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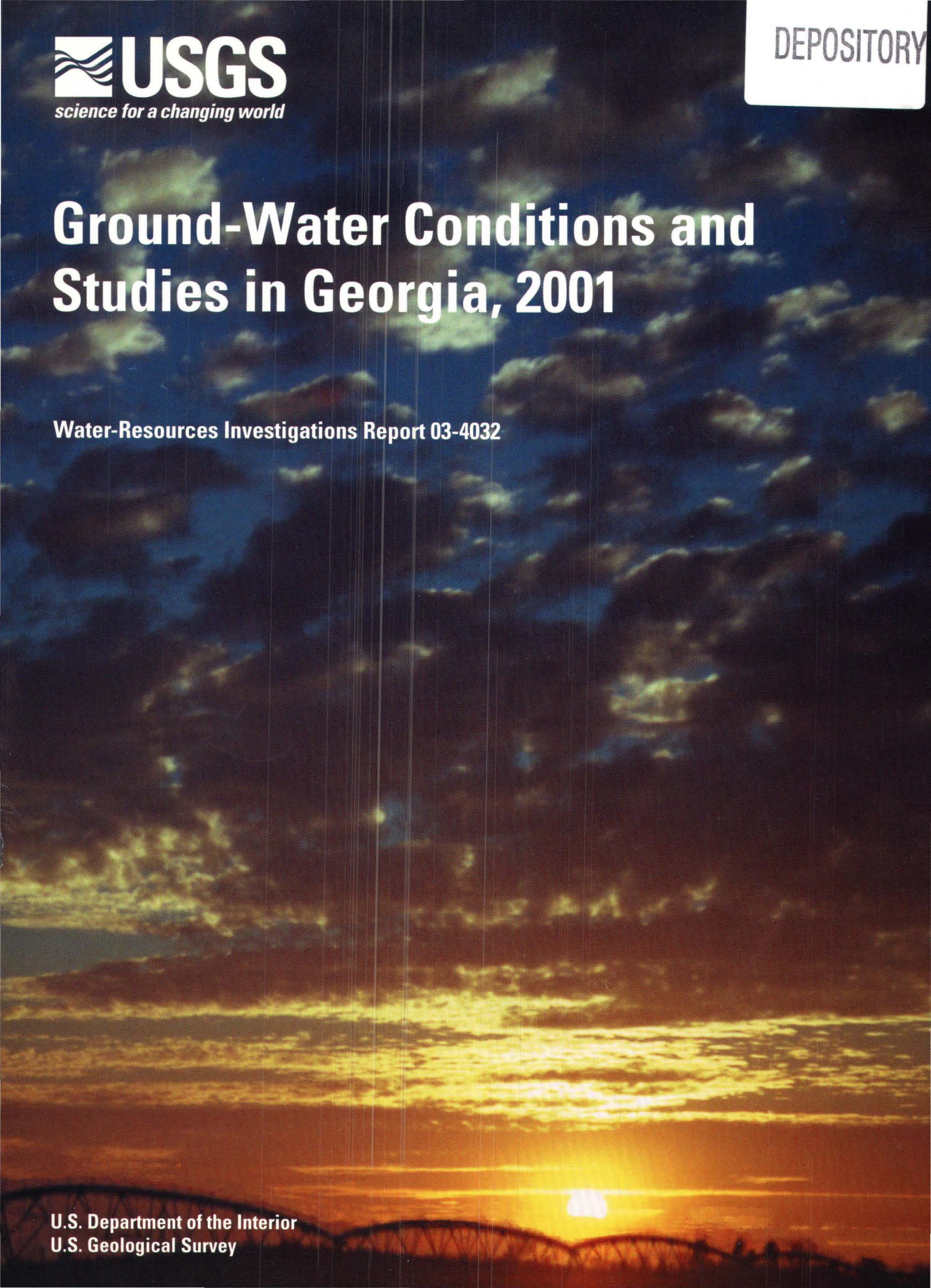

Ground-Water Conditions and Studies in Georgia, 2001

Water-Resources Investigations Report 03-4032

U.S. Department of the Interior
U.S. Geological Survey

PREFACE

This report is the culmination of a concerted effort by personnel of the U.S. Geological Survey who collected, compiled, organized, analyzed, verified the data, and edited and assembled the report. In addition to the authors, who had primary responsibility for ensuring that the information contained herein is accurate and complete, the following individuals contributed substantially to the collection, processing, tabulation, and review of the data:

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Cover photograph: Irrigation pivot near Brighams Landing, Burke County, Georgia
Photograph by Donald R. Dowling, U.S. Geological Survey, January 2003

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Ground-Water Conditions and Studies in Georgia, 2001

by David C. Leeth, John S. Clarke, Steven D. Craigg, and Caryl J. Wipperfurth

U.S. Geological Survey

Water-Resources Investigations Report 03-4032

Atlanta, Georgia
2003

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VERTICAL AND HORIZONTAL DATUMS

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88). Historical data collected and stored as National Geodetic Vertical Datum of 1929 have been converted to NAVD 88 for use in this publication.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Historical data collected and stored as North American Datum of 1927 (NAD 27) have been converted to NAD 83 for use in this publication.

Ground-Water Conditions and Studies in Georgia, 2001

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ABSTRACT

The U.S. Geological Survey (USGS) collects ground-water data and conducts studies to monitor hydrologic conditions, to better define ground-water resources, and address problems related to water supply and water quality. Data collected as part of ground-water studies include geologic, geophysical, hydraulic property, water level, and water quality. A ground-water-level network has been established throughout most of the State of Georgia, and ground-water-quality networks have been established in the cities of Albany, Savannah, and Brunswick and in Camden County, Georgia.

Ground-water levels are monitored continuously in a network of wells completed in major aquifers of the State. This network includes 17 wells in the surficial aquifer, 12 wells in the upper and lower Brunswick aquifers, 73 wells in the Upper Floridan aquifer, 10 wells in the Lower Floridan aquifer and underlying units, 12 wells in the Claiborne aquifer, 1 well in the Gordon aquifer, 11 wells in the Clayton aquifer, 11 wells in the Cretaceous aquifer system, 2 wells in Paleozoic-rock aquifers, and 7 wells in crystalline-rock aquifers. In this report, data from these 156 wells were evaluated to determine whether mean-annual ground-water levels were within, below, or above the normal range during 2001, based on summary statistics for the period of record. Information from these summaries indicates that water levels during 2001 were below normal in almost all aquifers monitored, largely reflecting climatic effects from drought and pumping. In addition, water-level hydrographs for selected wells indicate that water levels have declined during the past 5 years (since 1997) in almost all aquifers monitored, with water levels in some wells falling below historical lows. In addition to continuous water-level data, periodic measurements taken in 52 wells in the Camden County–Charlton County area, and 65 wells in the city of Albany–Dougherty County area were used to construct potentiometric-surface maps for the Upper Floridan aquifer.

Ground-water quality in the Upper Floridan aquifer is monitored in the cities of Albany, Savannah, and Brunswick and in Camden County; and monitored in the Lower Floridan aquifer in the Savannah and Brunswick areas. In the Albany area since 1998, nitrate concentrations in the Upper Floridan aquifer have increased in 4 of the 11 wells monitored, and in 1 well, concentrations were above the U.S. Environmental Protection Agency's (USEPA) 10 milligrams per liter (mg/L) drinking-water standard. In the Savannah area, chloride concentration in water from four wells in the Upper Floridan aquifer showed no appreciable change during 2001, remaining within the USEPA 250 mg/L drinking-water standard; in seven wells completed in the Lower Floridan aquifer and in underlying zones, the chloride concentration remained above the drinking-water standard, with one well showing an increase over previous years.

In the Brunswick area, water samples from 66 wells completed in the Upper or Lower Floridan aquifers were collected during June 2001 and analyzed for chloride. A map showing chloride concentrations in the Upper Floridan aquifer during June 2001 indicates that concentrations remained above USEPA drinking-water standards across a 2-square-mile area. In the north Brunswick area, chloride concentrations in the Upper Floridan aquifer continued to increase, whereas in the south Brunswick area, concentrations continued to decrease.

In the Camden County area, chloride concentrations in six wells completed in the Upper Floridan aquifer remained within drinking-water standards. With the exception of one well, concentrations remained the same and were below 40 mg/L. In one well, concentrations showed a sharp decline during 2001, but remained above 130 mg/L.

Ongoing studies during 2001 include evaluation of agricultural chemicals in shallow ground water in southwestern Georgia; evaluation of saltwater intrusion and water-level and water-quality monitoring in the city of Brunswick–Glynn County area; evaluation of ground-water flow, and water-quality and water-level monitoring in the city of Albany–Dougherty County area; evaluation of saltwater intrusion and alternative water sources as part of the Coastal Sound Science Initiative; assessment of the effects of impoundment of Lake Seminole on water resources in southwestern Georgia; assessment of stream-aquifer relations in the lower Apalachicola–Chattahoochee–Flint River Basin; assessment of ground-water availability and supply at Fort Gordon near Augusta; and evaluation of the hydrogeology of fractured crystalline-rock aquifers in the city of Lawrenceville area and Rockdale County.

Technical highlights from selected USGS ground-water studies during 2001 include the characterization of fractured crystalline-rock aquifers at selected sites in the Lawrenceville area, the hydrogeology and aquifer tests in the Floridan aquifer system at selected sites in coastal Georgia, and the hydrogeology and ground-water quality of coastal plain sediments at Fort Gordon. Also a listing is presented of selected publications, technical presentations, and outreach activities during 2001.

INTRODUCTION

Reliable and impartial scientific information on the occurrence, quantity, quality, distribution, and movement of water is essential to resource managers, planners, and others throughout the Nation. The U.S. Geological Survey (USGS) in cooperation with numerous local, State, and Federal agencies collects hydrologic data and conducts studies to monitor hydrologic conditions and better define the water resources of Georgia and the other States.

Ground-water-level and ground-water-quality data are essential for water-resource assessment and management. Water-level measurements from observation wells are the principal source of information about the hydrologic stresses on aquifers and how these stresses affect ground-water recharge, storage, and discharge. Long-term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time, develop ground-water models and forecast trends, and design, implement, and monitor the effectiveness of ground-water management and protection programs (Taylor and Alley, 2001).

Purpose and Scope

This report presents an overview of ground-water conditions and hydrologic studies conducted during 2001 by the USGS Water Resources Discipline office in Georgia. Summaries of selected ground-water studies with objectives and progress are presented, together with selected technical highlights. These summaries and highlights include:

- Ground-water-level and ground-water-quality conditions in Georgia during 2001, based on information collected from State and local monitoring networks;
- Characterization of fractured crystalline-rock aquifers at selected sites in the vicinity of Lawrenceville, Georgia, 2001;
- Hydrogeology and aquifer tests in the Floridan aquifer system at selected sites in coastal Georgia, 2001;
- Hydrogeology and ground-water quality of Coastal Plain sediments in the central Fort Gordon area, near Augusta, Georgia, 2001;
- Publications released and scientific conferences attended during 2001 also are summarized; and
- Previously published reports on Georgia ground-water conditions are listed in the table on the facing page.

Periodic water-level measurements were taken in 257 wells, and continuous water-level measurements were obtained from 156 wells. Of the 156 wells equipped with continuous water-level recorders, 146 wells had electronic data recorders, which recorded the water level at 60-minute intervals and these data were retrieved monthly. Thirteen wells had real-time satellite telemetry, which recorded the water level at 60-minute intervals and transmitted water-levels every 4 hours for display on the USGS Georgia District Web site at URL: *http://water.usgs.gov/ga/nwis/current?type=gw*.

Median-annual water levels for 2001 were compared to the normal range of ground-water levels for the period of record; the results of this comparison are shown on maps for selected aquifers and areas of the State. In addition, hydrographs showing monthly mean ground-water levels for the period 1997–2001 are shown with period-of-record water-level statistics.

In addition to continuous water-level records, periodic measurements in the Upper Floridan aquifer were collected during November 2001 in 65 wells in south-central Dougherty County near Albany, and a map showing the potentiometric surface of the aquifer was constructed. A similar map of the Upper Floridan aquifer was constructed for Camden and Charlton Counties and adjacent counties in Florida using water-level measurements collected during September 2001 from 52 wells (Knowles and Kinnaman, 2002).

Chloride concentrations in water collected from the Upper and Lower Floridan aquifers are shown in graphs for five wells in the city of Brunswick area, six wells in the city of Savannah area, and four wells in the Camden County area. A map showing the chloride concentration in water from the upper water-bearing zone of the Upper Floridan aquifer at Brunswick during June 12–13, 2001, was constructed using data from 65 wells. Nitrate concentrations in water from the Upper Floridan aquifer during November 13–16, 2001, were analyzed in 11 wells and plotted on a map for south-central Dougherty County near Albany.

Previous reports on ground-water conditions in Georgia

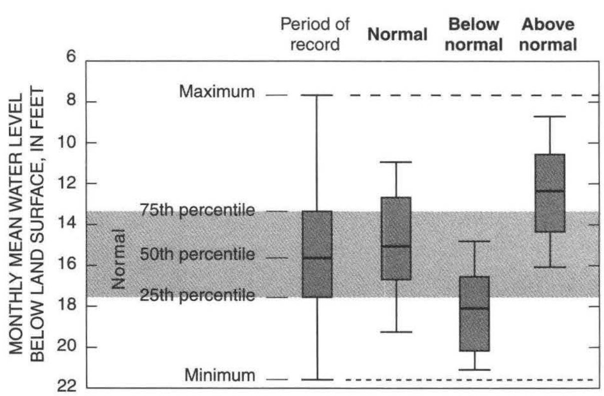
Year of data collection	USGS Open-File Report number	Author(s)	Year of publication
1977	79-213	U.S. Geological Survey	1978
1978	79-1290	Clarke, J.S., Hester, W.G., and O'Byrne, M.P.	1979
1979	80-501	Mathews, S.E., Hester, W.G., and O'Byrne, M.P.	1980
1980	81-1068	Mathews, S.E., Hester, W.G., and O'Byrne, M.P.	1981
1981	82-904	Mathews, S.E., Hester, W.G., and McFadden, K.W.	1982
1982	83-678	Stiles, H.R., and Mathews, S.E.	1983
1983	84-605	Clarke, J.S., Peck, M.F., Longsworth, S.A., and McFadden, K.W.	1984
1984	85-331	Clarke, J.S., Longsworth, S.A., McFadden, K.W., and Peck, M.F.	1985
1985	86-304	Clarke, J.S., Joiner, C.N., Longsworth, S.A., McFadden, K.W.,and Peck, M.F.	1986
1986	87-376	Clarke, J.S., Longsworth, S.A., Joiner, C.N., Peck, M.F., McFadden, K.W., and Milby, B.J.	1987
1987	88-323	Joiner, C.N., Reynolds, M.S., Stayton, W.L., and Boucher, F.G.	1988
1988	89-408	Joiner, C.N., Peck, M.F., Reynolds, M.S., and Stayton, W.L.	1989
1989	90-706	Peck, M.F., Joiner, C.N., Clarke, J.S., and Cressler, A.M.	1990
1990	91-486	Milby, B.J., Joiner, C.N., Cressler, A.M., and West, C.T.	1991
1991	92-470	Peck, M.F., Joiner, C.N., and Cressler, A.M.	1992
1992	93-358	Peck, M.F., and Cressler, A.M.	1993
1993	94-118	Joiner, C.N., and Cressler, A.M.	1994
1994	95-302	Cressler, A.M., Jones, L.E., and Joiner, C.N.	1995
1995	96-200	Cressler, A.M.	1996
1996	97-192	Cressler, A.M.	1997
1997	98-172	Cressler, A.M.	1998
1998	99-204	Cressler, A.M.	1999
1999	00-151	Cressler, A.M.	2000
2000	01-220	Cressler, A.M., Blackburn, D.K., and McSwain, K.B	2001

Methods of Analysis, Sources of Data, and Data Accuracy

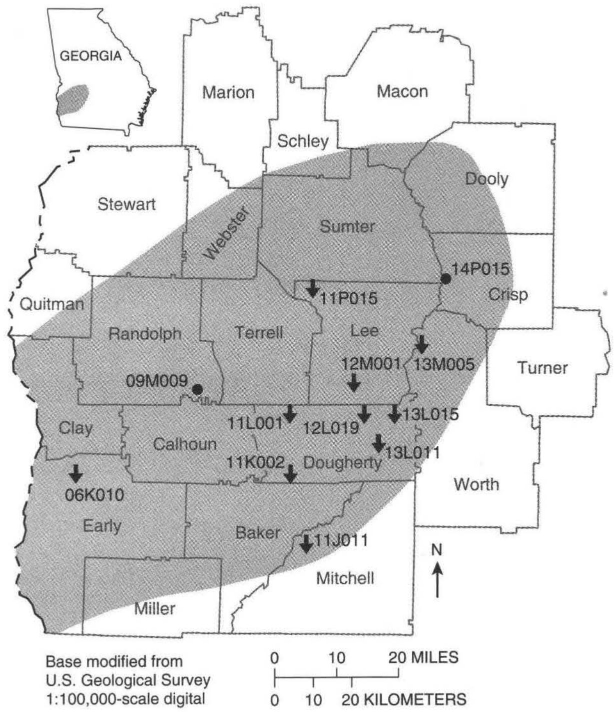
During 2001, ground-water levels were continuously monitored in 156 wells as part of Statewide and local networks and as part of studies of water resources in different parts of the State. Hydrographs from selected wells are presented in this report to compare 5-year trends and seasonal fluctuations to period-of-record statistics in major aquifers throughout the State. A more complete listing of water-level data from USGS continuously monitored wells is provided in the CD–ROM report, "Continuous ground-water-level data, and periodic surface-water- and ground-water-quality data, calender year 2001" (Coffin and others, 2002). That report includes annual and period-of-record ground-water-level hydrographs, summary statistics (maximum, minimum, and mean), and well information (construction and location). Additional well information can be obtained from the USGS National Water Information System (NWIS) at URL: *http://waterdata.usgs.gov/ga/nwis/gw.*

Median water levels for 2001 were compared to period-of-record normal water levels to determine if water levels were above normal, below normal, or normal. In this report, the normal range is defined as those water-level observations during the calendar year that lie between the 25th and 75th percentiles (first and third quartiles), also known as the inter-quartile range, for the period of record. The 75th percentile (third quartile) means that three-quarters of the observations lie below it; the 25th percentile (first quartile) means that one-quarter of the observations lie below it, and the median or 50th percentile (second quartile) means that two-quarters (one-half) of the observations lie below it and two-quarters (one-half) of the observations lie above it (Hamburg, 1985). This can be shown by examining a graphical representation of these values known as a boxplot (Tukey, 1977) (see below).

The results of this comparison are graphically represented on maps in the ground-water-level section of this report (see map to the right, for example) either by an up arrow—2001 monthly mean water levels above period-of-record normal values; a down arrow—2001 monthly mean water levels below the normal range for the period of record; or a circle—2001 monthly mean water levels within the normal range for the period of record.



*Boxplot depicting the method used to decide if 2001 water levels in a well were within, below, or above the normal range. If the median (50th percentile) water level for 2001 was between the 25th and 75th percentiles of period-of-record water levels, then water levels in the well were considered **normal**. If the median water level for 2001 was below the 25th percentile, then water levels in the well were considered **below normal**. If the median water level for 2001 was above the 75th percentile, then water levels were considered **above normal**.*



EXPLANATION

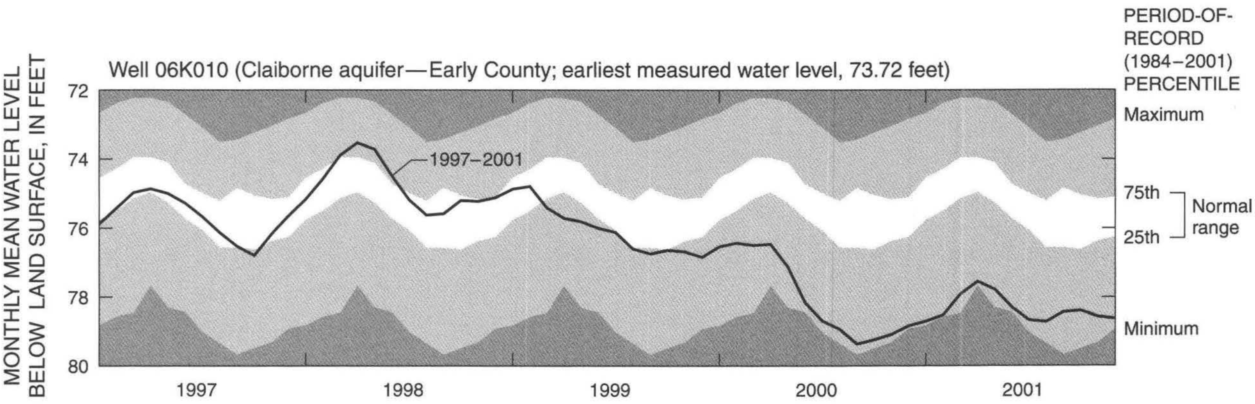
Observation well, site name, and comparison of monthly mean water level during 2001 to period-of-record water level

14P015 Normal—Between 25th and 75th percentile water levels for period of record

11J011 Below normal—Below 25th percentile water level for period of record

*Results of the comparison between period-of-record water levels and 2001 water levels in wells continuously monitored by the USGS. A circle represents water levels in a well that are within the normal range (**normal**). An arrow pointing upward represents water levels in a well that are above the normal range (**above normal**). An arrow pointing downward represents water levels in a well that are below the normal range (**below normal**).*

Hydrographs showing monthly mean ground-water levels during 1997–2001 were plotted together with hydrographs showing period-of-record water-level statistics (monthly mean normal, minimum, and maximum water levels) (see hydrograph, facing page). The period-of-record monthly statistics were calculated through December 2001 and are repeated on the graphs for 1997, 1998, 1999, and 2000. For example, statistics



Hydrograph showing monthly mean water level in well 06K010 for the period 1997–2001 and summary water-level statistics for the period of record 1985–2001.

for the month of June are the same on the plots for each year during 1997–2001. Land-surface altitude for most wells was determined from topographic maps, and is accurate to about one-half the contour interval (usually from 2.5 to 5 feet). Some land-surface altitudes were determined by surveying methods or Global Positioning System (GPS) and are more accurate.

Water samples were analyzed for nitrate at the USGS laboratory in Ocala, Florida. Chloride analyses were conducted at the USGS Ocala laboratory, the USGS Atlanta, Georgia, laboratory, and at the St. Johns River Water Management District in Palatka, Florida (for Camden County). Additional water-quality data for Georgia can be obtained from the USGS National Water Information System (NWIS) at URL: *http://waterdata.usgs.gov/ga/nwis/qw.*

Georgia Well-Naming System

Wells described in this report are given a well name according to a system based on the USGS index of topographic maps of Georgia. Each 7.5-minute topographic quadrangle in the State has been assigned a three- to four-digit number and letter designation (for example, 07H or 11AA) beginning at the southwestern corner of the State. Numbers increase sequentially eastward and letters advance alphabetically northward. Quadrangles in the northern part of the State are designated by double letters; AA follows Z, and so forth. The letters "I", "O", "II", and "OO" are not used. Wells inventoried in each quadrangle are numbered consecutively, beginning with 01. Thus, the fourth well inventoried in the 11AA quadrangle is designated 11AA04. In the USGS NWIS database, this information is stored under the field "Well Name."

Cooperating Organizations

Ground-water monitoring and hydrologic studies in Georgia are conducted in cooperation with numerous local, State, and Federal organizations. Cooperating organizations include:

- Albany Water, Gas, and Light Commission
- City of Brunswick
- City of Lawrenceville
- Georgia Department of Natural Resources
- Georgia Department of Agriculture
- Camden County
- Glynn County
- McIntosh County
- Rockdale County
- U.S. Department of the Army
- U.S. Department of the Air Force
- St. John's Water Management District (Florida)

With the exception of the Federal agencies, all of these organizations participate in the USGS Cooperative Water Program, an ongoing partnership between the USGS and non-Federal agencies. The program enables joint planning and funding for systematic studies of water quantity, quality, and use. Data obtained from these studies are used to guide water-resources management and planning activities and provide indications of emerging water problems. For a more complete description of the Cooperative Water Program, see Brooks (2001).

Ground-Water Resources

Contrasting geologic features and landforms of the physiographic provinces of Georgia (map, facing page, and table, following two pages) affect the quantity and quality of ground water throughout the State. The surficial aquifer is present in each of the physiographic provinces. In the Coastal Plain Province, the surficial aquifer consists of intermixed layers of sand, clay, and limestone. The surficial aquifer usually is under water-table (unconfined) conditions and is used for domestic and livestock supplies. The surficial aquifer is semiconfined to confined locally in the coastal area. In the Piedmont, Blue Ridge, and Valley and Ridge Provinces, the surficial aquifer consists of soil, saprolite, stream alluvium, colluvium, and other surficial deposits.

The most productive aquifers in Georgia are in the Coastal Plain Province in the southern half of the State. The Coastal Plain is underlain by alternating layers of sand, clay, dolomite, and limestone that dip and thicken to the southeast. Coastal Plain aquifers generally are confined, except near their northern limits where they crop out or are near land surface. Aquifers in the Coastal Plain include the surficial aquifer, upper and lower Brunswick aquifers, Upper and Lower Floridan aquifers, Gordon aquifer system, Claiborne aquifer, Clayton aquifer, and the Cretaceous aquifer system.

In the Valley and Ridge Province, ground water is transmitted through primary and secondary openings in folded and faulted sedimentary and metasedimentary rocks of Paleozoic age, herein referred to as "Paleozoic-rock aquifers."

In the Piedmont and Blue Ridge Provinces, the geology is complex and consists of structurally deformed metamorphic and igneous rocks. Ground water is transmitted through secondary openings along fractures, foliation, joints, contacts, or other features in the crystalline bedrock. In these provinces, aquifers are referred to as "crystalline-rock aquifers." For a more complete discussion of the State's ground-water resources, see Clarke and Pierce (1984).

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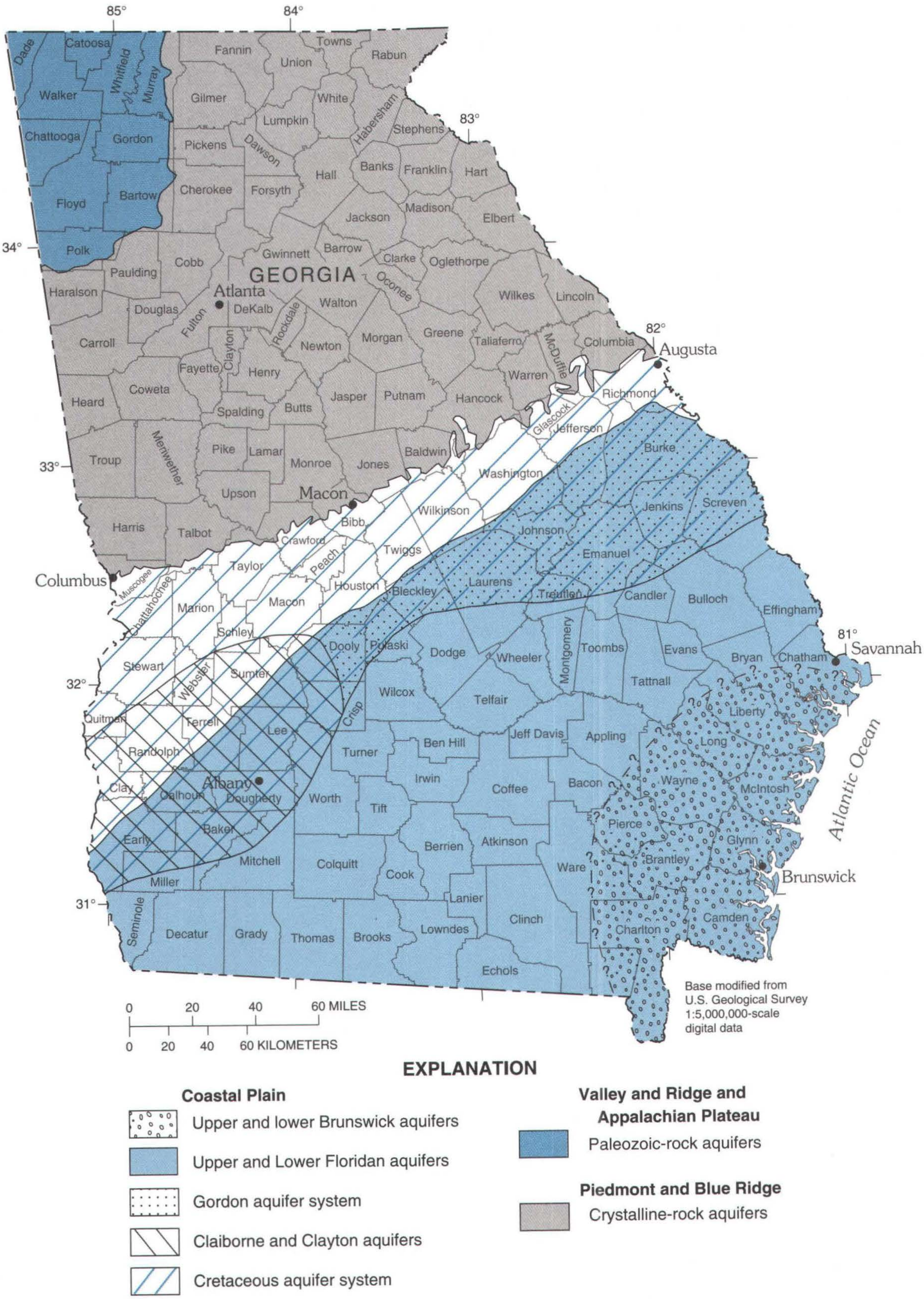

Areas of use of major aquifers in Georgia (modified from Clarke and Pierce, 1984). The surficial aquifer is present throughout the State and is not shown here.

Aquifer and well characteristics in Georgia [*modified from Clarke and Pierce (1984), and Peck and others (1992); ft, feet; gal/min, gallons per min*

Aquifer name	Aquifer description	Well characteristics		
		Depth (ft)	Yield (gal/min)	
		Typical range	Typical range	May exceed
Surficial aquifer	Unconsolidated sediments and residuum; generally unconfined	11–72	2–25	25
Upper and lower Brunswick aquifers	Phosphatic and dolomitic quartz sand; generally confined	85–390	10–30	180
Upper and Lower Floridan aquifers	Limestone, dolomite, and calcareous sand; generally confined	40–900	1,000–5,000	11,000
Gordon aquifer system	Sand and sandy limestone; generally confined	270–530	87–1,200	1,800
Claiborne aquifer	Sand and sandy limestone; generally confined	20–450	150–600	1,500
Clayton aquifer	Limestone and sand; generally confined	40–800	250–600	2,150
Cretaceous aquifer system	Sand and gravel; generally confined	30–750	50–1,200	3,300
Paleozoic-rock aquifers	Sandstone, limestone and dolomite; generally confined	15–2,100	1–50	3,500
Crystalline-rock aquifers	Granite, gneiss, schist, and quartzite; generally confined	40–600	1–25	500

Hydrologic response	Remarks
Water-level fluctuations mainly are caused by variations in precipitation, evapotranspiration, and natural drainage. In addition, water levels in the city of Brunswick area are influenced by nearby pumping, precipitation, and tidal fluctuations (Clarke and others, 1990). Water levels generally rise rapidly during wet periods and decline slowly during dry periods. Prolonged droughts may cause water levels to decline below pump intakes in shallow wells, particularly those located on hilltops and steep slopes, resulting in temporary well failures. Usually, well yields are restored by precipitation.	Primary source of water for domestic and livestock supply in rural areas. Supplemental source of water for irrigation supply in coastal Georgia.
In the coastal area, the aquifers may respond to pumping from the Upper Floridan aquifer as a result of the hydraulic connection between the aquifers. Elsewhere the water level mainly responds to seasonal variations in recharge and discharge. In Bulloch County, unnamed aquifers equivalent to the upper and lower Brunswick aquifers are unconfined to semiconfined and are influenced by variations in recharge from precipitation and by pumping from the Upper Floridan aquifer; in the Wayne and Glynn County area, the aquifers are confined and respond to nearby pumping (Clarke and others, 1990).	Not a major source of water in coastal Georgia, but considered a supplemental water supply to the Upper Floridan aquifer.
In and near outcrop areas, the aquifers are semiconfined and water levels in wells tapping the aquifers fluctuate seasonally in response to variations in recharge rate and pumping. Near the coast, where the aquifers are confined, water levels primarily respond to pumping, and fluctuations related to recharge are less pronounced (Clarke and others, 1990).	Supplies about 50 percent of ground water in Georgia. The aquifer system is divided into the Upper and Lower Floridan aquifers. In the Brunswick area, the Upper Floridan aquifer includes two freshwater-bearing zones, the upper water-bearing zone and the lower water-bearing zone. The Lower Floridan aquifer is not considered a major aquifer. In the Brunswick area and in southeastern Georgia, the Lower Floridan aquifer includes the brackish-water zone, the deep freshwater zone, and the Fernandina permeable zone (Krause and Randolph, 1989). The Lower Floridan aquifer extends to more than 2,700 ft deep and yields high-chloride water below 2,300 ft (Jones and Maslia, 1994).
Water levels are influenced by seasonal fluctuations in recharge from precipitation, discharge to streams, and evapotranspiration (Clarke and others, 1985).	Major source of water for irrigation, industrial and public-supply use in east-central Georgia.
Water levels mainly are affected by precipitation and by local and regional pumping (Hicks and others, 1981). The water level is generally highest following the winter and spring rainy seasons, and lowest in the fall following the summer irrigation season.	Major source of water for irrigation, industrial, and public-suppy use in southwestern Georgia.
Water levels are affected by seasonal variations in local and regional pumping (Hicks and others, 1981).	Major source of water for irrigation, industrial, and public-supply use in southwestern Georgia.
Water levels are influenced by variations in precipitation and pumping (Clarke and others, 1983, 1985).	Major source of water in east-central Georgia. Supplies water for kaolin mining and processing. Includes the Providence aquifer in southwestern Georgia, and the Dublin, Midville, and Dublin–Midville aquifer systems in east-central Georgia.
Water levels mainly are affected by precipitation and local pumping (Cressler, 1964).	Not laterally extensive. Limestone and dolomite aquifers are most productive. Storage is in regolith, primary openings, and secondary fractures and solution openings in rock. Springs in limestone and dolomite aquifers discharge at rates of as much as 5,000 gal/min. Sinkholes may form in areas of intensive pumping.
Water levels mainly are affected by precipitation and evapotranspiration, and locally by pumping (Cressler and others, 1983). Precipitation can cause a rapid rise in water levels in wells tapping aquifers overlain by thin regolith.	Storage is in regolith and fractures in rock.

GROUND-WATER LEVELS

The maps and hydrographs in this section of the report provide an overview of ground-water levels in major aquifers in Georgia during 2001. In addition, the hydrographs provide a visual summary of ground-water conditions for the past 5 years (1997–2001) compared to the period of record. Discussion about each aquifer is subdivided into areas where wells would likely have similar water-level fluctuations and trends. The map on the facing page gives the location of wells that were continuously monitored during the 2001 calendar year, including 13 wells that are monitored in real time.

Changes in ground-water levels measured in wells are caused by changes in aquifer storage. The many factors that affect ground-water storage are described by Taylor and Alley (2001) and are briefly discussed here. When recharge to an aquifer exceeds discharge, ground-water levels rise and when discharge exceeds recharge, ground-water levels decline. Recharge varies in response to precipitation and surface-water infiltration into an aquifer. Discharge occurs as natural flow from an aquifer to streams and springs, as evapotranspiration, and as withdrawal from wells. Hydraulic responses and controls on ground-water levels in major aquifers in Georgia are summarized in the table on the previous two pages.

Water levels in aquifers in Georgia typically follow a cyclic pattern of seasonal fluctuation, with rising water levels during winter and spring due to greater recharge from precipitation, and declining water levels during summer and fall due to less recharge, greater evapotranspiration, and pumping. The magnitude of fluctuations can vary greatly from season to season and from year to year in response to varying climatic conditions. This cyclic pattern can be seen on the 5-year hydrograph of well 31U009 in Bulloch County (below).

Ground-water pumping is the most significant human activity that affects the amount of ground water in storage and the rate of discharge from an aquifer (Taylor and Alley, 2001). As ground-water storage is depleted within the radius of influence of pumping, water levels in the aquifer decline, forming a cone of depression around the well. In areas having a high density of pumped wells, multiple cones of depression can form and produce water-level declines over a large area. These declines may alter ground-water-flow directions, reduce flow to streams, capture water from a stream or adjacent aquifer, or alter ground-water quality. The effects of sustained pumping can be seen on a hydrograph of well 07N001 in Randolph County (below).

Reference Cited

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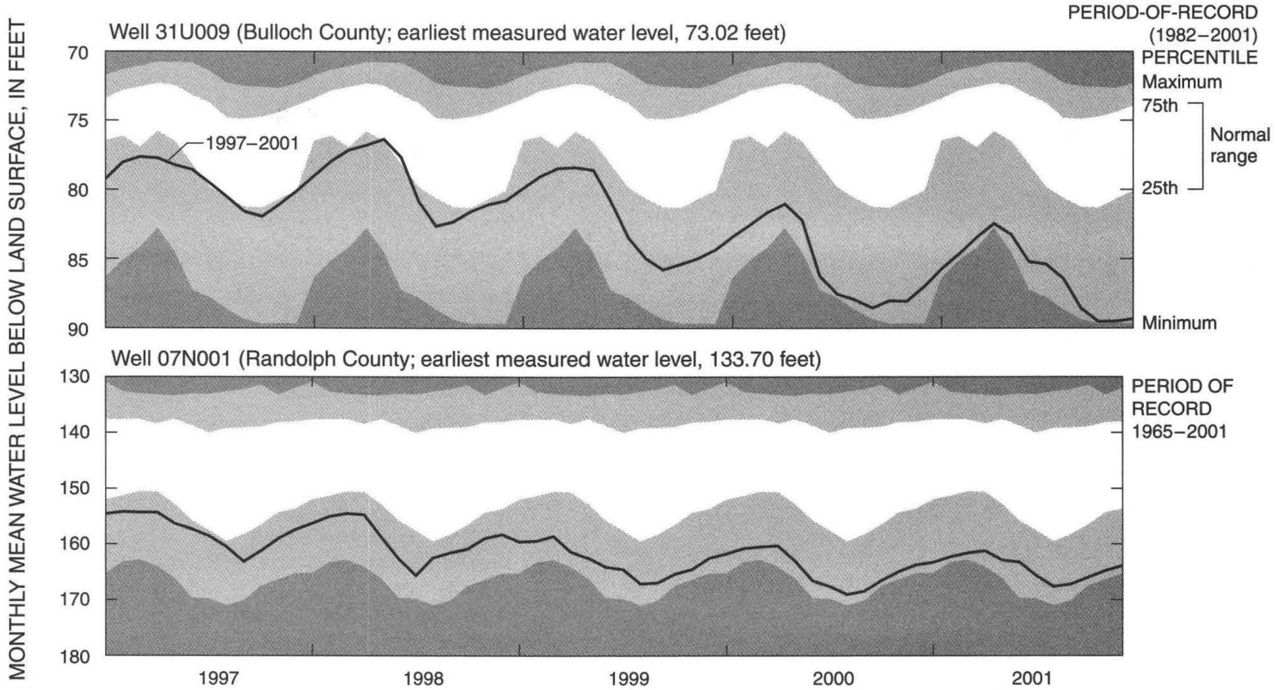


Example hydrographs showing monthly mean water levels in wells 31U009 and 07N001 for the period 1997–2001 and summary statistics for the period of record for these wells.

Ground-water-level monitoring wells used to collect long-term water-level data in Georgia during 2001.

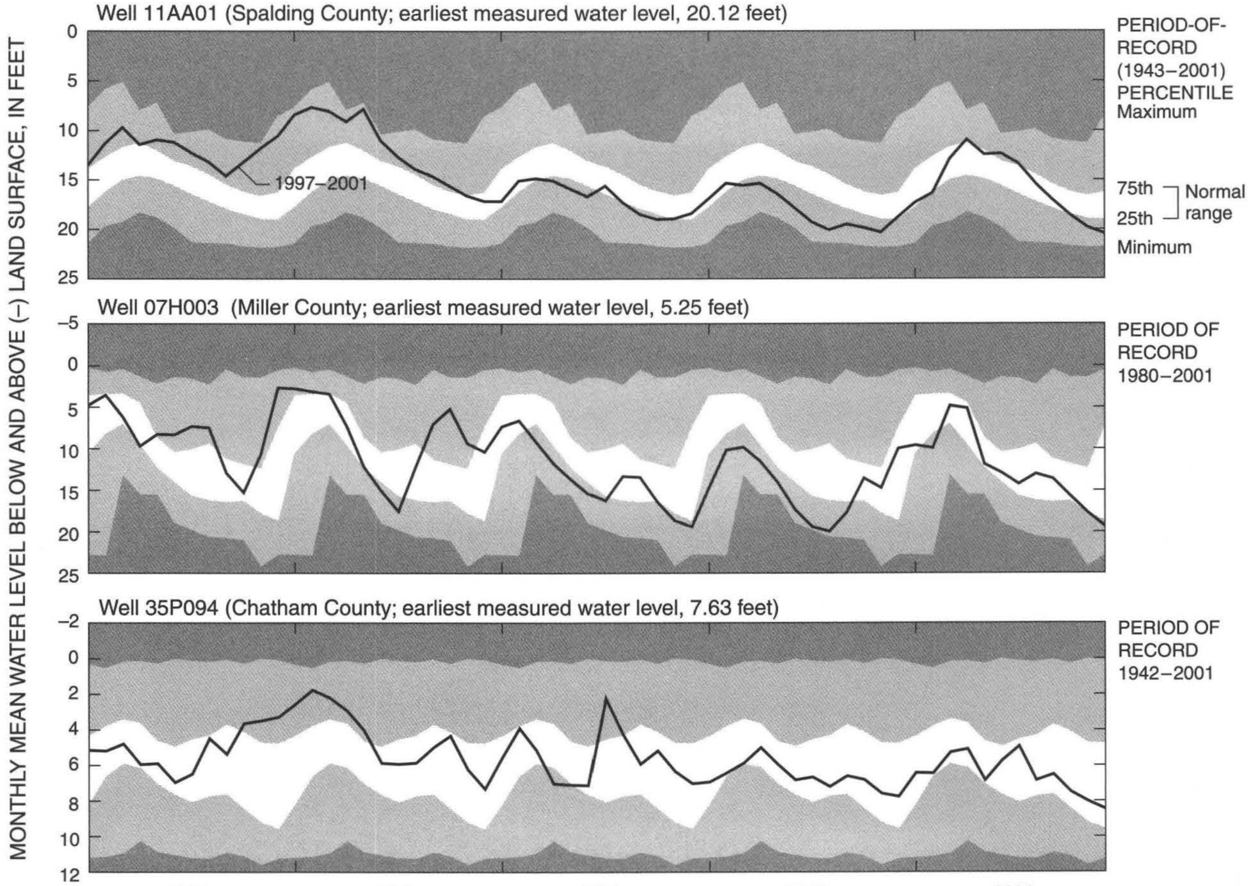
Surficial Aquifer

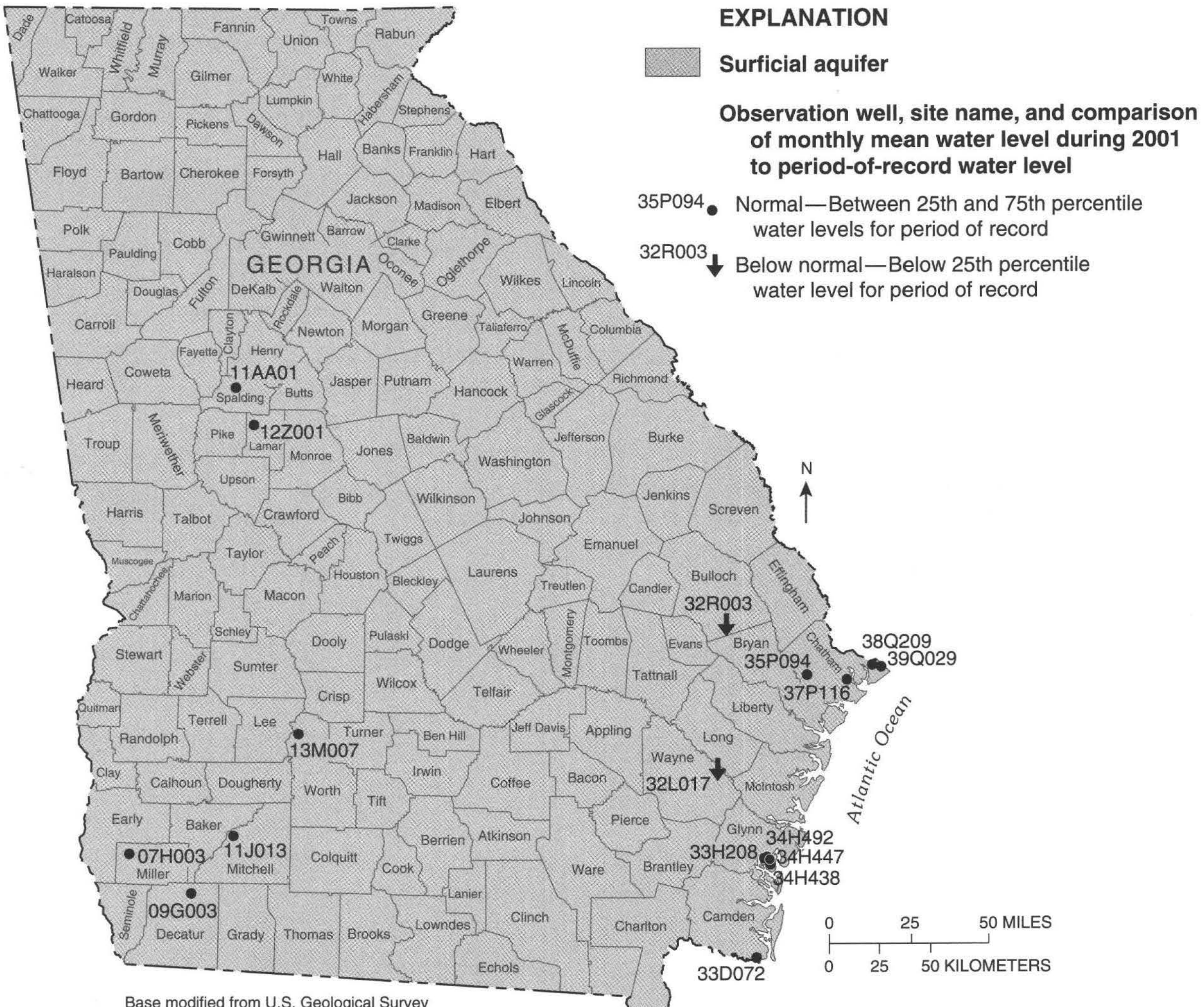
Water levels in 17 wells were used to define conditions in the surficial aquifer during 2001 (map and table, facing page). Water in the surficial aquifer typically is in contact with the atmosphere (referred to as an unconfined or water-table aquifer), but locally may be under pressure exerted by overlying sediments or rocks (referred to as a confined aquifer). Where unconfined, water levels change quickly in response to recharge and discharge. Consequently, hydrographs from these wells show a strong relation to climate.

