AN INVESTIGATION OF THE OCCURRENCE OF ARSENIC IN GROUND WATER IN THE GULF TROUGH AREA OF GEORGIA

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GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
WATERSHED PROTECTION BRANCH

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CHAPTER 1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This report, covering the period February 2010 through November 2010, is the twenty-fourth in the Circular 12 series. The first nineteen reports of the Circular 12 series dealt with the chemical quality of ground water Statewide. Following these, a series of four reports, now completed, examined potential ground-water impairment involving specific scenarios: 1) the Miocene and Surficial aquifers in the coastal region; 2) the Piedmont/Blue Ridge unconfined aquifer system; 3) the ground waters available to small public water systems; 4) the occurrence of uranium in the State's ground waters. The Georgia Environmental Protection Division's (EPD) Drinking Water Compliance Program and the Georgia Department of Public Health became concerned with arsenic detections, some in excess of the Primary Maximum Contaminant Level (MCL), in the Cairo area in Grady County. In February of 2010, EPD's Regulatory Support Program (subsequently reassigned to the Watershed Planning and Monitoring Program) decided to investigate the occurrence of arsenic in the State's ground water. This report comments on that effort.

These reports are among the tools used by 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). Five components comprise EPD's current ground-water quality assessment program:

1. The Georgia Ground-Water Monitoring Network. The Georgia Geologic Survey Branch (GGS) of EPD and its successors, the Regulatory Support Program and the Watershed Planning and Monitoring Program of the Watershed Protection Branch, maintain this program. Early in calendar year 2004, a three-part monitoring program replaced the Statewide aquifer-specific monitoring network. This program examined ground-water: a) in the coastal area for influx of connate brines, sea water, or low-quality surface water; b) in the Piedmont and Blue Ridge for impacts from development and rural land use as well as to gain a more thorough understanding of the area's ambient ground water; and c) from small public water systems to spot check for intermittent contamination that might escape detection under item 2) below. This series of reports is now completed. The new program, begun in March 2008, sampled and analyzed additional wells and springs located near sampling stations from studies b) and c) above which yielded samples with detectable uranium.

2. Sampling of public drinking water wells as part of the Safe Drinking Water Program, also of the Watershed Protection Branch. This program provides data on the quality of ground water that the residents of Georgia are using.

3. Special studies addressing specific water quality issues. Examples of these types of studies include a survey of nitrite/nitrate levels in shallow wells located throughout the State of Georgia (Shellenberger, et al., 1996; Stuart, et al., 1995), operation of a Pesticide Monitoring Network conducted jointly by the GGS and the Georgia Department of Agriculture (GDA) (Tolford, 1999; Glen, 2001), and the Domestic Well Pesticide Sampling Project conducted jointly by the GGS and the GDA (Overacre, 2004, Berry, 2005).

4. Ground-water sampling at environmental facilities such as municipal solid waste landfills, RCRA facilities, and sludge disposal facilities. The primary branches responsible for monitoring these facilities are EPD's Land Protection (including Hazardous Waste Management) and Watershed Protection Branches.

5. The wellhead protection program (WHP), which is designed to protect the area surrounding a municipal drinking water well 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 Georgia Safe Drinking Water Rules, effective July 1, 1993. The protection of public water supply wells from contaminants is important not only for maintaining ground-water quality, but also for ensuring that public water supplies meet health standards.

1.2 ARSENIC IN SOUTH GEORGIA GROUND WATER

In 2009, the City of Cairo in Grady County sought to augment its water supply with a new well. The City contracted with Greene's Water Wells, Inc., to drill a test well to draw from the Floridan aquifer at 30° 51' 54", -84° 14' 25", about 2.4 miles west southwest of the center of the City. The well intersected the Floridan near the axis of a geologic structure called the Gulf Trough. The well was completed to 580 feet and cased to 450 feet. Its yield was tested and, on June 4, 2009, a ground-water sample drawn for analysis. The arsenic content of the sample water registered at 3.6 micrograms per liter (ug/L). As the yield proved inadequate, the well was deepened to 780 feet and, again, a yield test performed and, on August 24, 2009, a ground-water sample collected. Yield proved to be adequate at about 222 gallons per minute; however, the arsenic content rose to 65 ug/L, well above the 10 ug/L Primary Maximum Contaminant Level established by EPD.

After being notified of the arsenic result, EPD's Drinking Water Compliance Program began an investigation of ground-water arsenic occurrences in Grady County. The Drinking Water Compliance staff approached the Regulatory Support Program about expanding the investigation. The Regulatory Support staff obtained a list of public water systems which used ground water and which had wells producing water with detectable arsenic. The staff also arranged to share information with the Georgia Public Health Department. A sampling proposal/plan was finalized, calling for 40 transects crossing the Gulf Trough at approximate six- mile intervals, with one sample each on the Trough's: northwest flank, southeast flank, northwest side, southwest side, and axis. Lists of prospective well owners, both of public water systems and private wells, were drawn up, the owners contacted. Interested owners were later contacted again and their wells sampled. The transect plan proved not to be very workable, since wells, not to mention interested well owners, could not always be found at the desired locations. Also, the 200 stations originally proposed for sampling campaign proved to be rather ambitious. The sampling campaign was eventually concluded after 67 stations were sampled. Figure 1-1 shows a map of the Gulf Trough and the locations of sampling stations. Figures B-1 through B-11 in Appendix B show the locations of the sampling stations by county.

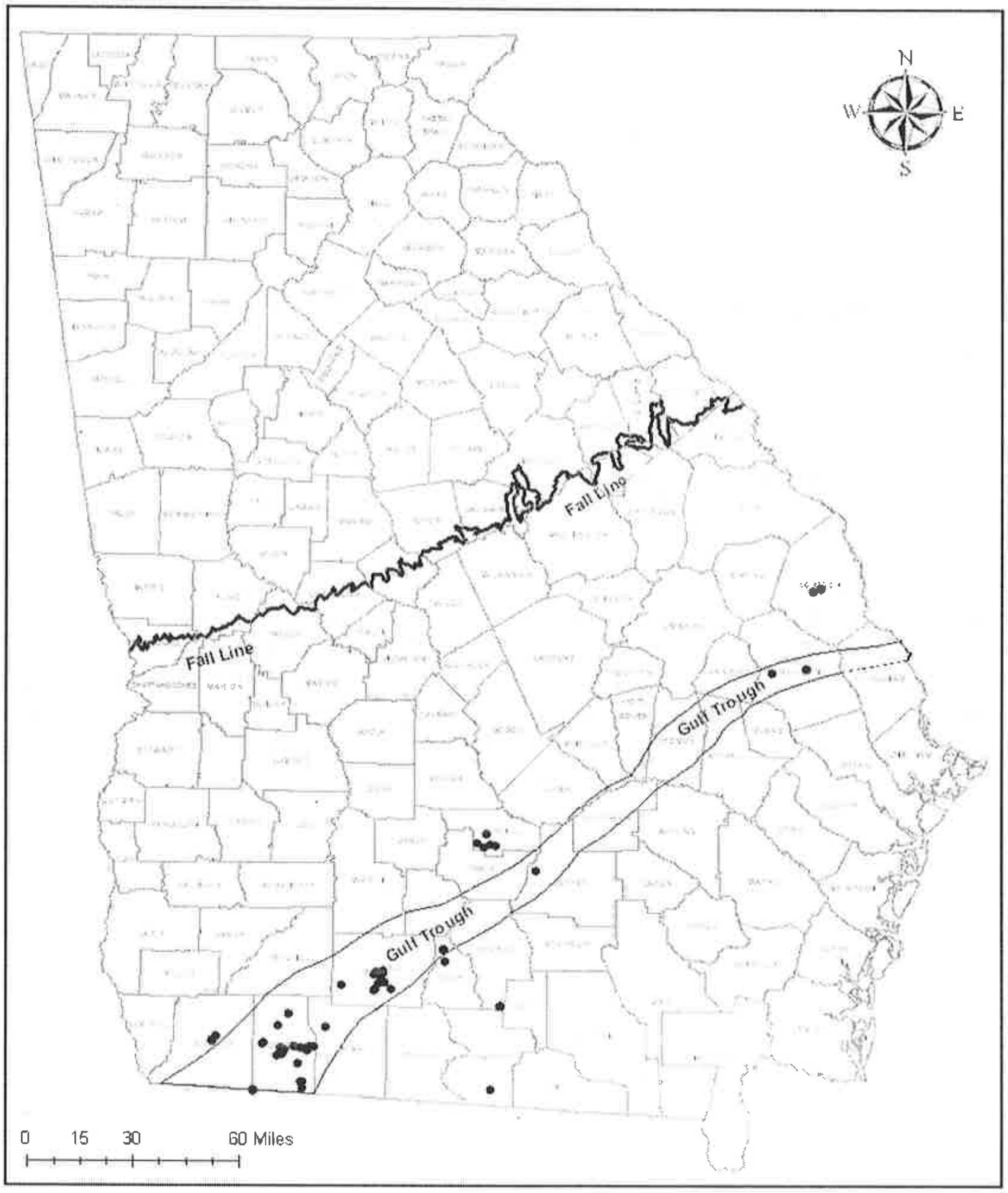

Figure 1-1. Map of Georgia, Showing the At-The-Surface Position of the Gulf Trough and the Locations of Sampling Stations. The Trough boundary is dashed where inferred.

CHAPTER 2 HYDROGEOLOGIC FRAMEWORK

2.1 THE DEVELOPMENT OF THE CHATTAHOOCHEE EMBAYMENT/GULF TROUGH

The Chattahoochee Embayment/Gulf Trough is a linear subsurface geologic feature in the Coastal Plain physiographic province that extends from the Florida Panhandle and adjacent areas of southwest Georgia to the Atlantic coast near Cape Fear, in the coastal North Carolina/South Carolina border area, an airline distance of about 500 miles (Popenoe et al., 1987; Kellam and Gorday, 1990, Huddleston, 1993). The part of the feature that flares southwestward from Tift County-Colquitt County area in Georgia, Huddlestun (1993) terms the Chattahoochee Embayment. Kellam and Gorday (1990) state that the width of the Embayment is about 35 miles wide in southwest Georgia, and, the Applied Coastal Research Laboratory (2002) gives a width of about 5 miles for the Trough south of Statesboro in Bulloch County. Huddlestun (1993) notes that as much as 600 feet of relief existed in the vicinity of the Trough in southwest Georgia and that the Trough shoals at its northeasterly extent in Georgia.

According to Huddlestun (1993) the Trough's origin can be placed during the middle to late Eocene epoch. The Suwanee current, a marine current similar to the present day Gulf Stream, conveyed water from the Gulf of Mexico to the Atlantic Ocean during that time. Sea levels were generally higher at that time than today. Bioclastic carbonate bank deposition was also proceeding during that time. The current retarded or prevented deposition under its path, while carbonate bank deposition continued uninhibited in waters away from the path of the current. After some time, the carbonate bank deposits built up to the point that they constrained the current to a channel way. With sea levels overall falling as the Eocene epoch gave way to the Oligocene epoch, the current slackened and eventually ceased operating, leaving behind a ditch-like sea bottom depression. Increased sedimentation accompanied the slackening and cessation of the current. The sediments, initially consisting of fine-grained carbonates of deep water origin, continued to accumulate in the Trough through the Oligocene. With the overall continuing fall in sea levels during the Miocene epoch, terrigenous sediments -- sands and clays – dominated the fill accumulating in the Trough and, eventually, completely filled the structure.

2.2 GEOLOGIC AND HYDROLOGIC CHARACTERISTICS

For purposes of discussion, the Gulf Trough and its surrounding areas in Georgia were divided into three sectors: a northeast area, a central area, and a southwest area. The northeast area is bounded by two lines, one about 30 miles distant from the Trough's northwestern edge, by another line about 30 miles out from the southeastern edge, by the Savannah River (State line), and by a transverse line crossing the Trough at or near the northeastern extent of Ochlockonee, Wolf Pit, and Okapilco formations. The southwestern area is similarly bounded by two lines, each about 30 miles distant from the northwestern and southeastern edges of the Trough, by a transverse line passing through or near the head of the Chattahoochee Embayment segment of the Trough, and by the State line. The central area lies between the two transverse lines and, similar to the other two areas, is bounded to the northwest and southeast by two lines 30 miles distant from the edges of the Trough. These areas and their boundaries should be considered schematic and conceptual rather than precise and rigid. Figure 2-1 displays the areas on a State map.

Tables 2-1 through 2-3 show the stratigraphic units present inside the Trough and on its flanks in the three areas and which units host the Floridan aquifer system. Most of the stratigraphic and lithologic information shown in these tables and discussed below was derived from Kellam and Gorday (1990) and Huddlestun (1988, 1993).

In the southwestern area, the Floridan aquifer in the northwestern flank of the Trough includes a limestone-rich part of the Lisbon Formation (Kellam and Gorday, 1990), the Ocala Group carbonates, and the Bridgeboro Limestone. The Floridan aquifer system in this area is confined below by clay-rich parts or glauconitic carbonate parts of the Lisbon Formation but, above, lacks a confining layer, except for a narrow band of Chattahoochee Formation and Hawthorne Group at the Trough's northwestern edge. The Bridgeboro Limestone (Kellam and Gorday 1990; Huddlestun, 1993) is present as an approximately 25 to 30-mile wide band along the northwestern edge of the Trough and consists of a high-purity limestone, with clays and quartz sand present only sporadically. Huddlestun (1993) notes that rhodolith fossils, the remains of generally rounded calcareous algae colonies (diameters ranging from 0.5 inch to about five inches at the Bridgeboro quarry), are usually abundant in the Bridgeboro. Sand-sized calcareous fossil fragments usually comprise the portion of the rock not occupied by rhodoliths.

In the interior of the southwestern area, the Floridan aquifer (Kellam and Gorday, 1990) is limited to the Ochlockonee Formation. Huddlestun (1993) has commented that the Wolf Pit Dolostone possesses a noticeable amount of secondary porosity, so including the Wolf Pit in the Floridan aquifer might be justified. The Floridan aquifer here is confined below by fine-grained, dense undifferentiated limestone and above by the sand-and-clay rich Hawthorne Group and, at the Trough edge, a thin band of the Chattahoochee Formation. Local carbonate beds at the bottom of the Hawthorne Group can be permeable enough to be included in the aquifer. The confining units are subject to breaching

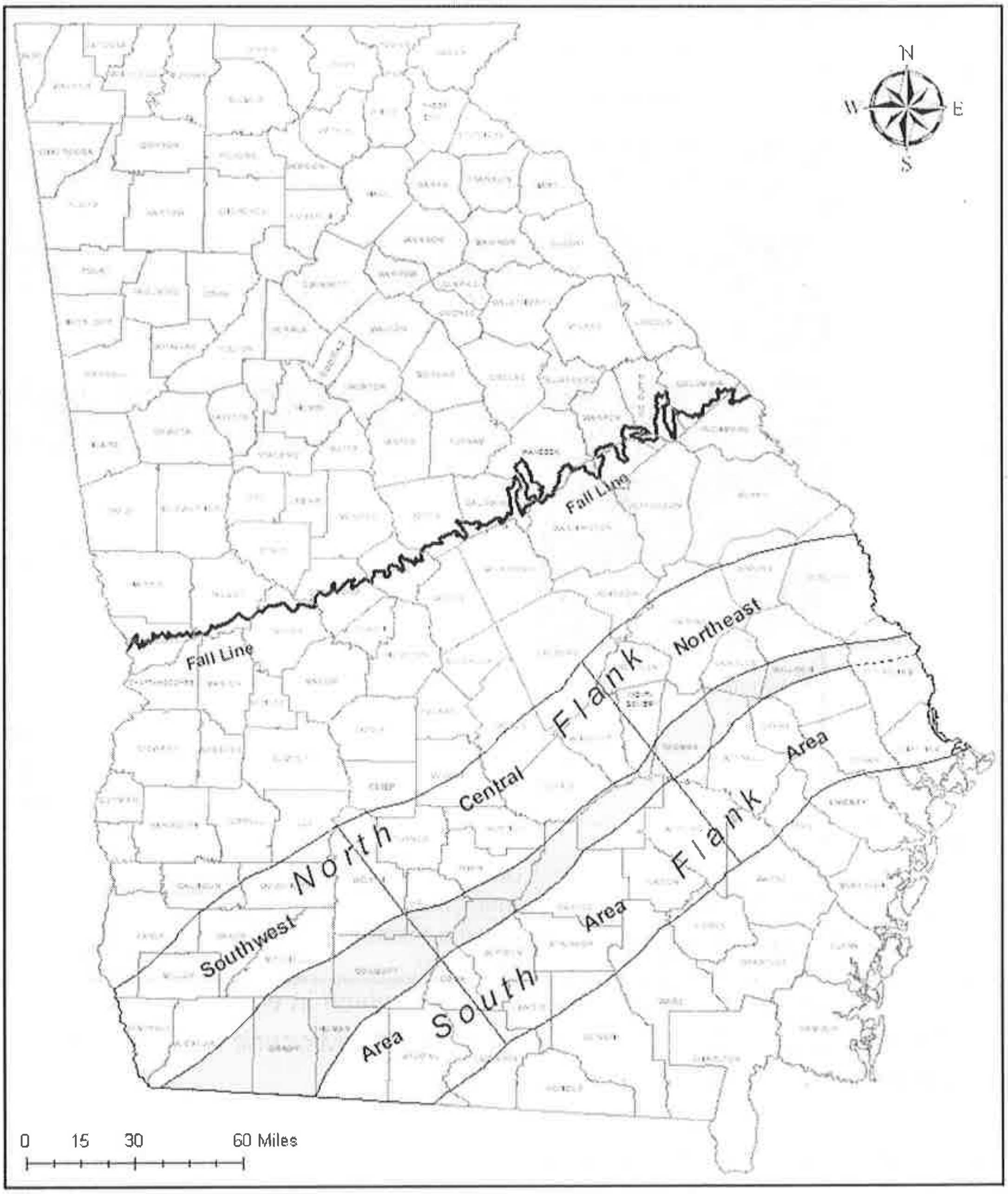

Figure 2-1. Map Showing the Southwest, Central, and Northeast Trough Areas, and the North and South Flanks. The trace of the Gulf Trough is shown in gray. The Trough boundary is dashed where inferred.

Table 2-1. Stratigraphic Units Occupying the Gulf Trough and Its Flanks.

	Southwestern Trough Area					
Epoch	**North Flank**		**Interior**		**South Flank**	
Pliocene						
	None Present	**Miccosukee Fm.**	**Miccosukee Formation**		**Miccosukee Formation**	
Miocene						
	None Present	Hawthorne Group	Hawthorne Group		Hawthorne Group	
		Chattahoochee Fm.			Chattahoochee Formation	
Oligocene						
upper	None Present		None Present		None Present	
middle			None Present		None Present	
lower			Unnamed Embayment Limestone	Okapilco Limestone	Suwanee Limestone	
			Wolf Pit Dolostone			
	Bridgeboro Limestone		Ochlockonee Formation		Bridgeboro Limestone (along flank)	Suwannacoochee Dolostone
						Ellaville Limestone
Eocene						
upper	Ocala Group		Undifferentiated limestone		Ocala Group	
middle	Lisbon Formation		Undifferentiated limestone		Unnamed limestone	

Note: Light gray shaded units are those, which in whole or in part, host the Floridan aquifer. Dark gray units host the Miocene aquifer. Cross-hatched units host the Surficial aquifer.

by sink holes. The Hawthorne holds up a prominent northwest-facing cuesta called the Pelham Escarpment. The Ochlockonee Formation (Huddlestun, 1993) is predominantly limestone, although some dolostone beds and rare beds of calcareous clay are present. In addition to calcite, the rock may contain dolomite, clays, chert, pyrite, phosphate (at the bottom of the formation), and rare and widely scattered occurrences of gypsum, quartz sand, and micas. Grain size is fine to very fine. Overlying the Ochlockonee Formation are, in order, the Wolf Pit Dolostone and the Okapilco Limestone (Huddlestun, 1993). The Bridgeboro Limestone does not occur in the Trough interior, and, the Ochlockonee, Wolf Pit, and Okapilco do not occur on the flanks of the Trough. According to Huddlestun

(1993), the Wolf Pit is fine-grained with a sucrosic texture and is a high-purity dolostone. The upper part of the formation may locally contain some gypsum, while the bottom may contain some pyrite and carbonaceous material. Grain sizes in the Okapilco range from fine to coarse, and, bioclastic materials predominate. The rock can be locally dolomitized and varies as to its degree of induration and porosity. Pyrite is locally abundant. Fossil corals can be abundant to the point of dominating the rock mass. In the Chattahoochee Embayment segment at the southwestern extremity in Georgia, the Okapilco grades into a dense fine-grained limestone with little porosity.

The Floridan aquifer on the southeastern flank of the Trough in the southwestern area includes in descending order, the Suwannee Limestone, the Bridgeboro Limestone, and the upper portion Ocala Group carbonates (Kellam and Gorday, 1990). The lower portion of the Ocala and an unnamed middle Eocene limestone apparently are insufficiently permeable and form the lower confining unit. The Chattahoochee Formation, a sandy, silty, clayey dolostone (Huddlestun, 1993) forms the upper confining layer away from the Trough interior. Some beds of limestone are also present in the formation. In addition to quartz sand and silt and clay minerals, the rock may contain calcite, phosphate, chert, micas, and heavy minerals. The Hawthorne Group overlies the Chattahoochee Formation and provides additional confinement. The Chattahoochee Formation is missing from the interior of the Trough in Georgia, its position occupied by the lower part of the Hawthorne Group. Sinkholes can breach the confining units.

Huddlestun (1993) describes the Suwanee Limestone as an even-textured medium- to coarse-grained high-purity limestone consisting of calcareous pellets, foraminifera tests, and fine bioclastic detritus. Dolostone beds occur, though rarely. Dolomitization of the limestone may be particularly intense near the edge of the Trough. Clays are not common in the limestone and rare chert lenses may occur locally. A little interstitial gypsum occurs in places. Glauconite, phosphate, and quartz sand and silt are absent.

