GROUND-WATER CONDITIONS IN THE SANTEE LIMESTONE AND BLACK MINGO FORMATION NEAR MONCKS CORNER, BERKELEY COUNTY SOUTH CAROLINA

Ground Water in Moncks Corner Area, Berkeley County, South Carolina

Meadows 1987

STATE OF SOUTH CAROLINA

WATER RESOURCES COMMISSION
REPORT NUMBER 156
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GROUND-WATER CONDITIONS IN THE SANTEE LIMESTONE AND BLACK MINGO FORMATION NEAR MONCKS CORNER BERKELEY COUNTY, SOUTH CAROLINA

by
J. Kevin Meadows

ABSTRACT

Rapid growth in and near Moncks Corner, Berkeley County, South Carolina, has escalated ground water use from the Santee Limestone Black Mingo aquifer system and caused water levels to decline in wells. Some residents with wells in these two units have had water availability problems.

The Tertiary-age Cooper Formation, Santee Limestone, and Black Mingo Formation compose a hydrologic system that supplies most of the ground water in the study area. The Cooper Formation is a confining unit that produces artesian conditions in the underlying Santee Limestone and Black Mingo Formation. Ground-water withdrawal in the Santee comes mostly from the lower part, called the Moultrie Member. Ground-water withdrawal in the Black Mingo comes mostly from sand and limestone beds in the upper part of the unit. Data indicate that these two water-yielding zones are hydraulically connected. Most wells are open to both zones.

Specific capacities of Santee-Black Mingo wells average 2 gallons per minute per foot, or less. Most 6-inch diameter and larger wells produce at least 100 gallons per minute. Transmissivity varies, but it generally ranges between 300 and 700 feet squared per day. Water from wells open to both units is a hard, alkaline, calcium or sodium bicarbonate type in the northern half of the study area, and a soft, more mineralized, sodium bicarbonate type in the southern half. Water quality deteriorates with depth below the uppermost sand beds of the Black Mingo.

Since 1970, static water levels have declined about 20 feet in the northern half of the study area and about 50 feet in the southwestern part. At present rates of decline (2-3 feet per year), pumping water levels in high-capacity wells will be low enough in the year 2000 that dewatering of the Santee-Black Mingo may occur locally.

Below the Santee-Black Mingo aquifer system, the Peedee, Black Creek, and Middendorf Formations contain aquifers available for use. Of these, the Black Creek and Middendorf are the most productive. Wells could yield as much as 1,000 gallons per minute. Static water levels would be at or above land surface. The water would be a soft, sodium bicarbonate type, similar to Santee-Black Mingo water.

INTRODUCTION

The study area surrounds the town of Moncks Corner in central Berkeley County and encompasses about 100 square miles (Fig. 1). The region from Moncks Corner south toward Summerville has been characterized by rapid growth. This has escalated demand on the area's ground-water resources. Most water users rely on two hydraulically connected water-bearing units, the Santee Limestone and the Black Mingo Formation. It is in this Santee Black Mingo aquifer system that most water use is concentrated.

During the summer of 1984, the South Carolina Water Resources Commission (SCWRC) began receiving reports of ground-water problems occurring just south of Moncks Corner. Residents reported that water levels were falling below the reach of pumps in some wells and that declining levels were causing low water pressure in others. As a result of these complaints, the SCWRC has made a study of the ground-water conditions of the area.

Purpose and Scope

The purpose of this study was to determine the cause of water level declines in wells near Moncks Corner, S.C., and propose a remedy. This involved: (1) identifying the aquifer tapped by the wells, (2) mapping the water level surface, (3) evaluating pumping effects, (4) obtaining data to help predict future water levels, and (5) examining alternative or supplemental ground-water supplies.

Previous Investigations

Previous South Carolina Coastal Plain investigations incorporating the Moncks Corner area include: Cooke (1936), who described Coastal Plain geology; Taber (1939), who described the geology of the Santee-Cooper reservoir area; Spiers (1975), who described the hydrogeologic effects of the Cooper River rediversion canal; Ward and others (1979), who described the stratigraphy of the Santee Limestone; and Park (1985), who described the hydrogeology of Charleston, Berkeley, and Dorchester Counties.

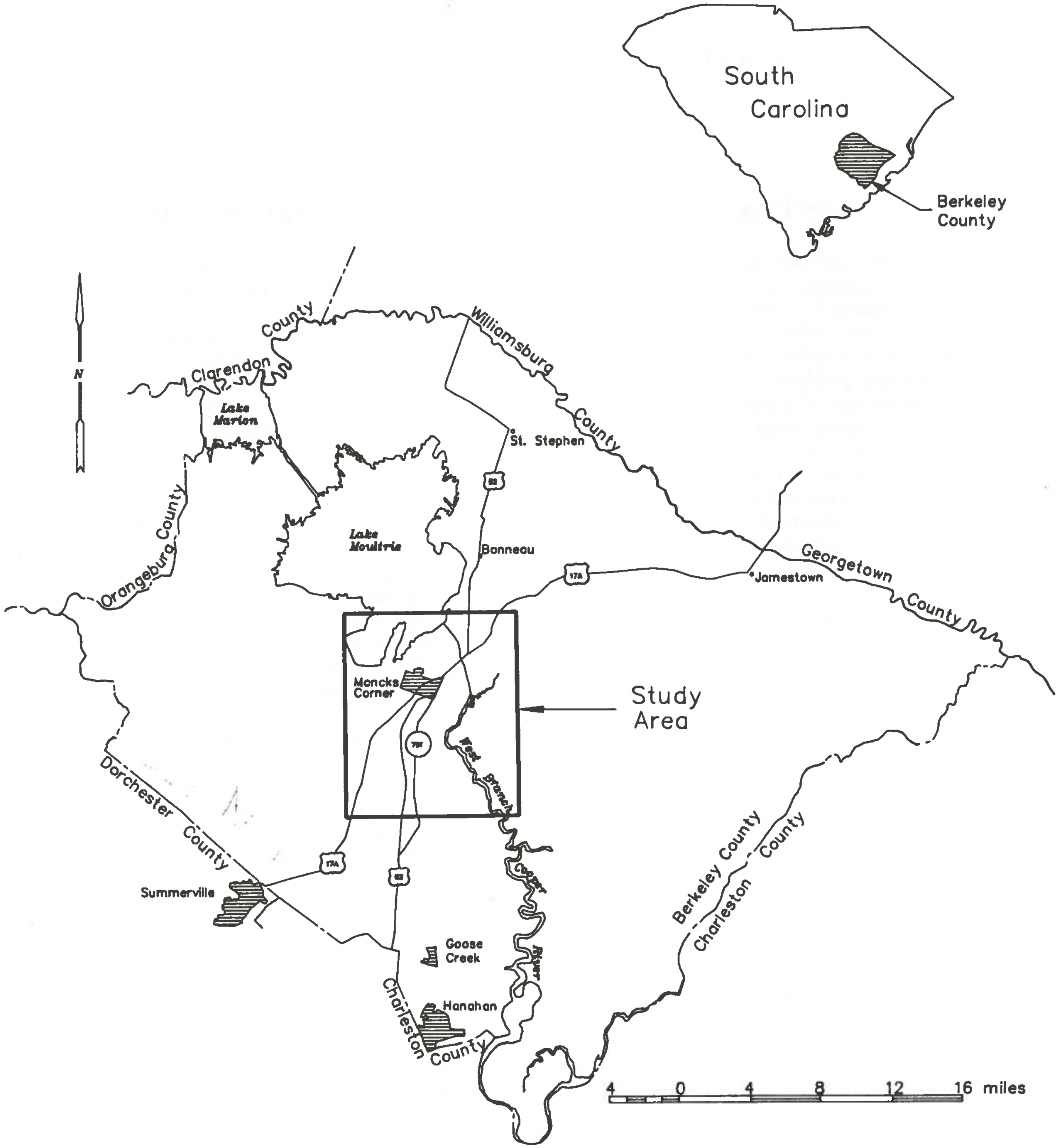

Figure 1. Location of study area.

Well-Numbering System

Each well inventoried in the study was assigned a SCWRC and a U.S. Geological Survey (USGS) well number. The SCWRC well-numbering system is a grid type that assigns a unique number to each well according to its latitude and longitude (Fig. 2). Each grid measures 5 minutes of latitude by 5 minutes of longitude and is assigned a number and an upper-case letter (18AA). Each of these 5-minute grids is further subdivided into 25 1-minute grids, each with a unique lower-case letter (18AA-e). As wells are located and inventoried within the 1-minute grids, they are assigned sequential numbers (18AA-e1, 18AA-e2, etc.). Figure 3 shows the grid pattern for the study area and the location of wells used in this report.

The USGS well-numbering system consists of an abbreviation for the county name followed by a sequentially assigned number. For example, BRK-173 represents the one hundred and seventy-third well recorded in Berkeley County.

Acknowledgments

Thanks are due the residents of the study area who permitted access to their wells for water-level measurement. Gratitude is also extended to officials of A.D. Hare Waterworks and Moncks Corner Waterworks for permitting measurement of their public supply wells. Ackerman Well & Pump Co. provided well construction data. Their cooperation is appreciated.

PHYSICAL ENVIRONMENT

Landforms and Drainage

The study area is in the lower Coastal Plain (Cooke, 1936). Elevations range from 10 to 90 feet above mean sea level (m.s.l.). The topography is typified by low relief, with well-drained areas separated by swamps. Several elliptical depressions, or "Carolina Bays", exist on the west edge of the area.

The West Branch Cooper River and Wadboo Creek are the dominant surface drainage features. Pinopolis Dam, north of Moncks Corner, impounds diverted water from the Santee River to form Lake Moultrie. The lake, whose spillway elevation is maintained at +75 feet m.s.l., occupies about 7 square miles in the northwest part of the study area. Tailrace Canal, a man-made canal used to drain Lake Moultrie, joins Wadboo Creek about 1 mile east of Moncks Corner and drains into the West Branch Cooper River.

Climate

The climate is typical of the lower Coastal Plain. Winters are short and mild; summers are long and humid. The mean annual temperature is 64°F. Precipitation, as rainfall, averages 50 inches per year (N.O.A.A., 1986).

GEOLOGIC FRAMEWORK

Between 65 million years ago and the present, the study area was alternately covered and exposed by the sea. As the sea advanced and retreated, sand, clay, and limestone were deposited. These deposits, alone or together, form the geologic formations important to a groundwater study of the area, namely: (1) the Cooper Formation, (2) the Santee Limestone, and (3) the Black Mingo Formation. Table 1 gives the ages and hydrogeologic properties of the formations, and Figure 4 shows the generalized areal distribution of the formations.

Surficial Pleistocene Deposits

A thin blanket of Pleistocene sediments partially covers the study area. Thickness varies from about 50 feet on high plateaus to zero in valleys where erosion has removed the sediments and exposed the Cooper Formation (Taber 1939).

Cooper Formation

The Cooper Formation was named from outcroppings on the Cooper River (Tuomey, 1848). Originally designated as the Cooper Marl, later studies (Malde, 1959; Pooser, 1965; and Ward and Others, 1979) used the name Cooper Formation.

The Cooper Formation occurs throughout the study area, and according to Taber (1939), consists of marl that is dark greenish-gray when moist, becoming light gray on drying. Drilling samples and geophysical logs indicate that the Cooper is a homogeneous, silty clay containing glauconite, phosphate, and calcium carbonate.

Three members of the Cooper Formation have been recognized by Ward and others (1979). These are (in ascending order): (1) the Harleyville Member, of Late Eocene age, (2) the Parkers Ferry Member, also of Late Eocene age, and (3) the Ashley Member, of Oligocene age. In the study area, member distinction has not been made by the author.

The unbedded, homogeneous nature of the Cooper is indicated on geophysical logs as a smooth, almost featureless log response (Fig. 5) except at the boundaries of the formation where concentrated glauconite and phosphate cause high count rates on gamma-ray logs.

The Cooper occurs throughout the study area (Fig. 4), but a few miles north of the study area it has been eroded away. Dip is south-southeasterly at about 5 feet per mile. The thickness on geologic section A-A′ (Figs. 6 and 7) is 60 feet in the north and 95 feet in the south. Wells on the northern boundary of the study area typically penetrate about 20 feet of Cooper; wells on the southern boundary about 140 feet.

