NORTH CAROLINA
DEPARTMENT OF WATER RESOURCES
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DIVISION OF GROUND WATER
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GROUND-WATER BULLETIN NUMBER 3

GEOLOGY AND GROUND-WATER RESOURCES of the FAYETTEVILLE AREA

By

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PREPARED COOPERATIVELY BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

1961

North Carolina Board of Water Resources

Letter of Transmittal

The Honorable TERRY SANFORD
GOVERNOR OF NORTH CAROLINA

DEAR GOVERNOR SANFORD:

I am pleased to submit Ground-Water Bulletin Number 3, "Geology and Ground-Water Resources of the Fayetteville Area."

This report gives the results of an investigation made by the U. S. Geological Survey, initiated in cooperation with the North Carolina Department of Conservation and Development and completed in cooperation with the North Carolina Department of Water Resources, as a part of the program of reconnaissance investigations to evaluate the ground-water resources of the State. It presents the data collected and describes the general geological and ground-water conditions in Cumberland, Harnett, Hoke, Lee, Montgomery, Moore, Richmond, Robeson, and Scotland Counties.

This report is a valuable contribution to the knowledge of the ground-water resources of the area. It will be available to all persons and agencies concerned with the development and conservation of those resources.

Respectfully submitted,

HARRY E. BROWN

Geology and Ground-Water Resources of the Fayetteville Area

By

Robert G. Schipf

ABSTRACT

The Fayetteville area, in south-central North Carolina, consists of Cumberland, Harnett, Hoke, Lee, Montgomery, Moore, Richmond, Robeson, and Scotland Counties, an area of 4,834 square miles. It has a population of 400,000, estimated in 1954, of which 77 percent is rural. Mineral products include sand and gravel, clay, and about 50 percent of the United States production of pyrophyllite.

The area includes the southern half of the Fall Zone in North Carolina and lies in both the Piedmont and the Coastal Plain physiographic provinces. The surface has a general southeast slope. In the Piedmont province, the land is rolling to hilly in the slate belt section but becomes level to undulating in the Triassic section. In the Coastal Plain province, the sandhills section consists chiefly of rounded hills and long, wide ridges, whereas the flatwoods section is an almost level, gently undulating plain marked by numerous Carolina bays.

The Piedmont province is underlain by the volcanic slate series of Paleozoic age and the Newark group of Late Triassic age. The volcanic slate series consists chiefly of interbedded tuff, breccia, rhyolite, slate, and schist, with associated granitic rocks, diabase dikes, and quartz veins. The rocks generally are metamorphosed and mineralization is extensive. The Newark group consists chiefly of shale, claystone, siltstone, diabase dikes, and two coal beds. These sedimentary rocks are synclinal, occupying a long, narrow graben. The rocks of both series are mantled by thick reddish soils. Most of the streams have deposited alluvial sediments in thin beds along their courses.

The Coastal Plain province is underlain by a monoclinal series of sand and clay beds which dip toward the southeast. The formations include the Tuscaloosa and Black Creek formations of Late Cretaceous age, isolated remnants of the Castle Hayne limestone of middle and late Eocene age, thin beds of

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the Duplin marl of late Miocene age, and widespread beds of sand—the undifferentiated surficial sediments. Alluvium crops out along all the streams.

Four towns in the Fayetteville area utilize springs for their water supplies, but most public ground-water supplies and almost all private supplies are obtained from wells of several kinds. Yields of wells differ greatly from place to place, but the quality of the ground water is generally good. Six main aquifers are recognized in the area: slate belt rocks, Triassic rocks, Cretaceous clay, Cretaceous sand, surficial sand, and alluvium.

In the slate belt rocks, permeability depends upon structure, the rocks being fine grained and dense. Usable water occurs chiefly in fracture systems at depths that rarely exceed 300 feet. Wells drilled in favorable locations may yield as much as 100 gpm (gallons per minute), but average yields are much less. The weathered rock that mantles the slate belt yields small supplies of water to shallow wells. The water is usually soft and somewhat acidic, and the iron content may be objectionable locally. The slate belt rocks yield sufficient quantities of water to wells for domestic and small industrial supplies.

The Triassic rocks are a poor aquifer, as they are compact and tightly cemented. Circulation of water depends upon fracturing and hence the best yields are obtained near faults and dikes. Yields average less than 10 gpm and deep wells rarely yield more than shallow ones. The water is generally alkaline and moderately hard to very hard, though satisfactory for most uses. This aquifer yields domestic and, occasionally, small industrial supplies of water to wells.

The Cretaceous clay aquifer has a maximum thickness of 375 feet. It is porous at most places but relatively impermeable. Yields of wells exceed 10 to 20 gpm only from the occasional beds of sand. The water is soft, slightly acidic, and suitable for all uses, but the iron content may be objectionable locally. This aquifer yields domestic and small industrial supplies of water to wells.

The Cretaceous sand aquifer ranges in thickness from about 250 to 600 feet and is permeable. Yields from properly developed wells generally exceed 1 gpm per foot of depth, and one well yields more than 5 gpm per foot of depth. The water generally is soft and slightly acidic but becomes hard and slightly alkaline locally. This aquifer yields domestic and large industrial supplies of water to wells.

The surficial sand aquifer underlies the Coastal Plain section of the area of investigation. Its permeability is high, but the sand beds are only 10 to 50 feet thick and yields are small—as great as 50 gpm only under optimum conditions. The water generally is soft and of good quality, though slightly acidic. Domestic and some small industrial supplies of water may be obtained from this aquifer.

The alluvium is a prolific aquifer at some places. A river infiltration system at a wartime army camp, Camp Mackall, tapped this aquifer and yielded 3,000,000 mgd, but no great use is now made of the aquifer. The water is of good quality.

Present consumption of ground water in the Fayetteville area is about 40 mgd, about 75 percent of the population using public or private ground-water supplies. The average annual rainfall of 47 inches adequately recharges the several aquifers, and ground-water use may be greatly increased throughout the area with no danger of overuse. Although the water table fluctuates readily from season to season, it is not being lowered permanently.

The geology and ground-water resources of the area by counties are described in detail. Geologic maps, well-location maps, tables of well data, chemical analyses, and other illustrative material are included in the report.

INTRODUCTION

This report summarizes the results of a preliminary investi-
ation of the geology and ground-water resources of the Fay-
tteville area in south-central North Carolina, including
'umberland, Harnett, Hoke, Lee, Montgomery, Moore, Rich-
nond, Robeson, and Scotland Counties (fig. 1). It is one of a
eries of similar reports which eventually will provide informa-
ion on the geology and ground-water resources of the entire
tate. The name "Fayetteville" has been given the area because
city of that name is the largest in the area.

The investigations are being made through a continuing
ooperative agreement between the State Department of Water
Resources and the Geological Survey, U. S. Department of the
nterior. The report was prepared under the general supervision
f A. N. Sayre and P. E. LaMoreaux, former and present chiefs,
Ground Water Branch, U. S. Geological Survey, and Harry E.
Brown, Director, State Department of Water Resources.

The field work in the Fayetteville area was done, chiefly,
n 1953 and 1954. It included reconnaissance geologic mapping
nd the location and observation of about 500 wells from which
ata were obtained. Samples of ground water were analyzed
nder the direction of G. A. Billingsley, district chemist, Quality
f Water Branch, U. S. Geological Survey.

The writer acknowledges the generous cooperation of those
who provided information for this report or aided in its prepara-
ion. Information on ground-water conditions was obtained
rom well drillers, well owners, water-supply superintendents,
ounty agriculture agents, and others.

GEOGRAPHY

Area and Population

The nine counties described in this report have a total area
f 4,834 square miles, almost two-thirds of which is in the
Coastal Plain. The population figure obtained from the 1950
ensus was 386,963. Some sections have had a rapid growth
ince 1950, however, and the estimated 1954 population was
lose to 400,000, almost half the people living in Cumberland
nd Robeson Counties.

Only about 23 percent of the population may be classed as
urban; the remainder is 37 percent rural farm and 40 percent
ural non-farm.

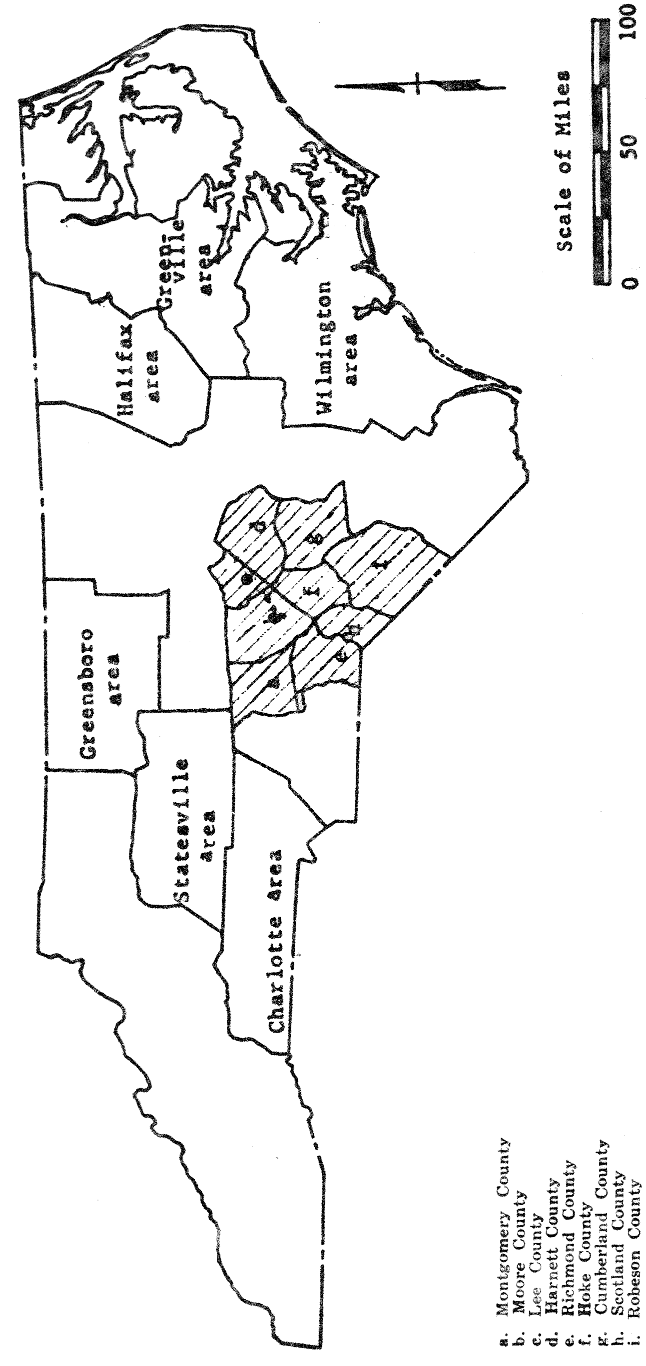

Figure 1. Map of North Carolina showing where major systematic ground-water investigations have been made.

Physiography and Drainage

The Fayetteville area lies in two of the major physiographic provinces of the United States, as outlined by Fenneman (1928). The northwestern one-third lies in the Piedmont province, which includes the Carolina slate belt and the Triassic lowland, and the southeastern two-thirds lies in the Coastal Plain province, which includes the sandhills and the flatwoods (pl. 1). Two major river systems, the Cape Fear River system and the Yadkin-Pee Dee River system, drain the area.

The boundary between the Piedmont and the Coastal Plain is usually referred to as the Fall Line (Atwood, 1940, p. 27-28) because falls or rapids have developed in some places where the streams pass from the hard Piedmont rocks to the soft Coastal Plain rocks. Because the boundary is not sharply defined, however, the term Fall Zone is preferable.

Carolina slate belt.—The Carolina slate belt, a terrane of metamorphosed volcanic rocks and associated intrusive rocks, all regarded as early Paleozoic in age, lies in the northwestern part of the area. These rocks usually are weathered deeply and, in places, have a mantle of residual clay as much as 120 feet thick, although the average is nearer 45 feet. The rocks have been sculptured into rounded, mature hills (fig. 2) and smooth interstream areas, but the swift-flowing streams, actively cutting into bedrock in the valleys, have developed a rough and broken topography. Many of the divides are narrow but are smooth in profile. Short, steep ravines are common. The streams have steep gradients and usually form a rectangular drainage pattern.

Although the general elevation throughout most of this subprovince is not more than 400 to 600 feet, some hills in western Montgomery County, capped by almost bare rock, attain elevations of 800 to 900 feet. These probably are monadnocks developed during a previous erosion cycle. The greater part of the slate belt section is forested.

Triassic lowland.—Southeast of the Carolina slate belt is a discontinuous area called the Triassic lowland. The rocks here are shale, siltstone, and sandstone of the Newark group of Late Triassic age. Because these rocks are eroded easily, the land lies 100 feet or more below the level of the bordering terrane (fig. 2).

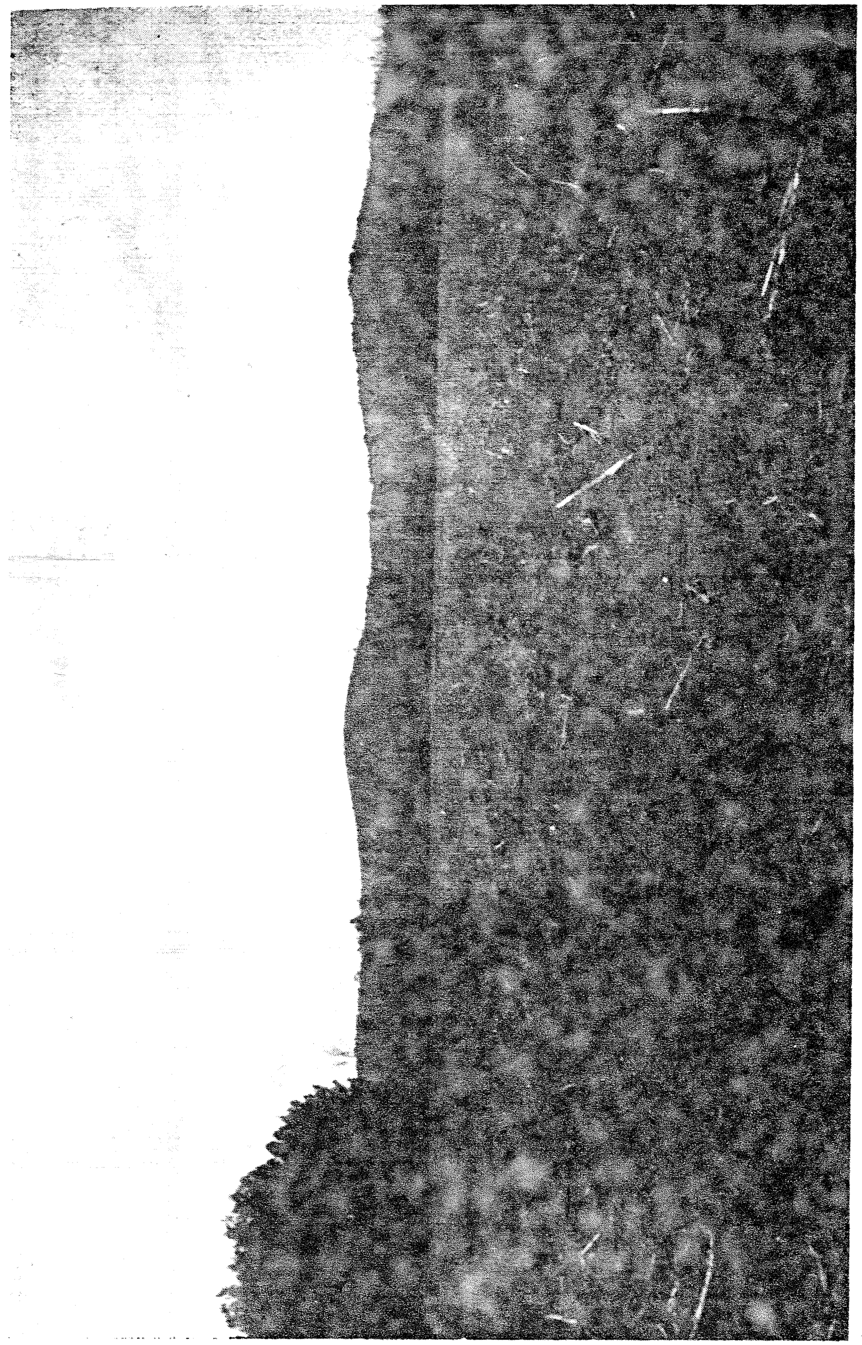

Figure 2. View near edge of Triassic lowland in southern Montgomery County.

The Triassic lowland is a rather smooth, mature area with wide valleys occupied by sluggish streams. The drainage pattern in Lee and Moore Counties is parallel; that in Montgomery and Richmond Counties is rectangular.

Elevations range from about 200 feet near the Pee Dee River to about 500 feet in Moore County, where overlying Coastal Plain sediments have protected the less resistant Triassic rocks. Most of the lowland, however, has a relief no greater than 50 to 100 feet. This region is well developed in northwestern Richmond and southeastern Montgomery Counties and, to the northwest, in central Moore and northwestern Lee Counties.

Sandhills.—Southwest of the Triassic lowland, and including parts of Cumberland, Harnett, Hoke, Lee, Montgomery, Moore, Richmond, and Scotland Counties, a distinctive area known as the Sandhills has developed. The Sandhills subprovince is characterized by rounded hills of loose to fairly well consolidated sands, which are chiefly Cretaceous in age.

The highest part of the Sandhills is near West End and Candor, where the elevation may exceed 700 feet along the main divide between the Cape Fear and the Pee Dee Rivers, but the average elevation is between 300 and 450 feet over most of the region. The northwest edge, where the streams are active, is about 500 feet higher than the southeast edge, where the streams have a lesser gradient. There are several long ridges in the northwestern part of the Sandhills near Norman and Eagle Springs. Some high hills are capped by a thin ironstone layer. The area is further characterized by a dendritic drainage pattern in which many streams have wide, swampy flood plains.

The eastern part of the Sandhills has several features which differentiate it from the main physiographic unit. Bordering the Flatwoods subdivision is a zone here named the Flat Sand Hills. The surficial lithology is nearly the same as that farther west, but the summits of the hills are broad, forming an extensive upland surface. Relief is as much as 60 feet in places, the belt rising from an elevation of 200 feet in the east to 300 feet at the edge of Sandhills proper.

The Flat Sand Hills are characterized by the development, on the upland surface, of shallow elliptical depressions, commonly called Carolina bays. The bays are small and few. The region is underlain by the thin, updip part of the Black Creek formation of Late Cretaceous age, which is well developed in

central Cumberland, Hoke, and Scotland Counties, where it roughly equals the Coharie terrace of Stephenson (Clark and others, 1912, p. 273).

Flatwoods.—The fourth subprovince is the Flatwoods section, which occupies all of Robeson and parts of Cumberland, Harnett, Hoke, and Scotland Counties. It is a gently dipping plain drained by many large, sluggish streams having swampy flood plains (fig. 3). The streams have developed a dendritic drainage pattern. Relief is slight in most places, rarely more than 50 feet. Elevations range from about 60 feet in the southeast near the Lumber River to about 200 feet adjoining the Sandhills.

The Flatwoods section is underlain chiefly by the Black Creek formation of Late Cretaceous age and is mantled by beds of loose sand and some clayey sand, which are probably of Quaternary age. The sand is mainly fine grained and consists of almost pure, clear quartz. The subprovince is further characterized by the development of numerous Carolina bays, some of which are large.

Climate

The Fayetteville area is in the humid, subtropical climatic zone. Temperature and precipitation vary seasonally, therefore, temperatures normally are mild and rainfall is adequate.

Weather records have been kept at several stations in the area for periods of from 13 to 40 years.

Average winter (January) temperatures range from 42° to 46°F, and average summer (July) temperatures from 78° to 81°F. The highest temperature recorded in the area was 108°F, at Fayetteville, Lumberton, and Rockingham; the lowest was —15°F, at Rockingham. Mean annual temperatures in the Fayetteville area range from 59° to 64°F. For the area as a whole, the average annual temperature is 60.8°F.

Precipitation generally is well distributed throughout the year. The average annual precipitation is 46.67 inches, the maximum rainfall occurring from June through September.

Mineral Resources

The Fayetteville area has an extensive nonmetallic mineral industry, of which the bulk is sand and gravel, clay, and pyrophyllite.

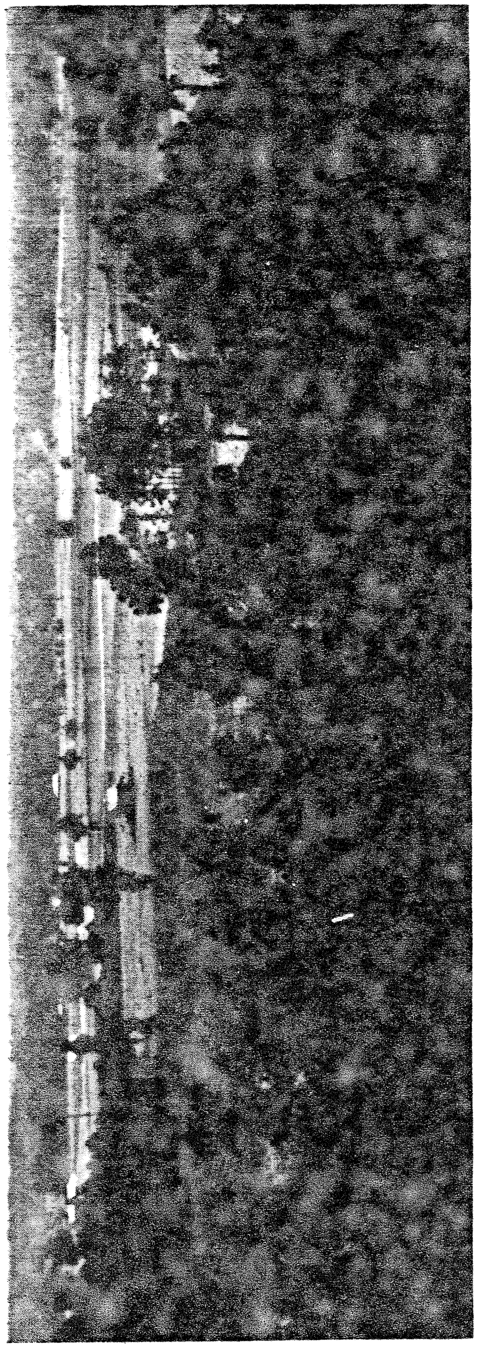

Figure 3. Flatwoods section in Robeson County.

Sand and gravel are mined throughout most of the Coastal Plain section but chiefly in the Sandhills. Most of the sand and gravel is used for road metal and construction. Most of the clay is used in the brick and tile industry. Pyrophyllite is mined in the Slate Belt for refractory and insulating purposes. Moore County accounts for about 50 percent of the United States production of this mineral. A small amount of building stone is quarried from thickly bedded siltstone in Montgomery County.

