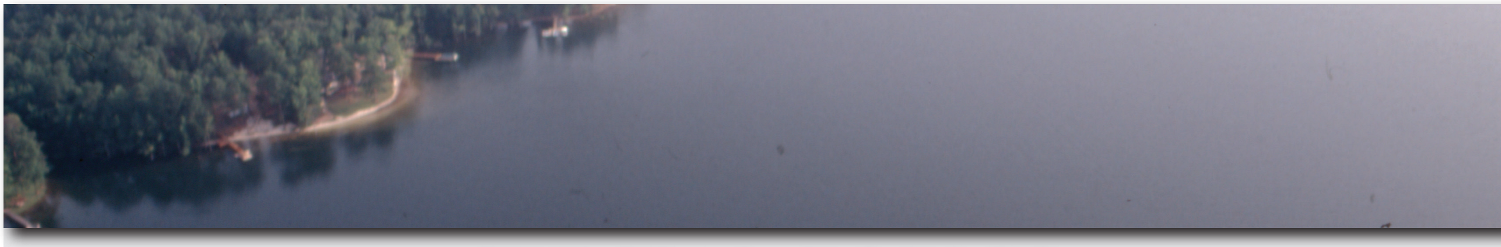


SPECIAL TOPICS

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

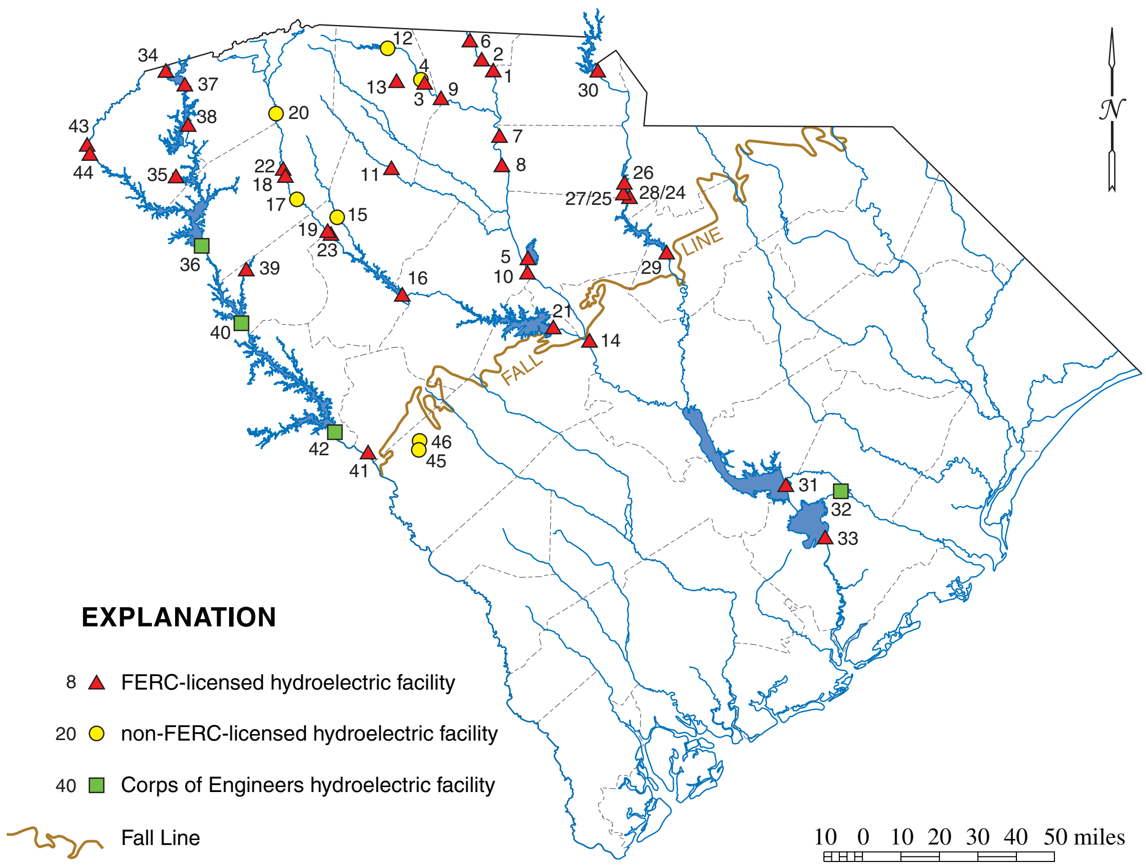


Figure 9-1. Existing hydroelectric power plants in and adjacent to South Carolina. See Table 9-1 for facility information.

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
	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
Broad	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
	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
Saluda	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
	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
Catawba-Wateree	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 thermoelectric 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

