ASSESSMENT OF THE HYDROGEOLOGY AND GROUND-WATER GEOCHEMISTRY OF SOUTHWESTERN ELMORE COUNTY, ALABAMA

Outcrop of Paleozoic metamorphic rock on the Coosa River below Jordan Lake Dam
GEOLOGICAL SURVEY OF ALABAMA

Berry H. Tew, Jr.
State Geologist

ASSESSMENT OF THE HYDROGEOLOGY AND GROUND-WATER GEOCHEMISTRY OF SOUTHWESTERN ELMORE COUNTY, ALABAMA

A REPORT TO THE
ELMORE WATER AUTHORITY
OPEN FILE REPORT 0802

By
Stephen P. Jennings
and
Marlon R. Cook

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ABSTRACT

Southwestern Elmore County is located at the junction of the Coastal Plain and Piedmont physiographic provinces where loosely consolidated sediments of Cretaceous and younger age unconformably overlie much older Paleozoic metamorphic and igneous rocks. Aquifers in the Coastal Plain stratigraphic section are composed primarily of sand deposits of the Coker Formation and sand and gravel beds of the overlying Gordo Formation. The Coker is the principal public-supply aquifer in the project area, and the Gordo is a significant secondary aquifer. However, additional development of large capacity wells in these aquifers is limited due to shallow depth and thin sediments in all but the southwestern part of the project area. A complexly folded and faulted section of Paleozoic rocks constitutes a potential, but as yet largely untested, aquifer. Analyses of available geologic data from wells and outcrops, water quality data, water level data, and high altitude aerial photographic imagery resulted in delineation of the subsurface geology, ground-water hydrology, and geochemistry. These data and analyses are presented as a series of maps, including recommended prospective areas for drilling and ground-water supply development.

INTRODUCTION

The assessment of hydrogeology and geochemistry in Elmore County was performed by the Geological Survey of Alabama (GSA) to develop options for additional ground-water sources in and near the current distribution area of the Elmore Water Authority (EWA) in southwestern Elmore County. The project area is underlain by relatively thin coastal plain sediments that overlie metamorphic and igneous rocks. Historically, water production rates from wells constructed in Coastal
Plain sediments are relatively small, with localized concentrations of iron and manganese above drinking water standards. The GSA evaluated available geologic, hydrologic, and geochemical data to determine optimum locations and depths for future ground-water exploration wells that will produce adequate quantities of good quality water. This study relied heavily on drillers’ logs and basic well data on file at the GSA (Gillett, 1991), data from EWA, along with reconnaissance field work by the authors.

PROJECT AREA

The Elmore Water Authority project area includes the service area for EWA (see plates for the general outline of the service area) plus the surrounding area of southwestern Elmore County, easternmost Autauga County, and northernmost Montgomery County (fig. 1). Analysis of data for the project extended to areas beyond the Elmore Water Authority service area in order to adequately evaluate the service area within the context of the geologic, hydrologic, and geochemical setting and to provide a more comprehensive study. Data from surrounding wells and geologic outcrops are significant in the assessment process and in making recommendations concerning the development of additional ground-water sources.

HYDROGEOLOGY

GENERAL GEOLOGIC SETTING

The project area lies at the junction of the Coastal Plain and Piedmont physiographic provinces—the Fall Line (fig. 2) (Dean, 1990). Cretaceous and younger sediments of the Coastal Plain occur primarily in the southern and western part of the project area and strike northwest-southeast, whereas metamorphic and igneous rocks of Paleozoic age that comprise the Piedmont Province crop out to the east and northeast and strike northeast (Osborne and others, 1988). A generalized stratigraphic column for the project area is shown in figure 3. Loosely consolidated sediments of the Cretaceous Coker and Gordo Formations of the Tuscaloosa Group and the overlying Eutaw Formation strike in a general northwest-southeast direction across the southwestern part of the area and dip less than one degree to the south-
Figure 1. – Index map showing the Elmore Water Authority project area.
Figure 2. –Physiographic provinces, geology, and Elmore Water Authority project area.
<table>
<thead>
<tr>
<th>SYSTEM/ERA THEM</th>
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<th>GROUP</th>
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<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
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<td>Quartz diorite, gneiss (intrudes the Wedowee Group)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zana Granite</td>
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<td>Granite, grano-diorite (intrudes the Emuckfaw Group)</td>
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<tr>
<td></td>
<td></td>
<td>Schist, phyllite, and gneiss</td>
<td>Emuckfaw Group</td>
<td>Schist and metasediments</td>
</tr>
</tbody>
</table>

