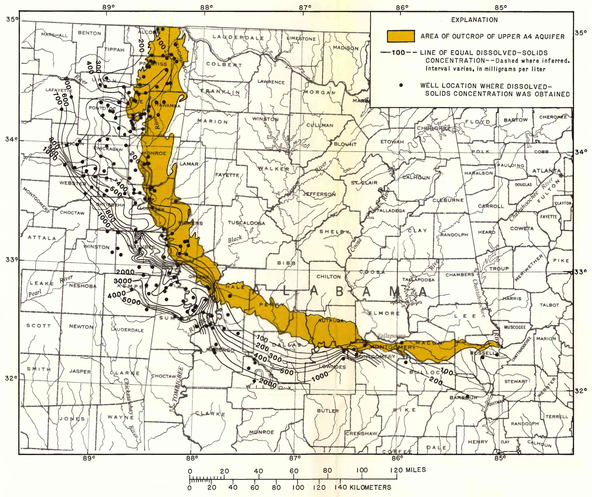
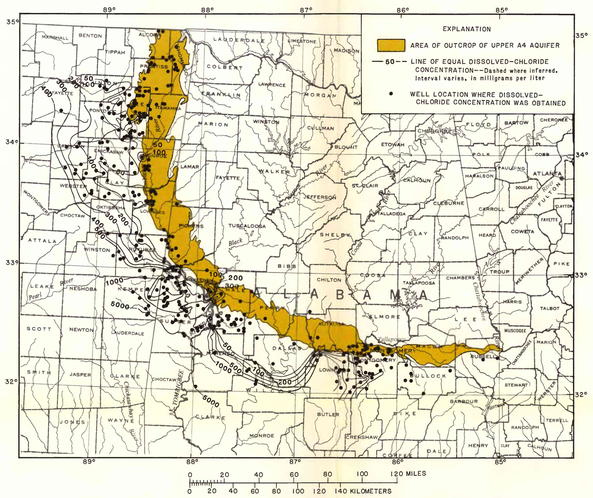
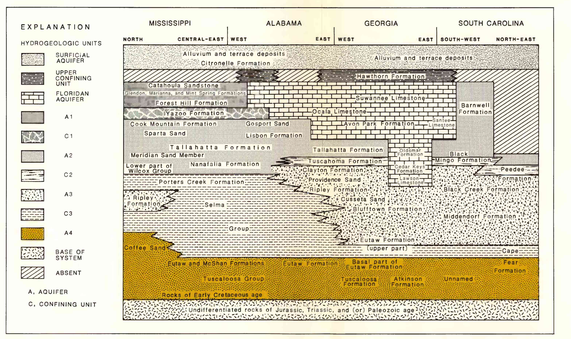


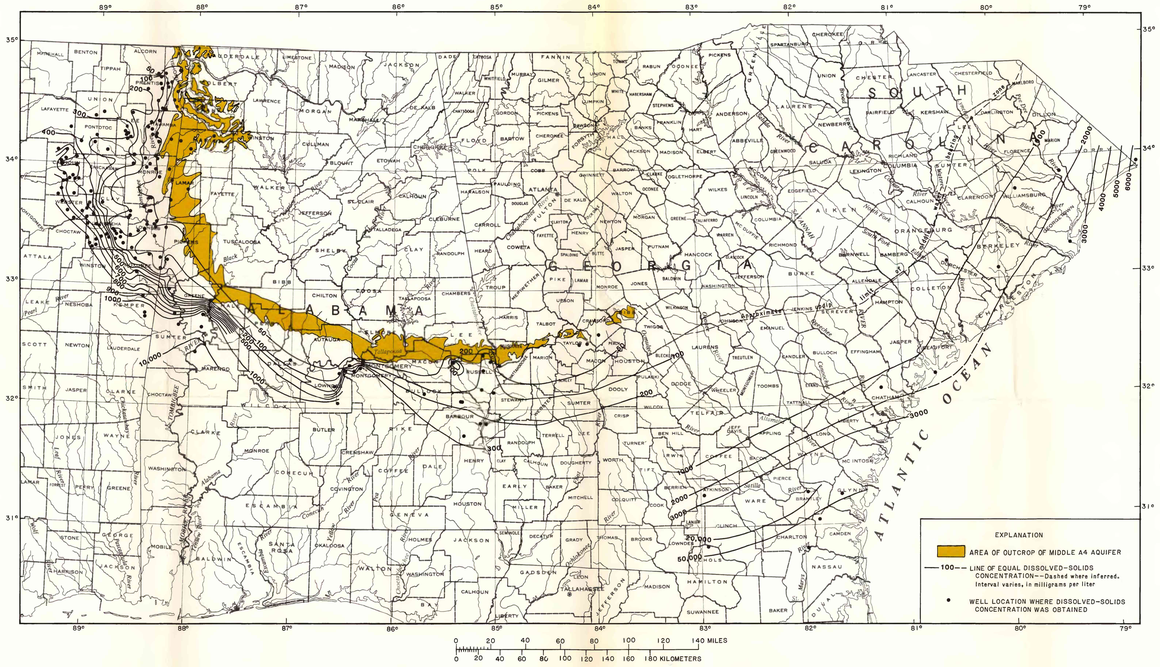
Dissolved solids in the upper water-bearing zone.



