GROUND-WATER QUALITY IN GEORGIA
FOR 2012

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ENVIRONMENTAL PROTECTION DIVISION
WATERSHED PROTECTION BRANCH
WATERSHED PLANNING AND MONITORING PROGRAM

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CIRCULAR 12Z

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CHAPTER 1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This report, covering the calendar year 2012, is the twenty-sixth of the Circular 12 series. The first 19 reports, Circulars 12A through 12S, summarized the chemical quality of ground water statewide across Georgia and utilized a static array of sampling stations that were sampled periodically, typically on an semiannual, annual, or biennial basis. The next five reports, Circulars 12T through 12X, dealt with specialized chemical ground-water quality issues: water quality in the Coastal region, water quality available to small public water systems, water quality in the Piedmont/Blue Ridge physiographic province, ground-water uranium in Georgia, and ground-water arsenic in Georgia. With this report and its predecessor, Circular 12Y, monitoring the chemical quality of ground water continues using a static array of periodically sampled stations.

These summaries are among the tools used by the Georgia Environmental Protection Division (EPD) to assess trends in the quality of the State's ground-water resources. EPD is the State organization with regulatory responsibility for maintaining and where possible, improving ground-water quality and availability. EPD has implemented a comprehensive statewide ground-water management policy of anti-degradation (EPD, 1991; 1998). Four components comprise EPD's current ground-water quality assessment program:

1. The Georgia Ground-Water Monitoring Network. EPD's Watershed Protection Branch, Source Water Assessment Program, took over the Georgia Ground-Water Monitoring Network from the Regulatory Support Program when that program disbanded. The Monitoring Network is designed to evaluate the ambient ground-water quality of eight aquifer systems present in the State of Georgia. The data collected from sampling of the Ground-Water Monitoring Network form the basis for this report.

2. Water Withdrawal Program (Watershed Protection Branch, Water Supply Section). This program provides data on the quality of ground water that the residents of Georgia are using.

3. Ground-water sampling at environmental facilities such as municipal solid waste landfills, RCRA facilities, and sludge disposal facilities. The primary agencies responsible for monitoring these facilities are EPD's Land Protection and Watershed Protection Branches.

4. The Wellhead Protection Program (WHP), which is designed to protect areas surrounding municipal drinking water wells from contaminants. The U.S. Environmental Protection Agency (EPA) approved Georgia's WHP Plan on September 30, 1992. The WHP Plan became a part of the 1-1 Georgia Safe Drinking Water Rules, effective July 1, 1993. The protection of public supply wells from contaminants is important not only for maintaining ground-water quality, but also for ensuring that public water supplies meet health standards.

Analyses of water samples collected for the Georgia Ground-Water Monitoring Network during the period January 2012 through December 2012 and from previous years form the database for this summary. The Georgia Ground-Water Monitoring Network is presently comprised of 80 stations, both wells and springs. Eighteen of the stations are scheduled for quarterly sampling; the remainder are scheduled to be sampled yearly. Each sample receives laboratory analyses for chloride, sulfate, nitrate/nitrite, total phosphorus, 26 metals, and volatile organic compounds (VOCs). Samples from the mineral spring and main well at Indian Springs State Park (stations P12A and P23) also receive analysis for fluoride. Field measurements of pH, conductivity, and temperature are performed on the sample water from each station. Field dissolved oxygen measurements are made on sample water from wells.

During the January 2012 through December 2012 period, Ground-Water Monitoring staff collected 141 samples from 74 wells and 6 springs. A review of the data from this period and comparison of these data with those for samples collected for preceding monitoring efforts indicated that ground-water quality at most of the 80 stations has remained good.

1.2 FACTORS AFFECTING CHEMICAL GROUND-WATER QUALITY

The chemical quality of ground water is the result of complex physical, chemical, and biological processes. Among the more significant controls are the chemical quality of the water entering the ground-water flow system, the reactions of the infiltrating water with the soils and rocks that are encountered, and the effects of the well-and-pump system.

Most water enters the ground-water system in upland recharge areas and areas of leakage from adjacent geologic units. Water seeps through interconnected pore spaces and fractures in the soils and rocks until discharged to a surface water body (e.g., stream, lake, or ocean). The initial water chemistry, the amount of recharge, and the attenuation capacity of soils have a strong influence on the quality of ground water in recharge areas. Chemical interactions between the water and the aquifer host rocks have an increasing significance with longer residence times. As a result, ground water from discharge areas tends to be more highly mineralized than ground water in recharge areas.

The well-and-pump system can also have a strong influence on the quality of the well water. Well casings, through compositional breakdown, can contribute metals (e.g., iron from steel casings) and organic compounds (e.g., tetrahydrofurans from PVC pipe cement) to the water. Pumps can aerate the water being drawn up and discharged. An improperly constructed or failing well can offer a conduit that allows local pollutants to enter the ground-water flow system

1.3 HYDROGEOLOGIC PROVINCES OF GEORGIA

This report defines three hydrogeologic provinces by their general geologic and hydrologic characteristics (Figure 1-1). These provinces consist of:

1. The Coastal Plain Province of south Georgia;
2. The Piedmont/Blue Ridge Province, which includes all but the northwestern corner of north Georgia;
3. The combined Valley and Ridge and Appalachian Plateau Provinces of northwest Georgia.

1.3.1 Coastal Plain Province

Georgia's Coastal Plain Province generally comprises a wedge of loosely consolidated sediments that gently dip and thicken to the south and southeast. Ground water in the Coastal Plain flows through interconnected pore space between grains and through solution-enlarged voids in rock.

The oldest outcropping sedimentary formations (Cretaceous) are exposed along the Fall Line (Figure 1-1), which is the northern limit of the Coastal Plain Province. Successively younger formations occur at the surface to the south and southeast.

The Coastal Plain of Georgia contains a number of confined and unconfined aquifers. Confined aquifers are those in which the readily permeable layer of aquifer medium is interposed between two layers of poorly permeable material (e.g. clay or shale). If the water pressure in such an aquifer exceeds atmospheric pressure, the aquifer is artesian. Water from precipitation and runoff enters the aquifers and aquifer systems in their updip outcrop areas, where permeable sediments hosting the aquifer are exposed. Water may also enter the aquifers downdip

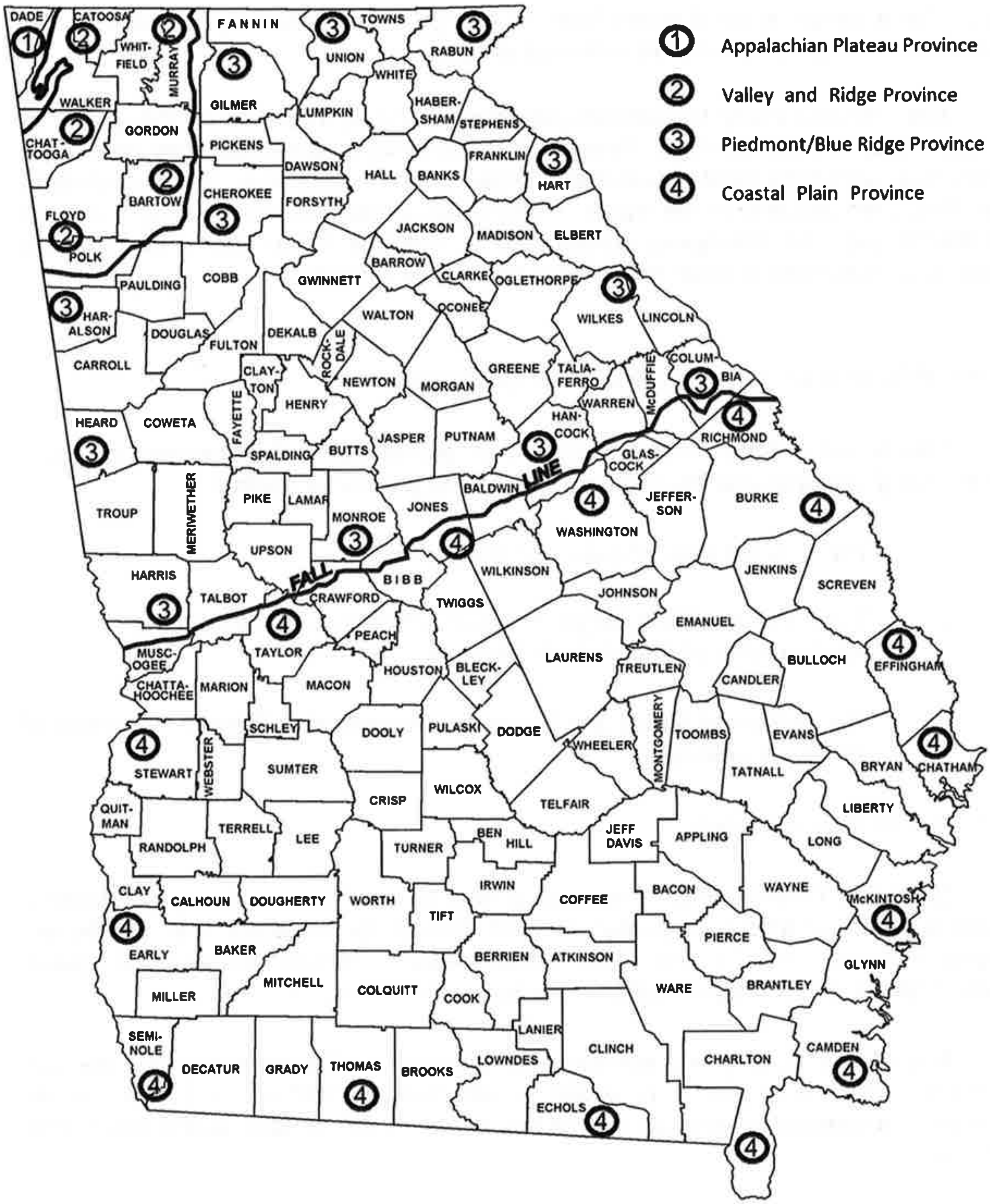


Figure 1-1. The Hydrogeologic Provinces of Georgia

from the recharge areas through leakage from overlying or underlying aquifers. Most Coastal Plain aquifers are unconfined in their updip outcrop areas, but become confined in downdip areas to the south and southeast, where they are overlain by successively younger rock formations. Ground-water flow through confined Coastal Plain aquifers is generally to the south and southeast, in the direction of dip of the sedimentary layers.

The sediments forming the major aquifer systems in the Coastal Plain range in age from Cretaceous to Holocene. Horizontal and vertical changes in the sediment layers that form these aquifer systems determine the thickness and extent of the aquifer systems. Several aquifer systems may be present in a single geographic area forming a vertical "stack".

The Cretaceous and Jacksonian aquifer systems (primarily sands) are a common source of drinking water within a 35-mile wide band that lies adjacent to and south of the Fall Line. A well has been planned to test the Cretaceous aquifer along the Atlantic coast for water supply development. Southwestern Georgia relies on three vertically stacked aquifer systems plus the upper part of the Cretaceous aquifer system for drinking water supplies: the Clayton, the Claiborne, and the Floridan aquifer systems. The Miocene/Surficial aquifer system (primarily sands) is the principal shallow aquifer system occupying much of the same broad area occupied by the Floridan aquifer system in central and eastern Georgia. The system is unconfined over most of its inland extent, but becomes in part confined both in the coastal area and in Grady, Thomas, Brooks, and Lowndes County area of South Georgia.

1.3.2 Piedmont/Blue Ridge Province

Though the Piedmont and Blue Ridge Physiographic Provinces differ geologically and geomorphologically, the two physiographic provinces share common hydrogeological characteristics and thus can be treated as a single hydrogeologic province. A two-part aquifer system characterizes the Piedmont/Blue Ridge Province (Daniel and Harned, 1997). The upper part of the system is the regolith aquifer, composed of saprolite and overlying soils and alluvium. The regolith aquifer is unconfined, and the water resides primarily in intergranular pore spaces (primary porosity). The lower aquifer in the Piedmont/Blue Ridge aquifer system is the bedrock aquifer. This aquifer is developed in metamorphic and igneous bedrock (mostly Paleozoic and Precambrian in age), and the water resides in fractures and solution-enlarged voids (secondary porosity). In contrast to the regolith aquifer, no intergranular (primary) porosity exists in the bedrock aquifer. The bedrock aquifer is semi-confined, with the overlying regolith aquifer media offering local confinement. The regolith aquifer also serves as the reservoir that recharges the bedrock aquifer.

1.3.3 The Valley and Ridge Province

Consolidated Paleozoic sedimentary formations characterize the Valley and Ridge Province. The principal porosity present in aquifer media consists of fractures and solution-enlarged voids; intergranular porosity may be important in some places. Locally, ground-water and surface-water systems closely interconnect. Dolostones and limestones of the Knox Group are the principal aquifers where they occur in fold axes at the centers of broad valleys. The greater hydraulic conductivities of the thick carbonate sections in this province permit higher yielding wells than in the Piedmont/Blue Ridge Province.

1.3.4 The Appalachian Plateau Province

Rocks in this province consist of consolidated Paleozoic sediments inclusive of the Mississippian and Pennsylvanian. Faulting and folding are less intense than in the Valley and Ridge province, and sediments tend to be flatter lying and more continuous areally. As in the Valley and Ridge Province, secondary porosity is the most important type of porosity. The highly fractured Fort Payne Chert and the Knox Group are major water-bearing units in this province.

Only a small part of this province extends into Georgia, at the State's far northwest corner (Dade County and parts of Chattooga and Walker Counties). Due to its small extent in Georgia and its lack of monitoring stations for the current project, the Appalachian Plateau Province is combined with the Valley and Ridge Province for the purposes of this report.

1.4 REGIONAL GROUND-WATER PROBLEMS

Data from ground-water investigations in Georgia, including those from the Ground-Water Monitoring Network, indicate that virtually all of Georgia has shallow ground water sufficient for domestic supply. Iron, aluminum, and manganese are the only constituents that occur routinely in concentrations exceeding drinking water standards. These metals are mostly naturally occurring and do not pose a health risk. Iron and manganese can cause reddish or yellowish-brown to dark brown or black stains on objects and can give water a bitter metallic taste. Aluminum can cause water to appear cloudy.

In the karstic carbonate terranes of the combined Valley and Ridge/ Appalachian Plateau Province, interconnection between the surface water systems and the ground-water systems can be extensive enough such that waters supplying some wells and springs (e.g., Crawfish Spring and Cedartown Spring) have been deemed under direct surface influence, requiring surface water type treatment if used for public supplies.

In the Piedmont/Blue Ridge Province, water available to wells drilled into bedrock consisting of granitic intrusive rocks, granitic gneisses, or hornblende gneiss/amphibolite assemblages occasionally may contain excessive naturally occurring uranium.

Aquifers in the outcrop areas of Cretaceous sediments south of the Fall Line typically yield acidic water that may require treatment. The acidity occurs naturally and results from the inability of the sandy aquifer sediments to neutralize acidic rainwater and from biologically influenced reactions between infiltrating water and soils. Ground-water from the Cretaceous aquifer along the coast is typically brackish.

Nitrate/nitrite concentrations in shallow ground water from the farm belt in southern Georgia are usually within drinking water standards, but are somewhat higher than levels found in other areas of the State.

Three areas of naturally reduced ground-water quality occur in the Floridan aquifer system. The first is the karstic Dougherty Plain of southwestern Georgia. The second is the Gulf Trough area. The third is in the coastal area of east Georgia.

In the Dougherty Plain, as with the carbonate terranes of northwestern Georgia, surface waters and the contaminants they entrain can directly access the aquifer through sink holes.

The Gulf Trough is a linear subsurface geologic feature extending from southwestern Decatur County through northern Effingham County and may represent a filled-in marine current channel way (Huddleston, 1993). Floridan ground water in and near the trough may be high in total dissolved solids and may contain elevated levels of sulfate, barium, radionuclides, and arsenic (Kellam and Gorday, 1990; Donahue et al., 2013).

In the Coastal area of east Georgia, the influx of water with high dissolved solids contents can dramatically raise levels of sodium, calcium, magnesium, sulfate, and chloride. In the Brunswick part of the Coastal area, ground-water withdrawal from the upper Floridan results in the upwelling of ground water with high dissolved solids content from the deeper parts of the aquifer system (Krause and Clarke, 2001). In the Savannah portion of the Coastal area, heavy pumping in and around Savannah has caused a cone of depression which has induced seawater to enter the Floridan aquifer system and to flow down-gradient toward Savannah. The seawater has not yet reached Savannah and may not for many years. The seawater then enters the aquifer system via breaches in the Miocene confining unit along the bottoms of waterways and sand-filled paleochannels offshore at the Beaufort/Hilton Head area of South Carolina (Foyle et al., 2001; Krause and Clarke, 2001).

CHAPTER 2 GEORGIA GROUND-WATER MONITORING NETWORK

2.1 MONITORING STATIONS

For the period January 2012 through December 2012, attempts were made to place sampling stations in the Coastal Plain Province's six major aquifer systems, in the Piedmont/Blue Ridge Province, and in the Valley and Ridge/Appalachian Plateau Province (Table 2-1). Stations are restricted to wells or springs tapping a single aquifer or aquifer system. Attempts were made to have some monitoring stations located in the following critical settings:

1. areas of recharge;
2. areas of possible pollution or contamination related to regional activities (e.g., agricultural and industrial areas) or to hydrogeologic settings (e.g., granitic intrusions, Dougherty Plain);
3. areas of significant ground-water use.

Most of the monitoring stations are municipal, industrial, and domestic wells that have well construction data.

2.2 USES AND LIMITATIONS

Regular sampling of wells and springs of the Ground-Water Monitoring Network permits analysis of ground-water quality with respect to location (spatial trends) and time of sample collection (temporal trends). Spatial trends are useful for assessing the effects of the geologic framework of the aquifer and regional land-use activities on ground-water quality. Temporal trends permit an assessment of the effects of rainfall and drought periods on ground-water quality and quantity. Both trends are useful for the detection of non-point source pollution. Non-point source pollution arises from broad-scale phenomena such as acid rain deposition and application of agricultural chemicals on crop lands.

It should be noted that the data of the Ground-Water Monitoring Network represent water quality in only limited areas of Georgia. Monitoring water quality at the 80 sites located throughout Georgia provides an indication of ground-water quality at the locality sampled and at the horizon corresponding to the open interval in the well or to the head of the spring at each station in the Monitoring Network. Caution should be exercised in drawing unqualified conclusions and applying any results reported in this study to ground waters that are not being monitored.

Table 2-1. Georgia Ground-Water Monitoring Network, Calendar Year 2012.

Aquifer or Aquifer System	**Number of Stations Visited (Samples Taken)**	**Primary Stratigraphic Equivalents**	**Age of Aquifer Host Rocks**
Cretaceous	12 stations (13 samples)	Ripley Formation, Cusseta Sand, Blufftown Formation, Eutaw Formation, Tuscaloosa Formation, Providence Sand, Steel Creek Formation, Gaillard Formation, Pio Nono Formation	Late Cretaceous
Clayton	1 station (1 sample)	Clayton Formation	Paleocene
Claiborne	3 stations (3 samples)	Claiborne Group	Middle Eocene
Jacksonian	5 stations (5 samples)	Barnwell Group	Late Eocene
Floridan	28 stations (58 samples)	Ocala Group, Suwanee Limestone	Middle Eocene to Early Oligocene
Miocene/Surficial	6 stations (6 samples)	Hawthorne Group, Miccosukee Formation, Cypresshead Formation	Miocene to Recent
Piedmont/Blue Ridge	19 stations (46 samples)	Various igneous and metamorphic complexes	Precambrian and Paleozoic
Valley and Ridge/ Appalachian Plateau	6 stations (9 samples)	Shady Dolomite, Knox Group, Conasauga Group	Paleozoic, mainly Cambrian, Ordovician

Stations of the Ground-Water Monitoring Network are intentionally located away from known point sources of pollution. The stations provide baseline data on ambient water quality in Georgia. EPD requires other forms of ground-water monitoring for activities that may result in point source pollution (e.g., landfills, hazardous waste facilities, and land application sites) through its environmental facilities permit programs.

Ground-water quality changes gradually and predictably in the areally extensive aquifer systems of the Coastal Plain Province. The Monitoring Network allows for some definition of the chemical processes occurring in large confined aquifers. Unconfined aquifers in northern Georgia and in the surface recharge areas of southern Georgia are of comparatively small extent and more open to interactions with land use activities. The wide spacing of most monitoring stations does not permit equal characterization of water-quality processes in these settings. The quality of water from monitoring stations drawing from unconfined aquifers represents only the general nature of ground water in the vicinity of the stations. Ground water in the recharge areas of the Coastal Plain aquifer systems is one of the future drinking-water resource for down-flow areas. Monitoring stations in these recharge areas, in effect, constitute an early warning system of potential future water quality problems in confined portions of the Coastal Plain aquifer systems.

2.3 ANALYSES AND DATA RETENTION

Analyses are available for 141 water samples collected from 80 stations (74 wells and 6 springs) during the period January 2012 through December 2012. In 1984, the first year of the Ground-Water Monitoring Network, EPD staff sampled from 39 wells in the Piedmont/Blue Ridge and Coastal Plain Provinces. Between 1984 and 2004, the network had expanded to include 128 stations situated in all three hydrogeologic provinces, with most of the stations being in the Coastal Plain Province.

Ground water from all monitoring stations is tested for chloride, sulfate, nitrate/nitrite, total phosphorus, a variety of metals, and VOCs. Water from stations P12A and P23 also receive testing for fluoride. Appendix Table A-9 lists the EPA methods used to test for these analytes along with a reporting limit for each analyte. The results of the chemical tests are reported in this Circular. Before collecting a sample, EPD personnel also observe certain field measurements – pH, conductivity, dissolved oxygen, and temperature. This Circular also reports these measurements.

Testing for aluminum, beryllium, calcium, cobalt, iron, potassium, magnesium, manganese, sodium, titanium, and vanadium was undertaken using the inductively-coupled plasma (ICP) method (EPA method 200.7 in Table A-9). This method works well for the mostly major metals listed above. This method was also used to test for arsenic, barium, cadmium, chromium, copper, nickel, lead antimony, selenium, thallium, and zinc. The inductively-coupled plasma mass spectrometry (ICPMS) method (EPA method 200.8 in Table A-9) was also used to test for the metals mentioned in the previous sentence as well as for molybdenum, silver, tin, and uranium. The ICPMS method generally gives better results for trace metals.

Pursuant to the Georgia Safe Drinking Water Act of 1977, EPD has established Maximum Contaminant Levels for certain analytes and other parameters, certain of which are included in analyses performed on Ground-Water Monitoring samples (EPD, 2009). Primary MCLs pertain to analytes that may adversely affect human health if the maximum concentration for an analyte is exceeded for drinking water. Secondary MCLs pertain to parameters that may give drinking water objectionable, though not health-threatening, properties that may cause persons served by a public water system to cease using the water. Unpleasant taste and the ability to cause stains are examples of such properties. Strictly, MCLs apply only to treated water offered for public consumption; nevertheless, they constitute useful guide lines for evaluating the quality of untreated (raw) water. Table A-10 in the Appendix lists the Primary and Secondary MCLs for Ground-Water Monitoring Network analytes.

Most wells currently on the Monitoring Network have in-place pumps. Using such pumps to purge wells and collect samples reduces the potential for cross-contamination that would attend the use of portable pumps. Two wells, PA9C and MI17, are flowing, which dispenses altogether with pumps and lessens the effects of the pump-well system on sample water. The pump on well MI9A, a shallow bored well formerly used for garden watering, is now out of operation, and, a bailer is used for sampling.

Sampling procedures are adapted from techniques used by USGS and USEPA. For wells except PA9C, MI9A, and MI17, EPD personnel purge the wells (EPA recommends removing three to five times the volume of the water column in the well) before collecting a sample to reduce the influence of the well, pump, and plumbing system on water quality. A purge of 15 to 20 minutes is usually sufficient to allow readings of pH, conductivity, temperature, and dissolved oxygen to stabilize and to allow corrosion films on the plumbing to be flushed away.