Minerals mined in former years include marl, kaolin, gold, silver, lead, zinc, copper, nitrogenous shale, sandstone, millstone, and coal. Mineral resources are discussed at greater length in the following sections on the several rock units in the area.

GEOLOGY

Because ground water occurs in the rocks of the earth's crust, its movement and availability depend upon several geologic factors. The following description of the rocks in the Fayetteville area is designed to give the reader information about the geology so that he may better understand the ground-water conditions.

The rocks in the Fayetteville area may be divided into three major units on the basis of lithology and age. These are: the volcanic slate series of probable Paleozoic age, the Newark group of Triassic age, and the rocks of the Coastal Plain of Cretaceous and younger age. Flood plain material, or alluvium, also will be considered.

The reconnaissance geologic maps that accompany this report delineate the boundaries of the volcanic slate series and Newark group and the several formations of the Coastal Plain recognized in the area. Surficial material usually has been mapped with the formation that underlies it. Base maps are county highway maps published by the North Carolina State Highway Commission. These maps do not show geographic features accurately, being designed to indicate only the length and general direction of the roads. Boundaries between the several map units, therefore, may not be geographically precise but are correct usually with respect to highway distances.

Lower Paleozoic(?) Rocks—Volcanic Slate Series

The rocks of the volcanic slate series have been called slates since the earliest years of geologic study in North Carolina.

Emmons (1856, p. 44) referred to the slate system, and in later years the use of the term Carolina Slate Belt became common. Although it is not entirely satisfactory geologically, the name remains a useful geographic term and is so used in this report.

The rocks of the Carolina slate belt are now referred to the volcanic slate series (Broadhurst and Councill, 1953, p. 5), this usage being more appropriate for a geologic unit. As used in this report, the volcanic slate series includes several small areas of granite which are not mapped separately.

The volcanic slate series crops out in a wide belt, trending northeast, in the Piedmont and Fall Zone sections of the Fayetteville area. This belt is divided into two parts by the Triassic graben (p. 20), which follows the trend of the slate through the Fall Zone. The Piedmont slate, northwest of the Triassic rocks, crops out in most of Montgomery County, the northwestern third of Moore County, and smaller parts of Lee and Richmond Counties. The Fall Zone slate crops out southeast of the Triassic rocks in many valleys in Richmond, Moore, Hoke, Lee, and Harnett Counties. The slate underlies the Coastal Plain sediments and is presumed to underlie the Triassic rocks.

West of the Fayetteville area, the volcanic slate series borders the extensive granite and gneiss series of central North Carolina, but the genetic relationship between these series has not been determined. Flood plain deposits occur along many streams, and sand of the Coastal Plain mantles the slate several miles inland from the main outcrop area of the Coastal Plain formations.

The volcanic slate series consists of interbedded tuffs, breccias, flows, and shales, slates, and schists derived from them. Tuff and breccia are the most abundant rock types, although slate and rhyolite are common (Broadhurst and Councill, 1953, p. 7). The rocks of igneous origin range in composition from rhyolite to andesite. Granitic intrusive rocks, diabase dikes (fig. 4), and quartz veins are common in the slate, and mineralization is extensive. Much of the rock is schistose and contains sericite and pyrophyllite. The rocks of this series appears to have been altered several times and show local evidence of regional, contact, and hydrothermal metamorphism.

In fresh outcrops, the rock is predominantly dark gray and greenish gray, whereas in weathered outcrops, the rock is usually deep red.

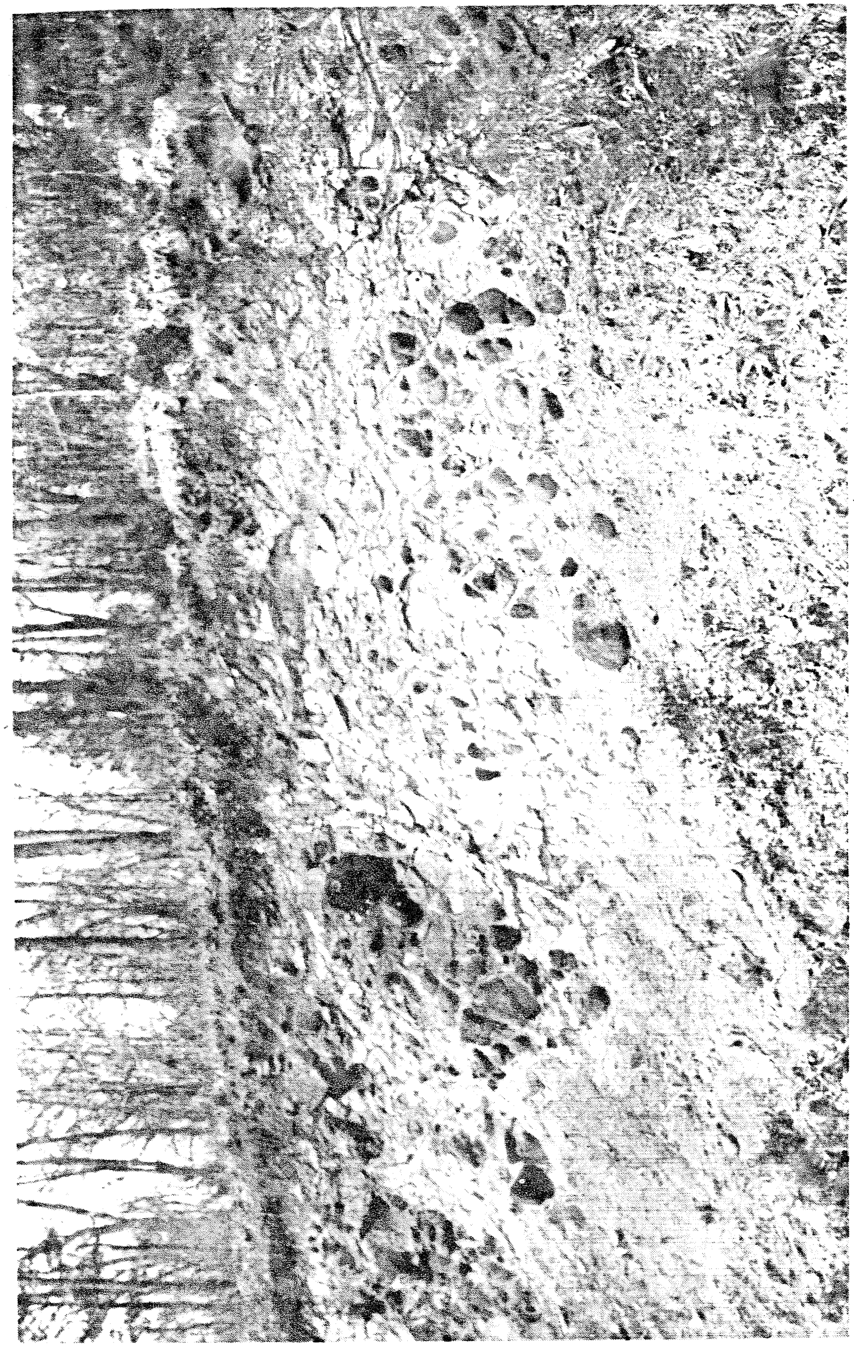

Figure 4. Spheroidal weathering of diabase in northwestern Richmond County.

Having been altered by earth movements and tipped on edge, the strike of the beds is generally northeast. Dips ordinarily are steep, although nearly horizontal beds are not uncommon, especially along the southeastern edge of the Triassic graben. Faulting and jointing are widespread. Many of the faults and diabase dikes which cut the Triassic rocks have also cut through the slates. Quartz veins are common and range in thickness from a fraction of an inch to several feet. The quartz in these veins is extensively fractured and, as far as the writer has observed, is exclusively milky quartz. Granitic intrusive rocks have been noted in well logs and cuttings at several places, but no regional subsurface distribution can be ascertained. A granite intrusive is exposed west of Rockingham in Richmond County and southwest of Duncan in Harnett County.

The thickness of the volcanic slate series is unknown. However, even a cursory field examination, indicates that many thousands of feet of material are involved. Folding, faulting, and areal compression are such that only an intensive study could yield a reasonable estimate of thickness.

No fossils have been found in these rocks, although similar slate in Virginia has yielded fossils of Ordovician age (Kay, 1951, p. 53). The determination of the age of the volcanic slate series, therefore, must depend upon an interpretation of the regional geology. The application of the theory of marginal volcanic geosynclines and island arcs, as developed by Kay (1944, 1951), suggests an early Paleozoic age for these rocks. During later geologic times, additional rock types were introduced into the slates to form the present complex.

Upper Triassic Rocks—Newark Group

The rocks of the Newark group were named for exposures in New Jersey and were assigned to the Triassic by Redfield (1856, p. 357), a correlation later extended to North Carolina by Kerr (1875, V. 1, p. 141-146). Several authors noted that three or more distinguishable units were present in the series but none were differentiated until the present century, when Campbell and Kimball (1923, p. 18) named three formations. These are, in ascending order, the Pekin, Cumnock, and Sanford formations. The series was mapped as a unit for the present report.

The rocks of the Newark group crop out in a northeast-trending belt which parallels the Fall Zone in parts of Richmond,

Montgomery, Moore, and Lee Counties. An additional area of small extent, separate from the main belt, has been mapped in Richmond County southwest of Ellerbe. A well drilled at Florence, S. C., is presumed to have encountered Triassic rocks below the Coastal Plain sediments. The samples have a strong resemblance to the sandy Triassic rocks in the outcrop area, and it is possible, therefore, that Triassic rocks underlie parts of Richmond and Scotland Counties beneath the Coastal Plain beds.

The rocks of the Newark group are bounded on both sides, and presumably underlain, by rocks of the volcanic slate series. In some places along the southeastern edge of the graben, sands of the Coastal Plain formations cover the Triassic rocks.

Reinemund (1949) states that the Pekin and Sanford formations consist mainly of red claystone, siltstone, sandstone, and conglomerate, whereas the Cumnock formation consists of gray and black shale, gray calcareous siltstone, fine-grained sandstone, and two coal beds. A bed of drab shale with a high salt content is reported (Campbell and Kimball, 1923, p. 20) in the Cumnock formation. Many diabase dikes, ranging in thickness from a few inches to several tens of feet, have intruded the rocks of the series. Where weathered, they impart a dark color to the soils derived from them.

Most of the outcrops of the Triassic rocks are weathered deeply and appear as reddish-brown residual clay. In only a few places are natural outcrops (fig. 5) fresh enough to observe original color and texture.

The chief mineral product of the Newark group is the clay derived from weathered shale. The clay is used in several brick, tile, and pottery plants. Some sandstone has been used for building, and a compact conglomerate formerly was quarried for millstones. Reinemund (1949) reports that the Triassic claystone can be combined with limestone to form a portland cement. He also states that some of the shale is rich in nitrogen and phosphorus and formerly was used as fertilizer.

Coal was mined at many places in Lee and Moore Counties, and abandoned mines are common. The coal is bituminous and has excellent coking qualities (Morfit, 1943). However, faulting of the two coal beds has prevented economical extraction of the coal. Oil shale associated with the coal (Vilbrandt, 1927) may have some future value, as it has an oil content of almost 10 gallons per ton.

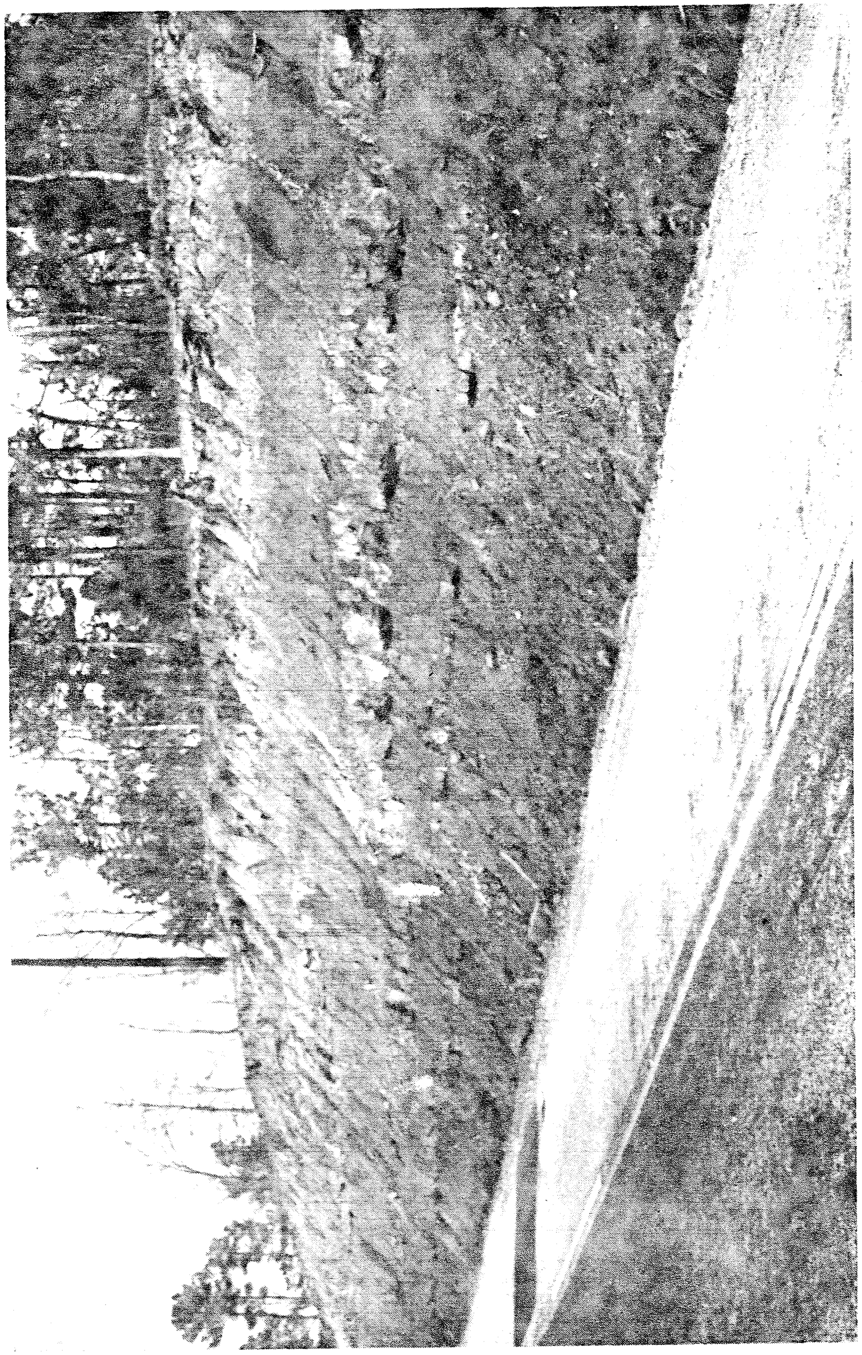

Figure 5. Triassic rocks at junction of N. C. Highways 22 and 27 in northern Moore County. The tan sandstone layers are more resistant than the red shale layers.

The rocks of the Newark group occupy a graben, or elongate downfaulted valley, which developed in the volcanic slate series during Triassic time. This graben is marked on both sides by linear tension faults which trend northeast. The major fault is probably that along the southeast edge of the belt. Reinemund (1949) reports that the sediments of the Pekin and Sanford formations, at least those in Lee County, become coarser toward the southeast, whereas those of the Cumnock formation are coarser toward the northwest.

There are many linear and transverse faults within the Triassic rocks, some extending into rocks of the volcanic slate series. Large numbers of diabase dikes have intruded the region along these faults. The Deep River fault (Reinemund, 1952, p. 2) has displaced the coal beds a vertical distance of 2,000 feet near the southeast border of the graben in Lee County.

The east edge of the main Triassic outcrop area in Richmond County is offset almost 10 miles (pl. 8) parallel to Naked Creek. Near this creek, coal has been found in a well at a depth of 47 feet, an indication that the Cumnock formation underlies the thin sand of the Coastal Plain. The small size of the Triassic outcrop area southwest of Ellerbe, also in Richmond County, and the fact that no coal was found there in a well which penetrated 260 feet of the sediments, suggest that the inlier is a remnant of the Pekin formation which underlies the Cumnock formation. The type section of the Pekin formation is 13 miles to the North, near Pekin in Montgomery County.

The extensive offset of the east edge of the graben, the apparent stripping of the Cumnock formation from the area southwest of Naked Creek, and the small size of the isolated area near Ellerbe suggest that a north-south rotational fault occurs in this area. The time of faulting can be noted only as post-Cumnock.

Faulting would account for the present width of the Triassic graben in northwestern Richmond County and in Anson County to the southwest. This portion of the graben is much narrower than it would be if the boundaries in Lee and Moore Counties were projected to the southwest. In northern Lee County the western edge of the graben is offset. In both areas, granitic rocks are exposed nearby.

The rocks of Triassic age, in addition to being faulted, are also downfolded. The resulting syncline is asymmetrical with its axis near the southeastern edge of the trough (Reinemund, 1952, p. 4). The beds strike northeast and dip 0° to 40°. More intricate folding occurs near some of the faults.

The thickness of the Newark group has been estimated by Campbell and Kimball (1923, p. 44) to be 7,000 to 8,000 feet. No wells are known to have penetrated the full thickness of the Triassic rocks in the Fayetteville area.

The sediments of the Newark group were deposited in a subsiding trough by streams which issued from the bordering uplands. The presence of alluvial fans and saline shale suggests an arid climate during some of the Newark time, whereas the coal beds suggest more humid conditions. Temperatures could not have been very low, as numerous reptilian remains occur in the Triassic beds as far north as Massachusetts.

Most of the rocks of the Newark group are easily eroded and are therefore in a topographical as well as a structural trough whose elevation is 100 feet or more below that of the bordering slate (fig. 2). The diabase dikes are more resistant to erosion and in many places form low ridges.

In Richmond and Montgomery Counties, a rectangular drainage pattern has developed similar to that of the slate belt, suggesting that dikes are sufficiently numerous and close to each other to control the direction of streamflow. In Moore and Lee Counties, where the Triassic belt is much wider, a parallel drainage system has developed.

Upper Cretaceous Rocks—Tuscaloosa Formation

The basal deposits of the Coastal Plain in North Carolina were first defined by Stephenson (1907, p. 95-99), who named them the Cape Fear formation. He correlated these beds with the Patuxent formation of Virginia and Maryland and later (Clark and others, 1912, p. 83) applied the name Patuxent to the formation in North Carolina, abandoning the name Cape Fear.

In South Carolina, Sloan (1904, p. 73-79) had described two clay and sand deposits which he named the Hamburg and Middendorf formations. He thought them to be Early Cretaceous in age, but Berry (1914, p. 68-72) recognized the Late Cretaceous affinities of the flora from the Middendorf locality. Stephenson (1912, p. 659) accepted Berry's correlation when he called the beds, in South Carolina, the Middendorf arkose member of the Black Creek formation, but he apparently did not consider that the same beds extended into North Carolina.

Later, Cooke (1926, p. 137-139) proposed to restore the Middendorf to formational rank and included in it the Hamburg beds. He correlated the Middendorf with the Tuscaloosa formation of Alabama (Smith and Johnson, 1887, p. 98-166) but did not abandon the local name until 10 years later, when he applied the name Tuscaloosa to the deposits in South and North Carolina (Cooke, 1936, p. 16-17). More recently, the beds in North Carolina were again identified (Stephenson and others, 1942, p. 446) with the Tuscaloosa formation of Alabama. In 1952, Dorf (p. 2184) referred the strata beneath the Black Creek formation in North Carolina to the Lower Cretaceous? (undifferentiated), considering them equivalent to the Albian (op. cit., p. 2181), where Clark (Clark and others, 1912, p. 306) had previously regarded them as Neocomian. The Tuscaloosa formation in North Carolina may include both Lower and Upper Cretaceous strata.

The Tuscaloosa formation, as used in this report, is the basal Coastal Plain formation in the Fayetteville area, cropping out in a roughly arcuate belt in parts of Cumberland, Harnett, Hoke, Lee, Montgomery, Moore, Richmond, and Scotland Counties. The inner boundary is irregular, the Coastal Plain strata having been considerably eroded in the Fall Zone. The Tuscaloosa formation appears to rest directly on rocks of the volcanic slate series and the Newark group and, to the southeast, extends beneath the Black Creek formation.

Throughout most of the area of outcrop, the Tuscaloosa formation appears as a series of beds of tan to reddish-brown loose to fairly well consolidated sandy clay (fig. 6) with loose sand at the surface, and occasional exposures of massive kaolin. Beneath these weathered beds, in deep exposures and well cuttings, the formation is predominantly a light-gray to bluish-gray clay. Near its inland limit, the formation is very fine grained, but it appears to become coarser downdip.