Water levels in 15 of the 17 wells measured were within the normal range during 2001, with wells 32R003 and 32L017 below normal. These two coastal wells (32R003 and 32L017) were likely constructed in confined parts of the surficial aquifer, and water levels may be influenced by nearby pumping, possibly the reason that water levels are not consistent with the rest of the wells in the State.

Water-level hydrographs for three surficial aquifer wells (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. These long-term water-level records indicate that during 1997 and 1998, water levels in the surficial aquifer were at or above normal throughout Georgia, but the effects of drought became apparent during the early part of 1999 and continue until early 2001.

The hydrograph for well 11AA01 in Spalding County shows that the water level during 1997–98 was in or above the normal range. During early 1999, the water level began to decline intermittently below the normal range until early 2001, when the water level rose into the normal range. The hydrograph for well 07H003 in Miller County shows a similar pattern in that the water level during 1997–98 was at or above normal, during 1999 and 2000 was mostly below normal, and recovered to normal during 2001 but dropped below normal during the last few months of the year. The hydrograph for well 35P094 in Chatham County shows a pattern quite different from the other two wells. The water level in this well has been at or above normal for the past 5 years, except for about 2 months during early 1999.





Base modified from U.S. Geological Survey
1:5,000,000-scale digital data

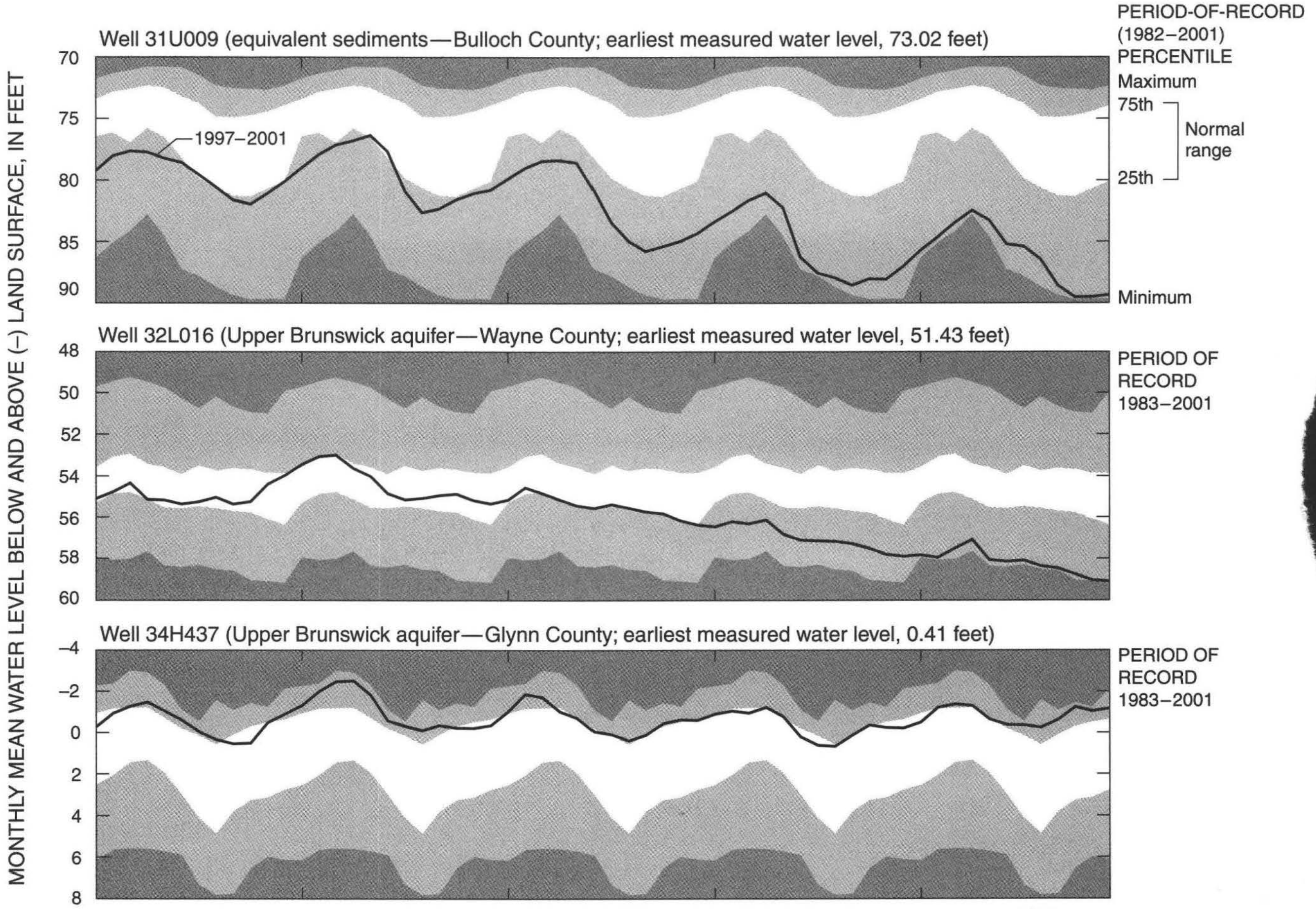
Site name	County	Other identifier
32R003	Bulloch	Bulloch South test well 2
33D072	Camden	Georgia Geologic Survey, St Marys, test well 3
35P094	Chatham	University of Georgia, Bamboo Farm well
37P116	Chatham	Georgia Geologic Survey, Skidaway Institute, test well 4
38Q209	Chatham	Fort Pulaski, Savannah Harbor Expansion, monitoring well 3
39Q029	Chatham	Tybee, Savannah Harbor Expansion, monitoring well 1, COE
09G003	Decatur	U.S. Geological Survey, test well DP-6
33H208	Glynn	Georgia–Pacific, south, test well 3
34H438	Glynn	Georgia Geologic Survey, Coffin Park, test well 3
34H447	Glynn	Glynn County Courthouse (shallow)
34H492	Glynn	Coastal Georgia Community College P-17
12Z001	Lamar	Dixie Pipeline
07H003	Miller	U.S. Geological Survey, test well DP-3
11J013	Mitchell	U.S. Geological Survey, test well DP-12
11AA01	Spalding	University of Georgia, Experiment Station
32L017	Wayne	Georgia Geologic Survey, Gardi, test well 3
13M007	Worth	U.S. Geological Survey, test well DP-9

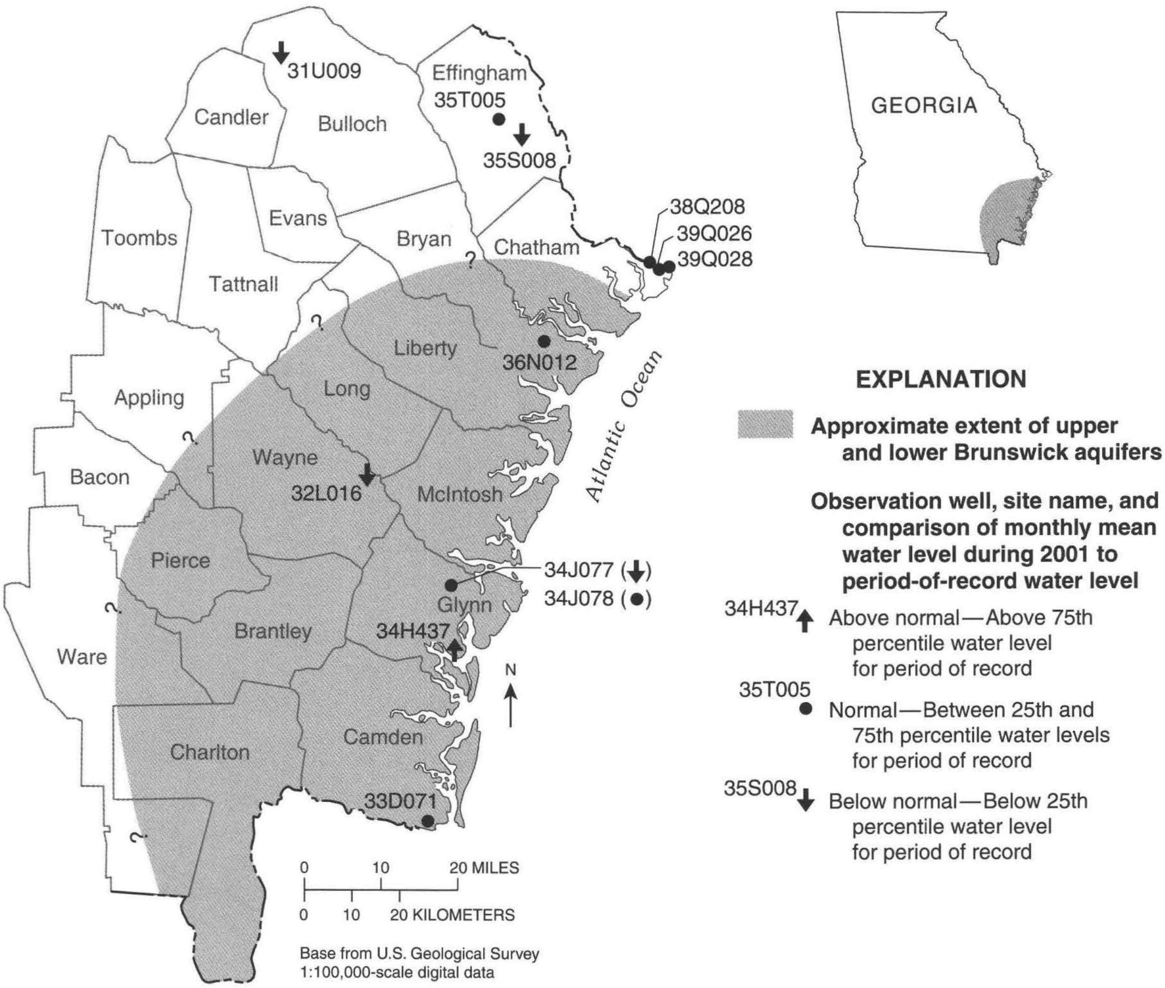
Upper and Lower Brunswick Aquifers

Water levels in 12 wells were used to define 2001 conditions in the upper and lower Brunswick aquifers and equivalent low-permeability sediments to the north and west in southeastern Georgia. Both the upper and lower Brunswick aquifers are confined throughout the known areas of extent (map and table, facing page). In seven wells, water levels were in the normal range; in four wells, water levels were below the normal range; and in one well (34H437), the water level was above the normal range. These variations reflect differences in local pumping, interaquifer leakage effects, and recharge.

Water-level hydrographs for three upper and lower Brunswick aquifer and equivalent-sediment wells (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. These water levels show that during 1997 and 1998, water levels in the upper and lower Brunswick aquifers were at, above, or slightly below normal in wells 31U009 and 32L016, but the effects of drought became apparent during 1999 and continued through 2001. Conversely, in well 34H437, the water level remained at or above normal during this same period.

The water level in well 31U009 (completed in undifferentiated sediments equivalent to the upper and lower Brunswick aquifers) was below normal during 1997–2001 (except during brief intervals during 1997 and mid-1998), likely due to the combined effects of drought and pumping. The hydrograph for well 32L016, completed in the upper Brunswick aquifer, shows the water level for 1997–98 in or above the normal range until early 1999, when the water level began to fall below the normal range. Well 34H437, also completed in the upper Brunswick aquifer, is unusual because the water level generally remained above normal for the entire period. In this area, the upper Brunswick aquifer is tightly confined and not widely used, and thus, water levels show little long-term trend.





Site name	Aquifer[1]	County	Other identifier
36N012	L	Bryan	Genesis Pointe
31U009	X	Bulloch	Georgia Geologic Survey, Hopeulikit, test well 2
33D071	U	Camden	Georgia Geologic Survey, St Marys, test well 2
38Q208	X	Chatham	Fort Pulaski, Savannah Harbor Expansion, monitoring well 4
39Q026	X	Chatham	Tybee Island, test well 3
39Q028	X	Chatham	Tybee, Savannah Harbor Expansion, monitoring well 2, COE
35S008	X	Effingham	Effingham County, Georgia Geologic Survey, corehole
35T005	X	Effingham	Springfield, Georgia, Miocene well
34H437	U	Glynn	Georgia Geologic Survey, Coffin Park, test well 2
34J077	U	Glynn	Golden Isle, test well 1S
34J078	L	Glynn	Golden Isle, test well 1D
32L016	U	Wayne	Georgia Geologic Survey, Gardi, test well 2

[1] U, upper Brunswick aquifer; L, lower Brunswick aquifer; X, undifferentiated, low-permeability equivalent to the upper and lower Brunswick aquifers

Upper Floridan Aquifer

The Upper Floridan aquifer underlies most of the Coastal Plain of Georgia, southern South Carolina, extreme southeastern Alabama, and all of Florida (Miller, 1986). The aquifer is one of the most productive in the United States, and a major source of water in the region. During 1995, approximately 700 million gallons per day (Mgal/d) was withdrawn from the Upper and Lower Floridan aquifers in Georgia, primarily for industrial and irrigation uses (Fanning, 1997).

The Upper Floridan aquifer predominately consists of Eocene to Oligocene limestone, dolomite, and calcareous sand. The aquifer is thinnest along its northern limit (map, facing page) and thickens to the southeast, where the maximum thickness is about 1,700 feet (ft) in Ware County (Miller, 1986). The aquifer is confined throughout most of its extent, except where it crops out or is near land surface along the northern limit, and in areas of karst topography in parts of southwestern and south-central Georgia.

The Coastal Plain of Georgia has been informally divided into four hydrologic areas for discussion of water levels (map, facing page)—the southwestern, south-central, east-central, and coastal areas. This subdivision is a modification of that used by Peck and others (1999) and is similar to that used by Clarke (1987).

Southwestern area

All or parts of 16 counties constitute the southwestern area. In this area, the Upper Floridan aquifer ranges in thickness from about 50 ft in the northwest to about 475 ft in the southeast (Hicks and others, 1987). The aquifer is overlain by sandy clay residuum that is hydraulically connected to streams. With the introduction of center pivot irrigation systems around 1975, the Upper Floridan aquifer has been widely used as the primary water source for irrigation in southwestern Georgia (Hicks and others, 1987). According to Torak and McDowell (1996), about 162 million gallons per day (Mgal/d) of water was withdrawn from the Upper Floridan aquifer in the southwestern area during 1990, 70 percent of which was used for irrigation.

Within the southwestern area, lies the city of Albany–Dougherty County area. In this area, most of the water withdrawn from the Upper Floridan aquifer is for public supply. About 20 Mgal/d was withdrawn during 1995. Irrigation withdrawal was about half that amount (11 Mgal/d; Fanning, 1997).

South-central area

Six counties constitute the south-central area. In this area, the Upper Floridan aquifer ranges in thickness from about 300 to 700 ft (Miller, 1986). Lowndes County is a karst region, having abundant sinkholes and sinkhole lakes that have formed where the aquifer crops out and the overlying confining unit has been removed by erosion (Krause, 1979). Direct recharge from rivers to the Upper Floridan aquifer occurs through these sinkholes at a rate of about 70 Mgal/d (Krause, 1979). In the south-central area, ground-water use totaled about 91 Mgal/d in 1995 with the majority of the withdrawal used for irrigation (Fanning, 1997).

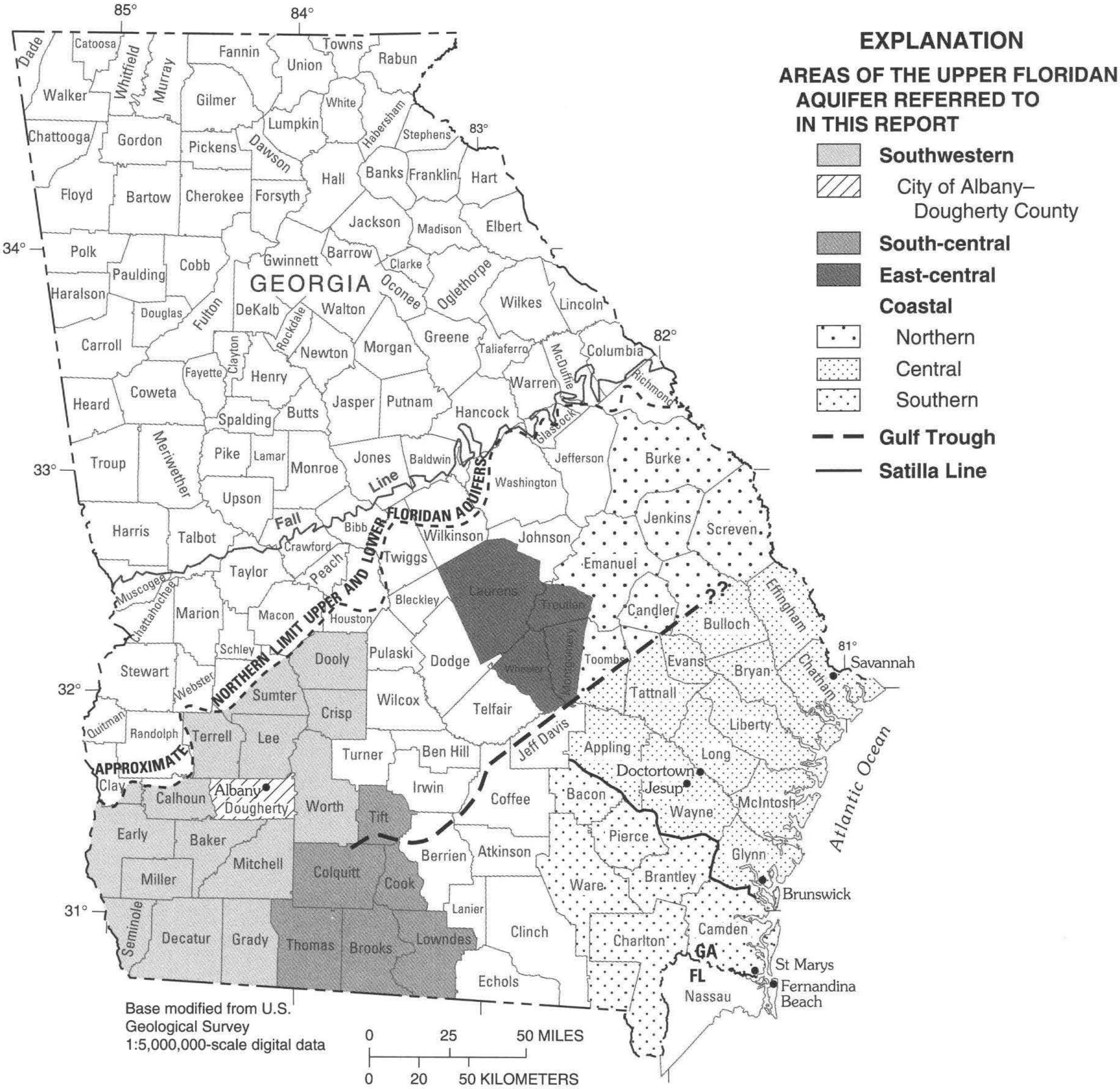
East-central area

Four counties constitute the east-central area. In this area, the Upper Floridan aquifer can be as thick as about 650 ft in the southeast to absent in the north. In this area, withdrawal totaled about 14 Mgal/d in 1995 and was used predominantly for irrigation (Fanning, 1997).

Coastal area

The Georgia Environmental Protection Division (GaEPD) defines the coastal area of Georgia to include the 6 coastal counties and adjacent 18 counties, an area of about 12,240 square miles. In this area, the Upper Floridan aquifer may be absent in the north (Burke County) to about 1,700 ft thick in the south (Ware County) (Miller, 1986). Excluding withdrawals for thermoelectric power generation, nearly 70 percent of all withdrawals in the area are from ground water (Fanning, 1999), primarily for industrial purposes. During 1997, about 347 Mgal/d was withdrawn from the Upper Floridan aquifer in the coastal area (Fanning, 1999).

The coastal area has been subdivided by GaEPD into three subareas—the northern, central, and southern—to facilitate implementation of the State's water-management policies. The central subarea includes the largest concentration of pumpage in the coastal area—the Savannah, Brunswick, and Jesup pumping centers. The northern subarea is northwest of the Gulf Trough (Herrick and Vorhis, 1963), a prominent geologic feature that is characterized by a zone of low permeability in the Upper Floridan aquifer that inhibits flow between the central and northern subareas. In this area, pumping from the aquifer is primarily agricultural, with no large pumping centers. The southern subarea is separated from the central subarea by the Satilla line, a postulated hydrologic boundary (W.H. McLemore, Georgia Environmental Protection Division, Geologic Survey Branch, oral commun. with John S. Clarke, Jan. 6, 2000). In this area, the largest pumping center is at St Marys, Georgia–Fernandina Beach, Florida.



Areas of the Upper Floridan aquifer referred to in this report.

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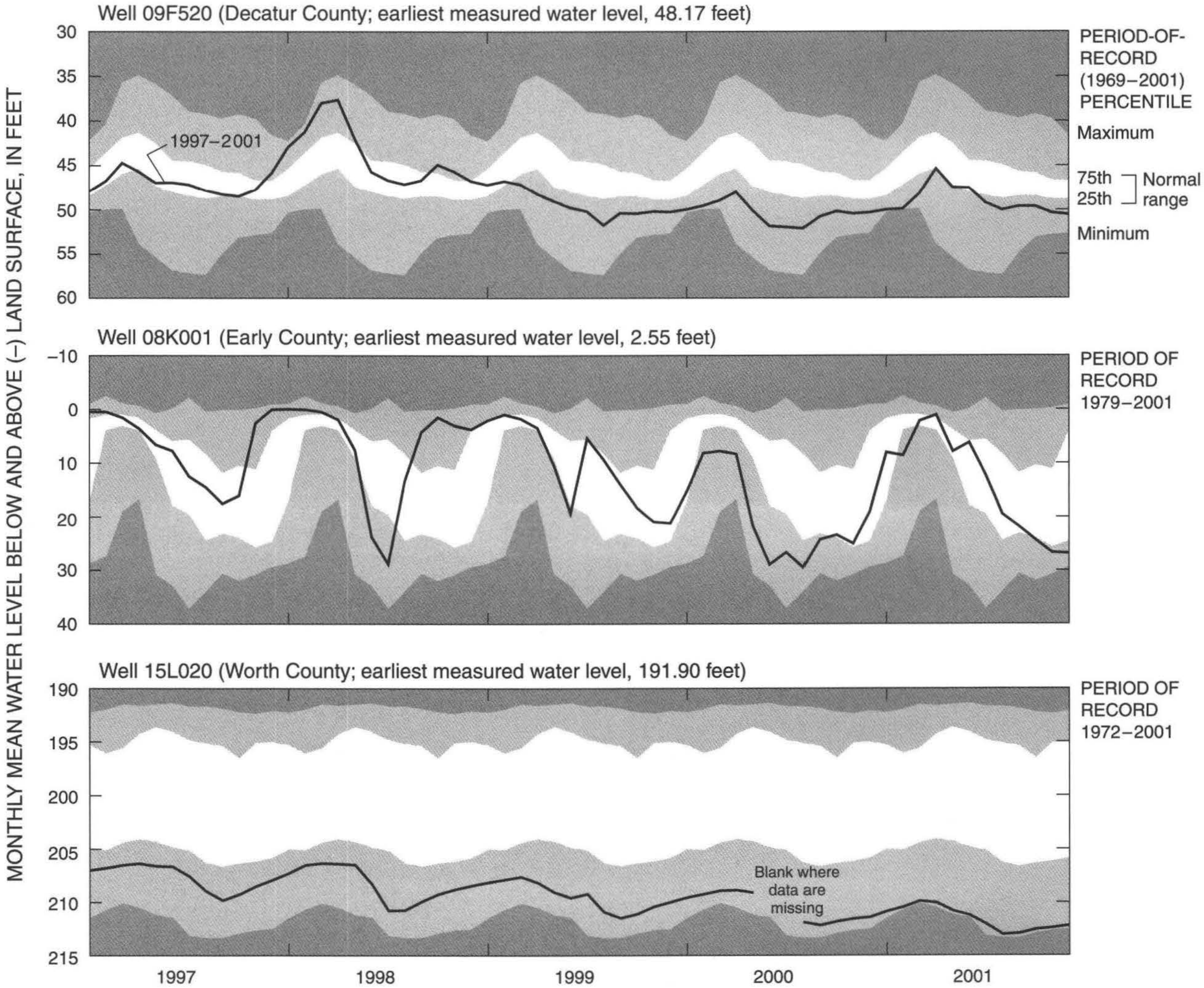
Torak, L.J., and McDowell, R.J., 1996, Ground-water resources of the lower Apalachicola–Chattahoochee–Flint River Basin in parts of Alabama, Florida, and Georgia—Subarea 4 of the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River Basins: U.S. Geological Survey Open-File Report 95-321, 145 p.

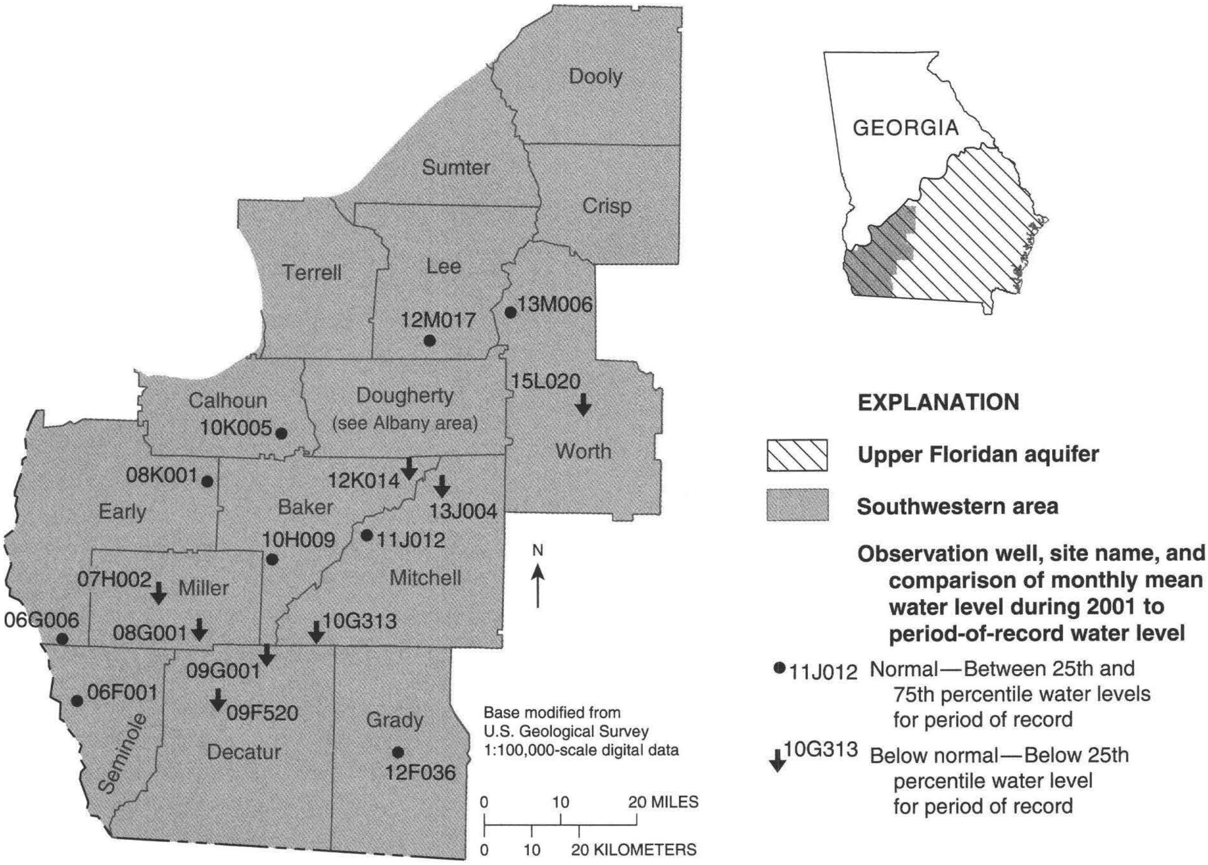
Upper Floridan Aquifer

Southwestern area

Water levels in 17 wells were used to define ground-water conditions in the Upper Floridan aquifer in south-western Georgia during 2001 (map, facing page). In this area, water in the Upper Floridan aquifer typically is confined; however, in areas where no sediments overlie the aquifer (typically to the north and west) water is unconfined. Water levels in 9 of the 17 wells were within the normal range during 2001. Water levels in the other eight wells in the area were below normal; these eight wells are located in areas where agricultural ground-water use is known to be prevalent.

Water-level hydrographs for three Upper Floridan aquifer wells in southwestern Georgia were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Drought effects are apparent from ground-water levels beginning during mid-1998 and continuing through 2001. Water levels in wells 09F520 and 08K001 show pronounced seasonal responses to climatic effects and irrigation pumpage. The water level in well 09F520 in Decatur County was at or above normal during 1997–98 but dropped below normal during 1999 and remained below normal through 2001. The water level in well 08K001 in Early County was at or above normal during 1997 and the beginning of 1998 and dropped below normal at least part of every year since. The water level in well 15L020 in Worth County has shown a downward trend for most of the period of record. The rate of this downward trend increased during early 1999 and by 2001 the water level in this well reached a record low. Here the aquifer is more deeply buried and water levels are influenced primarily by pumping changes.





Site name	County	Other identifier
10H009	Baker	Ichauway
12K014	Baker	Blue Springs, observation well
10K005	Calhoun	Bill Jordan, Ocala well
09F520	Decatur	Graham Bolton
09G001	Decatur	U.S. Geological Survey, test well DP-4
06G006	Early	Doug Harvey, test well 1
08K001	Early	Ike Newberry, test well 1
12F036	Grady	U.S. Geological Survey, Cairo
12M017	Lee	U.S. Geological Survey, test well 19
07H002	Miller	U.S. Geological Survey, test well DP-2
08G001	Miller	Viercocken
10G313	Mitchell	Harvey Meinders
11J012	Mitchell	U.S. Geological Survey, test well DP-11
13J004	Mitchell	Aurora Dairy
06F001	Seminole	Roddenbery Company Farms, test well 1
13M006	Worth	U.S. Geological Survey, test well DP-8
15L020	Worth	City of Sylvester

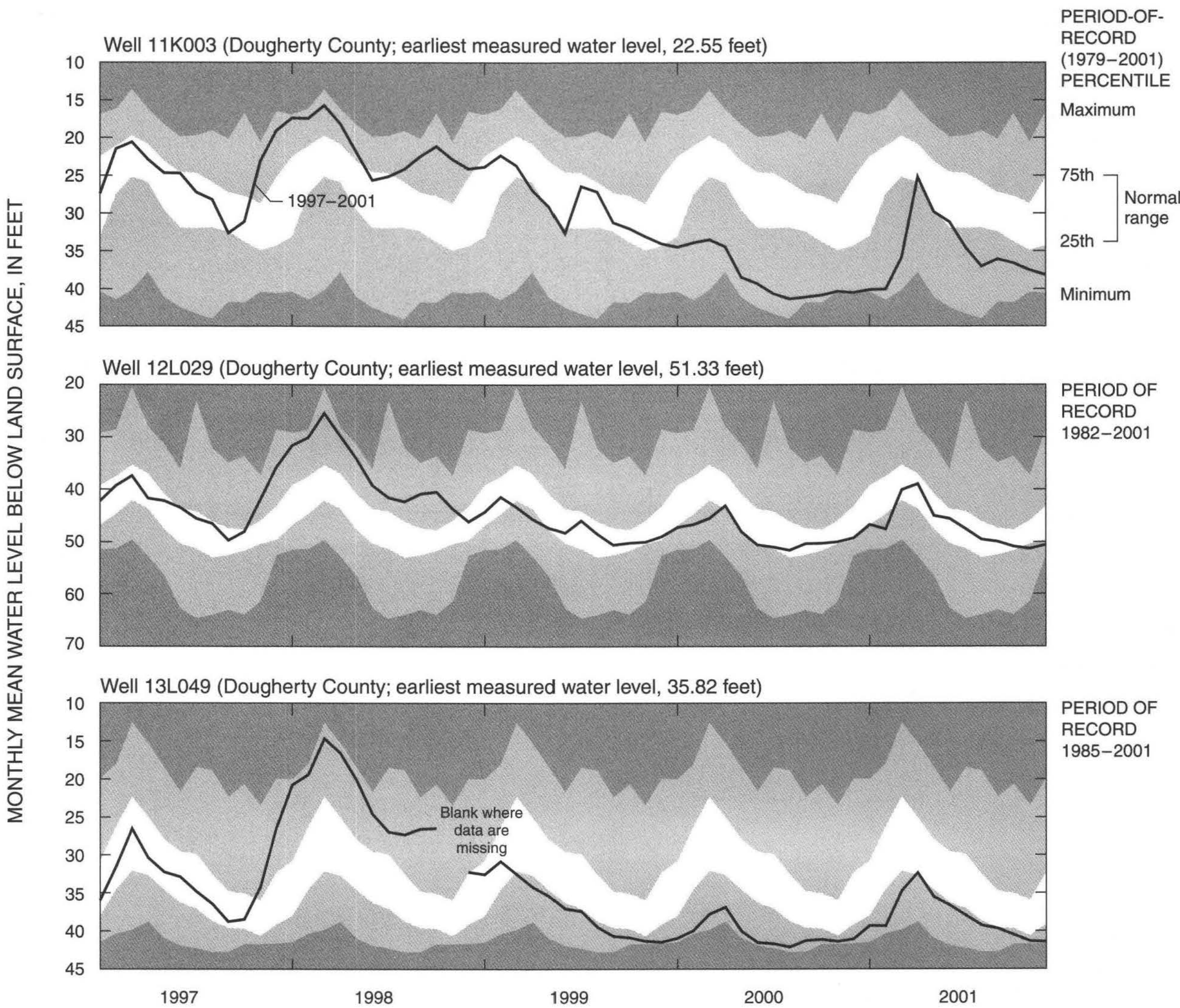
Upper Floridan Aquifer

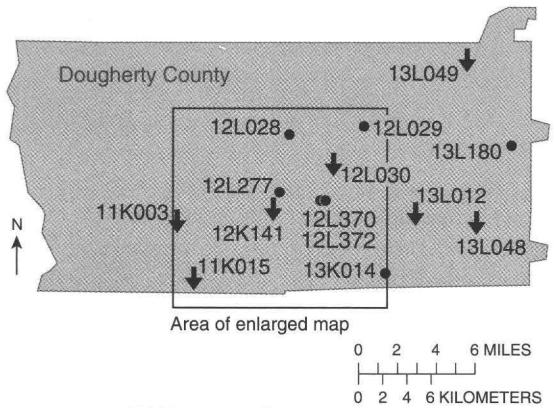
City of Albany–Dougherty County area

Water levels in 14 wells were used to define ground-water conditions in the Upper Floridan aquifer near Albany, Georgia, during 2001 (Dougherty County map, facing page). In this area, water in the Upper Floridan aquifer is confined. Water levels in 7 of the 14 wells were within the normal range during 2001. Water levels in the other seven wells were below normal.

Water-level hydrographs for three Upper Floridan aquifer wells in the Albany area (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Effects from drought are apparent from water-level declines of three wells beginning in mid-1998. The water level in well 11K003 in the southwest was at or above normal during 1997, 1998, and most of 1999, but dropped below normal for most of 2000 and 2001. The water level in well 12L029 in the northeastern area had a similar response to drought, except the water level returned to normal for most of 2001. The water level in well 13L049 also declined during 1998–2001 with the water level falling below normal earlier than in the other two wells.

In addition to continuous water-level monitoring, synoptic water-level measurements are periodically taken in wells in and around the Albany area. During November 2001, water-level measurements from 65 wells were taken and subsequently used to construct a map showing the potentiometric surface of the Upper Floridan aquifer. The potentiometric-contour map (facing page) shows that water generally flowed from northwest to southeast, toward the Flint River. A small mound was present in the center of the area. When this mound is present, water flows away from the mound in all directions. In the southeastern part of the mapped area, flow was away from the river to the southwest.





EXPLANATION

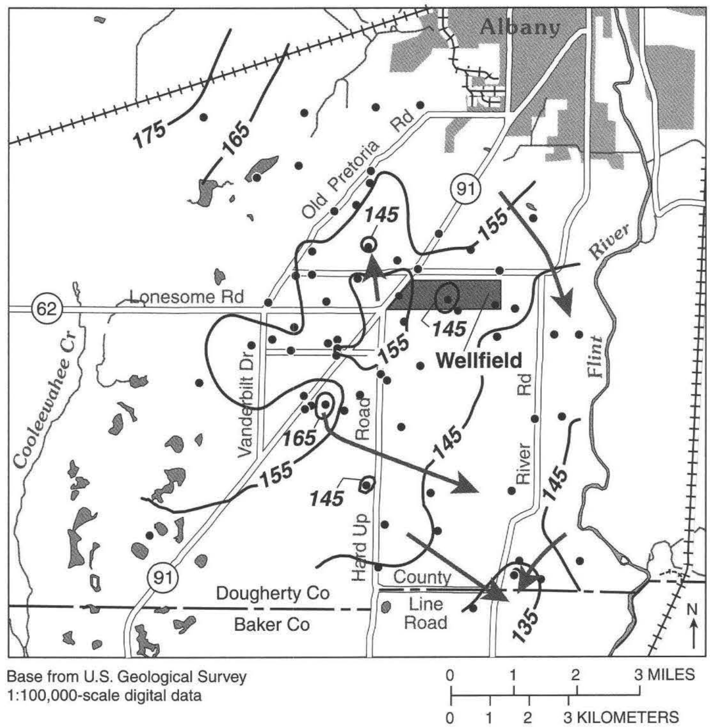
Upper Floridan aquifer

City of Albany–Dougherty County area

Observation well, site name, and comparison of monthly mean water level during 2001 to period-of-record water level

13K014 ● Normal—Between 25th and 75th percentile water levels for period of record

12K141 ↓ Below normal—Below 25th percentile water level for period of record



EXPLANATION

—*165*— **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells during November 2001. Contour interval 10 feet. Datum is NAVD 88

Direction of ground-water flow

● **Well**

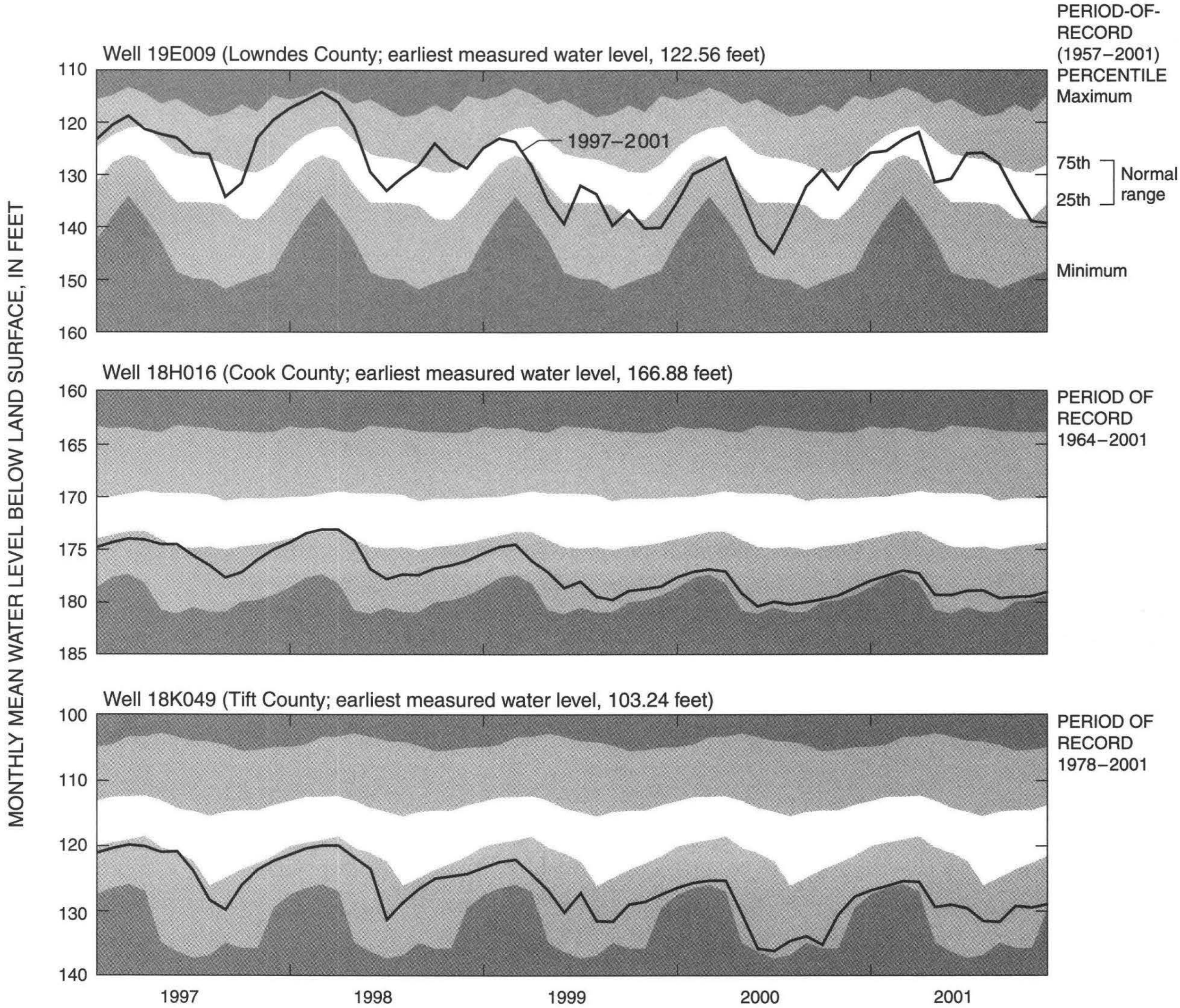
Site name	County	Other identifier
11K003	Dougherty	Nilo test well, north
11K015	Dougherty	U.S. Geological Survey, test well 14
12K141	Dougherty	Albany Water, Gas, and Light Commission, A750
12L028	Dougherty	Vandy W. Musgrove
12L029	Dougherty	U.S. Geological Survey, test well 13
12L030	Dougherty	U.S. Geological Survey, test well 16
12L277	Dougherty	Albany Water, Gas, and Light Commission, test well 1
12L370	Dougherty	Albany Water, Gas, and Light Commission, MW-100D
12L372	Dougherty	Albany Water, Gas, and Light Commission, MW-100I
13K014	Dougherty	U.S. Geological Survey, test well 15
13L012	Dougherty	U.S. Geological Survey, test well 3
13L048	Dougherty	U.S. Geological Survey, test well 17
13L049	Dougherty	Miller Ammo Supply
13L180	Dougherty	Marine Corps Logistic Base, core hole 3

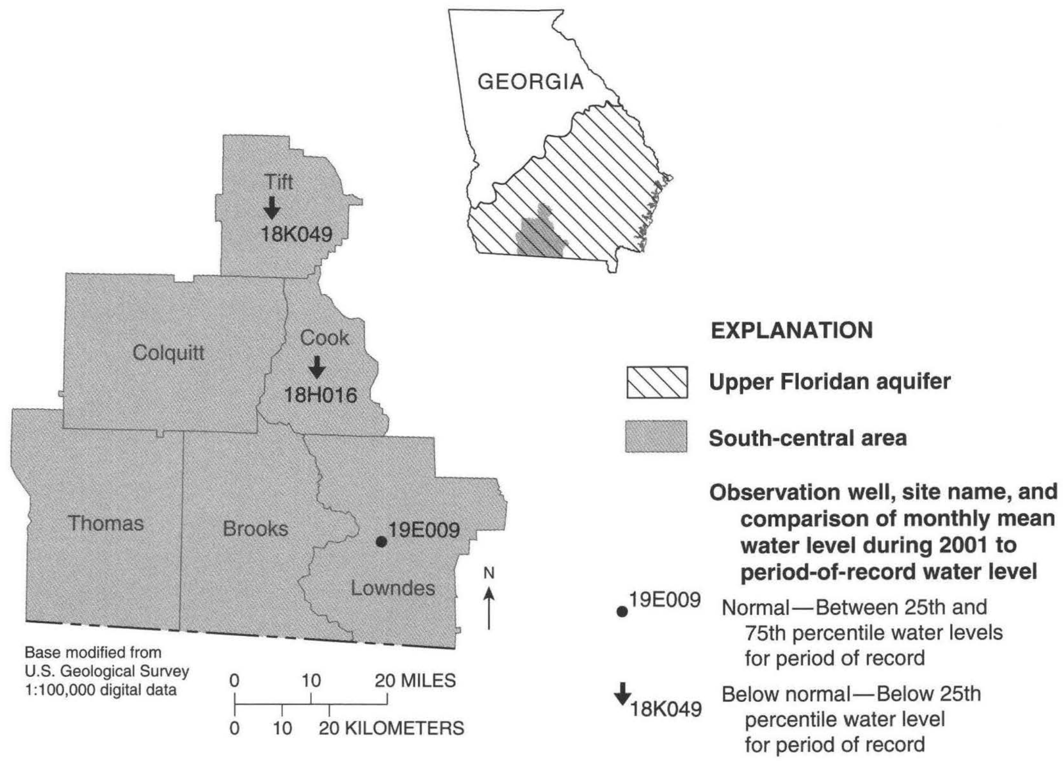
Upper Floridan Aquifer

South-Central area

Water levels in three wells were used to define ground-water conditions in the Upper Floridan aquifer in south-central Georgia during 2001 (map and table, facing page). In this area, water in the Upper Floridan aquifer is generally confined, but is locally unconfined in areas of karst features in Lowndes County. Water levels in two of the three wells were below normal during 2001.

Water-level hydrographs for the three Upper Floridan aquifer wells in south-central Georgia illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Drought effects are apparent in the three wells beginning mid-1998. The water level in well 19E009 in Lowndes County was at or above normal during 1997–98, but dropped below normal for most of 1999 and early 2000. During 2001, the water level recovered to normal until the last few months of the year when the water level declined to below normal. Here, the water level shows a more pronounced response to climatic effects because of the well's proximity to karst features. In the other two wells, climatic effects are less pronounced, and water levels are influenced primarily by pumping. The hydrograph for well 18H016 in Cook County shows a downward trend for most of the period of record; however, the rate of the trend increased in early 1999 and by early 2001, the water level in the well was near a record low. The hydrograph for well 18K049 in Tift County shows a similar pattern in that the rate of long-term decline increased during early 1999; and by early 2001, the water level in the well also was near a record low.