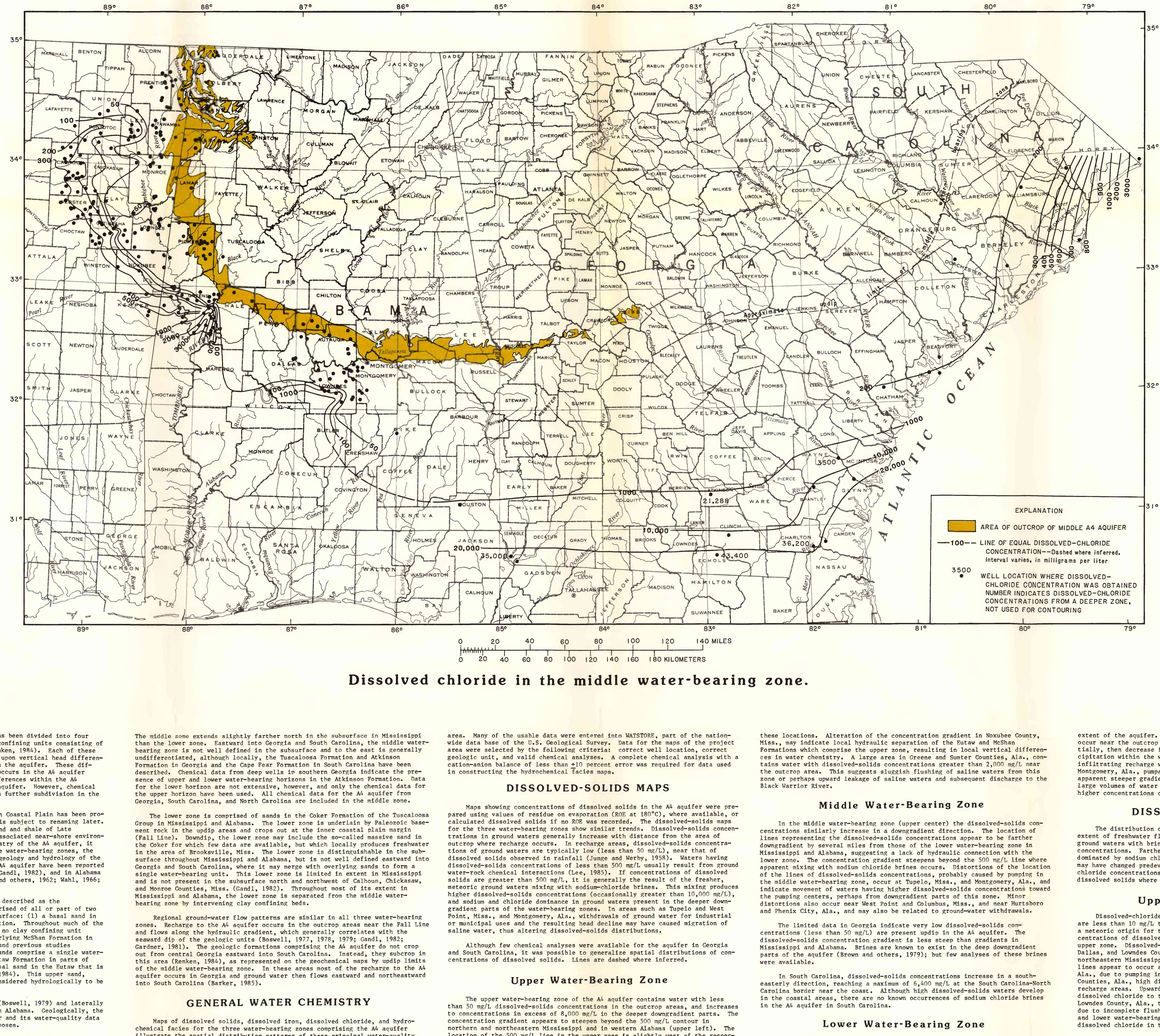
Dissolved chloride in the upper water-bearing zone.