Kaolin is the principal clay mineral in the Tuscaloosa formation suggesting that the source area was a moist, acid environment where drainage was good and leaching could occur (Williams and others, 1954, p. 329), but it is not known if the formation is marine or continental, owing to the lack of fossils. Stephenson (Clark and others, 1912, p. 292) originally believed the formation was deposited in a "shallow inland sea", but he

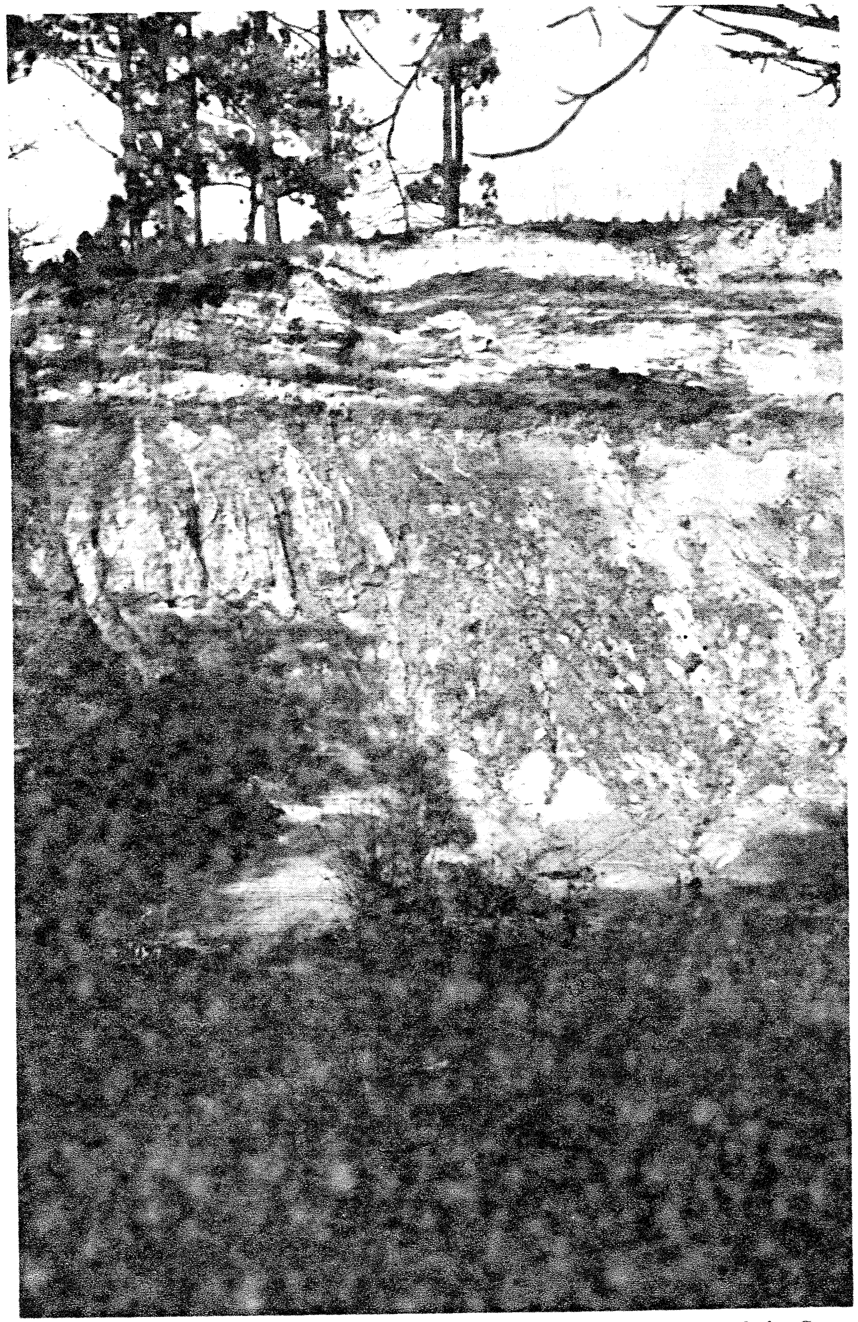

Figure 6. Exposure of Tuscaloosa formation along Rockfish Creek in Cumberland County.

later regarded it to be of alluvial origin "deposited by overloaded streams crossing a coastal plain belt" (Stephenson, 1923, p. 6). He also thought the beds were arkosic, and the Tuscaloosa formation has been described as "apparently of nonmarine origin" since that time (Richards, 1950, p. 6).

The clayey beds of the Tuscaloosa formation are well exposed only in stream valleys or a few road and railroad cuts, where they are mantled by weathered clay. The formation is not very resistant to erosion, but some streams, such as the Cape Fear River and Rockfish Creek in Cumberland County, have developed steep valley walls (fig. 6). A dendritic drainage pattern has developed throughout the Tuscaloosa terrane.

The Tuscaloosa formation is mainly a massive clay containing interbedded layers of sand. At the surface the clay and the coarser material are intimately mixed, and what may be graded bedding has been noted by the writer in only one exposure. In the subsurface section, beneath the Black Creek strata, alternating beds of clay and sand are typical. However, in the vicinity of Fayetteville, where it is about 250 feet thick, the Tuscaloosa formation consists of blue clay with only 1 or 2 feet of sand in the section. The maximum thickness of the formation is approximately 300 feet.

No animal fossils have been recovered from this formation in North Carolina. Fine particles of lignite are common and are apparently responsible for the dark color of the clay.

Large amounts of silicified wood are present in a recent gravel deposit along the Cape Fear River opposite Cedar Creek in Cumberland County. The origin of these fragments (some of them several feet long and very heavy) is unknown, but they came from upstream and probably from the Tuscaloosa formation. One of these fragments and a log found by the writer in 1953, in a railroad cut at Swann in Lee County, have been identified by Dr. R. W. Brown of the Paleontology and Stratigraphy Branch, U. S. Geological Survey. Both are specimens of *Cupressinoxylon* sp., a conifer found in both Lower and Upper Cretaceous strata.

Upper Cretaceous Rocks—Black Creek Formation

The Black Creek formation in North Carolina was first described by Stephenson (1907, p. 98) as the Bladen formation. He later (Clark and others, 1912, p. 112) observed the priority of the name Black Creek of Sloan (1907, p. 88), who described correlative beds in Florence and Darlington Counties, S. C. In North Carolina, the formation has two recognized members: a lower unnamed member and an upper marine member called the Snow Hill marl. Only the lower unnamed member is known to occur in the Fayetteville area and all references to the Black Creek formation apply to that member. At one time, part of the Tuscaloosa formation in South Carolina was called the Middendorf arkose member of the Black Creek formation. Dorf (1952, p. 2181) has recently suggested the restoration of the Middendorf member to the Black Creek formation in South Carolina but does not apply the term to North Carolina.

The Black Creek formation occurs southeast of and overlies the Tuscaloosa formation in all of Robeson County, large parts of Cumberland, Hoke, and Scotland Counties, and a small part of eastern Harnett County. The only recognizable exposures of the Black Creek formation are in southern Cumberland County. Here, along the Cape Fear River, the contact between the laminated Black Creek beds and the Tuscaloosa clay is seen to be unconformable. In the subsurface, the lithology of these formations is similar and they cannot be differentiated adequately on the basis of lithology. The Black Creek formation is everywhere overlain by surficial sediments and, in places, by the Duplin marl of late Miocene age.

The Black Creek formation typically consists of thin layers of brownish to black clay alternating with thin layers of gray to white fine-grained quartz sand, which are sometimes cross-bedded. The clay layers commonly contain large amounts of lignite, and at some places, seem to be composed entirely of fossilized plant remains. The pieces of lignite vary in color from brown to black and in size from microscopic particles to logs 30 feet or more long and several feet in diameter. The larger pieces are flattened usually, and some have been sufficiently compressed to form vitreous coal. Pyrite is common in the lignite, where it occurs as dowel-shaped pieces as much as several feet in length. In some places, weathering has caused the formation of free sulphur.

The Black Creek formation dips toward the southeast at about 16 feet per mile. Its thickness is unknown.

In the Fayetteville area, only fossil plants are found in the Black Creek formation. This flora has been described by Berry (1910, 1914, 1920) and is regarded as equivalent to that in the

Magothy formation of Late Cretaceous age in New Jersey. The Black Creek formation is equivalent (Richards, 1950, p. 54) to the Eutaw formation of the Gulf Coastal Plain.

The thin-bedded fine-grained sands in the Black Creek formation suggests that they were deposited by sluggish streams which issued from a source area to the west. Periods of alluvial and littoral deposition probably alternated with periods during which plant remains accumulated in swampy or lagoonal environments where much of the binding material was clay.

The Black Creek formation exerts some influence on topography. Where it crops out along creeks, the formation forms steep banks and small waterfalls. The clay layers probably are responsible for the rather level upland area described in this report.

Upper Eocene Rocks—Castle Hayne Limestone

Remnants of a formerly extensive Eocene formation in the Fayetteville area have been noted by several authors. These outcrops, all on high hills, are near Lillington and Spout Springs in Harnett County, near McCain in Hoke County, and at Fort Bragg in Cumberland and Hoke Counties. Only the locality near Spout Springs has been shown on the geologic maps which accompany this report, for this exposure alone has yielded definitely datable fossils.

Miller (Clark and others, 1912, p. 177) thought these rocks to be of Eocene age because of the fossils that both Kerr and he had found. Cooke (1936, p. 155) reported the presence, near Lillington, of fossils of early Eocene age, and Richards (1950, p. 14) regards these rocks as lower and middle Eocene. Recent work by P. M. Brown of the U. S. Geological Survey has revealed a Castle Hayne microfauna at the Spout Springs locality. Brown (personal communication) has identified, among others, the following Castle Hayne ostracods: *Cytheretta alexanderi* Howe and Chambers, *Actinocythereis davidwhitei* (Stadnichenko), *Paracypris franquesi* Howe and Chambers, *Loxoconcha jacksonensis* Howe and Chambers.

The Eocene remnants at Spout Springs are only a few feet thick and consist chiefly of a dark resistant ironstone overlying a weathered marl.

The Castle Hayne formation appears to rest upon the Tuscaloosa formation and is overlain by layers of surficial sand.

Upper Miocene Rocks—Duplin Marl

The Duplin marl was first defined by Dall (1898, p. 338), although references to these sediments had been made in many previous papers. The beds are named from an exposure at Natural Well near Magnolia in Duplin County, N. C. The only known occurrences of the Duplin marl in the Fayetteville area are in the southern half of Robeson County, where the beds are penetrated in wells and are exposed in marl pits. The Duplin marl overlies the Black Creek formation of Late Cretaceous age and is overlain by surficial sediments.

In samples from outcrops and wells, the Duplin sediments, consist of light-gray to dark-gray unconsolidated fine-grained quartz sand with much fragmental shell material. In past years, the Duplin marl has been dug for use as a fertilizer and a chicken grit.

The Duplin marl has no discernible structure but is presumed to dip slightly to the southeast, as do the other Coastal Plain rocks. Some well logs indicate that these beds are only a few feet thick at many places, whereas the deepest marl pits reveal a thickness of 10 to 20 feet.

The Duplin marl contains a large number of invertebrate fossils, chiefly molluscs, which have been exhaustively studied at Natural Well. Miller (Clark and others, 1912, p. 237) states: "This information has frequently been considered in the literature, and probably no Tertiary horizon is paleontologically more thoroughly known." It has been thought by some geologists that the marls in Robeson County are Pliocene in age and equivalent to the supposed Waccamaw formation nearer the coast. On a recent map (Berry, 1947) the marls in Robeson County are assigned to the Pliocene. The most complete study of molluscs from this county has been made by Gardner (1943), who published complete lists and descriptions of the fossils. She regards the Duplin as a warm-water facies equivalent to the upper part of the Yorktown formation of late Miocene age.

Undifferentiated Surficial Sediments

The undifferentiated surficial sediments include those described by Stephenson (Clark and others, 1912, p. 258-290) as the Pliocene Lafayette formation and the Pleistocene Columbia group, which included five marine terrace formations. The name Lafayette has been abandoned (Wilmarth, 1938, p. 1129), and

the Columbia group now includes as many as eight terrace formations (op. cit., p. 493). Similar deposits along the Fall Zone in northern North Carolina were described by Mundorff (1946, p. 7) as "unclassified high-level gravels, sands, and clays of Tertiary and Cretaceous (?) age" and "Pleistocene terraces and terrace deposits."

In the Flatwoods section of the Fayetteville area, the surficial sediments have a maximum thickness of about 30 feet. These beds generally consist of well-sorted, unconsolidated, fine to medium-grained sand in a clay matrix.

In the Sandhills and Fall Zone, the surficial sediments generally are poorly sorted and coarser than those of the Flatwoods. They are not always distinguishable from the coarse material in the Tuscaloosa formation (fig. 7) and, even where they rest on the older Piedmont rocks (fig. 8), they have been mapped with that formation.

Most of these surficial sediments are porous enough to reduce the effectiveness of sheet erosion so that the beds have not been greatly eroded.

Quaternary Rocks—Alluvium

The unconsolidated fluvial sediments along present-day streams rarely are assigned formational names but are called alluvium, alluvial deposits, flood-plain material, or similar terms. Such river plains are often called bottoms or bottom lands, especially if they are swampy. The present flood plain of a stream is the first bottom, the first terrace is called the second bottom, and higher terraces may be numbered consecutively.

Most of the streams in the Fayetteville area have flood plains, and some have terraces, which range in width from a few feet to several miles. Along each stream, the present flood plain tends to vary its width in response to geologic control but the stream, flood plain, terraces, and valley generally become wider downstream. The Lumber River has an especially wide flood plain in southern Robeson County, and the Cape Fear River has a wide terrace in Cumberland County near Fayetteville. The alluvium is the latest lithologic unit to be deposited in the Fayetteville area, and it overlies all other rocks in small areas.

The generally unconsolidated alluvial sediments are composed of gravel, sand, silt, and clay and mixtures of these. Silt

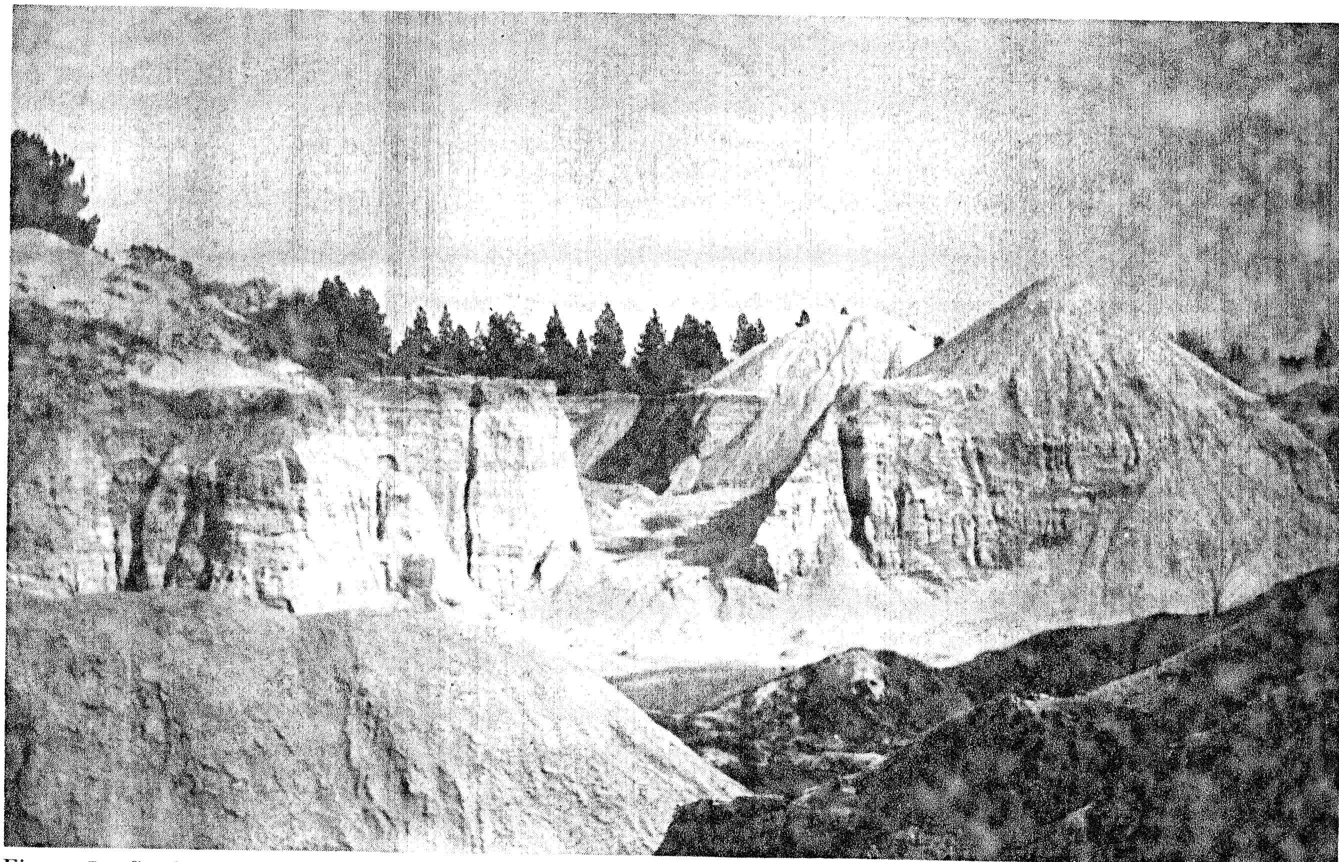

Figure 7. Sand pit near West End in Moore County showing cross-bedding in coarse sands of the Tuscaloosa Formation. These sands are relatively resistant to erosion as shown by almost vertical walls.

Figure 8. Volcanic slate series rocks in Harnett County.

and clay are the chief constituents; however, sand and gravel occur in many places, usually mixed with finer material, though in places as fairly pure deposits.

The color of the alluvium ranges from white, where the quartz sand has been leached, to brown or black, where clay or carbonaceous matter is retained.

Sand and gravel are quarried from the alluvium, notably along the Upper Little River in Harnett County and along the Cape Fear River near Cedar Creek in Cumberland County.

Structural features of river deposits may vary greatly over small areas because of the complexity of alluvial sedimentation. In general, the deposits dip downstream, and crossbedding is common only in the coarser sediments. The alluvium in the Fayetteville area is rarely very thick, but it may be 50 feet or more along the lower Lumber River.

The flood plains are almost level and usually are swampy and forested. Terraces, usually not extensive in the area, are extensive along the Lumber River in southern Robeson County, and along the Cape Fear River near Fayetteville in Cumberland County.

GROUND WATER

Source of Ground Water

Usable ground water originates from precipitation, which throughout the Fayetteville area averages almost 47 inches per year. Rainfall that reaches the earth's surface is dispersed in four ways. Part of the precipitation is soon removed by streams as direct runoff, part evaporates almost immediately and returns to the atmosphere, some is returned by transpiration from vegetation, and the remaining part percolates downward through the ground to become ground water. Meinzer (1942, p. 401) estimates that approximately a third of the precipitation in the eastern United States becomes runoff, a third is evaporated and transpired, and a third reaches the zone of saturation and becomes ground water.

More of the precipitation becomes runoff wherever the soil cannot absorb much water and wherever slopes are steep, such as in the Piedmont area. Evaporation is greater at high temperatures, a condition which is common during the summer on barren soils, cultivated fields, on lakes, and on other places

where there is no protective vegetation. Transpiration occurs whenever plants are active, during the growing season. Infiltration is greatest where permeable soils are protected from erosion by a cover of vegetation, such as in the Coastal Plain area.

Occurrence and Movement

The rocks of the earth's crust, including soils and other weathered material, are composed of mineral grains of different sizes and shapes. In most rocks, these grains are separated by innumerable spaces, or interstices, which may contain large amounts of water. The size of these interstices, ranging from minute pores in clay to caverns in limestone, is determined by many factors.

In unconsolidated sediments such as gravel, sand, and clay, the size of these spaces is determined by the shape, arrangement, and degree of assortment of the constituent mineral grains. In consolidated sediments, the interstices usually have been reduced in size by cementation and compaction, although removal of material by solution may enlarge some of the spaces and, in limestone, form caverns.

Igneous and metamorphic rocks have little or no space between the grains. Free water in such rocks generally occurs along planes of cleavage and schistosity and in fractures and solution channels.

Porosity is the ratio of the volume of the interstices to the total volume of the rock. Some igneous and metamorphic rocks have low porosities, generally less than 1 percent. Some well-sorted sediments, such as clay and sand, may have porosities of 20 to more than 50 percent. A porosity of more than 20 percent is considered high.

Permeability is the relative ability of a rock to transmit water under pressure. A porous rock may transmit water slowly or not at all if the interstices are so small that water is held in them by molecular or capillary attraction. In some rocks the interstices may be large but poorly interconnected. Clay is usually porous, but the pores are too small to allow the easy passage of water. A clean, well-sorted sand, on the other hand, may have less porosity yet transmit water readily because the spaces are interconnected. Any rock unit or formation that can yield water in significant quantities to wells is called an aquifer.

Ground water moves in response to differences in hydrostatic pressure. Precipitation usually infiltrates to the zone of saturation in interstream (recharge) areas and moves to points of lower pressure in streams (discharge) areas. When the water table, or upper surface of the zone of saturation, is high the hydrostatic pressure also is high, resulting in increased flow in the discharge areas.

Water-Table Fluctuations

Part of the precipitation on the earth's surface percolates downward until it reaches the zone of saturation where all interstices are filled with water. The upper surface of the zone of saturation is the water table, which rises or falls as water is added to or removed from the aquifer.

Because rainfall is the source of ground water, it might be expected that water levels would be highest during the months of greatest rainfall. In the Fayetteville area, the amount of rainfall is greatest from June through September, but, for several reasons, water levels are lowest during these months.

During the growing season, much more water is removed from the ground by vegetation than during the remainder of the year. Most of this moisture comes from the zone of æration above the water table, but rainfall is absorbed in this zone to make up any deficiency. Thus, significant amounts of water do not reach the water table after precipitation in heavily vegetated areas. Evaporation, too, is greatest during these months, when temperatures are high. Summer storms often produce heavy rains of short duration, much of which runs off the land surface and only a part of which is absorbed by the soil. Steady, gentle winter rains of long duration are usually more readily absorbed. Human use of water also is greater during the summer for a variety of reasons. All these factors tend to lower water levels during the summer, even when rainfall is greatest.

In the Fayetteville area natural recharge balances natural and artificial discharge so that the water table has not declined permanently over a period of years.

Since 1944, the Geological Survey has maintained a recording gage on a shallow well at Pinebluff in Moore County. The hydrograph of this well, showing the fluctuation of the water table from 1944 to 1955, may be compared with precipitation records for the same period in figure 9. In general, the water

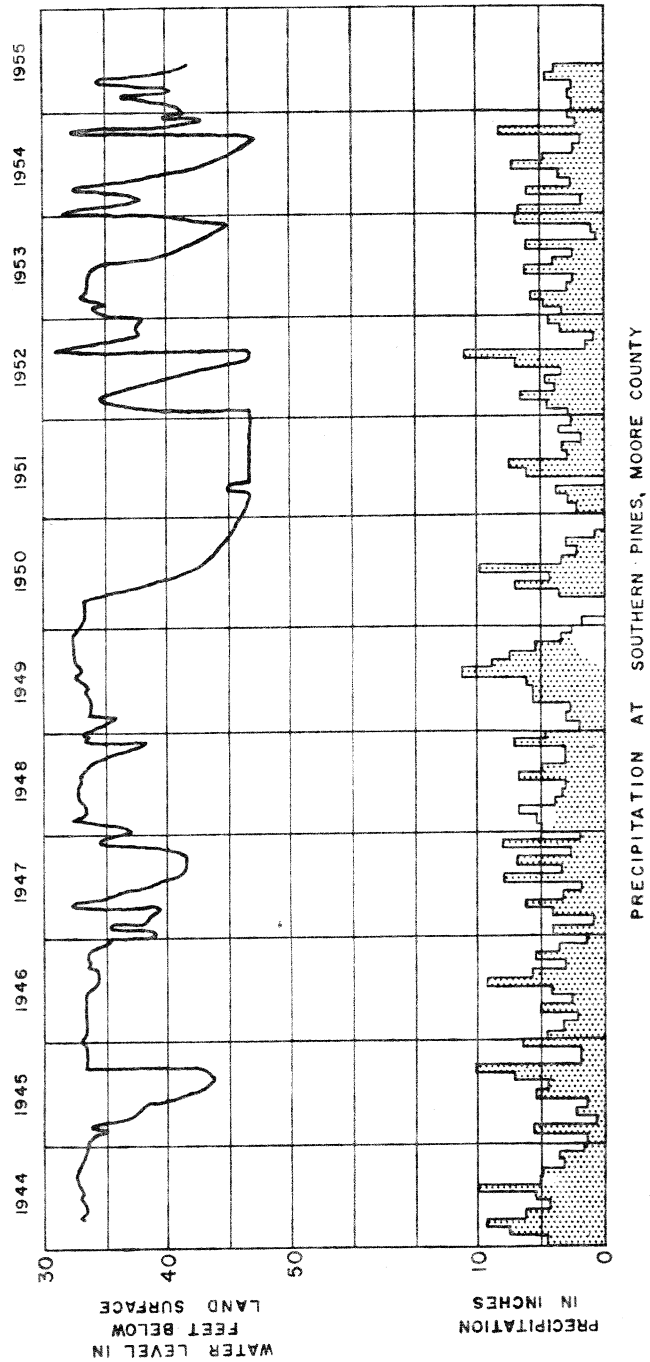

Figure 9. Hydrograph showing the fluctuation of the water level in a dug well 47 feet deep at Pinebluff, Moore County.

level rises rapidly to a peak soon after precipitation occurs and then declines more slowly until recharge and discharge reach a natural balance. It is evident from the hydrograph that the water table has not been permanently lowered but fluctuates as water leaves the aquifer or is added to it.

