WATER RESOURCES ACTIVITIES, SOUTH CAROLINA DISTRICT, 1989-91

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FOREWORD

The U.S. Geological Survey (USGS) was created by an Act of Congress in 1879, as a bureau of the U.S. Department of the Interior, to classify public lands and to examine the geologic structure, mineral resources, and products of the national domain. Since then, the USGS's responsibilities have expanded to include topographic mapping, geochemical and geophysical studies, and the assessment of the quantity, quality, and distribution of water resources. During the past 100 years, the USGS has become the Nation's principal fact-finding and research agency concerned with our physical resources. The mission of the Water Resources Division of the USGS is to provide hydrologic information needed for the development, management, and use of the Nation's water resources.

Although stream gaging began in 1884 as part of a study to identify irrigable land, the water-resources program of the USGS began in 1894 when a small appropriation was obtained for the specific purpose of "gauging streams and determining the water supply of the United States." In the years following 1884, the need for water-resources information grew rapidly, but the USGS was unable to meet the demand because of restricted budgets. Many States initiated water-resource programs to fill the deficiency and the USGS worked closely with the various State agencies. However, these efforts did not satisfy the need of the States and the Nation for a comprehensive water-resources information program. Accordingly, in 1928 Congress established the cooperative matching program by which the USGS's water-resources programs with State agencies may be funded on a 50-50 basis. This cooperative water-resources program has grown over the years into the primary source of water information for the Nation. This is accomplished through cooperation with State and local governments and other Federal agencies by:

- Collecting data on a systematic basis to determine the quantity, quality, and use of surface and ground water.
- Conducting interpretive water-resource appraisals to describe the consequences of alternative plans for developing land and water resources.
- Conducting basic and problem-oriented research in hydraulics, hydrology, and related fields.
- Developing information on water-related natural hazards such as floods, landslides, volcanoes, mudflows, and land subsidence.
- Coordinating the activities of all Federal agencies in the acquisition of water data.
- Disseminating data and findings through reports, maps, and other forms of public release.
- Providing scientific and technical assistance in the hydrologic fields to other Federal agencies, to State and local agencies, and, on behalf of the U.S. Department of State, to international agencies.

The Water Resources, National Mapping, and Geologic Divisions are the three operating Divisions of the USGS. General information pertaining to these Divisions may be obtained from the Information Office, U.S. Geological Survey, 119 National Center, Reston, VA 22092. Circular 900, "A Guide to Obtaining Information from the U.S. Geological Survey," can be obtained free from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, Colorado 80225.

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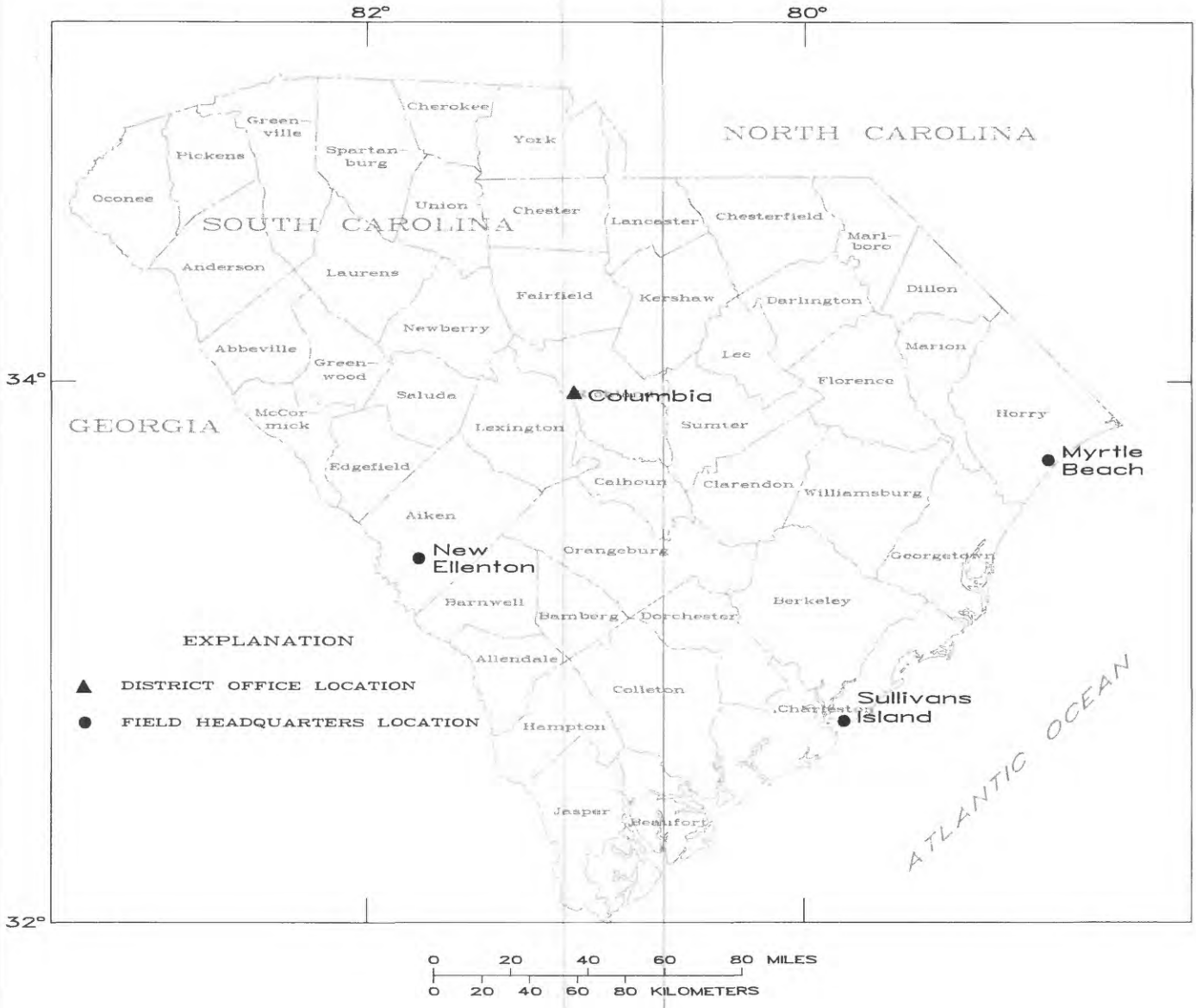
INTRODUCTION

This report describes data-collection activities and interpretive studies pertaining to water resources of South Carolina, conducted by the U.S. Geological Survey (USGS), Water-Resources Division (WRD) during 1989-91. These activities were conducted in cooperation with other Federal, State, and local agencies.

South Carolina's abundant surface- and ground-water resources are being stressed by the demands of an active and growing population. During moderate droughts, several of the State's rivers are barely adequate to provide the water supply needs of towns and industries, and to provide adequate dilution of wastewater effluents. Although the aquifers of the Coastal Plain contain large amounts of stored ground water, the water levels in some areas of the Coastal Plain are dropping due to withdrawal rates that exceed recharge rates. Leaking storage tanks and nonpoint-source runoff have contaminated localized parts of aquifers, lakes, streams, and estuaries.

Careful management of water resources in the face of these pressures requires an extensive information base, which is the aim of the WRD. Through its main office in Columbia, and its field offices in Myrtle Beach, Sullivans Island, and New Ellenton (fig. 1), the South Carolina District of the WRD monitors rainfall, streamflow, water quality, and ground-water levels. The data are stored in the USGS national data files and are available upon request. Most of the data are also published annually in a report entitled "Water-Resources Data for South Carolina."



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706 Main Street South
New Ellenton, SC 29809

Figure 1.--Location and addresses for the South Carolina District.

During the last decade, the South Carolina District has installed satellite telemetry equipment at most of its data-collection sites to provide water-resources data in near-real time to the District Office and to other agencies. This has reduced the amount of missing data, and has enhanced water managers' ability to make decisions in real time. Additionally, satellite telemetry equipment is installed at all new data-collection sites.

Interpretive studies seek to answer questions about long-term supply, effects of nonpoint-source runoff, remediation strategies for ground-water contamination, scour erosion at bridges, and other topics. Some interpretive projects are categorized as research, because they provide significant new insight into fundamental areas of hydrology, such as the interaction of bacteria and ground-water chemistry. Results of interpretive studies and research projects are published in USGS reports and in scientific journals. A reference list is provided at the end of this report.

TYPES OF FUNDING

Funding for programs of the South Carolina District falls into three categories:

1. Federal Program, which includes funds appropriated directly to the Geological Survey.

2. Other Federal Agencies (OFA) Program, which includes funds transferred from other Federal agencies.

3. Cooperative Program, which includes investigations supported by funds and(or) services provided by State and local agencies, usually matched on a 50-50 basis by Federal funds.

The distribution of funding in these three program categories in fiscal years 1989, 1990, and 1991 is shown in figure 2.

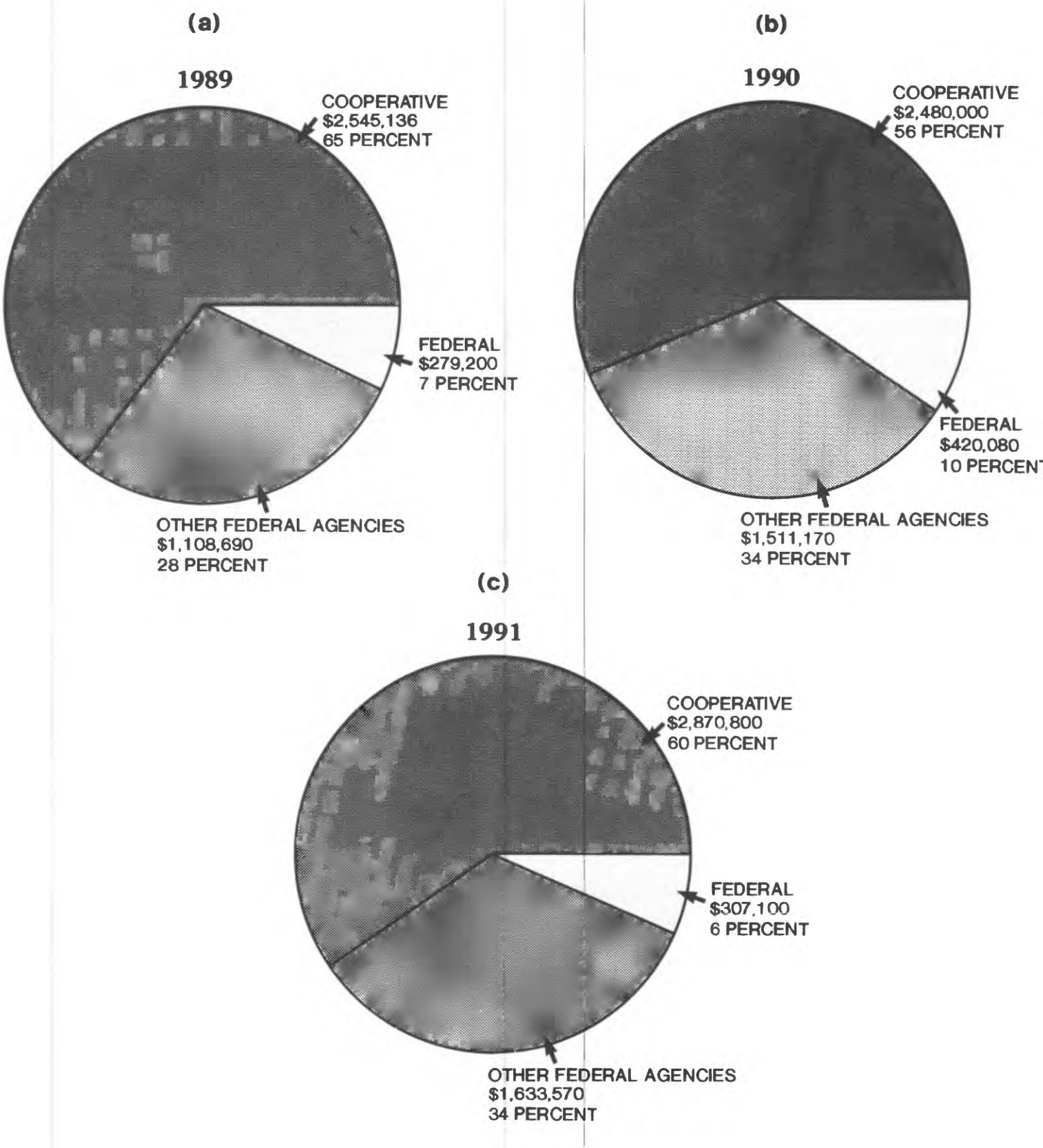

Figure 2.--Sources of funding for water-resources activities in South Carolina, fiscal years 1989-91.