The Bridgeboro Limestone is as described previously and grades away from the Trough into the Ellaville Limestone and the Suwannacoochee Dolostone. Whether or not the latter two formations could be included in the Floridan aquifer system is uncertain. Hydraulic gradients in the southwestern Trough interior decrease from the vicinity of 14 feet per mile to about two to two and one half feet per mile as one proceeds southwestward. The ground-water flow direction also changes from net southeastward flow to net southwestward flow.

The Floridan aquifer system in the north flank of the central portion of the Trough is developed in the Lisbon Formation, the Ocala Group, the Bridgeboro

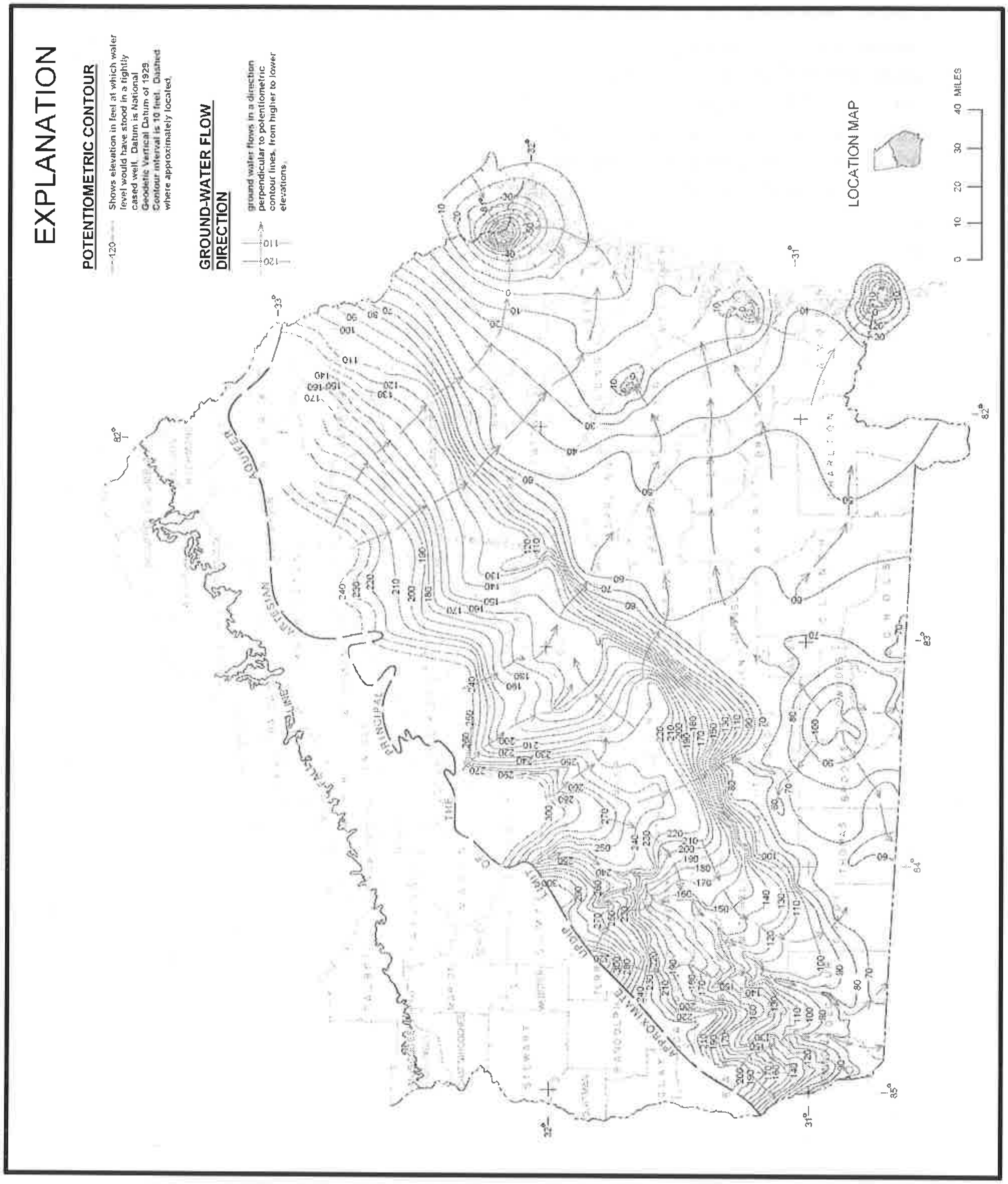

Figure 2-2. Map of the Potentiometric Surface of the Floridan Aquifer in Georgia, 1980. After Arora (1984) and Krause and Hayes (1981).

Table 2-2. Stratigraphic Units Occupying the Gulf Trough and Its Flanks.

	Central Trough Area		
Epoch	**North Flank**	**Interior**	**South Flank**
Pliocene			
	None Present	None Present	None Present
Miocene			
	Altamaha Formation	Altamaha Formation	Altamaha Formation
	Hawthorne Group	Hawthorne Group	Hawthorne Group
Oligocene			
upper			
middle			
lower		Okapilco Limestone	
		Wolf Pit Dolostone	
	Suwanee Limestone	Ochlockonee Formation	Suwanee Limestone
	Bridgeboro Limestone		Bridgeboro Limestone?
Eocene			
upper	Ocala Group	Undifferentiated limestone	Ocala Group
middle	Lisbon Formation	Undifferentiated limestone	Unnamed limestone Unnamed Limestone

Note: Light gray shaded units are those, which in whole or in part, host the Floridan aquifer. Dark gray units host the Miocene aquifer.

Limestone, and, the Suwanee limestone (Kellam and Gorday, 1990). The Floridan in this area is confined below by the lower Eocene Tallahatta Formation. The upper confining layer here is the Hawthorne Group. The Hawthorne Group is overlain by the sand- and clay-rich Altamaha Formation, which also serves as a confining unit and which covers the Floridan farther to the north than the Hawthorne Group (Huddlestun, 1988).

The Floridan in the central area's interior consists of undifferentiated upper Eocene limestone, the Ochlockonee Formation, the Wolf Pit Dolostone, and the Okapilco Limestone. A phase of the Ochlockonee Formation called by Huddlestun (1993) the Pridgen Limestone Member is present in and restricted to the central area Trough interior. Among the characteristics distinguishing the member from the main part of the Ochlockonee Formation are the presence of carbonaceous matter and sea grass impressions, the presence of more clay, and sparser dolomite.

The Floridan at the southeastern flank of the central Trough area includes the upper portion of an unnamed middle Eocene limestone, the Ocala Group carbonates, a possible narrow band of Bridgeboro Limestone, and the Suwannee Limestone (Kellam and Gorday, 1990). The Hawthorne Group serves to confine the aquifer system above and a poorly permeable phase of the unnamed middle Eocene limestone confines the aquifer system below. The upper confining units are subject to breaching. The Floridan attains its thickest in the central Trough area of any of the three Trough areas. The overlying cover is also at its thickest in the central Trough area. The hydraulic gradient in the central area is particularly steep, in the vicinity of eight to 15 feet per mile (Arora, Plate 15, 1984; Kellam and Gorday, 1990) with relatively flat potentiometric surfaces to the north and to the south of the Trough interior. The net flow direction is southeastward.

The northeastern Trough area contains the thinnest development of the Floridan aquifer system in any of the three Trough areas (Kellam and Gorday, 1990). The Floridan is developed in the Ocala Group and the Suwanee Limestone on both the interior and south flank of the Trough (see Table 2-3). The rock units specific to the Trough interior in the southwestern and central areas are absent in the northeastern area. The aquifer system is confined above

Table 2-3. Stratigraphic Units Occupying the Gulf Trough and Its Flanks.

Northeastern Trough Area			
Epoch	**North Flank**	**Interior**	**South Flank**
Pliocene			
upper	Cypresshead Formation	Cypresshead Formation	Cypresshead Formation
lower	None Present	None Present	None Present
Miocene			
upper	Hawthorne Group	Hawthorne Group	Hawthorne Group
middle			
lower			
Oligocene			
upper	None Present	None Present	None Present
middle	None Present	None Present	None Present
lower	Suwanee Limestone	Suwanee Limestone	Suwanee Limestone
Eocene			
upper	Barnwell Group	Ocala Group	Ocala Group
middle	Lisbon Formation Santee Limestone	Santee Limestone	Santee Limestone

Note: Light gray shaded units are those, which in whole or in part, host the Floridan aquifer. Dark gray units host the Miocene aquifer. Horizontally striped units host the Surficial aquifer. Vertically striped units host the Jacksonian aquifer.

by the Hawthorne Group. Northwestward from the north flank, the Altamaha Formation becomes the upper confining unit. The lower confining unit consists, in part, of Barnwell Group terrigenous sediments, which include clays and sands (Huddlestun and Hetrick, 1986). In the Screven County/Effingham County border area, the Barnwell Group gives way, by way of a facies change, to the Ocala Group (Kellam and Gorday, 1990). The Ocala Group overlays the Santee Limestone, which, in its up dip portions, is water-bearing.

The hydraulic gradient in the northeastern Trough area is gentler than in the central Trough area, ranging from about 10 feet per mile in the southwestern part of the area to about three feet per mile near the Savannah River (Arora, 1984, Plate 15).

In summary, the Chattahoochee Embayment/Gulf Trough is a marine current channel way that began developing in the middle to late Eocene epoch and that extends from the general area of Apalachicola and Port St. Joe in Florida to the Cape Fear area of North and South Carolina.

During its development, the northeast-flowing marine current retarded or halted sedimentary deposition in the interior of the Trough, while, away from the interior, carbonate bank deposition continued unabated. Continuing carbonate bank deposition eventually constraining the current to a channel way. Generally overall lowering of sea levels culminating in the Miocene caused the current to cease flowing and left a northeast southwest oriented sea bottom depression that was trench-like in its central and northeastern reaches and flared southwestward into the Gulf of Mexico. The current shoaled in its northeastern reach, which led to a shallower depression. As the current waned and ceased, sediments began filling in the depression, first with fine-grained deep water carbonate materials, later with coarser shallow water carbonate and finally terrigenous sediments.

The filled depression caused a permeability barrier in the Floridan aquifer system across most of Georgia. Well yields in the Trough tend to be lower than outside. In south central Georgia, the low hydraulic conductivity across the Trough impedes ground-water movement through the Trough and causes higher hydraulic heads on the upgradient side of the Trough, to the northwest. The potentiometric surfaces on both sides of the Trough are relatively flat. At the southwest extent of the Trough in Georgia, ground-water flow directions changed from southeastward to southwestward as hydraulic conductivity increases and allows ground water to escape to the southwest.

The Floridan aquifer system is under semi-confined conditions in the Dougherty Plain on the north flank of the Trough in the southwestern Trough area. The aquifer system is extensively and deeply confined in the central Trough area. The aquifer system is extensively confined in the northeastern Trough area. The Floridan is at its thinnest in the northeastern Trough area.

The aquifer system also thins toward the southwest in the southwestern Trough area due to a loss of permeability in the lower Trough/Embayment carbonates.Lithologies in the deepest parts of the trough consist of fine-grained carbonate, with coarser grained carbonates filling the shallower parts. Pyrite is present in the Ochlockonee Formation, the upper Wolf Pit Dolostone, and, with local abundance, in the Okapilco Limestone. Carbonaceous material is present in the lower Wolf Pit and the Pridgen Member of the Ochlockonee. Detrital quartz is uncommon in the Trough-fill carbonates, absent in the Suwanee Limestone, while clays are uncommon or rare in both Trough-fill and Trough flank carbonates.

CHAPTER 3 METHODS

3.1 FIELD METHODS

Conductivity, pH, temperature, and, where possible, dissolved oxygen were monitored in the field with Horiba Model U-10 water quality meters. Garmin® eTrex Legend GPS receivers were used to measure latitude and longitude at each sampling station.

The sampled wells had dedicated pumps and most had plumbing downstream of the wellhead that included spigots or other outlets. The outlet nearest the wellhead was typically used as the monitoring and collection point. A Y-tube formed of garden hose was fitted to the outlet. The Y-tube had a plastic pitcher fitted on one branch to accommodate the water quality meter probe, and the other branch of the Y-tube was left open to be used for sampling. The meter probe was inserted into the pitcher and the well's pump was turned on to initiate the purging process. Every five minutes conductivity, pH, dissolved oxygen, and temperature readings were taken and recorded. Monitoring continued until these parameters stabilized, which typically occurred after 15 to 20 minutes of continuous purging. The final recorded readings of pH, conductivity, dissolved oxygen, and temperature are reported in Table A-1. For the two wells (GRA-17 and GRA-19) with plumbing that would not allow the attachment of the Y-tube, the water quality meter's calibration cup was used to draw aliquots for monitoring. Dissolved oxygen content was not recorded for such wells, as spuriously high readings result when the sample water entrained air.

Once the field parameters stabilized, a metals sample was collected in a plastic 500 milliliter bottle containing a nitric acid preservative; a nitrate/nitrite-and-phosphorus sample was collected in a plastic 125 milliliter bottle containing a sulfuric acid preservative; and a chloride-and-sulfate sample was collected in a half-gallon (approx. 2 liter) plastic jug. VOC samples were collected in a triplet of septum vials containing a hydrochloric acid preservative.

When sampling was completed, the sample bottles, except for the half-gallon jug, were placed in doubled plastic bags. The bagged samples and the jug were then placed in ice water in a cooler. During transport, a trip blank, a single septum vial containing clean water and a hydrochloric acid preservative prepared by EPD laboratory personnel, accompanied each cooler holding VOC samples.

Three wells, public water system wells COL-12X-03 and GRA-12X-03 and domestic well GRA-12X-05 underwent follow-up sampling. Each well produced an initial sample with arsenic in excess of the Primary MCL of 10 micrograms per liter (ug/L). A fourth well, domestic well GRA-12X-04, also gave an initial sample with excessive arsenic but was abandoned before a follow-up sample could be taken. A sample taken from this well's replacement (GRA-12X-04N) yielded a sample even higher in arsenic.

3.2 LABORATORY METHODS

Laboratory measurements of the concentrations of VOCs, chloride, nitrate/nitrite, total phosphorus, and metals took place at the EPD laboratory. The USEPA has approved and assigned identification numbers to various testing procedures, termed EPA methods, used in environmental venues. The EPD lab used the methods given in the table below.

Table 3-1. Analytical Methods

Analyte	EPA Method	Method Type
Metals (1)	200.7	ICP
Metals (2)	200.8	ICP/MS
Chloride and Sulfate	300.0	Ion Chromatography
Nitrate/Nitrite	353.2	Colorimetric
Total Phosphorus	365.1	Colorimetric
VOCs	524.2	GC/MS

The reporting limit is the lowest concentration of a substance that can be accurately measured. These limits are given in Table A-2 in the Appendix. The typical reporting limit for nitrate/nitrite is 0.02 milligrams per liter (mg/L) as nitrogen, and for sulfate, the typical reporting limit is 10 mg/L. During the current project, higher concentrations of these two substances in some samples caused the reporting limits to be raised: diluting the sample water was necessary to bring the level of the analyte (sulfate or nitrate/nitrite) within the operating ranges of the testing instruments. Sulfate levels greater than 100 mg/L or nitrate/nitrite levels greater than 2 mg/L in a sample require the sample be diluted.

The ICP (inductively coupled plasma spectrometry) method is generally the better method for analyzing major metals and abundant minor metals: calcium, magnesium, sodium, iron, manganese, titanium, and, to a degree, potassium. The values reported in Table A-1 Part B for calcium, cobalt, iron, potassium, magnesium, manganese, sodium, titanium, and vanadium were derived from ICP analysis. The method involves ionizing analytes in plasma, then finding and measuring the intensity of their characteristic light spectra.

The ICP method is subject to interferences when used for analyzing some trace metals. These interferences can result in spuriously high reported concentrations for some metals. During this study, ICP analyses for zinc proved to be particularly vulnerable to interference. As a result, the values reported for chromium, nickel, copper, zinc, arsenic selenium, molybdenum, silver, cadmium, tin, antimony, barium, thallium, lead, and uranium were derived from ICP/MS (inductively-coupled plasma mass spectrometry) analysis. The ICP/MS method provides results for trace metals that are more accurate than those derived from the ICP method. The method involves ionizing analytes in plasma, then sorting them magnetically according to mass-to-electrical charge ratio.

Chloride and sulfate were analyzed using ion chromatography, which depends on the affinity of the analyte for an ion-exchange medium. Nitrate/nitrite and total phosphorus were analyzed using colorimetric techniques. These methods involve converting the analyte to a strongly colored substance, which can then be compared with a color standard. VOCs were analyzed with the GC/MS (gas chromatography mass spectrometry) technique. This method initially sorts analytes by allowing them to diffuse through a chromatographic column – most analytes diffuse through the column at different rates – then ionizing them and further sorting them according to charge-mass ratio in a mass spectrometer.

CHAPTER 4 RESULTS

4.1 INTRODUCTION

Seventy samples from 67 stations underwent testing at the EPD laboratory. These same sample waters also underwent field parameter measurement immediately prior to sampling. In order to verify the high arsenic levels in their sample waters, three stations (COL-03i, COL-12X-03i, GRA-12X-5i) received follow-up sampling. A fourth station (GRA-4) was scheduled for follow-up sampling, but, was abandoned and a replacement well drilled (GRA-4N). The replacement well was then sampled.

4.2 FIELD MEASUREMENTS

Field measurements made on the water samples consisted of pH, conductivity, and temperature. Dissolved oxygen is always measured in the field; however, because the parameter is denominated in mg/L, it is discussed in a following section dealing with anions and non-metals.

Measurements of pH ranged from 6.29 to 8.01. Sixty pH measurements on samples from 57 wells were basic. The remainder, 10 measurements for 10 wells, was acidic.

Conductivity measurements on the 70 samples ranged from 136 uS/cm (microSiemenses per centimeter) to 925 uS/cm. Temperatures for the 70 samples ranged from 20.7°C to 27.3°C.

4.3 ANIONS AND NON-METALS

The EPD laboratory carried out analyses for chloride, sulfate, nitrate/nitrite, total phosphorus for all 70 samples from all 67 stations. Budgetary restrictions did not permit the laboratory to analyze routinely for fluoride. EPD field staff performed dissolved oxygen measurements in the field for 68 samples from 65 wells. Dissolved oxygen contents were not recorded for two wells, because drawing sample water from the wells could not be done without exposing the water to air.

Dissolved oxygen contents of sample waters ranged from 0.49 mg/L to 6.99 mg/L. Detectable chloride occurred in 17 of 70 samples from 67 wells. Chloride content ranged from not detected to 65 mg/L. Thirty five of 70 samples from 35 of 67 wells contained detectable nitrate/nitrite, with concentrations ranging up to 3.00 mg/L. For one well, GRA-5, the follow-up sample contained detectable nitrate/nitrite, whereas the original sample did not. Forty five samples from 45 of 67 wells contained detectable phosphorus. Phosphorus (total phosphorus) ranged in concentration from undetected to 0.45 mg/L. For well GRA-3, the initial sample contained detectable phosphorus, while the follow-up sample did not. For well COL-3, the initial sample contained no detectable phosphorus, while the follow-up sample did.

4.4 MAJOR METALS

The EPD laboratory tested for the following major metals using the ICP method: aluminum, calcium, potassium, magnesium, manganese, sodium, and titanium. No detectable potassium or titanium was found. Only two of 67 wells gave samples with detectable aluminum. Calcium was found in all 70 samples from all 67 wells. Concentrations ranged from 1,300 ug/L to 110,000 ug/L, with a median of 32,500 ug/L. Detectable iron occurred in 38 samples from 37 wells and ranged up to 800 ug/L. Samples from wells GRA-19 and GRA-32 exceeded iron's Secondary MCL of 300 ug/L. Magnesium was found in 69 samples from 66 wells and ranged from undetected to 45,000 ug/L. Manganese occurred in 13 samples from 13 wells. Levels ranged from undetected to 60 ug/L, with wells BEN-5 and GRA-8 yielding samples with the metal in excess of the 50 ug/L Secondary MCL. Sodium occurred in all 70 samples from all 67 wells. Concentrations ranged from 2,100 ug/L to 49,000 ug/L, with a median of 9,750 ug/L.

4.5 TRACE METALS

The EPD laboratory tested all 70 samples from all 67 wells for beryllium, cobalt, and vanadium using the ICP method and found detectable amounts only of vanadium, in three samples from wells GRA-09, GRA-23, and GRA-27. The laboratory relied primarily on the ICPMS method to determine the following metals: chromium, nickel, copper, zinc, arsenic, selenium, molybdenum, silver, cadmium, tin, antimony, barium, thallium, lead, and uranium. No samples contained detectable nickel, selenium, silver, cadmium, tin, antimony, or thallium. Only the sample from well GRA-27 contained detectable chromium.

The most abundant trace metal was barium, detected in 69 samples from 66 wells. Its concentration range extended from undetected to 510 ug/L, with a median concentration of 71.0 ug/L. Next were arsenic and molybdenum, each detected in 30 samples from 27 wells. Arsenic contents in sample waters ranged from undetected to 20 ug/L, and, molybdenum contents ranged from undetected to 58 ug/L. Zinc was the third most abundant, being detected in samples from 27 samples from 25 wells and ranging from undetected to 190 ug/L. Lead was detected in 17 samples from 17 wells and ranged from undetected to 8.2 ug/L. 4-2Other than chromium and vanadium, copper and uranium were the least abundant of the trace metals, each being detected in seven samples from seven wells. Copper concentrations ranged from undetected to 19 ug/L, and, uranium concentrations ranged from undetected to 4.8 ug/L. Of the trace metals subject to MCLs or copper/lead action levels, only arsenic exceeded its Primary MCL of 10 ug/L. The arsenic excesses occurred in 11 samples from eight wells.

4.6 VOLATILE ORGANIC COMPOUNDS

The EPD laboratory analyzed 70 samples from all 67 stations for VOCs. Six samples from six stations tested positive for one or more of these compounds. Chloroform was the most widely occurring, being found in waters from five wells: BEN-01, BEN-02, COO-03, GRA-01, and GRA-02. Bromodichloromethane and chlorodibromomethane were next, being found in samples from four wells: BEN-01, COO-03, GRA-01, and GRA-02. Bromodichloromethane is the more abundant of the two compounds. The least widely occurring were bromoform and methyl tert-butyl ether (MTBE, also called 2-methoxy-2methyl-propane). The first compound was detected in a sample from COO-03 and the second from well GRA-17. The chloroform level in well COO-03 exceeded the total trihalomethanes Primary MCL of 80 ug/L. The total trihalomethane content of this sample amounted to 201.3 ug/L. VOCs did not exceed applicable MCLs in samples from any other wells.