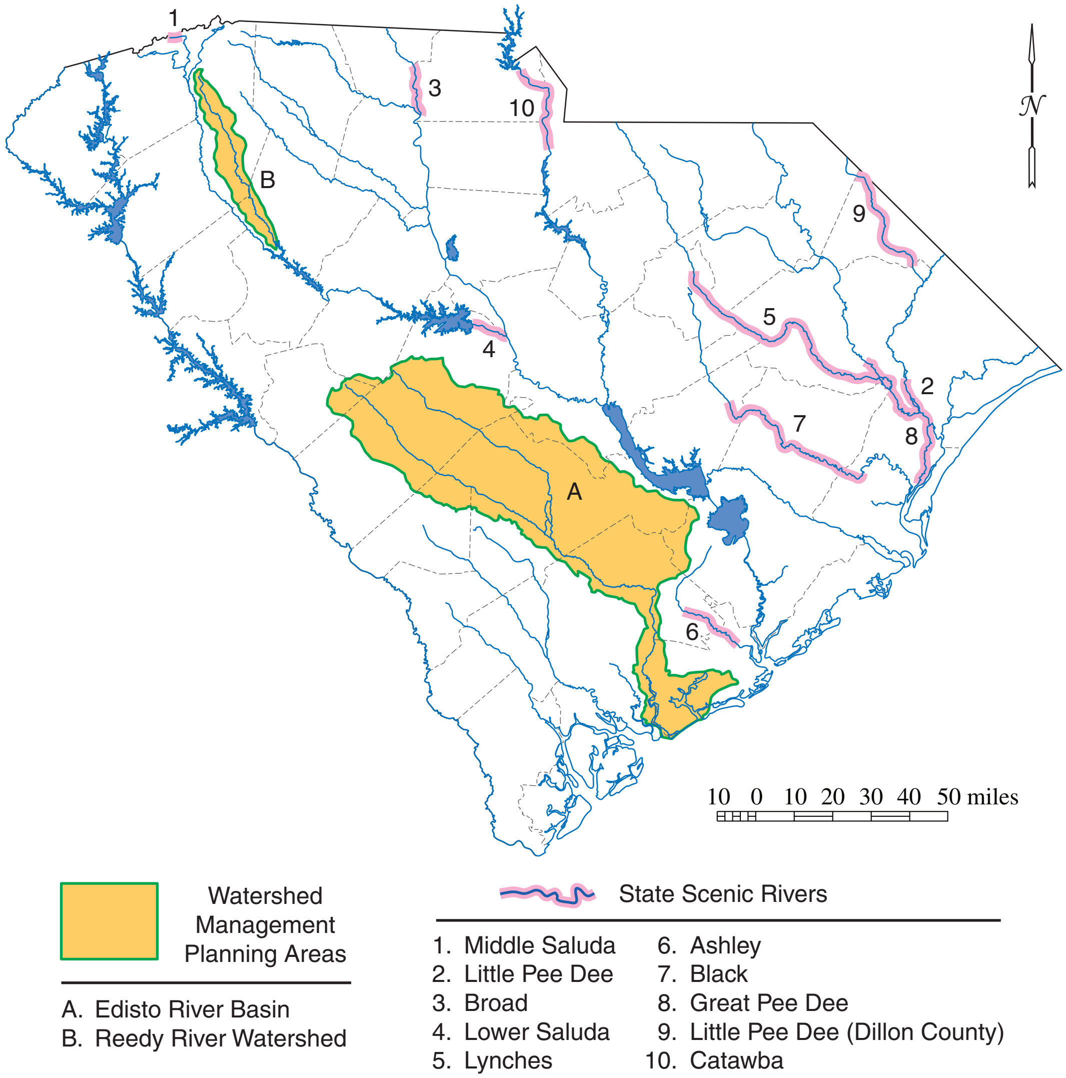


Figure 9-3. Scenic Rivers and Watershed Management Planning Areas in South Carolina.

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.

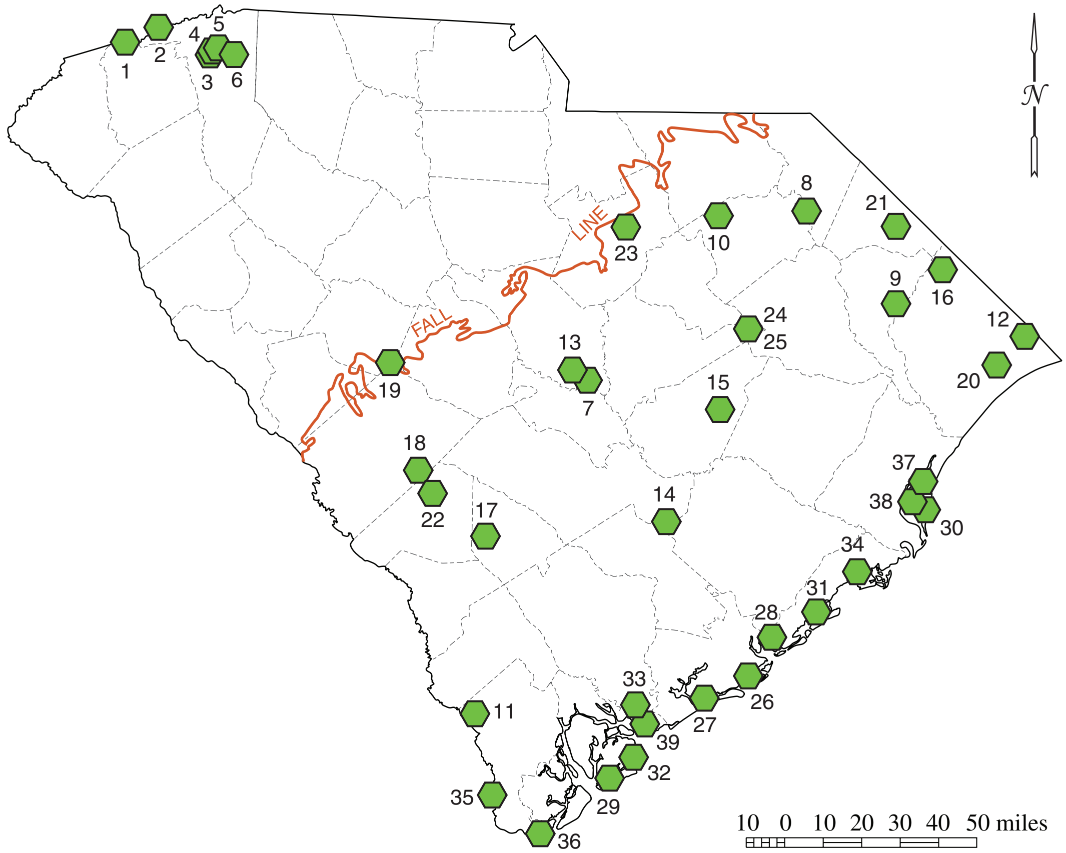
The diversity of South Carolina's wetland resources and the relative inaccessibility of these areas serve to increase the value of wetlands as natural areas by harboring and providing habitat for a variety of animal and plant species. South Carolina's wetlands also contain numerous animal and plant species 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