COOPERATING AGENCIES

Hydrologic activities are conducted in large part through cooperation with State, local, and other Federal agencies who share in the planning and financial support of the program. The cooperators are:

State Agencies

South Carolina Department of Health and Environmental Control
South Carolina Department of Highways and Public Transportation
South Carolina Geological Survey
South Carolina Public Service Authority
South Carolina Sea Grants Consortium
South Carolina Water Resources Commission
South Carolina Wildlife and Marine Resources Department
University of South Carolina

Local Agencies

Beaufort-Jasper County Water Authority
Charleston Commissioners of Public Works
City of Myrtle Beach
City of North Myrtle Beach
Cooper River Water Users Association
Donaldson Development Commission
Georgetown Water and Sewer District
Grand Strand Water and Sewer Authority
Lee County
Oconee County Sewer Commission
Pickens County
Spartanburg Sanitary Sewer District
Spartanburg Water System
Town of Pageland
Waccamaw Regional Planning and Development Council
Western Carolina Regional Sewer Authority
York County

Other Local Entities

Allied-Signal, Incorporated
Bowater Incorporated
Brewer Gold Company
Carolina Power and Light Company
Caro-Knit, Incorporated
Clifton Power Company
Duke Power Company
Martin Marietta Aggregates
Milliken Corporation
South Carolina Electric and Gas Company
Union Camp Corporation
Willamette Industries, Incorporated

Other Federal Agencies

Federal Emergency Management Agency
U.S. Army Corps of Engineers, Charleston District
U.S. Army Corps of Engineers, Kansas City, KS
U.S. Army Corps of Engineers, Savannah District
U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS
U.S. Defense Logistics Agency
U.S. Department of Energy
U.S. Environmental Protection Agency, Region IV
U.S. Environmental Protection Agency, R.S. Kerr Environmental Research Laboratory
U.S. Federal Energy Regulatory Commission
U.S. Navy, Southern Division Naval Facilities Engineering Command

SUMMARY OF HYDROLOGIC CONDITIONS, WATER YEARS 1989-91

The coast of South Carolina was devastated when Hurricane Hugo made landfall just north of Charleston in the early morning of September 22, 1989. High-water marks, surveyed after the storm, indicated the following average surge elevations (in feet above sea level) along the coast:

North Myrtle Beach	11.2	Sullivans Island	14.1
Garden City Beach	12.3	Charleston	11.2
McClellanville	16.4	South Kiawah Island	10.6
Moores Landing	20.2	North Edisto River	7.5

Rainfall totals throughout the State increased during the 1989 water year (October 1, 1988,-September 30, 1989), compared with the dry conditions of 1988, though many were still below normal. Rainfall in the Piedmont, as represented by the National Weather Service (NWS) station at the Greenville-Spartanburg Airport, was 0.2 percent below normal. Rainfall in the Coastal Plain was variable during 1989. Rainfall recorded near Columbia and Charleston by the NWS was 6 percent above and 6.8 percent below normal, respectively, for the water year.

During the 1990 water year, rainfall totals were lower than during 1989. Rainfall in the Piedmont, at the NWS station at the Greenville-Spartanburg Airport, was 10 percent below normal. Rainfall in the Coastal Plain was variable. Rainfall recorded near Columbia and Charleston by the NWS was 31 percent and 23 percent below normal, respectively, for the water year.

During the 1991 water year, rainfall totals were higher again. The dry conditions that had persisted over much of the State during the summer and fall of 1990 continued during the first weeks of October 1990. The drought was replaced with flooding problems on October 10-12 as heavy localized rains derived from Tropical Storms Klaus and Marco caused severe flooding in some areas. During this event, some parts of the State received as much as 10 inches of rain in a 24-hour period. The heaviest rain fell on October 11. The NWS rainfall totals, in inches, for selected cities on that day were:

Florence	5.27	Kershaw	9.85
Orangeburg	9.99	Aiken	4.04
Charleston	4.20	Columbia	3.98
Greenville	4.43	Greer	2.95

After the October floods, rainfall was below normal through February and well above normal for the remainder of the water year over most of the State.

Streamflow, like rainfall, was higher during water year 1989 than during the drought year of 1988, but was still below normal. During water year 1990, streamflow was lower than in 1988 in most parts of the State. In the upper Coastal Plain, daily mean streamflows set a new record low for the South Edisto River near Denmark during July 1990, and tied the record low streamflow for Black Creek near McBee during August 1990 (table 1).

Table 1.--Daily mean streamflow for 1989-91 water years

Station	Drainage area (square miles)	Minimum daily mean streamflow for period of record (cubic feet per second)	7-day, 10-year low flow streamflow (cubic feet per second)	Minimum daily mean streamflow 1989 water year (cubic feet per second)	Minimum daily mean streamflow 1990 water year (cubic feet per second)	Minimum daily mean streamflow 1991 water year (cubic feet per second)
Piedmont						
02154500 North Pacolet River at Fingerville	116	27	45	45	81	81
02162010 Cedar Creek near Blythewood	48.9	.07	.53	2	1.4	2.1
Upper Coastal Plain						
02130900 Black Creek near McBee	108	17	23	47	17	30
02173000 South Fork Edisto River near Denmark	720	133	200	245	133	189
02197300 Upper Three Runs near New Ellenton	98.7	53	56	65	59	64
Lower Coastal Plain						
02132000 Lynches River at Effingham	1,030	95	140	339	189	236
02176500 Coosawhatchie River near Hampton	203	0	0	.82	0	0

The floods of October 1990 brought record peak streamflows on many streams with small drainage areas. Streams with drainage areas greater than 200 square miles did not have record flows, because the heaviest rainfall was localized. The stations with the most significant flooding were Fork Creek at Jefferson, Black Creek near McBee, and Scape Ore Swamp near Bishopville, where peak flows were 2.8, 2.5, and 2.3 times the 100-year flood, respectively.

Following the October floods, streamflow remained above normal through December, especially in eastern South Carolina. Streamflow was near normal during most of the winter and spring, except for March, when flooding at the beginning and end of the month produced annual peak flows at several stations. During the last quarter of water year 1991, streamflow in western South Carolina was above normal.

Ground-water levels, like streamflow, reflect the climatic conditions of the region. This is especially true in shallow, unconfined aquifers such as those in the Piedmont, where ground water occurs in fractures in the crystalline bedrock and in pore spaces in the overlying saprolite and alluvium. During 1989-91, the water level in well GRV-709, an 80-foot-deep observation well in the water-table aquifer near Greenville, recovered from the low level of 1988, 35.62 feet below land surface. The recovery was cyclical, with highest water levels in the late spring and lowest in the late autumn. By July 1991, the level had reached 28.44 feet below land surface.

Ground water in the Coastal Plain occurs in multiple aquifer systems, mostly under artesian or confined conditions. Extensive use is made of ground water in the Coastal Plain, resulting in water-level declines in some areas. Some wells are separated from their aquifer recharge areas by 50 miles or more, and produce water that has been in the ground for thousands of years. Fluctuations in water levels reflect effects of withdrawals. During 1989-91, the water level in well HO-307, a 416-foot deep observation well at Conway, continued a long-term pattern of decline, from 56.83 feet below land surface in October 1988, to 63.40 feet in September 1991.

Water-quality data were collected at 44 to 60 sites during the 3 years. Record low dissolved-oxygen concentrations were recorded at many sites in the coastal area following Hurricane Hugo in September-October 1989. This was caused by large amounts of organic debris that were washed into the streams by the storm, and by bottom sediments that were stirred up by the winds.

WATER-RESOURCES INVESTIGATIONS IN SOUTH CAROLINA, 1989-91

The U.S. Geological Survey, Water Resources Division, conducts three major types of activities in South Carolina in order to provide the hydrologic information and understanding needed for the best management of South Carolina's and the Nation's water resources. The activities are:

1. Data collection and dissemination.
2. Water-resources appraisals (interpretive studies).
3. Research.

The descriptions of these activities for water-years 1989, 1990, and 1991 in this report include the following information:

- Project Number
- Title
- Principal Investigator (Project Chief)
- Period of Investigation
- Cooperating Agency
- Problem
- Objective
- Approach
- Progress

SUMMARIES OF WATER-RESOURCES ACTIVITIES BY PROJECT

The water-resources investigations or projects that were active in fiscal years 1989, 1990, and 1991, and the page on which project activities are described are listed as follows:

Project: SC001, Streamflow network in South Carolina

Location: Statewide

Project Chief: Theodore W. Cooney

Period of Project: Continuous since 1925

Cooperation: Various Federal, State, and local agencies

Problem: Surface-water information is needed for purposes of surveillance, planning, design, hazard warning, operation, and management in water-related fields such as water supply, hydroelectric power, flood control, irrigation, bridge and culvert design, wildlife management, pollution abatement, flood-plain management, and water-resources development. An appropriate data base is necessary to provide this information.

Objectives: (1) To collect surface-water data sufficient to satisfy needs for current uses, such as assessment of water resources, operation of reservoirs or industries, forecasting, disposal of wastes and control of pollution, and research or special studies. (2) To collect data necessary for analytical studies to define the statistical properties and trends in rainfall, streamflow, water levels, and water quality.

Approach: Standard methods of data collection are used as described in the USGS publications series "Techniques of Water-Resources Investigations of the United States Geological Survey." Partial-record gaging is used instead of complete-record gaging where it serves the required purpose. The network includes continuous and intermittent discharge stations (fig. 3), stage-only and lake stage stations (fig. 4), and peak or crest stage stations (fig. 5).

Progress: The surface-water network has grown to include operation and annual publishing of hydrologic data from 120 continuous-gaging stations, 22 stage only stream stations, and 13 lake-stage stations. Miscellaneous measurement data from 4 sites and data from 41 crest-stage partial-record stations are also published. Thirty-one raingages also are operated within the network.

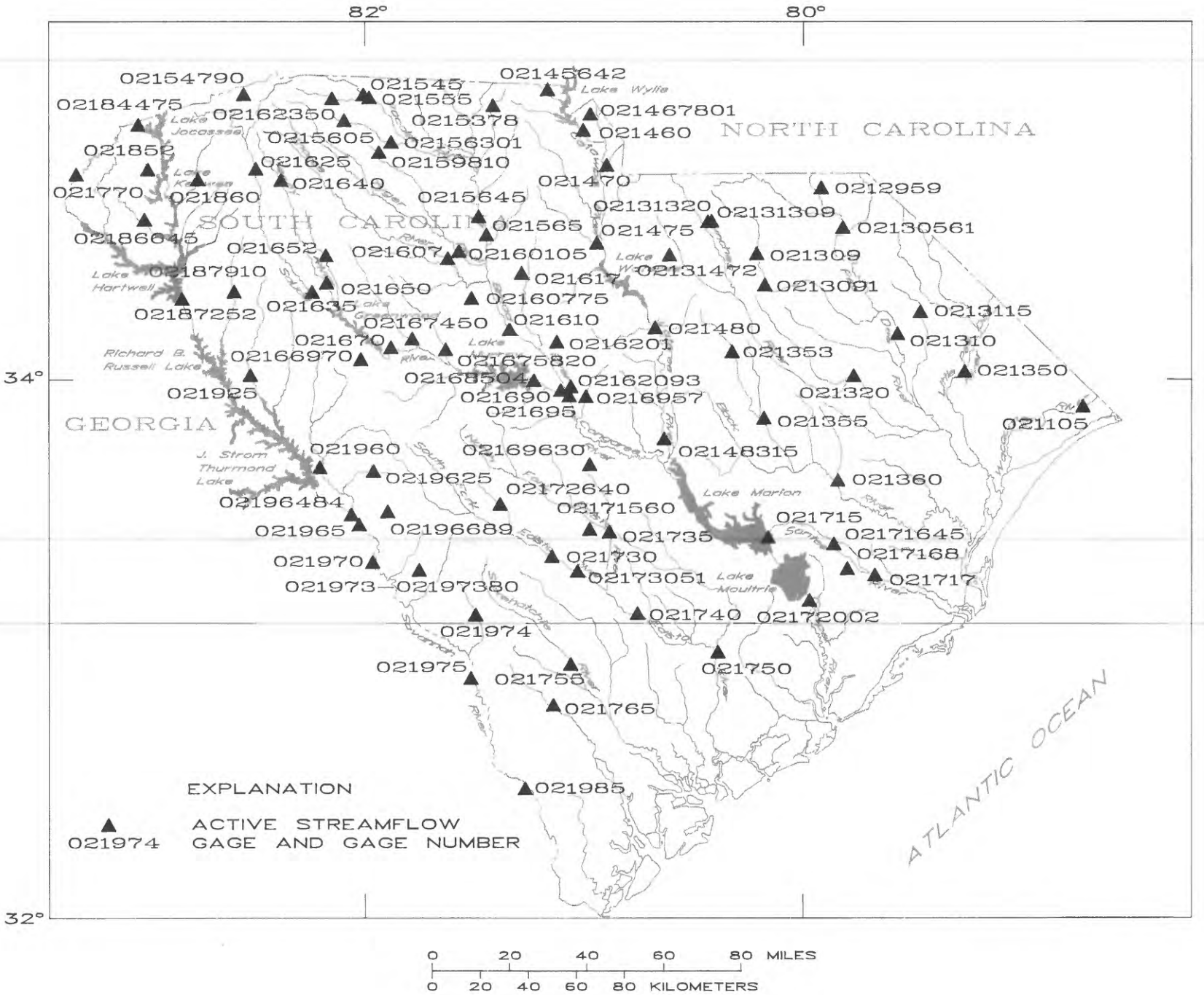

Figure 3.--Location of streamflow stations in the South Carolina District, 1989-91.