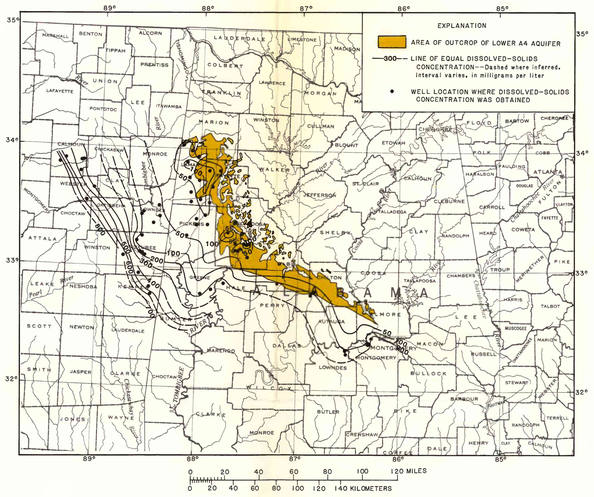
Schematic diagram of regional hydrogeologic units and selected rock-stratigraphic units in the Southeastern U.S.Coastal Plain. (After Renken, 1984)



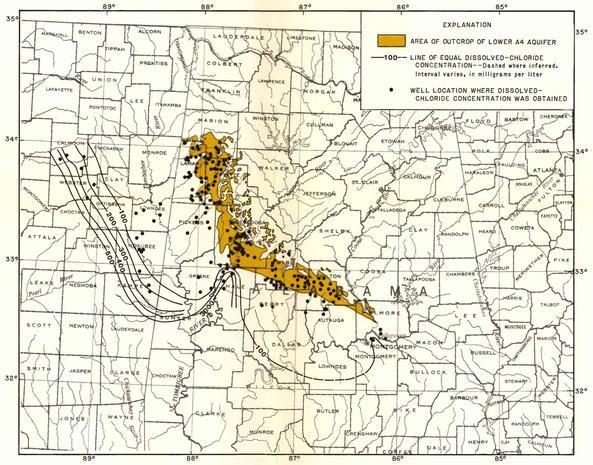
Dissolved solids in the middle water-bearing zone.



Dissolved chloride in the middle water-bearing zone.



Dissolved solids in the lower water-bearing zone.



Dissolved chloride in the lower water-bearing zone.

INTRODUCTION

This report shows spatial variations of water chemistry in water-bearing zones of regional extent in the Southeastern Coastal Plain of Mississippi, Alabama, Georgia, Southeastern Carolina, and North Carolina. The water-bearing zone discussed comprises a major hydrogeologic unit (An aquifer) of an extensive sand aquifer system characterized by regional ground-water flow in the Southeastern Coastal Plain (Barker, 1985). Chemical data utilized in this study were obtained from the U.S. Geological Survey WATSTORE data base. The report is one of a series of preliminary products depicting the hydrogeology and water chemistry of the sand aquifers that comprise the Southeastern Coastal Plain-Regional Aquifer System. This system is being studied as part of the U.S. Geological Survey's Regional Aquifer-System Analysis (RASA) program.

