# HYDROGEOLOGIC CHARACTERIZATION AND GROUNDWATER SOURCE DEVELOPMENT ASSESSMENT FOR THE SOUTH BULLOCK COUNTY WATER AUTHORITY

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# HYDROGEOLOGIC CHARACTERIZATION AND GROUNDWATER SOURCE DEVELOPMENT ASSESSMENT FOR THE SOUTH BULLOCK COUNTY WATER AUTHORITY

**OPEN-FILE REPORT 1309**

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Tuscaloosa, Alabama
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## INTRODUCTION

All public-water supplies in Bullock County are produced from groundwater sources. Due to increasing population in the northwest part of the county and concerns about the long-term viability of current water sources operated by South Bullock County Water Authority (SBCWA), the Geological Survey of Alabama (GSA) initiated the Groundwater Hydrogeologic Characterization and Source Development Project in July 2009. The study was a cooperative effort between SBCWA and the GSA.

The purpose of the project was to generate data that can be used by SBCWA to develop new groundwater sources and by GSA to better understand the hydrogeology of Bullock County and Southeast Alabama. Data from oil and gas and water wells provide opportunities to see into the subsurface to evaluate groundwater quantity and quality characteristics that can be used to develop and protect groundwater sources. Data from 6 oil and gas test wells and 123 water wells were evaluated during this investigation (plate 1). Hydrogeologic, geochemical, and land-use data were used to evaluate groundwater recharge, movement, aquifer storage, and the potential for developing additional groundwater sources from Cretaceous aquifers in the SBCWA service area.

## ACKNOWLEDGMENTS

The Geological Survey of Alabama acknowledges those individuals whose participation and cooperation made this study possible. Dixie Electric Cooperative Special Projects Manager Mr. Brent Moffett, SBCWA Manager, Mr. Randolph Hall, and Union Springs Utilities Board Superintendent, Mr. Eddie Davis, were instrumental in providing assistance for the completion of this research.

## PHYSIOGRAPHY AND TOPOGRAPHY

The area of investigation covers about 3,000 square miles ($mi^2$) in southeast and east-central Alabama, including the SBCWA service area (619 $mi^2$) that covers all of Bullock County excluding the city of Union Springs, which is served by the Union Springs Utilities Board (fig. 1). The investigation area lies in the East Gulf Coastal Plain physiographic section. The northern


Figure 1.—Bullock County project area.

part of the SBCWA service area lies in the Black Prairie physiographic district, characterized as an undulating, deeply weathered plain developed mainly on chalk and marl. The southern part of the service area is in the Chunnenuggee Hills physiographic district, characterized by a pine forested series of sand hills and cuestas developed on clay, siltstone, and sandstone (Sapp and Emplaincourt, 1975). Regional geology is dominated by Cretaceous stratigraphy common to the northern part of the East Gulf Coastal Plain physiographic section (fig. 2). Topography in the service area is dominated by an escarpment at the contact between the Blufftown Formation and more resistant clastic sediments of the Cusseta Member of the Ripley Formation. This escarpment has about 100 feet (ft) of relief and extends from just southwest of Union Springs in north-central Bullock County eastward for about 16 miles (mi). This topographic feature forms a surface-water drainage boundary where streams north of the escarpment flow northwestward to the Tallapoosa River and streams south of the escarpment flow southwestward to the Conecuh River or southeastward to the Chattahoochee River.

## GEOLOGY

The geology of the area of investigation is composed of about 2,500 ft of sediments of Cretaceous age, originating from environments of deposition that include marine, marginal marine, and fluvial (fig. 3). Cook (1993) described environments of deposition for Cretaceous formations in eastern Alabama with respect to global sea level change. Cretaceous sediments were deposited in alternating regressive and transgressive sequences of relatively deep marine shelf, marginal marine barrier, lagoonal back barrier, and terrestrial fluvial environments (fig. 4). Cretaceous sediments are underlain by crystalline rocks associated with the Alabama Piedmont province that outcrop about 25 miles north of the study area (fig. 5).

### CRYSTALLINE ROCKS

The Alabama Piedmont contains the southernmost exposed metamorphic and igneous rocks of the Appalachians. These rocks have been variously divided, on the basis of lithology, structures, and metamorphic grade, into fault-bounded lithotectonic belts with northeastern regional trends (Adams and others, 1933; Neathery and others, 1976). Subsurface extensions of these belts underlie Coastal Plain sediments in Alabama and have been penetrated by numerous water and oil and gas exploratory wells. The SBCWA Peachburg well in northeastern Bullock County and the Scientific Resources Schuessler 18-7 well (Alabama Oil and Gas Board permit number 4903) in southwestern Bullock County encountered crystalline rock at depths of 2,020 ft,

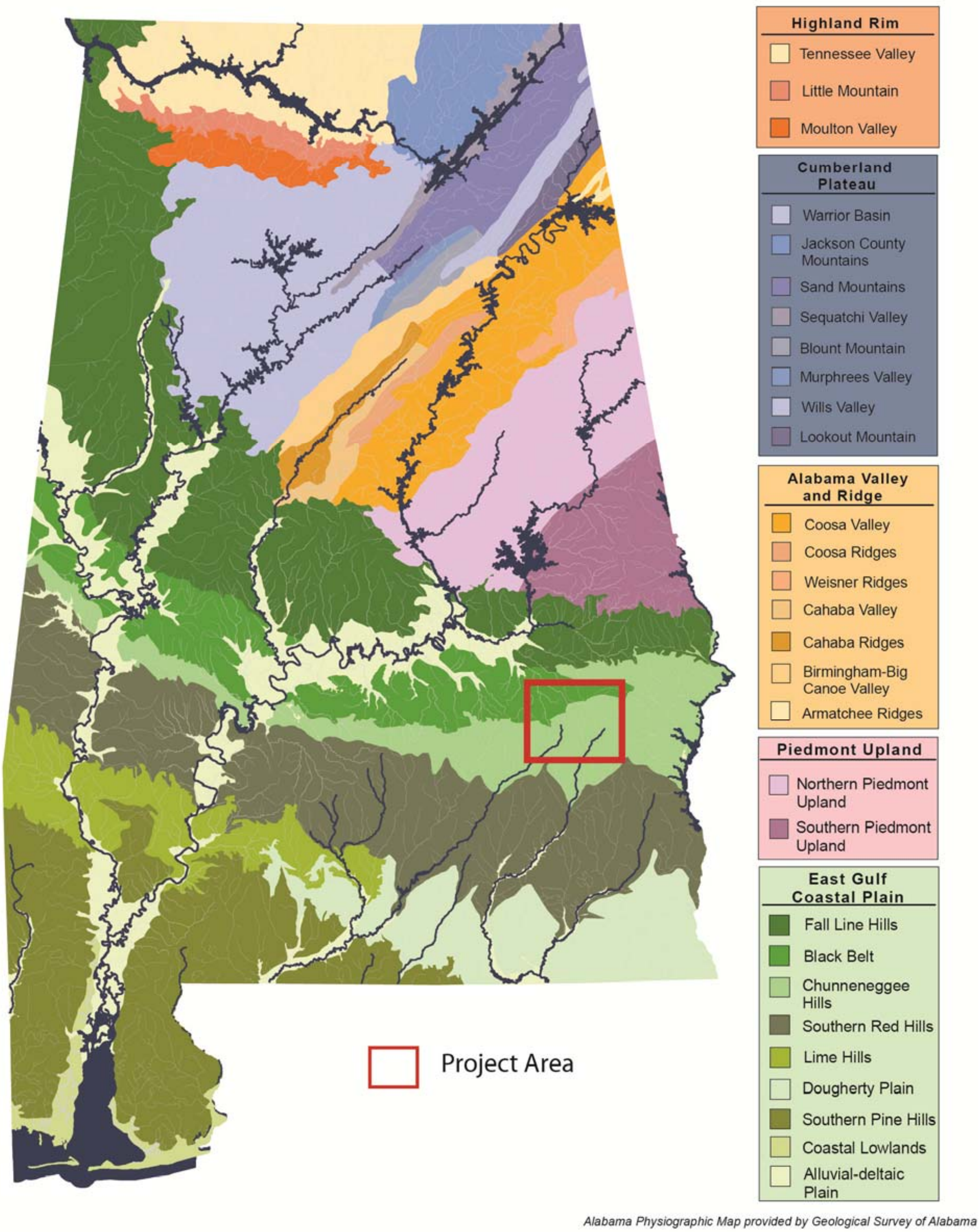


Figure 2.--Physiographic regions in Alabama.

