HYDROGEOLOGY OF THE LAWRENCEVILLE AREA, GEORGIA

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Abstract. The population of the Atlanta Metropolitan area of northern Georgia continues to grow at a rapid pace, and as a result, the demand for water supplies steadily increases. Exploration for ground-water resources, as a supplement to surface-water supplies, is being pursued by many city and county governments. The application of effective investigative methods to characterize complex igneous and metamorphic fractured bedrock aquifers of the Piedmont physiographic province is essential to the success of these ground-water exploration programs. The U.S. Geological Survey, in cooperation with the City of Lawrenceville, Ga., began a study in December 1994 to evaluate the applicability of various investigative techniques for field characterization of fractured crystalline-bedrock aquifers near Lawrenceville.

INTRODUCTION

Availability of water for public supply, industrial use, irrigation, and other uses is a major factor in the economy and quality of life in large urban areas of the southeastern United States. Water resources in fractured crystalline-bedrock aquifers are becoming more important in the Atlanta Metropolitan area as the need for water supplies escalates because of increased development and rapid population growth.

The City of Lawrenceville, Ga., a northeastern suburb of Atlanta (fig. 1), includes several of the fastest growing industrial and residential areas in the metropolitan area. The average demand for water ranges from a low of about 1.5 million gallons per day (Mgal/d) in the winter, to a high of about 2.9 Mgal/d in the summer (E&C Consulting Engineers, Inc., written commun., 1995). A small percentage of the city's public water supply, about 10 percent, currently (1998) is obtained from ground-water sources, and projects have been initiated to expand ground-water development. The city is investigating the possibility of using ground-water supplies to provide a primary water source to serve an estimated 20,000 people (Mr. Mike Bowie, City of Lawrenceville, oral commun., 1998). Well yields in this area, as well as in all igneous/metamorphic-rock terranes, are extremely variable and can range from zero to several hundred gallons per minute (gal/min) within a few hundred feet (ft) or less. Thus, there is imminent need to improve methods of ground-water resource evaluation in these complex igneous, metamorphic-rock hydrogeologic settings.

METHODS OF INVESTIGATIONS

The investigation of ground-water resources in the Lawrenceville area has included geologic mapping; compilation of well information; and collection and analysis of borehole geophysical logs, well cores, ground-water-level data, and ground-water-quality samples. Data (geology, well characteristics, topography, hydrography, and roads) were digitized and incorporated into a spatially oriented database for geographic information system applications. All well-construction information is stored in the USGS Ground-Water Site Inventory (GWSI) database for subsequent retrieval.

HYDROGEOLOGY

Five major lithologic units were mapped in the Lawrenceville, Ga., area as part of an ongoing study of ground-water resources—amphibolite, biotite gneiss, button schist, granite gneiss, and quartzite-aluminous schist. These units generally are thin in outcrop width, have low angles of dip (nearly 0 to 20 degrees; dip reversals occur over short distances), and exhibit some shearing characteristics. The most productive unit, on the basis of subsurface data collected through 1997, is the amphibolite. Historically, two wells drilled into this unit are recognized as having possibly the highest yields in the Piedmont region of northern Georgia. The City of Lawrenceville refurbished one well at the Rhodes Jordan Wellfield in 1990, and has pumped this well at an average rate of 230 gal/min since 1995.

Data collected from wells drilled into the amphibolite in the study area suggest that the amphibolite is more fractured at depth than are other lithologic units. These fractures constitute the secondary porosity and permeability that transmit ground water. Tectonic stresses, and