CHAPTER 5 DISCUSSION AND SUMMARY

5.1 COMPARISON OF FLORIDAN AQUIFER WATERS WITHIN THE GULF TROUGH TO FLORIDAN WATERS OUTSIDE THE TROUGH

More samples were collected from the Floridan aquifer inside the Gulf Trough than outside, and from fewer stations, which leads to some difficulty with making comparisons. Furthermore, the sampling areas outside the Trough have their own local characteristics: the wells sampled in Decatur County, where the Floridan is unconfined, give waters with different chemical characteristics from those of Ben Hill County, where the Floridan is deeply confined. Nevertheless, certain chemical characteristics of waters within the Trough differ from those of waters outside the Trough. The differences are discussed below.

5.1.1 Comparison of Sample Waters, Selected Field Measurements and Non-Metallics.

Table 5-1 lists the field measurements and non-metallic analyte levels for sample waters from inside the Trough, while Table 5-2 lists the same parameters for sample waters from outside the Trough. Location reference figures are in Appendix B.

Table 5-1. Parameters for Samples From Inside the Trough, Selected Field Measurements and Non-Metallic Analytes

Sample Number	pH	Conductivity uS/cm	Dissolved O_2 mg/L	Cl mg/L	SO_4 mg/L	Nitrate/ Nitrite mg/L as N	Total P mg/L	Location Reference
BUL-02	7.84	223	0.60	0	0	0	0.04	Fig. B-2
BUL-03	7.66	217	0.90	0	0	0	0.45	Fig. B-2
BUL-04	7.85	219	0.59	0	0	0	0.08	Fig. B-2
COF-01	7.61	247	1.80	0	0	0	0	Fig. B-4
COL-01	7.21	473	0.60	10	100	0.09	0.03	Fig. B-4
COL-03	7.53	223	0.54	0	0	0	0.04	Fig. B-4
COL-03R	8.01	219	0.56	0	0	0	0	Fig. B-4
COL-04	7.02	294	0.55	0	28	0	0.04	Fig. B-4
COL-05	7.41	368	0.58	0	65	0	0.02	Fig. B-4
COL-06	7.31	480	0.91	11	120	0	0	Fig. B-4
COL-07	7.01	925	0.78	16	380	0	0	Fig. B-4
COL-08	6.93	623	0.58	13	180	0.05	0	Fig. B-4
COL-09	7.38	570	0.59	12	150	0	0	Fig. B-4
COL-11	7.11	325	1.02	0	40	0.03	0.03	Fig. B-4
COL-12	7.27	517	0.97	13	120	0	0	Fig. B-4

Table 5-1, Continued. Parameters for Samples From Inside the Trough, Selected Field Measurements and Non-Metallic Analytes

Sample Number	pH	Conductivity uS/cm	Dissolved O_2 mg/L	Cl mg/L	SO_4 mg/L	Nitrate/ Nitrite mg/L as N	Total P mg/L	Location Reference
COL-13	7.26	603	0.84	14	170	0.04	0.02	Fig. B-4
COL-14	7.27	576	0.53	12	150	0	0.02	Fig. B-4
COL-15	7.48	422	0.53	10	89	0	0	Fig. B-4
COO-01	7.12	550	0.53	65	65	0	0	Fig. B-5
COO-02	7.71	585	0.53	57	87	0	0	Fig. B-5
COO-04	7.79	379	0.49	23	37	0	0.03	Fig. B-5
GRA-01	7.68	363	1.03	0	45	0	0.03	Fig. B-7
GRA-02	7.67	354	2.24	0	40	0	0.03	Fig. B-7
GRA-03	7.76	322	0.63	0	27	0	0	Fig. B-7
GRA-03R	7.21	330	0.60	0	29	0	0.02	Fig. B-7
GRA-04	7.28	276	1.81	0	0	0.04	0.02	Fig. B-7
GRA-04N	7.63	281	1.51	0	0	0.03	0.02	Fig. B-7
GRA-05	7.43	280	1.47	0	0	0	0.04	Fig. B-7
GRA-05R	7.53	284	1.48	0	0	0.05	0.02	Fig. B-7
GRA-06	6.29	136	2.80	0	0	0.05	0.16	Fig. B-7
GRA-07	7.70	260	1.27	0	0	0	0	Fig. B-7
GRA-08	6.62	372	0.64	0	0	0	0.05	Fig. B-7
GRA-09	7.84	240	3.23	0	0	0	0.03	Fig. B-7
GRA-11	7.93	266	5.90	0	0	0.04	0	Fig. B-7
GRA-12	7.70	266	3.83	0	0	0.03	0.04	Fig. B-7
GRA-13	7.64	261	1.23	0	0	0	0.03	Fig. B-7
GRA-14	6.76	345	6.99	0	0	0.42	0.03	Fig. B-7
GRA-15	7.12	308	No reading	0	14	0.14	0	Fig. B-7
GRA-16	7.19	295	2.67	0	13	0.19	0.03	Fig. B-7
GRA-17	6.70	279	4.21	0	0	0.42	0.09	Fig. B-7
GRA-18	6.74	334	0.82	0	0	0.03	0	Fig. B-7
GRA-19	7.65	304	No reading	0	10	0	0	Fig. B-7
GRA-20	7.02	382	1.06	30	18	0.08	0	Fig. B-7
GRA-21	7.45	357	0.54	18	16	0.04	0	Fig. B-7
GRA-22	7.40	285	1.56	0	0	0.05	0.03	Fig. B-7
GRA-23	6.82	189	5.27	0	0	0.06	0.04	Fig. B-7
GRA-25	7.34	312	0.58	0	32	0.03	0	Fig. B-7
GRA-26	6.79	254	6.93	0	0	0.53	0	Fig. B-7
GRA-27	7.45	251	3.94	0	0	0.06	0	Fig. B-7
GRA-28	7.23	375	0.55	10	47	0.03	0	Fig. B-7
GRA-29	7.86	180	6.80	0	0	0.06	0.02	Fig. B-7
GRA-30	7.79	194	5.80	0	0	0.04	0.03	Fig. B-7
GRA-31	7.78	246	1.73	0	0	0	0	Fig. B-7

Table 5-1, Continued. Parameters for Samples From Inside the Trough, Selected Field Measurements and Non-Metallic Analytes

Sample Number	pH	Conductivity uS/cm	Dissolved O_2 mg/L	Cl mg/L	SO_4 mg/L	Nitrate/ Nitrite mg/L as N	Total P mg/L	Location Reference
GRA-32	7.60	246	1.51	0	0	0	0.03	Fig. B-7
THO-01	7.77	357	4.83	11	36	0.10	0.04	Fig. B-11
Mean Level	7.385	342.218	1.896	--	--	--	--	
Median Level	7.43	304	1.02	--	--	--	--	
% Samples with detections	--	--	--	29.1	49.1	47.3	58.2	

Note: substances not detected in a sample have a "0" entry.

Table 5-2. Parameters for Samples From Outside the Trough, Selected Field Measurements and Non-Metallic Analytes.

Sample Number	pH	Conductivity uS/cm	Dissolved O_2 mg/L	Cl mg/L	SO_4 mg/L	Nitrate/ Nitrite mg/L as N	Total P mg/L	Location Reference
North Flank								
DEC-01	7.51	227	2.11	0	0	3.0	0.03	Fig. B-6
DEC-02	7.58	228	2.17	0	0	2.8	0.03	Fig. B-6
DEC-03	7.64	231	2.92	0	0	3.0	0.02	Fig. B-6
DEC-04	7.67	230	2.07	0	0	3.0	0.03	Fig. B-6
BEN-01	7.68	207	1.31	0	0	0.04	0.06	Fig. B-1
BEN-02	7.72	204	0.86	0	0	0	0.06	Fig. B-1
BEN-03	7.96	167	0.71	0	0	0	0.03	Fig. B-1
BEN-04	7.71	203	1.10	0	0	0	0	Fig. B-1
BEN-05	7.79	193	0.58	0	0	0.02	0	Fig. B-1
SCR-01	7.64	221	1.15	0	0	0	0.06	Fig. B-10
SCR-02	7.41	298	2.52	0	0	0.10	0.10	Fig. B-10
South Flank								
COO-03	7.49	524	6.31	44	65	0	0.02	Fig. B-5
LAN-01	6.86	259	0.88	0	20	0	0.03	Fig. B-8
LAN-02	6.34	259	0.66	0	20	0.03	0.03	Fig. B-8
LOW-01	7.58	233	0.81	0	0	0.02	0.04	Fig. B-9
Mean Level	7.505	245.6	1.744	--	--	--	--	
Median Level	7.64	228	1.15	--	--	--	--	
% Samples with detections	--	--	--	6.7	20.0	60.0	86.7	

Note: substances not detected in a sample have a "0" entry.

A review of the tables shows that sample waters inside the Trough tend to have lower pHs and higher conductivities. A high mean dissolved oxygen level coupled with a low median dissolved oxygen level signifies that most wells give low-oxygen water while a few yield water with very high oxygen contents. In-Trough waters appear overall somewhat lower in dissolved oxygen but with more high-oxygen spikes than their outside-the-Trough counterparts. In-Trough waters have more detections of chloride and sulfate and fewer detections of nitrate/nitrite and phosphorus than their outside counterparts. The Decatur County Wells, DEC-1 through DEC-4, which draw from the unconfined Floridan, have the highest nitrate/nitrite levels in this study.

The sample from well COO-03 has an extremely high trihalomethane concentration (see Table A-1 in the Appendix). Trihalomethanes usually arise from reactions between halogen-based disinfectants and organic matter naturally present in the water. Two common scenarios in which this occurs are 1) if a well has a faulty check valve or foot valve that allows treated water to flow back down the well and 2) if a well has undergone disinfection following an overhaul. In either case, the "ground water" can become exposed to air. The high oxygen level for well COO-3 may then be an artifact. If such is the case and the well's oxygen value removed from calculations, the mean dissolved oxygen level for sample waters outside the trough drops to 1.418 and the median level to 1.125.

Some differences may exist between samples from the north flank of the Trough and those from the south flank, as well as from different areas along each flank (See Fig. 2-1). The Decatur County samples have higher nitrate/nitrite contents and generally higher dissolved oxygen contents than other samples from both flanks of the Trough. South flank samples seem to have lower pHs and phosphorus contents and higher sulfate contents than north flank samples.

5.1.2 Comparison of Sample Waters, Selected Major Metals.

Table 5-3 lists concentrations of calcium, magnesium, sodium, iron, and manganese in samples from inside the Trough and Table 5-4 lists the same values for samples outside the Trough.

Table 5-3. Parameters for Samples From Inside the Trough, Selected Major Metals.

Sample Number	Ca ug/L	Mg ug/L	Na ug/L	Fe ug/L	Mn ug/L	Ca/Mg	Ca/Na	Location Reference
BUL-02	35000	3800	5500	0	36	9.21	6.36	Fig. B-2
BUL-03	20000	3600	5600	280	26	5.56	3.57	Fig. B-2
BUL-04	35000	4100	6100	30	0	8.53	8.54	Fig. B-2

Table 5-3 Continued. Parameters for Samples From Inside the Trough, Selected Major Metals.

Sample Number	Ca ug/L	Mg ug/L	Na ug/L	Fe ug/L	Mn ug/L	Ca/Mg	Ca/Na	Location Reference
COF-01	24000	14000	7600	0	0	1.71	3.15	Fig. B-3
COL-01	53000	26000	11000	0	0	2.04	4.82	Fig. B-4
COL-03	20000	9900	22000	51	0	2.02	0.91	Fig. B-4
COL-03R	18000	8600	18000	37	0	2.09	1.00	Fig. B-4
COL-04	41000	16000	5400	72	15	2.56	7.59	Fig. B-4
COL-05	28000	16000	27000	0	0	1.75	1.04	Fig. B-4
COL-06	39000	23000	29000	0	0	1.67	1.34	Fig. B-4
COL-07	110000	45000	28000	27	0	2.44	3.93	Fig. B-4
COL-08	63000	32000	21000	0	0	1.97	3.00	Fig. B-4
COL-09	54000	27000	25000	0	0	2.00	2.16	Fig. B-4
COL-11	34000	16000	9800	32	0	2.13	3.47	Fig. B-4
COL-12	50000	26000	22000	50	0	1.92	2.27	Fig. B-4
COL-13	60000	31000	21000	0	0	1.94	2.90	Fig. B-4
COL-14	58000	30000	18000	43	0	1.93	3.22	Fig. B-4
COL-15	34000	19000	26000	41	0	1.79	1.31	Fig. B-4
COO-01	37000	18000	49000	0	0	2.05	0.77	Fig. B-5
COO-02	40000	20000	46000	48	0	2.00	0.87	Fig. B-5
COO-04	32000	15000	25000	0	0	3.13	1.28	Fig. B-5
GRA-01	36000	18000	14000	42	0	2.00	2.57	Fig. B-7
GRA-02	35000	18000	13000	37	0	1.94	2.69	Fig. B-7
GRA-03	33000	17000	8700	0	0	1.94	3.79	Fig. B-7
GRA-03R	36000	18000	9700	0	0	2.00	3.71	Fig. B-7
GRA-04	23000	13000	19000	0	0	1.77	1.21	Fig. B-7
GRA-04N	23000	13000	18000	86	0	1.77	1.28	Fig. B-7
GRA-05	23000	13000	18000	0	0	1.77	1.28	Fig. B-7
GRA-05R	25000	13000	18000	0	0	1.92	1.39	Fig. B-7
GRA-06	11000	6400	6300	0	0	1.71	1.75	Fig. B-7
GRA-07	20000	11000	21000	52	0	1.82	0.95	Fig. B-7
GRA-08	44000	23000	3100	94	55	1.91	14.19	Fig. B-7
GRA-09	21000	15000	4800	0	0	1.40	4.38	Fig. B-7
GRA-11	1300	0	42000	40	0	<INF	0.03	Fig. B-7
GRA-12	25000	17000	4900	0	0	1.47	5.10	Fig. B-7
GRA-13	23000	11000	19000	240	0	2.09	1.21	Fig. B-7
GRA-14	38000	20000	2900	25	0	1.90	13.10	Fig. B-7
GRA-15	40000	16000	2700	21	0	2.50	14.81	Fig. B-7
GRA-16	36000	15000	2600	0	0	2.40	13.85	Fig. B-7
GRA-17	44000	12000	2600	0	0	3.67	16.92	Fig. B-7
GRA-18	40000	23000	5900	24	0	1.74	6.78	Fig. B-7
GRA-19	37000	21000	18000	800	14	1.76	2.06	Fig. B-7

Table 5-3, Continued. Parameters for Samples From Inside the Trough, Selected Major Metals.

Sample Number	Ca ug/L	Mg ug/L	Na ug/L	Fe ug/L	Mn ug/L	Ca/Mg	Ca/Na	Location Reference
GRA-20	32000	19000	23000	28	0	1.68	1.39	Fig. B-7
GRA-21	30000	18000	22000	31	0	1.67	1.36	Fig. B-7
GRA-22	25000	15000	18000	160	0	1.67	1.39	Fig. B-7
GRA-23	22000	15000	3500	0	0	1.47	6.29	Fig. B-7
GRA-25	27000	14000	27000	28	0	1.93	1.00	Fig. B-7
GRA-26	44000	8100	3400	0	0	5.43	12.94	Fig. B-7
GRA-27	29000	17000	4700	49	0	1.71	6.17	Fig. B-7
GRA-28	41000	19000	18000	31	0	2.16	2.28	Fig. B-7
GRA-29	21000	13000	3200	0	0	1.62	6.56	Fig. B-7
GRA-30	23000	13000	3500	0	0	1.77	6.75	Fig. B-7
GRA-31	22000	11000	19000	83	0	2.00	1.16	Fig. B-7
GRA-32	22000	12000	18000	400	0	1.83	1.22	Fig. B-7
THO-01	32000	19000	16000	0	10	1.68	2.00	Fig. B-11
Mean Level	33987	16555	15664	--	--	2.35	4.09	
Median Level	33000	16000	18000	--	--	1.93	2.43	
% Samples with detections	100.0	98.2	100.0	54.6	10.9			

Notes: substances not detected in a sample have a "0" entry. Ca/Mg ratio for GRA-11 left out of mean and median calculations.

Table 5-4. Parameters for Samples From Outside the Trough, Selected Major Metals.

Sample Number	Ca ug/L	Mg ug/L	Na ug/L	Fe ug/L	Mn ug/L	Ca/Mg	Ca/Na	Location Reference
North Flank								
DEC-01	43000	3600	2200	150	0	11.94	19.55	Fig. B-6
DEC-02	43000	4400	2200	0	0	9.77	19.55	Fig. B-6
DEC-03	41000	4200	2100	0	0	9.76	19.52	Fig. B-6
DEC-04	43000	4100	2200	0	0	10.49	19.55	Fig. B-6
BEN-01	30000	6200	2700	0	0	4.84	11.11	Fig. B-1
BEN-02	30000	5900	2700	82	18	5.08	11.11	Fig. B-1
BEN-03	21000	6000	3200	0	0	3.50	6.56	Fig. B-1
BEN-04	29000	5600	3100	250	37	5.19	9.35	Fig. B-1
BEN-05	26000	6500	3000	220	60	4.00	8.67	Fig. B-1
SCR-01	38000	3300	4700	36	47	11.52	6.38	Fig. B-10
SCR-02	52000	4100	6800	36	47	12.68	7.65	Fig. B-10

Table 5-4 Continued. Parameters for Samples From Outside the Trough, Selected Major Metals.

Sample Number	Ca ug/L	Mg ug/L	Na ug/L	Fe ug/L	Mn ug/L	Ca/Mg	Ca/Na	Location Reference
South Flank								
COO-03	53000	20000	29000	0	0	2.65	1.83	Fig. B-5
LAN-01	30000	14000	4000	0	0	2.14	7.50	Fig. B-8
LAN-02	30000	15000	4000	230	15	2.00	3.75	Fig. B-8
LOW-01	30000	12000	3200	55	33	2.50	9.38	Fig. B-9
Mean Level	35933	7660	5007	--	--	6.54	10.76	
Median Level	30000	5900	3100	--	--	5.08	9.35	
% Samples with detections	100.0	100.0	100.0	53.3	46.7			

Note: substances not detected in a sample have a "0" entry.

Calcium levels both in samples from the Trough and in samples from outside the Trough are somewhat similar. Calcium levels from inside the trough tend to be less variable, as the mean and the median lie close to each other. Samples from inside the Trough tend to be much richer in sodium and magnesium than those from outside. As Kellam and Gorday (1990) have noted, the ratios of calcium to other anions tend to be higher in Floridan aquifer ground waters near recharge areas. This observation is very evident for the Decatur County samples, with Ca/Mg ratios ranging from near 10 to near 12, in comparison to those of most of the remainder of the samples, both from inside and outside the Trough. The high Ca/Mg ratios of the Screven County samples, SCR-1 and SCR-2, suggest that the wells producing these samples may be drawing some surface recharge from the immediate area. Ca/Mg ratios from most of the inside samples are relatively low, in the one-to-three range, indicating their distal location to surface recharge. Ca/Na ratios of samples from inside the Trough generally tend to be lower than those of outside samples.

While iron contents of sample waters from inside the Trough are somewhat similar to those of samples from outside, manganese is generally more abundant in the outside samples, with about four times as many detections in outside samples as in inside ones.

Inspection of Table 5-4 shows that for samples outside the Trough, magnesium seems more abundant in samples from the south flank.

5.1.3 Comparison of Sample Waters, Selected Trace Metals.

Table 5-5 lists concentrations of copper, lead, zinc, arsenic, molybdenum, uranium, and barium in samples from inside the Trough and Table 5-6 lists the concentrations for samples outside the Trough.