Figure 3. –Generalized stratigraphic column of southwestern Elmore County, Alabama
southwest. Locally, Pleistocene and Holocene sediments unconformably overlie the Cretaceous units. Terrace sands and gravels of Pleistocene age cap many of the higher elevations, and younger (Holocene) fluvial sediments deposited by the Coosa and Tallapoosa Rivers and their tributaries occur at the surface in the lower elevations, primarily in the southern part of the area. The Paleozoic rocks and the Coker Formation Gordo Formations were evaluated during this project. Other geologic units, such as the Eutaw Formation, Pleistocene terrace deposits, and alluvial deposits were considered either too thin or too shallow and/or could contain water of objectionable quality and were not considered as viable ground-water sources.

PALEozoIC ROCKS

Northeast of the Coosa River and Jordan Lake, Paleozoic metamorphic and igneous rocks have been mapped along with large-scale thrust faults having displacements on the order of miles (Osborne and others, 1988). Folded and thrust-faulted metamorphic and igneous rocks generally strike about North 45° East and dip to the southeast at steep angles (60 to 80 degrees). Metamorphic and igneous rocks, interpreted from the trends of aeromagnetic data (plate 1) (Neathery and others, 1976; Wilson and Zietz, 2002) and from drillers’ logs, extend to the southwest beneath the Coastal Plain sediments (Dean, 1990). Aeromagnetic data show the total magnetic field intensity of the Earth as measured in gammas and represent variations in both the structural configuration of geological units and in the magnetic susceptibility of Earth materials. Aeromagnetic data shown in plate 1 indicate the dominant northeast-southwest structural trend and lithologic (rock type) variations of the Paleozoic rocks of the Piedmont. The ancient erosional surface (unconformity) of the top of the Paleozoic rocks generally slopes to the southwest at about 50 feet per mile, but evidence from well and test hole data indicates localized topographic relief on the surface (plate 2). This relief probably reflects differential weathering and erosion of the various metamorphic and igneous rock types. For example, outcrop evidence indicates that weathering of the Zana Granite, one of the mapped Paleozoic rock units (Osborne and others, 1988), has locally been severe, resulting in residuum overlying moderately weathered and/or unweathered granitic rocks. This residuum, where it is
sufficiently thick and exists under favorable hydrologic conditions, could provide enough storage capacity for significant quantities of ground water. However, the Zana Granite as well as the other Paleozoic metamorphic and igneous rocks of the project area are virtually untested as potential aquifers with only a small number of wells having been drilled more than a few feet below the Cretaceous sediments. Examination of outcrops of the metamorphic and igneous rocks in the course of this investigation also revealed the presence of joints and fractures, which may provide pathways for ground-water flow. Some areas appear to be favorable enough to warrant consideration for drilling to a depth of at least 100 feet into the Paleozoic rocks (see section on Conclusions and Recommendations) to test this hypothesis.

COKER FORMATION

The Coker Formation is the lowermost Cretaceous geologic unit in the project area, and it contains sand intervals that form the principal aquifers in the project area. As illustrated by the structure map of the top of the Coker (plate 3), the formation occurs at elevations of about 400 feet above sea level to the north and less than 50 feet above sea level to the south, indicating a dip rate of about 50 to 70 feet per mile to the southwest. Coker Formation outcrops in the northern and eastern parts of the project area are the recharge areas for the Coker aquifer sands. Recharge also likely occurs where sands of the overlying Gordo Formation and/or younger sand and gravel deposits are hydraulically connected to the Coker. Thin remnants of the lower part of the Coker occur northeast of the Coosa River and Jordan Lake, but those outliers are not physically nor likely hydraulically connected to the main body of the Coker Formation to the southwest and are not part of the recharge area for the Coker aquifer sands.