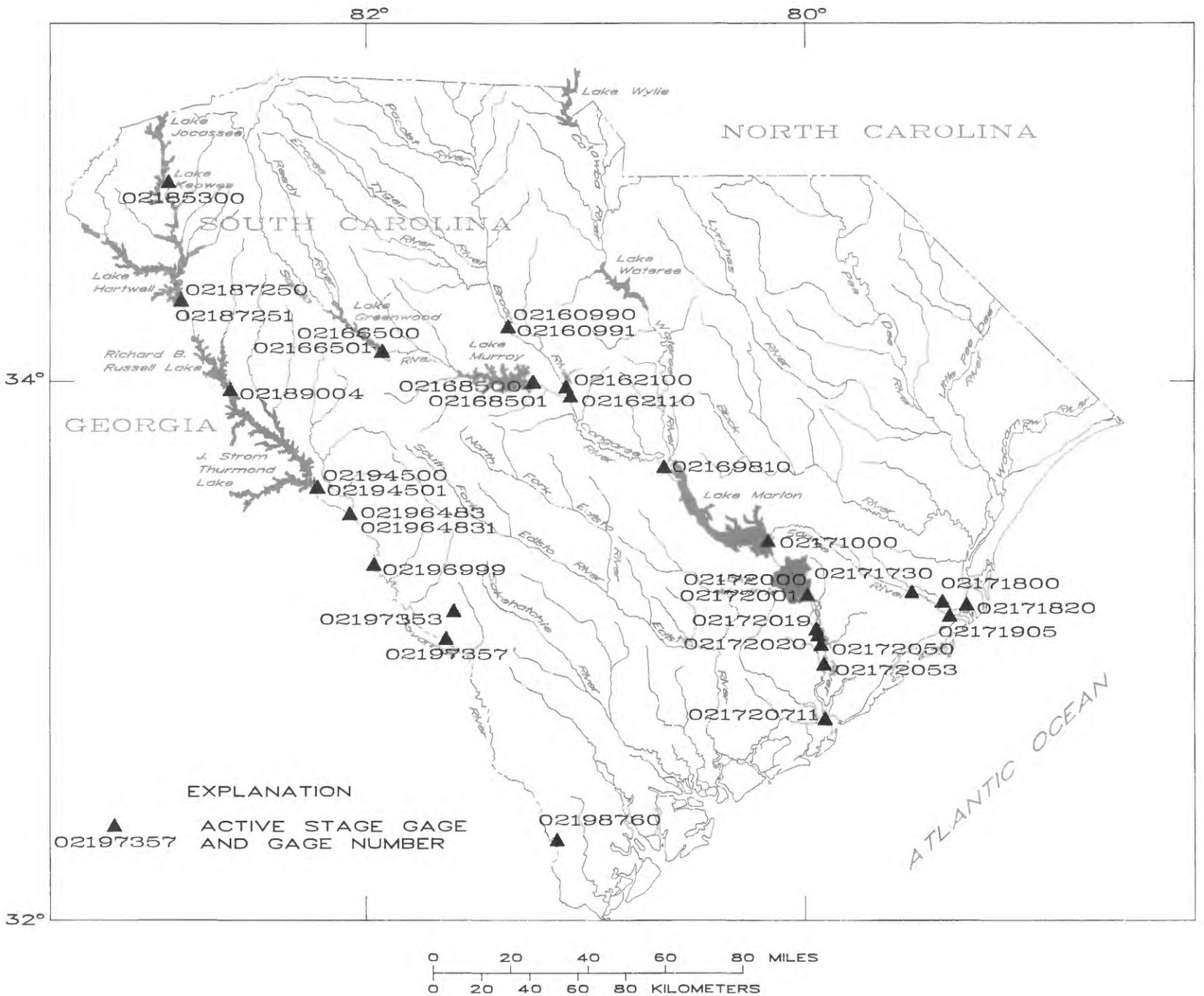

Figure 4.--Location of stage only stations in the South Carolina District, 1989-91.

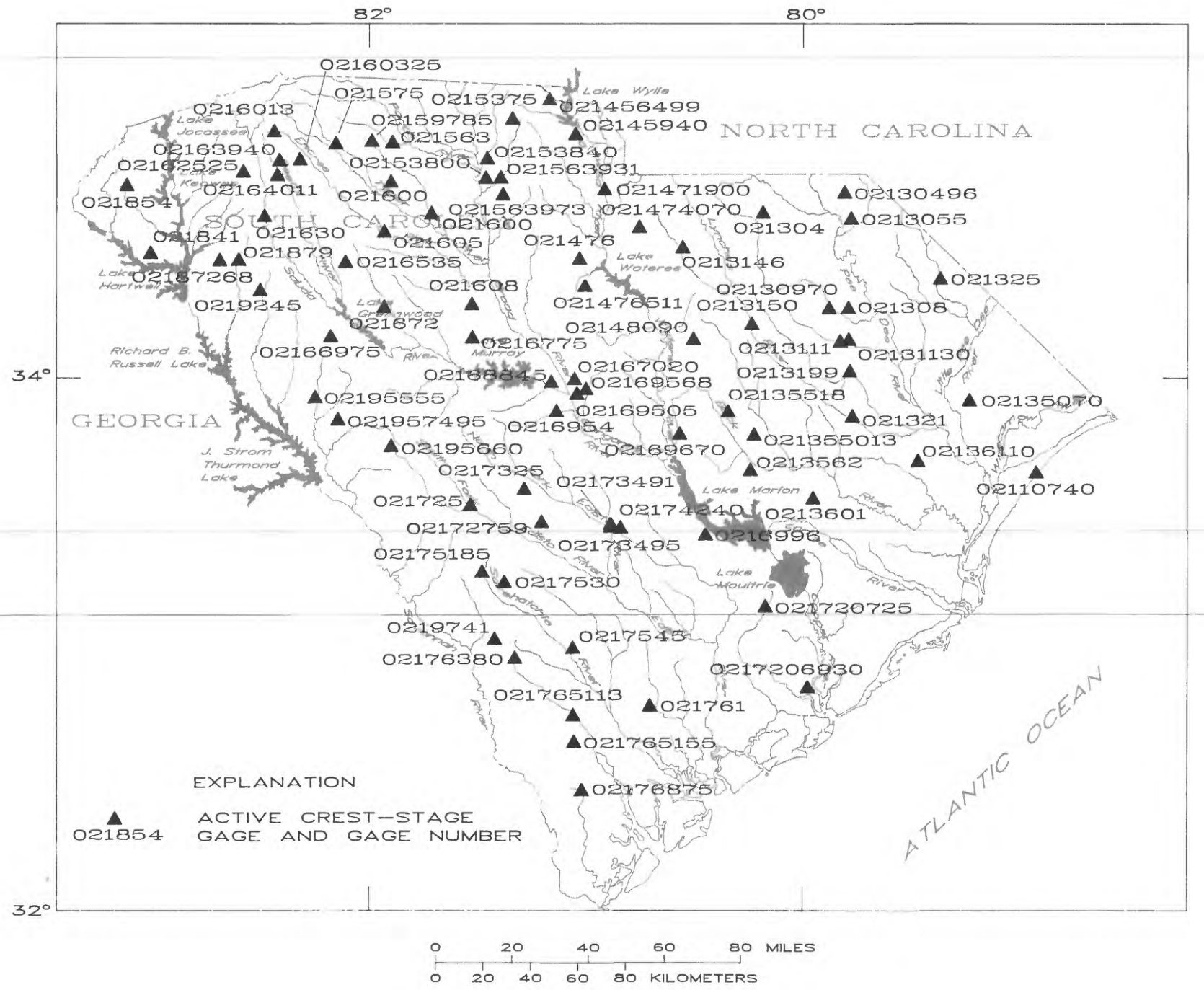

Figure 5.--Location of crest-stage stations in the South Carolina District, 1989-91.

Project: SC002, Ground-water network in South Carolina

Location: Statewide

Project Chief: Curtis S. Bennett, III

Period of Project: Continuous since 1952

Cooperation: Various Federal, State, and local agencies

Problem: Long-term water-level records are needed to evaluate the effects of climatic variations on the recharge to and discharge from the ground-water systems. Information is needed to provide a data base from which to measure the effects of development and to provide data for management of the resource.

Objectives: (1) To collect water-level data sufficient to provide a minimum long-term data base so that the general response of the hydrologic system to natural climatic variations and induced stresses is known and potential problems can be defined early enough to allow proper planning and management. (2) To provide a data base against which the short-term records acquired in areal studies can be analyzed to provide an assessment of the ground-water resource, allow prediction of future conditions, and detect and define pollution and supply problems.

Approach: Evaluation of regional hydrogeology allows broad, general definition of aquifer systems and their boundary conditions. Within this framework and with knowledge of the stresses on the systems, the best locations for observation wells are selected to detect short- and long-term system behavior. The network of wells is improved as records become available and detailed areal studies of the ground-water system more closely define the aquifers, their properties, and the stresses to which they are subjected. Locations of wells within the statewide network are shown in figure 6.

Progress: The ground-water network contains 63 wells located throughout the State. Water-level data and hydrographs are published annually.

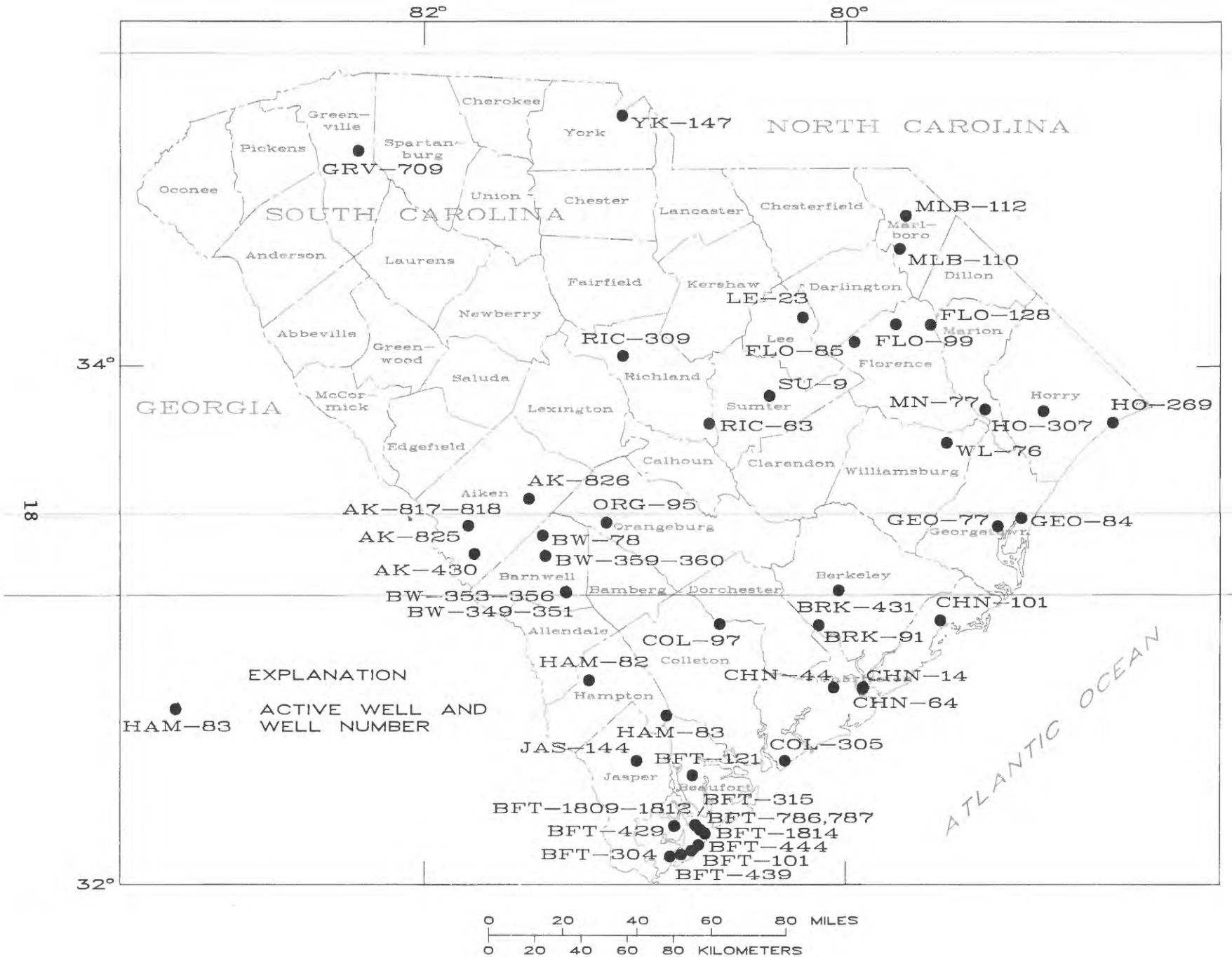

Figure 6.--Location of ground-water wells in the South Carolina District, 1989-91.

