological Survey. The U.S. Geological Survey (USGS) maintains a network of about 7,700 continuous-record streamflow gaging stations throughout the United States and Puerto Rico. Several thousand additional peak-stage stations supplement this network. Many gaging stations are serviced periodically by observers who generally reside near the gage site. Arrangements for direct telephone notification of flood conditions can usually be made with observers.

The USGS publishes an annual report entitled *Water Resources Data of South Carolina* that includes records of gage height, discharge, runoff, time of travel, and sediment discharge from a network of gaging stations. The agency also has information available on historic flood peaks and inundated areas and the magnitude, frequency, and duration of flood flows. Areas subject to inundation by floods of selected frequencies, usually 100-year floods, have been delineated on topographic maps for urban areas where the upstream drainage basin exceeds 25 square miles; smaller drainage basins depending on topography and potential use of the flood plain; rural areas in humid regions where the upstream drainage basin exceeds 100 square miles; and rural areas in semiarid regions where the upstream drainage basin exceeds 250 square miles.

Assistance is also available in interpreting flood-frequency relations and computed water-surface profiles and in identifying areas of potential flood hazard. Information concerning the availability of information for a specific community can be obtained from:

U.S. Geological Survey
Stephenson Center
Suite 129
720 Gracern Road
Columbia, SC 29210-7651
(803) 750-6100

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