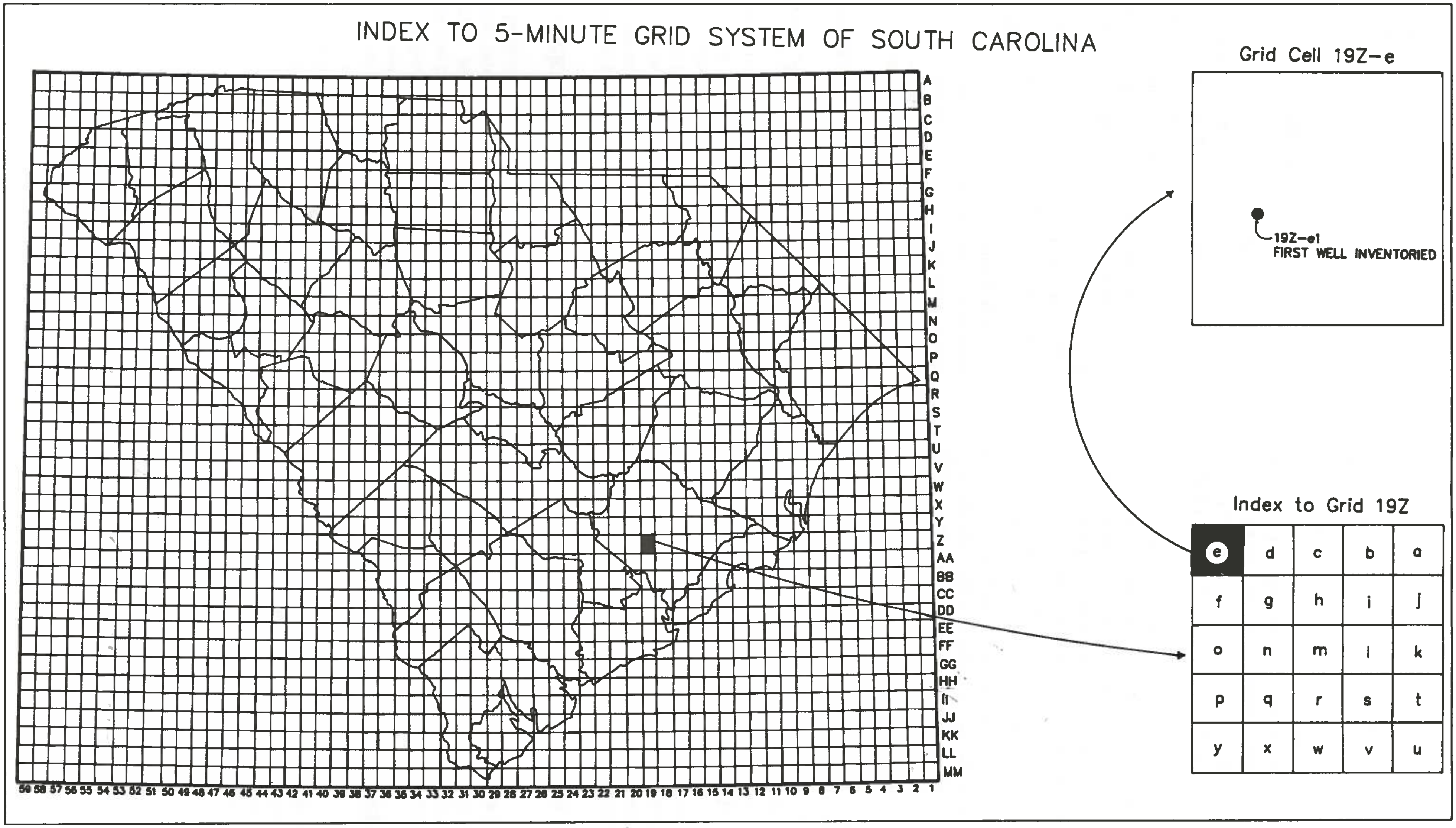

Figure 2. Well-numbering system.

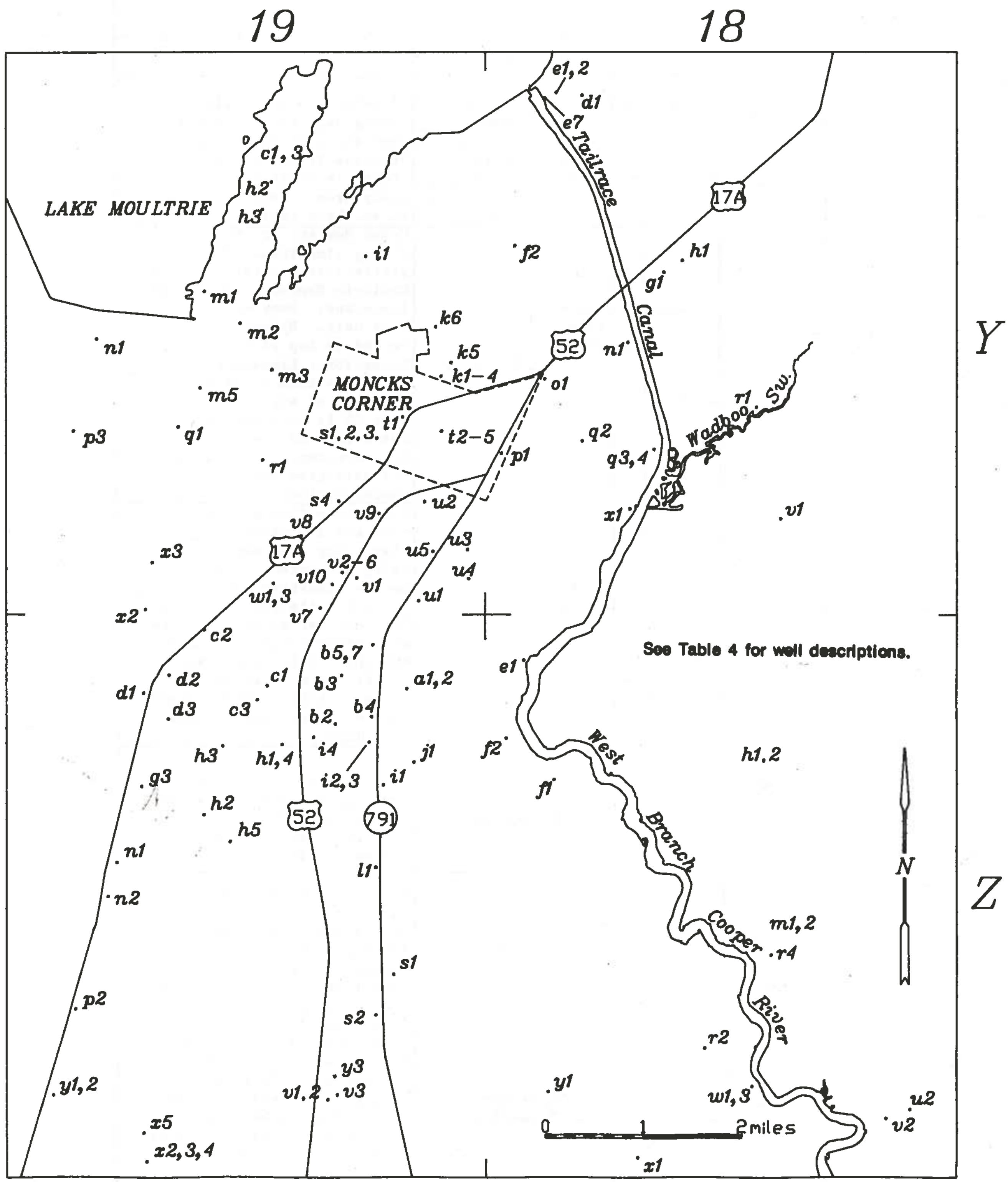

Figure 3. Location of study-area wells used in report.

Table 1. Generalized stratigraphic column and water-bearing character of geologic units beneath the Moncks Corner area and vicinity (modified from Ward and others, 1979)

Period	Epoch		Geologic Unit		Hydrogeologic Properties
Quaternary	Holocene		Surficial sediments		Not examined by this report.
	Pleistocene				
Tertiary	Pliocene		Waccamaw Formation		Occur south of the study area.
	Miocene		Hawthorn Formation		
	Oligocene		Cooper Formation	Ashley Member	Olive-green, silty clay. Confining unit causes artesian conditions in Santee Limestone Thickens from less than 20 ft (feet) in northern part of study area to more than 140 ft in southern part.
	Eocene	Upper		Parkers Ferry Member	
				Harleyville Member	
		Middle	Santee Lime-Stone	Cross Member	Cross Member: creamy-white, clayey limestone. Probably yields little water to wells. Moultrie Member: light-gray limestone. Some wells open to this unit. Hydraulically connected to top of Black Mingo Formation. Limestone thickens from less than 30 ft in northern part of study area to more than 70 ft in southern part. Contains hard, calcium bicarbonate water. Iron can exceed 0.3 milligram per liter in concentration.
				Moultrie Member	
		Lower	Black Mingo Formation		Fine- to medium-grained gray sand and limestone and black clay. Top sand beds hydraulically connected to bottom of Santee Limestone. Wells open to both units yield 100 gpm, (gallons per minute) or more, with several yielding up to 400 gpm. Unit is at least 370 ft thick in study area. Contains soft, sodium bicarbonate water, more mineralized with depth.
	Paleocene				
Cretaceous	Late Cretaceous		Peedee Formation		330 ft thick in study area. Poor aquifer and rarely used near coast. One study-area well produced 200 gpm of soft, sodium bicarbonate water.
			Black Creek Formation		650 ft thick in study area. Widely used aquifer. Wells in Mt. Pleasant yield up to 1,000 gpm of soft, sodium bicarbonate water. Wells in Jamestown produce 500 gpm of similar water.
			Middendorf Formation		Less than 850 ft thick in study area, although interval may contain older Cape Fear sediments. Widely used aquifer. One well, a mile south of study area, yielded 2,000 gpm of soft, sodium bicarbonate water, this well may also have tapped lower part of Black Creek Formation.
Precretaceous			Basement complex (Basalt, sandstone, crystalline rocks)		Unknown

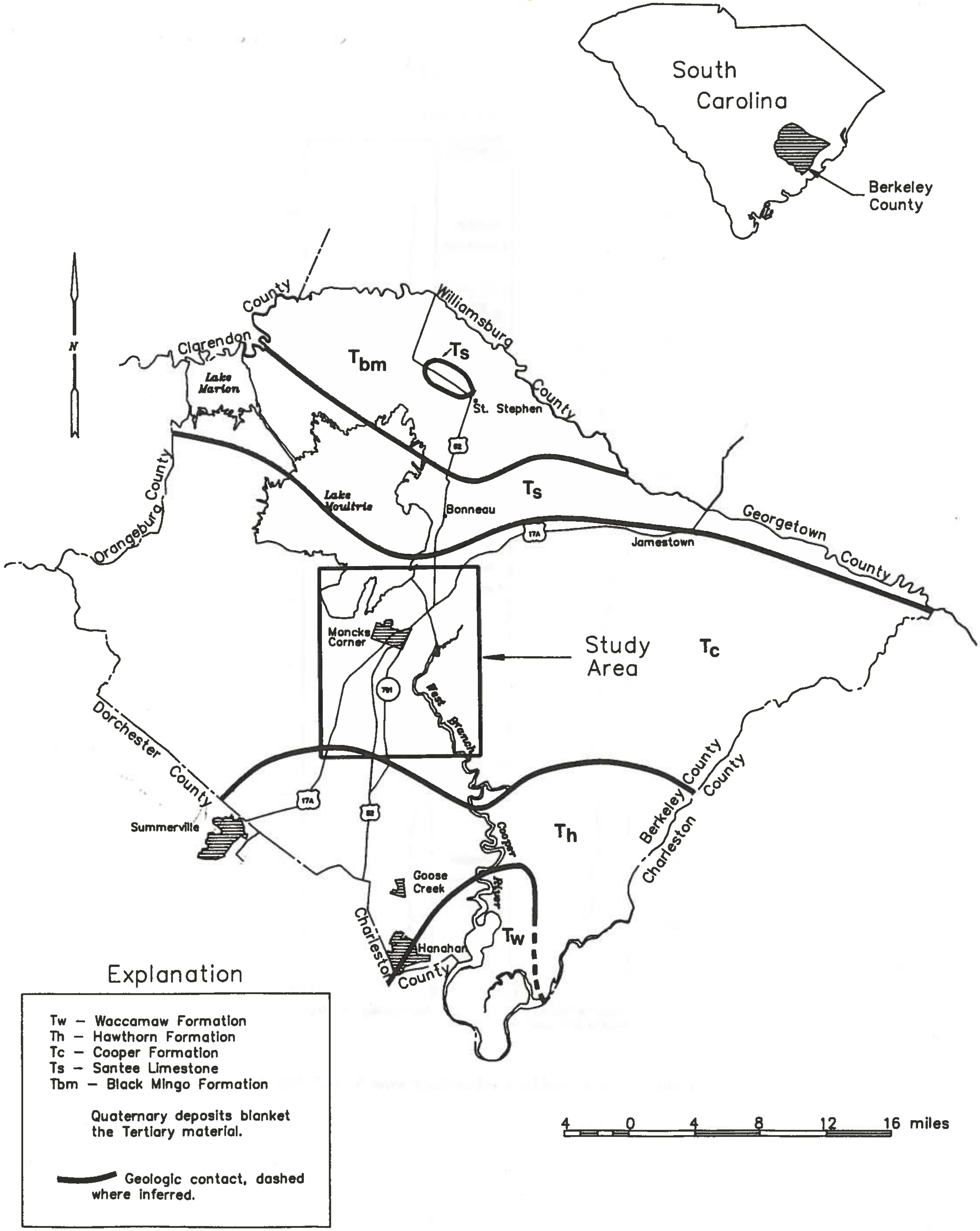

Figure 4. Generalized Tertiary geology of Berkeley County.

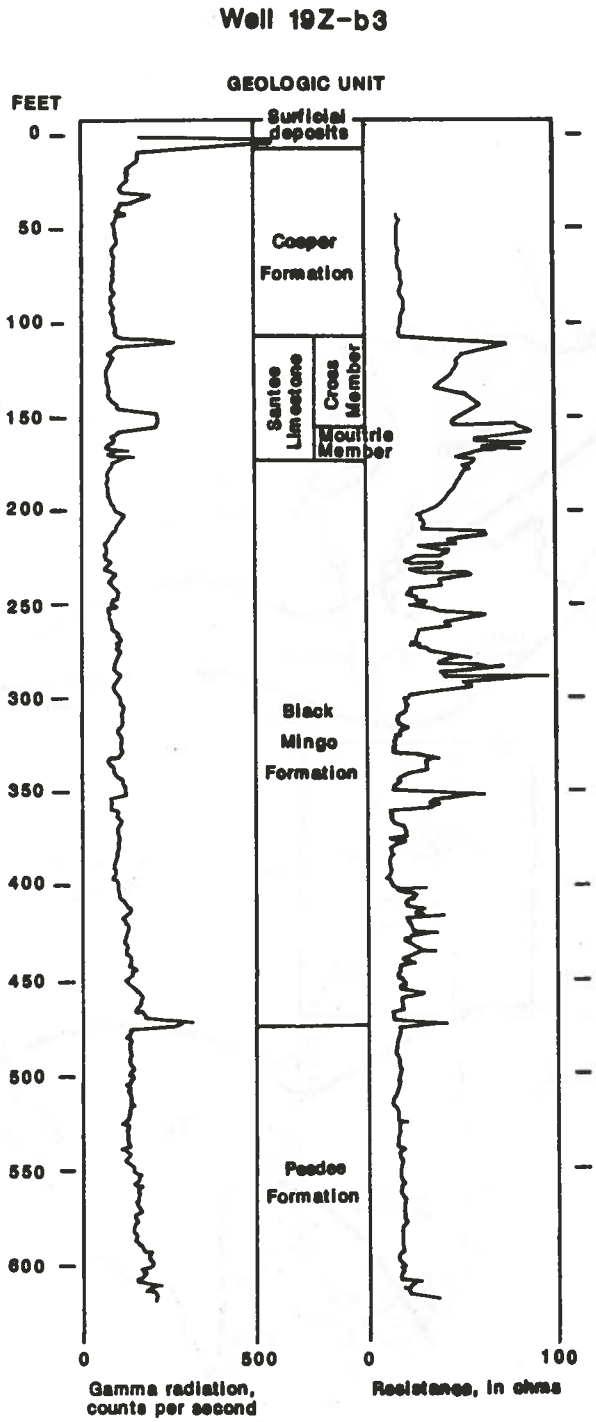

Figure 5. Geophysical logs and geologic units for well 19Z-b3.