Table 5-5. Parameters for Samples From Inside the Trough, Selected Trace Metals

Sample Number	Cu ug/L	Zn ug/L	Pb ug/L	As ug/L	Mo ug/L	Ba ug/L	U ug/L	Location Reference
BUL-02	0	0	0	7.9	9.1	10	0	Fig. B-2
BUL-03	0	0	0	6.0	0	26	0	Fig. B-2
BUL-04	0	47.0	0	9.8	0	35	0	Fig. B-2
COF-01	0	0	0	0	0	160	0	Fig. B-3
COL-01	0	17.0	2.7	8.7	0	72	0	Fig. B-4
COL-03	0	17.0	0	19.0	6.9	510	0	Fig. B-4
COL-03R	0	11.0	0	13.0	7.8	330	0	Fig. B-4
COL-04	0	13.0	0	7.7	0	68	0	Fig. B-4
COL-05	5.4	0	0	0	0	98	0	Fig. B-4
COL-06	0	0	0	0	0	91	0	Fig. B-4
COL-07	0	0	0	0	5.4	33	0	Fig. B-4
COL-08	0	0	0	0	0	28	0	Fig. B-4
COL-09	0	0	0	0	0	46	0	Fig. B-4
COL-11	0	0	0	0	0	70	0	Fig. B-4
COL-12	0	0	0	0	0	34	0	Fig. B-4
COL-13	0	13.0	0	0	0	22	0	Fig. B-4
COL-14	5.5	0	0	0	5.4	29	0	Fig. B-4
COL-15	0	0	0	0	0	100	0	Fig. B-4
COO-01	0	0	1.8	0	0	70	0	Fig. B-5
COO-02	0	0	0	0	0	68	0	Fig. B-5
COO-4	0	0	1.4	5.6	18.0	200	0	Fig. B-5
GRA-01	0	0	0	7.8	37.0	120	0	Fig. B-7
GRA-02	0	0	0	6.7	39.0	110	0	Fig. B-7
GRA-03	13.0	0	0	11.0	58.0	120	0	Fig. B-7
GRA-03R	0	0	0	13.0	52.0	140	0	Fig. B-7
GRA-04	0	87.0	0	11.0	15.0	230	0	Fig. B-7
GRA-04N	0	190.0	0	15.0	15.0	250	0	Fig. B-7
GRA-05	0	51.0	0	12.0	12.0	230	0	Fig. B-7
GRA-05R	0	43.0	0	15.0	13.0	250	0	Fig. B-7
GRA-06	0	0	0	0	0	38	0	Fig. B-7
GRA-07	0	0	0	0	25.0	190	0	Fig. B-7

Table 5-5, Continued. Parameters for Samples From Inside the Trough, Selected Trace Metals

Sample Number	Cu ug/L	Zn ug/L	Pb ug/L	As ug/L	Mo ug/L	Ba ug/L	U ug/L	Location Reference
GRA-08	0	0	0	0	0	19	0	Fig. B-7
GRA-09	0	0	0	7.4	18.0	40	0	Fig. B-7
GRA-11	0	91.0	0	0	5.0	19	1.7	Fig. B-7
GRA-12	0	12.0	0	7.5	8.2	21	3.5	Fig. B-7
GRA-13	8.4	23.0	1.7	20.0	17.0	250	3.7	Fig. B-7
GRA-14	0	160.0	1.4	0	0	22	0	Fig. B-7
GRA-15	0	59.0	1.8	0	0	43	0	Fig. B-7
GRA-16	0	17.0	4.9	0	0	37	0	Fig. B-7
GRA-17	0	0	1.4	0	0	24	0	Fig. B-7
GRA-18	0	0	0	6.0	23.0	85	0	Fig. B-7
GRA-19	19.0	15.0	1.6	5.0	0	160	0	Fig. B-7
GRA-20	0	0	0	0	8.9	170	0	Fig. B-7
GRA-21	0	0	0	0	6.2	200	3.0	Fig. B-7
GRA-22	0	50.0	0	7.5	5.4	230	0	Fig. B-7
GRA-23	7.3	0	8.2	5.5	0	8.8	0	Fig. B-7
GRA-25	0	0	0	0	15.0	320	0	Fig. B-7
GRA-26	0	33.0	1.1	0	0	67	0	Fig. B-7
GRA-27	0	75.0	1.9	0	0	220	1.8	Fig. B-7
GRA-28	0	30.0	0	0	13.0	140	4.8	Fig. B-7
GRA-29	0	0	0	0	0	0	0	Fig. B-7
GRA-30	0	28.0	0	0	0	7.4	0	Fig. B-7
GRA-31	0	22.0	0	14.0	18.0	230	0	Fig. B-7
GRA-32	0	74.0	1.7	17.0	18.0	230	0	Fig. B-7
THO-01	0	0	0	7.9	7.6	100	0	Fig. B-11
Mean Level	--	--	--	--	--	120.3	--	
Median Level	--	--	--	--	--	99	--	
% Samples with detections	10.9	43.6	23.6	47.3	50.9	--	10.9	

Note: substances not detected in a sample have a "0" entry.

Table 5-6. Parameters for Samples From Outside the Trough, Selected Trace Metals

Sample Number	Cu ug/L	Zn ug/L	Pb ug/L	As ug/L	Mo ug/L	Ba ug/L	U ug/L	Location Reference
North Flank								
DEC-01	0	0	0	0	0	6.7	0	Fig. B-6
DEC-02	0	0	0	0	0	5.1	0	Fig. B-6
DEC-03	0	0	1.6	0	0	6.8	0	Fig. B-6
DEC-04	0	0	0	0	0	4.9	0	Fig. B-6
BEN-01	0	0	0	0	0	350	0	Fig. B-1
BEN-02	0	0	0	0	0	180	0	Fig. B-1
BEN-03	0	0	0	0	0	270	0	Fig. B-1
BEN-04	0	0	0	0	0	120	0	Fig. B-1
BEN-05	0	0	0	0	0	410	0	Fig. B-1
SCR-01	0	18	0	5.4	0	50	0	Fig. B-10
SCR-02	0	15	1.2	6.1	0	46	0	Fig. B-10
South Flank								
COO-03	13	0	1.7	6.1	24.0	120	2.0	Fig. B-5
LAN-01	0	0	0	0	5.4	28	0	Fig. B-8
LAN-02	0	34	0	0	0	32	0	Fig. B-8
LOW-01	0	0	2.7	8.2	5.8	8.3	0	Fig. B-9
Mean Level	--	--	--	--	--	109.2	--	
Median Level	--	--	--	--	--	46	--	
% Samples with detections	6.7	20.0	26.7	26.7	20.0	--	6.7	

Note: substances not detected in a sample have a "0" entry.

Copper, lead, and zinc can be contributed by plumbing, therefore the levels of these metals found in water samples may not be representative of their actual levels in native ground water. While percentage of lead detections among samples from inside the Trough were roughly similar to the percentage of detections among samples from outside the Trough, the percentages of copper and zinc detections were higher in samples from inside the Trough,

About half the samples from inside the Trough contained detectable arsenic and molybdenum, with all samples containing arsenic in excess of the 10 ug/L Primary MCL coming from inside the Trough (samples COL-3, COL-3R, GRA-3, GRA-3R GRA-4, GRA-4N, GRA-5, GRA-5R, GRA-13, GRA-31, AND GRA-32, Table 5-5). Only about a quarter of the samples from outside the Trough contained detectable arsenic and only about a fifth contained detectable molybdenum. Uranium was detected in 6.7% of the outside samples and 10.9% of the inside samples.

Twenty out of 26 inside samples containing detectable arsenic also contained detectable molybdenum. Twenty eight inside samples contained detectable molybdenum. Among the outside samples, of four that contained detectable arsenic, two also contained detectable molybdenum. Three outside samples contained detectable molybdenum. Arsenic and molybdenum seem to be more abundant in waters from inside the Trough than in waters from outside.

Due to the sensitivity of the analytical instrumentation, barium can be analyzed at levels down to 2 ug/L. The element is nearly ubiquitous at low levels in ground water in Georgia. The high barium contents in the waters from Ben Hill County notwithstanding, barium was generally more abundant in waters from inside the Trough than in waters from outside the structure.

Molybdenum seems to be more abundant in samples from the south flank of the Trough than in ones from the north flank.

5.1.4 Chemical Associations of Arsenic

Displayed below are arsenic abundance tables for various parameters. Table 5-7 lists arsenic concentration versus pH and conductivity and the levels of dissolved oxygen, chloride, sulfate, nitrate/nitrite, and phosphorus. Table 5-8 lists arsenic concentration versus Ca, Mg, Na, Fe, and Mn concentrations. Table 5-9 lists arsenic versus the concentrations of Cu, Zn, Pb, Mo, U, and Ba. These tables are extracted by sorting from Table A-1 in Appendix A. Six samples containing detectable VOCs are not shown in Table 5-7. Five of these contained varying combinations of trihalomethanes. The sixth contained methyl-tert-butyl ether. Three of the samples with trihalomethanes also contained detectable arsenic.

The median pH of all sample waters was 7.50. Sixty six point seven percent of the waters with detectable arsenic and eight of the 11 samples with arsenic exceedances had pHs above the median. Of the 60 water samples that were basic, 28 showed detectable arsenic. Arsenic, then, generally tends to be more abundant in waters with higher pHs.

Fifty percent of the samples with detectable arsenic registered conductivities above the median of 280.5 uS/cm; however, seven of the 11 samples with exceedances had conductivities below the median. Fifty seven point one percent of the samples with detectable arsenic and seven of 11 samples with arsenic exceedances had dissolved oxygen concentrations above the median of 1.03 mg/L. Forty four point four percent of the samples with detectable phosphorus had detectable arsenic. Eight of the 11 samples with exceedances also had detectable phosphorus, though mainly in the lower concentration ranges. Arsenic would tend to have as many **detections** in waters of both high and low conductivities and high and low dissolved oxygen concentrations, though the element would tend to be overall more abundant in waters with higher oxygen concentrations and with lower conductivities. Arsenic would tend to more detections in waters with detectable phosphorus than in those with no detectable phosphorus, though abundance of arsenic would be greater at the lower levels of detectable phosphorus.

Table 5-7. Arsenic Concentrations Versus pH and Conductivity and the Levels of Dissolved Oxygen, Chloride, Sulfate, Nitrate/Nitrite and Phosphorus

pH	As ug/L	Conductivity mS/cm	As ug/L	dO_2 mg/L	As ug/L	Cl mg/L	As ug/L	SO4 mg/L	As ug/L	NOx mg/L	As ug/L	P mg/L	As ug/L
6.29	0	136	0	0.49	5.6	0	19.0	0	19.0	0	19.0	0	13.0
6.34	0	167	0	0.53	0	0	7.7	0	13.0	0	13.0	0	0
6.62	0	180	0	0.53	0	0	13.0	0	0	0	9.8	0	0
6.70	0	189	5.5	0.53	0	0	0	0	9.8	0	7.9	0	14.0
6.74	6.0	193	0	0.53	0	0	0	0	7.9	0	0	0	0
6.76	0	194	0	0.54	19.0	0	0	0	0	0	0	0	5.0
6.79	0	203	0	0.54	0	0	9.8	0	0	0	0	0	11.0
6.82	5.5	204	0	0.55	7.7	0	7.9	0	8.2	0	6.0	0	0
6.86	0	207	0	0.55	0	0	13.0	0	6.0	0	0	0	0
6.93	0	217	6.0	0.56	13.0	0	11.0	0	0	0	5.4	0	0
7.01	0	219	9.8	0.58	0	0	0	0	6.0	0	20.0	0	0
7.02	7.7	219	13.0	0.58	0	0	0	0	0	0	0	0	0
7.02	0	221	5.4	0.58	0	0	0	0	5.4	0	12.0	0	0
7.11	0	223	19.0	0.58	0	0	8.2	0	20.0	0	17.0	0	0
7.12	0	223	7.9	0.59	9.8	0	6.0	0	0	0	14.0	0	0
7.12	0	227	0	0.59	0	0	0	0	0	0	0	0	6.0
7.19	0	228	0	0.60	7.9	0	0	0	12.0	0	7.4	0	0
7.21	8.7	230	0	0.60	13.0	0	6.0	0	15.0	0	5.0	0	0
7.21	13.0	231	0	0.60	8.7	0	0	0	17.0	0	0	0	0
7.23	0	233	8.2	0.63	11.0	0	7.8	0	15.0	0	11.0	0	0
7.26	0	240	7.4	0.64	0	0	0	0	7.5	0	7.7	0	0
7.27	0	246	17.0	0.66	0	0	5.4	0	14.0	0	13.0	0	0
7.27	0	246	14.0	0.71	0	0	20.0	0	0	0	5.6	0	0
7.28	11.0	247	0	0.78	0	0	0	0	11.0	0	6.7	0	0
7.31	0	251	0	0.81	8.2	0	0	0	0	0	7.8	0	0
7.34	0	254	0	0.82	6.0	0	12.0	0	0	0	0	0.02	13.0
7.38	0	259	0	0.84	0	0	15.0	0	0	0	6.1	0.02	0
7.40	7.5	259	0	0.86	0	0	17.0	0	6.1	0	0	0.02	6.1
7.41	0	260	0	0.88	0	0	15.0	0	0	0	0	0.02	0
7.41	6.1	261	20.0	0.90	6.0	0	7.5	0	0	0	0	0.02	15.0
7.43	12.0	266	7.5	0.91	0	0	14.0	0	7.4	0	0	0.02	11.0
7.45	0	266	0	0.97	0	0	0	0	7.5	0	0	0.02	0
7.45	0	276	11.0	1.02	0	0	11.0	0	0	0	0	0.02	15.0
7.48	0	279	0	1.03	7.8	0	0	0	0	0	0	0.02	0
7.49	6.1	280	12.0	1.06	0	0	0	0	5.5	0	0	0.02	0
7.51	0	281	15.0	1.10	0	0	0	0	0	0.02	0	0.03	0
7.53	19.0	284	15.0	1.15	5.4	0	6.7	0	0	0.02	8.2	0.03	20.0
7.53	15.0	285	7.5	1.23	20.0	0	6.1	0	0	0.03	6.0	0.03	17.0

Table 5-7 Continued. Arsenic Concentrations Versus pH and Conductivity and the Levels of Dissolved Oxygen, Chloride, Sulfate, Nitrate/Nitrite and Phosphorus

pH	As ug/L	Conductivity mS/cm	As ug/L	dO_2 mg/L	As ug/L	Cl mg/L	As ug/L	SO4 mg/L	As ug/L	NOx mg/L	As ug/L	P mg/L	As ug/L
7.58	0	294	7.7	1.27	0	0	0	0	0	0.03	15.0	0.03	7.4
7.58	8.2	295	0	1.31	0	0	0	0	0	0.03	7.5	0.03	0
7.60	17.0	298	6.1	1.47	12.0	0	0	10	5.0	0.03	0	0.03	5.6
7.61	0	304	5.0	1.48	15.0	0	7.4	13	0	0.03	0	0.03	6.7
7.63	15.0	308	0	1.51	17.0	0	7.5	14	0	0.03	0	0.03	7.8
7.64	0	312	0	1.51	15.0	0	0	16	0	0.03	0	0.03	0
7.64	20.0	322	11.0	1.56	7.5	0	0	18	0	0.04	0	0.03	0
7.64	5.4	325	0	1.73	14.0	0	5.5	20	0	0.04	11.0	0.03	0
7.65	5.0	330	13.0	1.80	0	0	0	20	0	0.04	0	0.03	7.5
7.66	6.0	334	6.0	1.81	11.0	0	0	27	11.0	0.04	0	0.03	8.7
7.67	0	345	0	2.07	0	0	0	28	7.7	0.04	0	0.03	0
7.67	6.7	354	6.7	2.11	0	0	0	29	13.0	0.04	0	0.03	0
7.68	0	357	0	2.17	0	0	0	32	0	0.05	15.0	0.03	0
7.68	7.8	357	7.9	2.24	6.7	0	5.0	36	7.9	0.05	7.5	0.03	0
7.70	0	363	7.8	2.52	6.1	0	0	37	5.6	0.05	0	0.03	0
7.70	7.5	368	0	2.67	0	10	0	40	0	0.05	0	0.04	19.0
7.71	0	372	0	2.80	0	10	0	40	6.7	0.06	0	0.04	7.9
7.71	0	375	0	2.92	0	10	8.7	45	7.8	0.06	5.5	0.04	12.0
7.72	0	379	5.6	3.23	7.4	11	0	47	0	0.06	0	0.04	7.7
7.76	11.0	382	0	3.83	7.5	11	7.9	65	0	0.08	0	0.04	8.2
7.77	7.9	422	0	3.94	0	12	0	65	6.1	0.09	8.7	0.04	7.5
7.78	14.0	473	8.7	4.21	0	12	0	65	0	0.10	6.1	0.04	5.5
7.79	0	480	0	4.83	7.9	13	0	87	0	0.10	7.9	0.04	7.9
7.79	5.6	517	0	5.27	5.5	13	0	89	0	0.14	0	0.05	0
7.79	0	524	6.1	5.80	0	14	0	100	8.7	0.19	0	0.06	0
7.84	7.9	550	0	5.90	0	16	0	120	0	0.42	0	0.06	5.4
7.84	7.4	570	0	6.31	6.1	18	0	120	0	0.42	0	0.06	0
7.85	9.8	576	0	6.80	0	23	5.6	150	0	0.53	0	0.08	9.8
7.86	0	585	0	6.93	0	30	0	150	0	2.80	0	0.09	0
7.93	0	603	0	6.99	0	44	6.1	170	0	3.00	0	0.10	6.1
7.96	0	623	0	NA	5.0	57	0	180	0	3.00	0	0.16	0
8.01	13.0	925	0	NA	0	65	0	380	0	3.00	0	0.45	6.0

Of the samples with detectable chloride, 23.9 percent also had detectable arsenic. None of the samples with arsenic exceedances had detectable chloride. Thirty three point three percent of the samples with detectable sulfate also had detectable arsenic, with two of the 11 samples with arsenic exceedances also having detectable sulfate. Thirty one point four percent of the samples with detectable nitrate/nitrite also had detectable arsenic, with three samples having arsenic in excess of the Primary MCL. Generally, waters with higher chloride, sulfate, or nitrate/nitrite concentrations would tend to have lower arsenic concentrations.

A review of Table 5-8 shows that 56.7 percent of the samples containing detectable arsenic and nine of the 11 samples with excessive arsenic also contained sodium in excess of its median concentration of 9,750 ug/L. Arsenic thus shows some tendency to concentrate in waters with higher sodium levels. Eight out of 13 samples, or 61.5%, with detectable manganese also have detectable arsenic, though none of the eight samples showed any arsenic exceedances. Though the number of samples with detectable manganese

Table 5-8. Arsenic Concentrations Versus Concentrations of Calcium, Magnesium, Sodium, Iron, and Manganese.

Ca ug/L	As ug/L	Mg ug/L	As ug/L	Na ug/L	As ug/L	Fe ug/L	As ug/L	Mn ug/L	As ug/L
1300	0	0	0	2100	0	0	0	0	0
11000	0	3300	5.4	2200	0	0	0	0	0
18000	13.0	3600	6.0	2200	0	0	0	0	0
20000	6.0	3600	0	2200	0	0	0	0	0
20000	19.0	3800	7.9	2600	0	0	0	0	0
20000	0	4100	9.8	2600	0	0	0	0	0
21000	0	4100	0	2700	0	0	0	0	0
21000	7.4	4100	6.1	2700	0	0	0	0	0
21000	0	4200	0	2700	0	0	0	0	0
22000	5.5	4400	0	2900	0	0	0	0	0
22000	14.0	5600	0	3000	0	0	5.5	0	5.5
22000	17.0	5900	0	3100	0	0	0	0	0
23000	15.0	6000	0	3100	0	0	7.4	0	7.4
23000	11.0	6200	0	3200	0	0	7.5	0	7.5
23000	12.0	6400	0	3200	8.2	0	7.9	0	0
23000	20.0	6500	0	3200	0	0	0	0	0
23000	0	8100	0	3400	0	0	0	0	11.0
24000	0	8600	13.0	3500	0	0	11.0	0	13.0
25000	15.0	9900	19.0	3500	5.5	0	13.0	0	8.7
25000	7.5	11000	0	4000	0	0	8.7	0	12.0
25000	7.5	11000	14.0	4000	0	0	7.9	0	15.0
26000	0	11000	20.0	4700	5.4	0	12.0	0	11.0
27000	0	12000	17.0	4700	0	0	15.0	0	0
28000	0	12000	8.2	4800	7.4	0	11.0	0	0
29000	0	12000	0	4900	7.5	0	0	0	5.6
29000	0	13000	0	5400	7.7	0	0	0	0
30000	0	13000	15.0	5500	7.9	0	5.6	0	0
30000	0	13000	11.0	5600	6.0	0	0	0	6.1
30000	0	13000	12.0	5900	6.0	0	0	0	0
30000	0	13000	0	6100	9.8	0	6.1	0	0
30000	0	13000	15.0	6300	0	0	0	0	0
30000	8.2	14000	0	6800	6.1	0	0	0	6.0
32000	5.6	14000	0	7600	0	21	0	0	0
32000	7.9	14000	0	8700	11.0	24	6.0	0	0
32000	0	15000	7.4	9700	13.0	25	0	0	0
33000	11.0	15000	5.5	9800	0	27	0	0	0
34000	0	15000	7.5	11000	8.7	28	0	0	9.8

Table 5-8 Continued. Arsenic Concentrations Versus Concentrations of Calcium, Magnesium, Sodium, Iron, and Manganese.

Ca ug/L	As ug/L	Mg ug/L	As ug/L	Na ug/L	As ug/L	Fe ug/L	As ug/L	Mn ug/L	As ug/L
34000	0	15000	0	13000	6.7	28	0	0	0
35000	7.9	15000	5.6	14000	7.8	30	9.8	0	0
35000	9.8	15000	0	16000	7.9	31	0	0	0
35000	6.7	16000	0	18000	13.0	31	0	0	6.7
36000	7.8	16000	0	18000	17.0	32	0	0	13.0
36000	13.0	16000	0	18000	15.0	36	5.4	0	0
36000	0	16000	7.7	18000	12.0	36	6.1	0	0
37000	0	17000	7.5	18000	15.0	37	6.7	0	7.8
37000	5.0	17000	0	18000	7.5	37	13.0	0	0
38000	0	17000	11.0	18000	0	40	0	0	0
38000	5.4	18000	0	18000	5.0	41	0	0	0
39000	0	18000	6.7	18000	0	42	7.8	0	0
40000	0	18000	7.8	19000	14.0	43	0	0	19.0
40000	0	18000	13.0	19000	20.0	48	0	0	0
40000	6.0	18000	0	19000	11.0	49	0	0	14.0
41000	0	19000	7.9	21000	0	50	0	0	15.0
41000	7.7	19000	0	21000	0	51	19.0	0	0
41000	0	19000	0	21000	0	52	0	0	7.5
43000	0	19000	0	22000	19.0	55	8.2	0	20.0
43000	0	20000	0	22000	0	72	7.7	0	17.0
43000	0	20000	0	22000	0	82	0	10	7.9
44000	0	20000	6.1	23000	0	83	14.0	14	5.0
44000	0	21000	5.0	25000	5.6	86	15.0	15	7.7
44000	0	23000	0	25000	0	94	0	15	0
50000	0	23000	6.0	26000	0	150	0	18	0
52000	6.1	23000	0	27000	0	160	7.5	26	6.0
53000	8.7	26000	0	27000	0	220	0	33	8.2
53000	6.1	26000	8.7	28000	0	230	0	36	7.9
54000	0	27000	0	29000	6.1	240	20.0	37	0
58000	0	30000	0	29000	0	250	0	47	5.4
60000	0	31000	0	42000	0	280	6.0	47	6.1
63000	0	32000	0	46000	0	400	17.0	55	0
110000	0	45000	0	49000	0	800	5.0	60	0

is small, the occurrence of the two elements together in more than half the samples registering manganese suggests that samples showing detectable manganese have some tendency to contain detectable arsenic.

Seventy three point three percent of the samples containing arsenic and 10 of 11 samples with excessive arsenic also contained calcium below the median concentration of 33,500 ug/L. In general, arsenic tends to occur in waters with lower calcium levels.

