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Groundwater Conditions in Georgia, 2015–16

Scientific Investigations Report 2017–5142

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

Preface

This report is published biennially to summarize groundwater conditions in Georgia. The report, presented in stop format, is the culmination of a concerted effort by personnel of the U.S. Geological Survey South Atlantic Water Science Center, Norcross, Georgia, office who collected, compiled, organized, analyzed, verified, edited, and assembled the report. In addition to the authors, who were primarily responsible 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. Hydrologic technician collecting data at irrigation well, Dougherty County, Georgia. Photograph by Debbie Gordon.

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U.S. Department of the Interior
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William H. Werkheiser, Deputy Director
exercising the authority of the Director

U.S. Geological Survey, Reston, Virginia: 2018

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Contents

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

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.

Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Groundwater Conditions in Georgia, 2015–16

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Abstract

The U.S. Geological Survey collects groundwater data and conducts studies to monitor hydrologic conditions, define groundwater resources, and address problems related to water supply, water use, and water quality. In Georgia, water levels were monitored continuously at 157 wells during calendar years 2015 and 2016. Because of missing data or short periods of record (less than 5 years) for several of these wells, data for 147 wells are presented in this report. These wells include 15 in the surficial aquifer system, 18 in the Brunswick aquifer system and equivalent sediments, 59 in the Upper Floridan aquifer, 13 in the Lower Floridan aquifer and underlying units, 9 in the Claiborne aquifer, 1 in the Gordon aquifer, 8 in the Clayton aquifer, 16 in the Cretaceous aquifer system, 2 in Paleozoic-rock aquifers, and 6 in crystalline-rock aquifers. Data from the well network indicate that water levels generally rose during the 10-year period from 2007 through 2016, with water levels rising in 105 wells and declining in 31 wells; insufficient data prevented determination of a 10-year trend in 11 wells. Water levels declined over the long-term period of record at 80 wells, increased at 62 wells, and remained relatively constant at 5 wells.

In addition to continuous water-level data, periodic water-level data were collected and used to construct potentiometric-surface maps for the Upper Floridan aquifer in the Brunswick–Glynn County area during October 2015 and October 2016 and in the Albany–Dougherty County area during December 2015 and November and December 2016. Periodic water-level measurements were also collected and used to construct potentiometric-surface maps for the Cretaceous aquifer system in the Augusta–Richmond County area during July 2015 and June 2016. In general, water levels in the Upper Floridan aquifer were higher during 2015 than during 2016 in the Brunswick–Glynn County and Albany–Dougherty County areas due to higher precipitation during 2015. Water levels were lower, however, during 2015 than during 2016 in the Cretaceous aquifer system in the Augusta–Richmond County area.

In the Brunswick area, maps showing the chloride concentration of water in the Upper Floridan aquifer constructed using data collected from 33 wells during October 2015 and from 30 wells during October 2016 indicate that chloride concentrations remained above the U.S. Environmental Protection Agency’s secondary drinking-water standard in an approximately 2-square-mile area. During calendar years 2015–16, chloride concentrations generally were similar to those measured during 2012–14; however, some wells did show an increase in chloride concentration, likely due to increases in pumping.

Introduction

Reliable and impartial scientific information about 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 define the water resources of Georgia and other States and territories.

Groundwater-level and groundwater-quality data are essential for water-resources 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 groundwater recharge, storage, and discharge. Long-term, systematic measurement of water levels provides essential data needed to evaluate changes in the resource over time, develop groundwater models and forecast trends, and design, implement, and monitor the effectiveness of groundwater management and protection programs (Taylor and Alley, 2001). Groundwater-quality data are necessary to protect groundwater resources, because deterioration of groundwater quality may be virtually irreversible, and treatment of contaminated groundwater can be expensive (Alley, 1993).

Purpose and Scope

This report presents an overview of groundwater levels throughout the State and groundwater quality in the Brunswick–Glynn County area (see map page 13) of Georgia through calendar year 2016. The current report is a continuation of a series of reports begun in 1978 (see table page 4) and primarily follows the same format as the last report in the series, "Groundwater Conditions in Georgia, 2012–14" (Peck and Painter, 2016). As with previous reports, the data-collection period is based on a calendar year; for example, the phrase "during 2015" refers to the calendar year of January 1, 2015, through December 31, 2015. In Georgia, water levels were monitored continuously at 157 wells during 2015 and 2016; however, data for 147 wells are presented in this report because of missing data or short periods of record (less than 5 years) for several of these wells. Water-level data are summarized in graphs, maps, and tables. Groundwater levels in major aquifers are presented in hydrographs for selected wells. Previous reports presented water-level changes in wells for the period of record and for the last 2 or 3 years; however, in the current report, estimated annual water-level change is reported for the period of record and for 2007–16 for wells in which water levels have been recorded since 2007 and when no more than 20 percent of the data are missing for the period. To represent a more recent trend than the period of record, a 10-year trend period was used to replace the 2–3 year trend presented in previous reports. The change to a short-term trend with a longer period was made because, in some cases, the water-level change over the last 2–3 years deceptively magnified or minimized the trend in groundwater level. In addition to presenting the data that have been published previously, this report includes data from 2015 and 2016. Data from and additional information about the wells included in this report can be obtained from the USGS National Water Information System (NWIS) database at https://waterdata.usgs.gov/ga/nwis/gw/ (U.S. Geological Survey, 2017).

In addition to continuous water-level recording, periodic water-level measurements were made to complete potentiometric-surface maps of the Upper Floridan aquifer and the Cretaceous aquifer system. The Upper Floridan aquifer potentiometric-surface maps were completed in the Albany–Dougherty County area of southwestern Georgia using data collected from 50 wells during December 2015 and from 51 wells during November and December 2016. In the Brunswick–Glynn County area, water-level data were collected from 51 wells during October 2015 and from 52 wells during October 2016 to construct potentiometric-surface maps of the Upper Floridan aquifer. Water-level data were collected from 66 wells during July 2015 and from 73 wells during June 2016 in the Augusta–Richmond County area and were used to construct potentiometric-surface maps of the Cretaceous aquifer system.

The quality of groundwater in the Upper and Lower Floridan aquifers is being monitored in the Brunswick–Glynn County area along the Georgia coast. Chloride concentration maps were constructed using data from 33 wells during 2015 and from 30 wells during 2016.

Methods of Analysis, Sources of Data, and Data Accuracy

Continuous water-level data from 147 wells throughout Georgia are presented in this report. During 2015, 110 wells had electronic data loggers that recorded water levels at 60-minute intervals; these data were field checked to verify that the electronic water level was within 0.05 foot (ft) of the manual measurement, and data were retrieved generally every 2 months. Thirty-seven wells had real-time satellite telemetry that recorded water levels at 60-minute intervals. Real-time satellite telemetry data are transmitted every 1 to 4 hours (based on the equipment) and are available at https://waterdata.usgs.gov/ga/nwis/current/?type=gw (U.S. Geological Survey, 2017).

To illustrate long-term (period of record) and more recent (2007–16) water-level changes, hydrographs showing monthly mean water levels are presented together with maps showing water-level trends during 2007–16. To estimate water-level trends, the Levenberg–Marquardt (LMA) method for minimization of a weighted, least-squares merit function (Janert, 2010) was used to determine a straight-line fit to both recent and period-of-record monthly mean groundwater levels (example graph on facing page). Estimated water levels from these straight-line fits were used to compute an annual rate of change (yearly slope) for the period of record and for 2007–16. A more thorough discussion of the LMA method is presented in the appendix of this report along with associated summary statistics for each well and for straight-line fits. Use of trend calculations in this report should be informed by the summary statistics provided in the appendix where missing periods of data, when present, may affect the interpretation of a given trend.

Water-level trends are presented in tables, hydrographs, and maps for each aquifer and subarea in the groundwater-level section of this report. Trends for 2007–16 are denoted in maps either by an upward arrow for a positive rate of change of 0.01 foot per year (ft/yr) or greater, or a downward arrow for a negative rate of change of 0.01 ft/yr or greater. A circle is used to represent no water-level change when the change was less than ±0.01 ft/yr. Trends for 2007–16 are not presented if the period of record did not start before 2007. Additional well information can be obtained from the USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/ (U.S. Geological Survey, 2017). To find data for a specific well, follow these steps in NWIS:

1. Click on *Historical Observations*.
2. Click the box next to *Site Name* under the *Site Identifier* column.
3. Click *Submit*.
4. Type the well number (grid number) into the box under *Site Name*.
5. Click on *Well* under *Site type*.

6. Click the box next to *Depth to water level, ft below land surface* under *WaterLevel/Flow Parameters*.

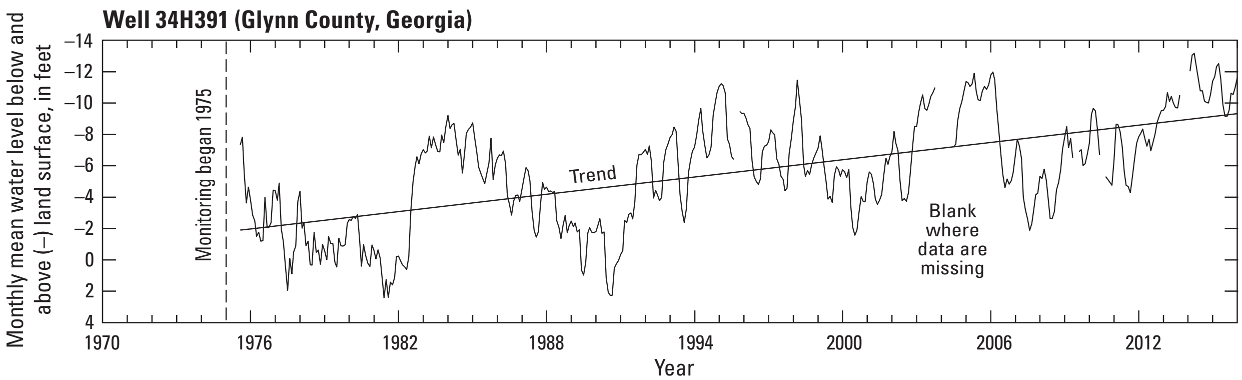
7. Click the circle next to *for the date range* under ***Retrieve data for***:

8. Enter the first and last dates of interest *(year-month-day)*. For example, *2015-01-01* and *2016-12-31* for the data presented in this report.

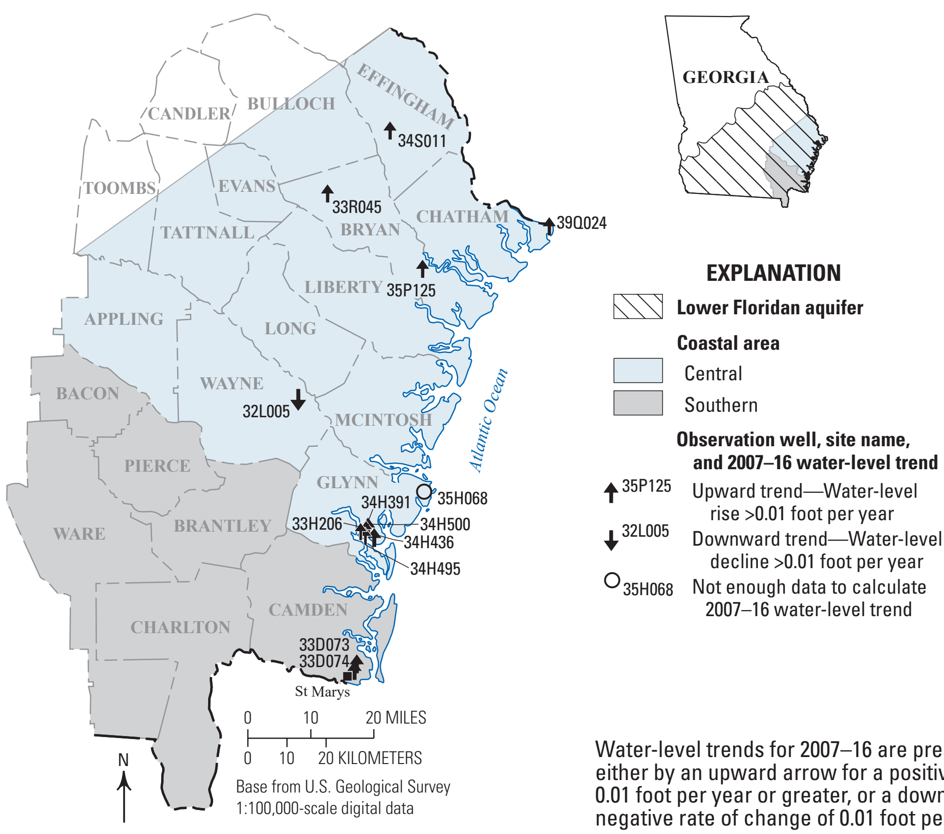
9. Click the circle next to *Graphs of data with long-term statistics*.

10. Click *Submit*.

Following the steps above will bring up a hydrograph for the well of interest for 2015 and 2016. The median daily statistic for the period of record, which is referred to in this report, will be displayed. All of the available data for the site can also be viewed from this web page.



Example hydrograph showing monthly mean water levels in well 34H391 for the period 1970–2016, and period-of-record trend.



Water-level trends for 2007–16 are presented on maps either by an upward arrow for a positive rate of change of 0.01 foot per year or greater, or a downward arrow for a negative rate of change of 0.01 foot per year or greater.

Previously published U.S. Geological Survey reports on groundwater conditions in Georgia.

[OFR, Open-File Report; WRIR, Water-Resources Investigations Report; SIR, Scientific Investigations Report]

Year of data collection	USGS report series and number	Author(s)	Year of publication
1977	OFR 79–213	U.S. Geological Survey	1978
1978	OFR 79–1290	Clarke, J.S., Hester, W.G., and O'Byrne, M.P.	1979
1979	OFR 80–501	Mathews, S.E., Hester, W.G., and O'Byrne, M.P.	1980
1980	OFR 81–1068	Mathews, S.E., Hester, W.G., and O'Byrne, M.P.	1981
1981	OFR 82–904	Mathews, S.E., Hester, W.G., and McFadden, K.W.	1982
1982	OFR 83–678	Stiles, H.R., and Mathews, S.E.	1983
1983	OFR 84–605	Clarke, J.S., Peck, M.F., Longsworth, S.A., and McFadden, K.W.	1984
1984	OFR 85–331	Clarke, J.S., Longsworth, S.A., McFadden, K.W., and Peck, M.F.	1985
1985	OFR 86–304	Clarke, J.S., Joiner, C.N., Longsworth, S.A., McFadden, K.W., and Peck, M.F.	1986
1986	OFR 87–376	Clarke, J.S., Longsworth, S.A., Joiner, C.N., Peck, M.F., McFadden, K.W., and Milby, B.J.	1987
1987	OFR 88–323	Joiner, C.N., Reynolds, M.S., Stayton, W.L., and Boucher, F.G.	1988
1988	OFR 89–408	Joiner, C.N., Peck, M.F., Reynolds, M.S., and Stayton, W.L.	1989
1989	OFR 90–706	Peck, M.F., Joiner, C.N., Clarke, J.S., and Cressler, A.M.	1990
1990	OFR 91–486	Milby, B.J., Joiner, C.N., Cressler, A.M., and West, C.T.	1991
1991	OFR 92–470	Peck, M.F., Joiner, C.N., and Cressler, A.M.	1992
1992	OFR 93–358	Peck, M.F., and Cressler, A.M.	1993
1993	OFR 94–118	Joiner, C.N., and Cressler, A.M.	1994
1994	OFR 95–302	Cressler, A.M., Jones, L.E., and Joiner, C.N.	1995
1995	OFR 96–200	Cressler, A.M.	1996
1996	OFR 97–192	Cressler, A.M.	1997
1997	OFR 98–172	Cressler, A.M.	1998
1998	OFR 99–204	Cressler, A.M.	1999
1999	OFR 00–151	Cressler, A.M.	2000
2000	OFR 01–220	Cressler, A.M., Blackburn, D.K., and McSwain, K.B.	2001
2001	WRIR 03–4032	Leeth, D.C., Clarke, J.S., and Craigg, S.D., and Wipperfurth, C.J.	2003
2002–2003	SIR 2005–5065	Leeth, D.C., Clarke, J.S., Wipperfurth, C.J., and Craigg, S.D.	2005
2004–2005	SIR 2007–5017	Leeth, D.C., Peck, M.F., and Painter, J.A.	2007
2006–2007	SIR 2009–5070	Peck, M.F., Painter, J.A., and Leeth, D.C.	2009
2008–2009	SIR 2011–5048	Peck, M.F., Leeth, D.C., and Painter, J.A.	2011
2010–2011	SIR 2013–5084	Peck, M.F., Gordon, D.W., and Painter, J.A.	2013
2012–2014	SIR 2016–5161	Peck, M.F., and Painter, J.A.	2016

U.S. Geological Survey Well-Identification System in Georgia

Wells described in this report are identified according to a system based on the index of USGS 7.5-minute topographic maps of Georgia. Each map in Georgia has been assigned a two- to three-digit number and letter designation (for example, 07H) 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 in the well-identification system to avoid ambiguity. Wells inventoried in each quadrangle are numbered consecutively beginning with 001. Thus, the fourth well inventoried in the 11A quadrangle is designated 11A004. This information is stored in the "Site Name" field in the USGS NWIS database.

Cooperating Organizations and Agencies

Groundwater monitoring in Georgia is conducted in cooperation with numerous local organizations, private companies, and State and Federal agencies. Cooperating organizations and agencies include the following:

- City of Albany Utility Operations
- Augusta Utilities Department, City of Augusta
- Georgia Department of Natural Resources, Environmental Protection Division
- Glynn County Joint Water and Sewer Commission
- Miller Coors LLC

All of these organizations participate in the USGS Cooperative Water Program, an ongoing partnership between the USGS and State and local partners. The program enables joint planning and funding for groundwater monitoring and systematic studies of water quantity, quality, and use. Data obtained from these studies can be used to guide water-resources management and planning activities and provide indications of emerging water problems. A more complete description of the Cooperative Water Program is provided in Taggart (2004).

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Janert, P.K., 2010, Gnuplot in action—Understanding data with graphs: Greenwich, Conn., Manning Publications, 360 p.

Peck, M.F., and Painter, J.A., 2016, Groundwater conditions in Georgia, 2012–14: U.S. Geological Survey Scientific Investigations Report 2016–5161, 55 p., accessed October 12, 2017, at https://doi.org/10.3133/sir20165161.

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U.S. Geological Survey, 2017, National Water Information System database, accessed November 17, 2017, at https://doi.org/10.5066/F7P55KJN.

Groundwater Resources

Contrasting geologic features and landforms of the physiographic provinces of Georgia (see map on p. 7 and table on p. 8–9) affect the quantity and quality of groundwater throughout the State. The surficial aquifer system is present in each of the five physiographic provinces in Georgia. In the Coastal Plain Province, the surficial aquifer system consists of layered sand, clay, and in some places limestone. The surficial aquifer system typically is under water-table (unconfined) conditions and provides water for domestic and livestock use. The surficial aquifer system is semiconfined to confined locally in the coastal area. In the Piedmont, Blue Ridge, and Valley and Ridge Provinces, the surficial aquifer system 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 the aquifers crop out or are near land surface. Aquifers in the Coastal Plain include the surficial aquifer system, Brunswick aquifer system, Floridan aquifer system, Gordon aquifer, Claiborne aquifer, Clayton aquifer, and Cretaceous aquifer system.

In the Valley and Ridge Province, groundwater is transmitted through primary and secondary openings in folded and faulted sedimentary and metasedimentary rocks of Paleozoic age. In this report, the aquifers are 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. Groundwater is transmitted through secondary openings along fractures, foliation, joints, contacts, or other features in the crystalline bedrock. In this report, the aquifers are referred to as “crystalline-rock aquifers.” A more complete discussion of the State’s groundwater resources is provided in Clarke and Pierce (1985).

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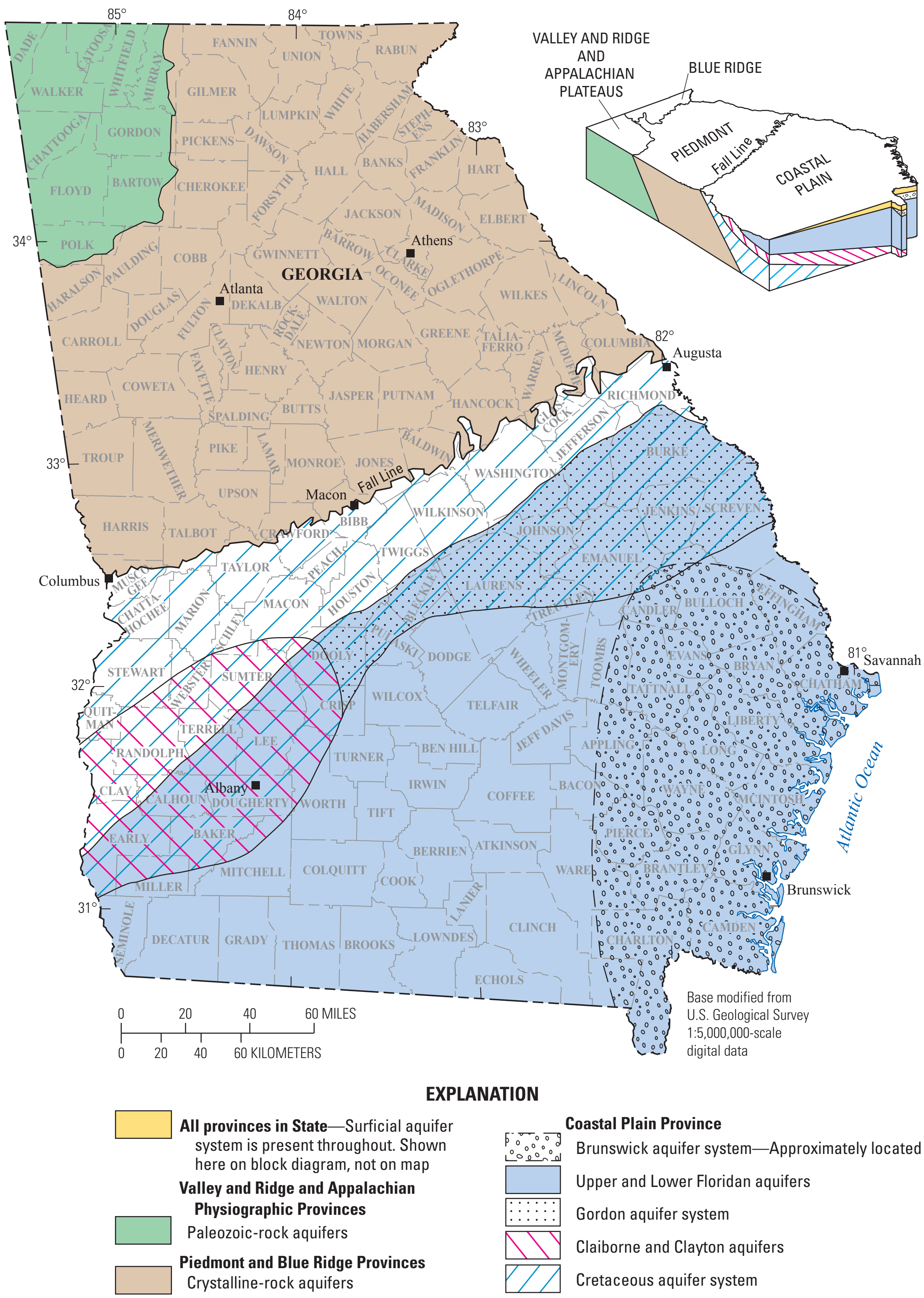


Areas of major aquifers in Georgia (modified from Clarke and Pierce, 1985).

Groundwater Resources

Aquifer and well characteristics in Georgia [modified from Clarke and Pierce, 1985; Peck and others, 1992; ft, foot; gal/min, gallon per minute]

Aquifer name	Aquifer description	Well characteristics		
		Depth (ft)	Yield (gal/min)	
		Typical range	Typical range	May exceed
Surficial aquifer system	Unconsolidated sediments and residuum; generally unconfined. However, in the coastal area of the Coastal Plain, at least two semiconfined aquifers have been identified	11–300	2–25	75
Brunswick aquifer system, including 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; confined and unconfined	40–600	1–25	500

Hydrologic response	Remarks
Water-level fluctuations are caused mainly by variations in precipitation, evapotranspiration, and natural drainage or discharge. 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 (Clarke, 2003).	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; Clarke, 2003).	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).	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. 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 in depth 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 are mainly 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-supply 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 are affected mainly by precipitation and local pumping (Cressler, 1964).	Not laterally extensive. Limestone and dolomite aquifers are the 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 are affected mainly 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.

Groundwater Conditions

Groundwater Levels

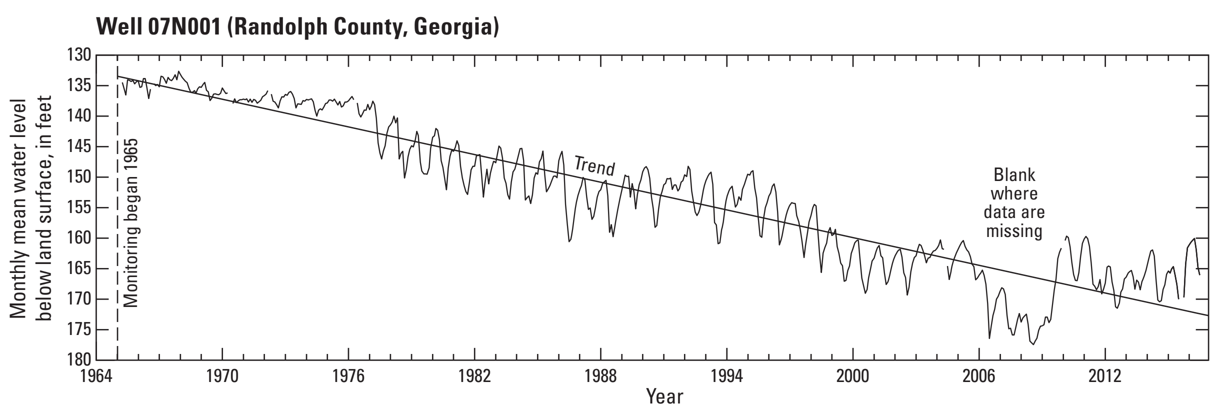
The maps and tables in this section provide an overview of groundwater levels in major aquifers in Georgia during 2007–16. Hydrographs of selected wells are presented to show period-of-record water-level trends. The discussion of each aquifer is subdivided into areas where wells likely would have similar water-level fluctuations and trends. The map on page 13 shows the locations of 147 wells that were continuously monitored by the USGS during the 2016 calendar year, including 37 wells that were monitored in real time.

Changes in aquifer storage cause changes in groundwater levels in wells. Taylor and Alley (2001) describe many factors that affect groundwater storage; these factors are summarized here. When recharge to an aquifer exceeds discharge, groundwater levels rise; when discharge from an aquifer exceeds recharge, groundwater levels decline. Recharge varies in response to precipitation and surface-water infiltration to an aquifer. Discharge occurs from an aquifer as natural flow to streams and springs, as evapotranspiration, and as withdrawal from wells. Hydrologic responses and controls on groundwater levels in major aquifers in Georgia are summarized in the table on pages 8–9.

Water levels in aquifers in Georgia typically follow a cyclical pattern of seasonal fluctuation. Water levels rise during winter and spring because of increased recharge from precipitation and decline during summer and fall because of decreased recharge, greater evapotranspiration, and increased pumping. The magnitude of fluctuations can vary greatly from season to season and from year to year in response to changing climatic conditions.

Precipitation is the primary driver of groundwater recharge and is directly related to water levels in many of the aquifers across the State. Many regions of the State received above average rainfall during 2015 and below average during 2016. For example, Atlanta, Athens, Brunswick, Macon, and Columbus received rainfall ranging from 4.5 (Macon) to 18.8 (Athens) inches above the 30-year average (table on page 12; Current Results Publishing, 2017). In contrast, many regions of the State received below average rainfall during 2016. For example, Albany, Atlanta, Athens, Augusta, Macon, and Columbus received rainfall ranging from 2.5 (Albany) to 12.0 (Macon) inches below the 30-year average (Weather Underground, 2017; Your Weather Service, 2017).