The apparatus used for monitoring field measurements and collecting samples consists of a garden hose with two branches at its end and a container. One branch conveys water to a container; the other branch allows the water to flow freely. On the container branch, water enters the bottom of the container, flows past the probe of the instrument taking field measurements, and discharges over the top of the container. Such an apparatus minimizes the exposure of the sample water to atmosphere. Once the field measurements have stabilized, sample containers are then filled with water discharging from the end of the free-flowing branch. Sample waters do not pass through a filter before collection. As a rule, trends for field measurements with increasing purge time include a lowering of pH, conductivity, and dissolved oxygen. For shallower wells, the temperature tends to approach the mean atmospheric temperature for the area. For deeper wells geothermal heating may become apparent.

Once the sample bottles are filled, they are promptly placed on ice to preserve water quality. EPD personnel transport samples to the laboratory on or before the Friday of the week during which the samples were collected, well before holding time for the samples lapse. Field measurements and analytical results are provided in Table A-1 in the Appendix.

Files at EPD contain records of the field measurements and chemical analyses. Owners of wells or springs receive copies of the laboratory analysis sheets as well as cover letters and laboratory sheet summaries. The cover letters state whether or not any MCLs were exceeded. The Drinking Water Program's Compliance and Enforcement Unit receives notification of Primary MCL exceedances involving public water supplies.

CHAPTER 3 CHEMICAL GROUND-WATER QUALITY IN GEORGIA

3.1 OVERVIEW

Georgia's major aquifer systems are grouped into three hydrogeologic provinces for the purposes of this report: the Coastal Plain Province, the Piedmont/Blue Ridge Province, and the Valley and Ridge/Appalachian Plateau Province.

The Coastal Plain Province comprises six major aquifer systems that are restricted to specific regions and depths within the Province (Figure 3-1). These major aquifer systems commonly incorporate smaller aquifers that can be locally confined. Ground-Water Monitoring Network wells in the Coastal Plain aquifer systems are generally located in three settings:

1. Recharge (or outcrop) areas that are located in regions that are geologically updip and generally north of confined portions of these aquifer systems;

2. Updip, confined areas that are located in regions that are proximal to the recharge areas, yet are confined by overlying geologic formations. These are generally south to southeast from the recharge areas;

3. Downdip, confined areas, located to the south or southeast in the deeper, confined portions of the aquifer systems, distal to the recharge areas.

The Piedmont/Blue Ridge Province comprises two regional aquifers, the regolith aquifer and the bedrock aquifer (Daniel and Harned, 1997). The regolith aquifer is composed of saprolite – bedrock that has undergone intense chemical weathering -- plus soil and alluvium. The regolith aquifer, highly porous and appreciably permeable, serves as the reservoir that recharges the bedrock. The igneous and metamorphic bedrock exhibits low porosity – nearly all of the porosity consists of fractures but can be very permeable as fractures can transmit water rapidly. Despite the regional scale of these two aquifers, flow systems are small-scale and localized, in contrast to those of the Coastal Plain.

Paleozoic sedimentary formations characterize the combined Valley and Ridge/Appalachian Plateau Province, although, unlike in the Coastal Plain, these sedimentary formations are consolidated and have been subjected to faulting and folding. Also in contrast to the case in the Coastal Plain Province, the faulting and folding has resulted in the creation of numerous, small-scale localized flow systems in the Valley and Ridge/Appalachian Plateau Province. The major water-bearing units in the province are carbonate rocks. Faulting and fracturing of the carbonates has led to the widespread development of karst features, which significantly

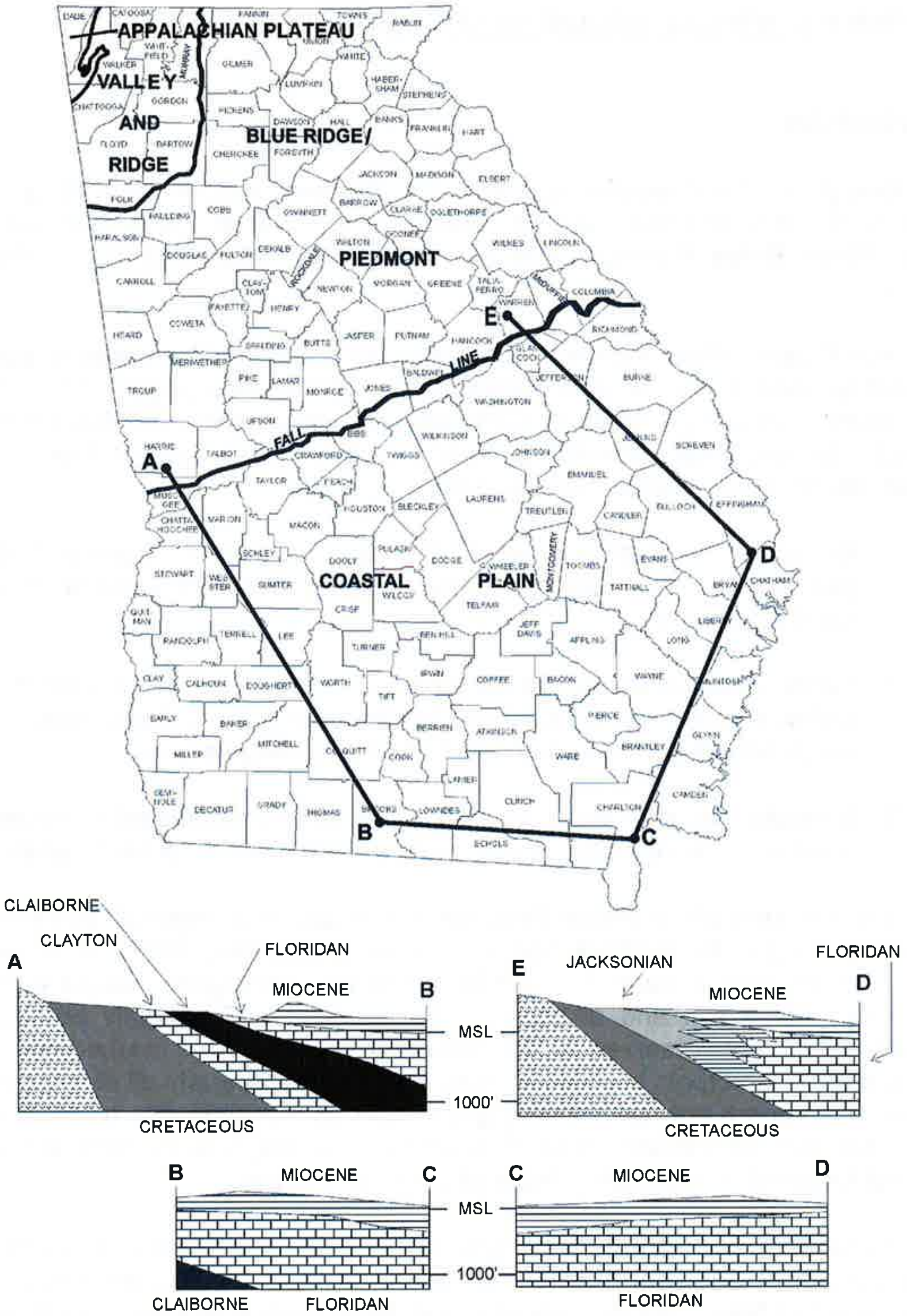


Figure 3-1. The Major Aquifers and Aquifer Systems of the Coastal Plain Province (after Davis, 1990).

enhance porosity and permeability and exert a strong influence on local flow patterns.

3.2 CRETACEOUS AQUIFER SYSTEM

3.2.1 Aquifer System Description

The Cretaceous aquifer system is a complexly interconnected group of aquifer subsystems developed in the late Cretaceous sands of the Coastal Plain Province. These sands crop out in an extensive recharge area immediately south of the Fall Line in west and central Georgia (Fig. 3-2). In east Georgia, overlying Tertiary sediments restrict Cretaceous outcrops to valley bottoms. Five distinct subsystems of the Cretaceous aquifer system, including the Providence aquifer, are recognized west of the Ocmulgee River (Pollard and Vorhis, 1980). These merge into three subsystems to the east (Clarke et al, 1985; Huddlestun and Summerour, 1996). The aquifer thickens southward from the Fall line, where the clays and sands pinch out against crystalline Piedmont rocks to a column approximately 2,000 feet thick or more at the southern limits of the main aquifer use area (limit of current utilization, Figure 3-2).

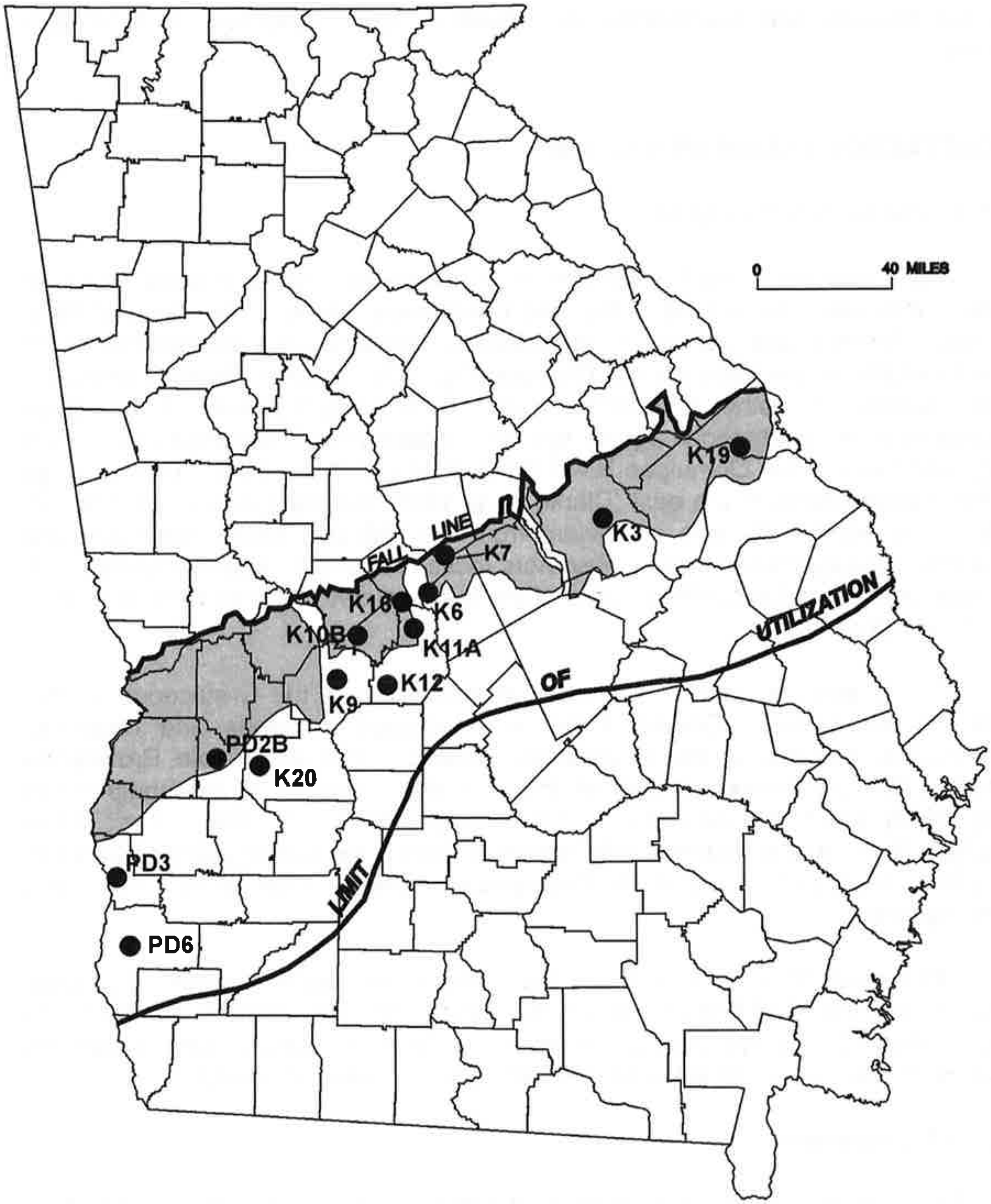
The Providence aquifer, a prominent subsystem of the Cretaceous aquifer system in the western Coastal Plain, is developed in sands and coquinoid limestones at the top of the Cretaceous column. The permeable Providence Formation-Clayton Formation interval forms a single aquifer in the updip areas (Long, 1989) and to the east of the Flint River (Clarke et al., 1983). East of the Ocmulgee River, this joint permeable interval is termed the Dublin aquifer (Clarke et al., 1985). This report considers the Providence aquifer as a part of the Cretaceous aquifer system.

EPD used 12 wells to monitor the Cretaceous aquifer system. Reported depths ranged from 128 feet (Jones Co. #4, K7) to 1025 feet (Blakely #4, PD6). All except KaMin #6 (K6) are local government owned public supply wells. KaMin #6 produces process water for a kaolin mill. All wells are sampled yearly.

3.2.2 Field parameters

The pHs of sample waters from all 12 wells ranged from 3.90 (K12) to 8.38 (PD6). As a rule, pHs of waters from the deeper wells are basic, while those from shallower wells are acidic. Well PD3 seems to be the exception. Its sampling pH of 8.37 would be expected for a well about twice its reported depth of 456 feet.

Conductivities are available for all 12 wells and ranged from 10 uS/cm (K10B) to 355 uS/cm (PD3), with a median of 39 uS/cm. As a rule, the deeper wells gave water with the higher conductivities. Again, well PD3 was the exception.



▨ General recharge area (from Davis et al., 1989)

● Sampling station

Figure 3-2. Locations of Stations Monitoring the Cretaceous Aquifer System.

The temperatures measured should be viewed as approximations of the temperature of the water in the aquifer. Temperatures over all 12 wells ranged from 17.7 degrees C (K7) to 28.9 degrees C (K20). Comparing well depths with sample water temperatures shows that the deeper wells generally tend to yield water with higher temperatures. The water temperature can also depend somewhat on the time of year measured, since sample water must traverse a zone influenced by surface temperature on its way from the aquifer to the measurement point.

Dissolved oxygen measurements are available for 11 of the 12 wells. Concentrations ranged from 0.01 mg/L (K9A) up to 8.00 mg/L (K19). Generally, the dissolved oxygen content of ground water decreases with depth. Dissolved oxygen measurements can suffer from various interferences, processes that can expose the ground water to air. An inadequately purged well may deliver water that has been in contact with air in the well bore. Pumping a well's water level down near the pump intake can entrain air in the pumped water. Also, pumping the water level in the well below a recharging horizon allows water to "cascade" or fall freely down the well bore and splash, thereby becoming aerated.

3.2.3 Major Anions, Non-Metals, and Volatile Organic Compounds

Testing for chloride, sulfate, combined nitrate/nitrite, total phosphorus, and volatile organic compounds (VOCs) was done for samples from all 12 wells. Detectable chloride, at a concentration of 10 mg/L, occurred only in a sample from well PD3. Sulfate was detected in samples from four wells, with concentrations all at or below 13 mg/L. Nitrate/nitrite, detected in eight samples from seven wells ranged from not detectable to 1.8 mg/L. Samples from seven wells contained detectable phosphorus, with concentrations ranging up to 0.43 mg/L.

3.2.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

All 12 samples contained detectable sodium, which ranged from 1,000 ug/L at two wells (K9A, K12) to 83,000 ug/L (PD3). Three wells - K20, PD3, and PD6 – gave samples with sodium contents an order of magnitude higher than the remainder of the wells. Two of these, K20 and PD6, were also the two deepest wells. A high reporting limit attends the laboratory's current procedure for analyzing potassium and contributes to the lack of potassium detections.

Five wells gave samples with detectable aluminum, with concentrations up to 490 ug/L (K9A). Seven samples from seven wells contained detectable calcium, and, eight samples from seven wells contained detectable iron. Calcium levels ranged up to 22,000 ug/L (K3). Iron levels ranged up to 650 ug/L (K6) with five wells giving samples exceeding the Secondary MCL of 300 ug/L. Samples from four wells contained detectable magnesium, with a maximum value of 4,200 ug/L

(PD6). Four wells gave samples with detectable manganese. None exceeded the Secondary MCL of 50 ug/L.

Beryllium, cobalt, potassium, vanadium, and titanium were undetected.

3.2.5 Metals by Inductively-Coupled Plasma Mass Spectrometry (ICPMS)

ICPMS analysis found only copper, zinc, barium, lead, and uranium. Barium was detected in samples from all wells except K20, with a maximum concentration of 28 ug/L (K3). Lead was detected in seven samples from six wells, with a concentration range up to 29 ug/L (K12). In addition to the exceedance for well K12, the lead concentration in the sample from well K19 also exceeded the action level of 15 ug/L. The K19 exceedance seems to have resulted from entrainment of a corrosion film on a little-used spigot into the sample water. Copper was detected in six samples from six wells and ranged in concentration up to 48 ug/L (K9A). Zinc was detected in five samples from four wells, at levels up to 180 ug/L (K19). A follow-up sample taken from a different spigot on well K19 registered a lead concentration of 1.2 ug/L, a zinc concentration of 14 ug/L, and no detectable copper. Copper, lead, and zinc are commonly introduced into sample water from plumbing and are not necessarily present naturally. Uranium was detected in one sample (K6) at a level of 1.1 ug/L.

3.3 CLAYTON AQUIFER

The Clayton aquifer of southwestern Georgia is developed mainly in the middle limestone unit of the Paleocene Clayton Formation. Limestones and calcareous sands of the Clayton aquifer crop out in a narrow belt extending from northeastern Clay County to southwestern Schley County (Figure 3-3). Aquifer thickness varies, ranging from about 50 feet in the outcrop area to 265 feet in southeastern Mitchell County (Clarke et al., 1984). Both the Flint River to the east and the Chattahoochee River, to the west are the areas of discharge for the aquifer in its updip extent. Leakage from the underlying Providence aquifer and from overlying permeable units in the Wilcox Formation confining zone provides significant recharge in downdip areas (Clarke et al., 1984). As mentioned previously, permeable portions of the Clayton and Providence Formations merge to form a single aquifer in the updip area and east of the Ocmulgee River. East of that river these combined permeable zones are called the Dublin aquifer.

Only one well (CT8), an 80-foot deep domestic well, was available to monitor the Clayton aquifer. The well is sampled yearly. The well water had a pH of 4.27, an electrical conductivity of 45 uS/cm, and a temperature of 18.2 degrees C. Dissolved oxygen was 7.90 mg/L and nitrate/nitrite registered at 2.1 mg/L as nitrogen. The water contained sodium at a level of 3,400 ug/L, magnesium at a level of 1,100 ug/L, aluminum at a level of 120 ug/L, and manganese at a level of 26

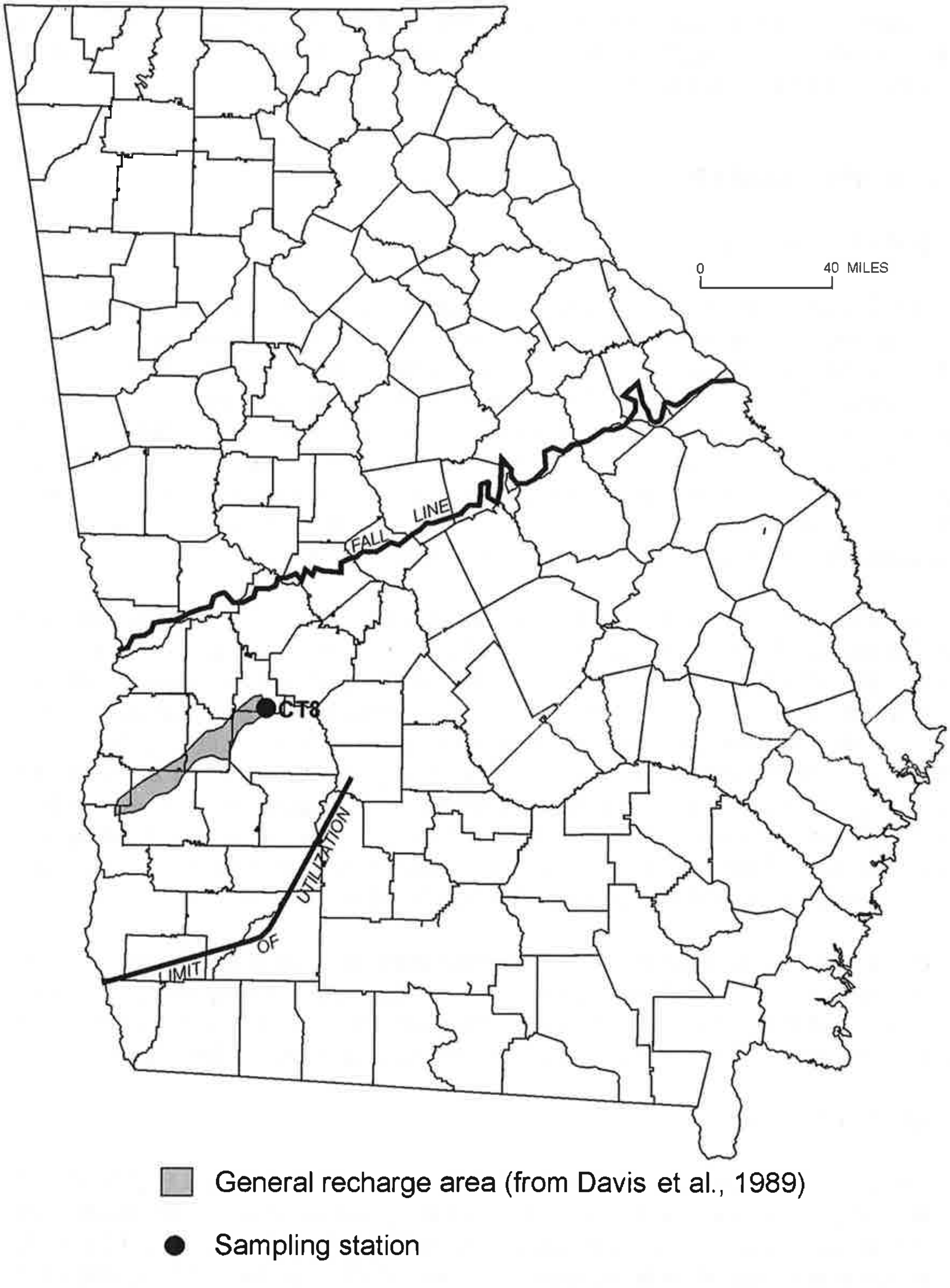


Figure 3-3. Location of the Station Monitoring the Clayton Aquifer.

ug/L. Copper at a concentration of 20 ug/L, lead at a level of 5.6 ug/L, and barium at a concentration of 26 ug/L were the trace metals detected. Copper and lead were probably leached from plumbing.

3.4 CLAIBORNE AQUIFER

3.4.1 Aquifer Description

The Claiborne aquifer is developed primarily in the sandy units in the middle and lower portion of the Middle Eocene Claiborne Group of southwestern Georgia. Claiborne Group sands crop out in a belt extending from northern Early County through western Dooly County. Recharge to the aquifer occurs both as direct infiltration of precipitation in the recharge area and as leakage from the overlying Floridan aquifer system (Hicks et al., 1981; Gorday et al., 1997). The discharge boundaries for the updip portion of the aquifer are the Ocmulgee River to the east and the Chattahoochee River to the west. The aquifer is more than 350 feet thick near its downdip limit of utilization (Figure 3-4) (Tuohy, 1984).

The aquifer generally thickens to the southeast. The clay-rich upper portion of the Claiborne Group, the Lisbon Formation, acts as a confining layer and separates the Claiborne aquifer from the overlying Floridan aquifer system (McFadden and Perriello, 1983; Long, 1989; Huddlestun and Summerour, 1996). The lower, water-bearing parts of the group had been correlated with the Tallahatta Formation (e.g., McFadden and Perriello, 1983; Long, 1989: Clarke et al., 1996) or more recently, have been divided into two formations, the upper one termed the Still Branch Sand and the lower one correlated to the Congaree Formation (Huddlestun and Summerour, 1996). East of the Ocmulgee River, permeable Congaree-equivalent sands are included in the Gordon aquifer (Brooks et al., 1985).

Three stations, all in or near the recharge area, were available to monitor the Claiborne aquifer. Wells CL2 and CL4A are municipal public supply wells, and, well CL8 supplies water for drinking and other purposes for a State tree nursery. Well CL2 is 315 feet deep, CL4A is 230 feet deep, and CL8 is about 90 feet deep.