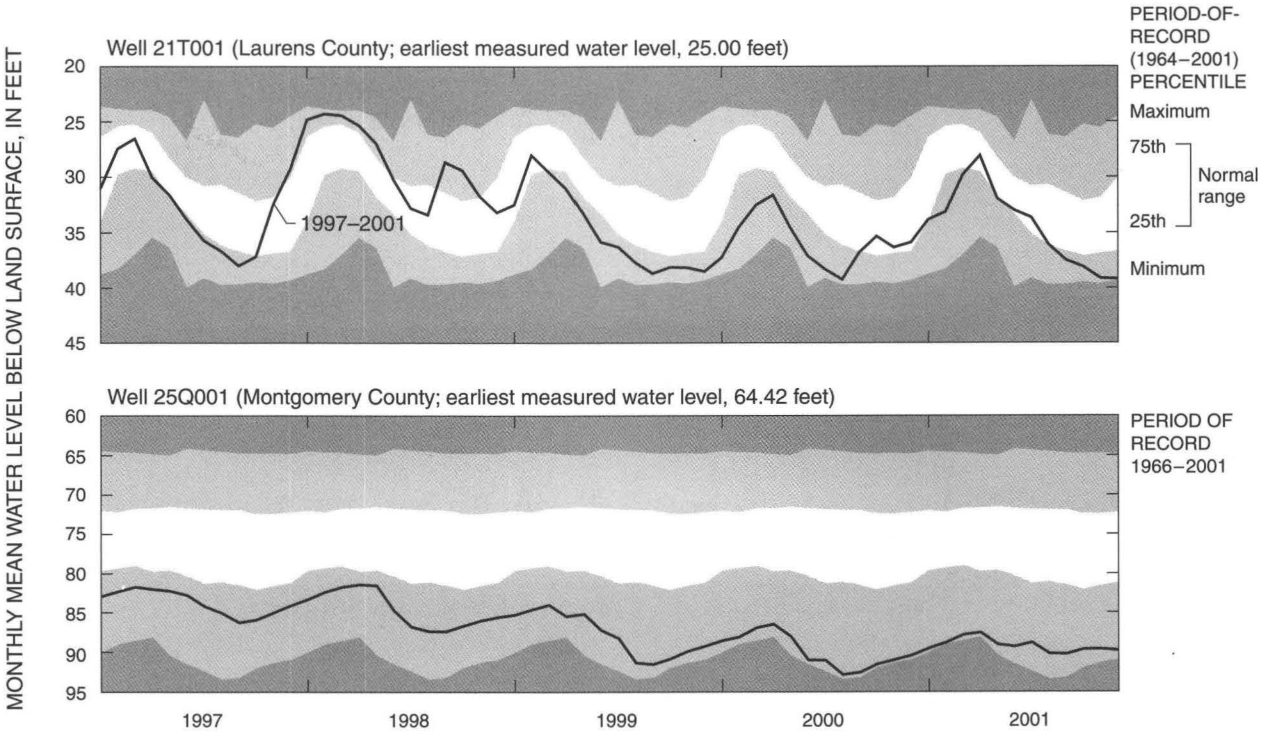
Site name	County	Other identifier
18H016	Cook	U.S. Geological Survey, Adel test well
19E009	Lowndes	City of Valdosta
18K049	Tift	U.S. Geological Survey, test well 1

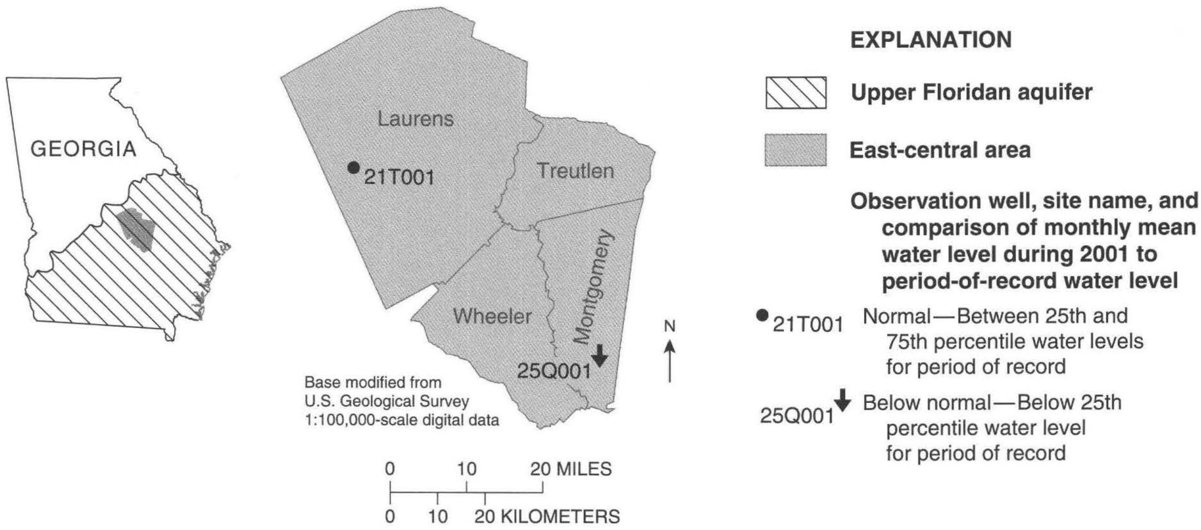
Upper Floridan Aquifer

East-Central area

Water levels in two wells were used to define ground-water conditions in the Upper Floridan aquifer in east-central Georgia during 2001 (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined to the southeast and is semiconfined to the northwest. The water level in one of the wells was within the normal range and in the other well was below normal during 2001.

Water-level hydrographs for both Upper Floridan aquifer wells in east-central Georgia illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Effects from drought are apparent in both wells beginning in early 1999. Well 21T001 in Laurens County is located in the northwestern part of the area, where the aquifer is semiconfined. The water level in the well was at or above normal during most of 1997–98, but dropped below normal for most of 1999, 2000 and 2001, and neared a record low by late 2001. Water levels in this area are influenced by climatic effects and agricultural pumping. Well 25Q001 in Montgomery County is located in an area where the aquifer is deeply buried and confined and is influenced by local and regional pumping. The water level in this well has shown a downward trend for most of the period of record. The rate of this downward trend increased during early 1999 and by mid-2000, the water level was near a record low, continuing through early 2001 after which a slight rise in water level is apparent.





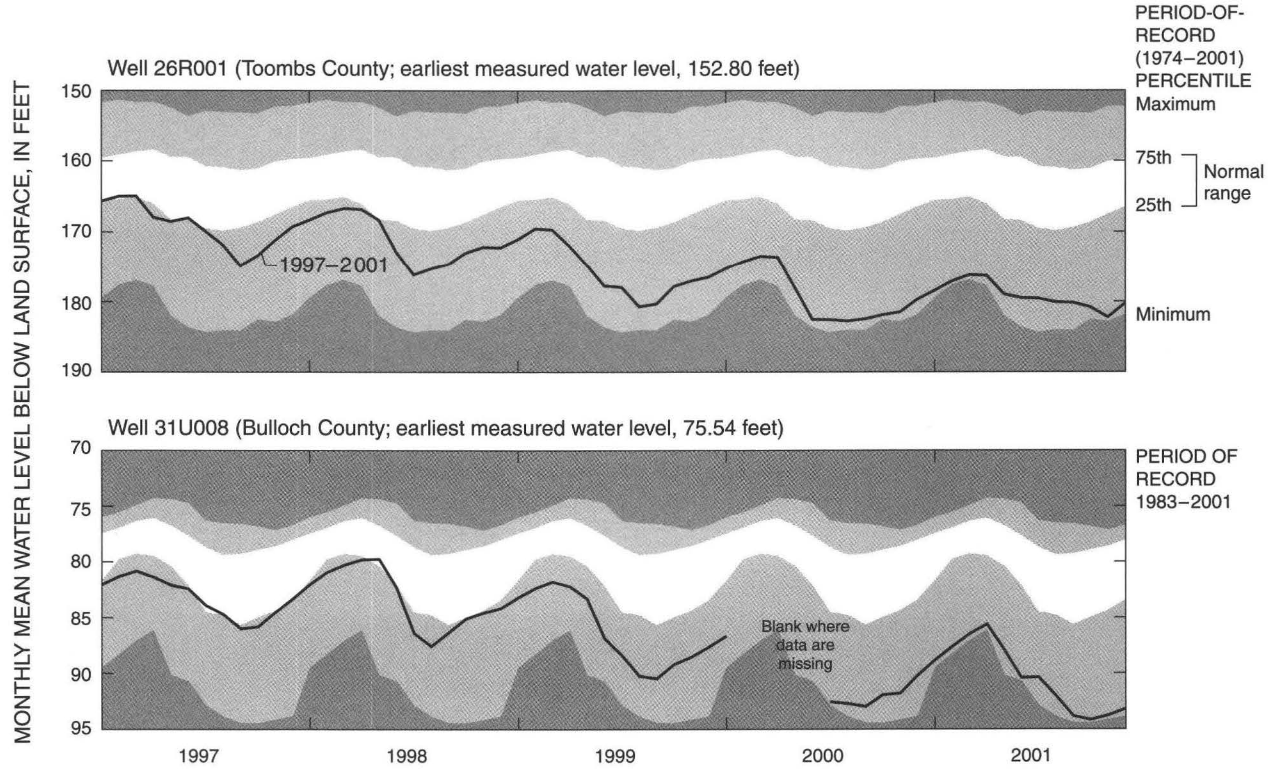
Site name	County	Other identifier
21T001	Laurens	Danny Hogan
25Q001	Montgomery	Montgomery County Board of Education

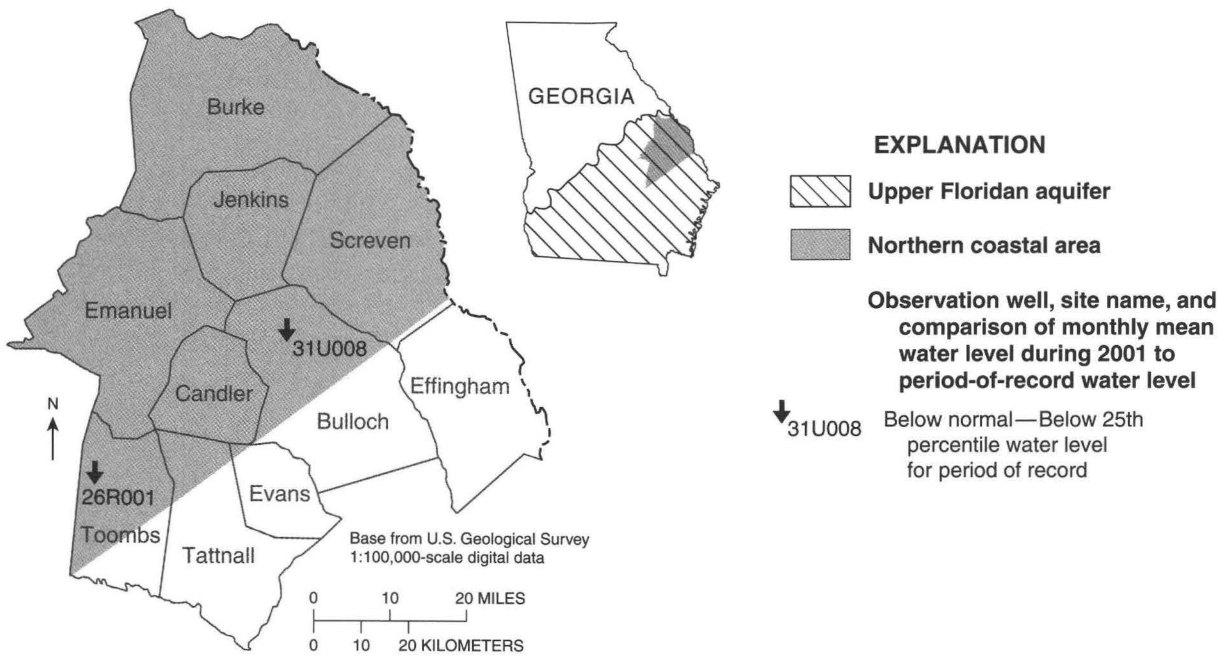
Upper Floridan Aquifer

Northern Coastal area

Water levels in two wells were used to define ground-water conditions in the Upper Floridan aquifer in the northern coastal area during 2001 (map and table, facing page). In this area, water in the Upper Floridan aquifer is both unconfined and confined. Water levels in both of the wells were below the normal range during 2001. Both wells are located in areas where agricultural water use is prevalent.

Water-level hydrographs for both Upper Floridan aquifer wells in northern coastal Georgia illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics (shown below). Drought effects are apparent in both wells. The water level in well 26R001 in Toombs County has a downward trend for most of the period of record; however, the rate of this downward trend increased during mid-1998 and by early 2001, the water level in this well was near a record low. The water level in well 31U008 in Bulloch County also was below normal because of long-term declines; however, during early 1999 the hydrograph shows that the rate of decline increased and the water level neared a record low by mid-2000.





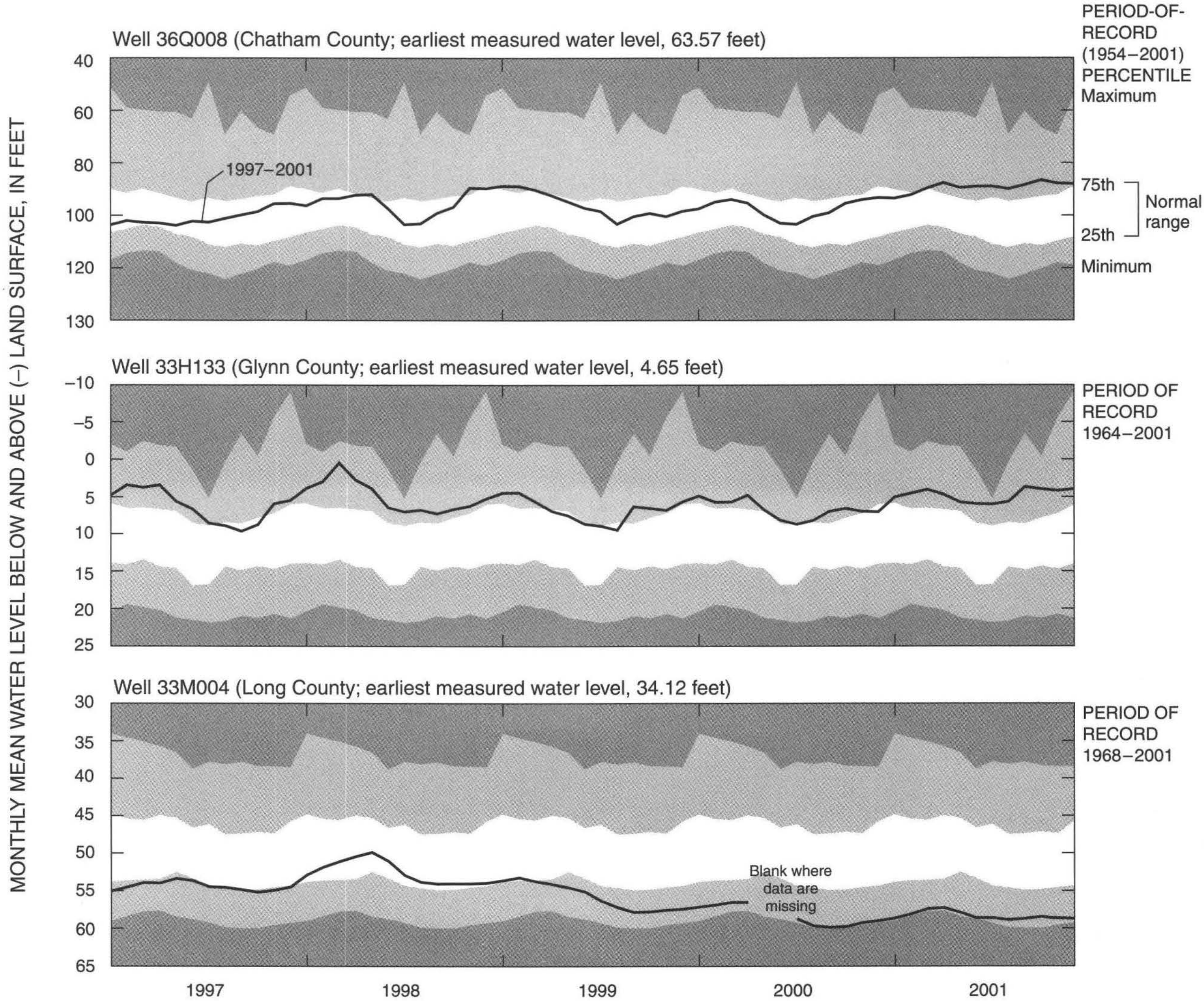
Site name	County	Other identifier
26R001	Toombs	City of Vidalia, well 2
31U008	Bulloch	Georgia Geologic Survey, Hopeulikit, test well 1

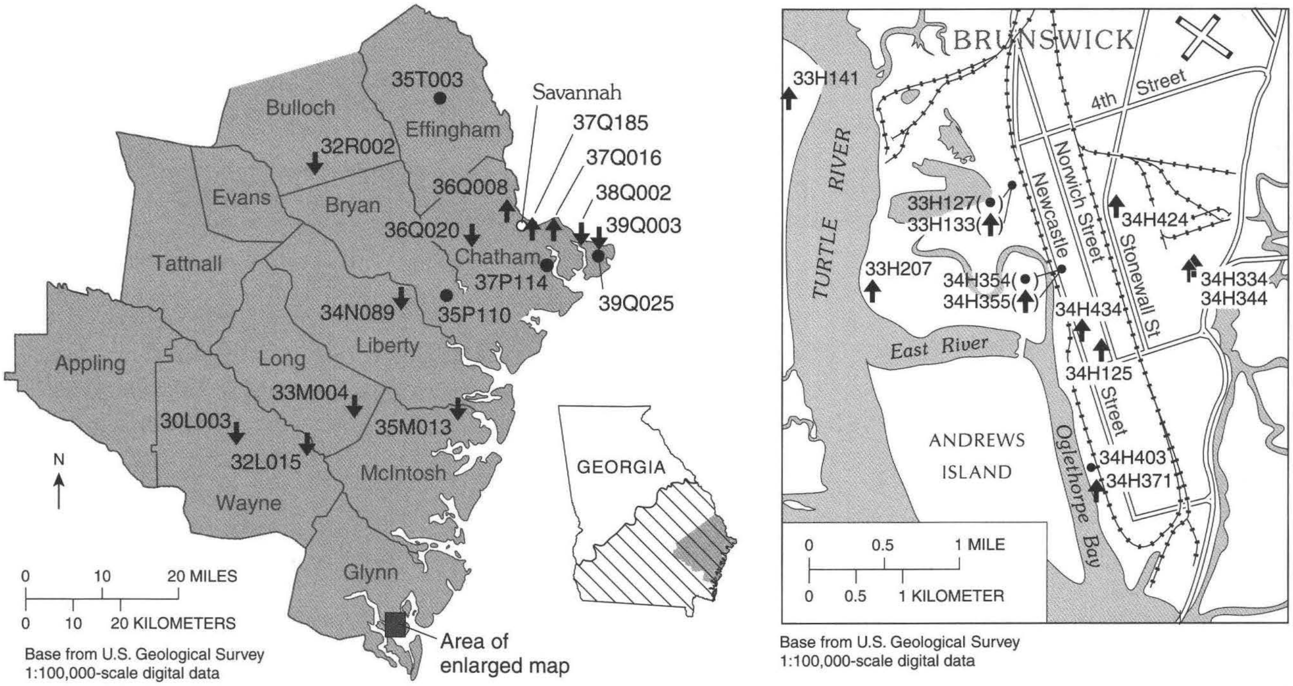
Upper Floridan Aquifer

Central Coastal area

Water levels in 29 wells were used to define ground-water conditions in the Upper Floridan aquifer in the central coastal area of Georgia during 2001 (map and inset, facing page). In this area, water in the Upper Floridan aquifer is confined and influenced primarily by pumpage. Water levels in 7 wells were within the normal range, water levels in 9 wells were below normal, and water levels in 13 wells were above normal. Wells with water levels in the normal to above-normal range typically are located near the cities of Savannah and Brunswick where water use is primarily for industrial and public supply. Water-level rises in these areas occurred as a result of conservation and decreased water use. Wells with water levels below normal during 2001 are mostly in areas farther away from the Savannah and Brunswick pumping centers, reflecting changing pumping patterns in those areas.

Water-level hydrographs for three Upper Floridan aquifer wells in the central coastal area of Georgia (shown below), were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. The water level in well 36Q008 near Savannah in Chatham County was normal or above normal from 1997 to 2001—likely due to a decrease in water use from conservation (Julia L. Fanning, U.S. Geological Survey, oral commun. with David C. Leeth, 2002). Similarly, the water level in well 33H133 at Brunswick in Glynn County has been at or above normal since 1997—likely due to decreased water use. The hydrograph for well 33M004 in Long County shows a long-term decline with the water level declining below normal during early 1999 and continuing through 2001.





EXPLANATION

(hatched)	**Upper Floridan aquifer**
(shaded)	**Central coastal area**

Observation well, site name, and comparison of monthly mean water level during 2001 to period-of-record water level

- ↑ 37Q016 — Above normal—Above 75th percentile water level for period of record
- ● 35T003 — Normal—Between 25th and 75th percentile water levels for period of record
- ↓ 39Q003 — Below normal—Below 25th percentile water level for period of record

Site name	County	Other identifier
35P110	Bryan	Richmond Hill, test well
32R002	Bulloch	Georgia Geologic Survey, Bulloch South, test well 1
36Q008	Chatham	Lance-Atlantic Company
36Q020	Chatham	H.J. Morrison
37P114	Chatham	Georgia Geologic Survey, Skidaway Institute, test well 2
37Q016	Chatham	East Coast Terminal well
37Q185	Chatham	U.S. Geological Survey, Hutchinson Island, test well 1
38Q002	Chatham	U.S. National Park Service, test well 6
39Q003	Chatham	U.S. Geological Survey, test well 7
39Q025	Chatham	Tybee Island, test well 2
35T003	Effingham	City of Springfield
33H127	Glynn	U.S. Geological Survey, test well 3
33H133	Glynn	U.S. Geological Survey, test well 6
33H141	Glynn	U.S. Geological Survey, test well 12

Site name	County	Other identifier
33H207	Glynn	Georgia-Pacific, south, test well 2
34H125	Glynn	U.S. Geological Survey, test well 1
34H334	Glynn	U.S. Geological Survey, test well 4
34H344	Glynn	U.S. Geological Survey, test well 7
34H354	Glynn	U.S. Geological Survey, test well 8
34H355	Glynn	U.S. Geological Survey, test well 9
34H371	Glynn	U.S. Geological Survey, test well 11
34H403	Glynn	U.S. Geological Survey, test well 24
34H424	Glynn	Hercules Inc., T well
34H434	Glynn	Glynn County Courthouse (deep)
34N089	Liberty	U.S. Geological Survey, test well 1
33M004	Long	U.S. Geological Survey, test well 3
35M013	McIntosh	U.S. Fish and Wildlife Service, Harris Neck 1
30L003[1]	Wayne	City of Jesup Housing Authority
32L015	Wayne	Georgia Geologic Survey, Gardi, test well 1

[1] Well completed in upper and lower Brunswick aquifers and the Upper Floridan aquifer

Upper Floridan Aquifer

Southern Coastal area

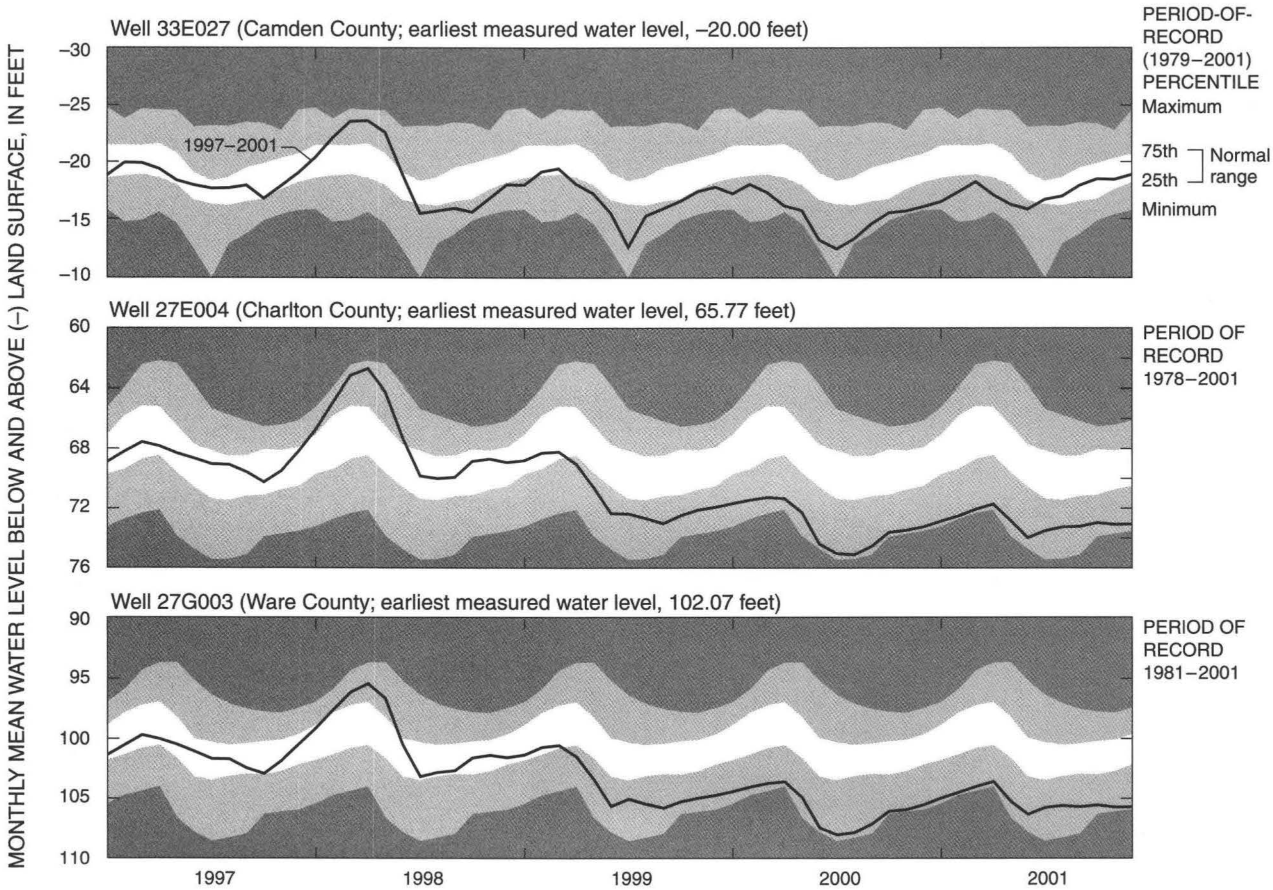
Water levels in six wells were used to define ground-water conditions in the Upper Floridan aquifer in the southern coastal area of Georgia during 2001 (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined and influenced mostly by pumping in the St Marys, Georgia–Fernandina Beach, Florida, area to the east, and by climatic effects and pumping to the west. The water level in one well in Camden County was within the normal range, and water levels in the remaining five wells were below normal.

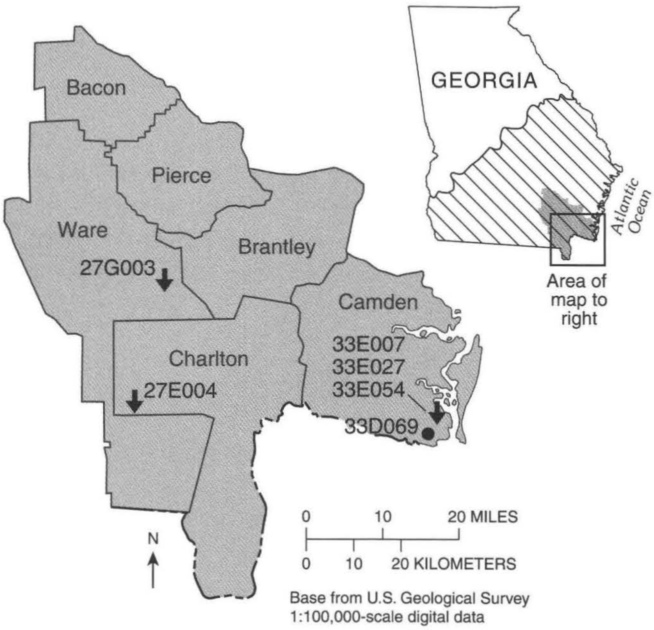
Water-level hydrographs for three Upper Floridan aquifer wells in the central coastal area (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Water-level declines are apparent in these three wells beginning in mid-1998 and continuing to early 2001. The water level in well 33E027 in Camden County was at or above normal during 1997–98, but dropped below normal for most of 1999 and early 2000. During 2001, the water level recovered to normal after the first few months of the year. The water level in well 27E004 in Charlton County was above normal until early 1999 when the water level dropped below normal; by late 2000, the water level in the well was at or near a record low. A hydrograph for well 27G003 in Ware County shows an almost identical pattern to that of well 27E004.

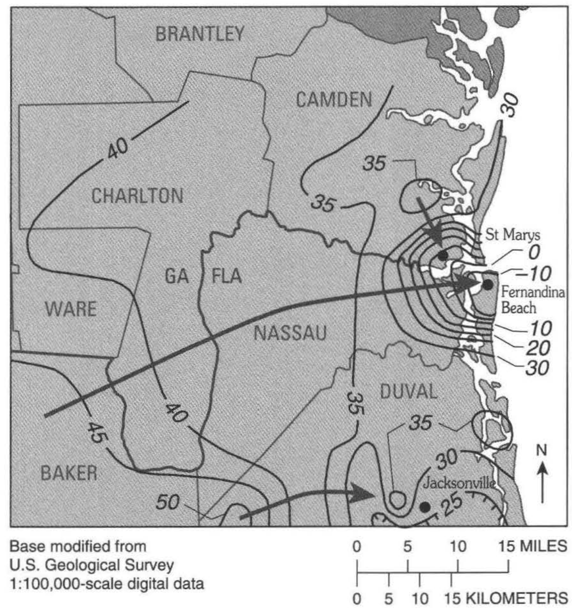
In addition to continuous water-level monitoring, synoptic water-level measurements are taken periodically, in cooperation with the St. Johns River Water Management District, in wells in and around the southern coastal area of Georgia and adjacent parts of Florida. During September 12–15, 2001, water levels were measured in 52 wells and subsequently used to construct a potentiometric-surface map of the Upper Floridan aquifer. The map (inset, facing page) shows that water generally flowed from west to east, toward the Atlantic Ocean, and pumping centers at St Marys, Georgia–Fernandina Beach, Florida, and Jacksonville, Florida.

Reference Cited

Knowles, Leel, Jr., and Kinnaman, S.L., 2002, Potentiometric surface of the Upper Floridan aquifer in the St. Johns River Water Management District and vicinity, Florida, September 2001: U.S. Geological Survey Open-File Report 02-182, 1 sheet.







EXPLANATION

Upper Floridan aquifer

Southern coastal area

Observation well, site name, and comparison of monthly mean water level during 2001 to period-of-record water level

33D069 ● Normal—Between 25th and 75th percentile water levels for period of record

33E054 ↓ Below normal—Below 25th percentile water level for period of record

EXPLANATION

— *45* — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells during September 2001. Hachures indicate depressions. Contour intervals 5 and 10 feet. Datum is NAVD 88. (Modified from Knowles and Kinnaman, 2002)

⟶ **Direction of ground-water flow**

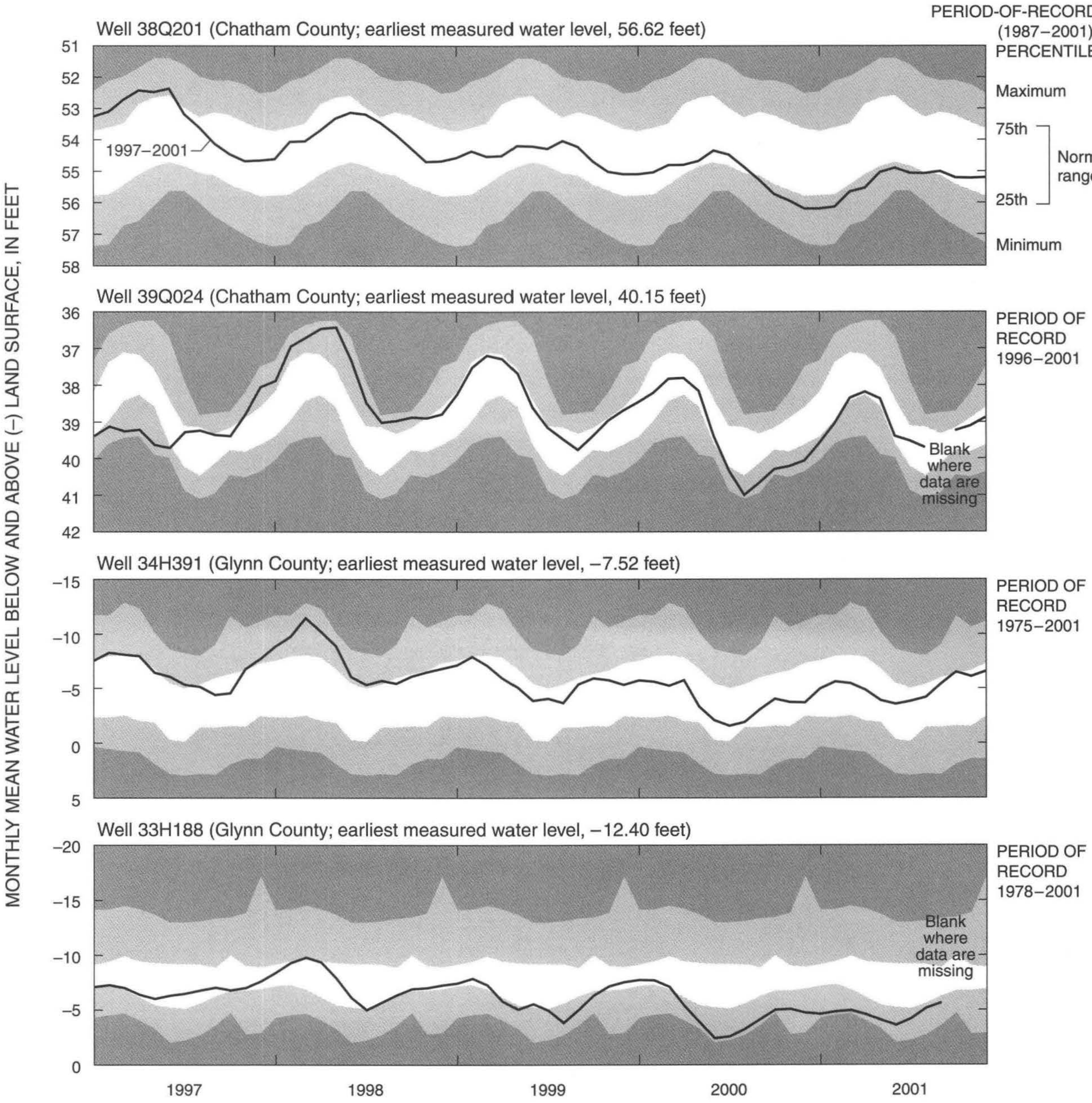
Site name	County	Other identifier
33D069	Camden	U.S. National Park Service, Cumberland Island National Seashore
33E007	Camden	Huntly-Jiffy
33E027	Camden	U.S. Navy, Kings Bay, test well 1
33E054	Camden	Rayland Company No. 1
27E004	Charlton	U.S. Geological Survey, test well OK-9
27G003[1]	Ware	U.S. Geological Survey, test well 1

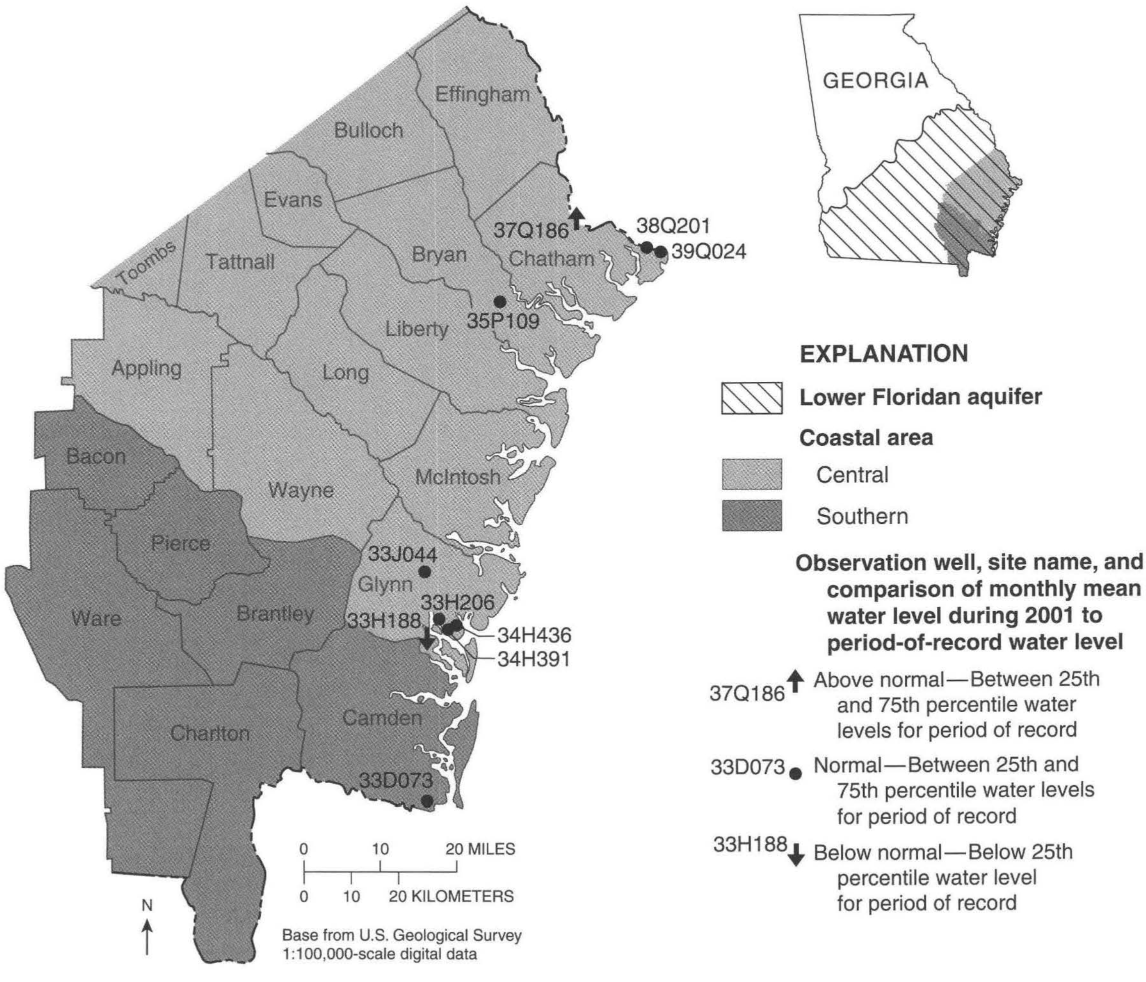
[1] Well completed in both Upper and Lower Floridan aquifers, with most contribution from the Upper Floridan aquifer

Lower Floridan Aquifer and Underlying Units in Coastal Georgia

Water levels in 10 wells were used to define ground-water conditions in the Lower Floridan aquifer and underlying units in central and southern coastal Georgia during 2001 (map and table, facing page). In this area, water in the Lower Floridan aquifer is confined and influenced mostly by pumping. Water levels in 9 of the 10 wells were within or above the normal range during 2001. The water level in one well was below normal.

Water-level hydrographs for four Lower Floridan aquifer wells in coastal Georgia, (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Water levels in all four wells declined from 1998 to mid-2000. In wells 38Q201 and 39Q024 in Chatham County, water levels were generally at or above normal during 1997–2001. Water levels dropped below normal in well 38Q201 in 2000, and in well 39Q024 during 1997 and 2000. Although the water level in well 34H391 in Glynn County declined during 1999–2000, it was within the normal range throughout 1997–2001. In well 33H188, the water level was below normal during parts of 1998–2001.





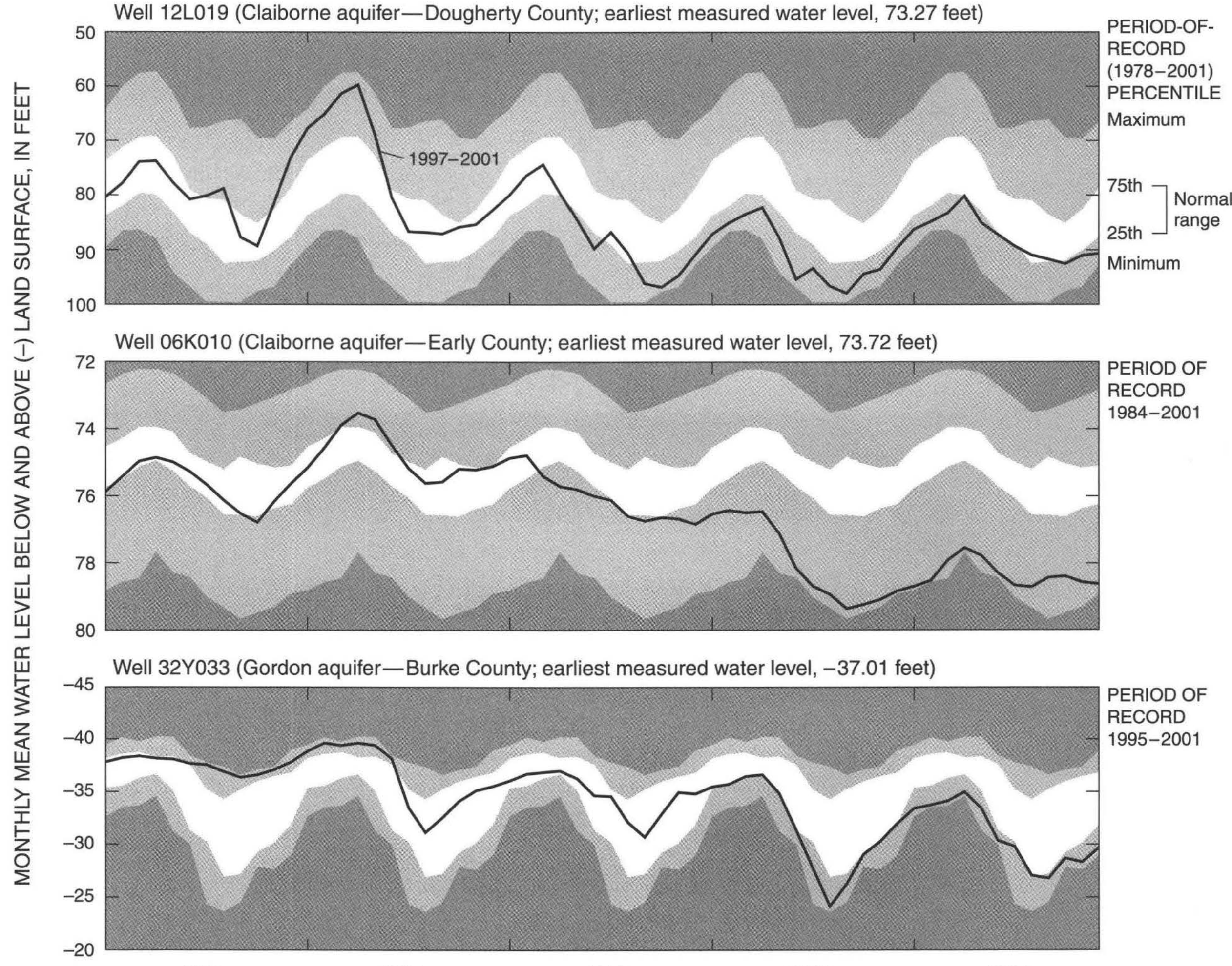
Site name	Water-bearing unit	County	Other identifier
35P109	LF	Bryan	Richmond Hill, test well
33D073	LF	Camden	St Marys, test well (deep)
37Q186	P	Chatham	Hutchinson Island, test well 2
38Q201	P	Chatham	Georgia Geologic Survey, Fort Pulaski, test well
39Q024	LF	Chatham	Georgia Geologic Survey, Tybee Island, test well 1
33H188	F	Glynn	U.S. Geological Survey, test well 26
33H206	LF	Glynn	Georgia-Pacific, south, test well 1
33J044	LF	Glynn	U.S. Geological Survey, test well 27
34H391	LF	Glynn	U.S. Geological Survey, test well 16
34H436	LF	Glynn	Georgia Geologic Survey, Coffin Park, test well 1

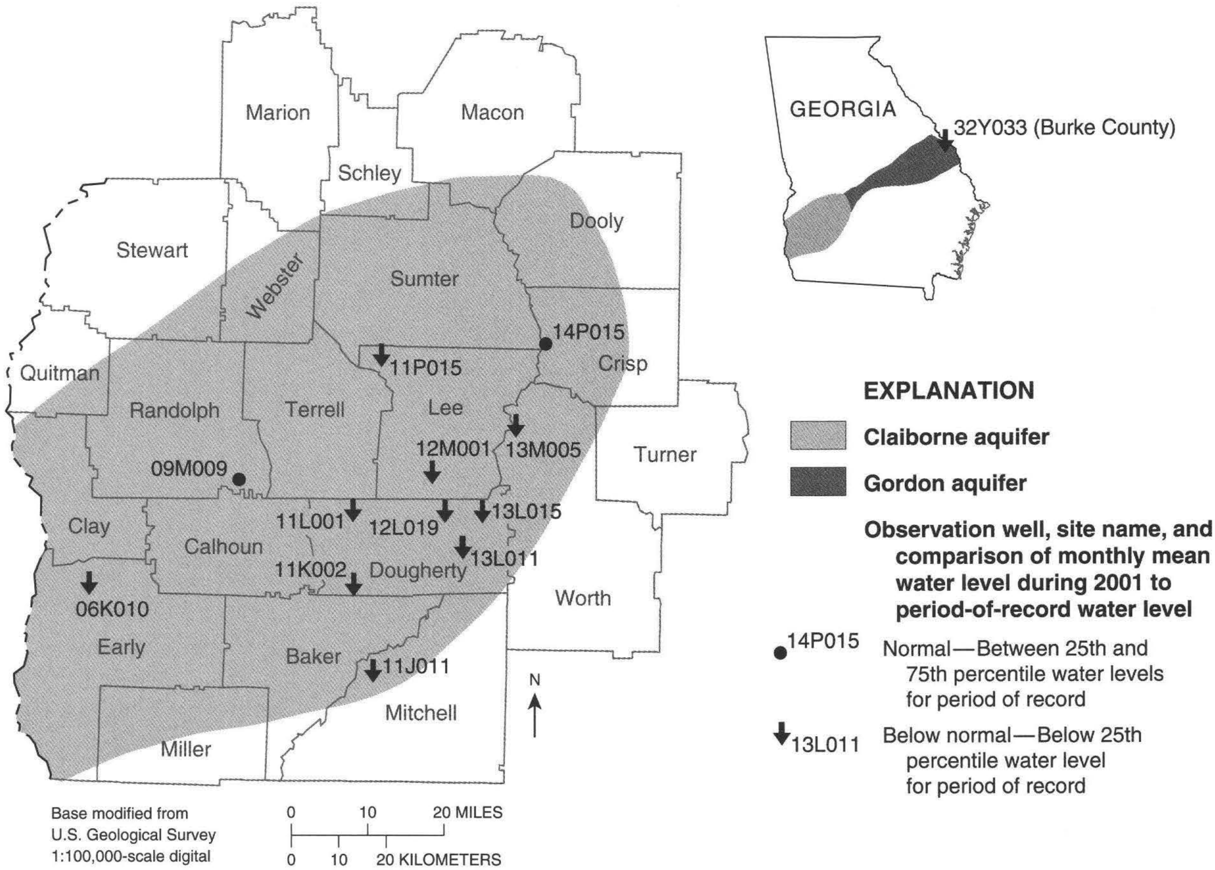
[1] LF, Lower Floridan aquifer; P, Paleocene unit of low permeability; F, Fernandina permeable zone

Claiborne and Gordon Aquifers

Water levels in 12 Claiborne aquifer wells and 1 Gordon aquifer well were used to define ground-water conditions in southwest and east-central Georgia during 2001 (map and table, facing page). Water in the Claiborne and Gordon aquifers can be confined or unconfined. Water levels in 10 of the 12 Claiborne aquifer wells and 1 Gordon aquifer well were below normal during 2001, likely reflecting pumping effects during drought.