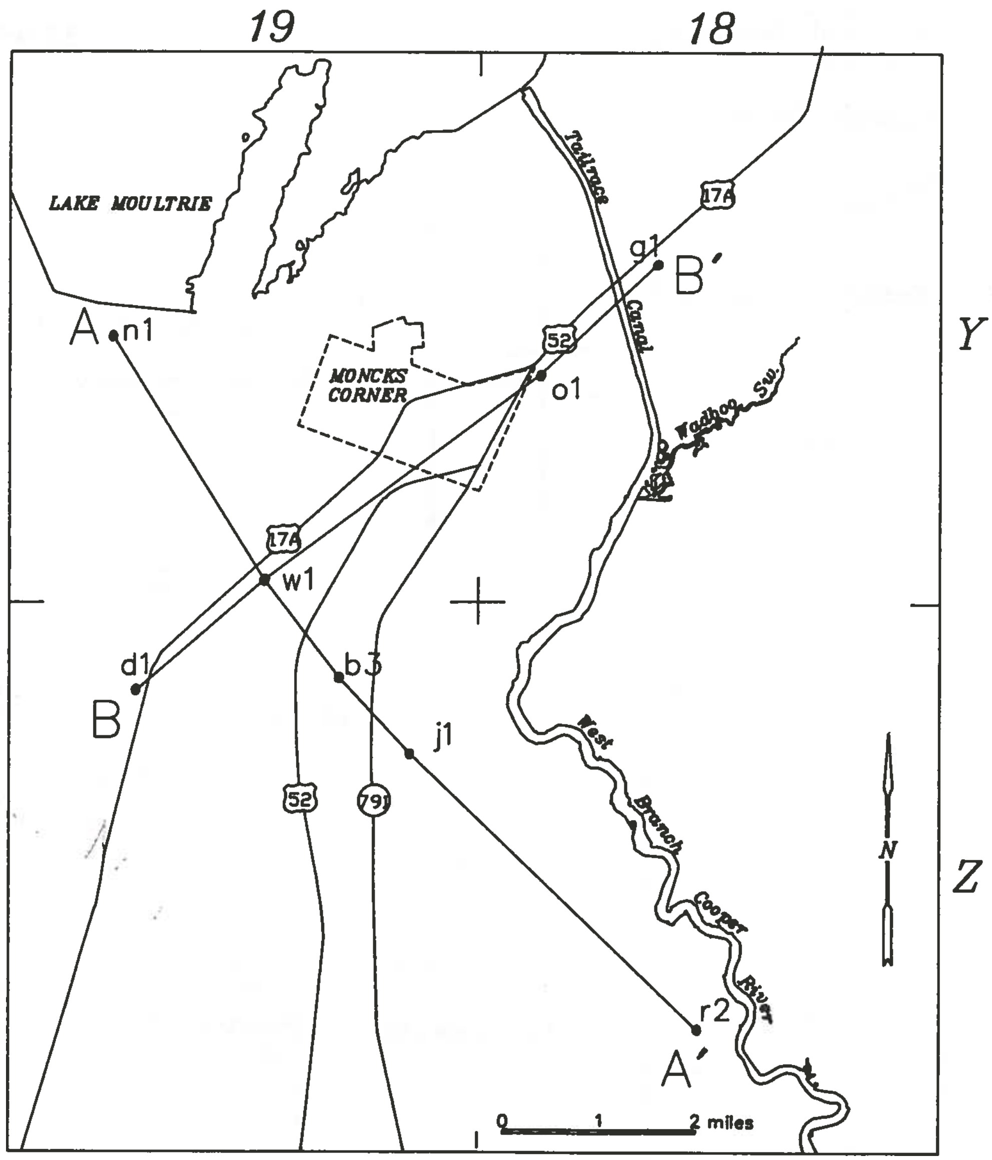

Figure 6. Location of geologic sections.

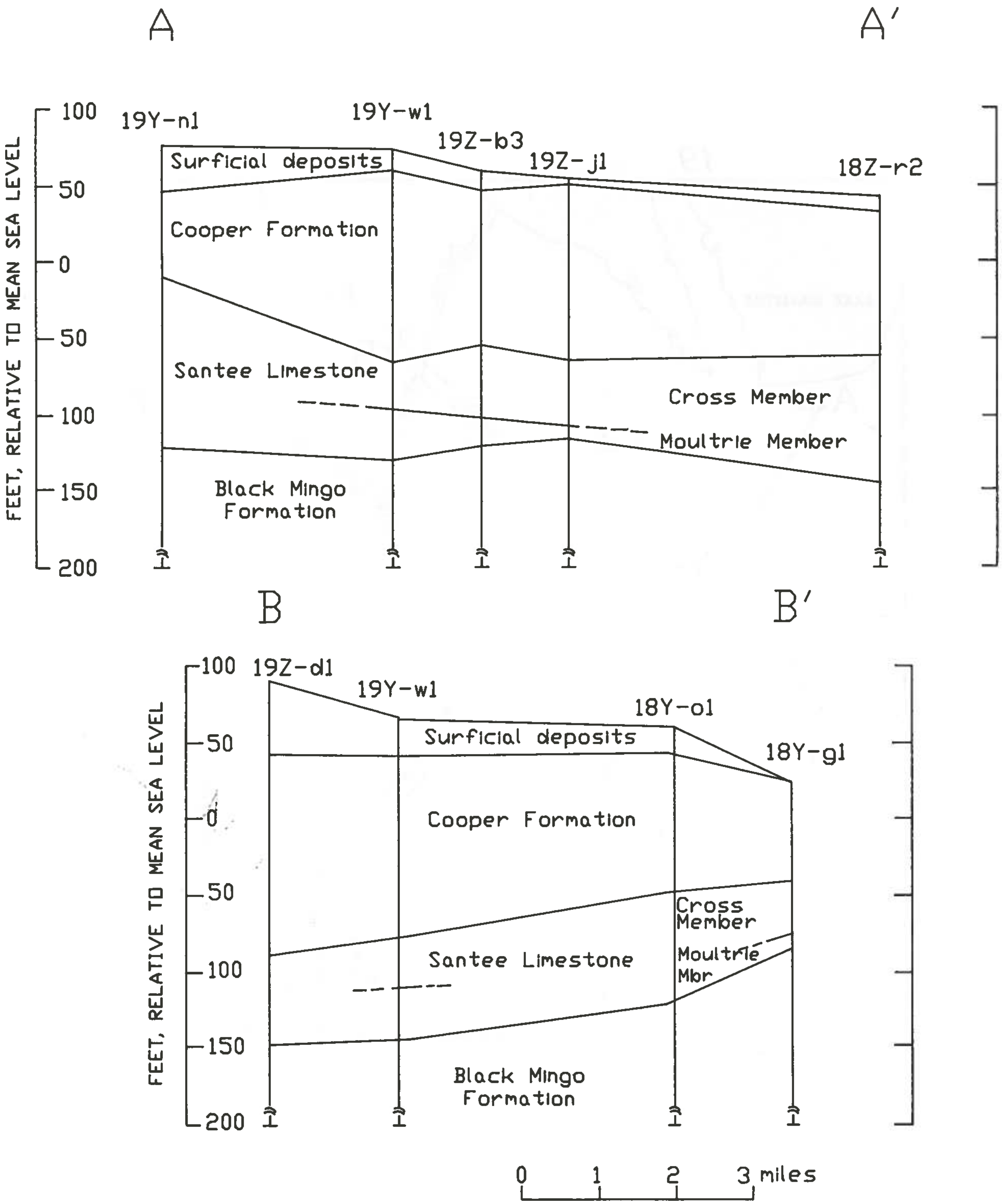

Figure 7. Geologic sections A-A′ and B-B′.

Santee Limestone

The Santee Limestone was named from outcrops along the Santee River described by Cooke (1936). At that time, Cooke considered the limestone to be of the Jackson Group (Upper Eocene age), but later he and McNeil (1952) classified it as being of the Claiborne Group (Middle Eocene age).

Two members are present in the Santee Limestone. As described by Ward and others (1979), the lower unit, or Moultrie Member, is Middle Eocene in age and is a fossiliferous, consolidated limestone. The upper unit, the Cross Member, is a fossiliferous, limy clay, also of Middle Eocene age. Drill cuttings from a well near Moncks Corner (19Z-b3) show the Moultrie Member to be a light gray, well-consolidated limestone, while the Cross Member appears as a creamy-white, limy clay. According to Ward and others (1979), the aragonitic shells in the Moultrie Member have been dissolved and precipitated as a cement, thus accounting for the Moultrie's consolidated nature. Apparently this phenomenon has not occurred in the Cross Member, and therefore that member is less consolidated.

The Santee occurs throughout the study area and dips in a southsoutheasterly direction at about 7 feet per mile. Thickness varies but generally increases from 30 feet in the north to 70 feet in the south (Fig. 7). The hydrologic effects of thickness variations will be discussed later in the well yields section.

Black Mingo Formation

The Black Mingo Formation was named from outcrops along Black Mingo Creek in Williamsburg and Georgetown Counties, as described by Sloan (1907). Cooke (1936) considered the Black Mingo to encompass all Eocene strata older than the McBean Formation (Middle Eocene). Gohn and others (1981) considered the Black Mingo to represent Paleocene material. Calcareous microfossils from well 19Z-b3 show the base of the Black Mingo Formation to be of lowermost Paleocene age and resting unconformably on the Peedee Formation, dated from foraminifers in well 19Z-b3 as uppermost Cretaceous age (Fig. 5). This report will consider the Black Mingo Formation to represent sediments between the Santee Limestone and the Peedee Formation.

Lithologically, the Black Mingo consists of sand, clay, and limestone. Drill cuttings show the upper half of the formation to be composed of fine to medium, gray sand interbedded with layers of well-consolidated, dark-gray limestone. The top bed of the Black Mingo is usually a fine, gray sand. The lower half of the formation consists of dark gray to black, silty clay. Thin layers of hard, silica-cemented sandstone occur throughout the formation.

The Black Mingo occurs throughout the study area, although few wells have penetrated its entire thickness. Well 19Z-b3, however, entered the Black Mingo at 180 feet below land surface and exited it at 485 feet below land surface, a total thickness of 305 feet (Fig. 7), and then penetrated about 170 feet of the Cretaceous Peedee Formation. Geophysical logs of well 19Y-s1 reveal a Black Mingo thickness of about 310 feet. The Black Mingo dips in a south-southeasterly direction at about 7 feet per mile.

GROUND-WATER AVAILABILITY

Cooper Formation

Because of its clayey nature, the Cooper Formation functions as a confining unit for the underlying Santee and Black Mingo (Park 1985). Taber (1939) reported that a Cooper sample from beneath Pinopolis Dam contained over 50 percent clay. This high clay content, and attendant low permeability is evidenced by a low-resistance trace on electric logs traversing the Cooper (Fig. 5). According to Park (1985), only a few feet of formation thickness is required to form an effective confining unit. Because of this, ground water in the Santee Limestone and Black Mingo Formation occurs under artesian conditions throughout the study area.

Santee Limestone

Cross Member. — The water-bearing properties of the Cross Member are directly related to its geologic nature. The high clay content and lack of soluble calcite to cause consolidation (and thus fracturing and porosity enhancement) make the Cross Member the less permeable of the two units in the Santee Limestone. It is doubtful, therefore, that this member yields significant amounts of water to wells. No wells in the study area are known to be completed solely in the Cross Member.

Moultrie Member. — As in the Cross Member, the water-bearing properties of the Moultrie Member are a function of lithology. Low clay content and solution channeling owing to soluble calcite give the Moultrie Member greater permeability than the Cross Member. According to Banks (1977) and Park (1985), ground water circulating through fractures in the limestone dissolves calcite and forms water-transmitting solution channels. This secondary permeability development is not uniform, however (Siple 1975), and because of this the water-yielding properties of the Moultrie Member can vary. Many of the older wells in the study area were completed in the Moultrie.

Black Mingo Formation

Most available ground water in the Black Mingo is in the upper half of the formation, particularly in sand and limestone beds of the top 50 feet. Clay and silt compose the lower half of the formation (Fig. 5), providing little or no ground water.