This report consists of maps depicting distributions of dissolved solids, dissolved iron, dissolved chloride, and hydrochemical facies (Back, 1966) for three subdivided water-bearing zones in the A4 aquifer: (1) a lower zone consisting mostly of sands in the Coker Formation, (2) a middle zone consisting mostly of sands in the Gordo Formation and (3) an upper zone consisting mostly of sands in the Eutaw and McShan Formations. Several hundred partial and complete chemical analyses were selected for mapping from WATSTORE by geologic unit corresponding to the A4 aquifer. An abundance of data was available in Mississippi and Alabama; however, few chemical analyses were available in Georgia, South Carolina, and adjacent areas in North Carolina. The nomenclature of the A4 aquifer is provisional and should be interchanged with more appropriate regional aquifer names for the Southeastern Coastal Plain when more conventional names have been selected. A regional aquifer framework has been developed by Renken (1984; lower left) which correlates the regional aquifers and confining beds with geologic units in each state within the study area.

HYDROLOGY

The hydrogeology of the South Atlantic-Gulf region has been generally described by Cederstrom and others (1979). More detailed descriptions of the geology and hydrology of the Southeastern Coastal Plain may be found in county or multiple county reports in each state. An objective of the SCP-RASA project is to delineate the geometry and character of sand and clay beds that comprise major aquifers and confining beds of the Southeastern Coastal Plain (Renken, 1984). The hydrogeologic framework will provide the basis for more detailed studies of the regional ground-water flow and lead to digital simulations of ground-water flow in the Southeastern Coastal Plain.

The Southeastern Coastal Plain aquifer system has been divided into four regionally extensive aquifers that are separated by confining units consisting of clay, chalk, or other low-permeability materials (Renken, 1984). Each of these regional aquifer can be subdivided into zones based upon vertical head differences or vertical differences of water chemistry within the aquifer. These differences in head and chemistry may be small, or, as occurs in the A4 aquifer described herein, they may be significant. Head differences within the A4 aquifer permit separation into an upper and a lower aquifer. However, chemical differences in the waters in the A4 aquifer suggest a further subdivision in the western part of the study area.

The basal hydrogeologic unit in the southeastern Coastal Plain has been provisionally named the A4 aquifer (Renken, 1984), and is subject to renaming later. This regionally extensive aquifer is comprised of sand and shale of late Cretaceous age which were deposited in deltaic and associated near-shore environments. To understand better the complex water chemistry of the A4 aquifer, it has been further subdivided in this report into three water-bearing zones, the upper, middle, and lower zones. In Mississippi the geology and hydrology of the upper, middle, and lower water-bearing zones of the A4 aquifer have been reported statewide (Boswell, 1977, 1978, 1979; Wasson, 1980; Gandl, 1982), and in Alabama in various county reports (Carlston, 1942; Paulson and others, 1962; Wahl, 1966; Gardner, 1981).

The upper water-bearing zone of the A4 aquifer, described as the Eutaw-McShan aquifer system (Boswell, 1977), is comprised of all or part of two geologic formations recognizable in outcrop and subsurface: (1) a basal sand in the Eutaw Formation and (2) sand of the McShan Formation. Throughout much of the project area where these geologic units are present, no clay confining unit separates the overlying Eutaw Formation and the underlying McShan Formation in the subsurface or outcrop. This strongly suggests, and previous studies (Boswell, 1977, Gardner, 1981) indicate that these sands comprise a single water-bearing zone. A sand present near the top of the Eutaw Formation in parts of Georgia is separated by interwoving clay from the basal sand in the Eutaw that is hydrologically connected to the A4 aquifer (Renken, 1984). This upper sand, although it occurs in the Eutaw Formation, is not considered hydrologically to be part of the A4 aquifer.

The Coffee Sand occurs in northern Mississippi (Boswell, 1979) and laterally grades into the Demopolis Chalk of the Selma Group in Alabama. Geologically, the Coffee Sand overlies the upper zone in the A4 aquifer and its water-quality data have been placed with the upper zone for mapping purposes.