Project: SC002 (subproject), Saltwater encroachment modeling, Port Royal Sound area, South Carolina

Location: Port Royal Sound, Beaufort County, South Carolina

Project Chief: James E. Landmeyer

Period of Project: October 1990 - January 1992

Cooperation: South Carolina Water Resources Commission

Problem: Saltwater intrusion into the Upper Floridan aquifer has adversely affected ground-water quality near Port Royal Sound. Intrusion is the result of ground-water withdrawal at nearby production wells and takes place through confining beds of the Hawthorn Formation. This formation overlies the Upper Floridan aquifer, and locally may be eroded and replaced by more permeable recent sediments. Port Royal officials have proposed long-term maintenance dredging of Battery Creek, a tributary to the Beaufort River and Port Royal Sound containing saline water. Dredging will thin the overlying confining Hawthorn Formation and(or) more recent sediments in the shipping channel. It is not known whether dredging will increase the amount and rate of saltwater intrusion into the Upper Floridan aquifer.

Objectives: To investigate (1) the 3-dimensional location of the steady-state freshwater/saltwater interface in the Upper Floridan aquifer beneath Port Royal Island adjacent to the Battery Creek turning basin, (2) the aquifer characteristics of the Upper Floridan aquifer, and (3) the effects of removing creek-bottom confining sediments overlying the Upper Floridan aquifer on the position of the freshwater/saltwater interface.

Approach: The ground-water hydrology of the aquifer in the study area was investigated by installing seven monitoring wells onshore and performing an aquifer stress test. The position of the freshwater/saltwater interface was determined by conductance measurements at three depth intervals in each monitoring well, before, during, and after the aquifer pump test. The direction of ground-water flow was determined by using automatic depth recorders installed at four of the seven wells. A ground-water flow and solute transport model was constructed by using field-gathered data to aid in predicting the effect that maintenance dredging of Battery Creek will have on the location of the interface.

Progress: A report has been written and is in the review process.

Project: SC003, Water-quality network in South Carolina

Location: Statewide

Project Chief: Curtis S. Bennett, III

Period of Project: Continuous since 1967

Problem: Water-resource planning and water-quality assessment require a nationwide data base of relatively standardized information. For intelligent planning and realistic assessment of the water resources, the chemical and physical quality of the rivers and streams must be defined and monitored.

Objectives: To (1) provide a national bank of water-quality data for broad Federal planning and action programs, and (2) provide data for Federal management of interstate and international waters.

Approach: The project involves the operation of a network of water-quality stations, which provide average chemical concentrations, loads, and time trends as required by planning and management agencies. This network presently consists of continuous water quality monitors, the National Stream Quality Accounting Network (NASQAN), and the Hydrologic Benchmark Network. Locations of the network stations are shown in figure 7.

Progress: Four sets of samples are collected bimonthly and one set quarterly for chemical and biological analyses at the five stations operated under the National Stream Quality Accounting Network (NASQAN). Two Benchmark stations are operated; one bimonthly and one quarterly. Samples for radiochemical analyses are collected at two NASQAN sites semiannually, and at two Benchmark sites semiannually. Multiple-parameter monitors are operated at 36 sites. Single-parameter monitors are operated at 16 sites.

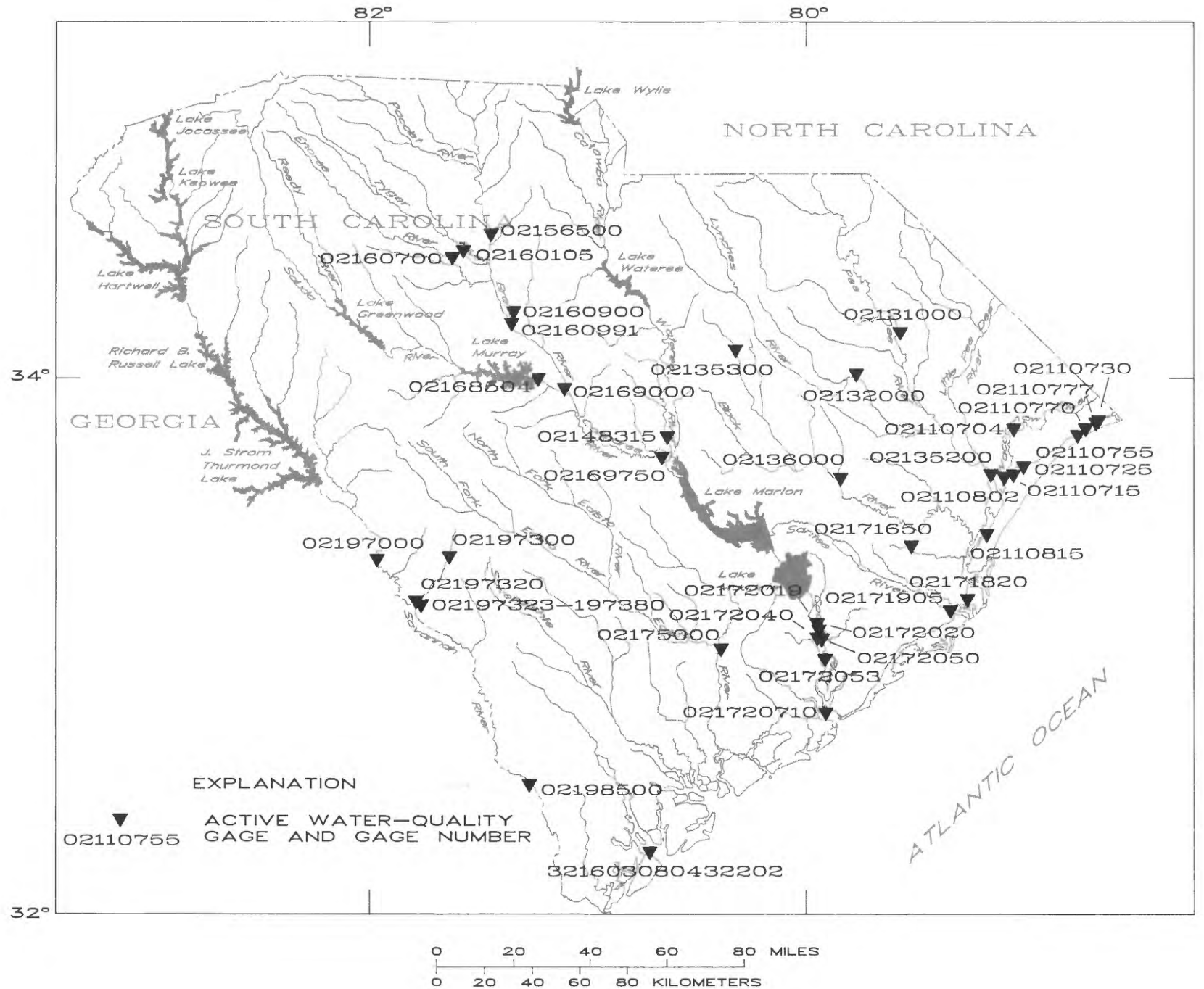

Figure 7.--Location of water-quality stations in the South Carolina District, 1989-91.

Project: SC003 (subproject), Dynamic assessment of the quality of water in the Atlantic Intracoastal Waterway, South Carolina

Location: Georgetown and Horry Counties, South Carolina

Project Chief: Paul Drewes

Period of Project: October 1989 - September 1992

Cooperation: Cities of Myrtle Beach, North Myrtle Beach, Conway, and Georgetown, the Grand Strand Water and Sewer Authority, and Waccamaw Regional Planning and Development Council

Problem: The city of Myrtle Beach plans to construct a canal to drain a large portion of the city's storm effluent, and is considering construction of a new wastewater treatment facility, both of which could discharge treated effluent into a section of the Atlantic Intracoastal Waterway (AIW). An existing wastewater treatment facility is in operation discharging variable rates of treated effluent into the Waccamaw River near Wachesaw Landing upstream of its confluence with the AIW. Because there would be concurrent withdrawals of drinking water from the AIW, an assessment of the assimilative capacity of the AIW is necessary to determine the quantity of treated effluent that can be discharged safely into the AIW. A recently completed unsteady flow model documents the variability in flow of the AIW, and suggests that a more accurate determination of varying assimilative capacity could be obtained by linking an unsteady water-quality model to the unsteady flow model. Results could then be used to determine a hydrograph-controlled release sequence of effluent discharge.

Objectives: To accurately assess the effluent assimilation potential of the Atlantic Intracoastal Waterway under varying flow and tidal conditions in an effort to optimize the assimilation capacity, while concurrently maintaining a high level of water quality for supply potential.

Approach: Dynamic-flow data were computed using the one-dimensional unsteady flow model (BRANCH). Flow data were coupled to a transport model, known as the Branched Lagrangian Transport Model (BLTM), which is capable of simulating the fate of water-quality constituents such as temperature and dissolved oxygen in networks of open channels with reversing flow.

Progress: The unsteady-flow model (BRANCH) has been calibrated. Simulated streamflows from the flow model were used with channel geometry information as input to the transport model, which has also been calibrated. Assessments currently are being made to determine the assimilative capacity under various flow conditions.

Project: SC004, Sediment station network in South Carolina

Location: Statewide

Project Chief: Curtis S. Bennett, III

Period of Project: Continuous since 1970

Problem: Water-resources planning and water-quality assessment require a nationwide data base of relatively standardized information. Sediment concentrations and discharges in rivers and streams must be defined and monitored.

Objectives: To (1) provide a national bank of sediment data for use in broad Federal and State planning and action programs and (2) provide data for Federal management of interstate and international waters.

Approach: The goal is to establish and operate a nationwide network of sediment stations to provide spatial and temporal averages and trends of sediment concentration, sediment discharge, and sediment-particle size transported by rivers and streams. The sediment data-collection network currently consists of two Hydrologic Benchmark Network and five National Stream Quality Accounting Network (NASQAN) stations.

Progress: Samples for concentration analyses were collected bimonthly at one Benchmark and seven NASQAN stations. Samples were also collected quarterly at one Benchmark and one NASQAN station.

Project: SC005, Effects of atmospheric deposition on water quality of South Carolina streams

Location: Santee Wildlife Refuge, Clarendon County, South Carolina

Project Chief: Curtis S. Bennett, III

Period of Project: Continuous since 1987

Problem: The extent and severity of atmospheric deposition and its effects on surface-water quality are poorly defined. Potential effects of acid inputs from this deposition include degradation of the biological communities of streams, increased rates of corrosion in water-supply systems, mobilization of trace metals, and threats to drinking-water supplies.

Objectives: To (1) determine variations in atmospheric deposition that occur on a week-to-week basis and (2) collect wet and dry deposition products for analysis of elements and compounds that can contribute to the chemical composition of surface waters.

Approach: The Santee Wildlife Refuge was selected as a site to be equipped to monitor amounts and quality of precipitation, stream discharge, stream-water quality, ground-water levels, and ground-water quality. Primarily, stream-water quality will be correlated with precipitation quality, but the influence of acid precipitation on ground-water quality will also be investigated.

Progress: One atmospheric deposition station has been operated since 1987.