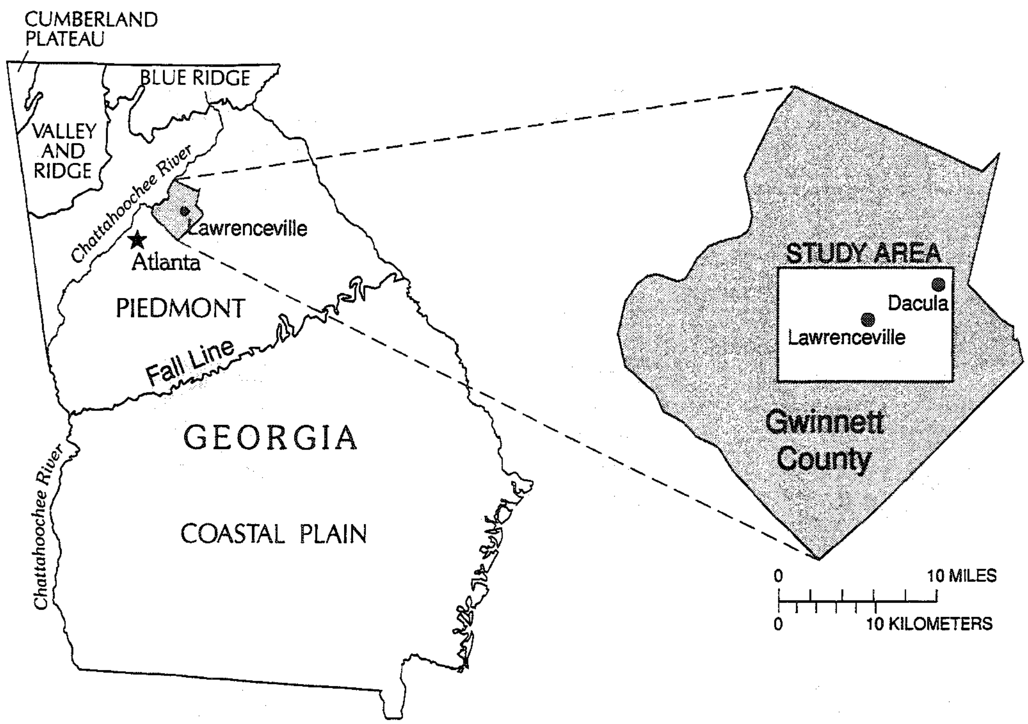

Figure 1. Location of study area in Gwinnett County and physiographic provinces in Georgia.

later erosional unloading, probably produced the closely spaced fractures in the amphibolite. The apparent increased presence of fracturing in the amphibolite may be related to the location of that unit at the crest of an apparent antiformal structure. Stress related to the folding may have enhanced fracturing potential of the amphibolite unit. In addition, well-developed compositional layering has produced zones of weakness, which were vulnerable to both tectonic stress and weathering, which also enhanced ground-water movement. With this compositional layering and a fracture network, subsequent unloading by erosion of broad valleys, could have resulted in "stress release" and opening of the fracture system. The "stress release" discussed herein is not a release of inherent stress associated with deep-seated igneous intrusions. Rather, it is more comparable to the upward expansion of the rock as a result of the removal of overlying rocks in broad valleys (elastic rebound). Large rock fragments noted during air-rotary drilling and from core samples often have fractures partially filled with minerals. Zeolites (stilbite) are the most abundant mineral, although epidote and iron sulfide minerals also are common. The presence of openings partly filled with mineral growth indicates that some of the stress-relief fractures have been open for considerable time.

As a result of the intense heat and pressure during metamorphism and structural deformation, bedrock of the Piedmont Province contains little or no primary porosity and is virtually impermeable, except where secondarily formed fractures are present. The fractures generally are discrete and discontinuous, having little storage capacity for ground water. However, when connected as a "network", together with the overlying regolith, which has large available ground-water storage capacity, these fractures can provide significant and sustained quantities of water to a well, and the encompassing rock unit is considered to be an "aquifer". The amphibolite unit mapped in Lawrenceville, Ga., is such an aquifer. Historical municipal supply records span several decades of reliable, high yields, and recent (1995-present) pumping has a sustained rate of more than 200 gal/min.

Subsurface information and lithology and fracture data are available at four sites in the study area: (1) Rhodes Jordan Park Wellfield; (2) Maltbie Street; (3) Pike Street; and (4) the Gwinnett County Airport. In some areas, natural gamma logs can be used to distinguish rock types and lithologic units. Geologic core was collected from wells at the Rhodes Jordan Park (14FF26, fig. 2) and Gwinnett County Airport (14FF42), and cuttings were collected from the Pike Street well (14FF27). The lithology in the Maltbie Street well (14FF08) was interpreted from borehole geophysical logs.

Of these four sites, the larger yielding wells, Rhodes Jordan Wellfield (14FF10, -16, -17, -18, -39, fig. 2) and Maltbie Street (14FF08), mainly penetrate the amphibo-