Groundwater pumping affects the amount of groundwater in storage and the rate of discharge from an aquifer (Taylor and Alley, 2001). Groundwater is the source of drinking water for about half of the U.S. population, and more than 50 billion gallons of groundwater per day is attributed to agricultural use in the United States (U.S. Geological Survey, 2017). As groundwater storage is depleted within the radius of influence of pumping, water levels in the aquifer decline and form a cone of depression around the well. In areas having a high density of pumped wells, multiple cones of depression can form and combine to produce water-level declines across a large area. These declines may alter groundwater-flow directions, reduce flow to streams, capture water from a stream or adjacent aquifer, or alter groundwater quality. The effects of sustained pumping can be seen in the hydrograph of well 07N001 completed in the Clayton aquifer in Randolph County (below).



Example hydrograph showing monthly mean water levels and trend line for well 07N001, Clayton aquifer, 1965–2016, Randolph County, Georgia.

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Current Results Publishing, 2017, Average annual precipitation for Georgia: Current Results Publishing Ltd. web page, accessed June 26, 2017, at https://www.currentresults.com/Weather/Georgia/average-yearly-precipitation.php.

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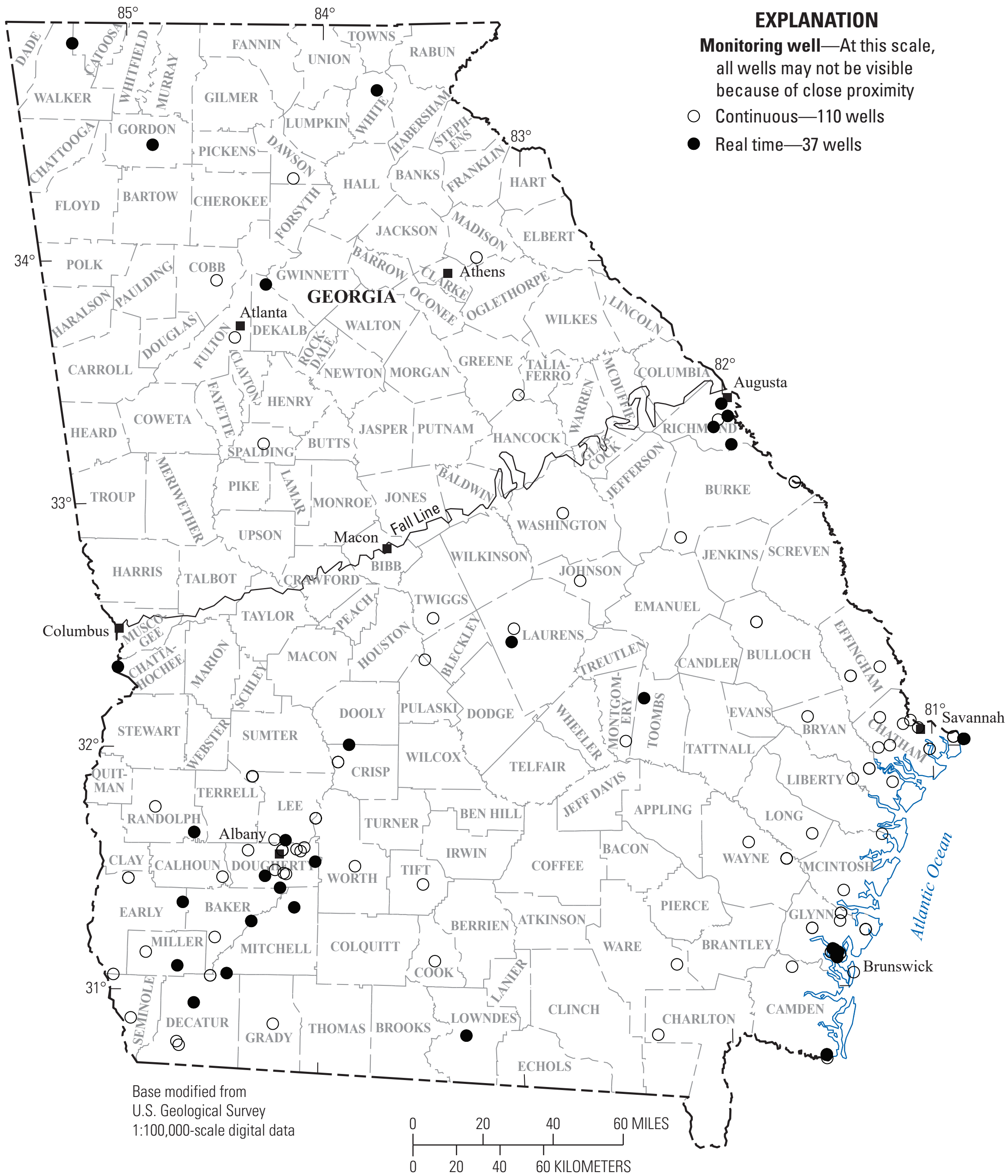
Your Weather Service, 2017, Climate Albany – Georgia: U.S. climate data web page, accessed June 26, 2017, at https://www.usclimatedata.com/climate/albany/georgia/united-states/usga0009.

Monthly precipitation totals for 2015 and 2016 and 30-year monthly averages, in inches, for selected cities in Georgia.

[Data were obtained on June 26, 2017 (Current Results Publishing, 2017; Weather Underground, 2017; Your Weather Service, 2017). Annual precipitation totals are averages based on weather data collected from 1981 to 2010 for the National Oceanic and Atmospheric Administration National Climatic Data Center. Blue, above average; Red, below average]

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Deviation from average
Albany															
	2015	3.3	4.0	2.2	5.2	1.2	5.4	4.2	5.4	3.9	0.7	7.0	6.9	49.2	2.3
	2016	3.6	6.7	4.8	6.9	0.8	4.4	2.2	4.7	3.3	0.0	1.0	10.7	49.0	2.5
1981–2010	30 year avg.	5.1	4.4	5.3	3.4	3.3	5.0	5.9	5.2	3.7	2.6	3.6	4.0	51.5	
Atlanta															
	2015	4.4	4.2	3.0	7.8	4.4	6.9	5.0	5.8	3.9	2.6	8.0	12.5	68.4	18.7
	2016	5.1	7.4	2.2	3.2	1.3	3.3	3.7	3.1	3.4	0.2	3.0	3.0	38.7	11.0
1981–2010	30 year avg.	4.2	4.7	4.8	3.4	3.7	4.0	5.3	3.9	4.5	3.4	4.1	3.9	49.7	
Athens															
	2015	3.0	4.0	2.8	8.0	2.6	2.8	5.1	6.8	3.5	5.0	9.3	12.4	65.2	18.8
	2016	3.7	4.5	2.0	2.6	2.5	4.1	1.6	10.1	1.2	0.0	2.2	2.4	36.9	9.5
1981–2010	30 year avg.	4.1	4.5	4.4	3.2	3.0	4.2	4.5	3.5	3.9	3.6	3.8	3.7	46.3	
Augusta															
	2015	1.3	3.5	2.6	3.5	1.5	3.2	2.5	6.4	2.8	3.9	3.2	5.5	39.7	3.9
	2016	1.7	2.9	2.1	3.3	4.3	1.3	5.9	3.7	5.3	1.9	1.4	4.2	37.9	5.7
1981–2010	30 year avg.	3.9	3.9	4.2	2.8	2.6	4.7	4.3	4.3	3.2	3.3	2.8	3.4	43.6	
Brunswick															
	2015	3.0	2.7	2.4	3.4	4.0	4.0	9.2	6.8	8.6	4.5	4.6	1.4	54.5	9.5
	2016	3.2	4.0	1.6	2.7	1.7	5.7	1.3	3.8	8.2	11.2	0.0	3.0	46.3	1.3
1981–2010	30 year avg.	3.2	3.5	3.9	2.5	1.9	4.8	4.1	6.3	5.8	4.5	2.1	2.6	45.0	
Macon															
	2015	2.4	4.4	2.3	6.3	1.2	3.8	1.6	5.1	2.1	1.7	6.9	12.6	50.2	4.5
	2016	2.5	3.2	2.6	7.6	2.0	1.9	2.3	2.0	2.2	0.2	1.2	6.0	33.7	12.0
1981–2010	30 year avg.	4.2	4.4	4.6	3.0	2.7	4.1	5.0	4.1	3.6	2.8	3.3	4.0	45.7	
Columbus															
	2015	3.2	4.2	2.5	6.5	3.2	4.1	2.2	7.5	1.9	1.1	9.4	17.4	63.1	16.4
	2016	3.2	4.2	2.6	6.9	2.5	2.2	1.0	4.4	0.8	0.9	2.2	4.4	35.1	11.6
1981–2010	30 year avg.	3.9	4.4	5.5	3.6	3.2	3.7	4.8	3.8	3.1	2.6	4.1	4.3	46.8	



Locations of monitoring wells used to collect long-term water-level data in Georgia during 2016.

Groundwater Levels

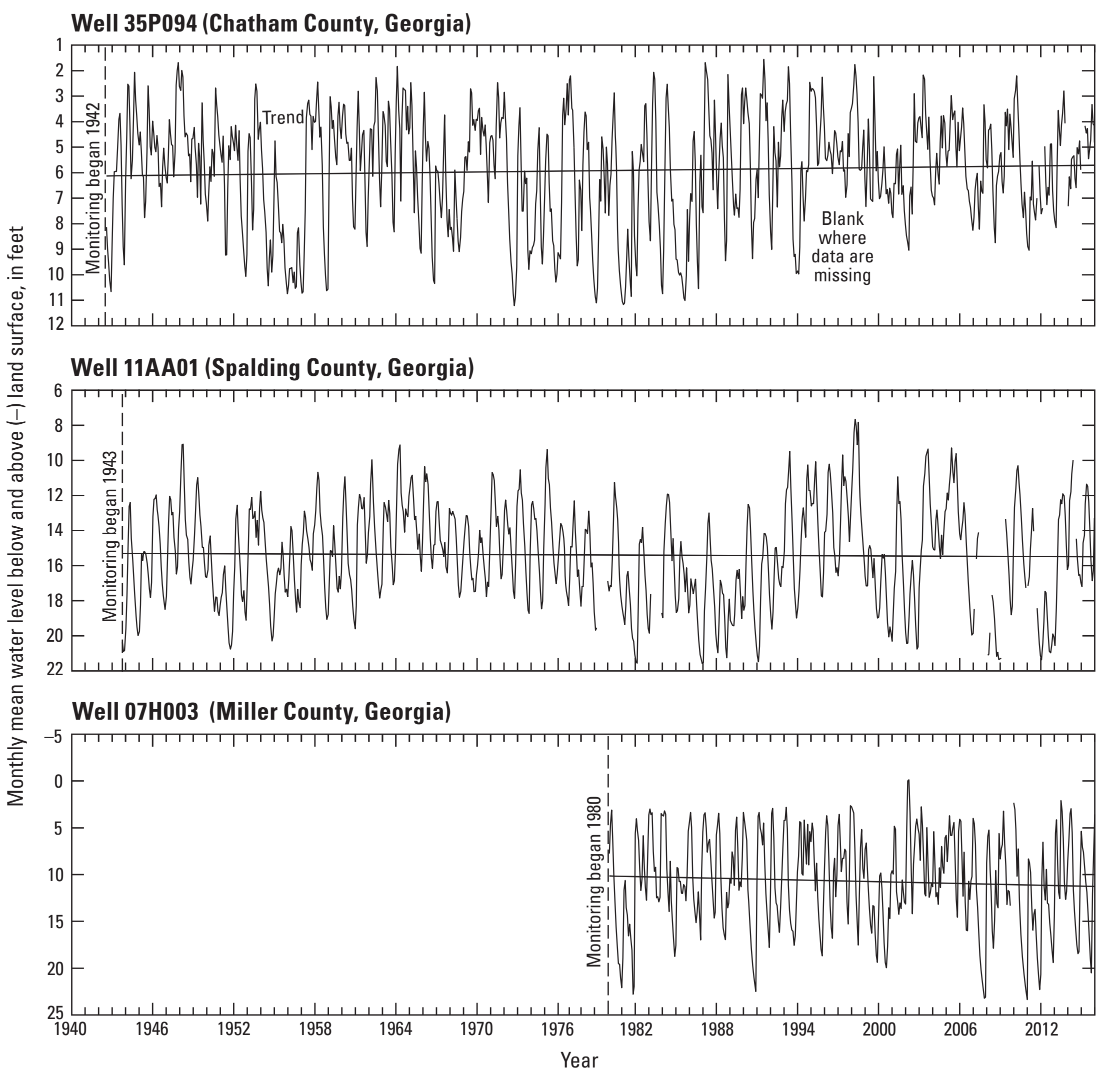
Surficial Aquifer System

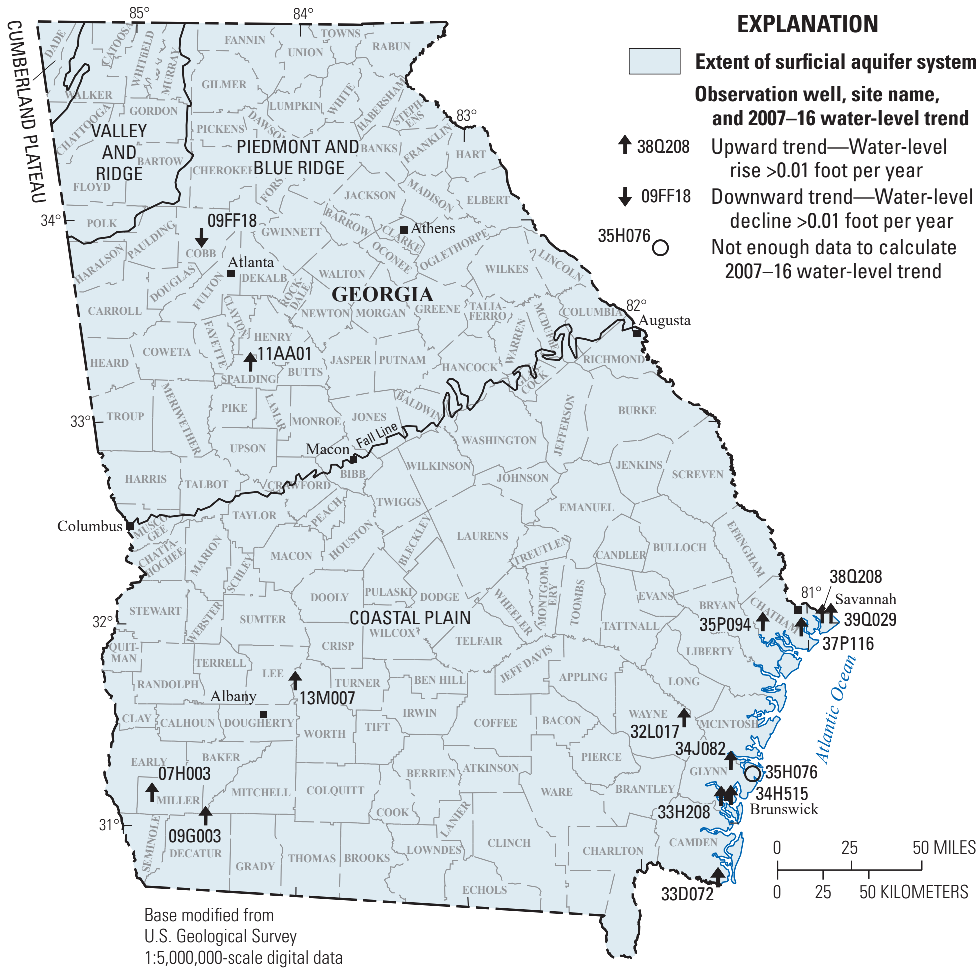
Water levels measured in 15 wells were used to define conditions in the surficial aquifer system (map and table, facing page). Groundwater in the surficial aquifer system typically is in contact with the atmosphere (referred to as an unconfined or water-table aquifer), but locally, especially in coastal Georgia, the water 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 climatic fluctuations. In parts of coastal Georgia, the surficial aquifer system is used as a source of irrigation supply and shows a response to local pumping. During 2010, about 1.3 million gallons per day (Mgal/d) were withdrawn from the surficial aquifer system in Georgia primarily for irrigation (Lawrence, 2016). Water-level hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show mostly seasonal variations, with periodic upward or downward trends that respectively reflect surpluses or deficits in rainfall. These periodic trends tend to be level over the long term.

Water levels in the surficial aquifer have shown little change in long-term trend during the period of record with rates of change less than ±0.01 ft/yr in two of the wells, declines of 0.01 to 0.13 ft/yr in four wells, and rises of 0.01 to 0.21 ft/yr in nine wells. During 2007–16, water levels in 14 of the 15 wells rose at rates of 0.01 to 0.43 ft/yr, and the water level in 1 well declined at the rate of 0.08 ft/yr. Due to above average rainfall during 2015, water levels in the surficial aquifer generally were higher in 2015 than in 2016.

Reference Cited

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 22, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
33D072	Camden	1998	0.21	0.14
35P094	Chatham	1942	0.01	0.09
37P116	Chatham	1984	<0.01	0.01
38Q208	Chatham	1998	0.01	0.06
39Q029	Chatham	1998	0.03	0.15
09FF18	Cobb	2001	–0.12	–0.08
09G003	Decatur	1980	0.01	0.26
35H076	Glynn	2005	0.07	([2])
33H208	Glynn	1983	0.15	0.27
34H515	Glynn	2005	0.02	0.03
34J082	Glynn	2002	0.02	0.17
07H003	Miller	1980	–0.03	0.16
11AA01	Spalding	1943	<0.01	0.43
32L017	Wayne	1983	–0.13	0.17
13M007	Worth	1980	–0.01	0.13

[1]See appendix for summary statistics.

[2]Not enough data to calculate 2007 to 2016 water-level trend.

Groundwater Levels

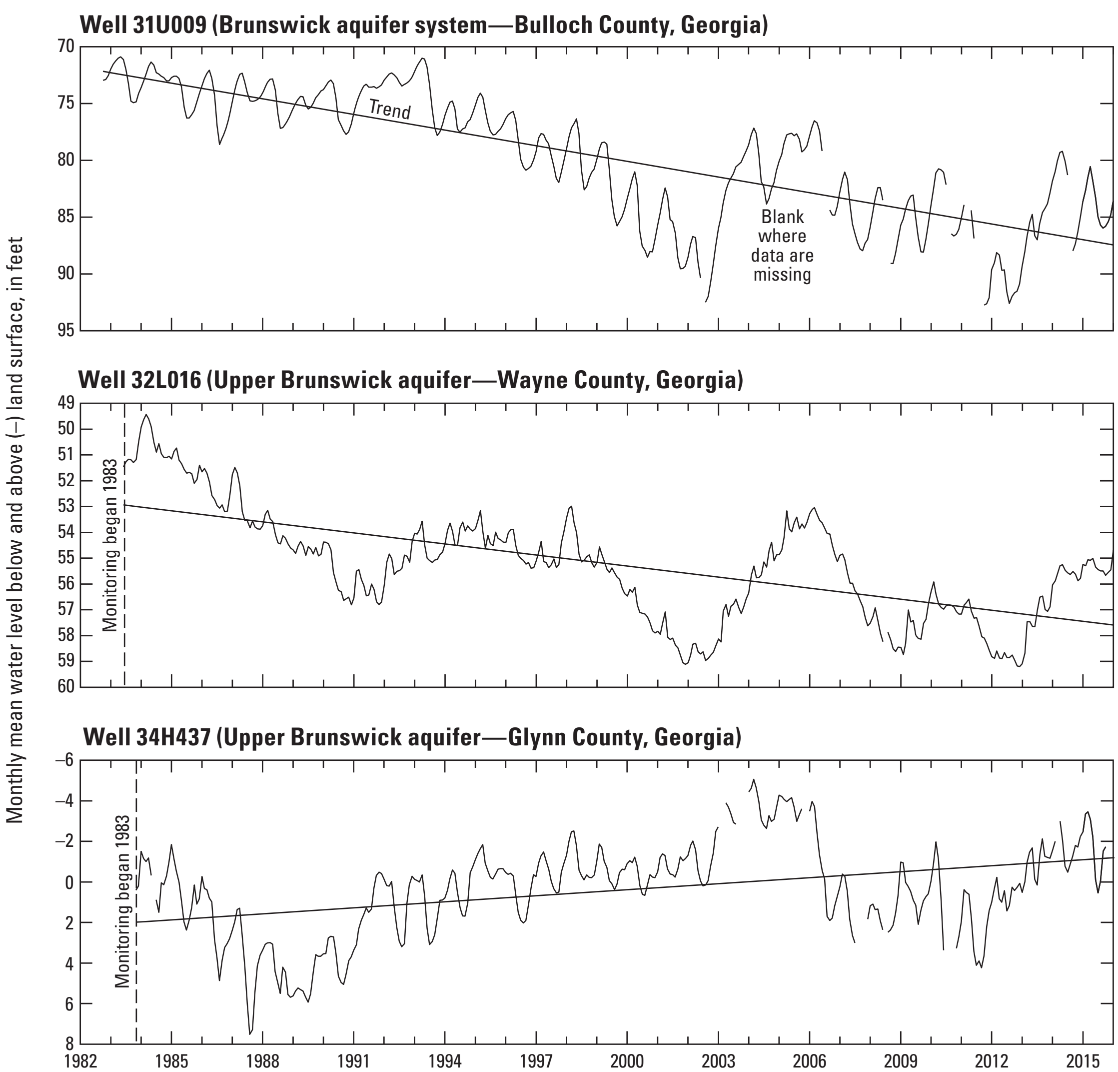
Brunswick Aquifer System

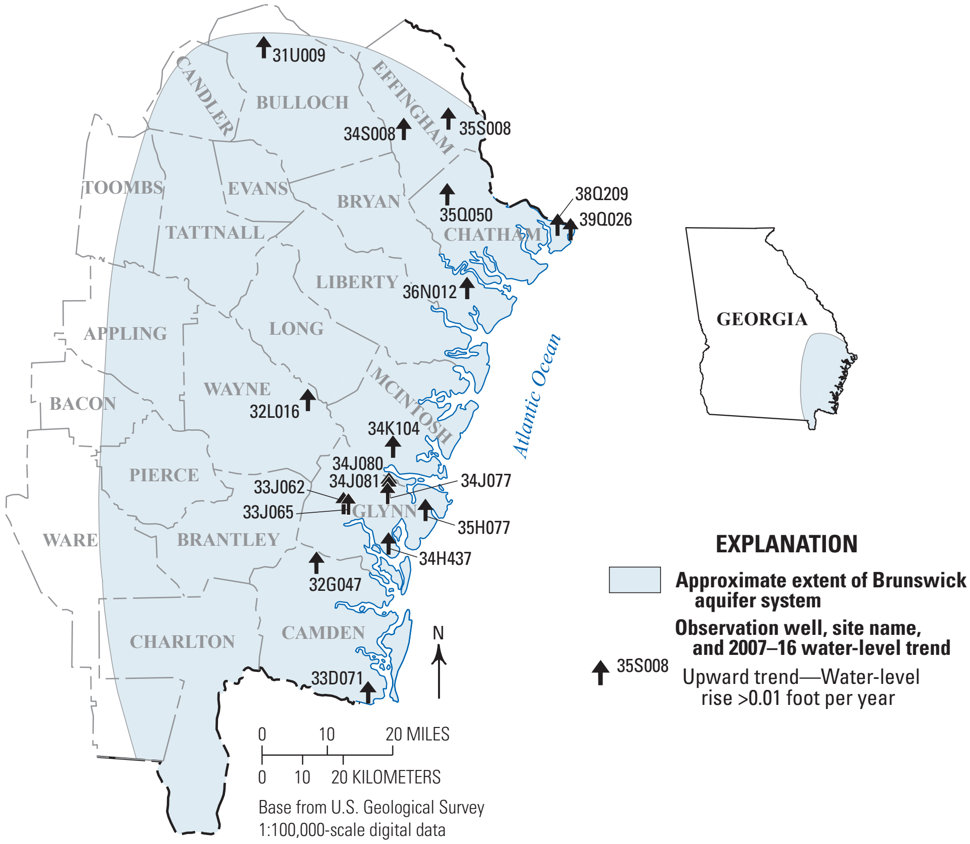
Water levels in 18 wells were used to define conditions in the Brunswick aquifer system. The aquifer system consists of the confined upper and lower Brunswick aquifers and equivalent low-permeability sediments to the north and west in southeastern Georgia (map and table, facing page). Water-level fluctuations reflect changes in local pumping, interaquifer-leakage effects, and recharge. During 2010, about 36 Mgal/d were withdrawn from the Brunswick aquifer system in Georgia, primarily for irrigation (Lawrence, 2016). Water-level hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surpluses or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in 14 of the 18 wells rose at rates of 0.03 to 1.15 ft/yr, and water levels in 4 wells declined at rates of 0.01 to 0.46 ft/yr. During 2007–16, water levels in all 18 wells rose at rates of 0.04 to 0.72 ft/yr. In general, water levels were higher in the Brunswick aquifer system during 2015 than during 2016.

Reference Cited

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 22, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	County	Water-bearing unit[1]	Year monitoring began	Water-level trend, in feet per year[2]	
				Period of record	From 2007 to 2016
36N012	Bryan	L	1999	0.30	0.72
31U009	Bulloch	UX	1982	–0.46	0.07
32G047	Camden	U	2004	0.24	0.64
33D071	Camden	U	1998	1.15	0.25
35Q050	Chatham	U	2001	0.15	0.21
38Q209	Chatham	B	1998	0.04	0.04
39Q026	Chatham	UX	1996	0.08	0.26
34S008	Effingham	LX	2001	0.45	0.70
35S008	Effingham	LX	2000	0.42	0.68
33J062	Glynn	L	2001	0.03	0.38
33J065	Glynn	U	2001	0.04	0.23
34H437	Glynn	U	1983	0.10	0.30
34J077	Glynn	U	1998	–0.25	0.33
34J080	Glynn	L	2002	–0.01	0.46
34J081	Glynn	U	2002	0.16	0.38
35H077	Glynn	L	2005	0.27	0.47
34K104	McIntosh	L	2005	0.29	0.50
32L016	Wayne	U	1983	–0.14	0.17

[1]L, lower Brunswick aquifer; UX, undifferentiated, low-permeability equivalent to the upper Brunswick aquifer; U, upper Brunswick aquifer; B, Brunswick aquifer system; LX, undifferentiated, low-permeability equivalent to the lower Brunswick aquifer.

[2]See appendix for summary statistics.

Groundwater Levels

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). This aquifer is one of the most productive in the United States and a major source of water in the region. During 2010, about 803 Mgal/d were withdrawn from the Upper and Lower Floridan aquifers in Georgia, primarily for irrigation, industrial, and public-supply uses (Lawrence, 2016).

The Upper Floridan aquifer predominately consists of Eocene- to Oligocene-age 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 ft in Ware County, Georgia (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 karst areas in parts of southwestern and south-central Georgia.

The Coastal Plain of Georgia has been divided informally 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, including the Albany–Dougherty County area, 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, which is hydraulically connected to streams. Since 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).

South-central area. Seven 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 that has 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).

East-central area. Four counties constitute the east-central area. In this area, the Upper Floridan aquifer can be as thick as 650 ft in the southeast or absent in the north.

Coastal area. The Georgia Environmental Protection Division (GaEPD) defines the coastal area of Georgia as a 24-county area that includes 6 coastal counties and the adjacent 18 counties—an area of about 12,240 square miles (mi^2; Clarke, 2003). In the coastal area, the Upper Floridan aquifer may be thin or absent in the north (Burke County) and about 1,700 ft thick in the south (Ware County; Miller, 1986).