Composite Santee Limestone and Black Mingo Formation

An examination of geophysical logs shows no hydraulic barrier between the bottom of the Santee Limestone (Moultrie Member) and sand beds in the top of the Black Mingo Formation (Fig. 5). Likewise, drilling samples and drillers logs show no barriers; the lithology changes abruptly from permeable limestone to sand at the contact of the two units. The bottom part of the Santee and the top part of the Black Mingo Formation both yield water to wells, (2) No hudraulic barriers are present, (3) Water levels in wells open only to the Santee Limestone and in nearby wells open to both the Santee Limestone and Black Mingo Formation have no apparent difference, suggesting similar heads for the two units, (4) Water-quality data (discussed later) for wells open only to the Santee Limestone indicate a mixture of Santee and Black Mingo water types, thereby suggesting an interchange of water between the two units, and (5) The majority of the wells in the study area are open to both units and thus represent a combination of the two units. Ground-water withdrawal from one unit probably causes withdrawal from the other, although not necessarily in equal proportion.

WELL CONSTRUCTION

Most wells in the study area are constructed as open holes in the Santee Limestone and Black Mingo Formation. Casing is usually seated in the Cooper Formation, leaving an open hole through the Santee and into the Black Mingo (Fig. 8). Some older wells tap only the Santee.

Domestic wells are usually 4 inches in diameter, and industrial wells are usually 6 inches or larger. Most domestic wells use l/2- to 1-horsepower submersible pumps. On the east and north edges of the study area, water levels are locally high enough to permit use of jet pumps. Some high-capacity wells utilize 6- to 8-inch diameter screens with slot size averaging 0.025 inch. Such wells commonly employ 20- to 30-horsepower surface or submersible turbine pumps. Well depth is a function of both the desired yield and the well-site elevation and hence can vary. Typically, wells are drilled deeper into the Black Mingo if increased yield is sought. For wells that do not penetrate below the uppermost sand beds of the Black Mingo, depths range from about 150 feet at the north edge of the study area to about 250 feet at the south edge.

WELL YIELDS

Well yields and specific capacities in the study area vary in accordance with well construction, the amount of Black Mingo penetration, and the degree of permeability enhancement in the Santee. Most 6-inch and larger wells open to both the Santee and Black Mingo appear to be capable of producing at least 100 gpm (gallons per minute). Several wells are capable of pumping more than 400 gpm, but these are not common. For the reasons given above, specific capacities vary, ranging between 1 and 17 gpm/ft (gallons per minute per foot of drawdown). Most commonly, specific capacities are less than 2 gpm/ft.

Such well performance figures result from the low transmissivity of the Santee-Black Mingo. Transmissivity values from eight pumping tests ranged from 130 to 1,300 ft²/day [1]. Most commonly, values were between 300 and 700 ft²/day. This contrasts with transmissivity values of 3,000 to 7,000 ft²/day reported by W.R. Logan and G.E. Euler (SCWRC, personal communications) for the Santee Limestone in Allendale County.

Park (1985) considered the permeability of the Black Mingo to be greater than that of the Santee and believed water in wells open to both units to come mostly from the Black Mingo. Regionally, this is probably the case, but flow-meter logs of two wells, 18Y-d1 and 19Y-c3, open to both the Santee and Black Mingo, showed that permeability varies locally. About 70 percent of thewater comes from the Black Mingo in well 18Y-d1, but only about 40 percent in well 19Y-c3. Such differences, if common to wells open to both units, are probably controlled by the degree of Black Mingo penetration, the thickness of water-yielding zones in both units, and the type of well construction (open-hole or screened).

Electric logs of two wells, 19Z-b3 and 19Z-b5 (Fig. 9) are helpful in understanding the variable nature of Santee-Black Mingo well yields. The logs show a typical geologic section for 19Z-b3, with thicknesses of about 45 feet for the Cross Member and 20 feet for the Moultrie Member, giving a total Santee Limestone thickness of 65 feet. Well 19Z-b5, however, shows a section with 55 feet of Cross Member but 85 feet of what appears to be Moultrie Member for a total Santee thickness of 140 feet.

The effect of the thicker Mountrie section on potential well yield is apparent in pumping tests of the two wells. The transmissivity at 19Z-b3 was calculated to be 1,250 ft²/day buth that at 19Z-b3 was only 710 ft²/day. This means that the aquifer at 19Z-b5 is capable of supporting nearly twice the well yield as at 19Z-b3. If 100-percent efficient, well 19Z-b5 would have a specific capacity of about 41/2 gpm/ft, but 19Z-b3 only 2 1/2 gpm/ft.

Thickening or thinning of an aquifer within the area of influence of a pumping well will affect the well's specific capacity. Depending on how far away the thickening or thinning occurs, how much change occurs, and how gradually it takes place, the specific capacity may be increased or decreased.

[1] Transmissivity units are feet squared per day (ft²/day), a reduction of cubic feet per day per foot. Transmissivity is often stated in gallons per day per foot, which can be divided by 7.48, the number of gallons in a cubic foot, to give feet squared per day.

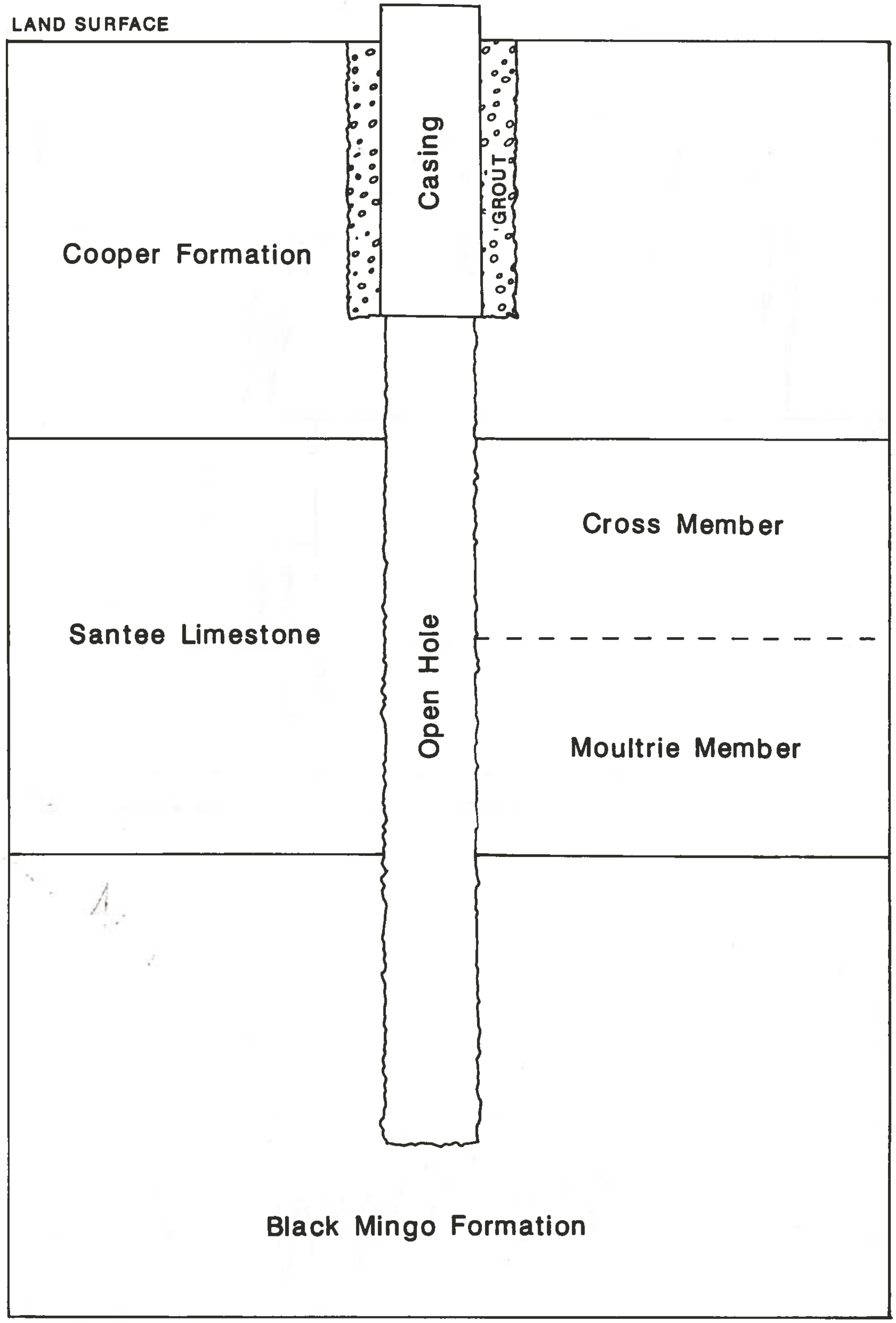

Figure 8. Generalized geologic units and typical well construction.

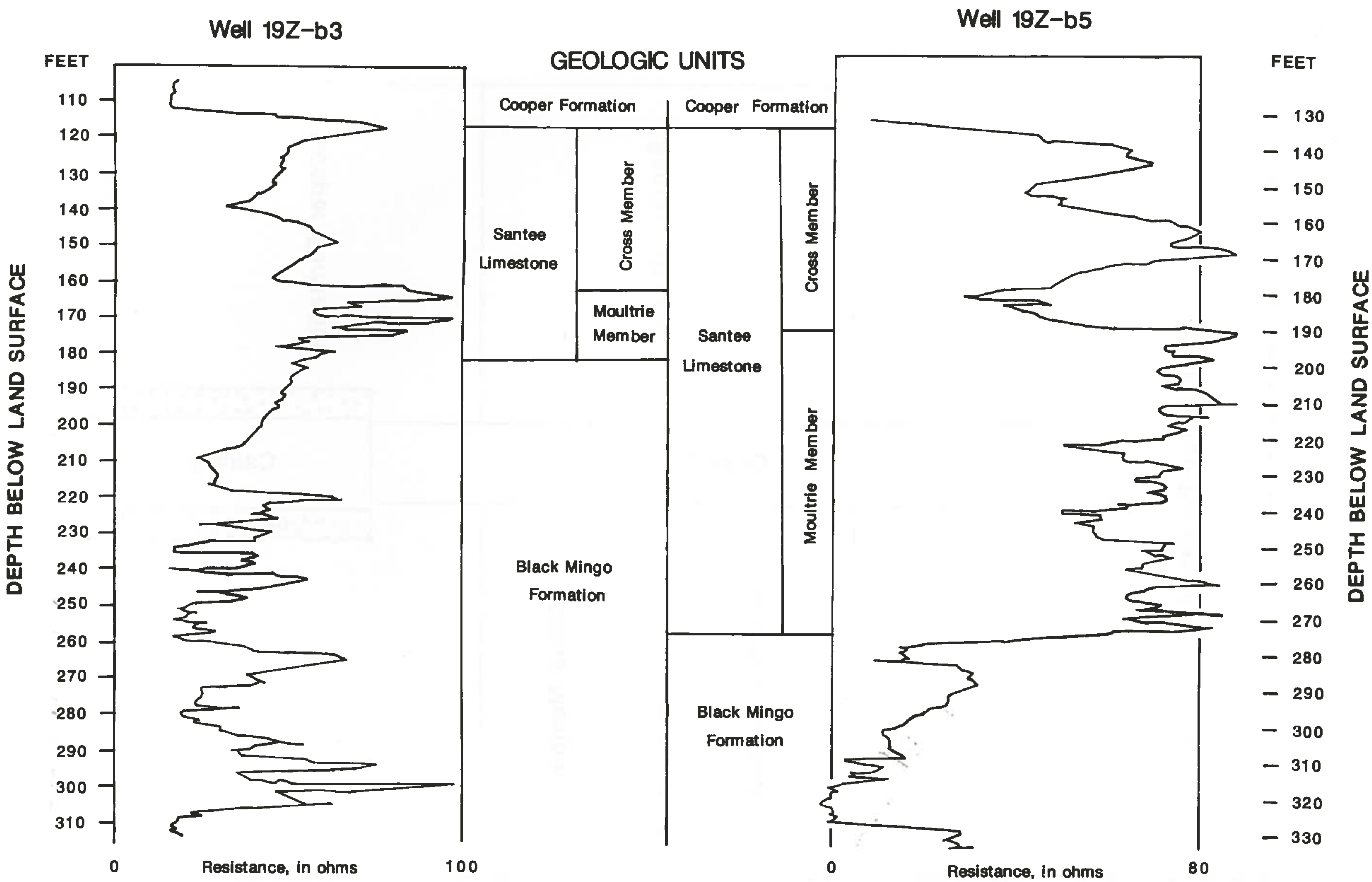

Figure 9. Comparison of geologic units and resistance logs for wells 19Z-b3 and 19Z-b5, showing variable thickness of the Moultrie Member of the Santee Limestone.

WATER QUALITY

The quality of water from wells open to the Santee and Black Mingo represents a mixture of the two units (Park 1985) and varies with location and the degree of Black Mingo penetration. The farther south a well is located, the more mineralized will be its water. Additionally, the deeper a well penetrates the Black Mingo, the more mineralized will be its water and the more it will assume Black Mingo water characteristics.

In the northern half of the study area, wells open to both units have hard, calcium bicarbonate or sodium bicarbonate water. Dissolved-solids concentrations are usually less than 350 mg/L (milligrams per liter), chloride less than 30 mg/L, and silica greater than 20 mg/L. The pH is between 7.0 and 8.0, and fluoride is less than 1.0 mg/L. In the southern half of the study area, such wells have softer, more mineralized, sodium bicarbonate water with total dissolved solids above 350 mg/L, chloride less than 100 mg/L, and silica around 40 mg/L. The pH is above 8.0 and fluorides can be as high as 3.0 mg/L. From north to south in the study area, hardness (caused by calcium and magnesium) decreases, whereas fluoride, total dissolved solids, and silica levels increase, along with a rising pH.

The quality of the water varies not only with location, but also with the degree of Black Mingo penetration. Park (1985) reported that water quality in the Black Mingo worsens with depth. This is shown by two wells in the southern half of the study area, 18Z-w1 and 18Z-w3. The wells are less than one-quarter mile apart and have the same elevation. Both wells are of the open-hole type with casing seated in the Cooper Formation. Both wells penetrate all of the Santee and the top of the Black Mingo. Well 18Z-w1 however, penetrates sand and limestone beds 20 feet deeper into the Black Mingo than does 18Z-w3. Because of this, 18Z-w1 has poorer water quality that 18Z-w3. Dissolved constituents in 18Z-w1 increase an average of 20 percent over 18Z-w3 (Table 2).