3.4.2 Field parameters

The pHs of sample waters from two wells was mildly acidic (CL8 at 6.20 and CL4A at 6.78) while the third was mildly basic (CL2 at 7.54). Conductivities registered at 53 uS/cm (CL8), 98 uS/cm (CL4A), and 127 uS/cm (CL2); and, temperatures registered at 19.8 degrees C (CL4A), 20.3 degrees C (CL2), and 20.7 degrees C (CL8). Dissolved oxygen contents measured at 0.02 mg/L (CL8) and 3.10 mg/L (CL2). Collecting a sample from well CL4A exposes the sample water to air; therefore water from CL4A received no dissolved oxygen measurement.

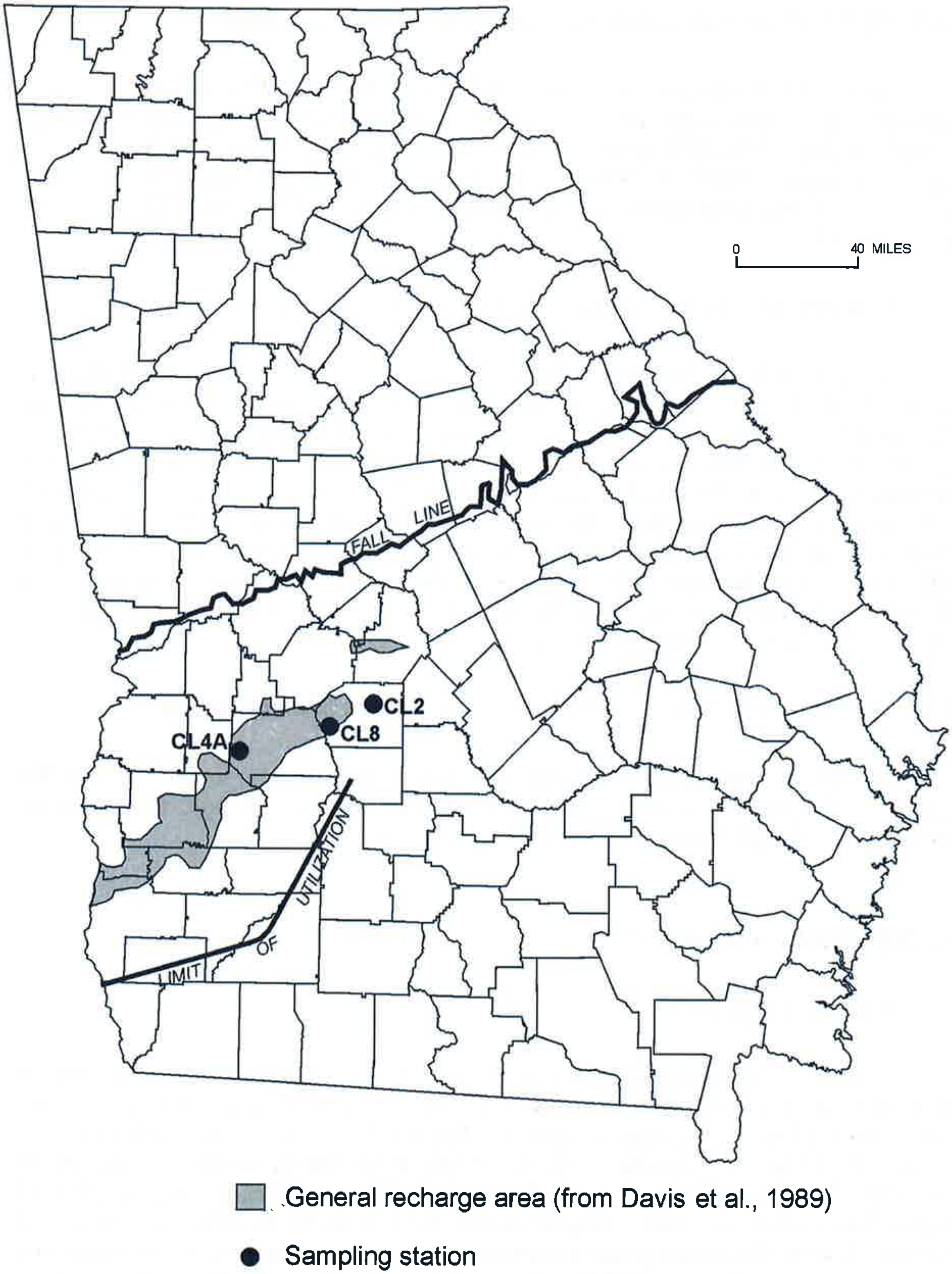


Figure 3-4. Locations of Stations Monitoring the Claiborne Aquifer.

3.4.3 Major Anions, Non-Metals, and Volatile Organic Compounds

None of the samples contained detectable chloride. The sample from well CL2 contained a little chloroform (0.55 ug/L). The sample from well CL4A contained 12 mg/L sulfate. Well CL2 gave a sample with a nitrate/nitrite concentration of 0.41 mg/L as nitrogen. The other two wells gave waters with no detectable nitrate/nitrite. Samples from two wells contained detectable phosphorus (CL4A at 0.35 mg/L, CL8 at 0.51 mg/L).

3.4.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

Calcium and sodium were detected in samples from all three wells. The maximum and minimum calcium concentrations were 39,000 ug/L and 12,000 ug/L (CL2 and CL8). The maximum and minimum sodium concentrations were 1,900 ug/L (CL8) and 1,700 ug/L (CL2 and CL4A). Detectable magnesium occurred in samples from wells CL4A (3,000 ug/L) and CL8 (1,200 ug/L). Wells CL4A and CL8 both gave samples containing detectable iron and manganese. With iron levels of 1,800 ug/L for the CL4A sample and 650 ug/L for the CL8 sample and waters from both wells exceeded the 300 ug/L Secondary MCL for iron. Likewise, the manganese levels of 56 ug/L for CL4A and 51 ug/L for CL8 both exceeded the Secondary MCL for that metal of 50 ug/L.

3.4.5 Metals by Inductively-Coupled Plasma Mass Spectrometry (ICPMS)

ICPMS analyses found no trace metals other than barium in any of the samples. Barium levels were 11ug/L for the CL2 sample, 12 ug/L for the CL4A sample, and 36 ug/L for the CL8 sample.

3.5 JACKSONIAN AQUIFER

3.5.1 Aquifer Description

The Jacksonian aquifer (Vincent, 1982) of central and east-central Georgia is developed primarily in sands of the Eocene Barnwell Group, though isolated limestone bodies are locally important. Barnwell Group outcrops extend from Macon and Crawford Counties (Hetrick, 1990) eastward to Burke and Richmond Counties (Hetrick, 1992). Figure 3-5 shows the extent and most significant Jacksonian recharge areas. Aquifer sands form a northern clastic facies of the Barnwell Group; the sands grade southward into less permeable silts and clays of a transition facies (Vincent, 1982). The water-bearing sands are relatively thin, ranging from 10 to 50 feet in thickness. Limestones equivalent to the Barnwell

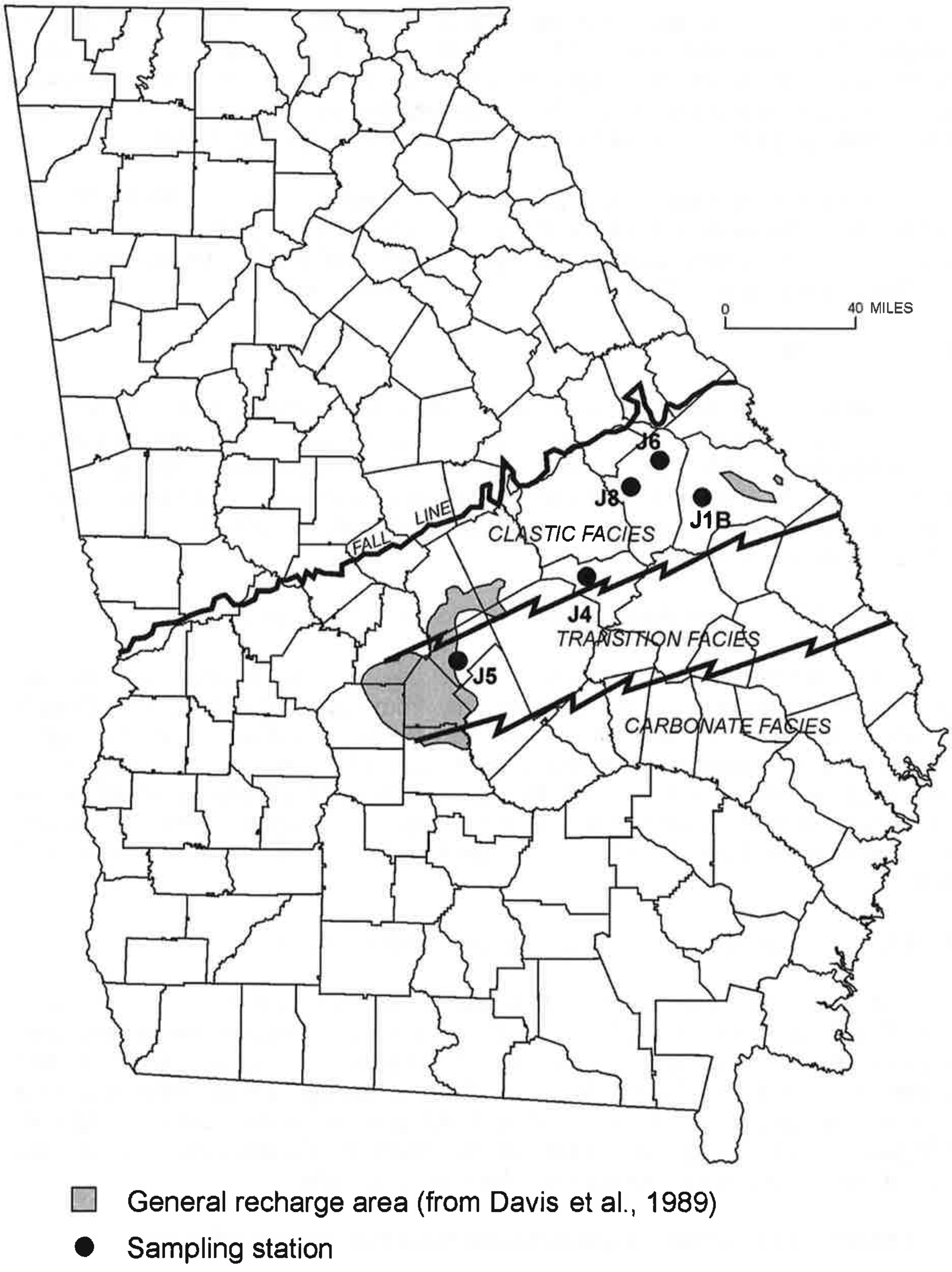


Figure 3-5. Locations of Stations Monitoring the Jacksonian Aquifer.

Group form a southern carbonate facies and are included in the Floridan aquifer system. The Savannah River and the Flint River are the eastern and western discharge boundaries for the updip parts of the Jacksonian aquifer. The Jacksonian aquifer is equivalent to the Upper Three Runs aquifer, as discussed by Summerour et al. (1994), page 2, and Williams (2007), "General Hydrogeology" table.

Five wells were available to monitor the Jacksonian aquifer. Wells J1B and J8A are domestic wells, while wells J4, J5, J6 are public supply wells. All are drilled wells, and, each is scheduled for yearly sampling. Well J8A was adopted as a substitute, replacing well J8 while it is down for maintenance.

3.5.2 Field parameters

The pHs for all wells except J6 were slightly basic, ranging from 7.13 (J1B) to 7.50 (J5). Well J6 was barely acidic at 6.97. Conductivities ranged from 212 uS/cm (J5) to 296 uS/cm (J8A). Temperatures ranged from 19.0 degrees C for J8A to 20.5 degrees C for J5, with water from the deeper wells registering higher temperatures. Dissolved oxygen concentrations ranged from 0.00 mg/L for well J5 to 5.98 mg/L for J1B and were lowest in the deeper wells.

3.5.3 Major Anions, Non-Metals, and Volatile Organic Compounds

No sample waters contained detectable volatile organic compounds. Chloride was detected in sample water only from well J1B (10 mg/L). Sample waters from wells J5 and J6 contained detectable sulfate (both 12 mg/L). Nitrate/nitrite was detected in samples from wells J1B (2.6 mg/L as nitrogen), J4 (0.06 mg/L as nitrogen), and J8A (0.04 mg/L as nitrogen), all measurements below the human-influenced range of greater than 3 mg/L as nitrogen. Phosphorus was detected in water from all wells and ranged from 0.03 mg/L (J4 and J8A) to 0.15 mg/L (J6).

3.5.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

All five wells gave waters with detectable calcium, with a rather tight range from 50,000 ug/L (J4 and J6) to 66,000 ug/L (J5). Magnesium ranged from undetected (J1B) to 2,600 ug/L (J4). Detectable sodium occurred in each well and ranged in concentration from 1,900 ug/L (J6) to 4,500 ug/L (J1B). Well J6 gave a sample containing 150 ug/L iron; and, well J8A gave a sample containing 22 ug/L manganese. According to a rule set forth in Kellam and Gorday (1990), all of these wells derive most of their recharge from local surface water.

3.5.5 Metals by Inductively-Coupled Plasma Mass Spectrometry (ICPMS)

All five wells yielded waters containing detectable barium, with a range from 7.5 ug/L (J6) to 21 ug/L (J1B). The only other detectable metal found with ICPMS was copper, with a level of 6.6 ug/L in water from well J4. The copper was likely leached from well plumbing.

3.6 FLORIDAN AQUIFER SYSTEM

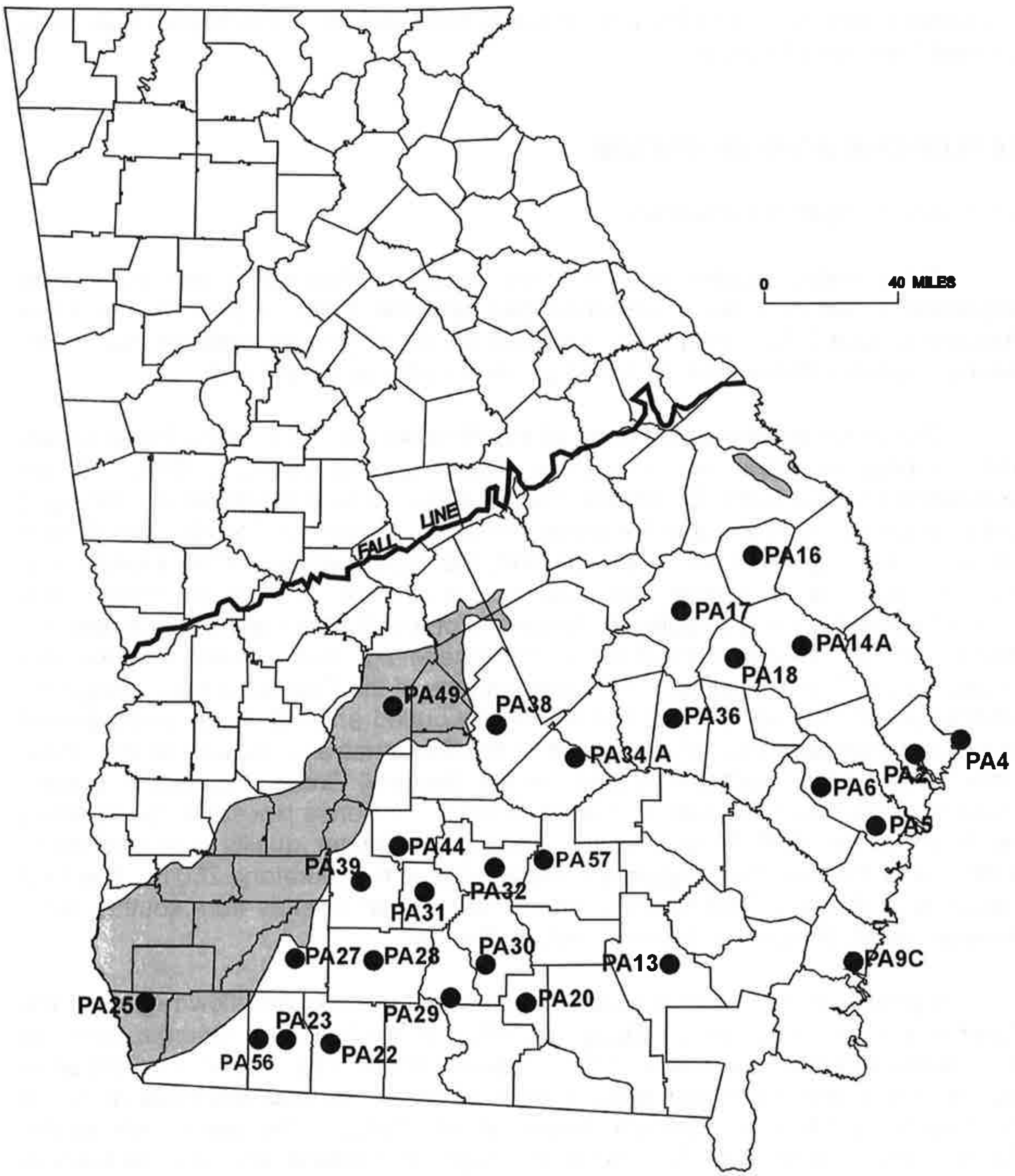
3.6.1 Aquifer System Description

The Floridan aquifer system is developed predominantly in Eocene and Oligocene limestones and dolostones that underlie most of the Coastal Plain Province (Figure 3-7). The aquifer is a major source of ground water for much of its outcrop area and throughout its downdip extent to the south and east.

The upper water-bearing units of the Floridan are the Eocene Ocala Group and the Oligocene Suwanee Limestone (Crews and Huddlestun, 1984). These limestones crop out in the Dougherty Plain (a karstic area in southwestern Georgia) and in adjacent areas along strike to the northeast. In parts of Camden and Wayne Counties, the Oligocene unit is absent, and, the upper portions of the Floridan are restricted to units of Eocene age (Clarke et al., 1990). The lower parts of the Floridan consists mainly of dolomitic limestone of middle and early Eocene age and pelletal, vuggy, dolomitic limestone of Paleocene age but extends into the late Cretaceous in Glynn County. The lower portions of the Floridan are hydrologically continuous with the upper parts but are deeply buried and not widely used, except for several municipal and industrial wells in the Savannah area (Clarke et al., 1990). From its updip limit, defined by clays of the Barnwell Group, the aquifer system thickens to well over 700 feet in coastal Georgia. A dense limestone facies along the trend of the Gulf Trough locally limits ground-water quality and availability (Kellam and Gorday, 1990; Applied Coastal Research Laboratory, 2001). The Gulf Trough is probably a filled marine-current channel that extends from southwestern Decatur County through northern Effingham County.

A ground-water divide separates a smaller southwestward flow regime in the Floridan aquifer system in the Dougherty Plain in southwestern Georgia from the large southeastward flow regime in the remainder of the State. Rainfall infiltration in outcrop areas and downward leakage from extensive surficial residuum recharge the Dougherty Plain flow system (Hayes et al., 1983). The main body of the Floridan aquifer system to the east is recharged by leakage from the Jacksonian aquifer system and by rainfall infiltration in outcrop areas and in areas where overlying strata are thin. Significant recharge also occurs in the area of Brooks, Echols, Lowndes, Cook, and Lanier Counties, where the Withlacoochee River and numerous sinkholes breach the upper confining units (Krause, 1979).

Monitoring water quality in the Floridan aquifer system made use of 28 wells, with 18 scheduled for sampling on a yearly basis and 10 on a quarterly basis. The total number of samples collected from the wells was 58, including a repeat sample



▨ General recharge area (from Davis et al., 1989)

● Sampling station

Figure 3-6. Locations of Stations Monitoring the Floridan Aquifer System.

(PA6) and a cancelled quarterly sample (PA44). All 28 wells are drilled wells. Twenty four wells are local-government-owned public supply wells. Two wells supply industrial process water. One remaining well (PA49) is a domestic-type well supplying a church and a pastorium, and the other (PA9C) is a former USGS test well. Depths range from 97 feet (PA49) to 1,211 feet (PA9C).

3.6.2 Field parameters

Measurements of pH are available for all samples and ranged from 6.59 (PA25) to 8.10 (PA49). Conductivities are also available for all samples and ranged from 120 uS/cm (PA44) to 492 uS/cm (PA28). Temperatures are available for all sampling events and ranged from 18.9 degrees C for well PA17 to 26.3 for well PA9C. Well PA9C is the deepest of the Floridan wells at 1211 feet, so the high temperature reflects the geothermal effect. Forty-six dissolved oxygen measurements are available from 26 wells. The available measurements range from 0 mg/L to 7.38 mg/L. At some stations, dissolved oxygen measurements were not taken because of instrument problems. No measurement was taken at well PA14A because the raw water outlet is such that exposure of monitoring/sampling water to air cannot be avoided.

3.6.3 Major Anions, Non-Metals, and Volatile Organic Compounds

Five Floridan wells yielded 10 samples containing detectable chloride. Chloride concentrations ranged from undetected to 760 mg/L (PA9C). The measurement for well PA9C is more than 16 times the next highest concentration of 45 mg/L for well PA4. Well PA9C derives water from the lower part of the Floridan aquifer.

Twenty five samples from 12 wells gave samples containing detectable sulfate. Levels ranged from undetected to 270 mg/L (PA9C).

Twenty water samples from 12 wells contained detectable nitrate/nitrite. Concentrations ranged from undetected to 2.3 mg/L as nitrogen (PA49). There is a general tendency for shallower wells to give samples with higher levels of nitrate/nitrite. Nitrate/nitrite levels in the samples from each quarterly sampled well tend, as a rule, to be similar to one another.

Phosphorus was detected in 27 samples from 18 wells. Phosphorus levels ranged up to 0.06 mg/L (PA20) as total phosphorus.

Volatile organic compounds (VOCs) were detected in seven samples from four wells (PA16, PA17, PA23, and PA44). VOCs of the trihalomethane family were found for three wells, with the detections in PA44 probably being maintenance related and in PA17 and PA23 probably being reflux related. For PA44, trihalomethanes were found exclusively in a sample taken shortly after maintenance was performed. For PA17 and PA23, trihalomethanes tend to be found in samples taken at any time, suggestive of leaky well plumbing valves that allow treated water to flow back down the well. The VOC found in the PA16 sample was a chlorinated alkene, not a disinfection byproduct, and indicative of solvent contamination.

3.6.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

ICP analyses found detectable levels of potassium, aluminum, manganese, iron, calcium, magnesium and sodium. Detectable potassium occurred in only one sample (PA9C). Failure to find detectable potassium in other samples results from the insensitivity of the testing procedure, as indicated by the high reporting limit (5,000 ug/L) for the metal.

Detectable aluminum was found in four samples from four wells. The levels lie within the 50 ug/L to 200 ug/L Secondary MCL range.

Detectable manganese occurred in 15 samples from six wells. The maximum concentration of 100 ug/L occurred in a sample from well PA34A. All four samples from quarterly-sampled well PA34A and samples from annually sampled wells PA16 and PA18 exceeded the Secondary MCL of 50ug/L. The manganese levels in the samples from each of the quarterly sampled wells vary within a restricted range. Wells giving samples with manganese detections seem clustered in an area in the east-central and south-central portions of the State (Cook, Irwin, Telfair Toombs, Jenkins, and Candler Counties).

Iron was detected in 20 samples from 12 wells. Only one sample, the annual sample from well PA9C, exceeded the Secondary MCL of 300 ug/L. The iron contents of samples from three quarterly wells (PA29, PA34A, and PA36) varied within restricted ranges, while iron contents of samples from quarterly well (PA23) varied considerably.

Detectable magnesium was found in all samples from all wells except for those from quarterly well PA25 and annual well PA49. Magnesium concentrations ranged up to 74,000 ug/L. Both PA25 and PA49 are Floridan recharge area wells. Kellam and Gorday (1990) have noted that Ca/Mg ratios are higher in ground waters from Floridan recharge areas, as is the case with these two wells. Magnesium levels in samples from each quarterly well seem to vary within relatively narrow ranges.