Project: SC007, Water-use data-collection program in South Carolina

Location: Statewide

Project Chief: Susan C. Lambert

Period of Project: Continuous since 1978

Cooperation: South Carolina Water Resources Commission

Problem: Information is being collected describing quantity and quality of available water, but relatively little information is being collected describing water use. The increased utilization of the water resources in South Carolina for domestic, industrial, agricultural, and other uses and the demands for greater protection of water quality dictate that available supplies are matched with uses most beneficial to the common good. Without adequate information on uses of water, decision makers cannot resolve critical water problems including water-quality management, environmental impact, energy development, and resource allocations.

Objectives: To provide water-use information for the optimum utilization and management of South Carolina's water resources for the overall benefit of the people of South Carolina and the United States.

Approach: Responsibilities are divided between the cooperator and the USGS to reflect the most efficient means of meeting the objectives of the program. Direction, management, and standards development to meet the national needs are the responsibility of the USGS. Field activities for the acquisition, storage, and dissemination of the data are the primary responsibility of the South Carolina Water Resources Commission (SCWRC). Water-use information is obtained from various governmental agencies that collect water-use data and from municipalities, self-supplied industries, agricultural irrigators, and other water users. Statewide estimates of water use are compiled for 12 categories of use and are published in a national water-use circular that is published every 5 years. In addition, water-use data are updated periodically, and detailed water-use surveys are conducted for special projects in certain study areas.

Progress: Water-use data in the following categories were checked for accuracy: irrigation, livestock, mining, wastewater, and water suppliers. Data from 1983-89 were published by the SCWRC. The SCWRC data were successfully transferred to a USGS geographic information system.

Project: SC010, Statewide flood studies and site assessment

Location: Statewide

Project Chief: Curtis L. Sanders, Jr.

Period of Project: Continuous since 1968

Cooperation: South Carolina Department of Highways and Public Transportation

Problem: A knowledge of flood characteristics of streams is essential to highway designers, planners, and zoning commissions for the design of highway drainage and for planning the best use of flood-prone lands. Only through reliable estimates of flood magnitude and frequency is it possible to obtain economically optimum designs of highway bridges and culverts and to prepare realistic zoning ordinances.

Objectives: To (1) collect flood-flow data, (2) assess the hydraulics and hydrologic characteristics of streams, (3) analyze the data and characteristics for specific sites and selected reaches, and (4) document and prepare reports of flood events.

Approach: Data were collected from specific flood events to supplement the statewide gaging station network. Computer files containing basin characteristics and peak flow data are updated and maintained for use in flood frequency analyses. Letter reports are forwarded to cooperators to answer specific requests for hydraulic and hydrologic information for selected stream reaches. Reports assessing and analyzing flood data are prepared and disseminated.

Progress: Water-Resources Investigations Report 91-4157, updating flood-frequency information in South Carolina has been released. High-water elevation data were collected at 39 bridge sites following the flood of October 12, 1990, in Kershaw, Lee, and Sumter Counties.

Project: SC049, Low-flow frequency and duration of South Carolina streams

Location: Statewide

Project Chief: Michael G. Zalants

Period of Project: October 1987 - September 1989

Cooperation: South Carolina Department of Health and Environmental Control

Problem: An update of low-flow frequencies at continuous-record sites was needed to incorporate stations that previously had record of insufficient length. The update was also needed for updating previously analyzed stations. Ten additional years of record were used, which contained two periods of significant drought.

Objectives: To provide estimates of consecutive 1-, 3-, 7-, 14-, 30-, 60-, and 90-day minimum discharges with recurrence intervals of 2, 5, 10, 20, 30, and 50 years, depending on the length of discharge record available, for 55 continuous-record stream-gaging stations in South Carolina for which at least 5 years of unregulated daily mean discharge data exist through 1987.

Approach: The logarithms of the annual low flows were fitted to a Pearson type III distribution or a graphical determination was made of the low flows for each recurrence interval. Three basic steps were used to compute low-flow frequency discharge estimates for continuous-record gaging stations: low-flow discharge data for a station were (1) retrieved and compiled, (2) analyzed for detection of trends, and (3) ranked and analyzed for frequency of occurrence. Flow-duration records of daily discharges equal to or exceeding selected percentages of time were incorporated into a data base from the historical files, and tabulated.

Progress: This information was published for gaging stations located on regulated streams. Computation of low-flow statistics at all unregulated and regulated continuous record stations was completed. Water-Resources Investigations Report 91-4170, discussing the low-flow frequencies and durations, has been released.

Project: SC056, Saltwater encroachment in the limestone aquifer in the Hilton Head Island area, South Carolina

Location: Southern South Carolina

Project Chief: Barry S. Smith

Period of Project: January 1984 - September 1991

Cooperation: South Carolina Water Resources Commission

Problem: Large withdrawals from the aquifer in the Savannah, Ga., area have created a deep cone of depression that includes the Hilton Head Island area. Flow from a saltwater recharge area near Parris Island to the center of the cone at Savannah would pass through the Hilton Head Island area. If a saltwater recharge area exists near Parris Island, the aquifer under Hilton Head Island will eventually become salty, even if ground water is not withdrawn on the island. However, the probability of saltwater intrusion in the aquifer under Hilton Head Island and the time frame in which it might occur are not known at this time.

Objectives: To determine (1) the location and nature of the interfaces between freshwater and saltwater in the aquifer in the Hilton Head area, (2) the hydrologic parameters of the aquifer and confining beds, (3) the rate and direction of the movement of the saltwater-freshwater interface, (4) the length of time before saltwater degradation of the aquifer might be expected to occur, (5) the extent of local recharge to the aquifer, (6) probable effects of increasing local freshwater recharge, and (7) the possibility of stabilizing the saltwater-freshwater interface offshore of the island by freshwater recharge on the island.

Approach: Existing wells on Hilton Head Island were inventoried, water levels measured, and samples taken where possible. Nine test holes were drilled in Port Royal Sound and offshore in the Atlantic Ocean near Hilton Head Island. Information on aquifer characteristics, water quality, and water levels was collected before the wells were plugged. Additional onshore sites of three wells each were installed on and near the island. Each site was used to measure water quality, water levels, and aquifer characteristics. These wells were monitored throughout the investigation. The shallow aquifer was studied to determine existing and potential recharge on the island. Data were analyzed using ground-water flow and transport models.

Progress: A report, titled "Saltwater movement in the Upper Floridan aquifer beneath Port Royal Sound, South Carolina," by B.S. Smith, describing the solute transport model has been approved. A report discussing the geochemical aspects of the saltwater encroachment is in the process of being published.

Project: SC056 (subproject), Capture zone delineation of recharge to wells, Hilton Head Island, South Carolina

Location: Hilton Head Island, South Carolina

Project Chief: James E. Landmeyer

Period of Project: March 1990 - October 1992

Cooperation: South Carolina Department of Health and Environmental Control

Problem: Using capture zone delineation methodologies developed by the U.S. Environmental Protection Agency, it has been shown that ground water flows toward individual wells from a distance greater than the currently regulated arbitrary radius of 100 feet. Various methods for determining the capture zones of wells need to be compared to each other and to an analytical method to examine the problem of underestimating the water contribution to a well.

Objectives: To investigate (1) the lateral extent of well capture zones for municipal production wells on southern Hilton Head Island, using different methodologies, (2) the comparative effectiveness of the various methodologies in delineating the capture zones, and (3) the potential for capture of increasing amounts of induced freshwater and saltwater recharge occurring on southern Hilton Head Island.

Approach: Hydrogeologic data necessary for the various methods were compiled from existing data from the South Carolina Water Resources Commission and U.S. Geological Survey. For each simulation used to determine the capture zone, all data were consistent, and only the method of delineation varied. The results of the different methods were plotted and compared to each other and to a standard analytical solution.

Progress: A report describing the capture zone methodology, simulations, and comparisons is currently in review. An abstract describing the conditions for induced recharge was presented and has been published. A separate report describing the geochemical effects of induced recharge in the study area is currently in review.

Project: SC058, Determination of flood hydrographs for South Carolina streams

Location: Statewide

Project Chief: Larry R. Bohman

Period of Project: May 1984 - September 1991

Cooperation: South Carolina Department of Highways and Public Transportation

Problem: The hydraulic design of highway drainage structures involves an evaluation of the flood hazard to the highway. Risk analysis is a useful tool in evaluating the effects of a proposed highway crossing with regard to human safety, property easements, and stream stability. The application of risk analysis to the design of drainage structures allows the designer to select the design that will provide the least expected cost to the public. In order to design using risk analysis, the South Carolina Department of Highways and Public Transportation needs information on flood hydrographs associated with peaks of specific recurrence intervals at proposed stream crossings.

Objectives: To (1) define techniques for simulating flood hydrographs for specific design discharges of ungaged rural and urban sites in South Carolina, and (2) develop a method for estimating peak discharges for ungaged urban sites.

Approach: Two approaches were investigated in this study; (1) a dimensionless hydrograph approach, and (2) a unit-hydrograph approach. In the dimensionless hydrograph approach, average unit hydrographs and lagtimes were computed for each station. These hydrographs were then transformed to unit hydrographs having durations of one-fourth, one-third, one-half, and two-thirds lagtime and then reduced to dimensionless terms. Regional dimensionless hydrographs were determined by comparing observed and predicted hydrograph widths. Regression equations to define lagtime from physical basin characteristics were developed. In the unit-hydrograph approach, gamma function and Soil Conservation Service methods were investigated. This approach assigned a recurrence interval based on the rainfall as compared to the dimensionless hydrograph, whose design recurrence was based on the peak discharge. An urban rainfall-discharge network consisting of 27 stations was used to collect data to calibrate a rainfall-runoff model. Long-term sequences of flood peaks were then synthesized and used in regression analyses to determine urban peak discharge magnitude and frequency. A hydrograph analysis similar to the rural dimensionless hydrograph was performed.

Progress: A rainfall-runoff model was calibrated for 26 urban basins. A long-term series of synthesized annual peak discharges were generated by using the calibrated models and long-term weather records. A frequency analysis of the annual peak series was made, and the results were related to basin characteristics using multiple regression. Regional dimensionless flood hydrographs were developed. A report has been published.

Project: SC064, Distribution of aquatic macrophytes in South Carolina waters

Location: Statewide

Project Chief: Glenn G. Patterson

Period of Project: October 1984 - September 1991

Cooperation: South Carolina Water Resources Commission

Problem: South Carolina, like other southeastern States, is experiencing problems caused by growth of aquatic macrophytes in reservoirs and rivers. The primary problem is interference with boat travel. Other problems include adverse impacts on water quality, fish growth, and aesthetics. In order to make the most effective use of available control measures, it is important to have an accurate determination of the locations and extent of aquatic macrophyte infestations in the State, and of the plant species distribution within the infestations.

Objectives: To determine the areal extent of the significant aquatic macrophyte infestations in the public waters of South Carolina, determine the major plant species in each infestation, and depict the information on maps of the study areas.

Approach: Water-resources managers around the State were consulted to determine the water bodies that have significant infestations of aquatic macrophytes. The field method used in mapping the distribution of aquatic macrophytes was based on a method developed and used successfully on Lake Marion, S.C. The method relied heavily on field surveying by boat, with guidance and verification from aerial photographs. Color infrared aerial photographs were obtained a short time prior to field surveying and compared to results from the field surveys. Boundaries of infestations were entered in digital form into a computer, and maps of each affected water body were produced showing plant type.

Progress: A report has been written and published.

Project: SC070, Bacterial influences on ground-water chemistry

Location: Central South Carolina

Project Chief: Francis H. Chapelle

Period of Project: October 1986 - October 1989

Problem: There is presently insufficient information on the abundance, ecology, and metabolic functions of bacteria in deep Coastal Plain sediments. Because bacteria can influence ground-water chemistry through their metabolic activity, this lack of information is an obstacle to increasing our understanding of water chemistry in Coastal Plain sediments.

Objectives: To (1) provide a basic characterization of the bacteria present in Coastal Plain sediments including abundance and types, and (2) examine some impacts of bacterial metabolism on the major-ion, carbon isotope, and oxygen isotope composition of ground water.

Approach: Fluorescent microscopy and cell-staining techniques were used to determine direct counts of total and viable bacteria per gram of sediment. Direct count data were compared with geologic characterization of sediments to determine how bacteria counts vary with sediment textures. Elemental analyses were performed on the lignite materials obtained from core samples of the aquifer material. In addition, Nuclear Magnetic Resonance (NMR) spectroscopy was used to compare the relative amounts of different hydrocarbon groups (aliphatic, aromatic, polysaccharide, and so forth) present in lignitic materials. Based on the results of the NMR spectroscopy, a series of enrichment studies were designed and performed using bacteria-containing core subsamples to inoculate each media.