Water levels in two Claiborne aquifer wells and one Gordon aquifer well (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Water levels in all three wells declined during 1998–2000. Water levels fell below normal during early 1999 and remained mostly below normal during 1999–2001 in Claiborne aquifer wells 12L019 in Dougherty County and 06K010 in Early County. The water level in the Gordon aquifer well 32Y033 in Burke County was mostly below normal in 2000–01.





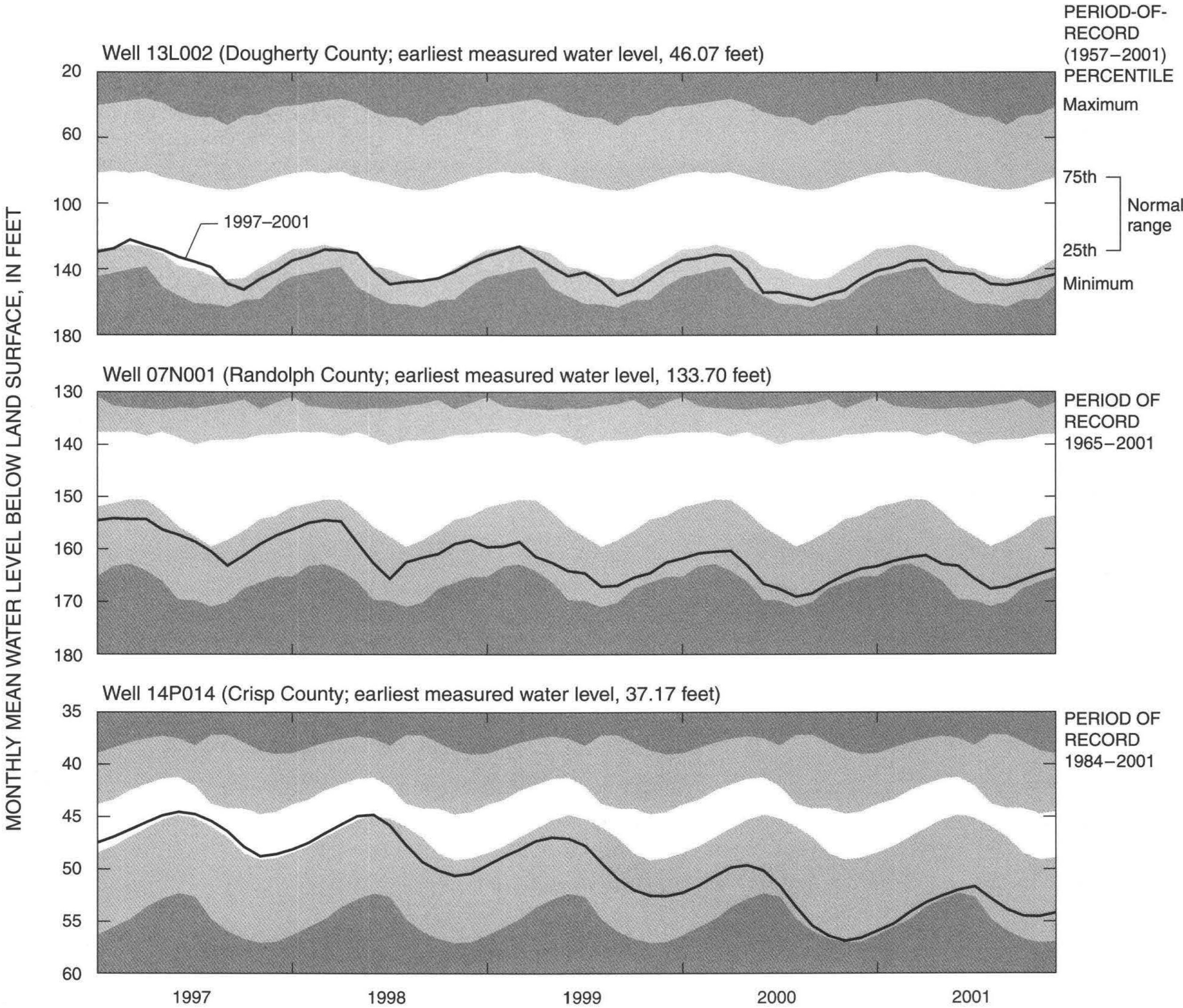
Site name	Aquifer[1]	County	Other identifier
14P015	C	Crisp	Georgia Geologic Survey, Veteran's Memorial State Park, test well 2
11K002	C	Dougherty	U.S. Geological Survey, test well 11
11L001	C	Dougherty	U.S. Geological Survey, test well 4
12L019	C	Dougherty	U.S. Geological Survey, test well 5
13L011	C	Dougherty	U.S. Geological Survey, test well 2
13L015	C	Dougherty	Miller Brewing Company
06K010	C	Early	Georgia Geologic Survey, Kolomoki Mounds State Park, test well 3
11P015	C	Lee	Pete Long, test well 2
12M001	C	Lee	U.S. Geological Survey, test well 8
11J011	C	Mitchell	U.S. Geological Survey, test well DP-10
09M009	C	Randolph	C.T. Martin, test well 1
13M005	C	Worth	U.S. Geological Survey, test well DP-7
32Y033	G	Burke	Brighams Landing, test well 3

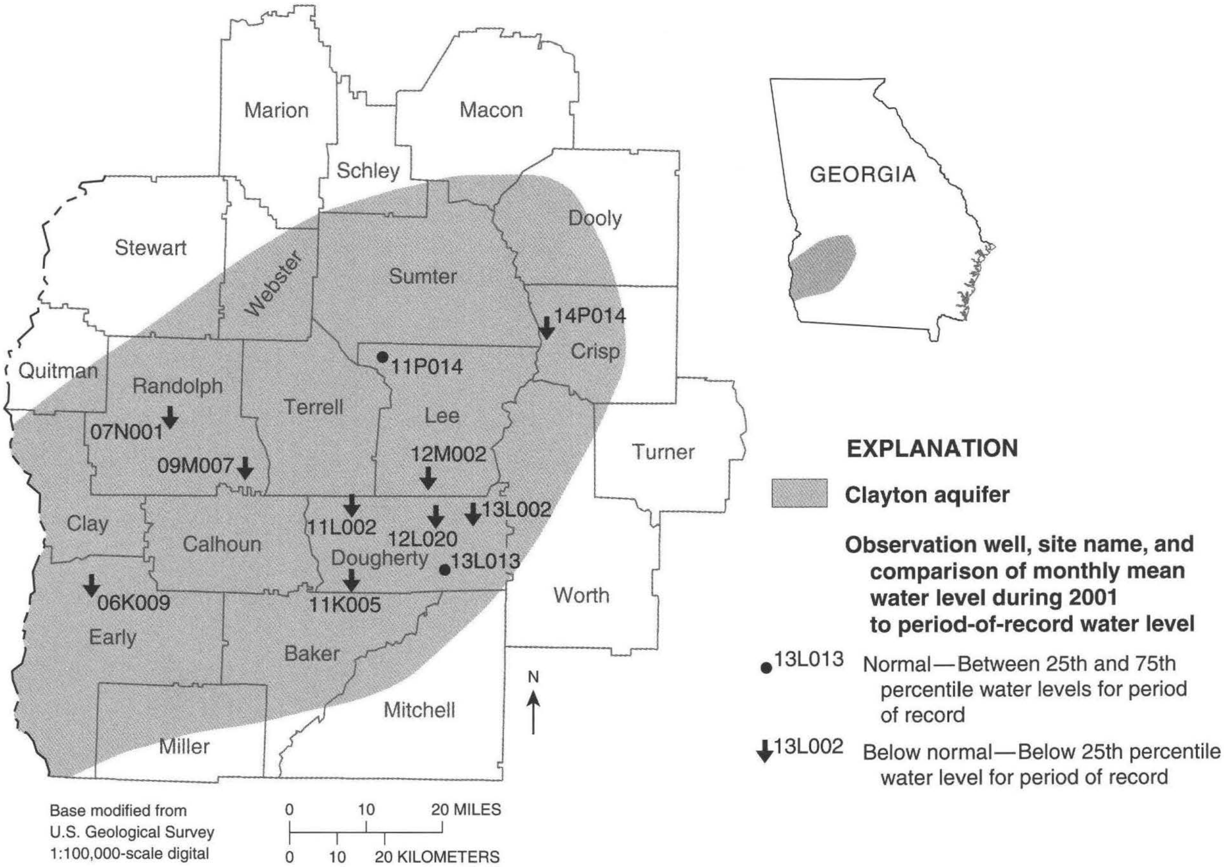
[1] C, Claiborne aquifer; G, Gordon aquifer

Clayton Aquifer

Water levels in 11 wells were used to define ground-water conditions in the Clayton aquifer in southwest Georgia during 2001 (map, facing page). In this area, water in the Clayton aquifer is confined and influenced mostly by pumping. Water levels in 9 of the 11 wells were below normal.

Water-level hydrographs for three Clayton aquifer wells in southwest Georgia (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Water levels in the three wells generally declined and were below the normal range during most of 1997–2001. The rate of water-level decline increased in well 13L002 in Dougherty County and well 07N001 in Randolph County in late 1997 and continued through 2001, reflecting the effects of drought. During this period, water levels were below normal and neared record lows by late 2000. The water level in well 14P014 in Crisp County shows effects from drought beginning in the middle of 1998, nearing a record low in late 2000 and continuing below normal through 2001.



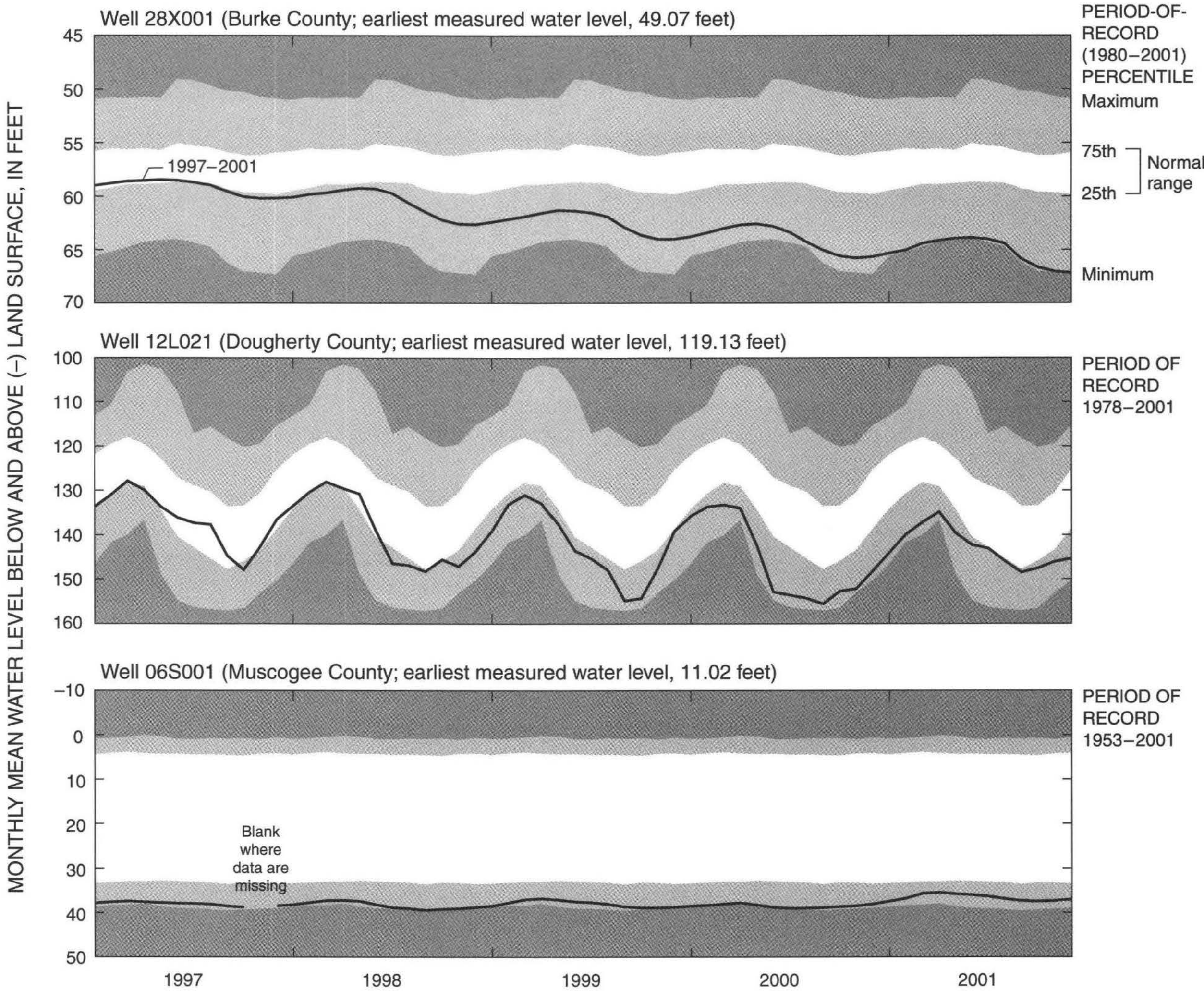


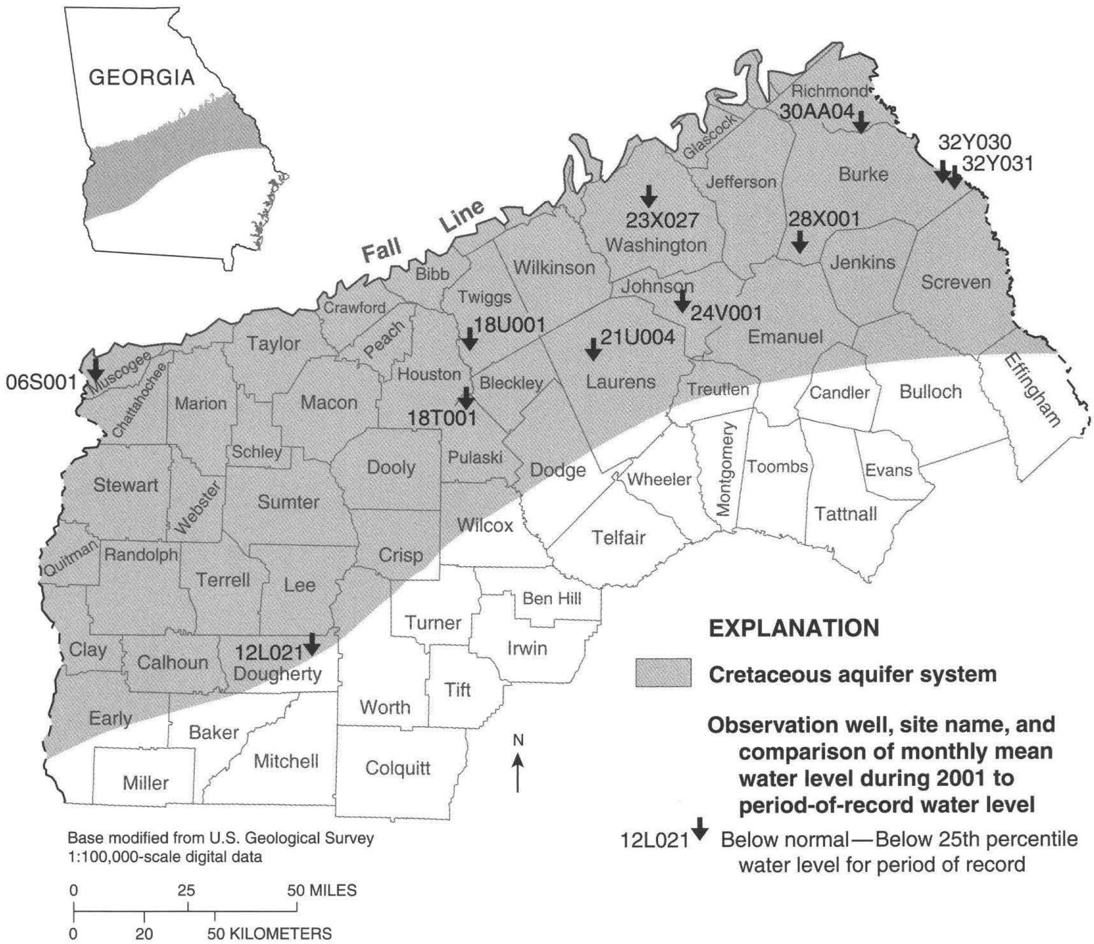
Site name	County	Other identifier
14P014	Crisp	Georgia Geologic Survey, Veteran's Memorial State Park, test well 1
11K005	Dougherty	U.S. Geological Survey, test well 12
11L002	Dougherty	Georgia Geologic Survey, Albany Nursery
12L020	Dougherty	U.S. Geological Survey, test well 6
13L002	Dougherty	Albany Water, Gas, and Light Commission, Turner City 2
13L013	Dougherty	U.S. Geological Survey, test well 7
06K009	Early	Georgia Geologic Survey, Kolomoki Mounds State Park, test well 1
11P014	Lee	Pete Long, test well 1
12M002	Lee	U.S. Geological Survey, test well 9
07N001	Randolph	City of Cuthbert
09M007	Randolph	C.T. Martin, test well 2

Cretaceous Aquifer System

Water levels from 11 wells that penetrate the Cretaceous aquifer system were used to define ground-water conditions throughout central Georgia during 2001 (map and table, facing page). In this area, water in the Cretaceous aquifer system mostly is confined but can be unconfined in stream valleys. Water levels in all 11 wells were below the normal range during 2001, reflecting declines related to ground-water pumping.

Water-level hydrographs for three Cretaceous aquifer system wells in central and southwestern Georgia (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Water levels in all three wells were generally below normal during 1997–2001. In well 28X001 in Burke County and well 12L021 in Dougherty County, water levels declined during 1997–2000. Record lows were reached in both wells during 2000. In well 06S001 in Muscogee County, the water level changed little during 1997–2001, but remained below normal because of long-term water-level declines.





Site name	Water-bearing unit[1]	County	Other identifier
28X001	M	Burke	U.S. Geological Survey, Midville, test well 1
32Y030	LM	Burke	Brighams Landing, test well 1
32Y031	LD	Burke	Brighams Landing, test well 2
06S001	T	Muscogee	U.S. Army, Fort Benning
12L021	P	Dougherty	U.S. Geological Survey, test well 10
24V001	M	Johnson	U.S. Geological Survey, test well 1
21U004	M	Laurens	Georgia Department of Natural Resources, No. 3
18T001	M	Pulaski	U.S. Geological Survey, Arrowhead test well 1
30AA04	DM	Richmond	Richmond County Water System, U.S. Geological Survey, McBean 2
18U001	D	Twiggs	Georgia Kraft, U.S. Geological Survey, test well 3
23X027	DM	Washington	City of Sandersville, well 8

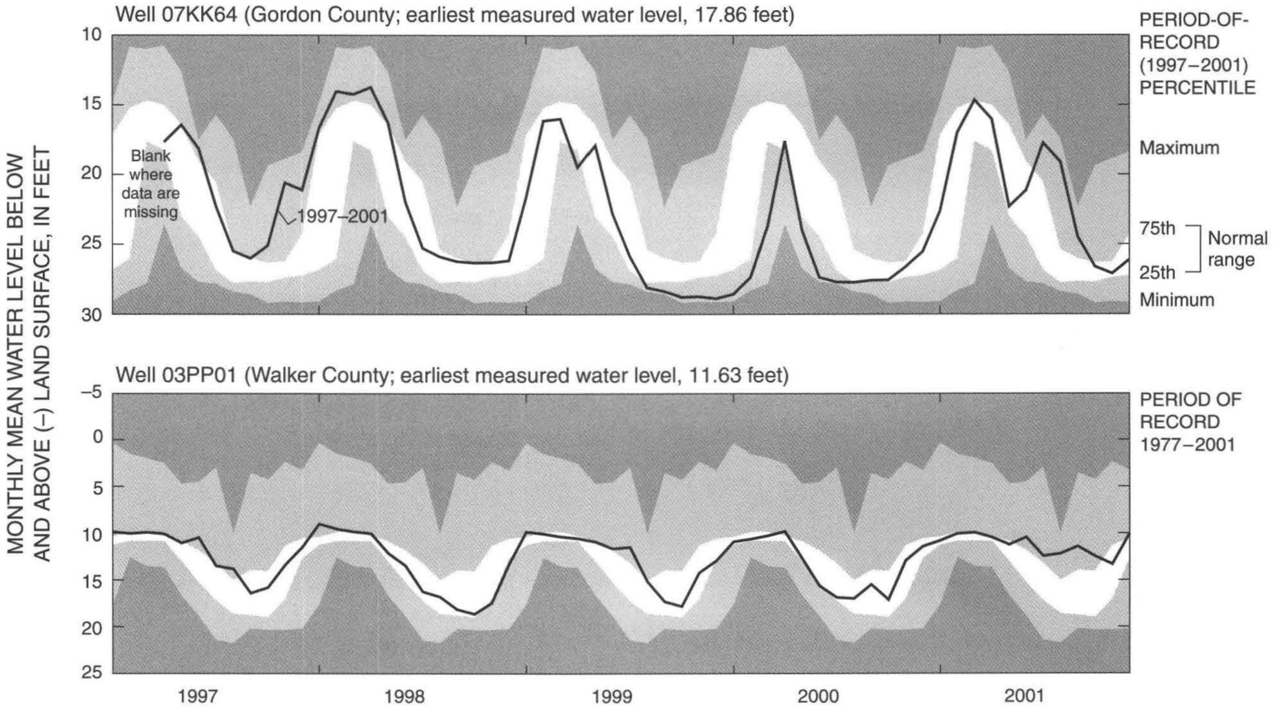
[1]D, Dublin aquifer system; DM, Dublin–Midville aquifer system; LD, Lower Dublin aquifer; LM, Lower Midville aquifer; M, Midville aquifer system; P, Providence aquifer; T, Tuscaloosa Formation.

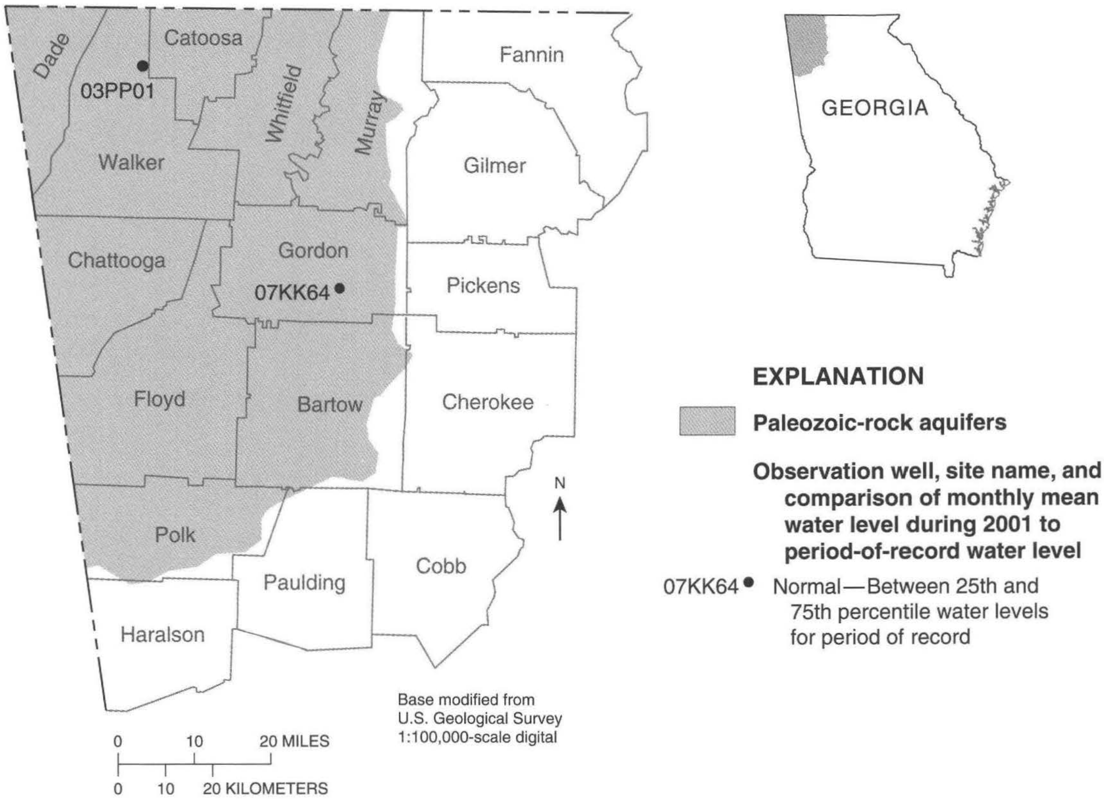
Paleozoic-Rock Aquifers

Water levels were measured in two wells in the Paleozoic-rock aquifers of northwest Georgia during 2001 (map and table, facing page). In this area, water in the Paleozoic-rock aquifer occurs under confined conditions. Water levels in the two wells were in or above the normal range during 2001, reflecting recovery from drought effects during the previous 3 years.

Water-level hydrographs for the two Paleozoic-rock aquifer wells in northwest Georgia (shown below) illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. It should be stressed that because the USGS monitors only two wells in this aquifer, these statistics likely represent only these wells and not the aquifer as a whole.

The water level in well 07KK64 in Gordon County was normal or above normal until mid-1999, when the water level dropped below normal and continued below normal until the last half of 2000, when the water level rose to normal or above normal. The water level in well 03PP01 in Walker County was normal or above normal during 1997–2001.



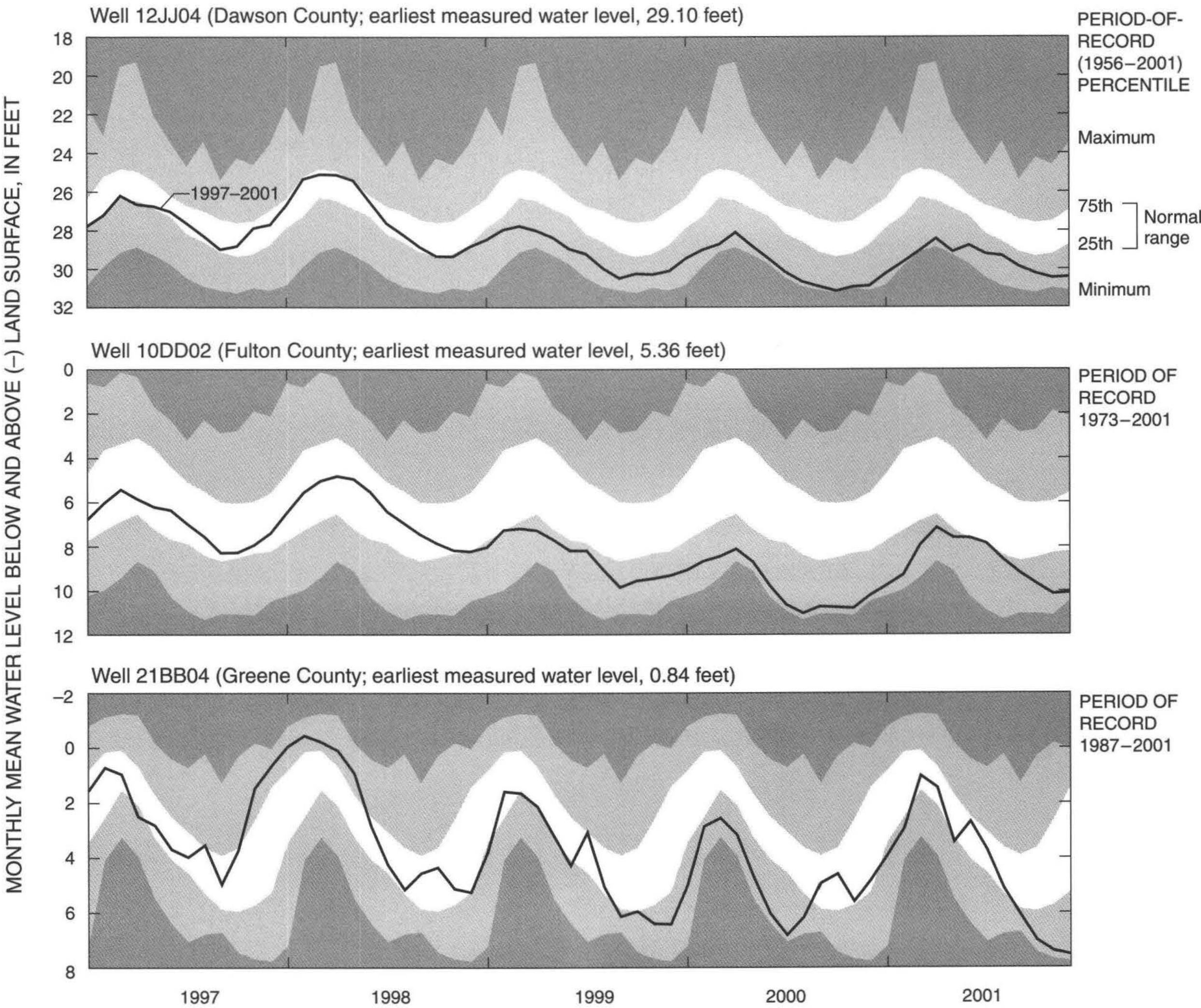


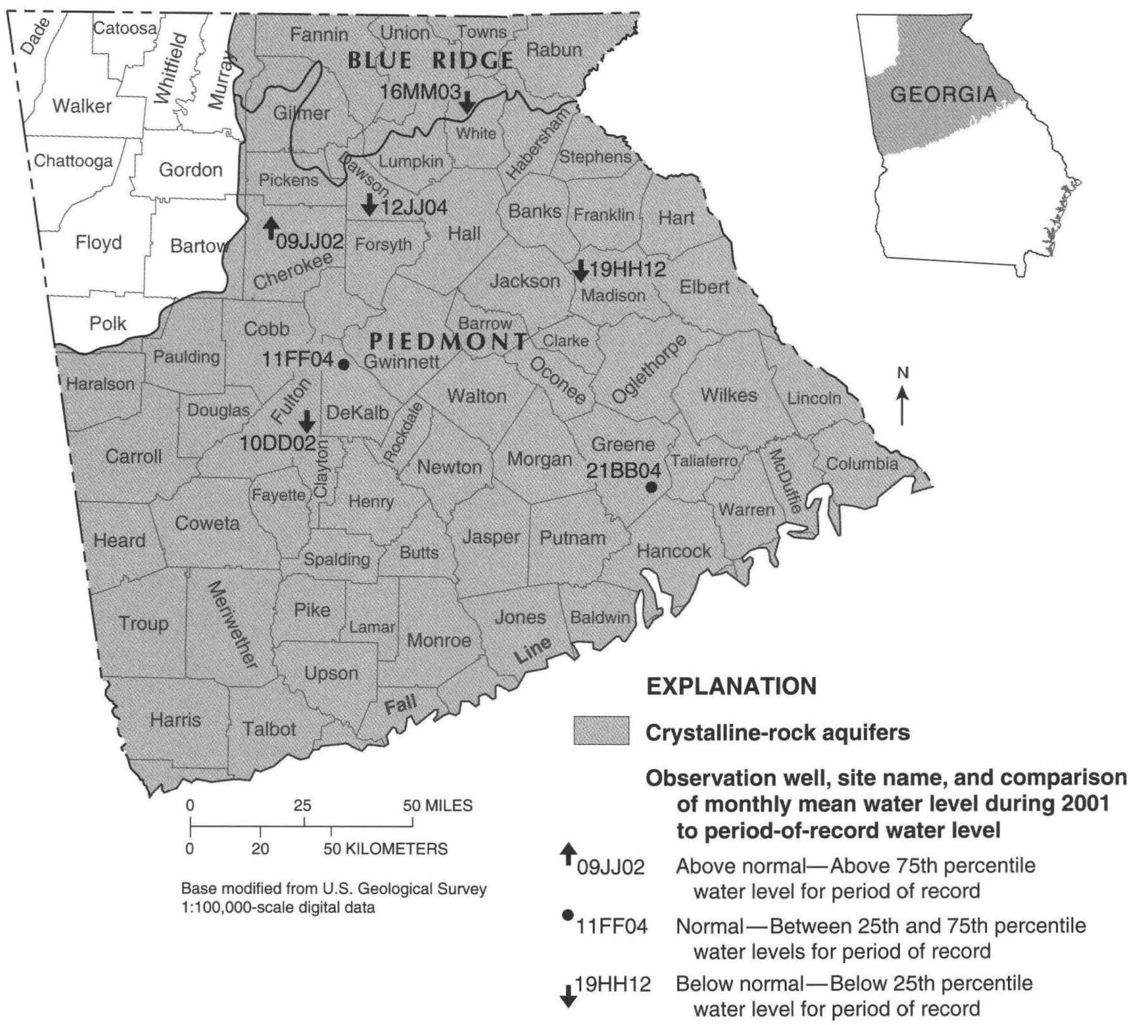
Site name	County	Other identifier
07KK64	Gordon	Calhoun, Georgia, test well 1
03PP01	Walker	U.S. National Park Service, Chickamauga Battlefield Park

Crystalline-Rock Aquifers

Water levels in seven wells were measured in crystalline-rock aquifers in the Piedmont and Blue Ridge physiographic provinces of Georgia during 2001 (map and table, facing page). In this area, water is present in discontinuous joints and fractures and may be confined or unconfined. Crystalline-rock aquifers typically have local extent and can be highly affected by localized water use and climate. Water levels in four of the wells were below the normal range and in three of the wells were above or within the normal range during 2001.

Water-level hydrographs for three crystalline-rock aquifers wells (shown below) were chosen to illustrate monthly mean water levels during 1997–2001 and period-of-record water-level statistics. Effects of drought are apparent in all three wells beginning in late 1998, and continuing through 2001. Water levels in the three wells declined during 1998–2000. Water levels in well 12JJ04 in Dawson County and well 10DD02 in Fulton County were within the normal range, but dropped below the normal range in late 1998, and continued to decline to near record lows by mid-2000. During 2001, these hydrographs show some water-level rise but water levels were still below normal for the year. The water level in well 21BB04 in Greene County also shows effects from drought beginning in late 1998 as well; however, the water level intermittently rose to the normal range throughout the year.





Site name	County	Other identifier
09JJ02	Cherokee	Reinhardt College, well A
12JJ04	Dawson	U.S. Geological Survey, test well 1
11FF04	DeKalb	U.S. Geological Survey, test well 5
10DD02	Fulton	U.S. Army, Fort McPherson
21BB04	Greene	Charles Veazey
19HH12	Madison	Meadowlake Estates
16MM03	White	Unicoi State Park, well 4

GROUND-WATER QUALITY OF THE UPPER AND LOWER FLORIDAN AQUIFERS

The quality of ground water from the Upper and Lower Floridan aquifers is monitored in the Albany and coastal areas. In the south-central part of Dougherty County near Albany, wells are monitored annually for nitrate concentration. In coastal Georgia, chloride concentration in water from the Upper and Lower Floridan aquifers has been monitored since the 1950s in the Savannah and Brunswick areas, and since the early 1990s in the Camden County area.

City of Albany area

The Upper Floridan aquifer is shallow in southwest Georgia where agricultural land use is prevalant, making the ground water susceptible to contamination from nitrates and other chemicals. Monitoring may serve as an early warning sign of potential contamination of water supplies. Nitrate levels greater than 10 milligrams per liter (mg/L) (the maximum contaminant level for nitrate set by the U.S. Environmental Protection Agency, 2000) have been detected in the area.

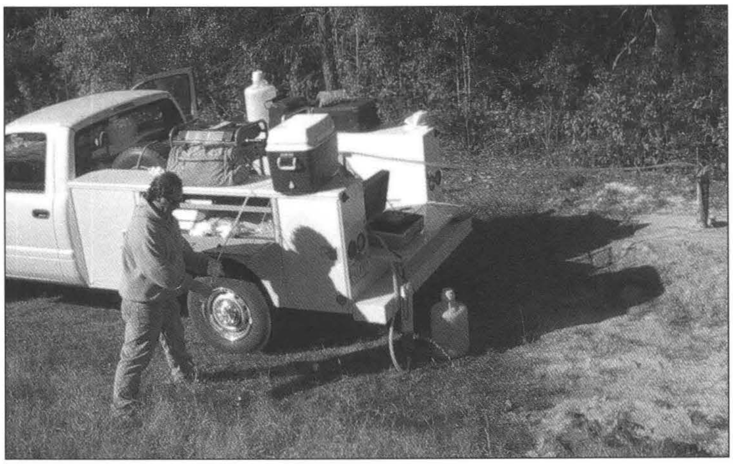
Samples were collected during November 13–16, 2001, from 11 wells southwest of Albany and analyzed for nitrate concentrations. Of those samples, one had a concentration greater than 10 mg/L, seven had concentrations ranging between 3 and 10, and three had concentrations less than 3 mg/L (map, facing page).

Since 1998, samples from four of the wells have shown an increase in nitrate concentration, samples from two of the wells have remained about the same, and samples from three of the wells have shown a decrease in nitrate concentration (table, facing page).

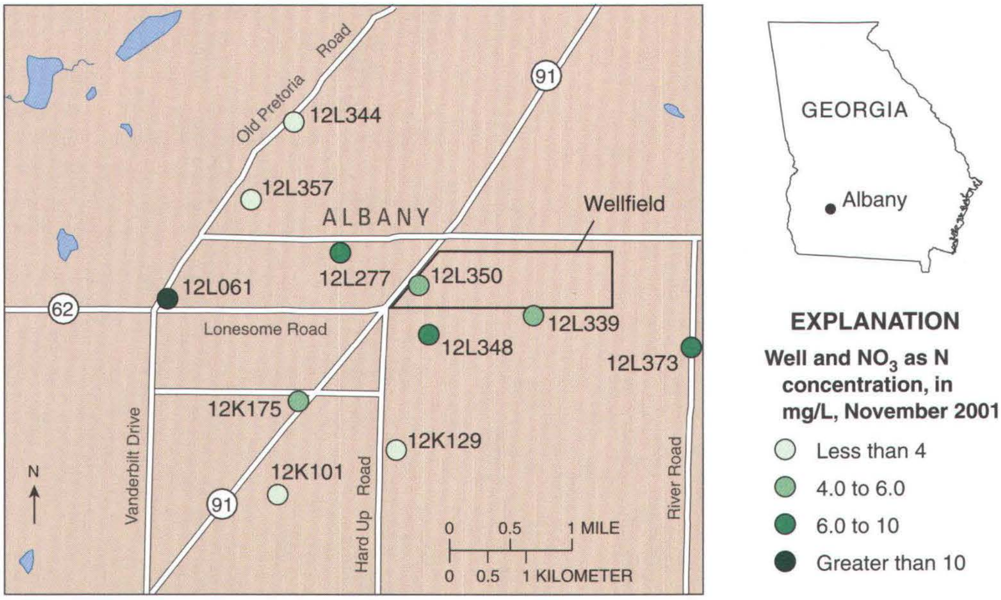
References Cited

Hippe, D.J., Wangsness, D.J., Frick, E.A., and Garrett, J.W., 1994, Water quality of the Apalachicola–Chattahoochee–Flint and Ocmulgee River Basins related to flooding from Tropical Storm Alberto; Pesticides in urban and agricultural watersheds; and nitrate and pesticides in ground water, Georgia, Alabama, and Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4183, 36 p.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, revised as of July 1, 2000, p. 612–614.



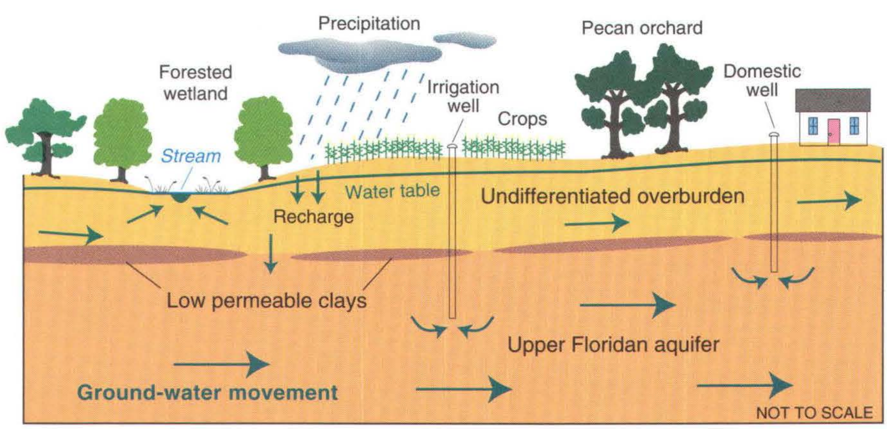
The USGS collects ground-water samples for nitrate analysis on an annual basis in the Albany area. The upper photo shows calibration of a flow-through chamber with multiple electrodes (Hydrolab II™) in preparation for sampling. The lower photo shows sample collection. Photos by Debbie Warner, USGS.



Base from U.S. Geological Survey 1:100,000-scale digital data

Site name	September 1998 NO_3-N, in mg/L	April 1999 NO_3-N, in mg/L	April 2001 $NO_2 + NO_3$ as N, in mg/L	November 2001 Dissolved NO_2+NO_3 as N, in mg/L
12K101	1.8	1.9	—	2.2
12K129	—	—	—	3.1
12K175	3.8	5.7	5.0	5.9
12L061	11	12	12	12
12L277	7.5	6.9	6.5	8.0
12L339	5.9	5.4	—	5.0
12L344	6.0	5.1	2.7	1.6
12L348	—	6.5	6.4	7.1
12L350	3.0	2.9	—	4.8
12L357	5.9	3.1	—	2.0
12L373	—	—	—	7.2

NO_3-N, nitrate as nitrogen; $NO_2 + NO_3$ as N, nitrite plus nitrate as nitrogen; mg/L, milligrams per liter; —, no data



This schematic diagram shows the ground-water flow system in the Upper Floridan aquifer, Albany area, Georgia. Water from the land surface enters the undifferentiated overburden through recharge areas. Water may then travel into the Upper Floridan aquifer through breaks in the low-permeabilty clays (modified from Hippe and others, 1994).

City of Savannah area

During 2001, 10 wells (table below) completed in the Upper and Lower Floridan aquifers and underlying units were pumped and sampled in the Savannah area. Chloride-concentration graphs are presented for two areas—Tybee Island and Skidaway Island. Data from these two areas indicate that chloride concentration generally increases with depth below land surface.