The coastal area of Georgia has been subdivided by GaEPD into three subareas—northern, central, and southern—to facilitate implementation of the State's water-management policies. 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 the northern subarea, pumping from the aquifer primarily is for agricultural use, and no large pumping centers are located in the area. The central subarea includes the largest concentration of pumping centers—Savannah, Brunswick, and Jesup—in the coastal area. The southern subarea is separated from the central subarea by the Satilla Line, a postulated hydrologic boundary (Applied Coastal Research Laboratory, Georgia Southern University, 2002). In the southern subarea, the largest pumping center is located immediately south of the area at Fernandina Beach, Nassau County, Florida.

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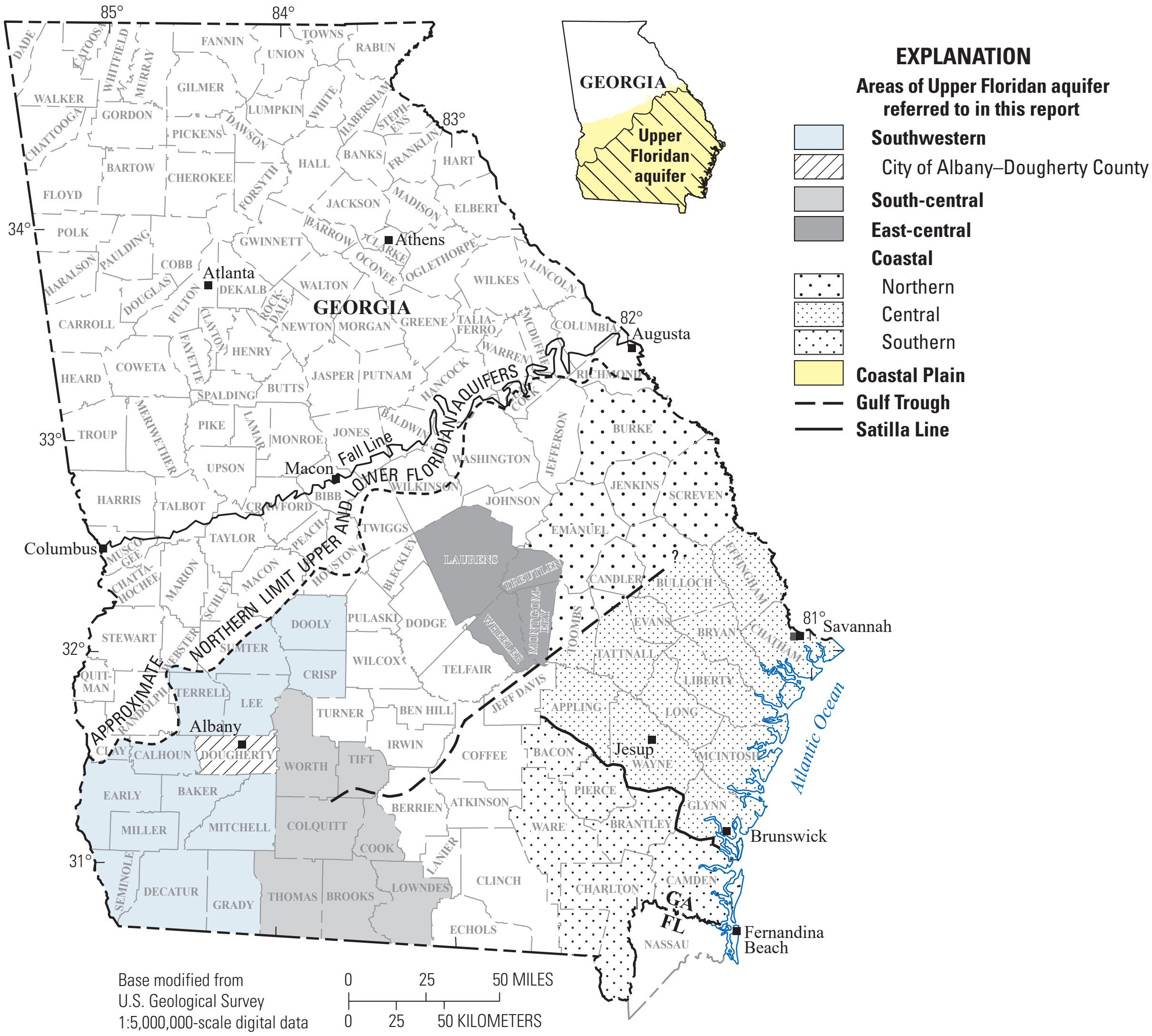
Clarke, J.S., 1987, Potentiometric surface of the Upper Floridan aquifer in Georgia, May 1985, and water-level trends, 1980–85: Georgia Geologic Survey Hydrologic Atlas 16, scale 1:1,000,000, 1 sheet.

Clarke, J.S., 2003 The surficial and Brunswick aquifer systems—Alternative ground-water resources for coastal Georgia, *in* Hatcher, K.A., ed., Proceedings of the 2003 Georgia Water Resources Conference, April 23–24, 2003, Institute of Ecology, The University of Georgia, Athens, Ga., accessed August 23, 2016, at https://ga.water.usgs.gov/publications/other/gwrc2003/pdf/Clarke-GWRC2003.pdf.

Herrick, S.M., and Vorhis, R.C., 1963, Subsurface geology of the Georgia Coastal Plain: Georgia Department of Natural Resources, Division of Mines, Mining, and Geology, Information Circular 25, 80 p.

Hicks, D.W., Gill, H.E., and Longsworth, S.A., 1987, Hydrogeology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia: U.S. Geological Survey Water-Resources Investigations Report 87–4145, 52 p., accessed August 23, 2016, at https://pubs.usgs.gov/wri/wri87-4145/pdf/wrir87-4145.pdf.

Krause, R.E., 1979, Geohydrology of Brooks, Lowndes, and western Echols Counties, Georgia: U.S. Geological Survey Water-Resources Investigations Report 78–117, 48 p.



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

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 30, 2016, at https://doi.org/10.3133/ofr20151230.

Miller, J.A., 1986, Hydrogeologic framework of the Floridan aquifer system in Florida and parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1403–B, 91 p.

Peck, M.F., Clarke, J.S., Ransom, Camille, III, and Richards, C.J., 1999, Potentiometric surface of the Upper Floridan aquifer in Georgia and adjacent parts of Alabama, Florida and South Carolina, May 1998, and water-level trends in Georgia, 1990–98: Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey, Hydrologic Atlas 22, 1 pl.

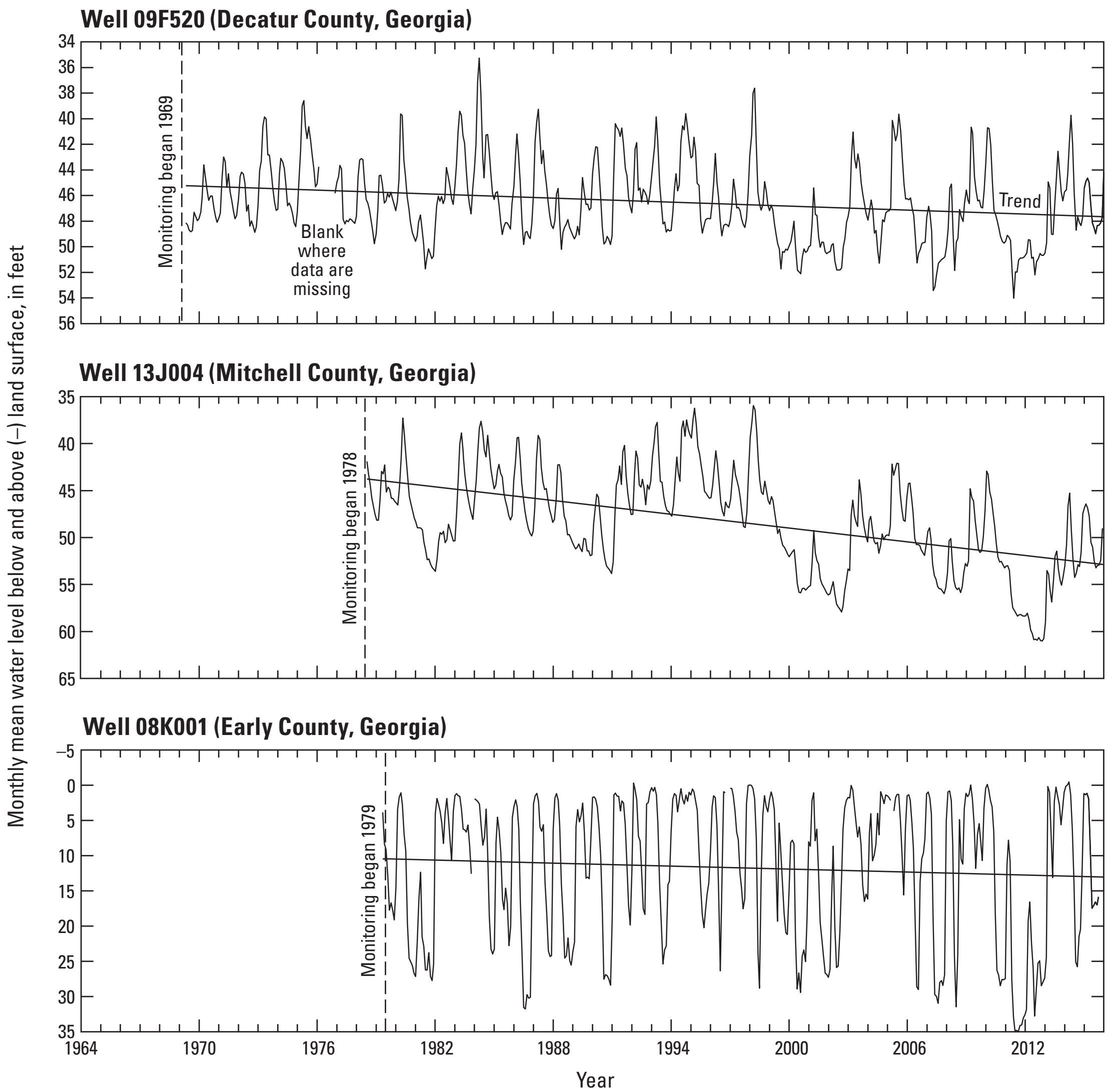
Groundwater Levels

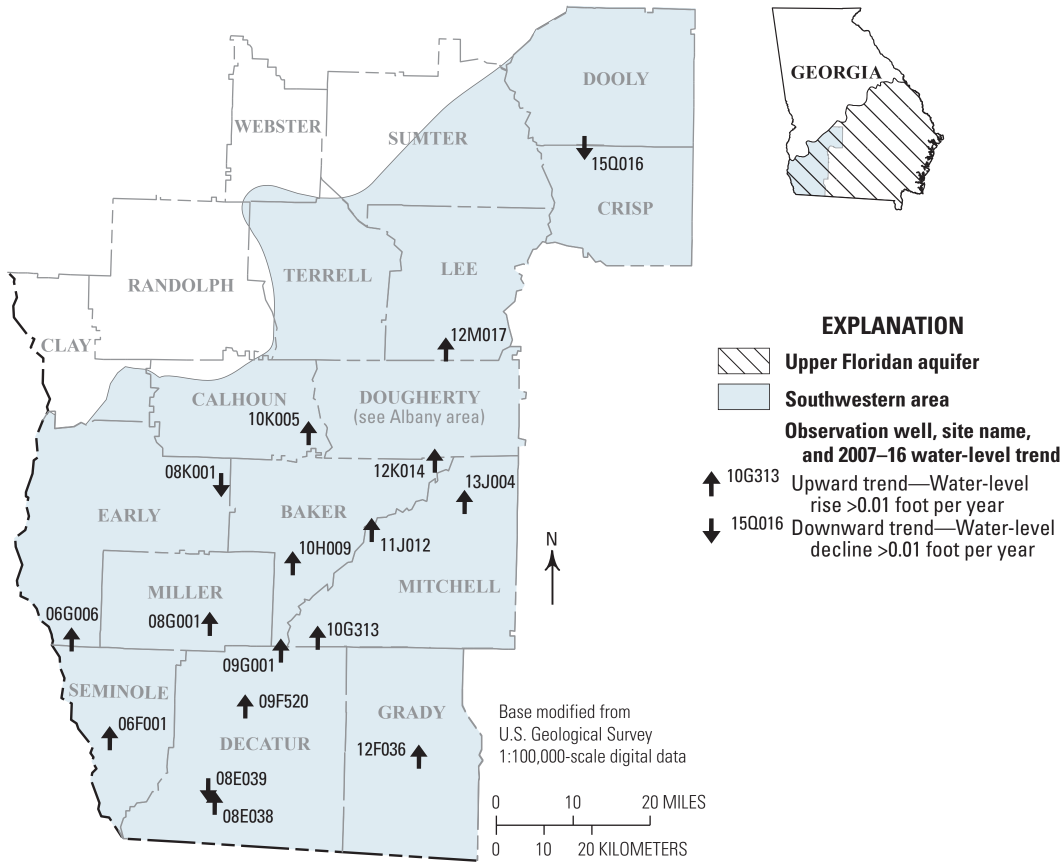
Upper Floridan Aquifer

Southwestern Area

Water levels in 17 wells were used to define groundwater conditions in the Upper Floridan aquifer in southwestern Georgia (map and table, facing page). Water typically is confined in this area of the Upper Florida aquifer; however, water is unconfined in areas where no sediments overlie the aquifer (typically to the north and west). Water levels in this area are affected by changes in precipitation and pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in 14 wells had declining trends of 0.01 to 0.60 ft/yr, and 3 wells had rising trends of 0.04 to 0.18 ft/yr. During 2007–16, water levels in 14 of the wells had rising trends of 0.05 to 0.86 ft/yr, and 3 wells had declining trends of 0.01 to 0.50 ft/yr. Water levels in this area were at or below the median daily statistic for much of 2015 and 2016 due to slightly below average rainfall (USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/).





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
10H009	Baker	1998	0.10	0.34
12K014	Baker	1982	–0.07	0.19
10K005	Calhoun	1983	–0.09	0.15
15Q016	Crisp	2002	–0.60	–0.50
08E038	Decatur	2001	0.04	0.05
08E039	Decatur	2002	–0.02	–0.01
09F520	Decatur	1969	–0.05	0.27
09G001	Decatur	1980	–0.05	0.34
06G006	Early	1982	–0.02	0.86
08K001	Early	1979	–0.07	–0.01
12F036	Grady	1971	0.18	0.18
12M017	Lee	1982	–0.01	0.06
08G001	Miller	1977	–0.11	0.74
10G313	Mitchell	1976	–0.09	0.33
11J012	Mitchell	1981	–0.06	0.11
13J004	Mitchell	1978	–0.24	0.06
06F001	Seminole	1979	–0.09	0.58

[1]See appendix for summary statistics.

Groundwater Levels

Upper Floridan Aquifer

City of Albany–Dougherty County Area

Water levels in six wells were used to define groundwater conditions in the Upper Floridan aquifer near Albany, Georgia (Dougherty County; map and table, facing page). Water levels in this area are affected by changes in precipitation and pumping (Gordon and others, 2012). Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in three of the six wells had declining trends ranging from 0.07 to 0.11 ft/yr; the other three wells had rising trends from 0.01 to 0.28 ft/yr. During 2007–16, water levels in all six wells increased at rates of 0.08 to 1.13 ft/yr. Despite slightly below average rainfall during much of 2015 and 2016, water levels in the Albany–Dougherty County area were above the median daily statistic for the first half of 2016 (USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/).

In addition to continuous water-level monitoring, synoptic water-level measurements are made periodically in wells southwest of Albany. Water-level measurements from 51 wells during November 2015 and 52 wells during November and December 2016 were used to construct maps showing the potentiometric surface of the Upper Floridan aquifer. Although water levels in 2015 generally were higher than in 2016, the configuration of the potentiometric-surface maps (facing page) was similar. The potentiometric-surface maps show that water generally flows from the northwest to southeast toward the Flint River.

Reference Cited

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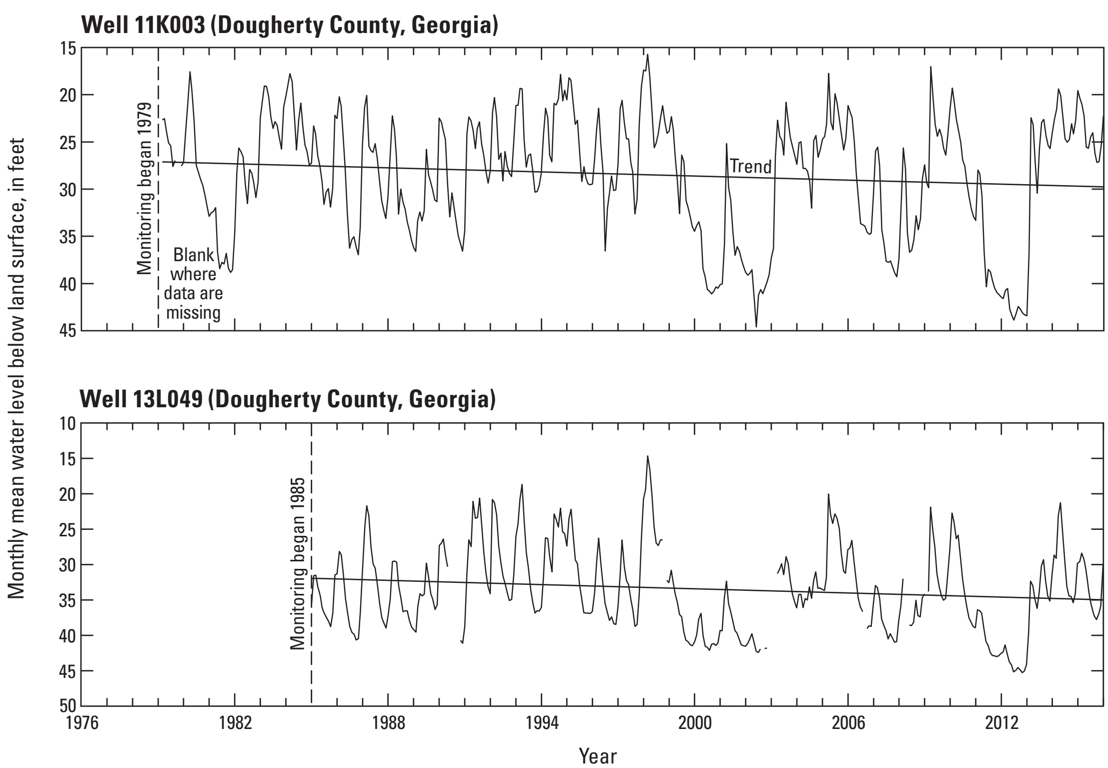
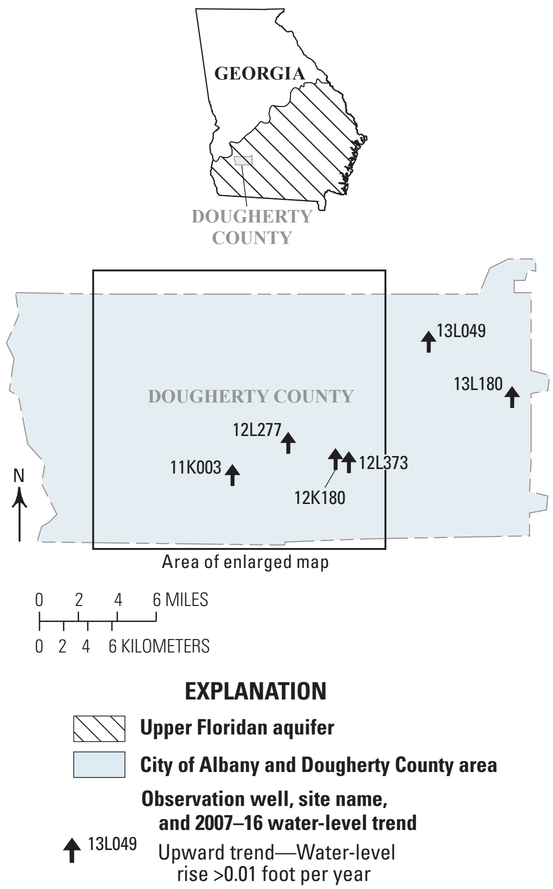
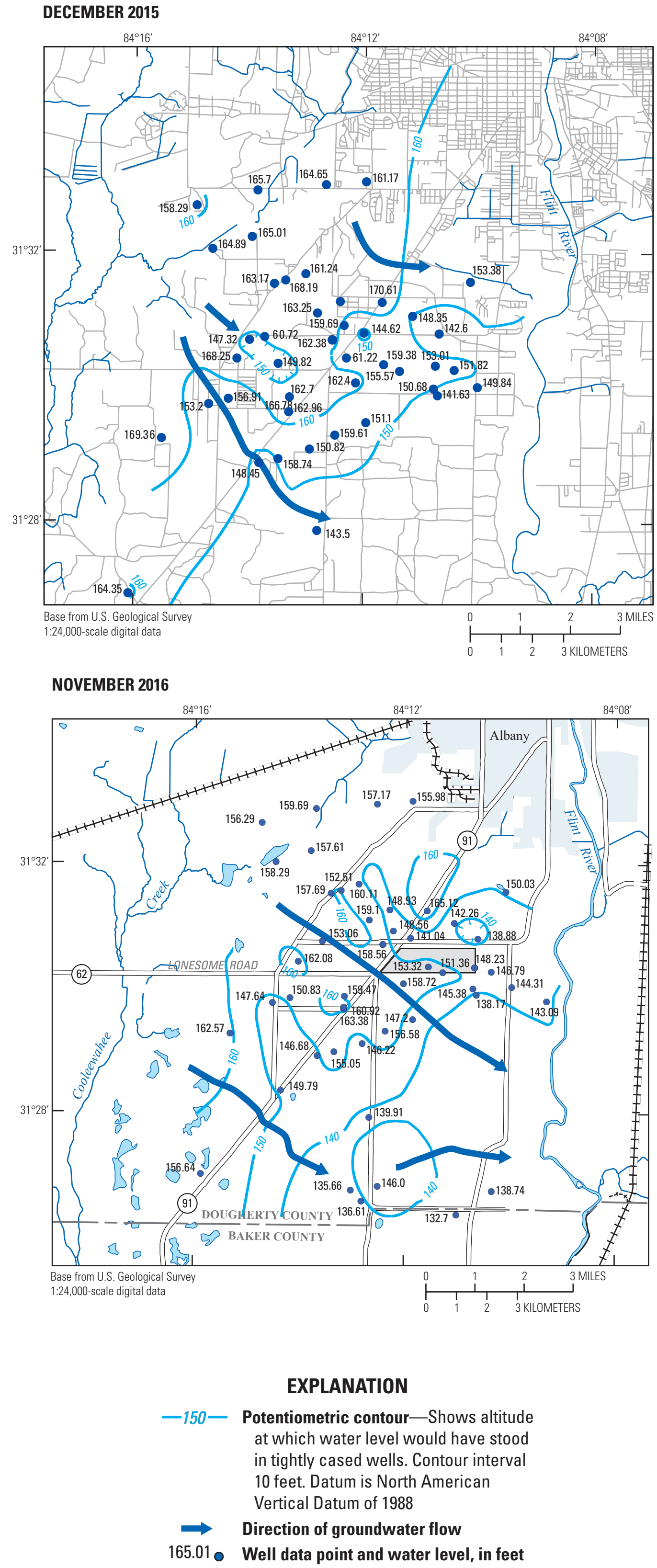






Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
11K003	Dougherty	1979	–0.07	0.76
12K180	Dougherty	2002	0.01	0.31
12L277	Dougherty	2000	0.28	1.13
12L373	Dougherty	2002	0.05	0.38
13L049	Dougherty	1985	–0.10	0.40
13L180	Dougherty	1996	–0.11	0.08

[1]See appendix for summary statistics.

Groundwater Levels

Upper Floridan Aquifer

South-Central Area

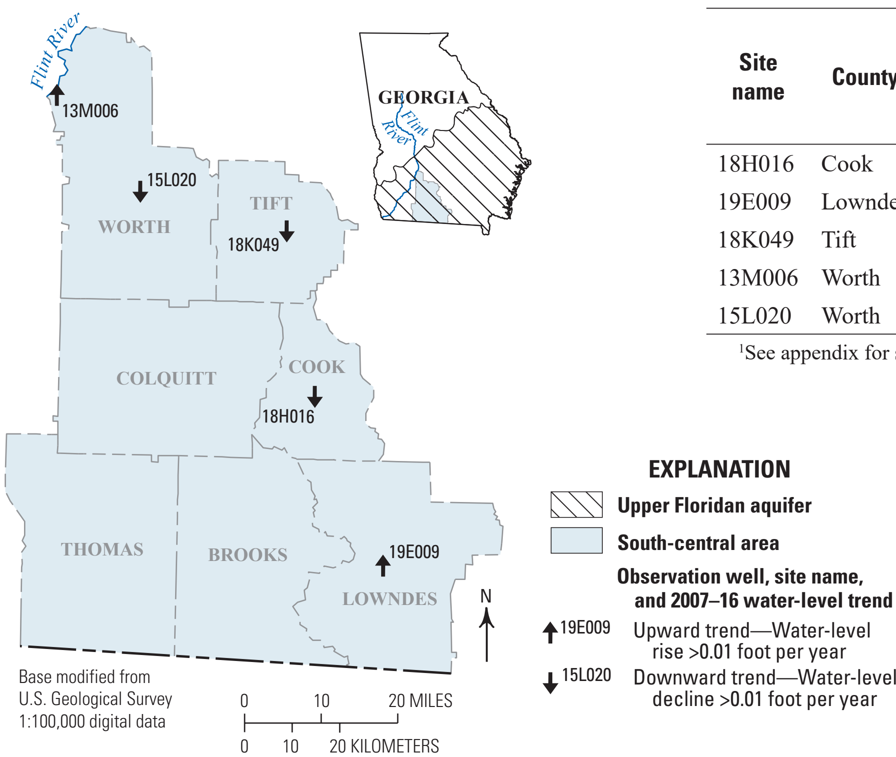
Water levels in five wells were used to define groundwater conditions in the Upper Floridan aquifer in south-central Georgia (map and table below). Water generally is confined in this area of the Upper Floridan aquifer but locally is unconfined in karst areas in Lowndes County. Water levels in this area are affected by changes in pumping and by precipitation. Climatic effects are more pronounced in areas where the aquifer is close to land surface, such as the karst area in Lowndes County and near the Flint River in the northwestern part of Worth County.

Hydrographs for selected wells (facing page) illustrate monthly mean water levels for the period of record. In Lowndes County, water-level fluctuations in well 19E009 show a pronounced response to climatic effects because the well is in a karst area. Climatic effects are less pronounced in the other four wells, and water levels primarily are influenced by pumping. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in all five of the wells monitored in the south-central area declined at rates of 0.09 to 0.91 ft/yr. The greatest declines were in Tift, Cook, and Worth Counties in the northern and eastern parts of the area, where recharge is limited by low-permeability overburden, and irrigation pumping is high (Torak and others, 2010). During 2007–16, water levels in three of the wells declined at rates ranging from 0.05 to 0.95 ft/yr and increased at two wells at rates of 0.10 and 0.55 ft/yr. Water levels continued to drop during 2015 and 2016 in Tift, Cook, and Worth Counties; however, water levels in well 19E009 in Lowndes County responded to rainfall events and were above median levels for about half of the 2-year period (USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/).