Fifty percent of the samples with detectable arsenic also contain magnesium at levels above the median of 15,000 ug/L. Nine of the 11 samples with arsenic in excess of the Primary MCL, however, contain magnesium in concentrations below the median. Fifty six point seven percent of the samples containing detectable arsenic and six of the 11 samples with excessive arsenic also contain detectable iron. Detectable arsenic, then, can be present in waters with a wide range of iron or magnesium contents. The element seems to be more abundant in waters with higher iron contents or lower magnesium contents.

Table 5-9. Arsenic Concentrations Versus Concentrations of Copper, Lead, Zinc, Molybdenum, Barium, and Uranium.

Copper ug/L	As ug/L	Zinc ug/L	As ug/L	Lead ug/L	As ug/L	Molybdenum ug/L	As ug/L	Uranium ug/L	As ug/L	Barium ug/L	As ug/L
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	4.9	0
0	0	0	0	0	0	0	0	0	0	5.1	0
0	0	0	0	0	0	0	0	0	0	6.7	0
0	0	0	0	0	0	0	0	0	0	6.8	0
0	0	0	0	0	0	0	0	0	0	7.4	0
0	0	0	0	0	0	0	0	0	0	8.3	8.2
0	0	0	0	0	0	0	0	0	0	8.8	5.5
0	0	0	0	0	7.9	0	6.0	0	6.0	10	7.9
0	7.9	0	7.9	0	6.0	0	0	0	0	19	0
0	6.0	0	6.0	0	0	0	0	0	0	19	0
0	9.8	0	0	0	0	0	0	0	0	21	7.5
0	0	0	0	0	0	0	0	0	0	22	0
0	8.7	0	0	0	0	0	0	0	0	22	0
0	19.0	0	0	0	0	0	0	0	0	24	0
0	13.0	0	0	0	0	0	0	0	0	26	6.0
0	7.7	0	0	0	0	0	0	0	0	28	0
0	0	0	0	0	0	0	0	0	0	28	0
0	0	0	0	0	0	0	0	0	0	29	0
0	0	0	0	0	7.8	0	0	0	0	32	0
0	0	0	0	0	6.7	0	0	0	0	33	0
0	0	0	5.6	0	13.0	0	7.7	0	7.7	34	0
0	0	0	7.8	0	0	0	0	0	0	35	9.8
0	0	0	6.7	0	0	0	5.4	0	5.4	37	0
0	0	0	13.0	0	0	0	0	0	0	38	0
0	0	0	0	0	7.4	0	0	0	0	40	7.4
0	0	0	0	0	6.0	0	9.8	0	9.8	43	0
0	5.6	0	0	0	0	0	0	0	6.1	46	0
0	7.8	0	7.4	0	0	0	6.1	0	0	46	6.1
0	6.7	0	0	0	0	0	0	0	0	50	5.4
0	13.0	0	6.0	0	0	0	0	0	0	67	0
0	0	0	0	0	6.0	0	9.8	0	9.8	43	0
0	5.6	0	0	0	0	0	0	0	6.1	46	0
0	7.8	0	7.4	0	0	0	6.1	0	0	46	6.1
0	6.7	0	0	0	0	0	0	0	0	50	5.4
0	13.0	0	6.0	0	0	0	0	0	0	67	0

Table 5-9 Continued. Arsenic Concentrations Versus Concentrations of Copper, Lead, Zinc, Molybdenum, Barium, and Uranium.

Copper ug/L	As ug/L	Zinc ug/L	As ug/L	Lead ug/L	As ug/L	Molybdenum ug/L	As ug/L	Uranium ug/L	As ug/L	Barium ug/L	As ug/L
0	15.0	0	0	0	0	0	0	0	5.0	68	0
0	15.0	0	0	0	7.9	0	5.0	0	0	68	7.7
0	0	0	0	0	0	0	0	0	0	70	0
0	0	0	0	0	0	0	0	0	8.7	70	0
0	0	0	0	0	11.0	0	0	0	0	72	8.7
0	7.4	0	8.2	0	13.0	0	8.7	0	5.5	85	6.0
0	0	0	7.9	0	7.5	0	0	0	0	91	0
0	7.5	0	0	0	7.7	0	5.5	0	0	98	0
0	11.0	0	0	0	0	5.0	0	0	0	100	0
0	12	0	5.5	0	19.0	5.4	0	0	7.5	100	7.9
0	0	0	6.1	0	5.4	5.4	0	0	8.2	110	6.7
0	0	0	11.0	0	14.0	5.4	0	0	0	120	0
0	0	11	13.0	0	0	5.4	7.5	0	19.0	120	7.8
0	0	12	7.5	0	0	5.8	8.2	0	7.9	120	11.0
0	6.0	13	7.7	0	0	6.2	0	0	13.0	120	6.1
0	0	13	0	0	15	6.9	19.0	0	7.9	140	0
0	0	15	6.1	0	9.8	7.6	7.9	0	12.0	140	13.0
0	7.5	15	5.0	0	7.5	7.8	13.0	0	0	160	0
0	0	17	8.7	0	12.0	8.2	7.5	0	15.0	160	5.0
0	0	17	19.0	0	11.0	8.9	0	0	0	170	0
0	0	17	0	0	0	9.1	7.9	0	11.0	180	0
0	0	18	5.4	0	15.0	12	12.0	0	15.0	190	0
0	0	22	14.0	1.1	0	13	0	0	20.0	200	0
0	0	23	20.0	1.2	6.1	13	15.0	0	14.0	200	5.6
0	14.0	28	0	1.4	5.6	15	0	0	5.6	220	0
0	17.0	30	0	1.4	0	15	11.0	0	17.0	230	7.5
0	0	33	0	1.4	0	15	15.0	0	6.0	230	12.0
0	0	34	0	1.6	0	17	20.0	0	0	230	11.0
0	8.2	43	15.0	1.6	5.0	18	7.4	0	7.8	230	14.0
0	5.4	47	9.8	1.7	6.1	18	14.0	0	6.7	230	17.0
0	6.1	50	7.5	1.7	20.0	18	5.6	0	13.0	250	15.0
0	7.9	51	12.0	1.7	17.0	18	17.0	0	11.0	250	15.0
5.4	0	59	0	1.8	0	23	6.0	1.7	7.4	250	20.0
5.5	0	74	17.0	1.8	0	24	6.1	1.8	0	270	0
7.3	5.5	75	0	1.9	0	25	0	2.0	6.1	320	0
8.4	20.0	87	11.0	2.7	8.2	37	7.8	3.0	0	330	13.0
13	6.1	91	0	2.7	8.7	39	6.7	3.5	0	350	0
13	11.0	160	0	4.9	0	52	13.0	3.7	7.5	410	0
19	5.0	190	15.0	8.2	5.5	58	11.0	4.8	0	510	19.0

Plumbing systems that incorporate galvanized steel or copper tubing, soldered joints, and valves, faucets, or other fittings made of lead-bearing brass or bronze alloys can introduce copper, zinc, or lead into sample water. Thus the copper, zinc, or lead concentrations reported here may not necessarily reflect the abundance of these metals in ambient ground water.

Five out of seven of or 71.4 percent of the samples with detectable copper also contained detectable arsenic, with two of these arsenic occurrences being excessive. Seventeen out of 27 or 63.0 percent of the samples with detectable zinc also contained detectable arsenic. Of the 17 samples, nine had arsenic in excess of the Primary MCL. Fifty two point nine percent or nine out of 17 of the samples containing detectable lead also had detectable arsenic, though only two arsenic occurrences exceeded the Primary MCL. Detectable arsenic, then, will likely be present in waters with detectable copper, zinc, or lead.

Twenty two out of the 31 samples, or 71.0%, containing detectable molybdenum also contained detectable arsenic. The arsenic in nine of the 22 samples was excessive. Waters with abundant molybdenum will likely have abundant arsenic. Sixty six point seven percent of the samples containing detectable arsenic also contained barium in excess of the median concentration of 71 ug/L. All 11 samples containing excessive arsenic also contained barium in excess of the median concentration. Waters with abundant barium should also contain abundant arsenic.

Only seven samples contained detectable uranium, and, of these only three contained detectable arsenic. Though the number of samples with detectable uranium was small, the indication is that waters with detectable uranium should contain detectable arsenic.

Concerning ground waters in the Trough area, both inside the Trough and on its flanks, arsenic is likely to be somewhat more abundant in waters with the higher pHs and higher dissolved oxygen contents. Waters with abundant sodium, barium or, especially, molybdenum are likely to have more abundant arsenic. On the contrary, waters with abundant calcium, magnesium, nitrate/nitrite, or, especially, chloride or sulfate would be expected to have depressed arsenic levels.

5.2 POSSIBLE SOURCES OF ARSENIC

As to anthropogenic arsenic sources, wood preserving facilities at Moultrie in Colquitt County and Valdosta in Lowndes County (EPD, 2012) have or may have used chromated copper arsenate (CCA) preservatives. No other industries that used arsenic were found in the study area. Moreover, the wide occurrence of arseniferous waters in the study area suggests that point sources such as these industries are not likely sources for the arsenic in the ground water.

As to non-point sources, arsenic compounds have been used as pesticides, though this use has been and is being much curtailed (EPA, 2009; ATSDR, 2007), and, portions of the area are intensely agricultural. CCA-treated timber products for long-term outdoor service could represent another non-point source of arsenic.

Where depths of wells yielding water with detectable arsenic and their casing depths are reported, the shallowest well is about 200 feet deep with a casing depth of 100 feet. The remainder is in the neighborhood of 300 hundred to 450 feet deep with up to 450 foot casing depths. The considerable depth of most wells yielding water with detectable arsenic suggests that the arsenic is, for most part, naturally occurring.

No petrographic or mineralogical investigations were performed for the current study. Arthur et al. (2002), Price and Pichler (2006), and Jones and Pichler (2007) have commented on the role of pyrite in causing large increases in the arsenic contents of recovered waters from aquifer storage and recovery sites developed in the Suwanee Limestone portion of the Floridan aquifer in Florida. These authors conclude that pyrite serves as the primary reservoir for arsenic in the limestone. The introduction of highly oxygenated waters for storage in the limestone results in an attack on pyrite which releases arsenic. During the storage period, the eventual make-up of the stored waters (a mix of oxidizing introduced waters and highly reducing ambient ground waters) remains too oxidizing to permit pyrite to be stable but too reducing to allow the precipitation of hydrous ferric oxides, which could adsorb arsenic. Since no aquifer storage and recovery operations exist in Georgia, this process could not account for the arsenic in the ground water. These studies do, however, point out the importance of pyrite as an arsenic reservoir.

In the Trough area in Georgia, Huddlestun (1993) noted pyrite in the Ochlockonee Formation, the Wolf Pit Dolostone, and the Okapilco Limestone though not in the Suwanee Limestone. The pyrite in these rock units could serve as an arsenic reservoir, and, the introduction of oxygenated ground water would destroy the pyrite and mobilize arsenic. The wells themselves present a possible avenue for oxidizing ambient ground waters. Leaky check valves on well heads could allow oxidizing water to leak back down the well into the aquifer. Also, the repeated cycling of pumps on and off allows air to contact ground water as the air is drawn into the well bore to replace the water drawn down. Another possible way for oxidizing water to enter an aquifer that is normally under reducing conditions is by cross-aquifer leakage, again induced by pumping.

5.3 SUMMARY

Waters from inside the Trough tend to have lower pHs and to have lower concentrations of dissolved oxygen, nitrate/nitrite, phosphorus, and manganese, and to have higher conductivities and higher concentrations of sodium, barium, magnesium, copper, zinc, molybdenum, and arsenic than their counterparts from outside the Trough. Ca/Mg and Ca/Na ratios for waters inside the Trough are lower than for those outside. Waters from recharge areas tend to have far higher Ca/Mg ratios than those away from recharge areas.

No tests were performed to differentiate between the arsenate and the arsenite anion species. Water samples were unfiltered, making impossible the distinction between analytes present as solutes and those present as fine particulates.

Waters with pHs greater than 7.50, sodium contents above 9,700 ug/L, and barium contents above 71 ug/L generally contain higher arsenic contents (range not detected to 20 ug/L). Waters with high contents of manganese (range not detected to 60 ug/L) and molybdenum (range not detected to 58 ug/L) can be expected to have high arsenic contents. The molybdenum-arsenic association appears to be an especially strong one. Water with higher contents of copper (range not detected to 19 ug/L), lead (range not detected to 8.2 ug/L), and zinc (range not detected to 190 ug/L) are also more likely to have higher arsenic contents, although these associations may be accidental because these three metals can be leached from plumbing.

Waters with conductivities below 280 uS/cm and with calcium contents below 33,500 ug/L tended to have higher arsenic levels. Likewise, waters with low phosphorus contents (range not detected to 0.45 mg/L), low nitrate/nitrite contents (range not detected to 3.00 mg/L as nitrogen), low chloride (range not detected to 65 mg/L), and sulfate (range not detected to 380 mg/L) tended to have higher arsenic contents. The disassociation between arsenic on one hand and sulfate and chloride on the other seems particularly strong.

Arsenic seemed to be present in waters with a wide range of iron contents, magnesium contents, and dissolved oxygen contents.

Though little detailed petrographic or mineralogical observations and data are available for the rocks hosting the Floridan aquifer in the Trough area, pyrite seems a possible reservoir for arsenic as is the case with the Suwanee Limestone in Florida. Destruction of pyrite present in certain rocks hosting the Floridan aquifer by oxidizing water seems a likely mechanism for the release of arsenic. Oxidizing water could enter the aquifer by several paths: leaky check valves on well heads, water brought into contact with air by displacement during pumping cycles, and cross-aquifer leakage induced by pumping.

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APPENDIX A

Laboratory and Well Data

LABORATORY AND WELL DATA

Table A-1 lists the values for both laboratory parameters and field parameters for each well or spring. For this table, the following abbreviations are used:

Parameters and Units of Measure

Cl = chloride
cond. = conductivity
dissO2 = dissolved oxygen
ICP = inductively coupled plasma (emission) spectroscopy
ICP/MS = 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. = total phosphorus
ug/L = micrograms per liter
uS/cm = microSiemenses per centimeter
VOC = volatile organic compound

Volatile Organic Compounds

TBM = bromoform
BDCM = bromodichloromethane
DBCM = dibromochloromethane
TCM = chloroform
MTBE = methyl tert-butyl ether

Table A-2 gives the reporting limits for the various analytes. The list of abbreviations used for Table A-1 also applies to Table A-2.

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part A: Station Identification and Location, 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
BEN-01 **Ben Hill**	Fitzgerald Well G	NG	NG	NG	8/26/2010	7.68	207	1.31	22.6	BDCM=1.2 DBCM=0.59 TCM=3.0	ND	ND	0.04	0.06
BEN-02 **Ben Hill**	Fitzgerald Well F	NG	NG	NG	8/26/2010	7.72	204	0.86	22.2	TCM=0.86	ND	ND	ND	0.06
BEN-03 **Ben Hill**	Fitzgerald Well J	NG	NG	NG	8/26/2010	7.96	167	0.71	22.6	ND	ND	ND	ND	0.03
BEN-04 **Ben Hill**	Fitzgerald Well I	NG	NG	NG	8/26/2010	7.71	203	1.10	22.4	ND	ND	ND	ND	ND
BEN-05 **Ben Hill**	Fitzgerald Well H	NG	NG	NG	8/26/2010	7.79	193	0.58	22.7	ND	ND	ND	0.02	ND
BUL-02 **Bulloch**	Cypress Lake Mobile Home Park Well	450	450	4	9/23/2010	7.84	223	0.60	21.0	ND	ND	ND	ND	0.04
BUL-03 **Bulloch**	Cambridge Subdivision Well 2	NG	NG	NG	9/23/2010	7.66	217	0.90	21.2	ND	ND	ND	ND	0.45
BUL-04 **Bulloch**	Cambridge Subdivision Well 1	NG	NG	NG	9/23/2010	7.85	219	0.59	20.9	ND	ND	ND	ND	0.08
COF-01 **Coffee**	Ambrose Jowers Crossing Well 2	NG	NG	NG	8/26/2010	7.61	247	1.80	22.8	ND	ND	ND	ND	0.08
C0L-01 **Colquitt**	Tallokas Trail Well 1	NG	NG	6	7/29/2010	7.21	473	0.60	23.2	ND	10	100	0.09	0.03
COL-03	Hamilton Elementary School Well	NG	NG	NG	7/29/2010	7.53	223	0.54	23.1	ND	ND	ND	ND	0.04
COL-03R **Colquitt**					9/21/2010	8.01	219	0.56	23.0	ND	ND	ND	ND	ND
COL-04 **Colquitt**	Col County Child Dev Center Well	NG	NG	NG	7/29/2010	7.02	294	0.55	23.1	ND	ND	28	ND	0.04

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part B: Metals.

Station No. County	Cr ppb	Ni ppb	Cu ppb	Zn ppb	**As ppb**	Se ppb	Mo ppb	Ag ppb	Cd ppb	Sn ppb	Sb ppb	Ba ppb	Tl ppb	Pb ppb	U ppb	Al ppb	Be ppb	Ca ppb	Co ppb	Fe ppb	K ppb	Mg ppb	Mn ppb	Na ppb	Ti ppb	V ppb
BEN-01 **Ben Hill**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	350	ND	ND	ND	ND	ND	30,000	ND	ND	ND	6,200	ND	2,700	ND	ND
BEN-02 **Ben Hill**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	180	ND	ND	ND	ND	ND	30,000	ND	82	ND	5,900	18	2,700	ND	ND
BEN-03 **Ben Hill**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	270	ND	ND	ND	ND	ND	21,000	ND	ND	ND	6,000	ND	3,200	ND	ND
BEN-04 **Ben Hill**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	120	ND	ND	ND	ND	ND	29,000	ND	250	ND	5,600	37	3,100	ND	ND
BEN-05 **Ben Hill**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	410	ND	ND	ND	ND	ND	26,000	ND	220	ND	6,500	60	3,000	ND	ND
BUL-02 **Bulloch**	ND	ND	ND	ND	**7.9**	ND	9.1	ND	ND	ND	ND	10	ND	ND	ND	ND	ND	35,000	ND	ND	ND	3,800	36	5,500	ND	ND
BUL-03 **Bulloch**	ND	ND	ND	ND	**6.0**	ND	ND	ND	ND	ND	ND	26	ND	ND	ND	ND	ND	20,000	ND	280	ND	3,600	26	5,600	ND	ND
BUL-04 **Bulloch**	ND	ND	ND	47	**9.8**	ND	ND	ND	ND	ND	ND	35	ND	ND	ND	ND	ND	35,000	ND	30	ND	4,100	ND	6,100	ND	ND
COF-01 **Coffee**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	160	ND	ND	ND	ND	ND	24,000	ND	ND	ND	14,000	ND	7,600	ND	ND
COL-01 **Colquitt**	ND	ND	ND	17	**8.7**	ND	ND	ND	ND	ND	ND	72	ND	2.7	ND	ND	ND	53,000	ND	ND	ND	26,000	ND	11,000	ND	ND
COL-03	ND	ND	ND	17	**19.0**	ND	6.9	ND	ND	ND	ND	510	ND	ND	ND	ND	ND	20,000	ND	51	ND	9,900	ND	22,000	ND	ND
COL-03R **Colquitt**	ND	ND	ND	11	**13.0**	ND	7.8	ND	ND	ND	ND	330	ND	ND	ND	ND	ND	18,000	ND	37	ND	8,600	ND	18,000	ND	ND
COL-04 **Colquitt**	ND	ND	ND	13	**7.7**	ND	ND	ND	ND	ND	ND	68	ND	ND	ND	ND	ND	41,000	ND	72	ND	16,000	15	5,400	ND	ND

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part A: Station Identification and Location, 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
COL-05 **Colquitt**	Moultrie Well 1	700	NG	NG	8/11/2010	7.41	368	0.58	23.7	ND	ND	65	ND	0.02
COL-06 **Colquitt**	Moultrie Well 2	700	NG	NG	8/11/2010	7.31	480	0.91	23.8	ND	11	120	ND	ND
COL-07 **Colquitt**	Moultrie Well 3	700	NG	NG	8/11/2010	7.01	925	0.78	24.6	ND	16	380	ND	ND
COL-08 **Colquitt**	Moultrie Well 5	700	NG	NG	8/11/2010	6.93	623	0.58	24.7	ND	13	180	0.05	ND
COL-09 **Colquitt**	Moultrie Well 6	700	NG	NG	8/11/2010	7.38	570	0.59	24.8	ND	12	150	ND	ND
COL-11 **Colquitt**	Pioneer Trail Well	NG	NG	NG	8/12/2010	7.11	325	1.02	23.1	ND	ND	40	0.03	0.03
COL-12 **Colquitt**	Tallokas Trail Well	NG	NG	NG	8/12/2010	7.27	517	0.97	23.8	ND	13	120	ND	ND
COL-13 **Colquitt**	Shade Murphy Well	NG	NG	NG	8/12/2010	7.26	603	0.84	24.3	ND	14	170	0.04	0.02
COL-14 **Colquitt**	Twin Lakes Well	NG	NG	NG	8/12/2010	7.27	576	0.53	24.5	ND	12	150	ND	0.02
COL-15 **Colquitt**	Crestwood Well 1	NG	NG	NG	8/12/2010	7.48	422	0.53	24.0	ND	10	89	ND	ND
COO-01 **Cook**	Lenox Broad Street Well 1	NG	NG	NG	9/22/2010	7.12	550	0.53	23.6	ND	65	65	ND	ND
COO-02 **Cook**	Lenox Gray Avenue Well 2	NG	NG	NG	9/22/2010	7.71	585	0.53	23.7	ND	57	87	ND	ND

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part B: Metals.