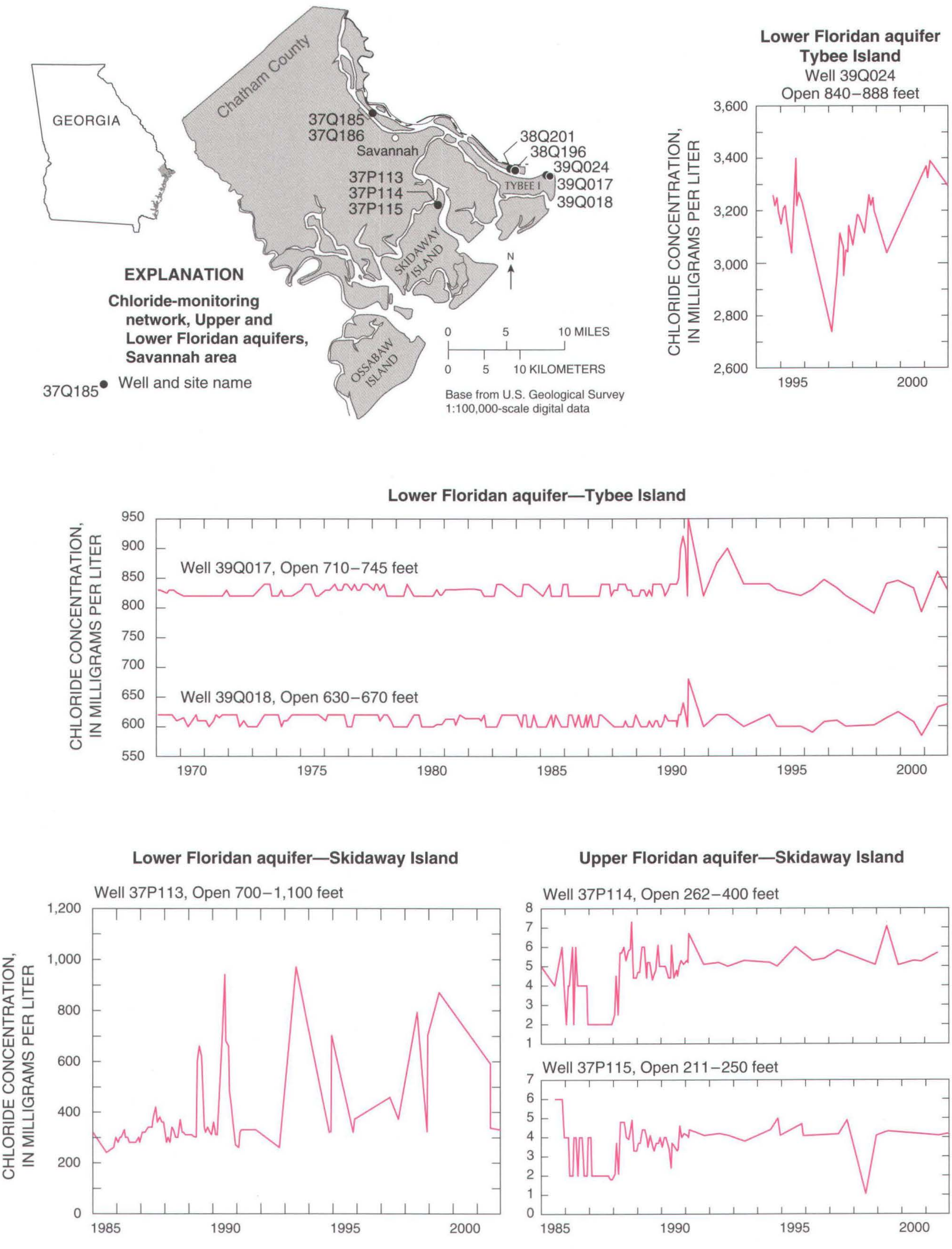
Tybee Island is the most seaward location in the Savannah area and likely the first location to be affected by saltwater migrating laterally from the sea. At Tybee Island, chloride concentrations during 2001 ranged from 632 milligrams per liter (mg/L) at a depth of 630–670 feet (ft) in well 39Q018, to 3,295 mg/L at a depth of 840–888 ft in well 39Q024. Chloride concentrations in wells 745 ft or less in depth (wells 39Q017 and 39Q018) have not changed appreciably since monitoring began. However, in well 39Q024 open to the Lower Floridan aquifer at depths of 840–888 ft, the chloride concentration has increased since the late 1990s to a maximum of 3,370 mg/L during July 2001.

At Skidaway Island, chloride concentrations during 2001 ranged from less than 5 mg/L at a depth of 211–250 ft in well 37P115, to 337 mg/L at a depth of 700–1,100 ft in well 37P113.

Chloride-monitoring network in the Upper and Lower Floridan aquifers, Savannah area
[mg/L, milligrams per liter; —, no data]

Site name	Other identifier	Open interval (feet below land surface)	Water-bearing unit[1]	Chloride concentration July 2001 (mg/L)	Chloride concentration December 2001 (mg/L)
37P113	Skidaway Institute, test well 1	700 – 1,100	L	337	330
37P114	Skidaway Institute, test well 2	262 – 400	U	7.0	5.7
37P115	Skidaway Institute, test well 3	211 – 250	U	4.1	4.2
37Q185	Huchinson Island, test well 1	274 – 344	U	5.7	5.6
37Q186	Huchinson Island, test well 2	1,380 – 1,520	P	1,965	1,917
38Q196	U.S. Geological Survey, test well 01 Pt 2	870 – 900	L	5,615	—
38Q201	Georgia Geologic Survey, Fort Pulaski, test well	1,358 – 1,546	P	18,900	20,300
39Q017	U.S. Geological Survey, test well 07 Pt 1	710 – 745	L	860	830
39Q018	U.S. Geological Survey, test well 07 Pt 2	630 – 670	L	632	637
39Q024	Georgia Geologic Survey, Tybee Island, test well 1	840 – 888	L	2/3,370	3/3,295

1/ L, Lower Floridan aquifer; U, Upper Floridan aquifer; P, underlying Paleocene unit of low permeability.
2/ Sampled January 2001.
3/ Sampled June 2001.


GEORGIA
Chatham County
37Q185
37Q186
Savannah
37P113
37P114
37P115
38Q201
38Q196
39Q024
39Q017
39Q018
TYBEE I
SKIDAWAY ISLAND
OSSABAW ISLAND
N
0 5 10 MILES
0 5 10 KILOMETERS
Base from U.S. Geological Survey 1:100,000-scale digital data
EXPLANATION
Chloride-monitoring network, Upper and Lower Floridan aquifers, Savannah area
37Q185 ● Well and site name
Lower Floridan aquifer Tybee Island
Well 39Q024
Open 840–888 feet
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
3,600
3,400
3,200
3,000
2,800
2,600
1995
2000
Lower Floridan aquifer—Tybee Island
Well 39Q017, Open 710–745 feet
Well 39Q018, Open 630–670 feet
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
950
900
850
800
750
700
650
600
550
1970
1975
1980
1985
1990
1995
2000
Lower Floridan aquifer—Skidaway Island
Well 37P113, Open 700–1,100 feet
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
1,200
1,000
800
600
400
200
0
1985
1990
1995
2000
Upper Floridan aquifer—Skidaway Island
Well 37P114, Open 262–400 feet
8
7
6
5
4
3
2
1
Well 37P115, Open 211–250 feet
7
6
5
4
3
2
1
0
1985
1990
1995
2000

City of Brunswick area

Water supply in the Brunswick area primarily is obtained from wells completed in the Upper Floridan aquifer. Intense pumping has reduced pressure in the aquifer and resulted in saltwater intrusion locally at Brunswick. Saltwater was first detected in the southernmost part of Brunswick during the late 1950s (Wait, 1965). Saltwater was migrating upward from deep saline zones through breaches in confining units as a result of reduced pressure in the aquifer. By the 1960s, a plume had migrated northward toward two major industrial pumping centers. Currently (June 2001), chloride concentration in water from the Upper Floridan aquifer is above State and Federal secondary drinking-water standards (Georgia Environmental Protection Division, 1997; U.S. Environmental Protection Agency, 2000) in a 2-square-mile area, and exceeds 2,250 milligrams per liter in part of the area.

During June 11–14, 2001, 66 wells completed in the Upper or Lower Floridan aquifers were sampled and analyzed for dissolved-chloride concentration and a map showing the plume of elevated chloride concentration in the Upper Floridan aquifer was produced (facing page). The map shows that areas of highest concentration are near the two industrial pumping centers in the northern part of the city, as well as the original area of contamination in the southern part of the city. Along the outer margin of the chloride plume, concentrations fluctuate in response to changes in ground-water pumping. For example, chloride concentration in the city of Brunswick Perry Park production well (34H468), located along the eastern margin of the area of chloride contamination, fluctuates rapidly in response to changes in pumping. Elevated chloride concentrations necessitated discontinuation of pumping from the well. The city currently is examining strategies to reduce chloride concentrations in the production well by adjusting pumping time and rate and by backfilling deeper parts of the well's production interval that may be contributing water having high chloride concentration.

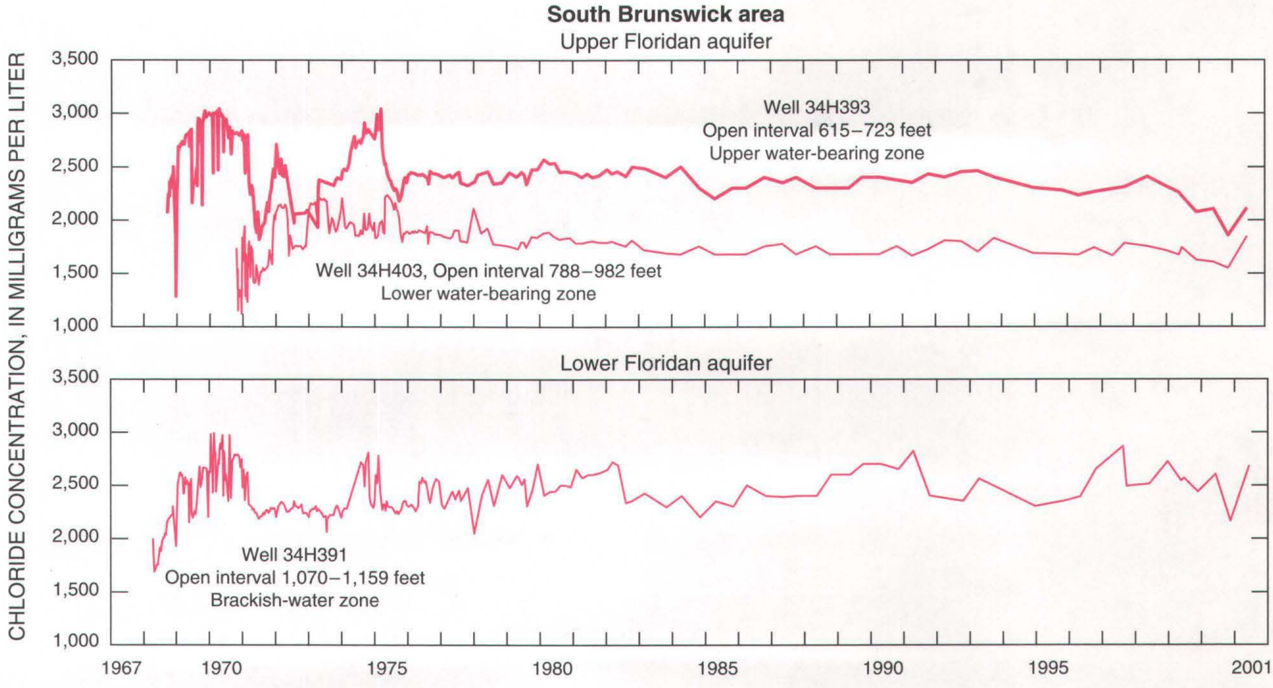
Chloride concentrations have been monitored in the Brunswick area since the late 1950s. Graphs of chloride concentration in water samples from wells in the upper and lower water-bearing zones of the Upper Floridan aquifer are shown for wells in the south Brunswick area (graphs for wells 34H393 and 34H403, below) and north Brunswick area (graphs for wells 33H127 and 33H133, facing page). Chloride concentration in water from the Lower Floridan aquifer is shown for well 34H391 in the south Brunswick area (graph, below). More information on the Brunswick area monitoring can be accessed at URL: *http://ga2.er.usgs.gov/Brunswick.*

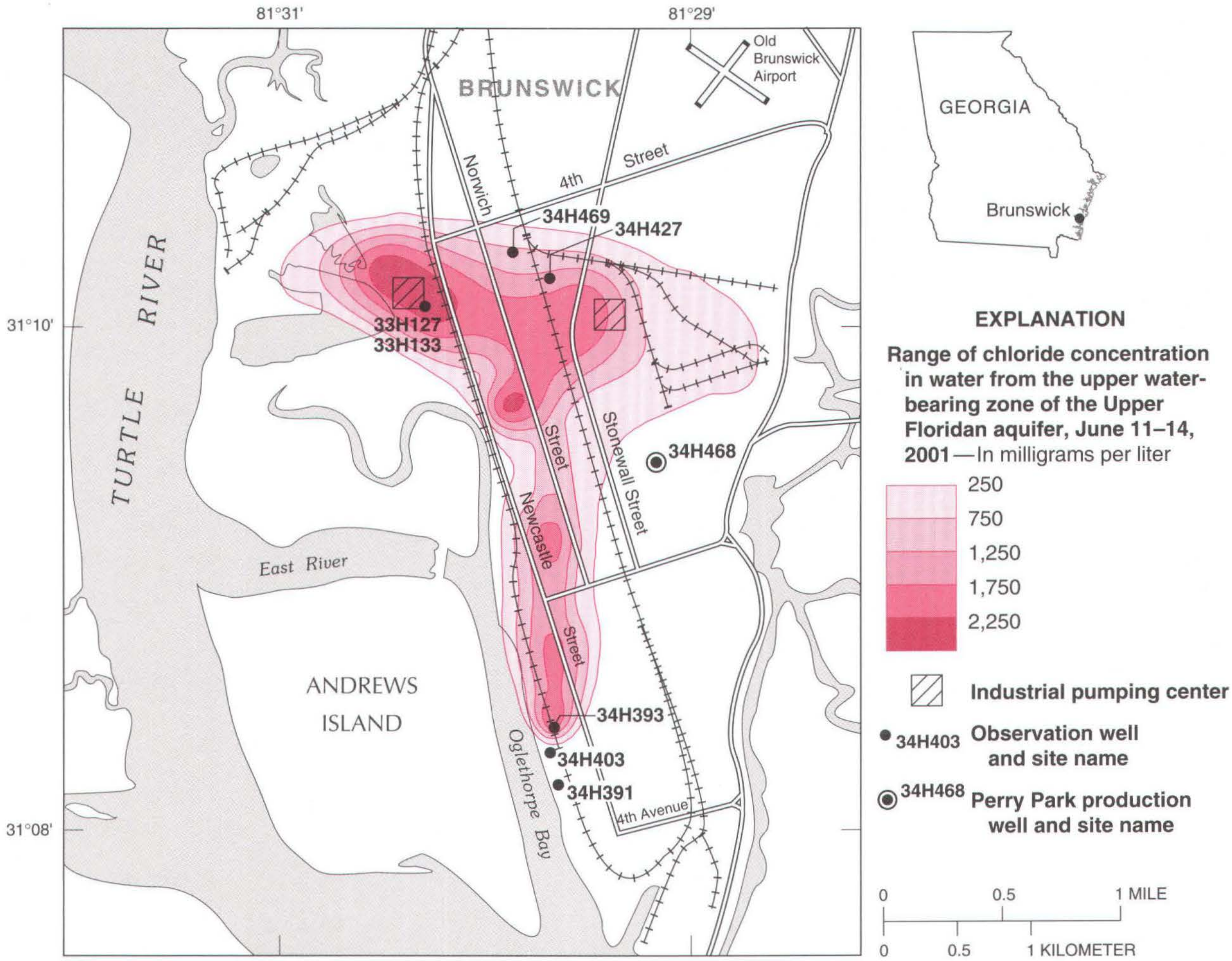
References Cited

Georgia Environmental Protection Division, 1997, Secondary maximum contaminant levels for drinking water: Environmental Rule 391-3-5-19, revised October 1997: Official Code of Georgia Annotated Statutes, Statute 12-5-170 (Georgia Safe Drinking Water Act), variously paginated.

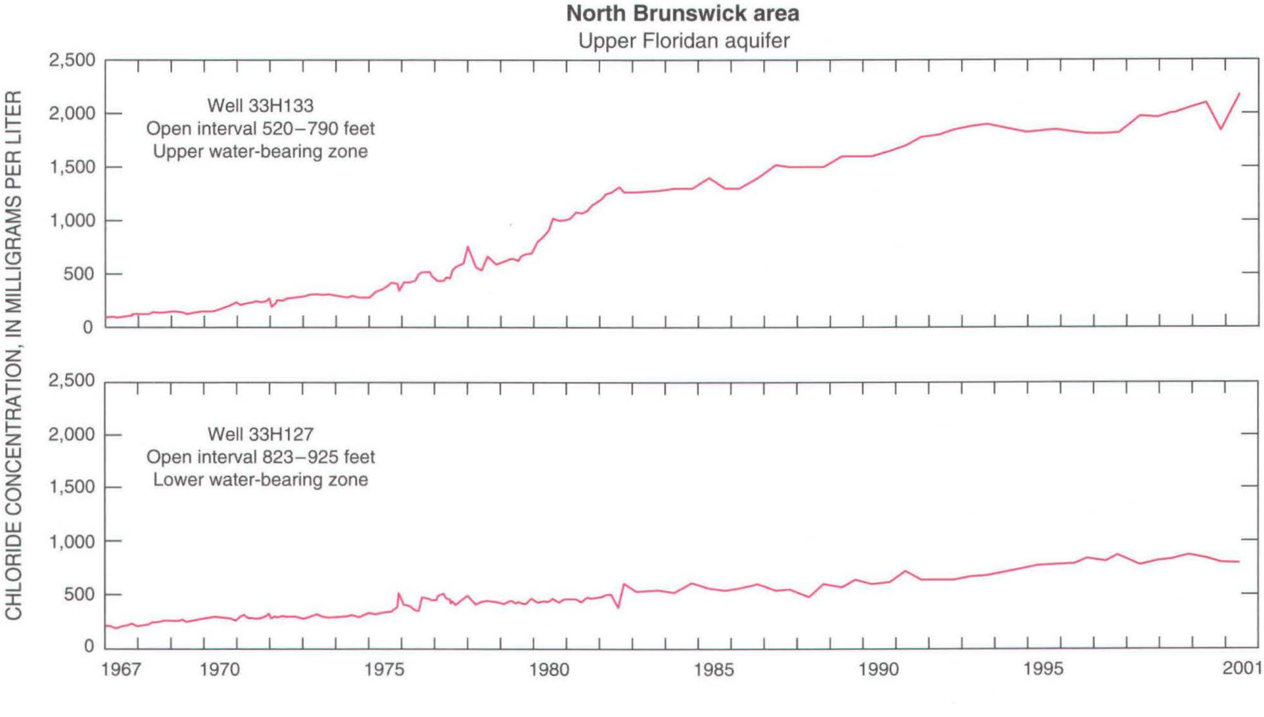
U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, revised as of July 1, 2000, p. 612–614.

Wait, R.L., 1965, Geology and occurrence of fresh and brackish ground water in Glynn County, Georgia: U.S. Geological Survey Water-Supply Paper 1613-E, 94 p.





Base modified from U.S. Geological Survey
1:24,000-scale digital data



Camden County area

Chloride concentrations in the Upper Floridan aquifer have been monitored in the Camden County area since 1994. During 2001, six wells (table, below) were pumped and sampled by the U.S. Geological Survey in the Camden County area, and analyses were performed by the St. Johns River Water Management District (Bill Osborne, St. Johns River Water Management District, written commun. with David C. Leeth, February 7, 2002). Data from these wells indicate chloride concentrations generally are less than 40 milligrams per liter (mg/L), with the exception of well 33D061, which had concentrations ranging from about 130 to 185 mg/L during 1994–2001. The source of the higher chloride concentrations in this well is not known; however, in adjacent Glynn County, chloride contamination of the Upper Floridan aquifer from deep saline zones has been documented by several investigators (Wait, 1965; Gregg and Zimmerman, 1974; Krause and Randolph, 1989; Clarke and others, 1990; Jones and others, 2002).

References Cited

Clarke, J.S., Hacke, C.M., and Peck, M.F., 1990, Geology and ground-water resources of the coastal area of Georgia: Georgia Geologic Survey Information Circular 113, 106 p.

Gregg, D.O., and Zimmerman, E.A., 1974, Geologic and hydrologic control of chloride contamination in aquifers at Brunswick, Glynn County, Georgia: U.S. Geological Water-Supply Paper 2029-D, 44 p.

Jones, L.E., Prowell, D.C., and Maslia, M.L., 2002, Hydrogeology and water quality (1978) of the Floridan aquifer system at U.S. Geological Survey test well 26, on Colonels Island, near Brunswick, Georgia: U.S. Geological Survey Water-Resources Investigations Report 02-4020, 44 pages, 1 plate.

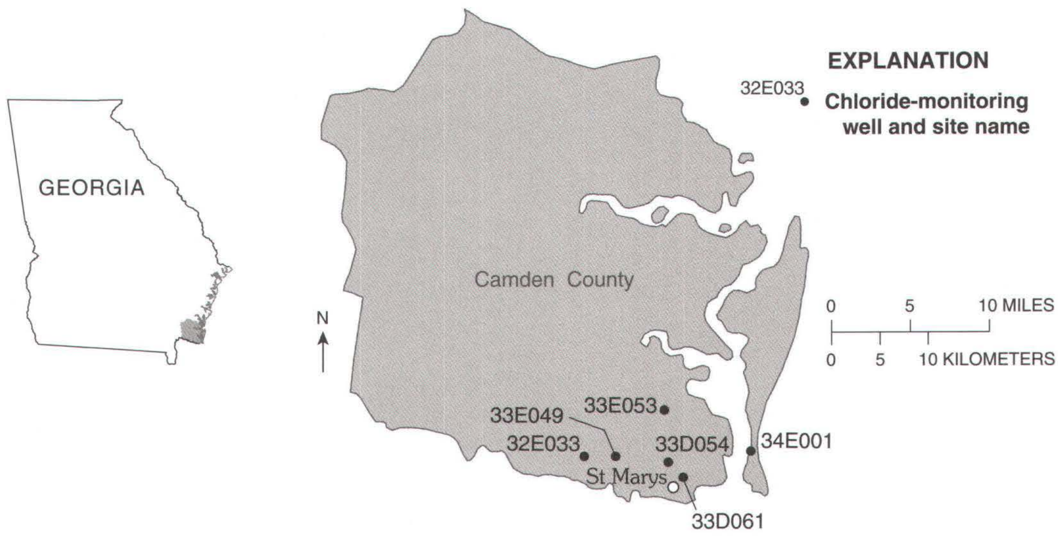
Krause, R.E., and Randolph, R.B., 1989, Hydrology of the Floridan aquifer system in southeast Georgia and adjacent parts of Florida and South Carolina: U.S. Geological Survey Professional Paper 1403-D, 65 p.

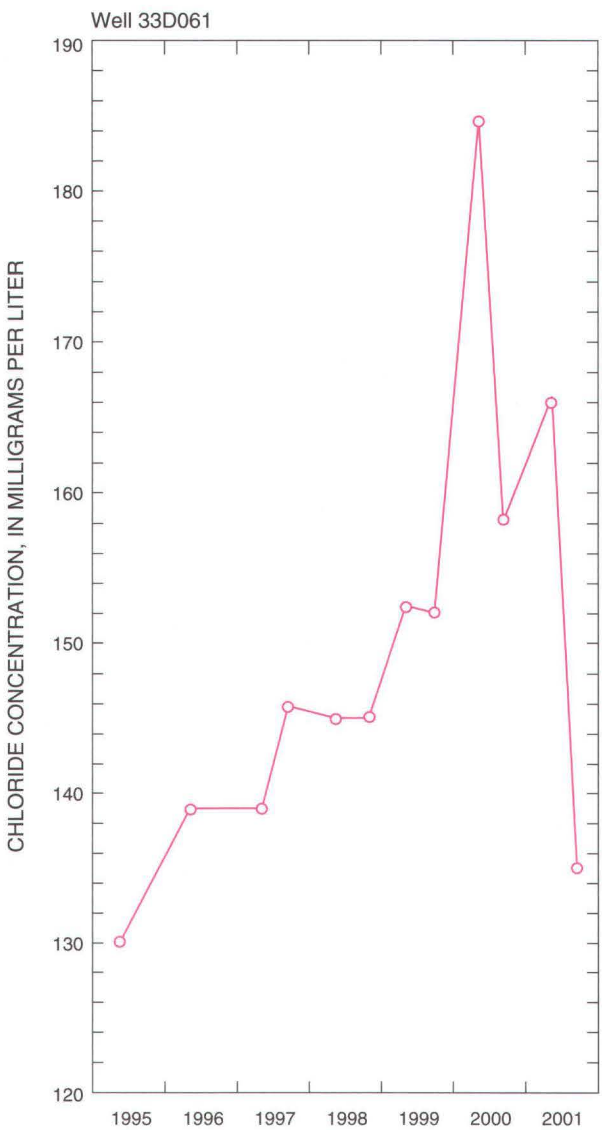
Wait, R.L., 1965, Geology and occurrence of fresh and brackish ground water in Glynn County, Georgia: U.S. Geological Survey Water-Supply Paper 1613-E, 94 p.

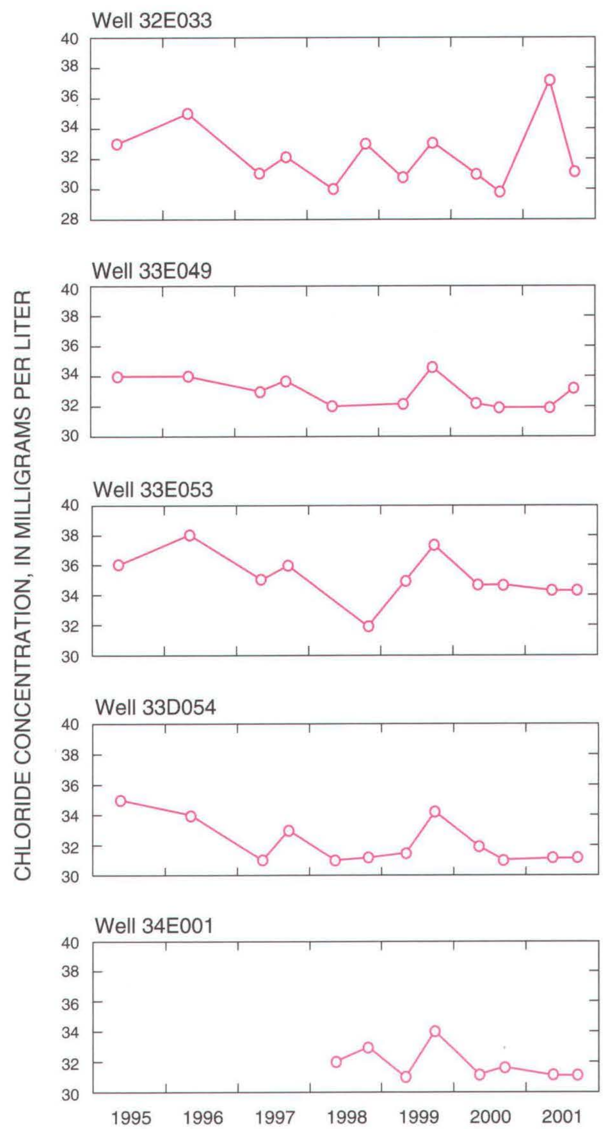
Chloride-monitoring network in the Upper Floridan aquifer, Camden County, Georgia [*mg/L, milligrams per liter*]

Site name	Other identifier	Open interval (feet)	Chloride concentration, May 2001[1] (mg/L)	Chloride concentration, August 2001[1] (mg/L)
32E033	Georgia Welcome Center	420 – 600	37	31
33D054	St Marys 2	563 – 1,000	31	31
33D061	Gilman Paper Company 11	550 – 1,090	166	135
33E049	Osprey Cove	522 – 840	32	33
33E053	Kings Bay 2	570 – 900	34	34
34E001	Cumberland Island Georgia Geologic Survey test well 1	540 – 640	31	31

[1/] Bill Osborne, St. Johns River Water Management District, written commun. with David C. Leeth, February 7, 2002


EXPLANATION
32E033 • Chloride-monitoring well and site name
GEORGIA
Camden County
N
0 5 10 MILES
0 5 10 KILOMETERS
33E049
33E053
32E033
33D054
34E001
St Marys
33D061

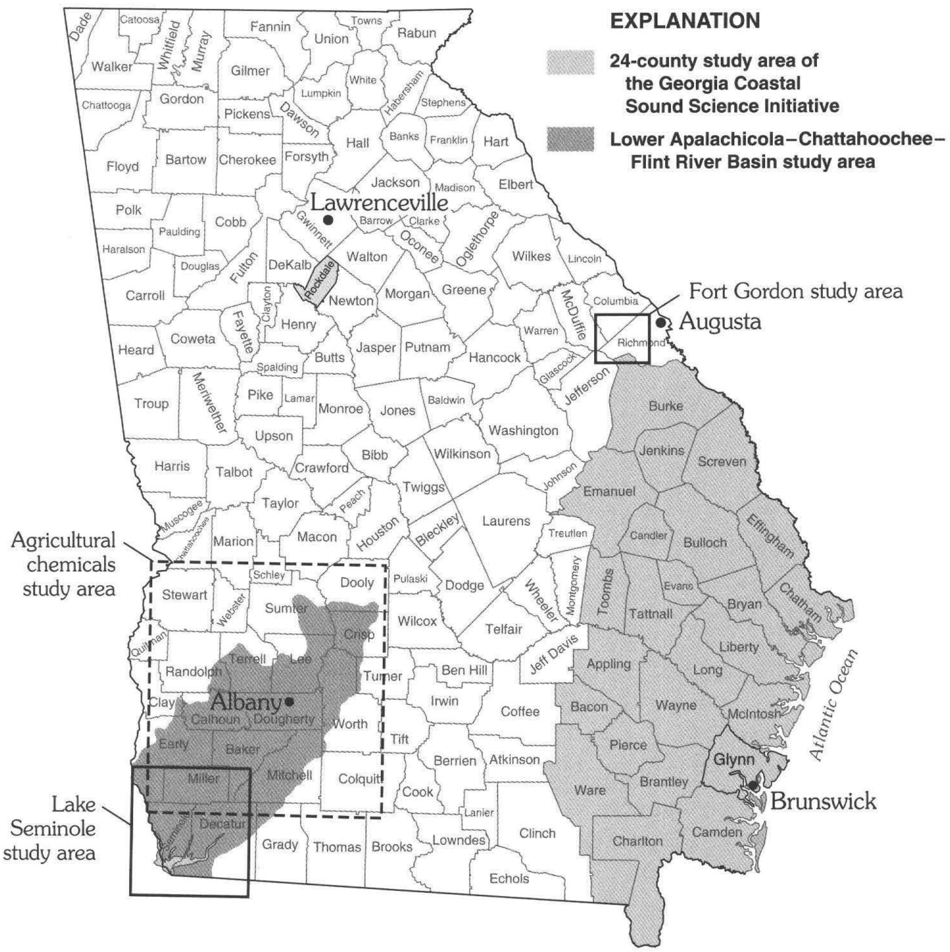

Well 33D061
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
190
180
170
160
150
140
130
120
1995
1996
1997
1998
1999
2000
2001


Well 32E033
Well 33E049
Well 33E053
Well 33D054
Well 34E001
CHLORIDE CONCENTRATION, IN MILLIGRAMS PER LITER
40
38
36
34
32
30
28
1995
1996
1997
1998
1999
2000
2001

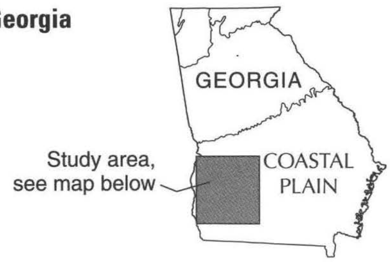
SELECTED GROUND-WATER STUDIES IN GEORGIA, 2001

The U.S. Geological Survey (USGS), in cooperation with State, local, and other Federal agencies, conducted several studies in Georgia and adjacent states during 2001 to better define the occurrence and quality of ground water and to monitor hydrologic conditions. Summaries of current USGS studies in Georgia are provided in the following sections and include information regarding:

- Study title
- Study area location
- Study chief
- Cooperating agency or agencies
- Year study began
- Problem
- Objectives
- Progress and significant results



Agricultural Chemicals in Shallow Ground Water in Southwestern Georgia



Study Chief Elizabeth A. Frick
Cooperator Georgia Department of Agriculture
Year Started 1999

Problem

Modern agricultural practices include the use of pesticides and fertilizers to increase crop yields. Application of these chemicals involves some risk of contamination to surface- and ground-water resources through runoff and infiltration. The Georgia Department of Agriculture has primary responsibility for pesticide regulation and is the lead agency for Georgia's ground-water protection program for pesticides. Data on the occurrence, in shallow ground water, of frequently used pesticides are not available throughout agricultural areas of Georgia. A ground-water-quality monitoring program is critical to determine if agricultural pesticide use contaminates ground-water resources, and if so, where.

Objectives

- Assess the quality of shallow ground-water resources in relation to agricultural chemical use in the Coastal Plain physiographic province in southwestern Georgia.
- Provide data on the occurrence of nitrate and pesticides in shallow ground water to help design a monitoring network for examining long-term trends in ground-water quality related to agricultural practices in Georgia.

Progress and Significant Results, 2001

- Eighteen ground-water samples were collected from 17 wells during 2001. Samples were analyzed for pesticides and nitrate. Twenty-eight wells and 11 springs were sampled during 1999 and 23 wells were sampled during 2000.
- The pesticides detected in ground water during 2001 included 10 herbicides, 4 degradation products of atrazine, 2 degradation products of the insecticide aldicarb, and 1 fungicide.
- In the 13 wells sampled for nitrate during 2001, concentrations ranged from 0.1 to 10 milligrams per liter (mg/L). The median nitrate concentration was 1.6 mg/L. The water sample from one well had a nitrate concentration of 10 mg/L, which is equal to the Maximum Contaminant Level (U.S. Environmental Protection Agency, 2000); however, no pesticides were detected in this sample. The water sample from another well had a nitrate concentration of 9.0 mg/L and five pesticides were detected.

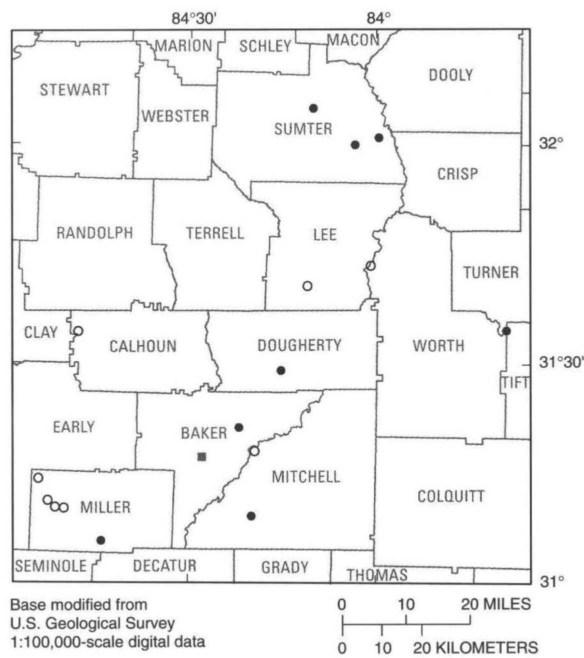
References Cited

Georgia Agricultural Statistics Service, 1998 and 2002, Georgia Agricultural Facts: Athens, Ga., Georgia Department of Agriculture, variously paginated.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program: Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p. [Available at URL: *http://water.usgs.gov/nawqa/OFR95-399.html*; accessed October 22, 2002.]

Nowell, L.H. and Resek, E.A., 1994, National standards and guidelines for pesticides in water, sediment, and aquatic organisms: Application to water-quality assessments, *in* Reviews in Environmental Contamination and Toxicology: v. 140, New York, N.Y., Springer-Verlag, 164 p.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Subpart B of part 141, National Primary Drinking-Water Regulations): U.S. Code of Federal Regulations, Title 40, parts 100-149, revised as of July 1, 2000, p. 334-560. [Available at URL: *http://www.epa.gov/safewater/mcl.html*; EPA 816-F-02-013; revised July 2002.]



EXPLANATION

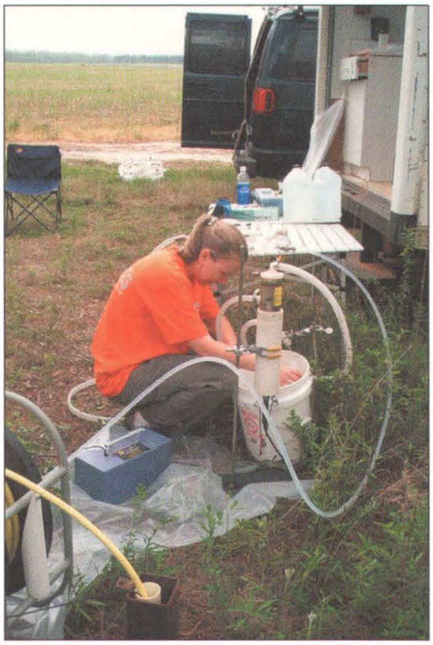
Well adjacent to agricultural field

- ● One or more pesticides detected
- ○ No pesticides detected

Well in forested area

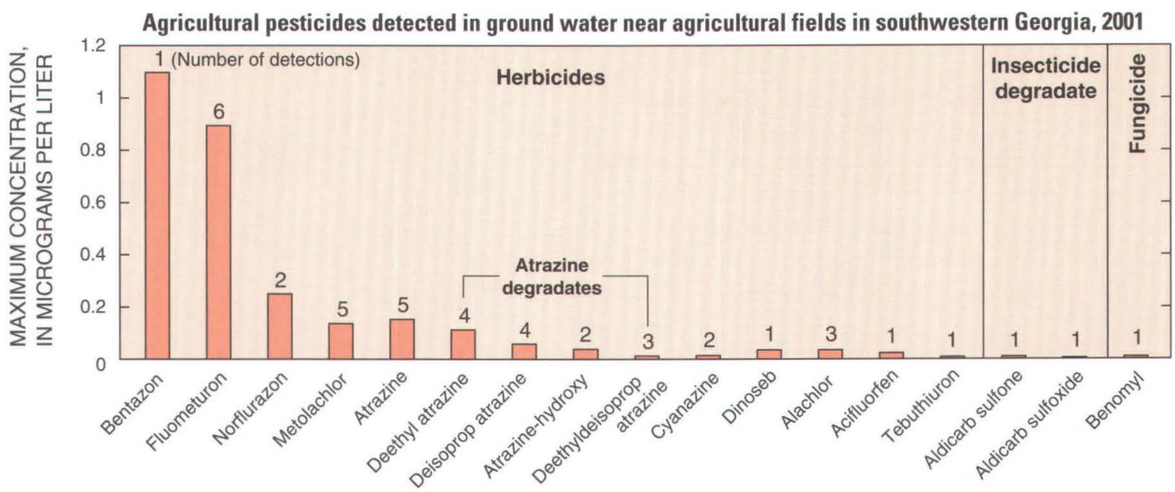
- ■ No pesticides detected

Wells sampled during 2001 for the U.S. Geological Survey/Georgia Department of Agriculture pesticide monitoring study.



The sampling protocols followed for this pesticide monitoring study are the same as those used for the National Water-Quality Assessment Program (Koterba and others, 1995). These protocols require rigorous cleaning of sampling equipment and strict handling procedures to ensure that there is no sample contamination. These protocols are necessary to achieve detection levels as low as 0.001 micrograms per liter. Photo by Andrew C. Hickey, USGS.

As the distribution of crops grown changes from year to year, the types and quantities of pesticides and fertilizer applied also changes. This is particularly true in Georgia where the number of acres planted in cotton has more than tripled in the last decade (Georgia Agricultural Statistics Service, 1998, 2002); cotton production relies on more pesticides and defoliants than other crops commonly grown within Georgia. Pesticides have the potential for leaching into shallow ground water and, in some cases, into the underlying aquifers that are used for drinking-water supplies. A monitoring program is essential to ensure that drinking water is protected. Photo by William B. Hughes, USGS.



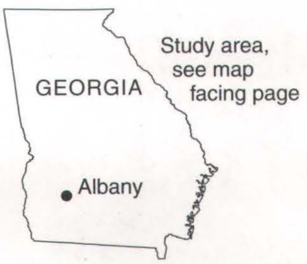
Ten herbicides, four degradates of the herbicide atrazine, two degradates of the insecticide aldicarb, and one fungicide were detected in the 18 ground-water samples collected during 2001. Fluometuron, metolachlor, and atrazine were detected in approximately one-third of the samples. Fluometuron is a pre- and post-emergence herbicide used on cotton. Metolachlor is a selective herbicide commonly used on corn, soybeans, peanuts, and cotton. Atrazine is used as a selective herbicide on a wide variety of crops. At higher application rates, it is used for nonselective weed control in noncropped areas. The pesticide concentrations measured were less than applicable maximum contaminant levels or lifetime health advisory levels (Nowell and Resek, 1994).

City of Albany Cooperative Water-Resources Program

Study Chief Debbie Warner

Cooperator Albany Water, Gas, and Light Commission

Year Started 1977



Problem

Long-term heavy pumping from the Claiborne, Clayton, and Upper Cretaceous aquifers, which underlie the Upper Floridan aquifer, has resulted in significant water-level declines in the deeper aquifers in the Albany area. These declines have raised concern over the ability of the deeper aquifers to meet the increasing demand for potable water supply. To provide additional water supply and reduce the demand on the deeper aquifers, the Albany Water, Gas, and Light Commission (WGL) is developing a large wellfield southwest of Albany. The supply wells at this location will primarily tap the Upper Floridan aquifer, a karstic unit that is the uppermost reliable source of water in the area. Because of local recharge to the aquifer, water quality may be affected by land-use practices. Nitrate levels exceeding the 10-milligram per liter Maximum Contaminant Level (MCL) (U.S. Environmental Protection Agency, 2000) have been detected in some wells upgradient of the proposed wellfield. The ground-water-flow system and water quality of the Upper Floridan aquifer in the vicinity of the wellfield are complex and poorly understood.

Objectives

- Monitor water-level fluctuations in the four aquifers used in the Albany area and relate water-level trends to changes in climatic conditions and pumping patterns.
- Describe the ground-water flow and water quality of the Upper Floridan aquifer in the southwestern Albany area including: identify ground-water-flow directions and gradients for the Upper Floridan aquifer; determine if there is a rapid hydrologic response between rainfall and ground-water levels; describe the distribution of ground-water ages for the Upper Floridan aquifer in the study area; and describe ground-water quality with a particular emphasis on nitrate concentrations.

Progress and Significant Results, 2001

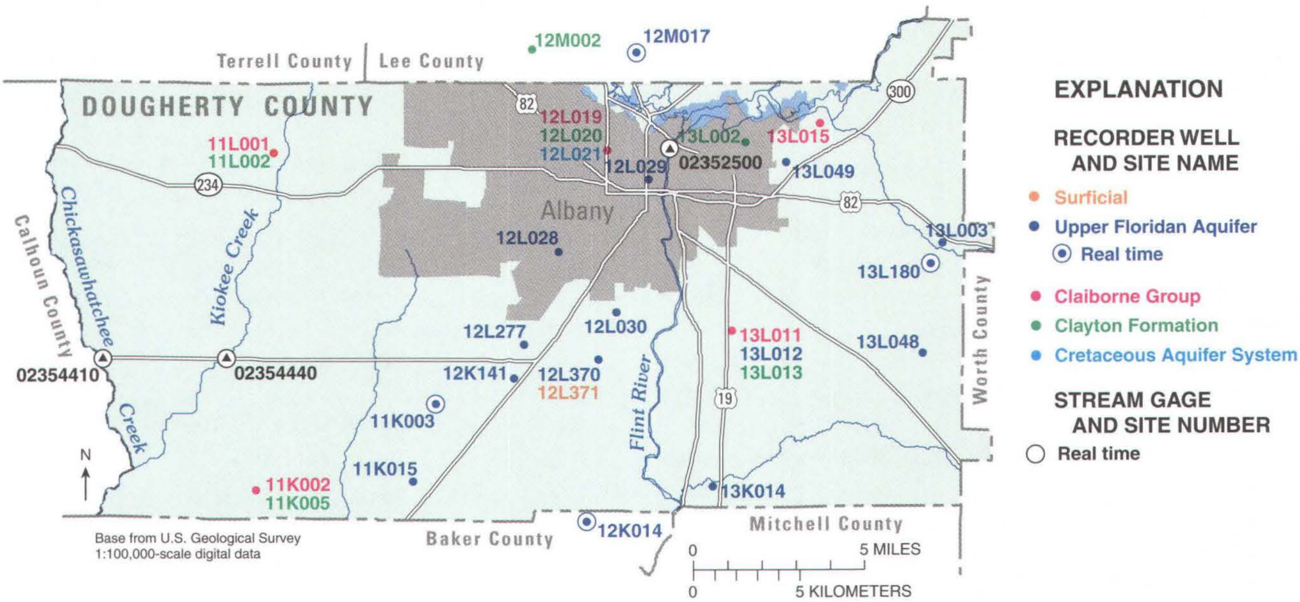
- Continued investigating of nitrate contamination in the vicinity of the southwestern Albany area wellfield. Samples were collected from six wells during March 2001 for field properties, dissolved nitrite plus nitrate, and nitrogen-15 and oxygen-18 isotopes to help determine the source of nitrate contamination.
- Continued hydrologic and water-quality monitoring, and operation of continuous ground-water-level monitoring network, which includes 23 wells in 5 aquifers;
  a. Added three new wells to continuous recorder network in the vicinity of the wellfield;
  b. Presented hydrographs from eight of the wells in the network in a monthly letter report and on the Web at URL: *http://ga.water.usgs.gov/projects/albany/conditions/;* and
  c. Summarized local water-resources conditions for year 2000 in the USGS Open-File Report "Ground-Water Conditions in Georgia, 2000" (Cressler and others, 2001).
- Collected water-level measurements from 66 wells in the southwest Albany area during October 29–30, 2001, and constructed a potentiometric-surface map.
- Collected water samples from 11 wells in the same area during November 13–16, 2001, are being analyzed for major cations, anions, and nutrients.
- Developed a Web site for the Albany program to provide the public with hydrologic information in the Albany area. Included on the Web site is information on ground-water activities; references and publications; ground-water, surface-water, and drought monitoring; ground-water-quality data; and links to many other Web pages related to Albany's water issues. The Web site may be accessed at URL: *http://ga.water.usgs.gov/projects/albany/*.
- Continued maintaining Albany area databases. During 2001, a water-quality database was developed to provide information on water-quality data collected since 1951 in the Albany area. This database is available on a CD–ROM (Warner and others, 2002) and is linked to the aforementioned Web site.

References Cited

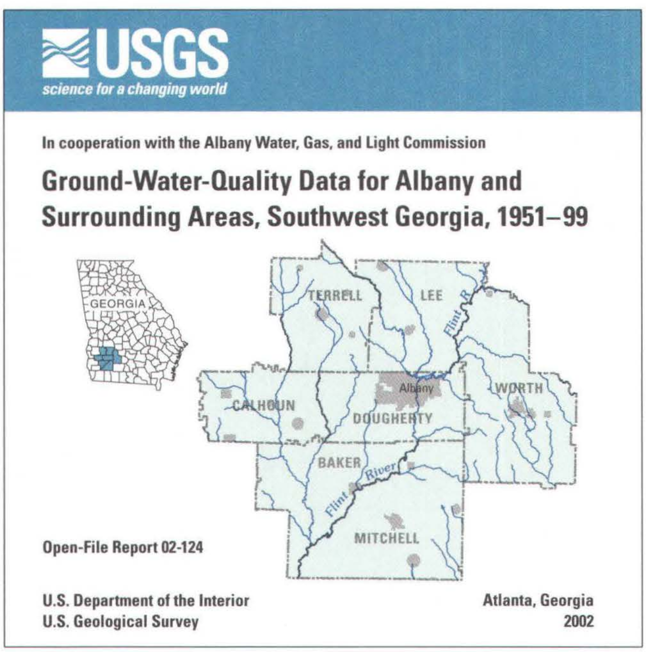
Cressler, A.M., Blackburn, D.K., and McSwain, K.B., 2001, Ground-water conditions in Georgia, 2000: U.S. Geological Survey Open-File Report 01-220, 182 p.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, revised as of July 1, 2000, p. 612–614.