Water quality deterioration with depth in the Black Mingo is also shown by wells 19Z-v3 and 18Y-g1, both of which are open solely to the Black Mingo. The water in well 19Z-v3 is a sodium bicarbonate type similar to other wells in the study area; however, it is the most highly mineralized of any post-Cretaceous formation well sampled. The chief constituents with higher concentrations were sodium, sulfate, and chloride. The fluoride level was 3.0 mg/L, matched only by one other well, 19Z-n1, and two to three times as high as other wells. The high fluoride level in 19Z-n1 is probably a result of penetrating about 75 feet of Black Mingo sediments. Such water quality results from using Black Mingo aquifers below the uppermost sand beds.

Like well 19Z-v3, well 18Y-g1 is open only to the Black Mingo. Since 18Y-g1 is located farther north than 19Z-v3, the water is less mineralized, but it is still more mineralized than surrounding wells open to both the Santee and Black Mingo. Again, the higher concentrations are in total dissolved solids, sodium, and chloride, but sulfate levels were lower than in surrounding wells (Table 2).

The foregoing leads to an important conclusion; namely, less mineralized and hence better water is obtained from wells that do not penetrate below the uppermost sand beds of the Black Mingo.

Water quality data for wells open only to the Santee are not abundant, since most wells also penetrate the Black Mingo. However, the town of Moncks Corner has several older wells completed only in the Santee, and the water in them is hard, bordering between a calcium bicarbonate and a sodium bicarbonate type similar to wells open to both the Santee and the top of the Black Mingo. One difference is that iron is higher in the Santee wells. Of all the post-Cretaceous formation wells sampled in the study area, these wells had the highest iron concentrations. The amount is near or above the recommended limit of 0.3 mg/L. Park (1985) reported that iron is commonly a problem in Santee wells, especially north of the study area where the Cooper Formation is absent and iron-rich, shallow ground water directly recharges the Santee.

Silica concentrations in three available analyses of water from Santee wells are higher than would be expected in water from a limestone aquifer. In fact, the silica is as high as in wells open to both the Santee and Black Mingo. According to Park (1985), relatively high silica levels are characteristic of Black Mingo water. The higher silica in the Santee wells, in conjunction with the water quality being similar to wells open to both the Santee and Black Mingo, indicates an interchange of water between the base of the Santee and the top of the Black Mingo. This would be expected, since the base of the Santee and the top of the Black Mingo are hydraulically connected.

GROWTH AND WATER USE

According to State figures, Berkeley County is the second fastest growing county in South Carolina (first is adjacent Dorchester County). Population totals from 1960 to present and projected totals up to the year 2000 are given below.

Historic and Projected Population 1960-2000, Berkeley County

Year	1960	1970	1980	1985	1990	2000
Population	38,196	56,199	94,745	122,400	138,400	190,500

Source: The Situation and Outlook for Water Resource Use in South Carolina, 1985-2000.

Notice how much the population increases each decade. The present population is more than twice what it was just 15 years ago. Such a growth rate places a burden on ground-water resources, because as population increases so does water use. In the study area, the Santee Black Mingo has been the chief aquifer system

Table 2. Selected water quality analysis for wells near Moncks Corner, S.C.

EXPLANATION OF TABLE

Well No.: SCWRC--South Carolina Water Resources Commission grid number
County--consecutive county number:
BRK, Berkeley
CHN, Charleston

Sampled interval: Interval between top of first opening in well and bottom of last opening, in feet below land surface

Aquifer: S, Santee; BM, Black Mingo; PD, Peedee; BC, Black Creek; M, Middendorf

Analysis by/date: Laboratory and date analyzed
SCWRC--South Carolina Water Resources Commission
USGS--United States Geological Survey
DHEC--South Carolina Department of Health and Environmental Control
Comm--Commercial

Chemical constituents: All constituents reported in milligrams per liter.

*Note: Some commercial laboratories compute dissolved solids differently from SCWRC and USGS, and their results may appear considerably greater.

Well No. SCWRC County	Sampled interval	Aqui-fer	Analysis by date	Total alka-linity	Dis-solved solids	Field pH	Hard-ness	Silica	Iron	Calcium	Magnes-ium	Sodium	Potas-sium	Bicar-bonate	Sulfate	Chloride	Fluoride
15X-11 BRK-84	770-891	BC	USGS 6-19-79	370	445	8.5	5	18	0	1.5	0.3	190	4.2	370	2.7	4.0	2.0
15X-15 BRK-26	700-880	BC	DHEC 10-19-76	350		8.8	11		<.1							15	2.0
17DD-m5 CHN-163	1829-1912	BC	SCWRC 3-27-81	841	1105	8.6	16	19.9	.01	2.1	.34	360	4.5	1010	4.0	135	4.4
18Y-g1 BRK-461	168-220	BM	Comm 7-7-84	260	461	7.8	95	22	.05	23.6	8.8	89.8		317	1	22	.8
18Z-w1 BRK-303	62-220	S,BM	SCWRC 4-82	444	499	8.5	20.7	43.6	.01	3.5	2.8	166		533	7.1	10	1.9
18Z-w3 BRK-312	62-200	S,BM	SCWRC 4-82	352	428	8.8	19.3	38	.01	3.3	2.5	159		429	4.9	4.2	1.0
18AA-e2 BRK-430	1548-1900	BC?M	SCWRC 3-22-82		643		5	13.3	.02	1.79	0	182	3.1	433	5.7	26	2.7
19Y-k4 BRK-96	173-252	S,BM	USGS 6-78		273	7.0	150	35	.01	26.0	19	44		250	3.9	17	.7
19Y-m1 BRK-92	156-229	S,BM	DHEC 9-78	350	390	7.8	165									50	.6
19Y-s1 BRK-87	633-693	PD	USGS 7-12-79	700	920	8.0	22	20	.02	5.1	2.3	400	10	700	.5	59	1.5
19Y-s3 BRK-460	187-251	S,BM	Comm 10-82	240	435	7.45	165	24	.01	44	13.4	54		240	3.0	28	.8
19Y-t1 BRK-4	?-147	S	USGS 12-55		389	7.4	174	37	.52	33	22	91		376	2.5	32	.7
19Y-t2 BRK-189	125-190	S,BM	USGS 12-55		308	7.4	165	36	.28	34	20	58		302	3.4	19	.6
19Y-t4 BRK-8	140-147	S	USGS 12-55		215	7.6	149	26	.27	29	19	29		222	1.8	12	.9
19Y-t5 BRK-9	?-160	S	USGS 12-55		236	7.7	151	32	.31	27	20	34		232	1.5	12	.9
19Y-u5 BRK-541	146-238	S,BM	Comm 8-55	295	515	7.95	128	18	.10	32.8	11.2	89.6		295	3.0	18	.7
19Y-v7 BRK-193	187-250	S,BM	Comm 4-76	222	397	8.0	93	32	.02	26.8	6.3	71.2		222	1.0	16	.8
19Y-w3 BRK-431	1602-1607	M	SCWRC 4-9-82	684	870	7.7	15.8	21.8	3.0	2.52	.45	336	4.86	821	7.5	68	3.8
19Z-n1 BRK-196	64-280	S,BM	DHEC 1-78	430	530		20		.1							23	3.0
19Z-v3 BRK-204	235-265	BM	SCWRC 3-82	584	922	8.1	28	42	.03	5.3	4.2	362		700	62	82	3.0
19CC-x1 CHN-172	1760-1840	BC	USGS 7-23-79	620	781	7.5	7	5.3	.3	2.3	.2	340	2.9	744	4.6	50	3.2

called upon to support the water use increase. Water use from the Santee-Black Mingo for all of Berkeley County in 1985 is shown in Table 3. Ninety percent of the total 7.822 mgd (million gallons per day) used in 1985 came from self-supplied withdrawals. This means that many members of the growing population are taking up residence outside the areas served by municipal systems and therefore must obtain their water from wells, typically (for reasons to be discussed) Santee-Black Mingo wells. Indeed, of 122,400 people in Berkeley County in 1985, only about 34,400 were served by municipal systems. The remaining 88,000 people supplied their own water or were served by rural public-supply systems. Assuming that a person typically uses about 80 gallons per day, multiplying this by the number of self-supplied people (88,000) gives a total of 7.040 mgd. This usage is reflected in declining Santee-Black Mingo ground water levels. Of the remaining Santee-Black Mingo water users in Berkeley County, municipal systems withdrew the most (0.486 mgd). Again, supplying water to the growing population was the main reason for this use. Industry withdrawals (0.296 mgd) rounded out the daily usage.

PRESENT WATER LEVELS

Most ground water users in the study area rely solely on the Santee-Black Mingo aquifer system as a water source for the following reasons:

(1) The shallow depth, typically less than 250 ft., helps avoid costly deep-well drilling (Table 4).

(2) The geologic nature of the system allows economical open-hole construction.

Because of this majority reliance, as the area has grown the Santee Black Mingo ground-water system has been heavily used, and a declining water level (artesian pressure) has become a problem. The hydrograph of well 20AA-n2 (Fig 10) readily shows this. Although the well is 3 miles south of the study area and is influenced by several nearby public supply wells (Park 1985), the overall trend it depicts is representative of declining water levels in the study area.

According to the hydrograph, water levels begin to drop in the spring and reach bottom as water usage peaks in the summer. With the onset of cooler weather in the fall and winter, water use declines and water levels begin recovering, continuing to do so until the following spring when the cycle begins anew. Each winter's recovery is not long enough to bring water levels back up to the previous year's high, and hence each new cycle starts with water levels lower than the year before. This recovery deficit is what causes the long-term water-level decline apparent in Figure 10.

Water levels in 1985 for the Santee-Black Mingo aquifer system are depicted in Figure 11. The map shows ground water in the northwestern part of the study area moving in a southeasterly direction as part of a regional trend. Near Moncks Corner, pumping has diverted historic groundwater flow so that the present trend is southwesterly. Pumping has also caused a trough-shaped depression to form in the water level surface, centered along highways U.S. 17-A and U.S. 52 between Moncks Corner and Summerville. From Figure 11, it appears that water level declines are the result of an increase in regional pumping.

Lake Moultrie provides recharge to the Santee-Black Mingo aquifer system (Park 1985). The geologic map (Fig. 4) shows how this recharge occurs. The relatively impermeable Cooper Formation, which serves as a confining unit for the Santee-Black Mingo by prohibiting downward percolation of water pinches out beneath Lake Moultrie. Since the lake's surface is maintained at + 75 ft m.s.l. and Santee-Black Mingo water levels near the lake are lower than that, and since no confining unit is present to retard it, lake water can readily filter down into the Santee-Black Mingo system and provide recharge.

HISTORIC WATER LEVELS

Historically, water levels in the study area were above mean sea level, and ground water moved southeasterly. Figure 12 shows water levels prior to 1970. The only significant ground-water withdrawal was at Moncks Corner.

By comparing the historic and present-day water levels, the effects of growth in the development corridor between Moncks Corner and Summerville become apparent. Where once water levels in the southwestern quadrant of the study area were + 25 to + 30 ft m.s.l., they are now below -20 ft m.s.l., a decline of 45 to 50 ft. Also, ground-water flow has changed direction in Moncks Corner and now is southwesterly, a change of nearly 90 degrees from the original southeasterly movement. Previously, water levels formed a mostly smooth surface (except in Moncks Corner), but presently a trough-shaped depression has been created along the development corridor. Water level declines of 45 to 50 feet within the corridor are the most profound in the study area, but declines of 10 to 20 feet have occurred outside the corridor as well.

The problems caused by the water level declines have prompted this report. Several miles south of Moncks Corner, the problems have been especially severe. Water levels in domestic wells have dropped below the reach of many pumps, especially in older, 2-inch diameter wells where low-output pumps have been unable to produce water. Because of this, many residents have had to lower pumps to keep them submerged. Others have been faced with the expense of having new wells drilled and equipped with pumps capable of withdrawing water from greater depths.