In order to document microbial impacts on ground-water quality, cores were obtained near 5 to 15 wells along well-defined flowpaths in the Cape Fear, Middendorf, and Black Creek aquifers. Water from each well was scanned for the presence and concentration of volatile fatty acids, alcohols, and other hydrocarbons. Samples for gas analysis of CH_4, N_2, CO_2, H_2S, and O_2 were obtained. Major and minor ion chemical analyses and determination of stable carbon isotope composition of dissolved carbonate species were made. Available techniques of inverse ground-water quality modeling were used to assess the impacts of microbial activity on water quality with a primary focus on the role of microbial activity on the formation of high-carbonate ground water.

Progress: Sediments from an 800-foot core hole near Lake City were sampled for concentrations of dissolved anions, acetate, and formate. Concentrations of sulfate were much higher in confining beds than aquifers, suggesting diffusive flux of sulfate to the aquifers.

Project: SC071, Transport simulation of striped bass eggs in Congaree, Wateree, and Santee Rivers, South Carolina

Location: Central South Carolina

Project Chief: Noel M. Hurley, Jr.

Period of Project: March 1987 - October 1989

Cooperation: South Carolina Wildlife and Marine Resources
South Carolina Electric and Gas Company
South Carolina Public Service Authority
South Carolina Department of Health and Environmental Control
Duke Power Company
South Carolina Water Resources Commission

Problem: The rate of reproduction of striped bass has decreased to a level that requires stocking to maintain the necessary population in Lake Marion.

Objectives: To predict and optimize the hatching location of striped bass eggs in the Congaree, Wateree, and upper Santee Rivers.

Approach: Hydrologic data from eight gaging stations were used to calibrate and verify simulation of mean cross-sectional velocities for both steady and unsteady flow conditions using the BRANCH model. The Lagrangian Transport Model was used to simulate the temperature and transport of the striped bass eggs. Dye tracer tests were used to simulate the longitudinal dispersion of the eggs.

Progress: A report was published in August 1991.

Project: SC073, Geohydrologic investigation in the vicinity of the hazardous-waste landfill near Pinewood, South Carolina

Location: Eastern South Carolina

Project Chief: Don A. Vroblesky

Period of Project: October 1987 - September 1990

Cooperation: South Carolina Public Service Authority

Problem: There is public concern regarding the potential for contamination of the ground-water and surface-water flow systems in the vicinity of the hazardous-waste landfill near Pinewood, South Carolina. These concerns are based on (1) recent detection of contamination in the upper Black Creek and water-table aquifers, (2) the recent release of two reports that cite inadequate knowledge of the ground-water flow system, and (3) the proximity of the landfill to the State's largest surface-water reservoir. Therefore, a comprehensive geohydrologic investigation of the landfill and vicinity is necessary to evaluate its potential vulnerability to ground-water and surface-water contamination.

Objectives: To (1) define the geohydrologic framework, (2) define water quality in aquifers, streams, and Lake Marion, (3) examine sediments and macroinvertebrates in the streams and Lake Marion, (4) measure seasonal flow characteristics of the surface-water resources, (5) define and mathematically model the ground-water flow system, and (6) numerically simulate movement of a potential conservative contaminant.

Approach: The first phase of the study included characterization of wastes, review of existing data, and installation of surface-water gaging stations. Data gaps were identified during the second phase, and data collection proceeded to provide information in the following areas: (1) surface water, (2) geohydrology, and (3) water quality and environmental monitoring. The final phase of the study concerned numerical modeling activities in which the areal ground-water flow system and the transport of conservative contaminants were examined.

Progress: Three reports discussing streamflow, benthic invertebrates, and geohydrology near Pinewood have been published. A modeling report has been written and is in review.

Project: SC074, Evaluation of techniques to assess ground-water resources in the Piedmont of South Carolina

Location: Hellers Creek, Newberry County, South Carolina

Project Chief: Larry G. Harrelson

Period of Project: December 1987 - September 1990

Cooperation: South Carolina Water Resources Commission

Problem: Ground-water resources in the Piedmont physiographic province of South Carolina are difficult to predict from well data. Ground water in the Piedmont is stored in saprolite, and, in places, is transmitted to wells that penetrate networks of open fractures, faults, joints, or foliation planes. Hydraulic properties of water-bearing zones in the Piedmont vary tremendously over short distances, and the zones of open networks containing ground water are difficult to define. Surface geophysical methods, remote-sensing techniques, ground-water flow modeling, geomorphology, topography, surface-water data, and ground-water data could be used separately or in combination to aid in assessing ground-water resources in the Piedmont.

Objectives: To (1) evaluate the utility of a variety of techniques for assessing the ground-water resources of a selected basin in the Piedmont and (2) assess the availability of ground water in the basin by using selected techniques, and where possible, verify the availability with well-production data.

Approach: To meet the objectives of this project, the following tasks will be performed: (1) a basin in the Piedmont will be selected for evaluation; (2) existing geologic and hydrologic data will be gathered and analyzed; (3) water-level and water-use data in the basin will be collected; (4) photos and images will be used to map and field check lineations; (5) geophysical surveys of control sites in the basin will be conducted to evaluate the capability and limitations of techniques; (6) selected geophysical surveys will be conducted to determine the water table, thickness of the alluvium and saprolite, bedrock surface, fracture zones, and impermeable boundaries; (7) data will be incorporated and analyzed with the aid of a Geographic Information System (GIS); and (8) the ground-water flow system will be analyzed with the aid of a flow model.

Progress: Objectives were modified and funding was reduced by agreement with the cooperator. Items (1) through (6) under Approach were completed.

Project: SC076, Work Plan for toxic waste research at Cone Mills Bleachery, Greenville, South Carolina

Location: Greenville, South Carolina

Project Chief: Glenn G. Patterson

Period of Project: August 1988 - September 1989

Problem: The Cone Mills Bleachery was selected as one of four sites in the Nation for development of a detailed work plan for federally funded toxic waste research. Plumes of water contaminated with chromium and organic compounds are moving through saprolite and fractured rock aquifers.

Objectives: To (1) develop an approved detailed work plan, and (2) determine effect of matrix diffusion on chromium transport and bacterial mediation of oxidation of organics in relation to chromium reduction in anaerobic subsurface environments.

Approach: Data pertaining to the site and processes used at the site were assembled and assimilated. Additional information pertinent to the investigation was obtained. The work plan was developed in consultation with other specialists.

Progress: Four wells were drilled and a stream sediment contamination survey was made. The work plan was completed and delivered to the Office of Water Quality, USGS. The site was not selected for further investigation.

Project: SC078, Remediation of JP-4 contamination by using hydraulic containment and in-situ biodegradation at the Defense Fuel Supply Point, Charleston, South Carolina

Location: Southeastern South Carolina

Project Chief: Don A. Vroblesky

Period of Project: October 1988 - September 1993

Cooperation: U.S. Department of the Navy

Problem: The shallow water-table aquifer near the Defense Fuel Supply Point (DFSP), Charleston, S.C., has been contaminated by JP-4 jet fuel. The contamination is present as dissolved organic compounds including benzene, toluene, ethylbenzene, and xylene (BTEX) in ground water and as organic compounds sorbed onto mineral grain surfaces of the sandy aquifer. Contaminated ground water extends below an adjacent subdivision. The South Carolina Department of Health and Environmental Control has approved a combination of hydraulic containment and in situ biodegradation as remediation strategy at the site.

Objectives: To (1) construct and calibrate a digital ground-water flow model of the DFSP site that can be used as a tool in designing the containment-biodegradation system, (2) estimate the amount of JP-4 sorbed onto aquifer materials prior to start-up of the containment-biodegradation system, (3) operate a monitoring program to measure water levels in pumped and monitoring wells, the quality of ground water recovered from pumped wells, and the amount and quality (including the amount of added nutrients) of water recirculated into the aquifer, and (4) construct a digital solute-transport model to estimate the time required to decontaminate the aquifer below a given threshold.

Approach: The McDonald-Harbough 3-dimensional ground-water flow model will be used as a tool to determine the placement and rate of pumping recovery wells. Aquifer materials will be analyzed for petroleum hydrocarbons by using infrared spectroscopy to estimate the amount of JP-4 on aquifer solids. Pumping and recirculation rates will be monitored with flow meters. Water-quality monitoring will be initiated at system start-up. Constituents to be monitored include bromide, phosphate, BTEX, and total organic carbon. Nitrate uptake associated with degradation of organic material will be coupled with a digital solute-transport model to estimate the time required to decontaminate the aquifer below a predetermined threshold.

Progress: Results of field analyses showed that contamination near tank 3 was of a different character than the contamination near tank 1. The contamination at tank 1 is JP-4, and the contamination near tank 3 may be a mixture of tank bottoms and motor or aviation fuel. The analyses also showed a high potential for precipitation of iron hydroxides from the extracted (contaminated) ground water during recirculation in the bioremediation system. Thus, it was necessary to locate an alternative water supply for the bioremediation system.

Project: SC079, Bacterial metabolism and the origin of high-iron ground water in Coastal Plain aquifers of South Carolina

Location: Florence County, South Carolina

Project Chief: Francis H. Chapelle

Period of Project: October 1989 - October 1991

Cooperation: South Carolina Water Resources Commission

Problem: Coastal Plain aquifers commonly exhibit zones of high-iron ground water. In spite of the wide occurrence of this problem, the fundamental cause is not understood. Because ferric oxyhydroxides are not reduced inorganically by naturally occurring organic material, a bacterially mediated mechanism for ferric oxyhydroxide dissolution, and resulting high iron concentrations, is possible. Data are presently unavailable to test this possibility.

Objectives: To (1) determine concentrations of dissolved fermentation products in relation to high-iron zones of ground water, (2) measure rates of bacterial metabolism in deep cored sediments by using radiotracer experiments, and (3) establish the presence or absence of iron-reducing bacteria by incubating deep-cored sediment in iron-reducer specific media.

Approach: (1) Sample water from wells and measure dissolved fermentation products such as organic acids and hydrogen; (2) quantify rates of $^{14}CO_2$ productions from deep-cored sediments amended with (^{14}C) glucose and (2-^{14}C) acetate; (3) isolate iron reducers using media containing ferric hydroxide as a sole electron accepter.

Progress: Published reports for this project are: (1) Fe(III)-reducing bacteria in deeply buried sediments of the Atlantic Coastal Plain, by D.R. Lovley, F.H. Chapelle, and E.J.P. Phillips, Journal of Geology; (2) Competitive exclusion on sulfate reduction by Fe(III)-reducing bacteria: A mechanism for producing discrete zones of high-iron ground water, by F.H. Chapelle and D.R. Lovley, Journal of Ground Water; (3) Geochemistry of dissolved inorganic carbon in a coastal plain aquifer: 1. Sulfate from confining beds as an oxiduct in microbial CO_2production, by F.H. Chapelle and P.B. McMahon, Journal of Hydrology.

Project: SC077, An evaluation of the hydraulic properties, geology, water quality, and water levels of ground-water aquifers under Florence, South Carolina, and surrounding counties

Location: Northeastern South Carolina

Project Chief: Bruce G. Campbell

Period of Project: October 1988 - September 1992

Cooperation: South Carolina Water Resources Commission

Problem: Florence and surrounding counties rely heavily on water from the Middendorf aquifer. Heavy pumping and rather low transmissivity have resulted in a large cone of depression in the potentiometric surface centered under Florence. Potentiometric levels in the center of the cone have declined more than 150 feet, and well yields have declined. Additionally, some parts of the study area experience problems with high concentrations of iron and low pH. A better understanding of the flow system, developed using a calibrated ground-water flow model, is needed to facilitate better management of the resource.

Objectives: To (1) delineate the aquifers in the area, (2) determine the hydraulic properties of the aquifers, (3) map historic water levels, (4) describe the water quality of each aquifer, (5) develop a digital flow model, and (6) simulate pumpage and its effects on aquifers on the area.

Approach: Available data are being evaluated, and supplemented with data from test drilling, from aquifer tests, water-quality analyses, water-level monitoring, and new production wells. A computer model of ground-water flow is being utilized to evaluate the aquifers.

Progress: A well data file for predevelopment to 1982 has been completed. Water-quality sampling has been completed and a report is in preparation. Steady-state model calibration has been completed. Transient model calibration has begun. The model has been reworked for transient runs.