| System | Series | Group | Geologic Unit | Thickness (ft) |
|---|---|---|---|---|
| Cretaceous | Upper Cretaceous | Selma | Providence Formation | outcrop |
| | | | upper Ripley Formation | 135 |
| | | | Cusseta Sand Member of the Ripley Formation | 50-150 |
| | | | Blufftown Formation | 300-550 |
| | | Tuscaloosa | Eutaw Formation | 225-250 |
| | | | Gordo Formation | 475-500 |
| | | | middle marine shale | 50-100 |
| | | | Coker Formation | 220-250 |
| | Lower Cretaceous | | Lower Cretaceous undifferentiated | 425-650 |

Figure 3.—Stratigraphic column for Bullock County.

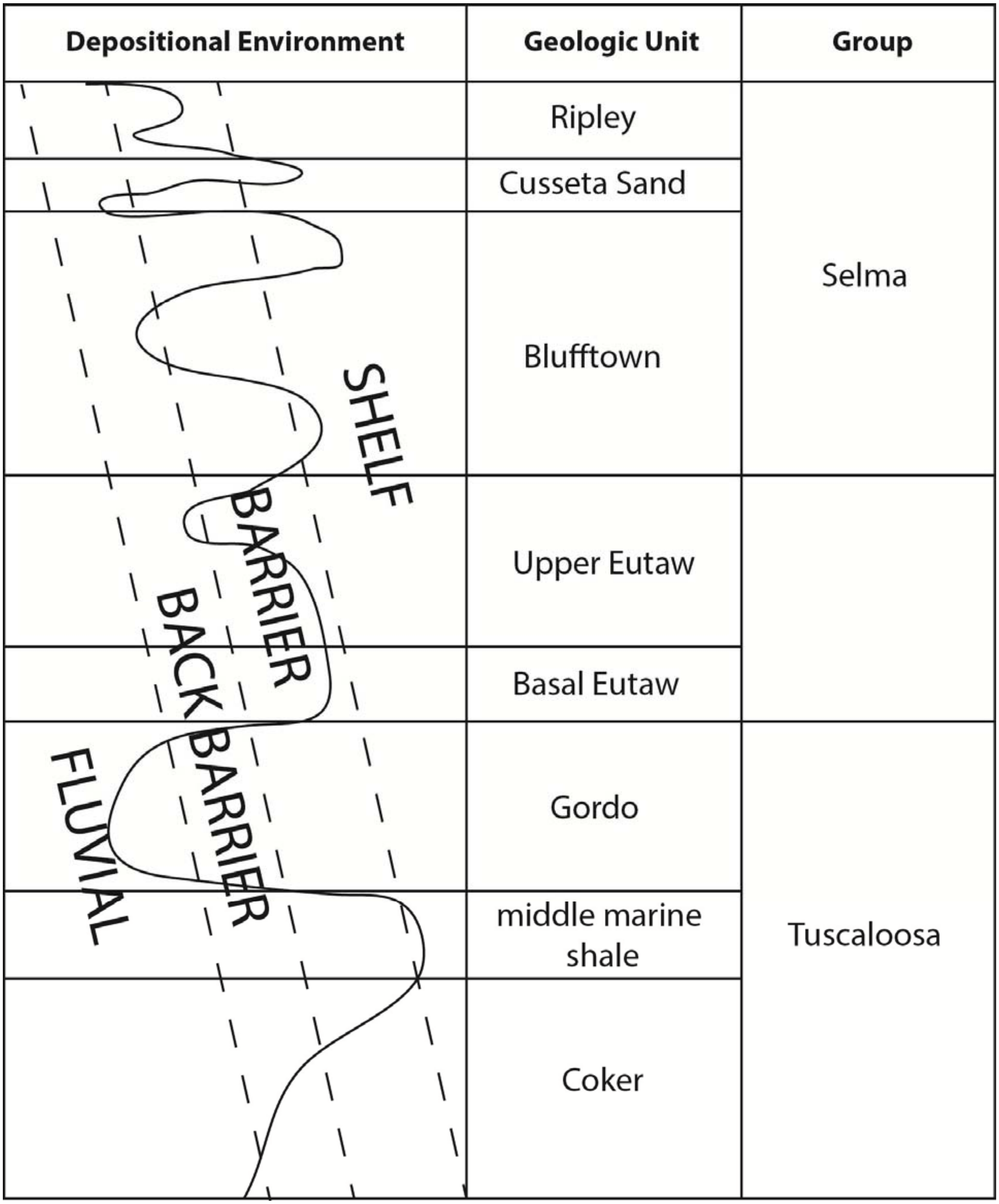


Figure 4.—Environments of deposition for Cretaceous age sediments in eastern Alabama (modified from Cook, 1993a).