The middle water-bearing zone consists of sands of the Gordo Formation, which comprises the upper formation of the Tuscaloosa Group and is distinguishable in the subsurface in Mississippi and Alabama (Boswell, 1978). The middle zone extends slightly farther north in the subsurface in Mississippi than the lower zone. Eastward into Georgia and South Carolina, the middle water-bearing zone is not well defined in the subsurface and to the east is generally undifferentiated, although locally, the Tuscaloosa Formation and Atkinson Formation in Georgia and the Cape Fear Formation in South Carolina have been described. Chemical data from deep wells in southern Georgia indicate the presence of upper and lower water-bearing horizons in the Atkinson Formation. Data for the lower horizon are not extensive, however, and only the chemical data for the upper horizon have been used. All chemical data for the A4 aquifer from Georgia, South Carolina, and North Carolina are included in the middle zone.

The lower zone is comprised of sands in the Coker Formation of the Tuscaloosa Group in Mississippi and Alabama. The lower zone is underlain by Paleozoic basement rock in the updip areas and crops out at the lower coastal plain margin (Fall line). Downdip, the lower zone may include the so-called massive sand in the Coker for which few data are available, but which locally produces freshwater in the area of Brooksville, Miss. The lower zone is distinguishable in the subsurface throughout Mississippi and Alabama, but is not well defined eastward into Georgia and South Carolina, where it may merge with overlying sands to form a single water-bearing unit. This lower zone is limited in extent in Mississippi and is not present in the subsurface north and northwest of Calhoun, Chickasaw, and Monroe Counties, Miss. (Gandl, 1982). Throughout most of its extent in Mississippi and Alabama, the lower zone is separated from the middle water-bearing zone by intervening clay confining beds.

Regional ground-water flow patterns are similar in all three water-bearing zones. Recharge to the A4 aquifer occurs in the outcrop areas near the Fall line and flows along the hydraulic gradient, which generally correlates with the seaward dip of the geologic units (Boswell, 1977, 1978, 1979; Gandl, 1982; Gardner, 1981). The geologic formations comprising the A4 aquifer do not crop out from central Georgia eastward into South Carolina. Instead, they subcrop in this area (Renken, 1984), as represented on the geochemical maps by updip limits of the middle water-bearing zone. In these areas most of the recharge to the A4 aquifer occurs in Georgia and ground water then flows eastward and northeastward into South Carolina (Barker, 1985).

GENERAL WATER CHEMISTRY

Maps of dissolved solids, dissolved iron, dissolved chloride, and hydrochemical facies for the three water-bearing zones overlying the A4 aquifer illustrate the spatial distribution patterns of these principal water-quality parameters in the Southeastern Coastal Plain. Chemical data used for the maps were collected by State and Federal agencies during the last half century and have been published in county or state reports in each state within the project area. Many of the usable data were entered into WATSTORE, part of the nationwide data base of the U.S. Geological Survey. Data for the area of the project area were selected by the following criteria: correct well location, correct geologic unit, and adequate chemical analyses. A complete chemical analysis with a cation-anion balance of less than ±10 percent error was required for data used in constructing the hydrochemical facies maps.

DISSOLVED-SOLIDS MAPS

Maps showing concentrations of dissolved solids in the A4 aquifer were prepared using values of residue on evaporation (ROE at 180°C), where available, or calculated dissolved solids if no ROE was recorded. The dissolved-solids maps for the three water-bearing zones show similar trends. Dissolved-solids concentrations in ground waters generally increase with distance from the area of outcrop where recharge occurs. In recharge areas, dissolved-solids concentrations of ground waters are typically low (less than 50 mg/L), near that of dissolved solids observed in rainfall (Junge and Werby, 1958). Waters having dissolved-solids concentrations of less than 500 mg/L usually result from ground water-rock chemical interactions (Lee, 1985). If concentrations of dissolved solids are greater than 500 mg/L, it is generally the result of the fresher, meteoric ground waters mixing with sodium-chloride brines. This mixing produces higher dissolved-solids concentrations (occasionally greater than 10,000 mg/L), and sodium and chloride dominance in ground waters present in the deeper downgradient parts of the water-bearing zones. In areas such as Tupelo and West Point, Miss., and Selma, Ala., withdrawals of ground water for industrial or municipal uses and the resulting head decline may have caused migration of saline water, thus altering dissolved-solids distributions.