Project: SC080, Bacterial metabolism and the development of secondary porosity and permeability in Coastal Plain aquifers, South Carolina

Location: Southeastern South Carolina

Project Chief: Peter B. McMahon

Period of Project: October 1988 - October 1991

Cooperation: South Carolina Water Resources Commission

Problem: Secondary porosity and permeability constitute significant conduits for ground-water movement. Data suggest a relation between bacterial metabolism and the development of secondary porosity and permeability. Data are presently insufficient, however, to quantitatively show the relation between bacterial activity in the subsurface and zones of high secondary porosity and permeability.

Objectives: To (1) identify zones of high bacterial activity in clastic and carbonate sediments of the Floridan aquifer system, (2) measure the amount and distribution of secondary porosity and permeability in these sediments, and (3) determine the relation between zones of high bacterial activity and high secondary porosity and permeability.

Approach: Cored sediments of the clastic and carbonate portions of the Floridan aquifer were analyzed for bacterial activity by amending them with ^{14}C labelled substrate and measuring the accumulation of $^{14}CO_2$. Secondary porosity and permeability were measured using petrographic image analysis. In order to relate bacterial activity to secondary porosity and permeability, mass balance and equilibrium speciation calculations on dissolved chemical constituents were used to estimate the amount of mineral dissolution and the geochemical reactions responsible.

Progress: An article on geochemistry and microbiology has been completed and published in NATURE. A report on the relation between bacterial metabolism and secondary porosity and permeability has been completed and will be published in January 1992 in the Journal of Sedimentary Petrology.

Project: SC081, Geohydrology of the Middendorf and Black Creek aquifers underlying Charleston, Berkeley, and Dorchester Counties, South Carolina

Location: Southeastern South Carolina

Project Chief: Bruce G. Campbell

Period of Project: January 1989 - September 1992

Cooperation: South Carolina Water Resources Commission

Problem: Increasing demands on the ground-water resources of the study area have caused documented water-level declines. The rate of the water-level declines over the three-county area has not been assessed and is of concern to the South Carolina Water Resources Commission and water users. A ground-water flow model is needed so we can better understand the system.

Objectives: To describe the geohydrologic framework of the Middendorf and Black Creek aquifers underlying the study area, define directions and rates of ground-water movement, evaluate the impact of increased pumpage on water levels, and define water chemistry, including the distribution of chloride in each major water-bearing zone.

Approach: The project will progress using the following plan: (1) Review existing data; (2) collect data, including hydrologic characteristics, water levels, and geochemical characteristics; (3) determine directions and rates of ground-water movement with the use of a three dimensional ground-water model; (4) use the model to evaluate effects of increases in pumpage on water levels.

Progress: The steady-state model calibration has been completed. Transient model calibration has begun. The well data file for predevelopment to 1982 has been completed and the model reworked for transient runs. A paper, titled "Recent Revisions to the Stratigraphy of the Subsurface Cretaceous Sediments in the Charleston, S.C., Area" was accepted for publication in South Carolina Geology. An abstract, titled "Water Level Declines in the Middendorf Aquifer, Charleston, Dorchester, and Berkeley Counties, South Carolina" was accepted for presentation of an AWRA Symposium in Raleigh, N.C. Water level changes have been correlated to pumping levels in the study area.

Project: SC082, Reconnaissance of potential for scour at bridges in South Carolina

Location: Statewide

Project Chiefs: Noel M. Hurley, Jr., and Stephen T. Benedict

Period of Project: April 1990 - September 1996

Cooperation: South Carolina Department of Highways and Public Transportation

Problem: Scour is water-caused erosion that degrades stream beds and banks. Scour at river-crossing structures can weaken the bridge or culvert or, in worst cases, cause structure failure that might result in injury or loss of life.

Objectives: To (1) evaluate stream-channel conditions in the vicinity of river-crossing structures relative to their role in affecting local scour; (2) identify trends in channel conditions with respect to region, drainage basin, stream, soil types, and so forth; (3) evaluate and rank river-crossing structures with respect to the potential for scour or filling; and (4) perform a more detailed analysis at bridge sites selected by South Carolina Department of Highways and Public Transportation (SCDHPT) to provide additional scour information.

Approach: Qualitative evaluations at bridge sites with channel beds consisting of alluvium will be made by observing and measuring the variables that have been deemed relevant to bed scour in previous studies. The variables will be separated into structural and channel categories. Structural variables include, but are not limited to, pier shape, number and type, under-clearance, abutment condition and type, slope protection, and number of relief bridges. Channel variables are more subjective and complex and include channel width and gradient, approach angle, bank height, bank angle, bank vegetative cover, bank material, bed material, debris present, location of meander impact points, and information concerning flood plain use and evolutionary development of the channel. These variables will be weighted as to their importance to scour potential and summed to produce a scour-potential index for each site. Summaries of channel conditions, based on the potential scour index, will be assembled and input to a Geographical Information System (GIS) for the identification of regional trends. A certain percentage of those bridges that have been ranked as having high scour (or fill) potential will be selected for more detailed field work and for flow and sediment modeling. Approximately 515 bridges will be selected for detailed analysis. The sediment model BRI-STARS or equations described in HEC-18/HEC-20 will be used to compute and combine general scour (degradation), contraction scour, and local scour to quantitatively estimate total potential scour at the site. The resulting values representing total potential for bed-level lowering will also be input to the GIS data base in order to identify problem areas within the State.

Progress: To date (1992), 3,500 bridges have been inspected, and preliminary data have been given to the South Carolina Department of Highways and Public Transportation. Personnel have attended classes covering BRI-STARS, stream bed and bank stability, and Hy-drain.

Project: SC083, Hurricane Hugo tidal floods of September 21-22, 1989, along the South Carolina coast

Location: Coastal South Carolina

Project Chief: R. Erik Schuck-Kolben

Period of Project: October 1989 - September 1991

Cooperation: Federal Emergency Management Agency

Problem: Just after midnight on September 22, 1989, Hurricane Hugo hit the mainland coast north of Charleston, S.C. A path of destruction 60 to 100 miles wide from the coast inland to the vicinity of Charlotte, North Carolina, was created by the storm, which had sustained winds of 135 miles per hour and was moving about 20 to 25 miles per hour at landfall. Twenty-nine persons in South Carolina lost their lives during the storm and its aftermath through drowning, falling trees, fires, electrocutions, and other causes. Approximately 22 counties in South Carolina were declared disaster areas. Hugo, the most expensive storm in United States history to that point, caused an estimated $6 billion of damage to South Carolina alone. The storm, which struck about 1 hour before high tide, caused heavy coastal flooding from the Charleston area to the North Carolina-South Carolina border area. Preliminary estimates indicate a maximum storm surge of about 17 feet occurred in the vicinity of Bulls Bay near Awendaw, S.C. A need exists by local, State, and Federal agencies for a report that documents the extent and magnitude of flooding caused by Hurricane Hugo tidal floods. Flood elevations experienced during Hurricane Hugo can be compared with flood frequency relations developed in earlier flood insurance studies to estimate the return intervals of flooding from Hugo at various locations.

Objectives: To collect, compile, analyze and map high-water elevation data from Edisto Beach to North Myrtle Beach.

Approach: (1) Collection of high-water elevation data: The USGS began flagging high-water marks from the storm surge within 2 days of the storm. These marks and the nearby ground elevations were surveyed in order to reference them to bench marks of known elevation. To the extent possible, maximum water elevations, including wave heights, were collected or estimated, as were maximum still-water storm-surge elevations. Data were collected along the South Carolina shoreline from the North Carolina border to Edisto Beach. Data collected were of sufficient density to develop profiles of storm-surge attenuation from the shoreline to the inland limit of flooding and to develop approximate profiles of wave-height attenuation from the shoreline to the inland limit of significant wave action in areas of heavy coastal development. (2) Compilation and analysis of data: The USGS analyzed surveyed high-water information and established best estimates of still-water storm-surge elevations and maximum wave-crest elevations at representative points within coastal areas inundated by Hurricane Hugo. Where sufficient data were available to do so, profile plots of still-water storm-surge elevations, maximum wave-crest elevations and ground elevations from the shoreline to the inland limits of flooding were developed. An alongshore profile of maximum storm-surge elevation also was developed for the reach of the coastline studied. (3) Mapping of data: Based on data collected and analyzed as described above, a map showing storm-surge elevations measured at various

points within the study area was developed. Mapping was prepared on USGS quadrangle maps at 1:24,000 and 1:100,000 scale.

Progress: Two reports have been written; one has been published, the other is in review.

Project: SC084, Simulation of flow-pattern changes in Foster Creek, Bushy Park Reservoir, and the Cooper River near Charleston, South Carolina, due to controlled opening of the Bushy Park Dam on the Back River

Location: Cooper River basin, South Carolina

Project Chief: David E. Bower

Period of Project: May 1990 - May 1992

Cooperation: Commissioners of Public Works, City of Charleston, SC

Problem: The city of Charleston currently (1992) withdraws up to one-third of its freshwater supply from Foster Creek, which, due to the hydraulics of the flow system, has substandard characteristics during certain times of the year. A model is needed to determine rates of flow at various points within the Cooper River-Back River-Foster Creek system and to simulate the effects of potential changes in the the flow system.

Objectives: To (1) determine the flow of water at various points within the Cooper River, Back River, and Foster Creek, and (2) determine changes in flushing times at various points due to potential modification of flow through the present South Carolina Highway 176 earthen dam on Back River.

Approach: The study utilized a one-dimensional unsteady flow model for simulation of flow in singular and interconnected channels (BRANCH) developed by the USGS. The model has the following capabilities: (1) computing discharges throughout the system, (2) providing a tool for simulating changes in withdrawals from the system or transfers from one part of the system to another, and (3) tracking of particles through the system from various points in order to determine "flushing" times unaffected by dispersion. A number of continuous stage recorders were established to provide the data required to operate the model and provide interior calibration points for water-surface elevations. Other field data required for calibration include cross-sectional data throughout the modeling reach and at least two tidal cycle discharge measurements at strategic points in the system. Once calibrated, various scenarios were modeled to determine the overall effects of changes within the flow system. The most important of these scenarios demonstrated the possible effect on water quality resulting from a controlled opening of the earthen dam, which currently separates the Back River Reservoir (Bushy Park Reservoir) from the Cooper River.

Progress: All required gaging stations were installed. Data collected through June 1991 were loaded into the data base. Water-use data have been obtained, converted, and loaded into the data base at hourly intervals through June 1991. Five separate versions of the BRANCH model have been implemented. They are (1) Pinopolis Dam to Stony Landing; (2) Pinopolis Dam to Durham Canal (station 02172025); (3) Station 02172025 to Back River Dam; (4) Station 02172025 to Yellowhouse Creek (station 02172065); (5) All of the above. This last version includes 33 branches, 32 junctions, 115 cross sections, and 28 measured data locations (stage and(or) discharge). External boundary data for the overall model are provided by three gaging stations. Final fit of this model has been completed. The report has been written and is in the review process.

Project: SC085, Hydrologic aspects of waste disposal in the Piedmont terrain of Pickens County, South Carolina

Location: Pickens County, South Carolina

Project Chief: Whitney J. Stringfield

Period of Project: November 1990 - September 1992

Cooperation: Pickens County, South Carolina

Problem: Increasing volumes of solid waste require development of additional sanitary landfills. The Piedmont province of the eastern United States is characterized by a heterogeneous hydrogeologic system consisting of hard, fractured parent rocks overlain by clay-rich saprolite derived from the weathering of the rocks. An improved understanding of existing and potential interactions between landfills and their local and regional hydrogeologic settings in the Piedmont region is necessary.

Objectives: To (1) describe the hydrogeologic framework underlying proposed landfills in Pickens County, S.C., including the relation between site and local/regional hydrogeology, (2) measure streamflow, analyze surface-water quality, and determine seasonal flow characteristics of any streams that drain or are adjacent to the landfill, and (3) define background water chemistry in the ground water in the vicinity of the landfill, which could be potentially impacted by contamination from the facility.

Approach: The project was undertaken in two phases: The first phase involved the characterization of existing data including published literature, information in unpublished works, and files of regulatory and other government agencies. Other information was collected by site inspection of the proposed landfill, and included an inventory of existing wells and borings and other hydrologic parameters such as geologic units, seismic activity and faulting, ground-water movement and quality, flood-plain delineation, and wetlands. The second phase involved a more intensive investigation including borings to determine depth and extent of saprolite, and construction and development of cluster wells. Surface-water quality samples were collected and analyzed from nearby streams, and biannual samples of ground water were collected and analyzed.

Progress: A site hydrogeologic characterization report has been written and is in review.