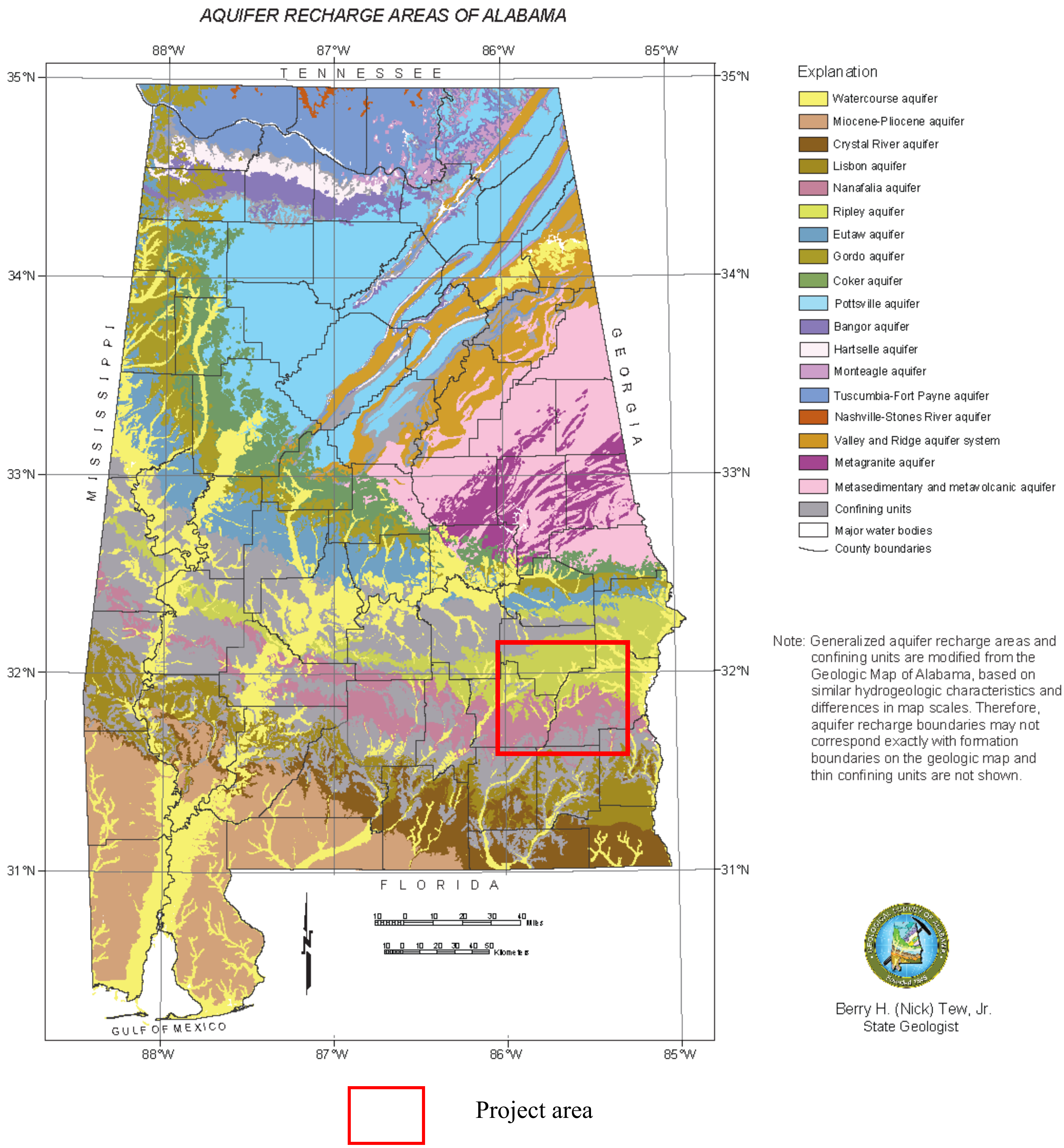


Figure 5.—Generalized geology and aquifer recharge areas in Alabama.

and 2,677 ft, respectively. Although variable amounts of fresh water are produced from fractured rocks in the Piedmont province, no economic quantities of water have been found in these rocks underlying Coastal Plain sediments. Therefore, crystalline rock formations are not viable targets for test wells in the SBCWA service area.

## LOWER CRETACEOUS UNDIFFERENTIATED

Lower Cretaceous sediments overlie metamorphic and igneous crystalline rocks in the Bullock County area. Pink nodular limestone fragments and red and green clay near the top of the unit distinguish it from the massive sands of the overlying Late Cretaceous Coker Formation of the Tuscaloosa Group (USGS, 1987). The total thickness of Lower Cretaceous sediments is known to reach more than 7,000 ft in Mobile Bay (Maher and Applin, 1968). Sediments of Early Cretaceous age do not crop out in Alabama, but thin northward and pinch out in the subsurface south of the Fall Line. The thickness of Lower Cretaceous sediments was documented in southwestern Bullock County in the Scientific Resources Schuessler 18-7 well (Alabama Oil and Gas Board permit number 4903), which penetrated about 650 ft before reaching total depth in crystalline rocks at 2,678 ft (-2,158 ft relative to mean sea level (MSL)) and in the Capitol Oil and Gas Company Gholson #1 well (Alabama Oil and Gas Board permit number 86) in northwestern Bullock County, which encountered about 430 ft before reaching total depth in crystalline rocks at a depth of 1,712 ft (-1,452 MSL). Descriptions of drill cuttings by Alabama State Oil and Gas Board personnel indicate that Lower Cretaceous sediments are composed of alternating sand, gravel and clay layers. Sands are described as medium to very coarse grained with abundant gravel and large pink feldspar crystals. Clays are purple, red, brown, and green and are micaceous.

Although there is currently no water production from the Lower Cretaceous in Alabama, the geophysical log in the Schuessler 18-7 well indicates that the Lower Cretaceous sediments contain numerous sand layers with relatively high resistivities that may be capable of yielding economic quantities of fresh water. The Lower Cretaceous should be considered as a water exploration target in future water source development plans.

## TUSCALOOSA GROUP

### *COKER FORMATION*

The Coker Formation typically composes the lower part of the Tuscaloosa Group in most of Alabama. However, Tuscaloosa sediments exposed in Macon, Lee, and Russell Counties are undifferentiated and are mapped as Tuscaloosa Group undifferentiated (Szabo and others, 1988) (fig. 5). Smith (2001) recognized a threefold subdivision of Tuscaloosa sediments in southeast Alabama that included the lower Tuscaloosa Coker Formation and overlying upper Tuscaloosa Gordo Formation separated by the "middle marine shale." This well defined stratigraphic separation was observed throughout Bullock County in oil and gas exploratory wells and water wells and was adopted for this research. Smith (2001) stated that the maximum thickness of the Coker Formation in southeast Alabama is about 400 to 450 ft. Descriptions of drill cuttings from the Capitol Oil and Gas Company Gholson #1 well in northwest Bullock County combined with geophysical log correlations indicate that the top of the Coker Formation was encountered at a depth of about 1,100 ft (-840 ft MSL) and the unit is about 220 ft thick, which indicates that the unit is thinning significantly northward toward the outcrop. Correlations from geophysical log data in the Schuessler 18-7 well in southwest Bullock County indicated that the top of the Coker Formation is at 1,780 ft (-1,260 ft MSL) and the unit is about 250 ft thick. Smith (2001) stated that the average rate of dip for the Coker Formation in southeast Alabama is about 42 feet per mile (ft/mi). However, data from Bullock County shows that the rate of dip is about 59 ft/mi, which indicates that the rate of dip increases northward as the formation nears the outcrop.

Smith (2001) described Coker sediments as light-gray to reddish-orange, ferruginous-stained, poorly sorted, invariably etched sand with trace amounts of coarse muscovite mica, igneous and/or metamorphic rock fragments, and coarse grains of orthoclase feldspar with grain size from fine to very coarse (0.03 to 2.0 millimeters (mm)), and gravel that is generally pale-pink to grayish-orange, usually somewhat rounded, and granular (2 to 4 mm) to rarely pebble (4 to 32 mm) in size. Interbedded clays are finely muscovitic, noncalcareous, silty, and varicolored yellow, orange, red and purple. The formation is described by Alabama Oil and Gas Board personnel from Bullock County well cuttings as alternating sand, gravel, sandy clay, and clay layers. Sands are fine to very coarse-grained and micaceous. Clays are green, reddish brown, purple, and gray, micaceous, and carbonaceous. The Coker Formation is a minor aquifer in southeast Alabama and has limited potential for economic water production in Bullock County.

### *"MIDDLE MARINE SHALE"*

The "middle marine shale" is an informal name for a relatively thin yet persistent clay or shale that occurs throughout Alabama (Smith, 2001). Although the unit is not recognized at the surface and has no significance as an aquifer, it is useful in determining the top of the Coker Formation and base of the overlying Gordo Formation for data correlation and drilling. The unit consists of medium-gray to olive-gray, massive-bedded to thinly laminated, finely muscovitic and lignitic, quartzose silty clay and shale, which in part is moderately calcareous and contains common to abundant thin-walled pelecypod shell fragments (Smith, 2001). The unit was encountered in the Capitol Oil and Gas Company Gholson #1 well in northwest Bullock County at a depth of 1,000 ft (-740 ft MSL) and is about 60 feet thick. A core taken from the unit in the Gholson #1 well was described as shale, dark-gray, micaceous, carbonaceous, with fossiliferous lenses, fine sand lenses, and embedded pyrite. Geophysical log data from the Schuessler 18-7 in southwest Bullock County show that the top of the unit is at a depth of 1,685 ft (-1,165 ft MSL) and is about 95 ft thick.