FUTURE WATER LEVELS

Comparing present-day water levels with historic water levels gives an indication of the rate of water-level decline in the study area. Although it is difficult

Table 3. Water use in 1985 from wells in the Santee-Black Mingo aquifer, Berkeley County

Type	Usage (in millions of gallons per day)
Self-supplied*	7.04 (estimated)
Municipal	0.486
Industrial	0.296
Total =	7.822

*Self-supplied estimated as follows:

Population (1985)	122,400	
Served by municipalities	-34,400	
Self-supplied	88,000	
Average use per person (gallons per day)	x80	
Estimated total usage	7.04	million gallons per day

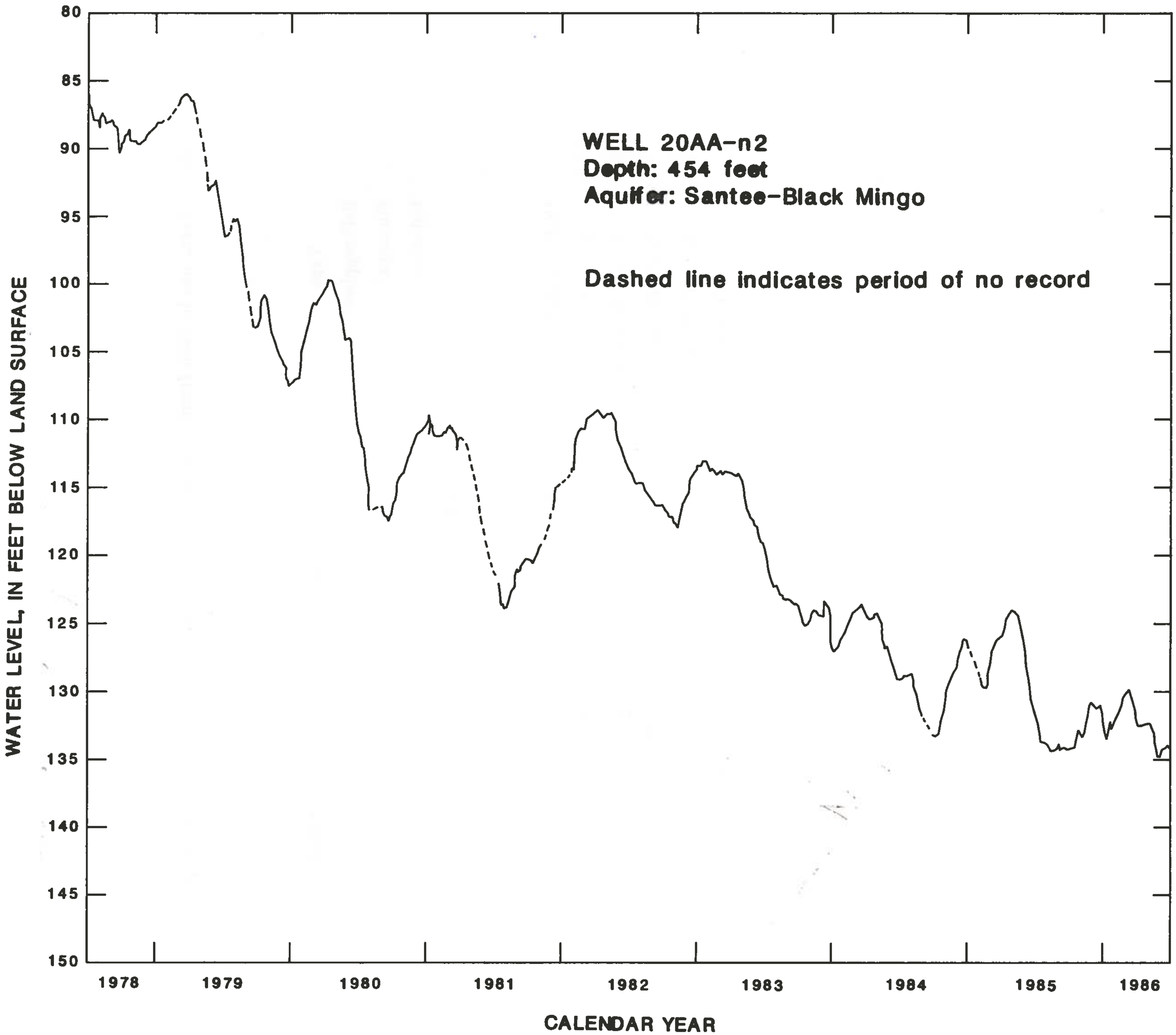

Figure 10. Hydrograph of well 20AA-n2.

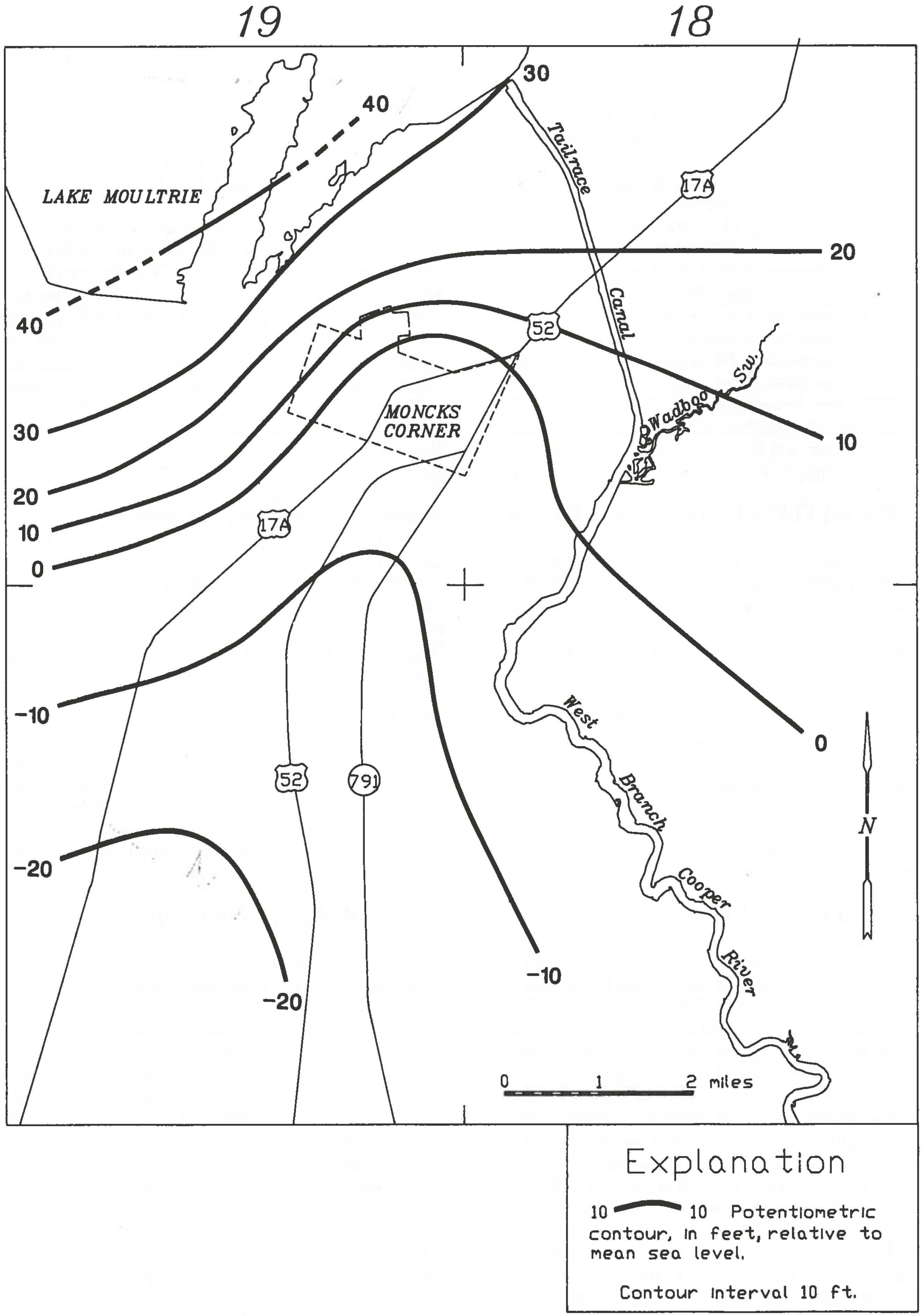

Figure 11. Santee-Black Mingo water levels in 1985.

to determine precisely, since no continuous water-level record dating before 1970 exists, conservative estimates indicate an average decline of about 3 ft per year in and south of Moncks Corner. Slightly less than 2 ft per year seems to be the average elsewhere. By assuming that decline rates will remain constant over the next 15 years (they may increase as ground water demand grows), future water levels can be predicted. Figure 13 shows predicted water levels in the study area for the year 2000. Contrasting these levels with those of the present (Fig. 11) reveals that water levels in the southwest corner of the study area in the year 2000 will have dropped below -70 ft m.s.l. Currently, they are slightly deeper than -20 ft m.s.l. If predictions are accurate, such declines here and throughout the study area will place static water levels close to the top of the Santee Limestone. Since large drawdowns are typical of Santee-Black Mingo wells, pumping levels in wells other than low-output domestic wells may be below the top of the aquifer. If they remain there, compaction will occur and the permeability of the aquifer will be permanently reduced (Freeze and Cherry 1979).

ALTERNATIVE WATER SOURCES

Population and water level trends show that the Santee-Black Mingo aquifer system cannot indefinitely continue supplying water to the growing population in and near the study area. Alternative sources should be developed, if possible, to slow water level declines. If it is intended that ground water continue to be a source, several aquifer systems are available.

The best prospects are aquifers in the three Cretaceous formations. All the systems, namely (in order of depth) the Peedee Formation, the Black Creek Formation, and the Middendorf Formation, are present beneath the study area but have yet to be used because ground water from the shallower Santee-Black Mingo system has been readily available. A summary of each system follows.

Peedee Formation

The Peedee Formation is the youngest and shallowest of the Cretaceous formations in the study area. It occurs from about -470 ft m.s.l. (at well 19Z-b1) to about -800 ft m.s.l. (Park 1985) for a total thickness of 330 ft. Only one well in the study area, 19Y-s1, owned by the town of Moncks Corner, taps the Peedee. It is screened from -578 to -638 ft m.s.l. The well flowed 10 gpm upon completion and produced 200 gpm with 240 ft of drawdown, for a specific capacity of 0.8 gpm/ft. This is typical of wells completed in the Peedee Formation near the coast (Park 1985), hence it has seldom been used as a water supply source.

Water quality in the Peedee is similar to that from Santee-Black Mingo wells in the southern half of the study area. Well 19Y-s1 yielded a soft, sodium bicarbonate water with total dissolved solids of 920 mg/L, chloride of 59 mg/L, and fluoride of 1.5 mg/L (Table 2).

Black Creek Formation

The Black Creek Formation is widely used as a water source throughout the State. Although no one in the study area uses it, nearby towns such as Summerville, Mt. Pleasant, St. Stephen, and Jamestown, have Black Creek wells. The unit immediately underlies the Peedee Formation and in the study area occurs between the depths of -800 and -1,450 ft m.s.l., for a thickness of 650 ft (Park 1985).

Black Creek aquifers are capable of yielding large amounts of water. Wells at Mt. Pleasant (in Charleston County 20 miles south-southeast of the study area) have been tested at over 1,000 gpm and have specific capacities around 7 gpm/ft. Yields seem to be lower in the Jamestown area, where 500 gpm could be considered maximum. Well performances in the study area would likely fall somewhere between these extremes.

Aucott and Speiran (1985) reported 1982 Black Creek water levels to be between +75 and +100 ft m.s.l. in the study area; therefore, water levels would be at or above land surface, depending on well site elevation. Water levels have declined in the Mt. Pleasant area because of heavy pumping from public supply wells, but it is unknown whether the declines would affect the study area.

Water from Black Creek aquifers is a soft, sodium bicarbonate type similar to that from Santee-Black Mingo wells in the southern half of the study area. Regionally, the water is more mineralized at the coast than inland. For example, total dissolved solids range from a low of 350 mg/L in well 15X-L5 at Jamestown to a high of 1,100 mg/L in well 17DD-m5 at Mt. Pleasant (Table 2). Chloride shows a similar trend with 4.0 mg/L occurring in Jamestown and 135 mg/L in Mt. Pleasant. Fluoride concentrations are about 2.0 mg/L in Jamestown and 4.4 mg/L in Mt. Pleasant. In the study area, total dissolved solids, chloride, and fluoride would probably lie between Jamestown and Mt. Pleasant values.

Middendorf Formation

Although the Middendorf Formation contains some of the most productive and widely used aquifers in the Coastal Plain, it is rarely tapped on the coast because of its greater depth and commonly more mineralized water than the above-lying Black Creek Formation. In the study area, the Middendorf lies between about -1,450 ft m.s.l. (Park 1985) and the crystalline rock basement at about -2,300 ft m.s.l. (Colquhoun and others 1983). This interval is probably not occupied totally by the Middendorf. Aucott and Speiran (1985) stated that sediments composing the lower portion of the Middendorf actually belong to the Cape Fear Formation, a unit older than the Middendorf.

Well-performance data for the Middendorf are sparse, since few wells near the study area tap the formation. Data for well 18AA-e4, about a mile south of the study area, show that yields can be very high. The

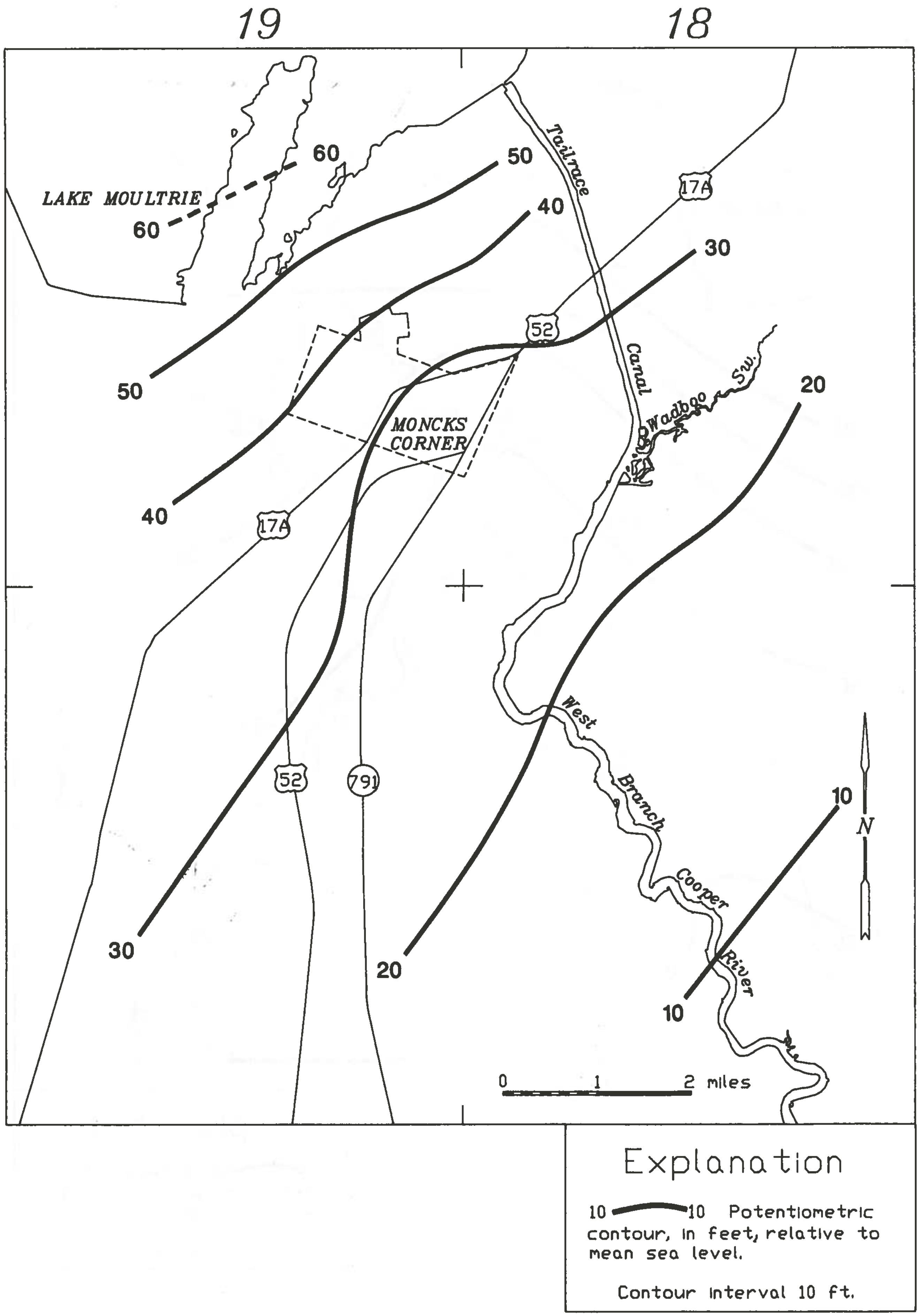

Figure 12. Santee-Black Mingo water levels prior to 1970.