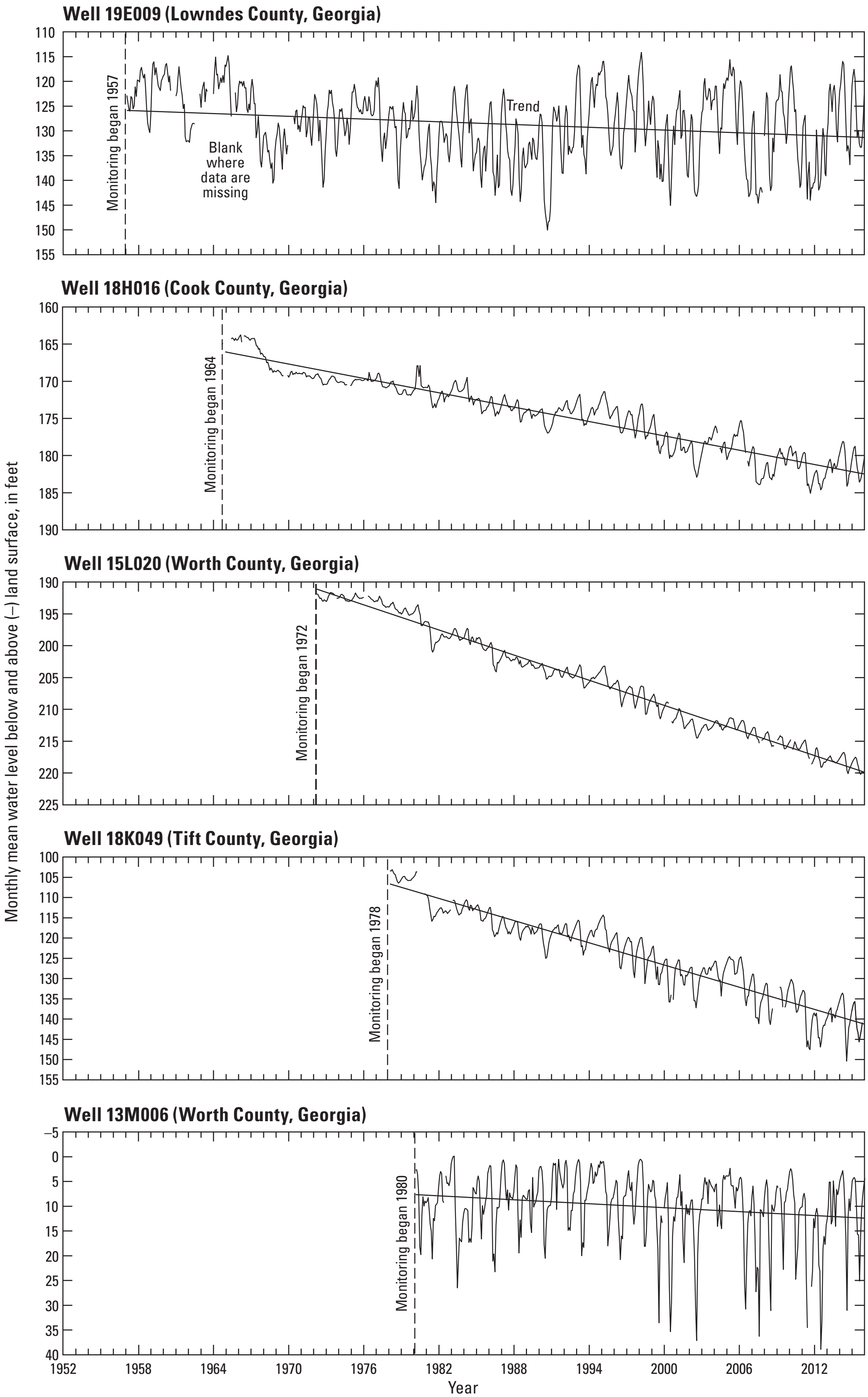
Reference Cited

Torak, L.J., Painter, J.A., and Peck, M.F., 2010, Geohydrology of the Aucilla-Suwannee-Ochlockonee River Basin, south-central Georgia and adjacent parts of Florida: U.S. Geological Survey Scientific Investigations Report 2012–5072, accessed August 24, 2916, at https://pubs.usgs.gov/sir/2010/5072/.



Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
18H016	Cook	1964	–0.32	–0.05
19E009	Lowndes	1957	–0.09	0.55
18K049	Tift	1978	–0.91	–0.95
13M006	Worth	1980	–0.13	0.10
15L020	Worth	1972	–0.66	–0.65

[1]See appendix for summary statistics.


Well 19E009 (Lowndes County, Georgia)
Monitoring began 1957
Trend
Blank where data are missing
Well 18H016 (Cook County, Georgia)
Monitoring began 1964
Well 15L020 (Worth County, Georgia)
Monitoring began 1972
Well 18K049 (Tift County, Georgia)
Monitoring began 1978
Well 13M006 (Worth County, Georgia)
Monitoring began 1980
Monthly mean water level below and above (–) land surface, in feet
Year
1952
1958
1964
1970
1976
1982
1988
1994
2000
2006
2012

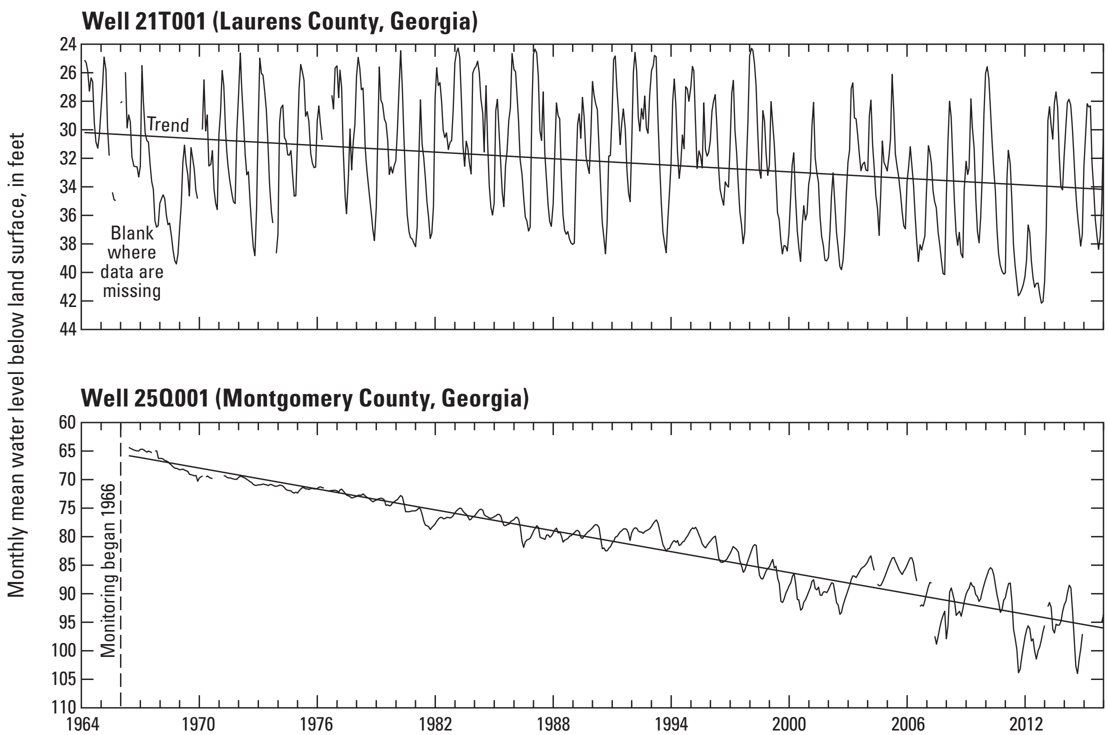
Groundwater Levels

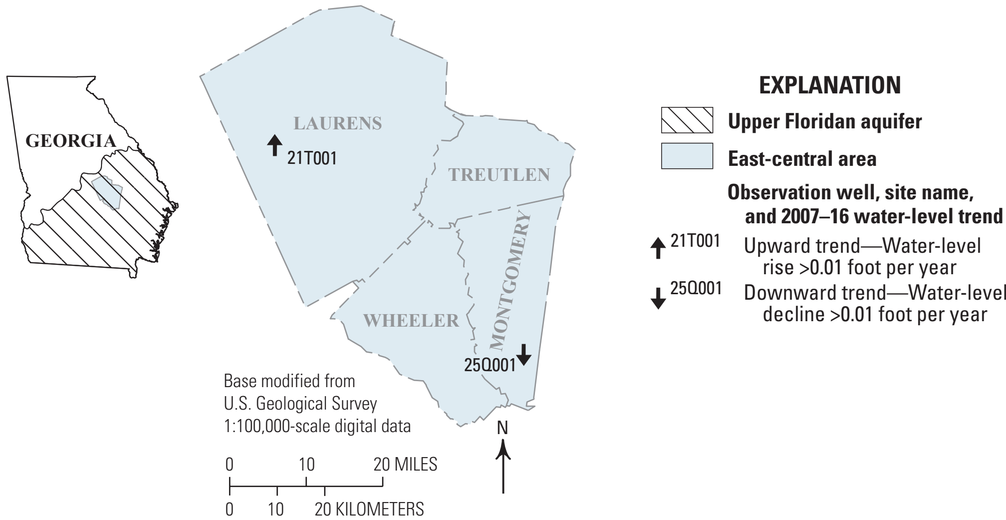
Upper Floridan Aquifer

East-Central Area

Water levels in two wells were used to define groundwater conditions in the Upper Floridan aquifer in east-central Georgia (map and table, facing page). Water is confined in the southeast area of the Upper Florida aquifer and is semiconfined in the northwest area, and water levels are influenced by climatic effects and agricultural pumping. Hydrographs for the two wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in both wells showed a decline, ranging from 0.08 ft/yr in well 21T001 to 0.60 ft/yr in well 25Q001. During 2007–16, water levels rose in well 21T001 at 0.12 ft/yr and declined in well 25Q001 at 0.94 ft/yr. These variations in water-level response may be related to differences in proximity to available recharge and to local pumping changes. Well 21T001 in Laurens County is in the northwestern part of the area where the aquifer is semiconfined and close to the area of recharge. Well 25Q001 in Montgomery County is in an area where the aquifer is deeply buried and confined and is more isolated from recharge sources. Water levels in well 21T001 were near median levels and dropped below median levels in late summer through fall in 2015 and 2016 (USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/). Water levels in well 25Q001 generally were higher during 2015 than in 2016.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
21T001	Laurens	1964	–0.08	0.12
25Q001	Montgomery	1966	–0.60	–0.94

[1]See appendix for summary statistics.

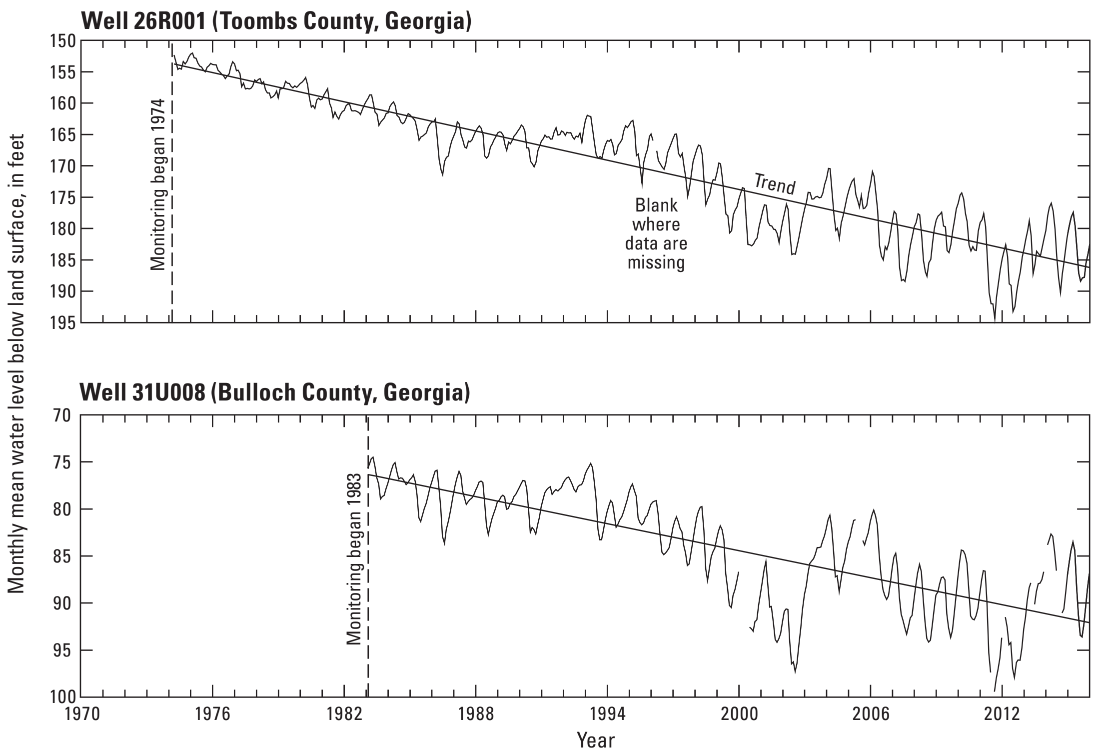
Groundwater Levels

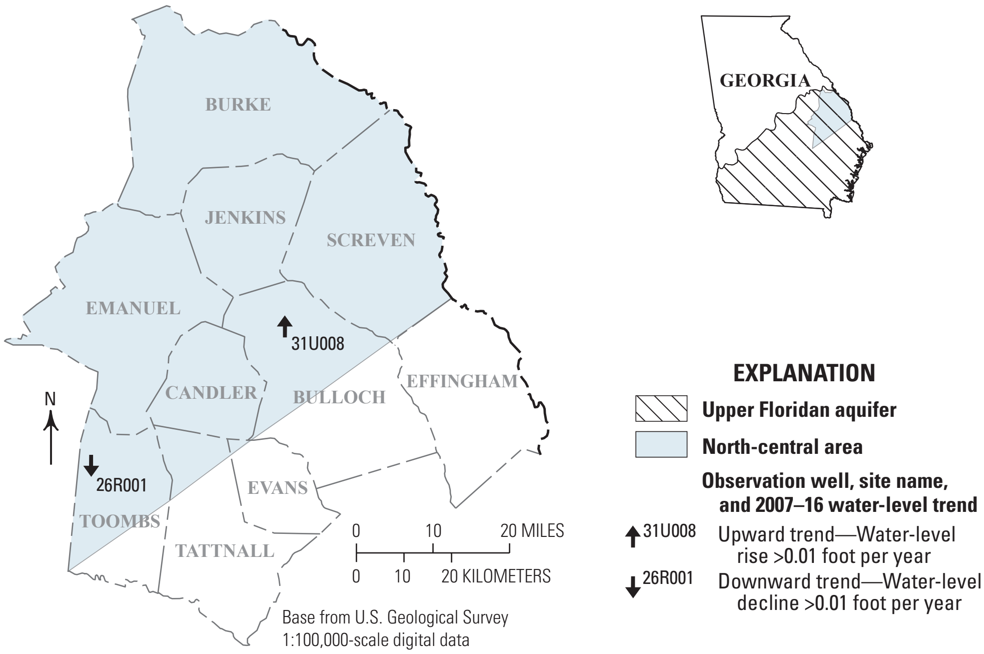
Upper Floridan Aquifer

Northern Coastal Area

Water levels in two wells were used to define groundwater conditions in the Upper Floridan aquifer in the northern coastal area (map and table, facing page). Water is confined in the southeast area of the Upper Florida aquifer and is semiconfined in the northwest area, and water levels are influenced by climatic effects and agricultural pumping. Hydrographs for the two wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels declined at rates of 0.51 ft/yr in well 31U008 and 0.79 ft/yr in well 26R001. During 2007–16, water levels rose at a rate of 0.06 ft/yr in well 31U008 and declined at 4.89 ft/yr in well 26R001. Water levels in both wells were below median levels during 2015 and 2016 (USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/).





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
31U008	Bulloch	1983	–0.51	0.06
26R001	Toombs	1974	–0.79	–4.89

[1]See appendix for summary statistics.

Groundwater Levels

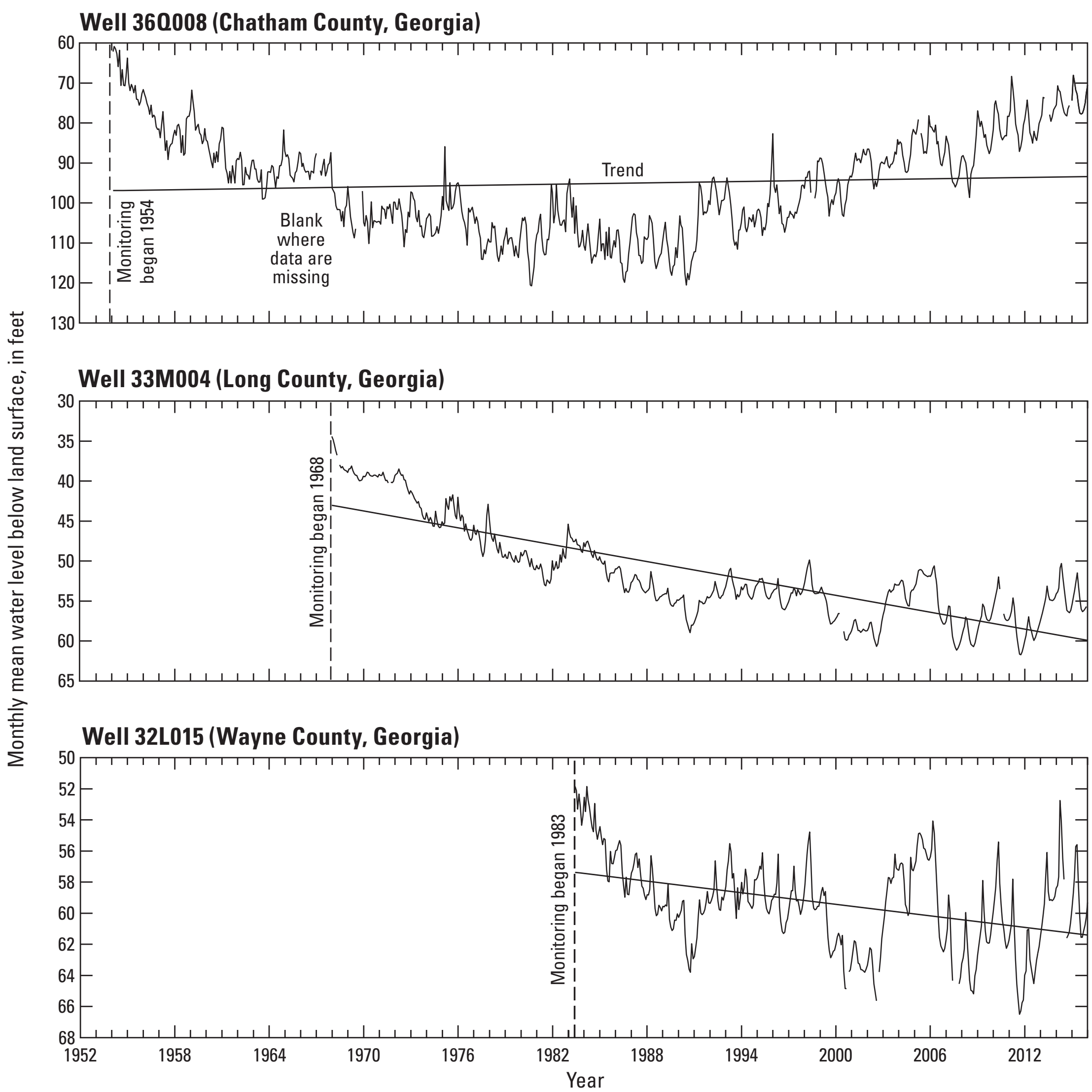
Upper Floridan Aquifer

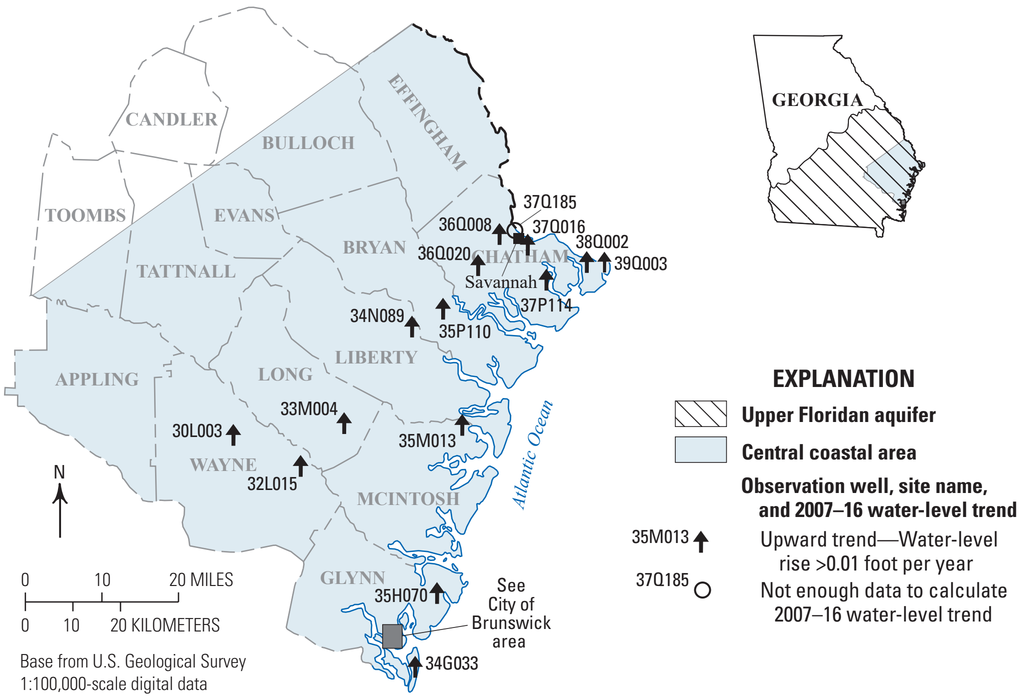
Central Coastal Area

Water levels in 15 wells were used to define groundwater conditions in the Upper Floridan aquifer in the central coastal area of Georgia (excluding the Brunswick area of Glynn County; map and table, facing page). Water is confined in the central coastal area of the Upper Floridan aquifer and primarily influenced by pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that primarily reflect changes in pumping.

During the period of record, water levels in 8 of the 15 wells declined at rates of 0.14 to 0.42 ft/yr. Water levels in six of the wells rose at rates of 0.11 to 1.55 ft/yr, and the water level in one well remained about the same. During 2007–16, water levels in all 15 wells rose at rates ranging from 0.26 to 2.08 ft/yr. Water levels generally were higher during 2015 than during 2016 in this area.

The hydrograph for well 36Q008 near Savannah in Chatham County shows an overall upward trend of 2.08 ft/yr in water levels during 2007–16. Since 1991, water levels have been rising in the well, largely as the result of decreased water use because of conservation practices in the area (J.L. Fanning, U.S. Geological Survey, oral commun., 2008). Water levels in well 36Q008 have recovered to what they were during the mid- to late-1950s.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
35P110	Bryan	2000	0.14	0.68
36Q008	Chatham	1954	<0.01	2.08
36Q020	Chatham	1958	–0.43	0.97
37P114	Chatham	1984	0.32	0.95
37Q016	Chatham	1955	0.11	1.77
37Q185	Chatham	1985	1.55	([2])
38Q002	Chatham	1956	–0.21	0.65
39Q003	Chatham	1962	–0.19	0.50
35H070	Glynn	2005	0.73	0.58
34G033	Glynn	2004	0.11	0.71
34N089	Liberty	1967	–0.42	0.56
33M004	Long	1968	–0.38	0.44
35M013	McIntosh	1966	–0.36	0.43
30L003	Wayne	1964	–0.40	0.26
32L015	Wayne	1983	–0.14	0.34

[1]See appendix for summary statistics.

[2]Not enough data to calculate 2007 to 2016 water-level trend.

Groundwater Levels

Upper Floridan Aquifer

City of Brunswick Area

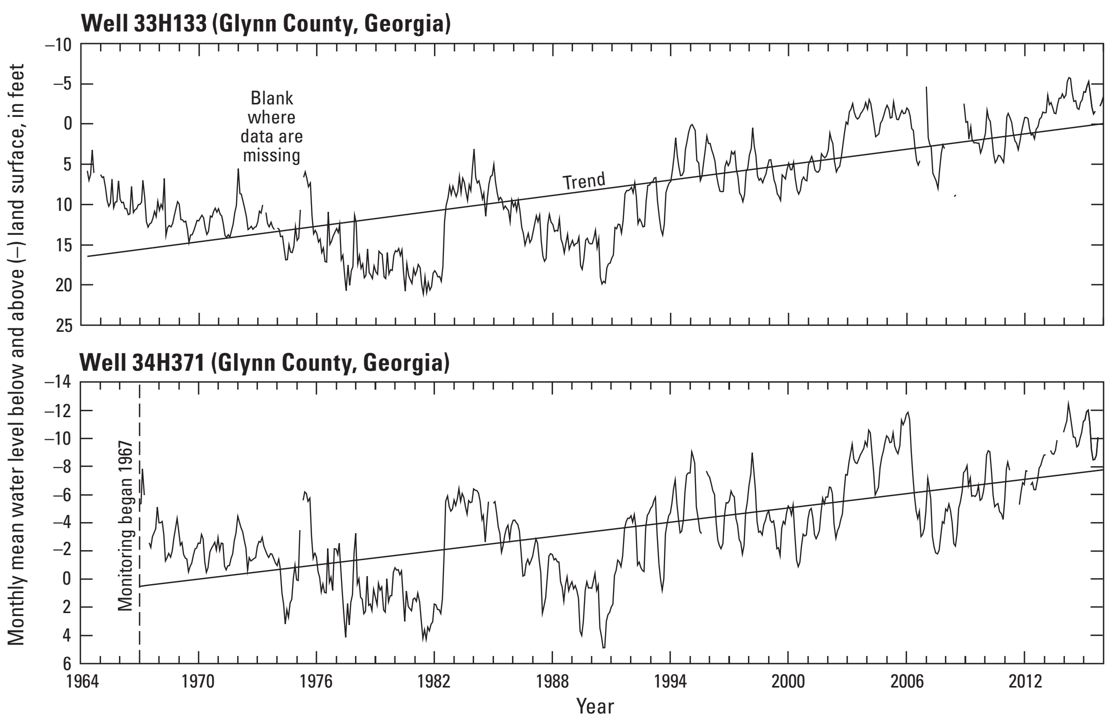
Water levels in nine wells were used to define groundwater conditions in the Upper Floridan aquifer near the city of Brunswick in the central coastal area of Georgia (maps and table, facing page). In this area, water in the Upper Floridan aquifer is confined, and groundwater flow paths are influenced primarily by pumping for industrial and public supply (Cherry and others, 2011).

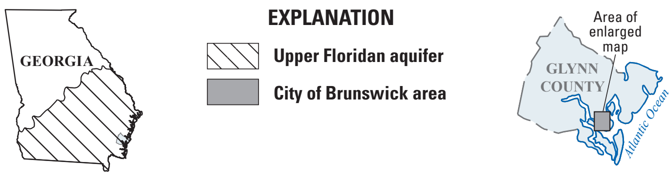
During the period of record, water levels in all of the wells had rising trends with rates of change that ranged from 0.10 to 6.48 ft/yr. Hydrographs for two wells in the Upper Floridan aquifer in the Brunswick area (below) illustrate monthly mean water levels for the period of record. Four of the nine wells have records greater than 10 years. Water levels in those four wells rose at rates ranging from 0.70 to 0.88 ft/yr from 2007 to 2016. The period-of-record water level in well 33H325 rose at a rate of 6.48 ft/yr during 2007–16; this well is located in an area of industrial pumping. Although well 33H324 is located adjacent to well 33H325, water levels in well 33H324 rose 1.49 ft/yr during the same period. The two wells are completed in different water-bearing zones of the Upper Floridan aquifer—the deeper zone in well 33H325 provides water to a nearby industrial user and, therefore, shows a greater response to changes in pumping at the industrial site (John S. Clarke, U.S. Geological Survey, written commun., August 17, 2012).

In addition to continuous water-level monitoring, synoptic water-level measurements are made periodically in wells in the Brunswick area. Water-level measurements from 48 wells during October 2015 and 51 wells during October 2016 were used to construct potentiometric-surface maps of the Upper Floridan aquifer. The maps on the facing page show that groundwater generally flows from the south and west, where water-level altitudes are greater than 15 ft, toward industrial pumping centers in northern Brunswick, where water-level altitudes are less than 10 ft. Water levels generally were higher during 2015 than during 2016.

Reference Cited

Cherry, G.S., Peck, M.F., Painter, J.A., and Stayton, W.L., 2011, Groundwater conditions in the Brunswick–Glynn County area, Georgia, 2009: U.S. Geological Survey Scientific Investigations Report 2014–5087, 58 p., accessed August 30, 2016, at https://pubs.usgs.gov/sir/2011/5087/.