Project: SC086, Ground-water flow and quality in the vicinity of the Savannah River at the Savannah River Site, Georgia and South Carolina

Location: Upper Coastal Plain of South Carolina and Georgia

Project Chiefs: John S. Clarke, Georgia
W. Fred Falls, South Carolina

Period of Project: August 1991 - September 1996

Cooperation: U.S. Department of Energy

Problem: The hydrologic relation of the Savannah River to the ground-water flow system in the Cretaceous- and Tertiary-age aquifers at the Savannah River Site (SRS) is not well understood. Concern over the possible migration of contaminants from hazardous-waste sites on the SRS has raised the question of whether trans-river flow is occurring in the aquifers under the Savannah River, and if not, under what conditions such trans-river flow might occur.

Objectives: Evaluate and describe the conditions under which ground water at SRS can migrate beneath the Savannah River to aquifers on either side.

Approach: The Georgia and South Carolina Districts will collaborate on most phases of the project. The Georgia District work will emphasize coring, well installation, geohydrology, modeling, borehole geophysics, water-quality sampling, and ground-water monitoring. South Carolina District work will emphasize geologic framework, coring, surface geophysics, surface water, some geohydrology, and some water-quality sampling. To acquire more geologic, hydrologic, and water-quality data in the Georgia part of the study area, several sites will be selected for continuous coring of a geohydrologic-test well from land surface to pre-Cretaceous rock and for construction of monitoring wells in pertinent hydrologic units. Data from the Georgia well clusters in combination with the existing database will be used to describe the geohydrology of the study area, determine hydrologic properties and background water quality for aquifers, and develop a digital model of ground-water flow to include the Savannah River site and adjacent areas of Georgia and South Carolina. Geochemical mass-balance modeling along flowpaths in the study area will be used to evaluate isotopic data and radiocarbon ages of ground water.

Progress: Literature review, data review, and well inventory are underway. The first three core sites have been selected and permission obtained from land owners for well installation. The first meeting of technical advisory committee was on September 11, 1991. A low-flow gain-loss study on the Savannah River identified a reach of the river with an apparent large ground-water discharge.

Project: SC087, Investigation of nonpoint-source pollutants in the Myrtle Beach area, South Carolina

Location: City of Myrtle Beach, South Carolina

Project Chief: Wladmir B. Guimaraes

Period of Project: December 1990 - September 1991

Cooperation: City of Myrtle Beach

Problem: The city of Myrtle Beach is a rapidly developing resort area on the northern South Carolina coast. The seasonal population can exceed several million as tourism is the main industry. As the tourist industry continues to expand, land development also expands, which decreases the amount of pervious land. Runoff volumes are increased as is the total pollutant load. The city's current stormwater collection system is antiquated, and consists of 180 24-inch pipes, which discharge onto the beach, and a canal system, which leads to a tidal micro-estuary. Previous studies have shown degraded water quality in the micro-estuary (swash), which drains approximately 60 percent of the city.

Objectives: To (1) characterize the quantity and chemical, physical, and biological composition of the water flowing into and out of the swash, (2) identify possible sources of pollutants, and (3) numerically simulate flow and water quality under existing conditions.

Approach: Continuous stage recorders will be installed on Withers Swash, the micro-estuary, and a principal tributary. The basins will be equipped with rainfall recorders as well. Stormwater quality samples will be collected at each gaging station for three summer thunderstorms, which follow a dry period of at least 3 days. Discrete water samples will be taken before the stream begins to rise, at some point during the initial "wash-off," at the peak discharge point of the hydrograph, and again at the midpoint of the recession. Physical parameters analyzed include temperature, pH, and conductance. Biological parameters such as fecal bacterial counts and biochemical oxygen demand samples will be collected for in-house analysis. Chemical analyses for alkalinity, chloride, suspended and dissolved solids, and nutrients including total nitrogen, nitrate, nitrite, ammonia, phosphate, and sulfate will be made. Analyses for toxic metals, metallic phenols, non-toxic metals, and oil and grease will also be made. Tests to detect the presence of certain organic toxic pollutants recommended by the Environmental Protection Agency (EPA) for inclusion in obtaining stormwater discharge permits under new National Pollution Discharge Elimination System (NPDES) regulations will also be made. The flow and water-quality data may be used to calibrate the Stormwater Management Model (SWMM) in order to facilitate decisions for remedial actions by the city of Myrtle Beach to improve beach water quality following storm events.

Progress: Water-quality sampling has been completed. Calibration of the SWMM is near completion.

Project: SC088, Contamination assessment of Foster Creek

Location: Foster Creek basin, Berkeley County, South Carolina

Project Chief: Ted R. Campbell

Period of Project: April 1991 - December 1992

Cooperation: U.S. Navy, Southern Division Naval Facilities Engineering Command

Problem: Foster Creek, a sluggish, small tidal creek near Charleston, S.C., has been made even more stagnant by a dam below its mouth. People served by a municipal water intake in Foster Creek complain of poor water quality. The Navy needs to know if their facilities adjacent to the creek may be contributing to the problem.

Objectives: (1) Assess the impact of operations at the Naval Weapons Station on water quality in Foster Creek, and (2) gain a better understanding of flow in Foster Creek.

Approach: Stated objectives will be met by collecting and analyzing water-quality samples in Foster Creek and its tributaries. The hydrodynamics of the system will be examined by using the one-dimensional unsteady BRANCH flow model and corresponding particle tracking. Three gages have been installed in headwater tributaries.

Progress: The project is currently on schedule. Preliminary screening samples have been collected and the first of two series of water-quality sampling has been completed. Modeling is underway.

Project: SC089, Use of nitrate for bioremediation of a jet fuel spill in a shallow aquifer at Hanahan, South Carolina

Location: Hanahan, Berkeley County, South Carolina

Project Chief: Don A. Vroblesky

Period of Project: August 1991 - July 1992

Cooperation: U.S. Environmental Protection Agency, Robert S. Kerr Laboratory

Problem: An ongoing bioremediation project at Hanahan in cooperation with the U.S. Navy needs better definition of the depth-specific distribution of contaminants (BTEX) in the aquifer before and at the end of the bioremediation process.

Objectives: Provide data regarding the extent of remediation throughout the three-dimensional extent of the contaminated zone.

Approach: Sediment core samples from 4 to 8 locations were collected for about 300 depth-specific samples, prior to and after remediation, for BTEX. Depth-specific monitoring-well clusters for water sampling were installed.

Progress: Wells were installed and pretreatment sediment cores were collected and analyzed.

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WATER RESOURCES DIVISION PROGRAMS AND SERVICES

Current programs and activities of the Water Resources Division are discussed briefly below. Addresses are given for sources of additional information or publications.

Water-Data Program

Water data are collected at thousands of locations throughout the Nation by the U.S. Geological Survey to monitor streamflow and stage (height), reservoir and lake storage, ground-water levels, well and spring discharge, and the quality of surface and ground water. These data provide a continuing record of the quantity and quality of the Nation's surface- and ground-water resources, and thus provide the hydrologic information needed by Federal, State, and local agencies and the private sector for the development and management of land and water resources. All data collected are stored in the Survey's National Water Data Storage and Retrieval System (see WATSTORE for additional information) and also are published by water year for each State in a publication series entitled "U.S. Geological Survey Water-Data Reports." Information about the Water-Data Program can be obtained from:

U.S. Geological Survey
Assistant Chief Hydrologist for Operations
441 National Center
Reston, Virginia 22092

or from the District Chief of the State of interest.

National Water Data Exchange

The National Water Data Exchange (NAWDEX) was established to assist users of water data in identifying, locating, and acquiring needed data. It provides a nationwide service for indexing and describing the characteristics of data available from the entire spectrum of data-collection activities throughout the Federal and non-Federal water-data community. NAWDEX maintains two data bases: (1) a Water-Data Sources Directory, which identifies organizations that are sources of water and water-related data and locations within these organizations from which data may be obtained, and (2) a Master-Data Index of data collection sites. For services or additional information, contact:

National Water Data Exchange
U.S. Geological Survey
421 National Center
Reston, Virginia 22092
(703) 648-5677

National Water Data Storage and Retrieval System

Access to all types of water data is available through the National Water Data Storage and Retrieval System (WATSTORE). Data are grouped and stored on the basis of common characteristics and data-collection frequencies. These data are organized into seven files: (1) Station Header File, (2) Ground-Water Site Inventory File, (3) Water-Use File, (4) Daily-Values File, (5) Peak-Flow File, (6) Water-Quality File, and (7) Unit-Values File. All types of water data can be retrieved through the central computer facilities in Reston, Va., from a number of localities nationwide. The requestor is charged a minimal fee plus the actual computer cost incurred in retrieving the data. Cost estimates and information about WATSTORE can be obtained from Water Resources Division District Offices and from:

Chief Hydrologist
U.S. Geological Survey
437 National Center
Reston, Virginia 22092

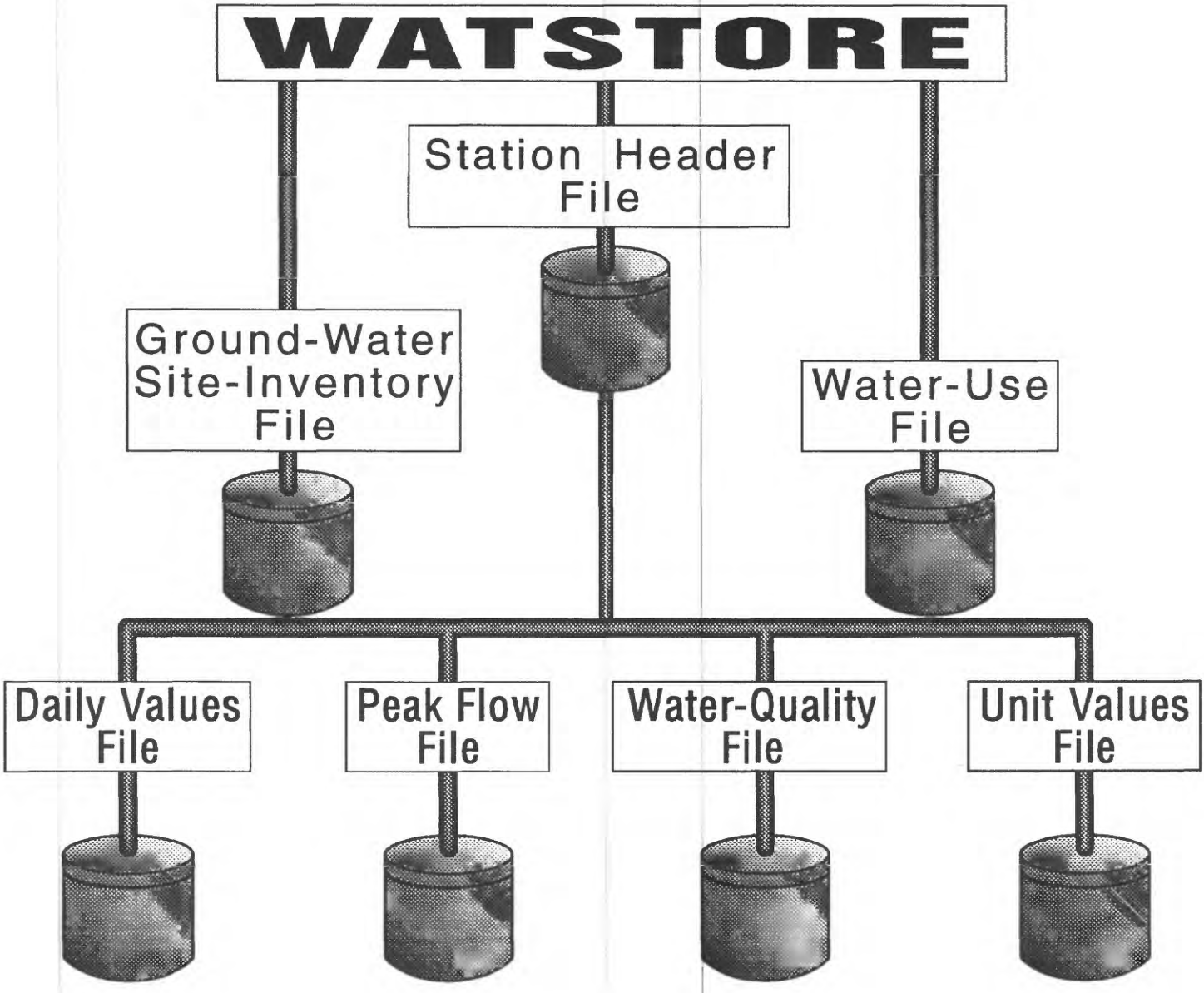

Figure 8.--Organization in National Water Data Storage and Retrieval System.

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Reston, VA 22092

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