### *GORDO FORMATION*

The Gordo Formation is the upper unit of the Tuscaloosa Group and although it is undifferentiated in outcrop in east Alabama it is well defined from drill cuttings and geophysical log character in the subsurface. The base of the unit is defined as the contact with the "middle marine shale." The upper contact with the Eutaw Formation is mainly defined by sediment color and relatively massive clay layers in the Gordo related to the different environments of deposition of the two units. However, identification of the contact between the Eutaw and underlying Gordo is more problematic in east Alabama than further west. The origin of the Eutaw Formation is primarily marginal marine whereas the Gordo originates from fluvial deposition (Cook, 1993). The basal Eutaw is composed of a regionally persistent massive sand layer with marine material including shell fragments, aragonite, and glauconite and colors from gray to buff. The top of the Gordo is nonfossiliferous and is characterized by relatively massive, varicolored (orange, brown, red, pink, and purple) clays, coarse-grained sand, and gravel. The Gordo Formation was encountered in the Ozark Utilities well in northern Dale County at a depth of 2,340 ft (-1,815 ft MSL) where it is 430 feet thick. In contrast, the Gordo in southwest Bullock County in the Schuessler 18-7 well was penetrated at 1,180 ft (-660 ft MSL) and was 500 ft thick and in the Gholson #1 well in northeast Bullock County at 525 ft (-265 ft MSL) where it was 475 ft thick (plate 2). Smith (2001) reported that the dip of the Gordo Formation in Coffee, Dale, and Henry Counties is to the south-southwest at about 35 ft/mi. The Gordo dips south-southwest at about 40 ft/mi in southern Bullock County but increases to about 48 ft/mi in the northern part of the county as it nears the outcrop (plate 2).

The undifferentiated Tuscaloosa Group, including Gordo sediments is exposed on the surface (recharge area) in east Alabama from northern Russell and southern Lee Counties westward through northern Macon County. The Gordo Formation is the primary aquifer for Bullock County. Although the water-producing sands are relatively thin, the accumulated contribution from the entire formation yields adequate quantities of excellent quality water.

### *EUTAW FORMATION*

The Eutaw Formation extends from west and central Alabama, where it is about 350 to 400 ft thick, to eastern Alabama where the formation thins to less than 300 ft. The formation outcrops just north of the Bullock/Macon County line (plate 3). The Eutaw is about 230 feet thick in both the Capitol Oil and Gas Company Gholson #1 well (Alabama Oil and Gas Board permit number 86) in northwestern Bullock County where the top of the Eutaw was penetrated at 30 ft MSL and the Scientific Resources Schuessler 18-7 well (Alabama Oil and Gas Board permit number 4903) in southwestern Bullock County where the top of the Eutaw was penetrated at 420 ft MSL. The formation dips to the south-southwest at about 39 ft/mi (plate 4).

Smith (2001) describes the Eutaw Formation in outcrop in east Alabama as light-gray to light-greenish-gray, glauconitic, muscovitic, fossiliferous, well-sorted, fine- to medium-grained quartzose sand with subordinate beds of thinly laminated to massive dark-gray, micaceous, lignitic and carbonaceous silty clay and clay. Smith (2001) described the subsurface Eutaw in Bullock, Pike, and Barbour Counties as very fine quartzose sandy clay and calcareous shale containing traces of glauconite and phosphatic grains with very rare pelecypod shell fragments. Clays and shales are interbedded with lenses and thin beds of indurated very fine- to fine-grained quartzose sandstone, sandy limestone, and thin beds of sand. The Eutaw is described from drill cuttings from the Capitol Oil and Gas Company Gholson #1 well in northwest Bullock County as fine-grained, micaceous sand with ostracod shell fragments, coarse-grained glauconite, and aragonite prisms and gray to greenish-gray, fossiliferous, chalky shale.

The Eutaw Formation in west and central Alabama can be divided into three distinctive lithologic layers: the lower basal sand unit, the middle Eutaw unit, and the upper Tombigbee

Sand member (Cook, 1993). In east Alabama the upper contact of the Eutaw with the overlying Blufftown Formation is not well defined and forms a gradational transition from carbonate to clastic sediment deposition. The basal sand unit is persistent and is recognized in geophysical log character across the state, including east Alabama and in Bullock County. Geophysical log character and net sand mapping suggests that the basal sand unit was deposited as a barrier island complex that extended from northeast Mississippi across much of Alabama (Cook, 1993). The basal sand supplies water for public water supplies throughout west and central Alabama but may not be a target for water well drilling in Bullock County due to the fine-grained character of the sand.

## SELMA GROUP

The Selma Group is upper Cretaceous in age and includes the Blufftown Formation, Mooreville Chalk, Ripley Formation and Cusseta Sand Member, Demopolis Chalk, and Providence Formation in east Alabama.

### *BLUFFTOWN FORMATION*

Sediments in the lower Selma Group vary significantly from west to east in Alabama. The Mooreville and Demopolis Chalk in west and central Alabama are from 800 to more than 1,000 ft thick (Smith, 2001). These chalky marls interfinger and are eventually replaced in Bullock County by the Blufftown Formation, which consists predominantly of marl, calcareous clay, and subordinate thin beds of very fine quartzose sand (Smith, 2001) (plate 3). Relatively impermeable beds that form the Blufftown create a major confining unit that separates upper and lower Cretaceous aquifers in east Alabama. The Blufftown is about 550 ft thick in the Scientific Resources Schuessler 18-7 well (Alabama Oil and Gas Board permit number 4903) in southwestern Bullock County and thins to about 300 ft in the Capitol Oil and Gas Company Gholson #1 well (Alabama Oil and Gas Board permit number 86), where it is described as sandy, glauconitic, micaceous clay with abundant fossils and gray micaceous chalky clay and shale with abundant fossils. The top of the Blufftown was at 370 ft MSL in the R. W. Williams Sorrell #1 well (Alabama Oil and Gas Board permit number 1401) in southwest Bullock County.

## *RIPLEY FORMATION*

### CUSSETA SAND MEMBER

Outcrop exposures of the Cusseta Sand Member of the Ripley Formation in Alabama extend from the Chattahoochee River in northeastern Barbour County and southeastern Russell County westward through Central Bullock County into southern Montgomery County (Smith, 2001). Along the Chattahoochee River, the Cusseta averages about 200 ft in thickness. Westward, the Cusseta gradually thins to about 125 ft in eastern and central Montgomery County and merges with the Demopolis Chalk in southwestern Montgomery County. In outcrop, the Cusseta consists predominantly of cross-bedded coarse quartzose sand and granular gravel with subordinate beds of dark-gray to black carbonaceous clay (Smith, 2001). The Cusseta surface exposure (recharge area) in Bullock County varies from 5 to 10 miles wide from the Barbour County line westward to Union Springs and thins to less than 2 miles wide into Montgomery County (plate 3).