Warner, Debbie, Easoz, J.E., and Priest, Sherlyn, 2002, Ground-water-quality data for Albany and surrounding areas, southwest Georgia, 1951–99: U.S. Geological Survey Open-File Report 02-124, CD–ROM.



The USGS continuously records water levels in 29 wells and 3 stream gages in the Albany area, shown on the map above. Data from four of these wells and the three stream gages are available in realtime at URL: ***http://ga.waterdata.usgs.gov/nwis/current/?type=gw.***



USGS
science for a changing world

In cooperation with the Albany Water, Gas, and Light Commission

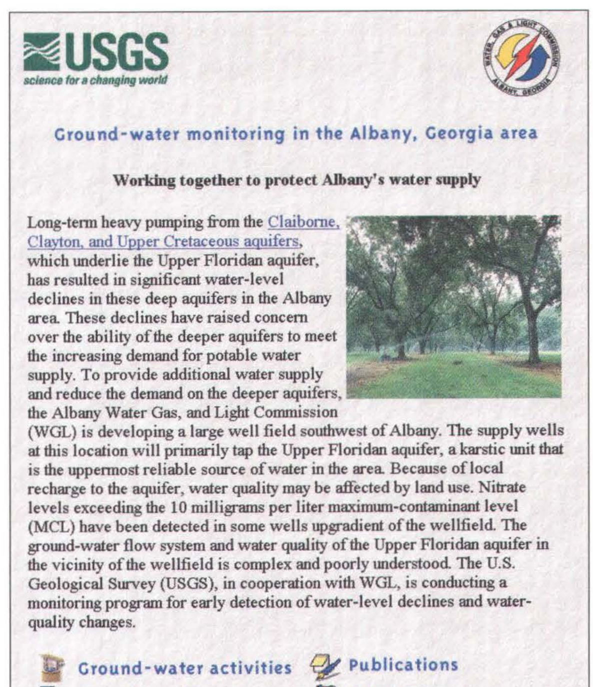
Ground-Water-Quality Data for Albany and Surrounding Areas, Southwest Georgia, 1951–99

Open-File Report 02-124

U.S. Department of the Interior
U.S. Geological Survey

Atlanta, Georgia
2002

A CD–ROM report entitled "Ground-Water-Quality Data for Albany and Surrounding Areas, Southwest Georgia, 1951–99" was published to provide information on water quality since 1951, in the Albany area.



USGS
science for a changing world

Ground-water monitoring in the Albany, Georgia area

Working together to protect Albany's water supply

Long-term heavy pumping from the Claiborne, Clayton, and Upper Cretaceous aquifers, which underlie the Upper Floridan aquifer, has resulted in significant water-level declines in these deep aquifers in the Albany area. These declines have raised concern over the ability of the deeper aquifers to meet the increasing demand for potable water supply. To provide additional water supply and reduce the demand on the deeper aquifers, the Albany Water Gas, and Light Commission (WGL) is developing a large well field southwest of Albany. The supply wells at this location will primarily tap the Upper Floridan aquifer, a karstic unit that is the uppermost reliable source of water in the area. Because of local recharge to the aquifer, water quality may be affected by land use. Nitrate levels exceeding the 10 milligrams per liter maximum-contaminant level (MCL) have been detected in some wells upgradient of the wellfield. The ground-water flow system and water quality of the Upper Floridan aquifer in the vicinity of the wellfield is complex and poorly understood. The U.S. Geological Survey (USGS), in cooperation with WGL, is conducting a monitoring program for early detection of water-level declines and water-quality changes.

Ground-water activities
Publications
Site information
References

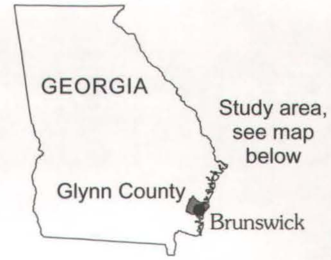
A Web site was developed for the Albany program to provide the public with hydrologic information in the Albany area. The Web site can be accessed at URL: ***http://ga.water.usgs.gov/projects/albany.***

City of Brunswick and Glynn County Cooperative Water-Resources Program

Study Chief James L. Labowski

Cooperator City of Brunswick/Glynn County

Year Started 1959



Problem

In the Brunswick area, saltwater has contaminated the Upper Floridan aquifer for nearly 50 years. Currently (2001) within an area of several square miles of downtown Brunswick, the aquifer yields water that has a chloride concentration greater than 2,250 milligrams per liter and is above State and Federal drinking-water standards (Georgia Environmental Protection Division, 1997; U.S. Environmental Protection Agency, 2000). Saltwater contamination has constrained further development of the Upper Floridan aquifer in the Brunswick area and prompted interest in the development of alternative sources of water supply, primarily from the shallower surficial and upper and lower Brunswick aquifers, and from the deeper Lower Floridan aquifer.

Objectives

- Better define mechanisms of ground-water flow and movement of saltwater in the Floridan aquifer system;
- Define the vertical geometry of the high-chloride plume;
- Assess alternative sources of water supply from the surficial aquifer, Brunswick aquifer system, and the Lower Floridan aquifer; and
- Monitor long-term ground-water levels and quality, and develop and maintain a comprehensive ground-water database.

Progress and Significant Results, 2001

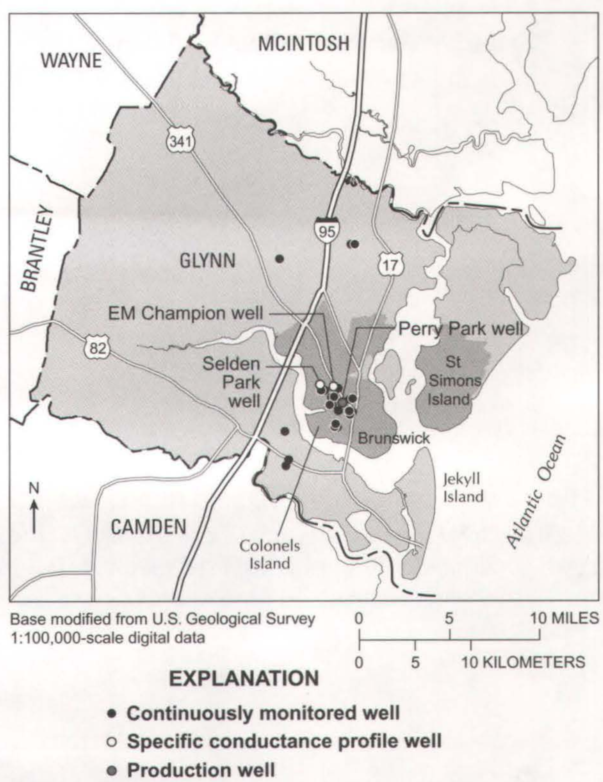
- Continued operating the 22-well continuous ground-water-level monitoring network (13 in the Upper Floridan aquifer, 4 in the Lower Floridan aquifer, 4 in the Brunswick aquifer system, and 1 well in the surficial aquifer).
- Collected samples from 65 wells during June 2001 for analysis of chloride concentration, and prepared chloride and water-level maps.
- Incorporated new well information into the U.S. Geological Survey (USGS) National Water Information System (NWIS) database, including 18 upper and lower Brunswick aquifer wells and 2 Upper Floridan aquifer wells.
- Obtained vertical specific conductance profiles at two well sites to better define the vertical geometry of the high-chloride plume at Brunswick. These data are being evaluated to determine applicability of similar efforts in the future.
- Compiled hydraulic properties of hydrogeologic units. Aquifer tests were conducted in wells completed in the Lower Floridan aquifer at a new test-well site in Brunswick.
- Developed aquifer test specifications for a combined test/production well to be completed in the Lower Floridan aquifer on St. Simons Island, east of Brunswick. Data from this well will be evaluated to determine the water quality and water-bearing properties of the Lower Floridan aquifer.
- Developed a Web site for the Brunswick program that may be accessed at URL: *http://ga2.er.usgs.gov/brunswick/*.

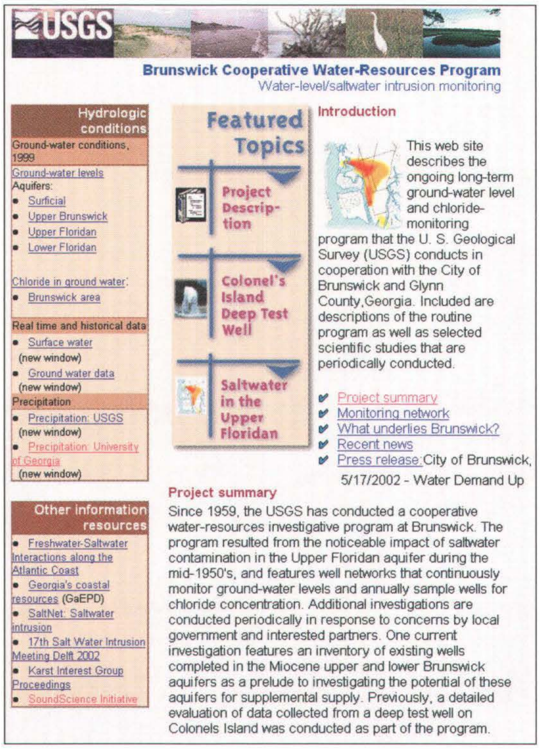
References Cited

Georgia Environmental Protection Division, 1997, Secondary maximum contaminant levels for drinking water: Environmental Rule 391-3-5-19, revised October 1997: Official Code of Georgia Annotated Statutes, Statute 12-5-170 (Georgia Safe Drinking Water Act), variously paginated.

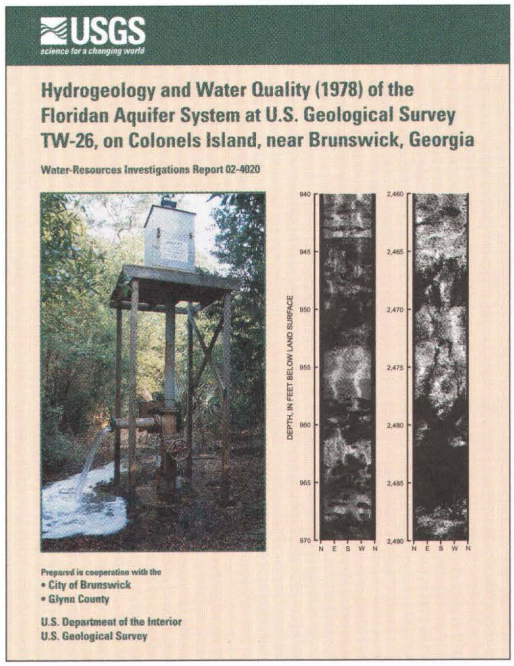
Jones, L.E., Prowell, D.C., and Maslia, M.L., 2002, Hydrogeology and water quality (1978) of the Floridan aquifer system at U.S. Geological Survey TW-26, on Colonels Island, near Brunswick, Georgia: U.S. Geological Survey Water-Resources Investigations Report 02-4020, 44 p.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, revised as of July 1, 2000, p. 612–614.



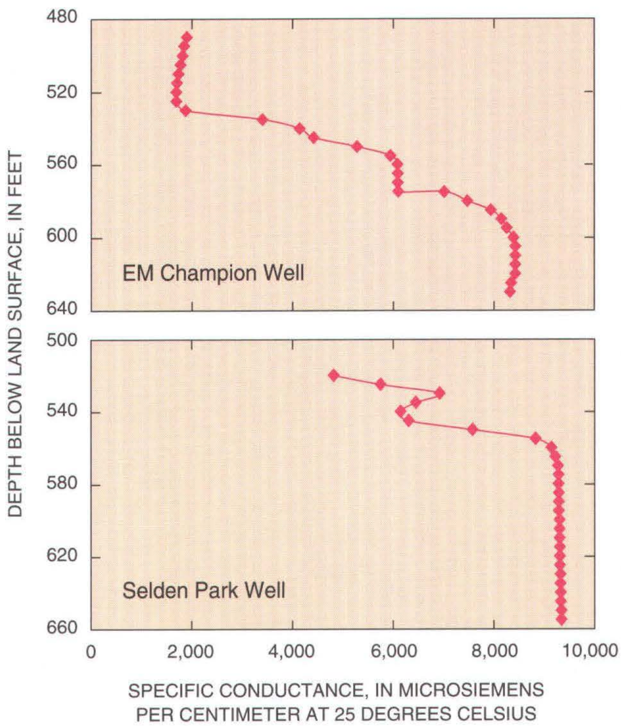


The USGS Brunswick Web site describes the ongoing long-term ground-water-level and chloride monitoring program that the USGS conducts in cooperation with the city of Brunswick, Glynn County, and industry partners. Included are descriptions of the core program, special scientific studies that are conducted periodically, and historical chloride concentration maps. The Web site can be accessed at URL: ***http://ga2.er.usgs.gov/brunswick/***.



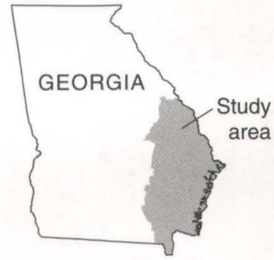
A recently published USGS report (Jones and others, 2002) describes data from the deep test well on Colonels Island (cover shown above).

The Perry Park production well is an example of how high-chloride ground water can be withdrawn from depth with pumping. The well is located near the boundary of the saltwater plume. Here, the well is being prepared for Hydrophysical™ logging in an attempt to identify the entrance depth of the high-chloride water. Photo by Welby L. Stayton, USGS.



Vertical profiles of specific conductance within the open interval of two wells (shown above) indicate stratification of chloride concentration in Upper Floridan aquifer wells located in or near to the high-chloride plume at Brunswick.

Coastal Sound Science Initiative



Study Chief Dorothy F. Payne

Cooperator Georgia Department of Natural Resources, Environmental Protection Division, Geologic Survey Branch

Year Started 2000

Problem

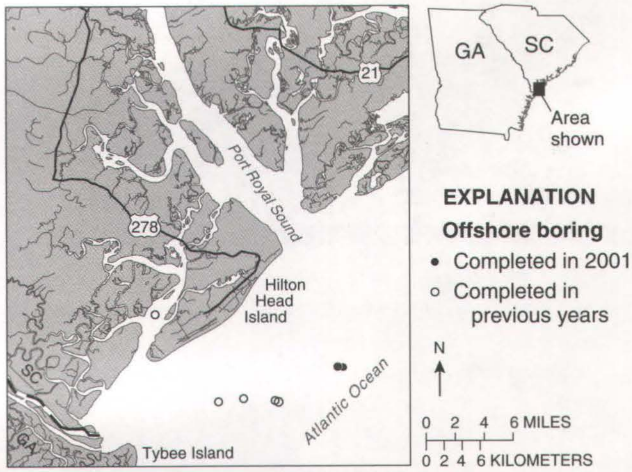
Pumping from the Upper Floridan aquifer has resulted in substantial water-level decline and saltwater intrusion at the northern end of Hilton Head Island, South Carolina, and at Brunswick, Georgia. This saltwater contamination has constrained further development of the Upper Floridan aquifer in the coastal area and created competing demands for the limited supply of water. The Georgia Environmental Protection Division (EPD) has capped permitted withdrawal from the Upper Floridan aquifer at 1997 rates in parts of the coastal area, prompting interest in the development of alternative sources of water supply, primarily from the shallower upper and lower Brunswick aquifers and surficial aquifers.

Objectives

- Better define mechanisms of ground-water flow and movement of saltwater;
- Delineate paths and rates of ground-water flow and intrusion of saltwater into the Upper Floridan aquifer and develop models to simulate a variety of water-management scenarios;
- Delineate areas where saltwater is entering the Floridan aquifer system offshore of the Savannah–Hilton Head Island area;
- Assess long-term ground-water levels and quality, and develop and maintain a comprehensive ground-water database; and
- Assess alternative sources of water supply from:
  - a. seepage ponds connected to the surficial aquifer,
  - b. the Lower Floridan aquifer, and
  - c. the upper and lower Brunswick aquifers.

Progress and Significant Results, 2001

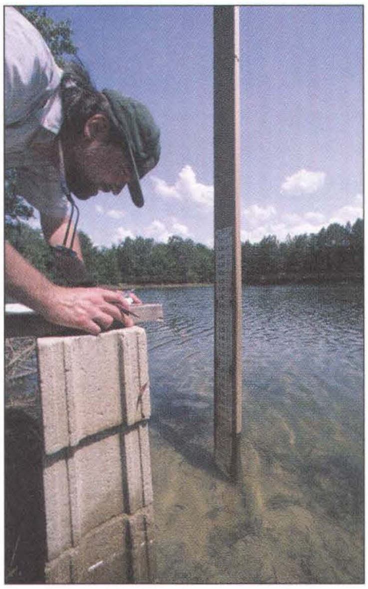
- Constructed three deep test wells penetrating the Lower Floridan aquifer and collected geologic and water-quality samples and geophysical logs from those wells. There are now 6 new Lower Floridan test wells in coastal Georgia, for a total of 13. Conducted pumping tests at the new sites to assess water-bearing properties.
- Completed borings at two sites offshore of Hilton Head Island, South Carolina, to investigate areas of possible paleo-river incision into the Upper Floridan aquifer and related effects on ground-water quality, head, and hydraulic properties (five other borings were drilled in previous years). Collected geologic and water-chemistry samples and geophysical logs from each of the borings.
- Completed calibration of ground-water-flow model for Brunswick seepage pond site. Completed field investigation of water availability at a seepage pond site in Bulloch County. This included installing test wells and monitoring equipment, conducting a pumping test, developing a detailed water budget, and developing a ground-water-flow model.
- Continued development of project database. Installed water-level recorders in 10 test wells and collected geophysical logs from 15 new and existing wells. Completed development of nonagricultural water-use database for Georgia. Data for 90 wells were incorporated into the U.S. Geological Survey (USGS) National Water Information System (NWIS) database.
- Continued development of ground-water-flow and solute transport models. Completed development of Geographic Information System (GIS) coverages and user interfaces for models. Preliminary solute transport models were developed for the Savannah–Hilton Head Island and Brunswick areas.
- Published reports describing (1) stratigraphy of Oligocene and younger units; and (2) coastal ground water at risk (poster). A project Web site was developed describing saltwater contamination in coastal Georgia, monitoring data, and ongoing project activities, which can be accessed at URL: *http://ga2.er.usgs.gov/coastal.*



Base from U.S. Geological Survey 1:100,000-scale digital data

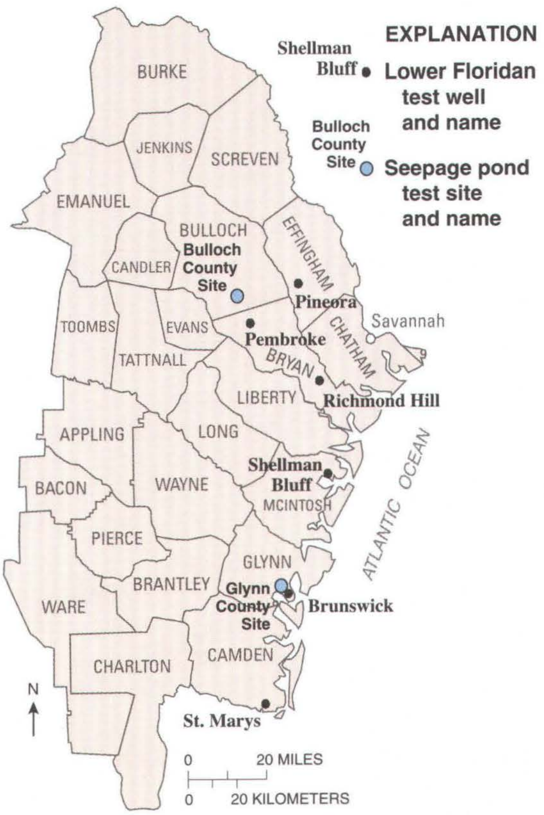
A 1,863-foot-deep exploratory boring was completed at a site in northern McIntosh County during 2001. Geologic, hydrologic, water-quality, and geophysical data are being evaluated to assess the viability of the Lower Floridan aquifer as a source of water and to support ground-water modeling investigations in coastal Georgia. In addition to the McIntosh County well, two additional wells were completed in Bryan and Effingham Counties during 2001. Photo by John S. Clarke, USGS.

The U.S. Army Corps of Engineers jack-up barge was used as a platform for drilling offshore test borings. Core, hydrologic, water-quality, and geophysical data were collected at five sites during 1999–2001. Data are being used to investigate the position of the freshwater-saltwater interface and to better define hydraulic head and hydraulic properties offshore of Tybee Island, Georgia, and Hilton Head Island, South Carolina. Photo by Michael F. Peck, USGS.



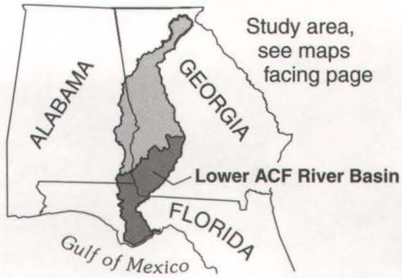
A USGS hydrologic technician takes a stage reading at a seepage pond in Bulloch County during a pumping test during May 2001. The test is being conducted to assess the viability of seepage ponds as an irrigation water supply. Test sites at Bulloch and Glynn Counties were instrumented with test wells, weather stations, and stage recorders to develop a detailed hydrologic budget and determine pond-aquifer relations. Photo by Alan M. Cressler, USGS.

The map on the left (facing page) shows locations of offshore test borings, coastal Georgia and South Carolina. Borings located at varying distances offshore of Tybee Island, Georgia, are being used to better define the position of the freshwater-saltwater interface. Locations of borings were guided, in part, by marine seismic surveys conducted by Georgia Southern University and the Skidaway Institute of Oceanography.



Locations of Lower Floridan test wells and seepage pond test sites in coastal Georgia that are part of the Coastal Sound Science Initiative.

Effects of Impoundment of Lake Seminole on Water Resources in the Lower Apalachicola–Chattahoochee–Flint River Basin in parts of Alabama, Florida, and Georgia



Study Chief Lynn J. Torak

Cooperator Georgia Department of Natural Resources Environmental Protection Division Geologic Survey Branch

Year Started 1999

Problem

Multiple uses of freshwater supplies in the lower Apalachicola–Chattahoochee–Flint (ACF) River Basin have been the concern of water managers in the States of Alabama, Florida, and Georgia for many years. Numerous studies have been conducted in an attempt to understand the complex relations that exist between hydrologic-system components and natural stresses, and to answer questions regarding the effects on those relations caused by human intervention. Although previous studies addressed important water-resource issues in the lower ACF River Basin, by design, none provided a mechanism for collecting real-time hydrologic data necessary to develop and maintain an accurate water budget for Lake Seminole and the stream-lake-aquifer flow system. None of these studies focused on investigating the hydrologic and hydrogeologic implications of impoundment of Lake Seminole by construction of Jim Woodruff Lock and Dam and the effect of the lake on other components of the flow system. In response to these needs, the U.S. Geological Survey (USGS) has entered into a cooperative agreement with the Georgia Department of Natural Resources to develop a water budget of the Lake Seminole area, to reasonably estimate the volume of water flowing into Florida before and after construction of the dam, and to monitor the effects of any sinkhole collapse beneath the lake.

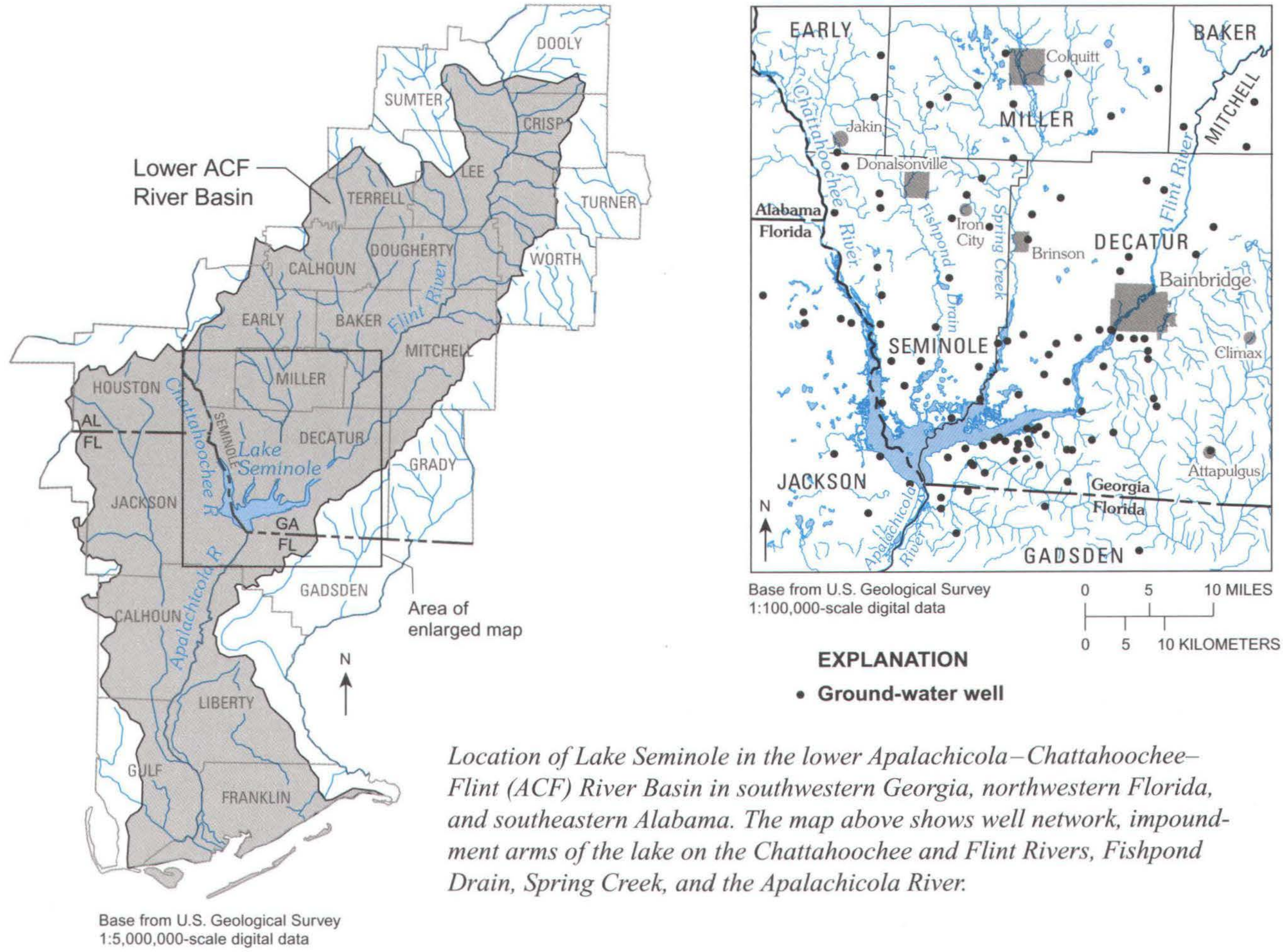
Objectives

- Develop a water budget for Lake Seminole that will result in reasonable understanding of the effect of the lake on the overall flow system in the lower ACF River Basin;
- Compare current (2001) and pre-Lake Seminole ground-water and surface-water flow to determine whether the volume of water flowing out of Georgia has changed significantly after construction of Jim Woodruff Lock and Dam and filling of the lake;
- Evaluate the possibility of a substantial amount of water entering the ground-water system from Lake Seminole, flowing beneath Jim Woodruff Lock and Dam, and entering Florida downstream of the dam; and
- Assess the likelihood of failure of dissolution features in the karst limestone of the lake bottom, such as sinkhole collapse, and the likelihood of sudden partial or complete draining of the lake. If these events are likely, then propose a data-collection system to monitor conditions that might lead to sudden draining of Lake Seminole.

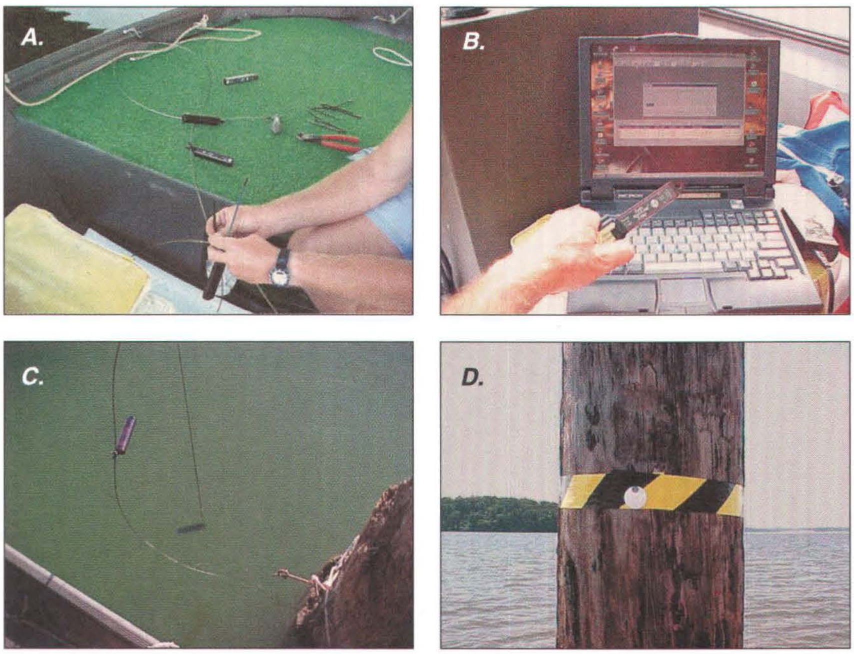
Progress and Significant Results, 2001

- Continued monitoring lake temperature, meteorological conditions, and ground-water levels near the lake. Lake-temperature profiles can identify seasonal springflow variation to impoundment arms and along the lake bottom.
- Completed sampling and chemical analysis of surface and ground water during 1-year period to evaluate lake-aquifer interconnection. Ground water and surface water have distinct chemical signatures that indicate complex inflow, outflow, and mixing processes.
- Assisted U.S. Army Corps of Engineers dye-tracing evaluation of leakage in the vicinity of the Jim Woodruff Lock and Dam by identifying temperature variations in dam pool and analyzing water samples at dye-collection sites beneath the dam. Preliminary results indicate that lake water mixes with ground water beneath and downstream of the dam.
- Compiled geophysical-log information from Florida and Alabama for developing hydrogeologic framework of Lake Seminole and vicinity.
- Began development of automated methods for water-budget calculations and flow-cell analyses.
- Developed ground-water model approach for evaluating pre- and post-impoundment flow and for computing ground-water inflow to and outflow from the lake.

Automated real-time weather station installed over water on piling to monitor atmospheric conditions at Sneads Landing, Florida. The weather station is part of the State of Georgia's Automated Environmental Monitoring Network accessed at URL: ***http://www.georgiaweather.net***.



Location of Lake Seminole in the lower Apalachicola–Chattahoochee–Flint (ACF) River Basin in southwestern Georgia, northwestern Florida, and southeastern Alabama. The map above shows well network, impoundment arms of the lake on the Chattahoochee and Flint Rivers, Fishpond Drain, Spring Creek, and the Apalachicola River.



Deployment of temperature probes in Lake Seminole:

(A) *attaching probes to weighted line at specified depths,*

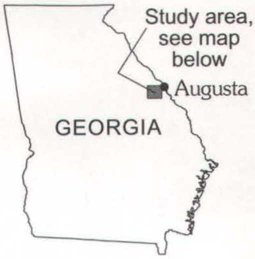
(B) *programming sampling interval and synchronizing start-up (launch) of probe,*

(C) *probe array attached to cypress stump in lake, and*

(D) *completed temperature-probe station marked with safety tape and medallion.*

Photos by Lynn J. Torak, USGS.

Fort Gordon Ground-Water Assessment



Study Chief Sherlyn Priest

Cooperator Environmental and Natural Resources Management Office of the U.S. Army Signal Center, and Fort Gordon, Georgia

Year Started 1998

Problem

Fort Gordon military installation near Augusta, Georgia, is experiencing increasing water-supply demands for ground-water sources. Development of ground-water supplies requires data on ground-water conditions. Training Area 25 is being considered to meet future water-supply demands on the base. The Georgia Department of Natural Resources (GaDNR), Environmental Protection Division (GaEPD), Georgia Geologic Survey, has water-use permitting authority in the State of Georgia to monitor large ground-water withdrawal and manage ground-water resources.

The Georgia Department of Human Resources, Environmental Health Division, requires an understanding of water-quality conditions to ensure that possible contamination of the water supply from industrial and commercial users near Training Area 25 does not exceed the U.S. Environmental Protection Agency (USEPA), National Primary Drinking Water Standards (U.S. Environmental Protection Agency, 2000). The U.S. Geological Survey (USGS), in cooperation with Fort Gordon, is providing an assessment of hydrogeology and ground-water conditions by collecting and evaluating borehole geophysical logs from wells near Training Area 25. Also, the USGS is conducting GaEPD annual compliance sampling at Fort Gordon.

Objectives

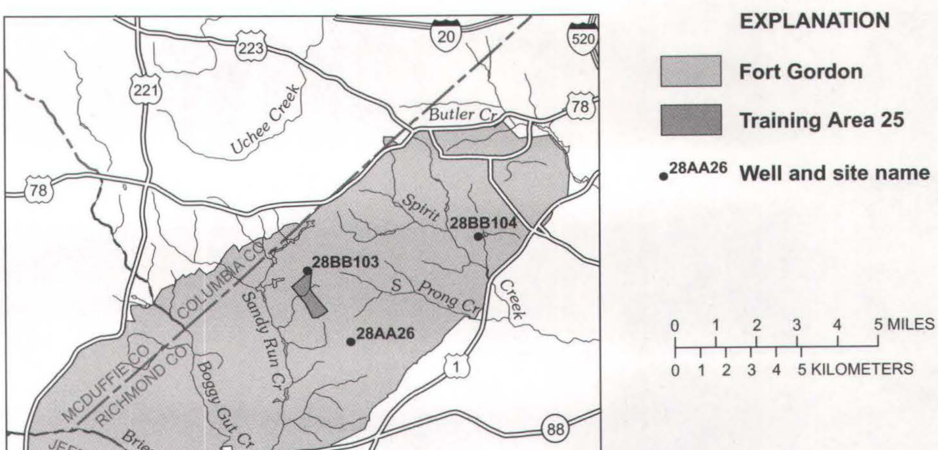
- Assist Fort Gordon in meeting water-supply demands by describing the hydrogeology of Training Area 25; and
- Assist Fort Gordon in meeting GaEPD permitting requirement to monitor water-quality conditions at Fort Gordon. The permit requires that Fort Gordon annually sample ground water for selected volatile organic compounds.

Progress and Significant Results, 2001

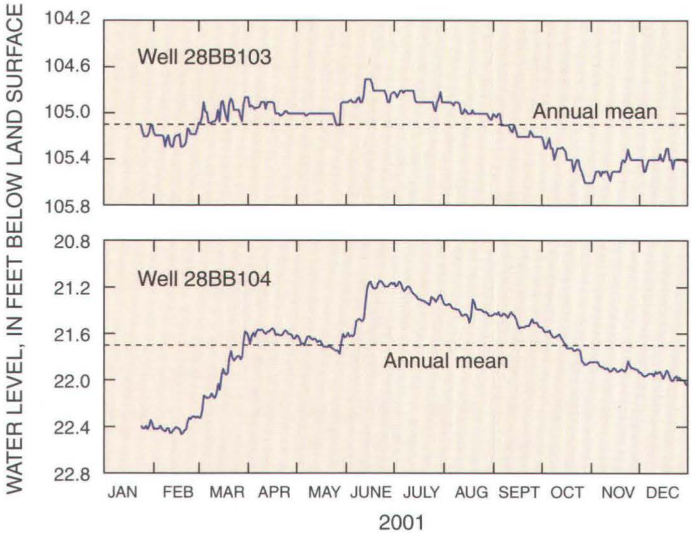
- Lithologic logs from five wells and geophysical logs from three wells are being used to construct a geologic cross section of Training Area 25 and vicinity. The geologic cross section will show water-bearing zones and confining units in the study area. Also, the USGS continued ground-water-level monitoring in wells equipped with continuous water-level recorders.
- USGS constructed a water-table well about 2 feet downgradient of a drain field. Water collected from the well was sent to a USEPA-approved laboratory and tested for benzene, toluene, ethyl benzene, xylene, and ethylene glycol.

Reference Cited

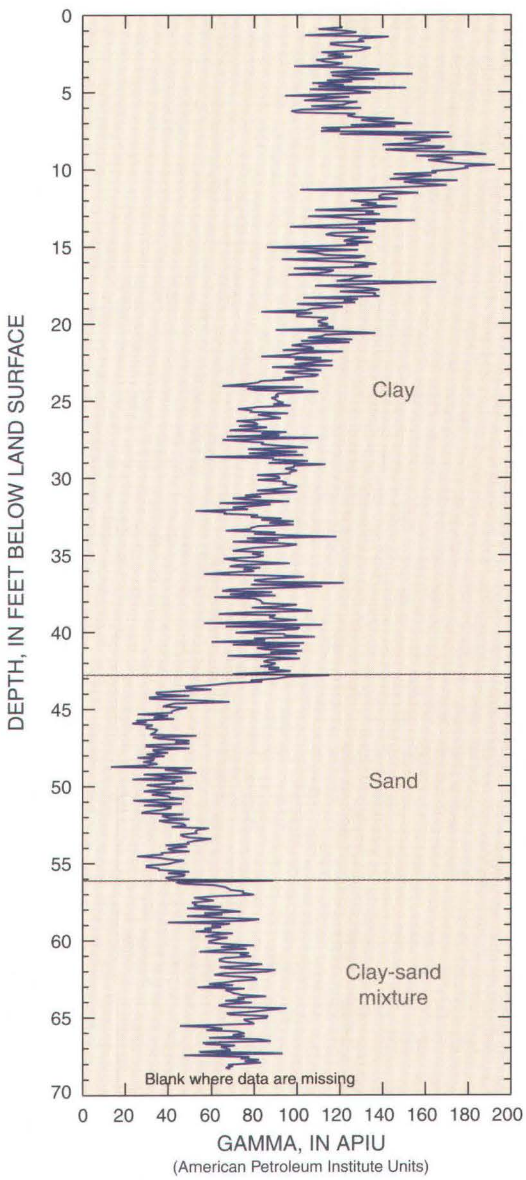
U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Subpart B of Part 141, National Primary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, revised as of July 1, 2000, p. 334–560.



Base from U.S. Geological Survey 1:100,000-scale digital data



Water-level measurements from two monitoring wells at Fort Gordon, Georgia, indicate a rise in water level from mid-winter to early summer, then a gradual decline. During the course of calendar year 2001, the water level at well 28BB103 declined about 0.2 foot, and the water level at well 28BB104 rose about 0.4 foot.



Natural gamma radiation log of well 28AA26 indicates the presence of clay from the surface to a depth of about 43 feet, where the strata becomes more sandy. At a depth of about 56 feet, the strata grades back into a clay-sand mixture.

A test well was completed near Training Area 25 at Fort Gordon, Georgia. The 260-foot-deep well was completed with a screened interval between 198 and 238 feet. Geologic and hydrologic data are being evaluated to assess the viability of ground water as a source of water supply to support increasing demands. Photo by Sherlyn Priest, USGS.

Location, construction, and water-level data for wells used in this study [NAVD 88, National Vertical Datum of 1988]

Site name	Other identifier	Latitude	Longitude	Depth, in feet below land surface		Altitude, in feet above NAVD 88	2001 annual-mean water level, in feet below land surface
				Top of screen or open interval	Bottom of screen or open interval		
28AA26	Wash Rack-Forestry Rd	33°20'53"	82°12'42"	51	71	457	57.0
28BB103	Range Control	33°22'41"	82°14'01"	198	238	500	105.1
28BB104	Mirror Lake	33°23'30"	82°08'39"	60	80	315	21.7

Geohydrology of the City of Lawrenceville area

Study Chief Lester J. Williams
Cooperator City of Lawrenceville
Year Started 1994

Problem

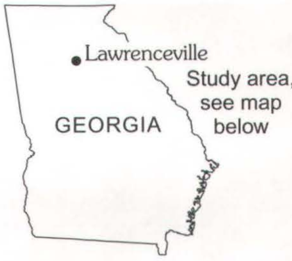
Areas of northern Georgia that are underlain by fractured igneous and metamorphic crystalline rock have almost exclusively used surface water drawn from rivers and lakes as a source for municipal water supply. The city of Lawrenceville in Gwinnett County is one of only a few municipalities in the Atlanta Region that uses ground water to supplement their water supply. Currently (2001) only a small part of the city's water supply (approximately 5 percent) comes from ground-water sources; however, the city is developing additional ground-water resources in the area to increase this amount. Information gained from this study will also benefit other communities planning to develop a ground-water supply in a fractured crystalline rock setting.

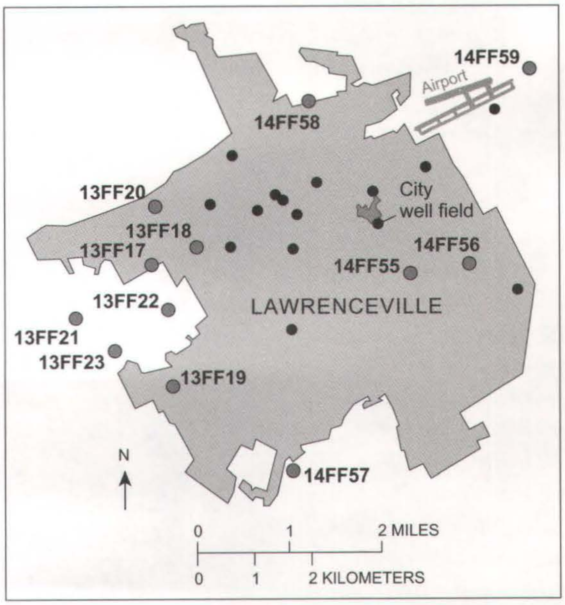
Objectives

- Evaluate the hydrogeology of the study area;
- Determine ground-water occurrence and flow near the city production wells;
- Determine areal extent and recharge pathways to pumped wells;
- Determine the storage potential and hydraulic characteristics of water-bearing zones at each site; and
- Improve methods of evaluating the ground-water resource potential of metamorphic and igneous rocks.

Progress and Significant Results, 2001

- Investigated site-specific geologic structure and hydrogeologic controls in various parts of the city in order to help identify potentially productive portions of the aquifer.
- Conducted detailed geologic mapping surveys in a number of small subareas between fall 2000 and spring 2001. The surveys were conducted to identify small-scale jointing, fracturing, and structural relations not mapped during an earlier regional-scale mapping effort. Two-dimensional-resistivity surface geophysical surveys were conducted at some of the sites to help identify potential open-fracture zones prior to test drilling.
- Selected locations, and drilled 12 test wells between May and August 2001. Subsurface structure and lithologic units penetrated at each test well were characterized using borehole geophysical techniques including: borehole television camera, electric logs, fluid temperature and resistivity, natural gamma, caliper, digital acoustic televiewer and flowmeter logs.
- Collected water samples to determine age using chlorofluorcarbon (CFC) techniques, to help evaluate recharge mechanisms to the fractured crystalline rock, and monitored the hydraulic response in the aquifer.

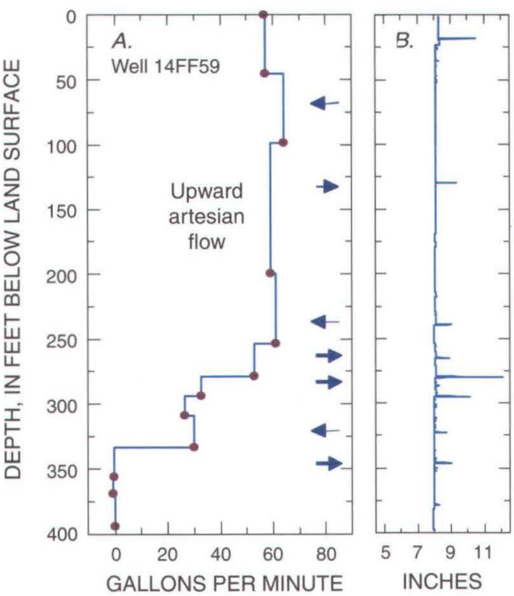




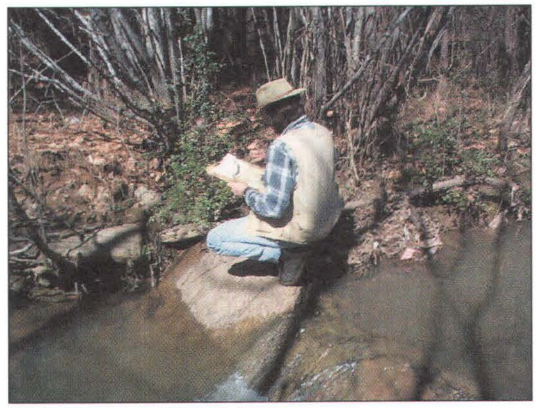
EXPLANATION

- **Existing well**
- **Recently drilled test well and site name**

Site name	Casing depth	Total depth
	In feet below land surface	
13FF17	15	480
13FF18	55	550
13FF19	65	477
13FF20	72	455
13FF21	40	505
13FF22	20	600
13FF23	30	400
14FF55	65	425
14FF56	26	605
14FF57	30	380
14FF58	34	550
14FF59	35	460

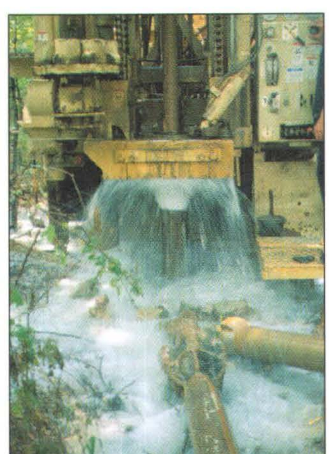


The photo above shows an electromagnetic flowmeter sonde used in Lawrenceville to measure precise flow rates along a borehole segment. The flowmeter log (A) from well 14FF59 shows most ground water is entering the borehole at fractures between 260 and 345 feet below land surface. The blue arrows indicate inflow (right facing arrows) and outflow (left facing arrows) from the borehole. The caliper log (B) shows peaks where the borehole diameter is enlarged at discrete fracture openings in the bedrock aquifer. Data are being used to characterize hydraulic properties of individual fracture zones. Photo by Lester J. Williams, USGS.



The USGS collected detailed structural and geologic information during 2001. Data are being used to relate surface and subsurface geologic features to better understand the geologic controls affecting the availability of ground water. Photo by Lester J. Williams, USGS.