Calcium was detected in all samples from the 28 Floridan wells. Concentrations ranged from 23,000 ug/L (PA2) to 100,000 ug/L (PA9C). For samples from quarterly wells, calcium concentrations seem to fall within a narrow range for each well. Ca/Mg ratios in well waters have already been mentioned.

Sodium was also found in all sample waters from all 28 wells and ranged in concentration from 1,800 ug/L (PA49) to 400,000 ug/L (PA9C). Sodium concentrations generally increase with depth.

3.6.5 Metals by Inductively-Coupled Plasma Mass Spectrometry (ICPMS)

ICPMS analysis found the following detectable metals in the Floridan samples: chromium, copper, zinc, arsenic, selenium, molybdenum, barium, uranium, lead.

A single sample from quarterly well PA23 gave an arsenic detection below the Primary MCL (10 ug/L). The well has given intermittent samples with detectable arsenic before. Two wells, annual well PA49 and quarterly well PA44, gave two samples with detectable chromium below the Primary MCL (100 ug/L). This same sample from well PA44 was the only sample from that well to register trihalomethane detections. Annual well PA9C gave a sample showing detectable selenium below the Primary MCL (50 ug/L).

Three samples contained detectable copper, below the action level of 1,300 ug/L. Two were from quarterly wells PA14A and PA36, and, one from annual well PA31. Well PA14A uses a small diameter copper tube for delivering sample water. Four quarterly wells and one annual well each gave one sample with detectable lead. All were below the action level of 15 ug/L. Two wells, annual well PA49 and quarterly well PA25, each gave a sample with detectable zinc. The levels were well below the Secondary MCL (5,000 ug/L).

Three quarterly wells, all from the Gulf Trough area, gave samples with detectable molybdenum. Wells PA23 and PA56 each gave four samples containing the metal, while only one of the samples from well PA28 contained a detectable amount.

Uranium was detected in 10 samples from two quarterly wells (PA44, PA56) and three annual wells (PA22, PA31, PA39). The maximum concentration was 3.2 ug/L for well PA56, below the Primary MCL of 30 ug/L.

Barium was detected in all samples from all wells and ranged in concentration from 3.9 ug/L to 190 ug/L, all below the Primary MCL of 2,000 ug/L. Barium seems to be more abundant in samples from wells of 400 foot to 700 foot depth range.

3.7 MIOCENE/SURFICIAL AQUIFER SYSTEM

3.7.1 Aquifer System Characteristics

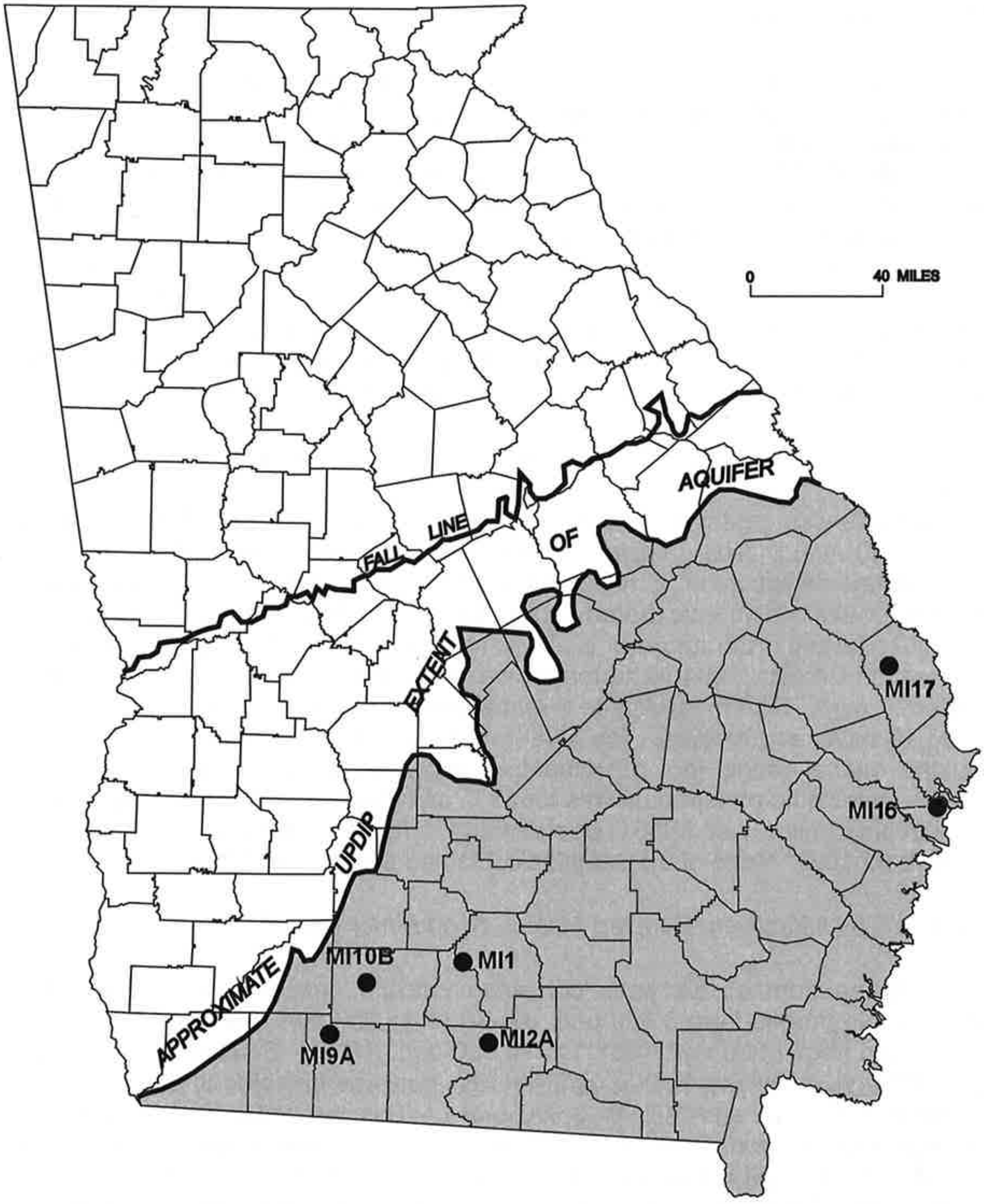
The Miocene/Surficial aquifer system is developed in sands of the Miocene Hawthorne Group and of the Pliocene Miccosukee and Cypresshead Formations of the Georgia Coastal Plain (Figure 3-6).

The Hawthorne Group covers most of the Coastal Plain and consists predominantly of sand and clay (Huddlestun, 1988), although carbonate rocks and phosphorites may locally be significant (Huddlestun, 1988; Clarke et al., 1990). Clarke et al., 1990, note that three sequences consisting of a basal dense phosphatic limestone layer, a middle clay layer, and an upper sand layer typify the Miocene section in the coastal area. The sand layers of two lowermost of these sequences host the lower and upper Brunswick aquifers, while the uppermost layer is hydraulically continuous with the Surficial aquifer. The Miocene/Surficial aquifer system of this report includes the two lower Miocene layers as well as the upper Miocene layer and the overlying sediments.

The Cypresshead Formation overlies the Hawthorne Group in the Coastal area (from the Atlantic coast to about 45 miles inland) and consists, in updip areas, predominantly of fine- to coarse-grained quartz sand and, in downdip areas, interbedded fine sand and clay (Huddlestun, 1988). In the Coastal Plain of far south central and southwestern Georgia, the Miccosukee Formation overlies the Hawthorne Group (Huddlestun, 1988).

The Miccosukee Formation consists predominantly of sand but contains some clay. The characteristic lithology consists of thin-bedded to laminated fine to medium sand with scattered layers or laminae of clay. Also included in the aquifer system are Pleistocene arkosic sands and gravels interbedded with clays and Holocene sands and gravels interbedded with muds. The upper part of the aquifer system is unconfined, whereas, the deeper parts of the system may be locally confined and under artesian conditions.

Six wells -- MI1, MI2A, MI9A, MI10B, MI16 and MI17 -- were used to monitor the Miocene/Surficial aquifer system. All are sampled once per year. Wells MI1, MI2A, MI9A and MI10B are private domestic wells, with MI9A and MI10B no longer being used as drinking water sources. MI16 is used for general purposes at a fire station. MI17 originated as a geologic bore hole that became a flowing well. It is currently used both as a domestic water source and as an augmentation well for maintaining a pond. MI2A and MI9A are bored wells. The remainder are drilled wells. Depths, actual or approximate, have been determined for all six wells. All wells are sampled yearly.



▨ General recharge area (from O'Connell and Davis, 1991)

● Sampling station

Figure 3-6. Locations of Stations Monitoring the Miocene/Surficial Aquifer System.

3.7.2 Field parameters

The pHs of the sample waters from the six wells used to monitor the Miocene/Surficial aquifer system ranged from 4.39 (MI2A) to 7.74 (MI1). Three of the six wells sampled (MI2A, MI9A, and MI10B) produced acidic water. The remaining three (MI1, MI16, and MI17) gave basic water. The acidic water-yielding wells included the two shallowest, while the basic water-producing wells included the two deepest. Conductivities ranged from 69 uS/cm (MI10B) to 317 uS/cm (MI16). Water temperatures ranged from 19.2 degrees C (MI17) to 23.9 degrees C (MI16). The 23.6 degrees C temperature probably has a geothermal component, as well MI16 is 400 feet deep. Dissolved oxygen data are available for four wells and range from 0.00 (MI17) to 6.70 (MI2A). Valid dissolved oxygen measurements cannot be made on well MI9A since it must be sampled with a bailer.

3.7.3 Major Anions, Non-Metals, and Volatile Organic Compounds

Chloride was detected in samples from the two bored wells MI2A (13 mg/L) and MI9A (10 mg/L). The sample from the deepest Miocene well, MI16, provided the only sulfate detection, at 35 mg/L. Nitrate/nitrite was detected in sample waters from three wells. The two bored wells, MI2A and MI9A, gave samples with nitrate/nitrite levels in the range of likely human influence ($\geq$ 3.1 mg/L as nitrogen) (Madison and Brunett, 1984). The former well registered 4.9 mg/L as nitrogen and the latter 11 mg/L. The nitrate/nitrite level for well MI9A also exceeded the Primary MCL of 10 mg/L as nitrogen. The level in the sample from drilled well MI1 was within the natural range (not detected to 3 mg/L as nitrogen) at 0.03 mg/L as nitrogen. Detectable phosphorus was found in samples from all wells except bored well MI2A and drilled well MI16. Concentrations ranged from 0.02 mg/L (MI1) to 0.33 mg/L (MI10B). None of the samples contained detectable VOCs.

3.7.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

Samples from all six wells contained calcium, magnesium, and sodium. Calcium levels ranged from 3,600 ug/L (MI2A) to 45,000 ug/L (MI17). Magnesium levels ranged from 1,900 ug/L (MI17) to 14,000 ug/L (MI16). Sodium levels ranged from 3,100 ug/L (MI9A) to 16,000 ug/L (MI16). Iron was detected in samples from wells MI9A (24 ug/L) and MI10B (3,600 ug/L). This last value far exceeds the Secondary MCL for iron of 300 ug/L. Manganese was found in samples from two wells, MI10B (98 ug/L) and MI17 (12 ug/L). The 98 ug/L level exceeds the Secondary MCL for manganese of 50 ug/L. The high iron and manganese levels in water from drilled well MI10B is the reason the residents ceased using the water for household purposes, i.e., cooking, drinking, and laundering. Aluminum was detected in two wells, MI2A (130 ug/L) and MI9A (82 ug/L).

3.7.5 Metals by Inductively-Coupled Plasma/Mass Spectrometry (ICPMS)

ICPMS analyses found detectable copper, zinc, selenium, barium, and lead in the Miocene aquifer samples. All six samples contained detectable barium, which ranged in concentration from 19 ug/L (MI1) to 190 ug/L (MI10B). Zinc was detected in samples from well MI1 (33 ug/L) and MI10B (130 ug/L). Detectable lead occurred in samples from bored wells MI2A (12 ug/L) and MI10B (1.7 ug/L). The sample from bored well MI2A contained copper at a level of 9.7 ug/L. The sample from drilled well MI10B contained selenium at a level of 14 ug/L). The copper, lead, and zinc in the water samples were likely derived from plumbing. Selenium at detectable levels is rare in Georgia's ground water.

3.8 PIEDMONT/BLUE RIDGE AQUIFER SYSTEM

3.8.1 Aquifer System Characteristics

The Piedmont/Blue Ridge aquifer system in Georgia is part of the Piedmont and mountain aquifer system that extends from New Jersey into Alabama (Daniel and Harned, 1997). The system is variously unconfined or semiconfined and is composed of two major hydrogeologic units: a) regolith and b) fractured igneous and metamorphic bedrock (Heath, 1980; Daniel and Harned, 1997). Figure 3-8 shows the extent of the system in Georgia.

Regolith comprises a mantle of soil or, in and near stream bottoms, alluvium, which is underlain by saprolite. Saprolite is bedrock that has undergone extensive chemical weathering in place. Downward percolating, typically acidic, ground water leaches alkali and alkaline earth and certain other metals from micas, feldspars, and other minerals composing the original rock, leaving behind a clay-rich residual material. Textures and structures of the original rock are typically well-preserved, with the saprolite appearing as a "rotten" version of the original rock. The regolith is characterized by high, mostly primary porosity (35% to 55%) (Daniel and Harned, 1998) and serves as the reservoir that feeds water into the underlying fractured bedrock. Though it can store a great deal of water, saprolite, owing to its clay content, does not give up its water very rapidly. Saprolite grades downward through a transition zone consisting of saprolite and partially weathered and some fresh bedrock into fresh bedrock.

The fractured bedrock hydrologic unit consists of fresh rock of igneous or metamorphic origin. In contrast to the regolith, the porosity in such rocks is almost totally secondary, consisting of fractures and solution-enlarged voids. In the North Carolina Piedmont, Daniel and Harned (1998) found 1% to 3% porosity typical for bedrock. Fractures consist of faults -- breaks in the rock with differential displacement between the broken sections -- and joints -- breaks in the rock with little or no differential displacement (Heath, 1980).

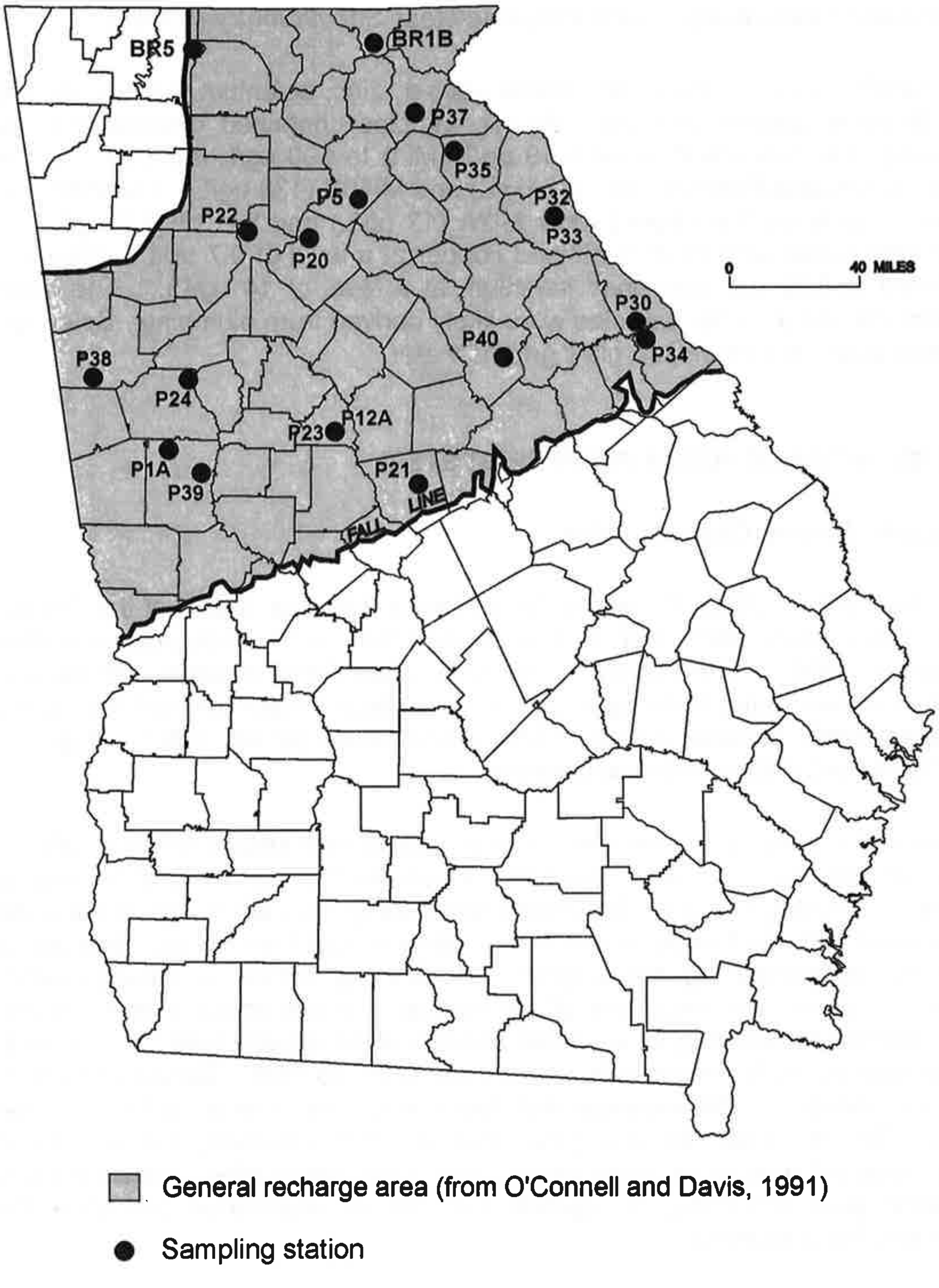


Figure 3-8. Locations of Stations Monitoring the Piedmont/Blue Ridge Aquifer System.

Fractures tend to be wider and more numerous closer to the top of the bedrock. Daniel and Harned (1998) noted that at a depth about 600 feet, pressure from the overlying rock column becomes too great and fractures are held shut. Fracturing in schistose rocks consists mainly of a network of fine, hair-line cracks which yield water slowly. Fractures in more massive rocks (e.g. granitic rocks, diabases, gneisses, marbles, quartzites) are mostly open and are subject to conduit flow. Thus wells intersecting massive-rock fractures are able to yield far larger amounts of water than wells in schistose rocks or even wells in regolith. Fractures can be concentrated along fault zones, shear zones, late-generation fold axes, foliation planes, lithologic contacts, compositional layers, or intrusion boundaries.

Forty-six samples from 17 wells and two springs were used to monitor water quality in the Piedmont/Blue Ridge aquifer system. Sixteen of these wells are drilled, with 12 being public supply wells and the remaining four being domestic. One domestic well is bored (P33) and is in domestic use. Of the two springs, one (P12A) is a mineral spring at a State park, and, the other spring (BR5) is a public supply source. The State park mineral spring and the following wells are scheduled for sampling on a quarterly basis: BR1B, P21, P23, P32, P33, P34, P35, and P37. The remaining stations are sampled on a yearly basis. Where their depths are known, wells deriving water from the bedrock aquifer range in depth from 150 feet to 600 feet. Domestic bored well P33, the only well drawing from the regolith, is 47 feet deep.

3.8.2 Field parameters

Forty six pH measurements from 19 stations are available for the Piedmont/Blue Ridge aquifer system. The pHs ranged from 4.52 to 7.99. Seven samples from wells P20, P32, and P35 and mineral spring P12A were basic; two samples from two wells (BR1B and P24) were neutral; 37 samples from 14 wells and the two springs were acidic. Of the quarterly stations, well P32 gave consistently basic water; and, wells P21, P23, P33, P34, and P37 gave consistently acidic water. The mineral spring P12A and wells P35 and BR1B each gave water samples that were variously acidic, neutral or basic. All samples from regolith well P33 were acidic.

Conductivity measurements are available for 46 samples from 19 stations. Conductivities ranged from 24 uS/cm (BR5) to 1280 uS/cm (P32).

Temperatures are available for all sampled waters and range from 10.5 degrees C (P34) to 23.7 degrees C (P32). The low temperature measurement for station P34, a quarterly well, was taken during a winter sampling. The warmest temperature registered on a quarterly sample collected in July from well P32. Geothermally elevated temperatures are not readily apparent for the Piedmont/Blue Ridge. Latitude, ground elevation, and season appear to have more influence on the sampling temperature.

Dissolved oxygen measurements are available for 41 samples from 17 stations. Dissolved oxygen levels were not measured on samples from springs BR5 and P12A, since sample waters are exposed to atmosphere at the spring pools upstream of measurement points. Dissolved oxygen levels ranged from 0.00 mg/L for quarterly well P32 to 15.25 mg/L for quarterly well P34. The 15.25 mg/L reading and the next highest reading, 11.62 mg/L for quarterly well P21, lie above the oxygen saturation levels for the temperatures at sampling (19.4 degrees C and 18.3 degrees C). These two readings suggest free-falling (cascading) water in the well or entrainment of air at the pump intake due to a low pumping water level and do not reflect the actual oxygen level in the ground water.

3.8.3 Major Anions, Non-Metals, and Volatile Organic Compounds

All samples received testing for chloride, sulfate, nitrate/nitrite, total phosphorus, and VOCs. Three samples each from spring P12A and well P23, both located at Indian Springs State Park, received testing for fluoride.

Detectable chloride was found in 11 samples from five stations. Well P37 gave the sample with the highest chloride level at 240 mg/L. Chloride levels in samples from mineral spring P12A are nearly constant. Detectable chloride levels in samples from other stations were more variable.

For the three samples from well P23 receiving fluoride testing, levels of the ion varied from 1.1 to 1.2 mg/L. Fluoride levels for three samples from spring P12A slightly exceeded the Primary MCL of 4 mg/L. Currently, as in the past, the spring has consistently given water with fluoride in the 4 mg/L to 5 mg/L range.

Sulfate was detected in 25 samples from nine stations, with the highest concentration (620 mg/L) occurring in a sample from well P32. Well BR1B and spring P12A each gave samples with sulfate levels showing only slight variability.

Nitrate/nitrite was detected in 35 samples from 17 stations but remained below detection in all samples from spring P12A and well P32 and in three of four samples from well P35. All other samples contained detectable nitrate/nitrite with levels ranging from 0.02 mg/L as nitrogen (well BR1B) to 1.7 mg/L as nitrogen (wells P5 and P30).

Detectable phosphorus occurred in 30 samples from 12 wells and 2 springs, with the highest concentration of 22 mg/L being found for quarterly well P34. Quarterly wells BR1B and P32 produced no samples with detectable phosphorus, while all samples from quarterly wells P21, P23, and P34 and from spring P12A contained detectable phosphorus. Phosphorus concentration varies little or not at all in samples from mineral spring P12A and in quarterly wells P21 and P23.

The trihalomethane compound chloroform was the only VOC encountered. This disinfection breakdown product was detected in one sample from quarterly well P34, at 0.58 ug/L, and in two sequential samples from quarterly well P37, at 2.7 ug/L then 0.96 ug/L. The Primary MCL for all trihalomethanes in any one given sample is 80 ug/L.

3.8.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

ICP analysis found detectable aluminum, calcium, iron, potassium, magnesium, manganese, and sodium. No beryllium, cobalt, titanium, or vanadium were detected.

Calcium was found in all samples except for the one from annual well P22. The highest calcium level occurred in the sample from quarterly well P32 (250,000 ug/L). The eight highest calcium levels occurred in samples from wells P32 and P37. As a rule, calcium levels of samples from each quarterly sampled well tend to fall close to the calcium levels in other samples from the same well.

Magnesium was detected in 39 samples from 15 stations. Magnesium contents of sample waters ranged up to 26,000 ug/L (well P37). As with calcium, magnesium levels in quarterly sampled wells generally tend to cluster for each well. Samples from the quarterly regolith well P33 contained no detectable magnesium.