The full thickness of the Coker Formation occurs only in the southwestern part of the project area (plate 4), the upper to middle beds of the formation having been removed by erosion to the east and northeast. To the southwest, well data indicate the Coker varies in thickness from 203 feet to 370 feet. However, one test well penetrated 390 feet of Coker Formation without reaching Paleozoic rock. Localized relief that developed on the Paleozoic-Cretaceous unconformity, coupled
with subsequent infilling by sediments of the Coker Formation, has likely resulted in areas where the Coker is unusually thick. Although net sand thicknesses could only be determined in a few wells, data indicate that, in most of the area underlain by the full formation thickness, there is more than 100 feet of total sand (plate 4). Intervals of sand vary from about 25 percent to greater than 50 percent of the formation.

Coker Formation sediments were deposited in shallow marine to marginal marine to fluvial environments that varied spatially and temporally across the project area. At an outcrop in northeastern Autauga County, Tew (1988) described and characterized approximately 48 feet of the lower Coker Formation as a sequence of marine sands, silts, and clays that grade upward into marginal marine sands, silts, clays, and lignite beds. Furthermore, the upper Coker there was described as consisting of approximately 18 feet of cross bedded sands of fluvial origin that sharply overly the lower Coker. Drillers’ logs in the project area indicate the Coker sands are generally fine grained with some intervals of medium- to coarse-grained sands in a few wells. Sands deposited in marine and marginal marine conditions are more likely to extend over wider areas than sand bodies deposited under nonmarine conditions. This is a significant positive factor in consideration of the recharge, water storage capacity, and hydraulic conductivity of the Coker aquifer sands and in exploration for ground-water sources.

The Coker is the principal water source for Elmore Water Authority as well as other public ground-water systems in the area. The EWA’s Estes, Airport, Dismukes, Blackmon, and Eagle Rock wells are screened in sands in the middle to lower part of the Coker. The Kenner well is screened in an upper Coker sand and in the overlying Gordo aquifer. Data from pump tests of six wells screened in Coker sands in the project area indicate specific capacities range from 2.2 to 6.7 gallons per minute per foot of drawdown.

GORDO FORMATION

The Gordo Formation overlies the Coker Formation and crops out in the western part of the project area. The formation dips to the south-southwest at 40 to 70 feet per mile with elevations above 500 feet (relative to sea level) to the north and
about 225 feet above sea level to the south (plate 5). The Gordo is recharged primarily from rainfall in its outcrop area and from water moving through the overlying thin Eutaw Formation and/or terrace or alluvial deposits. Where it is in hydraulic communication with the underlying Coker aquifer, recharge to the Gordo may also come from positive hydraulic head differences between the two aquifers.

The full thickness of the Gordo Formation occurs only in the westernmost parts of the project area. In that area, the Gordo Formation varies in thickness from 158 feet to 209 feet (plate 6). The Gordo is composed of sand and gravel beds as well as clay intervals. In wells penetrating the entire thickness of the Gordo, net sand and/or gravel bed thicknesses vary from 56 feet to 153 feet, and net sand and/or gravel percentages vary from about 30 percent to greater than 80 percent. Deposited in nonmarine conditions, the Gordo sand and gravel beds are commonly more variable in thickness and grain size both laterally and vertically than those of the Coker Formation. This characteristic also indicates that aquifer storage and transmissivity of the Gordo can vary significantly over relatively short distances, increasing risk for exploration of water-productive intervals.

In spite of its limitations for use in the project area, the Gordo is a significant aquifer and has been screened in several major water-supply wells, including the Elmore Water Authority “Kenner” well (screened in both the Gordo and Coker aquifers) and a City of Millbrook well in section 20, T. 18 N., R. 17 E. On a 6.5-hour pump test through 12-inch diameter casing and 35 feet of 6-inch diameter screen, the specific capacity of the Millbrook well was approximately 7.9 gallons per minute per foot of drawdown. The coarse grain size of some Gordo beds suggests high hydraulic conductivity (permeability) values are likely on a local scale.

LINEAMENTS

Aerial imagery from the National Agriculture Imagery Program (NAIP) for 2006 was used in this study to analyze the project area for lineaments, interpreted herein to be hydrogeological features (or that are related to the geology and/or hydrology of the area). Although their exact origin is unknown, the lineaments likely result from geomorphic, soil, vegetation, and/or drainage features that are surface...
expressions of geological features such as topography of the Paleozoic rock surface, faults, joints, fractures, and lithologic boundaries within the Paleozoic section and/or the overlying Cretaceous sediments. Lineaments are utilized in conjunction with geological data, well and test hole data, and geophysical data to assist in the hydrogeological analysis and interpretation. As shown in plate 7, two large scale lineament sets were identified in the analysis of the aerial imagery, one set of prominent lineaments that trend about North 41-46° East and another set trending about North 49-50° West. The northeast-southwest trending set of lineaments is interpreted to be related to the prominent trend of the Paleozoic rocks of the Piedmont Province discussed previously. The lineaments that trend northwest-southeast are interpreted to result from the outcrop patterns and lithofacies of the Coastal Plain sediments.