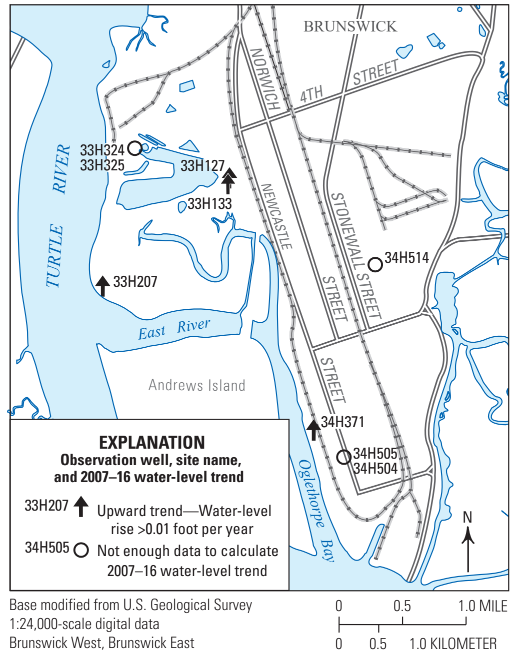




Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
33H127	Glynn	1962	0.10	0.88
33H133	Glynn	1964	0.31	0.80
34H504	Glynn	2007	0.80	([2])
34H505	Glynn	2007	0.84	([2])
34H514	Glynn	2007	0.99	([2])
33H207	Glynn	1983	0.42	0.74
33H324	Glynn	2007	1.49	([2])
33H325	Glynn	2007	6.48	([2])
34H371	Glynn	1967	0.16	0.70

[1]See appendix for summary statistics.

[2]Not enough data to calculate 2007 to 2016 water-level trend.



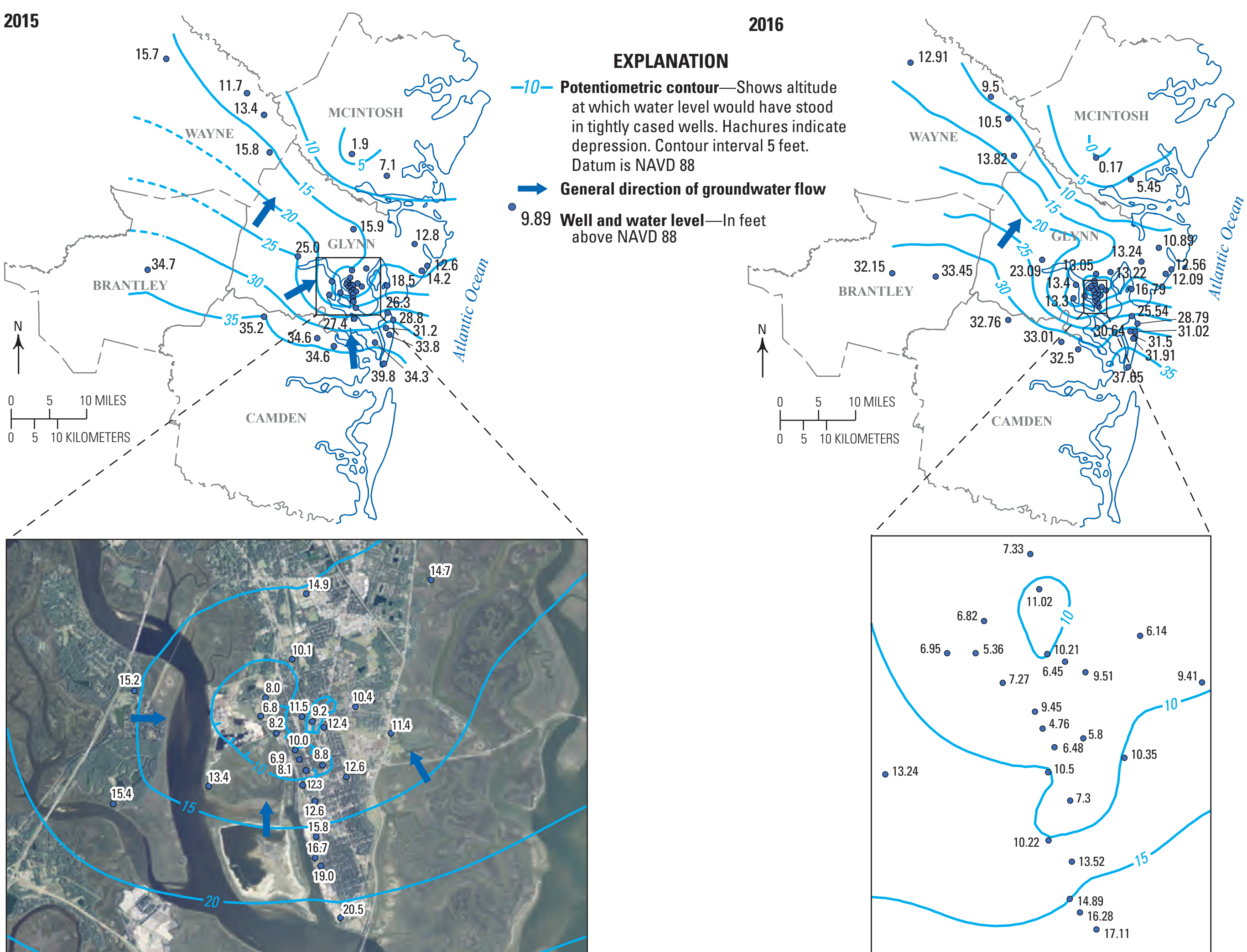


Image from National Agriculture Imagery Program 2010 east digital ortho quarter quad tiles, available via https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/index

Groundwater Levels

Upper Floridan Aquifer

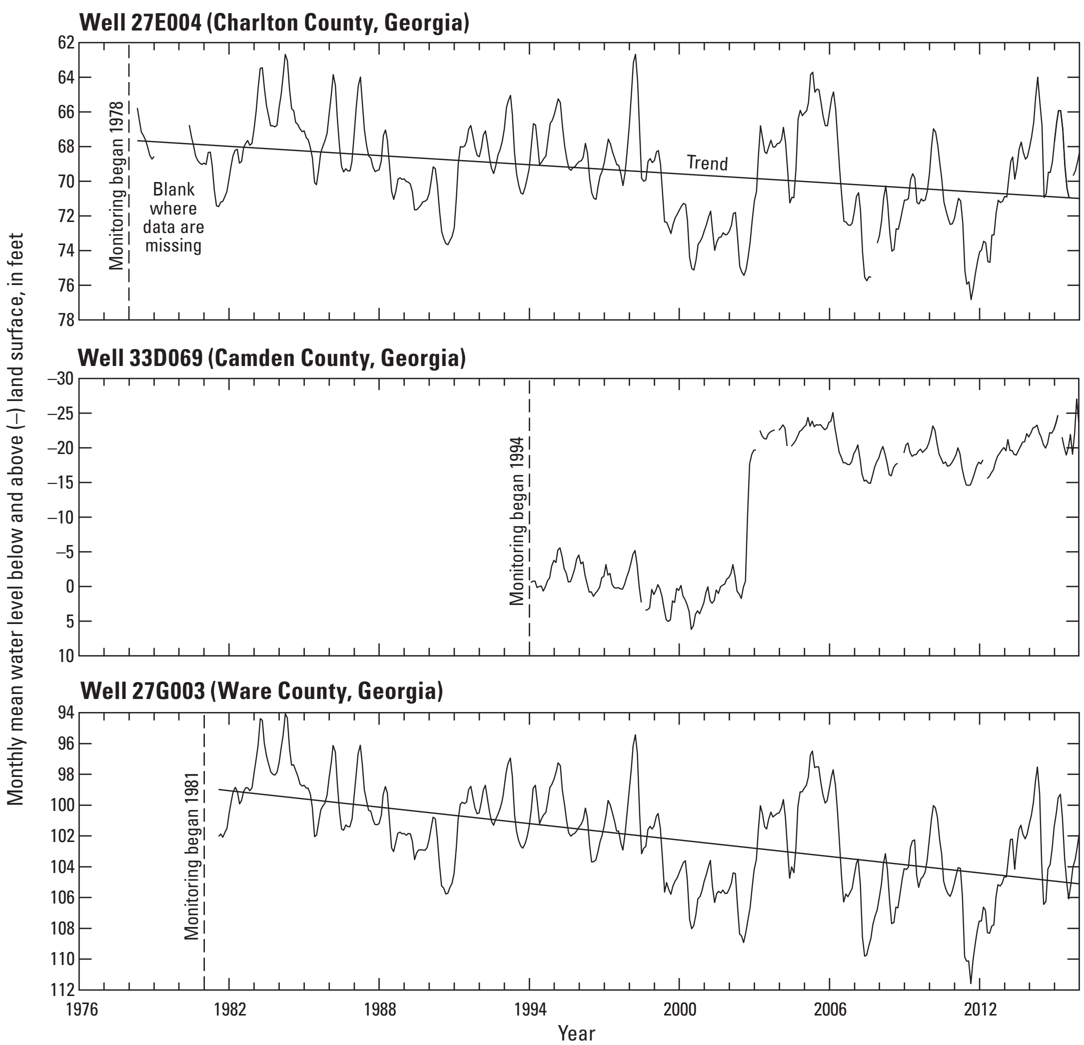
Southern Coastal Area

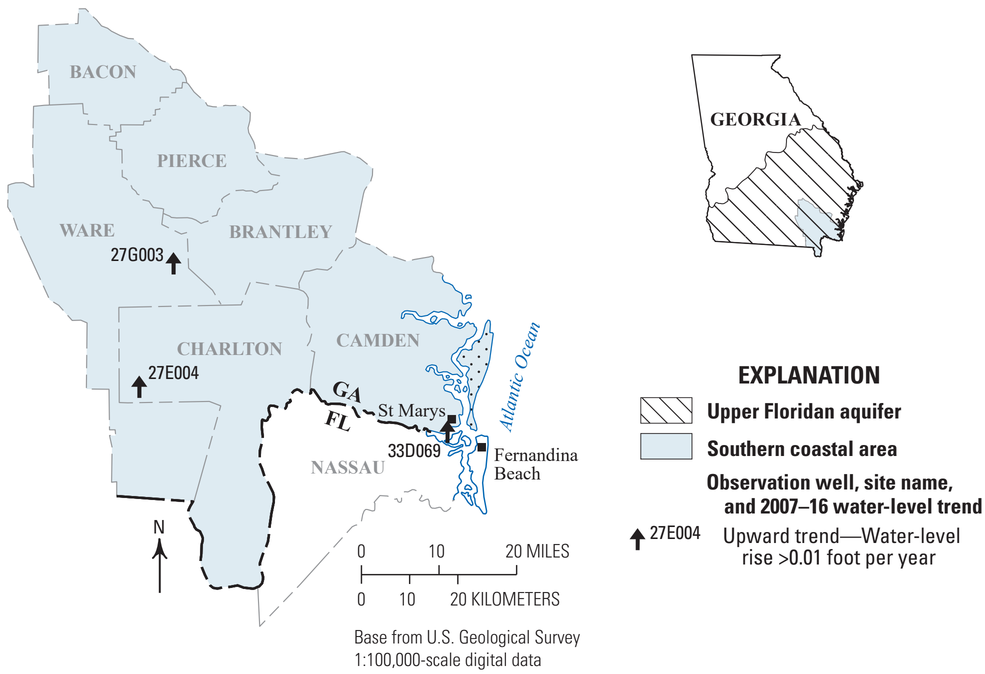
Water levels in three wells were used to define groundwater conditions in the Upper Floridan aquifer in the southern coastal area of Georgia (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined and influenced mostly by pumping to the south in the Fernandina Beach area, Florida, and by climatic effects and pumping to the west. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that primarily reflect changes in pumping.

Water-level changes during the period of record varied across the southern coastal area. In the western part of the area, water levels declined at rates of 0.10 to 0.19 ft/yr. In Camden County, in the eastern part of the area, water levels rose at a rate of 1.31 ft/yr. The sharp rise in water level in well 33D069 during late 2002 is the result of a decrease in pumping of 35 Mgal/d at an industrial site in nearby St. Marys, Camden County, not the overall water-level trend in the aquifer; therefore, a trend line is not shown on the graph (Peck and others, 2005). During 2007–16, water levels in all of the wells rose at rates ranging from 0.29 to 0.48 ft/yr. Water levels were lower during 2016 than during 2015, and water levels dropped well below median values in June 2016 through the end of the year (USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/).

Reference Cited

Peck, M.F., McFadden, K.W., and Leeth, D.C., 2005, Effects of decreased ground-water withdrawal on ground-water levels and chloride concentrations in Camden County, Georgia, and ground-water levels in Nassau County, Florida, from September 2001 to May 2003: U.S. Geological Survey Scientific Investigations Report 2004–5295, 36 p., accessed August 30, 2016, at https://pubs.usgs.gov/sir/2004/5295/.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
33D069	Camden	1994	1.31	0.48
27E004	Charlton	1978	–0.10	0.43
27G003	Ware	1981	–0.19	0.29

[1]See appendix for summary statistics.

Groundwater Levels

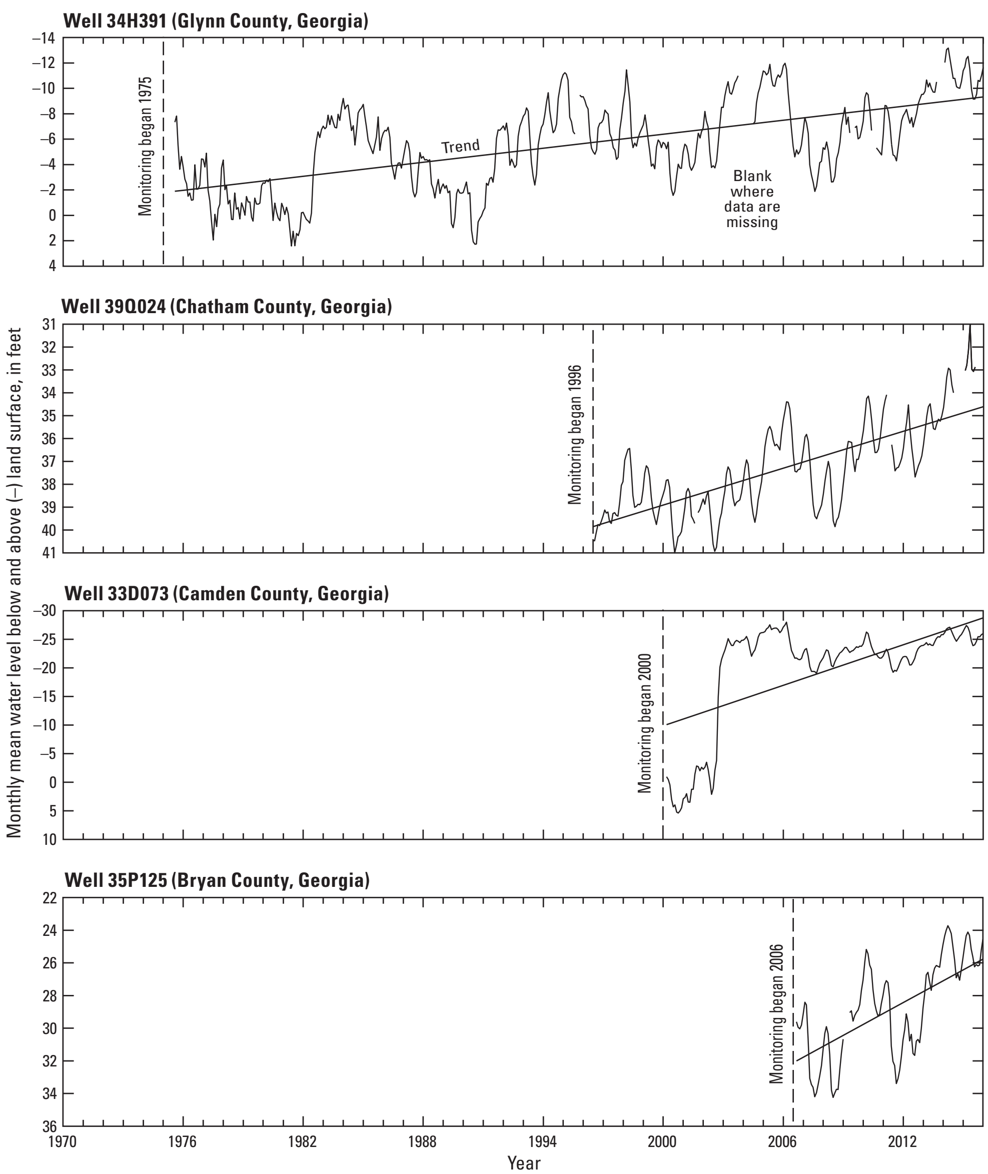
Lower Floridan Aquifer in Coastal Georgia

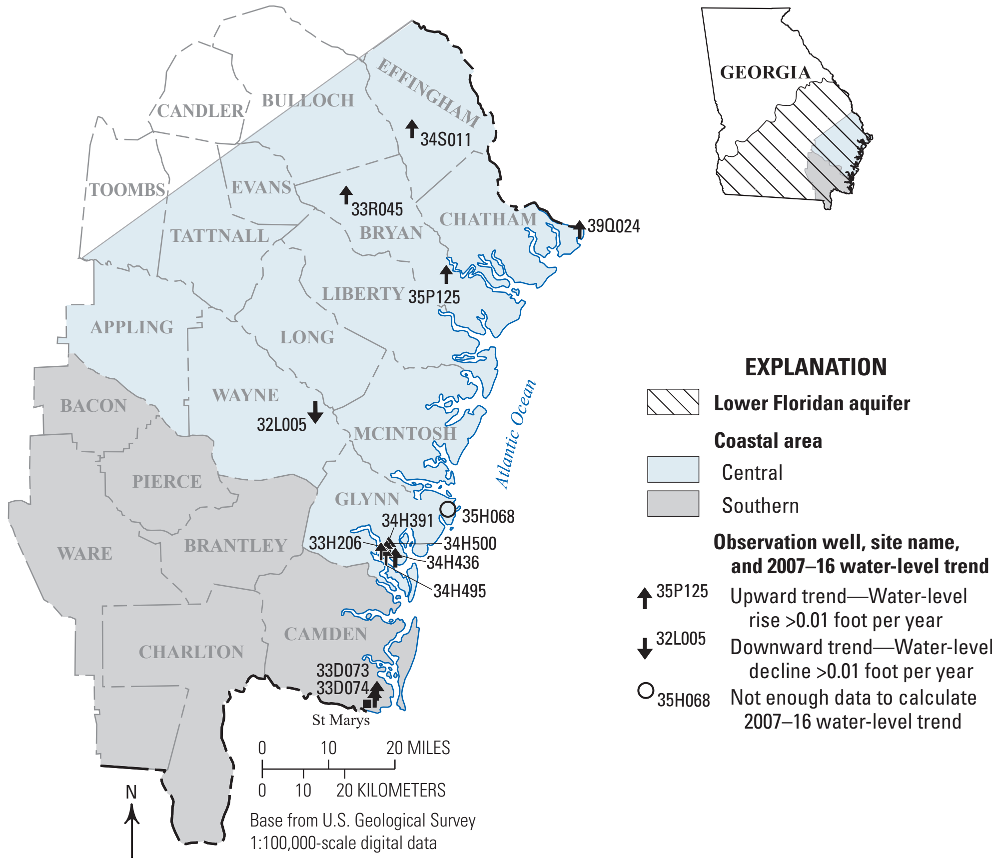
Water levels in 13 wells in central and southern coastal Georgia were used to define groundwater conditions in the Lower Floridan aquifer (map and table, facing page). In this area, water in the Lower Floridan aquifer is confined and influenced mostly by pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward trends that primarily reflect changes in pumping.

During the period of record, water levels in nine of the wells rose at rates of 0.17 to 1.41 ft/yr and declined in four wells at rates of 0.02 to 0.32 ft/yr. The largest rise occurred in well 33D073 near St. Marys, Camden County, in response to the shutdown of a local industrial site in 2002 (Peck and others, 2005). During 2007–16, water levels in 11 wells rose at rates ranging from 0.33 to 1.10 ft/yr. During the same period, water levels in one well declined at a rate of 0.24 ft/yr. Well 35H068 was instrumented during 2007 and has less than 10 years of record. Water levels generally were lower during 2016 than during 2015.

Reference Cited

Peck, M.F., McFadden, K.W., and Leeth, D.C., 2005, Effects of decreased ground-water withdrawal on ground-water levels and chloride concentrations in Camden County, Georgia, and ground-water levels in Nassau County, Florida, from September 2001 to May 2003: U.S. Geological Survey Scientific Investigations Report 2004–5295, 36 p., accessed August 24, 2016, at https://pubs.usgs.gov/sir/2004/5295/





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet per year[2]	
				Period of record	From 2007 to 2016
33R045	LF	Bryan	2002	–0.14	0.49
35P125	LF	Bryan	2006	0.69	0.71
33D073	LF	Camden	2000	1.41	0.44
33D074	LF	Camden	2003	–0.04	0.33
39Q024	LF	Chatham	1996	0.24	0.51
34S011	LF	Effingham	2002	–0.02	0.64
33H206	LF	Glynn	1983	0.25	0.68
34H391	LF	Glynn	1975	0.17	0.71
34H436	LF	Glynn	1983	0.20	0.71
34H495	LF	Glynn	2001	0.68	0.38
34H500	LF	Glynn	2001	0.38	1.10
35H068	LF	Glynn	2007	0.65	([3])
32L005	LF	Wayne	1980	–0.32	–0.24

[1]LF, Lower Floridan aquifer.

[2]See appendix for summary statistics.

[3]Not enough data to calculate 2007 to 2016 water-level trend.

Groundwater Levels

Claiborne and Gordon Aquifers

Water levels in nine Claiborne aquifer wells and one Gordon aquifer well were used to define groundwater conditions in southwestern and east-central Georgia (map and table, facing page). Water in the Claiborne and Gordon aquifers can be confined or unconfined. Hydrographs showing water levels in two wells in the Claiborne aquifer and one well in the Gordon aquifer (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in precipitation and pumping. During 2010, about 59 Mgal/d were withdrawn from the Claiborne aquifer in Georgia, primarily for irrigation (Lawrence, 2016).

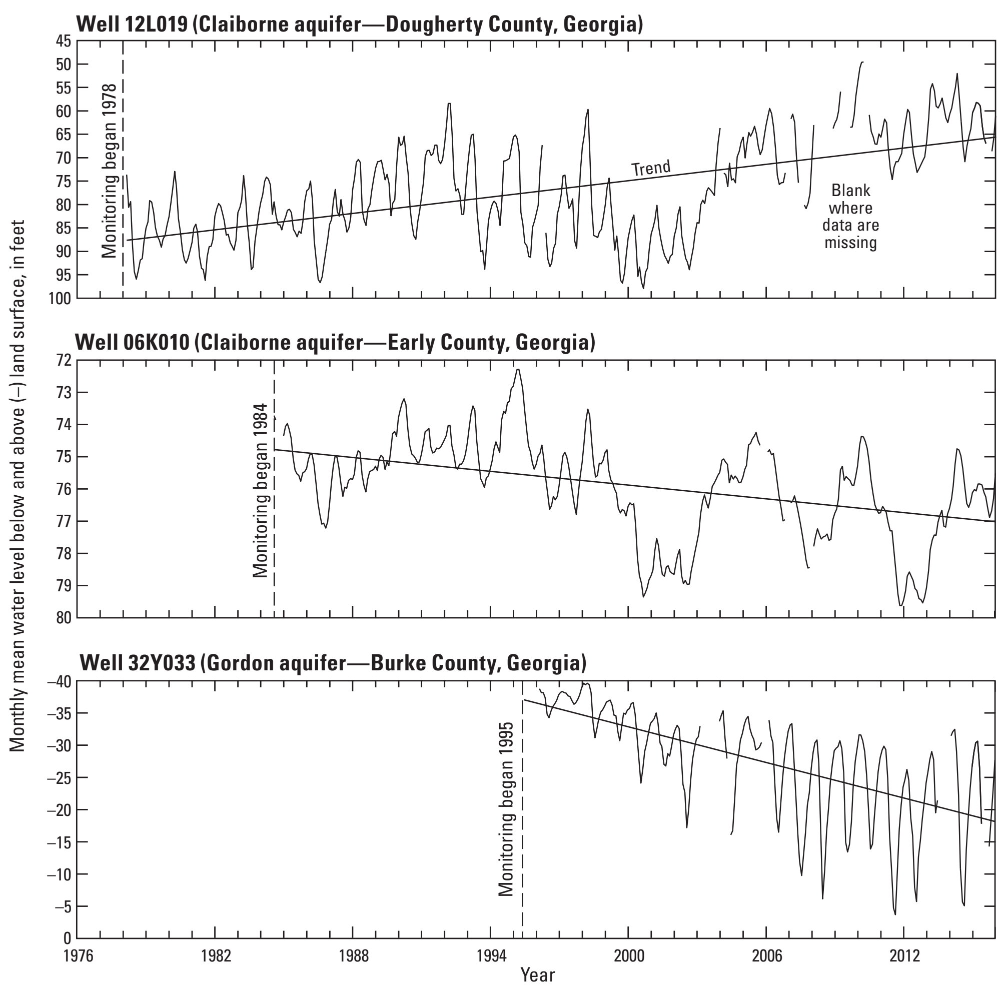
During the period of record, water levels in the Claiborne aquifer declined at rates of 0.09 to 0.75 ft/yr in seven of the nine wells monitored. The water levels in one well rose at a rate of 0.57 ft/yr and remained about the same in one well. During 2007–16, water levels in six of the nine Claiborne aquifer wells rose at rates of 0.01 to 0.86 ft/yr and declined in three wells at rates of 0.04 and 0.88 ft/yr. In most of these wells, water levels were higher during 2015 than 2016; however, water levels in well 06K010 in Early County were higher during 2016 than during 2015.

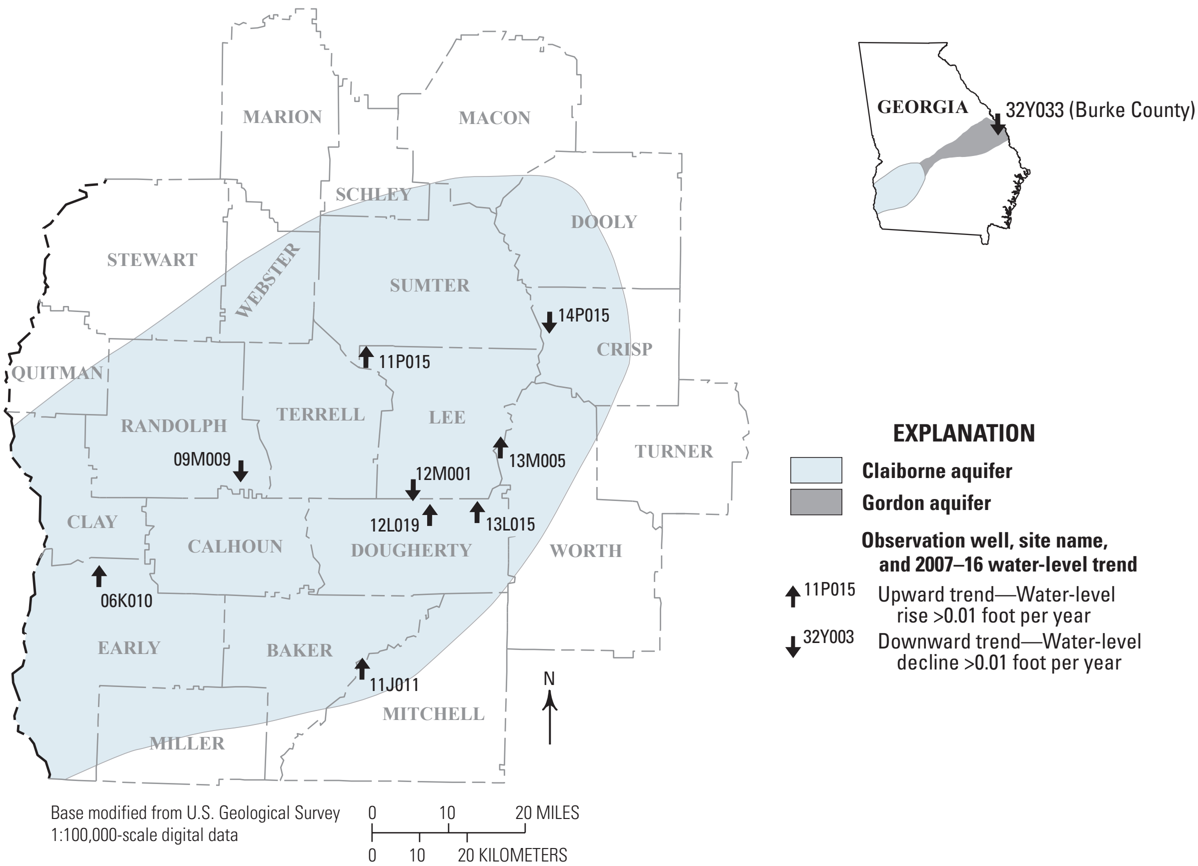
In the Gordon aquifer, water levels in well 32Y033 declined at a rate of 1.05 ft/yr for the period of record. During 2007–16, water levels continued to decline at a rate of 0.22 ft/yr. These declines correspond to increased agricultural use in east-central Georgia (Cherry, 2006).