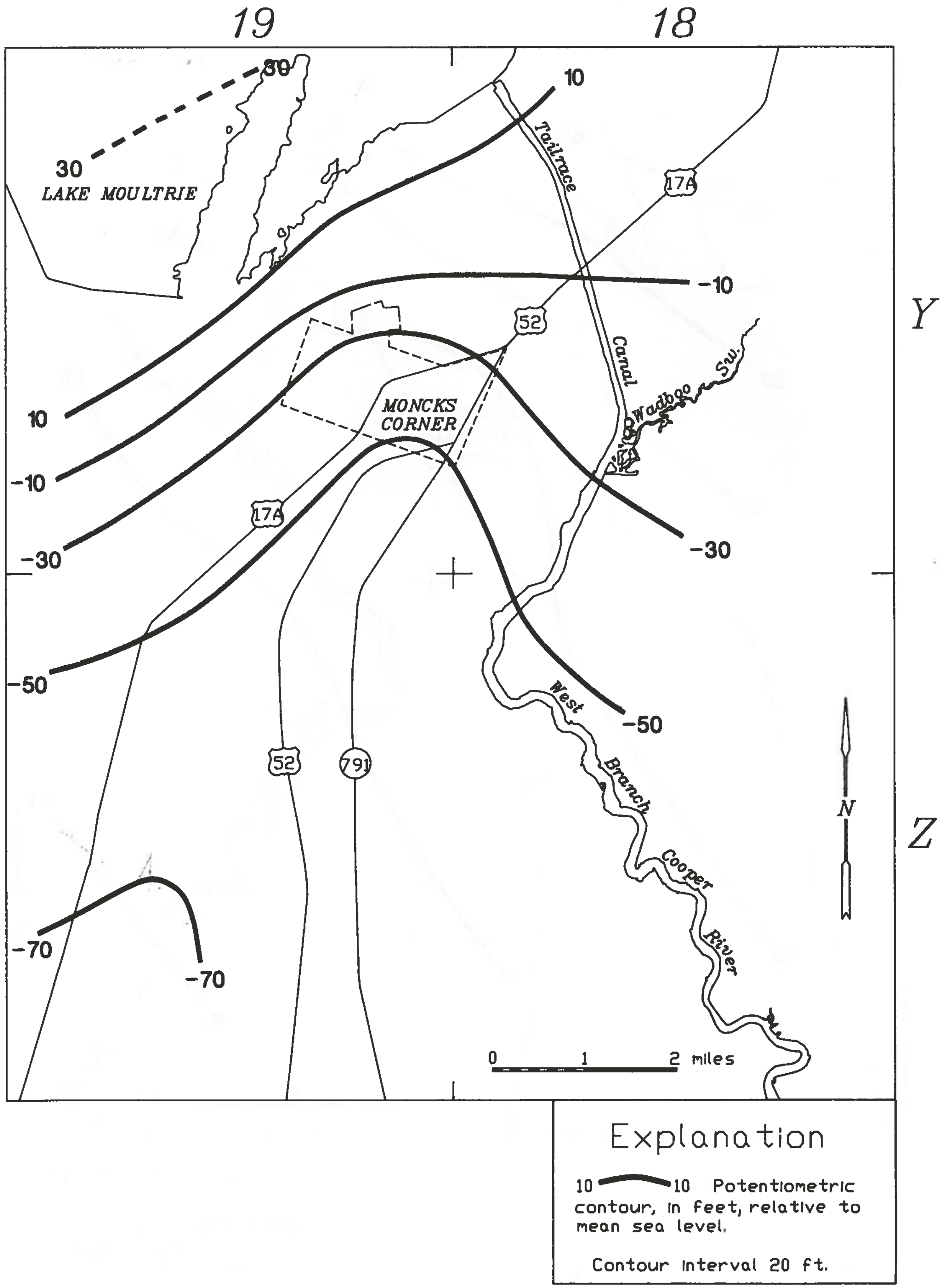

Figure 13. Predicted Santee-Black Mingo water levels for the year 2000, based on present rates of decline.

well was test pumped at more than 2,000 gpm, flowed naturally at 800 gpm, and had a specific capacity between 15 and 18 gpm/ft. Nearby well 18AA-e2 did not perform as well, as it had a specific capacity of only 0.8 gpm/ft. Both wells may also tap the lower portion of the Black Creek Formation. The difference in performance is probably due to well construction rather than to hydrogeologic factors.

Water level information for the Middendorf is also sparse. From Aucott and Speiran (1985), 1982 Middendorf water levels in the study area were between + 75 and + 100 ft m.s.l., the same as Black Creek levels. Of the few wells using the Middendorf, well 18AA-e4 had a static water level of + 16 ft m.s.l. in 1982, although it may not be representative. Well 19Y-w3, a Middendorf test well located in the middle of the study area, flowed at land surface, thus giving it a water level above + 67 ft m.s.l.

Middendorf water-quality information is available from only two wells in the study area. The Middendorf typically contains more mineralized water near the coast than the Black Creek, except in parts of southern Charleston County where Middendorf water is fresher than Black Creek water (Park 1985). In the study area, the only well to penetrate the Middendorf, 19Y-w3, was drilled as an exploratory well and is unused. Although the water quality results may be less than precise, since the well was never fully developed, it appears that Middendorf water beneath the study area is a soft, alkaline, sodium bicarbonate type. Total dissolved solids in the well were 870 mg/L, chloride was 68 mg/L, and fluoride was 3.8 mg/L (Table 2). Well 18AA-e2, about 1 mile south of the study area, also yielded a sodium bicarbonate type of water, although less mineralized, possibly because the well may tap the lower portion of the Black Creek Formation. Total dissolved solids were 643 mg/L, chloride was 26 mg/L, and fluoride was 2.7 mg/L (Table 2). The temperature of Middendorf water would be between 85 and 100 degrees Fahrenheit, the cooler temperature near the top of the formation and the warmer temperature near the bottom.

CONCLUSIONS

Most wells in the Moncks Corner area obtain water from the hydraulically connected Santee Limestone and Black Mingo Formation. These units are confined by the overlying Cooper Formation, hence ground water occurs under artesian conditions. In most wells, casing is seated in the Cooper Formation, leaving an open hole that penetrates the lower part of the Santee (Moultrie Member) and the upper part of the Black Mingo.

Many wells are capable of producing 100 gallons per minute. Specific capacities are usually less than 2 gallons per minute per foot of drawdown. Aquifer transmissivity ranges between 300 and 700 feet squared per day.

Water quality for Santee-Black Mingo wells varies by location and by depth. In the north half of the study area, water is a hard, calcium bicarbonate type low in dissolved solids. In the south half, soft, more mineralized, sodium bicarbonate water exists. Water quality worsens with depth below the uppermost sand beds of the Black Mingo.

Since 1970, Santee-Black Mingo water levels have declined at a rate of 2 to 3 feet per year, most apparent in the development corridor between Moncks Corner and Summerville. Prior to 1970, water levels were above sea level and ground water moved in a southeasterly direction from the recharge area at Lake Moultrie. By contrast, present-day water levels in the southwest portion of the study area are -20 feet m.s.l., a decline of 45-50 feet, and ground water flows southwesterly along the development corridor. The declines appear to be caused by rapid increases in regional pumping. If water level declines continue at their present rate, static water levels in the year 2000 will be near the top of the Santee, possibly causing high-output wells to partially dewater the aquifer.

Below the Santee-Black Mingo, the Black Creek and Middendorf Formations contain aquifers suitable for alternative or supplemental supplies in the Moncks Corner area. Wells could yield as much as 1,000 gallons per minute. Static water levels would be at or above land surface; highest in the Middendorf. The water would be a soft, sodium bicarbonate type similar to Santee-Black Mingo water in the south half of the study area. Middendorf water would be more mineralized than Black Creek water.

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Table 4. Selected wells near Moncks Corner, S.C.

EXPLANATION OF COLUMN HEADINGS

Well No.: SCWRC--South Carolina Water Resources Commission grid number
County--Consecutive county number.
BRK--Berkeley
CHN--Charleston
DOR--Dorchester

Latitude/Longitude: in degrees, minutes, and seconds

Elevation: in feet above mean sea level.

Well use:

Dom--domestic	Unu--unused
PS--public supply	Obs--observation
Irr--irrigation	Ind-industry

Depth: in feet

Casing diameter: in inches

Casing depth: top of open interval, in feet

Pump rate: in gallons per minute

Geophysical logs:

G--gamma-ray	R--resistance	T--temperature
SN--short-normal resisitivity		C--Caliper
SP--spontaneous potential		FR--fluid resistivity
LT--6-foot lateral resistivity		FM--flow meter
N--Neutron radiation		

Water level/Date--non-pumping water level, in feet below or above (+) land surface; Date measured.

Aquifer-- S-Santee, B-Black Mingo, PD-Peedee, BC-Black Creek, M-Middendorf

Well No. SCWRC County	Latitude Longitude	Elevation	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
15X-L1 BRK-84	33 17 07 79 41 42	32	PS	894	6	770	115	G	9 9/29/70	BC	
15X-L5 BRK-26	33 17 35 79 41 10	35	Ind PS	885	6	700	275	SP/R	+11.5	BC	Screened between 700 and 880 ft (five screens). Pumping test.
17DD-m5 CHN-163	32 47 17 79 52 18	26	PS	1919	8	1829	750	SP/R	+27.2 2/3/83	BC	Screened 1829-1912 ft. Pumping test.
18Y-d1 BRK-167	33 14 42 79 58 53	41.6	Obs	137	6	50		G, C, T/FR FM	17.7 8/22/85	S/BM	
18Y-e1 BRK-50	33 14 37 79 59 03	50	Ind	141	6	61			+5 12/27/66	S/BM	
18Y-e2 BRK-45	33 14 37 79 59 23	22	Ind	103	8	22	140		+7? 3/27/64	S	
18Y-e7 BRK-544	33 14 43 79 59 11	42	PS		4				17 8/21/85		
18Y-f2 BRK-554	33 13 19 79 59 50	57	Dom	240	4	75			33.5 12/11/85	S/BM	
18Y-g1 BRK-461	33 13 04 79 58 07	22	Unu	220	6	168	200±	G/R, SP/SN/LN, SP/LT, C	5.5 8/8/85	BM	
18Y-h1 BRK-542	33 13 17 79 57 56	32	Unu		2				16.5 8/8/85		
18Y-n1 BRK-168	33 12 41 79 58 52	10	PS	141	4	42	55		+18 5/29/68	S/BM	
18Y-o1 BRK-169	33 12 10 79 59 10	58	Unu	200	6	185			58.2 12/10/85	BM	WL 31 ft 12/4/73. Screened 185-200 ft.