Station No. County	Cr ppb	Ni ppb	Cu ppb	Zn ppb	As ppb	Se ppb	Mo ppb	Ag ppb	Cd ppb	Sn ppb	Sb ppb	Ba ppb	Tl ppb	Pb ppb	**U ppb**	Al ppb	Be ppb	Ca ppb	Co ppb	Fe ppb	K ppb	Mg ppb	Mn ppb	Na ppb	Ti ppb	V ppb
COL-05 **Colquitt**	ND	ND	5.4	ND	**ND**	ND	ND	ND	ND	ND	ND	98	ND	ND	ND	ND	ND	28,000	ND	ND	ND	16,000	ND	27,000	ND	ND
COL-06 **Colquitt**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	91	ND	ND	ND	ND	ND	39,000	ND	ND	ND	23,000	ND	29,000	ND	ND
COL-07 **Colquitt**	ND	ND	ND	ND	**ND**	ND	5.4	ND	ND	ND	ND	33	ND	ND	ND	ND	ND	#####	ND	27	ND	45,000	ND	28,000	ND	ND
COL-08 **Colquitt**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	28	ND	ND	ND	ND	ND	63,000	ND	ND	ND	32,000	ND	21,000	ND	ND
COL-09 **Colquitt**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	46	ND	ND	ND	ND	ND	54,000	ND	ND	ND	27,000	ND	25,000	ND	ND
COL-11 **Colquitt**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	70	ND	ND	ND	ND	ND	34,000	ND	32	ND	16,000	ND	9,800	ND	ND
COL-12 **Colquitt**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	34	ND	ND	ND	ND	ND	50,000	ND	50	ND	26,000	ND	22,000	ND	ND
COL-13 **Colquitt**	ND	ND	ND	13	**ND**	ND	ND	ND	ND	ND	ND	22	ND	ND	ND	ND	ND	60,000	ND	ND	ND	31,000	ND	21,000	ND	ND
COL-14 **Colquitt**	ND	ND	5.5	ND	**ND**	ND	5.4	ND	ND	ND	ND	29	ND	ND	ND	ND	ND	58,000	ND	43	ND	30,000	ND	18,000	ND	ND
COL-15 **Colquitt**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	100	ND	ND	ND	ND	ND	34,000	ND	41	ND	19,000	ND	26,000	ND	ND
COO-01 **Cook**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	70	ND	1.8	ND	ND	ND	37,000	ND	ND	ND	18,000	ND	49,000	ND	ND
COO-02 **Cook**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	68	ND	ND	ND	ND	ND	40,000	ND	48	ND	20,000	ND	46,000	ND	ND

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part A: Station Identification and Location, 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
COO-03 **Cook**	Lenox Highway 41 S Well 3	NG	NG	NG	9/22/2010	7.49	524	6.31	27.3	TBM=7.3 TCM=120 BDCM=48 DBCM=26	44	65	ND	0.02
COO-04 **Cook**	Lenox Brad Street Well	NG	NG	NG	9/22/2010	7.79	379	0.49	23.3	ND	23	37	ND	0.03
DEC-01 **Decatur**	Bainbridge MLK Jr Dr Well 4	NG	NG	NG	8/25/2010	7.51	227	2.11	20.9	ND	ND	ND	3	0.03
DEC-02 **Decatur**	Bainbridge Scott/Alice Well 2	NG	NG	NG	8/25/2010	7.58	228	2.17	21.0	ND	ND	ND	2.8	0.03
DEC-03 **Decatur**	Bainbridge Alice St Old Well 1	NG	NG	NG	8/25/2010	7.64	231	2.92	20.9	ND	ND	ND	3.0	0.02
DEC-04 **Decatur**	Bainbridge King/Scott 106	NG	NG	NG	8/25/2010	7.67	230	2.07	20.8	ND	ND	ND	3.0	0.03
GRA-01 **Grady**	City of Cairo Well 7	NG	NG	NG	3/31/2010	7.68	363	1.03	22.8	TCM=1.1 BDCM=0.94	ND	45	ND	0.03
GRA-02 **Grady**	City of Cairo Well 8	465	NG	16	3/31/2010	7.67	354	2.24	22.7	TCM=1.1 BDCM=1.10	ND	40	ND	0.03
GRA-03	City of Cairo Well 9	NG	NG	NG	3/31/2010	7.76	322	0.63	22.4	ND	ND	27	ND	ND
GRA-03R **Grady**					7/15/2010	7.21	330	0.60	22.8	ND	ND	29	ND	0.02
GRA-04	Crew House Well	NG	NG	NG	3/31/2010	7.28	276	1.81	22.1	ND	ND	ND	0.04	0.02
GRA-04N **Grady**	New Well	420	312	4	7/15/2010	7.63	281	1.51	25.5	ND	ND	ND	0.03	0.02
GRA-05	Walden House Well	280/300	NG	4	3/31/2010	7.43	280	1.47	21.4	ND	ND	ND	ND	0.04
GRA-05R **Grady**					7/15/2010	7.53	284	1.48	24.0	ND	ND	ND	0.05	0.02

Table A-1. Ground-Water Quality Analyses for ArsenicProject Stations.

Part B: Metals.

Station No. County	Cr ppb	Ni ppb	Cu ppb	Zn ppb	As ppb	Se ppb	Mo ppb	Ag ppb	Cd ppb	Sn ppb	Sb ppb	Ba ppb	Tl ppb	Pb ppb	**U ppb**	Al ppb	Be ppb	Ca ppb	Co ppb	Fe ppb	K ppb	Mg ppb	Mn ppb	Na ppb	Ti ppb	V ppb
COO-03 **Cook**	ND	ND	13	ND	**6.1**	ND	24.0	ND	ND	ND	ND	120	ND	1.7	2.0	ND	ND	53,000	ND	ND	ND	20,000	ND	29,000	ND	ND
COO-04 **Cook**	ND	ND	ND	ND	**5.6**	ND	18.0	ND	ND	ND	ND	200	ND	1.4	ND	ND	ND	32,000	ND	ND	ND	15,000	ND	25,000	ND	ND
DEC-01 **Decatur**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	6.7	ND	ND	ND	ND	ND	43,000	ND	150	ND	3,600	ND	2,200	ND	ND
DEC-02 **Decatur**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	5.1	ND	ND	ND	ND	ND	43,000	ND	ND	ND	4,400	ND	2,200	ND	ND
DEC-03 **Decatur**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	6.8	ND	1.6	ND	ND	ND	41,000	ND	ND	ND	4,200	ND	2,100	ND	ND
DEC-04 **Decatur**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	4.9	ND	ND	ND	ND	ND	43,000	ND	ND	ND	4,100	ND	2,200	ND	ND
GRA-01 **Grady**	ND	ND	ND	ND	**7.8**	ND	37.0	ND	ND	ND	ND	120	ND	ND	ND	ND	ND	36,000	ND	42	ND	18,000	ND	14,000	ND	ND
GRA-02 **Grady**	ND	ND	ND	ND	**6.7**	ND	39.0	ND	ND	ND	ND	110	ND	ND	ND	ND	ND	35,000	ND	37	ND	18,000	ND	13,000	ND	ND
GRA-03	ND	ND	13	ND	**11.0**	ND	58.0	ND	ND	ND	ND	120	ND	ND	ND	ND	ND	33,000	ND	ND	ND	17,000	ND	8,700	ND	ND
GRA-03R **Grady**	ND	ND	ND	ND	**13.0**	ND	52.0	ND	ND	ND	ND	140	ND	ND	ND	ND	ND	36,000	ND	ND	ND	18,000	ND	9,700	ND	ND
GRA-04	ND	ND	ND	87	**11.0**	ND	15.0	ND	ND	ND	ND	230	ND	ND	ND	ND	ND	23,000	ND	ND	ND	13,000	ND	19,000	ND	ND
GRA-04N **Grady**	ND	ND	ND	190	**15.0**	ND	15.0	ND	ND	ND	ND	250	ND	ND	ND	ND	ND	23,000	ND	86	ND	13,000	ND	18,000	ND	ND
GRA-05	ND	ND	ND	51	**12.0**	ND	12.0	ND	ND	ND	ND	230	ND	ND	ND	ND	ND	23,000	ND	ND	ND	13,000	ND	18,000	ND	ND
GRA-05R **Grady**	ND	ND	ND	43	**15.0**	ND	13.0	ND	ND	ND	ND	250	ND	ND	ND	ND	ND	25,000	ND	ND	ND	13,000	ND	18,000	ND	ND

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part A: Station Identification and Location, 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
GRA-06 **Grady**	Wight's Nursery Public Well GA 1310012	NG	NG	4	3/31/2010	6.29	136	2.80	22.4	ND	ND	ND	0.05	0.16
GRA-07 **Grady**	Wight's Nursery Public Well GA 1310039	NG	NG	4	3/31/2010	7.70	260	1.27	22.5	ND	ND	ND	ND	ND
GRA-08 **Grady**	Lewis Estates Subdivision Well	175	NG	6	3/31/2010	6.62	372	0.64	21.4	ND	ND	ND	ND	0.05
GRA-09 **Grady**	Southern Pines Plantation Well 1	NG	NG	6	4/1/2010	7.84	240	3.23	22.0	ND	ND	ND	ND	0.03
GRA-11 **Grady**	Shady Grove Village Well 1	NG	NG	4	4/1/2010	7.93	266	5.90	21.6	ND	ND	ND	0.04	ND
GRA-12 **Grady**	Shady Grove Village Well 2	NG	NG	4	4/1/2010	7.70	266	3.83	21.6	ND	ND	ND	0.03	0.04
GRA-13 **Grady**	Cairo Farm Well	NG	NG	4	7/15/2010	7.64	261	1.23	24.6	ND	ND	ND	ND	0.03
GRA-14 **Grady**	Beachton Meridian Well 1	NG	NG	NG	7/14/2010	6.76	345	6.99	21.4	ND	ND	ND	0.42	0.03
GRA-15 **Grady**	Beachton Hwy 93 Well 2	NG	NG	NG	7/14/2010	7.12	308	NA	21.3	ND	ND	14	0.14	ND
GRA-16 **Grady**	Beachton Hwy 93 Well 3	NG	NG	NG	7/14/2010	7.19	295	2.67	20.8	ND	ND	13	0.19	0.03
GRA-17 **Grady**	Plantation Parkway Well 1	NG	NG	NG	7/14/2010	6.70	279	4.21	20.7	MTBE=0.79	ND	ND	0.42	0.09

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part B: Metals.

Station No. County	Cr ppb	Ni ppb	Cu ppb	Zn ppb	As ppb	Se ppb	Mo ppb	Ag ppb	Cd ppb	Sn ppb	Sb ppb	Ba ppb	Tl ppb	Pb ppb	**U ppb**	Al ppb	Be ppb	Ca ppb	Co ppb	Fe ppb	K ppb	Mg ppb	Mn ppb	Na ppb	Ti ppb	V ppb
GRA-06 **Grady**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	38	ND	ND	ND	ND	ND	11,000	ND	ND	ND	6,400	ND	6,300	ND	ND
GRA-07 **Grady**	ND	ND	ND	ND	**ND**	ND	25.0	ND	ND	ND	ND	190	ND	ND	ND	ND	ND	20,000	ND	52	ND	11,000	ND	21,000	ND	ND
GRA-08 **Grady**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	ND	ND	44,000	ND	94	ND	23,000	55	3,100	ND	ND
GRA-09 **Grady**	ND	ND	ND	ND	**7.4**	ND	18.0	ND	ND	ND	ND	40	ND	ND	1.7	ND	ND	21,000	ND	ND	ND	15,000	ND	4,800	ND	12
GRA-11 **Grady**	ND	ND	ND	91	**ND**	ND	5.0	ND	ND	ND	ND	19	ND	ND	3.5	ND	ND	1,300	ND	40	ND	ND	ND	42,000	ND	ND
GRA-12 **Grady**	ND	ND	ND	12	**7.5**	ND	8.2	ND	ND	ND	ND	21	ND	ND	3.7	ND	ND	25,000	ND	ND	ND	17K	ND	4,900	ND	ND
GRA-13 **Grady**	ND	ND	8.4	23	**20.0**	ND	17.0	ND	ND	ND	ND	250	ND	1.7	ND	120	ND	23,000	ND	240	ND	11,000	ND	19,000	ND	ND
GRA-14 **Grady**	ND	ND	ND	160	**ND**	ND	ND	ND	ND	ND	ND	22	ND	1.4	ND	ND	ND	38,000	ND	25	ND	20,000	ND	2,900	ND	ND
GRA-15 **Grady**	ND	ND	ND	59	**ND**	ND	ND	ND	ND	ND	ND	43	ND	1.8	ND	ND	ND	40,000	ND	21	ND	16,000	ND	2,700	ND	ND
GRA-16 **Grady**	ND	ND	ND	17	**ND**	ND	ND	ND	ND	ND	ND	37	ND	4.9	ND	ND	ND	36,000	ND	ND	ND	15,000	ND	2,600	ND	ND
GRA-17 **Grady**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	24	ND	1.4	ND	ND	ND	44,000	ND	ND	ND	12,000	ND	2,600	ND	ND

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part A: Station Identification and Location, 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
GRA-18 **Grady**	Quail Ridge Isabelle Land 1	NG	NG	NG	7/14/2010	6.74	334	0.82	21.0	ND	ND	ND	0.03	ND
GRA-19 **Grady**	Quail Ridge Isabelle Land 2	NG	NG	NG	7/28/2010	7.65	304	NA	24.0	ND	ND	10	ND	ND
GRA-20 **Grady**	Whigham Davis Avenue 1	604	426	8	7/14/2010	7.02	382	1.06	23.1	ND	30	18	0.08	ND
GRA-21 **Grady**	Whigham Trulock St 3	746	430	8	7/14/2010	7.45	357	0.54	24.4	ND	18	16	0.04	ND
GRA-22 **Grady**	T Walden Domestic Well	NG	NG	4	7/15/2010	7.40	285	1.56	23.0	ND	ND	ND	0.05	0.03
GRA-23 **Grady**	Temple Terrace Well 1	NG	NG	NG	7/27/2010	6.82	189	5.27	22.2	ND	ND	ND	0.06	0.04
GRA-25 **Grady**	Wight's Nursery Hwy 111 Well	465	370	4	7/28/2010	7.34	312	0.58	22.9	ND	ND	32	0.03	ND
GRA-26 **Grady**	Wight's Nursery Hwy 112 Well	460	335	4	7/28/2010	6.79	254	6.93	21.5	ND	ND	ND	0.53	ND
GRA-27 **Grady**	Shiver Elementary School	NG	NG	NG	7/28/2010	7.45	251	3.94	22.3	ND	ND	ND	0.06	ND
GRA-28 **Grady**	Monterrey Park Hwy 111 Well	NG	NG	NG	7/29/2010	7.23	375	0.55	22.4	ND	10	47	0.03	ND
GRA-29 **Grady**	Pinecrest 1	300	180	NG	7/29/2010	7.86	180	6.80	22.3	ND	ND	ND	0.06	0.02
GRA-30 **Grady**	Pinecrest 2	300	180	NG	7/29/2010	7.79	194	5.80	22.3	ND	ND	ND	0.04	0.03

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part B: Metals.

Station No. County	Cr ppb	Ni ppb	Cu ppb	Zn ppb	As ppb	Se ppb	Mo ppb	Ag ppb	Cd ppb	Sn ppb	Sb ppb	Ba ppb	Tl ppb	Pb ppb	**U ppb**	Al ppb	Be ppb	Ca ppb	Co ppb	Fe ppb	K ppb	Mg ppb	Mn ppb	Na ppb	Ti ppb	V ppb
GRA-18 **Grady**	ND	ND	ND	ND	**6.0**	ND	23.0	ND	ND	ND	ND	85	ND	ND	ND	ND	ND	40,000	ND	24	ND	23,000	ND	5,900	ND	ND
GRA-19 **Grady**	ND	ND	19	15	**5.0**	ND	ND	ND	ND	ND	ND	160	ND	1.6	ND	400	ND	37,000	ND	800	ND	21,000	14	18,000	ND	ND
GRA-20 **Grady**	ND	ND	ND	ND	**ND**	ND	8.9	ND	ND	ND	ND	170	ND	ND	3.0	ND	ND	32,000	ND	28	ND	19,000	ND	23,000	ND	ND
GRA-21 **Grady**	ND	ND	ND	ND	**ND**	ND	6.2	ND	ND	ND	ND	200	ND	ND	ND	ND	ND	30,000	ND	31	ND	18,000	ND	22,000	ND	ND
GRA-22 **Grady**	ND	ND	ND	50	**7.5**	ND	5.4	ND	ND	ND	ND	230	ND	ND	ND	ND	ND	25,000	ND	160	ND	15,000	ND	18,000	ND	ND
GRA-23 **Grady**	ND	ND	7.3	ND	**5.5**	ND	ND	ND	ND	ND	ND	8.8	ND	8.2	ND	ND	ND	22,000	ND	ND	ND	15,000	ND	3,500	ND	10
GRA-25 **Grady**	ND	ND	ND	ND	**ND**	ND	15.0	ND	ND	ND	ND	320	ND	ND	ND	ND	ND	27,000	ND	28	ND	14,000	ND	27,000	ND	ND
GRA-26 **Grady**	ND	ND	ND	33	**ND**	ND	ND	ND	ND	ND	ND	67	ND	1.1	1.8	ND	ND	44,000	ND	ND	ND	8,100	ND	3,400	ND	ND
GRA-27 **Grady**	5	ND	ND	75	**ND**	ND	ND	ND	ND	ND	ND	220	ND	1.9	4.8	ND	ND	29,000	ND	49	ND	17,000	ND	4,700	ND	11
GRA-28 **Grady**	ND	ND	ND	30	**ND**	ND	13.0	ND	ND	ND	ND	140	ND	ND	ND	ND	ND	41,000	ND	31	ND	19,000	ND	18,000	ND	ND
GRA-29 **Grady**	ND	ND	ND	ND	**ND**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	21,000	ND	ND	ND	13,000	ND	3,200	ND	ND
GRA-30 **Grady**	ND	ND	ND	28	**ND**	ND	ND	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	23,000	ND	ND	ND	13,000	ND	3,500	ND	ND

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part A: Station Identification and Location, 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
GRA-31 **Grady**	Tootle Domestic Well	NG	NG	NG	8/25/2010	7.78	246	1.73	23.6	ND	ND	ND	ND	ND
GRA-32 **Grady**	Ferrell Domestic Well	NG	NG	NG	8/25/2010	7.60	246	1.51	24.7	ND	ND	ND	ND	0.03
LAN-01 **Lanier**	Newburn 1	220	220	NG	8/12/2010	6.86	259	0.88	21.9	ND	ND	20	ND	0.03
LAN-02 **Lanier**	Newburn 2	220	220	NG	8/12/2010	6.34	259	0.66	21.7	ND	ND	20	0.03	0.03
LOW-01 **Lowndes**	Bevel Creek	200	100	NG	9/21/2010	7.58	233	0.81	21.6	ND	ND	ND	0.02	0.04
SCR-01 **Screven**	Green Acres MH Park	NG	NG	NG	9/23/2010	7.64	221	1.15	20.9	ND	ND	ND	ND	0.06
SCR-02 **Screven**	Brinsons Trailer Park	NG	NG	NG	9/23/2010	7.41	298	2.52	21.1	ND	ND	ND	0.10	0.10
THO-01 **Thomas**	Sugar Mill Park	375	375	NG	9/21/2010	7.77	357	4.83	23.3	ND	11	36	0.10	0.04

Table A-1. Ground-Water Quality Analyses for Arsenic Project Stations.

Part B: Metals.

Station No. County	Cr ppb	Ni ppb	Cu ppb	Zn ppb	As ppb	Se ppb	Mo ppb	Ag ppb	Cd ppb	Sn ppb	Sb ppb	Ba ppb	Tl ppb	Pb ppb	**U ppb**	Al ppb	Be ppb	Ca ppb	Co ppb	Fe ppb	K ppb	Mg ppb	Mn ppb	Na ppb	Ti ppb	V ppb
GRA-31 **Grady**	ND	ND	ND	22	**14.0**	ND	18.0	ND	ND	ND	ND	230	ND	ND	ND	ND	ND	22,000	ND	83	ND	11,000	ND	19,000	ND	ND
GRA-32 **Grady**	ND	ND	ND	74	**17.0**	ND	18.0	ND	ND	ND	ND	230	ND	1.7	ND	ND	ND	22,000	ND	400	ND	12,000	ND	18,000	ND	ND
LAN-01 **Lanier**	ND	ND	ND	ND	**ND**	ND	5.4	ND	ND	ND	ND	28	ND	ND	ND	ND	ND	30,000	ND	ND	ND	14,000	ND	4,000	ND	ND
LAN-02 **Lanier**	ND	ND	ND	34	**ND**	ND	ND	ND	ND	ND	ND	32	ND	ND	ND	ND	ND	30,000	ND	230	ND	15,000	15	4,000	ND	ND
LOW-01 **Lowndes**	ND	ND	ND	ND	**8.2**	ND	5.8	ND	ND	ND	ND	8	ND	2.7	ND	ND	ND	30,000	ND	55	ND	12,000	33	3,200	ND	ND
SCR-01 **Screven**	ND	ND	ND	18	**5.4**	ND	ND	ND	ND	ND	ND	50	ND	ND	ND	ND	ND	38,000	ND	36	ND	3,300	47	4,700	ND	ND
SCR-02 **Screven**	ND	ND	ND	15	**6.1**	ND	ND	ND	ND	ND	ND	46	ND	1.2	ND	ND	ND	52,000	ND	36	ND	4,100	47	6,800	ND	ND
THO-01 **Thomas**	ND	ND	ND	ND	**7.9**	ND	7.6	ND	ND	ND	ND	100	ND	ND	ND	ND	ND	32,000	ND	ND	ND	19,000	10	18,000	ND	ND

TABLE A-2. ANALYTES AND REPORTING LIMITS

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

TABLE A-2. CHEMICAL COMPONENTS AND REPORTING LIMITS, CONTINUED.