Sodium was present in all samples and ranged from 2,000 ug/L in the sample from well P22 to 58,000 ug/L in a sample from well P37. Sodium levels for the quarterly wells have a general tendency to fall close to one another for each well, though this seems less pronounced than with calcium. Detectable potassium was found in six samples from two wells (PA35, PA37). The low sensitivity of the current laboratory testing procedure for the metal probably accounts for the apparent scarcity of the metal.

Aluminum was detected in six samples from three wells and the mineral spring. The quarterly regolith bored well P33 contributed three detections, while the spring and the two other wells contributed one detection each. All detections fell within the Secondary MCL range of 50 ug/L to 200 ug/L.

Nineteen samples from seven wells contained detectable iron, with a range up to 540 ug/L (P37). Two samples from drilled quarterly well P37 and one from bored quarterly well P33 exceeded the Secondary MCL of 300 ug/L. Another sample from the bored well equaled the Secondary MCL.

Manganese was detected in 28 samples from nine stations, with a maximum concentration of 260 ug/L (P37). All samples from quarterly wells P37 and P35, one sample from quarterly well P21, and the sample from annual well P20 exceeded the Secondary MCL of 50 ug/L.

3.8.5 Metals by Inductively-Coupled Plasma Mass Spectrometry (ICPMS)

ICPMS analysis of water samples detected the following metals: nickel, copper, zinc, arsenic, barium, lead, uranium. None of the following metals were found in detectable amounts: chromium, selenium, molybdenum, silver, cadmium, tin, antimony, and thallium.

Nickel was found in three samples from quarterly well P37. The maximum nickel level was 13 ug/L, much below the Primary MCL of 100 ug/L.

Copper occurred in 12 samples from six wells, with a maximum level of 44 ug/L in the sample from well P22. The samples with the five lowest pHs all contain some copper, with the 44 ug/L maximum occurring with the third lowest pH, 5.00. No detectable copper occurred in neutral or basic waters. Zinc was detected in 19 samples from seven wells, with the maximum level at 210 ug/L for well P24. All zinc detections except for two (P24 and P20) occurred in acidic waters. The pH of the sample from P24 (the well with the maximum level) was neutral, and, the pH of the sample from P20 was basic. Lead was detected in seven samples from seven wells. Quarterly wells P21, P33, P34, and P37 produced a single lead showing each. Only one lead detection occurred without a zinc detection or a copper detection.

Well P30 gave the only sample containing detectable arsenic at a level of 5.2 ug/L. The Primary MCL for arsenic is 10 ug/L.

Barium, as elsewhere in the State's ground water, was a nearly ubiquitous trace metal, being detected in 41 samples from 17 wells and two springs. Three samples from quarterly mineral spring P12A and in two samples from quarterly well P30 contained no detectable barium. The maximum concentration was 200 ug/L from a sample from annual well P20. No samples exceeded the Primary MCL of 2,000 ug/L.

Uranium was detected in 30 samples from 10 wells. Uranium concentrations ranged up to 19 ug/L in a sample from well P40. Granitic bedrock is present where four of the ten wells are drilled and is the most common bedrock type to host uraniferous water.

3.9 VALLEY AND RIDGE/APPALACHIAN PLATEAU AQUIFER SYSTEM

3.9.1 Aquifer System Characteristics

Since Georgia's portion of the Appalachian Plateau Province is restricted to a small area in the State's northwestern corner, this report includes that province with the Valley and Ridge Province for purposes of discussion. Bedrock in the combined

Province is sedimentary, comprising limestones, dolostones, shales, siltstones, mudstones, and sandstones.

Primary porosity in the province's bedrock is very low, leaving fractures and solution-enlarged voids as the main water-bearing structures. The bedrock in the province is extensively faulted and folded, which has served to proliferate fracturing and to segment water-bearing units into numerous local flow systems. Fractures in limestones and dolostones can become enlarged by solution, greatly increasing their ability to store and transmit water. Zones of intense fracturing are especially prone to weathering, giving rise to broad valleys with gently sloping sides and bottoms covered with thick regolith. Such weathering and dissolution also develops extensive karst topography. Carbonate bedrock beneath such valleys presents a voluminous source of typically hard ground water.

As in the Piedmont/Blue Ridge Province, this regolithic mantle of soil and residuum derived from weathered bedrock blankets much of the Valley and Ridge/ Appalachian Plateau Province. Where the water table lies within the mantle, the mantle yields soft typically acidic water ("freestone" water) sufficient for domestic and light agricultural use (Cressler et al., 1976; 1979). The mantle also acts as a reservoir, supplying water to the underlying bedrock, which, supplies most of the useful ground water in the province. The extensive faulting and folding has segmented otherwise expansive stratigraphically concordant aquifers into smaller ones with very local flow regimes, unlike the regional flow regimes that characterize the Coastal Plain aquifers.

`Monitoring water quality in the Valley and Ridge/Appalachian Plateau aquifers made use of four springs and two drilled wells (Figure 3-9). Springs VR2A, VR8, and VR10 are public supply springs; and, spring VR3 is a former public supply spring. Well VR1 is a public supply well, and, well VR6A is an industrial process water source. Spring VR8 is scheduled for sampling on a quarterly basis, while all other stations are sampled on a yearly basis. All stations tap carbonate bedrock aquifers.

3.9.2 Field parameters

Sample water pHs ranged from 6.55 for spring VR2A to 7.76 for well VR1. The springs all returned slightly acidic pHs for June through August measurements on sample waters.

Conductivities ranged from 155 uS/cm (well VR1) to 486 uS/cm (spring VR8).

Dissolved oxygen measurements are available for wells VR1 – 6.23 mg/L – and VR6A – 5.56 mg/L. Dissolved oxygen measurements were made on spring waters at or downstream of spring heads; however, due to atmospheric exposure at

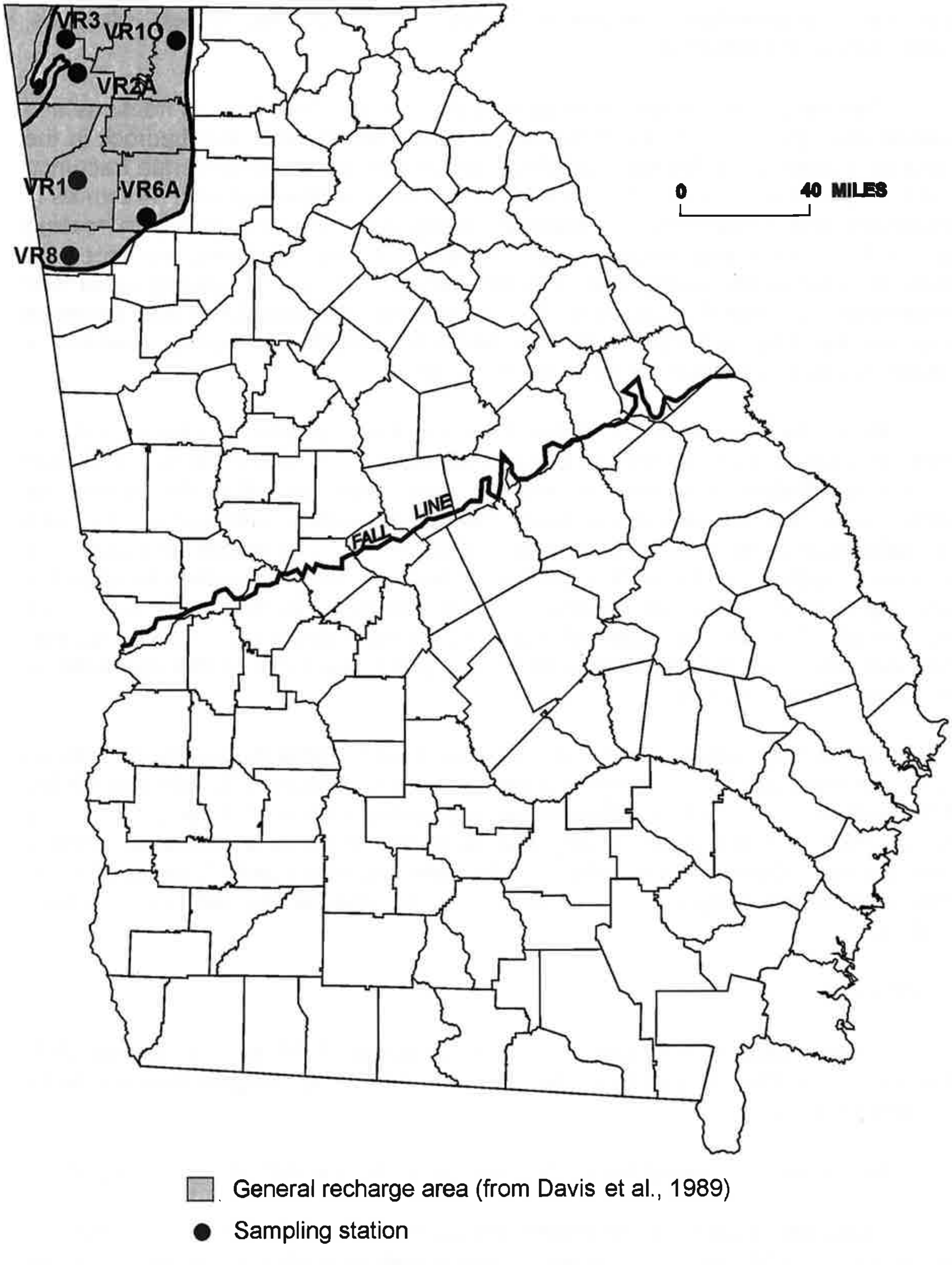


Figure 3-9. Locations of Stations Monitoring the Valley-and-Ridge/Appalachian Plateau Aquifer System.

the spring head and downstream, these measurements may not validly represent oxygen levels in the water prior to discharge.

The temperature of sample waters from well VR1 was 16.6 degrees C and from well VR6A was 17.8 degrees C, which varied little or not at all from the previous year's sample temperatures. Contact with the surface environment may have altered temperatures measured for spring waters, since most measurements were done downstream from the springheads.

3.9.3 Major Anions, Non-Metals, and Volatile Organic Compounds

Neither chloride, nor sulfate, nor phosphorus was detected in the sample waters. Nitrate/nitrite was present in all of the sample waters and ranged from 0.64 mg/L as nitrogen (well VR1) to 1.70 mg/L as nitrogen (spring VR10).

The sample from well VR6A was the only one to contain detectable VOCs. The compounds consisted of: 1,1-dichloroethylene at 1.8 ug/L (Primary MCL = 7 ug/L), tetrachloroethylene at 2.2 ug/L (Primary MCL = 5 ug/L), m-dichlorobenzene at 0.59 ug/L (no Primary MCL), and o-dichlorobenzene at 1.6 ug/L (Primary MCL = 600 ug/L). The compounds, particularly the chlorinated ethylenes, see use as solvents. O-dichlorobenzene additionally sees use as a starting material for some agricultural chemicals.

3.9.4 Metals by Inductively-Coupled Plasma Spectrometry (ICP)

ICP analysis found calcium, magnesium, and sodium in all samples. Detectable iron was present in three out of four samples from spring VR8, all at levels below the Secondary MCL of 300 ug/L. Neither manganese nor aluminum was detected in any of the samples. Calcium levels ranged from 27,000 ug/L (well VR1) to 38,000 ug/L (spring VR2A). Magnesium levels ranged from 14,000 ug/L (spring VR2A) to 17,000 ug/L (well VR6Aand spring VR8). Sodium levels ranged from 1,200 ug/L (spring VR3) to 5,000 ug/L (well VR6A).

3.9.5 Metals by Inductively-Coupled Plasma Mass Spectrometry (ICPMS)

ICPMS analysis found barium and zinc. Detectable barium was present in all samples and ranged from 13 ug/L (well VR1 and spring VR8) to 620 ug/L (well VR6A). All samples save the one from VR6A have barium levels below 100 ug/L. Well VR6A furnishes process water to a firm that manufactures barium and strontium compounds and is situated in an area that sees the mining and processing of barite.

Zinc at a level of 13 ug/L was found in the sample from spring VR10. A spigot in the treatment house near the spring head or related plumbing may have contributed the zinc. This spigot is the only source of untreated water from the spring.

CHAPTER 4 SUMMARY AND CONCLUSIONS

EPD personnel collected 141 water samples from 74 wells and six springs on the Ground-Water Monitoring Network during the calendar year 2012. The samples were analyzed for VOCs, chloride, sulfate, nitrate/nitrite, total phosphorus, 15 trace metals by ICPMS analysis, and 11 major metals by ICP analysis. Waters from two neighboring stations in the central Piedmont received analyses for fluoride because one of the stations was known to produce water with excessive levels of that ion. These wells and springs monitor the water quality of eight major aquifers and aquifer systems as considered for this report in Georgia:

Cretaceous aquifer system,

Clayton aquifer,

Claiborne aquifer,

Jacksonian aquifer

Floridan aquifer system,

Miocene/Recent aquifer system,

Piedmont/Blue Ridge aquifer system,

Valley and Ridge/Appalachian Plateau aquifer system.

4.1 PHYSICAL PARAMETERS AND pH

4.1.1 pH

The Cretaceous aquifer system, developed in Coastal Plain sands, furnished waters with the overall lowest pHs as well as the lowest pH measurement (well K12) of the study. Even though this aquifer system featured only two wells yielding waters with basic pHs, one of these two wells also produced waters with the highest pH (well PD3). The Floridan aquifer system, as might be expected for carbonate-rock aquifers, gave waters with mildly basic pHs; only two samples from two wells registered acidic. Waters from the Floridan are the most basic in pH of any in the study.

Not many stations were available to sample wells tapping the Clayton, Claiborne, or Jacksonian aquifers. However, the results are these: 1) Clayton –

acidic – as expected for updip portions of the aquifer, downdip portions should be basic; 2) Claiborne – one basic, two acidic – one acidic-yielding well is shallow and updip in sands; basic-yielding well is deeper and probably penetrates some limey sand or limestone; 3) Jacksonian – four basic, one acidic – basic waters should be expected from limey sands.

A few more stations were available to sample the Miocene and Valley-and-Ridge/Appalachian Plateau aquifer systems. The Valley-and-Ridge/Appalachian Plateau sampling stations are all located in the Valley-and-Ridge sector. With carbonate rocks being the major aquifer media, samples from the sector would be expected to be mildly basic. Of the nine samples taken in the sector, three were acidic: one each from two annually sampled springs and one from a quarterly sampled spring. Three of six stations, thus, gave acidic water, in contrast to the Floridan aquifer, where only two stations of 28 yielded two acidic samples. The seeming unusual high incidence of acidic water may be due to a larger amount of typically acidic precipitation entering the springs' flow systems than the carbonate bedrock can neutralize.

The Miocene aquifer system is developed in sands, however, these may include considerable shelly detritus in some places (evident at surface excavations near well MI17). Dissolution of such detritus is capable of raising the pHs of ground waters in such areas, giving water from this well a mildly basic pH. In places where such shelly matter is not available, waters emerge with low pHs, as at well MI2A.

Sample-water pHs in the Piedmont/Blue Ridge are general mildly acidic, with seven out of 46 sample measurements exceeding a pH of 7.00.

The very acidic pHs of the sample waters in the updip portions of the Jacksonian, Clayton, Claiborne, and, particularly, the Cretaceous can face metal plumbing with leaching and corrosion problems. Such waters may contain elevated or excessive, but not naturally occurring, levels of lead, copper, and zinc.

4.1.2 Conductivity

Conductivity in ground waters from the sandy Cretaceous aquifer system seems to be highest for the deeper wells near the Chattahoochee River. Overall, conductivities are relatively low, in the range of lower tens of microsiemenses.

Similar conductivities can be found in waters from the updip portions of the Clayton and Claiborne aquifers, where the media consist mostly of sand. For the Piedmont/Blue Ridge aquifer system, low conductivities could be associated with ground waters hosted by quartzites or quartz veins. High conductivities may arise in waters in deep flow regimes where waters are long in contact with granitic and other reactive host rocks.

Conductivities of ground waters in the Floridan and other carbonate rock aquifers are generally higher than those in siliceous rocks. This condition results from the dissolution of carbonate minerals, in cases augmented by dissolution of intergranular sulfate, where dissolved sulfate will also be present in the water.

4.1.3 Temperature

Ground-water temperatures measured under the current sampling procedure are only approximations of the actual ground-water temperature, as some heating can result from the action of pumping and heating or cooling can result from exposure to ambient surface conditions. Nevertheless, ground waters from shallower wells in the northern part of the State are overall somewhat cooler than those from the southern part; and, those from wells much deeper than about 400 to 500 feet show effects from geothermal warming.

4.2 ANIONS, NON-METALS AND VOCS

4.2.1 Chloride and Fluoride

Water samples receive testing for fluoride only at Piedmont/Blue Ridge stations P12A, a mineral spring, and P23, a nearby well. Testing more stations for fluoride could provide a better base level assessment of fluoride contents in the State's ambient ground waters.

Chloride at currently detectable levels is not too common in ambient ground waters. Abundance seems to be largest in the Miocene/Surficial, with two stations of less than 100 feet depth giving water with detectable chloride. Chloride is also relatively abundant in Piedmont/Blue Ridge waters, detected at five out of 19 stations, and in deeper Floridan waters, detected at five out of 28 stations. The Floridan occurrences seem restricted to the Gulf Trough and Coastal areas, with Coastal area sample from well PA9C giving the study's only Secondary MCL exceedance for chloride.

4.2.2 Sulfate

Sulfate is more widespread than chloride. Sulfate is more abundant in deeper waters, with the shallowest occurrence, aside from Piedmont/Blue Ridge mineral spring P12A, being 200 foot-deep well J6. The substance seems more abundant in the Piedmont/Blue Ridge, occurring in detectable amounts in waters from nine of 19 stations. Sulfate also has considerable presence in Floridan sample waters (detectable at 12 out of 28 stations), and in Jacksonian sample waters (2 out of 3 stations). The sample from Floridan well PA9C yielded the study's highest overall sulfate content and a Secondary MCL exceedance. The lowest incidences of detectable sulfate were in the Miocene/Surficial (at one of six stations) and in the sole Clayton station sample.

4.2.3 Nitrate/Nitrite

Eighty-one samples from 51 of the 80 stations sampled for this project contained detectable nitrate/nitrite. At least one sampling station drawing from each of the aquifers and aquifer systems discussed in this report gave a sample with detectable nitrate/nitrite. The combined substances are most widespread among the Valley and Ridge/Appalachian Plateau samples, where all stations gave samples containing detectable amounts. The combined substances are also widespread in Piedmont/Blue Ridge and Floridan waters. The two highest concentrations of nitrate/nitrite (11 mg/L at well MI9A, 4.9 mg/L at well MI2A) occurred at Miocene/Surficial stations. The first sample exceeded Primary MCL of 10 mg/L as nitrogen, and, the second exceeded the 3 mg/L (as nitrogen) level generally considered to indicate human influence (Madison and Brunett, 1984; Gaskin et al., 2003).

Since nitrate/nitrite, an oxidant, becomes depleted the farther water travels away from oxidizing, near-surface environments and toward reducing ones, a rude inverse relation exists between the concentration of nitrate/nitrite and well depths. The nitrate/nitrite concentrations in Floridan samples illustrate this: the combined substances are undetected in wells deeper than about 650 feet and reach a maximum concentration of 2.3 mg/L at well 97-foot deep PA49. The situation in the Piedmont/Blue Ridge is less straightforward, as mineral spring P12A lacks detectable nitrate/nitrite and well P24 at 700 feet gives water with a concentration of 0.23 mg/L.

4.2.4 Phosphorus

Analyses determine only total phosphorus; the method used (EPA Method 365.1) for testing cannot determine how the element is bound chemically. Arithmetic means cited for the following aquifers use a value of 0.01 mg/L where a phosphorus value of “not detected” is reported. Only three samples from three stations were collected for the Claiborne, however, the aquifer registered the highest phosphorus content encountered (0.51 mg/L) as well as a mean phosphorus content of 0.28 mg/L. Of the more extensively sampled Piedmont/Blue Ridge and Floridan aquifer systems, the former registered a mean phosphorus content of 0.04 mg/L and the latter a content of 0.02 mg/L. The high phosphorus value for the Piedmont/Blue Ridge was 0.22 mg/L and the high for the Floridan was 0.06 mg/L. The apparent low phosphorus content occurred for the Valley and Ridge/Appalachian Plateau aquifer system with no phosphorus detections.

4.2.5 Dissolved Oxygen

The measurement of dissolved oxygen contents is beset with some difficulties that can cause spurious values: instrument malfunction; aeration of well water due to cascading or to a pump's entraining air at low pumping water levels; measuring at spring pools or at sampling points that cannot be isolated from atmosphere. Nevertheless, measured dissolved oxygen generally decreases with well depth.

4.2.6 Volatile Organic Compounds

Volatile organic compounds (VOCs) were found in 13 samples from nine wells (see Table 4-2). None exceeded their respective Primary MCLs.

The trihalomethanes -- chloroform, bromodichloromethane, chlorodibromomethane and bromoform -- were the most widely occurring of the VOCs. These compounds result from the reaction of halogen-bearing disinfectants used to treat water with organic matter naturally present in the water. The occurrence of these compounds commonly arises from one of two scenarios. The first involves the disinfection of well and plumbing components incident to maintenance or repairs, as took place in 2012 with well PA44. The second scenario involves a leaking check valve or foot valve that allows disinfectant-treated water to flow back down a well when its pump is turned off, as apparently happened with well PA23.

Wells PA16 and VR6A yielded water containing chlorinated ethylene compounds. Sample water from VR6A also contained detectable chlorinated benzene compounds. The former are used as solvents; in addition to solvent uses, the latter can be used as disinfectants, fumigants, pesticides and starters for manufacturing other compounds. The owner of well VR6A, Chemical Products Corporation, manufactures barium and strontium compounds.

4.5 ICP METALS

Analysis using inductively coupled plasma spectrometry (ICP) works well for metals that are generally the more abundant in ground water samples. Samples in this study were not filtered, so the method measured analytes that occurred in fine suspended matter as well as those occurring as solutes. The laboratory used the technique to test for aluminum, beryllium, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, titanium, and vanadium. No beryllium, cobalt, titanium, or vanadium occurred in any samples at detectable levels.

4.3.1 Aluminum

Aluminum, a common naturally occurring metal in the State's ground water, may be present in particulate form or as a solute. Current sampling procedures do not allow particulates and solutes to be analyzed separately. For its Secondary MCL, aluminum is subject to a range of concentrations from 50 ug/L to 200 ug/L, depending on the ability of a water system to remove the metal from water undergoing treatment. The EPD laboratory's reporting level for the metal, 60 ug/L lies within the Secondary MCL range, placing any sample with detectable aluminum within the MCL range.

The metal appears to be most abundant in water samples with acidic pHs and, as a rule, is more concentrated the higher the acidity. The Miocene/Recent aquifer system, the updip portion Cretaceous aquifer system, and updip terrigenous clastic-rich portion of the Clayton aquifer are examples. Aquifers giving mildly basic samples such as the carbonate-hosted Floridan aquifer and carbonate portions of the Valley and Ridge/Appalachian Plateau aquifers produce few sample waters containing any detectable aluminum. The metal's abundance in bedrock waters from the Piedmont Blue Ridge aquifer system also seems low. Samples from deeper wells with more strongly basic pHs (approaching 8.00) may contain some detectable aluminum.

4.3.2 Iron and Manganese

Iron and manganese, also, are two naturally occurring metals in Georgia's ground water. Both, like aluminum, may occur as fine particulates or as solutes. Both seem more abundant in acidic waters. Manganese also seems more abundant in waters with low dissolved oxygen contents. Sand units (e.g., the Cretaceous and updip Clayton) and shallower igneous /metamorphic bedrock give waters with the highest iron or manganese concentrations. Waters with the lowest concentrations are drawn from carbonate units (e.g., the Floridan and the carbonates in the Valley and Ridge/ Appalachian Plateau province), which also usually have the higher pH waters.

4.3.3 Calcium, Magnesium, Sodium, and Potassium

Table 4-1 gives the abundance by aquifer system of calcium, magnesium, and sodium. Calcium is most abundant in sample waters from the Jacksonian aquifer. Sample waters from the Floridan and the Piedmont/Blue Ridge aquifer systems also contain high calcium levels. The metal could be considered least abundant in samples from the Cretaceous/ Providence aquifer system. Only a

Table 4-1. Contents of Calcium, Magnesium, and Sodium in Samples by Aquifer, with Concentration Mean and Range.