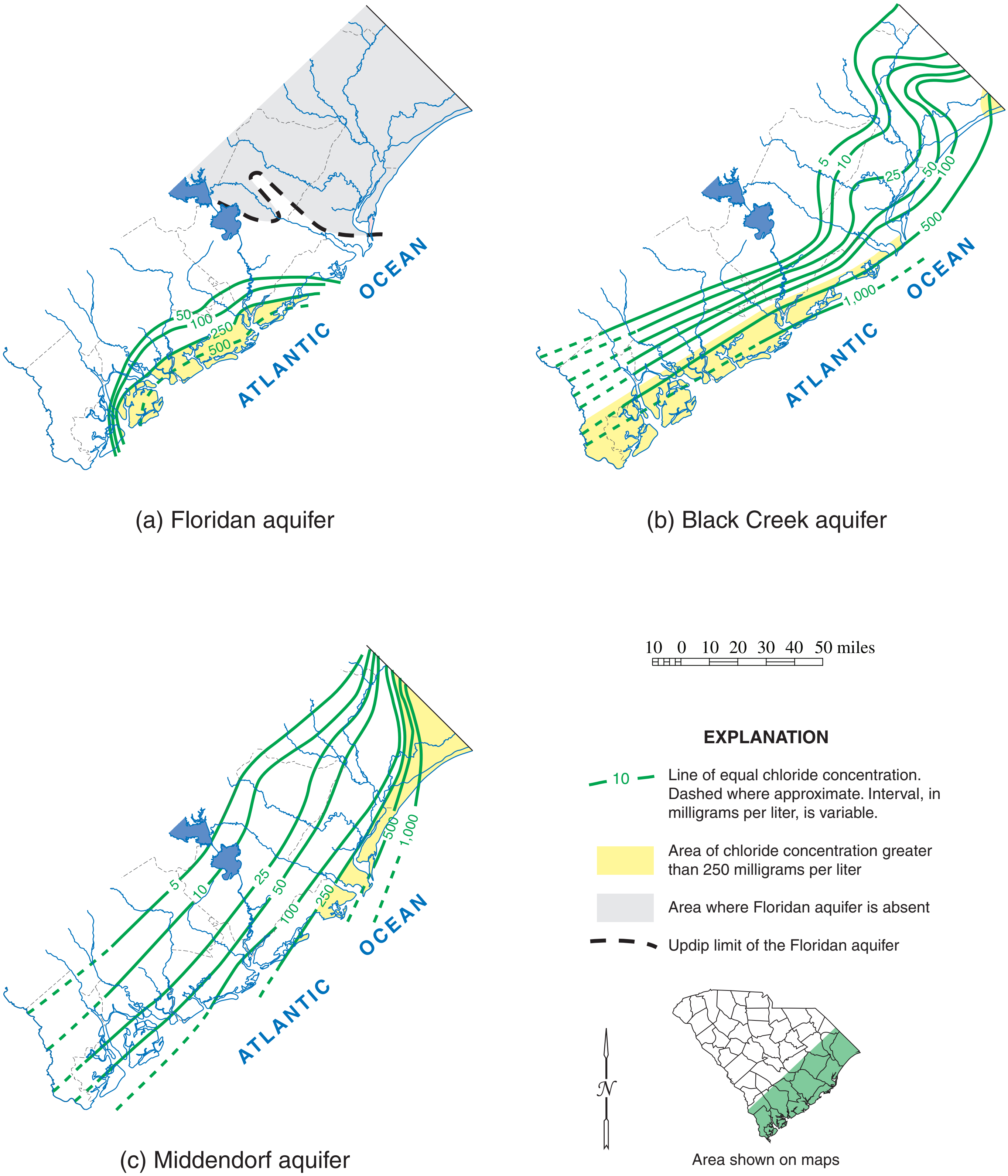


Figure 9-8. Saltwater intrusion into the (a) Floridan, (b) Black Creek, and (c) Middendorf aquifers along the coast of South Carolina (adapted from Hayes, 1979; Park, 1986; and Speiran and Aucott, 1994).