References Cited

Cherry, G.S., 2006, Simulation and particle-tracking analysis of ground-water flow near the Savannah River site, Georgia and South Carolina, 2002, and for selected water-management scenarios, 2002 and 2020: U.S. Geological Survey Scientific Investigations Report 2006–5195, 156 p., accessed August 30, 2016, at https://pubs.usgs.gov/sir/2006/5195/.

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 24, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet per year[2]	
				Period of record	From 2007 to 2016
14P015	C	Crisp	1984	–0.33	–0.88
12L019	C	Dougherty	1978	0.57	0.34
13L015	C	Dougherty	1979	–0.42	0.86
06K010	C	Early	1984	–0.09	0.11
11P015	C	Lee	1984	–0.09	0.02
12M001	C	Lee	1978	–0.75	–0.04
11J011	C	Mitchell	1981	–0.17	0.16
09M009	C	Randolph	1984	<0.01	–0.04
13M005	C	Worth	1980	–0.23	0.01
32Y033	G	Burke	1995	–1.05	–0.22

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

[2]See appendix for summary statistics.

Groundwater Levels

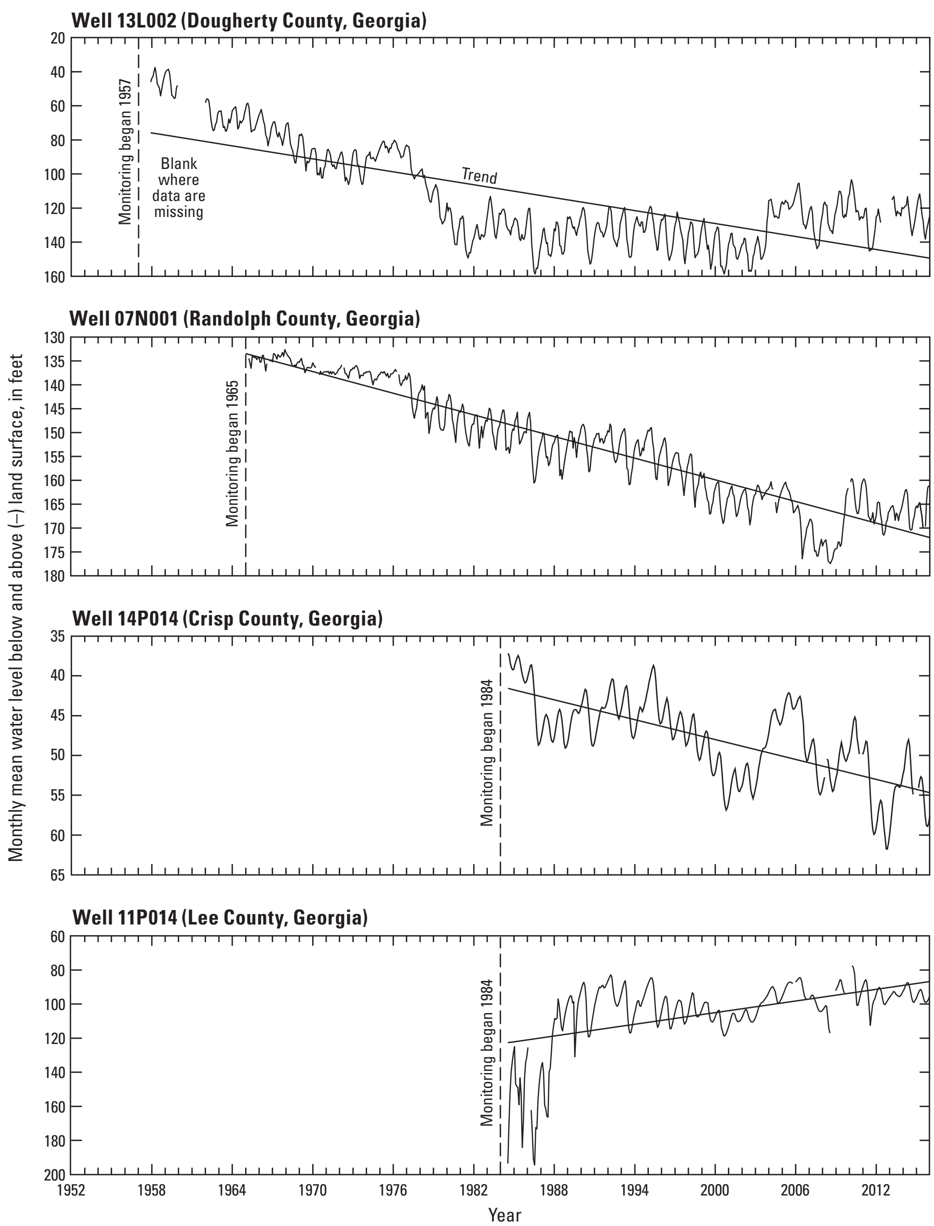
Clayton Aquifer

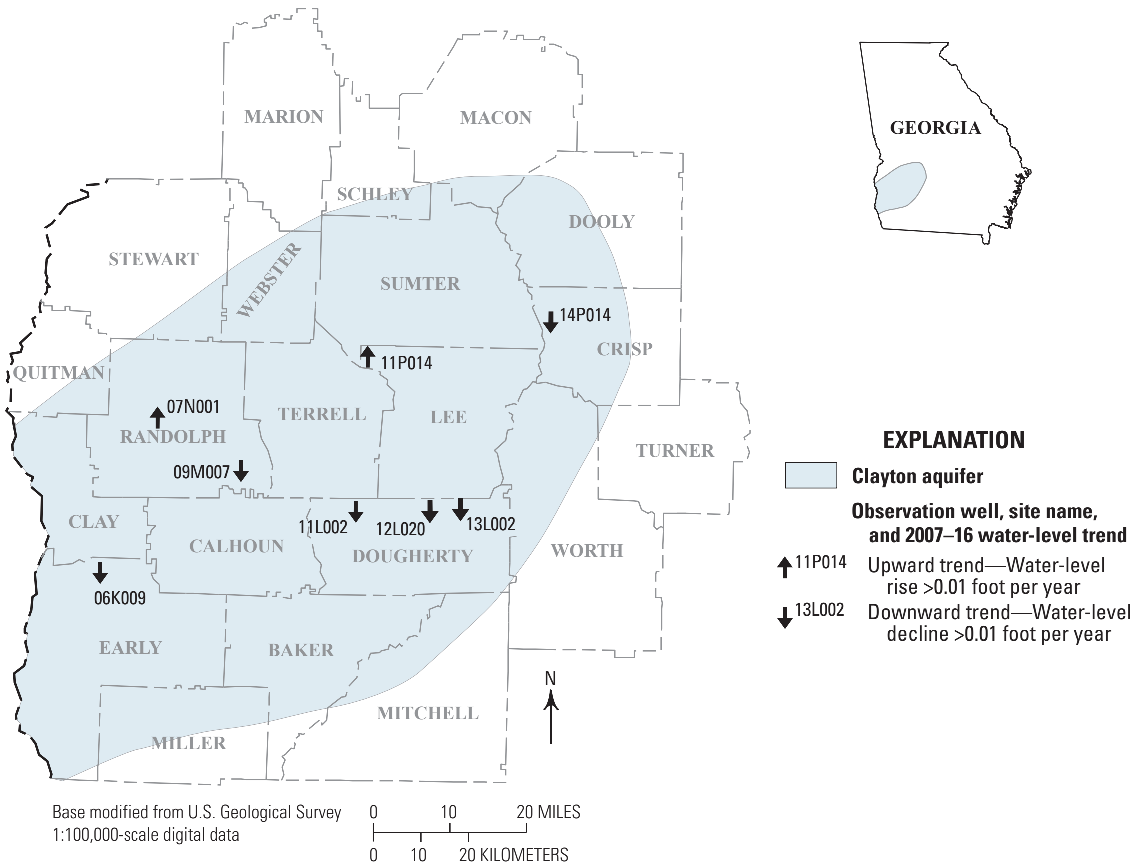
Water levels in eight wells were used to define groundwater conditions in the Clayton aquifer in southwestern Georgia (map and table, facing page). In this area, water in the Clayton aquifer is confined and influenced mostly by pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in pumping. During 2010, about 23 Mgal/d were withdrawn from the Clayton aquifer in Georgia, primarily for irrigation and public-supply use (Lawrence, 2016).

During the period of record, water levels in six of the eight wells declined at rates of 0.39 to 1.98 ft/yr. Water levels rose in two wells at rates of 0.50 and 1.25 ft/yr during the period of record. These increases and declines reflect variations in local and regional pumping. During 2007–16, water levels in six of the wells declined at rates of 0.20 to 2.46 ft/yr and rose in two wells at rates of 0.38 and 0.94 ft/yr. Water levels were lower during 2015 than in 2016 in Crisp and Randolph Counties, higher during 2015 than in 2016 in Dougherty County, and were similar during 2015 and 2016 in Lee County.

Reference Cited

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 24, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
14P014	Crisp	1984	–0.39	–0.69
11L002	Dougherty	1973	–1.63	–1.50
12L020	Dougherty	1980	0.50	–2.46
13L002	Dougherty	1957	–1.35	–0.20
06K009	Early	1986	–1.47	–1.10
11P014	Lee	1984	1.25	0.38
07N001	Randolph	1965	–0.78	0.94
09M007	Randolph	1984	–1.98	–1.73

[1]See appendix for summary statistics.

Groundwater Levels

Cretaceous Aquifer System

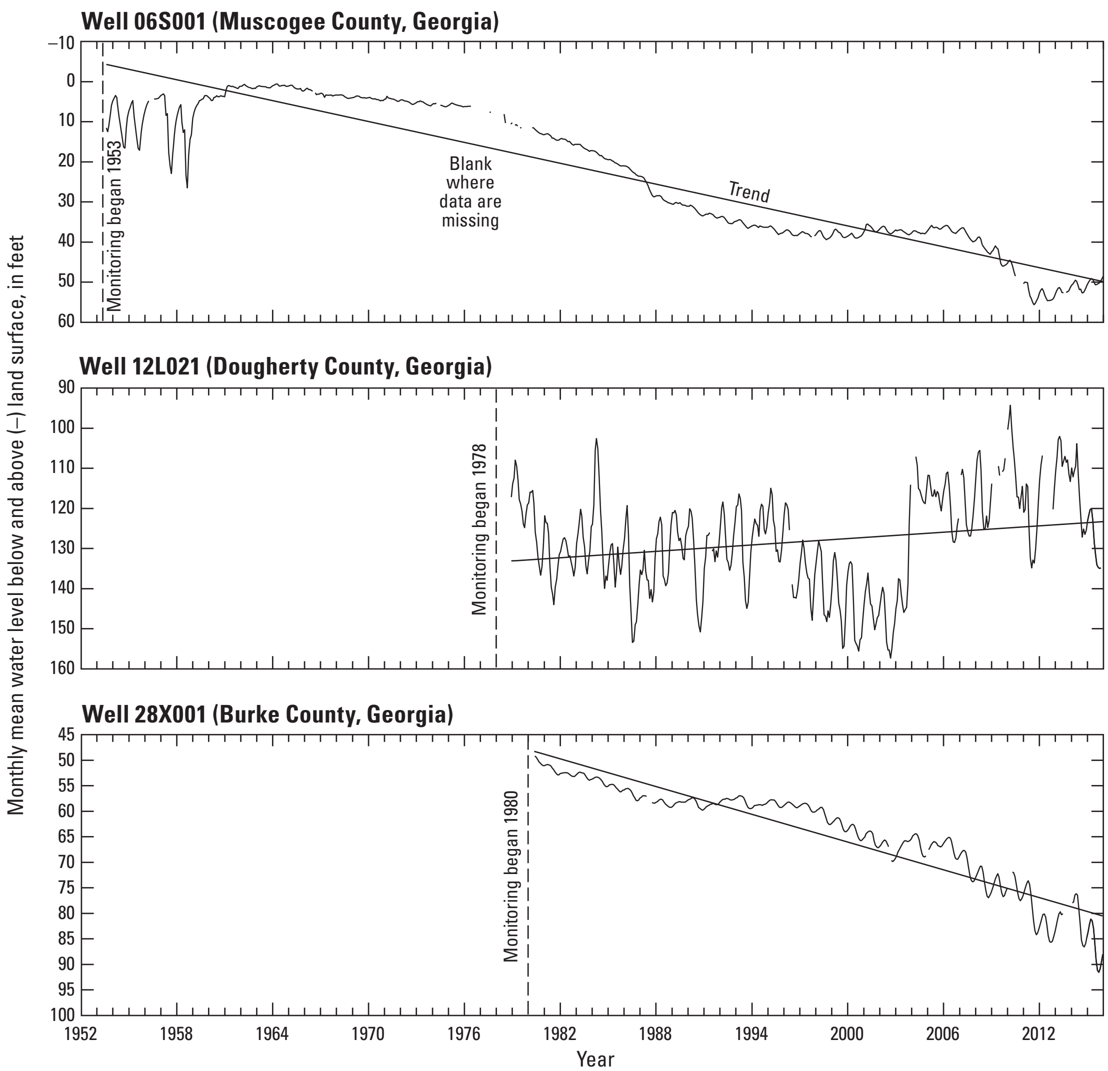
Water levels in 10 wells in the Cretaceous aquifer system were used to define groundwater conditions throughout central and southwestern Georgia (map and table, facing page). In this area, water in the Cretaceous aquifer system mostly is confined but can be unconfined in stream valleys. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that largely reflect changes in pumping. Water levels in well 06S001 (Muscogee County) and well 28X001 (Burke County) both show a long-term downward trend related to groundwater pumping. The hydrograph for well 12L021 (Dougherty County) shows a sharp water-level rise in 2003 when pumping from a nearby public-supply well was discontinued. During 2010, about 182 Mgal/d were withdrawn from the Cretaceous aquifer system in Georgia, primarily for public-supply, industrial, and irrigation use (Lawrence, 2016).

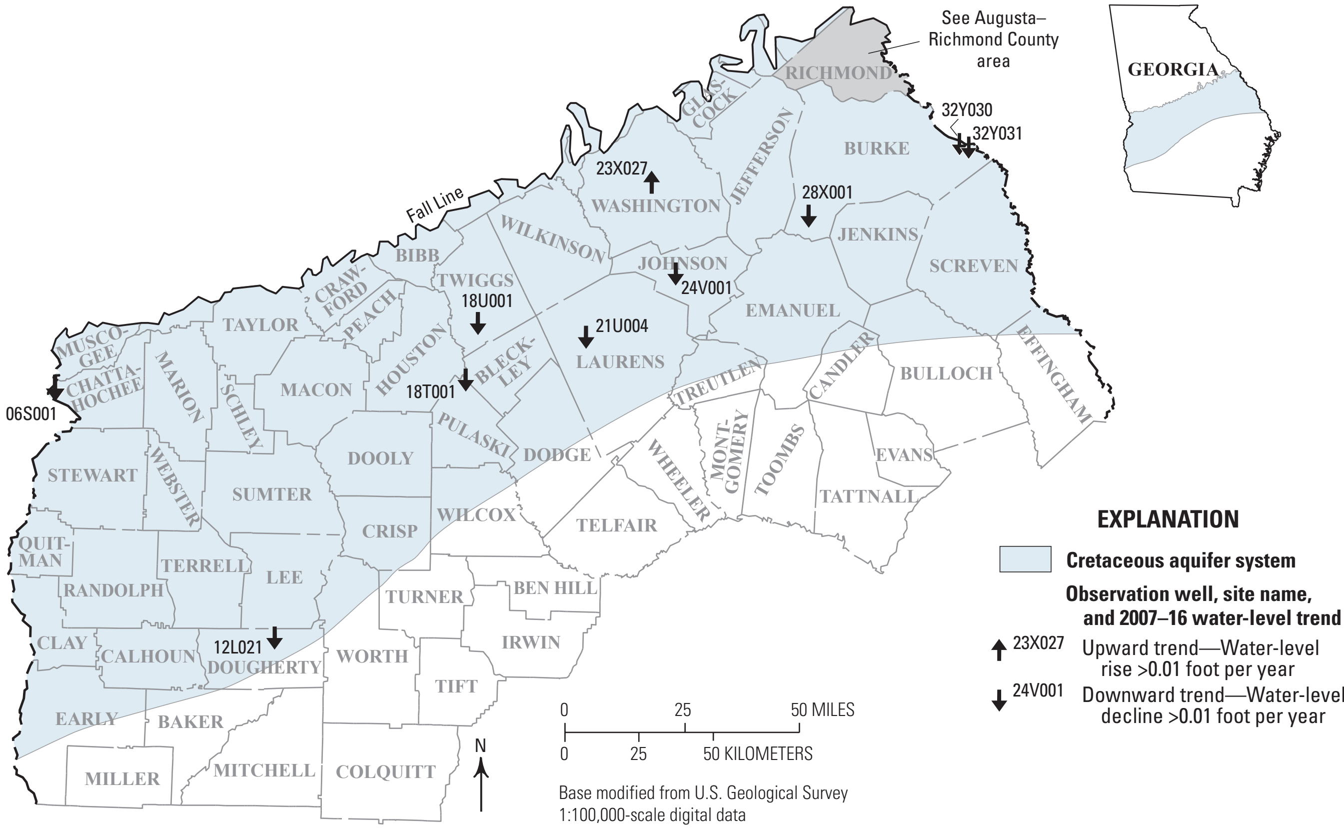
During the period of record, water levels in 9 of the 10 wells declined at rates of 0.14 to 0.86 ft/yr. The only water-level rise (0.33 ft/yr) during the period of record occurred in well 12L021 at Albany (Dougherty County) because of decreased pumping for public supply (Jim Stolze, City of Albany Utility Board, written commun., June 27, 2016).

During 2007–16, water levels in nine of the wells declined at rates of 0.10 to 1.98 ft/yr and rose in one well at a rate of 0.95 ft/yr. The largest decline occurred in well 28X001 in Burke County, reflecting changes in local pumping. Water levels generally were higher during 2015 than in 2016 in the Cretaceous aquifer system.

Reference Cited

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 30, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet per year[2]	
				Period of record	From 2007 to 2016
28X001	M	Burke	1980	–0.82	–1.98
32Y030	LM	Burke	1995	–0.49	–0.69
32Y031	LD	Burke	1995	–0.56	–0.73
12L021	P	Dougherty	1978	0.33	–1.25
24V001	M	Johnson	1980	–0.60	–0.81
21U004	M	Laurens	1982	–0.34	–0.41
065001	T	Muscogee	1953	–0.86	–1.41
18T001	M	Pulaski	1981	–0.27	–0.25
18U001	D	Twiggs	1975	–0.14	–0.10
23X027	DM	Washington	1985	–0.46	0.95

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

[2]See appendix for summary statistics.

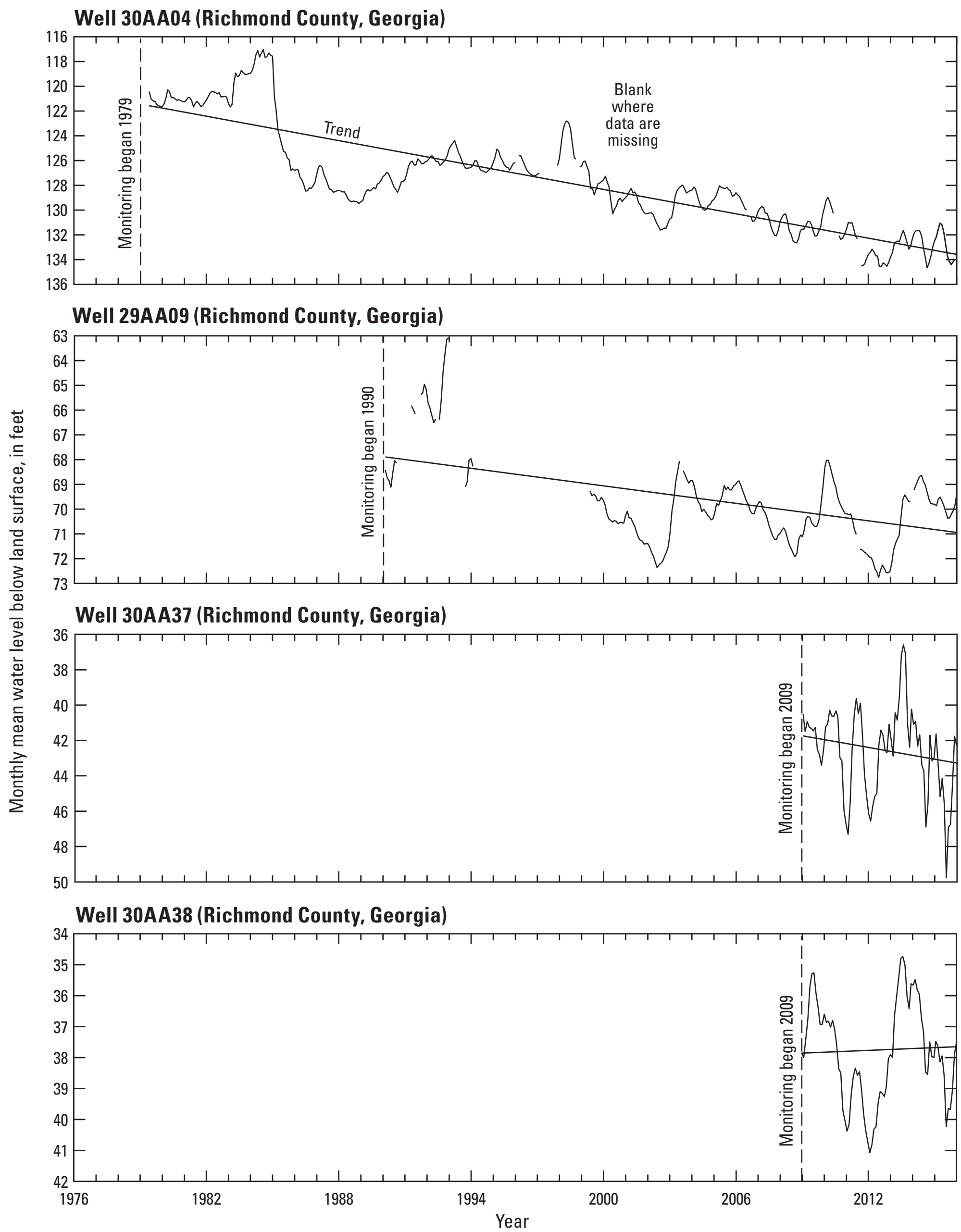
Groundwater Levels

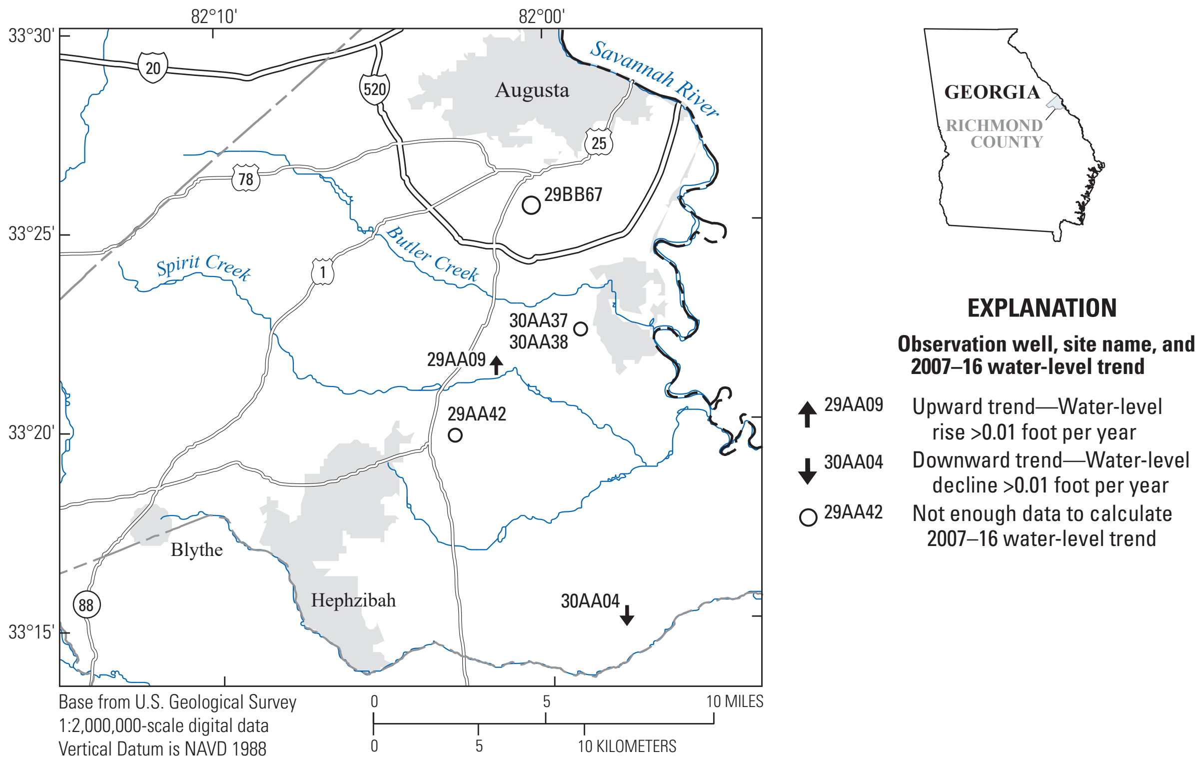
Cretaceous Aquifer System

Augusta–Richmond County Area

Water levels were continuously monitored in six wells in the Cretaceous aquifer system in the Augusta–Richmond County area (map and table, facing page). Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. During the period of record, water levels declined in three wells at rates of 0.10 to 0.33 ft/yr, rose in two wells at rates of 0.09 and 0.16 ft/yr, and remained about the same in one well. The period of record is greater than 10 years for two of the six wells. During 2007–16, water levels rose in well 29AA09 at 0.12 ft/yr and declined in well 30AA04 at 0.33 ft/yr. Water levels generally were higher during 2016 than in 2015 in the Cretaceous aquifer system in the Augusta–Richmond County area.

In addition to continuous water-level monitoring, synoptic water-level measurements were made in 60 wells during July 2015 and 63 wells during July 2016 to map the potentiometric surface of the Dublin–Midville aquifer system (Cretaceous) in the Augusta–Richmond County area. During both years, the general direction of groundwater flow was eastward toward the Savannah River.