Smith (2001) described the Cusseta Sand in the subsurface as a distinct unit in Crenshaw, northeastern Coffee, Dale, and Henry Counties but further westward the Cusseta quartzose sands are replaced with clays, marls, and thin beds of limestone so it can no longer be distinguished from the Ripley Formation or the underlying Blufftown Formation. The Cusseta Sand in Bullock County is described by Smith (2001) in the R. W. Williams Sorrell #1 well (Alabama Oil and Gas Board permit number 1401) in southwest Bullock County as clear to very light-gray, ferruginous-stained, quartzose, moderately well sorted, medium to very coarse sand with black, heavy minerals. Sands may include feldspar and they are finely fossiliferous with phosphatic fish tooth and bone fragments, rare oyster shell fragments, ostracods, and calcareous benthonic foraminifera, and they contain traces of light-olive-gray, noncalcareous, and micaceous clay. Although little subsurface control exists in Bullock County, the R. W. Williams Sorrell #1 well was spud in the Cusseta Sand where Smith (2001) described about 50 ft of the unit. The Cusseta Sand is historically a major water producer in northern Dale and southern Pike Counties. Numerous private wells are constructed in the Cusseta Sand in south Bullock County. However, it is probably too thin and shallow to be considered as a public water supply target in all but the southwestern part of the county.

### UNNAMED UPPER MEMBER

The unnamed upper member of the Ripley Formation extends in outcrop across the entire state of Alabama with the upgradient terminus in Bullock County extending from the town of Midway in the southeastern part of the county to High Ridge in the southwestern part of the county (plate 3). Smith (2001) described the surface exposed Ripley as massive-bedded to cross-bedded, glauconitic fine sands and sandy clay with thin indurated beds of fossiliferous sandstone having a total thickness of about 135 feet. Smith (2001) stated that the Ripley consists of predominantly fine-grained lithologies and serves as an aquiclude.

### *PROVIDENCE SAND*

The Providence Sand is the uppermost unit within the Cretaceous System in eastern Alabama. In outcrop, the Providence extends from the Georgia state line through northern Barbour, southern Bullock and Montgomery Counties and terminates in south-central Lowndes County (Szabo and others, 1988) (plate 3). The Providence Sand is a minor aquifer in southeast Alabama and is not present in the subsurface in Bullock County. Therefore it is not a target for water well drilling.

## HYDROGEOLOGY

Aquifers are parts of formal geologic units that are capable of storing and transmitting useful quantities of groundwater. Aquifers in east-central Alabama, including Bullock County, are contained in sedimentary geologic formations deposited in the area during the Cretaceous Period (66 to 145 million years ago). Those subsurface geologic strata or beds in the area of investigation that contain the highest percentages of sand and conversely the lowest percentages of silt, clay, and shale are most likely to contain large supplies of water in the intergranular pore spaces (storage) and have the critically important property of interconnectedness (permeability) of the porosity to allow water to flow through the sediment and to wellbores (transmissivity). Thus, locating porous and permeable sand beds within geologic formations and determining where they are thickest are important factors in predicting which geographic areas and geologic units have the greatest potential for containing and subsequently producing large supplies of groundwater.

Delineation of sand beds and the determination of their thicknesses in this study relied upon the use of geophysical well logs with the aid of drillers' logs and sample descriptions. Because geophysical well logs have only been acquired in a portion of the water wells and oil and gas test holes drilled in the area, the analyses and interpretations presented here do not constitute a comprehensive study of all wells. Continuous recordings of measurements of the natural gamma radiation (gamma ray logs) of the subsurface sediments, coupled with resistivity and spontaneous potential (SP) logs, were the principal means of determining the likely presence and thicknesses of quartz sand and limestone intervals in formations penetrated by boreholes. Gamma ray logs are not affected by formation water salinity, whereas resistivity and spontaneous potential logs are electrical measurements of the formation sediments and their contained water. Typically not recorded in water well test holes, due to costs and other considerations, are porosity measuring logging devices. These tools, as well as numerous other types of logs, have been utilized for years in the oil and gas exploration industry to help determine porous and permeable beds. However, they are rarely utilized in the water supply industry and were not available in any wells in the area of investigation. This study presents results of a method commonly used in oil and gas exploration called "net sand mapping" whereby each gamma ray log is calibrated as a measure of the percent sand and/or limestone. For the purposes of this water source assessment, summations of the thickness of sand recorded as the "net potential productive interval" (NPPI) for each well that penetrated and logged each potential aquifer were determined. Thicknesses of the NPPI were plotted on maps and the values were contoured. Data for this assessment were limited to the net thickness of sand in which the percentage of sand was analyzed to be greater than 75 percent for the logged interval. Limiting the net thicknesses to this high percentage of "clean" sand (less than 25 percent clay or silt-sized materials) provides optimum analysis of the highest quality aquifer (or potential productive intervals). It should be noted that maps depicting NPPI thicknesses do not always coincide with thicknesses of the geologic formations. For example, it is not uncommon for a geologic formation to thicken southward in the study area, while the net sand/limestone content thins. Depositional environments, sediment supply, and post-depositional geologic events determine the thicknesses of the geologic units and affect other characteristics such as porosity and permeability. It should also be stressed that whereas locating areas of thick NPPIs does increase the probability of finding usable aquifers, it does not guarantee that desired quantities of groundwater with desired water quality can be obtained. Resistivity logs generally show higher resistivity values in cleaner sand intervals where fresh water is present. Spontaneous potential logs can be helpful as well, especially in determining bed boundaries. Use of resistivity and SP logs complements the sand quality and thickness determinations, and, though less definitive, they can be used in those wells in which gamma ray logs were not acquired to give a general estimate of net sand thickness. Data generated from NPPI assessments commonly indicate limits of water production in an evaluated aquifer as a combination of net sand thickness and water-quality (salinity) estimation from geophysical logs. However, due to the up gradient location of Bullock County, only the deepest wells encountered transitions from fresh to saline water, so that water quality is not a major concern for this assessment.

## LOWER CRETACEOUS AQUIFER

As previously stated, the Lower Cretaceous in Alabama currently provides no water supplies. However, this assessment has determined that the Lower Cretaceous should be considered as a drilling target in Bullock County, although its depth may be a limiting factor when considering water well drilling options. A number of massive sand layers were identified from limited oil and gas exploratory well data in the Lower Cretaceous in southwestern Bullock County. Since no previous net sand mapping was done in southeast Alabama and well control in Bullock County is limited, NPPI values for the Lower Cretaceous are reported from only one well. The Scientific Resources Schuessler 18-7 well (Alabama Oil and Gas Board permit number 4903) in southwestern Bullock County has 280 ft of NPPI, which would probably be capable of significant water production. The resistivity log in this well also indicates the fresh/saline water transition zone, which occurs near the base of the Lower Cretaceous from 2,540 to 2,650 ft.

## COKER AQUIFER

The Coker Formation has limited development as a water production unit in east Alabama due to its depth and limited fresh-water extent. Smith (2001) reported that only three wells in east Alabama (Pike and Barbour Counties) are known to produce water from the Coker. As with the Lower Cretaceous, limited penetrations of the Coker Formation in Bullock County prevented construction of an NPPI map; however, GSA analyses of Coker penetrations in the Scientific Resources Schuessler 18-7 well in southwestern Bullock County, SBCWA Peachburg well in northeastern Bullock County, and SBCWA Halls Crossroads well in south-central Bullock County have 142, 64, and 52+ ft of NPPI, respectively. No saline water would be expected from the Coker in Bullock County.