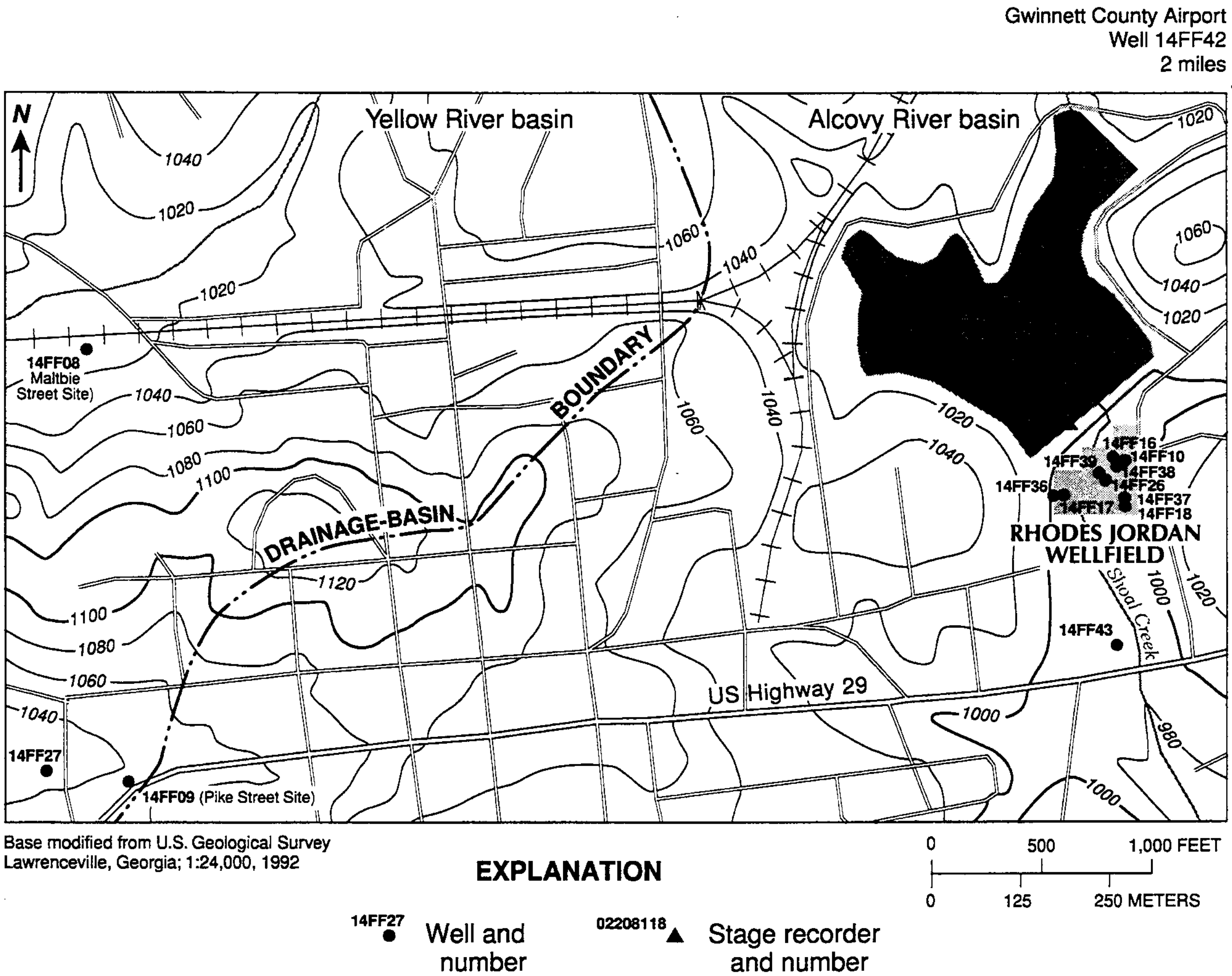

Figure 2. Location of the Rhodes Jordan Wellfield and observation wells in Lawrenceville, Georgia.

lite unit (fig. 1). Production at the Rhodes Jordan Wellfield averages about 230 gal/min. The Maltbie Street well (14FF08) has been tested at 350 gal/min. Originally projected to yield 100 gal/min, the Pike Street well (14FF27) penetrates five lithologic units; however, subsequent aquifer testing suggests a much lower overall yield. The Gwinnett County Airport well (14FF42) penetrates three lithologic units, and has an estimated yield of about 10 gal/min. In resistive crystalline rocks, such as those in the Piedmont of northern Georgia, fractures can be identified as distinctive anomalies on borehole geophysical logs. Typically, fractures are recognized most readily as an increase in borehole diameter on the caliper log, and a decrease in resistivity on electric logs (saturated fractures). Fractures intersecting the borehole in bedrock wells were identified using an integrated suite of borehole geophysical logs, including caliper, focused resistivity, long- and short-normal resistivity, gamma, acoustic televiewer and velocity, spontaneous potential, fluid temperature and resistivity, deviation, heat-pulse flowmeter, video camera logs, and single-borehole radar surveys. Subsequent to fracture zone identification, the orientation of each zone was interpreted from acoustic televiewer logs and directional borehole radar surveys (Chapman and others, 1999).