Artesian Water

Beneath the loose, surficial sand of the Coastal Plain section, the formations usually consist of alternating layers of clay and sand. (See pl. 1.) Under these conditions, water is confined in the more permeable sandy layers between less permeable layers of clay, and the water is known as confined or artesian water. When a well is drilled into one of these confined zones, the hydrostatic pressure is sufficient to force the water up the well above the confining layer. The well is then called an artesian well.

In some places the pressure may be enough to cause water to flow at the land surface or even to rise above the land surface. Such a well is called a flowing artesian well or, in the Fayetteville area, an overflow. Overflows in the area are common along the larger streams in Robeson County and at low elevations in Cumberland and Scotland Counties.

Quality of Ground Water

Ground water contains chemical constituents whose concentrations are due to the composition of the rocks and the length of time the water has been in contact with the rocks. Most wells in the Fayetteville area yield water of a quality suitable for nearly all purposes. In water from some wells in the Triassic rocks, chloride content is rather high, and iron in objectionable quantities is present in water from some Sandhills wells, but these seem to be exceptions.

Most ground-water supplies are drawn from sources that have not been contaminated biologically, and when wells are properly constructed chances of surface pollution are slight. Proper location and construction of wells to assure a sanitary supply is the responsibility of the well driller.

Ground-water temperatures usually do not fluctuate seasonally and the water is therefore useful for many cooling purposes,

certain industrial processes, and all household uses. Groundwater temperatures in the Fayetteville area commonly range from 60° to 65°F.

The quality of ground water is discussed further in the section on the water-bearing characteristics of the rocks and in the several county descriptions where analyses of ground water are tabulated.

Water-Bearing Character of the Rocks

In this report six principal aquifer systems are described, as follows:

Slate belt rocks, Triassic rocks, Cretaceous sands, Cretaceous clays, surficial sands, and alluvium. The approximate boundaries of the chief aquifer systems (the first four) are shown on figure 10.

Slate

The rocks included in the volcanic slate series vary in permeability as they vary in structure and lithology. Water in slate moves along planes of bedding, cleavage, and schistosity and through the fractures which have developed as a result of weathering and solution. Permeability of these rocks, therefore, is dependent upon secondary interstices, and these become less numerous with depth. Most of the fracturing is within 300 feet of the surface, and, generally, drilling to greater depths is uneconomical. Wells in rocks of schistose texture usually have greater yields than wells in rocks of granitic texture.

Hills commonly are underlain by rocks of superior resistance to erosion, whereas valleys are underlain by less resistant rocks.

Outcrops of veins or dikes also may indicate a fractured zone. Such intrusions generally occur along previously existing fractures and their emplacement generally results in increased fracturing and, consequently, in greater permeability.

Characteristically, the slates are weathered deeply, and the thick residual clay of the mantle rock may be more permeable than a similar clay of sedimentary origin. Bored wells in the weathered-clay residuum normally yield enough water for domestic purposes. Many wells on level uplands have gone dry, however, even though drilled through as much as 100 feet of residuum.

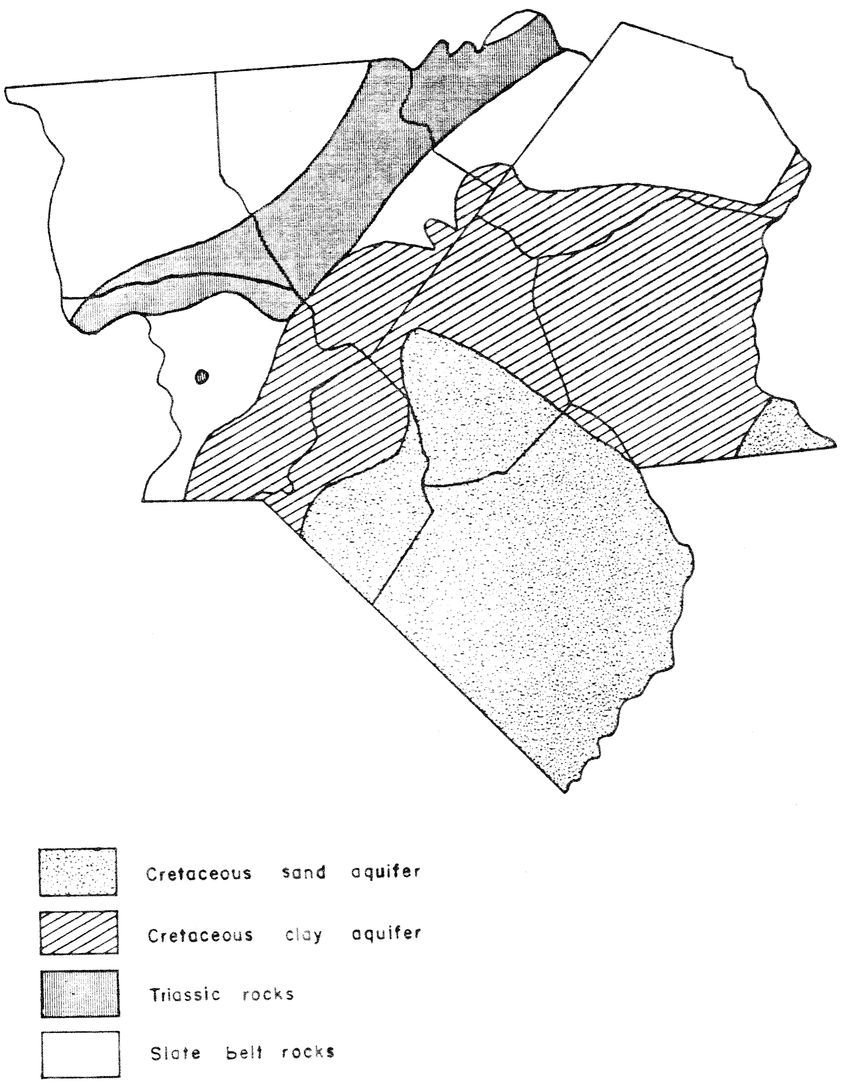

Figure 10. **Map outlining the major ground-water regions recognized in the Fayetteville area. The surficial sand aquifer and alluvium are not shown.**

Much of the water from the slate is somewhat acidic and the iron in the water resulting from corrosion of iron pipes is often objectionable. If this condition is remedied, the water may be considered suitable for all uses. The water usually is very soft and has a temperature of about 62°F.

In summary, it may be stated that the volcanic slate series is a satisfactory aquifer of considerable extent. Wells should be located where ground-water conditions are favorable and not solely for convenience of use. Ground-water conditions generally should be more favorable—(1) in draws, valleys, and other low places; (2) where the weathered zone is thick; and (3) where quartz veins (flint rock) or dikes crop out.

Triassic Rocks

Compaction and cementation have reduced the permeability and porosity of the Triassic rocks to the extent that they are the poorest aquifers in the area.

The few sandstones in the series have only slightly higher permeability than the shales in most places, and the weathered mantle rock also has low permeability.

The depth to the most permeable beds in a given locality in this part of the State is unknown, as no detailed subsurface mapping has been done except at the coal mines in Lee County. The only surface indication of a favorable well site is the outcrop of a dike. Numerous diabase dikes have cut through the Triassic rocks and fractured the intruded beds to some extent. A well drilled near a dike, therefore, may be a better than average producer, although no statistical data are available to support this hypothesis.

Throughout most of the area in which Triassic rocks crop out, the yield per foot of depth is small. Many drilled wells yield less than 5 gpm, even though they are several hundred feet deep.

Although adequate domestic supplies may be obtained from the Triassic rocks, adequate industrial or public supplies probably cannot be obtained from them. Several wells yield as much as 50 gpm but only 1 well in the area yields as much as 120 gpm. Apparently large yields cannot be sustained over long periods of time without excessive drawdown. No municipal supplies are now obtained from the Triassic rocks.

Water from the Triassic rocks is alkaline and is moderately hard to very hard.

The concentration of chloride in the water generally is low, but in some areas it may be as great as 250 ppm. The temperature of the water ranges from 58° to 66° F.

Coastal Plain Rocks

The permeability of the rocks of the Coastal Plain depends largely upon their texture. In most places, information that would enable identification of individual formations in the subsurface is lacking. However, enough information has been gathered to permit a discussion of the water-bearing properties of each aquifer system.

Surficial sand.—Surficial and weathered sediments blanket the entire Coastal Plain section of the Fayetteville area. These beds, Cretaceous and younger in age, are predominantly sandy but contain clay commonly as a binding agent and in lenses. Gravel occurs throughout the material or in lenses. The water-bearing beds generally are permeable but are thin bedded and do not contain large amounts of water.

In the Flatwoods section, the surficial sediments attain a maximum thickness of 30 feet and supply water only to dug or driven wells. Yields from the surficial sands usually are adequate for domestic uses except during prolonged dry weather. In the Sandhills section of the Coastal Plain, the surficial and weathered sands generally are thicker. In the valleys they may be less than 20 feet thick, but on the hills they may be more than 50 feet thick.

Although the permeability of the surficial material generally is high and the quality of the water is satisfactory, the sustained yields of wells are low because of the thinness of the aquifer. Only wells in extensive upland areas yield as much as 50 gpm.

Cretaceous sand.—The alternating strata of sand and clay that are designated the Cretaceous sand aquifer occur in Robeson County and in parts of Scotland, Hoke, and Cumberland Counties (fig. 10). The Cretaceous clay and Cretaceous sand aquifers apparently interfinger along the line which separates them in figure 10.

The sand beds in this aquifer are numerous in any vertical section, but they are probably lenticular. The total thickness of sand penetrated in a well averages about one-third the total depth of the well. Most of the sand strata are permeable and yield large supplies to wells.

This aquifer, which includes the Black Creek formation and most of the subsurface Tuscaloosa formation, is the best aquifer in the Fayetteville area.

In most of the area, water from this aquifer is very soft and rather acidic, pH lower than 6.0 being common, but at Lumberton the water from deep wells is moderately hard to hard and the pH exceeds 7.0. The temperature of ground water is approximately 63°F in the upper 100 feet of the sediments and increases about 1°F for every 75 feet of depth.

Cretaceous clay.—The Cretaceous clay aquifer consists of the dense blue-gray clay of the Tuscaloosa formation and contains 5 to 25 percent silt and sand intimately mixed throughout. The thickness increases from a featheredge in the Fall Zone to about 175 feet at Aberdeen in Moore County, about 250 feet at Fayetteville in Cumberland County, and about 325 feet at Gibson in Scotland County.

The permeability of the Cretaceous clay aquifer generally is low and yields of wells are low. Few wells, even gravel-walled wells, yield more than 15 gpm, and, where little sand has been tapped, a well must be drilled into the slates of the basement complex to obtain as much as 30 gpm.

The water from the Cretaceous clay aquifer is of excellent quality. Although slightly acidic, it is soft and generally suitable for all domestic or industrial purposes. At some places the water has an objectionable iron content. The temperature of the water ranges from 60° to 64°F.

Alluvium

Presently, no ground-water supplies are obtained from the flood-plain deposits of streams in the Fayetteville area. Camp Mackall in Richmond County formerly used such a source, however, and the potentialities of this aquifer may be large at some places. The yield of 48 shallow wells at Camp Mackall was 3,000,000 gpd, and it is possible that large yields may be obtained from similar deposits at other locations.

COUNTY DESCRIPTIONS

A brief summary of the geography, geology, and ground-water resources of each county in the Fayetteville area is presented in the following pages. With each county description are included tables of well data, water analyses, a geologic map, and a map showing the location of wells for which data are given.

Generally, the yield recorded in the table is the driller's estimate based on a bailing or pumping test of short duration. Because the yield increases as the drawdown of the water level increases, it is desirable to know the yield per foot of drawdown, or the specific capacity, of a well. If this is known, it is possible to determine proper pumping levels for maximum sustained yields. Only controlled pumping tests can furnish such data, and, therefore, specific capacities of wells in the Fayetteville area are not known accurately. Probably many wells are capable of larger yields than those indicated, especially in the Coastal Plain section.

Because many features of the geography, geology, and ground-water conditions are similar, if not identical, in several counties, the writer has omitted repetitious detail in these descriptions. A person interested in a particular site can locate the site on the geologic map, identifying the underlying geologic formation, and read the appropriate sections describing the geology and the ground-water conditions. In addition, he can use the well-location maps to compare the yields and other data of wells in his immediate vicinity.

Information concerning the geography of the counties was compiled from the 1950 census of the United States, from conversations with county agricultural agents, and from personal observation.

Cumberland County

(Area 661 square miles; population 96,006)

Geography.—Cumberland County is the third largest county in the Fayetteville area, but it contains the largest municipality, Fayetteville, and the greatest population. The chief crops are tobacco, corn, and cotton. The leading industries are textile manufacturing and lumbering; others include the manufacture of bricks, furniture, and the processing of various agricultural products. The main part of Fort Bragg is in the northwest corner of the county. This Army post with its large military and civilian complement accounts for a major part of the economic activity in the vicinity of Fayetteville.

The county is entirely within the Coastal Plain physiographic province. The Sandhills section in the northwestern part of the county has some long ridges and a few high hills, but the relief generally is moderate. The streams are generally swift flowing, although gradients of the larger streams are not great. Drainage is good and swampy places are uncommon.

The remainder of the county is in the Flatwoods section, which is a fairly level to rolling plain sloping to the southeast. Swamps are common along the streams.

The present flood plain of the Cape Fear River is narrow, but a terrace 50 feet or more above the modern stream is several miles wide and even wider on the eastern bank. Many tributaries to the Cape Fear flow through steep, narrow valleys, and Rockfish Creek has a deeply incised gorge through much of its length.

Geology.—Rocks of the volcanic slate series form the basement complex beneath the Coastal Plain strata but are not exposed. The Tuscaloosa formation crops out through most of the county, the most extensive exposures being along the Cape Fear River, Rockfish Creek, the Lower Little River, and in railroad cuts near Fort Bragg. The formation is about 120 feet thick at the northwest corner of the county but is at least 300 feet thick in the southern part of the county.

The Black Creek formation overlies the Tuscaloosa formation in the southern, eastern, and central parts of the county (pl. 2), and its unconformable contact is well exposed along the Cape Fear River below Cedar Creek. The best exposures of the Black Creek formation are near the southern boundary of the county along the Cape Fear River and U. S. Highway 87.

Remnants of the Castle Hayne limestone probably cap some high hills in the Fort Bragg reservation. The sands that mantle most of the county are surficial sediments, but in the Sand Hills they include leached beds of the Tuscaloosa formation. Alluvium has accumulated along several of the streams.

Ground water.—All private water supplies and three municipal supplies in Cumberland County are obtained from wells. Dug and driven wells are common on the smaller farms, whereas bored or drilled wells are common on the larger farms. Springs are common in the hilly sections but are not used. Artesian wells flow along Rockfish Creek near Hope Mills and in the lowlands near the South River, southeast of Cedar Creek.

Because of its depth below the surface, the volcanic slate series is used only occasionally as an aquifer. One well, 235 feet deep, yields 36 gpm from the slate and a sustained yield of 20 to 30 gpm may be obtained from other wells.

Most of the wells in the county obtain water from the Cretaceous clay aquifer, a bluish-gray clay of low permeability. The yields of wells tapping this aquifer are poor, averaging less than 15 gpm. Some wells tap the surficial sand aquifer, which is thin except in the Sandhills region, where, on wide upland surfaces, wells may yield 50 gpm.

The use of ground water may be safely increased throughout Cumberland County, but well yields in excess of 30 gpm should not be expected. The water is of good chemical quality; it is soft and slightly acidic.

Municipal supply systems (1959).—Spring Lake has four wells (Nos. 11-14). Average daily consumption is approximately 36,000 gallons, and the water from one well is treated.

Cumberland has two wells (Nos. 51, 52) owned by the Rockfish-Mebane Yarn Mills. Consumption is probably about 40,000 gpd, and the water is not treated.

Hope Mills has two wells (Nos. 55, 56). Average daily consumption is almost 100,000 gallons. Water from the deeper well is not treated, but that from the shallow well is chlorinated.

Fayetteville obtains its water supply from Little Cross Creek. The capacity of the treatment plant is 8,000,000 gpd.

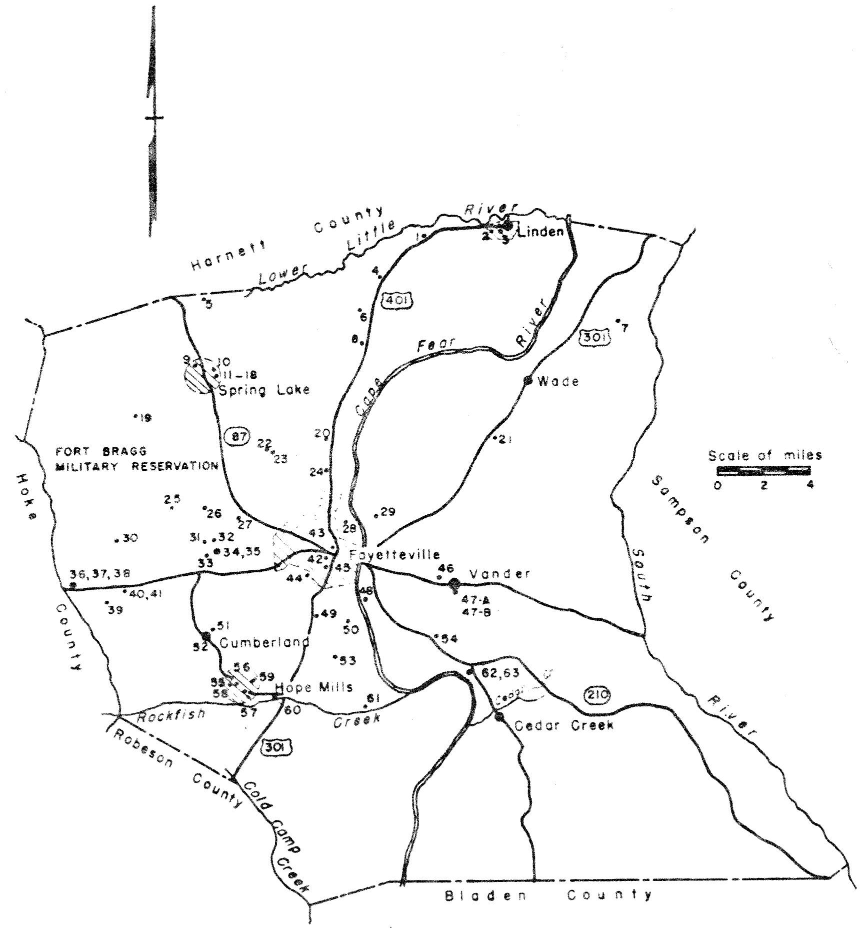

Figure 11. Map of Cumberland County showing location of wells

Table 1. Records of Wells in Cumberland County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	3 miles W of Linden	W. M. Barefoot	Open-end	165	4	152	Cretaceous clay	6	
2	Linden	Jessie Byrd	Screen	89	4	87	do	15	
3	do	Pine Knoll Farms	Open-end	35	4	22	Surficial sand	6	
4	5 miles SW of Linden	Forest Inn	do	235	6	189	Slate	10	Water level 95 feet, pumping level 200 feet.
5	3 miles N of Spring Lake	Overhills Land Company	do	235	6		do	36	Drawdown 120 feet.
6	7 miles NE of Spring Lake	I. L. Davis	do	245	4	200	do	9	
7	6 miles SE of Linden	Pentecostal Church	Screen	215	6	180	do	100	Analysis.
8	7 miles W of Spring Lake	Shriner's Home	do	227	4	210	Slate	10	
9	Spring Lake	Oxendine Cleaners	Open-end	212	4		do		Abandoned.
10	do	Cumberland County Schools	Screen	70	6	66	Surficial sand	30	Pumping level 60 feet.
11	do	Town of Spring Lake	do	81	8	76	do	90	
12	do	do	do	107	8		Cretaceous clay		
13	do	do	do	107	8		do		
14	do	do	do	108	8	88	do	180	Analysis.
15	do	do	do	70	8		Surficial sand	40	Not used.
16	do	do	Open-end	102	6	91	Cretaceous clay		do
17	do	do	Screen	75	8	75	Surficial sand	40	do
18	do	C. A. Kellum	do	75	4	73	do	12	
19	3 miles SW of Spring Lake	Fort Bragg	Open-end	312	6	135	do	30	
20	5 miles N of Fayetteville	W. L. Law	do	208	4	208	Slate	4	
21	9 miles NE of Fayetteville	Central High School	do	290	4	220	do	10	
22	5 miles NW of Fayetteville	Zeigler-Cline Construction Co.	Open-end	100	4	100	Cretaceous clay	15	
23	do	F. D. Cline Paving Co.	do	300	6	276	Slate	15	
24	4 miles N of Fayetteville	H. B. Meiselman	do	190	4	190	do	20	
25	7 miles NW of Fayetteville	Jack Hubbard	do	59	4	47	Cretaceous clay	8	

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
26	6 miles NW of Fayetteville	F. Jarvis Harris	Screen	55	6	53	do	10	
27	4 miles NW of Fayetteville	W. H. Marsh	do	62	6	58	do	20	
28	2 miles N of Fayetteville	Atlantic Coast Line Railroad	Open-end	150	6		Slate		
29	3 miles NE of Fayetteville	A. B. Breece	do	235	4	220	do	10	
30	6 miles NW of Cumberland	H. B. Hoppe	do	220	4	217	do	6	
31	4 miles N of Cumberland	J. T. Parnell	do	70	6	65	Cretaceous clay	25	
32	do	do	do	294	6	254	Slate	1	
33	3 miles N of Cumberland	Lewis Chapel School	do	481	6	261	do	1	
34	4 miles N of Cumberland	Ras Evans	Screen	65	6	61	Cretaceous sand	30	
35	do	do	do	50	6	48	do	20	Analysis.
36	6 miles NW of Cumberland	E. L. McNair Estate	Open-end	208	4	208	do	15	Drawdown 60 feet.
37	do	do	Screen	53	6	49	do	40	
38	do	do	Open-end	140	6	130	do	60	
39	5 miles NW of Cumberland	D. N. Blue	Screen	53	4	51	Surficial sand	10	Pumping level 45 feet.
40	do	Fish Hatchery							Flowing Well.
41	do	N. C. Wildlife Commission	Open-end	220	6	141	Cretaceous clay	8	
42	Fayetteville	Mrs. Lottie Shepherd	do	220	6		do	5	Pumping level 200 feet.
43	do	Dr. R. L. Pittman	do	289	8	236	Slate	15	
44	do	Martin Transfer and Storage Co.	do	259	4	216	do	12	Analysis.
45	do	N. C. Highway Maintenance Shops	do	365	6	225	do	30	
46	Vander	Paul Allen		170			Cretaceous clay	0	
47a	do	Ed Fellon	Driven	18	1¼	18	Surficial sand		Analysis.
47b	do		do	20	1¼		do		do
48	2 miles S of Fayetteville	Esso Standard Oil Company	Open-end	362	8	180	Slate	50	Water level 7 feet, drawdown 150 feet.
49	3 miles S of Fayetteville	Girl Scout Camp	do	125	4	34	Cretaceous clay	120	Water level 23 feet.
50	do	Portland Cement Products Co.	do	232	4	184	Slate	6	

Table 1. Records of Wells in Cumberland County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
51	Cumberland	Rockfish-Mebane Yarn Mills		72	8		Cretaceous clay	150	
52	do	do		69	8		do	80	
53	4 miles S of Fayetteville	Fayetteville Airport	do	58	6	53	Surficial sand	60	
54	2 miles S of Vander	S. C. Cain	do	175	4		Cretaceous clay	0	Abandoned.
55	Hope Mills	Town of Hope Mills	Screen	282	8		do	50	Water level 80 feet; analysis.
56	do	do	Open-end	51	8	41	do	70	
57	do	do					do	25	8 shallow wells, abandoned.
58	do	do	Open-end	531	8	228	Slate	10	
59	do	Rockfish-Mebane Yarn Mills #1	do	170	4		Cretaceous clay	15	Water level 12 feet above surface.
60	1 mile SE of Hope Mills	T. C. Bynum	do	225	4	206	do	2	
61	5 miles E of Hope Mills	Wilson Yarborough	Open-end	265	4	193	Slate	2	Pumping level 265 feet.
62	4 miles SE of Vander	Pipe Inc.	do	311	6	262	do	12	
63	do	North Carolina Products Co.	do	300		251	do	1	Water level 70 feet.