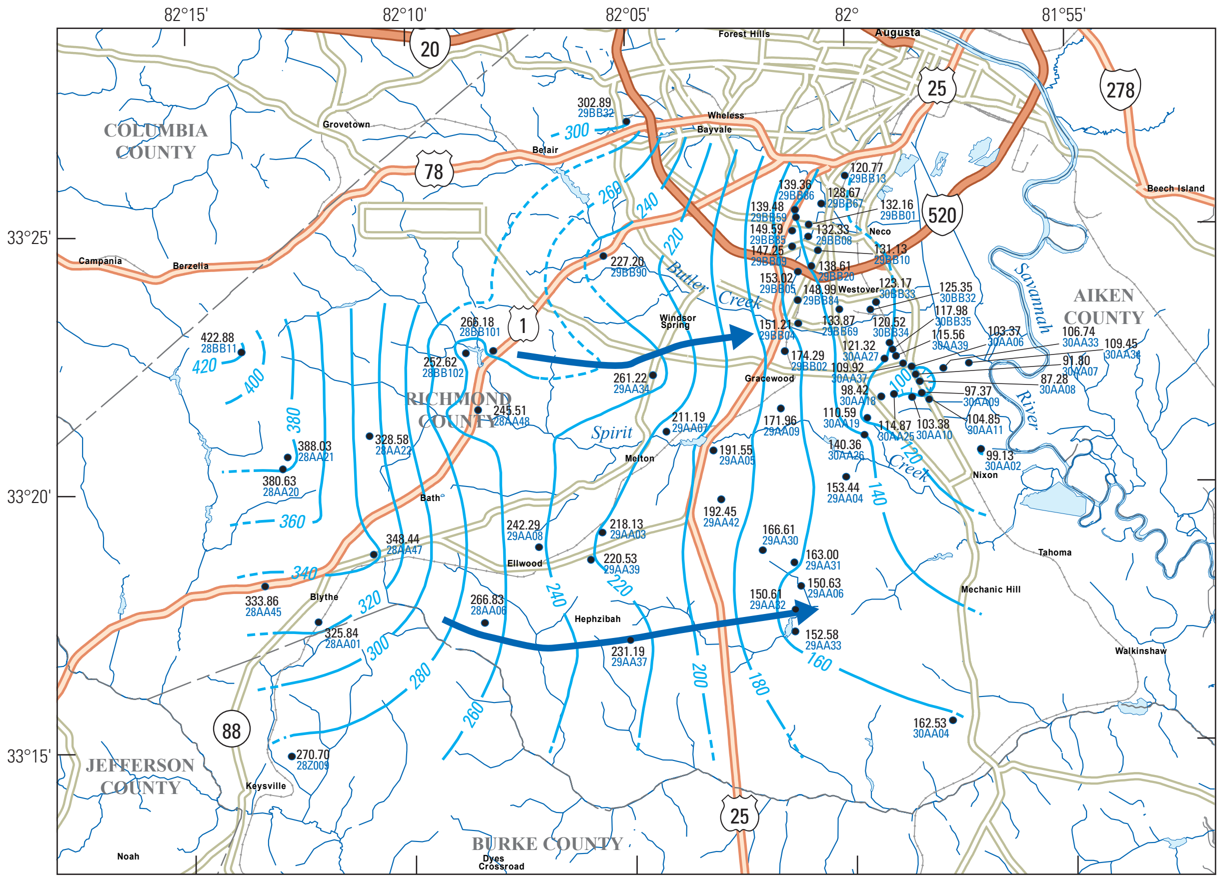
Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet per year[2]	
				Period of record	From 2007 to 2016
29AA09	UM	Richmond	1990	–0.16	0.12
29AA42	MD	Richmond	2010	0.16	([3])
29BB67	LM	Richmond	2011	–0.10	([3])
30AA04	DM	Richmond	1979	–0.33	–0.33
30AA37	MD	Richmond	2009	<0.01	([3])
30AA38	LD	Richmond	2009	0.09	([3])

[1]UM, upper Midville aquifer; MD, Midville aquifer system; LM, lower Midville aquifer; DM, Dublin-Midville aquifer system; LD, lower Dublin aquifer.

[2]See appendix for summary statistics.

[3]Not enough data to calculate 2007 to 2016 water-level trend.

JULY 2015



Base from U.S. Geological Survey
1:2,000,000-scale digital data
Vertical Datum is NAVD 1988

0 2 4 MILES
0 10 KILOMETERS

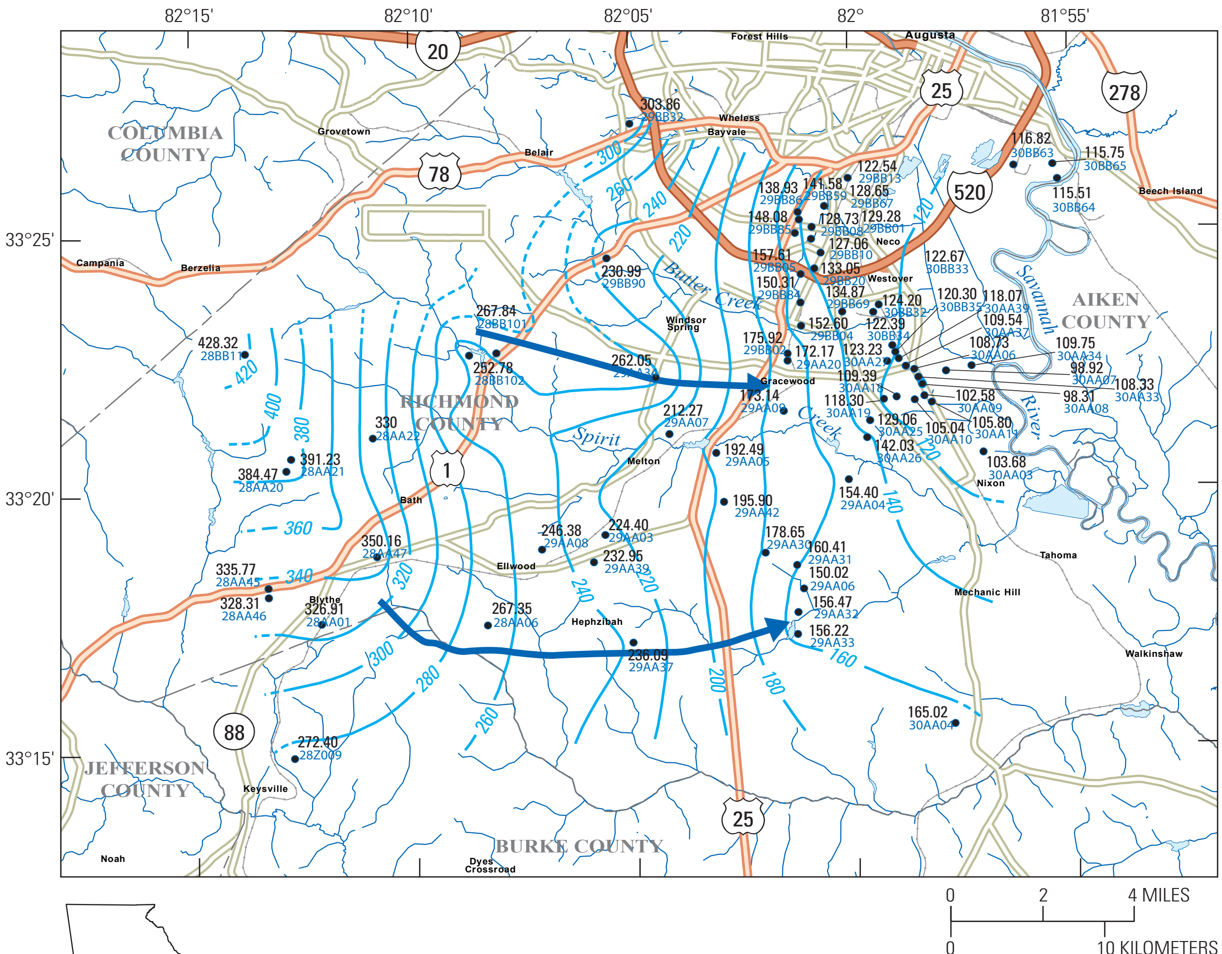
EXPLANATION

—150— **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Hachures indicate depression. Contour interval 20 feet. Datum is North American Vertical Datum of 1988

General direction of groundwater flow

192.45 • **Well data point and water level, in feet**

JUNE 2016



EXPLANATION

—150— **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Hachures indicate depression. Contour interval 20 feet. Datum is North American Vertical Datum of 1988

General direction of groundwater flow

192.45 • **Well data point and water level, in feet**

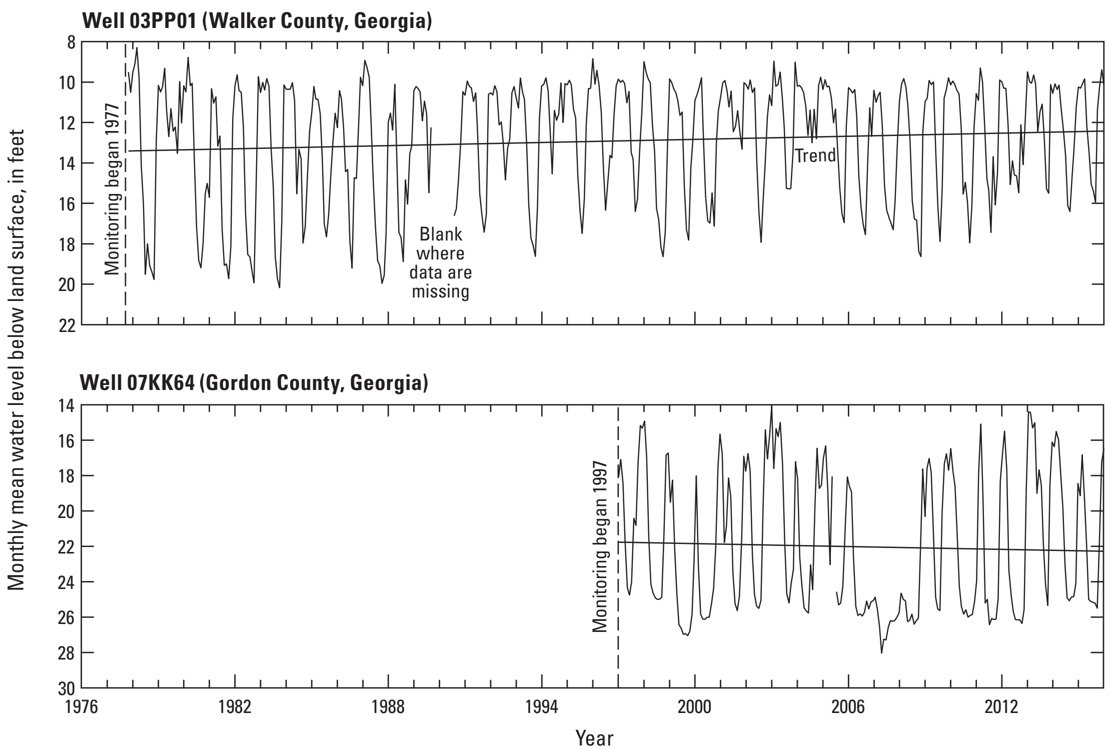
Groundwater Levels

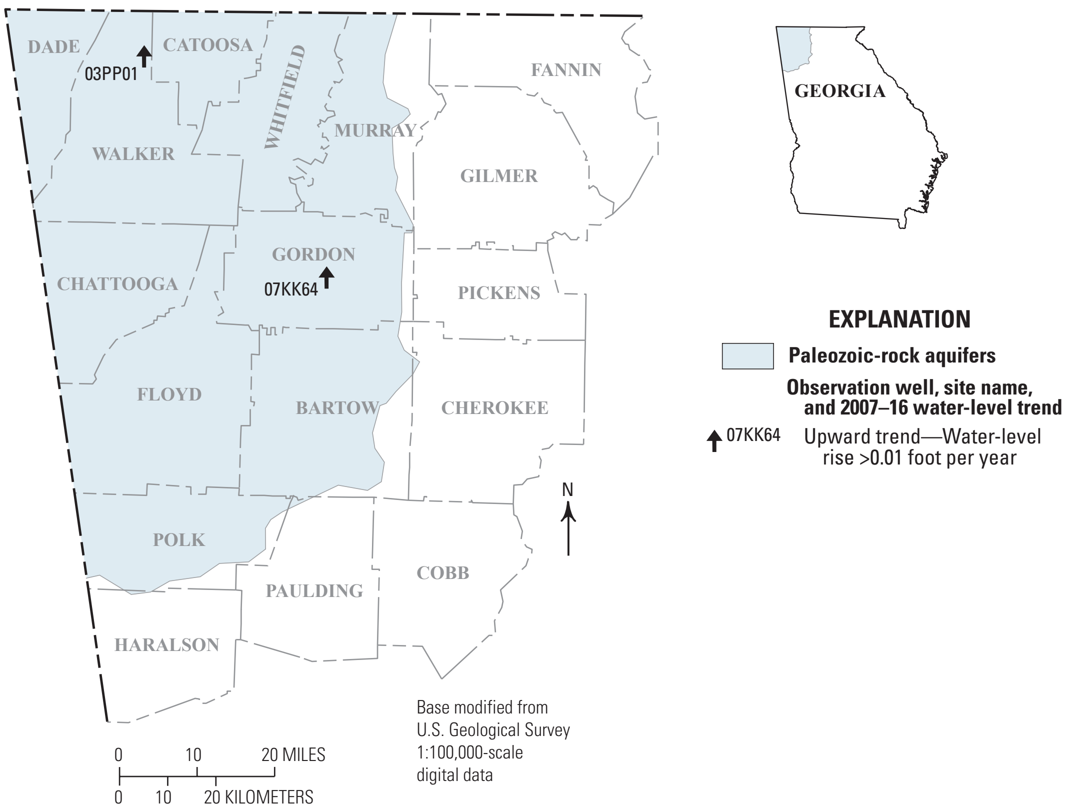
Paleozoic-Rock Aquifers

Water levels were measured in two wells in the Paleozoic-rock aquifers of northwestern Georgia (map and table, facing page). In this area, the Paleozoic-rock aquifers are unconfined and show a pronounced response to precipitation. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in precipitation and pumping. During 2010, about 21 Mgal/d were withdrawn from the Paleozoic-rock aquifer in Georgia, primarily for public-supply use (Lawrence, 2016). During the period of record, the water level in well 07KK64 (Gordon County) declined 0.02 ft/yr because of pumping from a nearby public-supply well. Conversely, the water level in well 03PP01 (Walker County) increased during the period of record, rising 0.03 ft/yr. During 2007–16, water levels in both wells increased at rates of 0.33 to 0.02 ft/yr. Water levels in both wells were lower at the end of 2016 than at any other time during 2015 and 2016.

Reference Cited

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 24, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
07KK64	Gordon	1997	–0.02	0.33
03PP01	Walker	1977	0.03	0.02

[1]See appendix for summary statistics.

Groundwater Levels

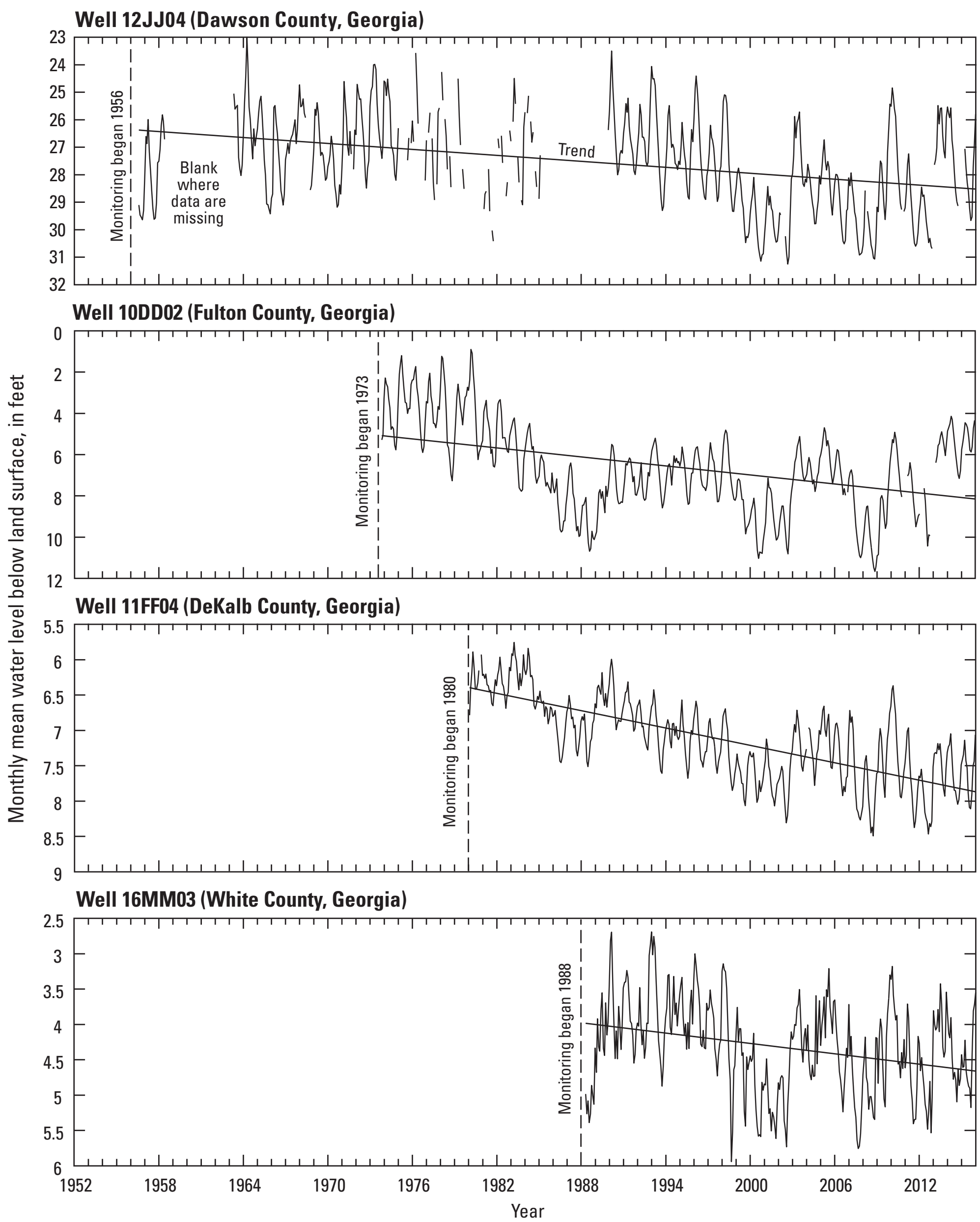
Crystalline-Rock Aquifers

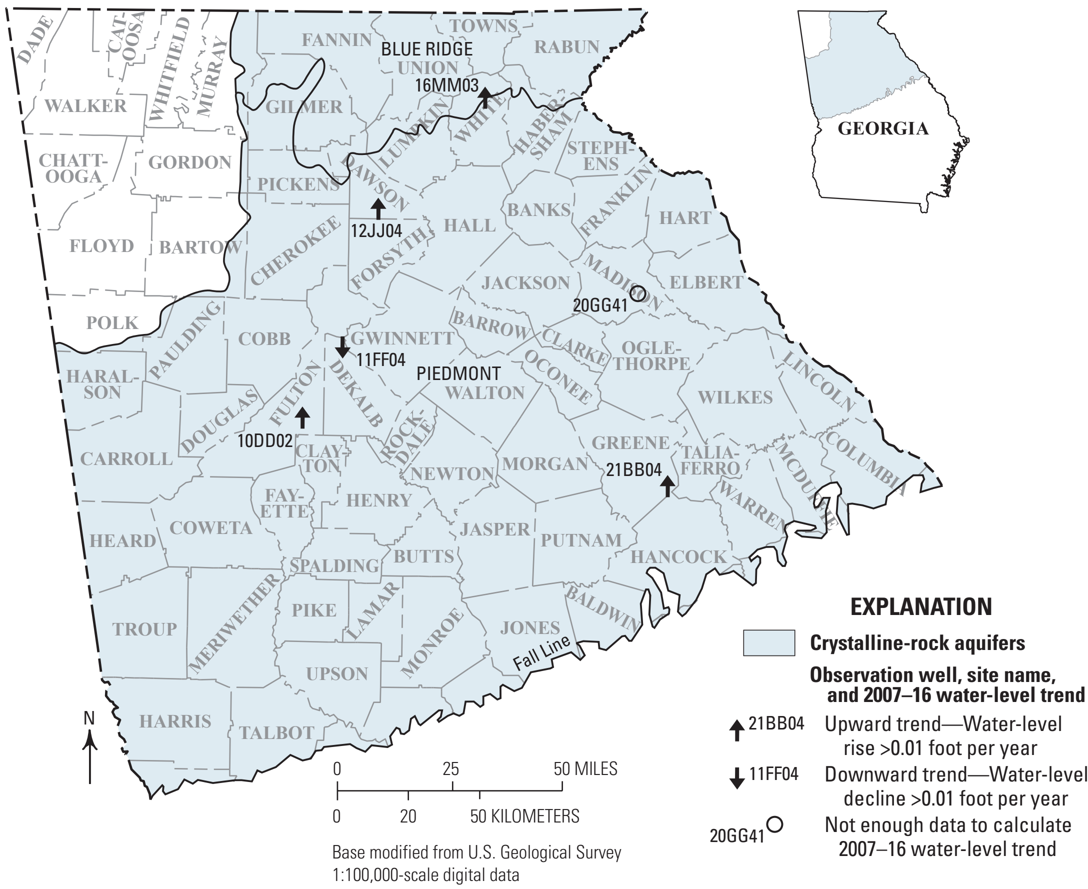
Water levels in six wells were measured in crystalline-rock aquifers in the Piedmont and Blue Ridge Provinces of Georgia (map and table, facing page). In this area, water is present in discontinuous joints and fractures and may be confined or unconfined. In general, crystalline-rock aquifers are local in extent and can be greatly affected by localized water use and climate. During 2010, about 64 Mgal/d were withdrawn from the crystalline-rock aquifers in Georgia, primarily for public-supply use (Lawrence, 2016). Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic downward trends that reflect changes in precipitation and pumping.

During the period of record, water levels declined in five of the wells at rates of 0.02 to 0.19 ft/yr and rose in one well at a rate of 0.36 ft/yr. During 2007–16, water levels in four wells rose at rates of 0.01 to 0.49 ft/yr. Water levels in well 11FF04 declined at 0.03 ft/yr, and well 20GG41 was not monitored for the full 10-year period. Water levels generally were higher during 2015 than in 2016 in the crystalline-rock aquifers.

Reference Cited

Lawrence, S.J., 2016, Water use in Georgia by county for 2010 and water-use trends, 1985–2010 (ver. 1.1, January 2016): U.S. Geological Survey Open-File Report 2015–1230, 206 p., accessed August 24, 2016, at https://doi.org/10.3133/ofr20151230.





Site name	County	Year monitoring began	Water-level trend, in feet per year[1]	
			Period of record	From 2007 to 2016
12JJ04	Dawson	1956	–0.04	0.15
11FF04	DeKalb	1980	–0.04	–0.03
10DD02	Fulton	1973	–0.10	0.49
20GG41	Madison	2007	0.36	([2])
21BB04	Madison	1987	–0.19	0.03
16MM03	White	1988	–0.02	0.01

[1]See appendix for summary statistics.

[2]Not enough data to calculate 2007 to 2016 water-level trend.

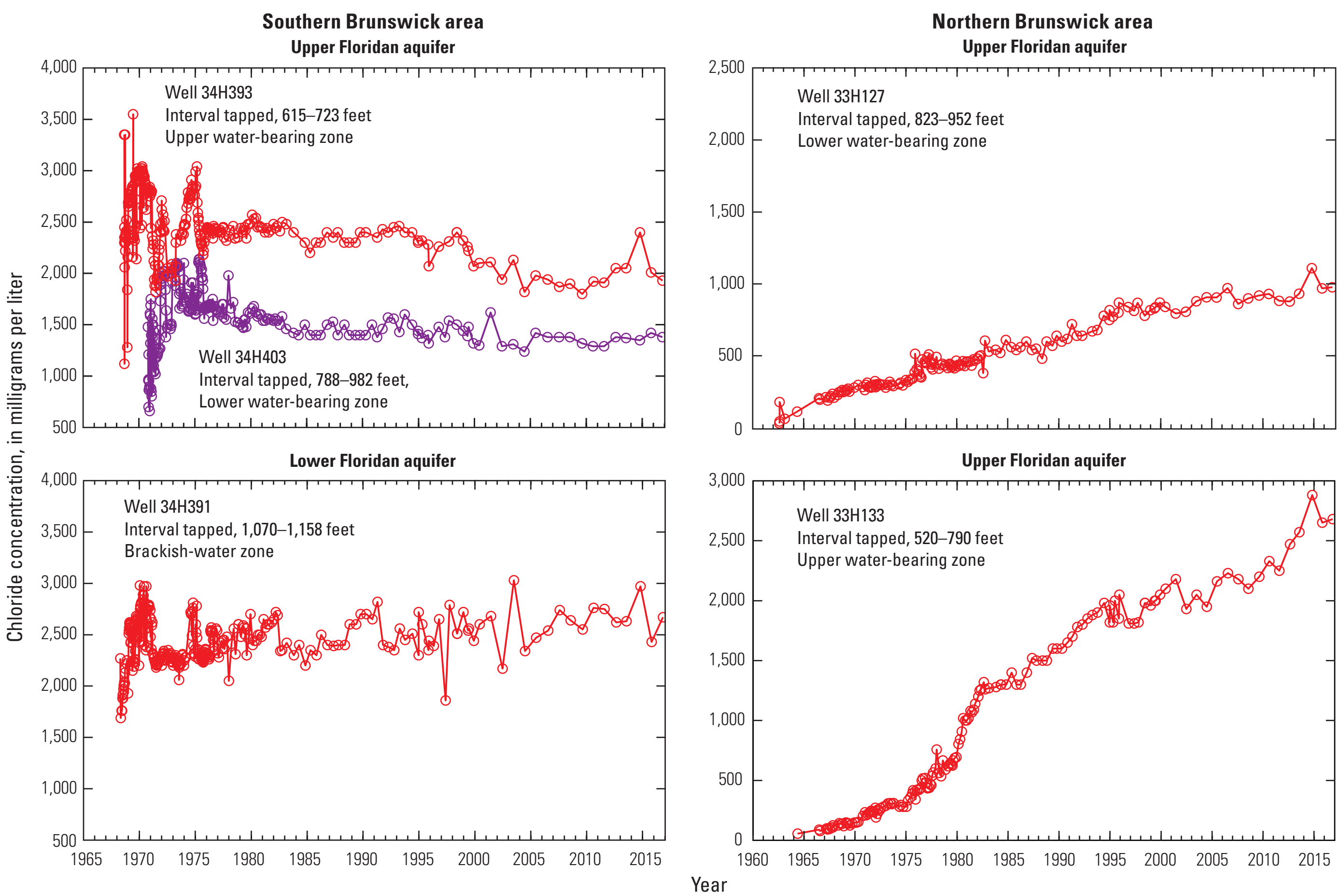
Groundwater Quality in the Upper and Lower Floridan Aquifers

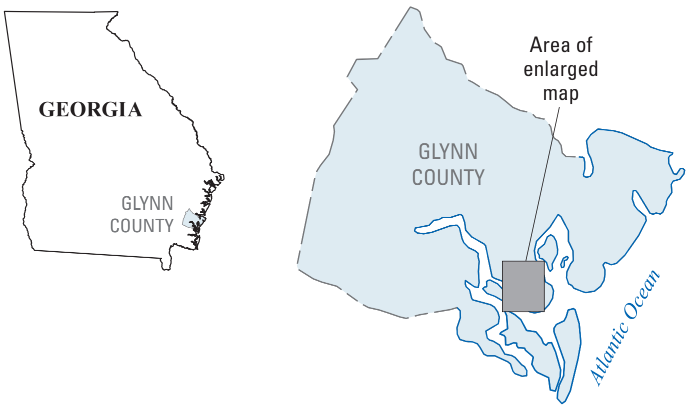
City of Brunswick Area

Chloride concentrations have been monitored in the Brunswick area since the late 1950s when saltwater was first detected in wells completed in the Upper Floridan aquifer in the southern part of the area (Wait, 1965; Cherry and Peck, 2017). By the 1960s, a plume of saltwater had migrated northward toward two major industrial pumping centers. Since 1965, chloride concentrations have increased markedly in wells completed in the Upper Floridan aquifer in the northern Brunswick area. During 2015–16, the chloride concentration was above the 250-milligrams-per-liter (mg/L) State and Federal secondary drinking-water standards (Georgia Environmental Protection Division, 1997; U.S. Environmental Protection Agency, 2000) in a 2-mi^2 area and exceeded 2,250 mg/L in part of the area. More information on monitoring groundwater quality in the Brunswick area is available at https://ga.water.usgs.gov/projects/brunswick/.