Pumping tests were conducted on six test wells during 2001, such as well 14FF55 above. The USGS used an orifice weir to measure pump discharge. The USGS collected chlorofluorocarbon samples from the wells and monitored water levels to better define aquifer hydraulic properties. Photo by Lester J. Williams, USGS.



Test wells in the Lawrencville study were drilled using an air rotary drilling rig. The photo to the left shows the discharge from air-lifting ground water from well 14FF59 after penetrating water-bearing fracture zones. Photo by Alan M. Cressler, USGS.

Ground-Water Information and Project Support

Study Chief David C. Leeth

Cooperators Georgia Department of Natural Resources
Environmental Protection Division
Georgia Geologic Survey
Albany Water, Gas, and Light Commission
City of Brunswick
Glynn County
St. Johns Water Management District, Florida

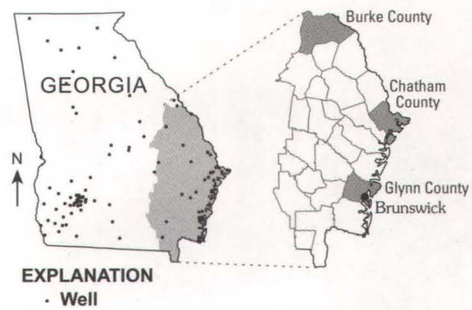
Year Started 1938

Problem

Ground water accounts for about 22 percent of freshwater withdrawals in Georgia—more than 2.7 billion gallons per day. More than 1.8 million people are served by ground-water supplies, and 734 million gallons per day are withdrawn for irrigation (Julia L. Fanning, U.S. Geological Survey, oral commun. with David C. Leeth, October 7, 2002). The distribution and quality of ground water are highly variable and directly related to geology, and natural and human stresses. Monitoring ground-water levels and ground-water quality is essential to the management and development of this resource.

Objectives

- Collect ground-water-level and ground-water-quality data to assess the quantity, quality, and distribution of ground water;
- Address water-management needs and evaluate the effects of national and local management and conservation programs;
- Advance the knowledge of the regional hydrologic system;
- Advance field or analytical methodology;
- Advance the understanding of hydrologic processes;
- Provide data or results useful to multiple parties in potentially contentious inter-jurisdictional conflicts about water resources;
- Furnish hydrologic data required for interstate and international compacts, Federal law, court decrees, and congressionally mandated studies;
- Provide water-resources information that will be used by multiple parties for planning and operational purposes; and
- Contribute data to national databases that will be used to advance the understanding of regional and temporal variations in hydrologic conditions.

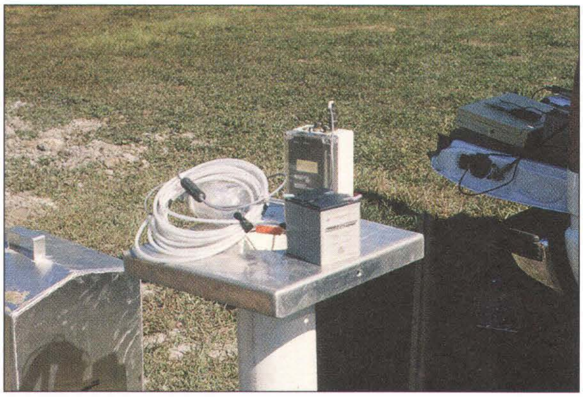


Progress and Significant Results, 2001

- Continuous water-level recorders were operated in 184 wells, and data from 159 wells (map, above; photo *A*, facing page) were reported in an annual data report (Coffin and others, 2002). Periodic water-level measurements were made in more than 257 wells throughout the State (photo *B*, facing page). Water-level data were collected to define potentiometric surfaces during the current severe drought. Water samples were collected for chloride analysis from 66 wells in the Brunswick area, 10 wells in the Savannah area, and 6 wells in Camden County. Borehole-geophysical logs were collected from 27 wells—12 in the Lawrenceville area and 15 in the coastal area. The type of logs collected include caliper, natural gamma (photo *C*, facing page), electric (lateral, long and short normal resistivity) fluid-temperature, fluid-resistivity, electromagnetic induction, full-wave sonic, acoustic televiewer, and spinner-flowmeter (photo *D*, facing page). Borehole video logs were collected in all of the Lawrenceville wells and in one well in Glynn County.
- Well-inventory, water-level, and geologic data were verified for entry into the National Well-Inventory System (NWIS) database. Field inventories were conducted to assist projects, and sites were added to the NWIS Ground-Water Site Inventory (GWSI) to improve ground-water data coverage in the State. Thirteen wells were instrumented with real-time transmission (satellite relay) of continuous water-level records to aid in drought planning. The NWIS database may be accessed on the Web at URL: *http://waterdata.usgs.gov/ga/nwis/current/?type=gw.*

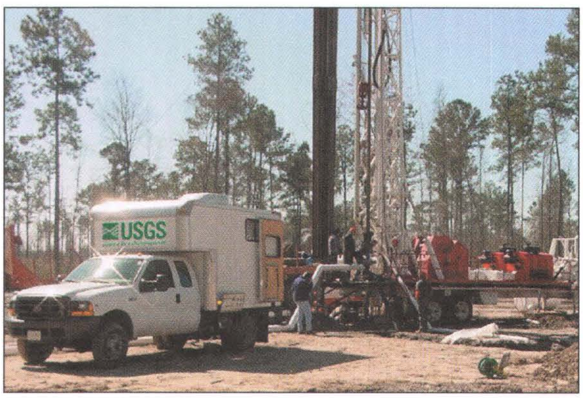
Reference Cited

Coffin, Robert, Grams, S.C., Cressler, A.M., and Leeth, D.C., 2002, Continuous ground-water-level data, and periodic surface-water- and ground-water-quality data, calendar year 2001, v. 2 *in* Alhadeff, S.J., and McCallum, B.E. (compilers), Water resources data–Georgia, 2001: U.S. Geological Survey Water-Data Report GA-01-2, CD–ROM.



A. *A typical continuous recorder setup on a well at Coastal Georgia Community College, Brunswick, which is part of the ground-water-level monitoring network. The equipment consists of a data logger, 30-pounds-per-square-inch transducer, and battery. The recorder is set to collect data on an hourly basis, downloaded on a monthly basis, and processed and stored in NWIS. Photo by Michael F. Peck, USGS.*

B. *A USGS employee using a graduated steel tape to measure the water level in an irrigation well in Burke County. Periodic water-level measurements were made in 257 wells throughout the State during 2001. These measurements are used to construct potentiometric-surface maps for selected aquifers. Photo by Michael D. Hamrick, USGS.*



C. *A logging truck collecting geophysical logs, and a hydraulic rotary drill rig at a well in Chatham County. As part of the Coastal Sound Science Initiative, geophysical, geologic, and water-quality data are collected from test wells drilled by the USGS and from wells drilled by private citizens. Photo by Michael F. Peck, USGS.*

D. *A public supply well in Glynn County is shown being pumped at about 1,000 gallons per minute while spinner flowmeter logs were collected to estimate percentages of water from different zones. This well is completed in the upper and lower Brunswick aquifers and the flowmeter logs help to quantify the ground-water contribution from each aquifer. Photo by Michael F. Peck, USGS.*

Ground-Water Resources and Hydrogeology of Crystalline-Rock Aquifers in Rockdale County, North-Central Georgia

Study Chief Lester J. Williams
Cooperator Rockdale County
Year Started 2001

Problem

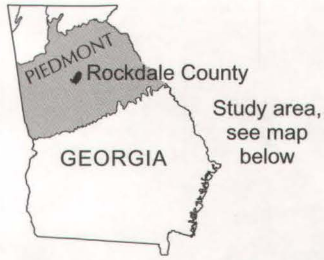
Until recently, it was widely accepted that little ground water was available from crystalline-rock aquifers of the Piedmont, and hence ground water was largely ignored as a viable water resource. Although ground water in the Piedmont may never be developed as a sole-source for a large municipality, this resource has been developed successfully as a dependable supplemental source for existing water supplies. If properly developed and managed, supplemental use of ground water can have great economic, environmental, and other practical benefits. Rockdale County is a high-growth area that plans to evaluate alternative sources of water to its existing surface-water supply. The county previously operated five wells that tapped into a productive granite gneiss unit; however, these wells are no longer used. The U.S. Geological Survey (USGS), in cooperation with Rockdale County, is evaluating ground-water availability and quality in crystalline-rock aquifers that underlie the area. Information from this project will be used for development of water resources. In addition, the ground-water studies in Rockdale County will allow the USGS to compile detailed information on rock types and geologic structures that tend to promote development of high-yielding water-bearing fractures. This information will help foster a better understanding of these aquifers and provide information for the future development and management of this resource.

Objectives

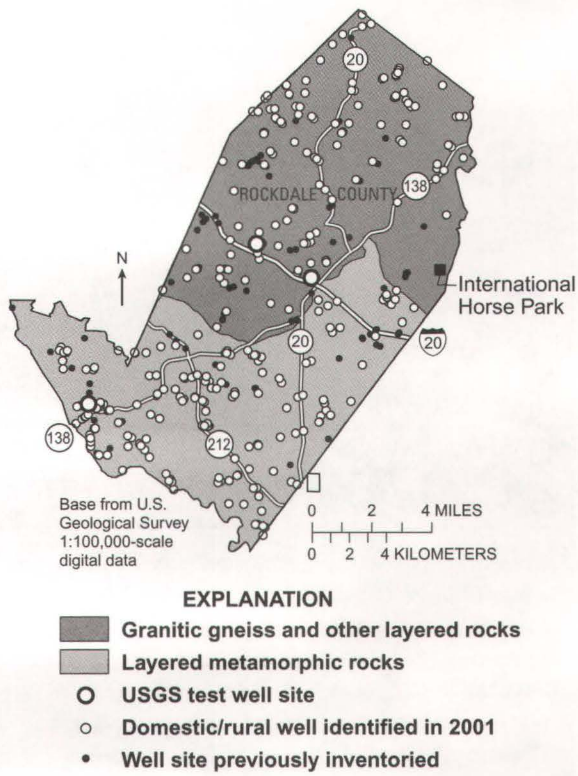
- Help define the best methods and approaches to characterize the availability of ground water in crystalline-rock areas. The USGS and others will use these methods for developing watersheds in similar geologic settings; and
- Provide baseline geologic and hydrologic information for a typical crystalline-rock aquifer setting in north Georgia. State and local water-management agencies will be able to use this information when developing ground-water-use policies for the region.

Progress and Significant Results, 2001

- Detailed record searches conducted at the Rockdale County Health Department and at the offices of two local well drillers provided information on more than 400 wells (primarily rural domestic) used to identify areas of Rockdale County that appear to have the greatest potential for ground-water development.

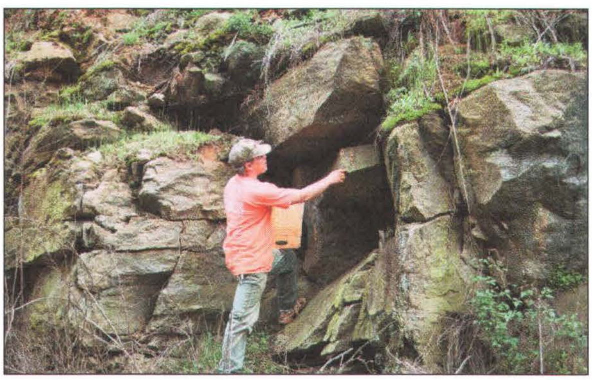


- A Geographic Information System (GIS) database is being developed to combine well data with existing geologic, topographic, hydrographic, and other geographic data. Approximately 50 percent of the GIS database was compiled during 2001.
- Initial geologic mapping and site reconnaissance were conducted in three smaller study areas in Rockdale County. In each of these areas, an unused water-supply well was identified for further subsurface and water-quality characterization.

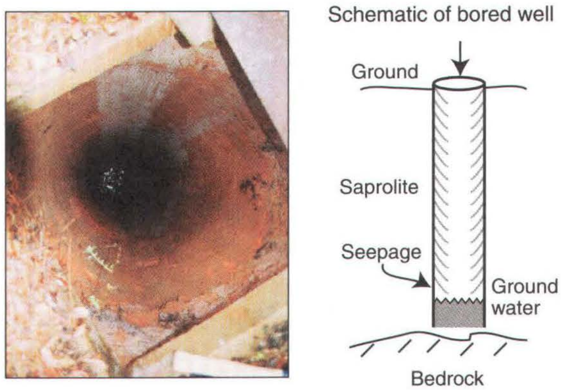


The northern part of Rockdale County is underlain mostly by massive granitic gneiss and the southern part is underlain by layered metamorphic rocks composed of biotite gneiss, quartzite, amphibolite, and schist. The USGS is trying to determine the differences in hydrologic properties of these geologic units.

The familiar sign, which can be seen when entering Rockdale County from Interstate 20 eastbound, is made from a large slab of migmatitic-granite gneiss. The granite-gneiss formation is exposed across a large area of northern Rockdale County and forms the hilly terrain and pavement outcrops that characterize this part of the county. Photo by Lester J. Williams, USGS.

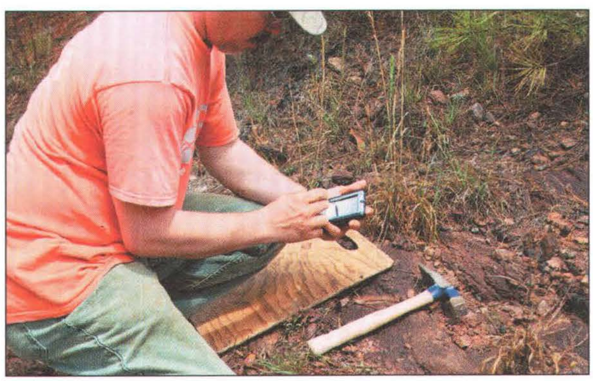


The photos above show the wide variation in fracturing that can be observed in the granite gneiss formation. The top photo, looking east, is a road cut of an unfractured granite gneiss located north of the International Horse Park in Conyers, Georgia. Photo by Lester J. Williams, USGS. The bottom photo shows a jointed granite gneiss located along Highway 138 approximately 2.5 miles north of the International Horse Park. The jointed granite gniess exhibits well developed fracture openings that parallel gneissic layering. Photo by Ethan W. Williams.



In parts of Rockdale County, ground water is obtained from large-diameter bored or dug wells. Ground water seeps into the well and collects at the bottom where it can be withdrawn (above, right). A bored or dug well is more susceptible to drought conditions than a deep drilled well. The sides of the bored well, shown in the photo above, are formed from saprolite derived from weathering of granite gneiss. Photo by Lester J. Williams, USGS.

A pavement outcrop of granite gneiss, north of the International Horse Park, is shown above. Wet areas on the pavement are the result of seepage of water from thin patchy soil areas following a recent rainfall. Photo by Ethan W. Williams.



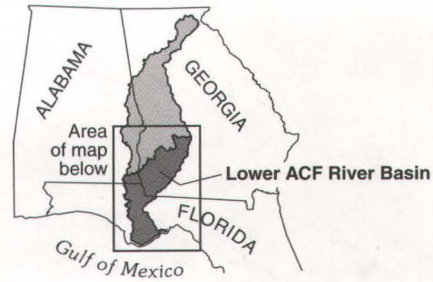
The USGS, working with Dr. Randy Kath of the State University of West Georgia, has developed a system for digital collection of structural data using a handheld computer and a global positioning system receiver. The photo above shows structural data being entered at a quartzite-schist outcrop. Photo by Ethan W. Williams.

Hydrogeologic Assessment and Simulation of Stream-Aquifer Relations in the Lower Apalachicola–Chattahoochee–Flint River Basin

Study Chief Lynn J. Torak

Cooperator Georgia Department of Natural Resources, Environmental Protection Division, Geologic Survey Branch

Year Started 2000



Problem

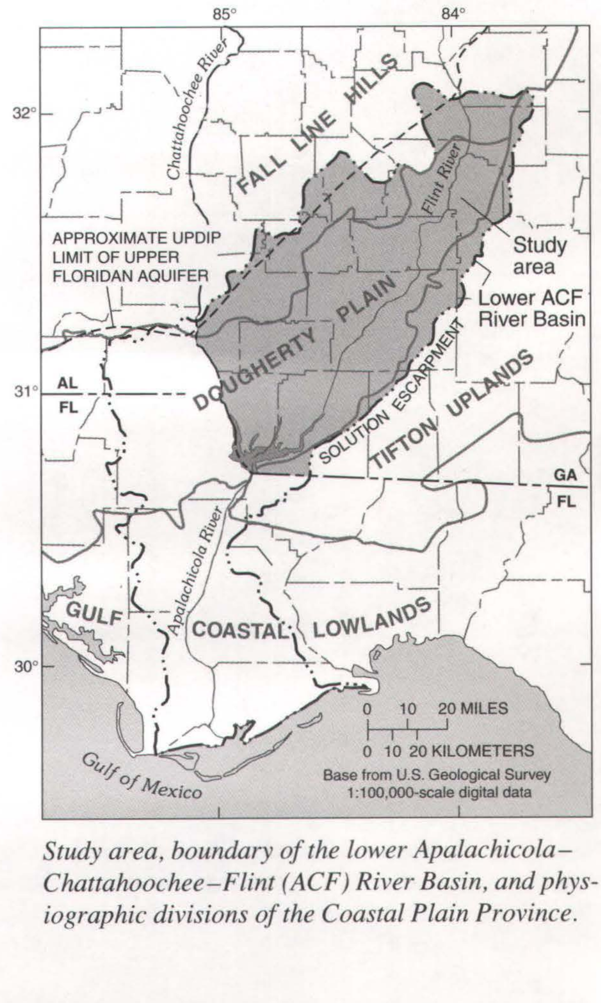
Current levels of hydrologic information and results of digital ground-water-flow modeling in the lower Apalachicola–Chattahoochee–Flint River Basin (map, facing page) are insufficient to describe effects of time-variant irrigation pumping on streamflow. Because of this, existing models cannot accurately predict ground-water or streamflow conditions during a growing season. The Georgia Department of Natural Resources is implementing a hydrologic assessment of the Upper Floridan aquifer in southwestern Georgia to obtain information on aquifer properties, pumping, ground- and surface-water levels, springflow, and streamflow. As part of this assessment and to further understanding of stream-aquifer relations and the effects of ground-water pumping on streamflow in a karst hydrologic setting, the U.S. Geological Survey (USGS) has engaged in a cooperative effort to develop a ground-water-flow model that can account for stream-aquifer interaction, especially streamflow reduction due to agricultural pumping. Information obtained from the model is vital for the State's management of ground-water resources and for providing early indications of low-streamflow conditions that would affect delivery of water to downstream, out-of-state users.

Objectives

- Develop new data for the Upper Floridan and surficial aquifers through evaluation of well-drilling and aquifer-test information;
- Obtain accurate locations of pumped wells for municipal, industrial, and irrigation purposes;
- Collect and compile ground-water level, stream-seepage, and off-stream spring-discharge data; and
- Develop a transient finite-element model of ground-water flow that incorporates newly collected and existing hydrologic data, having ability to simulate seasonal ground-water levels, stream-aquifer interaction, and pumpage-induced streamflow reduction.

Progress and Significant Results, 2001

- Located 25 sites for test boring, geophysical logging, well drilling and installation, and aquifer testing; 23 sites were found suitable for drilling and aquifer testing (map, facing page).
- Compiled existing hydrogeologic information into digital form and assembled structure-contour maps of Upper Floridan aquifer and surficial units. Maps enabled development of hydrogeologic framework.
- Prepared well data for entry to Ground-Water Site Inventory (GWSI) database.
- Initiated development of graphical user interface (GUI) for processing data into model inputs and for depicting model results.
- Estimated ground-water contribution to streamflow for selected reaches during three periods of low flow during 1999–2000 using hydrograph separation techniques.

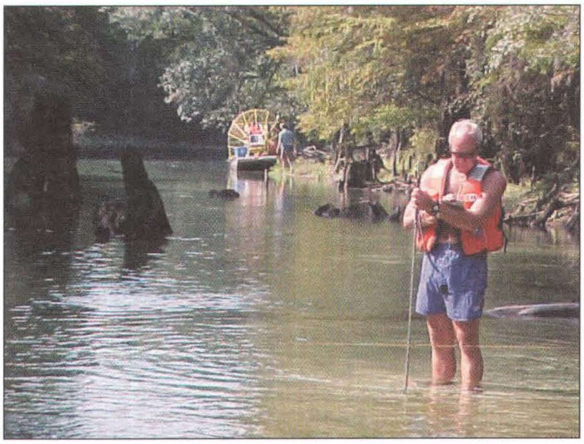


Study area, boundary of the lower Apalachicola–Chattahoochee–Flint (ACF) River Basin, and physiographic divisions of the Coastal Plain Province.

Location of test sites for drilling and aquifer testing in the lower Apalachicola–Chattahoochee–Flint (ACF) River Basin, and extent of existing digital model of Upper Floridan aquifer.

EXPLANATION

- Area of existing Upper Floridan model
- Lower ACF River Basin boundary
- Test site



Springflow discharge measurement on Spring Creek, near Brinson, Georgia. Photo by Lynn J. Torak, USGS.

Discharge measurement using acoustic Doppler current profiling at headwater of Apalachicola River at Chattahoochee, Florida, downstream of Jim Woodruff Lock and Dam. Photo by Lynn J. Torak, USGS.

Typical center-pivot spray irrigation system in use in lower Apalachicola–Chattahoochee–Flint River Basin, southwestern Georgia. Photo from Flint River Water Planning and Policy Center.

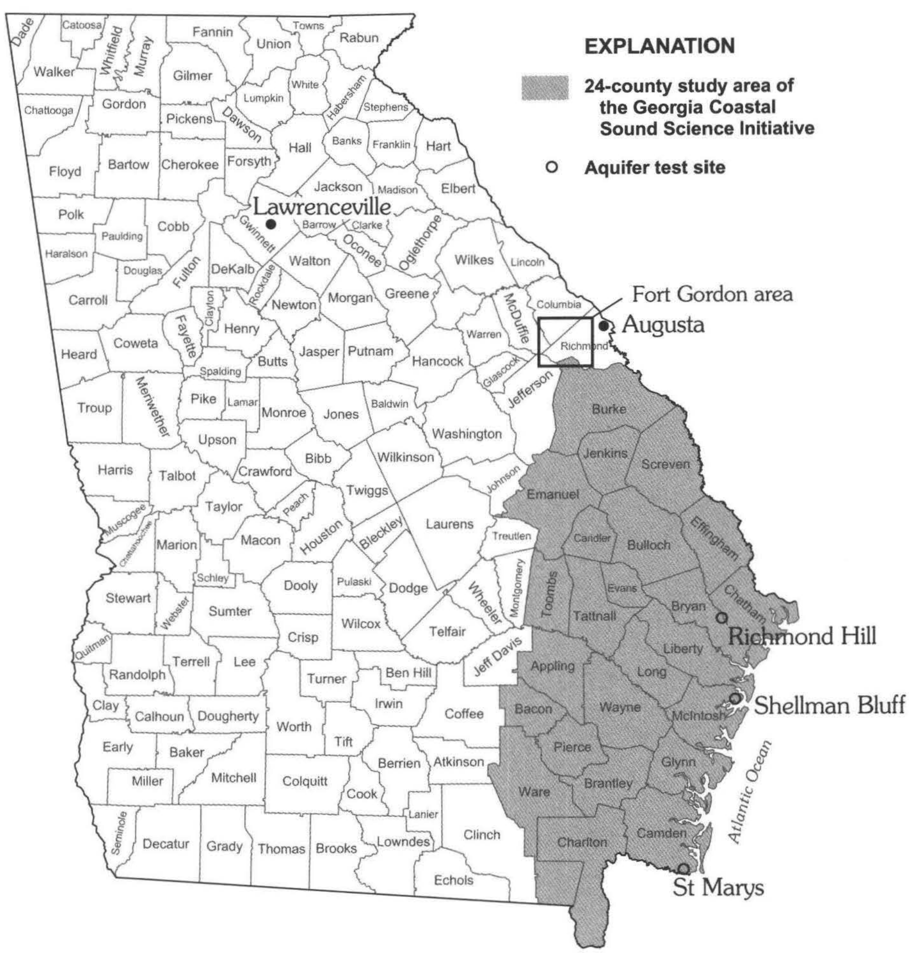
TECHNICAL HIGHLIGHTS

During 2001, various hydrologic studies conducted by the U.S. Geological Survey (USGS) in cooperation with State, local, and Federal agencies provided information to better define and manage the State's water resources. Selected technical highlights from the USGS programs conducted in Georgia include:

- Characterization of fractured crystalline rock aquifers at selected sites in the vicinity of Lawrenceville, Georgia, 2001
  by Lester J. Williams

- Hydrogeology and aquifer tests in the Floridan aquifer system at selected sites, Coastal Georgia, 2001
  by L.G. Harrelson and W.F. Falls

- Hydrogeology and ground-water quality of Coastal Plain sediments in the central Fort Gordon area, near Augusta, Georgia, 2001
  by Sherlyn Priest



Characterization of Fractured Crystalline-Rock Aquifers at Selected Sites in the Vicinity of Lawrenceville, Georgia, 2001

by Lester J. Williams

INTRODUCTION

The U.S. Geological Survey (USGS) in cooperation with the city of Lawrenceville has been studying the availability of ground water in crystalline-rock aquifers in the vicinity of Lawrenceville, Georgia (map, upper right). The study area is located in the Piedmont physiographic province, which is underlain by igneous and metamorphic rocks. The aquifers in this region consist of saturated overburden (soil, alluvium, and saprolite) overlying fractured bedrock. Municipal wells drilled for water-supply place casing through the overburden and penetrate water-bearing fractures in the bedrock at depths typically no deeper than 600 feet below land surface. The fractures are formed from a combination of stresses that produce both high-angle joints and subhorizontal fractures and fracture zones. Well yields in the Lawrenceville study area range from less than 1 gallon per minute (gal/min) to more than 400 gal/min.

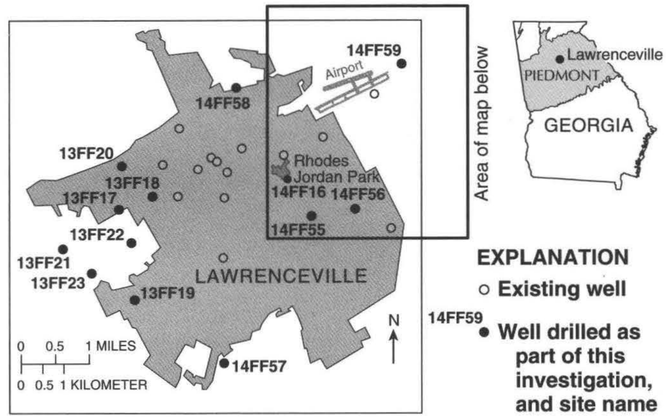
Objective

The primary objective for this study is to improve methods of evaluating the ground-water resource potential in igneous and metamorphic rocks. Because so little is known about crystalline-rock aquifers, this information is extremely valuable to municipalities like Lawrenceville that are trying to increase the amount of water that can be obtained from these aquifers. The technical highlights presented herein describe some of the results the USGS is obtaining from a subarea referred to as the Gwinnett County Airport vicinity (map, lower right).

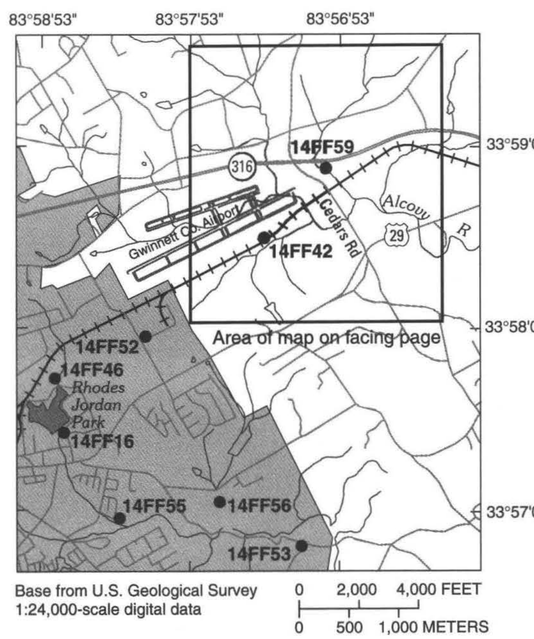
Results

As part of the study, the location of wells that have the potential for high yields, based on geologic and geophysical information, was chosen. One of these is well 14FF59, a flowing artesian well (photo, facing page) located east of the Gwinnett County Airport. The well penetrates a sequence of southward dipping (tilted) metamorphic rocks (map, facing page; geologic sections, following page). The well derives ground water from four major subhorizontal fractures at depths of 267, 282, 297, and 348 feet below land surface. The water-bearing fractures occur at a contact zone between major lithologic units and between layers in a layered metamorphic rock.

Well 14FF59 is located within the Alcovy River Basin and penetrates an amphibolite unit (nonwater bearing), button schist (nonwater bearing), and a biotite gneiss unit (water bearing). The fracture network in the vicinity of



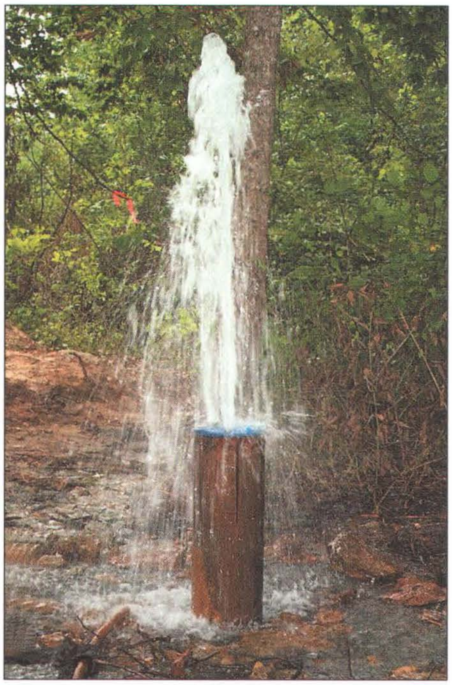
The study area encompasses approximately 44 square miles including the city of Lawrenceville and surrounding areas. The city well field is located at Rhodes Jordan Park and is pumped at a rate of 250 gal/min for 7.5 hours per day. Twelve new test wells were drilled during 2001 (shown in black) including well 14FF59, the subject of this technical highlight, located about 2.5 miles northeast of the Rhodes Jordan Park.



EXPLANATION

● 14FF55 **Well drilled as part of this investigation, and site name**

The study in the vicinity of the Gwinnett County Airport is an example of how the USGS uses geologic structural mapping and geophysical surveys to identify an area with a potential for high ground-water yields. The only previous well information in the area was from well 14FF42, which has a yield of less than 1 gal/min.

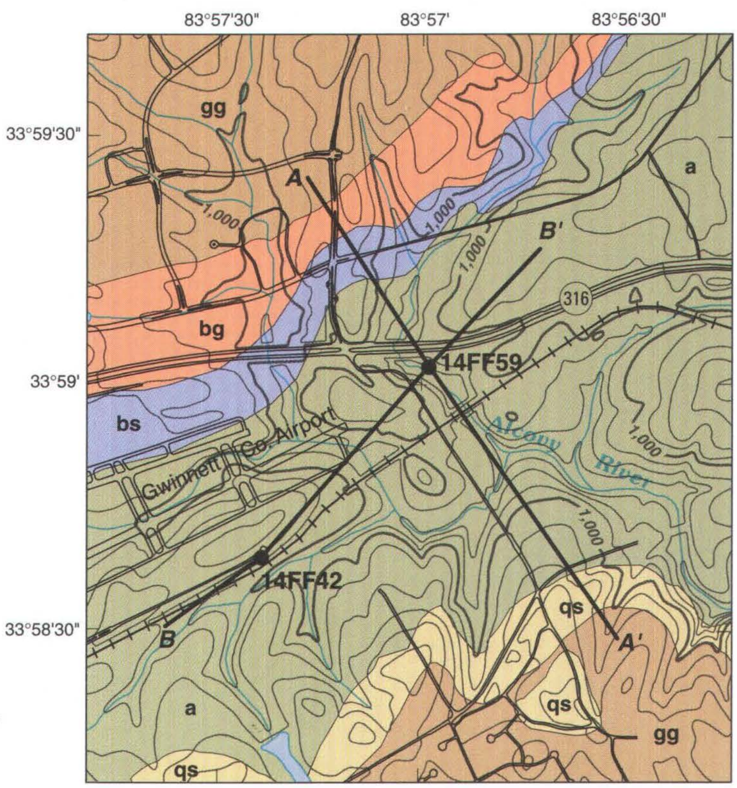


Flowing artesian wells, like 14FF59 shown above, are commonly found in areas that are topographically lower than the adjacent recharge area. This well flows about 40 gal/min out of two 1-inch openings through the blue pressure cap installed at the top of casing, and about 50–60 gal/min when left uncapped. The top of the stream of water is about 5.5 feet above land surface. (Photo by Randy Kath, State University of West Georgia.)

the well consists of well-developed, high-angle joint sets interconnected with subhorizontal, southeasterly dipping water-bearing fractures formed along compositional layering of the biotite gneiss. Well 14FF42, located 3,100 feet southwest of 14FF59 in an upland area, penetrates the same sequence of rocks, but the bedrock at this location lacks development of the subhorizontal water-bearing fracture zones and contains few high-angle joints.

The initial yield for well 14FF59, done by airlifting, was approximately 400–500 gal/min. A 72-hour pumping test indicated a yield of 300 gal/min with 82 feet of drawdown. Artesian flow from the well is about 50–60 gal/min.

High-yielding, water-bearing fracture zones have been penetrated in a number of other wells in the vicinity of Lawrenceville. The majority of these fractures are at contact zones between major lithologic units or along layering in metamorphic rock. Typically, yields of less than 10 gal/min occur in wells that penetrate only high-angle joints. A few wells in the Lawrenceville area intercept zones of concentrated jointing and joints that are enlarged through dissolution. These wells generally have yields greater than 10 gal/min but do not yield significant quantities of water compared to wells with open, subhorizontal fractures.



Base from U.S. Geological Survey
1:24,000-scale digital data

Land surface contour interval = 20 feet

0 1,000 2,000 FEET
0 250 500 METERS

EXPLANATION

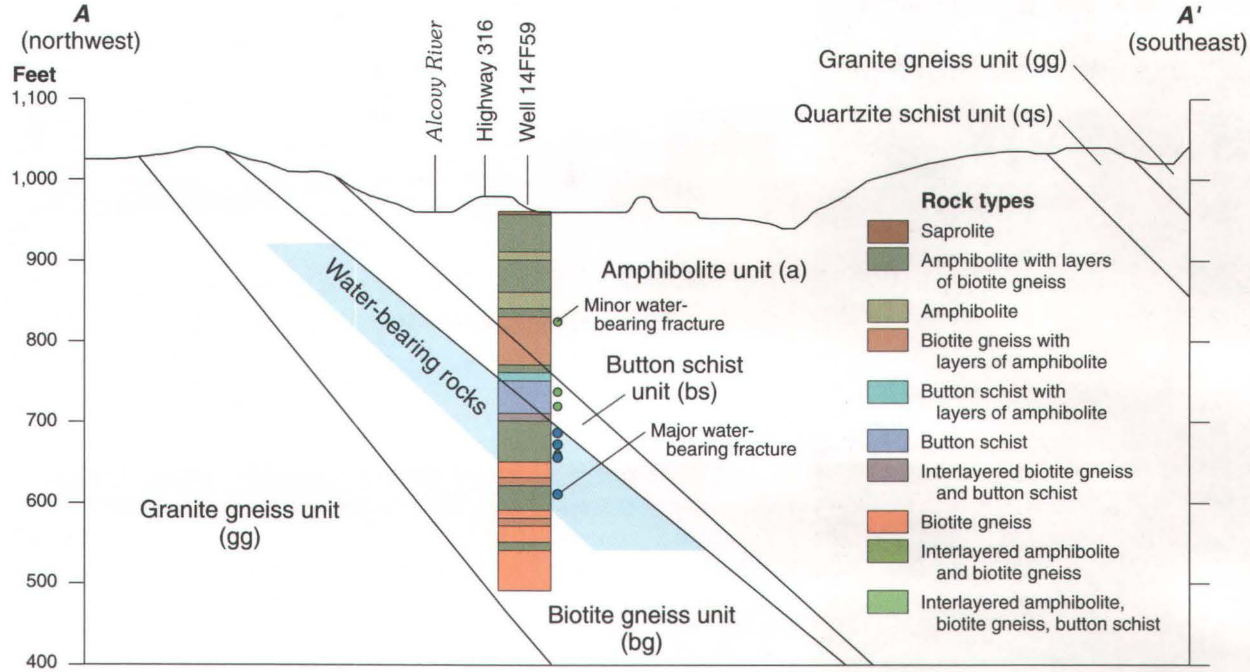
Lithologic unit

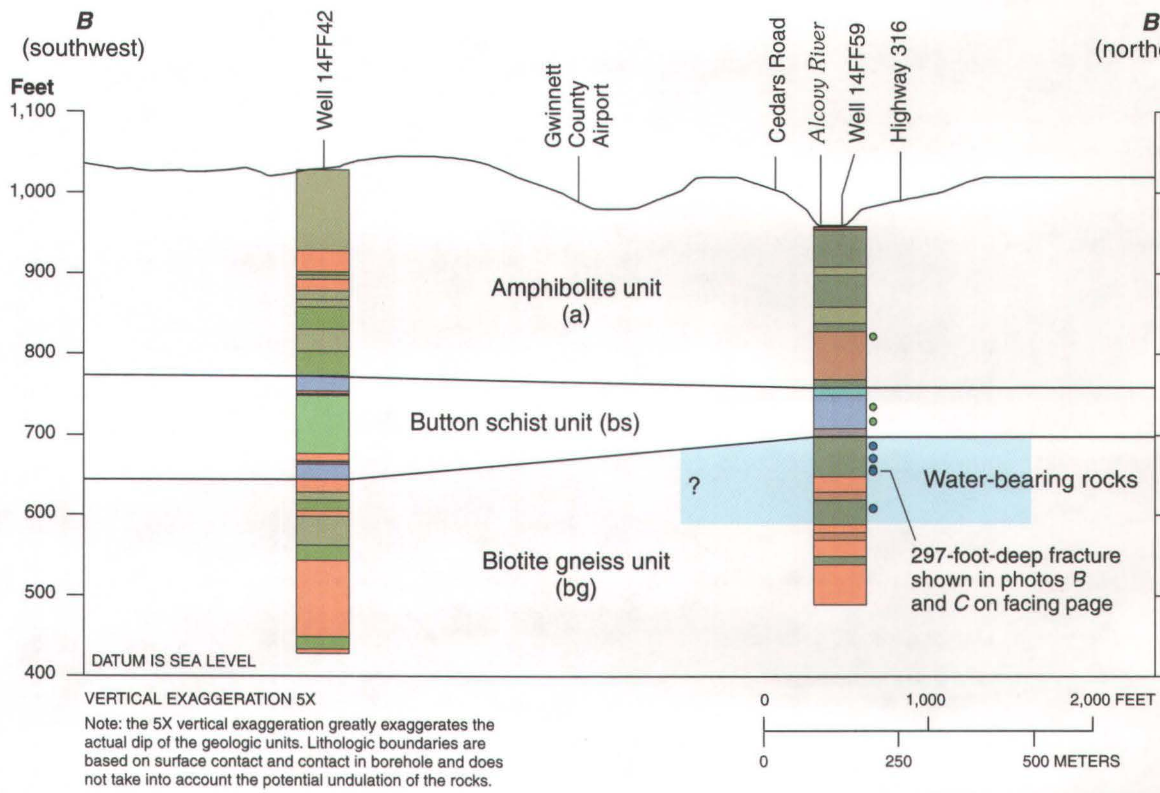
gg	Granite gneiss
bg	Biotite gneiss
bs	Button schist
a	Amphibolite
qs	Quartzite schist

A——*A'* **Line of geologic section**

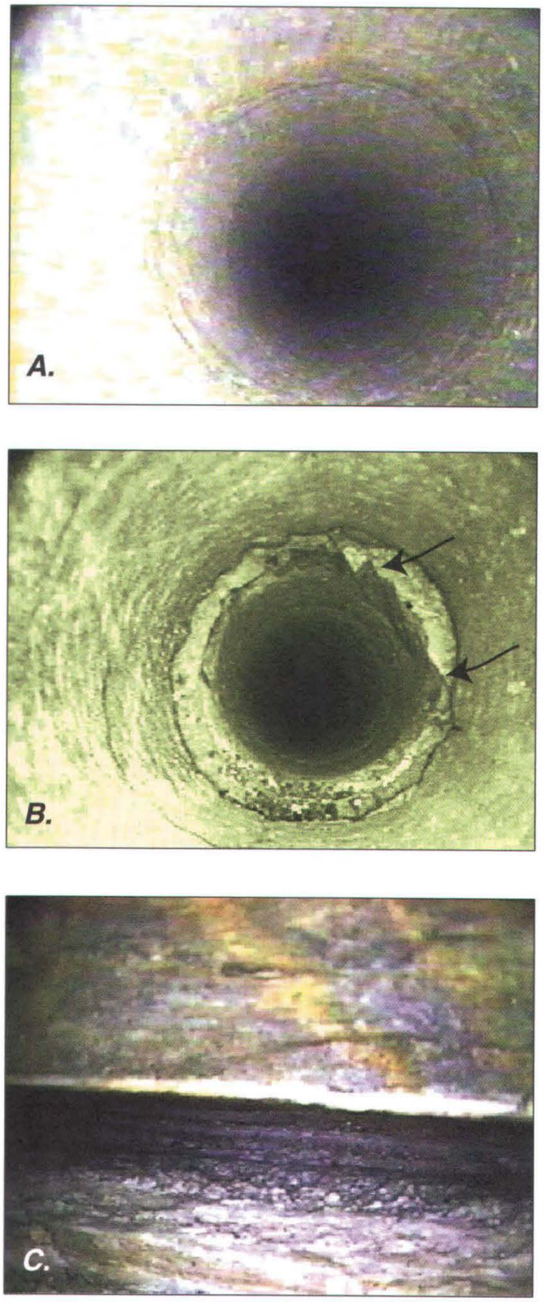
● 14FF42 **Well and site name**

*The USGS completed geologic maps near the well site to identify major and minor lithologic units and to identify potential structural and textural characteristics that may enhance ground-water availability. Mapping was conducted by geologists walking traverses along roads, creeks, and rivers throughout the area. Locations of geologic sections **A–A'** and **B–B'** also are shown.*





*Geologic section **A–A'** shows the southward dipping sequence of rocks penetrated by well 14FF59 and the location of water-bearing fracture zones. Section **B–B'** shows the lithologic correlation between wells 14FF42 and 14FF59. The water-bearing fracture zones in the lower biotite gneiss unit were not present in 14FF42.*



Borehole video images from well 14FF59

(A) looking downhole at an unfractured portion of borehole (155 feet deep);

(B) looking downward at the 297-foot-deep subhorizontal fracture, high angle joints (arrows) can also be seen; and

(C) sideview looking back into the 297-foot-deep subhorizontal fracture. Aperture is approximately 3 to 4 inches wide.

Summary and Conclusions

Well 14FF59 penetrates a sequence of layered metamorphic rocks that are well jointed and contain several large subhorizontal water-bearing fracture zones that deliver high yields of ground water into the well (cross sections, facing page; photos, to the left). Well 14FF42, located on a ridge top, penetrates the same sequence of rocks but is characterized by few joints, no development of open subhorizontal fractures, and low yield.

A 2.8-square-mile area was mapped to delineate the distribution of rock types and develop a preliminary structural interpretation for the area. The consistent strike and dip of the rocks allowed extrapolating lithologic units into the subsurface and anticipating depths of potential contact zones.

The relatively flat compositional layering (less than 20 degree dip), presence of high-angle joint sets, and development of subhorizontal water-bearing fractures along layering are believed to be key reasons for the high yield from well 14FF59.

The subhorizontal water-bearing fractures probably receive recharge from a relatively wide area. High-angle joint sets, which are pervasive throughout rocks in the study area, are probable conduits through which ground water can recharge the bedrock aquifer system.

The USGS continues to study the occurrence and interconnectivity of high-yielding water-bearing fracture zones in the vicinity of Lawrenceville. Techniques used in this study may be applied to other fractured crystalline-rock aquifers settings in the Piedmont.

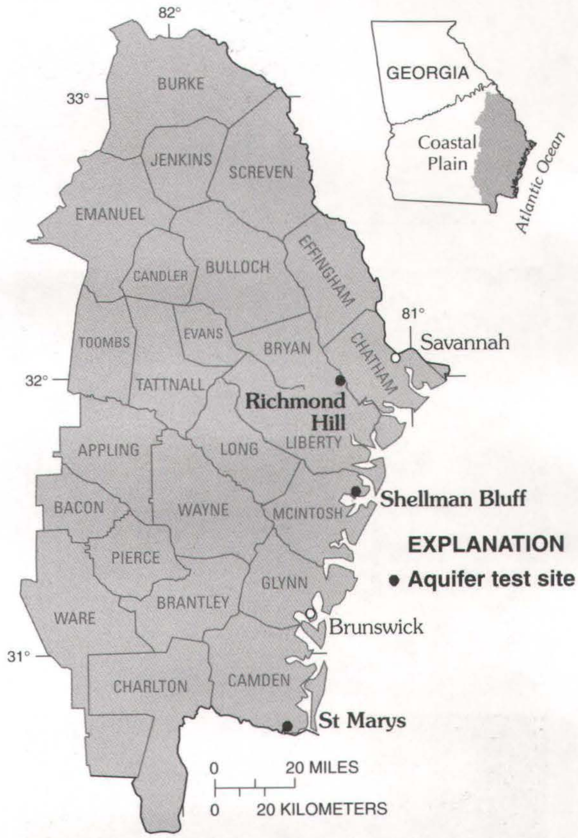
Hydrogeology and Aquifer Tests in the Floridan Aquifer System at Selected Sites, Coastal Georgia, 2001

by L.G. Harrelson and W. Fred Falls

INTRODUCTION

The Floridan aquifer system is one of the most productive ground-water resources in the United States and is the principal source of ground-water supplies in the coastal area of Georgia (Miller, 1986). The aquifer system consists of the Upper and Lower Floridan aquifers throughout most of the aquifer system's distribution in Georgia, South Carolina, Florida, and Alabama. Saltwater encroachment into the Upper Floridan aquifer has degraded the water quality in parts of the coastal area of Georgia, South Carolina, and Florida (Krause and Clarke, 2001).