Table 2. Chemical Analyses of Ground Water from Cumberland County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	7	14	35	44	47a	47b	55
Silica (SiO_2)	17	4.4	7.4	12	4.3	4.5	14
Iron (Fe), total	.00	.02	.00	.00	22	.01	.31
Iron (Fe) in solution	*.00	.00	.00	.00	2.0		.13
Calcium (Ca)	14	.4	1.2	4.0	1.6	4.0	3.0
Magnesium (Mg)	11	.2	1.2	2.1	1.2	.9	1.8
Sodium and potassium (Na + K)	89	2.4	12	124	10	8.2	113
Bicarbonate (HCO_3)	229	1	8	322	23	22	217
Sulfate (SO_4)	21	.0	.0	.2	.9	2.3	52
Chloride (Cl)	48	2.0	13	22	7.9	7.9	19
Fluoride (F)	.2	.0	.1	.7	.1	.0	.6
Nitrate (NO_3)	.3	4.3	16	.1	.0	.0	.0
Dissolved solids	308	17	60	328	39	37	310
Hardness as $CaCO_3$	82	3	8	19	9	14	15
pH	7.3	5.2	6.0	8.2	6.0	6.7	8.1
Chief Aquifer	Cretaceous clay	Cretaceous clay	Cretaceous clay	Slate	Surficial sand	Surficial sand	Cretaceous clay
Date of collection	Aug. 1955	May 1953	Jan. 1959	Feb. 1959	Jan. 1952		Jan. 1951

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Harnett County

(Area 606 square miles; population 47,605)

Geography.—Harnett County is the fourth county in size and the third in population in the Fayetteville area. Lillington is the county seat and Angier, Dunn, and Erwin are other large towns in the county. Tobacco, cotton, and corn are the chief crops but dairying also is important. The largest industries are textile manufacturing and lumbering. Important products are sand and gravel, bricks, and processed agricultural goods.

The Fall Zone passes through Harnett County, only the southern third being entirely within the Coastal Plain. The topography is gently rolling over most of the county but becomes rugged and hilly in the northwest corner near Duncan and near the larger streams. In the southwest, the Sandhills are typically rolling to hilly and exhibit long ridges. The land along the west bank of the Cape Fear River below Lillington is noticeably flat. The river has developed a terrace along its entire course in this county. Most of the streams are swift and flow through rugged topography.

Geology.—The rocks of the volcanic slate series are exposed over much of the county (pl. 3). East of Olivia the slate series contains a sericite schist, and rocks of granitic texture are exposed near Duncan and other places.

The Tuscaloosa formation overlies the slate in the southern part of the county. Only the light-colored, weathered sand is seen, generally, at the surface but the underlying dark clay is exposed along the railroad between Spout Springs and Olivia.

Ground water.—In Harnett County, the use of ground water may be increased greatly without danger of overuse. Moderate supplies are available throughout the county from properly located and developed wells. Infiltration systems may be feasible along the lower course of the Upper Little River and along other streams. Ground water from the slate in Harnett County is soft to moderately hard. Some well water has a high iron content and is slightly acidic to slightly alkaline. Ground water from the Coastal Plain rocks resembles water from the same strata in Cumberland County.

Municipal supply systems (1959).—Angier has three wells (Nos. 2, 3, 4) to supply an average daily consumption of 50,000

gallons. Water from well 2 is limed in order to minimize corrosion of pipes, but water from the other wells is not treated.

Coats has two wells (Nos. 12, 13) to supply an average daily consumption of 16,000 gallons. The water is not treated.

Dunn obtains its water supply from the Cape Fear River. The capacity of its treatment plant is 2,000,000 gpd.

Lillington obtains its water supply from the Cape Fear River. The capacity of its treatment plant is 500,000 gpd.

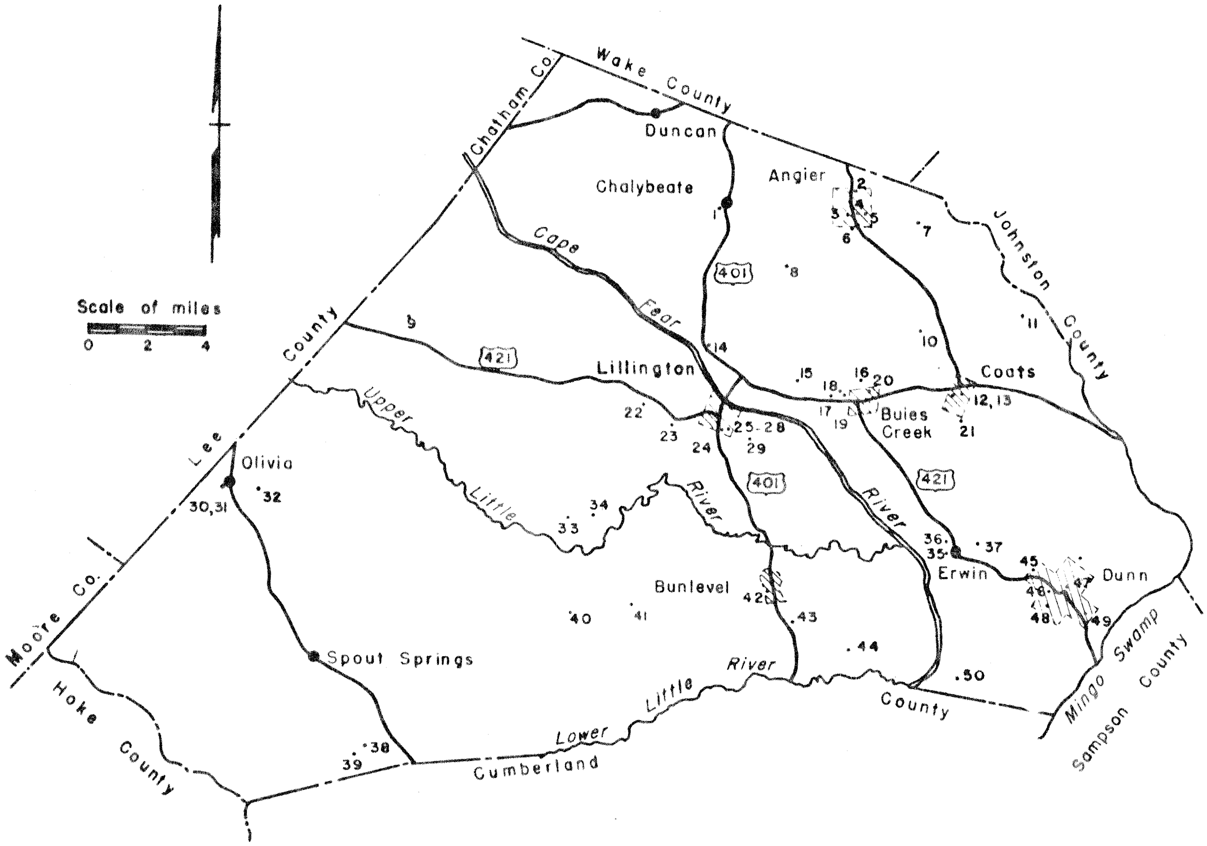

Figure 12. Map of Harnett County showing location of wells

Table 3. Records of Wells in Harnett County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diam-eter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	Chalybeate	Horne Turpentine Co.	Open-end	146	6-4½	48	Slate	25	
2	Angier	Town of Angier	do	292	8	120	do	80	Analysis.
3	do	do	Screen	250	8		do	60	
4	do	do	Open-end	190	6		do	80	
5	do	Angier High School	do	240	8	123	do		Abandoned.
6	1 mile S of Angier	J. P. Gardner	do	140	6	110	do	10	
7	2 miles SE of Angier	J. M. Williams	do	206		160	do		
8	3 miles SW of Angier	H. D. Honeycutt	do	124	5	89	do	1	
9	8 miles NE of Olivia	Holly Springs	do	184	6	151.5	do	10	
10	3 miles NE of Buies Creek	C. H. Joyner	do	155	6	125	do	6	
11	4 miles NE of Coats	J. C. Johnson	do	128	6	123	do	4	
12	Coats	Town of Coats	do	362	8	117	do	69	Analysis.
13	do	do	do	300	8	120	do	70	Do.
14	2 miles N of Lillington	W. T. Spence	do	76	6	28	do	24	
15	2 miles W of Buies Creek	J. A. Sawyer	do	222	6	208	do	1	
16	Buies Creek	Buies Creek School	do	138	6	70	do	40	
17	do	Leland Stewart	do	80	6	65	do	15	
18	do	Campbell College	do	152	6	54	do	60	
19	do	O. E. Dixon	do	180	6	100	do	10	
20	do	L. E. Chernault	do	60	6	40	do	30	
21	1 mile S of Coats	Benner & Robertson Lumber Co.	do	215	6	180	do	10	
22	2 miles W of Lillington	G. D. Monroe	do	151	4	75	do	6	
23	1 mile W of Lillington	William J. Paschal Lumber Co.	do	180	6	120	do	3	

Table 3. Records of Wells in Harnett County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
24	Lillington	Ice Plant	Open-end	295	6		Slate	30	Abandoned.
25	do	Town of Lillington	do	305	8		do	24	Analysis.
26	do	do	do	291	8	33	do	90	Abandoned.
27	do	do	do	462	8	50	do	43	Do.
28	do	do	do	465		103	do	43	Do.
29	1 mile SE of Lillington	Prison Camp	do	85.5	6	63	do	35	Analysis.
30	Olivia	W. B. Olive	do	150	6	133	do	2	
31	do	Mrs. Eva Douglas	Screen	82	4	79	Cretaceous clay	15	Do.
32	1 mile E of Olivia	Belhaven School	Open-end	269	6	69	Slate	12	
33	6 miles SW of Lillington	C. M. Johnson	do	200	6	182	do	5	
34	5 miles SW of Lillington	J. L. Stuckey	do	110		60	do	2	Do.
35	Erwin	Erwin Mills	do	501.5	3		do		Abandoned.
36	do	M. F. McLamb	do	175	6¼	148	do	12	
37	do	Alfred Blalock	do	250	6	175	do	17	
38	4 miles SE of Spout Springs	Overhills Farms	do	235	8		do	50	
39	do	do	do	170	8		do	50	
40	9 miles E of Spout Springs	Harnett Lumber Co.	do	255	8		do	100	Do.
41	4 miles W of Bunnlevel	C. W. Matthews	do	202	4		do	2	
42	Bunnlevel	Bunnlevel School	do	157	4	95	do	8	
43	1 mile SE of Bunnlevel	R. E. Byrd	do	79	4	71	Cretaceous clay	15	
44	4 miles SE of Bunnlevel	Ernice Elliot	do	143	4	121	Slate	15	Analysis.
45	1 mile NW of Dunn	Mrs. Fred McKay	Screen	34	6	32	Surficial sand	20	
46	Dunn	Coca Cola Co.	do	76	8	51	Cretaceous sand	45	
47	do	Town of Dunn	Open-end	434	10-8		Slate	200	Abandoned.
48	do	National Oil Co.	Screen	43	6	41	Cretaceous sand	10	
49	1 mile SE of Dunn	Tart Lumber Co.	Open-end	150	5	149	Cretaceous clay	10	
50	5 miles SW of Dunn	H. C. Magruder	do	216	6	207	Slate	2	

Table 4. Chemical Analyses of Ground Water from Harnett County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	2	12	13	27	31	34	44	25
Silica (SiO_2)	21	23	27	46	26	9.1	23	12
Iron (Fe), total	3.8	.1	.07	5.5	4.2	.02	.09	.06
Iron (Fe) in solution				.17				
Calcium (Ca)	8.8	13	14	8.3	4.8	6.7	22	5.1
Magnesium (Mg)	4.6	6.6	7.3	3.4	2.5	5.1	13	2.0
Sodium and potassium (Na + K)	4.3	19	17	7.6	6.5	10	21	9.8
Bicarbonate (HCO_3)	55	111	103	19	34	34	182	32
Sulfate (SO_4)	1.8	11	11	6.3	2.1	1.7	.1	1.7
Chloride (Cl)	1.6	2.0	1.5	2.9	3.0	14	5.3	7.8
Fluoride (F)	.3	.2	.4	.1	.1	.0	.2	.1
Nitrate (NO_3)	.6	.0	.2	.1	.1	12	.0	3.8
Dissolved solids	80	131	124	103	77	85	180	58
Hardness as $CaCO_3$	42	60	64	35	34	39	110	21
pH	7.5	8.0	7.7	6.3	7.1	6.4	7.5	6.3
Chief Aquifer	Slate	Slate	Slate	Slate	Cretaceous clay	Slate	Slate	Slate
Date of collection	Mar. 1958	Mar. 1959	Mar. 1959	Oct. 1950	Jan. 1959	Jan. 1959	Jan. 1959	Nov. 1947

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Hoke County

(Area 414 square miles; population 15,756)

Geography.—Hoke County is seventh in size in the Fayetteville area and has the smallest population. Tobacco, cotton, corn, and small grains are the chief crops. Dairying and poultry raising are important activities, and Raeford, the county seat, has textile plants and several smaller industries. Most of the northern half of the county is within the boundaries of Fort Bragg.

Hoke County is almost entirely within the Coastal Plain physiographic province. Two-thirds of the county is in the Sandhills section, where the topography is rolling and where several long ridges and a few high hills are prominent. In the Flatwoods section the land is level to gently rolling. Carolina bays are numerous and many are swampy. The streams are swift flowing but usually have swampy flood plains.

Geology.—Rocks of the volcanic slate series underlie the alluvium in a small area at the northern tip of the county and underlie sediments of Cretaceous age elsewhere in the county (pl. 4).

The Tuscaloosa formation crops out northwest of Raeford, where only its weathered upper beds are exposed. To the southeast, the Tuscaloosa dips beneath the Black Creek formation. Both formations are mantled by surficial sands.

Remnants of the Castle Hayne limestone cap a few high hills near McCain.

Ground water.—All public and private water supplies in Hoke County are obtained from wells. Most of the county outside the boundaries of Fort Bragg is underlain by the sand and clay strata of the Cretaceous sand aquifer. Wells tapping this aquifer may yield more than 2 gpm per foot of depth. Where the Cretaceous clay is the chief aquifer, yields of wells are much less. The surficial sand aquifer also is productive, but over much of the county sand of this aquifer is not distinguishable from that of the underlying beds.

Springs are common but are not used to any significant extent. No flowing wells are known, but they may be developed along the creeks near the Robeson County line. Dug and driven wells are common only in the southern part of the county. Bored or drilled wells are used in the Sandhills section, where the water table is 20 to 30 feet below the land surface.

The most productive wells in the county are at McCain, where the following yields have been obtained: 900 gpm from a gravel-walled well 285 feet deep; 500 gpm from a gravel-walled well 278 feet deep; and 200 gpm from a screened well 250 feet deep. At Raeford, a gravel-walled well 290 feet deep yields 300 gpm. No large wells have been drilled south of Raeford, but yields similar to the above may be obtained.

Ground water in Hoke County is acidic and very soft. The water is corrosive but is generally of suitable quality for most purposes.

Municipal supply systems (1959).—Raeford has 6 wells, 3 of which (Nos. 17, 18, 19) are in use and supply an average daily consumption of 44,000 gpd. The water is treated to raise the pH.

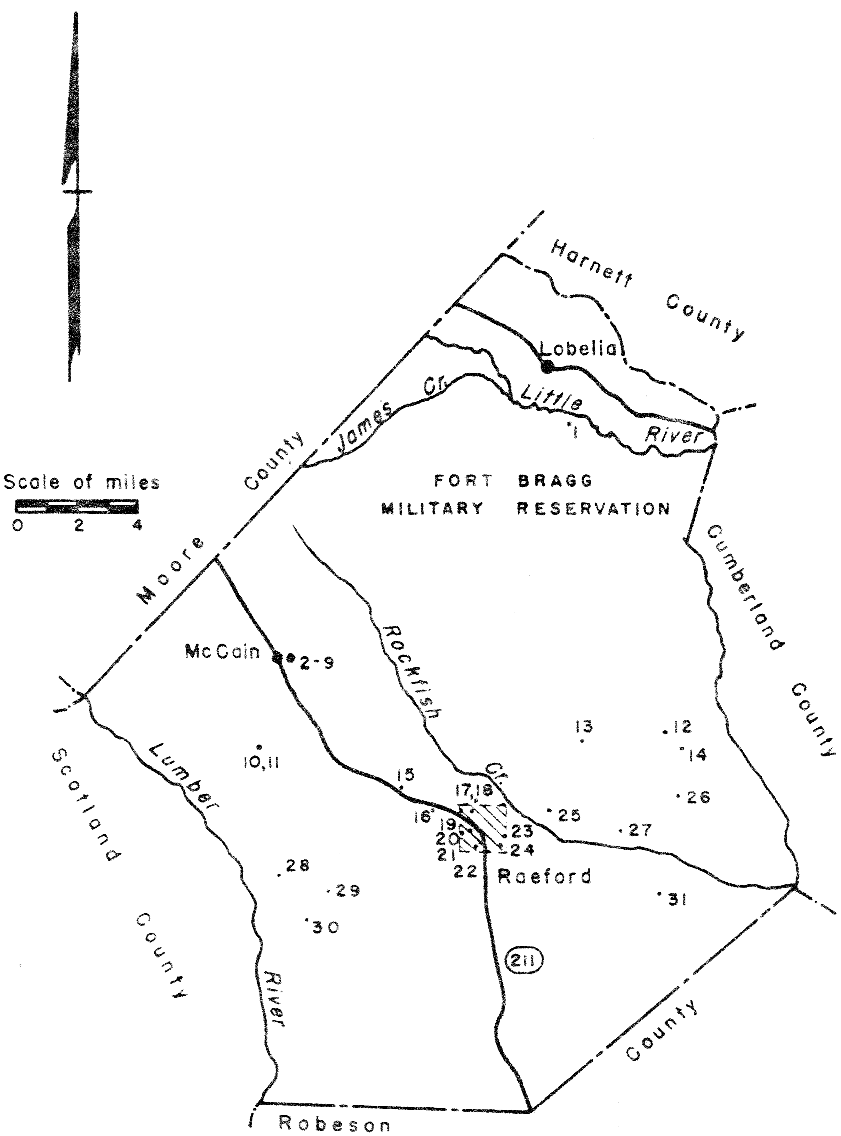

Figure 13. Map of Hoke County showing location of wells

Table 5. Records of Wells in Hoke County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	4 miles S of Lobelia	Ranger Station 3, Fort Bragg	Screen	91	6	91	Cretaceous clay	10	
2	McCain	N. C. Tuberculosis Sanatorium	do	251	8		Cretaceous sand	100	
3	do	do	Gravel-walled	284	8		do	100	Analysis.
4	do	do	Screen	250	8	250	do	200	Abandoned.
5	do	do	Gravel-walled	309	21		do	50	
6	do	do	Open-end	115			do	120	
7	do	do	Gravel-walled	401	18–10		do	450	
8	do	do	do	285	20–10		do	900	Analysis.
9	do	do	do	278	20–10		do	508	do
10	do	W. H. Calloway	Screen	70	6	68	do	10	
11	do	do	do	74	4	72	do	8	
12	7 miles NE of Raeford	Newton Service Station	do	93	4	91	Cretaceous clay	10	
13	5 miles NE of Raeford	G. W. Ray	do	72	4	68	do	10	
14	7 miles NE of Raeford	Marshall Newton	do	89	4	85	do	15	
15	3 miles NW of Raeford	J. O. Veezey	Open-end	110	4	80	Cretaceous sand	10	
16	2 miles NW of Raeford	J. L. Wood	Screen	114	4	112	do	8	
17	Raeford	Town of Raeford	do	95	4		do	100	Analysis.
18	do	do	do	95	4		do	100	do
19	do	do	Gravel-walled	262	6		do	300	do

Table 5. Records of Wells in Hoke County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
20	Raeford	Town of Raeford	Screen	97	4	97	Cretaceous sand		
21	do	do	do	100	4	100	do		
22	do	do	do	146	4	146	do	10	
23	do	J. W. McDermid	Open-end	110	4	18	do	10	
24	do	Jim Howell	Screen	105	4	101	do	8	
25	2 miles E of Raeford	George Freeman	do	97	4	93	do	10	
26	7 miles E of Raeford	Douglas Monroe	do	57	4	53	Cretaceous clay	10	
27	4 miles E of Raeford	D. P. Gillis	do	127	4	125	Cretaceous sand	15	
28	7 miles W of Raeford	Marven Gainey	do	46	4	44	Surficial sand	10	
29	5 miles SW of Raeford	Ed Penny	do	55	4	53	Cretaceous sand	10	
30	7 miles SW of Raeford	Luther Clark	do	94	4	92	do	19	
31	6 miles SE of Raeford	R. J. Morman	Open-end	76	4	60	do	8	

Table 6. Chemical Analyses of Ground Water from Hoke County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	3	8	9	17	18	19
Silica (SiO_2)	5.6	8.1	6.4	7.5	7.7	7.5
Iron (Fe), total	.05	.32	.42	.17	.13	.18
Iron (Fe) in solution	.03	.03	.05	.02	.04	.02
Calcium (Ca)	.6	1.2	3.1	.6	.7	2.0
Magnesium (Mg)	.4	.4	.7	.4	.4	.7
Sodium and potassium (Na + K)	5.0	1.8	.1	2.0	1.6	3.4
Bicarbonate (HCO_3)	4	5	4	3	3	8
Sulfate (SO_4)	1.9	1.2	2.1	.6	.6	1.4
Chloride (Cl)	4.1	2.2	3.2	2.6	2.4	3.2
Fluoride (F)	.0	.9	.0	.0	.0	.0
Nitrate (NO_3)	3.7	.2	1.1	1.0	.6	3.5
Dissolved solids	24	18	21	20	16	24
Hardness as $CaCO_3$	3	7	11	3	3	8
pH	5.5	5.8	5.3	5.3	5.3	5.9
Chief Aquifer	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand
Date of collection	5/27/53	12/3/53	10/8/53	3/7/51	2/21/52	11/7/53

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Lee County

(Area 255 square miles; population 23,522)

Geography.—Lee County is the smallest county in the Fayetteville area and is seventh in population. The chief crops include tobacco, corn, hay, and cotton. Machinery is manufactured at Sanford, and textile mills, brick plants, potteries, and lumber mills also are important to the economy. Coal formerly was mined near Cumnock.