**POTENTIOMETRIC AND WATER TABLE SURFACE**

The potentiometric water level is the elevation to which water rises in a well that penetrates a confined aquifer (fig. 4). 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 ground-water movement, hydraulic gradients, and depths from which water can be pumped at particular locations.

When water is removed from the aquifer by pumping, the potentiometric surface will fluctuate accordingly (drawdown). Drawdown measured from pumping water levels may be indicative of recent pumping intensity. 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, the potentiometric surface provides important information to determine the effects of water production, strategies for water source protection, and future water availability.
An aquifer that is unconfined or is partially confined exhibits water table conditions in which little or no pressure head is present. Therefore, water surfaces in wells indicate the top of the saturated zone in the aquifer. The water table surface is profoundly influenced by topography and surface-water bodies.

Most wells in the project area are unconfined or partially confined. Plate 8 shows the top of the saturated zone mapped from wells in the area. The water surface indicated by the contour lines resembles the surface topography and is particularly influenced by streams in the area, including Kenner Creek and the Coosa River.
GROUND-WATER QUALITY

Ground-water quality in southwestern Elmore County is generally good with the exception of locally elevated concentrations of iron and manganese above drinking water standards. Factors controlling concentrations of these metals include proximity of iron and manganese sources to aquifers, pH, and Eh (redox potential, oxidizing or reducing subsurface environment). Sources of iron and manganese include many igneous and metamorphic minerals. When these minerals are weathered, metals are released in the aqueous environment. Much of it is reprecipitated as sedimentary species under strongly oxidizing or reducing conditions. The remainder, under specific conditions of pH and Eh, is in a stable dissolved phase that is undesirable in drinking water in excessive concentrations. Plate 9 shows pH values of water samples collected from selected wells in the project area. Values of pH are highly variable from 6.2 to 8.6 with high pH values occurring in a linear trend that extends from near Millbrook to just south of the Walter Bouldin Dam. This northeast-trending linear configuration is similar to the trend of geologic units and faults in the underlying Piedmont rocks and suggests that water quality in the Cretaceous aquifers is probably influenced by mixing with waters from the underlying units. Limited Eh values in and near the project area (Cook, 2002) vary from 0.03 to 0.36 millivolts and are conducive to excessive concentrations of dissolved iron and manganese in ground water from Cretaceous aquifers. Figures 5 and 6 are phase diagrams that illustrate the relationships between pH and Eh and the occurrence of iron and manganese (Hem, 1985).

IRON AND MANGANESE

Mapping dissolved iron and manganese will increase the likelihood of avoiding excessive concentrations of these undesirable metals in future test drilling. Dissolved iron concentrations in excess of drinking water standards (0.3 milligrams per liter (mg/L) occur in the north-central and northeastern parts of the project area where values of pH and Eh are conducive to elevated concentrations of dissolved iron
Figure 5. – Phase diagram for the occurrence of iron (from Hem, 1985).
Figure 6. –Phase diagram for the occurrence of manganese (from Hem, 1985).
The highest iron concentrations (3.5 mg/L) occur in the northeastern part of the area. Concentrations of dissolved manganese in excess of drinking water standards (0.05 mg/L) are relatively uncommon in Alabama but occur in the project area. Excessive manganese concentrations occur in the central part of the project area where values of pH and Eh are conducive to the presence of dissolved manganese (plate 11). The highest concentrations exceed 0.18 mg/L from two test wells in the northwest part of the Elmore Water Authority service area.

CONCLUSIONS AND RECOMMENDATIONS

The principal aquifer in southwestern Elmore County is fine- to medium-grained sand deposits that occur within the Coker Formation. The marine and marginal-marine sands of the formation are generally areally extensive, and at least some portion of the Coker is present across the Elmore Water Authority system area. However, water-quality concerns, especially relatively high levels of dissolved iron and manganese, can render some sand intervals less desirable.