Component	Reporting Limit	Component	Reporting Limit
Bromobenzene	0.5 ug/L	Silver (ICP)	10 ug/L
1,2,3-Trichloropropane	0.5 ug/L	Aluminum (ICP)	60 ug/L
n-Propylbenzene	0.5 ug/L	Arsenic (ICP)	80 ug/L
o-Chlorotoluene	0.5 ug/L	Barium (ICP)	10 ug/L
1,3,5-Trimethylbenzene	0.5 ug/L	Beryllium (ICP)	10 ug/L
p-Chlorotoluene	0.5 ug/L	Calcium (ICP)	2000 ug/L
Tert-Butylbenzene	0.5 ug/L	Cobalt (ICP)	10 ug/L
1,2,4-Trimethylbenzene	0.5 ug/L	Chromium (ICP)	20 ug/L
Sec-Butylbenzene	0.5 ug/L	Copper (ICP)	20 ug/L
p-Isopropyltoluene	0.5 ug/L	Iron (ICP)	20 ug/L
m-Dichlorobenzene	0.5 ug/L	Potassium (ICP)	5000 ug/L
n-Butylbenzene	0.5 ug/L	Magnesium (ICP)	1000 ug/L
1,2-Dibromo-3-chloropropane	0.5 ug/L	Manganese (ICP)	10 ug/L
Hexachlorobutadiene	0.5 ug/L	Sodium (ICP)	1000 ug/L
Naphthalene	0.5 ug/L	Nickel (ICP)	20 ug/L
1,2,3-Trichlorobenzene	0.5 ug/L	Lead (ICP)	90 ug/L
Methyl-tert-butyl ether (MTBE)	0.5 ug/L	Antimony (ICP)	120 ug/L
Chloride	10 mg/L	Selenium (ICP)	190 ug/L
Sulfate*	10 mg/L	Titanium (ICP)	10 ug/L
Nitrate/nitrite*	0.02 mg/L as Nitrogen	Thallium (ICP)	200 ug/L
Total Phosphorus	0.02 mg/L	Vanadium (ICP)	10 ug/L

TABLE A-2. CHEMICAL COMPONENTS AND REPORTING LIMITS, CONTINUED.

Component	Reporting Limit	Component	Reporting Limit
Zinc (ICP)	20 ug/L	Silver (ICP/MS)	5 ug/L
Chromium (ICP/MS)	5 ug/L	Cadmium (ICP/MS)	0.7 ug/L
Nickel (ICP/MS)	10 ug/L	Tin (ICP/MS)	30 ug/L
Copper (ICP/MS)	5 ug/L	Antimony (ICP/MS)	5 ug/L
Zinc (ICP/MS)	10 ug/L	Barium (ICP/MS)	2 ug/L
Arsenic (ICP/MS)	5 ug/L	Thallium (ICP/MS)	1 ug/L
Selenium (ICP/MS)	5 ug/L	Lead (ICP/MS)	1 ug/L
Molybdenum (ICP/MS)	5 ug/L	Uranium (ICP/MS)	1 ug/L

* **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.

APPENDIX B

Well Location Details

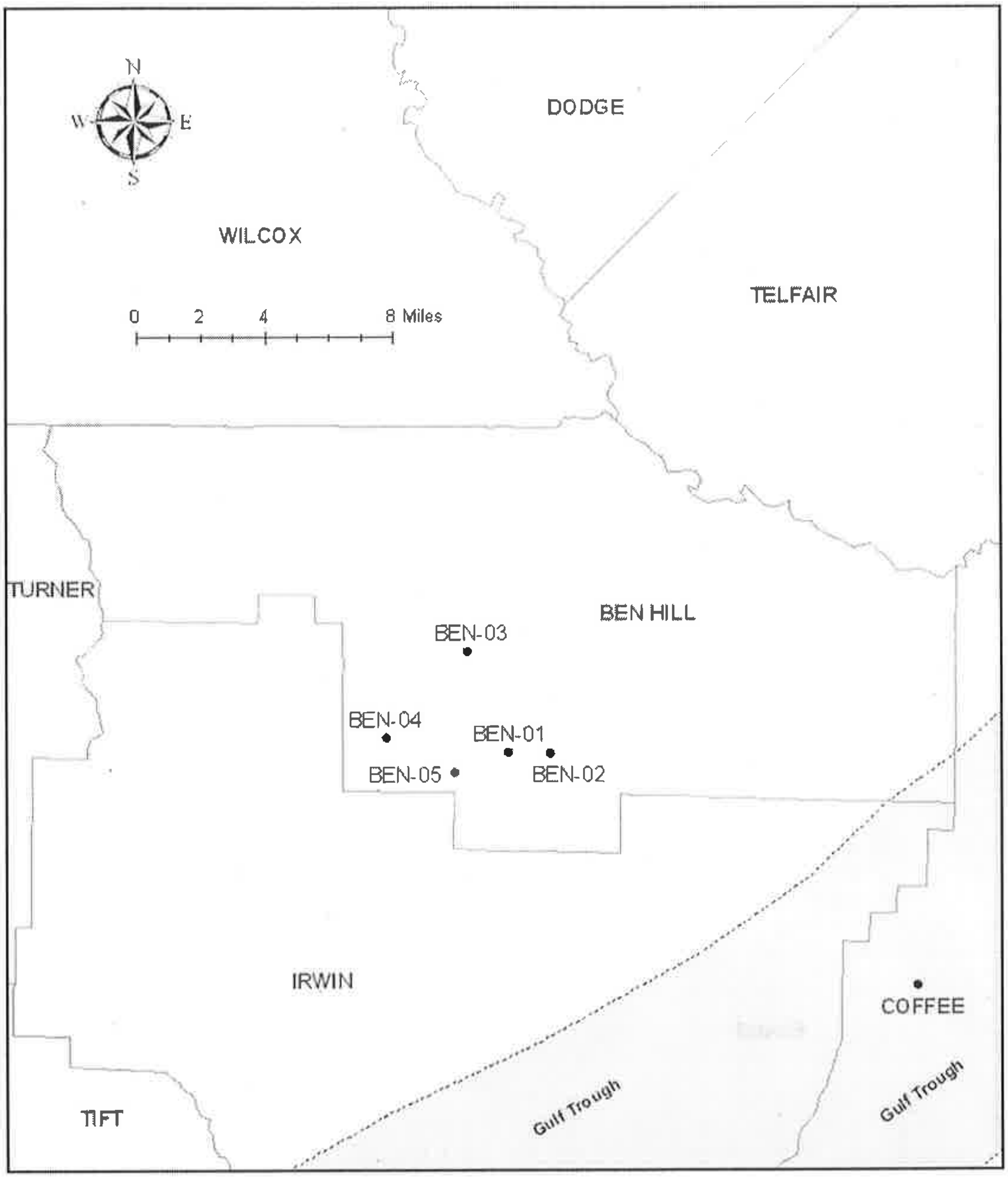

Figure B-1. Well Locations for Ben Hill County.

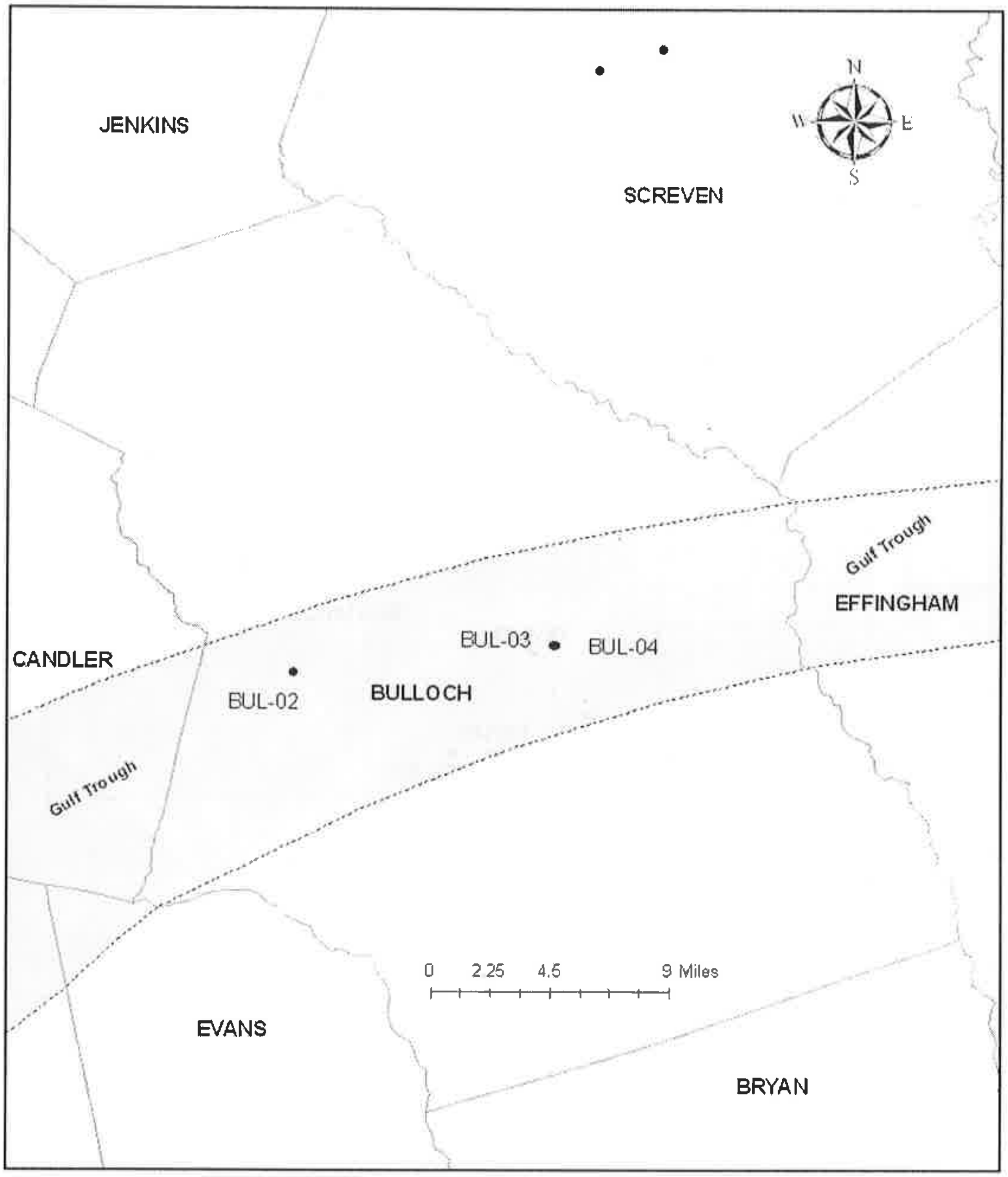

Figure B-2. Well Locations for Bulloch County.

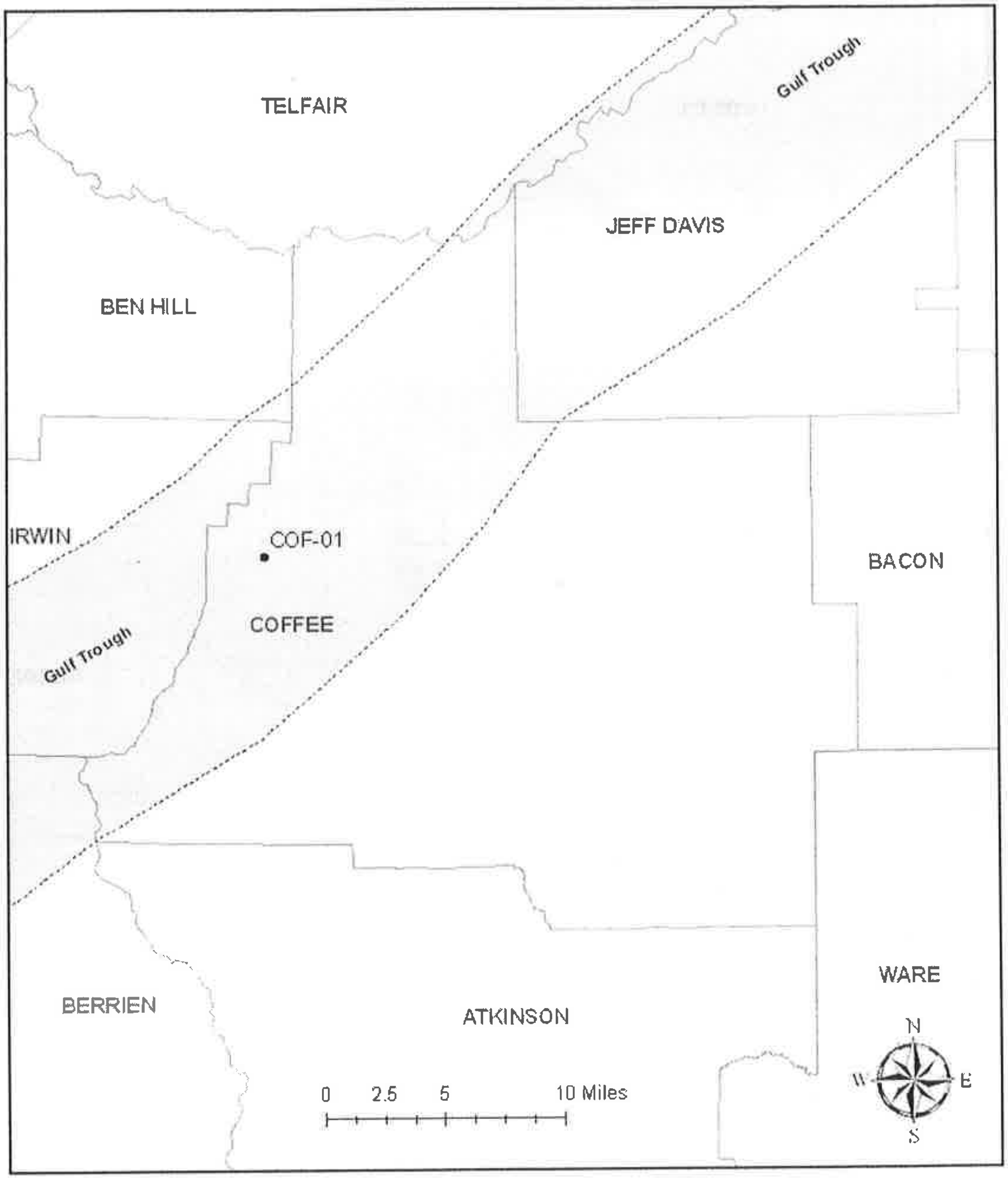

Figure B-3. Well Locations for Coffee County.

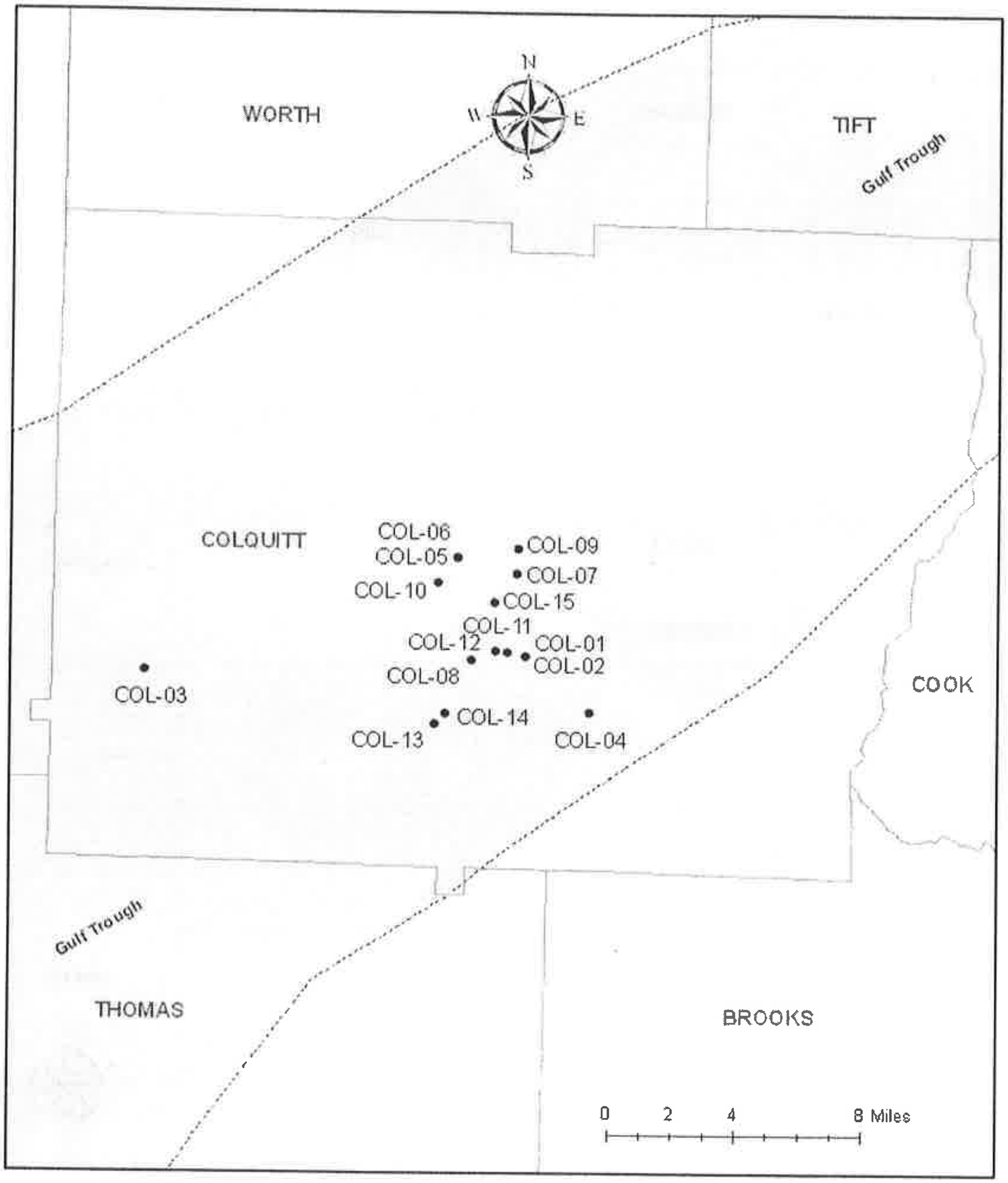

Figure B-4. Well Locations for Colquitt County.

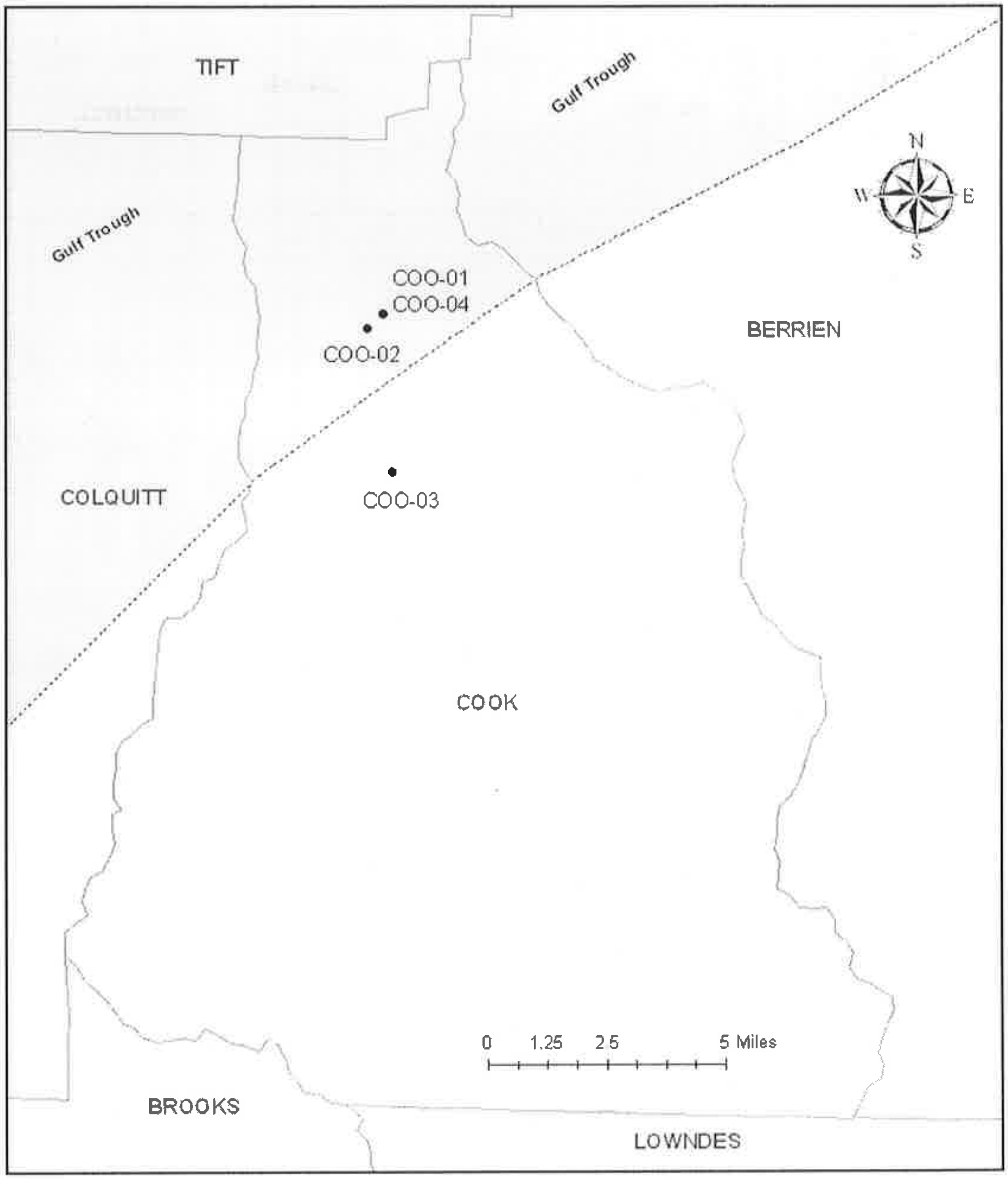

Figure B-5. Well Locations for Cook County.