The Fall Zone passes through the county, and Coastal Plain sediments are common south and southeast of Sanford. The surface of the county is fairly level in general, but it becomes dissected near the streams. Much of the county is in the Triassic lowland, where the relief is slight. The Coastal Plain section has greater relief, particularly where the streams have exposed the underlying rocks of the slate belt. Most of the streams are swift flowing, especially near the Deep River and the Upper Little River.

Geology.—Rocks of the volcanic slate series crop out in the northern tip of the county and in the southeastern third where they are overlain by Coastal Plain sediments (pl. 5). The Newark group crops out in a wide belt which occupies most of the northwestern two-thirds of the county. Shale predominates, but sandstone is common near Sanford.

In the Coastal Plain section, the bulk of the sediments consists of the weathered sands of the Tuscaloosa formation, which attains its greatest thickness in the southern tip of the county south of Lemon Springs.

Ground water.—No municipal supplies are obtained from ground water in Lee County, but all domestic and some industrial supplies are obtained from wells. Bored and drilled wells are common. Springs occur locally, and some of these were formerly the source of medicinal waters. There are no flowing wells in the county.

Although ground-water conditions in Lee County are not favorable for the development of large supplies, in most places adequate domestic supplies may be obtained from all the aquifers. The Triassic rocks are the most widespread water-bearing formations, but their yield to wells is low. Wells in the slate commonly yield as much as 50 gpm. The Coastal Plain strata are thin in Lee County and yields of wells are small.

Ground water from the Triassic rocks is alkaline, is soft to hard, and contains a relatively large amount of dissolved solids.

Municipal supply systems (1959).—Sanford obtains its water supply from Letty Creek, Miry Creek, and Bames Branch. The capacity of its treatment plant is 3,000,000 gpd.

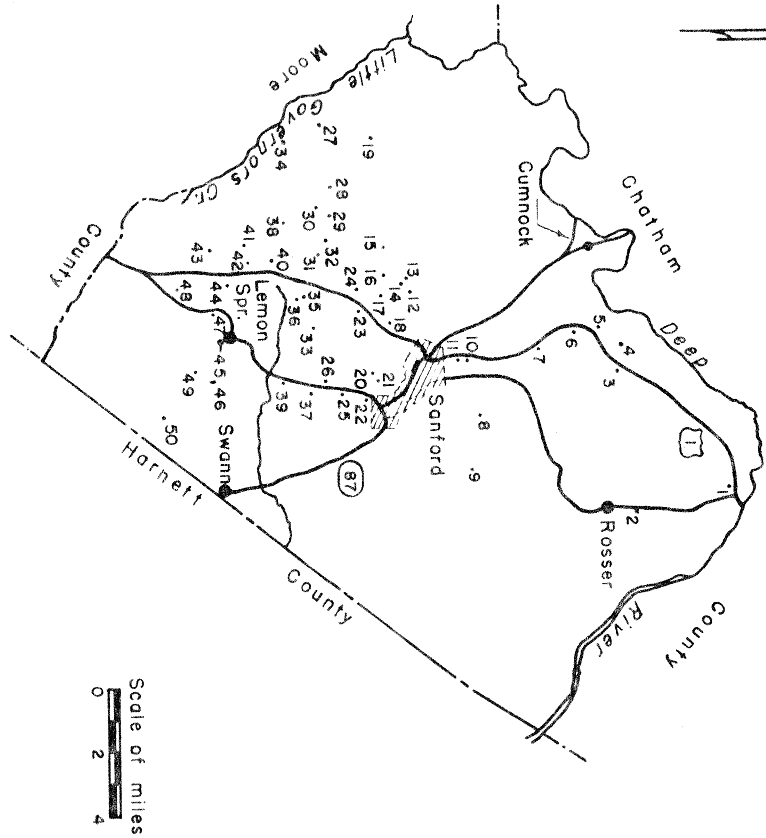

Figure 14. Map of Lee County showing location of wells

Table 7. Records of Wells in Lee County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	10 miles NE of Sanford	J. D. Crutchfield	Open-end	46	6	26	Slate	20	
2	8 miles NE of Sanford	Paul Thomas	do	88	6	24	Triassic	15	
3	7 miles N of Sanford	J. R. Smith	do	72	6	21	Slate	10	
4	do	C. R. Hall	do	74	6	26	do	3	
5	6 miles N of Sanford	Sir Walter Motor Court	do	93	6		Triassic	5	Analysis.
6	do	Lee Brick Co.	do	100	10		do	30	
7	4 miles N of Sanford	Lyons Motor Court	do	151	6		do		Analysis.
8	3 miles NE of Sanford	W. H. Fitts	do	101	6	40	do	6	
9	do	E. H. Harrington	do	160	6½	22	do	1	
10	2 miles N of Sanford	Buttercup Ice Cream Co.	do	134	6	35.5	do	10	
11	do	Roberts Co.	do	300	8	20	do	10	
12	3 miles W of Sanford	Ralph L. Groce	do	100	6	31	do	3	
13	do	Charles Lilly	do	90	6	65	do	12	
14	do	S. V. Lore	do	85	6	21	do	15	
15	5 miles W of Sanford	A. W. Payne	do	64	5	32	do	6	
16	4 miles W of Sanford	J. A. Christian	do	64	6	35	do	15	
17	do	do	do	74	6	30	do	30	
18	2 miles W of Sanford	Jeff Johnson	do	80	5	21	do	5	
19	8 miles W of Sanford	A. B. Coley	do	80	6	5	do	1	
20	Sanford	B. H. Jones	do	128	6	115	do	5	
21	do	J. P. McDavid	do	93	6	73	Slate	3	
22	do	C. S. Bullock	do	52	6	32	do	12	
23	2 miles SW of Sanford	Dr. Hayden Lutterlok	do	62	6	49	Triassic	3	
24	3 miles SW of Sanford	H. A. Riddle	do	155	6	20	do	10	
25	2 miles S of Sanford	Brooks Television Co.	do	65	5	53	Slate	15	
26	do	Mrs. A. R. Kelly	do	72	5	43	do	20	

Table 7. Records of Wells in Lee County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
27	9 miles SW of Sanford	Mrs. Beulah Harris	Open-end	84	6	12	Triassic	3	
28	7 miles SW of Sanford	J. R. Dycus	do	86	6	32	do	3	
29	6 miles SW of Sanford	Floyd Holt, Jr.	do	116	6	20	do	15	
30	do	Fred Matthews	do	60	8 6	21	do	15	
31	5 miles SW of Sanford	Paul Faushee	do	90	5	34	do	5	
32	do	W. T. Pyrant	do	170	6	30	do	5	
33	3 miles SW of Sanford	Ralph Payne	do	55	4		do	2	
34	9 miles SW of Sanford	K. E. Craven	do	80	6	44	do	1	
35	4 miles SW of Sanford	M. L. Medlin	do	90	6½	24	do	4	
36	do	W. B. Medlin	do	70	6	30	do	20	
37	3 miles S of Sanford	E. C. Winstead	do	65	6	52	Slate	30	
38	7 miles SW of Sanford	K. S. Coffer	do	45	6	21	Triassic	3	
39	4 miles S of Sanford	W. F. Bowling	do	50	6	37	Slate	20	
40	6 miles SW of Sanford	Rip Van Winkle Motel	do	318	6		Triassic		Analysis.
41	7 miles SW of Sanford	Henry F. McIver	do	122	6	106	Slate	1	
42	6 miles SW of Sanford	Green Gables Motor Court	do	185	6		do		
43	7 miles SW of Sanford	Miss Mary E. Chandler	do	160	6	107	do	1	
44	2 miles W of Lemon Springs	Luther Tippett	do	58	6	52	Surficial sand	10	
45	Lemon Springs	Earnest Wilson	do	79	6	48	Slate		
46	do	Claude A. Ferguson	do	68	6	59	do	6	
47	1 mile W of Lemon Springs	L. M. McGilvary	do	102	6	42	do	10	
48	2 miles SW of Lemon Springs	Virgil Cole	do	160		17	do	5	
49	2 miles SE of Lemon Springs	James Brantley	do	100	6	45	do	1	
50	3 miles SE of Lemon Springs	W. E. Fallin	do	125	6	103	do	15	Analysis.

Table 8. Chemical Analyses of Ground Water from Lee County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	5	7	40	49
Silica (SiO_2)		14	41	32
Iron (Fe), total		.09	3.8	.03
Iron (Fe) in solution		.00	.00	.00
Calcium (Ca)		30	8.0	7.9
Magnesium (Mg)		20	1.9	3.0
Sodium and potassium (Na + K)		228	11	8.1
Bicarbonate (HCO_3)	181	319	73	52
Sulfate (SO_4)	4	12	.1	.8
Chloride (Cl)	9.0	267	4.0	3.0
Fluoride (F)	.1	.6	.2	.3
Nitrate (NO_3)		1.4	.2	.2
Dissolved solids		741	101	109
Hardness as $CaCO_3$	130	157	43	32
pH	7.4	7.6	7.2	7.6
Chief Aquifer	Triassic	Triassic	Triassic	Slate
Date of collection	Dec. 1950	Apr. 1954	Jan. 1959	Jan. 1959

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Montgomery County

(Area 488 square miles; population 17,260)

Geography.—Montgomery County is the fifth largest county in the Fayetteville area but is eighth in population. Peaches are the major crop in the Sandhills, and tobacco, corn, and cotton are other important crops. Textile manufacturing and lumbering are the chief industries.

The county is a dissected plateau with some high hills in the northwestern third. In the slate belt the surface is rolling and long ridges are common. U. S. Highway 220 follows the crest of a broad ridge which extends the full length of the county. The streams are actively downcutting.

Part of the Triassic lowland lies along the south edge of Montgomery County, where the topography is fairly level and the streams are bordered by swamps. The southeast corner of the county is occupied by the Sandhills, where the upland surface is gently undulating.

Geology.—Most of the county is underlain by rocks of the volcanic slate series (pl. 6). These rocks generally are dense and greatly contorted, and they contain well-developed fracture systems.

Rocks of the Newark group, predominantly shale, crop out in the southern part of the county. In the Sandhills section, the weathered sands of the Tuscaloosa formation mantle the underlying Triassic and Paleozoic rocks to a depth of 75 feet or more. Alluvial deposits are extensive only along streams in the Triassic lowland.

Ground water.—One municipal and all domestic water supplies in Montgomery County are obtained from ground-water sources. Most of the wells are bored, but many are drilled. Springs are common and many formerly were used for domestic supplies. A well drilled at Biscoe flowed many years ago, but no flowing wells are now known in the county.

Throughout the slate belt section of the county, yields of as much as 50 gpm can be obtained if the wells are located properly. Wells tapping the relatively impermeable Triassic rocks rarely yield as much as 25 gpm. The surficial sand aquifer south of Candor furnishes moderate amounts of water to shallow wells.

Ground water from the slate is slightly acidic, soft or only moderately hard, and sometimes high in iron content. The Triassic rocks contain alkaline water which is hard or very hard. Water from the Coastal Plain strata is acidic and very soft.

Municipal supply systems (1959).—Biscoe obtains its water supply from the Little River. The capacity of its treatment plant is 500,000 gpd.

Candor obtains its water supply from Drowning Creek. The capacity of its treatment plant is 500,000 gpd.

Mt. Gilead obtains its water supply from the Pee Dee River. The capacity of its treatment plant is 250,000 gpd.

Star has two wells (Nos. 4 and 7) in use to supply an average daily consumption of 20,000 gallons. The water from well 7 is treated to remove iron.

Troy obtains its water supply from Denison Creek. The capacity of its treatment plant is 500,000 gpd.

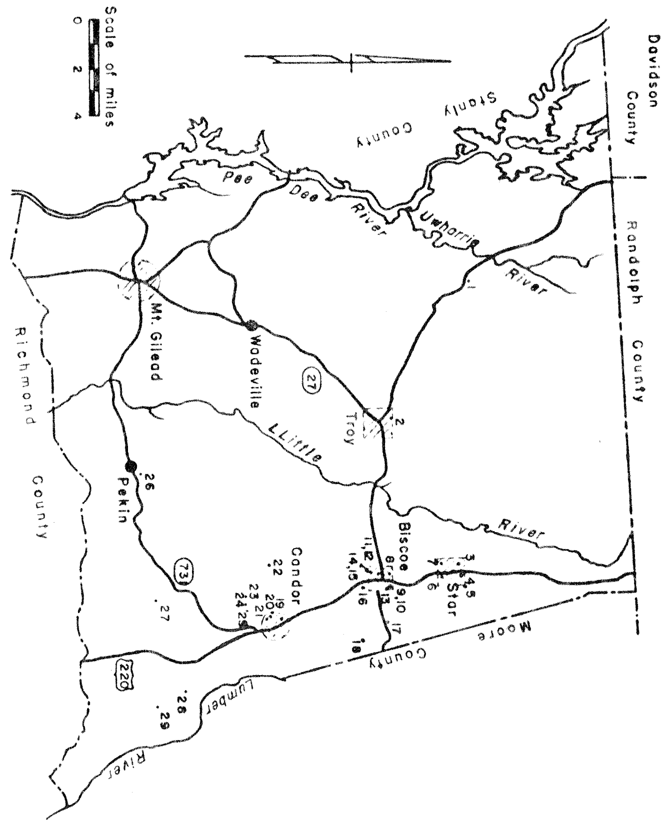

Figure 15. Map of Montgomery County showing location of wells

Table 9. Records of Wells in Montgomery County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diam-eter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	7 miles NW of Troy	A. O. Vanhoy	Bored	77	6		Slate	8	Analysis.
2	Troy	Smitherman Cotton Mills	Open-end	200	8	65	do	22	
3	Star	Town of Star	do	313	8	170	do	39	Abandoned.
4	do	do	do	190	8	40	do	55	Analysis.
5	do	do	do	200	8	50	do	35	
6	do	do	do	336	8		do		
7	do	do	do	300	10	86	do	137	Analysis.
8	Biscoe	Town of Biscoe	do	178	8		do	15	do
9	do	do	do	400	8	84	do	6	
10	do	do	do	336	8	71	do	29	Analysis.
11	do	do	do	212	6	92	do	10	
12	do	do	do	400	8		do	15	
13	do	do	do	209	8		do	8	Analysis.
14	do	do							
15	do	Aileen Mill Co.	Open-end	390	8		Slate	22	
16	1 mile S of Biscoe	J. A. Holt	do	72	6	52	do	20	
17	1 mile E of Biscoe	R. L. Myrick	do	68	6	21	do	20	
18	2 miles SE of Biscoe	Walter McLeod	do	78	6	66	do	8	
19	Candor	Town of Candor	do	175	8	170	do	50	Analysis.
20	do	do	Screen	70	8	70	Surficial sand	15	do
21	do	do	do	65	6	60	do	10	do
22	2 miles W of Candor	Mrs. G. W. Kellis	Open-end	101	6	46	Slate	10	
23	2 miles SW of Candor	Alvin Chappel	do	175	4	156	Triassic	10	
24	do	Lory Chappell	Screen	56	4	54	do		
25	do	Max Harris	Open-end	90	6	43	do	5	
26	Pekin	B. E. Johnson	do	130	6	15	do	1	Analysis.
27	5 miles SW of Candor	Luther Robinson	do	164	4	103	Triassic	10	
28	5 miles SE of Candor	M. C. Blue	do	67	4	64	Surficial sand	12	
29	6 miles SE of Candor	P. C. Harman, Jr.	do	350	4	137	Triassic	1	

Table 10. Chemical Analyses of Ground Water from Montgomery County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	1	4	7	8	10	13	19	20	21	26
Silica (SiO_2)	14	16	31	30	52	30	21	2.9	4.2	16
Iron (Fe), total	.29	.01	2.2	.06	.65	.88	7.1	.20	.07	.11
Iron (Fe) in solution	.08									.08
Calcium (Ca)	2.5	2.9	10	24	32	12	11	.9	1.4	58
Magnesium (Mg)	1.2	1.2	2.0	5.8	4.1	5.5	3.5	.9	.9	42
Sodium and potassium (Na + K)	5.4	6.1	6.4	12	20	15	8.1	2.4	9.0	472
Bicarbonate (HCO_3)	21	18	10	115	115	88	60	2.0	1.0	608
Sulfate (SO_4)	1.0	1.2	9.7	7.4	7.7	2.6	6.7	.7	.9	3.0
Chloride (Cl)	2.5	1.9	2.8	1.5	8.5	6.8	1.9	3.2	8.6	560
Fluoride (F)	.1	.1	.1	.1	.2	.1	.2	.0	.0	.9
Nitrate (NO_3)	1.0	2.8	.0	.8	.0	1.1	.1	5.2	16	.3
Dissolved solids	46	46	82	141	199	116	84	22	47	1,310
Hardness as $CaCO_3$	11	12	33	84	97	53	42	6	7	317
pH	6.2	5.9	6.4	7.2	7.2	6.7	6.8	5.2	5.0	7.3
Chief Aquifer	Slate	Slate	Slate	Slate	Slate	Slate	Slate	Surficial sand	Surficial sand	Triassic
Date of collection	Apr. 1954	Mar. 1948	Mar. 1948	Mar. 1948	Mar. 1948	Mar. 1948	Dec. 1948	Dec. 1948	Dec. 1948	Apr. 1954

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Moore County

(Area 672 square miles; population 33,129)

Geography.—Moore County is the second largest county in the Fayetteville area and ranks fifth in population. Tobacco, peaches, corn, and cotton are the chief crops. The tourist trade is important near Southern Pines, where golf courses and other recreational facilities are maintained. Textile manufacturing and lumbering are the principal industries, and Moore County produces about 50 percent of the pyrophyllite mined in the United States.

The northwestern third of the county is in the slate belt, where the surface is a gently rolling dissected plateau. North of Carthage, in the Triassic lowland, the topography is more subdued, and the gently undulating surface is drained by numerous swamps.

The southern half of the county is in the Sandhills section. A few long ridges occur here, but the topography generally is rather smooth and broad interstream areas prevail. The area in the vicinity of Southern Pines may be called typical sandhill country.

Geology.—The northwestern third of Moore County is underlain by the volcanic slate series, consisting of slate, schist, and related rocks (pl. 7). Similar rocks crop out also in the east corner of the county near Cameron, where the streams have cut through the Coastal Plain rocks to expose the older rocks beneath.

The formations of the Newark group occupy a broad belt which strikes northeast through the center of the county. North of Carthage these rocks are at the surface, but southeast of Carthage they generally are covered by Coastal Plain sediments.

The Coastal Plain strata cover most of the county and are about 220 feet thick at Aberdeen. Sand mantles the slate near Samarcand, covers much of the Triassic belt between Carthage and Jackson Springs, and is the surface material in the southern third of the county. Some of the sand beds are of the surficial sand series but generally are the weathered upper beds of the Tuscaloosa formation. Alluvium has accumulated along most of the streams.

Ground water.—Five municipal and all domestic water supplies are obtained from ground-water sources. The municipal supply at Carthage is a mixture of ground and surface water.

Bored and drilled wells are common in Moore County, and driven wells also are numerous. Flowing wells may be developed in the southern part of the county but none are known.

Ground-water supplies generally are adequate throughout much of Moore County. The slate yields moderate amounts of water to properly located wells. The Triassic rocks yield only small quantities of water to wells.

In the Coastal Plain section, the surficial sand aquifer is usually productive, although it probably does not exceed 75 feet in thickness. The underlying Tuscaloosa formation, the Cretaceous clay aquifer, does not yield water readily to wells. The largest yield from a well in the county is from a gravel-walled well at Aberdeen, reported to yield 208 gpm. This well is 210 feet deep, but only 45 feet of sand was penetrated in its drilling. Wells yielding more than 50 gpm are not common in Moore County, and no thick, permeable aquifer underlies the county.

Municipal supply systems (1959).—Aberdeen has several improved springs (No. B) and one well (No. 76). Average daily consumption is 225,000 gallons, and the water is treated.

Carthage has a series of 20 springs (No. A). Average daily consumption is 160,000 gallons, and the water is treated.

Niagara has two wells (Nos. 69 and 70) to supply an average daily consumption of about 15,000 gallons.

Pine Bluff has several improved springs (No. C) which supply an average daily consumption of 25,000 gallons.

Pinehurst obtains its water supply from Rattlesnake Creek. The capacity of its treatment plant is 750,000 gpd.

Robbins obtains its water supply from Bear Creek. The capacity of its treatment plant is 1,000,000 gpd.