Although porous and permeable sand and gravel beds of the overlying Gordo Formation constitute locally important aquifer intervals, the relatively shallow depths and the thinness of the Gordo except in the westernmost part of the project area restrict its development as a major aquifer. Moreover, the nonmarine depositional environments of the Gordo generally resulted in less areally extensive sand and gravel deposits than those of the Coker Formation.

Metamorphic and igneous rocks of Paleozoic age are considered here to be probable but as yet mostly untested sources of ground water. A long and complex geologic history that includes folding, faulting, prolonged weathering, and the formation of joints and fractures indicates that ground water of suitable quantity and quality are likely present in the Paleozoic rocks in the project area. Under favorable conditions, especially where discontinuities in the crystalline rocks, both lithologic and structural, allow ground-water recharge from the overlying Cretaceous and younger sediments, the Paleozoic rocks should be capable of producing ground water at relatively high flow rates. Although the Paleozoic rocks and faults extend
southwestward beneath the Coastal Plain sediments, available data are not sufficient to accurately map specific water-bearing discontinuities such as fractures or fault planes.

The five areas shown on plate 12 and the accompanying comments are presented here as recommended areas and ideas for further investigation. In Area 1 the full thickness of both the Coker and Gordo Formations maximizes the opportunity to drill more potential aquifer sands. Water-quality data indicate acceptable concentrations of iron and manganese and good pH. Water level elevations in this area are about 220 feet above sea level. The area is not on a major lineament, however, indicating uncertain potential for the Paleozoic rocks. Anticipated drill depth would be about 600 feet to reach the top of Paleozoic rock.

Area 2 is primarily a Coker aquifer test site, with the Gordo Formation thin or absent and with no major lineaments in the area. Water-quality parameters are favorable, as indicated from nearby wells, and the water level elevation is likely to be above 200 feet. A projected drill depth of 350 feet is estimated for a test well that would be drilled to the top of Paleozoic rock in this area.

In Area 3, the Coker Formation is likely to be thicker than average due to a trough mapped on the Paleozoic surface. Most, if not all, of the Gordo Formation is present in the area, presenting possible secondary, shallow aquifer sand intervals. Concentrations of manganese and iron are expected to be acceptable, pH is good, and water level elevations are probably at or slightly below 200 feet above sea level. A major northeast-southwest lineament transects the area—possibly the southwest extension of the Alexander City Fault zone—indicating potential for fracture development in Paleozoic rock. A test well drilled in this area would reach a total depth of about 550 feet, including drilling approximately 100 feet of Paleozoic rock.

Relatively young (Holocene) river alluvial sediments overlie Coker Formation sediments in Area 4. Water level elevations are anticipated to be about 160 feet above sea level with ground-water flow to the southeast. Ground water likely contains acceptable concentrations of manganese and iron and has a pH of approximately 7.0. Area 4 is also on a major northeast-southwest-trending lineament of unknown origin, but possibly related to features in the underlying Paleozoic rocks.
Assuming penetration of 100 feet of the Paleozoic rock, a test well in this area would reach total depth of about 450 feet.

Area 5 is included here primarily as a test well site for the lower Coker Formation, which is productive at the nearby Draper Prison. Acceptable dissolved iron and manganese and a pH of 7.0 is anticipated in the area. A projected total depth of 220 feet is likely for a test well to reach the base of the Coker aquifer.

Screening a high percentage of the net sand thickness has been proven elsewhere to be an effective means of increasing well yields. Although the cost of well construction is increased by setting more and/or longer screens, the long-term benefits of higher yields over the lifetime of the well make this a cost-effective measure. Knowledge of appropriate intervals to screen is a very important factor in well construction and development, but the common practice of relying only on the driller’s observations and logs is generally insufficient to detect relatively thin sand beds. Supplementing the driller’s observations with geophysical well logs is a time- and experience-proven method of increasing knowledge of the intervals penetrated by drilling and therefore can greatly aid in deciding which intervals to screen and test. It is recommended that these measures be employed in future drilling and ground-water resource development projects in the project area.

REFERENCES CITED


Wilson, G.V. and Zietz, Isidore, 2002, Aeromagnetic map of Alabama: Tuscaloosa, State Oil and Gas Board of Alabama, Oil and Gas Special Map 8B.