## GORDO AQUIFER

All public water supplies in Bullock County originate from the Gordo aquifer. Previous GSA mapping in southeast Alabama indicates that the thickest Gordo aquifer NPPI (about 200 ft) occurs across southern Barbour, northern Henry, Dale and Coffee, southwestern Pike, and central Crenshaw Counties (plate 5). GSA analyses indicate that the Bullock County Gordo aquifer NPPI thins generally from south to north, with the thinnest NPPIs occurring in eastern and western parts of the county. A thick NPPI trend extends south to north from Perote in south-central Bullock County and Linwood in northeastern Pike County (about 150 ft), through Union Springs to Fort Davis in south-central Macon County (about 100 ft) (plate 6). Due to the nonmarine depositional history of the Gordo, this may indicate the location of a paleo-river valley that eroded underlying Coker sediments and concentrated coarse-grained sediment deposition in the Gordo Formation. Evaluation of specific capacities for selected wells constructed in the Eutaw and Gordo aquifers in Bullock County indicates that the most productive wells correspond to the general area with the thickest NPPI (plate 7). Although specific capacities may be impacted by factors other than aquifer quality, plate 7 shows a range of 1.0 to more than 4.0 gallons per foot of drawdown. The Gordo aquifer is the primary objective for water well drilling in Bullock County.

## EUTAW AQUIFER

The Eutaw aquifer in west and central Alabama is a major public water supply source. However, in east-central and southeast Alabama the Eutaw is a secondary water source and is commonly screened with the Gordo due to its close proximity. The NPPI for the Eutaw aquifer thickens southward from less than 20 ft along the Macon County line to 60 ft in the southern part of Bullock County (plate 8). As discussed previously, the upper part of the formation is transitional from the overlying Blufftown Formation and is not considered as a water source. The basal part of the formation is water bearing and is a target for water well drilling as a secondary objective.

## BLUFFTOWN AQUACLUDE

The Blufftown Formation is not considered to be an aquifer but serves as a confining unit for underlying water bearing zones. This is an important role in that it provides protection for underlying aquifers from threats occurring on the land surface such as drought and contaminants and facilitates substantial hydraulic head in the underlying aquifers, which reduces water lift costs and increases productivity.

### CUSSETA SAND MEMBER AQUIFER

The Cusseta Sand Member of the Ripley Formation is an important aquifer in areas immediately south of Bullock County. However, although little data are available, it is likely that the Cusseta is too thin for significant water production in Bullock County.

## GROUNDWATER LEVELS

### POTENTIOMETRIC SURFACES AND RESIDUAL DRAWDOWN

A potentiometric groundwater level is the elevation to which water rises in a well that penetrates a confined aquifer (fig. 6). The potentiometric surface is an imaginary surface representing the confined pressure (hydrostatic head) throughout all or part of a confined aquifer. This surface is helpful in determining directions of groundwater movement, hydraulic gradients, depths from which water can be pumped at particular locations, and impacts of pumping. When water is removed from the aquifer by pumping, the potentiometric surface will fluctuate accordingly (drawdown). The difference between the pre-pumping static water level and the partially recovered water level affected by pumping is termed residual drawdown (Driscoll, 1986). It is important to note that as long as the potentiometric surface remains above the stratigraphic top of the aquifer, the aquifer media remains saturated so that the declining surface only represents a decline in hydrostatic pressure. If the water level declines below the stratigraphic top of the aquifer, the aquifer becomes unconfined, possibly causing irreversible formation damage. Therefore, potentiometric surfaces and residual drawdown values provide important information to determine the affects of water production, strategies for water source protection, and future water availability.

Potentiometric surface and residual drawdown values were determined from 35 private, state-owned, and public water supply wells for two time periods (original static water levels when the wells were constructed and current static water levels in 2012 and 2013). Five public water supply wells operated by SBCWA and four public water supply wells operated by the Union Springs Water Department were measured. Each public water supply well had an average water level recovery time of 18 hours before water levels were measured. Most measured private

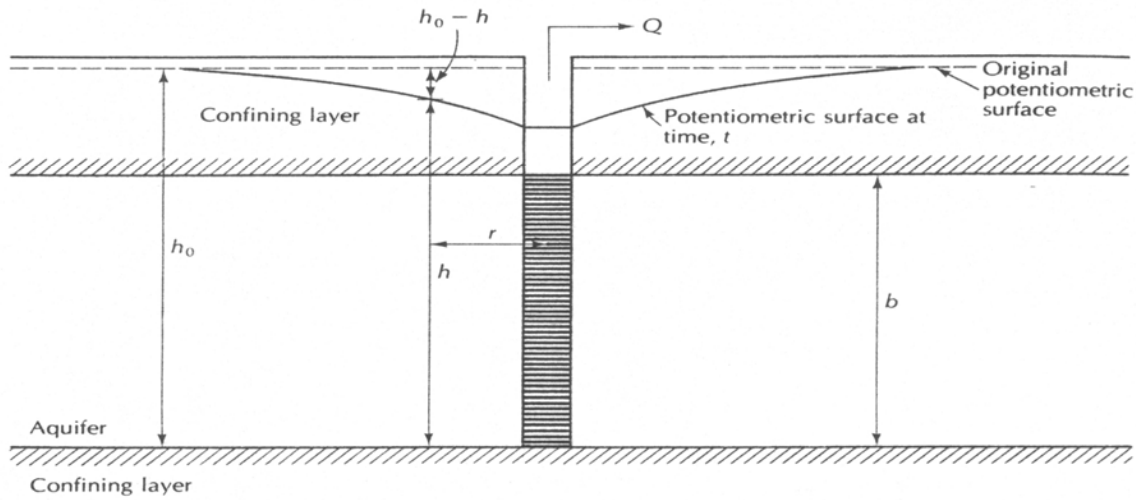


Figure 6.—Diagram depicting drawdown and potentiometric surfaces prior to and after pumping in a confined aquifer (modified from Fetter, 1994).

wells were not currently used. However, water levels in private wells with operational pumps were measured without planned recovery time due to minimal pumping time and rates.

Plate 9 is a potentiometric surface map for the Eutaw and Gordo aquifers constructed from initial static water levels for wells constructed between 1920 and 1979. Groundwater levels indicate that the Eutaw and Gordo are hydraulically connected. Therefore, a single potentiometric surface portrays water level conditions for both aquifers. Plate 9 shows southward water movement from southern Macon County where water levels are about 240 ft MSL to central Bullock County where a low water level trough (about 180 ft MSL) extends from about 5 miles north of Pine Level in east-central Montgomery County to about 3 miles south of Union Springs to about 5 miles north of Comer in northern Barbour County. South of the trough, groundwater flows northward from elevations of about 220 ft MSL. The only production impact was under the city of Union Springs, where the potentiometric surface was depressed about 30 ft over an area of less than 1 $mi^2$ (plate 9).

Plate 10 is a potentiometric surface map for the Eutaw and Gordo aquifers constructed from groundwater levels measured in 2012 and 2013. It shows southward water movement from southern Macon County where water levels are about 180 ft MSL and a minor production impact area about 2 miles southeast of Mitchell in northwest Bullock County where the potentiometric surface is depressed about 10 ft. Plate 10 also shows a major production impact area under the city of Union Springs, where the potentiometric surface is depressed about 100 ft over an area of more than 30 $mi^2$. Cook (1993) constructed a state wide potentiometric surface for the Eutaw aquifer from water levels measured in April 1991. The Bullock County part of this map has similar contour trends and directions of groundwater movement as the potentiometric surface map constructed in 2013.