Southern Pines obtains its water from Southern Pines Lake. The capacity of its treatment plant is 2,000,000 gpd.

Vass uses two wells (Nos. 60 and 62) to supply an average daily consumption of 40,000 gallons. The water is not treated.

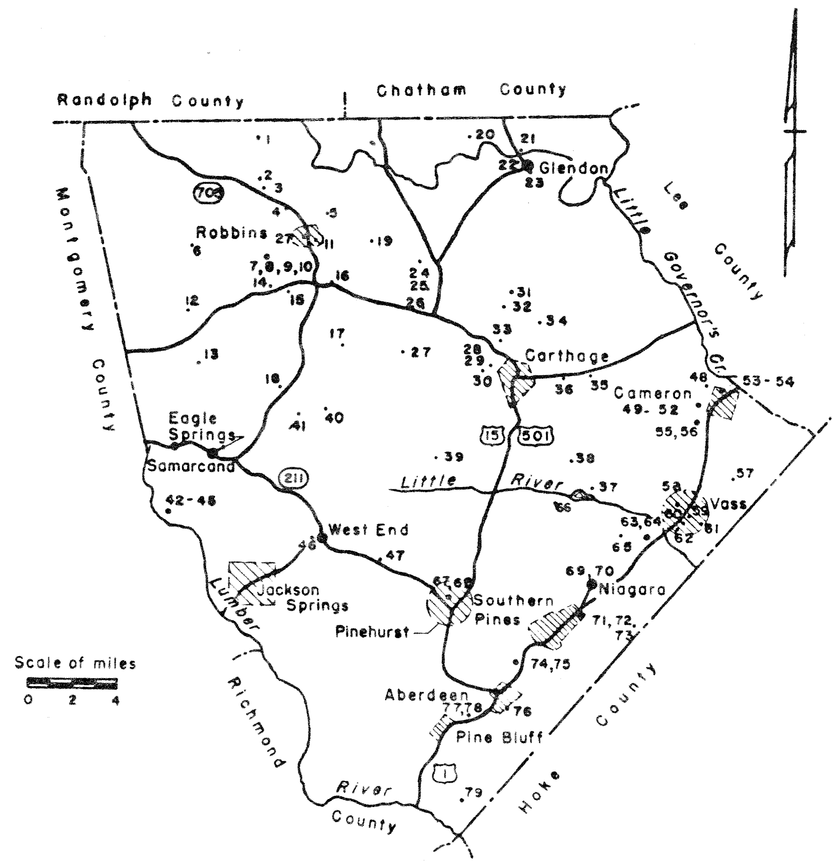

Figure 16. Map of Moore County showing location of wells

Table 11. Records of Wells in Moore County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	5 miles NW of Robbins	Franklin Hussey	Open-end	72	6	42	Slate	3	
2	4 miles NW of Robbins	W. C. Garner	do	89	6	61	do	10	
3	3 miles NW of Robbins	Mrs. Charlie Maness	do	104	6	7	do	1	
4	1 mile NW of Robbins	R. D. Enloe, Sr.	do	102	6	28	do	10	
5	1 mile NE of Robbins	Talbert Maness	do	100	6	32	do	2	
6	5 miles W of Robbins	Moore County Schools	do	82	6	68	do	45	
7	2 miles W of Robbins	Standard Mineral Co.	do	110	6	40	do	59	
8	do	do	do	93	6	40	do	49	
9	do	do	do	200	8		do	15	
10	do	do	do	178	9	43	do	1	
11	Robbins	Pinehurst Silk Mills		203			do	30	Abandoned.
12	6 miles SW of Robbins	C. P. Myrick	do	125	6	21	do	12	
13	7 miles SW of Robbins	Edgar Bailey	do	68	6	43	do	5	
14	3 miles SW of Robbins	E. R. Sheffield	do	117	6	22	do	2	
15	do	W. C. Brown	do	100	6	39	do	10	
16	2 miles S of Robbins	E. T. Williams	do	128	6	21	do	10	
17	5 miles S of Robbins	J. A. Wallace	do	72	6	22	do	6	
18	7 miles S of Robbins	E. L. Kelly	do	87	6	84	do	5	
19	3 miles E of Robbins	O. A. Manness	do	35	6	15	do	8	
20	3 miles NW of Glendon	C. L. Cheek	do	194	6	10	Slate	1	
21	Glendon	Bob Paschal	do	150	6	42	Triassic	2	
22	do	Richard Dowd	do	140	6	12	do	3	
23	do	Eugene D. Phillips	do	100	6	7	do	15	
24	7 miles NW of Carthage	O. T. Parks	do	140	6	41	Slate	1	
25	5 miles NW of Carthage	W. N. Caldwell	do	88	6	78	Triassic	7	
26	do	E. T. Flinchum	do	209	6	39	do	12	
27	do	Warren Harris	do	89	6	32	do	29	
28	2 miles NW of Carthage	M. M. Way	do	129	6	44	do	2	
29	1 mile NW of Carthage	Mrs. Carl Kivett	do	107			do	8	
30	1 mile W of Carthage	J. G. Kivett	do	90	6	32	do	15	
31	4 miles N of Carthage	Hubert Speer	do	195	6	13	do	9	
32	3 miles N of Carthage	W. M. Warner	do	116	6	22	do	2	
33	2 miles N of Carthage	J. B. Muse	do	90	6	31	do	5	
34	3 miles NE of Carthage	Helen Dunlap	do	200	6	20	do	1	
35	3 miles E of Carthage	W. M. McLaughlin	do	111	6	55	do	2	
36	2 miles E of Carthage	N. C. Highway Commission	do	779	6		do	4	Analysis.
37	6 miles SE of Carthage	J. H. Matthews		70	6	16	do	4	
38	4 miles SE of Carthage	C. L. Ragsdale	do	120	6	88	Slate		
39	5 miles SW of Carthage	C. M. Jackson	do	206	6¼	22	Triassic	1	
40	9 miles W of Carthage	Miss Sarah Dunlap	do	110	6	32	do	12	
41	6 miles N of West End	Ed DeWitt Caviness	do	98	6	68	do	15	
42	7 miles NW of West End	Samarcand Manor	do	386	8	1	do	17	Analysis.
43	do	do	Screened	85	8		do	30	
44	do	do	Open-end	83		60	do	12	Analysis.
45	do	do	do	265	8	200	do	50	do
46	West End	Sandhille Furniture Co.	do	175	6	101	do	15	do
47	3 miles SE of West End	R. A. Hamon	Screened	61	6	57	Surficial sand	10	
48	1 mile NW of Cameron	N. A. Graham	Open-end	108	6	85	Slate	5	
49	Cameron	A. G. Edmonds	do	101	6	63	do	30	
50	do	J. H. Edmonds	do	75	6	46	do	29	
51	do	J. Walter McDonald	do	125	6	83	do	10	
52	do	M. W. Harbour	do	100	6	75	do	10	
53	do	H. E. Wall	do	37	6	22	do	10	
54	do	P. R. McKinney	do	78	6	50	do	15	
55	1 mile SW of Cameron	J. Abner Thomas	do	52	6	38	do	10	
56	do	J. W. Rogers	do	40	6	21	do	20	
57	4 miles SE of Cameron	Raymond Burnette	do	100	6	57	do	2	
58	Vass	Town of Vass	do	315	6	58	do		Abandoned.
59	do	do	do	320	6	121	do	12	do
60	do	do	do	225	6		do	45	do
61	do	do	do	325	6		do	15	
62	do	do	do	475	8	70	do	25	
63	2 miles SW of Vass	T. M. Baker	do	91	4	71	do	12	

Table 11. Records of Wells in Moore County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
64	2 miles SW of Vass	T. M. Baker	Open-end	84	4	72	Slate	10	
65	3 miles SW of Vass			57			Surficial sand	10	
66	6 miles N of Southern Pines	Mrs. Clifford King	Open-end	145	6	112	Slate	4	
67	5 miles NW of Southern Pines		do	730	8		do		
68	do	Leonard Tufts Hotel	do	681	6		do	120	
69	Town of Niagara	Town of Niagara	do	85	6	85	do	10	Analysis.
70	do	do	do	209	6	209	do	10	do
71	Southern Pines	W. O. Moss	Screen	106	6	100	Cretaceous clay	35	
72	do	do	do	202	8		do	40	
73	3 miles E of Southern Pines	Hugh Griard	do	119.5	6		do	20	
74	3 miles SW of Southern Pines	A. W. Atherton	do	98	6		do	30	
75	do	C. D. Westbrook	do	65	4	61	do	10	
76	Aberdeen	Town of Aberdeen	Gravel-walled	210	10		do	208	
77	1 mile SW of Aberdeen	J. L. Collins	Screen	62	4	36	do	8	
78	do	L. B. Monroe	do	45	4	43	do	8	
79	4 miles S of Aberdeen	C. H. Maness	do	57	6	52	do	15	

Table 12. Records of Springs in Moore County

No.	Location	Owner	Chief aquifer	Yield (gpm)	Remarks
A	Carthage	Town of Carthage	Surficial sand	45	Analysis.
B	Aberdeen	Town of Aberdeen	do	156	do
C	Pinebluff	Town of Pinebluff	do	40	do

Table 13. Chemical Analyses of Ground Water from Moore County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	36	42	44	45	69	70	76	A	B	C
Silica (SiO_2)	2.7	16	21	20	5.2	32	12	3.8	2.4	3.7
Iron (Fe), total	.71	.99	6.1	.73	.03	1.4		.03	.11	.06
Iron (Fe) in solution	.02	.52	.00				.01			
Calcium (Ca)	.8	16	9.3	16	.7	7.3	3.0	1.2	.3	.8
Magnesium (Mg)	.6	5.1	4.6	5.6	.5	3.8	.5	.5	.2	.3
Sodium and potassium (Na + K)	7.5	17	13	15	1.4	17	3.3	4.9	3.3	1.9
Bicarbonate (HCO_3)	9	97	66	96	2	57	7	3	4	3.0
Sulfate (SO_4)	1.5	8.3	11	9.3	1.0	21	2.9	.9	.8	.4
Chloride (Cl)	5.6	5.5	2.2	1.6	1.6	1.6	4.0	4.5	2.5	2.1
Fluoride (F)	.0	.1	.1	.1	.1	.2	.1	.1	.1	.0
Nitrate (NO_3)	1.9	.1	.1	.1	2.7	.1	2.6	7.2	1.0	2.0
Dissolved solids	32	120	97	118	16	110	37	26	14	16
Hardness as $CaCO_3$	4	60	42	63	4	34	10	5	2	3
pH	6.3	7.0	6.7	7.0	5.6	6.85	6.0	5.4	5.6	5.6
Chief Aquifer	Triassic	Triassic	Triassic	Triassic	Slate	Slate	Cretaceous sand	Surficial sand	Surficial sand	Surficial sand
Date of collection	Oct. 1950	Nov. 1954	Nov. 1954	May 1949	July 1959	Sep. 1948	Sep. 1954	Nov. 1946	Apr. 1947	Oct. 1948

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Richmond County

(Area 477 square miles; population 39,597)

Geography.—Richmond County is the sixth largest county in the Fayetteville area and ranks fourth in population. The chief crops include peaches, tobacco, cotton, and corn. Textile manufacturing is the most important industry.

Most of the county is in the Sandhills section. The topography there is smooth and includes extensive gently-rolling interstream areas. Wherever the rocks of the slate belt crop out, principally along the Pee Dee River and its tributaries, the topography is more rugged. There the streams have excavated many deep narrow valleys. High cliffs are found where these streams descend to join the Pee Dee River.

In the northwest corner of the county, and also southwest of Ellerbe, the Triassic lowland is well developed. Sluggish streams drain a low-lying swampy area.

Geology.—The rocks of the volcanic slate series crop out in the western part of the county and in many stream valleys in the Coastal Plain section (pl. 8). Granitic rocks are exposed west of Rockingham. The Triassic rocks in the northern part of the county consist of beds of reddish-brown shale, which are continuous, beneath the surficial cover, with the Triassic rocks of adjoining counties. Southwest of Ellerbe is a small area of Triassic rocks in a separate basin.

The Coastal Plain strata consist of blue-gray clay overlain by weathered sandy beds of the Tuscaloosa formation, which crop out in the central and eastern parts of the county. They increase in thickness from a featheredge in the northwest part of the county to about 200 feet southeast of Hamlet and 175 feet east of Hoffman.

Alluvial deposits are common along many of the streams in the Triassic lowland and the Coastal Plain.

Ground water.—Four municipal and all domestic water supplies in Richmond County are obtained from wells.

Driven wells are the most common type of well in the Sandhills section, but bored and drilled wells yield more water. Only one well is known to flow in this county.

Ground-water supplies generally are adequate for domestic purposes, even though some wells in the Triassic rocks have low yields. The slate aquifer yields as much as 35 gpm to wells. Granite in the area generally yields less water than the slate.

The surficial sand aquifer yields moderate supplies of water to wells; as much as 50 gpm at some places. The Cretaceous clay aquifer, the Tuscaloosa formation, is not permeable enough to yield adequate amounts of water to any but domestic wells.

Water from the slate generally is soft and slightly acidic. Water from the Triassic rocks is alkaline and moderately hard. Water from the Coastal Plain rocks is acidic and very soft.

Municipal supply systems (1959).—Cordova alternates the use of five wells (Nos. 23-27) to supply an average consumption of 40,000 gpd. The water supply, owned by the Burlington Mills Corporation, is chlorinated.

Ellerbe uses three wells (Nos. 3, 6, 7) that have an aggregate yield of 123,000 gpd. The average daily consumption is about 35,000 gallons. The water is not treated.

Hamlet obtains its water supply from Marks Creek. The capacity of its treatment plant is 1,500,000 gpd.

Roberdell uses one well (No. 19), capable of yielding 72,000 gpd. Average daily consumption is unknown.

Rockingham obtains its water from Falling Creek. The capacity of its treatment plant is 1,500,000 gpd.

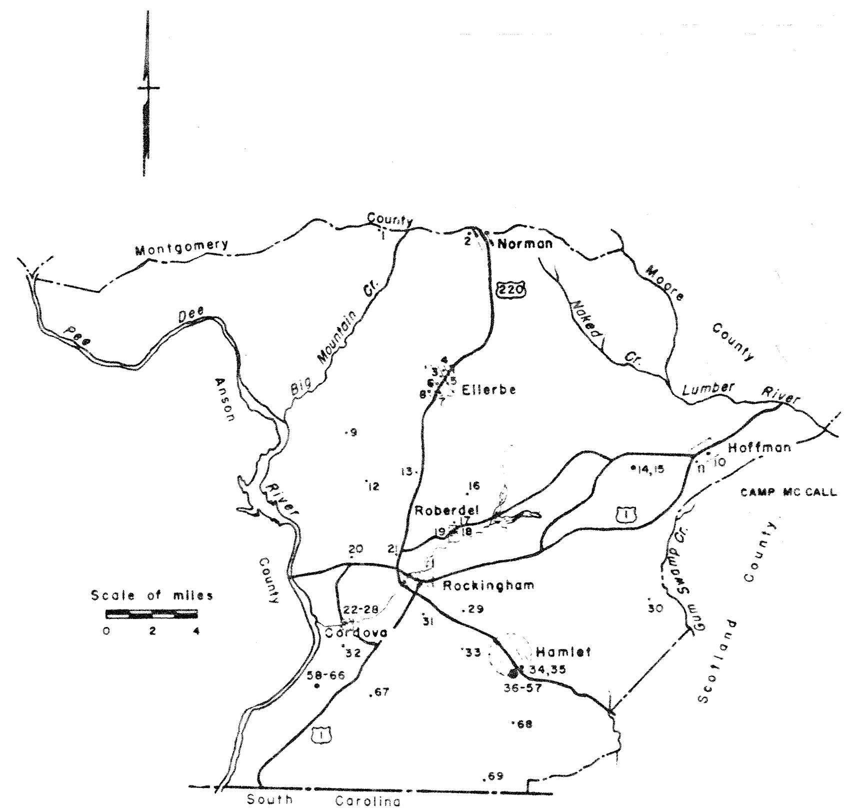

Figure 17. Map of Richmond County showing location of wells

Table 14. Records of Wells in Richmond County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	5 miles W of Norman	John W. Allred	Open-end	101	6	33.5	Triassic	5	
2	Norman	Roy Martin	do	138	6	66	do	124	
3	Ellerbe	Town of Ellerbe	Screen	115	8	93	Slate	15	Analysis.
4	do	do	Open-end	449	10	170	do	25	do
5	do	do					do		
6	do	do	Gravel-walled	120	10	110	do	16	
7	do	do	Open-end	200	8-6	177	do	55	
8	do	do		110	10		do	18	Analysis.
9	4 miles SW of Ellerbe	W. W. King	Open-end	110	6	88.5	do	3	
10	Hoffman	Seaboard Railroad	Screen	85	6	83	Surficial sand	12	
11	do	N. C. Division of Forestry	do	120	4	116	do	7	
12	5 miles SW of Ellerbe	J. P. Leak	Open-end	260	5	34.5	Triassic	1	Analysis.
13	4 miles S of Ellerbe	Claude D. Smith	do	156	6	43.5	do	60	
14	3 miles W of Hoffman	Morrison Training School	Screen	130	26		Cretaceous clay	65	
15	do	do	do	160	6	55	do	60	
16	5 miles SE of Ellerbe	J. T. Baxley	Open-end	92	6	53.5	Slate	15	
17	3 miles NE of Rockingham	Mrs. J. W. Miller	do	75	6	34.5	do	20	
18	do	Roberdel School	do	178	6	116	do	30	
19	Roberdel	Town of Roberdel	do	200	8		do	50	Analysis.
20	4 miles NW of Rockingham	Zack Nichols	do	120	6	62	do	2	
21	2 miles NW of Rockinghma	C. E. Whitley	do	197	6	156	do	2	
22	Cordova	Burlington Mills Corp.	Tile	60	60		do	18	
23	do	do	Open-end	80			Slate	5	
24	do	do	do	180	6		do	27	
25	do	do		130	6		do		
26	do	do	Open-end	139	6		do	10	
27	do	do		475	6		do	11	
28	do	do	Open-end	268	26-12	26	do	22	Not used.
29	2 miles SE of Rockingham	M. L. Hinson	do	106	6	65.5	do	3	
30	7 miles NE of Hamlet	Mr. McLaurin		20			Surficial sand		Flowing well
31	1 mile S of Rockingham	Rohanen School		393	6	145	Slate	16	
32	1 mile S of Cordova	C. A. Macon	Open-end	114	6	77.5	do	4	
33	3 miles SE of Rockingham	V. L. Hudson	Screen	219	2		Cretaceous clay		
34	Hamlet	Hamlet Ice Co.	do	155	6	73	do	15	
35	do	do	do	80	6	70.5	do	35	
36	do	Buttercup Ice Cream Co.	do	59	6	62	do	38	
37	do	do	do	70	8	65	do	32	
38	3 miles SW of Cordova	Wolf Pitt Farms		128	4	117	Slate	2	
39	do	do	Screen	57	4	46	Surficial sand	5	
40	do	do		158	4	118	Slate	1	
41	do	do		106	4	90	Surficial sand	10	
42	do	do		200	4	152	Slate	2	
43	do	do		41	4	41	Surficial sand	5	
44	do	do		96	4	86	Slate	5	
45	do	do		110	4	106	Surficial sand	4	
46	do	do		112	4	83	Slate	3	
47	5 miles SW of Rockingham	W. L. Brigman	Open-end	59	6	58.5	do	25	
48	3 miles S of Hamlet	Arthur Cappel	Screen	69	2	69	Surficial sand		
49	6 miles SW of Hamlet	Joe Brooks	do	107	2	104	do	4	

Table 15. Chemical Analyses of Ground Water from Richmond County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	3	4	8	12	19
Silica (SiO_2)	4.7	4.8	6.1	19	11
Iron (Fe), total	.13	.31	.16	.06	.00
Iron (Fe) in solution				.00	.00
Calcium (Ca)	.8	.7	1.6	13	9.2
Magnesium (Mg)	1.2	1.0	1.1	7.7	5.2
Sodium and potassium (Na + K)	7.3	4.8	14	33	4.5
Bicarbonate (HCO_3)	1.0	1.0	1.0	152	29
Sulfate (SO_4)	.9	.8	8.8	3.8	2.2
Chloride (Cl)	5.8	4.6	15	5.0	8.5
Fluoride (F)	.0	.0	.0	.2	.0
Nitrate (NO_3)	16	10	8.6	.0	20
Dissolved solids	40	33	61	155	95
Hardness as $CaCO_3$	7	6	8	64	44
pH	5.3	5.1	5.3	7.7	6.9
Chief Aquifer	Slate	Slate	Slate	Triassic	Slate
Date of collection	Oct. 1947	Oct. 1947	Oct. 1947	Apr. 1954	Apr. 1955

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Robeson County

(Area 944 square miles; population 87,769)

Geography.—Robeson County is the largest county in the Fayetteville area and is second in population. The chief crops are tobacco and cotton. Textile manufacturing and lumbering are the major industries.

Robeson County is entirely within the Coastal Plain physiographic province. The surface is a level to undulating plain which slopes to the south and southeast. In the northwest, the topography is more rolling. The streams of the county have wide, swampy flood plains, and some, including the Lumber River, have a rapid flow. Carolina bays are common throughout the county.

Geology.—The basement rocks beneath the Coastal Plain sediments are those of the volcanic slate series. They are several hundred feet beneath the surface and are reached only rarely in wells.

The basal unit of the Coastal Plain strata in Robeson County is the Tuscaloosa formation, and this is overlain by the Black Creek formation (pl. 9). Both formations apparently consist of alternating beds of clay and sand, but clay predominates.

The Duplin marl occurs in scattered interstream areas in the southern half of the county, where it probably does not exceed 25 feet in thickness. The entire county is mantled by deposits of loose, surficial sand and clay, and along most of the streams are alluvial deposits.

Ground water.—Six municipal and all domestic water supplies in Robeson County are obtained from wells. In addition, Lumberton, the county seat, has a deep well to supplement its surface-water supply during emergencies.

All types of wells are used in the county. Driven and dug wells are the most common, but bored and drilled wells also are numerous. There are many springs in the hilly regions in the northwestern part of the county, and wells flow in the lower lands along all the streams. Supplies of ground water are ample throughout the county.

The surficial sand aquifer is not thick, but it furnishes water to many shallow wells. Beneath the surficial sand aquifer are alternating clay and sand strata of the Cretaceous sand aquifer, which consists of the Black Creek formation above and the Tuscaloosa formation below. This aquifer is thick, increasing in thickness from more than 300 feet in the north to about 600 feet in the south. Large yields are obtained from wells in this aquifer. Screened wells may yield 300 to 600 gpm and gravel-walled wells as much as 900 gpm.