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.

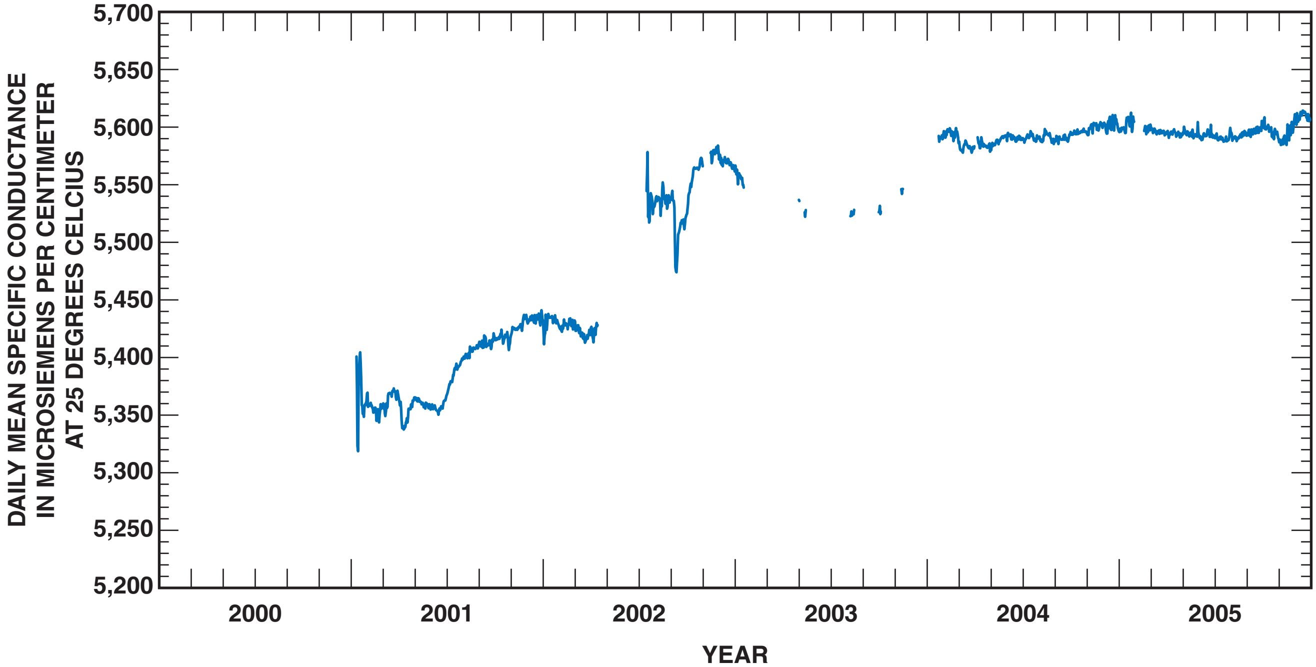


Figure 9-9. Daily mean specific conductance in well COL-301 at Edisto Beach State Park, years 2001–2005.