Plate 11 is a residual drawdown map for the Eutaw and Gordo aquifers. It shows an area of excessive drawdown under the city of Union Springs ranging from about 100 ft to more than 163 ft. This is one of the largest drawdown areas in Alabama. Figure 7 is a hydrograph for well F-1 just west of downtown Union Springs, which illustrates the impact of pumpage in the Union

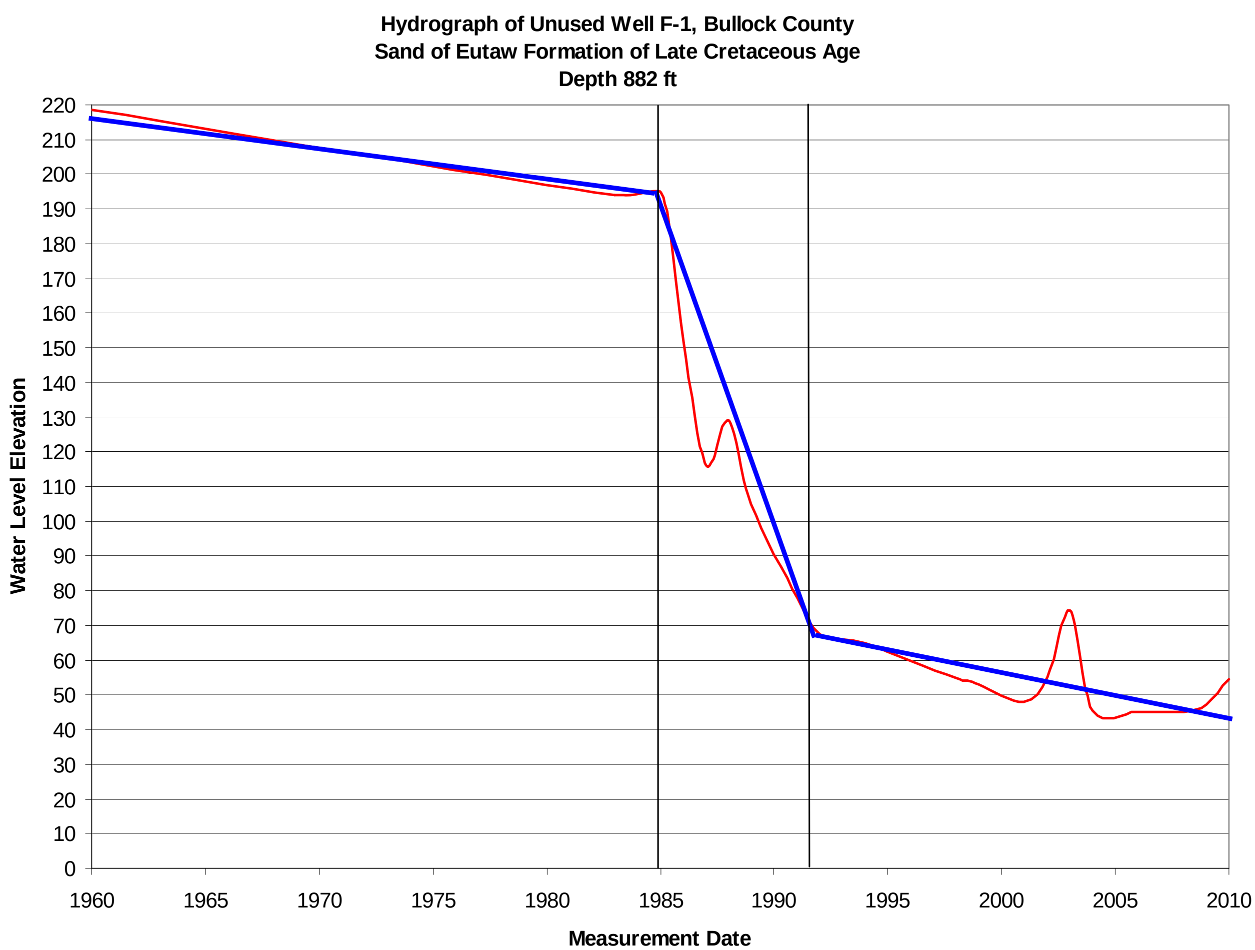


Figure 7.--Hydrograph of well F-1 constructed in the Eutaw aquifer at Union Springs.

Springs area. The hydrograph shows that the major period of impact was from 1985 to 1992 when the water level was declining at about 19 ft/yr. However, since 1992 the decline rate has slowed significantly, but continues to decline at a rate of about 1.2 ft/yr.

Plate 11 also shows that there is a regional groundwater level decline in the Eutaw and Gordo aquifers from 60 to 80 ft in much of Bullock County. A potentiometric surface map constructed by Cook (1993) from water levels measured in 1991 shows that the potentiometric surface for the Eutaw aquifer was about 30 feet higher in 1991 than in 2013. Most of this regional decline occurred after 1980 and is not related to excessive groundwater production, but is most likely the result of less precipitation and less groundwater recharge since 1980. Figure 8 is a hydrograph for well N-7 located in rural west-central Bullock County. This well is constructed in the Eutaw aquifer and has been monitored by GSA since 1967 and illustrates the regional groundwater level decline and pre- and post-1980 annual water level decline rates. The water level in the well has declined 65 ft since 1967. However, the water level declined 0.2 ft/yr

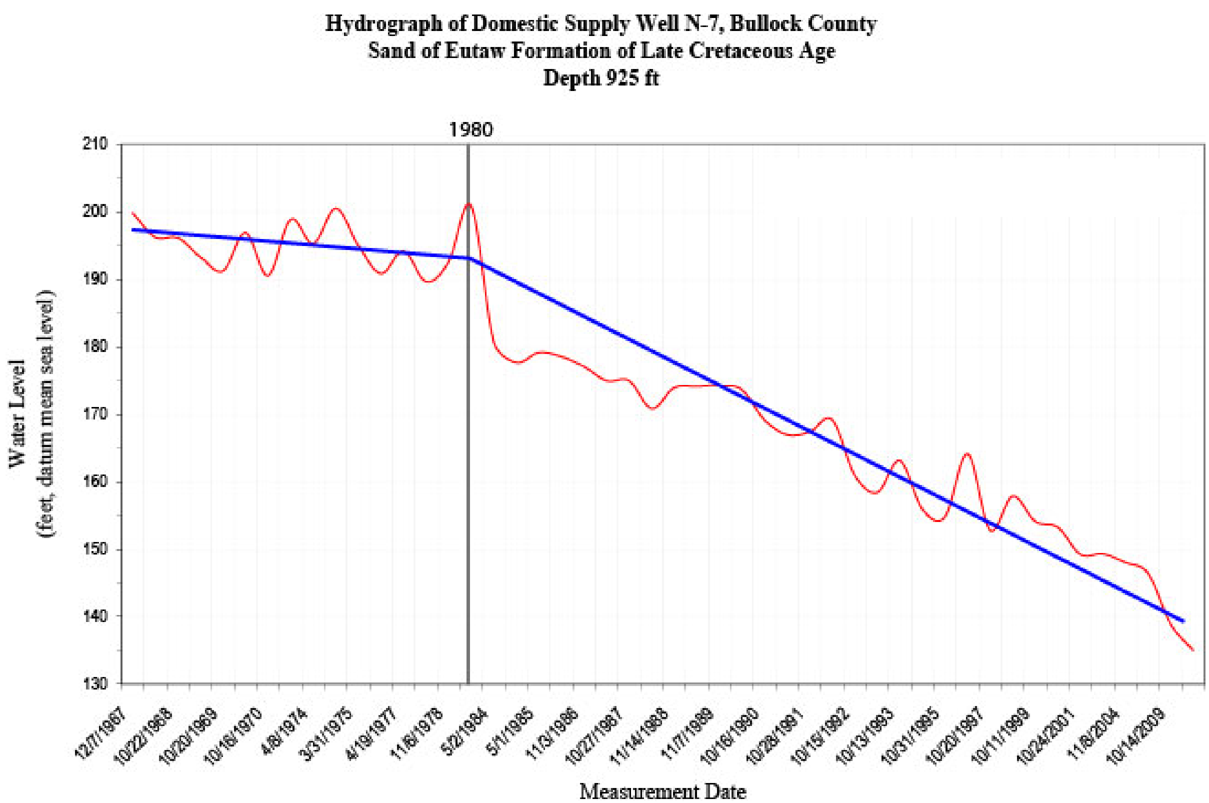


Figure 8.--Hydrograph of well N-7 constructed in the Eutaw aquifer in west-central Bullock County.

between 1967 and 1980 and 1.4 ft/yr between 1980 and 2012. An evaluation of hydrographs for more than 55 wells constructed in the Eutaw aquifer by Cook (1993) showed that water levels declined at an average annual rate 0.64 ft/yr. Most of these wells were in rural areas with no production impacts.