The U.S. Geological Survey (USGS)—in cooperation with the Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey—is investigating the Lower Floridan aquifer as an alternative source of ground water in a 24-county area in coastal Georgia as part of the Coastal Sound Science Initiative. As part of this evaluation, test wells were drilled and completed in the Lower Floridan aquifer at Richmond Hill, Bryan County; Shellman Bluff, McIntosh County; and St Marys, Camden County. Additionally, one well was completed in the Upper Floridan aquifer at Richmond Hill. The USGS planned and completed a single-well aquifer test at each site.



Twenty-four-county study area of the Georgia Coastal Sound Science Initiative and aquifer test sites, Georgia.

General Description of Test Sites

The aquifer-test sites are in the Coastal Plain physiographic province of eastern Georgia (map, to the right). The Richmond Hill site is located in Bryan County, Georgia, approximately 26 miles (mi) west of the Atlantic Ocean and 15 mi southwest of Savannah, Georgia. Land surface altitude is approximately 13 feet (ft) above the National Vertical Datum of 1988 (NAVD 88). A 1- to 2-acre wastewater treatment pond is located approximately 40 ft from the two wells. The pond is partially filled and discharged daily.

The Shellman Bluff site is in McIntosh County, Georgia, approximately 33 mi north of Brunswick and 36 mi south of Savannah, Georgia. Land surface altitude is approximately 10 ft above NAVD 88. An extensive tidal saltwater marsh is present near the well site.

The St Marys site is in Camden County, Georgia, approximately 24 mi north of Jacksonville, Florida, and 51 mi south of Brunswick, Georgia. Land surface altitude is approximately 10 ft above NAVD 88. A large paper mill is present near the site that withdraws water from the Upper and possibly the Lower Floridan aquifers.

HYDROGEOLOGY

At the Richmond Hill site, the Upper Floridan aquifer consists of limestone (Falls and others, 2001). Well 35P110 is open to the aquifer from 315 to 441 ft (table, facing page; well construction diagram, following page) (all depths are reported from land surface). The Lower Floridan aquifer has a porous, permeable zone consisting mostly of limestone with some dolomitic limestone from 950 to 1,076 ft. Strata below the permeable zone consists of fine-grained limestone from 1,076 to 1,293 ft; clay from 1,293 to 1,318 ft; clayey limestone with chert nodules from 1,318 to 1,624 ft; and black marine clay from 1,624 to 1,677 ft. No permeable zone could be identified in the fine-grained lithologies beneath 1,318 ft (Falls and others, 2001). Well 35P109 is open to the

Well location, construction, average pumping rate, aquifer, and calculated transmissivity for aquifer tests
[NAVD 88, National Vertical Datum of 1988]

USGS site name	Site location (map, facing page)	Aquifer	Altitude of land surface (feet above NAVD 88)	Hole depth (feet below land surface)	Well depth (feet below land surface)	Depth of open interval (feet below land surface)	Average pumping rate (gallons per minute)	Calculated transmissivity (feet squared per day)	Date of aquifer test
35P110	Richmond Hill	Upper Floridan	13	441	441	315–441	735	70,000	May 09–10, 2001
35P109	Richmond Hill	Lower Floridan	13	1,677	1,275	1,010–1,275	750	8,300	May 16–17, 2001
35L085	Shellman Bluff	Lower Floridan	10	1,863	1,422	1,144–1,422	700	6,000	June 14–15, 2001
33D073	St Marys	Lower Floridan	10	1,500	1,500	1,360–1,500	710	13,000	July 26–27, 2001

Lower Floridan aquifer from 1,010 to 1,275 ft (table, above; well construction diagram, following page).

At the Shellman Bluff site, the Floridan aquifer system extends from 345 to 1,438 ft with the Lower Floridan aquifer present from 1,196 to 1,438 ft. The Floridan aquifer system consists of limestone that is dolomitic in several intervals; however, beds of dolomite are present only near the contact between the Lower Floridan aquifer and the underlying marl. Well 35L085 is open to the Lower Floridan aquifer from 1,144 to 1,422 (table, above); however, the most permeable zone is from 1,190 to 1,225 ft (well construction diagram, following pages).

At the St Marys site, the Upper Floridan aquifer consists of limestone from 513 to 814 ft and interbedded limestone and dolomite from 814 to 1,115 ft. The Lower Floridan aquifer consists of thick beds of dolomite and interbedded limestone and dolomite (well construction diagram, following pages). Well 33D073 is open to the Lower Floridan aquifer from 1,360 to 1,500 ft (table, above). The base of the Lower Floridan aquifer was not penetrated during drilling (Falls and others, 2001).

AQUIFER TESTS

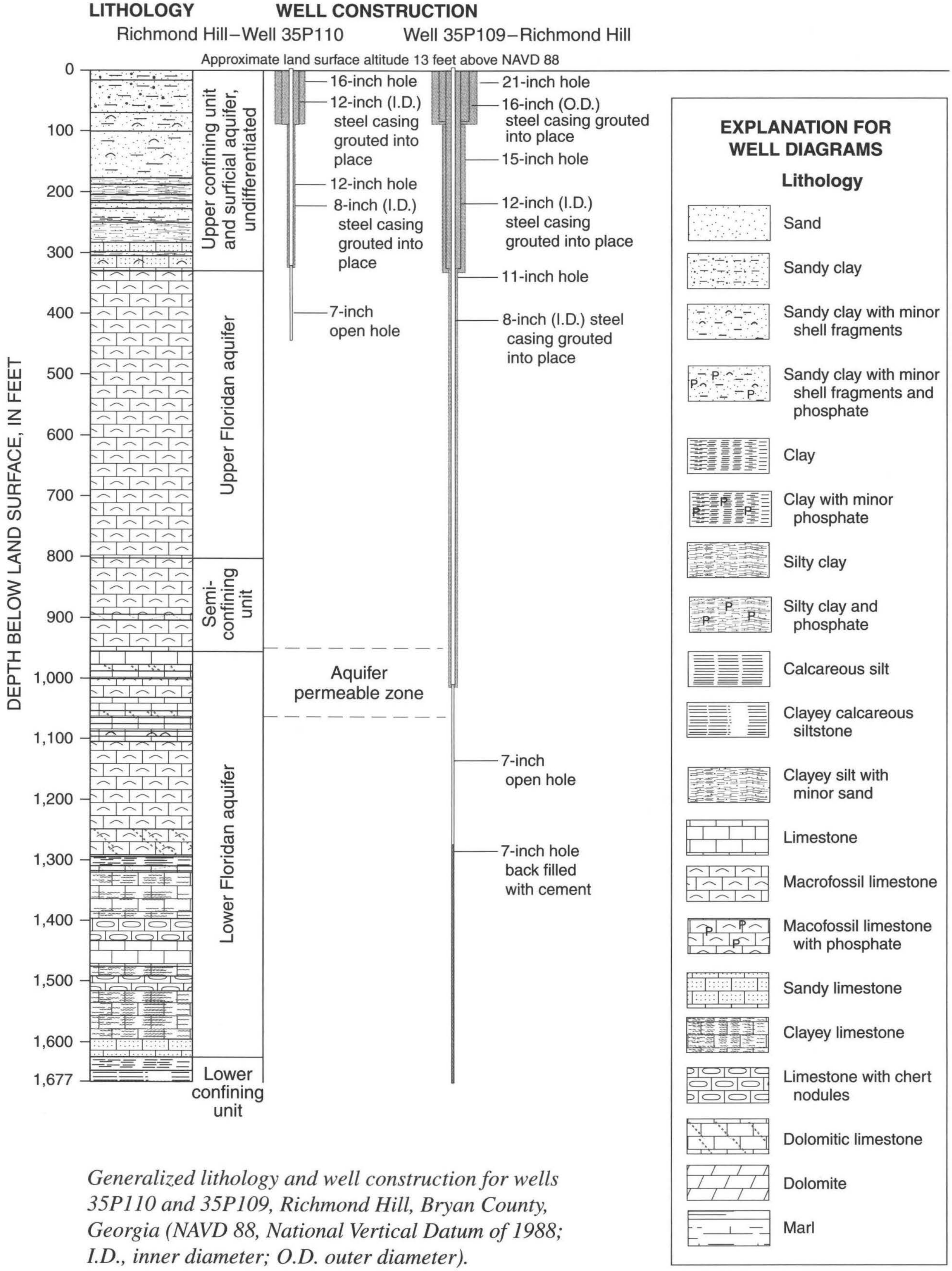
Each single-well aquifer test was designed to provide a reliable estimate of transmissivity. The aquifer tests consisted of four phases. Ideally, the four phases were as follows:

1. A 4-hour (hr) pre-test pumping was done to ensure that each well was fully developed prior to the pumping test. During the pretest, discharge was monitored to verify that a constant discharge could be maintained. Water levels were monitored to ensure that drawdown in the well would not exceed the depth of the pump intake or pressure transducer.
2. A 24-hr pretest (background) monitoring of the atmospheric pressure and water levels in the well(s) was conducted to investigate the water-level fluctuations caused by changes in atmospheric pressure, loading by external forces, regional ground-water withdrawals, and tidal cycles.
3. The well was pumped for 24 hrs while concurrently monitoring ground-water discharge, water level, and atmospheric pressure.
4. Following completion of pumping, the atmospheric pressure and water levels were monitored for 24 hrs.

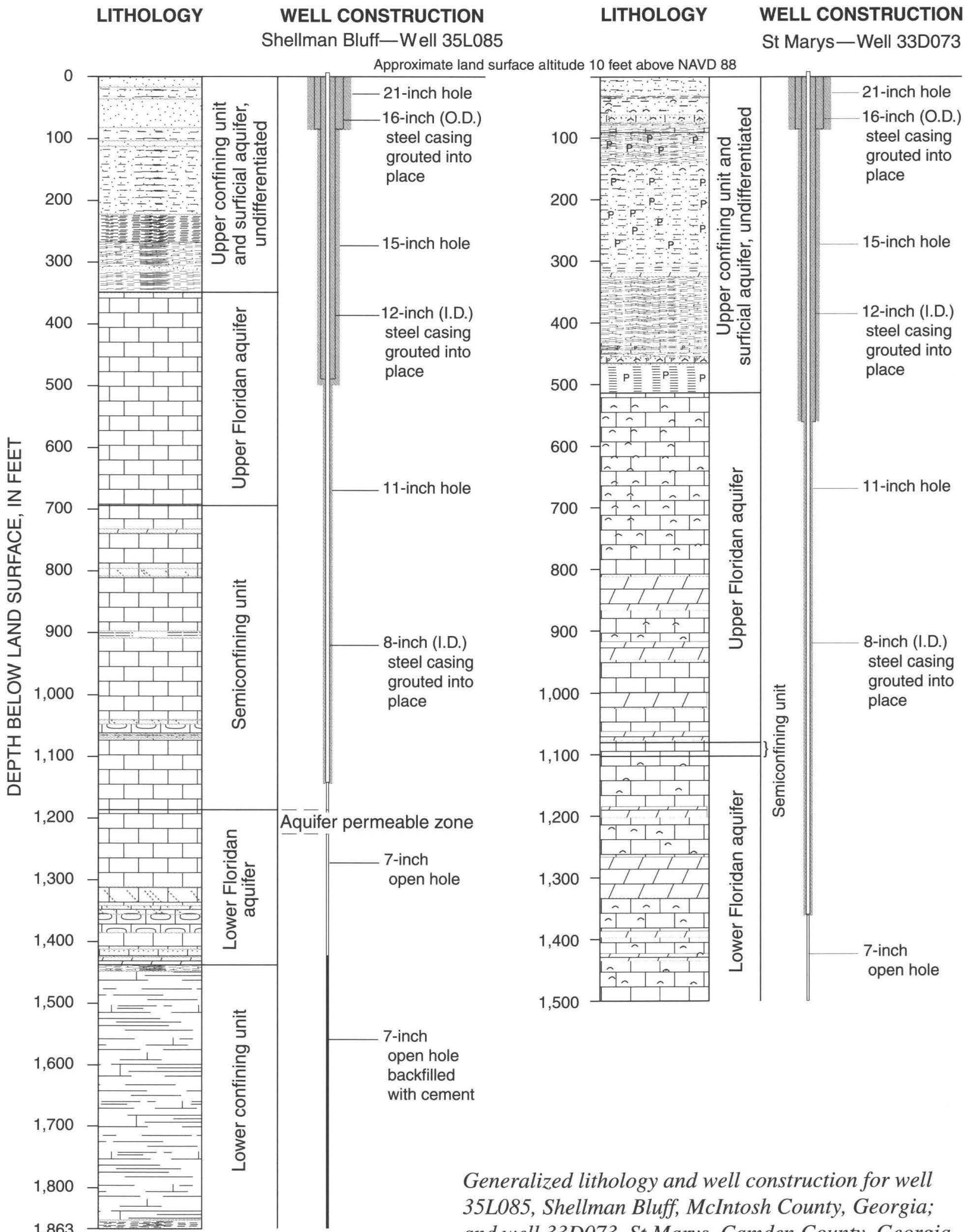
In general, each aquifer test followed the same procedure and used comparable equipment. A 30- or 100-pound-per-square-inch pressure transducer was installed into a 0.75-inch polyvinylchloride pipe in the well. An internal pressure sensor in the data logger measured atmospheric pressure. The data logger was programmed to collect data in logarithmic sample intervals with a maximum sample interval of 5 or 10 minutes. This method allowed for rapid collection of data during the initial period of the 24-hr aquifer and recovery tests. During each test, water levels were measured periodically with a steel or electric tape and compared to pressure transducer readings to verify the accuracy of the pressure transducer.

A 30-horsepower submersible pump with a 5-inch (internal diameter) riser pipe was used to produce ground-water discharge. The pump was set at approximately 100 ft below land surface. A foot valve was installed in the riser pipe just above the submersible pump to prevent backflow into the well. Power for the submersible pump was provided by a trailer-mounted, diesel-powered, electric generator.

Ground-water discharge was determined by using an inline totalizing flowmeter. An inline gate valve was installed downstream of the flowmeter. The gate valve was shut in at approximately 55 percent of maximum flow permitting the pumping discharge to be maximized while applying sufficient backpressure to minimize pump-related water-level fluctuations.



Generalized lithology and well construction for wells 35P110 and 35P109, Richmond Hill, Bryan County, Georgia (NAVD 88, National Vertical Datum of 1988; I.D., inner diameter; O.D. outer diameter).



Generalized lithology and well construction for well 35L085, Shellman Bluff, McIntosh County, Georgia; and well 33D073, St Marys, Camden County, Georgia (NAVD 88, National Vertical Datum of 1988; I.D., inner diameter; O.D., outer diameter).

ANALYTICAL SOLUTIONS

During each aquifer test, the magnitude of water-level fluctuation produced by changes in atmospheric pressure, local pumping, or tidal oscillation was minor in comparison with the amount of drawdown induced by the pump. Therefore, drawdown data used in the analysis of these aquifer tests were not corrected for atmospheric pressure, local pumping, or tidal fluctuations.

Initial estimates of transmissivity were derived using the Cooper and Jacob (1946) modified nonequilibrium equation. Additionally, digital analytical models were used to analyze these aquifer-test data including Theis (1935) nonequilibrium equation, Cooper and Jacob (1946) modified nonequilibrium equation, and Hantush (1961) nonequilibrium equation for a partially penetrating well. The Hantush (1961) method was used in the data analysis of partial penetration for wells 35P110, 35P109, and 33D073. Vertical to horizontal conductivity (Kz/Kr) ratios of 0.01, 0.1, and 1.0 were applied to the data set for aquifer tests. For each aquifer test, the estimated transmissivity derived by the various analytical methods provided similar results.

Atmospheric and water-level recovery data were analyzed using the Jacob (1963) analysis for water-level recovery data. This method produced lower estimates of transmissivity than was calculated using the pumping (drawdown) water levels. For each of the aquifer tests, the intercept line did not pass through the origin of the semi-log graph as it should if all conditions governing the model were met. Jacob (1963) indicated that transmissivity values calculated from an aquifer test with a partially penetrating well may underestimate the true transmissivity of the aquifer. For this reason, reported transmissivity estimates reflect analysis of drawdown data.

Richmond Hill Test

Two 24-hr aquifer tests were conducted at the Richmond Hill site—well 35P110, completed in the Upper Floridan aquifer, was tested May 9–10, 2001; and well 35P109, completed in the Lower Floridan aquifer, was tested May 16–17, 2001. Water levels in both of these wells respond to regional pumping, as indicated on long-term hydrographs collected at the site (Michael F. Peck, U.S. Geological Survey, written commun., September 17, 2001).

Upper Floridan Aquifer

During May 8–9, 2001, pretest water-level and atmospheric pressure data were collected in well 35P110. During this period, the water level in the well rose about 0.3 ft. The water level changed from 30.84 to 31.27 ft below land surface (total change was 0.43 ft). During this time, atmospheric pressure fluctuated from 30.28 to 30.45 inches (mercury), or 34.3 to 34.5 ft (water). Assuming a barometric efficiency of 50 percent for the Upper Floridan aquifer, the barometric effect would be less than 0.1 ft. The effect of tidal cycles were observed in the water level for well 35P110. Amplitude for tidally induced water-level fluctuations was about 0.2 ft.

During May 9–10, 2001, a 24-hr aquifer test was conducted with an average discharge of 735 gallons per minute (gal/min), which varied by about +/– 0.3 percent. The total amount of ground water withdrawn from the Upper Floridan aquifer during the test was about 1,092,000 gallons. The drawdown resulting from the 24 hrs of pumping was about 17 ft. During May 11–12, 2001, 24 hrs of recovery water-level and atmospheric pressure data were collected. Estimated transmissivity of the Upper Floridan aquifer was 70,000 feet squared per day (ft^2/d) at the Richmond Hill site.

Lower Floridan Aquifer

During May 11–16, 2001, pretest water-level and atmospheric pressure data were collected in well 35P109. A slight water-level decline of 0.04 ft was observed during this period. The water level changed from 31.82 to 32.16 ft below land surface (total change was 0.34 ft). During this time, atmospheric pressure fluctuated from 30.10 to 30.34 inch (mercury), or 34.10 to 34.38 ft (water). Assuming a barometric efficiency of 50 percent for the Lower Floridan aquifer, the barometric effect would be less than 0.14 ft. Amplitudes for tidally induced water-level fluctuations were about 0.2 ft.

During May 16–17, 2001, a 24-hr aquifer test was conducted for the Lower Floridan aquifer using well 35P109. During the test, the average discharge was 750 gal/min and varied by about +/- 0.1 percent. The total amount of ground water withdrawn from the Lower Floridan aquifer during the aquifer test was about 1,091,000 gallons. The overall drawdown resulting from the 24 hrs of pumping was about 45 ft. During May 17–18, 2001, 24 hrs of recovery water-level and atmospheric pressure data were collected. Estimated transmissivity of the Lower Floridan aquifer was 8,300 ft^2/d.

Shellman Bluff Test

During June 6–11, 2001, atmospheric pressure and background water-level data were collected in well 35L085. The water level in the well changed from 22.81 to 23.23 ft below land surface (total change was 0.42 ft). During this time, barometric pressure fluctuated from 30.04 to 30.3 inches (mercury), or 34.04 to 34.33 ft (water). Assuming a barometric efficiency of 50 percent for the Lower Floridan aquifer, the barometric effect would be less than 0.15 ft. Amplitude for tidally induced water-level fluctuations was about 0.3 ft.

During June 14–15, 2001, a 24-hr aquifer test was conducted for the Lower Floridian aquifer using well 35L085. During the test, the average discharge was 700 gal/min and varied by about +/– 6.69 percent. The total amount of ground water withdrawn from the Lower Floridan aquifer during the test was about 1,016,000 gallons. The overall drawdown resulting from the 24-hrs of pumping was about 60 ft. During June 15–18, 2001, 69.5 hrs of recovery water-level and atmospheric pressure data were collected. Estimated transmissivity of the Lower Floridan aquifer was 6,000 ft^2/d.

St Marys Test

During July 25–26, 2001, atmospheric pressure and background water-level data were collected in well 33D073, which flows above land surface. The water level in the well changed from 0.9 to 2.6 ft above land surface (total change of 1.7 ft). During this time, barometric pressure fluctuated from 30.38 to 30.22 inches (mercury) or 34.42 to 34.24 ft (water). Assuming a barometric efficiency of 50 percent for the Lower Floridan aquifer, the barometric effect would be less than 0.01 ft. Amplitude for tidally induced water-level change was about 0.5 ft.

During July 26–27, 2001, a 24-hr aquifer test was conducted for the Lower Floridian aquifer using well 33D073. During the test, the average discharge was 710 gal/min and varied by approximately +/–1.15 percent. The total amount of ground water withdrawn from the Lower Floridan aquifer during the test was about 1,021,000 gallons. The overall drawdown resulting from the 24 hrs of pumping was about 82 ft. During July 27–28, 2001, 24-hrs of recovery water level and atmospheric pressure data were collected. Estimated transmissivity of the Lower Floridan aquifer was 13,000 ft^2/d.

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Hydrogeology and Ground-Water Quality of Coastal Plain Sediments in the Central Fort Gordon Area, near Augusta, Georgia, 2001

by Sherlyn Priest

INTRODUCTION

Fort Gordon, near Augusta, Georgia, is experiencing increased demand for ground-water supplies. To meet the demand, the U.S. Geological Survey (USGS) in cooperation with the Environmental and Natural Resources Management Office of the U.S. Army Signal Center and Fort Gordon is conducting an investigation of the hydrogeology and water quality of water-bearing units in the vicinity of Training Area 25. The investigation includes: drilling a test well to determine ground-water quality in the study area; compiling a well inventory and performing geophysical logging of new and existing wells; determining the hydrogeologic framework; monitoring water levels; and collecting water-quality samples.

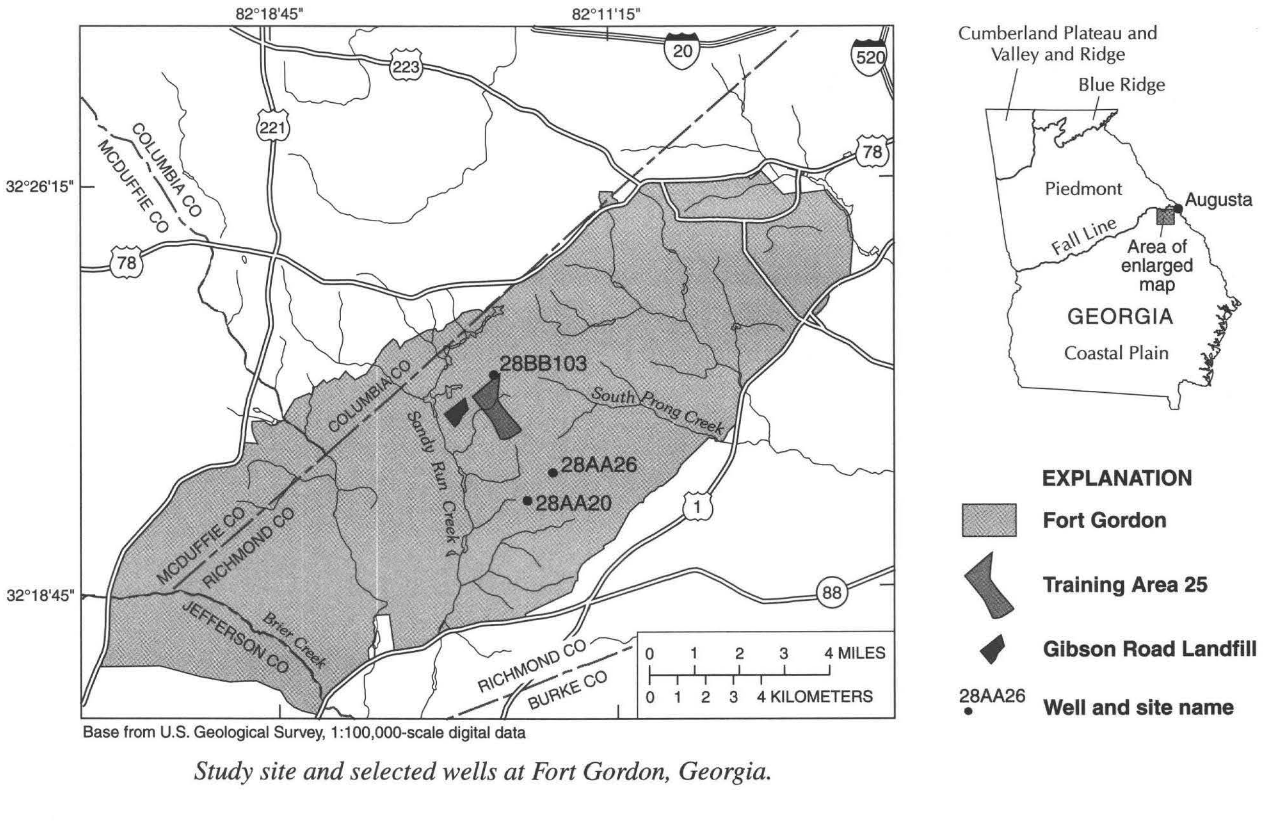
Description of Study Area

Fort Gordon is located southwest of Augusta, Georgia, in western Richmond County and in adjacent parts of Columbia, Jefferson, and McDuffie Counties (map, below). Fort Gordon is located in the Coastal Plain physiographic province near the Fall Line (Clark and Zisa, 1976)—a transition zone between the Coastal Plain and Piedmont physiographic provinces. The general topography along the Fall Line is typified by rolling hills with local rock outcroppings in stream valleys. Topographic relief across Fort Gordon is moderate; land-surface altitudes range from about 225 feet (ft) above National Vertical Datum of 1988 (NAVD 88) in the east to about 500 ft in the northwest.

Training Area 25 and Gibson Road Landfill are located in the central part of Fort Gordon. The area is densely wooded and is drained by an unnamed tributary of Sandy Run Creek. Local topography slopes primarily to the west. Runoff is to the southwest to Sandy Run Creek.

Method of Study

The study included test-well drilling and geophysical logging well 28AA26 and geophysical logging existing



Study site and selected wells at Fort Gordon, Georgia.

well 28BB103. These data were used to identify water-bearing zones and to correlate the local hydrogeology to the regional hydrogeologic framework.

Geophysical logs made from measurement of the natural-gamma radiation of sediments underlying the study area were used to aid in correlating stratigraphic units and water-bearing zones. At well 28AA26, a continuous core was collected from land surface to a depth of about 75 ft; lithologic and geophysical data from this borehole and from well 28BB103 were used to evaluate local and regional hydrogeology.

A continuous water-level recorder was installed in well 28AA26 in August 2001, and was used with previously installed continuous water-level recorders in wells 28AA20 and 28BB103 to assess water-level fluctuations and trends. To describe the general ground-water quality, a water sample was taken from well 28AA26 and analyzed for dissolved constituents and organic compounds.

HYDROGEOLOGY

Fort Gordon is underlain by Upper Cretaceous and middle Tertiary sediments (correlation chart, to the right). These sediments unconformably overlie Paleozoic igneous and metamorphic rocks (Chowns and Williams, 1983). In this study, sediments of the Eocene Barnwell Group through the undifferentiated Upper Cretaceous were penetrated during drilling. The stratigraphic descriptions in this report are derived from Hetrick (1992) and Falls and others (1997).

Geologic Units

The undifferentiated Upper Cretaceous sediments are the basal Coastal Plain unit in the area and consist of unconsolidated, moderately to poorly sorted, fine to very coarse sand with interbedded sandy clay. The Cretaceous sediments can be micaceous and have granules and pebbles within the sand or as layers (William F. Falls, U.S. Geological Survey, written commun., 2002). In Richmond County, the Upper Cretaceous sediments range from 100 to 150 ft thick.

The Huber Formation unconformably overlies the Upper Cretaceous sediments in Fort Gordon. The Huber Formation is composed of kaolinitic sand, sand, sandy kaolin, and kaolin (Hetrick, 1992). The sands are coarse and poorly sorted. Mica and heavy minerals are present in the upper portions of the Huber Formation and the upper sandy kaolin are cemented by silica (Hetrick, 1992). In Richmond County, the Huber Formation is less than 50 ft thick.

System	Series	Georgia Geologic Survey nomenclature[1]	This study[2]	
		Formation/Member	**Geologic unit**	**Hydrologic unit**
Tertiary	Eocene	Tobacco Road Sand Dry Branch Formation Albion Member Clinchfield Formation	Barnwell Group	Upper Three Runs and Gordon aquifers undifferentiated
Tertiary	Eocene			
Tertiary	Eocene	Conagree Formation	Huber Formation[3]	Lower Dublin confining unit
Tertiary	Paleocene			
Cretaceous	Upper Cretaceous	Gaillard Formation	Undifferentiated Upper Cretaceous sediments	Lower Dublin aquifer and upper and lower Midville aquifers undifferentiated

[1]Huddlestun and Summerour, 1996
[2]Falls and others, 1997
[3]Hetrick, 1992

Generalized correlation of Coastal Plain hydrologic and geologic units in east-central Georgia (modified from Hetrick, 1992; Huddlestun and Summerour, 1996; Falls and others, 1997).

The Barnwell Group unconformably overlies the Huber Formation and consists of poorly sorted to moderately well sorted medium to very coarse quartz sand with minor interstitial clay. Maximum thickness of the Barnwell Group is about 200 ft in parts of southern Burke County, but averages 100 ft thick or less at most localities (Falls and others, 1997). The Barnwell Group thins from Burke County updip toward the Fall Line. Huddlestun and Summerour (1996) defined the Barnwell Group as three formations in Georgia: Clinchfield Formation (including the Albion member), Dry Branch Formation, and Tobacco Road Sand. In Richmond County, the Barnwell Group is about 100 ft thick.

Hydrogeologic Units

Principal water-bearing units in the central Fort Gordon area are, in order of increasing depth, the Upper Three Runs and Gordon aquifers, undifferentiated, and the lower Dublin and the upper and lower Midville aquifers, undifferentiated (correlation chart, previous page). These units are separated by a low permeability clayey confining unit. Several hydrogeologic units identified by Falls and others (1997) are absent in the central Fort Gordon area due to nondeposition or erosional unconformities. These include the Gordon confining unit, the Millers Pond aquifer and confining unit, the upper Dublin aquifer and confining unit, and the basal confining unit. The updip limit of most of these units is to the east of Fort Gordon.

Hydrogeologic units were characterized at wells 28BB103 and 28AA26 on the basis of lithologic and borehole geophysical logs (well diagrams, facing and following pages). Data from these wells were interpolated to other sites to determine water-bearing units tapped by other wells in the area. Water-bearing units tapped by selected wells in central Fort Gordon are listed in the table below.

In Richmond County, the Upper Three Runs aquifer coalesces with the underlying Gordon aquifer because several intervening units are absent in the area (Falls and others, 1997). These aquifers are present between land surface and a depth of 75 ft at well 28AA26 and between land surface and a depth of approximately 120 ft in well 28BB103. The undifferentiated Upper Three Runs and Gordon aquifers consist of quartz, calcareous sand, and limestone of the Barnwell Group. The sands are highly permeable; however, low permeability clay beds and lenses occur within the Tobacco Road Sand at the top of the Barnwell Group (Huddlestun and Summerour, 1996).

The lower Dublin confining unit underlies the undifferentiated Upper Three Runs and Gordon aquifers and is present between depths of approximately 124 and 164 ft in well 28BB103. The confining unit consists of very poorly to poorly sorted, fine to very coarse sand, sandy kaolin, and kaolin of the Huber Formation.

In the central Fort Gordon area, the lower Dublin aquifer and the upper and lower Midville aquifers coalesce because several intervening units are absent. These aquifers underlie the lower Dublin confining unit and are present between depths of approximately 164 and 260 ft in well 28BB103. The aquifers consist of poorly to moderately sorted fine to very coarse sand with interbedded clay of the undifferentiated Upper Cretaceous sediments. The base of these aquifers overlies the bedrock in the central Fort Gordon area (Wait and Davis, 1986).

Ground-Water Levels

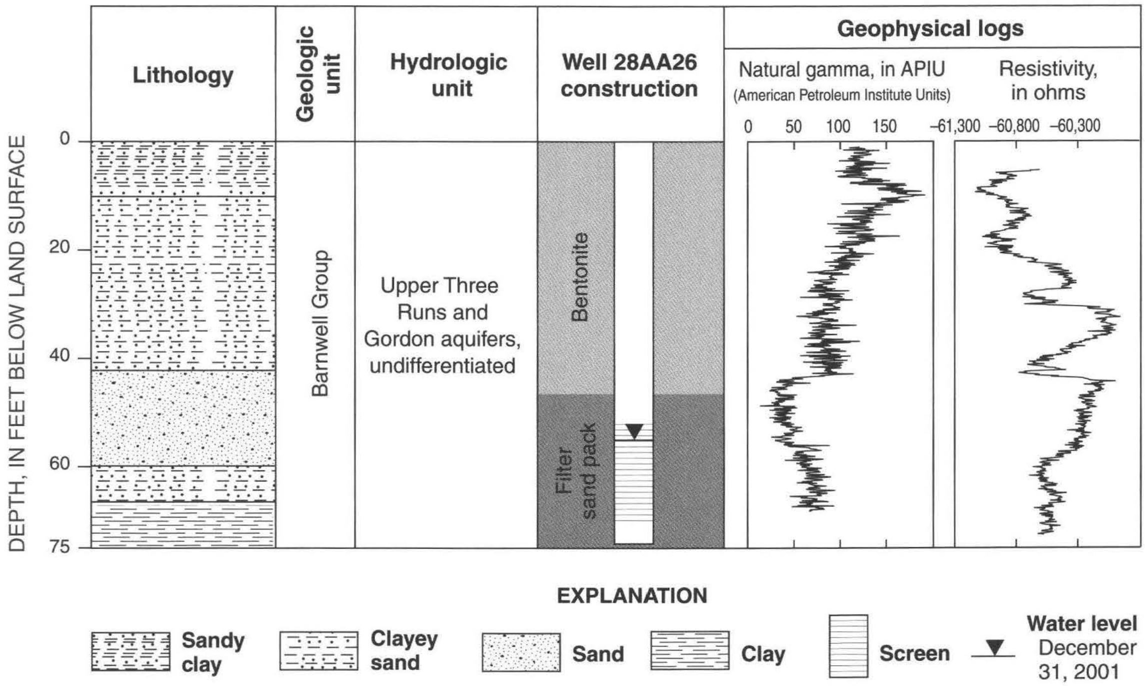
Ground-water levels are affected by changes in recharge and discharge, which are mainly affected by precipitation, evapotranspiration, and pumping. Daily mean water-level fluctuations in the central Fort Gordon area are shown in hydrographs of wells completed in the undifferentiated Upper Three Runs and Gordon aquifers and the undifferentiated lower Dublin and upper and lower Midville aquifers (hydrographs, following pages). The updip limit of these aquifers is present in Richmond County causing the aquifers to be affected by seasonal climatic variations.

The water level in well 28AA26 has declined about 0.75 ft from the time the well was installed until the end

Location and construction data for wells used in this study [—, no data; NAVD 88, National Vertical Datum of 1988]

Site name	Other identifier	Latitude	Longitude	Altitude (feet above NAVD 88)	Depth, feet below land surface: Top of screen or open interval	Depth, feet below land surface: Bottom of screen or open interval	Water-bearing units
28AA20	Fish and Wildlife	33°20'29"	82°12'59"	463	—	[1]89	Lower Dublin and upper and lower Midville aquifers, undifferentiated
28AA26	Washrack–Forestry Road	33°20'53"	82°12'42"	468	51	71	Upper Three Runs and Gordon aquifers, undifferentiated
28BB103	Range Control	33°22'41"	82°14'01"	500	223	243	Lower Dublin and upper and lower Midville aquifers, undifferentiated

[1] Initial depth of well was 200 feet. Geophysical logging indicates obstruction in well.



Lithologic and hydrologic units, construction, and geophysical logs of well 28AA26, Fort Gordon, Georgia.

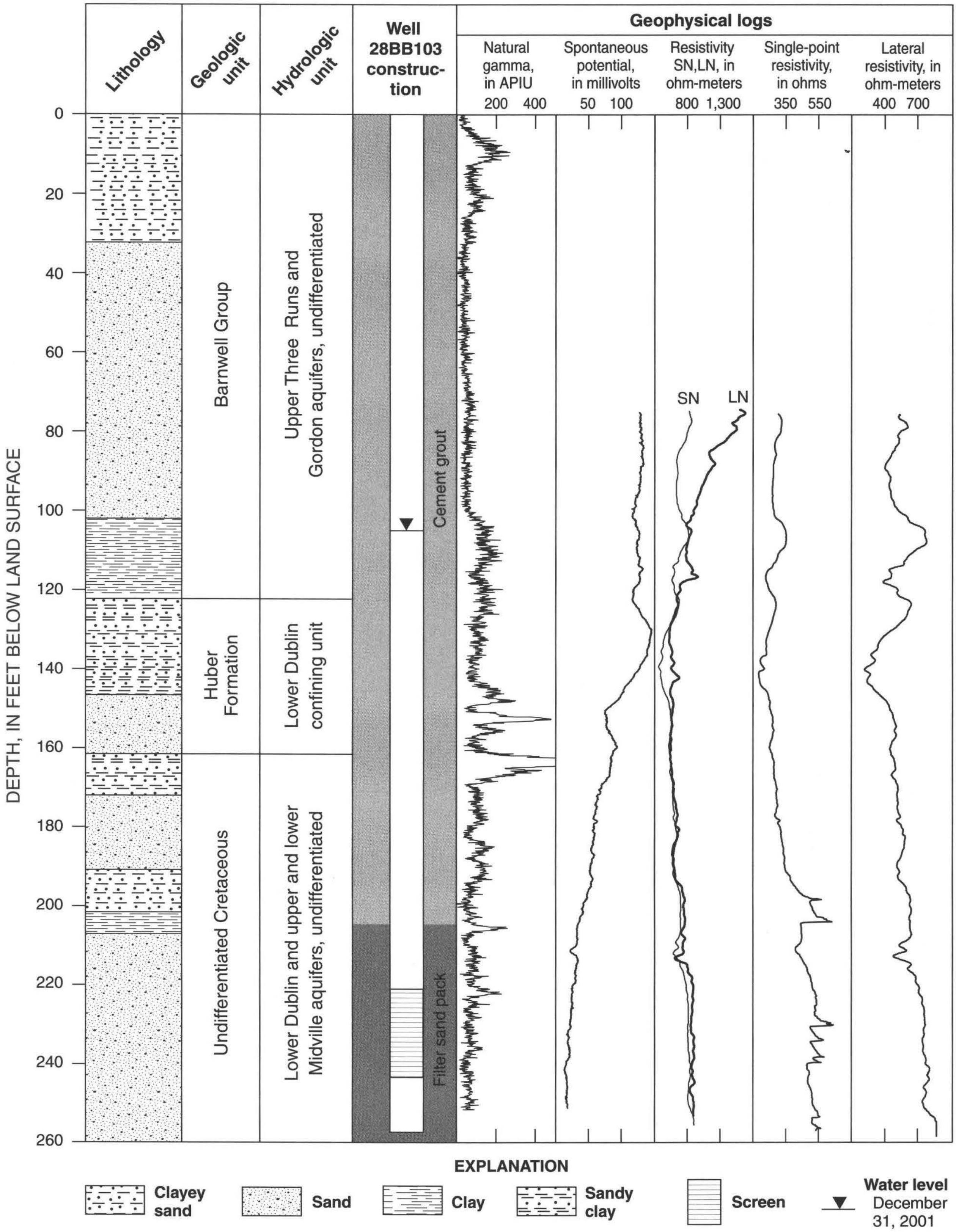
of the year (2001) corresponding to a period of low precipitation and increased evapotranspiration. The water level in well 28AA20 declined about 1 ft from January to March, remained stable until September, then declined about 1 ft from September to December. The fluctuation is due to seasonal precipitation, evapotranspiration, and pumping. The water level in well 28AA20 declined about 2 ft during 2001.

The water level in well 28BB103 was stable from January to June, then declined from June to October due to pumping and decreased precipitation. In November, the water level began to rise as the aquifer was recharged from precipitation. Overall, the water level in well 28BB103 declined about 0.5 ft during 2001.

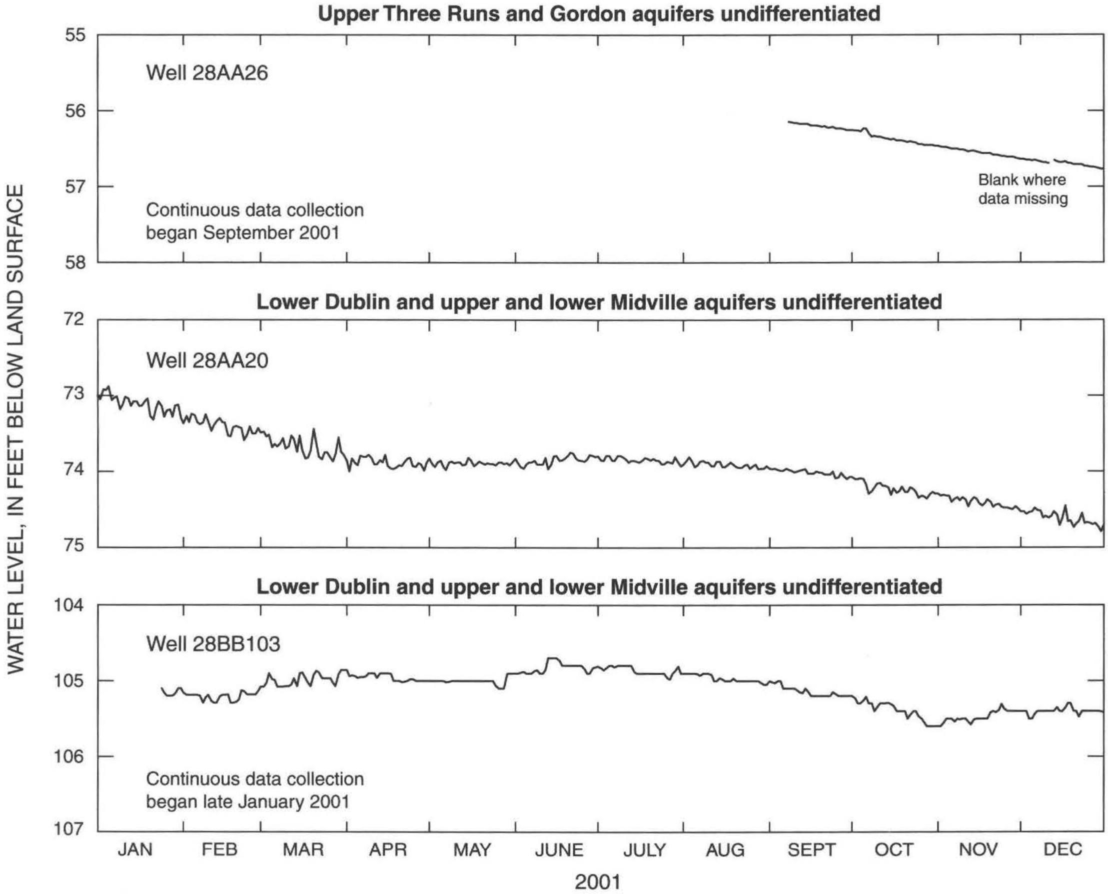
Ground-Water Quality

Information on ground-water quality in the central Fort Gordon area is limited to data collected at the Gibson Road Landfill (Priest and McSwain, 2002) and to a sample collected in well 28AA26. At the Gibson Road Landfill, Priest and McSwain (2002) reported that selected trace elements and organic compounds exceeded the maximum contaminant levels (MCL, formerly known as the primary maximum contaminant level) of the U.S. Environmental Protection Agency (2000), National Primary Drinking Water Standards in several wells surrounding the landfill. The selected trace elements reported are: arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, sulfide, thallium, vanadium, and zinc. Water in 6 of the 10 wells from the study had selected trace elements exceeding the MCL. The selected trace element and organic compound detections showed that a ground-water contaminant plume was present in the vicinity of the landfill (Priest and McSwain, 2002).

Additionally, specific conductance measured in 10 wells ranged from 22 to 755 microsiemens per centimeter and pH ranged from 4.78 to 7.32. In well 28AA26, a sample collected in December 2001 was analyzed for benzene, toluene, ethyl benzene, xylene (BTEX), and ethylene glycol. The analyses indicated that BTEX was not detected above its reporting limit of 0.50 micrograms per liter and ethylene glycol was not detected above its reporting limit of 25 milligrams per liter.



Lithologic and hydrologic units, construction, and geophysical logs of well 28BB103, Fort Gordon, Georgia. [APIU, American Petroleum Institute Units; SN, 16-inch (short) normal; LN, 64-inch (long) normal]



Daily ground-water levels in wells 28AA26, 28AA20, and 28BB103 during 2001.

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SELECTED GROUND-WATER PUBLICATIONS, CONFERENCES, AND OUTREACH, 2001

INTRODUCTION

During 2001, numerous reports, conference proceedings papers, and abstracts authored by U.S. Geological Survey (USGS) scientists were published on the ground water of Georgia; selected publications are listed below. Oral and poster presentations were given at various technical conferences and outreach events throughout the State. Most of these publications and talks presented results of investigations conducted in cooperation with agencies including the Georgia Department of Natural Resources; city of Brunswick and Glynn County; Albany Water, Gas, and Light Commission; city of Lawrenceville; U.S. Department of Defense; and U.S. Fish and Wildlife Service. Abstracts of many of the publications and ordering information are available on the Web at URL: *http://ga.water.usgs.gov/ga004.html.*

Georgia Water Resources Conference for 2001

An important conference that was co-sponsored by the USGS and where results of several USGS investigations were highlighted was the 7th Biennial Georgia Water Resources Conference, held at the University of Georgia in Athens, in March 2001. Thirty-two USGS-authored papers (16 of which were ground-water related) were published and presented either as oral or poster presentations. The USGS Director, Charles G. Groat, was a keynote speaker at this conference.

Other Conferences and Outreach Events for 2001

Other conferences and outreach events in which USGS ground-water scientists participated include:

- Geological Society of America, Southeastern Section Meeting, held in Raleigh, North Carolina (April);
- U.S. Geological Survey, Appalachian Region Integrated Workshop, held in Gatlinburg, Tennessee (October);
- National Ground Water Association, Southeast FOCUS Ground Water Conference, held in Atlanta, Georgia (September);
- CoastFest 2001, held in Brunswick, Georgia (October);
- SunBelt Exposition, held in Moultrie, Georgia (October); and
- First International Conference on Saltwater Intrusion and Coastal Aquifers, held in the Country of Morocco (April).

Selected USGS Reports and Conference Proceedings Articles Published in 2001

Abu-Ruman, Malek, and Clarke, J.S., 2001, Preliminary simulation of pond-aquifer flow and water availability at a seepage pond near Brunswick, Georgia; *in* Hatcher, K.J., ed., Proceedings of the 2001 Georgia Water Resources Conference, Athens, Georgia, March 26–27, 2001: The University of Georgia, Institute of Ecology, p. 669–672.

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