Well No. SCWRC County	Latitude Longitude	Eleva-tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
18Y-p1 BRK-170	33 11 18 79 59 56	53.9	PS	211	8	174	200		56.9 4/11/85	S,BM	WL 22 ft in 1968.
18Y-q2 BRK-301	33 11 47 79 58 49	50	PS	340	6	216	177		33.5 11/12/80	BM	Screened between 216 and 335 ft (five screens).
18Y-q3 BRK-537	33 11 32 79 58 11	7	Dom		3				+2 4/13/85		Flows 3-4 gpm.
18Y-q4 BRK-538	33 11 31 79 58 12	12	Unu		2				5.7 4/13/85		
18Y-r1 BRK-530	33 11 44 79 57 11	5	Unu		2				+2 4/12/85		Flows about ½gpm.
18Y-v1 BRK-525	33 10 42 79 56 58	20	Unu	174	6	46		G/R, T/FR, C	14.5 4/12/85	S	
18Y-x1 BRK-550	33 10 54 79 58 26	10	Dom	138	4	42		G/R, T/FR, C	4.5 12/4/85	S/BM	WL +5.6 ft 6/3/67.
18Z-e1 BRK-555	33 09 36 79 59 38	11	Dom	165	4				15 12/11/85	S/BM	
18Z-f1 BRK-171	33 08 28 79 59 19	20	Irr	227	6	68				S/BM	
18Z-f2 BRK-539	33 08 54 79 59 51	10	Dom		4				15.9 4/13/85		
18Z-h1 BRK-526	33 08 42 79 57 21	35	Irr		4				36.4 4/12/85		
18Z-h2 BRK-527	33 08 42 79 57 22	36	Irr		6				37.4 4/12/85		

Well No. SCWRC County	Latitude Longitude	Eleva- tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
18Z-m1 BRK-545	33 07 07 79 57 10	32	PS		6				34.5 8/22/85		
18Z-m2 BRK-546	33 07 07 79 57 09	32	PS		8				34.5 8/22/85		
18Z-r2 BRK-404	33 06 02 79 57 48	12	Dom	205	4	65				S/BM	
18Z-r4 BRK-557	33 06 59 79 57 08	31	PS	200	4	60		G/R, T/FR, C	36.0 6/12/86	S/BM	
18Z-v2 BRK-528	33 05 21 79 56 03	12	PS	216	2				+4 4/12/85		Flows.
18Z-w1 BRK-303	33 05 37 79 57 09	10	Dom	220	4	63				S/BM	
18Z-w3 BRK-312	33 05 45 79 57 13	10	Dom	200	3	62			10 10/7/63	S/BM	
18Z-x1 BRK-531	33 05 05 79 58 23	13	Unu	200	2				15 4/12/85	S	
18Z-y1 BRK-551	33 05 49 79 59 31	31	Dom		3				36 12/11/85		
18AA-e2 BRK-430	33 04 41 79 59 58	18	Ind	1900	4	1548	135	G, SP/SN/LN/R	+83 11/20/81	? BC/M	Screened between 1548 and 1960 ft (10 screens). Pumping test.
18AA-e4 BRK-444	33 04 36 79 59 44	18	Ind	1642	8	1530	2000		+79 7/23/82	? BC/M	Screened between 1530 and 1642 ft (three screens). Pumping test.
19Y-c1 BRK-552	33 14 05 80 02 08	85	PS	240	4	147			38 12/11/85	S/BM	

Well No. SCWRC County	Latitude Longitude	Eleva-tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Y-c3 BRK-556	33 14 05 80 02 12	86	PS	225	6	176	164	G/R, T/FR, C, FM	37 5/15/86	S/BM	
19Y-h2 BRK-549	33 13 54 80 02 07	90	Dom		4				45 1/5/85		
19Y-h3 BRK-553	33 13 33 80 02 15	87	PS	238	4	158			47.5 12/11/85	BM	Screened 206-226 ft.
19Y-i1 BRK-520	33 13 00 80 01 30	75	Dom		4				50.6 4/11/85		
19Y-k1 BRK-94	33 12 11 80 00 14	50	Ind	252	8	173	55		30.52 5/28/78	BM	Screened 173-188 and 229-239 ft. Pumping test.
19Y-k2 BRK-95	33 12 14 80 00 12	50	Ind	264	4	230			23.20 5/28/78	BM	Screened 230-260 ft. Pumping test.
19Y-k3 BRK-2	33 12 04 80 00 16	50	Unu	172	8				33.29 5/28/78	S	Caved in below (?) 103 ft. Pumping test.
19Y-k4 BRK-96	33 12 05 80 00 16	50	Ind	185	6	145	189		37.6 5/28/78	S/BM	Pumping test.
19Y-k5 BRK-413	33 12 03 80 00 25	50	Unu	104	10	47		G, C	42.79 11/11/82	S	
19Y-k6 BRK-521	33 12 41 80 00 39	65	Dom		4				49.3 4/11/85		
19Y-m1 BRK-92	33 12 58 80 02 47	90	PS	229	6	156	412	G, R, C	32 5/14/65	S/BM	
19Y-m2 BRK-184	33 12 44 80 12 34	86.2	PS	240	4	170			55 12/11/85	BM	Screened 170-240 ft.

Well No. SCWRC County	Latitude Longitude	Eleva- tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Y-m3 BRK-185	33 12 08 80 02 08	72	Unu	261	4	145	90		32 3/14/67		Screened 170-240 ft.
19Y-m5 BRK-517	33 12 07 80 02 55	91	Unu		4				65.2 4/10/85	S/BM	
19Y-n1 BRK-186	33 12 30 80 03 45	70	Ind	352	6	84				S/BM	
19Y-p3 BRK-548	33 11 41 80 04 06	75	Dom	172	4	120		G/R, T/FR, C	48 12/4/85	S/BM	
19Y-q1 BRK-518	33 11 44 80 03 03	90	Ind	380	6	120		G/R, T/FR, C	66 4/13/85	S/BM	
19Y-r1 BRK-516	33 11 19 80 02 09	72	Unu		6				62.1 4/10/85		WL 27 ft in 1967.
19Y-s1 BRK-87	33 11 32 80 01 00	55	PS	709	8	633	200	G, SP/R	67.9 4/11/85	PD	Screened 633-693 ft. Formerly flowed.
19Y-s3 BRK-460	33 11 29 80 01 02	58	PS	261	6	187	388	G/R, SP/SN/LN, SP/LT, N	62.8 4/11/85	S/BM	Screened 187-207 and 231-251 ft. WL 54 ft 9/16/82.
19Y-s4 BRK-506	33 11 03 80 01 24	47	Dom		4				52.5 4/8/85		
19Y-t1 BRK-4	33 11 49 80 00 58	45	PS	147	4		300			S	
19Y-t2 BRK-189	33 11 42 80 00 23	58.4	PS	190	8	125	60		66 4/10/85	S/BM	
19Y-t3 BRK-10	33 11 41 80 00 53	55	PS	186	4	30			25 3/15/46	S/BM	

Well No. SCWRC County	Latitude Longitude	Eleva-tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Y-t4 BRK-8	33 11 36 80 00 20	55	PS	170	8	140±	50		30 9/13/59	S	WL 23 ft 3/15/46.
19Y-t5 BRK-9	33 11 36 80 00 20	55	PS	160	8		50		53.5? 4/10/85	S	WL 24 ft in 1944.
19Y-u1 BRK-492	33 10 10 80 00 47	50	PS	300	4				50.8 4/8/85	S/BM	
19Y-u2 BRK-498	33 10 59 80 00 45	50	Unu	166	3				59 3/8/85	S	
19Y-u3 BRK-513	33 10 33 80 00 11	25	Unu		4				25.2 4/9/85		
19Y-u4 BRK-514	33 10 18 80 00 17	27	Unu		4				29.5 5/9/85		
19Y-u5 BRK-541	33 10 31 80 00 33	45	PS	238	4	146		G/R	48 8/7/85	S/BM	
19Y-v1 BRK-486	33 10 18 80 01 25	50	PS		3						
19Y-v2 BRK-487	33 10 18 80 01 28	50	PS		4				63.6 4/8/85		
19Y-v3 BRK-488	33 10 24 80 01 27	53	Dom		3						
19Y-v4 BRL-489	33 10 22 80 01 29	51	Dom		4				62.9 4/8/85		
19Y-v5 BRK-490	33 10 30 80 01 37	40	Dom		4				58.7 4/8/85	S/BM	

Well No. SCWRC County	Latitude Longitude	Eleva-tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Y-v6 BRK-491	33 10 19 80 01 29	52	Dom		4	260				S/BM	
19Y-v7 BRK-193	33 10 02 80 01 40	40	PS	250	6	187	275		54 3/10/85	BM	Screened 187-197 ft and 234-250 ft. WL 27 ft 10/28/76.
19Y-v8 BRK-507	33 10 39 80 01 58	51	Dom		4				58.4 4/8/85		
19Y-v9 BRK-508	33 10 57 80 01 01	61	Dom	300	4				68.4 4/8/85	S/BM	
19Y-v10 BRK-512	33 10 21 80 01 32	50	PS	385	4				67.4 4/8/85	S/BM	
19Y-w1 BRK-190	33 10 22 80 02 15	65	PS	315	12	183	275	G, C	54 9/9/76	S/BM	
19Y-w3 BRK-431	33 10 22 80 02 15	65	Unu	1607	4	1602		G/SP/R, SN, N, T/FR	Flows 4/3/84	M	Screened 1602-1607 ft. See also 19Y-w2.
19Y-x2 BRK-515	33 10 02 80 03 16	88			4				93 5/9/85		
19Y-x3 BRK-519	33 10 39 80 03 14	94	Dom	245	4	135			93.9 4/10/85	S/BM	
19Z-a1 BRK-192	33 09 15 80 00 51	40	PS	172	8	47	150		56.12 4/8/85	S/BM	WL +3 ft 3/28/61.
19Z-a2 BRK-493	33 10 10 80 00 47	40	Irr		4				45.3 4/8/85		
19Z-b2 BRK-445	33 09 04 80 01 40	41	Ind		6				56.7 4/11/85		

Well No. SCWRC County	Latitude Longitude	Elevation	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Z-b3 BRK-457	33 09 27 80 01 30	40	Ind	256	10	177	300	G/R, C	33 1/27/84	S/BM	Screened between 177 and 246 ft (three screens). Pumping test. Geologic age dates.
19Z-b4 BRK-458	33 09 03 80 01 14	40	Ind	320	10	182	350±	G, SP/R	44 4/6/84	BM	Screened between 182 and 310 ft (three screens).
19Z-b5 BRK-459	33 09 38 80 01 10	35	Ind	305	10	195	437±	G, SP/R, T/FR	30 4/2/84	S/BM	Screened 195-260 ft and 295-305 ft. Pumping test.
19Z-b7 BRK-523	33 09 27 80 01 30	41	Unu	220	4	40			46 4/11/85	S/BM	
19Z-c1 BRK-495	33 09 20 80 02 19	51	Dom		4				65.1 3/8/85		
19Z-c2 BRK-505	33 09 57 80 02 56	75	PS		4				80 4/8/85		
19Z-c3 BRK-510	33 09 12 80 02 22	51	Dom	217	4				65.2 4/8/85	S/BM	
19Z-d1 BRK-194	33 09 20 80 03 35	91	PS	436	8	79	35		55 9/61		
19Z-d2 BRK-496	33 09 09 80 03 23	80	Dom	250	4				85.1 3/8/85		
19Z-d3 BRK-504	33 09 29 80 03 27	90	PS		4				96.3 4/8/85		
19Z-g3 BRK-502	33 08 28 80 03 38	84	Dom	320	4				111.7 4/8/85		
19Z-h1 BRK-497	33 08 39 80 02 08	51	Dom		4				75 3/8/85		

Well No. SCWRC County	Latitude Longitude	Eleva-tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Z-h2 BRK-501	33 08 17 80 02 58	60	Dom	280	4				55? 4/8/85		
19Z-h3 BRK-503	33 08 55 80 02 49	60	PS		4				71.25 4/8/85		
19Z-h4 BRK-509	33 08 50 80 02 01	52	Dom		4				63.8 4/8/85		
19Z-h5 BRK-500	33 08 04 80 02 40	50	Dom		4				64.2 4/8/85		
19Z-i1 BRK-182	33 08 28 80 01 08	38	Dom	225	4	68	Rept 467?		47 12/12/85	S/BM	WL 16.5 ft in 1977.
19Z-i2 BRK-494	33 08 51 80 01 14	43	Dom	160	4				55.5 4/8/85	S	
19Z-i3 BRK-511	33 08 55 80 01 15	43	Unu		6				57.7 4/8/85		
19Z-i4 BRK-524	33 09 47 80 01 45	48	PS		4				61.5 4/11/85		
19Z-j1 BRK-195	33 08 43 80 00 45	33	Unu	203	6	165	75	G, N	40.5 3/8/85	S/BM	Screened 165-198 ft. WL 25 ft 6/10/68.
19Z-L1 BRK-499	33 07 45 80 01 09	18	Dom		4				28 4/8/85		
19Z-n1 BRK-196	33 07 30 80 03 35	65	PS	280	4	64				S/BM	
19Z-n2 BRK-536	33 07 31 80 03 59	82	PS		4				105.3 4/12/85		

Well No. SCWRC County	Latitude Longitude	Eleva- tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19Z-p2 BRK-535	33 06 25 80 04 26	79	PS		4				101 8/21/85		
19Z-s1 BRK-201	33 06 47 80 01 07	20.5	PS	252	6	65	250		34.9 4/12/85	S/BM	WL 30 ft 10/23/74.
19Z-s2 BRK-202	33 06 02 80 01 09	25	PS	235	4	63			14 9/18/64	S/BM	
19Z-v1 BRK-203	33 05 24 80 01 50	30	Ind	280	6	152			46.8 4/12/85	S/BM	
19Z-v2 BRK-138	33 05 21 80 01 44	30	Ind	248	6	120		G, C, SP, R	49.3 4/12/85	S/BM	
19Z-v3 BRK-204	33 05 33 80 01 46	33	Ind	265	4	235	106	G	43 1/7/76	BM	Screened 235-265 ft.
19Z-x2 BRK-532	33 05 10 80 03 29	47	Dom		4				93.5 4/12/85		
19Z-x3 BRK-533	33 05 10 80 03 28	46	Dom		4				68.1 4/12/85		
19Z-x4 BRK-534	33 05 10 80 03 28	46	Unu	360	3				68.6 4/12/85	S/BM	
19Z-x5 BRK-551	33 05 19 80 03 36	51	Dom	262	4	56		G, T/FR, C	73 12/11/85	S/BM	
19Z-y1 BRK-205	33 05 50 80 04 38	77	Ind	353	6	75			74 8/28/70	S/BM	
19Z-y2 BRK-543	33 05 51 80 04 30	68	PS		4				93.5 8/21/85		

Well No. SCWRC County	Latitude Longitude	Eleva- tion	Well use	Depth	Casing diam.	Casing depth	Pump rate	Geophysical logs	Water level Date	Aquifer	Remarks WL, water level
19CC-x1 CHN-172	32 50 49 80 00 53	15	PS	1843	8	1760	250		+88 4/19/71	BC	Screened 1760-1840 ft. Pumping test.
20AA-n2 BRK-91	33 02 18 80 08 07	66.6	Obs	454	6	74		N, SN/LN, SP/R, G, C		S/BM	Yielded 50 gpm. WL recorder since 1978.