Dissolved chloride concentrations in the upper water-bearing zone of the Upper Floridan aquifer at Brunswick were mapped using a spline interpolation for October 2015 using data from 33 wells, and for October 2016 using data from 30 wells (graphs below and maps on facing page). The 2015 and 2016 maps are similar to previously published maps for 2012 and 2014 (Peck and Painter, 2016) and show that areas having the highest chloride concentrations are near the two industrial pumping centers in the northern part of the city and the original area of contamination in the southern part of the city. Groundwater-quality data can be obtained from the USGS NWIS database at https://waterdata.usgs.gov/ga/nwis/gw/ (U.S. Geological Survey, 2017).

Changes in chloride concentration during 1960–2016 are illustrated on graphs for selected wells in the southern and northern Brunswick areas (below), and on a map showing changes during 2015–16 (facing page). Chloride concentrations within the plume area increased in 13 of 31 wells sampled during 2015–16 (facing page). The greatest decrease in concentration was 90 mg/L at well 34H401 in the central part of the plume. Chloride concentrations in two wells increased more than 100 mg/L during 2015–16; the largest increase, 260 mg/L, occurred in well 34H374 in the northern part of the plume, and concentrations increased 148 mg/L in well 33H227 near the chloride plume boundary. These changes likely reflect seasonal fluctuations and shifts in local pumping patterns.





EXPLANATION

MAPS BELOW

Chloride concentration in water from wells completed in upper water-bearing zone of Upper Floridan aquifer—In milligrams per liter

- 0 to 250
- 251 to 750
- 751 to 1,250
- 1,251 to 1,750
- 1,751 to 2,250
- 2,251 to 2,880

● **Location of wells**

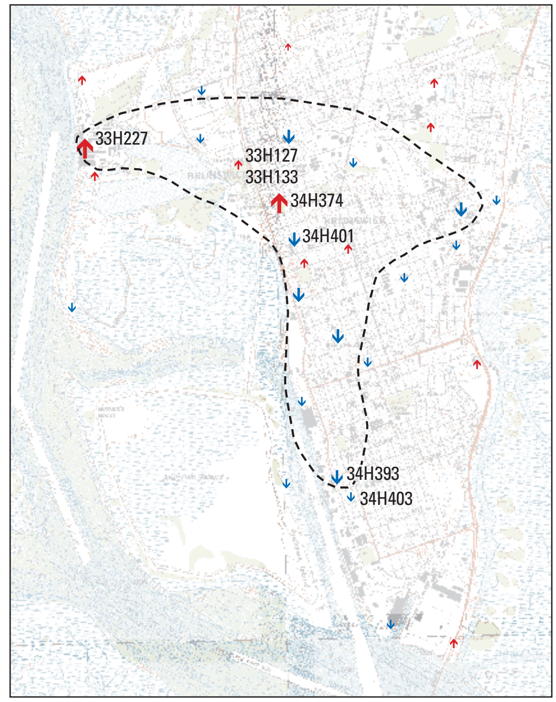
MAP AT RIGHT

Change in chloride concentration from 2015 to 2016
In milligrams per liter

- –50.01 to –100
- –50 to 0.0
- 0.001 to 50
- 50.01 to 100
- >100

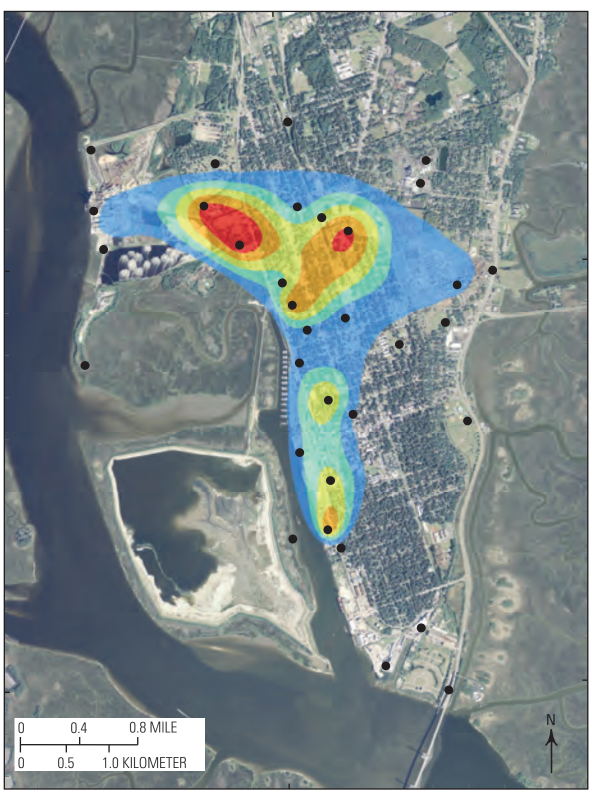
33H133 **Well identifier**

CHANGE IN CHLORIDE CONCENTRATION FROM AUGUST 2015 TO OCTOBER 2016



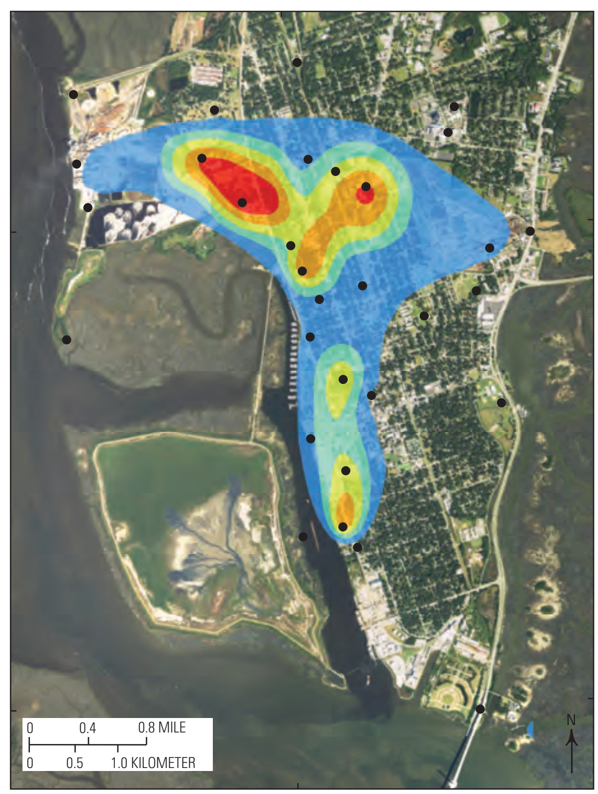
Base modified from U.S. Geological Survey
1:24,000 scale digital data
Brunswick West, Brunswick East

2015–CHLORIDE CONCENTRATION



Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

2016–CHLORIDE CONCENTRATION



References Cited

Cherry, G.S., and Peck, M.F., 2017, Saltwater intrusion in the Floridan aquifer system near downtown Brunswick, Georgia, 1957–2015: U.S. Geological Survey Open-File Report 2017–2010, 10 p., accessed June 20, 2017, at https://doi.org/10.3133/ofr20171010.

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.

Peck, M.F., and Painter, J.A., 2016, Groundwater conditions in Georgia, 2012–14: U.S. Geological Survey Scientific Investigations Report 2016–5161, 55 p., accessed June 20, 2017, at https://doi.org/10.3133/sir20165161.

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Appendix 1. Regression Statistics

Water-level trends in this report were estimated by applying the Levenberg-Marquardt algorithm (LMA; Moré, 1978) to monthly mean water-level data for the period of record and for 2007–16. Although the LMA typically is used for nonlinear fitting, it also can be used for linear fittings that are very near values derived using ordinary least-squares fitting. The LMA optimizes a mathematical function—the merit function—that measures how well the results represent the data. In this report, the merit function is the weighted sum of the squares of the differences (informally known as chi-squared and represented in equations and tables as χ^2).

In this report, the steps involved in minimizing the merit function are as follows:

1. Estimate a value for the slope and intercept, and calculate a line based on this estimate.
2. Calculate how far this line lies from the data (using the χ^2). Adjust the line so that it lies closer to the center of the data.
3. Repeat adjustments until they no longer affect the χ^2 value.

Each step is completed through manipulations of algebraic matrices that are fully explained in Moré (1978).

Summary statistics for the straight line (linear) fits of water-level trends described in the main body of the report are provided here as an indicator of goodness of fit (Janert, 2010). Missing periods of data, where indicated, could affect the goodness of fit and statistical strength of the reported trend. Users of the trend results presented in this report can apply the following statistics to inform interpretation:

- The degrees of freedom represent the number of data points minus the variables used. For these trend evaluations, two variables are used—slope (m) and intercept (b). For example, there are 118 degrees of freedom if 10 years of monthly mean water-level measurements in the 10-year period from 2007–16 are available for statistical calculations. The number of degrees of freedom decreases by one for each month of missing mean monthly water-level measurements. The 2007–16 summary statistics were deleted from table 1–1 for six wells that had less than 96 degrees of freedom signifying greater than 20 percent of missing record.
- The root mean square error (RMSE) is a measure of the sample standard deviation of differences between the values predicted by the trend line and the observed data. RMSE units are the same units as the quantity being estimated (in this report, feet). In general a lower RMSE is preferred because it suggests that the water level estimated is very close to the actual water-level measurements.
- The χ^2 value is the sum of squared residuals (differences) between the monthly mean water level and the monthly mean water-level values computed by the algorithm after the final iteration. The χ^2 from the fit along with χ^2 distribution tables may be used to estimate confidence intervals. A general rule of thumb is that the residuals and the χ^2 should be in the same order of magnitude for the fit to be reasonable. Exceptions to the rule include but are not limited to the following: data that are modeled linearly, but are not linear (having a strong curvature); outliers in the data that exert inordinate leverage; residuals that are not normally distributed; or variables that are serially correlated. For long periods of data that were examined, none to few of these exceptions apply. For the shorter time spans, all of these exceptions apply, but trend line statistical calculations are included so readers can draw their own conclusions.
- The standard error (SE) of a variable (m or b in this report), expressed as a percentage, is a measure of how well m or b has been estimated and affects the location of the regression line. The greater the standard error, the greater the scatter (dispersion) around the regression line.

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Moré, J.J., 1978, The Levenberg-Marquardt algorithm—Implementation and theory, *in* Watson, G.A., ed., Numerical analysis, v. 630: Berlin, Springer–Verlag, p. 105.

Table 1–1. Regression summary statistics.

[Blank cells indicate not enough data to calculate summary statistics]

Well name	Period of record summary statistics					2007–16 summary statistics				
	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)
03PP01	458	2.95497	8.73183	–46.43	–1.10	117	2.78676	7.76603	–403.50	–8.33
06F001	427	7.58692	57.5614	–39.43	–1.40	105	7.66781	58.7953	–45.98	–9.28
06G006	274	9.04318	81.779	–283.10	–1.04	109	8.87842	78.8264	–34.27	–5.86
06K009	370	8.36029	69.8945	–3.25	–0.25	111	9.61834	92.5125	–27.85	–2.12
06K010	378	1.3735	1.8865	–10.60	–0.09	116	1.35888	1.84655	–40.29	–0.70
06S001	719	5.98799	35.856	–1.39	–0.79	112	3.50012	12.2509	–7.86	–4.45
07H003	439	5.09844	25.9941	–74.43	–2.28	116	5.70024	32.4927	–109.90	–15.92
07KK64	234	3.96403	15.7135	–167.40	–1.88	118	3.95632	15.6524	–38.03	–5.84
07N001	606	3.9916	15.9329	–1.45	–0.12	110	3.96003	15.6818	–14.49	–0.92
08E038	173	0.758085	0.574693	–29.58	–0.58	115	0.696538	0.485165	–41.07	–1.19
08E039	166	1.15896	1.34318	–120.80	–1.60	109	1.05734	1.11797	–428.70	–3.10
08G001	477	8.76209	76.7743	–30.54	–1.31	118	9.34436	87.3171	–40.07	–8.47
08K001	443	10.0848	101.703	–62.69	–4.08	115	12.1287	147.105	–4,201	–33.20
09F520	561	3.03234	9.19507	–17.84	–0.30	118	3.03513	9.21201	–35.36	–2.32
09FF18	165	0.524839	0.275456	–6.82	–0.43	99	0.429186	0.184201	–18.92	–0.89
09G001	426	3.50286	12.27	–30.53	–0.33	108	3.42089	11.7025	–33.93	–2.47
09G003	414	2.39001	5.71214	–81.88	–0.32	107	2.40293	5.77406	–30.78	–2.49
09M007	377	25.0724	628.623	–6.81	–0.74	114	30.0503	903.023	–56.37	–6.66
09M009	376	1.577	2.48693	–1,068	–0.29	109	1.84682	3.41075	–169.50	–2.75
10DD02	505	1.94882	3.79789	–9.54	–1.33	108	1.6086	2.5876	–10.46	–4.81
10G313	547	5.42744	29.4571	–18.22	–0.48	117	5.37469	28.8873	–52.44	–3.63
10H009	220	6.29536	39.6315	–80.66	–1.89	118	6.73431	45.3509	–62.24	–6.13
10K005	387	2.0351	4.14163	–12.35	–0.46	109	2.74632	7.54227	–60.36	–4.53
11AA01	842	2.86969	8.23512	–180.50	–0.89	101	3.32794	11.0752	–27.73	–7.18
11FF04	439	0.411706	0.169502	–4.50	–0.27	118	0.50582	0.255854	–63.11	–2.69
11J011	429	3.79447	14.398	–11.57	–0.45	118	3.83943	14.7412	–73.99	–3.30
11J012	422	3.59831	12.9478	–29.03	–0.38	112	3.57101	12.7521	–110.10	–3.03
11K003	450	6.36775	40.5482	–38.16	–1.06	118	7.02635	49.3696	–29.04	–7.04
11L002	502	16.3675	267.895	–3.60	–0.65	106	18.5256	343.197	–40.40	–6.28
11P014	371	16.2125	262.845	–7.92	–0.80	106	6.30275	39.7246	–55.54	–2.66
11P015	380	1.79074	3.20673	–12.54	–0.24	113	1.80228	3.2482	–257	–1.85
12F036	600	5.75589	33.1303	–8.47	–0.20	109	2.39798	5.75029	–44.41	–0.68
12JJ04	541	1.55818	2.42792	–10.60	–0.28	110	1.65591	2.74205	–36.18	–2.19
12K014	414	4.07909	16.639	–28.67	–0.47	117	4.2947	18.4445	–69.95	–3.67
12K180	163	4.29555	18.4518	–744.50	–3.47	111	4.41128	19.4594	–47.57	–6.37
12L019	442	8.61742	74.2599	–6.28	–0.57	99	6.63162	43.9784	–70.98	–4.48
12L020	435	14.5028	210.331	–15.28	–0.53	99	12.0638	145.536	–16.15	–5.90
12L021	435	12.0599	145.442	–19.84	–0.46	103	9.70182	94.1253	–25.59	–3.86

Table 1–1. Regression summary statistics.—Continued

[Blank cells indicate not enough data to calculate summary statistics]

Well name	Period of record summary statistics					2007–16 summary statistics				
	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)
12L277	210	6.69703	44.8502	–31.39	–2.49	113	6.57203	43.1916	–18.89	–5.93
12L373	172	4.66566	21.7684	–175.10	–2.37	118	4.76314	22.6875	–39.42	–4.41
12M001	413	12.9247	167.047	–7.86	–0.59	100	14.0678	197.904	–1167	–5.37
12M017	410	5.53147	30.5972	–196.60	–0.87	118	6.71635	45.1093	–372.30	–7.93
13J004	461	4.56612	20.8495	–7.87	–0.44	118	4.25959	18.1441	–241	–3.09
13L002	675	18.7971	353.33	–3.46	–0.69	110	9.50033	90.2562	–152.90	–3.01
13L015	436	9.50221	90.292	–13.99	–0.50	110	7.54087	56.8648	–29.31	–3.00
13L049	368	5.95277	35.4354	–33.73	–0.93	115	5.69847	32.4726	–45.81	–5.71
13L180	221	5.77604	33.3626	–62.52	–1.20	118	5.82628	33.9455	–230.30	–4.10
13M005	430	5.57094	31.0354	–10.98	–1.88	110	6.80096	46.2531	–2,341	–15.29
13M006	434	6.91772	47.8549	–23.66	–3.27	114	8.2993	68.8784	–263.60	–23.51
13M007	435	2.25957	5.10565	–179.40	–1.31	117	2.50184	6.25922	–59.23	–9.73
14P014	379	3.76001	14.1377	–4.97	–0.40	110	3.66841	13.4572	–17.39	–3.27
14P015	383	10.858	117.897	–15.29	–2.35	115	14.1374	199.866	–51.11	–31.73
15L020	521	1.17282	1.3755	–0.61	–0.03	110	0.879394	0.773335	–4.50	–0.17
15Q016	160	10.3369	106.852	–34.40	–3.95	118	11.0308	121.679	–70.02	–7.30
16MM03	342	0.632613	0.400199	–16.91	–0.84	118	0.612876	0.375617	–148.60	–5.06
18H016	611	1.6247	2.63965	–1.37	–0.04	118	1.87396	3.51173	–122.70	–0.40
18K049	449	3.50157	12.261	–1.62	–0.13	109	4.25258	18.0844	–14.83	–1.38
18T001	414	1.42896	2.04192	–2.46	–0.12	112	1.2662	1.60325	–16.73	–0.81
18U001	487	1.21203	1.46903	–3.19	–0.03	110	1.25025	1.56312	–42.24	–0.30
19E009	697	7.00577	49.0808	–16.80	–0.25	117	7.81042	61.0027	–44.78	–2.24
20GG41	101	2.06876	4.27978	–17.75	–5.29	101				
21BB04	338	2.21994	4.92814	–8.95	–2.90	102	2.3286	5.42237	–29.25	–9.82
21T001	620	4.05386	16.4337	–13.92	–0.58	118	4.5536	20.7353	–119.90	–4.92
21U004	407	0.813038	0.661031	–1.17	–0.10	108	0.918376	0.843414	–7.32	–0.90
23X027	367	5.9907	35.8885	–8.84	–0.13	109	4.3179	18.6443	–15.09	–0.67
24V001	413	1.23448	1.52393	–0.97	–0.04	98	1.68834	2.85048	–7.65	–0.55
25Q001	582	2.7981	7.82937	–1.34	–0.16	105	4.68157	21.9171	–17.21	–2.34
26R001	510	3.53087	12.4671	–1.63	–0.10	118	4.5709	20.8931	–36.42	–1.00
27E004	443	2.62069	6.86804	–13.08	–0.18	114	2.46792	6.09062	–18.94	–1.31
27G003	423	2.77797	7.71709	–7.42	–0.13	118	2.82381	7.97391	–30.99	–1.02
28X001	422	3.65981	13.3942	–1.87	–0.27	108	3.2378	10.4834	–5.29	–2.31
29AA09	234	1.49258	2.22778	–11.48	–0.19	116	1.10975	1.23154	–28.89	–0.60
29AA42	77	0.810134	0.656317	–22.76	–0.30	77				
29BB67	61	0.534228	0.2854	–88.16	–10.69	61				
30AA04	431	2.12097	4.49853	–2.84	–0.08	112	1.20136	1.44326	–11.90	–0.37
30AA37	85	2.34045	5.4777	–49.06	–4.11	85				

Table 1–1. Regression summary statistics.—Continued

[Blank cells indicate not enough data to calculate summary statistics]

Well name	Period of record summary statistics					2007–16 summary statistics				
	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)
30AA38	85	1.57394	2.47728	–243.30	–2.85	85				
30L003	509	3.68918	13.6101	–3.23	–0.21	113	2.99505	8.97034	–38.05	–1.33
31U008	387	3.69043	13.6193	–4.04	–0.22	108	3.9352	15.4858	–214.80	–1.75
31U009	394	3.3864	11.4677	–3.78	–0.21	106	3.29966	10.8878	–160.50	–1.56
32G047	129	2.02048	4.08236	–19.82	–17.01	98	1.25204	1.56761	–6.28	–20.50
32L005	195	0.937679	0.879241	–2.08	–0.13	96	0.549699	0.302169	–7.37	–0.40
32L015	395	2.66567	7.1058	–11.10	–0.23	114	2.57543	6.63283	–24.55	–1.60
32L016	400	1.58023	2.49711	–5.71	–0.14	117	1.15209	1.32731	–21.54	–0.77
32L017	393	1.6286	2.65235	–6.58	–0.19	117	1.46274	2.13962	–26.69	–1.26
32Y030	223	1.03894	1.0794	–2.13	–0.10	96	0.912122	0.831966	–4.72	–0.43
32Y031	236	1.51516	2.29571	–2.74	–0.18	106	1.44344	2.08353	–6.60	–0.76
32Y033	231	6.21491	38.6251	–7.14	–1.72	107	7.78627	60.626	–117.30	–12.87
33D069	265	6.05565	36.6709	–4.59	–8.45	114	2.05313	4.21536	–13.74	–5.92
33D071	218	5.13562	26.3746	–5.48	–12.01	116	0.912496	0.832649	–11.87	–6.66
33D072	214	1.42289	2.0246	–8.23	–3.13	107	0.857257	0.73489	–20.63	–7.81
33D073	200	7.10497	50.4806	–8.72	–10.25	118	1.6684	2.78355	–12	–3.59
33D074	161	1.64601	2.70936	–126.40	–1.05	118	1.22149	1.49204	–11.85	–1.58
33H127	616	4.43391	19.6595	–9.44	–38.77	107	2.28717	5.23113	–8.58	–14.45
33H133	610	4.38728	19.2482	–3.69	–4.17	107	2.32872	5.42293	–9.90	–10.13
33H206	385	3.05431	9.3288	–6.25	–2.79	113	1.73625	3.01455	–8.12	–268
33H207	375	3.55804	12.6597	–4.51	–20.99	105	1.74507	3.04526	–7.73	–11.51
33H208	387	1.27931	1.63663	–4.44	–1.71	118	0.746185	0.556791	–8.87	–5.37
33H324	111	2.05641	4.22881	–5.84	–3.87	111				
33H325	111	9.43554	89.0293	–6.17	–4.18	111				
33J062	176	2.57244	6.61747	–132.20	–3.89	109	1.64916	2.71972	–14.90	–10.52
33J065	172	1.09516	1.19938	–51.06	–92.75	104	0.691321	0.477925	–9.98	–9.88
33M004	578	3.28685	10.8034	–2.76	–0.29	114	2.24782	5.05269	–16.28	–1.43
33R045	173	3.34897	11.2156	–275.50	–0.97	117	2.71898	7.39285	–17.50	–1.48
34G033	143	2.54461	6.47505	–29.79	–3.91	116	1.59868	2.55579	–7.26	–5.95
34H371	575	2.82188	7.96303	–4.92	–2.71	102	1.5693	2.4627	–7.54	–75.34
34H391	477	2.70185	7.3	–5.63	–2.05	110	1.73407	3.007	–7.82	–115.50
34H436	389	2.76024	7.61893	–6.98	–1.54	113	1.68004	2.82253	–7.90	–25.15
34H437	370	2.11984	4.49373	–11.75	–28.40	101	1.49566	2.237	–17.83	–16.76
34H495	172	2.53663	6.43451	–6.55	–3.48	105	1.18154	1.39605	–11.65	–3.82
34H500	178	3.04113	9.24845	–12.20	–5.00	108	1.53094	2.34378	–4.86	–53.16
34H504	114	1.61744	2.61611	–7.94	–32.15	114				
34H505	113	1.76497	3.11511	–8.26	–69.90	113				
34H514	116	1.89078	3.57505	–7.40	–6.45	116				

Table 1–1. Regression summary statistics.—Continued

[Blank cells indicate not enough data to calculate summary statistics]

Well name	Period of record summary statistics					2007–16 summary statistics				
	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope, in percent (SE_m)	Standard error of intercept (SE_b)
34H515	131	0.510984	0.261104	–57.55	–5.02	112	0.486283	0.236471	–58.36	–6.28
34J077	215	4.18516	17.5156	–21.46	–2.54	113	3.25031	10.5645	–31.27	–4.88
34J080	172	2.35971	5.56823	–578.70	–11.80	116	1.80983	3.27549	–12.71	–7.22
34J081	170	1.79663	3.22789	–20.94	–2.22	116	1.72931	2.99053	–14.43	–3.67
34J082	165	0.921542	0.849241	–77.92	–2.39	109	0.723583	0.523572	–14.24	–3.15
34K104	125	2.07914	4.3228	–18.29	–1.86	107	1.36914	1.87453	–8.79	–1.51
34N089	590	3.57335	12.7688	–2.63	–0.69	112	2.07488	4.30515	–12.33	–2.56
34S008	182	1.53691	2.36208	–5.62	–0.82	118	1.51807	2.30452	–6.87	–1.67
34S011	172	3.154	9.94772	–44.92	–0.79	116	2.49923	6.24614	–12.24	–1.20
35H068	113	1.71357	2.93632	–10.57	–6.40	113				
35H070	116	1.97222	3.88967	–10.65	–4.43	115	1.9798	3.91961	–11.04	–4.59
35H076	89	0.547589	0.299854	–25.44	–1.18	86				
35H077	128	7.08655	50.2191	–67.55	–9.64	110	7.47841	55.9267	–51.17	–11.83
35M013	581	3.01097	9.06593	–2.59	–0.65	102	1.57999	2.49637	–10.48	–2.24
35P094	884	2.1753	4.73195	–60.22	–1.75	111	1.48393	2.20206	–51.79	–8.64
35P110	192	2.83594	8.04256	–20.04	–1.38	115	2.20809	4.87564	–10.33	–2.34
35P125	119	2.17343	4.7238	–9.90	–2.22	115	2.17157	4.71572	–9.76	–2.32
35Q050	171	1.27273	1.61985	–15.26	–1.26	109	1.0755	1.15669	–17.94	–2.36
35S008	199	1.47075	2.16309	–5.09	–0.39	118	1.22032	1.48919	–5.64	–0.83
36N012	194	2.27254	5.16445	–10.61	–0.69	105	1.78887	3.20005	–8.25	–1.50
36Q008	733	12.5455	157.389	–45.40	–0.64	107	4.48314	20.0985	–7.54	–1.78
36Q020	674	5.56572	30.9772	–3.18	–0.57	103	2.87975	8.29297	–10.27	–2.06
37P114	383	3.13748	9.84379	–4.88	–0.32	110	2.77442	7.6974	–9.59	–1.95
37P116	385	0.312514	0.0976652	–119	–0.19	114	0.342483	0.117295	–116	–1.61
37Q016	728	9.61069	92.3653	–12.32	–0.58	115	4.22834	17.8788	–7.74	–1.92
37Q185	301	5.47515	29.9773	–2.39	–0.31	77				
38Q002	720	3.78256	14.3078	–4.32	–0.55	113	1.74221	3.03528	–8.96	–1.86
38Q208	208	0.424679	0.180352	–38.15	–0.79	104	0.490801	0.240886	–28.87	–2.97
38Q209	221	0.331621	0.109972	–9.30	–0.42	114	0.359722	0.1294	–25.79	–1.56
39Q003	624	3.14549	9.89412	–4.88	–0.52	113	1.48486	2.2048	–9.75	–1.78
39Q024	226	1.34782	1.81661	–5.86	–0.34	101	1.29517	1.67746	–9.12	–1.31
39Q026	226	1.55005	2.40264	–23.17	–1.32	107	2.12003	4.49454	–27.77	–6.10
39Q029	209	0.963209	0.927772	–35.76	–1.11	103	0.92433	0.854386	–19.37	–3.27

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