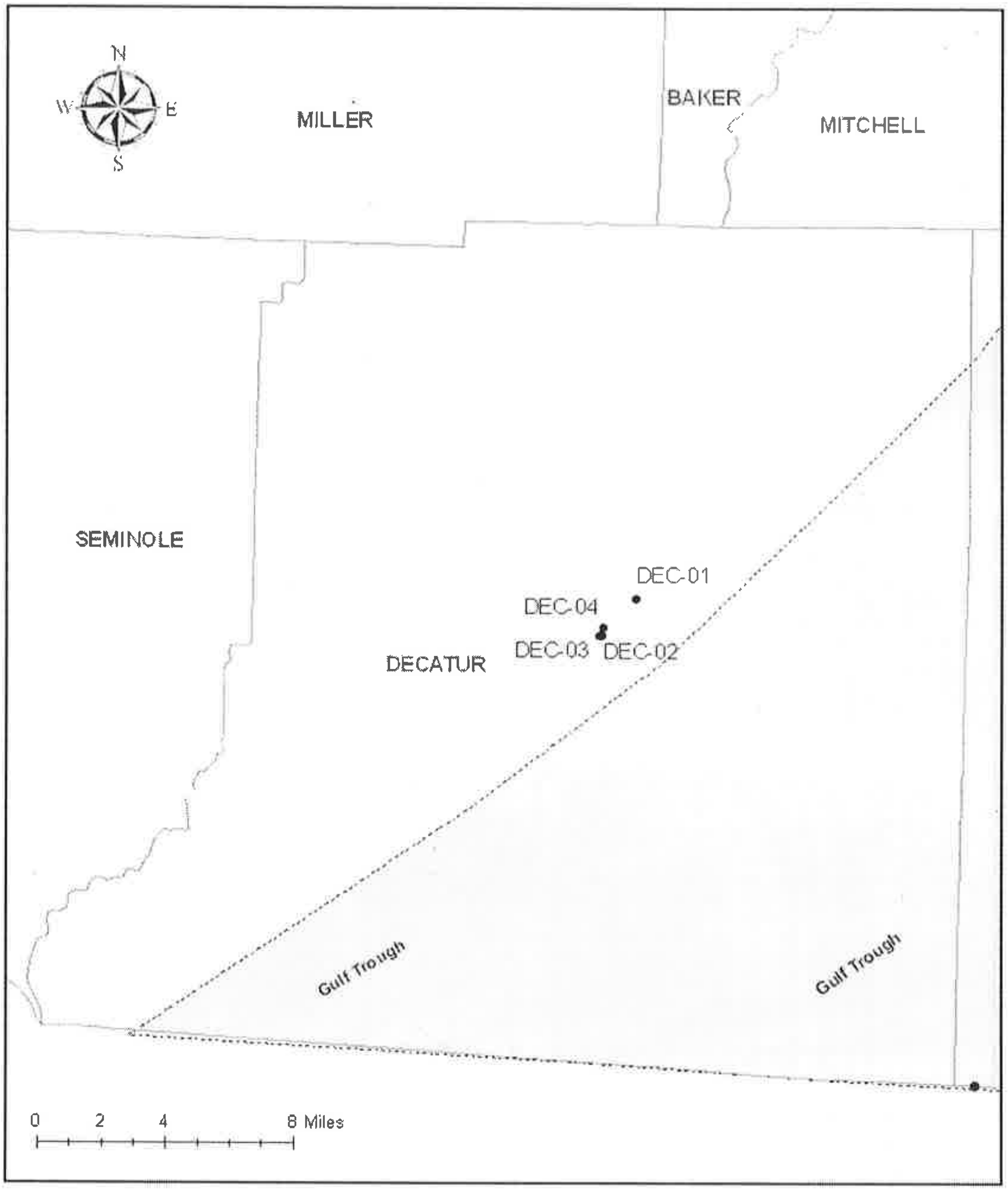

Figure B-6. Well Locations for Decatur County.

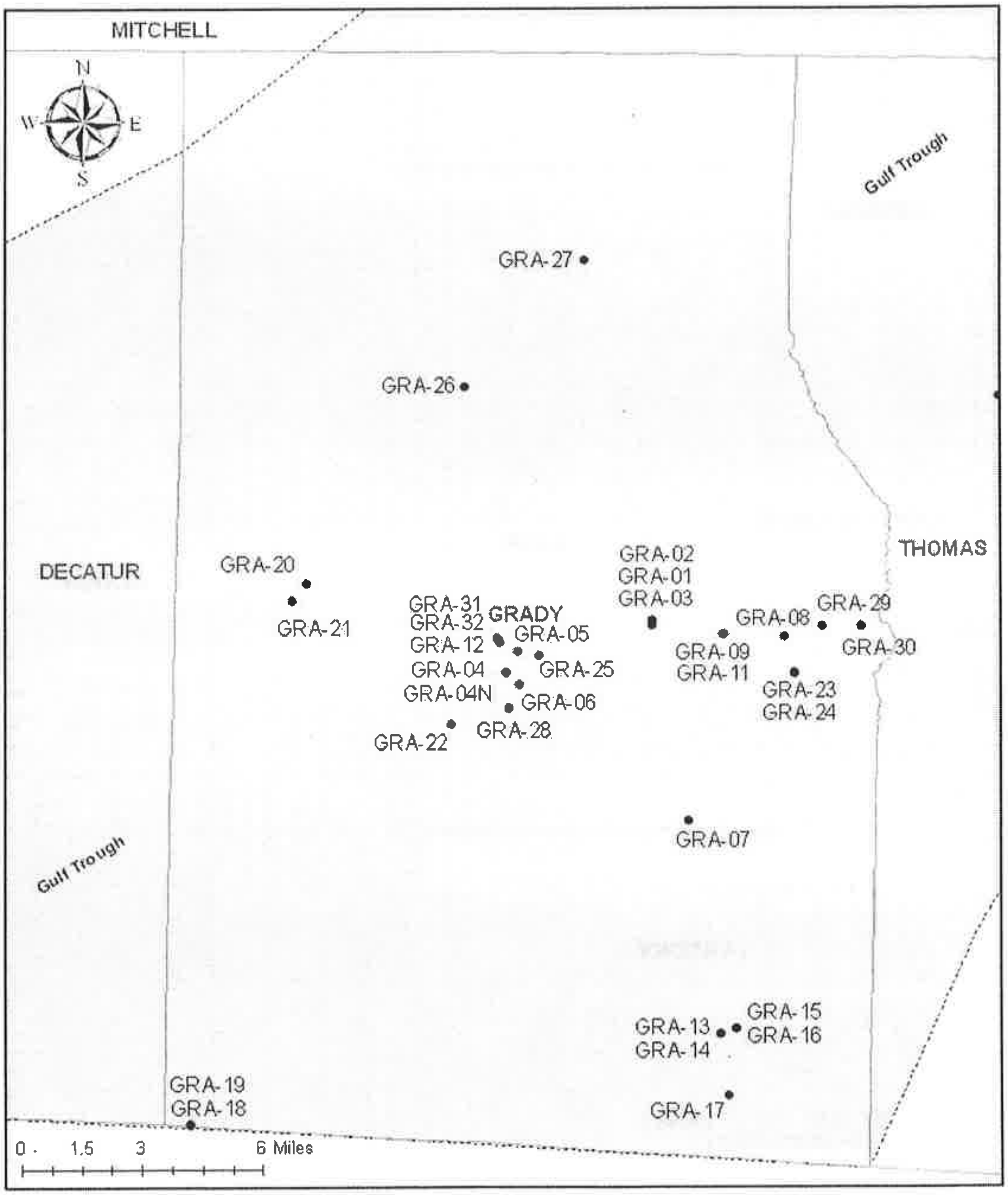

Figure B-7. Well Locations for Grady County.

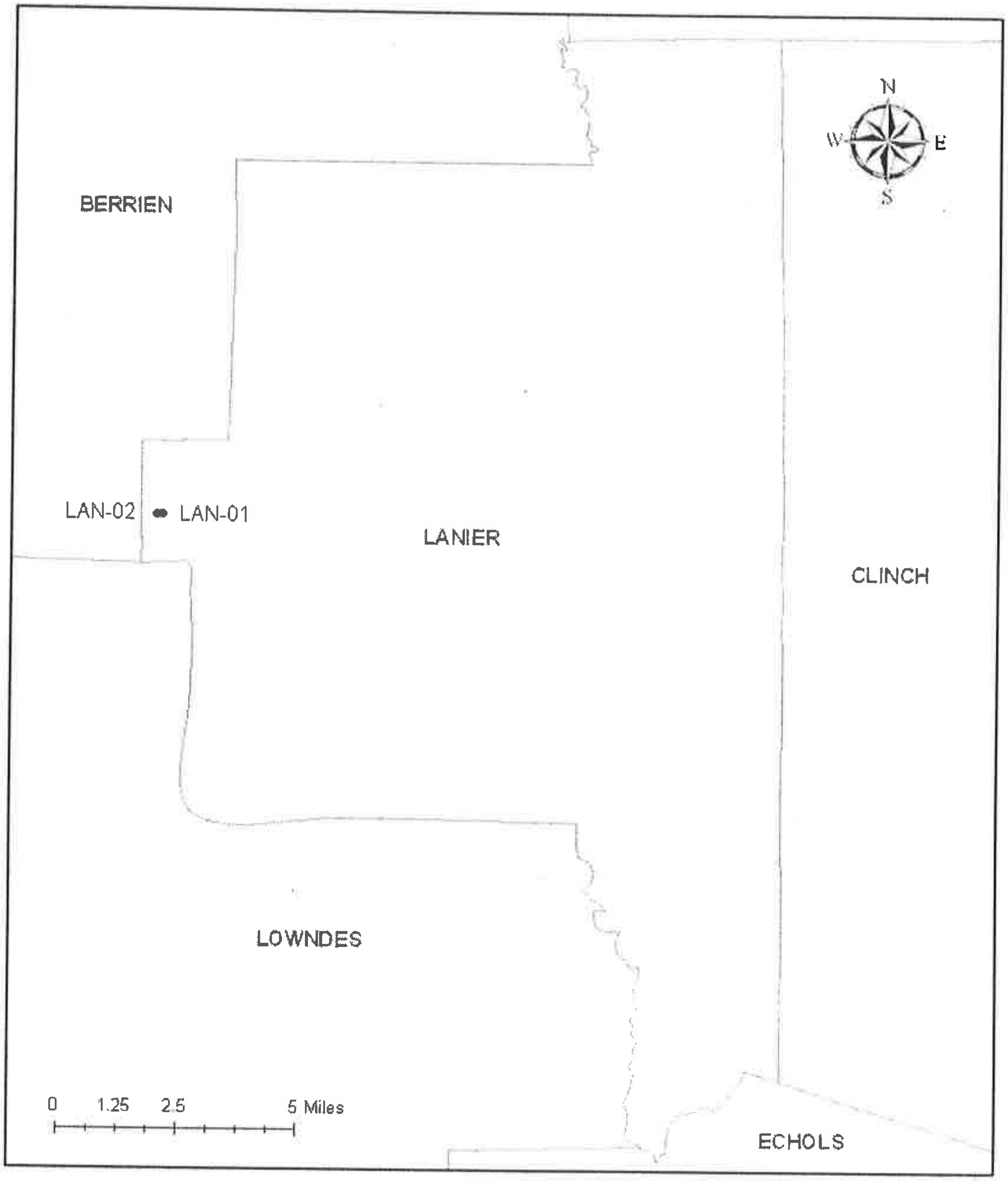

Figure B-8. Well Locations for Lanier County.

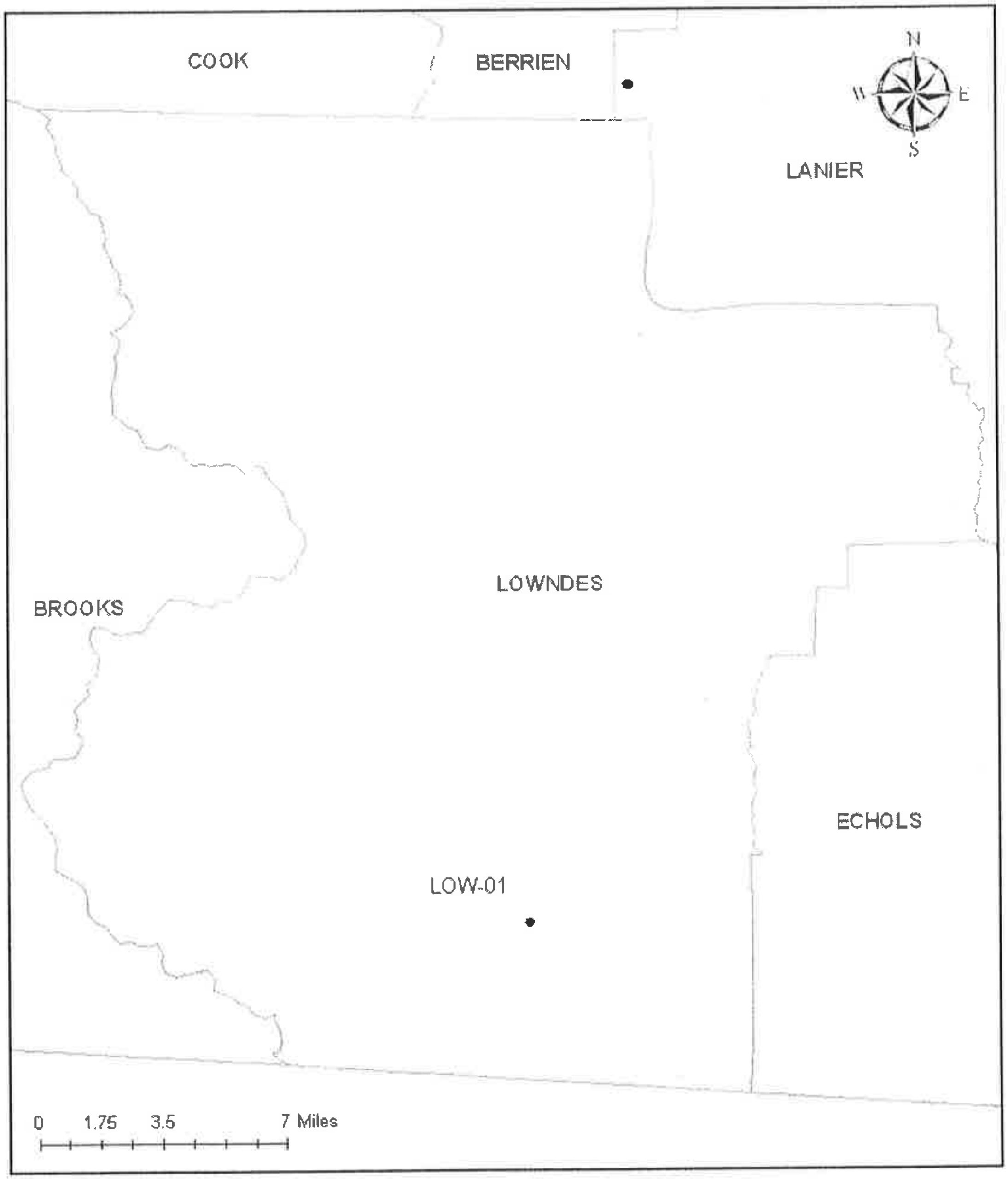

Figure B-9. Well Locations for Lowndes County.

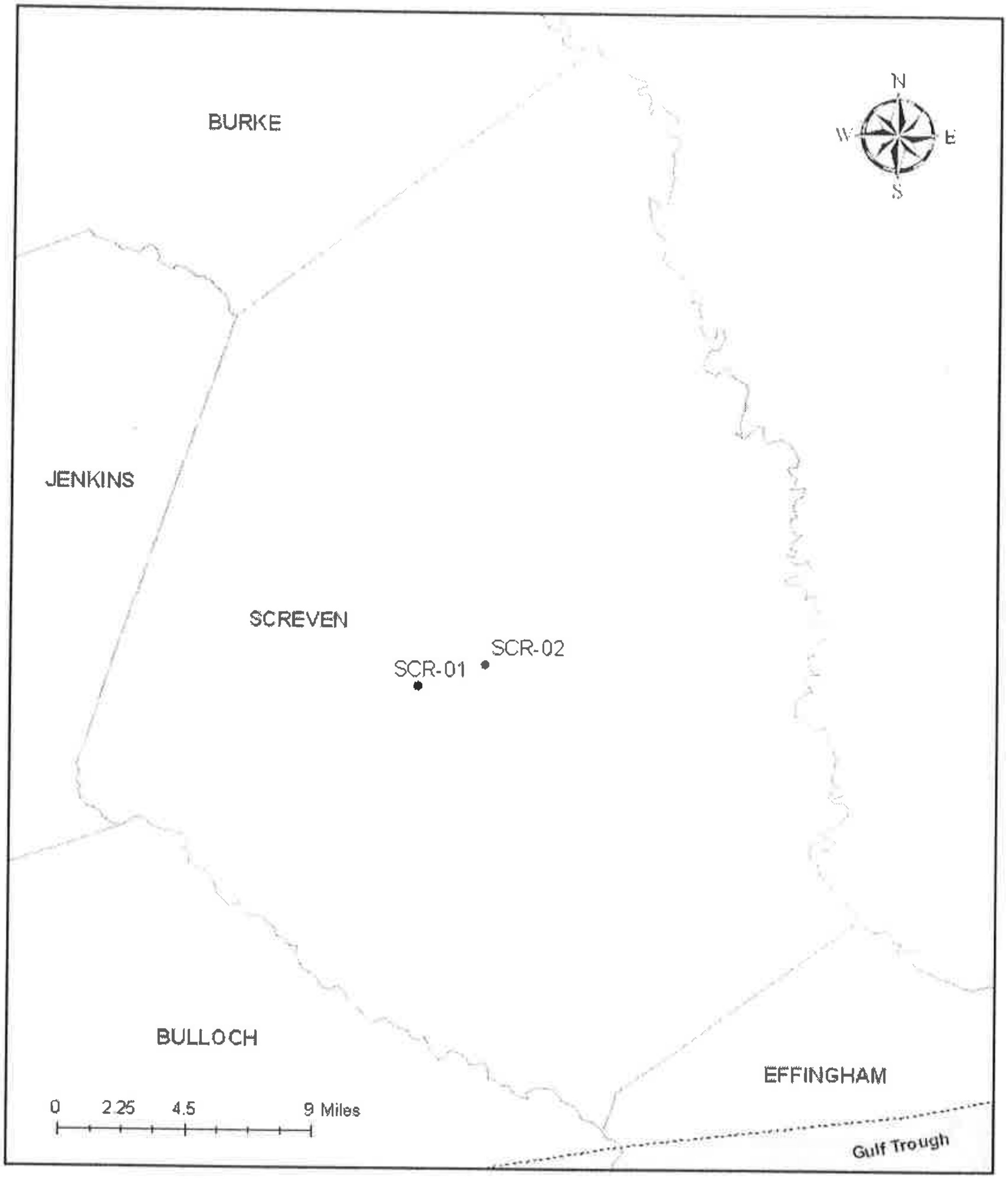

Figure B-10. Well Locations for Screven County.

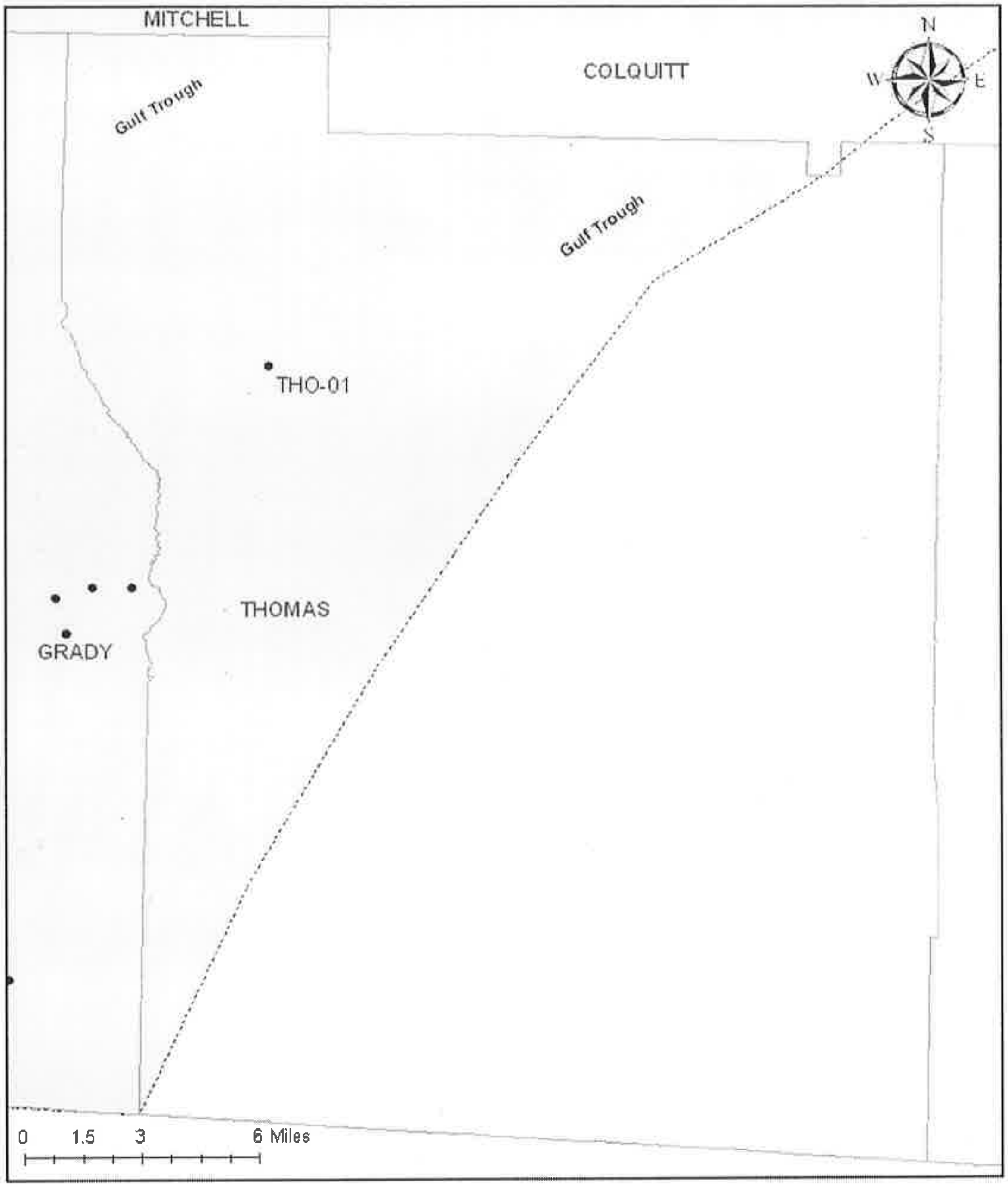

Figure B-11. Well Locations for Thomas County.