Aquifer/ Aquifer System		Calcium ug/L	Magnesium ug//L	Sodium ug/L
Cretaceous Providence	Mean*	4,246	954	14,954
	Range	ND - 22,000	ND - 1,400	1,000 - 73,000
Clayton	Mean	1,100	1,100	3,400
	Range	1,100	1,100	3,400
Claiborne	Mean	24,333	1,567	1,767
	Range	12,000 - 39,000	ND - 3,000	1,700 - 1,900
Jacksonian	Mean	55,600	1,640	3,100
	Range	50,000 - 66,000	ND - 2,600	1,900 - 4,500
Floridan	Mean	38,966	12,621	17,453
	Range	23,000 - 100,000	ND - 74,000	1,800 - 400,000
Miocene/Surficial	Mean	21,100	7,033	7,583
	Range	3,600 - 45,000	1,900 - 14,000	3,100 - 16,000
Piedmont/Blue Ridge	Mean*	38,802	5,637	16,202
	Range	ND - 250,000	ND - 26,000	2,000 – 58,000
Valley and Ridge	Mean	33,222	15,778	2,022
Appalachian Plateau	Range	27,000 - 38,000	14,000 - 17,000	1,200 – 5,000

*Non- detections (ND) are assigned a value of 1000 ug/L for calculating the arithmetic mean.

single, updip sample is available from the Clayton aquifer, making this lowest average calcium content hardly representative.

Magnesium appears most abundant in the Valley and Ridge/Appalachian Plateau aquifer system and least abundant in the Cretaceous system. Again, the average magnesium value for the Clayton aquifer depends on a single sample and is not representative for the aquifer.

Detectable sodium is nearly ubiquitous. The metal is most abundant in waters from the Floridan and the Piedmont/Blue Ridge but least so in waters from the more updip Cretaceous. The testing method used by the EPD laboratory to analyze for potassium is not very sensitive (reporting limit 5,000 ug/L), therefore, detectable potassium was found in only seven samples from three stations – one from the Floridan and two from the Piedmont/Blue Ridge.

Kellam and Gorday (1990) observed that Ca/Mg ratios are highest in the Floridan where recharge areas are closest. Their observation also applies to Floridan in this study, and, a wide range of Ca/Mg ratios from indefinitely large (division by zero or a very small number) to 1.25 exists. However, for carbonate or carbonate-bearing aquifer media in the Valley and Ridge/Appalachian Plateau, the Jacksonian, the Claiborne, the Miocene/Surficial aquifers and aquifer systems, the rule does not seem to apply. The ratios seem to cluster around 2.00 for the Valley and Ridge/Appalachian Plateau samples, and to range from 19.23 up to indefinitely large for the Jacksonian. The low number of sampling stations situated in these other aquifers or aquifer systems might cause the differences between Floridan Ca/Mg ratios and ratios for the other aquifers and aquifer systems to be apparent.

4.4 ICPMS METALS

The ICPMS method works well for most trace metals. Sample waters undergoing testing by this method, as with the samples subject to ICP testing, were unfiltered. The EPD laboratory tested for the following trace metals: chromium, nickel, copper, zinc, arsenic, selenium, molybdenum, silver, cadmium, tin, antimony, barium, thallium, lead, uranium. Silver, cadmium, tin, antimony, and thallium remained below detection in all samples. Of the remaining metals, only lead registered any levels above its action level.

4.4.1 Chromium and Nickel

Detectable chromium occurred in two samples from two Floridan stations. One station, well PA49, is shallow at a 97-foot depth. The other, well PA44, and its downstream plumbing had recently undergone extensive maintenance. As the metal ordinarily does not accumulate in marine carbonate bedrock; outside contamination seems a likely source. In the case of station PA44, if maintenance practices employed coating compounds containing chromium, a possible source would exist. Well P37 gave three of four samples with low-level nickel. The metal would not be out of character in Piedmont/Blue Ridge bedrock.

4.4.2 Arsenic, Selenium, Uranium, and Molybdenum

Arsenic was detected in a sample from the Piedmont/Blue Ridge (well P30) and in one from the Floridan (quarterly well PA23). The Floridan sample came from the Gulf Trough area of Grady County, the scene of other ground-water arsenic detections, some above the Primary MCL (10 ug/L) (Donahue et al., 2012).

Selenium was found in two samples, one from Miocene/Surficial well MI10B and the other from Floridan well PA9C. The element may accompany uranium in deposits formed by the reduction of oxic ground waters.

Nine samples from three Floridan stations are the only samples containing detectable molybdenum. The stations – PA23, PA28, and PA56 – are all Gulf Trough area wells. Like selenium, molybdenum can be associated with uranium in deposits formed through the reduction of oxic ground waters (Turner-Peterson and Hodges, 1986).

Uranium appears to be most abundant in Piedmont/Blue Ridge, with 10 of 19 stations giving 30 of 46 samples containing detectable uranium. The remaining uranium detections were divided between the Floridan, with samples from five stations containing detectable uranium, and the Cretaceous, with one station. Uranium minerals, sometimes accompanied by molybdenum and selenium minerals, can precipitate as secondary mineralization from oxic ground waters subjected to strong reduction.

4.4.3 Copper, Lead, and Zinc

Copper, lead, and zinc detections are more numerous in acidic samples. Lead exceeded its action level in two samples yielding acidic water from wells K12 and K19. Copper did not exceed its action level nor zinc its Secondary MCL in any samples. Out of a total of 141 samples taken for the study, 31 samples with pHs below 7.00 contained detectable amounts of at least one of these metals. In contrast, only 11 samples with basic pHs and one sample with a neutral pH contained detectable amounts of any of these metals. Experiences, such as at station K19, where two samples, each drawn from a different spigot, had different copper, zinc, and lead values, suggest that these metals are, at least in part, derived from plumbing. Therefore, the copper, lead, and zinc levels in the samples are not necessarily representative of those in the ambient ground water at these locations.

4.4.4 Barium

A possible effect of the sensitivity of the testing method, barium detections occur in almost every sample. Because, perhaps, nearby barite deposits and associated mining and processing activities greatly increased the barium level in ground water at station VR6A, a sample from that station has caused the Valley and Ridge/Appalachian Plateau samples to have the highest average barium level. Samples from the Floridan and Miocene/Surficial aquifer systems also have elevated average barium levels. Ground water containing excessive barium

(Primary MCL of 2,000 ug/L) has not been a problem since the in-town public well field, drawing from the Floridan at Fitzgerald, Ben Hill County, closed in 1995.

4.5 CONTAMINATION OCCURRENCES

According to the Safe Drinking Water Act (Public Law 93-523, section 1401, Dec. 16, 1974) a "contaminant" is any "physical, chemical, biological, or radiological substance in water" – almost anything except water itself. Some contaminants can be innocuous or even beneficial; others can be undesirable or harmful.

Modeled after limits the USEPA has established concerning the quality of water offered for public consumption, the State established limits on certain contaminants in water for public use (Table 4-2). Some contaminants may endanger health, if present in sufficient concentrations. Two types of limits apply to such contaminants.

The first, the Primary MCL, imposes mandatory limits applying to treated water at the point of its production. The second, the action level, sets forth mandatory limits that regulate copper and lead contents and apply to water at the point where the consumer can partake of it.

Secondary MCLs (Table 4-2) are suggested limits established for substances imparting only unpleasant qualities to water. The unpleasant qualities include bad taste and staining ability -- such as with iron and manganese.

4.5.1 Primary MCL and Action Level Exceedances

Three wells and one spring produced samples with substances that exceeded Primary MCLs or action levels (Table 4-2). Mineral spring P12A gave three samples that exceeded the Primary MCL for fluoride (4 mg/L). The spring has, in the past, regularly given samples that fall in a range from 4 mg/L to slightly above 5 mg/L fluoride. The fluoride is almost certainly natural.

Lead exceeded its action level of 15 ug/L in samples from two public wells, K12 and K19. A second sample retrieved from well K19 using a different, more frequently used spigot contained lead well below the action level, suggesting that the little-used spigot was the source of the contamination. The source of the excessive lead in well K12 is likely also the well plumbing. Lengthening the purge time before sampling, sampling from frequently used spigots, and increasing the flow through the sampling point have all resulted in reductions in the lead content of sample waters.

Nitrate/nitrite exceeded its Primary MCL of 10 mg/L as nitrogen in well MI9A. The well, a former garden well, 22 feet deep and located adjacent to a row-crop field, has yielded water with excessive nitrate/nitrite before.

Table 4-2. Primary MCL and Copper/Lead Action Level Exceedances, Calendar Year 2012.

Station	Contaminant	MCL	Type Source	Date Sampled
MI9A	Nitrate/nitrite = 11 mg/L as N	10 mg/L	domestic well	06/06/12
K12	Lead = 29 ug/L	15 ug/L	public well	05/10/12
K19	Lead = 20 ug/L	15 ug/L	public well	05/09/12
P12A	Fluoride = 4.7 mg/L	4 mg/L	mineral spring	01/12/12
P12A	Fluoride = 4.7 mg/L	4 mg/L	mineral spring	04/12/12
P12A	Fluoride = 4.3 mg/L	4 mg/L	mineral spring	07/25/12

.4.5.2 Secondary MCL Exceedances

Substances occurring in excess of Secondary MCLs (Table 4-3) consisted of manganese, iron, aluminum, sulfate, and chloride. Manganese, aluminum, and iron are common natural metals in Georgia's ground water.

Manganese exceeded its MCL in 19 samples from 10 wells. Three of the wells were quarterly (P21, P35, P37, PA34A), with the latter three each gave four samples with excessive manganese

The Secondary MCL for aluminum is established as a range, varying from 50 ug/L to 200 ug/L. The range is designed to accommodate the varying ability of water treatment facilities to remove aluminum from water being treated. Treatment facilities must manage a tradeoff between treating water with coagulants containing soluble aluminum and allowing suspended aluminum-bearing metals to bypass part of the treatment process. The aluminum present in waters covered by this study is naturally occurring rather than introduced. Of additional note, water in shallow wells may experience an increase in suspended matter (turbidity) during prolonged rain events, which may result in an increased aluminum value. Aluminum excesses, those which exceeded the 50 ug/L level (most ground water used for public consumption lacks measureable suspended matter), were found in 18 samples from 15 wells and one spring. Aluminum excesses were the most regularly occurring in the domestic bored Piedmont regolith well P33.

Table 4-3. Secondary MCL Exceedances, Calendar Year 2012.

	Excessive Contaminant									
	Manganese		Aluminum		Iron		Sulfate		Chloride	
Aquifer/ Aquifer System	No. of samples	No. of stations	No. of samples	No. of stations	No. of samples	No. of stations	No. of samples	No. of stations	No. of samples	No. of stations
Cretaceous	0	0	5	5	5	5	0	0	0	0
Clayton	0	0	1	1	0	0	0	0	0	0
Claiborne	2	2	0	0	2	2	0	0	0	0
Jacksonian	0	0	0	0	0	0	0	0	0	0
Floridan	6	3	4	4	1	1	1	1	1	1
Miocene/ Surficial	1	1	2	2	1	1	0	0	0	0
Piedmont/ Blue Ridge	10	4	6	4	3	2	3	1	0	0
Valley and Ridge/ Appalachian Plateau	0	0	0	0	0	0	0	0	0	0

Iron exceeded its Secondary MCL in 13 samples from 11 wells. Iron is another common naturally occurring metal in Georgia's ground water. Two of the wells are quarterly (P33 and P37) but it gave only Two samples each that exceeded the MCL.

Two wells (P32 and PA9C) gave four samples with excessive sulfate. Well P32 is a Piedmont/Blue Ridge bedrock well drawing from the Elberton granite, and Well PA9C draws from a zone in the Floridan at Brunswick affected by brine intrusion.

The sample from well PA9C with an excessive sulfate level also contained excessive chloride.

4.5.3 Volatile Organic Compounds

Trihalomethanes are the most common of the VOCs detected (Table 4-4). Chloroform, the most commonly detected of VOCs, was present in 10 samples from six stations. Bromodichloromethane and chlorodibromomethane are next, with seven detections apiece in four stations. Detectable bromoform occurred in two samples from two stations. In ground water, these compounds originate as by-products when halogenous disinfectants react with naturally-occurring organic matter present in the water. The disinfectants are introduced to the water through cleaning processes incident to well maintenance or through leaky check valves or foot valves allowing treated water down a well during normal operation.

Two stations also gave two samples containing detectable perchloroethylene. One of these stations (VR6A) also gave water with detectable 1,1-dichloroethylene, n-dichlorobenzene, and p-dichlorobenzene. Well V6A, an industrial process water well, is in an industrial area and is within about two miles of former and current landfills. The former landfills utilized unlined exhausted barite pits. Cressler et al. (1979) had warned of the danger of using these sorts of pits for waste disposal in the Cartersville area because of the karstic bedrock. The VOCs at station V6A may originate from the pits, industrial establishments, or both.

Table 4-4. VOC Contamination Incidents, Calendar Year 2012.

Station	Contaminant	Primary MCL	Type Source	Date Sampled
GWN-P34	chloroform = 0.58 ug/L	See note	public	02/22/12
GWN-P37	chloroform = 2.7 ug/L	See note	public	01/11/12
GWN-P37	chloroform = 0.96 ug/L	See note	public	04/11/12
GWN-PD6	bromodichloromethane = 0.75 ug/L	See note	public	08/0812
	chlorobibromomethane = 0.95 ug/L			

Table 4-4 Continued. VOC Contamination Incidents, Calendar Year 2012

Station	Contaminant	Primary MCL	Type Source	Date Sampled
GWN-CL2	chloroform = 0.58 ug/L	See note	public	01/26/12
GWN-PA16	tetrachloroethylene = 0.53 ug/L	5 ug/L	public	03/21/12
GWN-PA17	chloroform = 1.8 ug/L	See note	public	03/22/12
	bromodichloromethane = 1.4 ug/L			
	chlorobibromomethane = 1.1 ug/L			
GWN-PA23	chloroform = 0.81 ug/L	See note	public	01/12/12
	bromodichloromethane = 0.66 ug/L			
	chlorobibromomethane = 0.59 ug/L			
GWN-PA23	chloroform = 1.9 ug/L	See note	public	04/11/12
	bromodichloromethane = 1.4 ug/ L			
	chlorobibromomethane = 1.4 ug/L			
GWN-PA23	chloroform = 1.9 ug/L	See note	public	07/11/12
	bromodichloromethane = 1.5 ug/ L			
	chlorobibromomethane = 1.2 ug/L			
GWN-PA23	chloroform = 1.7ug/L	See note	public	10/24/12
	bromodichloromethane = 1.6 ug/L			
	chlorodibromomethane = 1.6 ug/L			
GWN-PA44	bromoform = 0.5 ug/L	See note	public	04/12/12
	chloroform = 8.7 ug/L			
	bromoform = 0.8 ug/L			
	bromodichloromethane = 3.3 ug/L			
	chlorodibromomethane = 2.2 ug/L			

Table 4-4 Continued. VOC Contamination Incidents, Calendar Year 2012				
Station	**Contaminant**	**Primary MCL**	**Type Source**	**Date Sampled**
GWN-VR6A	1,1-dichloroethylene = 1.8 ug/L	7 ug/L	industrial	05/23/12
	tetrachloroethylene = 2.2 ug/L	5 ug/L		
	1,2-dichlorobenzene = 1.6 ug/L	75 ug/L		
	1,3-dichlorobenzene = 0.59 ug/L	No MCL		

Note: The sum of all trihalomethane compounds, i.e. chloroform, bromoform, chlorodibromomethane and dichlorobromomethane must not exceed a Primary MCL of 80 ug/L.

4.6 GENERAL QUALITY

A review of the analyses of the water samples collected during calendar year 2012 indicates that the chemical quality of ground water sampled for most of the Ground-Water Monitoring Network stations is quite good.

However, as mentioned in Chapter 1, areas of elevated risk for low-quality ground water exist:

1) Valley and Ridge/Appalachian Plateau Province – surface influence;
2) Piedmont/Blue Ridge Province – in areas excluding the eastern metavolcanic terranes -- uranium and radionuclides;
3) Coastal Plain agricultural areas – high nitrate/nitrite;
4) Coastal Plain, Dougherty Plain – surface influence;
5) Coastal Plain, Gulf Trough – high total dissolved solids, especially sulfate – high radionuclides, high barium, high arsenic;
6) Coastal Plain, Atlantic coast area – saline water influx.

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APPENDIX

LABORATORY AND STATION DATA

Tables A-1 through A-8 list the values for both laboratory parameters and field parameters for each well or spring. The following abbreviations are used on these tables:

Parameters and Units of Measure

Cl = chloride
cond. = conductivity
diss O2 = dissolved oxygen
F = fluoride
ICP = inductively coupled plasma (emission) spectroscopy
ICPMS = inductively coupled plasma/mass spectrometry
mg/L = milligrams per liter
mgN/L = milligrams per liter as nitrogen
NA = not available; not analyzed

ND = not detected
NG = not given
NOx = nitrate/nitrite
P = total phosphorus
SO4 = sulfate
Temp. = temperature
ug/L = micrograms per liter
uS/cm = microSiemenses per centimeter
VOC = volatile organic compound

Volatile Organic Compounds

1,1dce = 1,1-dichloroethylene
bdcm = bromodichloromethane
dbcm = dibromochloromethane
pce = tetrachloroethylene

odcb = o-dichlorobenzene
pdcb = p-dichlorobenzene
tbm = bromoform
tcm = chloroform

Table A-9 gives the reporting limits for the various analytes. The abbreviations used for Tables A-1 through A-8 also apply to Table A-9.

Table A-1. Ground-Water Quality Analyses for Cretaceous/Providence Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-K3 **Washington**	Sandersville Well #7B	697	NG	NG	05/09/12	5.97	131	5.93	21.3	ND	ND	11	0.42	0.43
GWN-K6 **Twiggs**	KaMin Well #6	400	NG	NG	12/12/12	5.56	100	6.59	19.36	ND	ND	ND	ND	ND
GWN-K7 **Jones**	Jones County #4	128	NG	NG	05/10/12	4.79	24	7.02	17.7	ND	ND	ND	0.53	ND
GWN-K9 **Macon**	Marshallville Well #1	550	NG	NG	01/26/12	4.02	30	0.01	19.6	ND	ND	11	ND	ND
GWN-K10B **Peach**	Fort Valley Well #6	600	NG	NG	01/26/12	4.66	10	7.70	18.3	ND	ND	ND	0.68	ND
GWN-K11A **Houston**	Warner Robins Well #2	540	NG	NG	03/08/12	4.69	12	5.76	18.8	ND	ND	ND	0.79	ND
GWN-K12 **Houston**	Perry/Holiday Inn Well	550	NG	NG	05/10/12	3.90	47	0.63	19.5	ND	ND	10	ND	0.02
GWN-K19 **Richmond**	Hephzibah/Murphy Street Well	484	NG	NG	05/09/12 12/05/12	4.86 4.75	13 32	8.00 7.49	20.3 19.84	ND ND	ND ND	ND ND	0.11 0.10	0.02 ND
GWN-K20 **Sumter**	Plains Well #7	1000	NG	NG	06/07/12	7.76	72	NA	28.9	ND	ND	ND	ND	0.18
GWN-PD2A **Webster**	Preston Well #4	205	NG	NG	03/08/12	5.50	39	7.70	19.2	ND	ND	ND	1.8	0.13
GWN-PD3 **Clay**	Fort Gaines Well #2	456	NG	NG	03/08/12	8.38	355	0.58	21.7	ND	10	ND	ND	0.02
GWN-PD6 **Early**	Blakely Well #4	1025	NG	NG	03/08/12	7.85	338	2.03	22.9	dbcm=0.95 bdcm=0.75	ND	13	0.24	0.02

Table A-1. Ground-Water Quality Analyses for Cretaceous/Providence Stations.

Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-K3 **Washington**	ND	ND	6.1	ND	ND	ND	ND	ND	ND	ND	ND	28	ND	2.0	ND	75	ND	22,000	ND	510	ND	1,400	21	2,600	ND	ND
GWN-K6 **Twiggs**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17	ND	ND	1.1	ND	ND	5,000	ND	650	ND	ND	ND	3,100	ND	ND
GWN-K7 **Jones**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18	ND	1.8	ND	ND	ND	2,100	ND	ND	ND	ND	ND	1,800	ND	ND
GWN-K9A **Macon**	ND	ND	48	88	ND	ND	ND	ND	ND	ND	ND	3.8	ND	4.0	ND	490	ND	ND	ND	450	ND	ND	ND	1,000	ND	ND
GWN-K10B **Peach**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,200	ND	ND
GWN-K11A **Houston**	ND	ND	7.9	13	ND	ND	ND	ND	ND	ND	ND	6.7	ND	ND	ND	ND	ND	ND	ND	310	ND	ND	14	1,700	ND	ND
GWN-K12 **Houston**	ND	ND	27	47	ND	ND	ND	ND	ND	ND	ND	5.6	ND	29	ND	430	ND	ND	ND	170	ND	ND	12	1,000	ND	ND
GWN-K19 **Richmond**	ND ND	ND ND	13 ND	180 14	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	6.3 5.5	ND ND	20 1.2	ND ND	ND ND	ND ND	ND ND	ND ND	400 23	ND ND	ND ND	11 ND	1,200 1,300	ND ND	ND ND
GWN-K20 **Sumter**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3,100	ND	ND	ND	ND	ND	22,000	ND	ND
GWN-PD2A **Webster**	ND	ND	9.9	ND	ND	ND	ND	ND	ND	ND	ND	20	ND	2.6	ND	110	ND	4,500	ND	54	ND	1,200	ND	1,500	ND	ND
GWN-PD3 **Clay**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.6	ND	ND	ND	61	ND	6,300	ND	ND	ND	1,100	ND	83,000	ND	ND
GWN-PD6 **Early**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.4	ND	ND	ND	ND	ND	9,200	ND	ND	ND	4,200	ND	73,000	ND	ND

Table A-2. Ground-Water Quality Analyses for Clayton Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-CT8 **Schley**	Weathersby House Well	80	NG	NG	05/10/12	4.27	45	7.90	18.2	ND	ND	ND	2.1	ND

Table A-2. Ground-Water Quality Analyses for Clayton Stations.

Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-CT8 **Schley**	ND	ND	20.0	ND	ND	ND	ND	ND	ND	ND	ND	26	ND	5.6	ND	120	ND	1,100	ND	ND	ND	1,100	26	3,400	ND	ND

Table A-3. Ground-Water Quality Analyses for Claiborne Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-CL2 **Dooly**	Unadilla Well #3	315	315	24	01/26/12	7.54	127	3.10	19.8	tcm=0.55	ND	ND	0.41	ND
GWN-CL4A **Sumter**	Plains Well #8	230	NG	NG	06/07/12	6.78	98	NA	20.3	ND	ND	12	ND	0.34
GWN-CL8 **Dooly**	Flint River Nursery Office Well	90	NG	NG	01/26/12	6.20	53	0.02	20.7	ND	ND	ND	ND	0.51

Table A-3. Ground-Water Quality Analyses for Claiborne Stations.

Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-CL2 **Dooly**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	39,000	ND	ND	ND	ND	ND	1,700	ND	ND
GWN-CL4A **Sumter**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	ND	ND	22,000	ND	1,800	ND	3,000	56	1,700	ND	ND
GWN-CL8 **Dooly**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	36	ND	ND	ND	ND	ND	12,000	ND	650	ND	1,200	51	1,900	ND	ND

Table A-4. Ground-Water Quality Analyses for Jacksonian Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No.	Well Name	Well Depth	Casing Depth	Well Size	Date	pH	cond.	diss O2	Temp	VOCS	Cl	SO4	NOx	P
County		feet	feet	Inches	sampled		uS/cm	mg/L	°C	ug/L	mg/L	mg/L	mg N/L	mg/L
GWN-J1B **Jefferson**	McNair House Well	~90	NG	NG	03/21/12	7.13	270	5.98	19.1	ND	10	ND	2.6	0.06
GWN-J4 **Johnson**	Wrightsville #4	520	NG	8	02/21/12	7.35	251	0.88	20.4	ND	ND	ND	0.06	0.03
GWN-J5 **Bleckley**	Cochran #3	307	NG	NG	03/08/12	7.50	212	0.00	20.5	ND	ND	12	ND	0.04
GWN-J6 **Jefferson**	Wrens #4	200	NG	NG	03/21/12	6.97	255	2.71	19.5	ND	ND	12	ND	0.15
GWN-J8A **Jefferson**	Kahn House Well II	NG	NG	NG	03/21/12	7.35	296	1.99	19.0	ND	ND	ND	0.04	0.03

Table A-4. Ground-Water Quality Analyses for Jacksonian Stations.