Ground water in Robeson County is slightly acidic in the northwestern part of the county but becomes alkaline with depth in the southeastern part of the county. The water generally is soft and is low in dissolved solids.

Municipal supply systems (1959).—Fairmont uses four wells (Nos. 73-76) to supply an average daily consumption of 1 million gallons. The water is not treated.

Lumberton has a deep well (No. 55) which can furnish an emergency supply of water to supplement the surface-water supply from the Lumber River. The capacity of Lumberton's treatment plant is 5,250,000 gpd.

Maxton has two wells (Nos. 30, 31) to supply an average daily consumption of 70,000 gallons. The water is treated.

Pembroke uses two wells (Nos. 26, 27) to supply an average daily consumption of 40,000 gallons. The water is treated.

Red Springs has two wells (Nos. 5, 6) to supply an average daily consumption of 300,000 gallons. The water is treated.

Rowland has three wells (Nos. 39, 40, 41) to supply an average daily consumption of 300,000 gallons. The water is not treated.

St. Pauls has two wells (Nos. 18, 19) to supply an average consumption of 300,000 gpd. The water is treated.

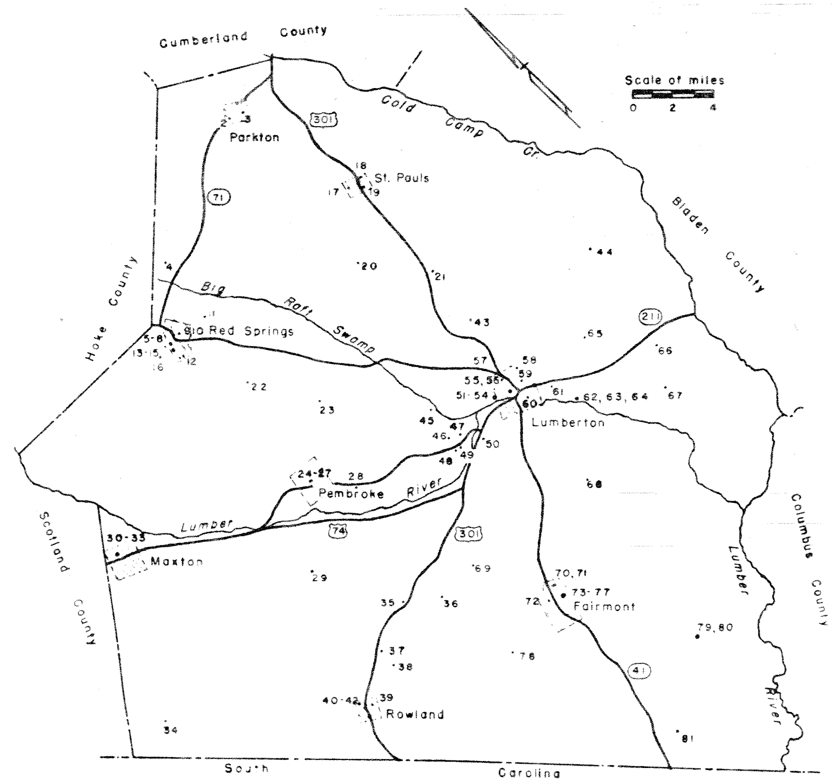

Figure 18. Map of Robeson County showing location of wells

Table 16. Records of Wells in Robeson County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	7 miles NW of St. Pauls	J. Q. Parnell	Open-end	127	6	107	Cretaceous sand	100	
2	do	Parkton School	Screen	95	4	54	do	50	
3	do	Proctor's Nursery	do	108	6	100	do	75	
4	4 miles N of Red Springs	J. H. Humphrey	Open-end	55	4	46	do	20	
5	Red Springs	Town of Red Springs	Screen	400	8	400	do	600	
6	do	do	Gravel-walled	400	8	400	do	514	Analysis.
7	do	do	do	350	28-8		do	180	Not used.
8	do	do	do	206	24-8		do	450	do
9	do	B. W. Townsend		90	2		do	20	Flowing well.
10	do	S. R. Townsend		75	2		do	30	do
11	2 miles E of Red Springs	Mary McLean Dillard	Open-end	280	4	150	do		
12	Red Springs	Red Springs Ice Plant	do	137	6	117	do	75	
13	do	Robbin's Mill Inc.	Screen	300	4		do	250	
14	do	do	do	210	24-8		do	280	Flowing well.
15	do	do	do	90	8		do	60	
16	1 mile W of Red Springs	Spring Side Dairy	do	90	6	74	do	75	
17	St. Pauls	Town of St. Pauls	do	135	8		do	120	Analysis.
18	do	do	Gravel-walled	365			do	350	do
19	do	do	Screen	358	8	320	do	300	do
20	4 miles SW of St. Pauls	R. B. Tolar	do	65	4	53	do	45	
21	7 miles N. of Lumberton	D. B. Humphrey		50	2		do		Flowing well.
22	4 miles S of Red Springs	Mrs. J. Amanda Brown		100	2		do	6	do
23	4 miles NE of Pembroke	Robeson County Schools	Screen	162	4	158	do	20	
24	Pembroke	Town of Pembroke	do	200	8		do	125	Not used.
25	do	do	do	165	8	155	do	165	do
26	do	do	do	190	8	180	do	150	
27	do	do	do	312	8	312	do	600	
28	2 miles SE of Pembroke	Gaston Lewis	do	79	4	71	do	25	
29	4 miles SW of Pembroke	Robeson County Schools	do	120	4	116	do	20	
30	Maxton	Town of Maxton	Gravel-walled	400	24-8	370	do	500	Analysis.
31	do	do	Screen	70	6		do	125	do
32	do	do		50	6		do	60	Not used.
33	do	do	Screen	70	6		do	40	do
34	8 miles SW of Maxton	Piney Grove School	do	88	4	79	do	30	
35	6 miles NE of Rowland	L. R. Hamer		100	2		do	8	Flowing well.
36	7 miles NE of Rowland	J. L. Townsend		100	2		do	3	do
37	3 miles NE of Rowland	Angus Pate	Screen	115	4	109	do	100	
38	3 miles E of Rowland	Ashpole Center School	do	76	4	67	do	35	Not used.
39	Rowland	Town of Rowland	Gravel-walled	421	24-8	421	do	425	
40	do	do	do	269	24-8	265	do	160	
41	do	do	do	250	8		do	775	
42	do	do		268	8	265	do		Analysis. Abandoned.
43	4 miles N of Lumberton	J. L. Jones	Screen	78	4	66	do	40	
44	8 miles NE of Lumberton	Robeson County Schools	do	66	6	64	do	15	Abandoned.
45	4 miles NW of Lumberton	Russell Duncan	do	61	4	57	do	40	
46	4 miles W of Lumberton	Pine Crest Country Club	do	122	8	102	do	240	
47	3 miles W of Lumberton	Robeson County Health Center	do	118	6	108	do	35	
48	4 miles W of Lumberton	R. A. Hedgepeth	Open-end	91	4	83	do	50	Flowing well.
49	do	Robeson County Prison Camp	Screen	88	6		do	90	Analysis.
50	3 miles W of Lumberton	Lumberton Airport	do	191	8	191	do	400	Flowing well.
51	1 mile NW of Lumberton	Jennings Mills, Inc.	do	107	6	87	do	75	
52	do	do	do	103	2		do	90	Flowing well.
53	do	do	do	107	6		do	125	
54	do	do	do	113	6	102	do	60-80	
55	Lumberton	Town of Lumberton	Gravel-walled	540	8	540	do	800-1,000	Analysis.
56	do	do	Screen	100	2		do	2-3	Flowing well.
57	do	McMillan's Beach		61	2		do	5	Analysis.
58	do	Lumberton Ice & Fuel Co.	Gravel-walled	405	8	390	do	150-200	
59	do	Coca Cola Co.	Screen	96	8-6	96	do	60	

Table 16. Records of Wells in Robeson County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
60	Lumberton	7-Up Bottling Co.	Screen	158	4	112	Cretaceous sand	25	
61	2 miles SE of Lumberton	Farmer's Cooperative Exchange	Gravel-walled	260			do	200	Analysis.
62	do	Carolina Power & Light Co.	do	310	12 6		do	126	
63	do	do	do	225	12 6	193	do	20	
64	do	Elaseo Services, Inc.	Screen	130	8	122	do	84	
65	4 miles E of Lumberton	W. M. Bowman	do	215	6	207	do	80	
66	7 miles E. of Lumberton	L. J. Cottingham Lumber Co.	do	151	4		do		
67	7 miles SE of Lumberton	Mr. Johnson	do	200	8		do	200	
68	5 miles S of Lumberton	Southern Sawmills & Lumber Co.	do	100	10		do	150	
69	4 miles N of Fairmont	Robeson County Schools	do	230	4	226	do	30	
70	Fairmont	O. M. Huggins	do	110	4	130	do	20	
71	do	do	Open-end	85	4	65	do	15	Flowing well.
72	do	C. S. McKinzie		57½	1¼		do	9	do
73	do	Town of Fairmont	Screen	300	10	236	do	120	Analysis.
74	do	do	do	306	8		do	45	
75	do	do	do	277	10	251	do	100	
76	do	do	Gravel-walled	380	8	323	do	775	do
77	do	do	Screen	478	8	265	do	700	
78	3 miles W of Fairmont	Robeson County Schools	do	130	4	126	do	50	
79	7 miles SE of Fairmont	Barnesville School	do	65	6		do	40	
80	do	do		210	4	210	do	25	Abandoned.
81	9 miles S of Fairmont	Marietta School	Screen	178	4	170	do	20	

Table 17. Chemical Analyses of Ground Water from Robeson County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	6	17	18	19	30	31	42
Silica (SiO_2)	11	11	11	8.8	7.9	9.3	14
Iron (Fe), total	3.3	.31	.20	.49	.26	.33	.17
Iron (Fe) in solution	.03			.03			
Calcium (Ca)	.3	2.8	3.9	1.4	2.1	2.0	8.3
Magnesium (Mg)	.3	.9	1.6	.5	1.0	1.0	1.0
Sodium and potassium (Na + K)	3.3	5.3	3.6	1.9	3.2	5.4	7.8
Bicarbonate (HCO_3)	2	0	0	4	1.0	2.0	38
Sulfate (SO_4)	2.9	10	11	2.3	2.7	4.4	4.7
Chloride (Cl)	3.1	8.1	8.2	2.8	6.0	8.1	3.8
Fluoride (F)	.0	.0	.0	.0	.1	.1	.1
Nitrate (NO_3)	.1	3.0	2.6	.0	4.9	3.7	.2
Dissolved solids	23	48	42	25	33	39	59
Hardness as $CaCO_3$	2	13	17	6	9	9	25
pH	4.9	4.3	4.3	5.1	4.7	4.8	6.3
Chief Aquifer	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand
Date of collection	Dec. 1949	Jan. 1949	Jan. 1949	-------	Jan. 1949	Jan. 1949	Feb. 1947

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Table 17. Chemical Analyses of Ground Water from Robeson County—Concluded

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	49	55	57	61	73	76
Silica (SiO_2)	15	19	18	16	32	29
Iron (Fe), total	4.4	.82	.34	.46	.32	.31
Iron (Fe) in solution	.02	.04	.08	.03		
Calcium (Ca)	3.0	36	1.8	47	.4	2.0
Magnesium (Mg)	.4	1.8	.2	1.6	.7	2.0
Sodium and potassium (Na + K)	5.0	17	9.3	5.9	39	29
Bicarbonate (HCO_3)	16	153	20	142	99	82
Sulfate (SO_4)	2.4	2.5	4.0	3.0	2.2	3.1
Chloride (Cl)	3.1	3.4	3.4	5.0	2.8	2.9
Fluoride (F)	.0	.1	.1	.1	.3	.2
Nitrate (NO_3)	.1	.1	.0	.1	.3	.2
Dissolved solids	39	154	53	157	131	110
Hardness as $CaCO_3$	9	97	5	124	4	13
pH	5.8	7.2	5.9	8.2	6.9	6.8
Chief Aquifer	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand	Cretaceous sand
Date of collection	Oct. 1950	Jan. 1950	June 1949	Aug. 1949	July 1948	July 1948

Analyzed by the Quality of Water Branch, U. S. Geological Survey

Scotland County

(Area 317 square miles; Population 26,836)

Geography.—Scotland County is the eighth county in size and the sixth in population in the Fayetteville area. The chief crops include cotton, vegetables, and tobacco. Textile manufacturing, lumbering, and chemical production are the most important industries.

Scotland County lies entirely within the Coastal Plain physiographic province. The northwestern half of the county is in the Sandhills section, where the topography is moderately hilly. The remainder of the county is in the Flatwoods section, which is fairly level but has a few sandy ridges. Most of the streams that drain the county rise in the Sandhills section and flow toward the southeast and south. The streams in the Flatwoods section are bordered by wide swamps.

Geology.—Rocks of the volcanic slate series underlie the Coastal Plain sediments and some Triassic rocks also may be present, but only the Coastal Plain sediments are exposed.

The Coastal Plain strata consist of the Black Creek and Tuscaloosa formations together with some surficial beds of sand (pl. 10). The total thickness of these beds increases from about 200 feet in the northwest to about 400 feet in the southeast.

In the northwestern part of the county, the Tuscaloosa formation consists of weathered sandy beds overlying bluish-gray clay. To the southeast, beneath the Black Creek formation, the beds consist of alternating strata of clay and sand.

Ground water.—Three municipal and all domestic water supplies in Scotland County are obtained from wells. In addition, Laurinburg has one standby well to supplement its surface-water system.

Most wells are dug or driven, but many are drilled or bored. Springs discharge in the hilly areas and flowing wells are common.

The Cretaceous sand aquifer yields large quantities of water to wells in the southeast half of the county. In this area, a screened well probably would yield 1 gpm per foot of depth and a gravel-walled well more than twice that quantity. One gravel-walled well (No. 30) yields more than 5 gpm per foot of depth.

To the northwest, where the county is underlain by the Cretaceous clay aquifer, yields are much less. Screened wells in this part of Scotland County do not yield more than 25 gpm.

The surficial sand aquifer yields sufficient quantities of water to wells for domestic supply during most of the year, but shallow wells in this aquifer commonly go dry during prolonged drought.

Future development of large ground-water supplies is possible only in that part of the county underlain by the Cretaceous sand aquifer. (See fig. 10.)

Ground water in Scotland County generally is rather acidic and very soft. At some places the iron content is sufficiently high to be objectionable. The corrosion of iron pipes is a problem, but the water otherwise is suitable for all purposes.

Municipal supply systems (1959).—Gibson has one well (No. 31) to supply the average daily consumption of 30,000 gallons. The water is treated.

Laurel Hill has one well (No. 12) to supply an average daily consumption of 20,000 gallons. The water is treated.

Laurinburg has one well (No. 18) to supplement its surface-water supply obtained from Jordan Creek. The capacity of Laurinburg's treatment plant is 1,000,000 gpd.

Wagram has two wells (Nos. 5, 6) to supply the average daily consumption of 15,000 gallons. The water is not treated.

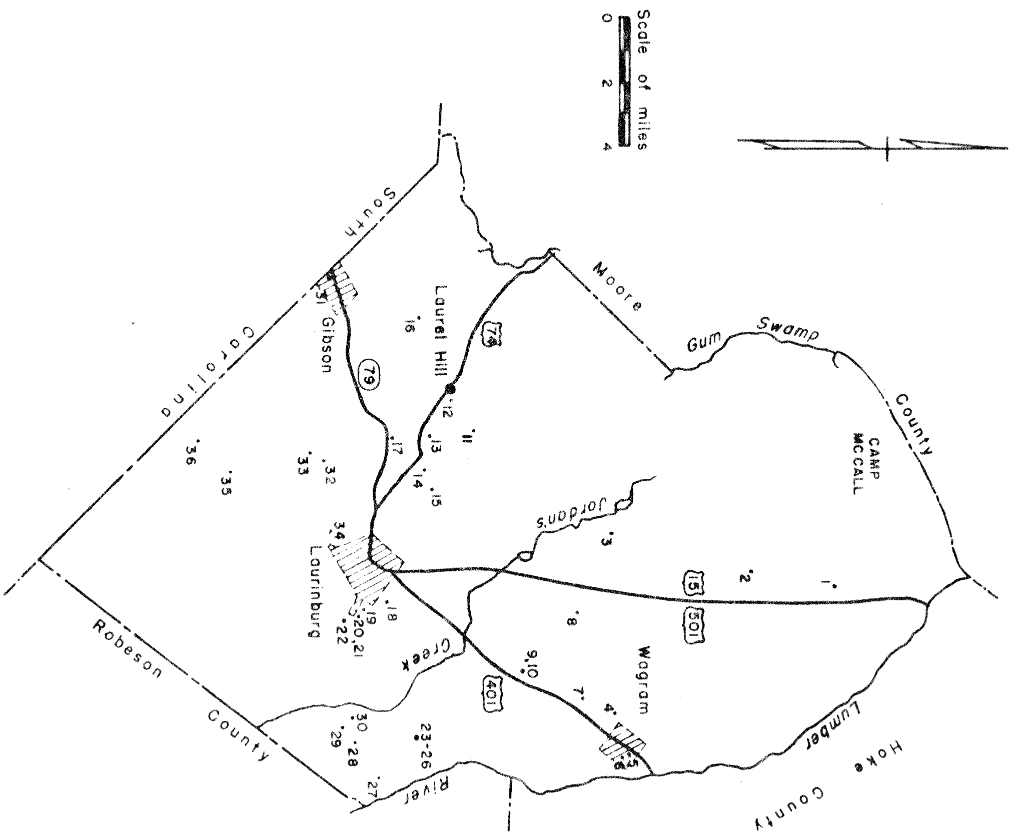

Figure 19. Map of Scotland County showing location of wells

Table 18. Records of Wells in Scotland County

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
1	8 miles NW of Wagram	W. L. Dawson	Screen	76	4	74	Cretaceous clay	10	
2	7 miles NW of Wagram	John F. McNair, Inc.	do	58	6	51	do	35	
3	7 miles W. of Wagram	W. M. Monroe	do	80	4	78	do	10	
4	Wagram	Jim Cooley	do	95	4	91	do	15	
5	do	Town of Wagram	do	50	6	50	do	75	Analysis.
6	do	do	do	50	6		do	30	do
7	2 miles SW of Wagram	Scotland County Prison Camp	do	80	6	68	do	25	do
8	4 miles SW of Wagram	E. L. McNair Estate	do	86	4	84	do	10	
9	4 miles SW of Wagram	J. L. McNair	do	30	6	20	Surficial sand	100	Drawdown 17 feet, water level 3 feet.
10	do	do	do	150	6	140	Cretaceous sand	25	
11	5 miles NW of Laurinburg	Morgan Mills		105	8		do	180	Flows 30 gpm.
12	do	Town of Laurel Hill	Screen	166	8	159	do	150	
13	4 miles NW of Laurinburg	Morgan Mills	do	72	4	70	do	35	Drawdown 10 feet.
14	3 miles NW of Laurinburg	McNair Farms	do	93	4	77	do	15	
15	do	John F. McNair, Inc.	do	31	4	29	Surficial sand	5	
16	2 miles N of Gibson	J. W. McNeill	do	82	4	77	Cretaceous sand	12	
17	4 miles W of Laurinburg	Morgan Mills	do	325	8	288	do	400	
18	1 mile NE of Laurinburg	Town of Laurinburg	Gravel-walled	390	8		do	600	Analysis.
19	1 mile E of Laurinburg	Willie Evans	Screen	75	4	71	do	10	
20	2 miles E of Laurinburg	Morgan Mills	Screen	100	6	92	Cretaceous sand	40	
21	do	do	do	137	8	127	do	65	

Table 18. Records of Wells in Scotland County—Continued

Well no.	Location	Owner	Type of well	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Chief Aquifer	Yield (gpm)	Remarks
22	2 miles SE of Laurinburg	Laurinburg Plywood Corp.		40	2		do	25	3 wells; water level +2 feet, flows 10 gpm.
23	8 miles NE of Laurinburg	Laurinburg-Maxton Air Base	Gravel-walled	346	8	346	do	1000	Drawdown 46 feet, water level 7 feet.
24	do	do	Screen	123	8	91.5	do	250	Drawdown 55.5 feet.
25	do	do	do	193	8	173	do	75	Drawdown 116.5 feet, water level 21 feet.
26	do	do	do	152	8	115	do	200	Drawdown 67 feet.
27	do	do	do	230	8	198	do		Not used.
28	do	do	do	165	8	156	do	300	Drawdown 48 feet, water level 29.7 feet. Analysis.
29	do	do	do	140	8	105	do	500	Water level 22 feet; present supply.
30	do	do	Gravel-walled	167	8	163	do	900	Drawdown 27 feet, water level 6 feet; reserve supply.
31	Gibson	Town of Gibson	do	123	8		Cretaceous clay	150	Analysis.
32	3 miles SW of Laurinburg	H. E. Myers	Screen	68	4	64	Cretaceous sand	18	
33	do	Frank Perkins	do	77	4	69	do	10	
34	1 mile SW of Laurinburg	Bill Adams	Open-end	114	6	90	do	25	
35	5 miles SW of Laurinburg	H. B. Revels	do	74	4	74	do	15	
36	6 miles SW of Laurinburg	John K. Bostick	Screen	60	4	58	do	10	

Table 19. Chemical Analyses of Ground Water from Scotland County

(Numbers at heads of columns correspond to well numbers in table of well data)

(Parts per million)

	5	6	7	18	28	31
Silica (SiO_2)	3.2	4.7	9.2	8.7	9.4	4.7
Iron (Fe), total	2.4	1.7	.20	.27	.40	.28
Iron (Fe) in solution			.04	.04	.13	
Calcium (Ca)	2.6	3.0	.9	1.3	1.0	1.4
Magnesium (Mg)	1.9	2.1	.3	.5	.5	1.2
Sodium and potassium (Na + K)	11	12	2.2	2.6	3.0	15
Bicarbonate (HCO_3)	1.0	1.0	4	1	1	2.0
Sulfate (SO_4)	.5	.6	2.0	6.4	5.6	5.1
Chloride (Cl)	10	12	1.9	2.2	3.1	15
Fluoride (F)	.0	.0	.0	.0	.0	.5
Nitrate (NO_3)	20	31	.3	.1	.0	15
Dissolved solids	59	73	21	27	24	61
Hardness as $CaCO_3$	14	16	4	5		8
pH	4.7	4.7	5.3	4.8	54.7	4.8
Chief Aquifer	Cretaceous clay	Cretaceous clay	Cretaceous clay	Cretaceous sand	Cretaceous sand	Cretaceous clay
Date of collection	Dec. 1948	Dec. 1948	Nov. 1950	June 1953	Mar. 1950	May 1947

Analyzed by the Quality of Water Branch, U. S. Geological Survey

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