RESPONSE OF AQUIFER TO PUMPING

A major objective of this study is to evaluate the effects of ground-water withdrawal on the bedrock aquifer in Lawrenceville. Continuous water-level data—recorded in wells at 30-minute intervals—were collected from March 1995 through the present. Analyses of continuous ground-water-level data suggest that the response of the aquifer (drawdown and recovery) is directly related to the volume removed and the overall stress on the ground-water system (Chapman and others, 1999).

Various hydrologic conditions have been observed since continuous pumping began at the Rhodes Jordan Wellfield on February 1, 1996. The bedrock ground-water system reached full recovery after the shutdown for several months of the production well 14FF10 (fig. 2) on September 18, 1995. Pumping resumed in early February at a rate of about 230 gal/min. The main pumping schedule used by the City of Lawrenceville, is 5 days on and 2 days off (weekend), resulting in weekly withdrawal ranging from about 1.2 to 1.5 Mgal (E&C Consulting Engineers, Inc., written commun., 1996). The early drawdown during the first week (five days) of pumping was about 75 ft; weekend recovery ranged from about 15 to 30 ft. As pumping continues, weekly and daily drawdown decreases, and the bedrock ground-water level approaches equilibrium with the pumping rate. Although "steady-state" conditions may never actually occur, weekly net drawdown in the bedrock aquifer may be only 1 to 2 ft. In general, at the 230 gal/min pumping rate, the lowest ground-water level observed was about 135 ft below land surface at the Rhodes Jordan Wellfield.

As the demand for water supply increased in Lawrenceville, particularly during the summer, the pumping cycle was extended to as many as 18 days. When the pumping period was extended on a daily basis by the number of hours per day or by several days (assuming the pumping rate remains constant), a unique hydrologic condition of net recovery was observed.

The unusual hydrologic condition of net recovery in the bedrock aquifer was observed after a 12-day pumping cycle in September 1996. Well 14FF10 was pumped at an average rate of about 0.26 Mgal/d, and recovering for only a few hours each day. Total volume pumped during this 12-day cycle was about 3.1 Mgal. At the conclusion of the 12-day pumping cycle, the well was shut down to recover for the usual 2-day weekend period. As the 5-day, weekly pumping cycle resumed, instead of the normal loss or decline of hydraulic head in the bedrock aquifer, the net effect was an increase, or gain, in the bedrock ground-water level of about 6 ft over a period of about 3 weeks. The weekly pumping volume increased from 1.26 to 1.38 Mgal during the observed "recovery" period (Tharpe and others, 1997). This apparent recovery condition has been observed several times during this study.

The cause of the net recovery observed during pumping is indiscernible at this time. The areal influence of pumping may extend across a hydraulic boundary in the ground-water system, or the ground-water system may exhibit a pressure response, resulting in a more regional rate of recovery that is greater than pumpage at the Rhodes Jordan Wellfield. Or, the recovery may reflect the presence of steeper hydraulic gradients, from the over-stressed period, resulting in larger induced ground-water flow to the wellfield, that is apparently unaffected by the 5-day pumping cycle. The influence of rainfall on the bedrock ground-water levels is uncertain at this time. However, this unusual recovery response has been observed during relatively dry periods in the spring, summer, and fall (Chapman and others, 1999).

Tharpe and others (1997) discussed the areal effects of pumping from the Rhodes Jordan Wellfield. Two bedrock observation wells located 0.9 mi N80W (Maltbie St. well 14FF08, fig. 2) and 1.0 mi S80W (Pike St. well 14FF27) from the production well, were monitored. Weekly pumping cycles are evident in records of ground-water levels in both wells. The Maltbie Street well (14FF08) had the greater drawdown. Additional significance was noted, in that these two bedrock observation wells are located in a different drainage basin than the Rhodes Jordan Wellfield production well. The Rhodes Jordan Wellfield is located in the Alcovy River basin, the Maltbie Street observation well (14FF08, fig. 2) is located in the Yellow River basin, and the Pike Street observation well (14FF27) is located near the divide between the two basins.

CONCLUSIONS

The exploration for ground-water resources is being pursued by many local municipalities in the Atlanta Metropolitan area because of the continuing rapid pace of population growth, and the corresponding increased demand for water supplies. The igneous and metamorphic fractured bedrock aquifers in this area of the Piedmont physiographic province are highly complex and often difficult to characterize. The application of effective methods of characterization is essential to the success of these ground-water exploration programs.

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