Although few chemical analyses were available for the aquifer in Georgia and South Carolina, it was possible to generalize spatial distributions of concentrations of dissolved solids. Lines are dashed where inferred.

Upper Water-Bearing Zone

The upper water-bearing zone of the A4 aquifer contains water with less than 50 mg/L dissolved-solids concentrations in the outcrop areas, and increases to concentrations in excess of 8,000 mg/L in the deeper downgradient parts. The concentration gradient appears to steepen beyond the 500 mg/L contour in northern and northeastern Mississippi and in western Alabama (upper left). The location of the 500 mg/L line in the upper zone is slightly west of the respective 500 mg/L lines of the lower and middle water-bearing zones. Some alteration of the concentration gradient is observed at Tupelo, Miss., and Montgomery, Ala., probably due to large ground water withdrawals from the upper zone at these locations. Alteration of the concentration gradient in Noxubee County, Miss., may indicate local hydraulic separation of the Eutaw and McShan Formations which comprise the upper zone, resulting in local vertical differences in water chemistry. A large area in Greene and Sumter Counties, Ala., contains water with dissolved-solids concentrations greater than 2,000 mg/L near the outcrop area. This suggests sluggish flushing of saline waters from this zone or perhaps upward leakage of saline waters and subsequent discharge to the Black Warrior River.

Middle Water-Bearing Zone

In the middle water-bearing zone (upper center) the dissolved-solids concentrations similarly increase in a downgradient direction. The location of lines representing the dissolved-solids concentrations appear to be farther downgradient by several miles from those of the lower water-bearing zone in Mississippi and Alabama, suggesting a lack of hydraulic connection with the lower zone. The concentration gradient steepens beyond the 500 mg/L line where apparent mixing with sodium chloride brines occurs. Distortions of the location of the lines of dissolved-solids concentrations, probably caused by pumping in the middle water-bearing zone, occur at Tupelo, Miss., and Montgomery, Ala., and indicate movement of waters having higher dissolved-solids concentrations toward the pumping centers, perhaps from downradient parts of this zone. Minor distortions also occur near West Point and Columbus, Miss., and near Hurtsboro and Peerly City, Ala., and may also be related to ground-water withdrawals.

The limited data in Georgia indicate very low dissolved-solids concentrations (less than 50 mg/L) are present updip in the A4 aquifer. The dissolved-solids concentration gradient is less steep than gradients in Mississippi and Alabama. Brines are known to exist in the deep downgradient parts of the aquifer (Brown and others, 1979); but few analyses of these brines were available.

In South Carolina, dissolved-solids concentrations increase in a southeasterly direction, reaching a maximum of 6,400 mg/L at the South Carolina-North Carolina border near the coast. Although high dissolved-solids waters develop in the coastal areas, there are no known occurrences of sodium chloride brines in the A4 aquifer in South Carolina.

Lower Water-Bearing Zone

In the lower water-bearing zone of the A4 aquifer (upper right) data extend from east of Montgomery, Ala., westward into north-central Mississippi. No chemical data were available in a four-county area of Mississippi near the northern extent of the aquifer. Two large areas of closed lines of equal concentrations occur near the outcrop area, indicating that the dissolved solids increase initially, then decrease farther downgradient, either as a result of chemical precipitation within the water-rock system (Lee, 1984b), or by mixing with infiltrating recharge waters containing lower dissolved solids. Near Montgomery, Ala., pumpage from the lower water-bearing zone may have caused an apparent steeper gradient, although data are sparse. The continuous removal of large volumes of water in this area has likely caused ground water containing higher concentrations of dissolved solids to move toward this pumping center.