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

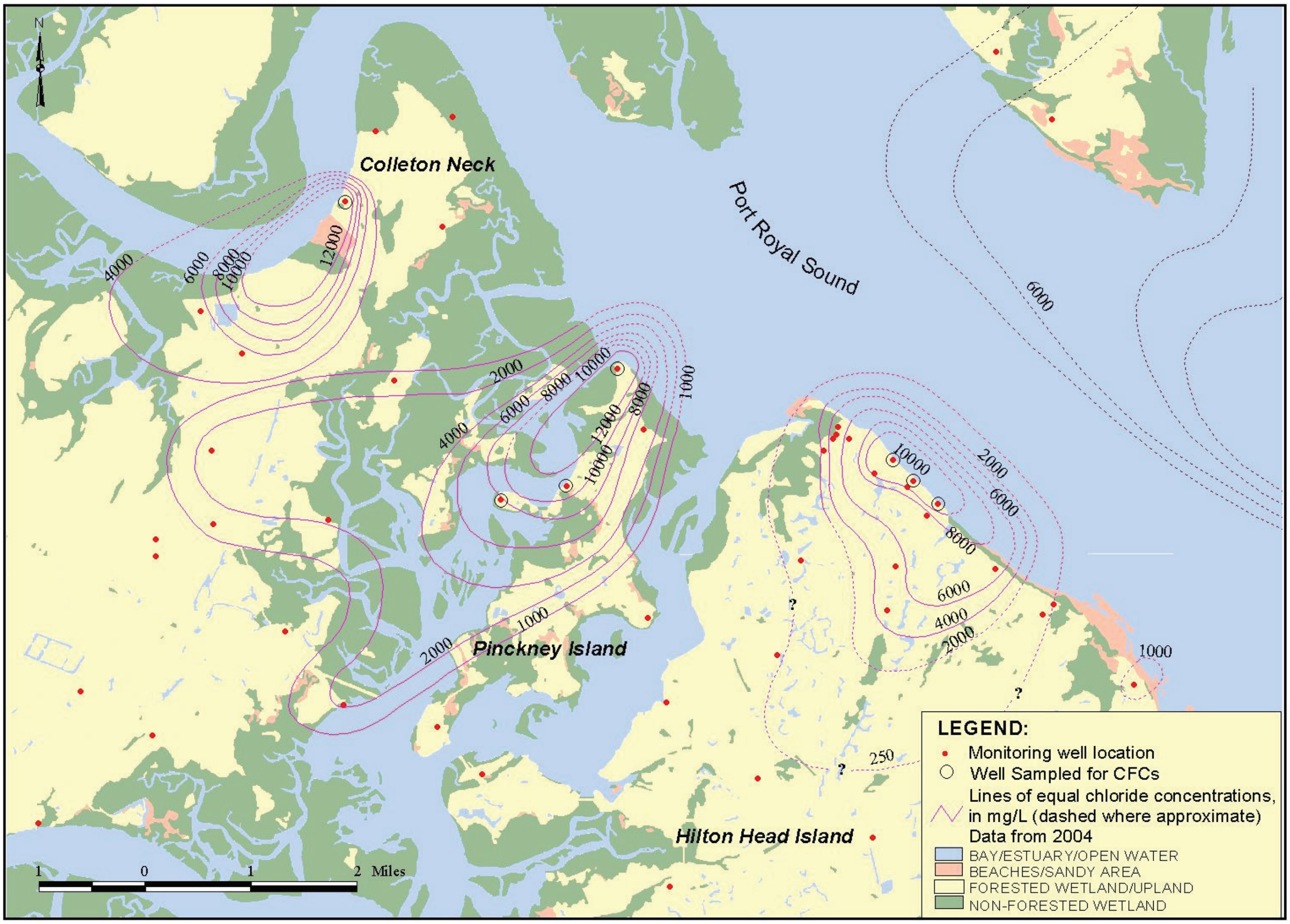


Figure 9-10. Seawater contamination in the upper permeable zone of the Floridan aquifer, Hilton Head Island, S.C., year 2004 (courtesy of S.C. Department of Health and Environmental Control, Bureau of Water).