Part B: Metals.

Station No. County	Chro-mium ug/L	Nick-el ug/L	Cop-per ug/L	Zinc ppb ug/L	Arsen-ic ug/L	Selen-ium ug/L	Molyb-denum ug/L	Silver ppb ug/L	Cad-mium ug/L	Tin ppb ug/L	Anti-mony ug/L	Barium ppb ug/L	Thal-lium ug/L	Lead ppb ug/L	Ura-nium ug/L	Alumi-num ug/L	Beryl-lium ug/L	Calcium ug/L	Co-balt ug/L	Iron ug/L	Potas-sium ug/L	Magne-sium ug/L	Manga-nese ug/L	Sodium ug/L	Tita-nium ug/L	Vana-dium ug/L
GWN-J1B **Jefferson**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	21	ND	ND	ND	ND	ND	53,000	ND	ND	ND	ND	ND	4,500	ND	ND
GWN-J4 **Johnson**	ND	ND	6.6	ND	ND	ND	ND	ND	ND	ND	ND	8.2	ND	ND	ND	ND	ND	50,000	ND	ND	ND	2,600	ND	3,500	ND	ND
GWN-J5 **Bleckley**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.8	ND	ND	ND	ND	ND	66,000	ND	ND	ND	2,500	ND	3,200	ND	ND
GWN-J6 **Jefferson**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.5	ND	ND	ND	ND	ND	50,000	ND	150	ND	1,500	ND	1,900	ND	ND
GWN-J8A **Jefferson**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.7	ND	ND	ND	ND	ND	59,000	ND	ND	ND	1,100	22	2,400	ND	ND

Table A-5. Ground-Water Quality Analyses for Floridan Stations.

Part A: Station Identification , Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-PA2 **Chatham**	Savannah Well #13	1004	NG	NG	05/10/12	8.02	149	NA	22.7	ND	ND	ND	ND	0.04
GWN-PA4 **Chatham**	Tybee Island Well #1	402	NG	NG	05/10/12	8.00	406	0.00	22.9	ND	45	150	ND	0.04
GWN-PA5 **Liberty**	Interstate Paper Well #1	810	NG	NG	05/09/12	7.95	197	0.00	24.6	ND	ND	34	ND	0.03
GWN-PA6 **Liberty**	Hinesville Well #5	806	NG	NG	05/09/12	7.99	174	0.03	24.7	NA	ND	22	ND	0.03
					09/26/12	7.76	285	0.53	24.7	ND	ND	23	ND	ND
GWN-PA9C **Glynn**	Miller Ball Park North East Well	1211	NG	NG	05/09/12	7.71	311	0.14	26.3	ND	760	270	ND	0.03
GWN-PA13 **Ware**	Waycross Well #3	775	NG	NG	03/22/12	7.97	248	0.00	25.0	ND	14	50	ND	ND
GWN-PA14A **Bulloch**	Statesboro Well #4	413	NG	NG	03/07/12	7.52	163	NA	23.3	ND	ND	ND	ND	0.04
					05/23/12	7.36	234	NA	23.4	ND	ND	ND	ND	0.03
					08/22/12	7.54	238	NA	24.1	ND	ND	ND	ND	0.03
					11/28/12	7.82	258	NA	23.35	ND	ND	ND	ND	0.03
GWN-PA16 **Jenkins**	Millen Well #1	500	NG	NG	03/21/12	7.61	270	1.17	21.5	pce=0.53	ND	ND	ND	0.02
GWN-PA17 **Emanuel**	Swainsboro Well #7	260	NG	NG	03/22/12	7.45	241	5.56	18.9	tcm=1.8 bdcm=1.4 dbcm=1.1	ND	ND	0.03	ND
GWN-PA18 **Candler**	Metter Well #2	540	NG	NG	03/21/12	7.85	208	0.62	21.8	ND	ND	ND	ND	0.03
GWN-PA20 **Lanier**	Lakeland Well #2	340	NG	NG	03/22/12	7.97	222	0.09	22.0	ND	ND	65	ND	0.06
GWN-PA22 **Thomas**	Thomasville Well #6	400	NG	NG	03/07/12	7.62	374	3.99	22.2	ND	ND	65	0.15	ND

Table A-5. Ground-Water Quality Analyses for Floridan Stations.
Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-PA2 **Chatham**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	ND	ND	23,000	ND	ND	ND	8,400	ND	14,000	ND	ND
GWN-PA4 **Chatham**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.6	ND	ND	ND	ND	ND	35,000	ND	ND	ND	28,000	ND	58,000	ND	ND
GWN-PA5 **Liberty**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	29	ND	ND	ND	ND	ND	26,000	ND	ND	ND	15,000	ND	17,000	ND	ND
GWN-PA6 **Liberty**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23.0	ND	ND	ND	160	ND	24,000	ND	ND	ND	12,000	ND	14,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25.0	ND	ND	ND	ND	ND	24,000	ND	ND	ND	13,000	ND	15,000	ND	ND
GWN-PA9C **Glynn**	ND	ND	ND	ND	ND	10.0	ND	ND	ND	ND	ND	57	ND	ND	ND	ND	ND	100,000	ND	550	8,100	74,000	ND	400,000	ND	ND
GWN-PA13 **Ware**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	67	ND	ND	ND	ND	ND	40,000	ND	ND	ND	19,000	ND	16,000	ND	ND
GWN-PA14A **Bulloch**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.1	ND	ND	ND	ND	ND	35,000	ND	ND	ND	6,700	ND	7,700	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.2	ND	ND	ND	ND	ND	34,000	ND	ND	ND	6,500	ND	7,300	ND	ND
	ND	ND	7.4	ND	ND	ND	ND	ND	ND	ND	ND	3.9	ND	1.4	ND	ND	ND	34,000	ND	ND	ND	6,700	ND	7,600	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.1	ND	ND	ND	ND	ND	34,000	ND	ND	ND	6,800	ND	7,400	ND	ND
GWN-PA16 **Jenkins**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.2	ND	ND	ND	ND	ND	47,000	ND	ND	ND	3,700	60	5,300	ND	ND
GWN-PA17 **Emanuel**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	ND	ND	ND	ND	ND	48,000	ND	ND	ND	1,900	ND	3,300	ND	ND
GWN-PA18 **Candler**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25	ND	ND	ND	ND	ND	30,000	ND	ND	ND	3,700	64	11,000	ND	ND
GWN-PA20 **Lanier**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26	ND	ND	ND	190	ND	43,000	ND	ND	ND	18,000	ND	4,900	ND	ND
GWN-PA22 **Thomas**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	24	ND	ND	1.3	ND	ND	47,000	ND	ND	ND	22,000	ND	7,600	ND	ND

Table A-5, Continued. Ground-Water Quality Analyses for Floridan Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-PA23 **Grady**	Cairo #8	465'	NG	NG	01/12/12	7.78	247	1.33	22.6	tcm=0.81 bdcm=0.66 dbcm=0.59	ND	42	0.02	ND
					04/11/12	7.72	338	2.84	23.0	tcm=1.9 bdcm=1.4 dbcm=1.4	ND	39	ND	ND
					07/11/12	7.86	215	NA	23.3	tcm=1.9 bdcm=1.5 dbcm=1.2	ND	38	ND	ND
					10/24/12	7.44	353	2.18	22.9	tcm=1.7 bdcm=1.6 dbcm=1.6 tbm=0.5	ND	39	ND	ND
GWN-PA25 **Seminole**	Donalsonville / 7th Street Well	174	NG	NG	03/07/12	7.22	280	5.44	21.10	ND	ND	ND	1.6	0.02
					06/06/12	7.51	183	NA	21.10	ND	ND	ND	1.7	ND
					09/12/12	6.59	294	5.60	21.30	ND	ND	ND	1.6	ND
					12/12/12	7.53	282	7.14	21.72	ND	ND	ND	1.6	ND
GWN-PA27 **Mitchell**	Camilla Industrial Park Well	360	NG	NG	03/21/12	7.84	150	3.91	20.7	ND	ND	ND	0.60	ND
GWN-PA28 **Colquitt**	Moultrie Well #1	750	NG	NG	01/12/12	8.05	339	0.48	23.5	ND	11	120	ND	ND
					04/11/12	7.89	430	0.59	23.8	ND	ND	96	ND	ND
					07/11/12	7.97	310	NA	23.7	ND	11	120	ND	ND
					10/24/12	7.57	492	0.54	23.6	ND	11	120	ND	ND
GWN-PA29 **Cook**	Adel Well #6	405	NG	NG	01/12/12	7.84	233	0.04	22.0	ND	ND	50	ND	0.05
					04/11/12	7.68	326	1.21	22.3	ND	ND	51	ND	0.05
					07/12/12	7.82	212	NA	22.0	ND	ND	50	ND	0.04
					10/24/12	7.39	351	0.57	22.2	ND	ND	55	ND	0.04
GWN-PA30 **Berrien**	Propex/Nashville Mills Well #2	410	NG	NG	03/22/12	8.05	218	0.01	23.7	ND	ND	61	ND	ND
GWN-PA31 **Tift**	Tifton Well #6	652	NG	NG	01/25/12	7.43	263	1.20	22.2	ND	ND	ND	0.02	ND
GWN-PA32 **Irwin**	Ocilla Well #3	637	NG	NG	03/07/12	7.28	137	0.00	20.9	ND	ND	ND	ND	0.03

Table A-5. Ground-Water Quality Analyses for Floridan Stations.
Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-PA23 **Grady**	ND	ND	ND	ND	5.0	ND	18	ND	ND	ND	ND	120	ND	ND	ND	ND	ND	36,000	ND	24	ND	17,000	ND	16,000	ND	ND
	ND	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	120	ND	ND	ND	ND	ND	35,000	ND	34	ND	17,000	ND	15,000	ND	ND
	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	ND	110	ND	ND	ND	ND	ND	34,000	ND	140	ND	17,000	ND	15,000	ND	ND
	ND	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	130	ND	ND	ND	ND	ND	34,000	ND	ND	ND	17,000	ND	15,000	ND	ND
GWN-PA25 **Seminole**	ND	ND	ND	34	ND	ND	ND	ND	ND	ND	ND	9.5	ND	2.2	ND	110	ND	61,000	ND	65	ND	ND	ND	3,800	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.0	ND	ND	ND	ND	ND	57,000	ND	ND	ND	ND	ND	3,600	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.4	ND	ND	ND	ND	ND	56,000	ND	ND	ND	ND	ND	3,500	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.0	ND	ND	ND	ND	ND	61,000	ND	ND	ND	ND	ND	3,900	ND	ND
GWN-PA27 **Mitchell**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	46,000	ND	ND	ND	1,500	ND	1,900	ND	ND
GWN-PA28 **Colquitt**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	87	ND	ND	ND	ND	ND	38,000	ND	ND	ND	23,000	ND	27,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	90	ND	ND	ND	ND	ND	36,000	ND	ND	ND	21,000	ND	28,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	88	ND	ND	ND	ND	ND	40,000	ND	ND	ND	24,000	ND	28,000	ND	ND
	ND	ND	ND	ND	ND	ND	5.2	ND	ND	ND	ND	95	ND	ND	ND	ND	ND	40,000	ND	ND	ND	24,000	ND	29,000	ND	ND
GWN-PA29 **Cook**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	44,000	ND	28	ND	15,000	17	3,300	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	46,000	ND	28	ND	16,000	17	3,400	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	43,000	ND	28	ND	15,000	15	3,200	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	ND	ND	48,000	ND	24	ND	18,000	17	3,600	ND	ND
GWN-PA30 **Berrien**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	50	ND	ND	ND	ND	ND	40,000	ND	210	ND	18,000	ND	5,200	ND	ND
GWN-PA31 **Tift**	ND	ND	7.4	ND	ND	ND	ND	ND	ND	ND	ND	65	ND	2.1	1.6	ND	ND	42,000	ND	22	ND	8,100	ND	2,400	ND	ND
GWN-PA32 **Irwin**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	73	ND	ND	ND	ND	ND	34,000	ND	88	ND	5,900	28	2,500	ND	ND

Table A-5, Continued. Ground-Water Quality Analyses for Floridan Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-PA34A **Telfair**	McRae Well #3	600	NG	NG	02/21/12	7.34	304	4.93	22.3	ND	ND	ND	ND	0.03
					05/23/12	7.10	325	0.60	22.6	ND	ND	ND	ND	0.02
					08/22/12	6.75	322	0.53	22.5	ND	ND	ND	ND	ND
					11/28/12	7.38	350	0.60	22.3	ND	ND	ND	ND	ND
GWN-PA36 **Toombs**	Vidalia Well #1	808	NG	NG	02/21/12	7.75	216	0.58	23.1	ND	ND	ND	ND	0.03
					05/23/12	7.59	221	0.60	24.0	ND	ND	ND	ND	0.03
					08/22/12	7.11	220	0.53	23.3	ND	ND	ND	ND	ND
					11/28/12	7.88	241	1.07	23.41	ND	ND	ND	ND	ND
GWN-PA38 **Dodge**	Eastman Well #4	410	NG	NG	04/12/12	7.49	244	4.01	20.4	ND	ND	ND	0.28	0.03
GWN-PA39 **Worth**	SylvesterWell #1	196	NG	NG	03/21/12	7.75	180	0.92	21.8	ND	ND	ND	0.04	ND
GWN-PA44 **Turner**	Sycamore Well #2	501	NG	NG	04/12/12	7.75	204	2.90	22.3	tcm=8.7 tbm=0.8 bdcm=3.3 dbcm=2.2	ND	ND	0.1	0.03
					07/11/12	8.02	120	NA	21.5	ND	ND	ND	0.24	ND
					10/25/12	7.49	196	3.31	21.4	ND	ND	ND	0.24	ND
GWN-PA49 **Dooly**	Harmony Church Well	97	NG	NG	03/21/12	8.10	122	7.38	20.9	ND	ND	ND	2.3	ND
GWN-PA56 **Grady**	Whigham / Davis Avenue Well	604	NG	NG	03/07/12	7.56	377	1.30	23.0	ND	34	19	0.06	ND
					06/06/12	7.85	253	NA	23.0	ND	36	22	0.05	0.02
					09/12/12	7.32	412	1.10	23.0	ND	37	20	0.05	ND
					12/12/12	7.81	410	1.39	23.37	ND	34	20	0.06	ND
GWN-PA57 **Coffee**	Ambrose Well #2	600	465	10	01/12/12	7.87	174	0.21	22.3	ND	ND	ND	0.03	0.02
					04/12/12	7.74	241	2.36	22.3	ND	ND	ND	ND	0.02
					07/11/12	8.00	157	NA	22.8	ND	ND	ND	ND	ND
					10/25/12	7.54	255	0.67	22.6	ND	ND	ND	ND	ND

Table A-5. Ground-Water Quality Analyses for Floridan Stations.

Part B: Metals.

Station No. County	Chro-mium ug/L	Nick-el ug/L	Cop-per ug/L	Zinc ppb ug/L	Arsen-ic ug/L	Selen-ium ug/L	Molyb-denum ug/L	Silver ppb ug/L	Cad-mium ug/L	Tin ppb ug/L	Anti-mony ug/L	Barium ppb ug/L	Thal-lium ug/L	Lead ppb ug/L	Ura-nium ug/L	Alumi-num ug/L	Beryl-lium ug/L	Calcium ug/L	Co-balt ug/L	Iron ug/L	Potas-sium ug/L	Magne-sium ug/L	Manga-nese ug/L	Sodium ug/L	Tita-nium ug/L	Vana-dium ug/L
GWN-PA34A **Telfair**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	180	ND	ND	ND	ND	ND	51,000	ND	260	ND	11,000	100	4,700	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	190	ND	ND	ND	ND	ND	47,000	ND	230	ND	10,000	94	4,400	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	160	ND	1.4	ND	ND	ND	50,000	ND	240	ND	11,000	99	4,900	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	190	ND	ND	ND	ND	ND	47,000	ND	230	ND	11,000	93	4,500	ND	ND
GWN-PA36 **Toombs**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	140	ND	ND	ND	ND	ND	28,000	ND	25	ND	5,400	36	11,000	ND	ND
	ND	ND	6.1	ND	ND	ND	ND	ND	ND	ND	ND	140	ND	ND	ND	ND	ND	27,000	ND	23	ND	5,400	36	11,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	130	ND	1.5	ND	ND	ND	28,000	ND	20	ND	5,600	37	11,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	150	ND	ND	ND	ND	ND	29,000	ND	ND	ND	5,900	36	12,000	ND	ND
GWN-PA38 **Dodge**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	110	ND	ND	ND	ND	ND	51,000	ND	ND	ND	1,500	ND	2,300	ND	ND
GWN-PA39 **Worth**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	190	ND	ND	2.3	ND	ND	47,000	ND	ND	ND	7,900	ND	3,800	ND	ND
GWN-PA44 **Turner**	5.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	130	ND	ND	1.4	ND	ND	33,000	ND	ND	ND	4,900	ND	3,500	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	140	ND	ND	1.3	ND	ND	32,000	ND	ND	ND	4,500	ND	2,400	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	150	ND	ND	1.3	ND	ND	30,000	ND	ND	ND	4,500	ND	2,400	ND	ND
GWN-PA49 **Dooly**	5.2	ND	ND	21	ND	ND	ND	ND	ND	ND	ND	18	ND	ND	ND	ND	ND	37,000	ND	31	ND	ND	ND	1,800	ND	ND
GWN-PA56 **Grady**	ND	ND	ND	ND	ND	ND	8.3	ND	ND	ND	ND	140	ND	ND	2.8	ND	ND	34,000	ND	ND	ND	21,000	ND	25,000	ND	ND
	ND	ND	ND	ND	ND	ND	8.8	ND	ND	ND	ND	150	ND	ND	2.9	ND	ND	29,000	ND	ND	ND	18,000	ND	21,000	ND	ND
	ND	ND	ND	ND	ND	ND	9.9	ND	ND	ND	ND	160	ND	ND	3.2	ND	ND	31,000	ND	ND	ND	20,000	ND	23,000	ND	ND
	ND	ND	ND	ND	ND	ND	9.0	ND	ND	ND	ND	150	ND	ND	2.7	ND	ND	33,000	ND	ND	ND	20,000	ND	24,000	ND	ND
GWN-PA57 **Coffee**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	ND	ND	ND	ND	ND	27,000	ND	ND	ND	15,000	ND	7,800	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	ND	ND	ND	ND	ND	26,000	ND	ND	ND	15,000	ND	7,600	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	170	ND	ND	ND	94	ND	24,000	ND	ND	ND	14,000	ND	7,300	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	190	ND	ND	ND	ND	ND	24,000	ND	ND	ND	15,000	ND	7,500	ND	ND

Table A-6. Ground-Water Quality Analyses for Miocene Stations.

Part A: Station Identification , Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-MI1 **Cook**	Adel/McMillan	220	NG	NG	01/25/12	7.74	228	3.23	21.4	ND	ND	ND	0.03	0.02
GWN-MI2A **Lowndes**	Boutwell House Well	70	NG	NG	01/25/12	4.39	93	6.70	21.5	ND	13	ND	4.9	ND
GWN-MI9A **Thomas**	Murphy Garden Well	22	NG	NG	06/06/12	6.89	131	NA	22.3	ND	10	ND	11	0.12
GWN-MI10B **Colquitt**	Calhoun House Well	150	NG	NG	06/06/12	6.54	69	NA	22.2	ND	ND	ND	ND	0.33
GWN-MI16 **Liberty**	Liberty County East District Fire Station Deep Well	400	NG	NG	09/26/12	7.38	317	1.19	23.9	ND	ND	35	ND	ND
GWN-MI 17 **Effingham**	Springfield Egypt Road Test Well	120	NG	NG	05/10/12	7.72	159	0.00	19.2	ND	ND	ND	ND	0.03

Table A-6. Ground-Water Quality Analyses for Miocene Stations.

Part B: Metals.

Station No. County	Chro-mium ug/L	Nick-el ug/L	Cop-per ug/L	Zinc ppb ug/L	Arsen-ic ug/L	Selen-ium ug/L	Molyb-denum ug/L	Silver ppb ug/L	Cad-mium ug/L	Tin ppb ug/L	Anti-mony ug/L	Barium ppb ug/L	Thal-lium ug/L	Lead ppb ug/L	Ura-nium ug/L	Alumi-num ug/L	Beryl-lium ug/L	Calcium ug/L	Co-balt ug/L	Iron ug/L	Potas-sium ug/L	Magne-sium ug/L	Manga-nese ug/L	Sodium ug/L	Tita-nium ug/L	Vana-dium ug/L
GWN-MI1 **Cook**	ND	ND	ND	33	ND	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	ND	ND	23,000	ND	ND	ND	14,000	ND	6,500	ND	ND
GWN-MI2A **Lowndes**	ND	ND	9.7	ND	ND	ND	ND	ND	ND	ND	ND	21	ND	12	ND	130	ND	3,600	ND	ND	ND	2,500	ND	4,800	ND	ND
GWN-MI9A **Thomas**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	71	ND	ND	ND	82	ND	22,000	ND	24	ND	4,200	ND	3,100	ND	ND
GWN-MI10B **Colquitt**	ND	ND	ND	130	ND	14	ND	ND	ND	ND	ND	190	ND	1.7	ND	ND	ND	8,000	ND	3,600	ND	5,600	98	6,700	ND	ND
GWN-MI16 **Liberty**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23	ND	ND	ND	ND	ND	25,000	ND	ND	ND	14,000	ND	16,000	ND	ND
GWN-MI 17 **Effingham**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23	ND	ND	ND	ND	ND	45,000	ND	ND	ND	1,900	12	8,400	ND	ND

Table A-7. Ground-Water Quality Analyses for Piedont-Blue Ridge Stations.

Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-P1A **Meriwether**	Luthersville Well #3	185	NG	NG	06/06/12	5.76	81	7.52	17.5	ND	ND	ND	0.99	0.08
GWN-P5 **Hall**	Flowery Branch Well #1	240	NG	NG	06/07/12	6.34	179	6.03	17.0	ND	ND	ND	1.70	0.04
GWN-P12A **Butts**	Indian Spring	0	NG	NG	01/12/12	6.80	246	NA	15.7	ND	11	26	ND	0.03
					04/12/12	7.41	159	NA	16.8	ND	11	25	ND	0.03
					07/25/12	6.66	250	NA	19.4	ND	11	26	ND	0.02
					10/18/12	6.97	270	NA	18.3	ND	11	26	ND	0.02
GWN-P20 **Gwinnett**	Suwanee #1	600	NG	NG	01/11/12	7.52	205	0.13	17.7	ND	ND	15	0.29	ND
GWN-P21 **Jones**	Gray/Bragg Well	405	NG	NG	02/21/12	6.54	285	1.94	19.6	ND	10	22	0.08	0.04
					05/24/12	6.31	287	4.89	19.4	ND	ND	19	0.06	0.04
					08/09/12	6.07	294	11.62	19.7	ND	ND	29	0.05	0.03
					11/15/12	6.57	479	5.67	18.37	ND	ND	26	0.06	0.03
GWN-P22 **Fulton**	Rahbar Well	200	NG	NG	6/6/2012	5.00	24	6.54	17.1	ND	ND	ND	0.89	ND
GWN-P23 **Butts**	Indian Springs State Park New Main Well	NG	NG	NG	01/12/12	6.78	249	2.07	18.1	ND	36	ND	0.23	0.08
					04/12/12	6.44	88	1.44	18.2	ND	ND	ND	0.25	0.08
					07/25/12	5.62	140	1.76	18.5	ND	ND	ND	0.21	0.08
					10/18/12	6.10	152	1.58	18.3	ND	ND	ND	0.18	0.08
GWN-P24 **Coweta**	The Gates Well #1	705	NG	NG	05/24/12	7.00	203	2.99	19.2	ND	ND	12	0.23	0.05
GWN-P30 **Lincoln**	Fizer House Well	220	NG	NG	08/10/12	6.55	407	1.28	19.1	ND	14	18	1.60	0.03
GWN-P32 **Elbert**	Cecchini Deep Well	400	NG	NG	01/11/12	7.92	874	1.36	16.6	ND	ND	340	ND	ND
					04/11/12	7.99	452	0.00	18.1	ND	ND	220	ND	ND
					07/11/12	7.30	1280	0.52	23.7	ND	ND	620	ND	ND
					10/17/12	7.14	714	0.66	18.6	ND	ND	300	ND	ND

Table A-7. Ground-Water Quality Analyses for Piedmont-Blue Ridge Stations.
Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-P1A **Meriwether**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	42	ND	ND	ND	ND	ND	9,000	ND	ND	ND	1,900	ND	4,300	ND	ND
GWN-P5 **Hall**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	42	ND	ND	ND	ND	ND	25,000	ND	ND	ND	4,800	ND	3,900	ND	ND
GWN-P12A **Butts**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16,000	ND	ND	ND	2,500	19	40,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16,000	ND	ND	ND	2,500	19	39,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0	ND	ND	ND	64	ND	16,000	ND	ND	ND	2,600	19	41,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16,000	ND	ND	ND	2,700	21	43,000	ND	ND
GWN-P20 **Gwinnett**	ND	ND	ND	15	ND	ND	ND	ND	ND	ND	ND	200	ND	ND	4.1	ND	ND	45,000	ND	ND	ND	9,200	62	13,000	ND	ND
GWN-P21 **Jones**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14	ND	ND	9.3	ND	ND	38,000	ND	ND	ND	8,400	48	16,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	8.0	ND	ND	34,000	ND	ND	ND	7,800	35	14,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14	ND	1.2	5.9	ND	ND	34,000	ND	ND	ND	7,600	59	15,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	7.8	ND	ND	36,000	ND	ND	ND	8,100	47	15,000	ND	ND
GWN-P22 **Fulton**	ND	ND	44	ND	ND	ND	ND	ND	ND	ND	ND	17	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	2,000	ND	ND
GWN-P23 **Butts**	ND	ND	ND	39	ND	ND	ND	ND	ND	ND	ND	4.7	ND	ND	2.2	ND	ND	11,000	ND	93	ND	3,600	ND	44,000	ND	ND
	ND	ND	ND	28	ND	ND	ND	ND	ND	ND	ND	5.0	ND	ND	2.1	ND	ND	11,000	ND	110	ND	3,600	ND	14,000	ND	ND
	ND	ND	ND	30	ND	ND	ND	ND	ND	ND	ND	5.4	ND	ND	2.3	ND	ND	12,000	ND	35	ND	3,700	ND	14,000	ND	ND
	ND	ND	ND	42	ND	ND	ND	ND	ND	ND	ND	4.2	ND	ND	2.3	ND	ND	12,000	ND	120	ND	4,000	ND	15,000	ND	ND
GWN-P24 **Coweta**	ND	ND	ND	210	ND	ND	ND	ND	ND	ND	ND	5.0	ND	ND	1.5	ND	ND	26,000	ND	ND	ND	4,200	ND	10,000	ND	ND
GWN-P30 **Lincoln**	ND	ND	ND	ND	5.2	ND	ND	ND	ND	ND	ND	2.6	ND	ND	ND	ND	ND	41,000	ND	ND	ND	23,000	ND	16,000	ND	ND
GWN-P32 **Elbert**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.0	ND	ND	160,000	ND	ND	ND	2,000	18	25,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.3	ND	ND	14.0	ND	ND	210,000	ND	ND	ND	2,000	19	30,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.0	ND	ND	12.0	ND	ND	250,000	ND	49	ND	1,300	16	32,000	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.0	ND	ND	160,000	ND	ND	ND	2,300	19	26,000	ND	ND

Table A-7, Continued. Ground-Water Quality Analyses for Piedont-Blue Ridge Stations.
Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-P33 **Elbert**	Cecchini Bored Well	47	NG	NG	01/11/12	6.75	110	6.59	17.8	ND	ND	ND	0.37	0.03
					04/11/12	6.82	70	4.70	17.6	ND	ND	ND	0.37	0.03
					07/11/12	5.03	60	7.00	18.4	ND	ND	ND	0.23	ND
					10/17/12	5.11	87	6.61	18.3	ND	ND	ND	0.39	0.02
GWN-P34 **Columbia**	Mistletoe State Park Cottage Area Well	NG	NG	NG	02/22/12	5.77	81	15.26	10.5	tcm=0.58	ND	ND	0.66	0.11
					05/09/12	6.13	150	8.20	18.8	ND	ND	16	0.44	0.22
					08/10/12	4.67	59	7.06	18.7	ND	ND	ND	0.54	0.08
					11/15/12	6.15	221	8.27	18.29	ND	ND	10	0.57	0.20
GWN-P35 **Franklin**	O'Connor Well	150	NG	NG	01/11/12	6.23	181	0.77	16.9	ND	ND	ND	ND	0.02
					04/11/12	7.23	118	0.03	17.1	ND	ND	ND	ND	0.03
					07/11/12	6.25	180	0.67	17.5	ND	ND	ND	ND	ND
					10/17/12	6.55	186	0.71	17.1	ND	ND	ND	0.05	0.03
GWN-P37 **Habersham**	Mt. Airy/City Hall Well	500	NG	NG	01/11/12	5.50	172	3.43	13.3	tcm=2.7	240	38	0.80	0.03
					04/11/12	6.24	589	1.87	16.5	tcm=0.96	220	46	0.63	ND
					07/11/12	5.91	663	2.20	16.7	ND	160	29	0.36	ND
					10/17/12	5.92	638	2.81	16.6	ND	120	32	0.37	ND
GWN-P38 **Carroll**	Roopville Well #1	230	NG	NG	06/08/12	4.52	38	6.66	18.0.	ND	ND	ND	1.70	ND
GWN-P39 **Meriwether**	Gay Well #1	600	NG	NG	05/24/12	5.89	63	8.77	17.7	ND	ND	ND	1.00	0.06
GWN-P40 **Greene**	Siloam Well #2	300+	NG	NG	06/20/12	6.25	70	5.80	19.5	ND	ND	ND	1.20	0.09
GWN-BR1B **Towns**	Young Harris/ Swanson Road Well	265	NG	NG	02/22/12	7.00	158	1.14	15.6	ND	ND	19	0.05	ND
					06/07/12	6.82	160	1.02	15.8	ND	ND	20	0.02	ND
					08/08/12	6.18	155	7.37	15.8	ND	ND	20	0.05	ND
					11/14/12	6.95	300	1.60	15.45	ND	ND	21	0.04	ND
GWN-BR5 **Murray**	Chatsworth/ Nix Spring	0	NG	NG	05/24/12	5.72	24	NA	14.6	ND	ND	ND	0.43	0.06

Table A-7. Ground-Water Quality Analyses for Piedmont-Blue Ridge Stations.
Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-P33 Elbert	ND	ND	18	27	ND	ND	ND	ND	ND	ND	ND	21	ND	ND	ND	180	ND	16,000	ND	310	ND	ND	ND	4,100	ND	ND
	ND	ND	20	29	ND	ND	ND	ND	ND	ND	ND	19	ND	1.5	ND	79	ND	17,000	ND	300	ND	ND	ND	4,700	ND	ND
	ND	ND	13	35	ND	ND	ND	ND	ND	ND	ND	23	ND	ND	ND	ND	ND	7,500	ND	60	ND	ND	ND	3,800	ND	ND
	ND	ND	19	42	ND	ND	ND	ND	ND	ND	ND	25	ND	ND	ND	85	ND	13,000	ND	230	ND	ND	ND	4,400	ND	ND
GWN-P34 Columbia	ND	ND	18	41	ND	ND	ND	ND	ND	ND	ND	23	ND	ND	5.2	ND	ND	4,700	ND	70	ND	2,700	18	9,500	ND	ND
	ND	ND	6.7	22	ND	ND	ND	ND	ND	ND	ND	16	ND	ND	16.0	ND	ND	11,000	ND	ND	ND	5,300	ND	12,000	ND	ND
	ND	ND	9.8	15	ND	ND	ND	ND	ND	ND	ND	31	ND	5.9	3.7	ND	ND	2,800	ND	ND	ND	2,100	13	6,400	ND	ND
	ND	ND	7	13	ND	ND	ND	ND	ND	ND	ND	13	ND	ND	13.0	ND	ND	8,300	ND	ND	ND	4,300	ND	10,000	ND	ND
GWN-P35 Franklin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	32	ND	ND	3.0	ND	ND	20,000	ND	78	6,200	5,700	120	7,400	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	30	ND	ND	3.7	ND	ND	22,000	ND	43	7,100	6,600	130	7,800	ND	ND
	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	ND	30	ND	ND	4.0	ND	ND	20,000	ND	28	6,600	6,300	120	7,500	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	30	ND	ND	1.9	ND	ND	19,000	ND	110	6,400	6,100	120	7,900	ND	ND
GWN-P37 Habersham	ND	12	ND	22	ND	ND	ND	ND	ND	ND	ND	130	ND	ND	2.1	170	ND	99,000	ND	540	5,200	25,000	240	58,000	ND	ND
	ND	13	ND	20	ND	ND	ND	ND	ND	ND	ND	110	ND	ND	1.0	ND	ND	100,000	ND	180	5,200	26,000	260	40,000	ND	ND
	ND	11	ND	12	ND	ND	ND	ND	ND	ND	ND	98	ND	1.7	ND	ND	ND	75,000	ND	220	ND	20,000	250	27,000	ND	ND
	ND	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	75	ND	ND	1.2	ND	ND	68,000	ND	330	ND	16,000	140	19,000	ND	ND
GWN-P38 Carroll	ND	ND	6.2	ND	ND	ND	ND	ND	ND	ND	ND	27	ND	1.8	ND	65	ND	1,200	ND	ND	ND	ND	25	4,900	ND	ND
GWN-P39 Meriwether	ND	ND	26	21	ND	ND	ND	ND	ND	ND	ND	38	ND	3.1	ND	ND	ND	4,700	ND	57	ND	1,100	ND	6,400	ND	ND
GWN-P40 Greene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	18	ND	ND	19.0	ND	ND	11,000	ND	ND	ND	2,000	ND	13,000	ND	ND
GWN-BR1B Towns	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	78	ND	ND	9.3	ND	ND	22,000	ND	ND	ND	4,800	20	4,200	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	75	ND	ND	8.3	ND	ND	20,000	ND	ND	ND	4,500	22	3,900	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	74	ND	ND	7.5	ND	ND	20,000	ND	ND	ND	4,600	20	3,900	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	86	ND	ND	9.2	ND	ND	21,000	ND	ND	ND	4,900	21	4,100	ND	ND
GWN-BR5 Murray	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	ND	ND	3,200	ND	ND	ND	ND	ND	3,200	ND	ND

Table A-8. Ground-Water Quality Analyses for Valley-and-Ridge/Appalachian Plateau Stations.
Part A: Station Identification, Date of Sampling, Field Parameters, VOCs, Anions, and Non-Metals.

Station No. County	Well Name	Well Depth feet	Casing Depth feet	Well Size Inches	Date sampled	pH	cond. uS/cm	diss O2 mg/L	Temp °C	VOCS ug/L	Cl mg/L	SO4 mg/L	NOx mg N/L	P mg/L
GWN-VR1 **Floyd**	Floyd County Kingston Road Well	280	NG	NG	05/23/12	7.76	155	6.23	16.6	ND	ND	ND	0.64	ND
GWN-VR2A **Walker**	LaFayette Lower Big Spring	0	NG	NG	06/20/12	6.78	294	6.02	16.1	ND	ND	ND	1.60	ND
GWN-VR3 **Walker**	Chickamauga Crawfish Spring	0	NG	NG	06/20/12	6.55	256	8.30	15.4	ND	ND	ND	0.81	ND
GWN-VR6A **Bartow**	Chemical Products Corp. South Well	300	NG	NG	05/23/12	7.61	173	5.56	17.8	1,1dce=1.8 pce=2.2 odcb=1.6 mdcb=0.59	ND	ND	0.84	ND
GWN-VR8 **Polk**	Cedartown Spring	0	NG	NG	02/22/12	7.28	274	7.64	16.8	ND	ND	ND	0.78	ND
					05/23/12	7.53	170	6.88	16.7	ND	ND	ND	0.72	ND
					08/08/12	6.84	265	8.00	17.0	ND	ND	ND	0.91	ND
					11/14/12	7.44	486	10.75	16.15	ND	ND	ND	0.70	ND
GWN-VR10 **Murray**	Eton Spring	0	NG	NG	05/24/12	7.30	162	NA	18.0	ND	ND	ND	1.70	ND

Table A-8. Ground-Water Quality Analyses for Valley-and-Ridge/Appalachian Plateau Stations.
Part B: Metals.

Station No. County	Chromium ug/L	Nickel ug/L	Copper ug/L	Zinc ppb ug/L	Arsenic ug/L	Selenium ug/L	Molybdenum ug/L	Silver ppb ug/L	Cadmium ug/L	Tin ppb ug/L	Antimony ug/L	Barium ppb ug/L	Thallium ug/L	Lead ppb ug/L	Uranium ug/L	Aluminum ug/L	Beryllium ug/L	Calcium ug/L	Cobalt ug/L	Iron ug/L	Potassium ug/L	Magnesium ug/L	Manganese ug/L	Sodium ug/L	Titanium ug/L	Vanadium ug/L
GWN-VR1 **Floyd**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13	ND	ND	ND	ND	ND	27,000	ND	ND	ND	16,000	ND	1,600	ND	ND
GWN-VR2A **Walker**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	90	ND	ND	ND	ND	ND	38,000	ND	ND	ND	14,000	ND	1,600	ND	ND
GWN-VR3 **Walker**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	83	ND	ND	ND	ND	ND	35,000	ND	ND	ND	16,000	ND	1,200	ND	ND
GWN-VR6A **Bartow**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	620	ND	ND	ND	ND	ND	29,000	ND	ND	ND	17,000	ND	5,000	ND	ND
GWN-VR8 **Polk**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	ND	37,000	ND	26	ND	17,000	ND	1,700	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	33,000	ND	36	ND	15,000	ND	1,500	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	ND	34,000	ND	31	ND	16,000	ND	1,500	ND	ND
	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	13	ND	ND	ND	ND	ND	34,000	ND	ND	ND	17,000	ND	1,500	ND	ND
GWN-VR10 **Murray**	ND	ND	ND	13	ND	ND	ND	ND	ND	ND	ND	48	ND	ND	ND	ND	ND	32,000	ND	ND	ND	14,000	ND	2,600 2,022	ND	ND

Table A-9. Analytes, EPA Analytical Methods, and Reporting Limits.

Analyte	Reporting Limit/ EPA Method	Analyte	Reporting Limit/ EPA Method
Vinyl Chloride	0.5 ug/L / 524.2	Dichlorodifluoromethane	0.5 ug/L / 524.2
1,1-Dichloroethylene	0.5 ug/L / 524.2	Chloromethane	0.5 ug/L / 524.2
Dichloromethane	0.5 ug/L / 524.2	Bromomethane	0.5 ug/L / 524.2
Trans-1,2-Dichloroethylene	0.5 ug/L / 524.2	Chloroethane	0.5 ug/L / 524.2
Cis-1,2-Dichloroethylene	0.5 ug/L / 524.2	Fluorotrichloromethane	0.5 ug/L / 524.2
1,1,1-Trichloroethane	0.5 ug/L / 524.2	1,1-Dichloroethane	0.5 ug/L / 524.2
Carbon Tetrachloride	0.5 ug/L / 524.2	2,2-Dichloropropane	0.5 ug/L / 524.2
Benzene	0.5 ug/L / 524.2	Bromochloromethane	0.5 ug/L / 524.2
1,2-Dichloroethane	0.5 ug/L / 524.2	Chloroform	0.5 ug/L / 524.2
Trichloroethylene	0.5 ug/L / 524.2	1,1-Dichloropropene	0.5 ug/L / 524.2
1,2-Dichloropropane	0.5 ug/L / 524.2	Dibromomethane	0.5 ug/L / 524.2
Toluene	0.5 ug/L / 524.2	Bromodichloromethane	0.5 ug/L / 524.2
1,1,2-Trichloroethane	0.5 ug/L / 524.2	Cis-1,3-Dichloropropene	0.5 ug/L / 524.2
Tetrachloroethylene	0.5 ug/L / 524.2	Trans-1,3-Dichloropropene	0.5 ug/L / 524.2
Chlorobenzene	0.5 ug/L / 524.2	1,3-Dichloropropane	0.5 ug/L / 524.2
Ethylbenzene	0.5 ug/L / 524.2	Chlorodibromomethane	0.5 ug/L / 524.2
Total Xylenes	0.5 ug/L / 524.2	1,2-Dibromoethane	0.5 ug/L / 524.2
Styrene	0.5 ug/L / 524.2	1,1,1,2-Tetrachloroethane	0.5 ug/L / 524.2
p-Dichlorobenzene	0.5 ug/L / 524.2	Bromoform	0.5 ug/L / 524.2
o-Dichlorobenzene	0.5 ug/L / 524.2	Isopropylbenzene	0.5 ug/L / 524.2
1,2,4-Trichlorobenzene	0.5 ug/L / 524.2	1,1,2,2-Tetrachloroethane	0.5 ug/L / 524.2

Table A-9, Continued. Analytes, EPA Analytical Methods, and Reporting Limits.

Analyte	Reporting Limit/ EPA Method	Analyte	Reporting Limit/ EPA Method
Bromobenzene	0.5 ug/L / 524.2	Total Phosphorus	0.02 mg/L / 365.1
1,2,3-Trichloro-propane	0.5 ug/L / 524.2	Fluoride	0.20 mg/L / 300.0
n-Propylbenzene	0.5 ug/L / 524.2	Silver	10 ug/L / 200.7 (ICP)
o-Chlorotoluene	0.5 ug/L / 524.2	Aluminum	60 ug/L / 200.7
1,3,5-Trimethyl-benzene	0.5 ug/L / 524.2	Arsenic	80 ug/L / 200.7
p-Chlorotoluene	0.5 ug/L / 524.2	Barium	10 ug/L / 200.7
Tert-Butylbenzene	0.5 ug/L / 524.2	Beryllium	10 ug/L / 200.7
1,2,4-Trimethyl-benzene	0.5 ug/L / 524.2	Calcium	1000 ug/L / 200.7
Sec-Butylbenzene	0.5 ug/L / 524.2	Cobalt	10 ug/L / 200.7
p-Isopropyltoluene	0.5 ug/L / 524.2	Chromium	20 ug/L / 200.7
m-Dichlorobenzene	0.5 ug/L / 524.2	Copper	20 ug/L / 200.7
n-Butylbenzene	0.5 ug/L / 524.2	Iron	20 ug/L / 200.7
1,2-Dibromo-3-chloropropane	0.5 ug/L / 524.2	Potassium	5000 ug/L / 200.7
Hexachlorobutadi-ene	0.5 ug/L / 524.2	Magnesium	1000 ug/L / 200.7
Naphthalene	0.5 ug/L / 524.2	Manganese	10 ug/L / 200.7
1,2,3-Trichloro-benzene	0.5 ug/L / 524.2	Sodium	1000 ug/L / 200.7
Methyl-tert-butyl ether (MTBE)	0.5 ug/L / 524.2	Nickel	20 ug/L / 200.7
Chloride	10 mg/L / 300.0	Lead	90 ug/L / 200.7
Sulfate*	10 mg/L / 300.0	Antimony	120 ug/L / 200.7
Nitrate/nitrite*	0.02 mg/L as Nitrogen / 353.2	Selenium	190 ug/L / 200.7

Table A-9, Continued. EPA Analytical Methods, and Reporting Limits. Analytes and Reporting Limits.

Analyte	Reporting Limit/ EPA Method	Analyte	Reporting Limit/ EPA Method
Titanium	10 ug/L / 200.7	Molybdenum	5 ug/L / 200.8
Thallium	200 ug/L / 200.7	Silver	5 ug/L / 200.8
Vanadium	10 ug/L / 200.7	Cadmium	0.7 ug/L / 200.8
Zinc	20 ug/L / 200.7	Tin	30 ug/L / 200.8
Chromium	5 ug/L / 200.8 (ICPMS)	Antimony	5 ug/L / 200.8
Nickel	10 ug/L / 200.8	Barium	2 ug/L / 200.8
Copper	5 ug/L / 200.8	Thallium	1 ug/L / 200.8
Zinc	10 ug/L / 200.8	Lead	1 ug/L / 200.8
Arsenic	5 ug/L / 200.8	Uranium	1 ug/L / 200.8
Selenium	5 ug/L / 200.8		

* **Note:** Reporting limits for sulfate and nitrate/nitrite are subject to change. A sample with a concentration of either analyte greater than certain ranges may need to be diluted to bring the concentration within the analytical ranges of the testing instruments. This dilution results in a proportional increase in the reporting limit.

Table A-10. Analytes, Primary MCLs(A), and Secondary MCLs(B).

Analyte	Primary MCL	Secondary MCL	Analyte	Primary MCL	Secondary MCL
Vinyl Chloride	2 ug/L	None	p-Dichlorobenzene	75 ug/L	None
1,1-Dichloroethylene	7 ug/L	None	o-Dichlorobenzene	600 ug/L	None
Dichloromethane	5 ug/L	None	1,2,4-Trichlorobenzene	70 ug/L	None
Trans-1,2-Dichloroethylene	100 ug/L	None	Chloroform (1)	Total 1,2,3,4 = 80 ug/L	None
Cis-1,2-Dichloroethylene	70 ug/L	None	Bromodichloromethane (2)	Total 1,2,3,4 = 80 ug/L	None
1,1,1-Trichloroethane	200 ug/L	None	Chlorodibromomethane (3)	Total 1,2,3,4 = 80 ug/L	None
Carbon Tetrachloride	5 ug/L	None	Bromoform (4)	Total 1,2,3,4 = 80 ug/L	None
Benzene	5 ug/L	None	Chloride	None	250 mg/L
1,2-Dichloroethane	5 ug/L	None	Sulfate	None	250 mg/L
Trichloroethylene	5 ug/L	None	Nitrate/nitrite	10 mg/L as Nitrogen	None
1,2-Dichloro-propane	5 ug/L	None	Fluoride	4 mg/L	2 mg/L
Toluene	1,000 ug/L	None	Aluminum	None	50 -200 ug/L
1,1,2-Trichloroethane	5 ug/L	None	Antimony	6 ug/L	None
Tetrachloroethylene	5 ug/L	None	Arsenic	10 ug/L	None
Chlorobenzene	100 ug/L	None	Barium	2000 ug/L	None
Ethylbenzene	700 ug/L	None	Beryllium	4 ug/L	None
Total Xylenes	10,000 ug/L	None	Cadmium	5 ug/L	None
Styrene	100 ug/L	None	Chromium	100 ug/L	None

Table A-10, Continued. Analytes, Primary MCLs*, and Secondary MCLs*.

Analyte	Primary MCL	Second-ary MCL	Analyte	Primary MCL	Second-ary MCL
Copper	Action level = 1,300 ug/L(C)	1000 ug/L	Selenium	50 ug/L	None
Iron	None	300 ug/L	Silver	None	100 ug/L
Lead	Action level = 15 ug/L(C)	None	Thallium	2 ug/L	None
Manganese	None	50 ug/L	Zinc	None	5,000 ug/L
Nickel	100 ug/L	None			

Notes:

(A) Primary MCL = Primary Maximum Contaminant Level, a maximum concentration of a substance (other than lead or copper) allowed in public drinking water due to adverse health effects.

(B) Secondary MCL = Secondary Maximum Contaminant Level, a maximum concentration of a substance suggested for public drinking water due solely to unpleasant characteristics such as bad flavor or stain-causing ability.

(C) Action Level = the maximum concentrations of lead or copper permitted for public drinking water as measured at the user's end of the system. Water issuing from at least ninety percent of a representative sample of user's end outlets must contain copper or lead concentrations at or below their respective action levels.

mg/L = milligrams per liter.

ug/L = micrograms per liter.