DISSOLVED CHLORIDE MAPS

The distribution of chloride in the three water-bearing zones shows the extent of freshwater flushing of brines or relict seawater. Mixing of meteoric ground waters with brines is indicated by the pronounced increase in chloride concentrations. Farther downgradient, beyond the mixing zone, the aquifer is dominated by sodium chloride brines. Pumping centers in the freshwater areas may have changed predevelopment chloride distributions. Maps of dissolved-chloride concentrations should show similar trends to concentrations of dissolved solids where dissolved solids exceed 500 mg/L.

Upper Water-Bearing Zone

Dissolved-chloride concentrations in waters of the upper zone (center left) are less than 10 mg/L throughout most of the outcrop-recharge areas, indicating a meteoric origin for these ground waters. Significant increases in concentrations of dissolved chloride occur in the downgradient parts of the upper zone. Dissolved-chloride gradients increase sharply in Greene, Marengo, Dallas, and Lowndes Counties, Ala., but these gradients are less steep toward northeastern Mississippi. Alterations of the dissolved-chloride concentrations lines appear to occur at Tupelo and West Point, Miss., and west of Montgomery, Ala., due to pumping in the upper water-bearing zone. In Greene and Sumter Counties, Ala., high dissolved-chloride concentrations occur near the unconfined recharge areas. Upward discharge of deep water having high concentrations of dissolved chloride to the Black Warrior River could be the cause. In northern Lowndes County, Ala., the increased dissolved-chloride concentrations are likely due to incomplete flushing of saline waters in the upper zone because the middle and lower water-bearing zones produce waters containing low concentrations of dissolved chloride in this area.

Middle Water-Bearing Zone

The distribution of dissolved chloride in the middle zone (lower center) is similar to the upper zone. The chloride concentration gradient appears to steepen in Mississippi and Alabama where concentrations are greater than 50 mg/L; whereas most of the upgradient ground waters contain less than 5 mg/L dissolved chloride. Ground-water withdrawals at Tupelo and West Point, Miss., cause some movement of waters containing relatively high concentrations of dissolved chloride toward the pumping centers. Dissolved-chloride concentrations in excess of 3,000 mg/L were observed in Greene, Hale, and Lowndes Counties, Ala. This is an area of high salinity, and as in the upper zone, may be the result of hydraulic properties such as low transmissivity or upward leakage of saline water to the Black Warrior River.

In Georgia, few data were available to describe chloride distribution in the freshwater part of the A4 aquifer. Available data in WATSTORE were from the western part of the state and all showed concentrations less than 10 mg/L. Several water analyses from drill-eten tests of water-bearing zones of the A4 aquifer in southern Georgia indicate that at least two horizons contain sodium chloride brines (Brown and others, 1979). Lines of equal concentrations of dissolved chloride were drawn on the basis of data obtained from the upper part of the A4 aquifer in Georgia. Chloride data obtained for the lower part were not used in contouring. In South Carolina dissolved chloride in the A4 aquifer increases from Parris Island, S.C., to Calabash, N.C. Dissolved chloride concentrations also increase from the outcrop area and seaward along the southern flank of the Cape Fear arch.

Lower Water-Bearing Zone

The lower water-bearing zone (lower right) contains water with dissolved-chloride concentrations of less than 10 mg/L in the outcrop-recharge areas. Chloride concentrations increase downgradient from the recharge areas with steeper concentration gradients beyond 100 mg/L. Upward discharge of saline waters from deeper zones, or incomplete flushing of brines may be the cause of high dissolved-chloride concentrations observed in wells in Montgomery, Ala., and in Hale County, Ala. Dissolved-chloride concentrations from the lower water-bearing zone in Greene County, Ala., are much less than waters from the middle and upper water-bearing zones indicating that incomplete flushing of seawater in the upper zones is the more likely source of saline water instead of upward leakage from the lower water-bearing zone. More data from the lower zones in this area are needed to characterize the saline water distribution.

WATER-QUALITY MAPS FOR SELECTED UPPER CRETACEOUS WATER-BEARING ZONES IN THE SOUTHEASTERN COASTAL PLAIN

By
Roger W. Lee
1985