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

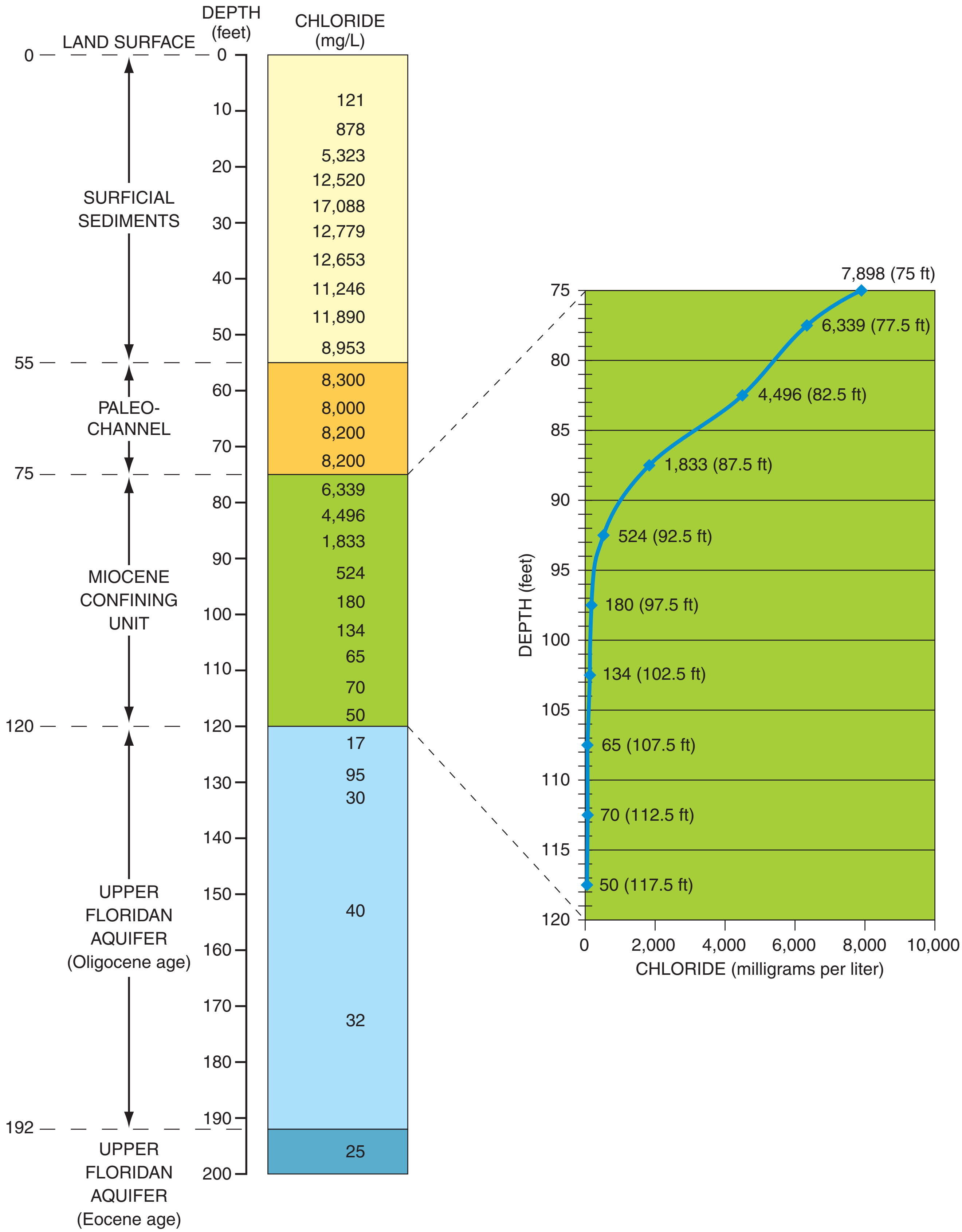


Figure 9-11. Geology and chloride distribution in the Bull River test well near Tybee Island, Ga. (Ransom and others, 2006).