## GROUNDWATER EXPLORATION AND ADDITIONAL GROUNDWATER SOURCE DEVELOPMENT

One of the primary purposes of this GSA Groundwater Assessment Program (GAP) investigation was to recommend sites for test well drilling in the SBCWA service area. Test well locations were developed from interpretation of field assessments and available hydrogeologic data. Possible test well locations were determined after discussions with SBCWA management to assure that the needs and requirements of SBCWA were addressed in the location process. General locations are given in this report. However, specific locations will be determined by SBCWA based on land availability and engineering requirements. Three initial requirements for test well locations were areas with optimum NPPIs, areas with adequate separation from other wells constructed in the same aquifer, and areas that would permit the most efficient and economical water production while providing additional water supplies to areas with the most critical need. Based on discussions with SBCWA management, areas with the largest potential for increased future water demand are near the Bonnie Plants facilities in south-central Bullock County and expanding suburbs of the city of Montgomery in northwestern Bullock County.

Four areas for test well drilling are recommended by the GSA GAP.

- Area 1 is in northwestern Bullock County immediately south of the Mitchell community and northwest of the SBCWA Greenwood well (plate 1). A test well at this location would be in a critical area as identified by SBCWA and would be relatively shallow (about -300 ft MSL or 1,100 ft drilling depth), compared with areas further south (plate 2). However, the NPPI for the Gordo aquifer thins significantly in this area (50 to 75 ft of potential productive sand) (plate 6).
- Area 2 is in the west-central part of Bullock County from Shopton eastward to Simsville to Union Springs (plate 1 location map). This area would be suitable for test well drilling in the Gordo aquifer with an NPPI of 125 to 150 ft. However, past unsuccessful test wells near Simsville may exclude this area from consideration.

- Area 3 is in extreme southwestern Bullock County along the Pike County line, west of the Inverness and Perote communities and south and west of the SBCWA Halls Crossroads well (plate 1). The NPPI for the Gordo aquifer in this area is the thickest in Bullock County (>150 ft) (plate 6). Hydrogeologic cross section A-A′ (plate 12) illustrates depths and stratigraphic composition of geologic units near area 3. Drilling depth for a test well to the base of the Gordo aquifer in the area would be about 1,800 ft. Also, it is probable that there are significant productive intervals in the Coker (2,150 ft drilling depth) and Lower Cretaceous aquifers (2,500 ft drilling depth). However, due to test well depths and distance from distribution lines, this area may not be considered for test well drilling at this time.
- Area 4 is in the vicinity of the Bonnie Plants facilities, south of Union Springs near the Aberfoil community (plate 1). The NPPI for the Gordo aquifer is 125 to 150 ft (plate 6). Hydrogeologic cross section A-A′ (plate 12) illustrates depths and stratigraphic composition of geologic units in Area 4. Drilling depth to the base of the Gordo aquifer in this area will be about 1,600 ft (-600 ft MSL) (plate 2). However, it is probable that there are significant productive intervals in the Coker (1,950 ft drilling depth) and Lower Cretaceous aquifers (2,250 ft drilling depth). The SBCWA Sardis well is in this test well area (plate 1). Therefore, consideration must be given to allowing adequate separation with any test well.

After a well location is secured, proper well drilling, construction, and testing plans are essential for a successful test well. This is especially true for wells constructed in Eutaw or Tuscaloosa Group aquifers where drilling depths and stratigraphic composition create unique challenges for drilling operations.

Sediments that comprise the Gordo aquifer are characterized by fluvial depositional environments composed of point bar, channel fill, and over bank deposits. These environments result in numerous relatively thin sand layers that individually contribute relatively small quantities of water separated by clay layers. However, collectively, these sand layers yield adequate or, in some cases large, quantities of water. Past GSA GAP experience with the Gordo aquifer indicates that wells should be designed with numerous screen and blank sections to capture as much water as possible from sand layers while preventing any water quality problems that might arise from screened clay units. GSA GAP recommends this type of well design for SBCWA test wells.

## SUMMARY

All public-water supplies in Bullock County are produced from groundwater sources. Due to increasing population in the northwest part of the county and concerns about the long-term viability of current water sources operated by South Bullock County Water Authority (SBCWA), the Geological Survey of Alabama (GSA) initiated the Groundwater Hydrogeologic Characterization and Source Development Project in July 2009.

The geology of the area of investigation is composed of about 2,500 ft of sediments of Cretaceous and Tertiary age, originating from environments of deposition that include marine, marginal marine, and fluvial. Geologic units in ascending order are the Lower Cretaceous Undifferentiated, Coker, Gordo, Eutaw, and Blufftown Formations, Providence Sand, Ripley Formation, and the Cusetta Sand Member. The primary aquifers in Bullock County are the Gordo and overlying Eutaw Formations.

The potentiometric surface is an imaginary surface representing the confined pressure (hydrostatic head) throughout all or part of a confined aquifer. This surface is helpful in determining directions of groundwater movement, hydraulic gradients, depths from which water can be pumped at particular locations, and impacts of pumping. Groundwater levels indicate that the Eutaw and Gordo are hydraulically connected. Mapping of original static water levels from wells constructed between 1920 and 1979 shows southward water movement from southern Macon County where water levels are about 240 ft MSL to central Bullock County where a low water level trough (about 180 ft MSL) extends from about 5 miles north of Pine Level in east-central Montgomery County to about 3 miles south of Union Springs to about 5 miles north of Comer in northern Barbour County. South of the trough, groundwater flows northward from elevations of about 220 ft MSL. The only production impact to 1979 was under the city of Union Springs, where the potentiometric surface was depressed about 30 ft over an area of less than 1 $mi^2$. A potentiometric surface map for the Eutaw and Gordo aquifers constructed from groundwater levels measured in 2012 and 2013 shows southward water movement from southern Macon County where water levels are about 180 ft MSL and a minor production impact area about 2 miles southeast of Mitchell in northwest Bullock County where the potentiometric surface is depressed about 10 ft. A major production impact area under the city of Union Springs, where the potentiometric surface is depressed about 100 ft over an area of more than 30 $mi^2$.

One of the primary purposes of this GSA Groundwater Assessment Program (GAP) investigation was to recommend sites for test well drilling in the SBCWA service area. Four areas for test well drilling are recommended by the GSA GAP. Area 1 is in northwestern Bullock County immediately south of the Mitchell community and northwest of the SBCWA Greenwood well. Area 2 is in the west-central part of Bullock County from Shopton eastward to Simsville to Union Springs. However, past unsuccessful test wells near Simsville may exclude this area from consideration. Area 3 is in extreme southwestern Bullock County along the Pike County line, west of the Inverness and Perote communities and south and west of the SBCWA Halls Crossroads well. However, due to test well depths and distance from distribution lines, this area may not be considered for test well drilling at this time. Area 4 is in the vicinity of the Bonnie Plants facilities, south of Union Springs near the Aberfoil community.

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