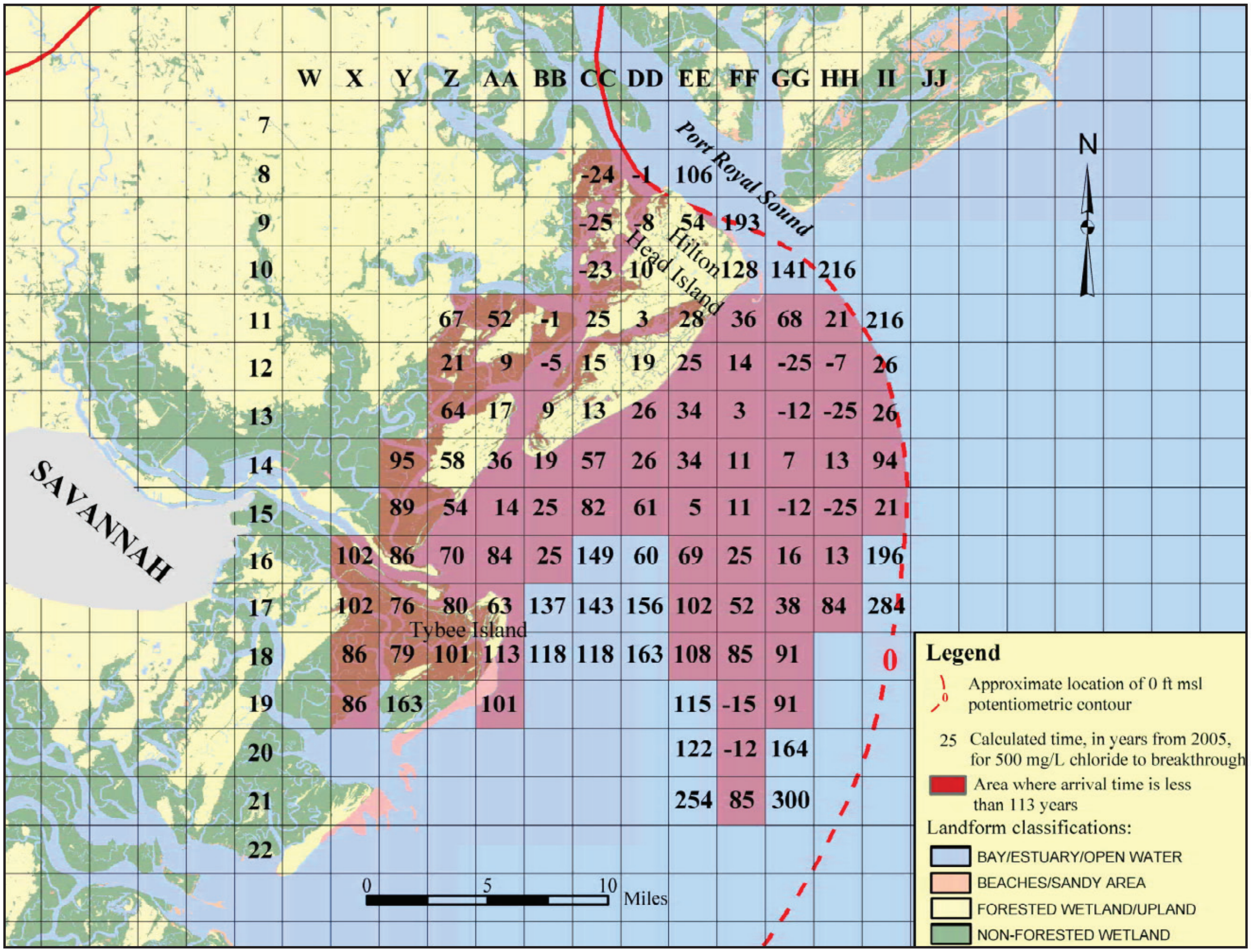


Figure 9-12. Estimated time to 500-mg/L chloride breakthrough in the Floridan aquifer confining unit, Beaufort and Jasper Counties, S.C., and Chatham County, Ga., from the year 2005 (Ransom and others, 2006).

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